EXPERIENCE FROM FINESSE ON COSTING BLANKET R&D

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Why Develop Cost Estimates?

[help make R&D plan practical]

- Obtain Overall Program Cost
- Anticipate Period in Time when Major Expenditures will be Required
- Identify Issues, Experiments and Facilities that are Major Cost Drivers. These can then be examined in more technical detail
- (Cost/risk tradeoffs) Provide Guidance on the Necessity for Early Selection of Concepts, Reducing Scope of Experiments, Etc.
- Input for Decision on International Cooperation

Uncertainties in Cost Estimates

- Major Uncertainties are due primarily to accuracy and completeness of the description of the facility characteristics.
- Costing Algorithms introduce less errors

Suggestions

- Improve facility description as the key to improving cost estimates
- Perform detailed cost estimates only for major items. Collect smaller items under a larger heading (breakdown into tasks of comparable cost proved useful)
- Provide a range (within a factor of ~ 2) for the cost of major tasks
- Accuracy of overall program cost is better than that of individual tasks

Elements of Experimental Task Costs

Direct

- Design Engineering
- Buildings (Less Land)
- Materials and Systems
- Assembly and Test
- Analysis of Results
- Professional Staff
- Operating Costs

Indirect

- Equipment and Instrumentation Development
- Scoping Tests
- Modelling and Code Development
- Design Studies
- Program Administration
- Overhead
- Contingency

METHODOLOGY - GROUNDRULES AND ASSUMPTIONS FOR FACILITIES COSTING

1. ALL FACILITIES OR TEST STANDS ARE STAND ALONE (ASSUMING NO EXISTING BUILDINGS OR EQUIPMENT AVAILABLE)

2. CONSTANT 1985 DOLLARS

3. TRITIUM COSTS $15K/GRAM

4. ELECTRICITY COST: 5¢ PER KWHR

5. PROFESSIONAL YEARLY COST: $130-150K

6. TECHNICIAN AND OTHERS: $100K

7. NO COST FOR NEUTRON (FISSION) SOURCES

8. TEST STANDS - 2 YEARS FROM DESIGN START TO TEST

9. TEST STANDS - 4 YEAR LIFE

10. CONTINGENCY $ NOT INCLUDED

11. NO COST FOR LAND

12. NO DISPOSAL/DECOMMISSIONING COSTS INCLUDED

Some Major Cost Elements for Liquid Metal Blanket Facilities

Materials and Systems

- Magnets
- Power Supplies
- I & C
- Safety Systems
- Heat Transfer System
  (pumps, Hx, plumbing)
- Raw Materials
- Fabrication
- Energy Input

Manpower

- Scientific Staff
- Technical Staff

Table 10. Representative Costs of Key Liquid Breeder Blanket Facilities[a]

Item	Capital Cost (M$)	Operating Cost (M$/yr)	Duration (years)	Total Cost (M$)
Advanced liquid metal flow facility (LMF1)	7-10	0.5	4-6	10-15
Integral Parameter Experiment (LMF2)	7-10	0.5	4-6	10-15
MHD mass transfer facility (MHDM)	8-12	1.0	6-8	15-20
Corrosion loops	6-10	1.6	8-12	12-20
Tritium extraction test (2)	2-3	0.4	3-4	3-5
Tritium transport loop test	6-8	0.6	5-7	9-12
Partially Integrated Test Facility (PITF)	estimate not available			
Thermomechanical Integrated Test Facility (TMIF)	20-25	2.0-3.0	8-10	35-60
Analysis and model development	0	2.0-4.0	15	30-60

[a]In 1985 constant dollars

Table 9. Representative Costs of Major Solid Breeder Tasks[a]

Task	Capital cost (M$)	Operating cost (M$/yr)	Duration (years)	Total cost (M$)
Solid Breeder Characterization and Development (Fabrication, properties, closed/open capsule irradiations)	5-7	5-8	5 (initial)	30-50
Multiplier Characterization and Development (Fabrication, properties, closed capsule irradiations)	1-2	1-2	5	6-12
Blanket Thermal Behavior				
A. Breeder thermal behavior	0.8-1.5	0.8-1.5	3-5	3-8
B. Non-neutron (sub)module thermomechanics	3-8	0.8	4	5-10
Neutronics and Tritium Breeding				
A. Simple geometry	3-6	0.8-1.5	5	7-14
B. Engineering mockup	4-7	0.8-1.5	3	6-12
Advanced In-Situ Recovery (Two sequential subassemblies with multiple open capsules)	3-5 each	0.8 each	6 each	12-16
Nuclear submodules (Two parallel submodules)	5-7 each	1-1.5 each	7 each	20-30
Analysis and Model Development	0	2-3	15	30-45

[a] 1985 constant dollars

Neutron facility and neutron costs not presently charged, but would be ~0.5 M$/yr/subassembly, assuming shared use of the facility.

Appendix

The following pages are reproduced from the FINESSE Phase I Report (UCLA-ENG-85-39), December 1985. They help explain some of the items discussed in this presentation.

3.7 Liquid Metal Blanket Facilities Costing

It is necessary to know the approximate cost of individual facilities both for short term planning of the facilities and for long term decisions regarding the overall test plan (cost-to-benefit ratios, funding scenarios, etc.). Because of the limited amount of detail now known about future facilities, only an approximate estimate of test plan costs could be generated. The costing relied on the approximate definitions of facilities contained in the previous sections of this chapter. Only the most critical facilities were costed, as listed in Table 3.7-1.

The process of costing has resulted in a methodology for costing, ground-rules for estimates, basic cost data and a series of conclusions. These are provided in the remainder of this section.

3.7.1 Methodology for FINESSE Costing

Figure 3.7-1 represents the role of costing in the FINESSE process. In previous phases of the FINESSE process, the critical issues were used to generate testing needs and requirements for testing, which were then used to define the facilities. The cost estimates are based on the facilities definitions and will be used as one of the inputs to the test plan generation and evaluation.

Table 3.7-1. Key Liquid Metal Blanket Facilities Which Were Costed

1. MHD Pressure Drop/Fluid Flow
2. Thermal Convection Corrosion Loop
3. Forced Convection Corrosion Loop
4. MHD Heat Transfer
5. MHD Corrosion
6. Tritium Extraction System
7. Tritium Permeation and Transport Loop
8. Thermal Hydraulic and Mechanical Safety Test
9. Thermomechanical Integrated Test

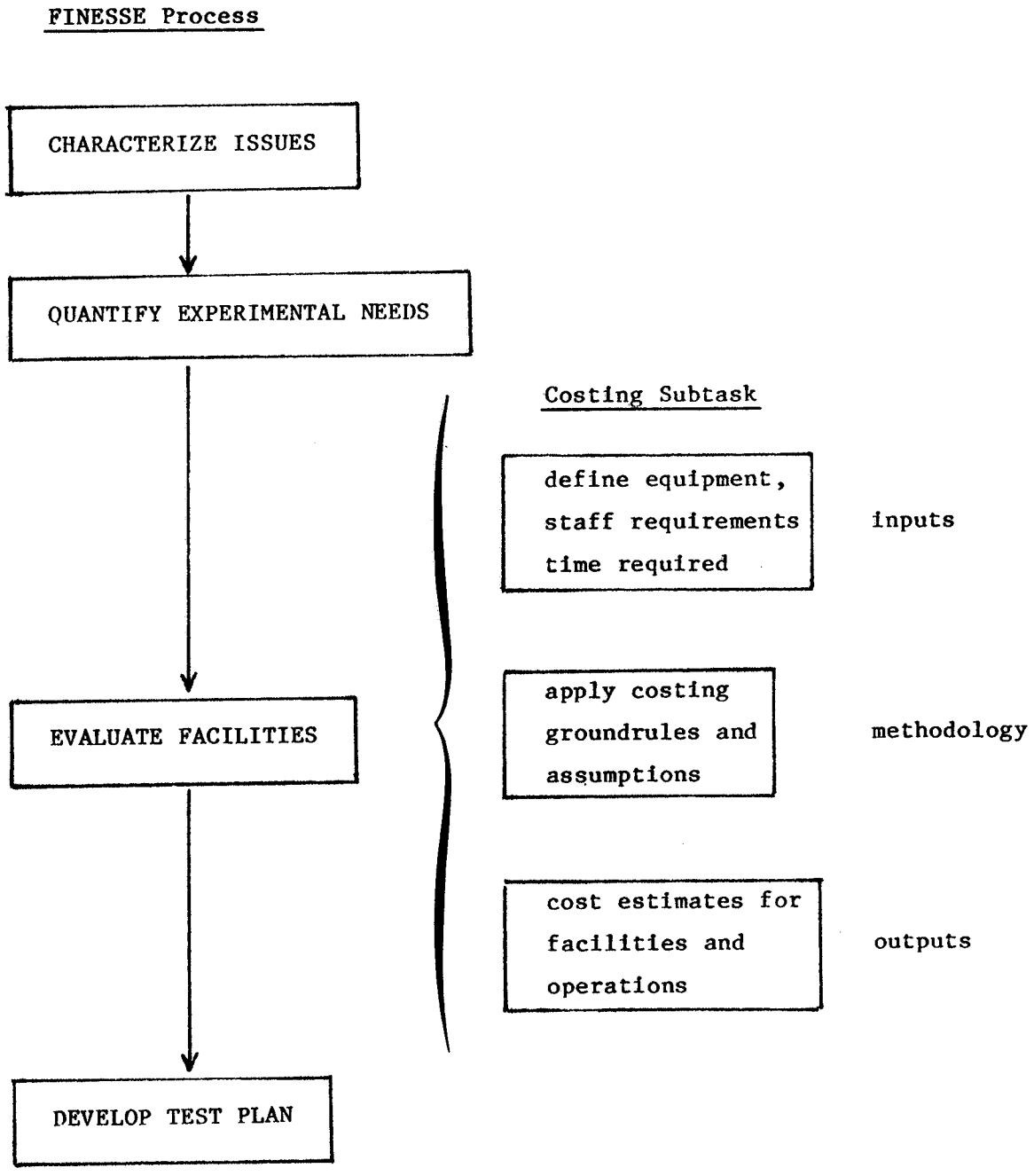

Figure 3.7-1. The relationship of the costing task to the FINESSE process

The facility requirements were provided in the form of system block diagrams, equipment listings and similarities with other systems currently utilized in the liquid metal blanket program. After refining the definitions of the required facilities, costing information was gathered relevant to the systems. Costing data sources included industry and national laboratory experience; similiar equipment costs and basic equipment costs were defined through contacts with equipment/material suppliers.

Operating costs were prepared by estimating the professional, technician and support labor required for each facility on a stand alone basis and then applying an annual rate for each category of labor/skills. Cost estimates also included the building (less land) costs to house the experiment as well as provision for office, experiment and storeroom space.

The estimated direct cost of each facility includes the items listed in Table 3.7-2. In developing an overall cost for the complete test program, it

Table 3.7-2. Direct and Indirect Costs Associated with Experiments

Direct	
	design engineering
	buildings (less land)
	materials and systems
	assembly and test
	professional staff (experimental)
	operating costs (less utilities)
Indirect	
	equipment and instrumentation development
	scoping tests
	modelling and code development
	design studies
	program administration
	contingency

is important to include indirect as well as direct costs associated with each facility. The cost items that are classified as indirect are also listed in Table 3.7-2. Because of the difficulty in specifying indirect costs for individual experiments, they are added into the total test plan cost as a constant factor of 1.5 times the total direct costs.

Design engineering. Design engineering is the effort associated with design, specifications and procurement of the facility and equipment. As mentioned previously, each requirement is considered as a stand-alone, independent entity. Design engineering costs include staff to perform the functions of:

- project management (as necessary)
- specification preparation
- procurement of systems/equipment
- systems design
- fabrication and installation liaison

Personnel for this function would normally be engineers from various disciplines, facility designers, specification and purchasing personnel. Technicians and engineers that oversee the installation of systems are also included in this category. This cost averages 18-20% of total experiment costs.

Buildings. Since at this time, location of a particular experiment cannot be defined, we have assumed that each system defined as a requirement will have a building to house the equipment and personnel. A Butler type building is envisioned for the simple test loops whereas a facility such as the TMIF will require substantial office and experimental space. Experiments of the single purpose type such as corrosion or tritium extraction for which the purchased material and systems are less than $0.5M assume no office or clerical space provisions. More expensive experiments are estimated at a higher cost for the buildings which were included at a maximum of 10 percent of total experiment costs.

Materials and systems. This cost category includes the experiment hardware such as magnets, power supplies, piping, heaters, pumps, etc. Also included are safety systems, heat exchanges, raw material and instrumentation and control systems. As will be shown later, this category of cost averaged 40-50% of the experiment cost.

Assembly and testing. This category of cost includes those costs associated with assembly of the experiment and performance of initial systems verification tests and operation of the facility for the 1st year after installation of the required systems. Included in this period are initial systems hookup, installation and checkout of hardware and software (if any) and the generation of any related test plan or procedures. The cost of assembly and testing varied from 8 percent on the largest devices to 25 percent of the cost on the smaller experiment. This variance is due to the 1st year operating costs and the fact that, in general, a mechanical and electrical technician is required for any experiment, regardless of the equipment involved.

Professional Staff. This category includes the theoretical support groups who define the testing requirements and parameters, provide guidance to the design engineers, specify data requirements and interpret and publish test results and provide feed back for subsequent experiments. They are assumed to be assigned to the particular experiment at its inception and are estimated against the facility cost though the first year of operation. Subsequent years would be part of the estimated operating costs. In general, this staff was minimal - in the range of 1-2 professionals for 1 to 2 years or through the 1st year of operation. The professional staff generally accounted for 15 to 20 percent of the total experiment cost.

3.7.2 Groundrules for Estimates

In preparing estimates for liquid metal and solid breeder blanket test facility costs, several groundrules and assumptions were employed, as shown in Table 3.7-3.

Stand alone facilities. During preparation of the costs for facilities, it became apparent that many possible locations/facilities can be possible for the test stands and loops required for the liquid metal blanket test program. However, the availability within the program's required time frame, staffing availability and existing or surplus equipment status could not be ascertained within the scope of this study. Therefore, the groundrule was established that all facilities and equipment would be costed on a basis that assumes no transfer of resources from existing or contemplated assets.

Table 3.7-3. Groundrules and Assumptions for Facilties Costing

1. all facilities or test stands are stand alone (assuming no existing buildings or equipment available)
2. constant 1985 dollars
3. tritium costs: $15K/gram
4. electricity cost: 5¢ per KWHR
5. professional yearly cost:$130-150K
6. technician and others: $100K
7. no cost for neutron (fission) sources
8. test stands - 2 years from design start to test
9. test stands - 4 year life
10. contingency $ not included
11. no cost for land
12. no disposal/decommissioning costs included

Constant 1985 dollars. Constant Dollars (1985) was chosen because at the present stage of test planning, it is believed that cost estimates are best used for comparison of facilities rather than absolute or projected total program costs. In deciding on the cost effectiveness of a facility vs. the technical risk, we felt that measuring each test requirement against constant dollars would be the most effective measure rather than to attempt projected dollar costs.

Tritium costs. A cost of $15,000/gram was a concensus of the FINESSE team as representing the most likely cost under conditions expected during the test period.

Electricity costs. 5¢ per KWAR was selected as a concensus based up U.S. average for commercial, high volume consumers and is applicable mainly to operational costs of the large (FERF) type facilities discussed in Chapter 9 of this report.

Professional (130-150K) and technician (100K) costs. These cost estimates represent burdened industrial and governmental personnel cost used in this study and are representative of expected costs in a technology such as liquid metal blankets.

No cost for neutron (fission) sources. This groundrule applies to Solid Breeder and materials testing. FINESSE estimates have assumed that experiments are "piggy back" on existing reactors that have primary missions other than in support of fusion. Therefore other than operating staff associated with the particular experiment, no costs have been allowed for running of the reactors, maintenance or operation of the source of neutrons. Design and operation of equipment unique to the tests defined in the FINESSE plan have been included.

Test stand life and construction times. An assumption that two years from start of design to first test, with a lifetime of four years should be representative of the facilities defined in this study. These are not applicable to FERF type facilities but are representative of the type of test facility described for the liquid metal blanket and solid breeder test plans.

Contingency costing. Since the main purpose of costing the various experiments was comparision between facilities, cost vs risk assessment and an understanding of what the total program might cost, no contingency factors were applied to estimated costs.

Land cost and disposal/decommissioning costs. These costs were not considered due to the variances between geographical locations and since construction on government or public land is the most probable scenario for a fusion facility. Disposal and decommissioning were not considered due to the fact that unlike major FERF type facilities, the buildings and test stand described herein would have application to future tests and most would not be contaminated. These costs can be factored into the cost estimates should they be considered necessary for any particular study using the estimates provided herein.

3.7.3 Cost Data for the Liquid Metal Blanket Test Program

The FINESSE pricing matrix (Table 3.7-4) below represents the current

cost estimates for the major liquid metal blanket experimets. Each item Comments, estimated capital and annual operating costs complete the matrix. It should be recognized that these estimates are first-cut estimates since definition of the facilities was not performed at a very detailed level. But these estimates should be adequate for the purpose of planning a liquid metal blanket test program.

Table 3.7-5 presents a breakdown of the capital costs presented previously. The costs are shown for the following categories that were discussed in Section 3.7.1, namely:

engineering design
buildings
material
assembly and test
professional staff

The costs shown were prepared in concert with costing groundrules and material etimates.

Figure 3.7-6 presents a breakdown of the materials & systems portion of total capital costs. This material is the necessary equipment that must be procured or fabricated to implement the particular experiment, test loop or test stand defined in column 1 of the table. Costs are catalogued by:

magnets
power supplies
instrumentation and control
safety systems
plumbing and pumps
blankets (or simulator)
heat exchanger
raw material (fluid medium or special materials)
miscellanious
heating equipment

The cost of these systems was generated by analysis of the test objectives, basic schematic diagrams and costs of similar systems previously estimated or built in support of similar programs.