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LA-UR -88-2956

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LA-UR--88-2956

DE89 000373

TITLE THE LABORATORY MICROFUSION FACILITY STANDARIZED COSTING METHODOLOGY

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SUBMITTED TO American Nuclear Society, 8th Fusion Topical
Salt Lake City, Utah
9-13 October 1988

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THE LABORATORY MICROFUSION FACILITY STANDARDIZED COSTING METHODOLOGY

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ABSTRACT

The DOE-organized Laboratory Microfusion Facility (LMF) has a goal of generating 1000 MJ of fusion yield in order to perform weapons physics experiments, simulate weapons effects, and develop high-gain inertial confinement fusion (ICF) targets for military and civil applications. There are currently three options seriously being considered for the driver of this facility: KrF lasers, Nd:glass lasers, and light-ion accelerators. In order to provide a basis for comparison of the cost estimates for each of the different driver technologies, a standardized costing methodology has been devised. This methodology defines the driver-independent costs and indirect cost multipliers for the LMF to aid in the comparison of the LMF proposal cost estimates.

INTRODUCTION

The goal of the DOE-organized Laboratory Microfusion Facility (LMF) Scoping Study is to determine the characteristics and gather information on the different driver options for an inertial confinement fusion (ICF) facility capable of generating 1000-MJ of fusion yield per shot.[1-8] Based on current experience, the cost of the driver will probably dominate the total cost of the LMF. Complications can arise if the LMF study is used to compare different driver options because each organization is performing cost estimates for their driver concept using different assumptions for technology projections, costs, and work breakdown structure (WBS). Therefore, as part of Phase I of the LMF Scoping Study, this methodology has been developed to establish a standardized costing methodology that will diminish misleading comparisons in the estimated LMF cost for different driver options.

There are four problems with attempting to compare cost estimates for different LMF drivers generated at different laboratories:

1. Varying degrees of completeness may cause one cost estimate to include an item that is excluded by another. Examples of this for the LMF study may include the target fabrication facility, radiation waste disposal, or fire/safety/security costs.
2. Differing indirect cost multipliers can lead to significantly different total cost estimates. For example, in a recent cost estimate, the cost of ED&I (engineering, design, and inspection) was estimated at only 5%, and no allowance was made for contingency. These underestimates are totally unacceptable for construction of a first-of-a-kind facility that is estimated to cost one- to two-billion dollars.
3. Differing degrees of optimism or assumptions on technology development can significantly affect cost estimates.
4. Projecting future unit costs and quantity scaling in a subjective way can have a strong impact on the cost estimate.

The LMF standardized costing methodology solves the first two problems by defining what is to be included in the LMF cost estimates, providing cost estimates for the driver-independent items, and specifying the indirect costs for all of the items to be included in the LMF cost estimate. Items three and four list subjective factors that will have to be weighed by decision makers. One option being considered for the LMF Study is to hire a contractor that has the ability to estimate the cost of all of the driver candidates being considered.

WORK BREAKDOWN STRUCTURE

A general work breakdown structure has been defined in order to classify all of the components required for the LMF (see Table 1). This particular WBS was devised to be driver independent. Some drivers may not use all of the cost categories, while others may need to include additional categories. In all cases, the WBS is not defined in sufficient detail for accurate cost estimates. For example, the driver is listed as just one cost element because any additional detail will be driver dependent. Clearly a finer detail is needed to estimate the cost of the LMF driver.

The WBS is organized into the six major sections defined below:

1.1 **Site Improvement** includes clearing the site and preparing for construction of the buildings, all roads on the site, a parking lot, and all general land improvements. It has been assumed that a road to the site already exists and this cost item is not included.

1.2 **Buildings** consists of an office building, a building for target fabrication, shops, laboratories, and support buildings such as a warehouse and a fire/security facility.

1.3 **Special Structures** include the driver and target buildings because of their special construction and/or safety requirements. Facilities in this section include some

TABLE 1

LMF WORK BREAKDOWN STRUCTURE

1. LABORATORY MICROFUSION FACILITY

1.1 SITE IMPROVEMENTS	1.2 BUILDINGS	1.3 SPECIAL STRUCTURES	1.4 SPECIAL EQUIPMENT	1.5 UTILITIES	1.6 STANDARD EQUIPMENT
Clear and grub site	Office	Driver building	DRIVER SYSTEM	Sewage	Furnishings
Roads	Target fabrication	Target building		Water	Communications
Parking lot	Shops	Oil handling	Prototype module	Electricity	Computers
General land improvement	Laboratories	Water handling	Laser or accelerator	Natural gas	Scientific equip
	Support	Rad waste storage	Driver diagnostics	Rad waste disposal	Mechanical equip
			Vacuum subsystem	Liquid He	
			Alignment subsystem		
			Control subsystem		
			Gas-handling subsystem		
			TARGET SYSTEM		
			Target chamber		
			Target diagnostics		
			Target fabrication equip		
			Target assist equip		
			Vacuum subsystem		
			Remote handling equip		

potentially driver-dependent facilities such as structures for the handling and storage of deionized water and transformer oil. Additionally, a radioactive waste storage facility is included in this category.

1.4 **Special Equipment** is where the driver and target systems are categorized. Most of the items in this section are clearly driver dependent. The cost of the items in this section will probably dominate the LMF's total cost.

1.5 **Utilities** consist of sewage, water, electrical, and natural gas connections. Radioactive waste disposal and a capability to handle liquid helium are included here. Only on-site utilities costs are included. The cost of bringing utilities to the site can depend strongly on the site selection, and the electrical power requirement may be strongly driver dependent. Because a site has not been selected, these costs have not been estimated.

1.6 **Standard Equipment** includes furnishings for the office building, communications equipment, computers (both mainframe and personal), standard equipment for the laboratories and shops, and other off-the-shelf scientific equipment.

These sections of the WBS define the major items in the second and third level of the WBS for the LMF. Finer detail will be needed to accurately estimate the cost of the LMF.

DRIVER-INDEPENDENT COST ESTIMATES

The cost data developed for the driver-independent aspects of the LMF are presented in 1987 dollars. All estimates are developed according to the WBS format shown above in Table 1. The cost estimates for the driver-independent systems come from several different sources. Very few of the components needed for the LMF have ever been constructed. Therefore, the main source of cost information is obtained from experienced experts in the different technical areas. These estimates will need to be refined as more detailed designs are done for the LMF.

Refined cost estimates will be possible after certain decisions are made about the LMF. For example, site selection will have significant cost implications. The cost of installation and connection of utilities is strongly dependent on the site selection, as is the cost of labor. The cost of construction can vary by as much as a factor of two between states or even between regions of a state. For the purpose of this study, national average labor rates have been assumed. This results in an approximate uncertainly of 50% for the cost of labor.

Escalation is not included in this study because the date and schedule for construction are not determined. When a construction date and schedule are defined, then escalation can be estimated. Escalation will need to be included in the line item proposal for the LMF.

Several assumptions are needed before making cost estimates for the driver-independent aspects of the LMF. Whereas the site has not been selected for the LMF, it was assumed in this study that the site would be on existing federal land. This siting would streamline environmental approval and there would be no cost for the land. It was also assumed that utilities and roads exist at the site boundary, so no costs of bringing these items to the site are included. Finally, it was assumed that target fabrication will exist at the site: facilities existing elsewhere will not be used. The advantage of this system is it avoids transportation of targets and poor response time. It was estimated that target fabrication needs to have the capability to produce and deliver two targets per day; therefore, the transportation and response time factors were considered quite important.

Standard values of indirect costs for the construction of the LMF are used. The indirect cost values were obtained from References 9 and 10 and are shown in Table 2. Variations from the standard markup values are allowable if done in a consistent manner for all of the driver candidates. For example, there is no question that certain diagnostics for high-yield target shots will be difficult. It may be appropriate that diagnostics have a 30% contingency (or more!) instead of the default 25% and that the program management markup for target diagnostics be 5% instead of 2%. The most important aspect of the cost estimates be that agreement is reached on the values and that they be consistently used in each of the driver design cost estimates.

TABLE 2
MARKUP RATE FACTORS

Markup	Rate
Labor fringes, taxes, and insurance	0.30
Warehouse and handling rate	0.04
Subcontractor mark-up rate	0.03
Equipment rate	0.04
Overhead rate	0.07
Profit rate	0.04
Gross receipts tax rate	0.05
Bond rate	0.01
Special engineering rate	0.02
Escalation rate*	0.00
Engineering, design, and inspection rate	
Standard Equipment	0.00
Construction	0.15
Special facilities equipment	0.10
Project management mark-up rate	
Standard Equipment	0.03
Construction	0.03
Special facilities equipment	0.02
Contingency	
Standard Equipment	0.15
Construction	0.20
Special facilities equipment	0.25

* Future escalation is not included in this study as there is no assumed construction date

Table 3 shows the direct cost analysis for all of the elements of the WBS that are considered to be driver independent. The direct cost of an item is defined as the sum of the material cost; the labor cost; cost of rental, maintenance, and fuel for construction equipment; and a markup for a subcontractor. Cost estimates in Table 3 are qualified under the column called "Note." All the costs in Table 3 are site dependent as the labor rates vary in different locations. If a cost is judged to be site dependent by more than a factor of two, an estimate is still given with an indication of the uncertainty. Other costs have been determined to be driver dependent so estimates are not given here.

The total cost of an item is the sum of the the direct and indirect costs. As shown in Table 4, the indirect costs consist of contractor mark-up; project management costs; engineering, design, and inspection (ED&I); and contingency. The values used for the indirect cost multipliers are taken from Table 2 with some variations based upon engineering judgments about the specific item.

SUMMARY

The standard costing methodology described here addresses the problem of comparing different LMF cost estimates. This methodology lists the items to be included in LMF cost estimates, defines the cost of all driver-independent components, and defines the indirect cost multipliers to be used for the cost estimate. A work breakdown structure has been developed for driver-independent items as a means to subdivide the cost of the LMF. A more detailed work breakdown structures will be needed for each alternative driver concept in order to estimate the total cost of the LMF; these will require conceptual designs for each alternative. The problems associated with normalizing assumptions on projections of technology advancements, future unit costs, and cost scaling are not addressed with this methodology. However, the issues not solved will need to be resolved by other means in order for LMF proposal cost estimates to be compared fairly.

A means of fair comparison of the alternative drivers has been devised. For example, default values of indirect cost fractions have been defined. Variations from these defaults are appropriate if they are done consistently for all driver alternatives.

The cost estimates for the driver-independent elements of the WBS for the LMF are listed in Tables 3 and 4, and the indirect cost multipliers for all items of the WBS are defined. The driver-independent cost estimates and indirect cost multipliers will be subject to change as more details become known about the design of the LMF.

The driver-independent costs of the LMF total approximately $300 million and are not insignificant since the total LMF cost goal is less than $2 billion. It is also expected that the driver and target systems (that have not been estimated) will dominate the cost of the LMF. Based on this [illegible]

TABLE 3
DIRECT COST ANALYSIS

WBS DESIGNATION	DESCRIPTION	NOTE	QUANTITY #	TOTAL MATERIAL COST k$	TOTAL LABOR COST k$	CONSTRUCTION EQUIPMENT COST k$	SUB CONTRACTOR MARK-UP k$	COMPONENT DIRECT COST k$
1.	**LABORATORY MICROFUSION CAPABILITY**							
1.1	SITE IMPROVEMENTS							
1.1.1	Clear and grub	[1,2]	-	-	-	-	-	-
1.1.2	Roads		2000 m	195	95	57	31	378
1.1.3	Parking lot		125 x 250 m	404	164	72	52	692
1.1.4	General land improvements	[1,2]	-	-	-	-	-	-
1.2	BUILDINGS							
1.2.1	Office bldg	[3,4]	1	20000	0	800	600	21400
1.2.2	Target fab bldg	[4]	1	14250	0	570	428	15248
1.2.3	Shops	[4]	3	3000	0	120	90	3210
1.2.4	Laboratories	[4]	3	8000	0	320	240	8560
1.2.5	Support bldgs	[4]	2	4000	0	160	120	4280
1.3	SPECIAL STRUCTURES							
1.3.1	Driver bldg	[2]	1	-	-	-	-	-
1.3.2	Target bldg	[2]	1 or 2	-	-	-	-	-
1.3.3	Oil handling	[2]	-	-	-	-	-	-
1.3.4	Water handling	[2]	-	-	-	-	-	-
1.3.5	Rad waste storage	[4]	1	5000	0	200	150	5350
1.4	SPECIAL EQUIPMENT							
1.4.1	Driver module prototype	[2]	1	-	-	-	-	-
1.4.2	Laser or accelerator	[2]	1	-	-	-	-	-
1.4.3	Driver diagnostics	[2]	-	-	-	-	-	-
1.4.4	Vacuum subsystem	[2]	-	-	-	-	-	-
1.4.5	Alignment subsystem	[2]	-	-	-	-	-	-
1.4.6	Control subsystem	[2]	1	-	-	-	-	-
1.4.7	Gas handling subsystem	[2]	-	-	-	-	-	-
1.4.8	Target chamber	[2]	1 or 2	-	-	-	-	-
1.4.9	Target diagnostics		1	30000	0	0	0	30000
1.4.10	Target fab equip		1	28500	0	0	0	28500
1.4.11	Target assist equip	[4]	-	-	-	-	-	-
1.4.12	Vacuum subsystem	[2]	-	-	-	-	-	-
1.4.13	Remote handling equip		1	5000	0	0	0	5000
1.5	UTILITIES							
1.5.1	Sewage	[1]	1000 m	63	66	18	16	163
1.5.2	Water	[1]	1000 m	30	24	5	2	61
1.5.3	Electrical	[1,4]	-	-	-	-	-	-
1.5.4	Natural gas	[1]	1000 m	13	23	4	4	44
1.5.5	Rad waste disposal	[3]	1	25	0	10	8	43
1.5.6	Liquid He	[3]	1	10	0	2	2	14
1.6	STANDARD EQUIPMENT							
1.6.1	Furnishings	[2]	400	800	0	0	0	800
1.6.2	Communications	[4]	-	1600	0	0	0	1600
1.6.3.1	Computers - mainframes	[2]	2	5000	0	0	0	5000
1.6.3.2	Computers - PCs	[4]	400 PCs	2000	0	0	0	2000
1.6.4	Scientific equip	[4]	-	24000	0	0	0	24000
1.6.5	Mechanical equip	[4]	-	7000	0	0	0	7000

Notes:
[1] Cost is site dependent, which results in more than a factor of two uncertainty.
[2] Cost is driver dependent to more than a factor of five uncertainty.
[3] Cost is based upon offline specs for 400 personnel and may need to be scaled.
[4] Labor cost is combined with material cost.

estimated that the *minimum* cost of the total LMF is probably in the range of one- to two-billion dollars.

ACKNOWLEDGEMENTS

The authors appreciate the contributions of Phillip Goldstone, Douglas Wilson, David Duchene, and John Pendergrass, all of Los Alamos National Laboratory. The authors also acknowledge the effort of the Los Alamos National Laboratory Engineering Division for their valuable estimates of mark-up factors and indirect costs. The contributions of Timothy Henderson and Jon Larson of KMS Fusion, Inc. and Donald Cook of Sandia National Laboratories are also appreciated.

TABLE 4
TOTAL COST ANALYSIS

WBS DESIGNATION	DESCRIPTION	INDIRECT COST MULTIPLIERS RATES PM* %	EDⅈ* %	CONT* %	COMPONENT DIRECT COST k$	CONTRACTOR MARK-UP COST k$	INDIRECT COSTS AND SUBTOTALS SUB TOTAL k$	PM COST k$	EDⅈ COST k$	CONTINGENCY COST k$	COMPONENT TOTAL COST k$
1.	LABORATORY MICROFUSION CAPABILITY										
1.1	SITE IMPROVEMENTS										
1.1.1	Clear and grub	3.0	15.0	20.0	-	-	-	-	-	-	-
1.1.2	Roads	3.0	15.0	20.0	378	95	473	14	71	95	653
1.1.3	Parking lot	3.0	15.0	20.0	692	174	866	26	130	174	1196
1.1.4	General land improv	3.0	15.0	20.0	-	-	-	-	-	-	-
1.2	BUILDINGS										
1.2.1	Office bldg	3.0	15.0	20.0	21400	5350	26750	802	4012	5350	36914
1.2.2	Target fab bldg	3.0	20.0	25.0	15248	3812	19060	570	3812	4767	28209
1.2.3	Shops	3.0	15.0	20.0	3210	803	4013	120	602	803	5538
1.2.4	Laboratories	3.0	20.0	20.0	8560	2140	10700	321	2014	2014	15049
1.2.5	Support bldgs	3.0	15.0	20.0	4280	1070	5350	161	803	1070	7384
1.3	SPECIAL STRUCTURES										
1.3.1	Dr vr/ Bldg	5.0	15.0	20.0	-	-	-	-	-	-	-
1.3.2	Target bldg	4.0	20.0	25.0	-	-	-	-	-	-	-
1.3.3	Oil handling	3.0	15.0	20.0	-	-	-	-	-	-	-
1.3.4	Water handling	3.0	15.0	20.0	-	-	-	-	-	-	-
1.3.5	Rad waste storage	3.0	20.0	25.0	5350	1445	6795	204	1359	1699	10057
1.4	SPECIAL EQUIPMENT										
1.4.1	Drive module prototype	3.0	25.0	30.0	-	-	-	-	-	-	-
1.4.2	Laser or accelerator	2.0	10.0	25.0	-	-	-	-	-	-	-
1.4.3	Driver diagnostics	2.0	10.0	25.0	-	-	-	-	-	-	-
1.4.4	Vacuum subsystem	2.0	10.0	25.0	-	-	-	-	-	-	-
1.4.5	Alignment subsystem	2.0	15.0	25.0	-	-	-	-	-	-	-
1.4.6	Control subsystem	3.0	20.0	20.0	-	-	-	-	-	-	-
1.4.7	Gas handling subsystem	2.0	10.0	25.0	-	-	-	-	-	-	-
1.4.8	Target chamber	5.0	20.0	30.0	-	-	-	-	-	-	-
1.4.9	Target diagnostics	4.0	25.0	30.0	30000	8100	38100	1524	9525	11430	60579
1.4.10	Target fab equip	3.0	15.0	25.0	28500	7695	36195	1083	5429	9049	51756
1.4.11	Target assmt equip	4.0	20.0	30.0	-	-	-	-	-	-	-
1.4.12	Vacuum subsystem	2.0	10.0	25.0	-	-	-	-	-	-	-
1.4.13	Remote handling equip	2.0	20.0	30.0	5000	1350	6350	127	1270	1905	9652
1.5	UTILITIES										
1.5.1	Sewage	3.0	15.0	20.0	163	41	204	6	31	41	282
1.5.2	Water	3.0	15.0	20.0	61	15	76	2	11	15	104
1.5.3	Electrical	3.0	15.0	20.0	-	-	-	-	-	-	-
1.5.4	Natural gas	3.0	15.0	20.0	44	11	55	2	8	11	76
1.5.5	Rad waste disposal	4.0	15.0	25.0	43	11	54	2	8	11	75
1.5.6	Liquid He	3.0	10.0	15.0	14	3	17	1	2	3	23
1.6	STANDARD EQUIPMENT										
1.6.1	Furnishings	3.0	0.0	15.0	800	0	800	24	0	120	944
1.6.2	Communications	3.0	0.0	15.0	1600	0	1600	48	0	240	1888
1.6.3.1	Computers - main/remote	3.0	0.0	15.0	5000	1250	6250	188	0	938	7118
1.6.3.2	Computers - PCs	1.0	0.0	10.0	2000	0	2000	20	0	200	2220
1.6.4	Scientific equip	3.0	0.0	20.0	24000	6480	30480	914	0	6096	37490
1.6.5	Mechanical equip	3.0	0.0	15.0	7000	1750	8750	263	0	1313	10326

PM = Project management
EDⅈ = Engineering, design, and inspection
CONT = Contingency

REFERENCES

1. D. J. Dudziak, D. B. Harris, and J. H. Pendergrass, "Goals, Requirements, and Desirable Characteristics of the LMF Inertial Fusion Driver," 12th IEEE Symposium on Fusion Engineering, Monterey, California, 12-16 October 1987.

2. R. E. Olson, "Conceptual Design of a 10 MJ Driver for a High Gain Target Development Facility (LIFE)," 12th IEEE Symposium on Fusion Engineering, Monterey, California, 12-16 October 1987.

3. J. H. Pitts, "Using the Nova Target Chamber for High Yield Targets," 12th IEEE Symposium on Fusion Engineering, Monterey, California, 12-16 October 1987.

4. M. T. Tobin, "Neutronics Issues for a Laboratory Microfusion Capability," 12th IEEE Symposium on Fusion Engineering, Monterey, California, 12-16 October 1987.

5. W. J. Hogan, "Design Issues for a High Gain Fusion Facility: Implications of Recent Program Results," 12th IEEE Symposium on Fusion Engineering, Monterey, California, 12-16 October 1987.

6. C. Orth, "Calculations of Ablated Mass and Ablation Momentum Transfer for the First Walls of ICF Facilities," Bulletin of the American Physical Society, 32, 9, 1788 (1987).

7. W. J. Hogan, "Target Chamber Design Issues for a High-Gain Inertial Fusion Test Facility," Bulletin of the American Physical Society, 32, 9, 1788 (1987).

8. D. B. Harris and D. J. Dudziak, "Major Cost Factors," Los Alamos National Laboratory report LA-UR-87-4142 (December 1987). Prepared for inclusion in the Laboratory Microfusion Facility Phase I Final Report.

9. "Dual-Axis Radiographic Hydrotest Facility: Conceptual Design Report," Los Alamos National Laboratory document ENG- CD-82.13, revised March, 1986.

10. "SSC Conceptual Design Cost Estimate Details," prepared by the SSC Central Design Group, report SSC-SR-2020D (March, 1986).