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Report No. 12486A
Cost Addendum

Laser Fusion Systems Design Study

Final Technical Report

UNIVERSITY OF CALIFORNIA
Lawrence Livermore Laboratory

13640

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Final Technical Report

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COST ADDENDUM

This document is an addendum to Perkin-Elmer Report No. 12486, Final Technical Report, Laser Fusion System Analysis, prepared under University of California, Lawrence Livermore Laboratory Contract No. 5379315. Contained herein are the budgetary cost estimates prepared for the baseline design described in the Final Technical Report. Cost tradeoffs performed during the study are covered in paragraph 4.

1. SYSTEM SUBASSEMBLY DEFINITION

Figure 1 is a breakdown of the major SHIVA alignment and wavefront control system assemblies and subassemblies. The number next to each item represents the number of these subassemblies proposed for the baseline system.

2. BASES FOR PRICING ESTIMATES

For pricing purposes a three-phase program was assumed as follows:

Phase I: Design and Development

During this phase concepts are refined and design of all hardware is completed. All assembly, subassembly, and detail drawings are prepared. Component and sub-system specifications for all purchase items are completed. Prototype test plans are prepared and necessary test fixtures are designed. Included also is a detailed design review and subsequent revisions to the design.

Phase II: Prototype Construction and Testing

This phase covers both prototype construction and prototype testing.

Phase II commences with the release of drawings and specifications for purchase or manufacture. It is intended during this phase to construct all the

Figure 1. SHIVA Alignment and Wavefront Control System
Major Assemblies and Subassemblies

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hardware needed for alignment and wavefront control of a single laser chain. This includes:

- The oscillator alignment subsystem
- One beam-centering subsystem
- One turning mirror gimbal and gimbal controller
- One alignment sensor assembly
- One deformable mirror and controller
- The path length control system sensor with one actuator and controller
- The data processing and control subsystem sufficiently complete to be able to control one chain.
- Construction of prototype test fixtures

Software for the implementation of control algorithms will be written.

The prototype will then be tested at Perkin-Elmer. Since complete testing of the pointing and focusing subsystem requires a focus drive assembly and suitable surrogate targets, it is assumed that this will be provided. Each subassembly will be tested to assure conformance to performance specifications. A full-up system test demonstration will be performed showing operation of all automatic functions and proper software implementation.

At the completion of the tests any necessary design modifications will be made to affected drawings and specifications.

Phase III: Fabrication of 20 Units

This phase consists of upgrading of prototype hardware for use on the SHIVA, fabrication and subassembly testing of the hardware for the remaining 19 chains, refining of computer software for control of all 20 chains.

Provision has also been made for integration of the alignment and control hardware with the SHIVA laser facility at LLL plus subsequent field service.

3. BUDGETARY ESTIMATE FOR BASELINE SYSTEM

Budgetary price breakdown for the three phases is given in Table I. Prices listed under Phases I and II can be regarded as fixed costs per arm while price under Phase III, with the exception of system integration and field service, can be considered variable with the number of arms. The cost per arm listed is for a 20-arm system.

Two options are shown. Option A allows for the addition of individual controllers for the 37-actuator deformable mirror. This represents a convenience option that permits setting of the deformable mirror without switching the controller output cable from mirror to mirror. Option B presents the cost reduction obtainable, at the expense of system flexibility, by replacing the deformable mirror with a fixed corrector. Option B is not recommended.

Additional performance improvement can be obtained by using a larger number of actuators behind the deformable mirror. Figure 5 in the following paragraph treats the cost impact per arm resulting from this upgrading.

4. PERFORMANCE VERSUS COST TRADEOFFS

The following paragraphs summarize the results of various cost versus performance tradeoffs that were performed during the study.

4.1 Wavefront Phase Correction

A cost tradeoff comparing performance of a fixed corrector versus a deformable corrector was performed. The results are presented graphically in Figures 2 through 5.

Figure 2 shows estimated costs of a fixed corrector turning mirror as a function of its performance. This curve was based on the fabrication of a corrector by numerically controlled polishing techniques having peak-to-valley surface variations of 3.0 wavelength at 1.06 μm at spatial frequencies

TABLE I. BUDGETARY ESTIMATE FOR BASELINE SYSTEM

Task	Number Proposed System (20 Arms)	Phase I	Phase II	Phase III	Total	Cost Per Arm	Option A		# of Corrections	Option B		Cost Per Arm
							Add Number	Price Add		Delete	Cost Per Arm	
<u>Goniometer Alignment</u>	1	108	92		200	10.0						
<u>Beam Centering:</u>												
Translation Sensor	20	23	27	128	178	8.9						
and Electronics		12	15	30	57	2.9						
Fold Mirror Gimbals	20	11	12	98	121	6.1						
and Controllers												
<u>Pointing and Focusing</u>												
Turntable Mirror Gimbals	20	40	31	381	462	23.1						
and Controllers												
<u>Alignment Sensor</u>	20	59	51	466	576	28.8						
<u>Wavefront Control</u>												
Deformable Mirror	20	42	89	385	496*	24.8						20.1
Actuator Controllers	1						19	305	20	(94)		
<u>Optical Path Control</u>												
Scatter Assembly	1	25	18	60	103	5.2						
Path Length Actuators	1	13	12	25	25							
and Controllers	20	12	6	60	78							
<u>Data-Proc. and Control</u>												
CPU and Peripherals	1	61	115	135	311	15.6						
Interface and Elec.	1											
Control and Display	1											
Power Supply	1											
Console	1											
Remote Meter	1											
Cables	AR											
Shutters	20											
<u>System Integration</u>	N/A			45	45							
Field Service	N/A		108	27	27							
<u>Program Management</u>	N/A	17		11	136							
TOTAL		375	531	1028	2534			2830				2440

includes price of 1 set of
actuator controllers
Option A - Add individual
controllers for
each deformable
mirror
Option B - Use fixed correctors only

Figure 2. Cost of Fixed Corrector Versus Performance

Figure 3. Estimated Cost of Refiguring Based on the Initial Departure from the Designed Figure

Figure 4. Accrued Cost of Mirror Not Including Removal and Installation

Figure 5. Deformable Mirror Performance and Cost as a Function of Number of Actuators

of 2 cycles per mirror diameter. Once the fixed corrector has been made, refiguring to provide a new phase correction profile may be necessary. Figure 3 plots the estimated cost of refiguring based on the initial departure from the desired figure. From these data the accrued cost of the corrector mirror was estimated for various correction magnitudes. These data are shown in Figure 4. It should be noted that the costs presented for figuring or refiguring the fixed correctors do not include costs of measurement of the wavefront for each arm of the SHIVA or costs of removing, shipping, and reinstalling the mirrors in their respective arms. Measuring of the wavefront error when a fixed corrector is used requires an interferometric analysis of the wavefront as was described in Section VIII of the report.

Figure 5 presents cost estimates as a function of number of actuators for a deformable mirror of the design described in Section VIII of this report. It is to be noted that the cost per mirror rises linearly with the number of actuators. This curve can be used to estimate the cost of wavefront improvement.

4.2 Alignment Sensing: Photon Bucket vs. Imaging Sensor

A cost comparison between two alignment sensing schemes discussed in Section III of the Technical Report was performed. This tradeoff was an important factor in selecting the "photon-bucket" sensing approach of the baseline system. The cost comparison between the two systems is shown in Table II.

These comparisons and estimates do not include design, development or prototyping costs. These are expected to bear a similar relationship in cost between the two techniques.

4.3 Focus Lens Designs

In Appendix F various focus lens designs were evaluated. These were investigated to determine the effects of beam translation on image quality. Cost comparisons of these designs were also made. These are summarized in Table III.

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TABLE II. COST COMPARISON

<u>Cost Element</u>	<u>Relative Costs</u>	
	<u>Photon Bucket</u>	<u>TV Sensor</u>
Condensing Lens	1	1.8
Detector and Electronics	1	2.25
Housing and Structure	1	1
Logic and Control Electronics	1	3.5
Total Sensor	1	2.14

	<u>Estimated Price</u>	
	<u>Photon Bucket</u>	<u>TV Sensor</u>
One Arm	\$23.3K	\$50.0K
Total (20 Arms)	\$ 466K	\$1,000K

TABLE III. BUDGETARY COST COMPARISON OF CANDIDATE SHIVA FOCUS LENSES

Configuration	Dwg. 660-	Cost for Qty. of 20 Units				Unit Cost	Relative Unit Cost
		Labor	Mat'ls	Tooling	Total		
BK7 Spherical Singlet	3201 Without Aspheric	\$ 45K	\$ 49K	\$ 6K	\$100K	\$ 5K	0.4
BK7 Aspherical Singlet	3201	120K	49K	11K	180K	9K	0.7
BK7 Aspherical Singlet + Window	3204	160K	90K	14K	264K	13K	1.0
BK7 Aspherical Doublet	3202	160K	90K	17K	267K	13K	1.0
Replacement Window	3204 Second El. Only	40K	41K	-	81K	4K	0.3
Replacement Lens	3202 Second El. Only	42K	57K	-	99K	5K	0.4

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