Evaluation Methodology

for Comparing Laser and Heavy Ion PROMETHEUS

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IFE Project Meeting, November 18, 1991 at TRW

Action Items for Evaluation Methodology

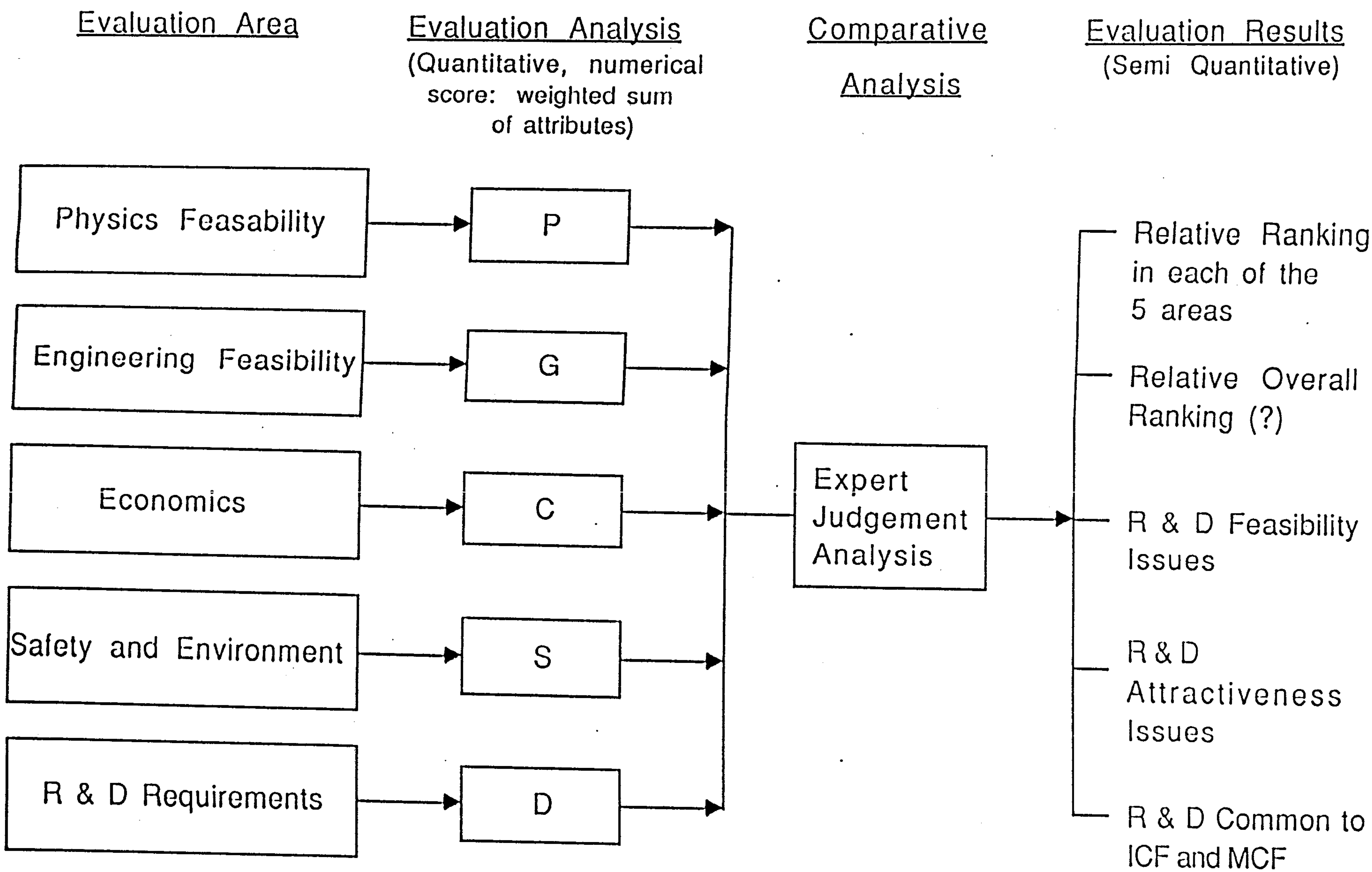
1. Form Evaluation Methodology Group (responsible for reviewing Methodology, performing the comparison and writing Chapter VII of the final report.

   M. Abdou (Group Leader)
   L. Waganer
   D. Drake
   D. Driemeyer
   G. Linford
   S. Marschke
   M. Tillack
   A. Ying
   D. Lee

2. Responsibilities (For the comparison by Evaluation Area)
   Physics Feasibility (Linford, Driemeyer, Drake)
   Engineering Feasibility (Tillack, Lee, Ying)
   Economics (Waganer)
   Safety and Environment (Marschke, Ying)
   R & D Requirements (Abdou)

3. Each Evaluation Area Leader:
   - Review and suggest changes (and develop missing details if any) to M. Abdou by December 3, 1991
   - Coordinate (start immediately) all input required from team members.

Fig. 1: Evaluation Methodology Approach



Economics

- Overall Figure of Merit is Cost of Energy
- Separate document describes details of costing and economic analysis

Evaluation Methodology for
R & D Requirements

- Focus for now is on R & D required to resolve the issues

- The R & D Figure of Merit amounts for three important areas:

1) Cost

   a. average annual operating cost
   b. capital cost of required facilities (new or upgrades)

2) Time

   total time to complete the R & D

3) Risk

   measure of relative risk is not successfully resolving key issues weighed by the potential consequence of negative results

Figure of Merit for R & D

$$RD = W_c R_c + W_t R_t + W_r R_r$$

R_c = Figure of merit for cost

R_t = Figure of merit for time

R_r = Figure of merit for risk

W_c, W_t, W_r = weighting factors

1) Cost (R_c)

$$R_c = 0.5\,(A + F)$$

A = score for average annual operating cost

F = score for capital cost of required facilities

Average Annual Operating Cost	Score A	Capital Cost of Required Facilities*	Score F
> $100 M	1	> $500 M	1
$50 - 100 M	2	$200 - 500 M	2
< $50 M	3	< $200 M	3

* Summation for all key issues

* Specific $ numbers for categories may change depending on the issues included and the purpose of comparison

2) <u>Time</u> (R_t)

Time is the longest time required to resolve the issues. It is either cumulative time for sequential task or the longest time for parallel tasks.

Time Scale	Score R_t
> 30 yr	1
15 - 30 yr	2
< 15 yr	3

3) Risk (R_r)

- The figure of merit R_r accounts for the probability of not resolving the key issues and the consequence of negative results.

$$R_r = \frac{1}{3n} \sum_{i=1}^{n} P_i \, C_i$$

where n = number of key issues

- The Fa Dividing by the Factor 3n ensures the maximum score for R_r is 3

- P_i is the probability of not resolving the issue (negative result)

Relative Probability	P_i
unlikely	3
even (50/50)	2
likely	1

- C_i is the consequence of not resolving the issue (i.e. of negative results)

Relative Consequence	C_i
severe impact	3
moderate impact	2
low impact	1

Fig. 2: Safety and Environment Evaluation Approach

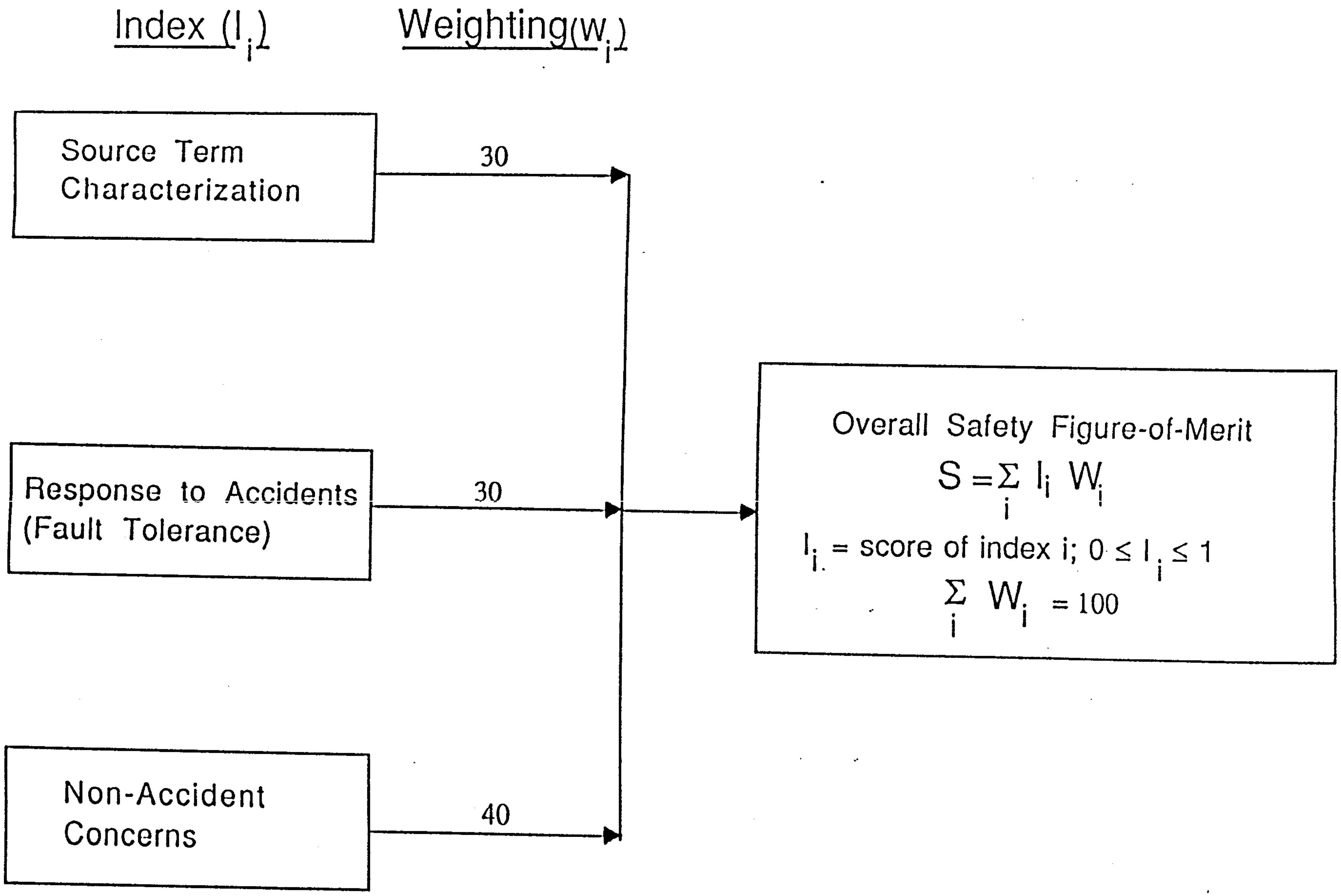
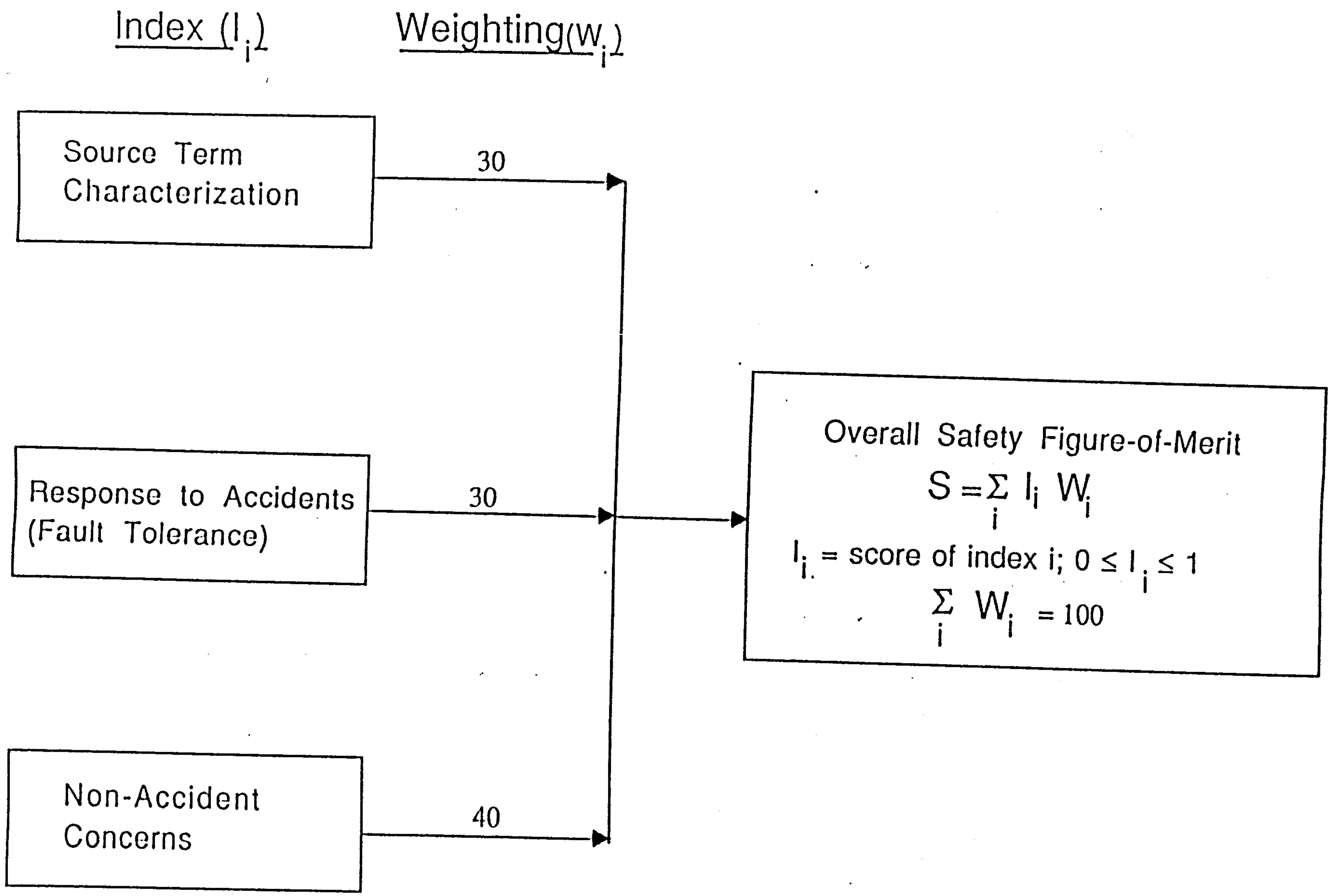


Fig. 2: Safety and Environment Evaluation Approach



Safety and Environmental Evaluation Categories

	ω_j	(Laser) f_j	(HI) f_j
Source Term Characterization (Score=I_S,W_S=30%)			
Source Term in Target Factory	0.2		
Source Term in the the First Protection Chamberwall	0.2		
Source Term in the breeding blanket and shield	0.2		
Source Term in the driver	0.2		
Non-radiological sources (e.g fluorine)	0.2		
Sum of weighted Score for Source Term $I_S = \Sigma\ f_j\ \omega_j$	//////////////		
Response to Accidents (Fault Tolerance) (Score=I_R,W_R=30%)			
Response to LOCA and LOFA in the first protection chamberwall	0.15		
Response to LOCA and LOFA in the breeding blanket and shield	0.15		
Response to beam pellt misfire accident in the chamberwall	0.15		
Response to loss of coolant in the final optics or focusing magnet or vacuum pumping system	0.15		
Fault tolerance to loss of T_2 and D_2 containers	0.10		
Fault trolerance to containment integrity	0.10		
Fault tolerance to target factory integrity	0.10		
Fault tolerance to driver system	0.10		
Sum of weighted score for Response to Accidents (Score=$I_R = \Sigma\ \omega_j f_j$	//////////////		
Non-Accident Concern (Score=I_N,W_N=40%)			
Occupational exposure (regular, maintenance)	0.25		
Routine Radioactive emission rate	0.25		
Waste Disposal (radiological, hazardous, mixed)	0.2		
Non-radiological hazards (florine, lead)	0.15		
Heat Dissipation	0.10		
Construction impacts	0.05		
Sum of Weighted Score for non-accident concerns $I_N = \Sigma\ f_j\ \omega_j$	//////////////		
Overall Safety Figure of Merit=W_S,I_S,$W_R I_R$,+ W_N,I_N	//////////////		

<u>Engineering Feasibility Evaluation Indices</u>

Index Name	Weighting Value (ω_i)	Score(I_i) Laser	HI
1. Tritium self-sufficiency, control, and recovery	15		
2. Fusion reaction support systems requirements	20		
3. High erosion and heat flux /Wall Protection components	10		
4. Engineering complexity and fabrication requirements	20		
5. Maintenance and repair	10		
6. Startup/shutdown	5		
7. Potential for inherent safety	10		
8. Potential for low long-term activation	10		
9. Overall Figure of Merit			

Engineering Feasibility Overall Figure of Merit = $\sum I_i W_i$

Tritium Self-Sufficiency, Control, and Recovery Subcategory

Sub-index (i)	Weighting (ω_i)	Score Laser	Score HI
Self Sufficiency Margin	40		
Tritium Permeation	20		
Tritium Recovery from Blanket, Coolant, Wall Protection	20		
Unburned Tritium Recovery(target debris, reaction chamber)	20		
	100		

Tritium Self-Sufficiency Score sub-index I_T

$$I_T = \sum_i \beta_i \omega_i$$

β_i = Score of sub-index i

$0 \leq \beta_i \leq 1$

Fusion Reaction Support System Requirements

Sub-index	Weight

- Driver
  Efficiency
  Cost
  Pulse repetition
  Driver energy
  Target coupling
  Reliability

- Target
  Illumination Requirements
  Tracking and survivability
  Mass production techniques and cost
  Quality control

- Cavity clearing and vacuum

High Erosion and Heat Flux/Wall Protection Components

Sub-index	Weighting
- Ability to accommodate the pulsed irradiation and stress cycling resulting from successive target microexplosions	
- Provision for an appropriate environment to allow efficient transport of the driver beam from the final driver element to the point of interception with the target	

Engineering Complexity and Fabrication Requirements Subcategory

Sub-index (i)	Weighting (ω_i)	Score = 1 if
Subsystem modularity		highest modularity
Machine interface		least interface
Components interlocking		least interlocking
Combining functions		highest possibility
Vacuum volume requirement		least volume required
Welding/brazing requirements		least requirements
Machining tolerance/precision		least precision required

$$I_E = \sum_i \beta_i \omega_i \qquad \beta_i = \text{Score of sub-index } i$$

$$0 \leq \beta_i \leq 1$$

Startup/shutdown Operation Subcategory

Sub-index	Weighting
A. I & C system requirements for each subsystem Parameters for measurements and operating ranges Adequate sensoring methods to cover each range Sensors communication relationship Sensor size, sensitivity, efficiency, response time and resistance to radiation damage	
B. Allowable rate of changes in operating parameter Engineering constraints Physics constraints Tritium constraints	
C. Additional auxillary subsystems required	
D. Required signal processing and reactor shutdown initiation	

Maintenance and Repair Subcategory

Sub-index	Weighting
A. Desirable Maintainability Features	60

(1) Use maximum contact maintenance while minizing added shielding requirements
(2) Minimize vacuum chamber welded or sealed joints between modules
(3) Provide redundancy of methods
(4) Maximize replacement rather than repair in place
(5) Use minimum number of connections for component replacement, particularly fluid connections
(6) Maximize concurrent replacement of subsystem components
(7) Maximize module size for scheduled replacement
(8) Minimize module size for unscheduled replacement

B. Summary of optimum maintenance procedures	40

(1) Plant availability
(2) Annular personnel exposure