

UCLA Activities and Proposed Work On the IFE Development Plan

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Outline

- A. Summary of LLNL/UCLA Meeting on
June 7, 1995 at UCLA
- B. Near Term Effort on IFE Development
Plan

Presented at the IFE Technology Meeting,
July 27-28, 1995

Summary of LLNL/UCLA Meeting at UCLA June 7, 1995

- LLNL/UCLA interaction on the IFE development plan has been productive and it will help improve the plan. Our goal should be a plan that 1) can help guide R&D, and 2) will withstand scrutiny.
- Several comments made by UCLA regarding the plan were discussed with LLNL group. The main points raised during the discussion and further discussed in a response sent by LLNL group to UCLA on June 16, 1995 include:

1. DEMO Goal and Definition:

It was agreed that further effort should be made to clearly define the goals and characteristics of DEMO. The definition should be clearly stated in the plan.

Summary of LLNL/UCLA Meeting at UCLA

(Cont'd)

2. Availability/Reliability Assessment of Components and Interface with the Development Plan:

It was agreed that some in-depth work to be started on assessment of failure modes and availability/reliability of various components in order to develop more sound engineering development plan. Reliability estimates of a) goals, and b) what is likely to be achieved for IFE components should be examined.

3. Plan for Chamber Technology Development:

As it stands now, the plan does not specify the details of the Chamber Technology Development Path. UCLA would develop a comprehensive chamber technology development plan for the IFE chamber concepts. [At least, two generic lines of chamber technology development activities need to be specified].

Summary of LLNL/UCLA Meeting at UCLA

(Cont'd)

4. Staging vs. Independent Sequential Facilities:

- The plan, as it stands now, is based on our current understanding of engineering and physics issues involved. As technologies develop over 30-yr period other routes for R&D may be more appropriate. The staged one facility approach limits flexibility.
- Staging development plan as presently envisioned might be feasible for Linac driver; however, the upgradability for recirculators could be difficult.
- The specific development path should be tailored to the specific driver.
- Advantages and disadvantages of staging vs. sequential independent facilities should be evaluated.

Summary of LLNL/UCLA Meeting at UCLA

(Cont'd)

5. Alternative Approaches to IFE Development (e.g., smaller-size less costly development steps)

- IFE development can be fundamentally different from MFE if a 100 MWe DEMO is possible.
- Previous study has shown that gains of 10-20 at driver energies between 1 and 2 MJ and 2 GeV design (100 MWe) offer an attractive development pathway.

6. Activation and Remote Maintenance

It was agreed that an effort should be devoted to addressing these two items in the IFE development plan.

Near Term Effort on IFE Development Plan

1. DEMO Goal and Definition

- Top Level Mission Requirements
- Specific Goals for performance parameters of DEMO components (such as Chamber). These goals for components are necessary to define development pathways.

Example DEMO Chamber Component (Minimum)
Performance Requirements (Working Draft)

Parameter	Value
X-ray energy, MJ/m ²	> 0.2 (HYLIFE II: 17)
Debris energy, MJ/m ²	0.4 - 0.5
Neutron wall load, MW/m ²	2 -3
Radiation heat load, MJ/m ²	
Isochoric heating, J/g	100
Impulse,MPa (Instaneous,Average)	30x10 ³ , <1
Repetition rate, Hz	5
Availability (MTBF, MTTR)	0.95(1 FPY, 2.5 weeks)
Tritium fuel cycle	Self sufficiency
Lifetime neutron fluence goal, MWy/m ²	10- 20
Environmental consideration	Low activation materials
Thermal efficiency	> 30%

TOP LEVEL MISSION REQUIREMENTS FOR DEMO

Rev D. 2/2095

Requirement	Demo	Commercial	Mission Statement
• Must use technologies to be employed in Commercial Plant	Yes	Yes	1. Tech/Perf
• No Evacuation Plan required	1 rem Total Dose at Site Boundary	1 rem Total Dose at Site Boundary	4. Licensable
• Generate no Radioactive Waste greater than:	Class C	Class C	5. Waste Disposal
• Must Demonstrate Public's day-to-day activities not disturbed	Yes	Yes	4. Safety
• Must not Expose Workers to a higher risk than other power plants	Yes	Yes	4. Safety
• Demonstrate a Closed Tritium Fuel Cycle	Yes	Yes	1. Tech/Perf
• Net Electric Output must greater than:	75% of Commercial	Not Applicable	2. Scalability
• Must Demonstrate Operation at Partial Load Conditions	50%	50%	10. Operability
• Demonstration of Robotic or Remote Maintenance of Power Core	Yes	Yes	8. Maintainability
• Must Demonstrate Routine Operation with less than Unscheduled Shutdowns/yr including disruptions	1	1/10	10. Operability
• Cost of Electricity must be competitive (in 1995 \$)	(Goal) 80 mil/kWh (Reqmt) 90 mil/kWh	65 mil/kWh 80 mil/kWh	3. Economics

Page 1

GOALS FOR THE DEMONSTRATION POWER PLANT

Rev D. 2/2095

- Plant should be simple to operate (No more than 10 people/shift?)
- Demonstrate recycle of radioactive and hazardous materials
- Demonstrate high level of investment safety
- Keep exposure and release of radioactive materials "As Low As Reasonably Achievable (ALARA)"
- Demonstrate Load Following Capability

Page 2

TOP LEVEL MISSION REQUIREMENTS FOR DEMO
Subtier Requirements Included

Rev D, 2/2095

<u>Requirement</u>	<u>Demo</u>	<u>Commercial</u>	<u>Mission Statement</u>
• Must use technologies to be employed in Commercial Plant	Yes	Yes	1. Tech/Perf
• No Evacuation Plan required	1 rem Total Dose at Site Boundary	1 rem Total Dose at Site Boundary	4. Licensable
• Generate no Radioactive Waste greater than:	Class C	Class C	5. Waste Disposal
• Demonstrate a Closed Tritium Fuel Cycle	Yes	Yes	1. Tech/Perf
• Demonstrate Adequate Net Breeding Ratio greater than:	1.01	1.01	3. Economics
• Demonstrate Complete Recovery, Storage, and Fueling System	Yes	Yes	1. Tech/Perf
• Net Electric Output must greater than:	75% of Commercial	Not Applicable	2. Scalability
• Must Demonstrate Operation at Partial Load Conditions	50%	50%	10. Operability
• Demonstration of Robotic or Remote Maintenance of Power Core	Yes	Yes	8. Maintainability
• Complete Removal of First Wall, Blanket and Divertor	Yes	Yes	8. Maintainability
• Removal of one TF Coil, PF Coil, and section of Vacuum Vessel	Yes	All if required	8. Maintainability
• Must Demonstrate Routine Operation with less than Unscheduled Shutdowns/yr including disruptions	1	1/10	10. Operability
• Cost of Electricity must be competitive (in 1995 \$)	(Goal) 80 mill/kWh (Reqmt) 90 mill/kWh	65 mill/kWh 80 mill/kWh	3. Economics 3. Economics
• Capital Cost less than:	\$5000M	\$4000M	3. Economics
• Operating and Maintenance Cost less than:	\$120M	\$80M	3. Economics
• Plant Availability greater than:	87% (for 3-4 y)	90%	9. Availability
• Gross Thermal Efficiency greater than:	46%	48%	1. Tech/Perf
• Recirculating Power less than:	120 MW	100 MW	1. Tech/Perf
• Must be Constructed (and Licensed) in this period:	Alternate Method: < 15% of Gross 5 y	< 10% of Gross 4 y	1. Tech/Perf 3. Economics

TOP LEVEL MISSION REQUIREMENTS FOR DEMO (Continued)
Subtier Requirements Included

Rev D, 2/2095

<u>Requirement</u>	<u>Demo</u>	<u>Commercial</u>	<u>Mission Statement</u>
• Must Demonstrate Public's day-to-day activities not disturbed	Yes	Yes	4. Safety
• Must not Expose Workers to a higher risk than other power plants	Yes	Yes	4. Safety

<u>Radiological Requirements</u>		<u>Public</u>	<u>Facility Worker</u>
<u>Description of Event</u>	<u>Probability of Occurrence/y</u>	<u>Off-site Level (rem)</u>	<u>On-site Level (rem)</u>
Normal and Anticipated Operational Occurrences	$10^{-2} \leq P \leq 1$	-0.01/y ^(a)	5/y ^(c)
Unlikely Event	$10^{-4} \leq P \leq 10^{-2}$	1/Event ^(b)	5/Event ^(b)
Extremely Unlikely Event	$10^{-6} \leq P \leq 10^{-4}$	1/Event ^(b)	5/Event ^(b)

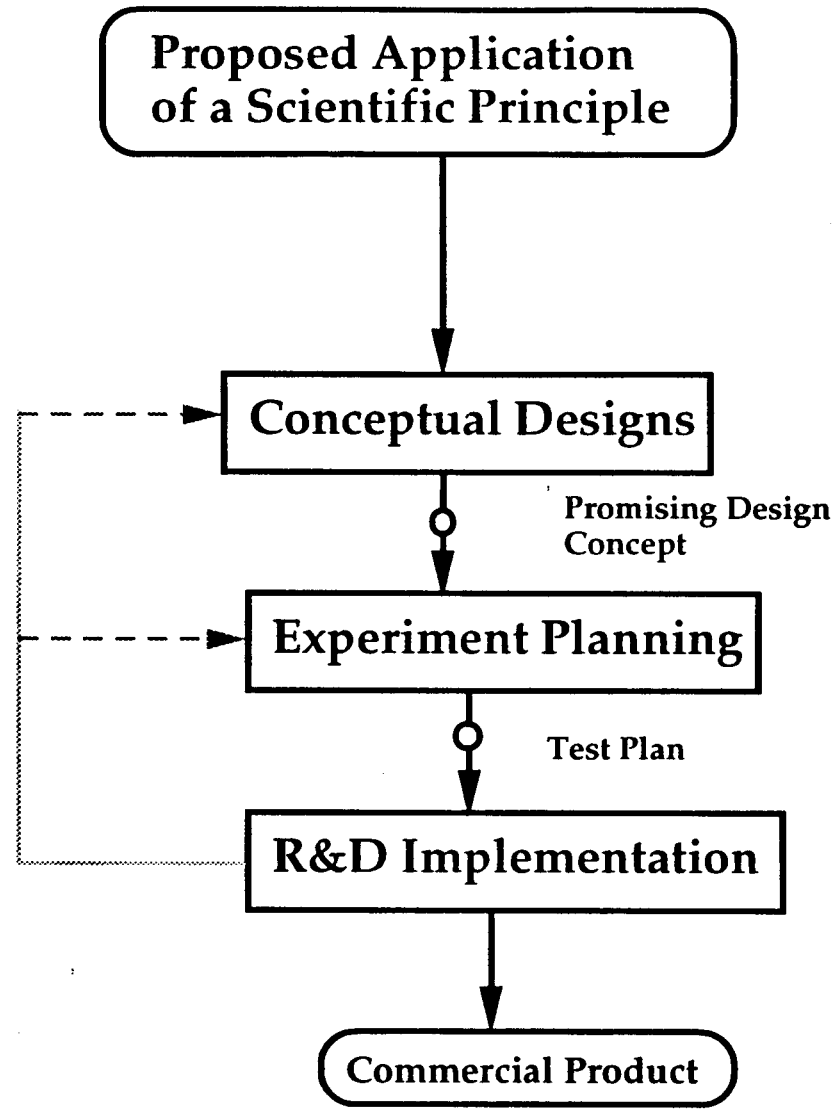
a According to 10CFR30 Appendix I, Acceptable Annual Dose is in range 0.003-0.015 rem depending on Inm of effluent & affected organ.
b To avoid sheltering or evacuation, dose per event cannot exceed 1 rem (EPA-520/1-75-001) at site boundary.
c Consistent with 10CFR20.
d Consistent with 10CFR33.1302, however, on certain activities (lifesaving/protection of large populations) higher doses are permitted.

<u>Toxic Material Requirements^a</u>		<u>Public</u>	<u>Facility Worker</u>
<u>Description of Event</u>	<u>Probability of Occurrence/y</u>	<u>Off-site Level</u>	<u>On-site Level</u>
Normal and Anticipated Operational Occurrences	$10^{-2} \leq P \leq 1$	PEL-TWA $2 \times 10^{-6} \times \text{ICR}$	ERPG-1 $2 \times 10^{-4} \times \text{ICR}$
Unlikely Event	$10^{-4} \leq P \leq 10^{-2}$	ERPG-1 $2 \times 10^{-4} \times \text{ICR}$	ERPG-2 $2 \times 10^{-2} \times \text{ICR}$
Extremely Unlikely Event	$10^{-6} \leq P \leq 10^{-4}$	ERPG-1 $2 \times 10^{-4} \times \text{ICR}$	ERPG-2 $2 \times 10^{-2} \times \text{ICR}$

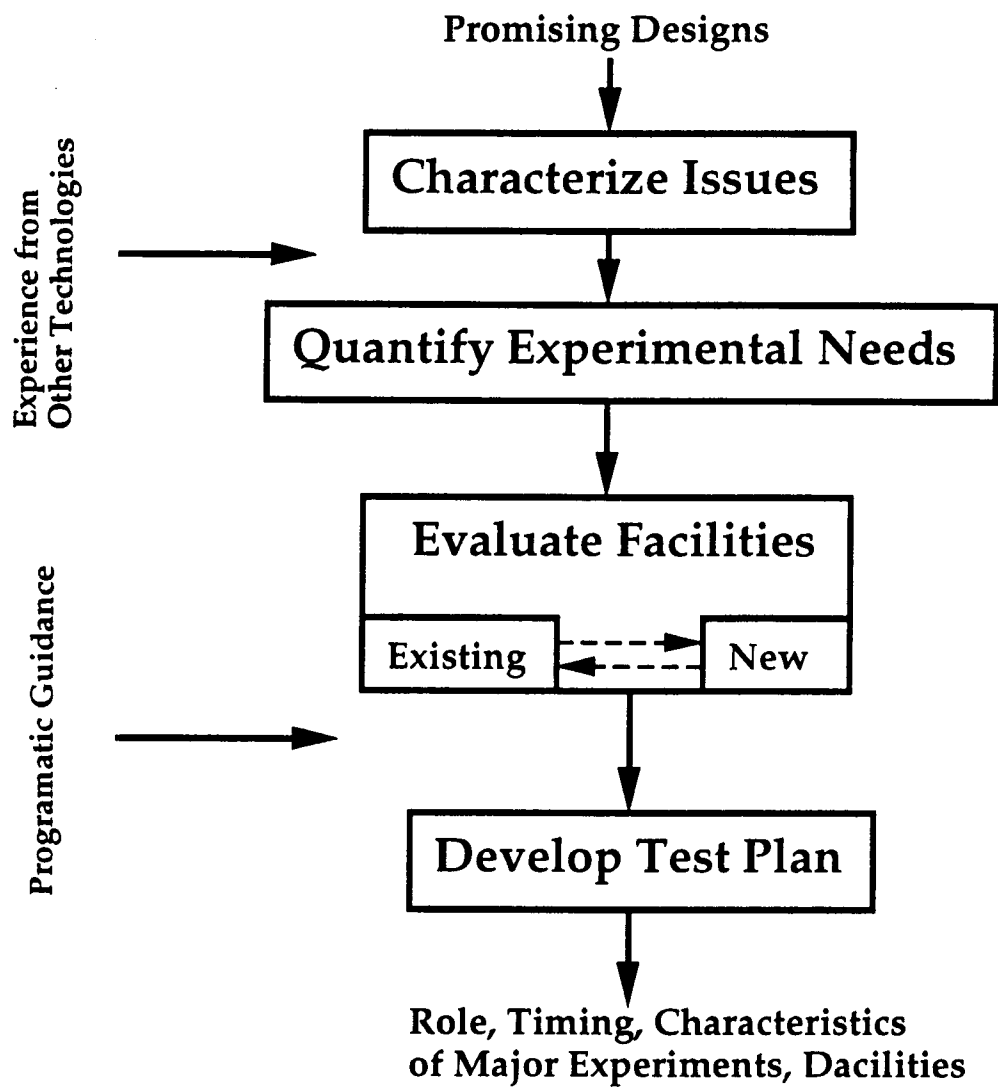
^a ERPG-1,2,3 refer to emergency response planning guidelines for the toxic material published by the American Industrial Hygiene Association (AIHA). PEL-TWA is time weighted average of permissible exposure limits of toxic material. ICR is the probability based incremental cancer risk guidelines based on EPA's IRIS database

<u>Static Electromagnetic Field Exposure Limits^(a,b)</u>		<u>Facility Worker</u>	
<u>Magnetic Field</u>	<u>Exposure Time</u>	<u>Body Region</u>	<u>Comments</u>
0.06 Tesla	Continuous 8 hour day	Trunk	max ave/d in peak fields > 0.5 T or ave/w in peak fields < 0.5 T
0.6 Tesla	Continuous 8 hour day	Extremities	max ave/w in peak fields < 0.5 T or ave/d in peak fields > 0.5 T
2 Tesla	Short (a few minutes)	Whole body	peak exposure limit

^a Based on LLNL evaluation (1987)
^b Recommendations are also available for gradient and time-varying fields, but were judged to be too detailed for top tier requirements.

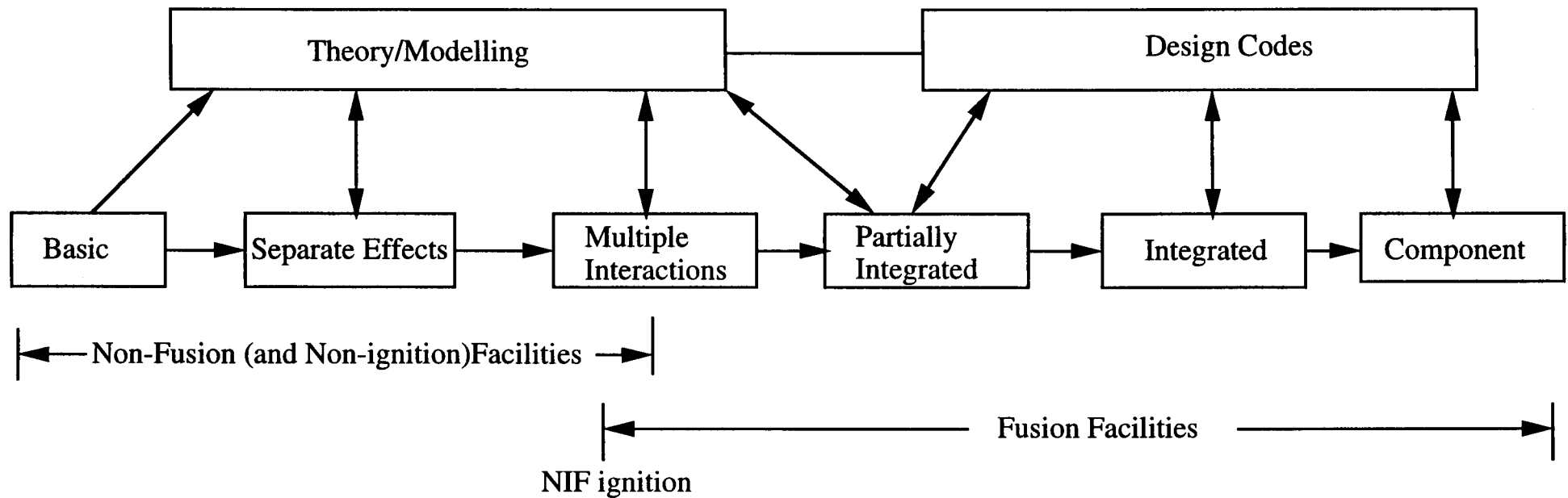


Role of Experiment Planning in Technology Development



Process for Experimental Planning

Types and Roles of Experiments and Facilities for IFE Technology Development



ISSUES THAT CAN BE ADDRESSED NOW

For chamber technology [Example]

1. Vertical Jet Alignment
2. Material Compatibility
3. Oscillating Jet Characteristics
4. Film Flow Control (thickness)
5. Flow on Inverted Surfaces
6. Film Flow Response to Impulsive Loading
7. Tritium Recovery based on Vacuum Disengager (for Flibe)

For target technology [Example]

1. Target Injection and Tracking Techniques
2. Target Element Development (manufacturability) (such as membrane support)

Near term focus: Explore IFE technology testing strategies with non-fusion and non-ignition devices

Development Issues for IFE⁺

- Neutron, x-ray, and gamma ray damage to reflective optics and polymers over time
[basic to multiple, non-fusion/fusion for material characterization, fusion for integrated tests]
- Disassembly of liquids isochorically heated by neutrons
[multiple effects, fusion facility]
- First wall vaporization and condensation phenomenology
[multiple effects, fusion facility]
- Neutron and gamma-ray damage from pulsed irradiation sources
[basic to multiple, non-fusion /fusion for material characterization, fusion for integrated tests]
- Cracking and fracturing of solids as a result of cyclic temperature and pressure changes in the pulsed radiation environment
[basic to multiple, non-fusion/fusion for material characterization, fusion for integrated tests]
- Maximum target-chamber particle densities at which satisfactory driver-beam propagation is possible
[separate effect, non-fusion test/development]
- Viability of concepts for protection of optical systems (if needed)
[basic to multiple, non-fusion /fusion for material characterization, fusion for integrated tests]
- Automated production of targets; target injection; pointing and tracking; reprocessing of target materials
[separate effect, non-fusion test/development]

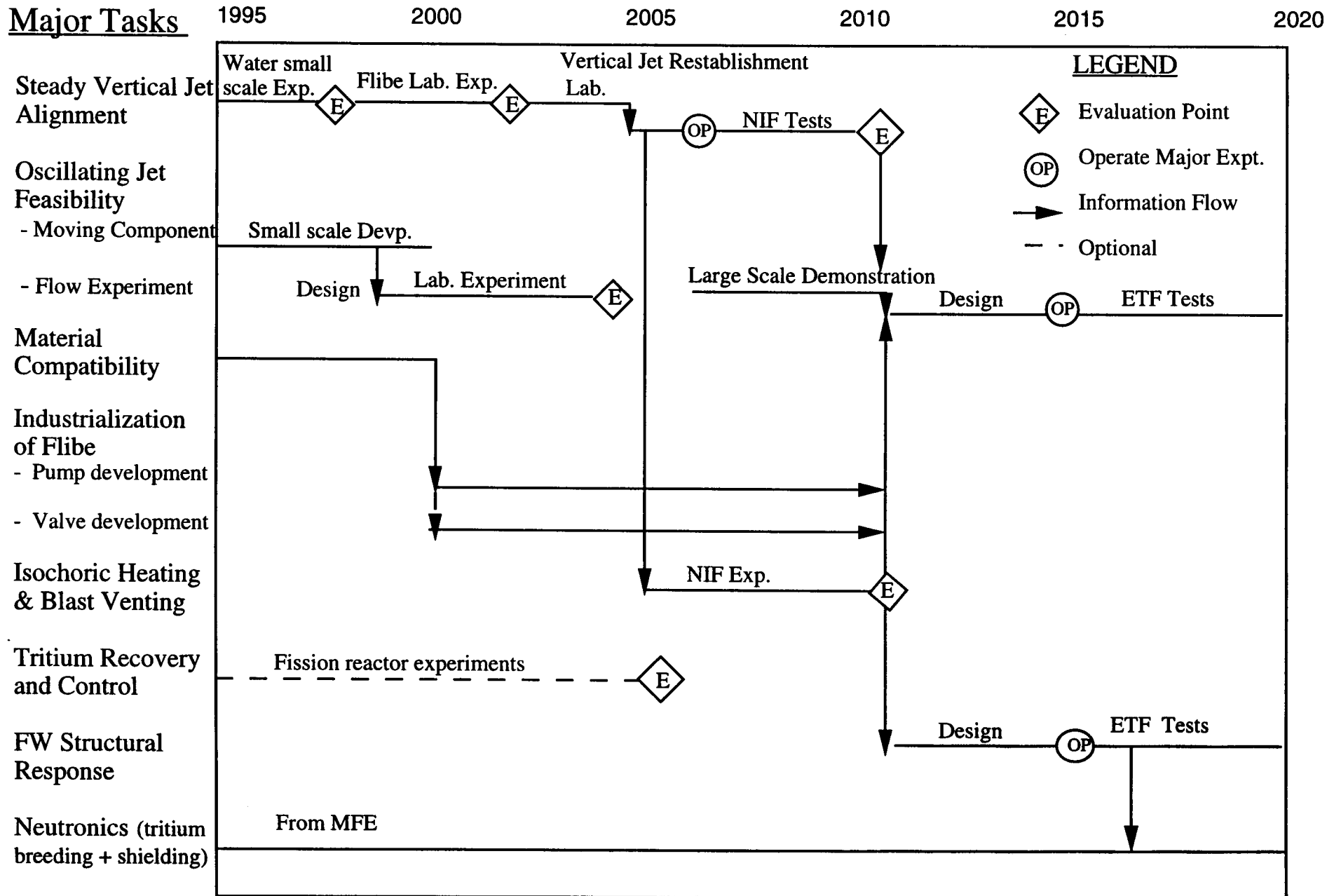
+ Development issues taken from M. T. Tobin, etc., "Electrical Power from Inertial Confinement Fusion: Issues and Prospects," UCID- 21849, March 1990

List of Critical Issues for IFE

[From M. Abdou et al, Fusion Eng. and Design, 1993]

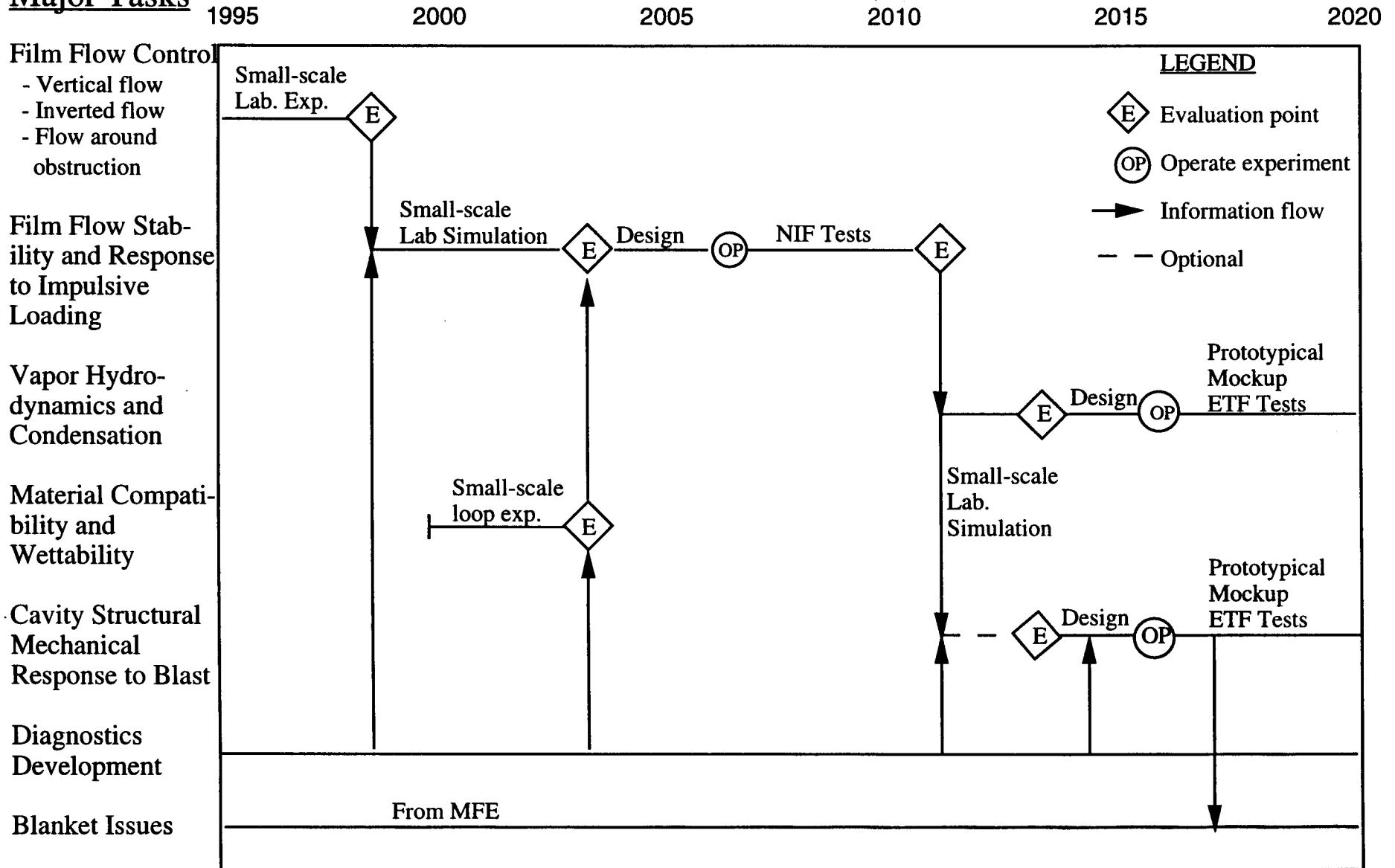
1. Demonstration of Moderate Gain at Low Driver Energy
2. Feasibility of Direct Drive Targets
3. Feasibility of Indirect Drive Targets for Heavy Ions
4. Feasibility of Indirect Drive Targets for Lasers
5. Cost Reduction Strategies for Heavy Ion Drivers
6. Demonstration of Higher Overall Laser Driver Efficiency
7. Tritium Self Sufficiency in IFE Reactors
8. Cavity Clearing at IFE Pulse Repetition Rates
9. Performance, Reliability and Lifetime of Final Laser Optics
10. Viability of Liquid Metal Film for First Wall Protection
11. Fabricability, Reliability and Lifetime of SiC Composite Structures
12. Validation of Radiation Shielding Requirement, Design Tools and Nuclear Data
13. Reliability and Lifetime of Laser and Heavy Ion Drivers
14. Demonstration of Large-Scale Non-Linear Optical Laser Driver Architecture
15. Demonstration of Cost Effective KrF Amplifiers
16. Demonstration of low Cost, High Volume Target Production Techniques

Example Test Sequence for Major Thick Liquid Jet Tasks (i.e. HYLIFE II Chamber)



Example Test Sequence for Major Thin Flow Tasks (i.e. Prometheus First Wall Protection Scheme)

Major Tasks



Proposed Approach for Developing IFE Development Plan

- Define Key Technology Areas for IFE:
 - Driver Technology System
 - Chamber Technology System (First Wall Protection and Interface)
 - Materials, Blanket, and Shield
 - Target System
 - IFE Development Studies

- Identify, Characterize and Prioritize Technical Issues Associated with Each Technology Area
 - e.g.
 - For accelerator development and the supporting physics program

 - For chamber technology: Scale mockups experiments to characterize thick liquid jet, thin flow and flow through porous materials

Proposed Approach for Developing IFE Development Plan(cont'd)

- Define Program Strategy

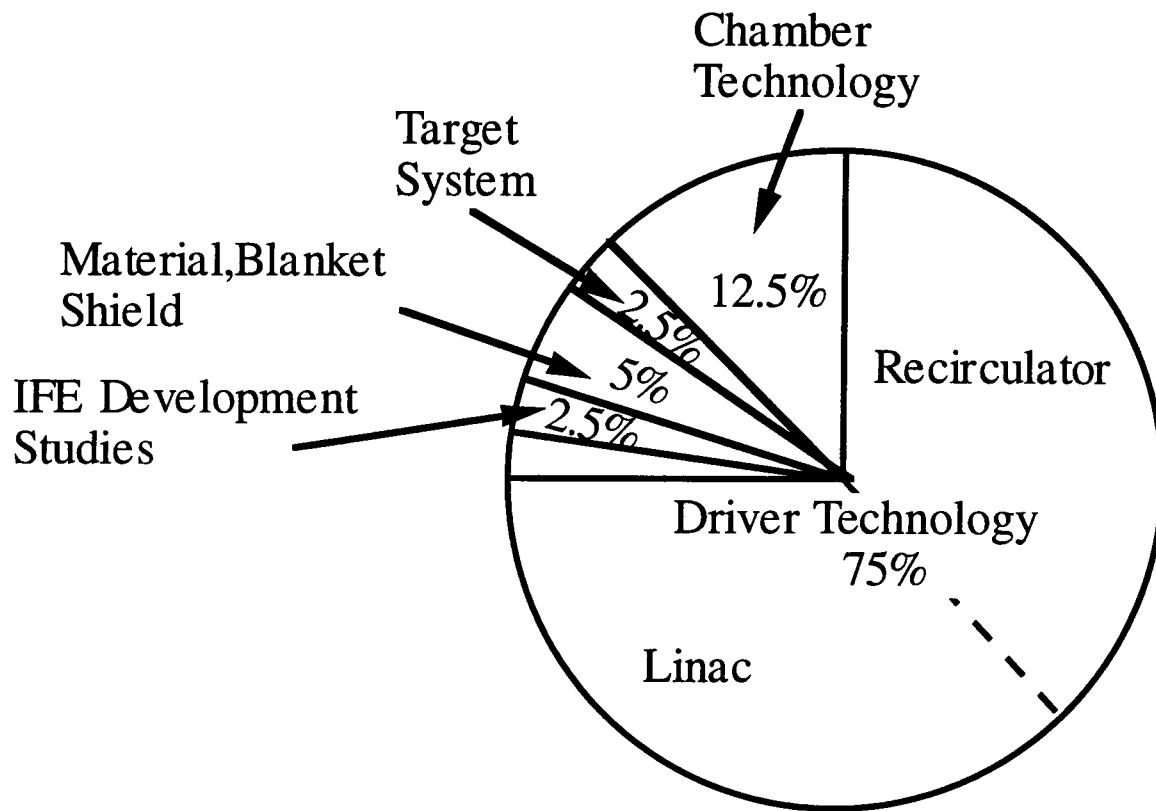
e.g.

- Most of the reactor design parameters have been based upon analysis, rather than upon experimental evidence
- Near term focus on R&D program to establish basic data related to inertial fusion science and technologies and integrate these in the long term to develop inertial fusion energy

- Define Program Schedule

e.g.

- By 2000, preliminary decision on heavy ion driver option (impact on the budget distribution)
- By 2005, complete experiments to establish driver beam propagation characteristics, adequacy of non-nuclear technologies, acceptability of materials performance and of target fabrication and insertion techniques



Possible Budget Allocation