

# Requirements and Designs for IFE and MFE First Wall and Blankets

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# The ARIES Team Has Examined Several Magnetic Fusion Concept as Power Plants in the Past 10 Years

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- TITAN reversed-field pinch (1988)
- ARIES-I first-stability tokamak (1990)
- ARIES-III D-<sup>3</sup>He-fueled tokamak (1991)
- ARIES-II and -IV second-stability tokamaks (1992)
- Pulsar pulsed-plasma tokamak (1993)
- SPPS stellarator (1994)
- Starlite study (1995) (goals & technical requirements for power plants & Demo)
- ARIES-RS reversed-shear tokamak (1996)
- ARIES-ST spherical torus (1999)



**Main Goal:** To guide physics and technology R&D by identifying critical and high-leverage issue.

# Typical MFE Fusion Core Environmental Conditions

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- Heat loads:
  - First Wall (400 m<sup>2</sup> ) ~ 0.5 - 1 MW/m<sup>2</sup>
  - Divertor (40 m<sup>2</sup>) ~ 2 - 10 MW/m<sup>2</sup>
  - Blanket ~ 30 MW/m<sup>3</sup>
  - Disruption (10-40 m<sup>2</sup>) ~ 150 MJ over 5-50 μs
  - Other off-normal events (e.g., Giant Elms).
  
- Spectrum:
  - neutrons 14 MeV
  - X rays 10eV to 30 keV
  - ions 1 - 100 eV (Divertor mode of operation)

# Comparison of IFE and MFE Chambers

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- IFE chamber wall loading are similar to disruption loads in tokamaks. MFE experiments are designed for several thousand disruptions, MFE power plants are designed for ~10 disruptions.
- “Conventional” MFE solutions for first-wall and divertor probably will not extrapolate to IFE power plants.
- Almost every IFE wall protection scheme has been proposed and examined for MFE divertors!
  - Liquid surfaces,
  - Pebble/granular flows,
  - Gas protection (gas injection in divertor).

# Comparison of IFE and MFE Chambers

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- Blanket loading in IFE and MFE chambers are identical specially if liquid breeders are used.
- Lessons from MFE work:
  - Blankets absorb ~70% of fusion energy as volumetric heating in a rather benign environment (compared to first wall).
  - Fusion systems require high thermal conversion efficiency to be economical. As most of the power is in the blanket, this is a critical component for fusion attractiveness.
  - Old MFE thinking: First wall, blanket, and divertor should use the same technology.
  - New Approach: Loadings and functions are different, so optimize each region per its “mission.”

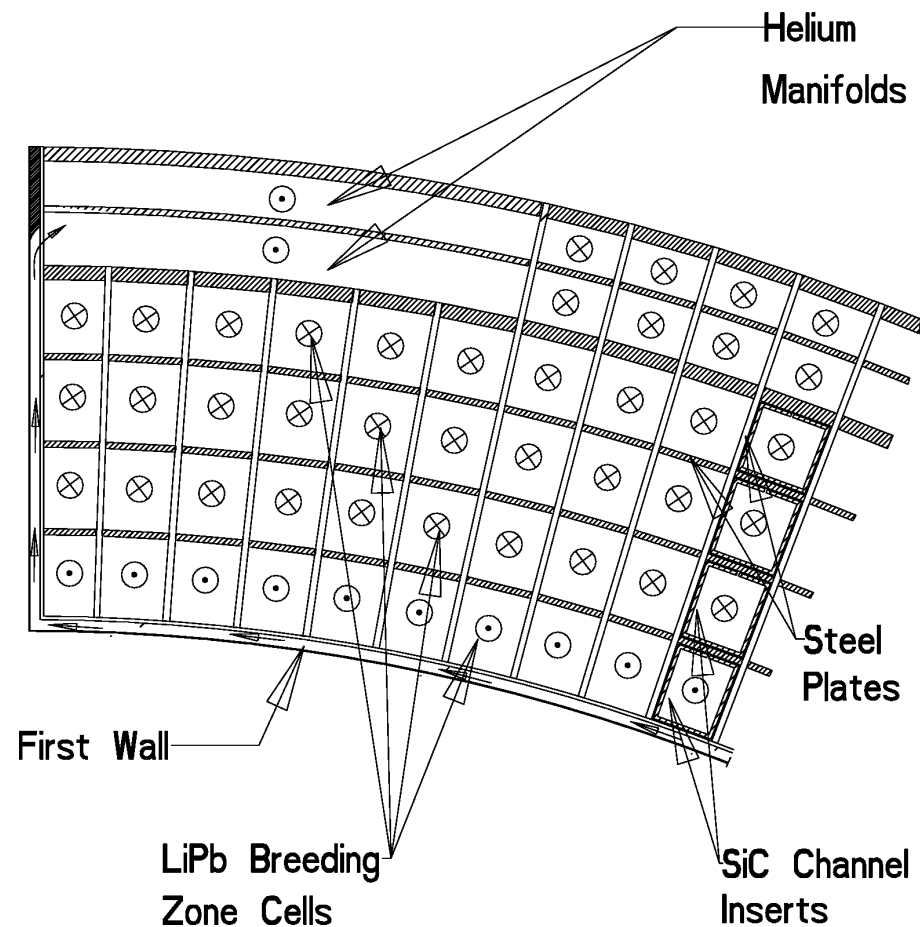


# ARIES-ST Features a High-Performance Ferritic Steel Blanket

- Typically, the coolant outlet temperature is limited to the max. operating temperature of structural material ( $550^{\circ}\text{C}$  for ferritic steels).
- By using a coolant/breeder (LiPb), cooling the structure by He gas, and SiC insulators, a coolant outlet temperature of  $700^{\circ}\text{C}$  is achieved for ARIES-ST leading to 45% thermal conversion efficiency.

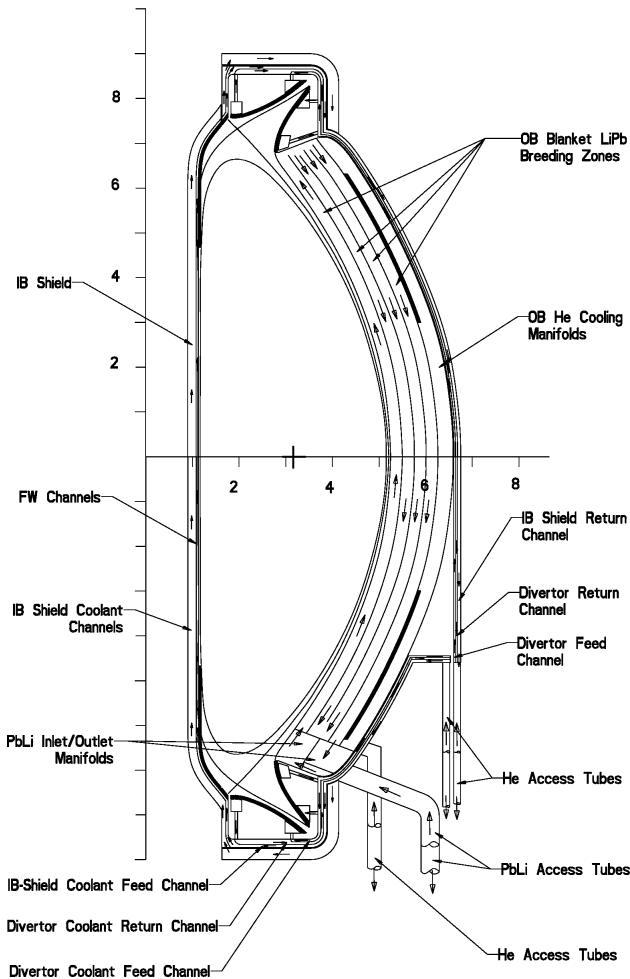
OB Blanket thickness	1.35 m
OB Shield thickness	0.42 m
Overall TBR	1.1

Partial Cross Section of Outboard Blanket



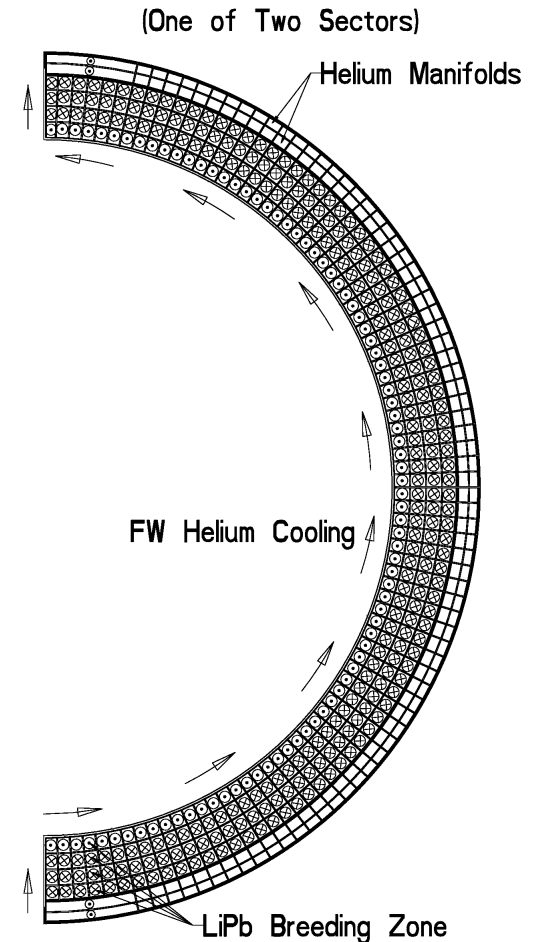
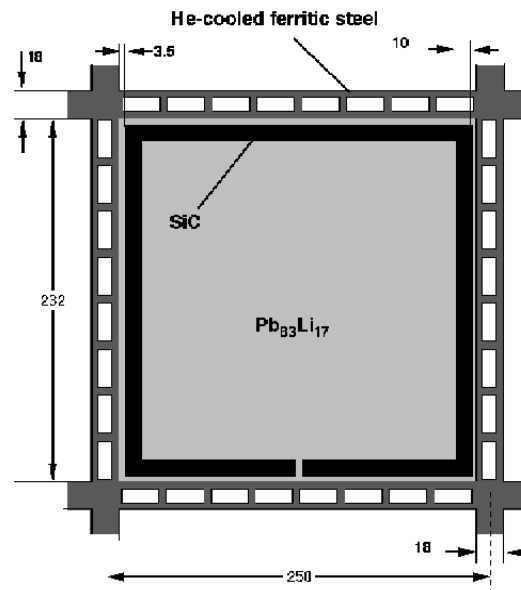
# Coolant Flow Is Chosen Carefully to Maximize Coolant Outlet Temperature

Blanket/Divertor/Shield Coolant Routings



Power in Steel 330 MW  
 Power in LiPb 1614 MW  
 He pressure 12 MPa  
 He inlet 300 °C  
 He Outlet 525 °C  
 LiPb Inlet 550 °C  
 LiPb Outlet 700 °C

Cross Section of ARIES-ST Outboard Blanket



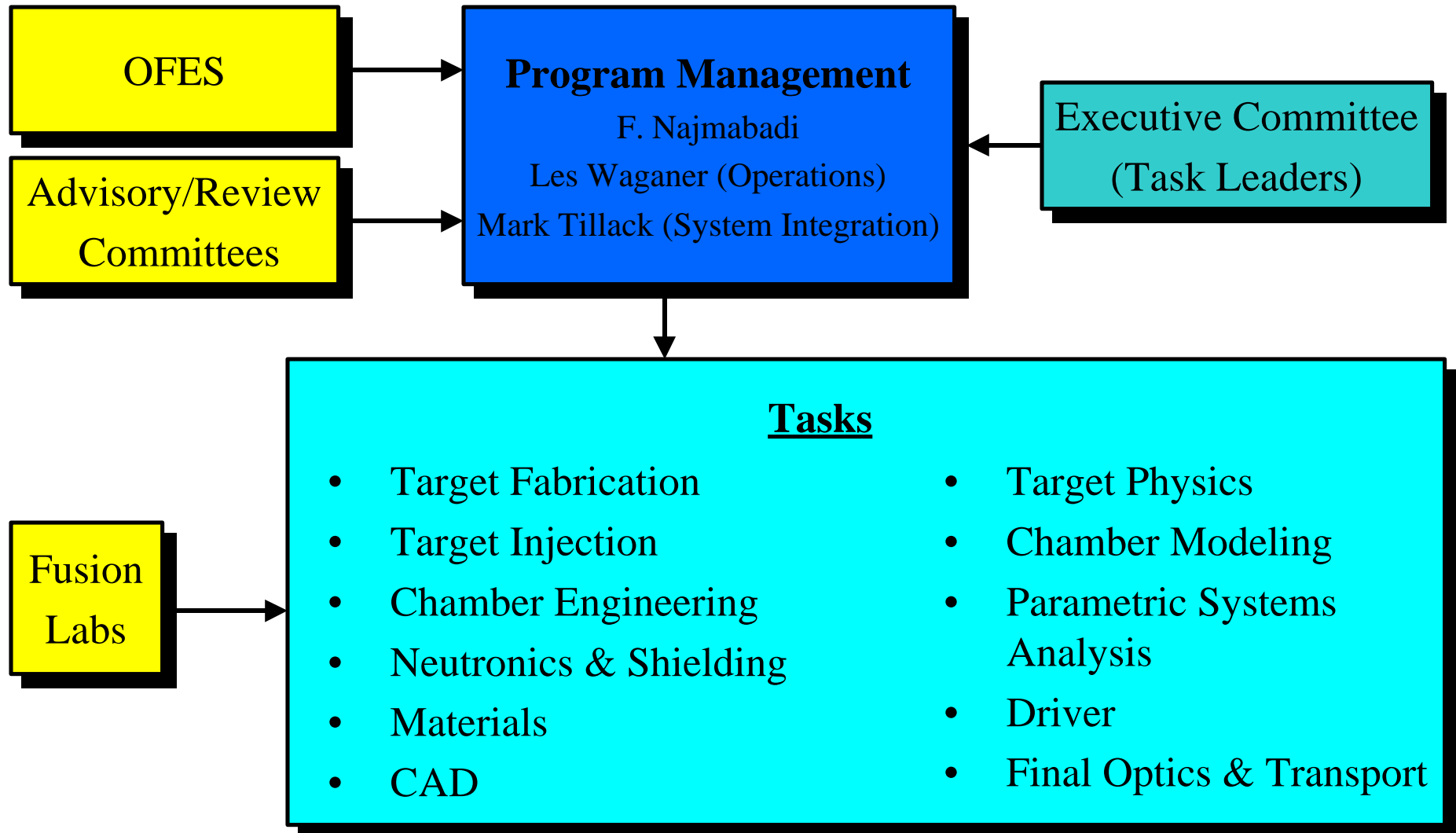
# ARIES IFE Assessment Study (FY 2000)

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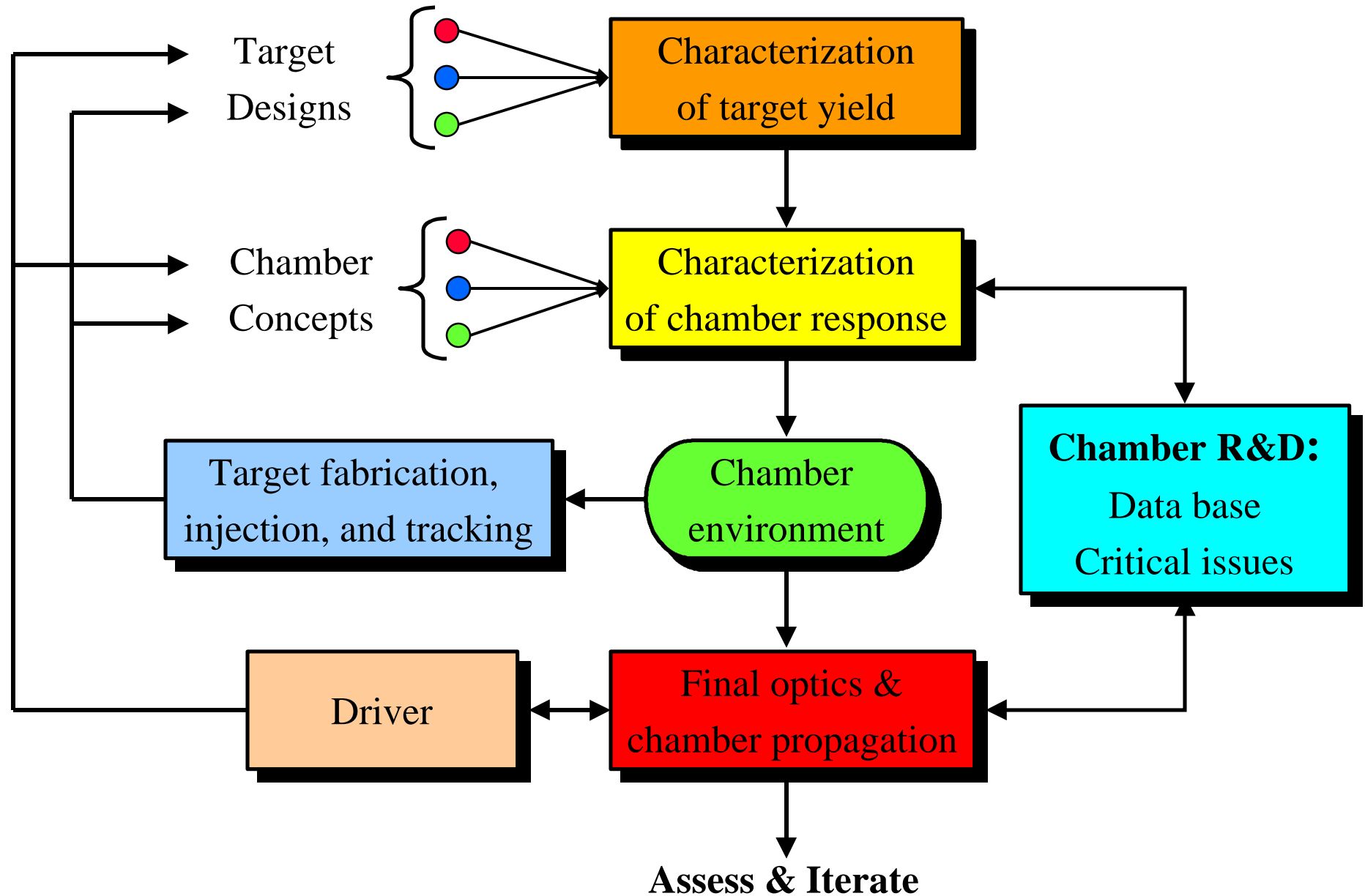
- Eight years since major IFE studies. Substantial progress has been made since that time. Declassification of the ICF program allows, for the first time, a thoroughly integrated IFE power plant study.
- An integrated study will develop a framework to assess options and help define key high-leverage directions for the R&D program.
- Substantial chamber R&D program is initiated.
- It will underscore that IFE and MFE programs are coming together into a cohesive national fusion program. It uses MFE community expertise to resolve challenges of IFE. It enhances the credibility of IFE options with the MFE community.
- Goal: Identify and explore design window for direct-drive laser IFE chambers.

# Program is Organized as a Team

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# An Integrated Assessment Defines the R&D Needs



# UCSD Research in IFE Chambers

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- 2 J Nd:YAG laser (8 ns) at 10Hz with frequency multiplier crystals (1x, 2x, 3x, and 4x)
- Host of beam profiling diagnostics (photo diodes, CCD camera, wave-front, ...).
- Program started in July 1999. Laser purchased by UCSD internal fund but not yet delivered (due to problems at vendor).
- We have started to bring various diagnostic on-line using a 20kHz, 20 $\mu$ J, Nd:YAG “laser on a chip” with green light.
- Research Plan for the next year.
  - Breakdown threshold on grazing-incident metal mirrors
  - Gas breakdown threshold for high-Z gases (Xe, Kr).
- Substantial interest by other scientists to use this facility for collaborative experiments.

# Summary

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- Blanket loading in IFE and MFE chambers are identical specially if liquid breeders are used. Consider different technologies for the wall and blanket. Optimize blanket for maximum thermal conversion efficiency without using “exotic” technologies. Use MFE experience in this area.
- The ARIES Team will perform an IFE assessment study in 2000. The goal of this activity is to identify and explore design window for direct-drive laser IFE chambers.
- There are a large number of fundamental scientific phenomena in an IFE chamber environment that are not understood. Small experiments can resolves a large potions of these engineering sciences issues.
- Multi-dimensional code verified and benchmarked by experiments should be developed and continually refined.