MFE Chamber Overview

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Chamber Technology

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Chamber Technology Research Advances the Science and Energy Goals of Fusion in the Near and Long Term

Mission

To extend the engineering science knowledge base, explore innovative concepts, and resolve key feasibility issues for Chamber Technologies that:

1) in the near-term, enable better capabilities in plasma experiments, and

2) in the long-term, improve the economics, safety, and environmental attractiveness of fusion energy systems

The US Chamber Technology Program has established leadership in the world program on exploring *innovative* concepts and advancing the underlying science, while maintaining access to the larger international program on *evolutionary* concepts

US Chamber Program SUB-ELEMENTS:

1. APEX (started in 1998)

- Innovative (revolutionary) concepts, Advance underlying science(s)
- US multi-institutional, multidisciplinary team with voluntary international participation

2. Material System Thermomechanics Interactions

- Modelling and experiments for ceramic breeder/Be/structure thermomechanics interactions
- Framework: IEA collaboration; part of US strategy to gain access to the larger international program

3. JUPITER-II (started April 2001)

- Joint Japan-US collaboration on scientific and technical issues of common interest
- Japan pays (matches US funds) for use of unique US thermofluid and thermomechanics facilities

4. Neutronics (< 3%)

Outline

- **Mission and Program Elements**
- **“Historical Perspective”**
- **APEX**
  - Objectives, Approach, Organization
  - Liquid Walls
    - **Thermofluid Modeling & Experiments**
    - **Plasma-Liquid Interactions**
    - **Examples of Creative Innovations**
    - **LW testing in NSTX**
  - Solid Walls (W-alloys, EVOLVE)
    - **Materials**
    - **Heat Transfer and other analysis**
- **Thermomechanics Interactions**
  - Modeling
  - Experiments
- **JUPITER-II**
  - Thermofluids
  - Thermomechanics
- **Neutronics**

“HISTORICAL PERSPECTIVE”

Brief notes on achievements
and restructuring events
prior to 1998

The Chamber Technology Program Has Fully Implemented the RESTRUCTURED US Fusion Program Goals and the Broad Fusion Community Views

Prior to 1997

Major Contributions to fusion R&D with “development” goals

1997: The “Transition Year”

1998 - Present: “Restructured Program”

- Explore Innovative, possibly revolutionary, concepts
- Emphasis on understanding phenomena and theory, modeling, and experiments to advance the underlying engineering sciences
- Partnership with Physics community and other Technology Program Elements (e.g. PFC, Materials, Safety, etc.)

Examples of Major Accomplishments Prior to 1997

- **BCSS (1982-1984)**

- *Provided Conceptual Designs and Selected Primary Conventional Blanket Concepts*

- **FINESSE (1984-1987)**

- *Most Comprehensive Study on Fusion Nuclear Technology*

- *Major Impact on the World Program:*

  - **Provided the basis for FNT R&D facilities in Japan, EU & US**
  - **Identified a "Two-facilities" pathway as optimum approach for fusion development [one for physics (large size, low fluence) and one for technology (small size, high fluence)]**
  - **Provided incentives for alternative confinement concepts, e.g. ST, as an effective approach for VNS**

- **VNS and HVPNS (1993-1996) and Leadership on ITER Technology Testing**

- *Most Comprehensive analysis of the requirements on fusion testing facilities* (burn length, dwell time, wall load, fluence, availability, etc.)

- *Provided effective approaches to VNS; sparked world interest*

- *IEA initiated a study in 1994 on VNS, called HVPNS*. A scholarly, comprehensive paper was published in Fusion Technology (January 1996) by key scientists and engineers from the world program confirming US results on testing requirements and the effectiveness/importance of VNS

- **Pioneering and Comprehensive Dynamic Fuel Cycle Modeling**

- Pioneering modeling that identified the permissible physics and technology parameters to satisfy tritium self sufficiency (e.g. tritium fractional burn-up in plasma, reliability of tritium system)

- Served as the basis for ITER and many R&D programs

- **US-JAERI Collaboration on Integral Neutronics Experiments (10 years), TFTR/ITER Shielding**

- Most comprehensive neutronics modeling & experiments

- Many "breakthroughs"; evolved the field to "maturity"

1997: The "Transition Year"

Environment in 1997

- The prevailing mood in the technology community was dominated by "pessimism" and frustration (e.g. Chamber Technology in ISFNT-4, April 1997, Tokyo)

    - Budget Cuts in the US
    - Technical limitations of conventional blankets
    - Predicted High cost and long time for testing & development in fusion facilities

- The US developed a Restructuring Plan (Leesburg, FESAC, OFES, etc.)

    - Emphasis on Science and Innovation

- The US Chamber Technology community had intensive discussion for restructuring.

- (Independently and about the same time frame)

  Letter (1/16/98) from 23 Senior US Scientists to Dr. Anne Davies encouraging research on innovative high power density concepts ("we believe that it is timely for the technology side of OFES to consider a new focus to develop first wall/blanket schemes which can demonstrate high heat and neutron fluxes")

New Strategic Pathway and New Initiatives for Implementation of Community Views and Program Restructuring Plan

- The old blanket program that focused on traditional concepts of limited potential was mostly eliminated (reduced from annual budget of ~ $6M to ~ $1M)
- A new strategic pathway for Chamber Technology was developed to reflect the new restructured programs and goals:

\- *Focus the greater part of resources on exploration of INNOVATIVE concepts with emphasis on understanding and advancing the underlying phenomena and engineering sciences*

\- *Provide a smaller part of the resources to international collaboration on selected R&D areas for EVOLUTIONARY concepts in order to: a) gain access to much larger R&D programs, and b) learn the actual technological limits, which is essential to our endeavor to extend these limits*

- DOE and the Community agreed on initiating APEX (and ALPS) in 1998

APEX

APEX Web Site: www.fusion.ucla.edu/APEX

APEX Objectives

Identify and explore NOVEL, possibly revolutionary, concepts for the Chamber Technology that might:

1. In the near-term: enable plasma experiments to more fully achieve their scientific research potential

2. In the long-term: substantially improve the attractiveness of fusion as an energy source

3. Lower the cost and time for R&D

APEX Approach has Proved Effective

1) Emphasize Innovation

2) Understand and Advance the underlying Engineering Sciences

3) Utilize a multidisciplinary, multi-institution integrated TEAM

4) Provide for Open Competitive Solicitations

5) Close Coupling to the Plasma Community

6) Direct Participation of Scientists from Materials, PFC, Safety, and System Design Programs

7) Direct Coupling to IFE Chamber Technology Community

8) Encourage International Collaboration

APEX is Organized as a Team

US Organizations (13 Universities and National Labs)

UCLA	ANL	PPPL	ORNL
LLNL	SNL	GA	UW
INEEL	U. Texas	LANL	UCSD / U. IL

Important Contributions from International Organizations

- FZK, Germany (Dr. S. Malang, Dr. L. Barleon)
- Japanese Universities
  - Profs. Kunugi (Kyoto), Satake (Toyama), Uchimoto (Tokyo), others
  - Joint Workshops on APEX/HPD

APEX Steering Committee includes Leaders from the Physics and Technology Community

M. Abdou (UCLA)	R. Kaita (PPPL)	K. McCarthy/D. Petti (INEEL)
N. Morley (UCLA)	B. Nelson (ORNL)	T. Rognlien (LLNL)
M. Sawan (UW)	D. Sze (ANL)	M. Ulrickson/R. Nygren (SNL)
C. Wong (GA)	A. Ying (UCLA)	S. Zinkle (ORNL)

APEX has progressed along carefully planned and well documented phases

(Early 1998)

Preparation Phase

Attract Innovators →

- Understand Technological Limits
- Define Objectives/Criteria

→ APEX Website

→ FED Paper

(late 1998-99)

Idea Formulation Phase

VLT-PAC, Dec 98 →

Snowmass, Jul 99 →

- Many concepts proposed and analyzed
- Most promising concepts identified: EVOLVE and Liquid Walls

→ Snowmass report

→ APEX Website

→ Journal publications

→ Interim Report, 600 p.

(Nov 1999- Present)

Concept Exploration Phase

VLT-PAC, Dec 00 →

Peer Review, Apr 01 →

- Model development
- Small scale experiments
- Critical Issue analysis

→ APEX Website

→ Journal publications

→ Special issue planned

R&D Requirements and POP Definition

Economics Principles motivated our Chamber Technology Goals

APEX

Need High Power Density/Physics-Technology Partnership

- High-Performance Plasma
- Chamber Technology Capabilities

Need Low Failure Rate

$$COE = \frac{C \cdot i + \text{replacement cost} + O \,\&\, M}{P_{fusion} \cdot \text{Availability} \cdot M \cdot h_{th}}$$

Energy Multiplication

Need High Temp. Energy Extraction

Need High Availability / Simpler Technological and Material Constraints

$$\frac{(1/\text{failure rate})}{1/\text{failure rate} + \text{replacement time}}$$

- **Need Low Failure Rate:**
  - Innovative Chamber Technology
- **Need Short Maintenance Time:**
  - Simple Configuration Confinement
  - Easier to Maintain Chamber Technology