VLT Budget Information: FY2003/2004

Attachment 1

? **Program Element:**	CHAMBER TECHNOLOGY (MFE)
? **Element Mission and Scope**	Explore innovative concepts, advance the underlying engineering sciences, 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. <u>APEX (involves 12 US institutions)</u> ✍ Perform free-surface liquid metal MHD and high Prandtl fluid flow experiments to address the critical data needs for plasma experiments (e.g. in NSTX) and liquid walls in fusion energy systems. ✍ Develop phenomenological and computational models to understand fundamental free-surface flow phenomena and to advance the conceptualization of liquid wall designs ✍ Explore effects of liquid walls on enhancing MHD plasma stability and performance through design exploration and analysis using MHD equilibrium & stability codes ✍ Evaluate the performance and attractiveness of advanced solid and liquid wall concepts and assess facility needs for research and development <u>JUPITER-II Thermofluid (Collaborative Program with Japan)</u> ✍ Experimental exploration and model development to quantify flow phenomena, temperature fields, and heat transfer enhancement techniques for high Prandlt Number liquids (e.g. flibe) in complex geometries and in the presence of magnetic fields. <u>Pebble Bed Thermomechanics and JUPITER-II SiC Material System Thermomechanics (Collaborative Program with IEA)</u> ✍ Conduct small-scale pebble bed thermal-mechanical experiments and develop phenomenological and computational models for determining the thermomechanical constraints of the ceramic breeder material systems in material combinations involving advanced structural materials, beryllium, and high-temperature coolants.

? **Element Anticipated Five-Year Accomplishments and Deliverables**	Liquid Walls 1. Fundamental understanding and predictive capability for free-surface fluid flow phenomena and plasma-liquid interactions verified by theory and experiments. 2. Operating flowing liquid walls in a major experimental device (e.g. NSTX) 3. Initiating construction of an integrated thermofluid research facility to simulate flowing liquid walls for both IFE and MFE 4. Evaluating advantages and implications of using LW's in fusion energy systems Solid Walls 5. Advancing novel concepts that can extend the capabilities and attractiveness of solid walls 6. Contribution to international effort on key feasibility issues for evolutionary concepts in selected areas of unique expertise, particularly thermofluids and thermomechanics data base, predictive models, and experiments

? **Principal FY2001/2002 Achievements: (list up to five)**	1. Completed construction and successfully operated three new facilities: MTOR (Toroidal magnetic Facility) for LM MHD free surface flow FLIHY for Free Surface Transport Phenomena JUPITER-II Thermofluid Loop for MHD flow in closed channels Initial experiments were performed in all 3 facilities 2. Development, testing, and utilization of 2-D MHD codes for predicting free-surface flows fluid dynamics and transport phenomena. Initiation of an "ambitious" model and code development of 3-D MHD free-surface flows in complex geometries with a space varying multi-component magnetic field (in collaboration with SBIR company). 3. Substantial code development and analysis of plasma-liquid "surface" and "bulk" interactions yielding important results on: a) temperature limits of liquid surfaces facing the plasma, and b) innovative schemes for utilization of liquid metals to enhance plasma MHD stability and performance in tokamaks. 4. Explored options, identified issues, and initiated R&D for implementing a flowing liquid module in NSTX and CMOD (coordinated effort with ALPS/ALIST). 5. Design exploration and analysis of innovative liquid walls (both liquid metals and low-conductivity

	fluids) and advanced solid wall concepts. (Identified a promising low-melting point molten salt (flinabe), jointly exploring with the material program high-temperature nano-composited ferritic steel, etc.)

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FY2003	
? **Reference Budget: (Congressional Request)**	$3201
? **Key Milestones**	*APEX* *Dec. 02* Completion of plan for increasing MTOR toroidal field coils current to 4000A and addition of additional coils for multi-component field simulation *Jan. 03* Initiation of curved wall experiments in FLIHY using water as Flibe simulant *Feb. 03* Decision on deploying liquid surface module in NSTX in late FY04 *Jun. 03* Complete phase 1 experiments for characterizing free-surface GaInSn and lithium flows under NSTX and C-Mod prototypical transverse field gradient configurations *Sep. 03* Initial report on modeling and experimental investigation of inclined plane flows in variable magnetic field in MTOR and free-surface heat transfer and wave structure using flibe simulant in FLIHY *Sep. 03* Report on issues and assessments of high-performance solid wall design, low-conductivity liquid wall design, and liquid metal design *JUPITER II Thermofluid* *Jan. 03* Complete packed-bed flow PIV experiments *Aug. 03* Begin heat transfer experiments in JUPITER-II thermofluid loop *Thermomechanics and JUPITER II SiC System thermomechanics* *Apr. 03* Data on the effective thermal conductivity and interface conductance of a Be pebble bed/SiC/He system under applied pressures *Sep. 03* Model prediction for effective thermal physical properties of a Be pebble bed under externally applied pressure

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? **Participating Institutions and Proposed Funding:** **(Based on FY 2003 Congressional Request)**	UCLA (APEX+JUPITER-II + Pebble Bed Thermomechanics + Neutronics+Surface Renewal): 1915 K$ ORNL (APEX+ Neutronics +JUIPTER-II): 237 K$ UW (APEX): 148 K$, ANL (APEX): 138 K$ PPPL (APEX+ JUPITER-II): 141 K$ GA (APEX): 103 K$, LLNL (APEX): 60 K$ SNLA (APEX+JUPITER-II): 266 K$ U. Texas (APEX): 99 K$ U. Illinois (APEX): 10K$, TSI (Neutronics): 35K$
? **Additional Expected Deliverables With 10% Budget Increase:**	- Provide pulsed magnetic field and flowloop upgrade for large volumes (up to axisymmetric) MHD flows in MTOR - Critical enhancement of the simulation of the time-dependent plasma behavior in the presence of liquid metal walls using the Tokamak Simulation Code (TSC). - Much needed enhancement of APEX Task V to investigate innovative options for the use of flowing liquid metals (in both open and closed channel flow) for improved plasma stabilization and performance - Fabrication and deployment of a liquid module on a fusion device will require at least a +10% increase in the budget in both FY03 and FY04
? **Impact of 10% Budget Reduction:**	? With a 10% budget cut it will be impossible to complete the R&D and fabricate and install a liquid module on a fusion device in 2004. The window of opportunity will pass and we will have to renegotiate an opportunity in the future ? Many of the exciting new initiatives on experiments and modeling of liquid walls will suffer ? Chamber research is barely at a critical level now. We can not weaken research in this critical area any further!

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FY2004	
? **Reference Budget:** **(same as FY03 Congressional Report)**	3201 K$
? **Key Milestones:**	APEX Nov. 03 Initiation of penetration experiments on curved liquid wall test section in FLIHY using water as Flibe simulant Nov. 03 Document design and critical issues for a high performance solid wall concept Dec. 03 Complete characterization of free lithium surface flow options for NSTX or Alcator C-Mod Dec. 03 Completion of MTOR current increase to 4000A. Jan. 04 Test prototype module for installation on an existing plasma device (depends on decision in FY03 to deploy a module) Feb. 04 Initiation of curved wall flow and inverted flow liquid metal experiments with magnetic propulsion, pulsed fields, multi-component fields, in upgraded MTOR Aug. 04 Completion and testing of HIMAG code for 3-D free-surface MHD flows in complex geometry Sep. 04 Complete engineering designs of the proposed free lithium surface flow options for NSTX or Alcator C-Mod Sep. 04 Complete documentation of proposed experiments in NSTX or Alcator C-Mod Sep. 04 Determine effects of fast flowing liquid metal stream on plasma equilibria Sep. 04 Comprehensive report on experimental and modeling program, innovative design exploration results, and status and findings for APEX. JUPITER-II Thermofluid Feb. 04 Completion of heat transfer experiments in pipe flow designed for heat transfer enhancement Apr. 04 Initiation of MHD experiments for turnbulence visualization and heat transfer in FLIHY-closed channel facility Thermomechanics and JUPITER II SiC System Thermomechanics

	Mar. 04 Data on effect of thermal creep on ceramic breeder pebble bed system thermomechanics interaction Sep. 04 Modeling prediction on stress relaxation with respect to thermal creep in the ceramic breeder pebble beds
? **Additional Expected Deliverables With 10% Budget Increase:**	? Completion of MTOR flow loop upgrade for large volumes (up to axisymmetric) flows ? More comprehensive simulations of time-dependent plasma and liquid metal behavior in NSTX or C-Mod ? Fabrication and deployment of a liquid module on a fusion device will require at least a +10% increase in the budget
? **Impact of 10% Budget Reduction:**	? With a 10% budget cut it will be impossible to fabricate and install a liquid module on a fusion devise in 2004. The window of opportunity will pass and we will have to renegotiate an opportunity in the future ? It will be very difficult to complete experiments, modeling, and analysis necessary for an integrated assessment of the feasibility of innovative chamber concepts