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. APEX (involves 12 US institutions) ❑ 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 and predict fundamental free-surface fluid flow phenomena with and without MHD, and to advance the conceptualization of liquid wall designs ❑ Perform modeling, experiments, and analysis to understand and predict plasma-liquid "bulk" and "surface" interactions (surface interactions are mostly under PFC/ALPS) ❑ Explore novel technologies which simultaneously allow high power density, high temperature, improved plasma MHD stability and performance, and improved safety and engineering. ❑ Evaluate the performance and attractiveness of advanced solid and liquid wall concepts and assess facility needs for research and development JUPITER-II Thermofluid (Collaborative Program with Japan) ❑ 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 closed geometries and in the presence of magnetic fields. Pebble Bed Thermomechanics and JUPITER-II SiC Material System Thermomechanics (Collaborative Program with IEA and Japan) ❑ Conduct small-scale pebble bed thermal-mechanical experiments and develop phenomenological and computational models for determining the thermomechanical performance and 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 (Proof-of-Principle Experiment for LW's) 4. Explore, advance, and develop liquid wall concepts and evaluate advantages and implications of their use 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 using NSTX and ALCATOR-CMOD as examples (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.)

VLT Budget Information: FY2003/2004

Attachment 1

FY2003	
• **Reference Budget: (Congressional Request)**	$3201 K
• **Key Milestones**	*APEX* *Jan. 03* Initiation of 4-m curved wall free surface fluid flow dynamics experiments in FLIHY with Flibe simulant *Jun. 03* Complete phase 1 experiments for simulating MHD free-surface GaInSn and lithium flows under NSTX and C-Mod prototypical transverse field gradients *Aug. 03* Complete formulation of 3-D MHD fluid flow model and numerical technique development *Sep. 03* Initial report on experimental investigation of: a) inclined plane MHD flows in variable magnetic field in MTOR, and b) free-surface heat transfer and wave structure using flibe simulant in FLIHY *Sep. 03* Report on progress of exploring innovative designs for a) high-performance solid walls, b) a low-conductivity liquid wall with flinabe, and c) liquid metal walls *JUPITER II Thermofluid* *Sep. 03* Complete packed-bed flow PIV experiments and begin innovative heat transfer enhancement experiments in JUPITER-II thermofluid loop *Thermomechanics and JUPITER II SiC System thermomechanics* *Sep. 03* Report experimental data and model prediction for the thermophysical properties of a Be pebble bed/SiC/He system under applied pressure
• **Participating Institutions and Proposed Funding:** (Based on FY 2003 Congressional Request)	UCLA (APEX+JUPITER-II + Pebble Bed Thermomechanics + Neutronics+Surface Renewal): 1915 K$ ORNL (APEX+ Neutronics +JUIPTER-II): 237 K$ UCSD: (under VLT) 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 diagnostics capabilities for free surface flow facilities ($ 150 K; recommended in Peer Review) - Hire (young) experimental fluid mechanics person ($ 200 K)
• **Impact of 10% Budget Reduction:**	- Eliminate the R&D and reduce the design exploration for advanced solid wall concepts in APEX. (- $200 K; represents 50% reduction of research on advanced solid walls in APEX!!; serious harm to already small program; will lose connection to JUPITER-II) - Other cuts will have to come from the liquid wall program which is barely critical now - It will be impossible to complete the R&D required for a liquid module in a plasma device in 2004

VLT Budget Information: FY2003/2004

Attachment 1

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 Flibe simulant Dec. 03 Provide fluid flow database for engineering design of the free lithium surface flow for NSTX or ALCATOR C-Mod module Feb. 04 Initiation of MHD liquid metal experiments with curved wall, inverted surfaces, magnetic propulsion, pulsed fields and, multi-component fields May 04 Test prototype module for installation on an existing plasma device (jointly with ALIST; depends on decision in FY03 to deploy a module) Jul. 04 Completion and initial benchmarking of codes for 3-D free-surface MHD flows in complex geometry. Aug. 04 Determine effects of fast flowing liquid metal stream on plasma equilibria Sep. 04 Comprehensive report on experimental and modeling programs, innovative design exploration results, and status and findings for APEX. JUPITER-II Thermofluid Apr. 04 Initiation of MHD experiments for turnbulence visualization and heat transfer enhancement in FLIHY-closed channel facility Thermomechanics and JUPITER II SiC System Thermomechanics Sep. 04 Provide experimental data and model prediction for effect of thermal creep on ceramic breeder pebble bed system thermomechanics interaction

VLT Budget Information: FY2003/2004

Attachment 1

• **Additional Expected Deliverables With 10% Budget Increase:**	- Double the field in MTOR to 1.2 T to allow more relevant experiments of free-surface MHD liquid metal flows ($ 250 K) - Enhance the investigation of innovative options for the use of flowing liquid metals to improve plasma stabilization and performance ($ 100 K)

• **Impact of 10% Budget Reduction:**	- It will be impossible to complete the R&D (modelling and experiments) required to install a liquid module in a plasma device in 2004
	- It will be very difficult to complete experiments, modelling, and analysis necessary for a meaningful assessment of the feasibility of liquid walls and other innovative chamber concepts
	- Since the Chamber Research Program is barely at a critical level now, budget cuts will require community deliberation to consider among painful alternatives:
	    - Put research on advanced solid walls on "hold"
	    - Move plasma-liquid "bulk" interactions to another program?

• **More than 10% Budget Increase**	Substantial enhancement of the R&D (experimental and computational modelling) effort for liquid metal MHD ($ 620K) 1. Items under the + 10% above (double the field on MTOR; investigation of plasma stabilization by LM) ($350 K) 2. A large volume liquid metal loop to allow axisymetric MHD flow experiments on MTOR ($ 120 K) 3. Add pulsed coils on MTOR to allow MHD flow experiments with space varying, time dependent multi-component magnetic fields ($ 150 K) • Begin an initiative (~$500K per year for 3 years) to explore chamber concepts for the PRODUCTION OF HYDROGEN. This may prove to be an attractive application of fusion (in addition to electricity generation). High temperature chamber concepts currently being explored in APEX Task IV for electricity generation look promising for hydrogen production.
•	