**The Importance of the US Enabling R&D Program to the Development of Fusion Energy**

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The Virtual Laboratory for Technology (<http://vlt.ornl.gov>) represents the diverse activities of 24 organizations involved in fusion technology research and development for the DOE Office of Fusion Energy Sciences. The VLT is organized into 11 technical program elements that span the spectrum of technologies required to carry out its mission

“*To contribute to the national science and technology* *base by 1) developing the enabling technology for existing* *and next-step experimental devices, by 2) exploring and* *understanding key materials and technology feasibility* *issues for attractive fusion power sources, by 3) conducting* *advanced design studies that integrate the wealth of our understanding to guide R&D priorities and by developing design solutions for next-step and future devices.*

The three legs of this mission are critical elements of the DOE mission to develop the knowledge base for practical magnetic fusion energy systems.

**ITER Project Support**

ITER has recently become the primary focus of the VLT’s first mission. As the first fusion device to operate at high levels of sustained fusion power, ITER will provide significant opportunities (and challenges) to advance the development of enabling technologies to the scale required for follow-on devices that will deliver commercial levels of electrical power production. VLT participants led in the planning activities and are actively engaged in design, R&D and qualification of many of the U.S. ITER Project Office (USIPO) hardware packages including:

* The feed system for the 20-MW ion cyclotron heating and current drive antenna which will require the development of actively cooled coaxial transmission lines operating at up to 6 MW each.
* Low loss 2-MW electron cyclotron transmission line systems that supply 24 MW to the electron cyclotron heating and current drive launchers.
* The design and qualification of actively cooled Be-clad first wall armor panels and shield block module assemblies that must withstand the combined effects of high surface heat loads from the plasma and nuclear heating levels of 1 MW/m3.
* The high throughput steady-state DT pellet injectors for fueling ITER with 5-mm size pellets at high repetition rates.
* Pellet ELM pacing injectors to mitigate heat flux from low frequency natural ELMs using up to 30-Hz, 3-mm size pellets to trigger ELMs.
* Disruption mitigation technologies to rapidly inject large quantities of gas and solid deuterium or neon into disrupting plasmas for thermal heat load mitigation and runaway electron suppression and dissipation.
* Specialized cryogenic pumps for the ITER roughing pump system to collect tritiated torus exhaust gases while allowing helium generated by the fusion burn to flow through the pump.

VLT participants have also been actively engaged in several cross cutting support activities for ITER including 3-D CAD based high fidelity neutronics modeling of nuclear heating in support of the design of in-vessel components, and analysis and mitigation of hazard potentials associated with reactor levels of tritium inventory and various energy sources (chemically reactive dust, magnet arcs etc.).

**Research Supporting ITER and Utilization of ITER as a Test Bed**

Apart from direct contributions to the ITER project, VLT members perform R&D and deploy advanced technologies that are destined for use on ITER on fusion research facilities to assess their effectiveness. Examples include pellet and massive gas injection systems for mitigating the effects of plasma disruptions and pellet ELM pacing systems presently deployed on DIII-D. R&D in the US was critical in the design of an ITER-like load-tolerant, high-power density ion cyclotron antenna concept that allows the radio frequency transmitters to operate closer to full power output at high antenna strap voltage. This antenna was deployed on JET and operated successfully at ITER relevant power densities. Similarly, research on electron cyclotron heating systems using gyrotrons that employ depressed collector technology and improved internal mode convertors promises to deliver 1.5-MW systems at overall efficiencies exceeding ITER’s target of 50%. Experiments on the PISCES device are shedding light on a range of plasma materials interaction phenomena associated with ITER first wall and divertor materials with particular emphasis on the critical issue of tritium co-deposition and retention.

As part of its mission to demonstrate the feasibility of fusion energy, ITER will deploy several blanket modules using various combinations of coolants employing solid and liquid breeders for testing tritium breeding concepts. VLT participants have been engaged in international planning activities for the ITER test blanket module (TBM) program and have taken the lead on developing an advanced PbLi self cooled TBM concept. Using helium-cooled, reduced-activation ferritic steel for the TBM structure and silicon carbide composite flow channel inserts to electrically and thermally insulate the flowing PbLi primary coolant from the steel structure, this concept has the potential to operate at high temperature for the extraction of higher grade heat needed to achieve the high thermodynamic efficiencies of our advance reactor concepts.

**Beyond ITER**

ITER is the stepping stone to devices that must employ or develop the high performance materials and the fusion nuclear technologies that are required for electrical power production. The VLT conducts broadly based research in these areas primarily through its Materials Science, Chamber Systems, Safety and Tritium Research and ARIES program elements. The materials program focuses primarily on basic and applied research on reduced activation conventional and advanced ferritic steels and SiC composites, and cross cutting theory and modeling of radiation damage effects on the mechanical properties of materials. A long standing collaboration with the Japan Atomic Energy Agency is investigating the effects of thermo mechanical processing, joining, and high dose neutron irradiation on conventional and advanced nano particle strenghtened steels. An important collaboration with Japan’s National Institute of Fusion Sciences is addressing a range of fusion nuclear technology issues with a focus on plasma facing components and structural materials. These include synergistic effects of high heat fluxes, radiation damage and tritium permeation and retention. The Magnet Program area has turned its attention to the applicability of high temperature superconductors, which allow higher temperatures and fields compared to classical superconductors in next-step devices, to provide higher power densities to improve the economics fusion energy delivery.

Finally, the ARIES advanced systems studies program integrates our present understanding of magnetic confinement systems and state-of-the-art technologies to examine the potential of the portfolio of fusion concepts as power sources**.** Relying extensively on new 3-D design and analysis tools, the ARIES team recently completed the compact stellarator reactor study concluding that a stellarator power plant with acceptable alpha power losses can be similar in size and mass to an advanced tokamak.

**Concerns and Recommendations**

A FESAC 2003 report entitled, “A Plan for the Development of Fusion Energy,” provided recommended budgets for the enabling R&D program including all of the elements outlined above for an MFE roadmap that incorporated ITER and a Component Test Facility (CTF) leading to a DEMO 35 years after initiation of the plan. This plan started with an actual technology and materials budget of $34M which corresponds to $41M in FY12 dollars. The budget was projected to grow to $205M in the twelve-year period leading up to start of CTF construction. This budget allocated roughly $60M each to **Plasma Technologies** (heating and current drive, fueling, PFCs, magnets), **Fusion Energy Technologies** (blankets, tritium control, remote handling etc.) and **Materials Science** with $25M going to **Systems Analysis and Design Studies**. In contrast, the FY13 request budget is $22.6M for the entire program and this is cut $3.3M from FY12 levels. The request includes a needed increase in materials research of ~ $1.5M but deeply reduces support for advanced technologies (rf heating and current drive) and design studies for needed future confinement facilities including ITER and CTF. This also curtails our ambitions to take the lead on a test blanket module for ITER. The problem will be even greater when R&D currently supported by the ITER project in ion and electron cyclotron heating and current drive, fueling and pumping, etc., winds down in the not-too-distant future. Unless the cuts are restored and the trend is reversed, critical expertise needed to design the next step and deliver the technology developments to create control and confine its plasma will be lost to the program. I urge FESAC to consider the impact of these cuts and a longer term program that looks broadly at the technology program as did the 2003 FESAC development plan.