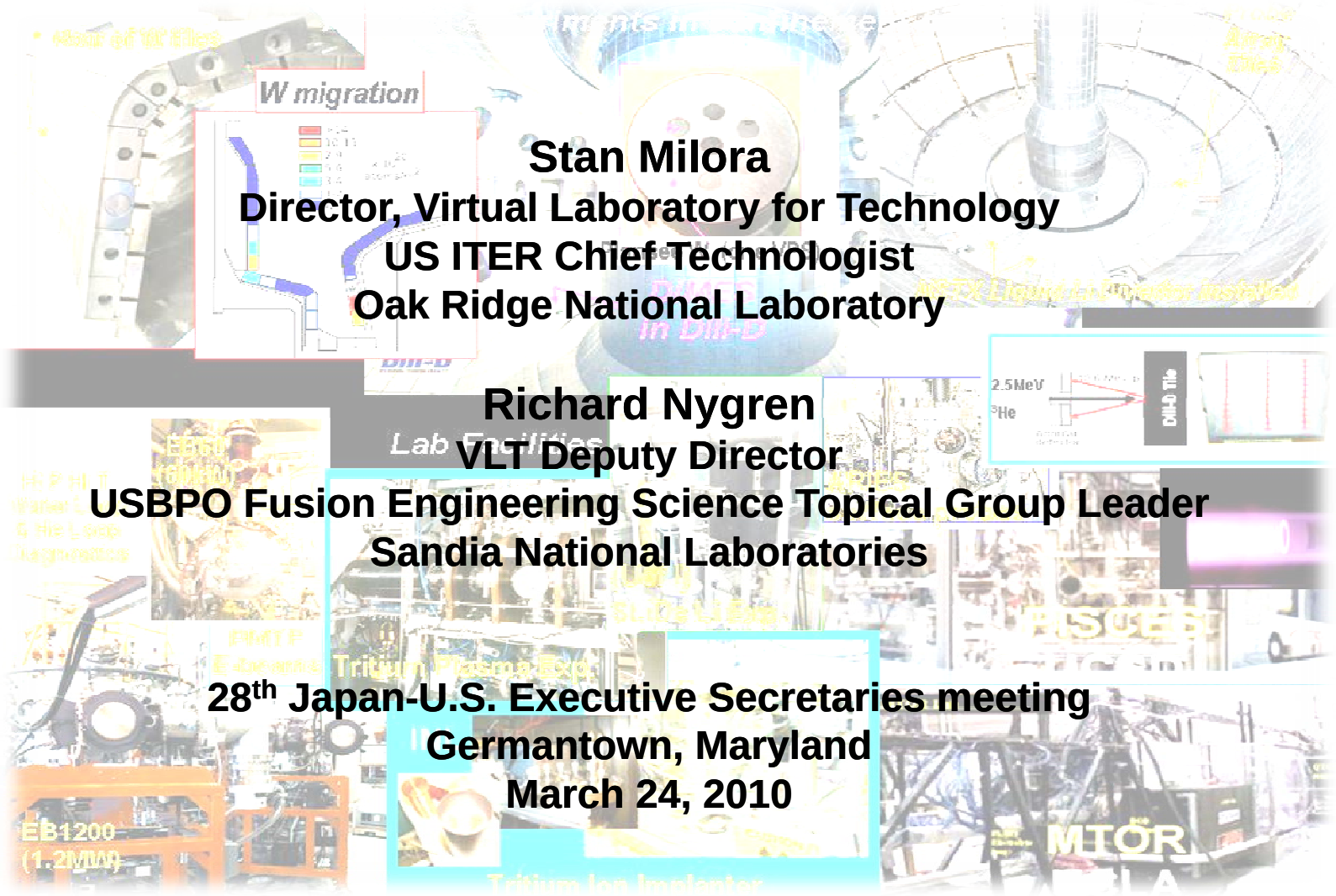
Status of the Virtual Laboratory for Technology

VLT
Virtual Laboratory for Technology
For Fusion Energy Science



Stan Milora
Director, Virtual Laboratory for Technology
US ITER Chief Technologist
Oak Ridge National Laboratory

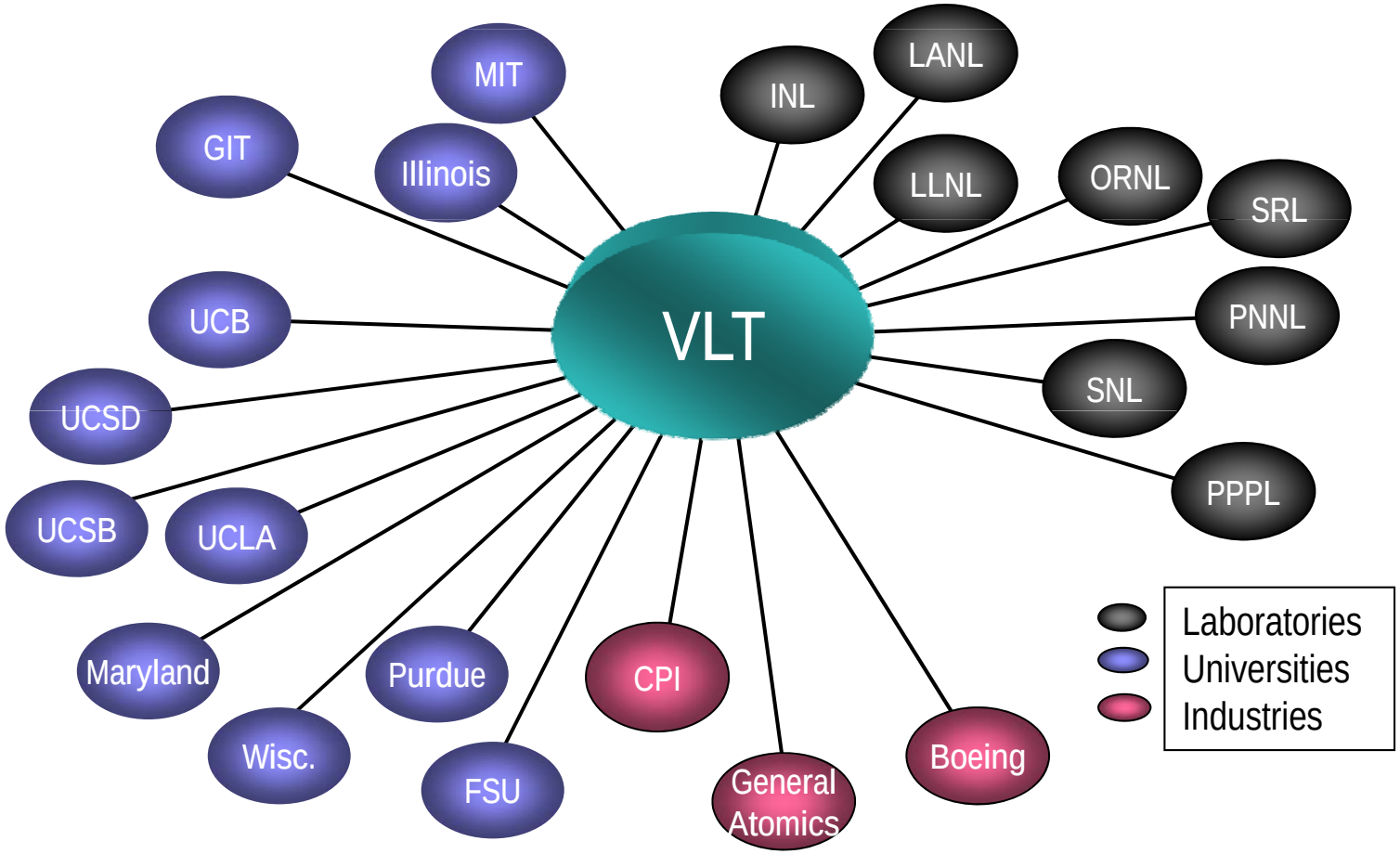
Richard Nygren
VLT Deputy Director
USBPO Fusion Engineering Science Topical Group Leader
Sandia National Laboratories

28th Japan-U.S. Executive Secretaries meeting
Germantown, Maryland
March 24, 2010

The VLT represents the technology research activities of 22 organizations

VLT
Virtual Laboratory for Technology
For Fusion Energy Science

http://www.ornl.gov/sci/vlt



VLT Program Elements and Leaders

VLT
Virtual Laboratory for Technology
For Fusion Energy Science

Program Element	Element Leader
Magnets	J. Minervini - MIT
PFC	R. Nygren - SNL
Chamber	M. Abdou - UCLA
ICH	D. Rasmussen - ORNL
ECH	R. Temkin - MIT
Fueling	S. Combs - ORNL
Tritium Processing	S. Willms – LANL
Safety & Tritium Research	P. Sharpe – INL
Materials	R. Kurtz - PNNL
ARIES	F. Najmabadi - UCSD
Socio-Economic	L. Grisham - PPPL

The VLT contributes to ITER in three important ways

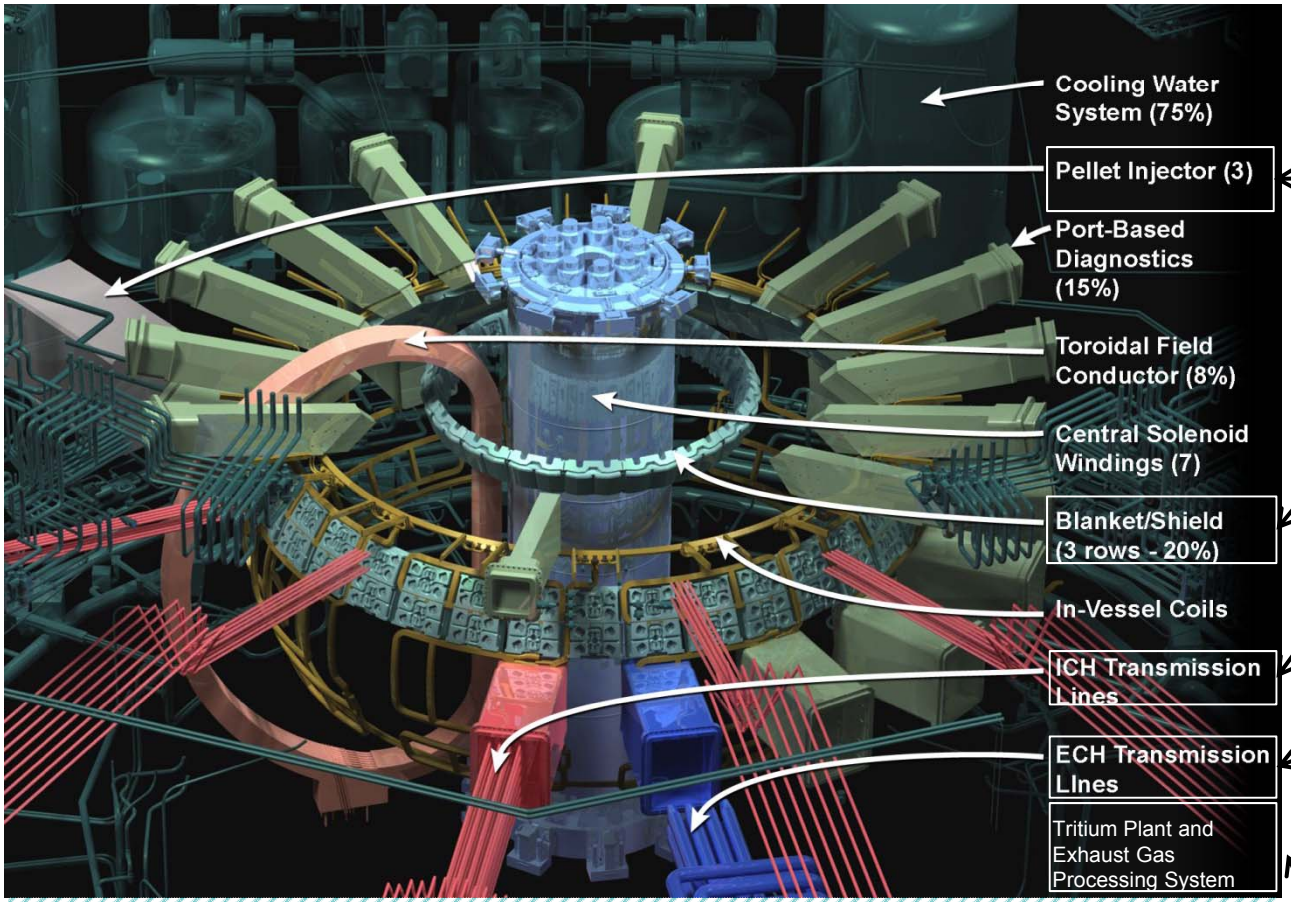
VLT
Virtual Laboratory for Technology
For Fusion Energy Science

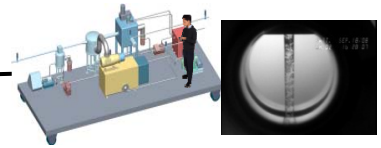
- Contributions to the ITER Project (R&D and design)
- Base program research addressing
  - high priority ITER issues (ELM and disruption mitigation, choice of divertor materials) and
  - operational issues and potential performance enhancements (higher efficiency/power ECH systems and ITER relevant ICH antennas)
- Utilizing ITER as a fusion engineering science test bed and stepping stone to complementary facilities and next step devices such as FNSF.

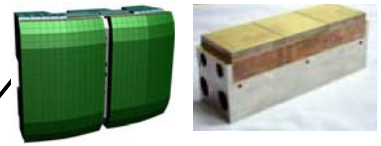
"The base technology program, through the Virtual Laboratory (VLT), is clearly well linked to the ITER project. The IO is using the US analyses to support high-priority needs. As is true in the physics area, the US is contributing to the ITER technology needs well in excess of its status as a "junior" partner. " US ITER TAC report, April 2009

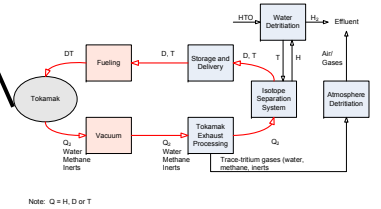
VLT engagement in the ITER Project

VLT
Virtual Laboratory for Technology
For Fusion Energy Science





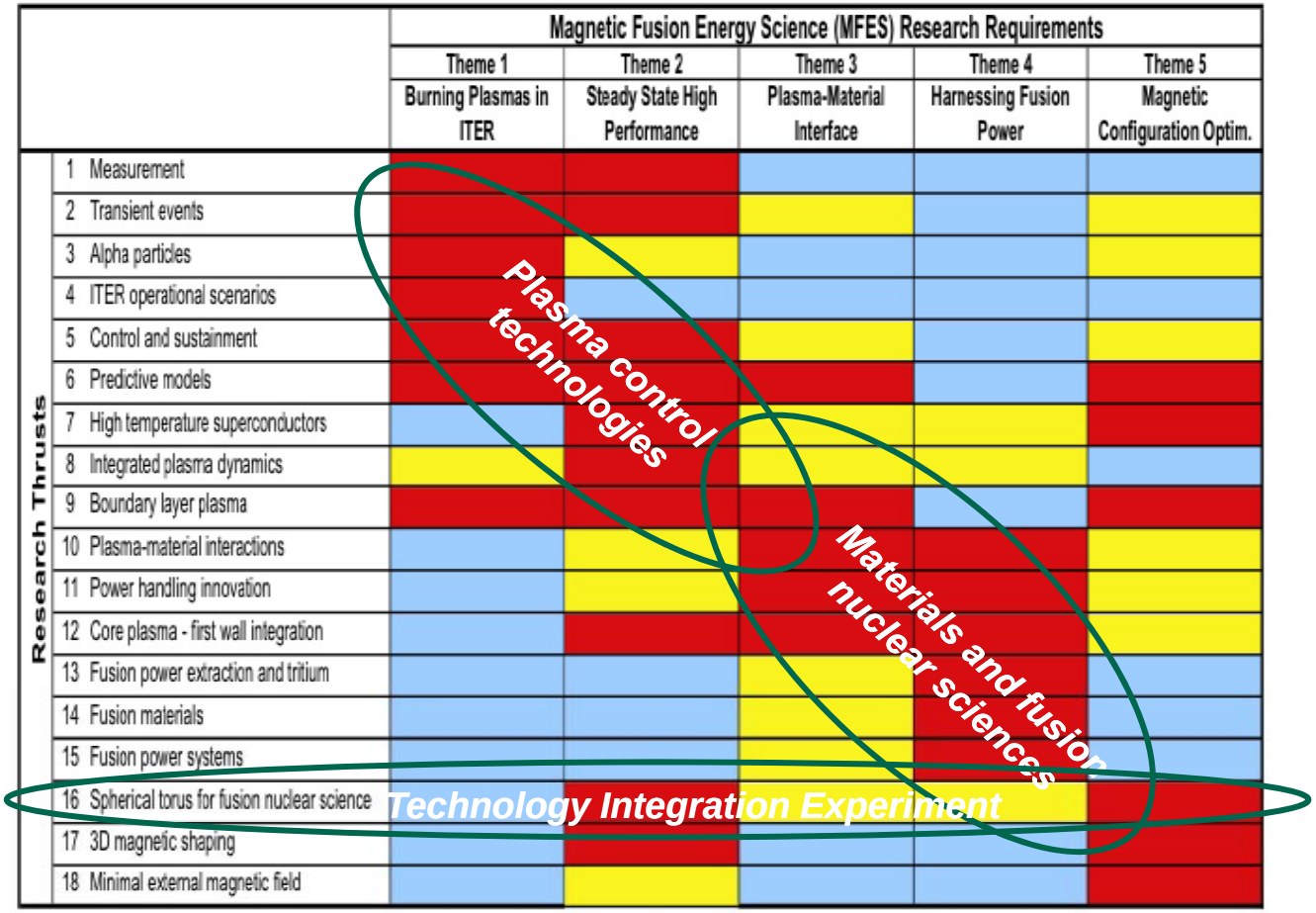




Cross cutting activities (Materials, Nuclear Analysis, Safety),
Test Blanket Program Committee and Port Interface Coordination
Fuel Cycle IPT Deputy Lead, STAC, IRP

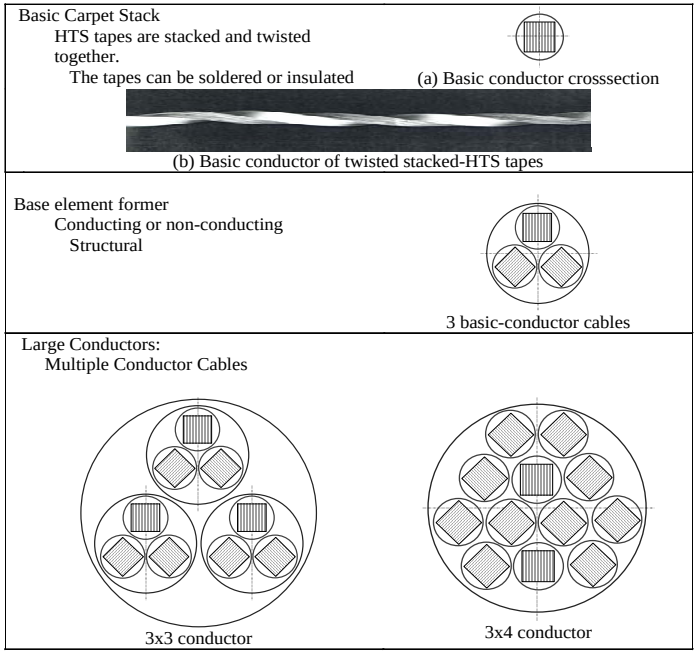
Engineering science and technology issues and VLT performers figured prominently in ReNeW.

VLT
Virtual Laboratory for Technology
For Fusion Energy Science



Magnet Research Status and Plans

- Developed new concept for making high current cables from HTS tapes
  - 4-tape twisted stacked conductor test using BSCCO (1G) and YBCO (2G) tapes
- Critical current tests in magnetic fields up to 1.8 T at 77 K
  - Magnetic field orientation tests at 77 K
- Joint development
  - Two strand model analysis
  - Joint finite element model analysis
  - Joint test at 77 K
- AC loss analysis of twisted stack cable
- Fatigue analysis of magnet structural materials
- Development of Quench Code SOLXPORT3-D
  - 3D simulation of quench in all hydraulic circuits of CICC fusion magnets
  - Includes field effects from plasma currents and passive structure eddy currents
  - Includes criteria to dump energy upon quench propagation



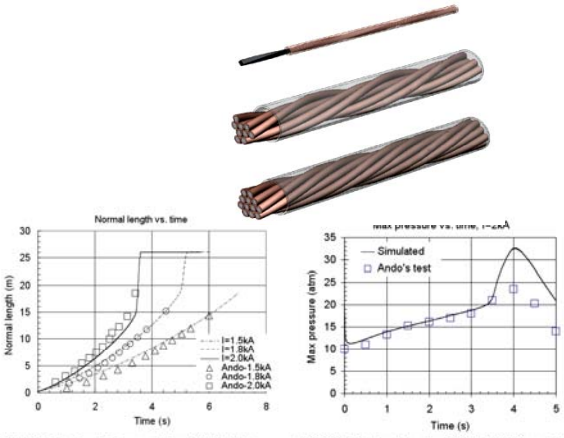


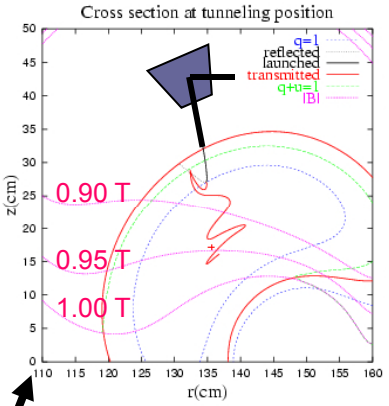
FIGURE 1.5 Simulation results by SOLXPT3D-Quench for normal length compared to Ando results.

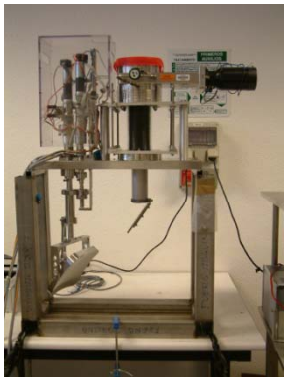
FIGURE 1.6 Simulation by SOLXPT3D-Quench for max helium pressure compared to Ando results.

VLT
Virtual Laboratory for Technology
For Fusion Energy Science

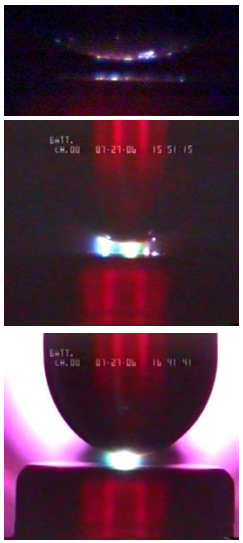
RF Research and Development

- Reliability improvements to increase power and pulse length of DIII-D Fast Wave systems.
- Obtained improved power limits and core heating with modified NSTX HHFW antenna.
- Analysis of load-tolerant JET antenna matching systems to guide ITER matching design.
- Completed conceptual design study for DIII-D long pulse 60 MHz Fast Wave antenna.
- Commissioned test facilities for ITER ICH transmission line and tuning system.
- Initiated EBW H&CD collaboration with MAST.
- Measured mode conversion efficiency with steerable **EBW emission radiometers on TJ-II**.
- Measured and analyzed **RF breakdown limits and arc precursors** with imposed ultraviolet light and as a function of plasma density and surface imperfections (ORNL and UIUC).
- Fabrication, operation, analysis of reflectometer edge density profiles - optimize coupling on C-Mod, DIII-D and NSTX RF antennas.





EBW emission pattern => Optimum launch angle for EBW heating of TJ-II



- Unipolar arcs
- Initial small breakdown arc
- Large breakdown arc

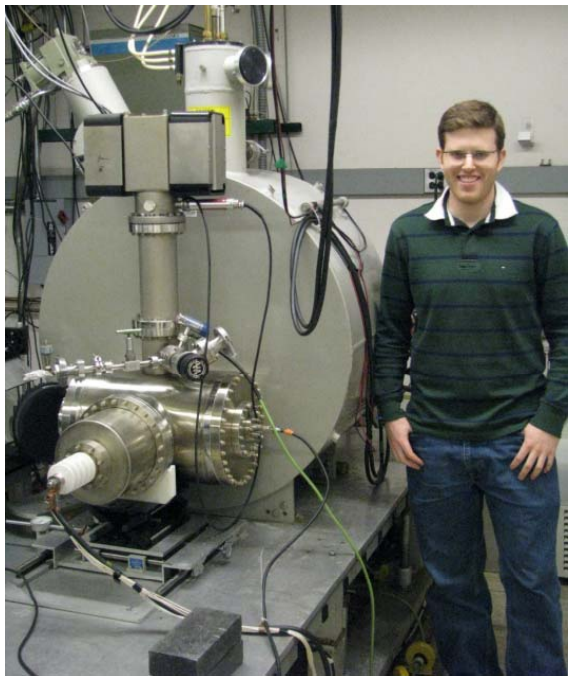
Increasing rf voltage

VLT
Virtual Laboratory for Technology
For Fusion Energy Science

ECH Technology

- **Tests of ITER ECH Transmission Line (TL) Components at JAEA Test Stand** (GA, JAEA)
  - Sliding joint compressed and expanded as expected
- **Analysis of losses on the ITER test line using new EM theoretical approach (MIT, JAEA)**
  - HE_{11} mode purity > 95% required
- **Design and demonstration of internal mode converter with smooth mirrors**
  - Successfully tested at MIT (MIT, Univ. Wisconsin, Calabazas Creek Res.)
  - Mirrors are easier to fabricate and more tolerant to misalignment

GA Sliding Joint Tested at JAEA



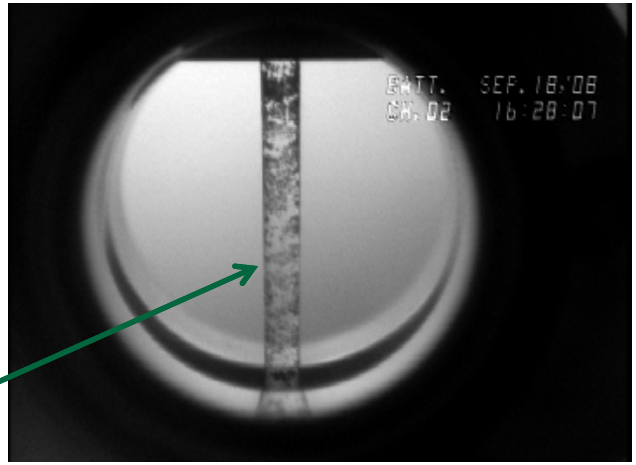
Advanced internal mode converter tested on MIT Gyrotron Test Stand (grad student David Tax)

MIT PSFC · GENERAL ATOMICS · UNIVERSITY of WISCONSIN MADISON · UNIVERSITY OF MARYLAND 18 56

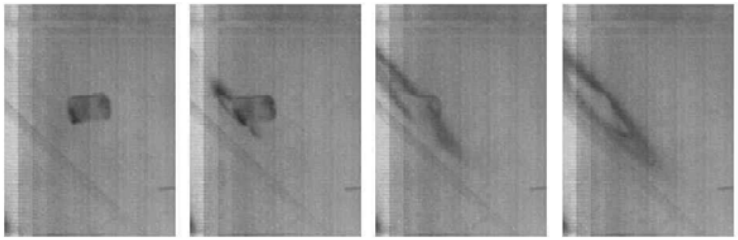
VLT Virtual Laboratory for Technology For Fusion Energy Science

Fueling Development

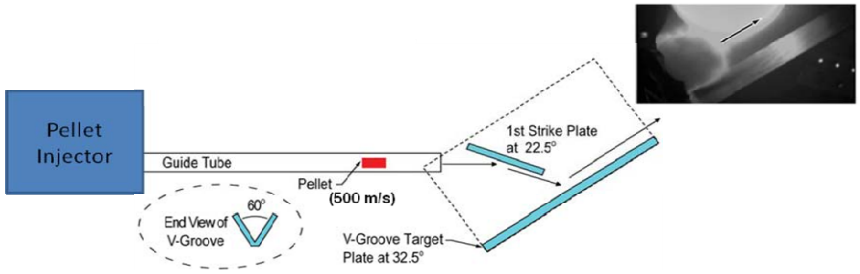
- Development of shattered pellet injection technique for disruption mitigation (ITER relevant)
- Installation/Operation of shotgun pellet injector on DIII-D for disruption mitigation studies
- Flexible pellet injector development and upgrades for MST and TJ-II fueling and transport studies
- Continuous twin-screw extruder demonstration for ITER D-T pellet injector design
- Modeling of ITER fueling and pellet ELM pacing scenarios
- High speed two-stage gas gun injector commissioned with ENEA



Solid deuterium extrusion from twin-screw extruder.



16.5 mm diameter Ne pellet impacting a plate at 340 m/s



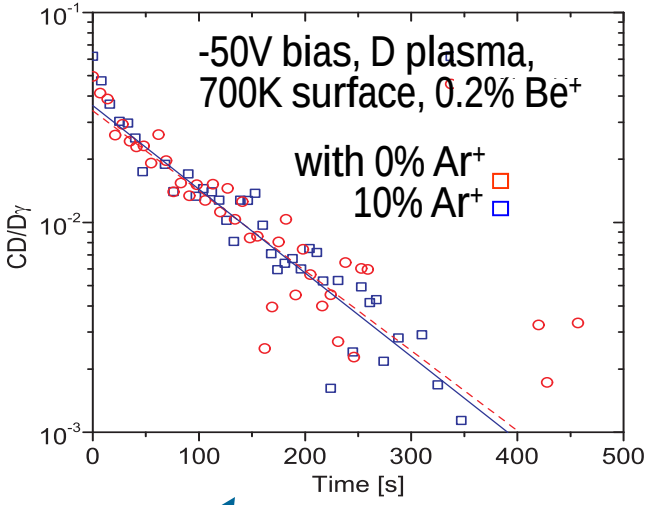
DIII-D NATIONAL FUSION FACILITY SAN DIEGO

VLT Virtual Laboratory for Technology For Fusion Energy Science

Plasma Facing Components

High Heat Flux Testing

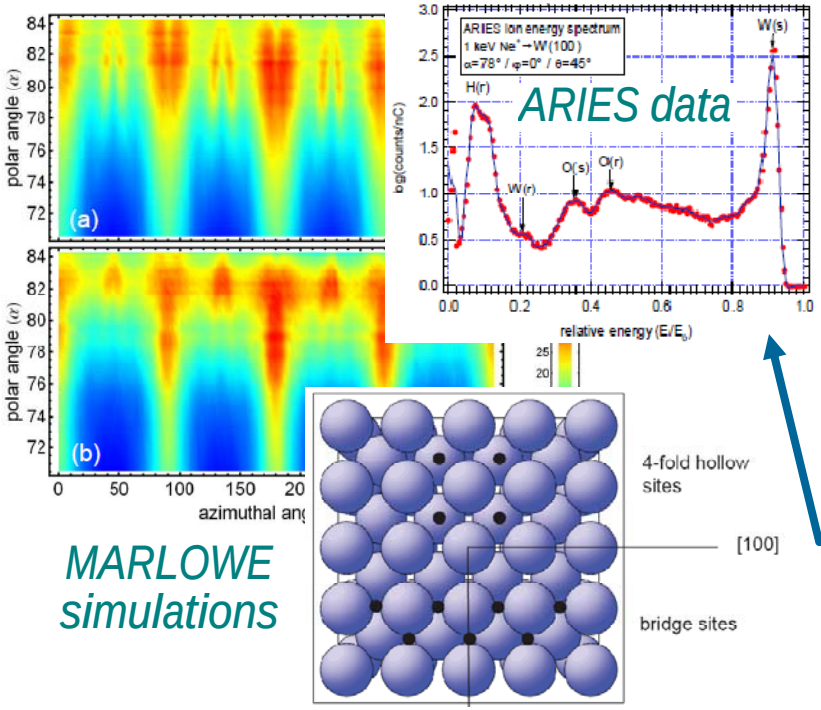
- **PMTF test capability to support ITER** *(Sandia)*
  Unique: large targets IR views, handle Be *(toxic)*
  tests: FW quality mockups (R,J,K,C); Critical Heat Flux for hypervaportron FW (new ITER enhanced heat flux units)
  - First Be cleanup of EB1200
  - **Prepare EB1200 for FW semi-prototpype**



PSI Tests

- **PISCES- B** *(UCSD)*
  - Be mitigates chemical erosion of C, *and* the beneficial effect survives Argon sputtering
  - Continued work on W "fuzz"

- **Dust on DiMES; mirrors in MiMES** *(GA/UCSD/SNL/ANL)* → *Gas puff mitigates C deposition*



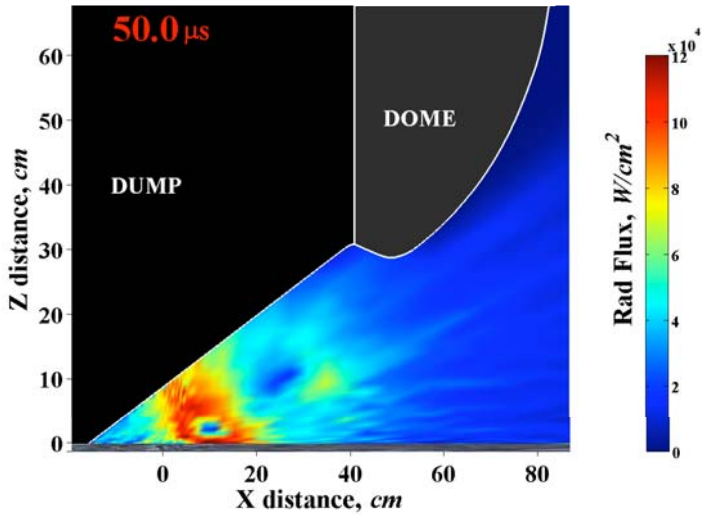
MARLOWE simulations

- **D (T) retention in He damaged W; C erosion marker in EAST tile for ITER; ARIES spectroscopy D on W** *(Sandia)*

Plasma Facing Components

Modeling and Simulation

- Mixed-material sputtering & mixing for ITER, materials on DiMES/MiMES *UCSD/PU/LLNL*
- PFC response to ELMs, disruptions *PU*
- *Thermal model LLD* [grant] *SNL*
- CFD models of He cooling *SNL*
- Free surface liquid metal divertors *UCLA*
- D/T on Be surfaces *SNL*

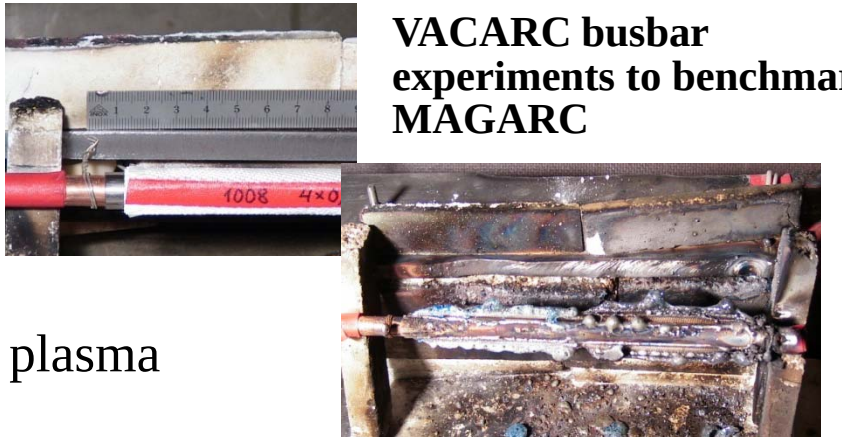


Radiation Fluxes to nearby components during ELM with 0.1 ms duration (Purdue)

Tritium Research & Safety

SAFETY AND ENVIRONMENT

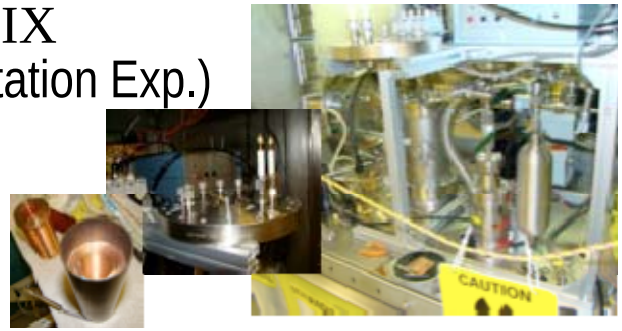
- Initiated testing for dust explosion indices of Be, W, C, and mixtures
- Magnets safety code MAGARC extended to evaluate busbar behavior
- Extended failure rate database to include plasma diagnostics systems & tritium monitors



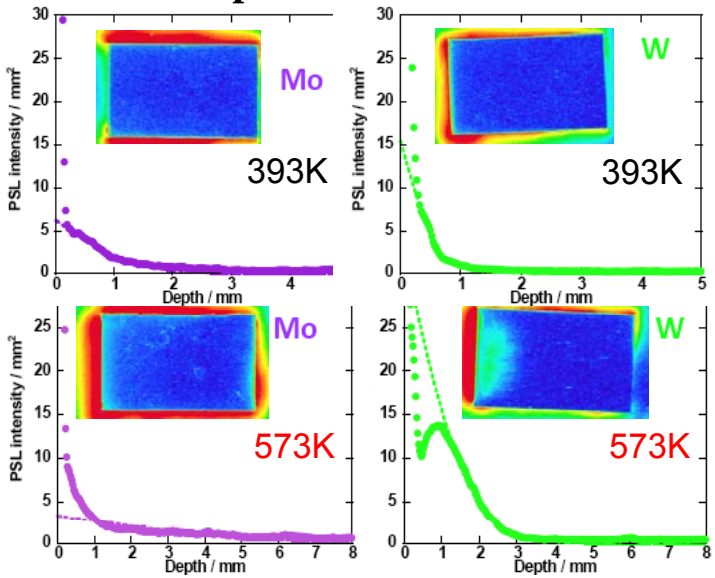
VACARC busbar experiments to benchmark MAGARC

TRITIUM SYSTEMS

- Tritium retention tests, irradiated W & Mo
- Extended measurement of tritium solubility in molten Pb-Li eutectic at very low partial pressures
- Evaluated concepts and requirements for a tritium extraction test loop
- Operated the TRIIX (Tritium Ion Implantation Exp.) for irradiated samples



Tritium profiles in W & Mo



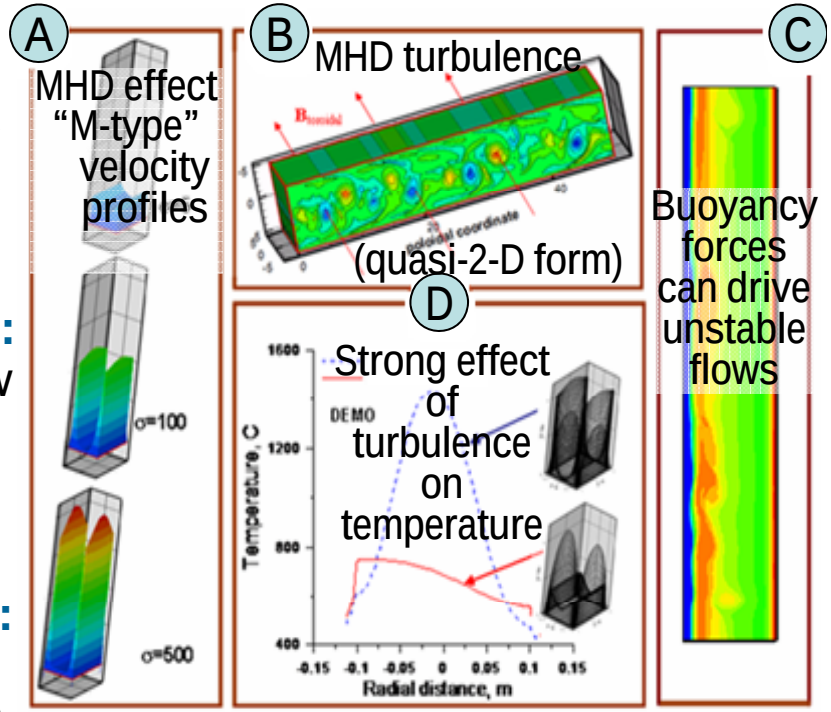
LLE solubility test system

VLT
Virtual Laboratory for Technology
For Fusion Energy Science

Chamber Systems

Theory and Modeling

- **Continue to develop integrated FW-blanket simulations:** mate different meshes/codes for neutronics-thermofluid-thermomechanics integrated analysis for tritium blankets* [UCLA]
- **MHD flow & mass transfer theory/modeling:** improve simulations of MHD effects on 3D flow elements plus physics of turbulence, wall wetting, and non-uniform properties* [UCLA]
- **US expertise on TBM* and interfaces for IO:** help JA/KO coordinate half-port in Port 18; provide US expertise to ITER TBM Program Comm.



MHD severely modifies flow dynamics, heat & mass transport in liquid metal blankets.

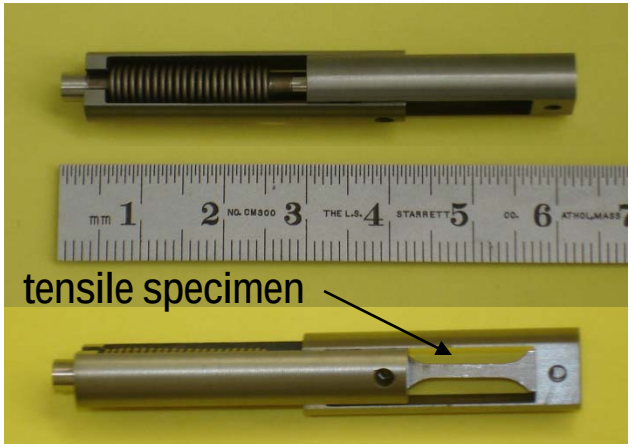
Experiments LM-MHD Experiments for the US/JA TITAN Collaboration:

- Year-3 experiments on impact of MHD on transition (3-D to 2-D) fluctuations and turbulence completed.
- Establish high temperature PbLi flow capability and initial experiments.

Materials

Experimental results

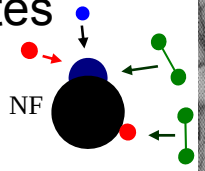
- **Predicted changes due to irradiation verified**
  - Change in flow (yield) stress vs. shift in temperature below which (brittle) fracture occurs
  - Cavity evolution in He implanter using advanced multi-scale model of He transport and fate
- **Completed two irradiation experiments**
  - Post-irradiation examination of DOE/MEXT 18J: *determined response of SiC and SiC composites to high-temperature irradiation*
  - DOE/JAEA 15J (lithium-bonded experiment): *microstructural evolution and mechanical properties of advanced RAFM and ODS ferritic alloys*

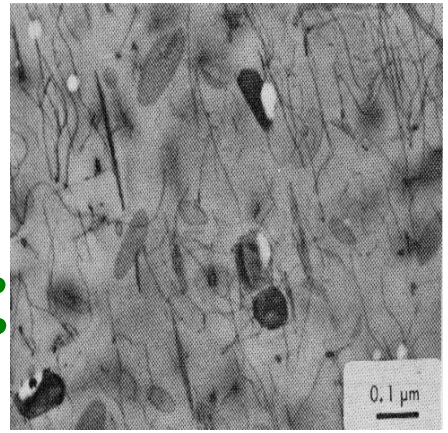


Novel capsule to test in-reactor creep of metals and ceramics with internal load frame

Theory - Extensive computational studies

- He diffusion & clustering to form bubbles, and ballistic escape
- Dislocation interaction with nano-scale oxide precipitates
- Major progress in how to manipulate nano-features that imbue ODS ferritic alloys with remarkable high-temperature strength and tolerance to neutron damage

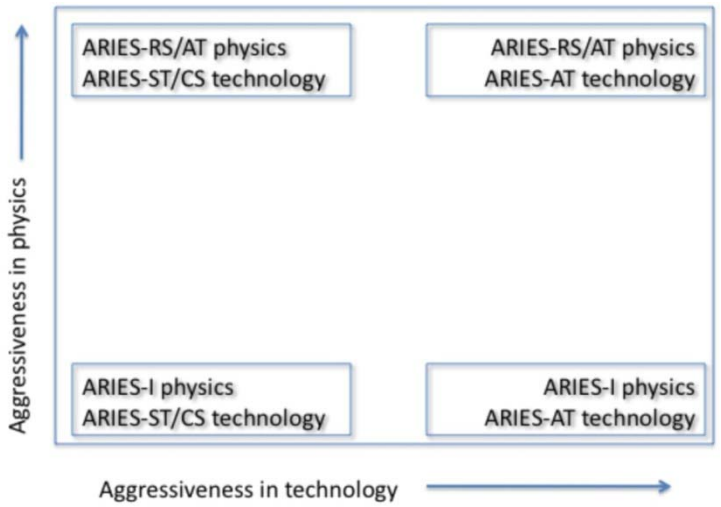




ARIES (MFE Systems Studies)

Completed "ARIES Pathways" study: ***tools to aid in R&D planning***

- Application of "Technical Readiness Levels" to quantify gaps
- Fielding of new Systems Analysis tool for improved exploration of parameter space
- Application of the tool to analyze "four corners" of tokamak operation



1) Initiated study of edge plasma physics and plasma-material interactions, high heat flux components and off-normal events *in a fusion power plant*.

VLT
Virtual Laboratory for Technology
For Fusion Energy Science