Idaho National Engineering and Environmental Laboratory

Safety and In-vessel Tritium Plans: FY-05 and FY-06

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US Fusion Safety Program

VLT PAC Meeting

UCSD

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Outline

- Fusion Safety Program Mission
- Outstanding ITER safety issues
- Recent Accomplishments
- FY-05 and FY-06 Plans - Safety and In-Vessel Tritium
- Summary/Issues

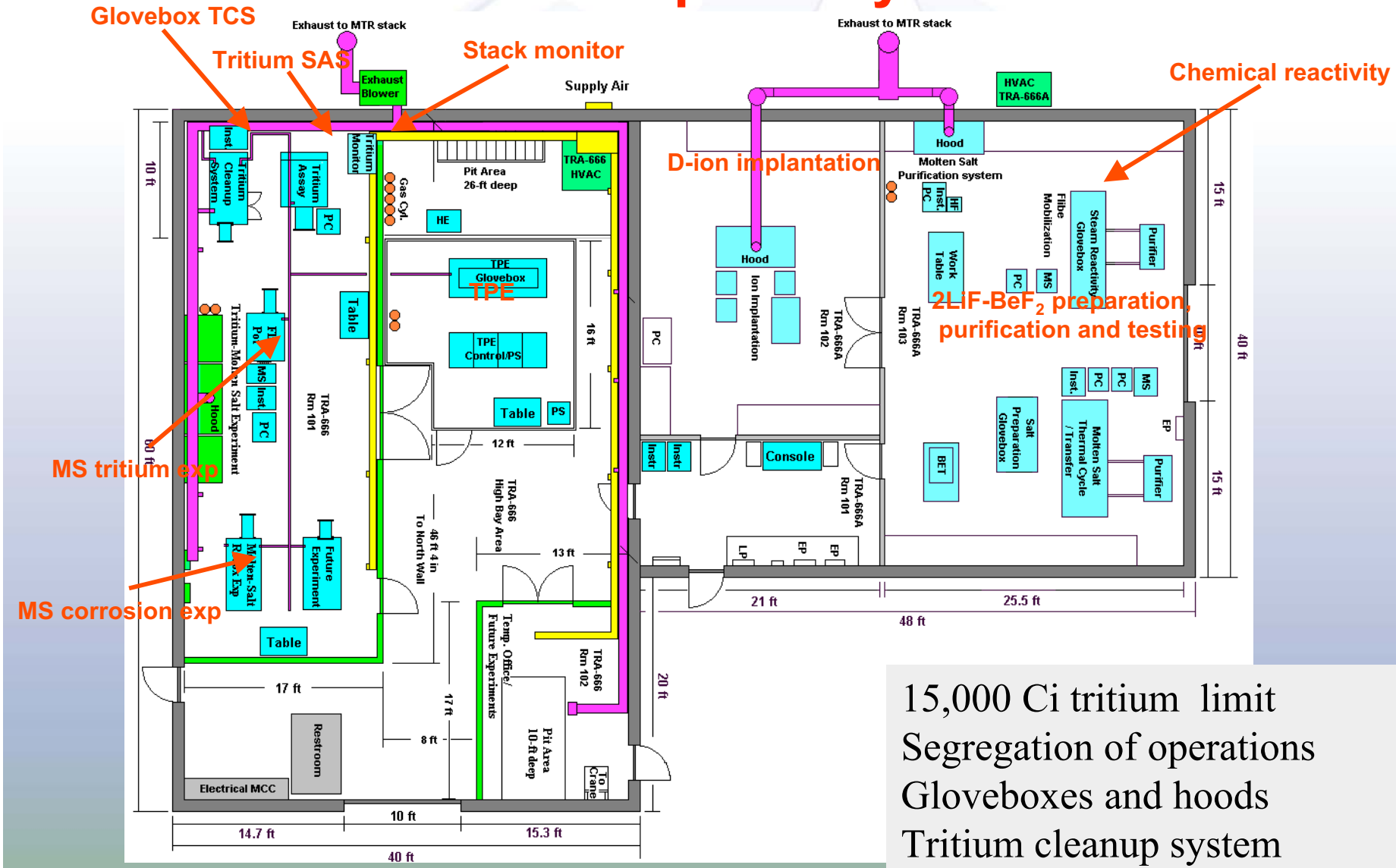
Fusion Safety Program Mission

- Characterize and assess the safety and environmental issues associated with magnetic and inertial fusion. Assist the various design teams in improving the safety and environmental attributes of their design.
- Demonstrate the safety and environmental potential of fusion by (1) avoiding any need for off-site public evacuation during worst case accidents and (2) minimizing the amount of radioactive waste that would pose a burden for future generations.
- This is accomplished by:
  - Understanding the behavior of the largest sources of radioactive and hazardous materials in a D-T machine
  - Understanding how energy sources in a fusion facility could mobilize those materials
  - Developing integrated state of the art analytic tools to demonstrate the safety and environmental potential of fusion
  - Assessing/evaluating safety and environmental issues associated with emerging fusion concepts such as those studied in the MFE ARIES, ALPS, APEX, NSO projects, and the IFE program

Outstanding ITER safety issues

- Validate US safety analysis tools (calculations with quantified uncertainties with the level of detail to depend on regulatory requirements of the actual site) that underpin the ITER safety analysis
- Validate magnet safety codes against medium scale magnet and busbar arcing experiments to demonstrate that ITER can tolerate large internal and external arcs in the magnet systems without violating the integrity of the radioactive confinement barriers.
- Validate dust inventory estimates in ITER and develop a dust removal strategy that will demonstrate compliance against dust safety limits in ITER and not hamper operational flexibility of the machine
- Validate tritium inventory estimates in ITER mixed material PFCs and demonstrate that removal strategies are effective at the ITER scale to comply with safety limits

STAR Floorplan Layout

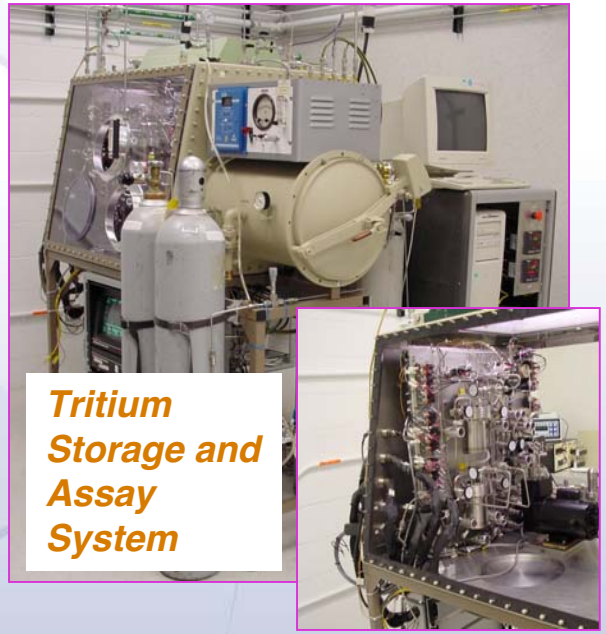


15,000 Ci tritium limit
Segregation of operations
Gloveboxes and hoods
Tritium cleanup system
Once-through room ventilation

Key systems in STAR

Tritium Plasma Experiment and Enclosure

Molten Salt Tritium Behavior Experiment



Tritium Storage and Assay System

Tritium Cleanup System

Molten Salt Preparation, Purification, and REDOX Experiments

Steam and air chemical reactivity test apparatus

Current and Planned Safety Allocation

Tasks (Yellow represents ITER relevant R&D task from the base program, Magenta ITER project tasks, white base program tasks)	FY-04	FY-05	FY-06 - 10%	FY06 Nominal	FY-06 +extra
Fusion Safety Codes	260 K	450 K	450 K	450 K	450 K
Magnet Safety	120 K	150 K	150 K	150 K	650 K
Dust source term validation	140 K	450 K	325 K	450 K	450 K
In-vessel Tritium source term validation (and STAR Upgrades - FY-04 only)	960 K	600 K	600 K	600 K	600 K
JUPITER II	275 K	290 K	290 K	290 K	290 K
Risk	100 K	100 K	100 K	100 K	100 K
Safety Support (ARIES, FIRE, ITER TBM, ITER)	230 K	200 K	100 K	200 K	200 K
On-Site or VHTP for Regulatory Support					300 K
Total	2085 K	2240 K	2015 K	2240 K	3040 K

Fusion Safety Codes

- Work is focused on upgrades, re-analysis/refinement of specific ITER accident calculations, verification and validation of fusion safety codes (MELCOR and ATHENA) used in ITER safety analysis.
- Currently working under an ITER task agreement through Dec. 2004. Extension into FY-06 expected.

Base	FY-05	Final report on upgrades of codes and installation at ITER	Dec. 2004
Base	FY-05	Report on validation activities with EVITA experiment	Sept. 2005

Base	FY-06 -10%	Document results of reanalysis and/or refinement of ITER accident calculations	Dec. 2005
Base	FY-06 -10%	Report on validation activities with new set of EVITA experiments	Sept. 2006

Magnet Safety Codes

- Work is focused on upgrading INEEL developed magnet safety code, performing magnet arcing calculations, and verification and validation of the code with upcoming EU experiments (under an IEA-ESE task).
- Currently working under an ITER task agreement through Dec. 2004. Extension into FY-06 expected.

Base	FY-05	Analyze arcing in PF magnet system of ITER	Dec. 2004
Base	FY-06 - 10%	Report documenting magnet validation activities	Sept. 2006
Base	FY-06 + extra	Begin design of medium scale magnet arcing experiments	Sept. 2006

Dust Source Term Validation

- Work is focused on dust characterization from existing tokamaks, dust mobilization under air ingress conditions, dust chemical reactivity in slots/grooves, dust cleanup techniques, and re-evaluation of dust inventory mitigation strategy used in ITER
- Expecting an ITER task agreement soon in this area

Base	FY-05	Dust mobilization experiment results	Dec. 2004
Base	FY-05	Dust chemical reactivity experiment results	Sept. 2005

Base	FY-06 -10%	Complete dust chemical reactivity experiments	Feb. 2006
Base	FY-06 -10%	Re-evaluation dust mitigation stategy for ITER	Sept. 2006

Base	FY-06	Evaluate dust cleanup techniques	Sept. 2006

Tritium Source Term Validation

- Work is focused on tritium behavior in tungsten, mixed materials, and dust
- Work will utilize the tritium plasma experiment and is being planned jointly with SNL. Mixed materials work is part of on-going EU/US task in conjunction with PISCES. Tritium will be used in these experiments.

Base	FY-05	Tritium behavior in tungsten	June 2005
Base	FY-05	Initiate experiments on tritium behavior in mixed materials	Sept. 2005

Base	FY-06 -10%	Complete experiments on tritium behavior in mixed materials	Sept. 2006

JUPITER-II Molten Salt Work

- Work is focused on demonstrating REDOX behavior in molten salt and beginning design of corrosion experiments
- Work is part of JUPITER-II materials program and is matched by Japanese money

Base	FY-05	Demonstrate REDOX	Feb. 2005
Base	FY-05	Initiate corrosion experiments	Sept. 2005

Base	FY-06 -10%	Document results of corrosion experiments	Sept. 2006

Risk Analysis and Data Collection

- Work is focused on providing data on reliability of fusion components for use in fusion safety analysis and evaluating worker safety issues for fusion
- Synthesis/evaluation of operating experience of current machines may be ask for by ITER regulators to make sure past lessons learned have been incorporated into the design of ITER
- Work is planned under an IEA-ESE task in this area

Base	FY-05	Reliability estimation/tokamak operating experience report on in-vessel components from DIII-D	Sept. 2005

Base	FY-06 -10%	Worker risk assessment for high consequence scenarios	Sept. 2006

Safety Support

- Work is focused on providing support for ARIES and US ITER Test Blanket Module (TBM) activities.

Base	FY-05	Safety assessment of ARIES compact stellarator design	Sept. 2005
Base	FY-05	Provide molten salt and safety support to US ITER TBM	Sept. 2005

Base	FY-06 -10%	Safety support for ARIES	Sept. 2006

Base	FY-06	Support of ITER TBM	Sept. 2006

Potential New Task: Regulatory Support and Design Integration
(from ITER project funds)

- Precedent is very important in regulatory matters
- Specific regulatory requirements imposed by the host on ITER can have ramifications for ANY future fusion facility built anywhere in the world
- US safety team needs to be actively engaged in discussions with the ITER safety team and the regulatory authorities to “push back” on requirements that do not make sense for fusion
- US goal is to obtain maximum operational flexibility for ITER, given its experimental nature, yet still meet a set of regulatory requirements that make sense for fusion
  - When ITER enters the operations phase, limits may be placed on operation based on the traditional fission approaches. This could potentially hinder future operations. US needs to be involved here.
- Safety/design integration is also an area where the US has been strong. Integration of safety requirements into the design in a rational coherent manner is very important to retain maximum flexibility and still have an adequate safety envelope for operations

ITER Project Funds	FY-06	VHTP and/or ITER site representative for regulatory support and/or design integration	~ 300 K/yr

FY-05 Summary Tasks/ Milestone	Date	FY-05
Fusion Safety Codes		**400 K**
Final report on upgrades of codes and installation at ITER	Dec. 2004	
Report on validation activities with EVITA experiment	Sept. 2005	
Magnet Safety		**150 K**
Analyze arcing in PF magnet system of ITER	Dec. 2004	
Dust source term validation		**450 K**
Dust mobilization experiment results	Dec. 2004	
Dust chemical reactivity experiment results	Sept. 2005	
In-vessel Tritium source term validation		**600 K**
Tritium behavior in tungsten	Feb. 2005	
Tritium behavior in mixed materials	Sept. 2005	
JUPITER II Molten Salt Activites		**290 K**
Demonstrate REDOX	Feb. 2005	
Initiate corrosion experiments	Sept. 2005	
Risk		**100 K**
Reliability estimation/tokamak operating experience report on in-vessel components	Sept. 2005	
Safety Support (ARIES, FIRE, ITER TBM, ITER)		**200 K**
Safety assessment of ARIES compact stellarator design	Sept. 2005	
Provide molten salt and safety support to US ITER TBM	Sept. 2005	
Total		**2240 K**

FY-06 Summary Tasks/ Milestone/Resources	Date	($)
Fusion Safety Codes		400 K
Document results of reanalysis and/or refinement of ITER accident calculations	Dec. 2005	
Report on validation activities with new set of EVITA experiment	Sept. 2006	
Magnet Safety		150 K
Report documenting magnet validation activities	Sept. 2006	
Dust source term validation		450 K
Complete dust chemical reactivity experiments	Feb. 2005	
Re-evaluation of dust mitigation strategy for ITER	Sept. 2006	
In-vessel Tritium source term validation		600 K
Complete Tritium behavior in mixed materials	Sept. 2006	
JUPITER II Molten Salt Activites		290 K
Status on corrosion experiments	Sept. 2006	
Risk		100 K
Worker risk assessment for high consequence scenarios	Sept. 2006	
Safety Support (ARIES, FIRE, ITER TBM, ITER)		200 K
Safety assessment of ARIES design	Sept. 2006	
Total (-10% option)		**2015 K**
Evaluate dust cleanup strategies	Sept. 2006	125 K
Safety support of ITER TBM		100 K
Total (flat FY-06 option)		**2240 K**
Begin design of medium scale magnet arcing facility	Sept. 2005	500 K
ITER VHTP or JCT assignee for regulatory support and/or design integration		300 K
Total		**3040 K**

Summary

- Safety program is re-directing two-thirds of it program toward ITER.
- FSP is focused on validating the safety codes and the source term assumptions used in the ITER analysis
- Need for a VHTP or JCT assignee to deal with regulatory issues is very important