

VLT Activities Highlight
20 June 2007 Conference Call

**US Activities in Safety and
Standards in Support of the
ITER Preliminary Safety Report**

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Outline

- Overview of ITER Licensing Process
- US Safety Activities for Rapport Préliminaire de Sûreté (RPrS)
 - MELCOR Code QA and Support
 - Accident Analysis Identification Process
 - Development of Dust Procedure
 - US-TBM Safety Analysis and Assessment
- ITER QA Program
- Application of Codes and Standards

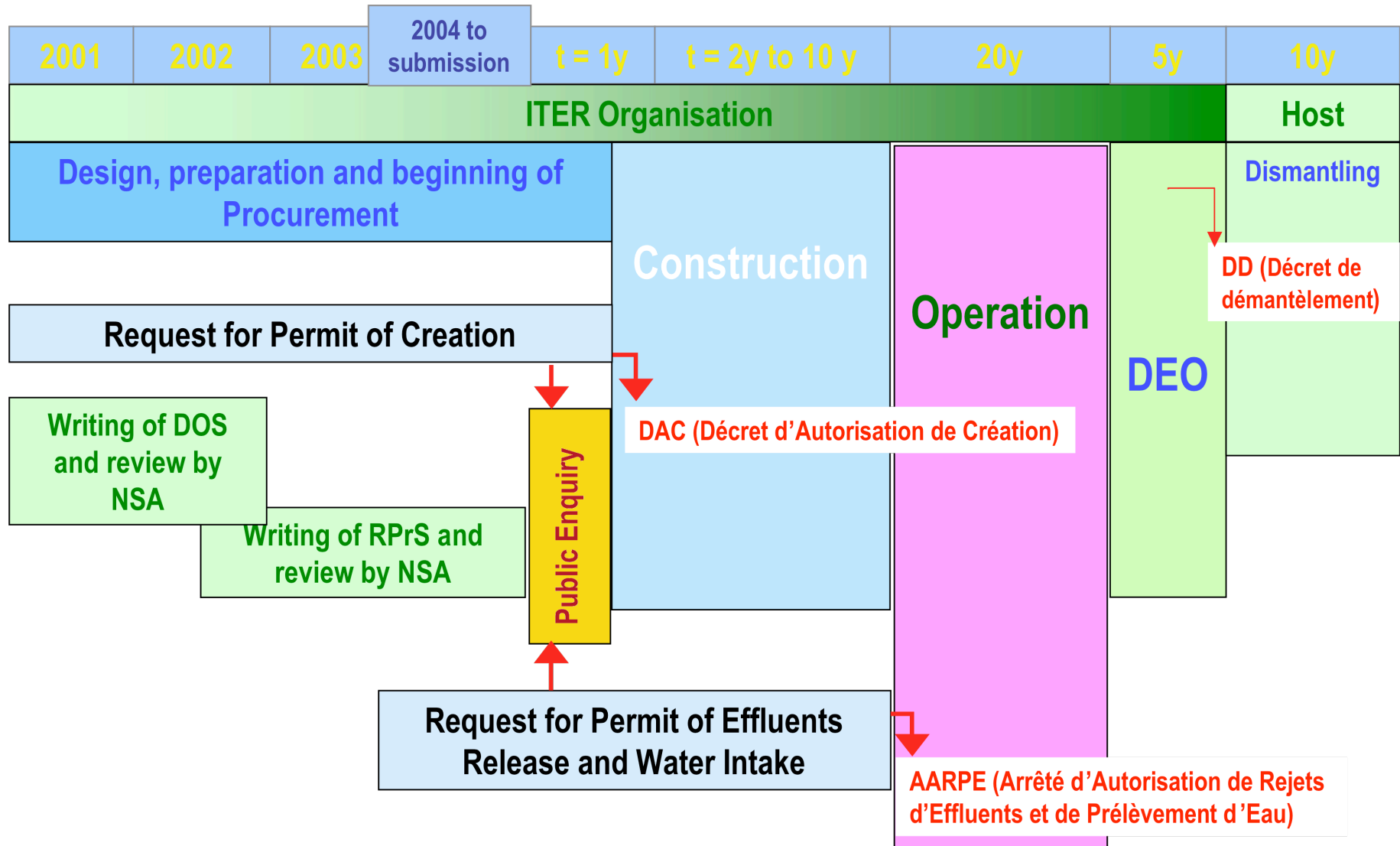
Note: The information presented here on the ITER licensing and accident analysis sequence processes was derived from discussions with J.-P. Girard, leader of the ITER Safety, Environment, and Health Group.

ITER Licensing Process

As ITER will be built in France, French regulatory framework applies:

- France has already implemented ~160 INB (Installation de Nucléaire de Base) facilities
 - Including 59 nuclear power plants
 - ~20 civil nuclear facilities at CEA-Cadarache
- There is a well-established “roadmap” for licensing nuclear *experiments*
- Broadly, there are three stages:
 - Safety Options Report- completed and reviewed by ASN (Autorité de Sûreté Nucléaire) in 2002
 - Preliminary Safety Report (RPrS), and associated documents- DAC and DARPE lead to *construction permit* after review and public hearings
 - Safety File (final safety report) for operation together operational rules before start-up (>2016) leads to *operations permit*

ITER Licensing Process, cont.



ITER Licensing Process, cont.

Objectives of the Preliminary Safety Report:

(*Rapport Préliminaire de Sécurité*, or RPrS)

- To describe the ITER facility (e.g. DDD-level)
- To present the postulated accidental situations
 - Show how the safety design approach keeps the plant in a safe state
 - Show that limits and guidelines will be followed
 - Justify assumptions, correctness of models, etc.
- To provide complementary safety analyses and site adaptations in comparison to the host state regulations
 - Internal (fire) and external hazards (earthquake, external flood, aircraft impact,...)
- To show an adequate ultimate safety margin
 - No “cliff edge effects” in beyond design basis events
- Must show that experience from existing and past facilities has been taken into account
- Where necessary, show that ongoing R&D is in place to resolve issues

ITER Licensing Process, cont.

RPrS Schedule (at present):

- Safety options report (DOS) **submitted** to NSA and **reviewed** 2002
- Public debate **held** January – May 2006 (20 meetings)
 - report from CDNP available (www.debatpublic-iter.org), under review by CEA and ITER
- First version of RPrS **prepared** by *l'Agence ITER France* in 2005
 - drafted in French, translation to English is pending
 - review of GSSR (2001) chapters for applicability
- CEA subcontracted work on new RPrS during October 2006
- Draft RPrS to be complete **mid-2007**
 - followed by internal and external reviews
 - the technical project review will also be an input to validate the safety analysis
- Formal submission of RPrS, DAC and DARPE, **end 2007**
- Review by DGSNR, IRSN, and Groupe Permanent during 2008
- Public hearing (DAC and DARPE) **mid-2008**
- Construction permit, and start of the construction **beginning of 2009**

US Safety Program Activities for RPrS

MELCOR Code QA and Support

MELCOR is a code developed at Sandia National Laboratory for severe accidents in fission reactors and is part of the NRC licensing toolkit.

INL Fusion Safety Program researchers modified MELCOR during the EDA for ITER applications, and its proven useful for fusion power plant design safety assessments (e.g. ARIES).

The **MELCOR-Fusion** code solves mass, momentum, and energy equations for two-phase fluid flow, heat conduction equations for walls, and aerosol transport equations for estimating release of radioactive materials to the environment.

Ongoing analysis work for the ITER includes:

- **Quality assurance** of the fusion modifications made to **MELCOR**
- **Accident analysis** for the ITER device

RPrS US Activities: MELCOR Code QA and Support, cont.

AN ITER Task Agreement for QA MELCOR has been established. The deliverables of this agreement are:

- A 'pedigreed' version of MELCOR operating on a Linux and Windows operating system by **June 2007**
- Supply ITER with required QA documentation by **September 2007**
- Assist the ITER IT in performing accident analyses with MELCOR for the RPrS by **October 2007**
- QA of MELCOR input decks for these analyses by **July 2007**

Accident definitions, sequence, and specifications are still being finalized, but are similar in nature and consequence to those considered in the GSSR (as well as the preceding NSSR-1 and NSSR-2).

RPrS US Activities: Accident Analysis Process

Four approaches are used to produce exhaustive accident sequence listings:

- Deterministic selection of “reference event sequences”
- Bottom-up component-level Failure Modes and Effects Analyses (FMEA)
- Top-down global event tree (Master Logic Diagram)
- Postulated Initiating Event/Potential Impacts Table (PIE/PIT)- combines top-down and bottom-up

25 Reference Cases were selected using deterministic approach and to ensure inclusion of

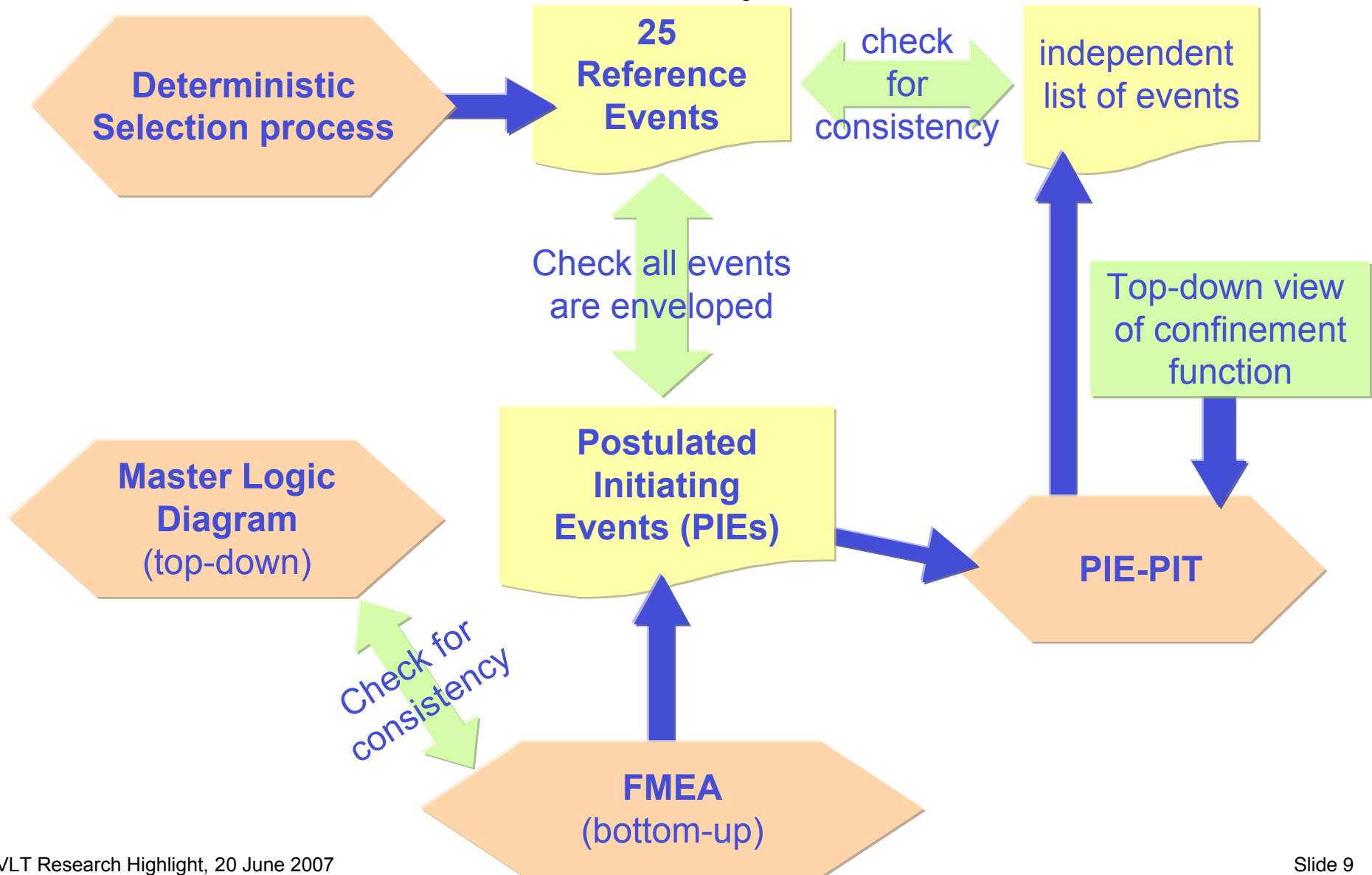
- all major ITER systems
- all significant radioactive inventories distributed amongst these systems
- all initiator types that have the potential to cause releases

TABLE VII-2
Reference Events Analysed in Detail.

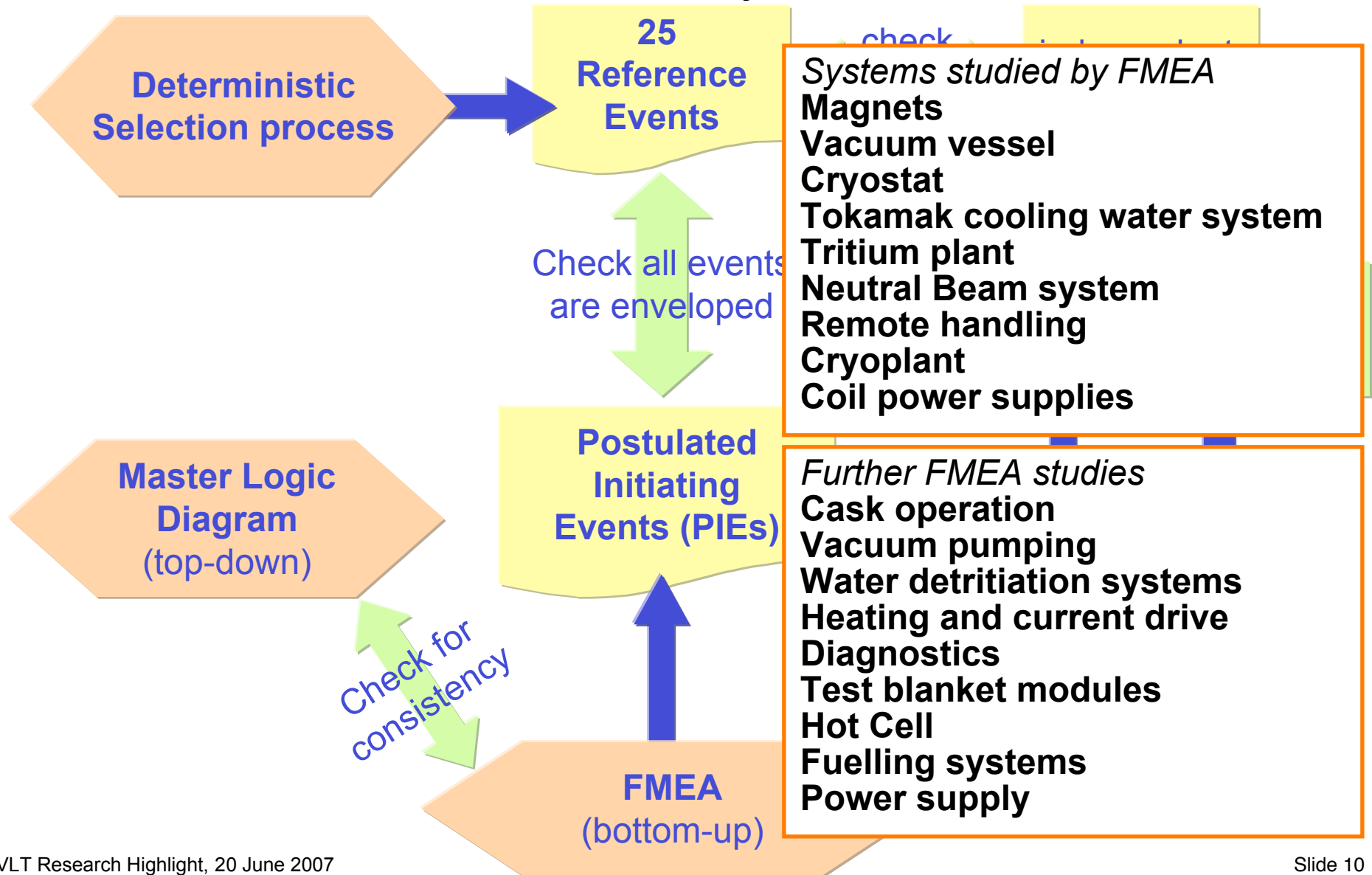
Plasma events
Loss of plasma control (Plasma control) (i,a)
Loss of power
Loss of off-site power (LOOP 1 h) (i)
Loss of off-site power (LOOP 32 h) (a)
Blackout for one hour (Blackout) (a)
In-vessel events
In-vessel FW pipe leakage (FW pipe break) (i)
Multiple FW pipe break (Multiple FW break) (a)
Loss of vacuum through one VV/cryostat penetration line (a)
Ex-vessel HTS events
Loss of divertor heat sink (Loss of heat sink) (i)
Pump trip in divertor HTS (DV pump trip) (i)
Pump seizure in divertor (DV pump seizure) (a)
Large VV coolant pipe break (VV coolant leak) (a)
Large DV ex-vessel coolant pipe break (DV ex-coolant leak) (a)
Heat exchanger leakage (HX leakage) (i)
Heat exchanger tube rupture (HX tube rupture) (a)
Maintenance events
Stuck divertor cassette and failure of cask (Cask failure) (a)
Air leakage into VV during maintenance (VV maintenance) (a)
Tritium plant and fuel cycle events
Tritium process line leakage (Tritium leakage) (i)
Accident with transport hydride bed (Hydride bed) (a)
Isotope separation system failure (ISS failure) (a)
Failure of fuelling line (Fuelling failure) (a)
Magnet Events
Toroidal field coil short (TF short) (a)
Arc near confinement barrier (Magnet arc) (a)
Cryostat Event
Cryostat air ingress (Cryostat air) (a)
Cryostat water and helium ingress (Cryostat He) (a)
Hot Cell Events
Loss of confinement in hot cell (Hot cell) (a)

(i) Incidents are event sequences or conditions not planned but likely to occur during the life of the plant
(a) Accidents are event sequences or conditions not likely to occur during the plant life but are postulated to demonstrate the safety of the plant.

RPrS US Activities: Accident Analysis Process, cont.



RPrS US Activities: Accident Analysis Process, cont.



RPrS US Activities: Development of Dust Procedure

The dust issue for ITER is mainly a concern because of associated uncertainties in amounts, locations, success of detection and removal schemes...

The approach taken for the RPrS is to demonstrate R&D pathways are being pursued to resolve issues resulting in the uncertainties. A consistent plan of dust R&D, i.e. the dust procedure, with contingency consideration is under development. A very preliminary draft procedure outline is:

STAGE 1 - Maturation

Procedure Set 1.1: Dust Safety Knowledge Base (Years 1-4)

- 1.1.A: Generation Mechanisms
- 1.1.B: Transport Mechanisms
- 1.1.C: Hazard Phenomena

Procedure Set 1.2: Inventory Manipulation (Years 1-6)

- 1.2.A: Localized Detection Systems
- 1.2.B: Global Quantification Systems and Protocols
- 1.2.C: Cleaning Systems

Procedure Set 1.3: Prototype Testing (Years 4-8)

- 1.3.A: Lower-vessel Mockup
- 1.3.B: Mid-plane Mockup
- 1.3.C: Ducting Utility Mockup
- 1.3.D: Design and Procure Systems for Deployment in ITER

STAGE 2 - Integration

Procedure Set 2.1: Baseline Testing of Detection Systems and Quantification Protocols (Years 9-10)

- 2.1.A: Collect and Characterize ITER Dust
- 2.1.B: Initial Verification of Dust Properties and Transport Behavior
- 2.1.C: Experience-based Adjustments to "Dust Limitations Guidelines" for ITER Operation

Procedure Set 2.2: Deployment of Cleaning Tools (Year 10)

- 2.2.A: Determine Cleaning Efficiencies
- 2.2.B: Verify Global Quantization Protocols
- 2.2.B: Final Chamber Cleanup and Verification

STAGE 3 - Application

Procedure Set 3.1: Implement Staged Assessment of Quantification Protocols

Procedure Set 3.2: Implement Cleaning Systems

RPrS US Activities: TBM Accident Analysis and Assessment

The ITER IO expects to license Test Blanket Modules within the overall ITER machine licensing process. Hence for a viable TBM program in ITER, interested parties **must** provide for the RPrS the following:

- Technical description (DDD)- **completed**
- Source terms (radioactive, energy, and chemical) - **completed**
- Operational releases - **completed**
- Failure modes and effects analysis (FMEA) study – **completed**
- Plant worker occupational radiation exposure (ORE) estimates – **deadline July**
- Consequence analysis for selected accident scenarios –**accident analyses have been completed for DDD; awaiting guidance/specifications from ITER**
- Waste disposal analysis – **deadline August**

RPrS US Activities: TBM Accident Analysis..., cont.

Reference Accidents Analyzed for TBM:

Code analyzed with

MELCOR

- In-vessel TBM coolant leak analysis to demonstrate:
 - A small pressurization of first confinement barrier (i.e., ITER VV)
 - Passive removal of TBM decay heat
 - Limited chemical reactions and hydrogen formation
- Coolant leak into TBM breeder or multiplier zone analysis to assess:
 - Module and tritium purge gas system pressurization
 - Chemical reactions and hydrogen formation
 - Subsequent in-vessel leakage
- Ex-vessel LOCA analysis to determine:
 - Pressurization of TBM vault
 - Behavior of TBM without active plasma shutdown

CHEMCON

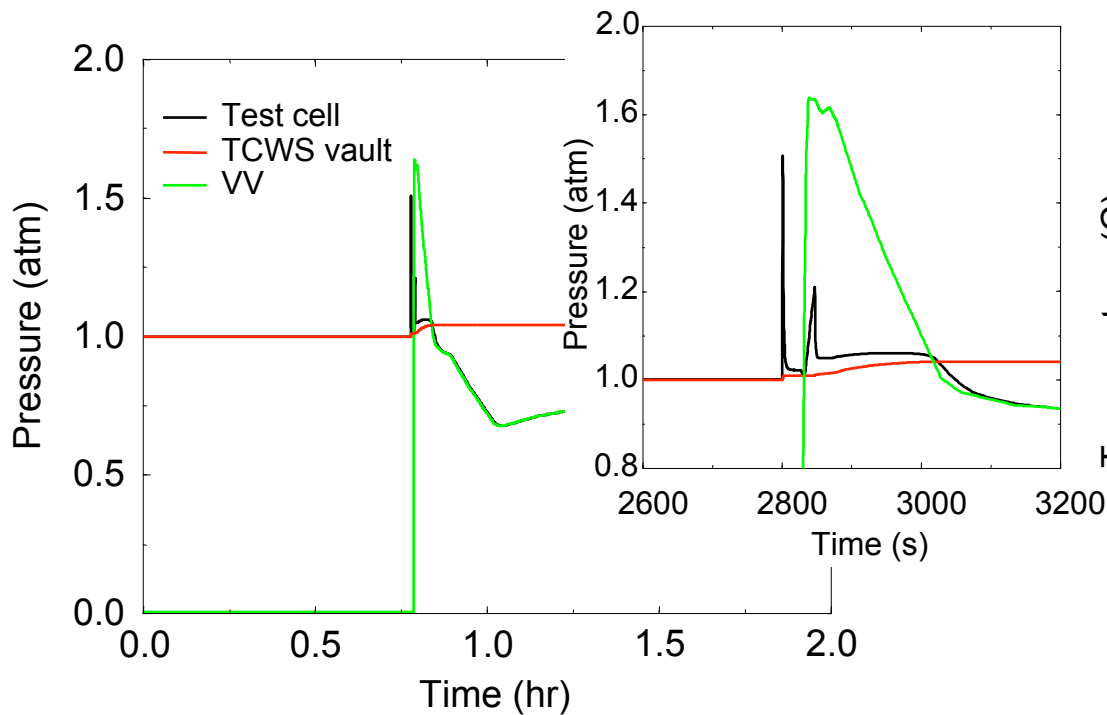
- Complete loss of TBM active cooling

RPrS US Activities: TBM Accident Analysis..., cont.

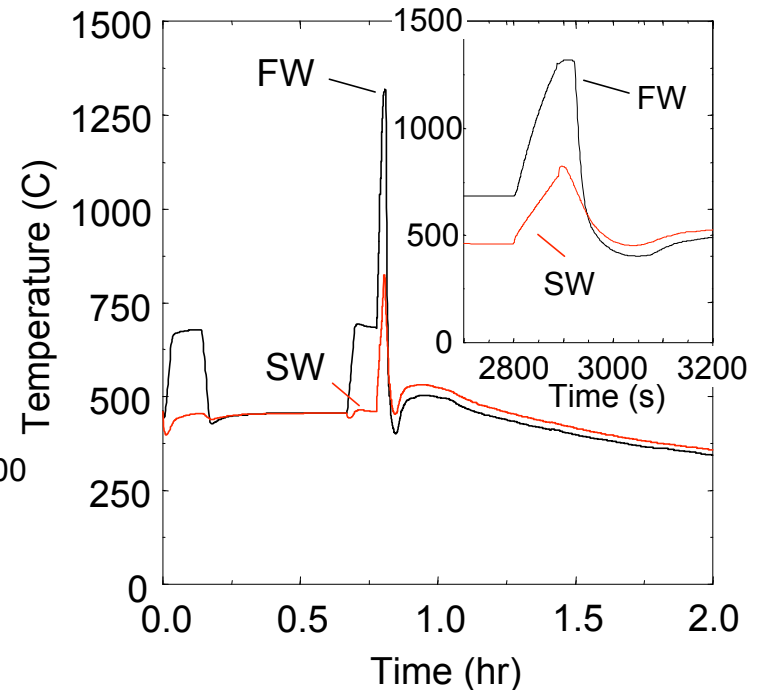
Typical Results for TBM Ex-vessel LOCA

- LOCA assumed to start at 100 s before the end of a reactor pulse flat top (at 300 s of burn)
- Port cell relief valve (set to open at 0.4 atm pressure differential with TCWS vault and to re-seat at 0.01 atm pressure differential) limits test cell pressure to 1.5 atm, not exceeding confinement barrier design limits of 2 atm

Expanded view



Expanded view



RPrS US Activities: TBM Accident Analysis..., cont.

Preliminary US-TBM Safety Summary

- US DCLL TBM will not have a major impact on ITER Safety
 - TBM T2 inventory is 1600 times less than ITER mobilizeable inventory
 - Po-210 & Hg-203 inventories if released are 600 times less than ITER accident dose limit at site boundary
 - oxidation of irradiated FS in steam is less than 0.01% of limit per day
- TBM pressurization of the VV, vaults and test cell is within ITER IT acceptance criterion
- Helium inventory is estimated to be ~20 kg for the FW helium loop, which is less than the ITER limit is 40 kg
- TBM FW beryllium oxidation produces less than 0.2 kg of H₂, which is less than the ITER allowed limit of 2.5 kg (1/4th deflagration limit) and would remain below the ITER limit even if all of TBM FW beryllium oxidizes (1.2 kg of H₂)
- DCLL TBM and ancillary PbLi inventory is over the allowed 0.28 m³ (2.5 kg of H₂ produced if 100% of Li reacts), but the argument will be advanced for the RPrS that not all of the PbLi is released during accidents and that at most only 70% of Li will react based on experimental data for the most violent contact mode – high pressure water injection into a PbLi pool. *Safety tests are being planned...*

ITER QA Program

Overview:

- IO Quality Assurance Program approved by IO Director General and DG staff.
- The PT/DA's proposed draft QA Programs with implementing procedures corresponding to the ITER QA requirements have been developed and submitted to IO for comments.
- IO's comments completed and returned to the respective PT/DA QA representatives for their consideration and response. Final ITER acceptance will be based on satisfying the ITER comments and the approval signature of the DA QA Program by the respective DA Leader.

Present Activities:

- Identifying and Revising present Management and Quality Program (MQP) to better fit the future procurement/construction focus of the IO Project
- Procurement Arrangements are being written to provide the legal framework and direction to the DA's for the official procurements of ITER items and components
- Quality Affecting Activities are being classified for each procurement item and component for both Safety Related (SIC) and non-Safety. ITER IO retains strict control over SIC items.

Application of Codes and Standards

- Recognized early on that C&S would pose great challenge to the ITER project; but convergence on a solution is occurring
- Developing IO Project Codes and Standards positions for IO Procured Items and Components recognizing host country and regional requirements such as EU Directives (such as the Pressure Equipment Directive, *PED*) and French Nuclear Rules (such as ESPN)
- Begin planning for the February 25-28 2008 international Codes and Standards meeting being hosted by ITER IO at the Cadarache JWS. The two day meeting will precede the 3 day ASME Board of Nuclear Codes and Standards meeting.

That's all, folks!

Brief Questions?