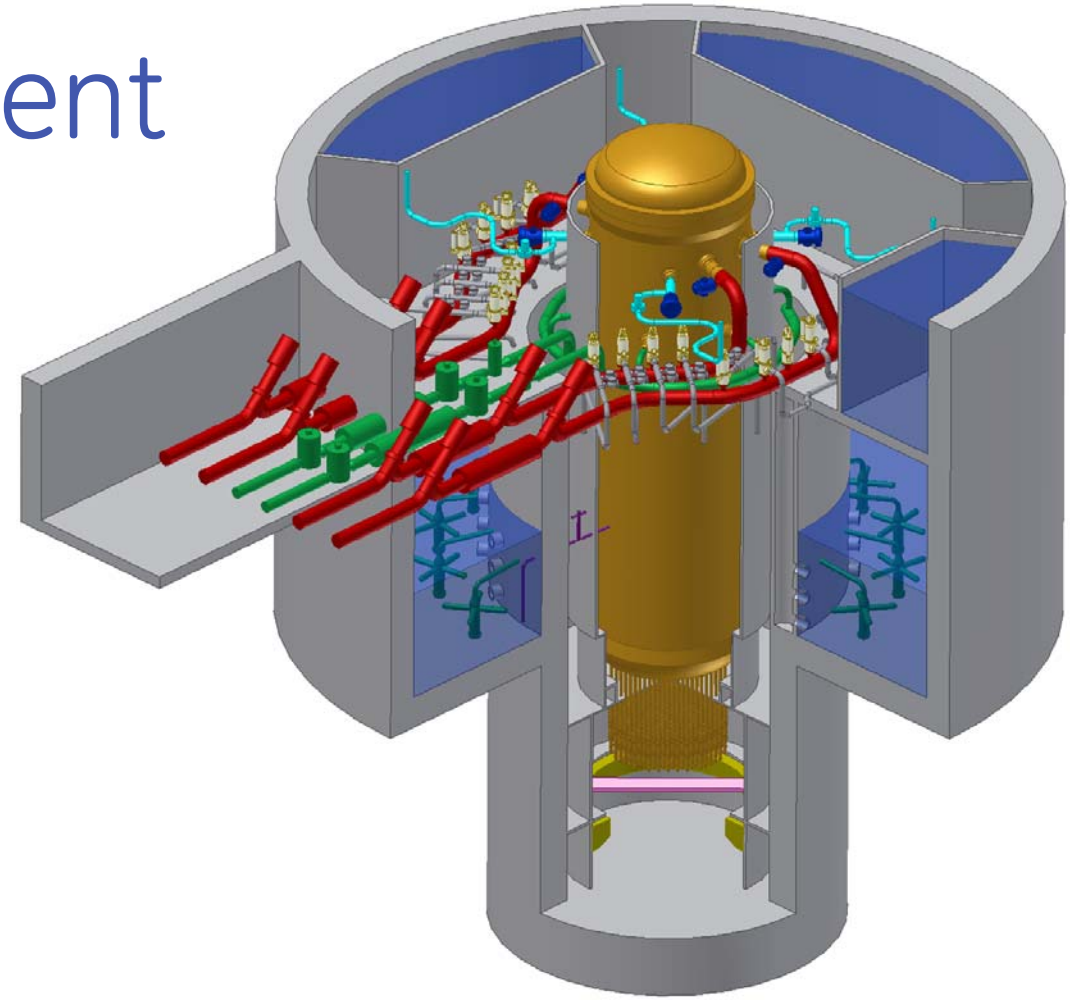
ESBWR Probabilistic Risk Assessment and Severe Accident Treatment



J. Alan Beard
September 15, 2006

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imagination at work

PRA Scope

Internal Events, Power Operation

> Level 1, 2, and 3

Internal Events, Shutdown (SD)

> Level 1

> 99% SD CDF in mode 6, so no level 2 required

External Events (non-Seismic)

> Screening shows no impact on risk

Seismic

> Seismic margins analysis identified no outliers

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PRA Quality

Follows ASME Standard Principles

> Where applicable, meets capability category 3

> Some plant specific information not available until COL or construction

Certification PRA Capability

> Determine that ESBWR meets risk goals

> Determine importance at a system level

> Determine overall importance of operator action

Each Element Appropriate for Certification

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Definitions

Core Damage

- PCT > 2200 ^{o}F (calculated by TRACG)
- Core Uncovered (estimated by hand calc, MAAP, other)

Containment Failure

- Uncontrolled Release
- Venting Release

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Basic Event Data

Generic Data Used

Generally from URD

Equipment in Harsh Environments Increased

> Example: GDCS Squib Valves

Failure Rates Increased for Components with Long Test Intervals

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Human Actions

Pre-Accident

> e.g. Misposition of valves following maintenance

Post-Accident

> e.g. Backup of automatic actuation

Screening Values Used

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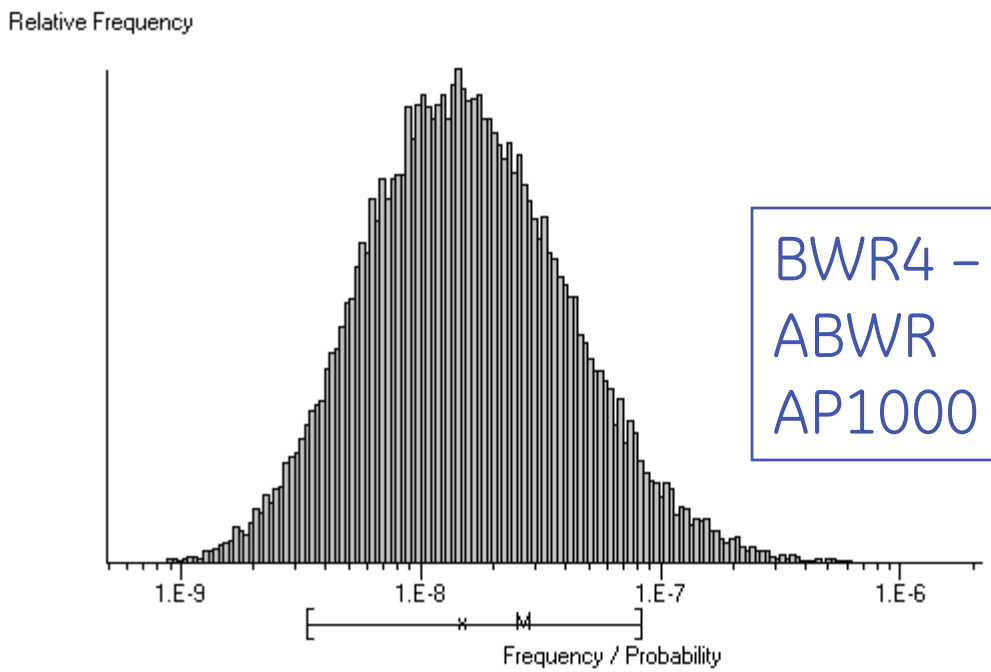
Level 1 Results

CDF = 2.9 x 10^{-8} per year



Mean - M	: 2.64E-08
5% - [	: 3.34E-09
50% - x	: 1.50E-08
95% -]	: 8.28E-08
Std Dev	: 4.14E-08

BWR4 – BWR6	$2x10^{-5}$ – $1x10^{-6}$
ABWR	$1.6x10^{-7}$
AP1000	$2.4x10^{-7}$

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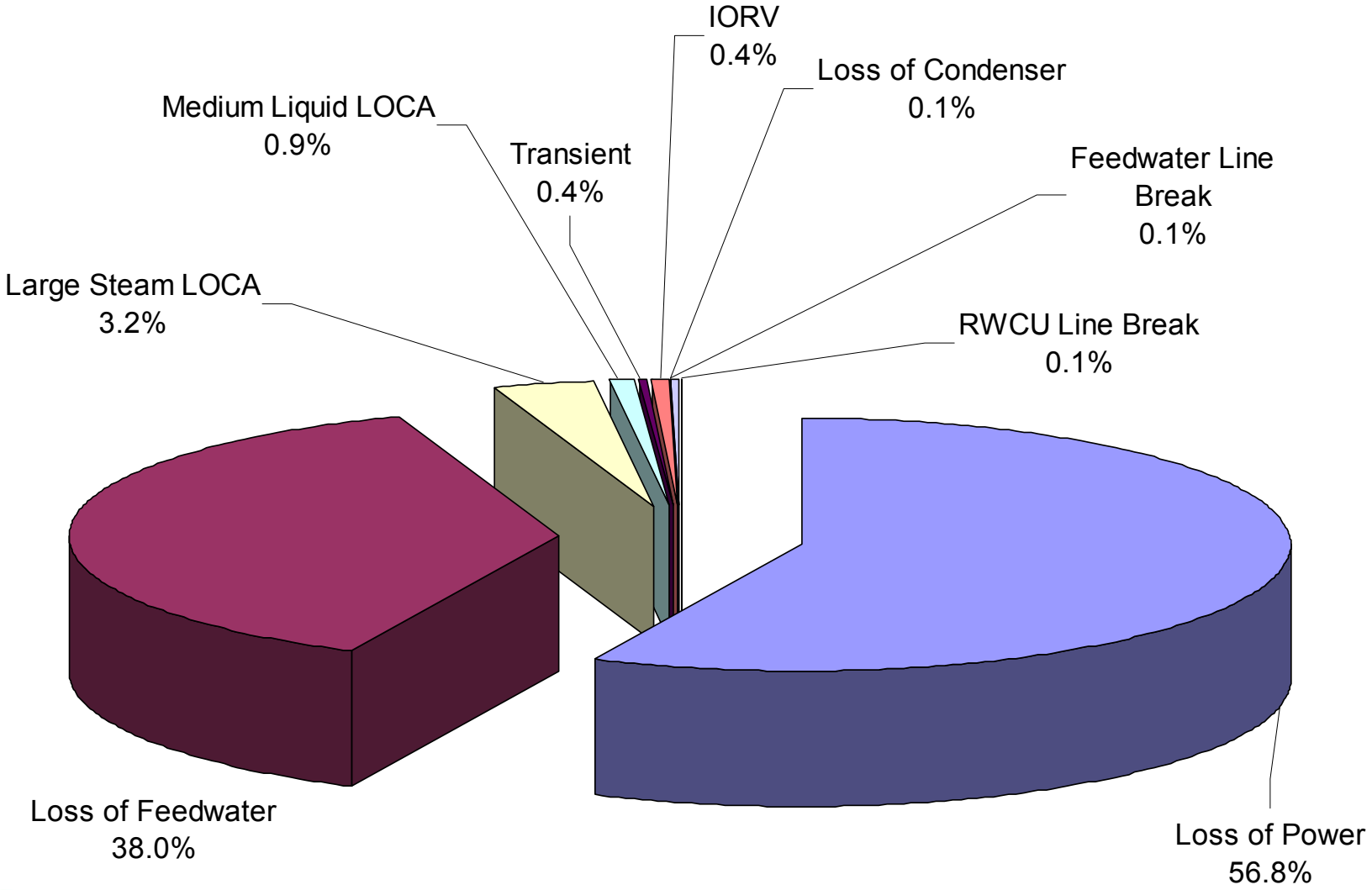
Breakdown By Initiating Event



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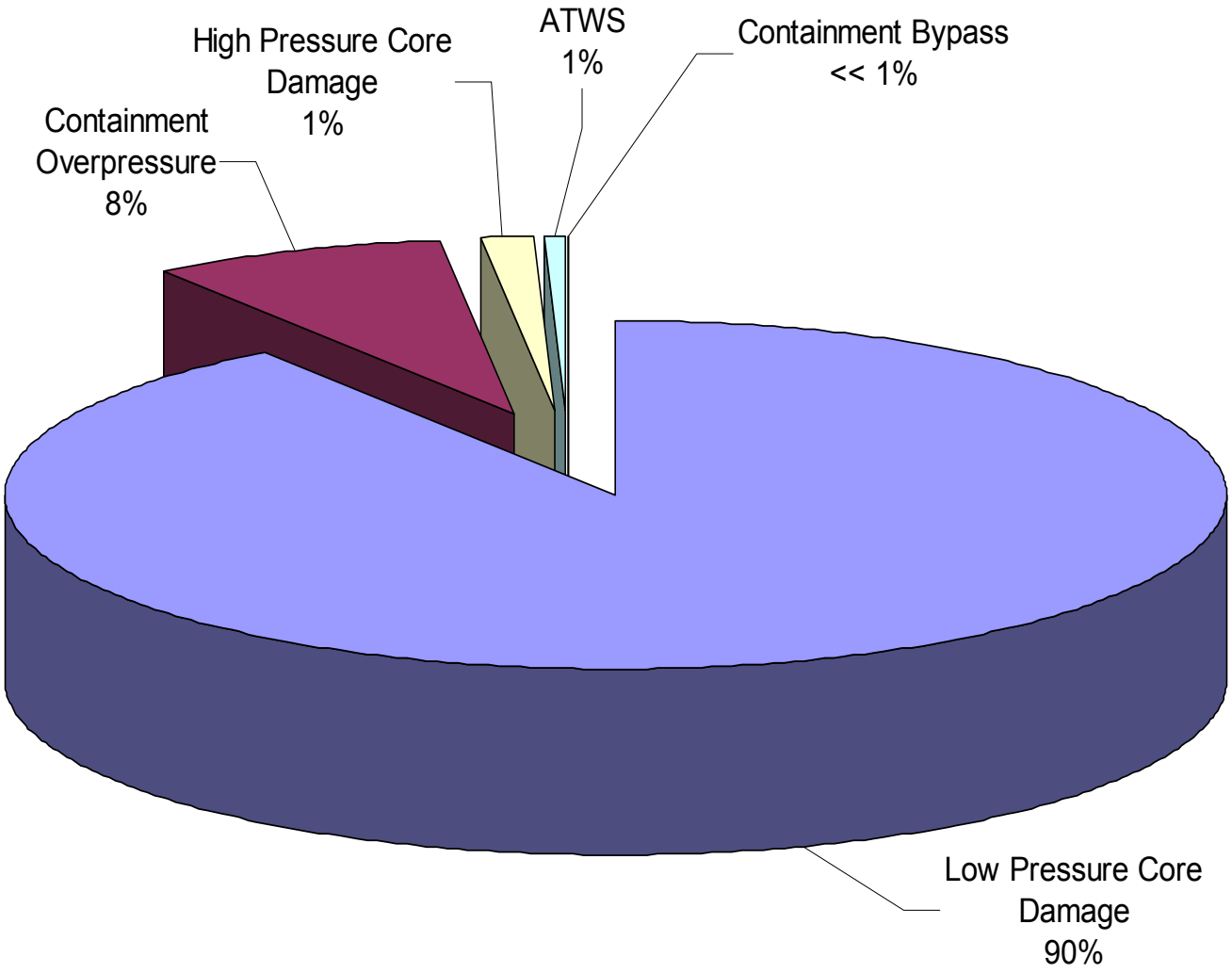
Breakdown By Accident Class



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Shutdown Results

CDF 6 x 10^{-9} per year

Dominated by LOCA Events (> 99%) With Containment Open

LDW Hatch Disables Passive Containment

90 – 360 Minutes to Close Hatch

Operator Action ~ 0.01

ABWR	< 1×10^{-7}
AP1000	1.2×10^{-7}

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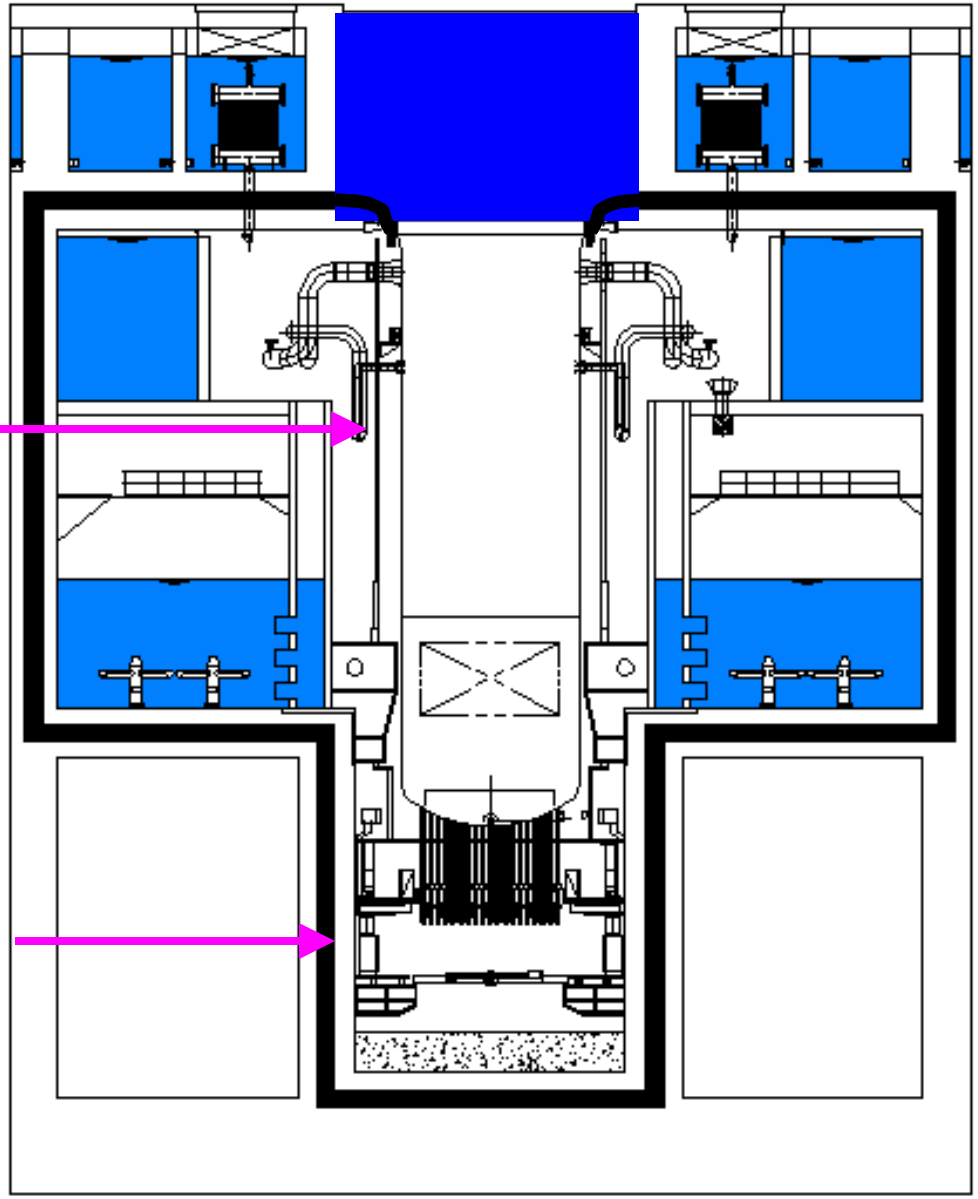
Containment Capacity During Shutdown LOCA

Approximate Water Level With Hatch Closed

Elevation of Hatch



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Flood Screening Analysis

Assumes Separated Divisions

Flood Zones Aggregated into Super-Zones

> Flood fails entire division

Uses NUREG-5750 Frequency

> 10% floods exceed floor drain capacity

Consideration for Propagation Included

CDF Due to Flood is Negligible

ABWR	2.9×10^{-8}
AP1000	1.0×10^{-9}

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Fire Screening Analysis

Assumes Separated Divisions

Fire Zones Aggregated into Super-Zones

> Fire fails entire division

Fire Barrier Failures Considered in Analysis

FIVE Ignition Frequencies

Bounding CDF is ~3×10^{-8}

ABWR	$< 1 \times 10^{-7}$
AP1000	5.6×10^{-8}

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Treatment of Severe Accidents

Severe Accidents in ESBWR.....CDF ~ 10^{-8} per year

- That is, they are Remote & Speculative
- Could be treated as Residual Risk

GE Designs for Defense-In-Depth

> Assess full compliment of severe accident threats

> Determine and Enhance ESBWR capabilities

> Verify by a full ROAAM treatment

Conclusion:

Containment Failure is Physically Unreasonable

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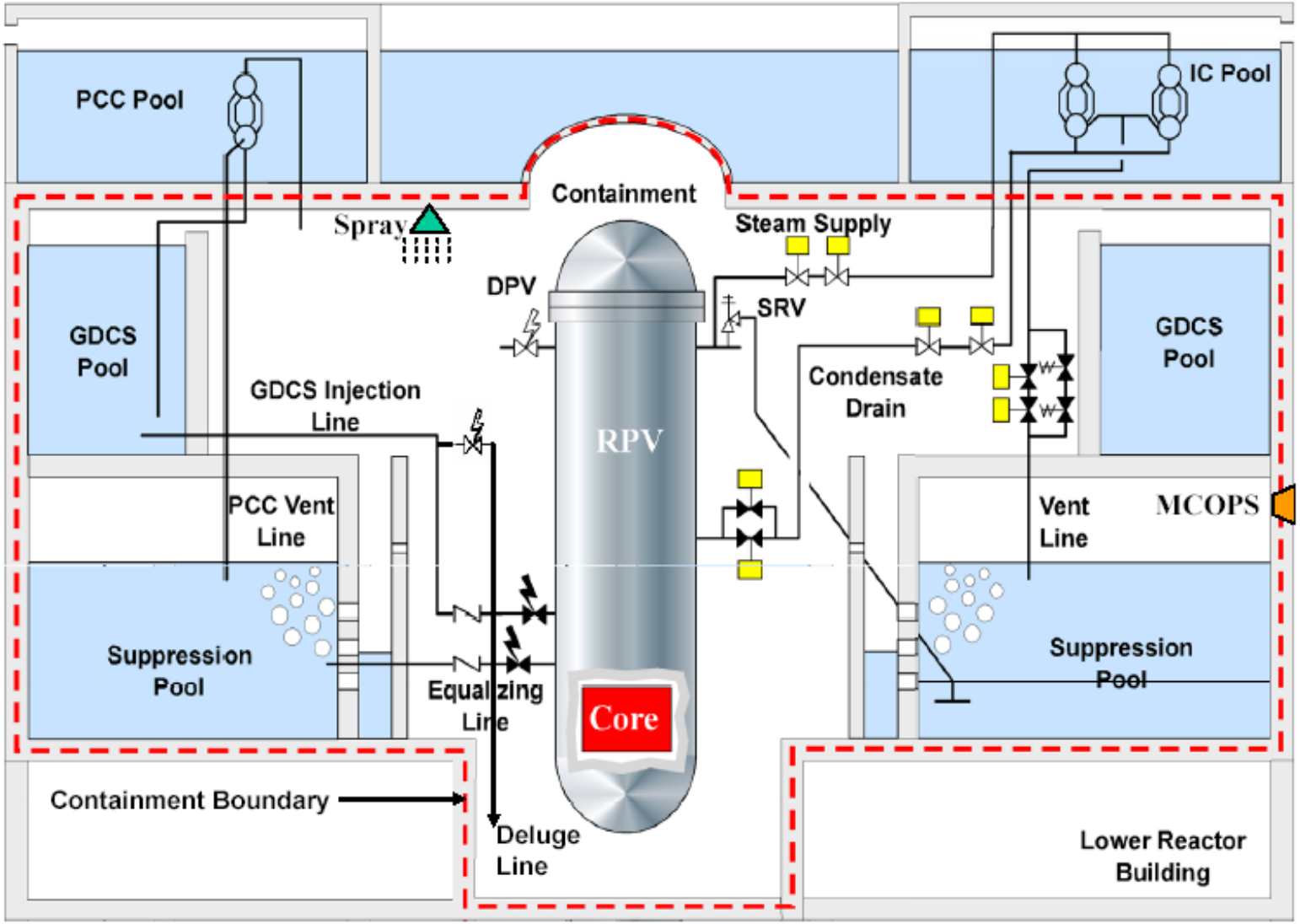
ESBWR SA Containment Highlights



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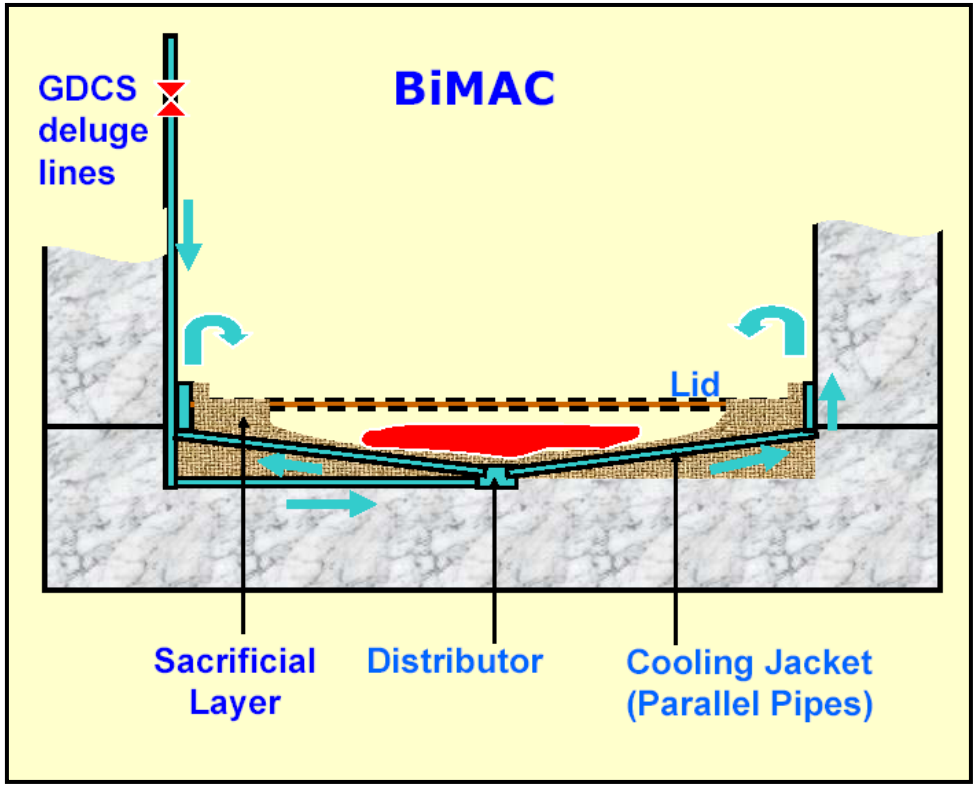
The Basemat internal Melt Arrest and Coolability (BiMAC) device



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SA Threats and Failure Modes

Direct Containment Heating (DCH)

- Energetic Failure of UDW
- Liner Failure of UDW/LDW

Ex-Vessel Explosions (EVE)

- Pedestal/Liner Failure
- BiMAC-Pipes Crushing

Basemat Melt Penetration (BMP)

- BiMAC Thermal Failure (Burnout, Dryout)

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The Bottom Line

Internal Events CDF	2.9×10^{-8}
Internal Events LRF	1×10^{-9}
CCFP	0.03
Probability of Exceeding 25 Rem at 1/2 Mile	2×10^{-9}
External Events Contribution	negligible
Shutdown CDF	6×10^{-9}

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Attributes of ESBWR Risk

Redundancy and Diversity!!

At Least 3 I&C Systems Need to Fail for Core Damage

Top Cutsets Involve:

- CCF of Batteries
- CCF of Squib Valves

Loss of All Electric Power (AC & DC) Itself Does Not Cause Core Damage

Containment Failure Does Not Lead to Core Damage within 72 Hours

Containment Can Be Flooded Above Core Using Passive Systems

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Attributes Affecting Risk (continued)

High Containment Ultimate Strength

- High confidence pressure 1.2 MPaG
- Most scenarios well below 0.9 MPaG

Ex-Vessel Explosion

- Does not occur if water in lower drywell less than 0.7 m. This is the likely case.
- Containment survives EVE pressure pulse
- Consideration for localized failures included

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Attributes Affecting Risk (continued)

Direct Containment Heating

- Containment survives initial pressurization
- Long term high temperatures do not fail liner or penetrations
- Lower to upper drywell configuration minimizes relocation of core debris
- Containment spray added as defense-in-depth

Basemat Melt Penetration

- Precluded by BiMAC
- Diverse actuation
- Cools debris from above, below, and on sides

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Regulatory Treatment of Non-Safety Systems

Two Systems Identified

- Fire water refill of IC/PCC pools
- BiMAC

Sensitivity Analysis Provides Basis

- Calculated CDF using only safety-related and special treatment systems
- CDF = 7×10^{-6}
- LRF = 4×10^{-7}

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Conclusions

PRA Report Provides a Comprehensive Assessment of ESBWR Mitigation Capabilities

Incorporating Risk Insights During Design Drives Reliability

ESBWR Satisfies Risk Goals With Significant Margin

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