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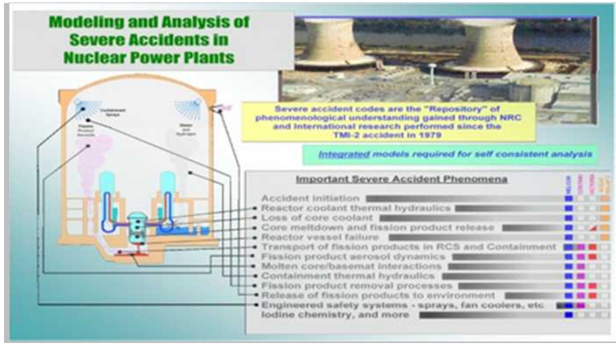

SNL BSAF Update

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Sandia National Laboratories

U.S. DEPARTMENT OF ENERGY

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Topics for discussion

- Executive Summary
- Brief Model Background
- 1F1 best estimate case results
- 1F3 best estimate case results
- Impact of uncertainty on results
  - why is this important
  - 1F1 and 1F3 example results
- Summary

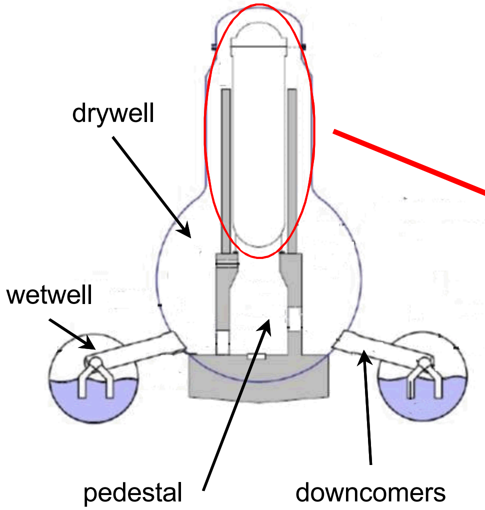
Executive Summary

- 1F1 and 1F3 BSAF best estimate cases completed
  - Accident signatures look similar to previous results; and to most of the TEPCO data
  - Event timings and values are different, but not markedly so
  - ready to move forward to Phase II source term analyses
- Accounting for uncertainty is important in forensic analyses (locus of inputs) and predictive analyses (locus of solutions)

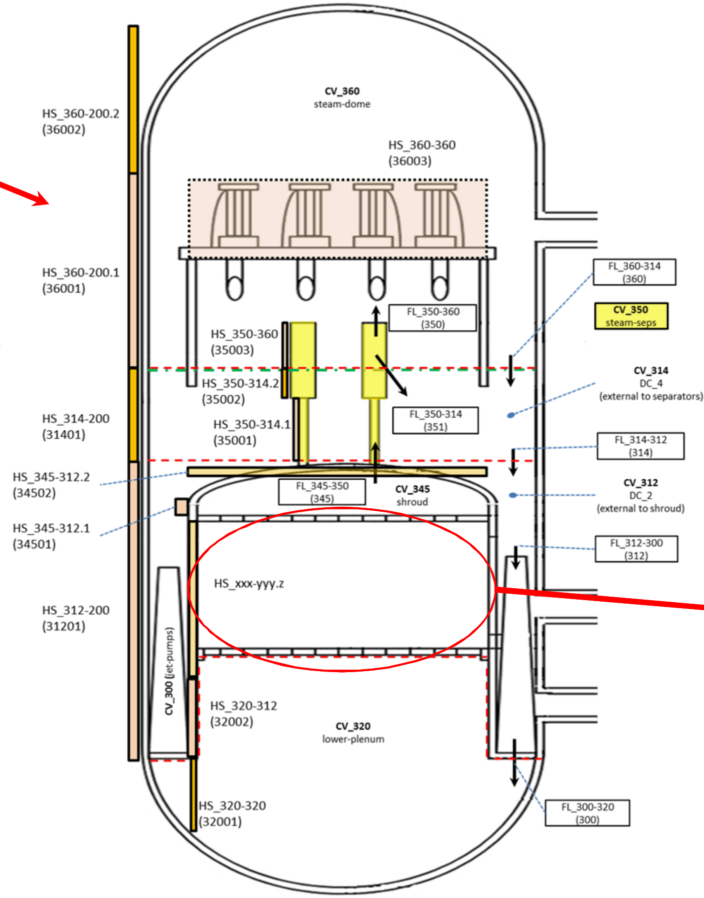
Brief Model Background

- SNL MELCOR Fukushima models are based the Peach Bottom SOARCA model; reflects current MELCOR BWR Mk-I best practices
- Models have been updated with the best-available Fukushima inputs (e.g., TEPCO December 2011 data set, IEA November 2013 data set, BSAF BCs); developed surrogate inputs where necessary

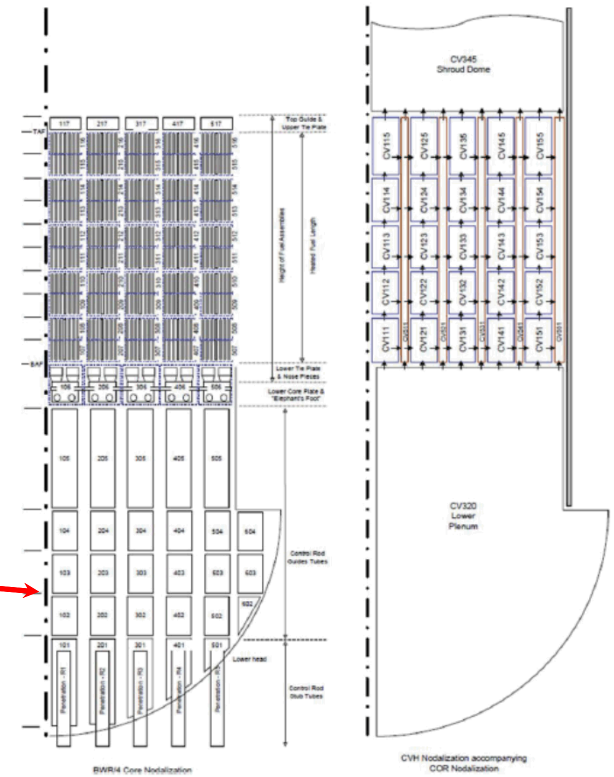
Brief Model Background



containment CVH nodalization (4 CVs)



RPV CVH nodalization (7 CVs)



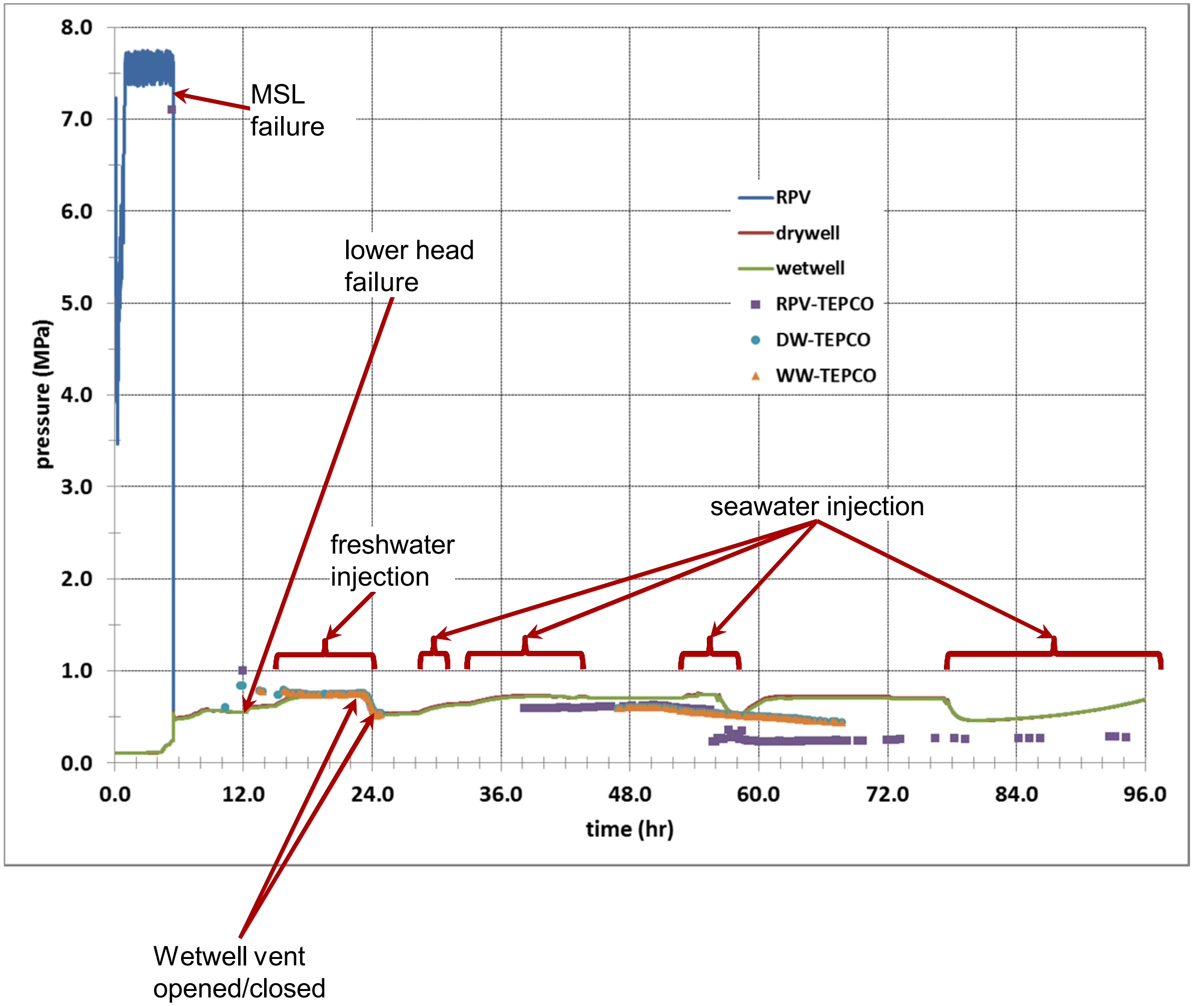
Lower RPV COR/CVH nodalization

- 5 active fuel rings, 10 active fuel axial levels
- 5 rings, 1 axial level above the active fuel
- 6 LP rings (lvls 2-4), 6 axial levels
- 5 ch x 5 byp CVs or 5 ch x 1 byp CVs

1F1 Best Estimate (BE) Case

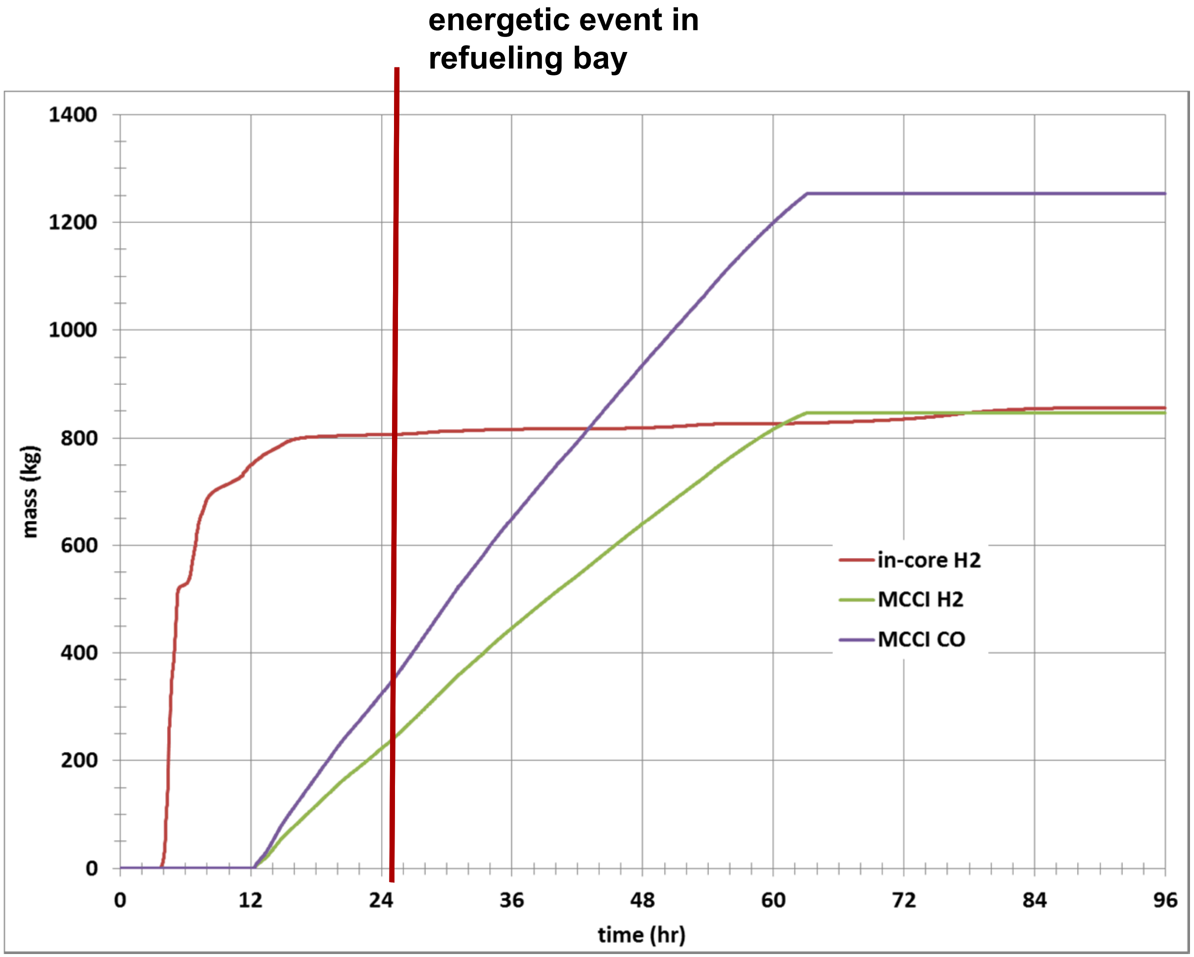
- Revised decay heat/RN inventory input with results from SNL SCALE6 analyses
- Implemented BSAF feedwater coastdown injection rate
- IC implementation includes efficiency as a function of RPV pressure; carry-over from previous 1F1 analyses
- SRV gasket failure not implemented; MSL failure model activated
- Did not implement wetwell stratification; not amenable MELCOR lumped-parameter conceptual model nor with the SPARC90 scrubbing model
- BSAF Water injection rates (2% of total) increased by 20x; needed for drywell head lifting/leakage to occur

1F1 BE– RPV/DW/WW pressure



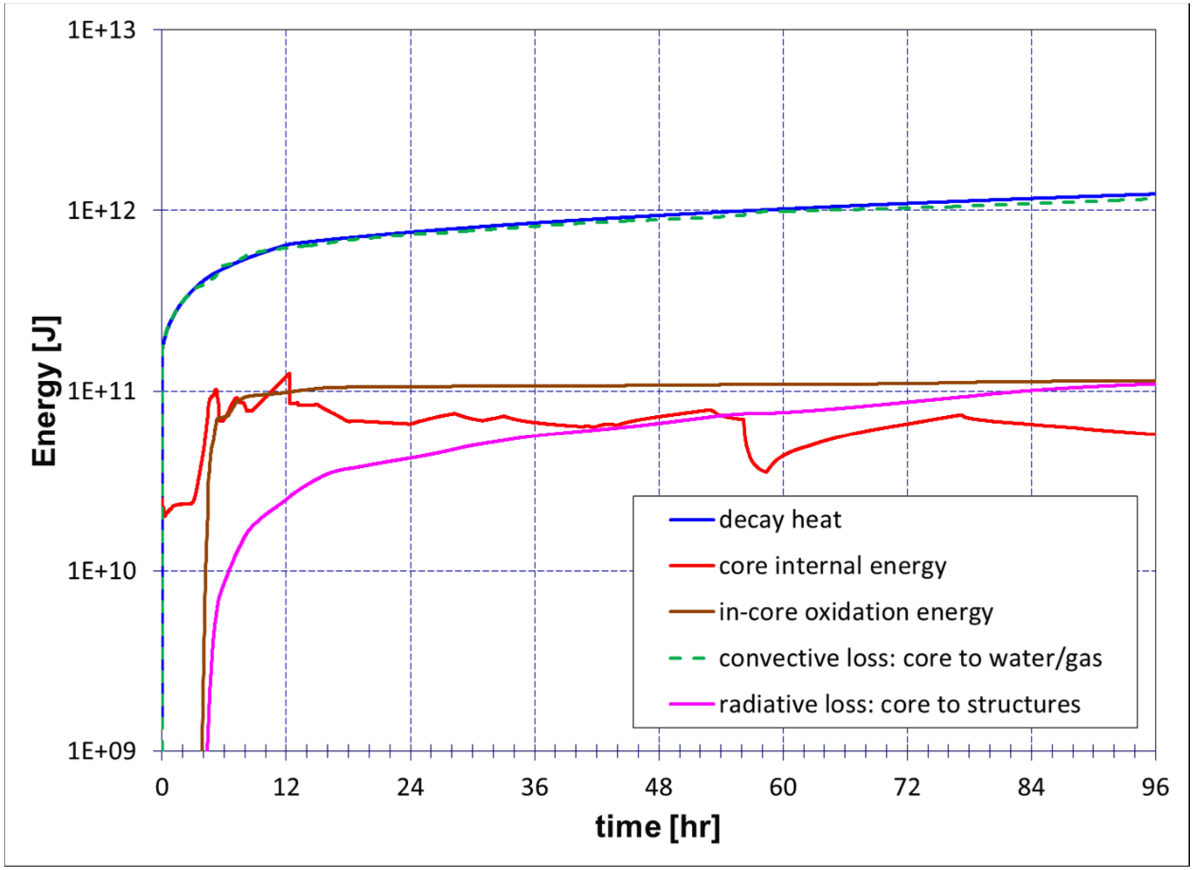
- MSL failure at ~6 hr
- LH failure at ~12 hr
- Containment pressure increase at ~12 hr not captured; likely due to relatively "cold" particulate debris (rather than "hot" molten pool) ejection
- late-time pressure changes are related to changes in water injection
- ad hoc leakage model will need to be implemented to capture late-time leakage

1F1 BE – combustible gases



- sufficient mass of combustible gases (H_2, CO) produced to support an energetic event in the refueling bay at ~25 hr
- lumped-parameter codes operate at too high a granularity to really predict gas composition time evolution; requires detailed analysis (i.e., CFD) to quantify
  - concentrations
  - buoyancy effects
  - steam condensation
  - leakage to/from environment
  - building heat transfer

1F1 BE – energy balance

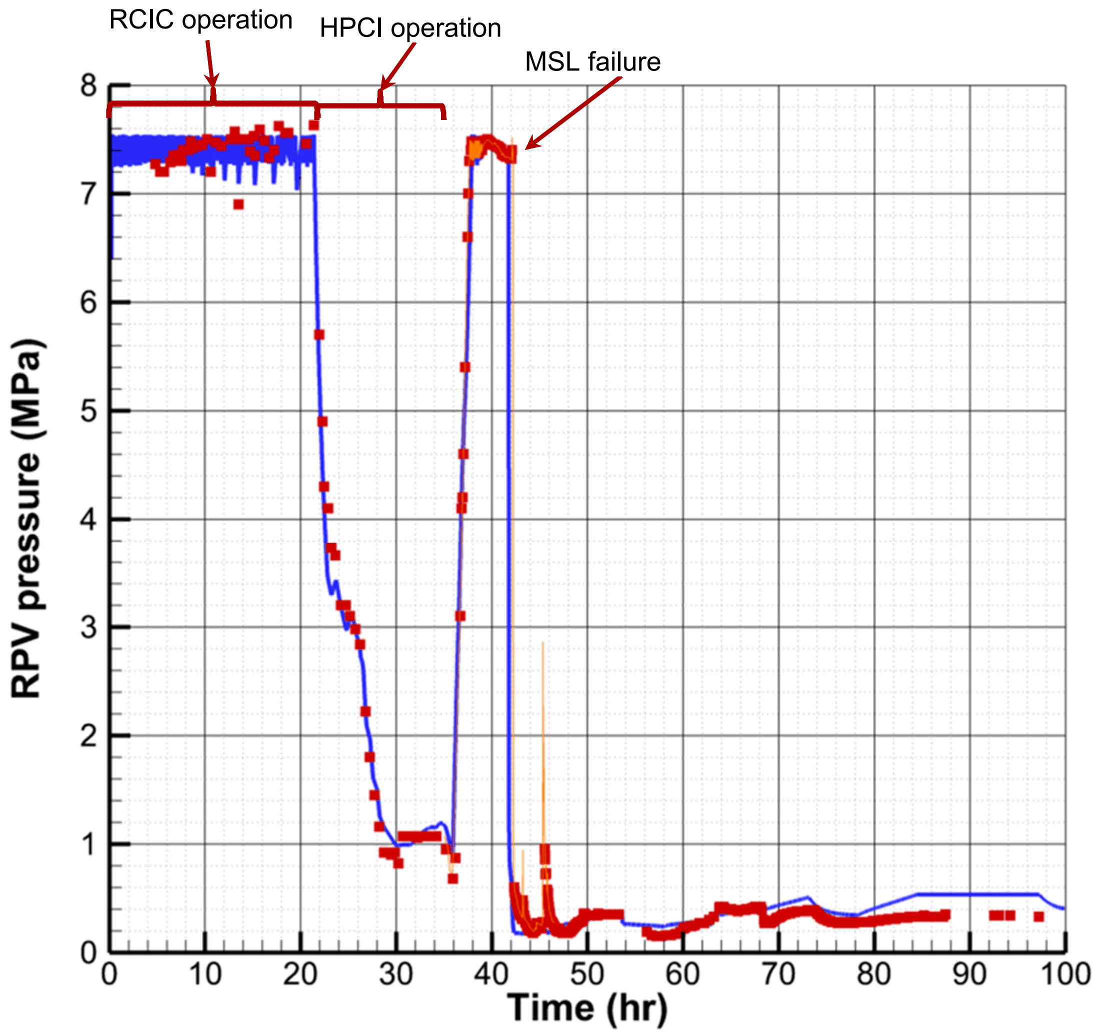


- Majority of core energy input rejected by convection to gas/water (green dashed line = blue line)
- Leads to "cold" particulate debris (instead of "hot" molten pool)
- Likely cause of lack of pressure spike at time of LH failure and need for 20x BSAF water injection to lift drywell head
- This was identified in the MAAP/MELCOR Crosswalk study; path forward yet to be determined

1F3 BE Case

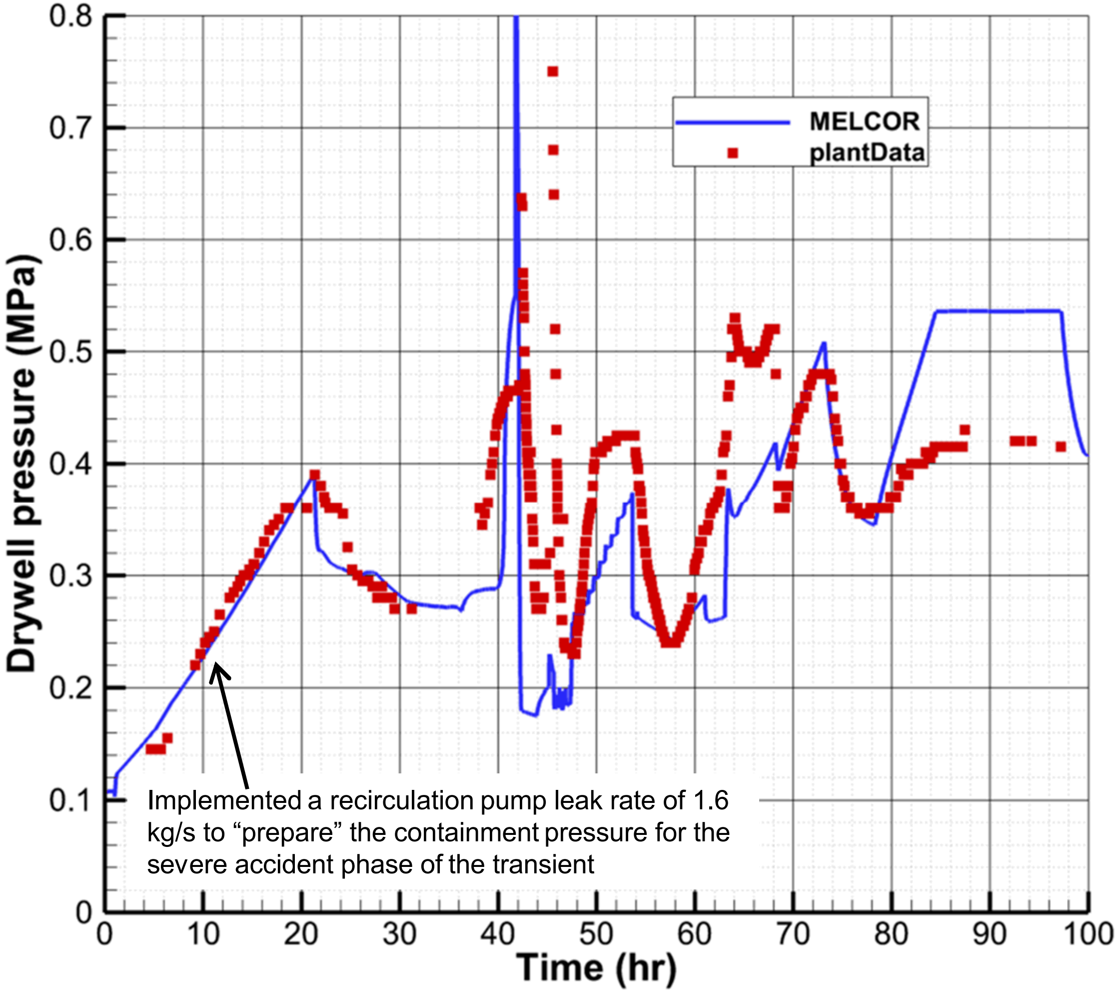
- BSAF B.C.s included
  - Wetwell and drywell sprays; timing and flow rate
  - Containment vents (via wetwell) and timing
  - After-scram trip and coast-down curves: MSIVs, turbine stop valve, feedwater, fission power, etc.
- BSAF B.C.s not included:
  - RCIC and HPCI
  - Freshwater and seawater injection rates
  - In-core tube failure (SRM, IRM, TIP)
  - Wetwell thermal stratification
- Non-BSAF B.C.s included
  - RCIC B.C. with a level controller – otherwise very comparable flow rates to the BSAF RCIC
  - HPCI B.C. based on preliminary BSAF information – assumes degraded injection after ~30 hours due to low RPV pressure; HPCI tuned to facilitate in-core oxidation to get MSL failure at the “correct” time
  - MSL failure model
  - Seawater injection rates adjusted to get lower head failure
  - Recirculation pump leak added to obtain reasonable containment pressure since the wetwell is only 1 node – ‘primes’ the containment pressure for the severe accident

1F3 BE– RPV pressure



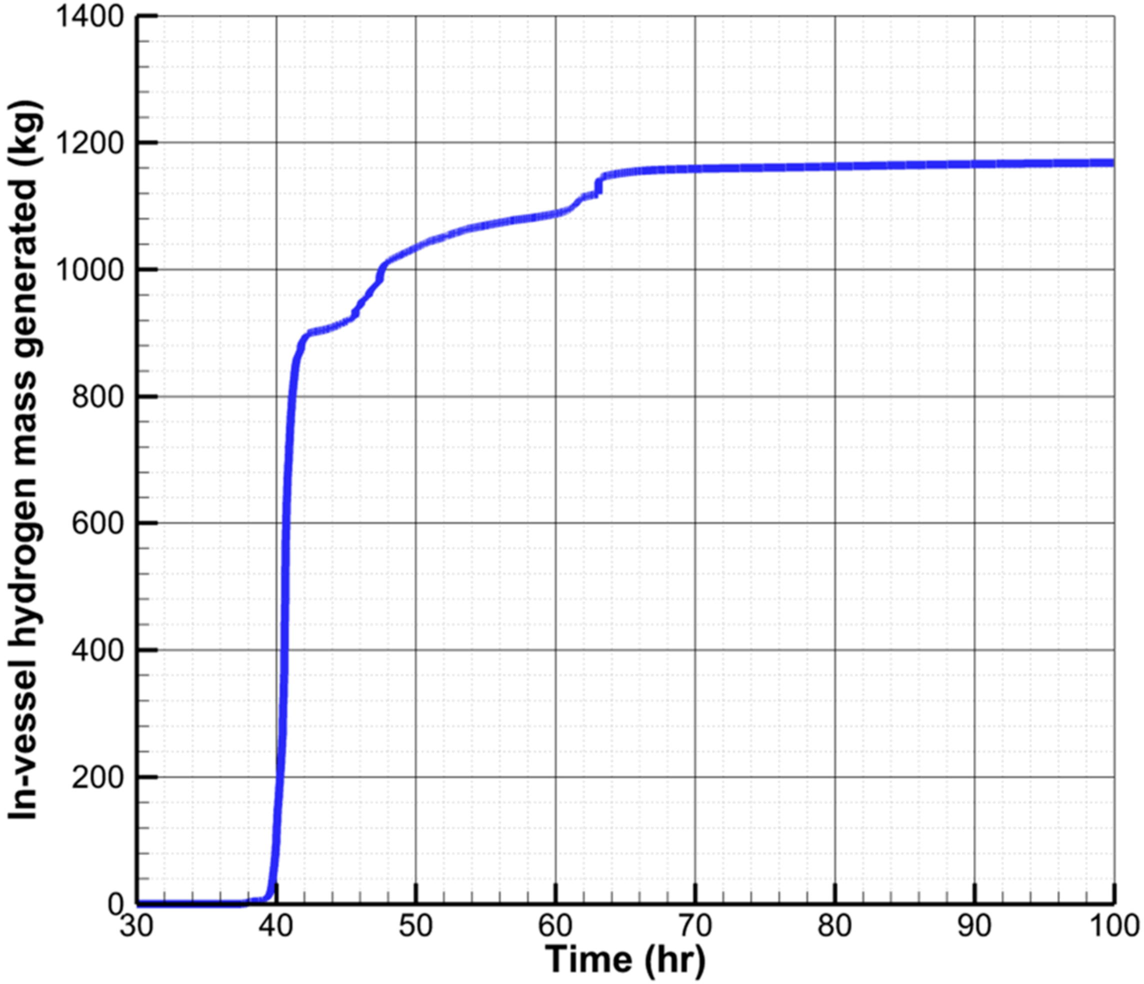
- RCIC and HPCI B.C.s based on initial BSAF information; allowed for general agreement with plant data
- Sets up the severe accident portion of the sequence
- MSL failure calculated to occur around 42 hr

1F3 BE– DW pressure



- general agreement with plant data
- The largest containment pressure peak (near 45 hours after the initial RPV depressurization and first major containment peak) may be caused by core slumping into the lower plenum
- This peak and subsequent peaks are strongly dependent on the assumed WW venting behavior,
  - seawater injection magnitudes
  - core/RPV degradation progression
- too much injection (subcooling) AND too little injection (no water to boil) can suppress containment pressure during certain time periods
- the flatline after 80 hours is an assumed WW gas leak that levels out around 0.53 MPa (based on the plateau around 65-68 hours in the plant data)
- some sort of leak assumption is necessary to transport combustible gas to the Rx building

1F3 BE– H_2 generation

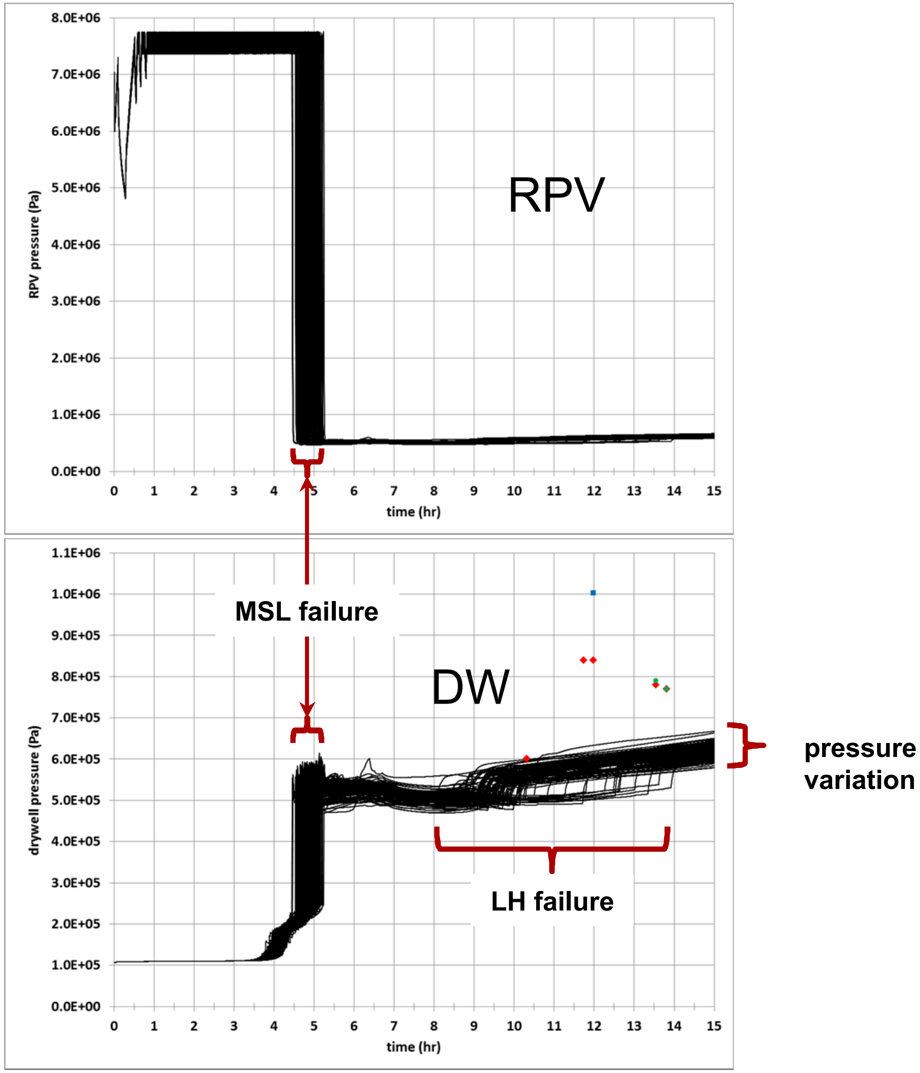


- Rapid oxidation begins about 5 hr after water level drops below TAF

But what about uncertainty?

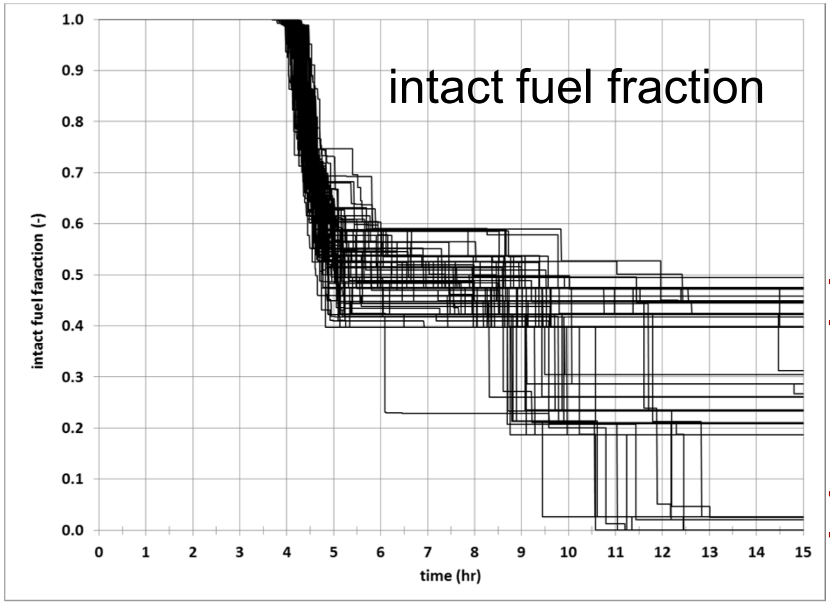
- All of our best-estimate/best-practices cases are but one of a locus of potential inputs and their results are but one of a locus of potential solutions
- Uncertainty (in input parameters and models) will produce significant variations the accident sequences
- The impact of this is that…
  - "tweaks" made to fit the forensic data may not be valid over the entire range of input parameter and model uncertainty
  - The next accident may not be within the range of validity of the "tweaks" and current "best-practices"

1F1 Example

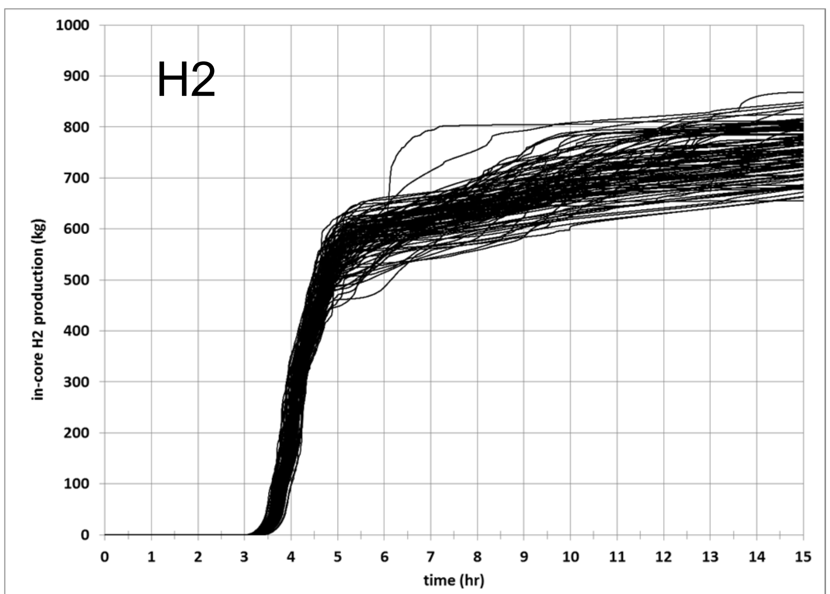


- 100 realizations with random sampling from the distribution of decay heat curves
- decay heat characterized by combining the ANS-5.1 decay heat uncertainties on primary fissile nuclides with SCALE best-estimate calculations
- Yields variation in
  - MSL failure time
  - LH failure time
  - RPV/containment pressure

1F1 Example



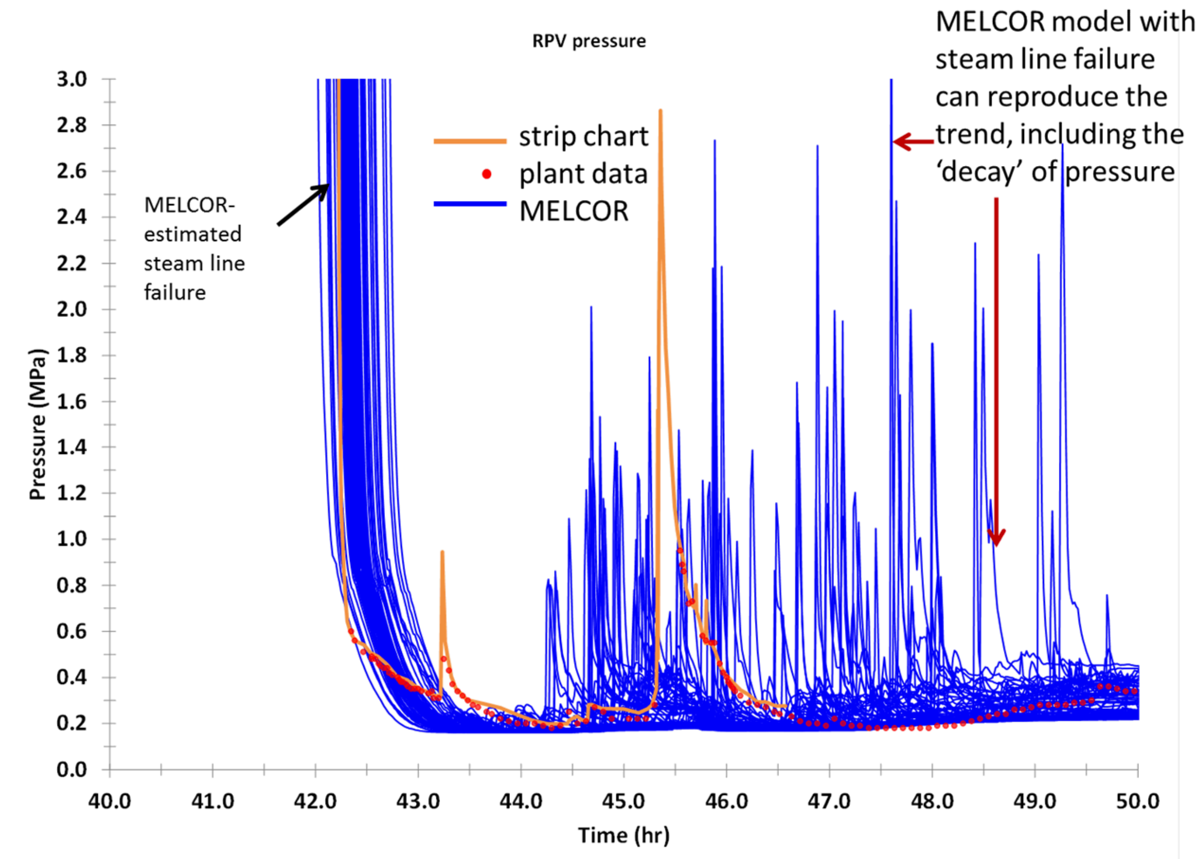
different possible final core degradation states



enough H2 to support an energetic event

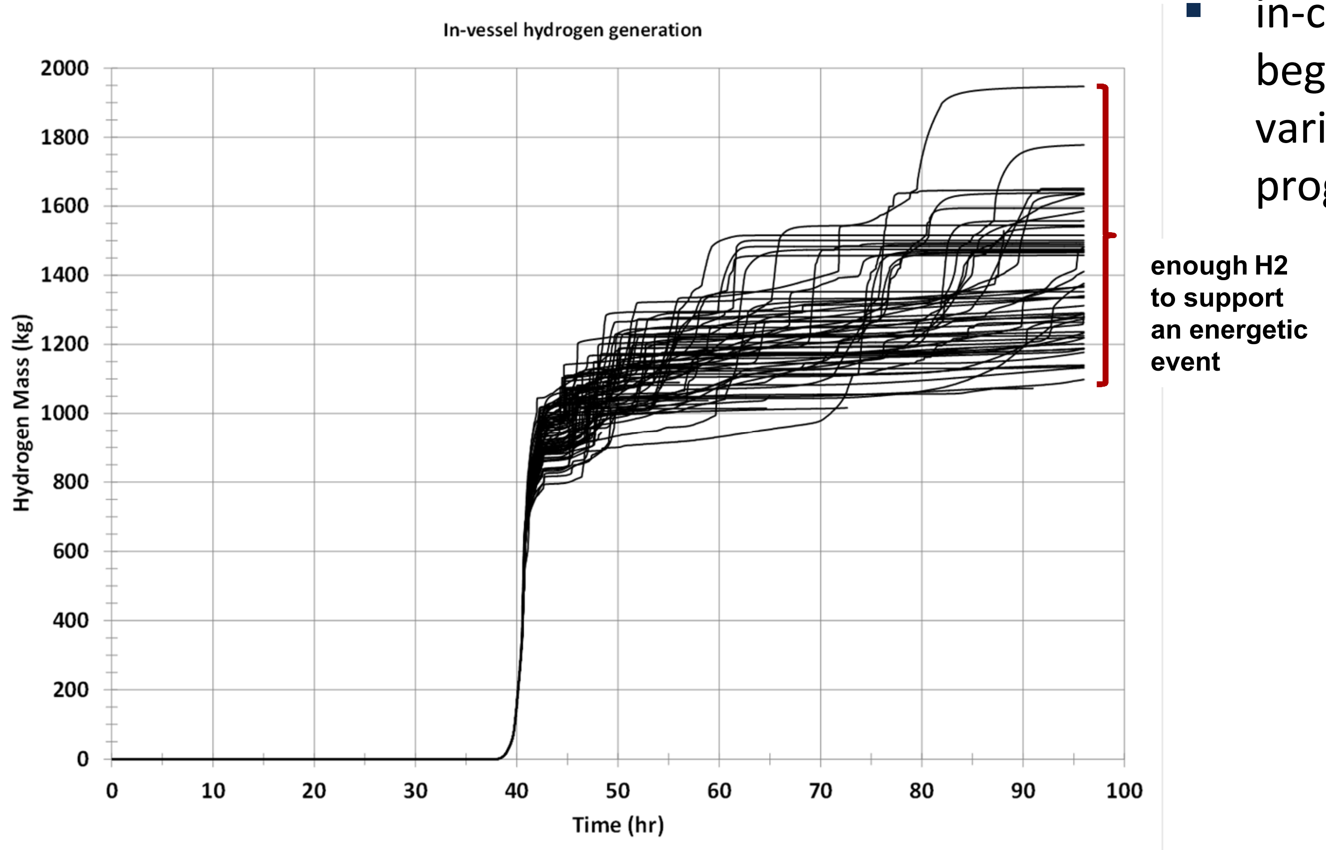
- H_2 in-core production results have variation in initiation time and late-time value
- These results and those for RPV and containment pressure (previous slide) are due to variation in core melt progress

1F3 Example



- 100 realizations that vary
  - wetwell vent opening fraction
  - water injection rate
  - quench parameters
- Some realizations capture the timing, some capture the peak
- There is not a single solution; several different combinations of uncertain variables can reproduce the data trend

1F3 Example



- in-core H2 generation begins to deviate due to variation in core melt progression

…and what does this all mean?

- “Tweaked” deterministic analyses are useful for identifying/handling ill-defined phenomena that are postulated to influence forensic results (e.g., 1F2 torus cooling, venting, water injection)
- However, input and model uncertainty have the potential to invalidate “tweaks” tied to forensic results, which can render them invalid for predictive analyses
- Experience has shown that source term results have significant variation; this will be important to handle for BSAF Phase II analyses

Summary

- 1F1 and 1F3 best estimate accident signatures are similar to those from older models/analyses; they match well enough with the limited data
- Still looking at 1F1 initial ex-vessel behavior
- Accident signatures are very dependent on boundary conditions (e.g., water injection rate, RPV depressurizations mechanism, RCIC & HPCI operation)
- Signatures can be sensitive to uncertainty in BCs and other inputs (explicitly seen in these results and those in the results of a separate 1F1 core-damage progression uncertainty analysis)