# RELAP5-3D Development & Application Status

Presented by

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# Outline

- Overview of development and application activities
- Selected reviews
  - Pb-Bi Reactor Studies
  - ATHENA/RELAP5-3D Validation
- Future activities

# Development Activities

| Item | Objective |
|---|---|
| PVM Executive for Coupling* | Control the startup, advancement and termination of tow or more coupled codes |
| 64 Bit Upgrade | Allow for 64 bit integers |
| Further Parallelization | Complete conversion to OpenMP directives in 3D and kinetics routines |
| Level Position in a Stack | Add output to indicate level position in a vertical stack of volumes |
| FORTRAN 90 Bit Packing | Convert archaic bit packing to FORTRAN 90 standard |

* Presentation in Seminar

# Development Activities (cont'd)

| Item | Objective |
|---|---|
| Critical Flow Anomaly* | Resolve discontinuity near saturation line |
| Stack Fill Temperature Anomaly | Resolve unphysical temperatures while filling a vertical stack |
| RGUI Enhancement* | Add heat slab data visualization |
| PYGMALION* | Refurbish |
| Couple RELAP5-3D to Fluent* | Application to HTGR |
| RELAP5-3DK* | Assist INER in developing an Appendix K version |

* Presentation in Seminar

# Applications at INEEL

| Project | Objective |
| --- | --- |
| International Nuclear Safety Program* | Development, assessment, and training for VVER and RBMK applications |
| Fusion Safety | Assessment of ATHENA/RELAP5-3D |
| Advanced designs | Lead-Bismuth, Pebble Bed design studies |
| ATR* | Safety margin assessments, design studies |
| RELAP5/RT* | Assist DS&S in simulator upgrades |
| Municipal Steam Supply Systems | Design and transient studies |

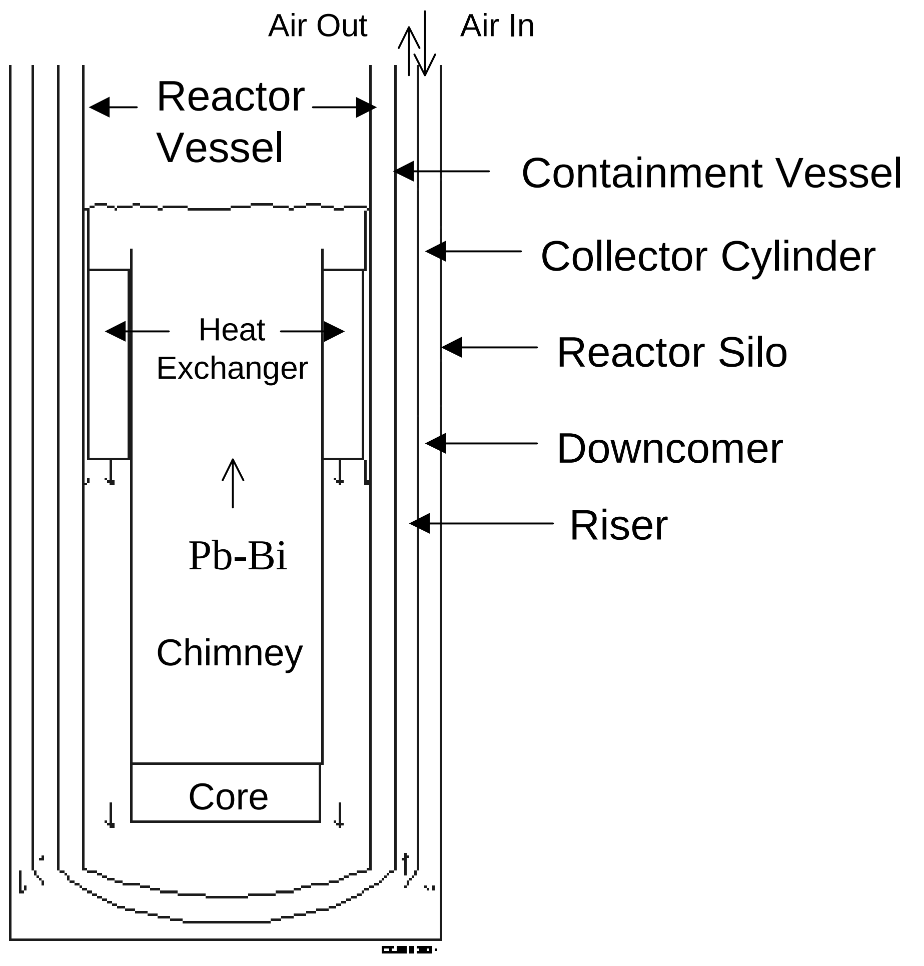
* Presentation in Seminar

# Pb-Bi Reactor Studies*

- ATHENA calculations were performed to investigate the transient response of three plant options:
  - Natural circulation primary, water secondary
  - Forced circulation primary, water secondary
  - Natural circulation primary, helium secondary
- Transients were analyzed to evaluate plant operability and determine margins to safety limits

* Work performed by Cliff Davis

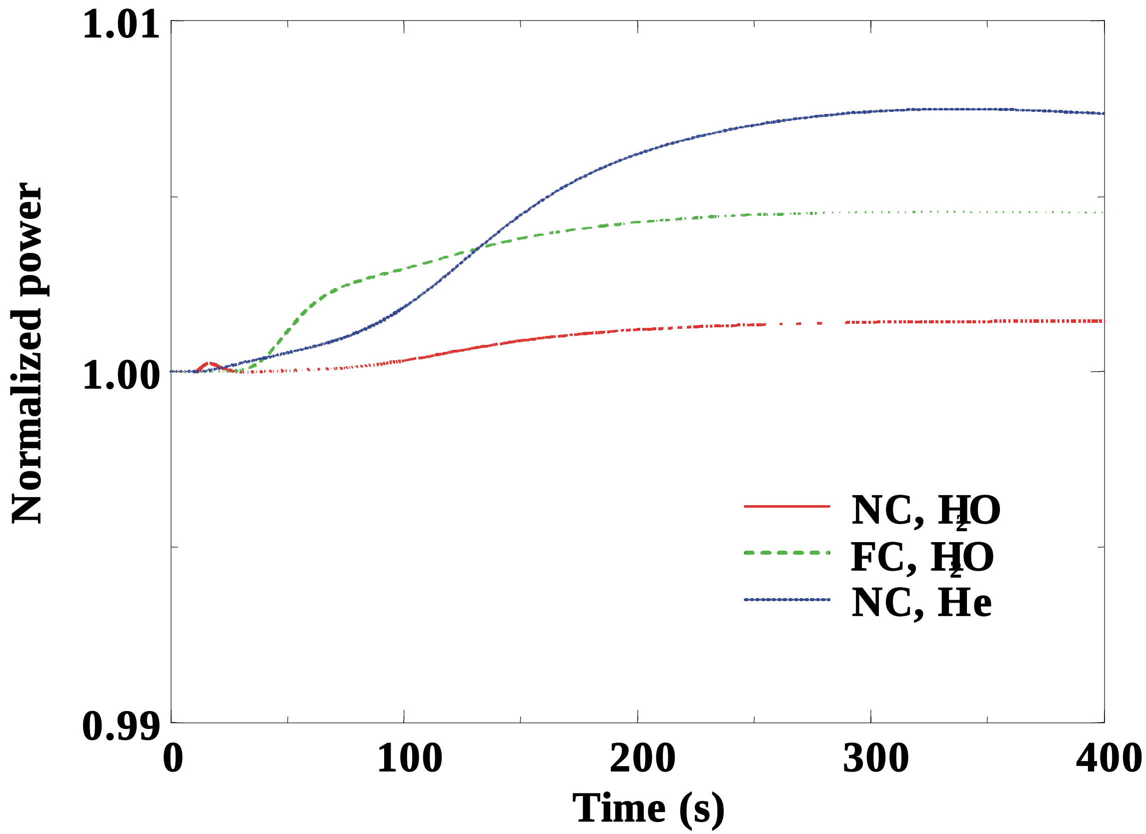
# Pb-Bi Reactor Design



# Transients to be analyzed

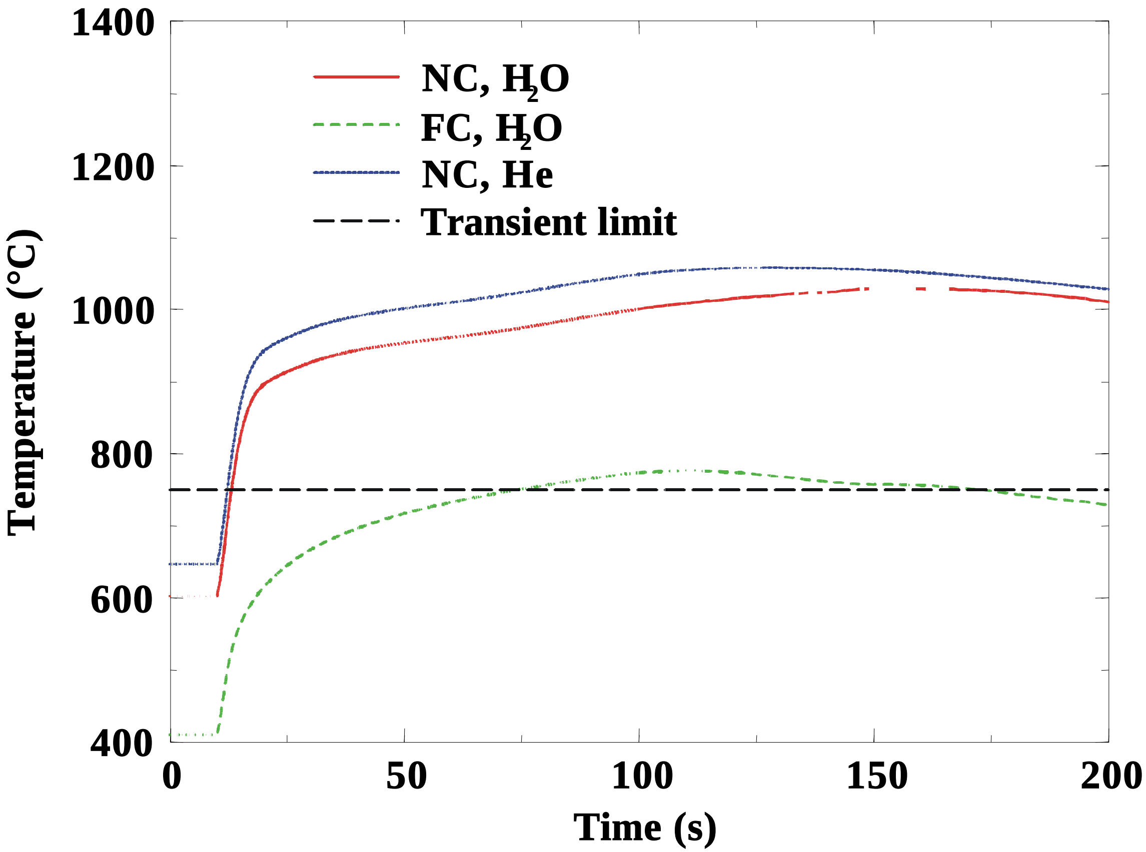
- Operability
  - Step change in load
  - Plant startup
- Accidents
  - Loss of heat sink with scram
  - Control rod ejection without scram
  - Large rupture of secondary outlet piping without scram
  - Heat exchanger tube rupture without scram
  - Primary coolant pump trip without scram
  - Loss of feedwater heating without scram

# *The plant is not sensitive to a 10% step change in load*



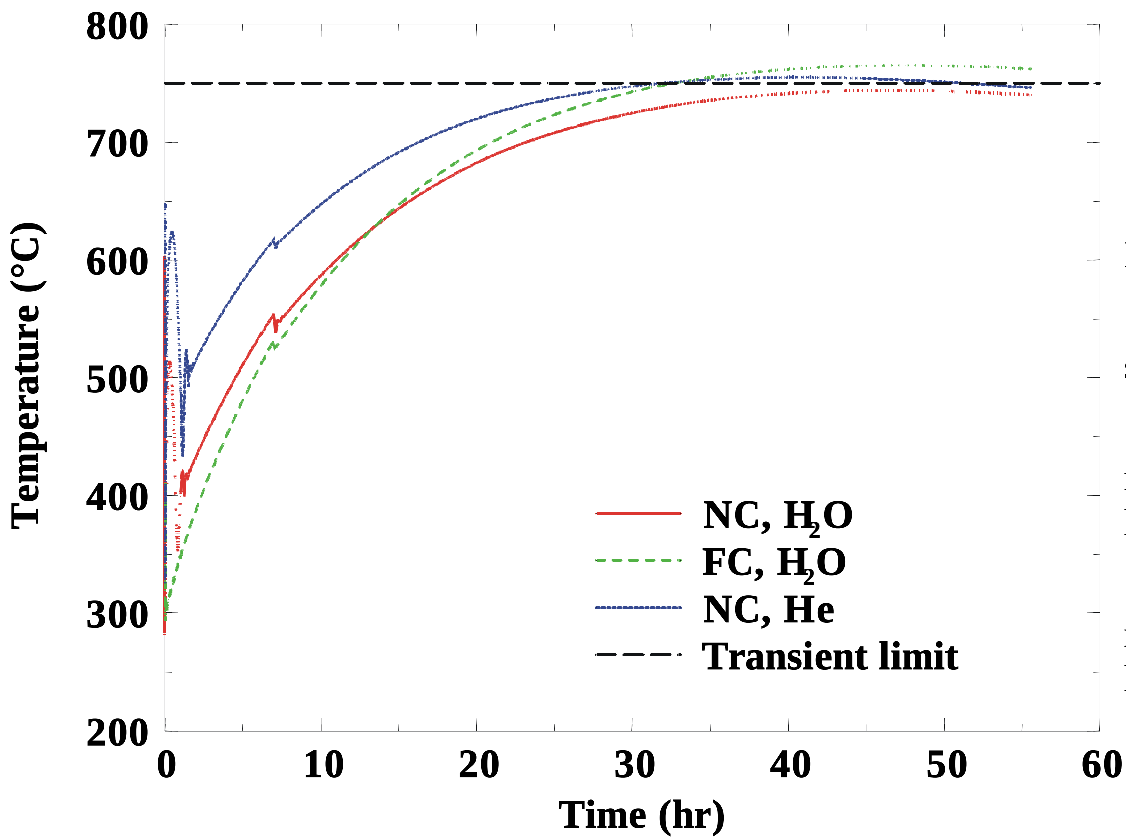

- Step decrease in secondary pressure at 10 s
- Secondary inlet flow assumed constant
- Evaluation of margin to scram, not load following capability

# *Scram is required to meet cladding thermal limit following control rod ejection*



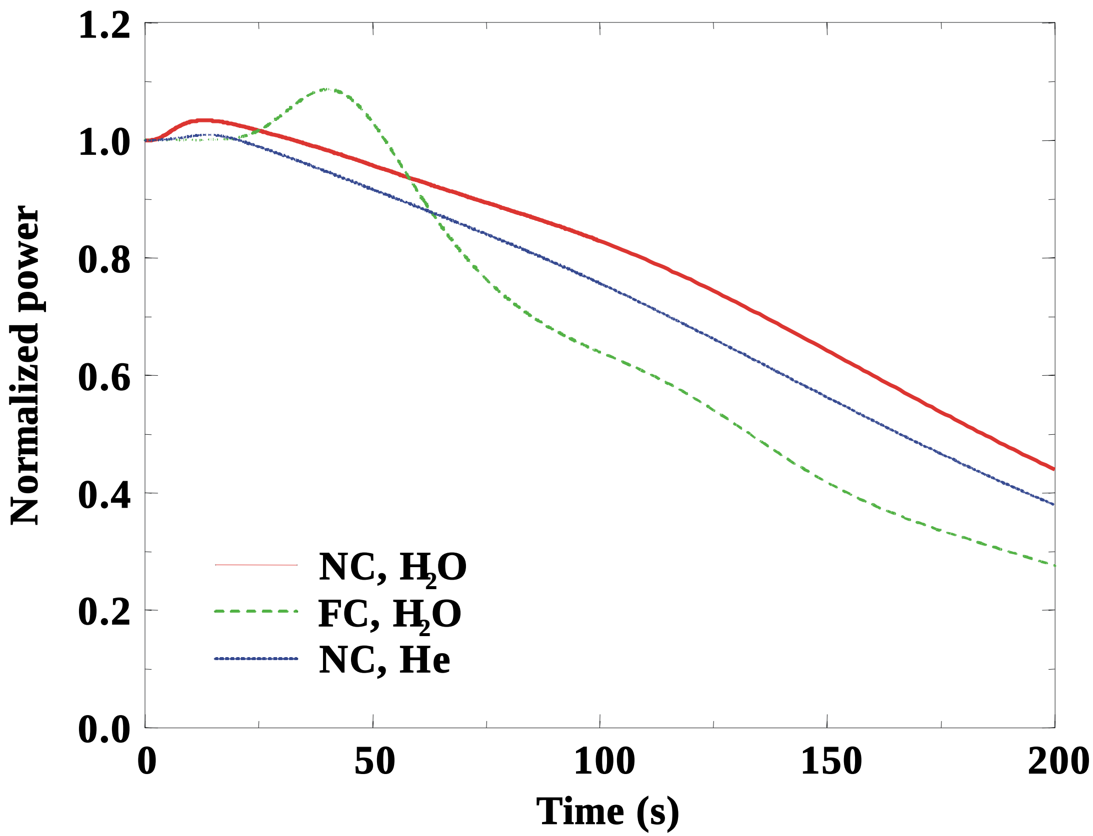

- 0.5$ step at 10 s representing ejection of average control rod (unlikely with fertile-free fuel)
- No scram
- Beyond design basis
- Scram must occur within 2 s with natural circulation
- More margin exists with forced circulation

# The pump should be tripped following a loss of heat sink




- With scram, pump running
- $Q_0$ = 650 MW
- Traditional RVACS
- Pump heat increases load on RVACS
- If pump is tripped, PCT is similar to NC case
- Transient limits will be more restrictive than steady-state limits for FC
- Initial power should be reduced by 3% to meet thermal limit with helium

# *The plant is not sensitive to a large rupture of the secondary outlet piping*




- $Q_0$ = 650 MW
- No scram
- All heat exchangers blow down, with no flow restrictors
- Power increases quickly with natural circulation, delayed until cold water reaches core with forced circulation
- Cladding temperatures remain below thermal limit

# Pb-Bi Design Preliminary Conclusions

- The plant demonstrates good operating characteristics
- The most limiting design-basis transient so far is the loss of heat sink
- Scram is required for the loss of heat sink and control rod ejection accidents
- The transient responses of all three plant configurations are acceptable
  - Reactor coolant pumps should be tripped or run back following a loss of heat sink
  - Reactor scram is almost not required for a control rod ejection accident with forced circulation

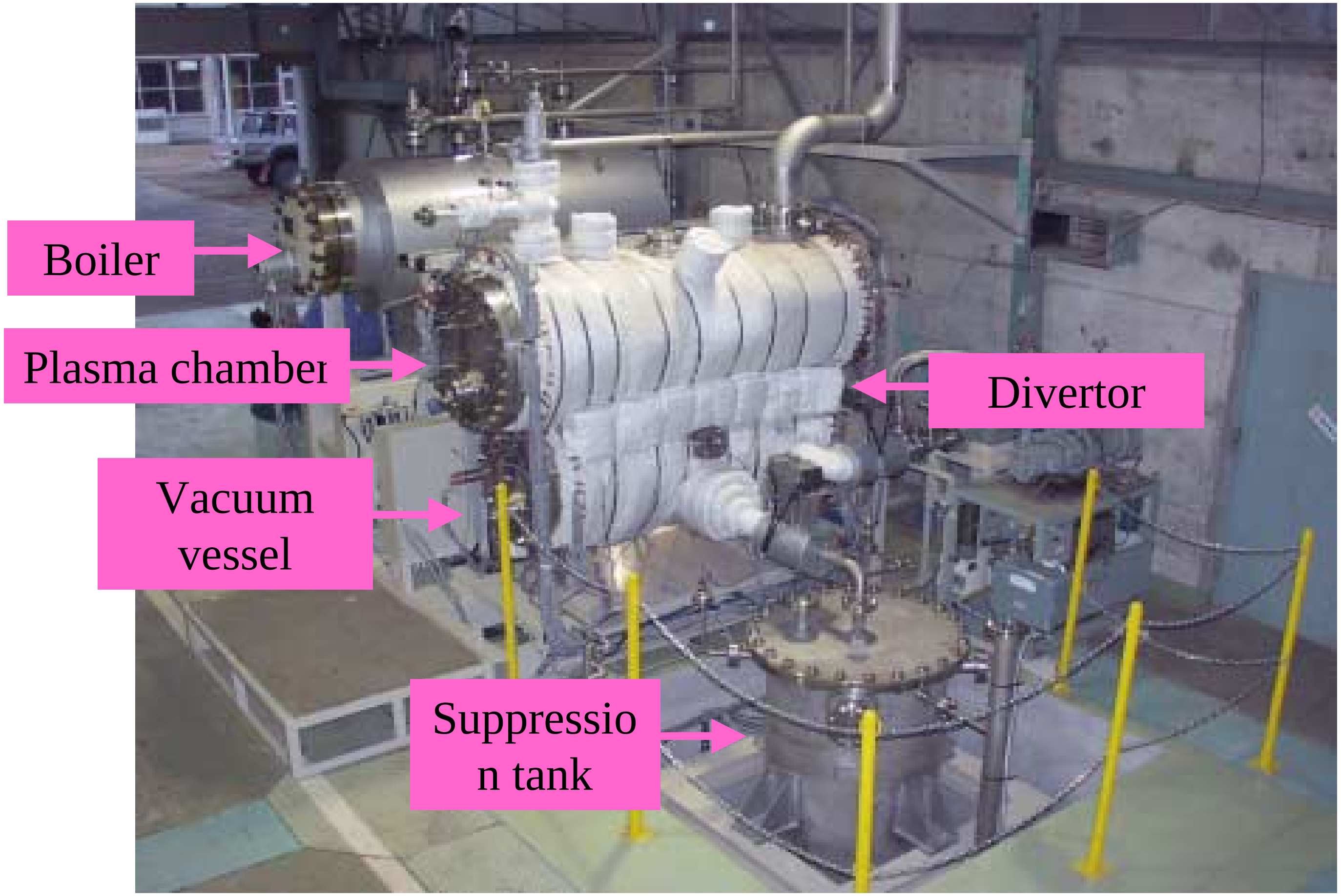
# ATHENA/RELAP5-3D Validation For Fusion Reactor Studies*

## Japanese Ingress of Coolant Experiment (ICE)

- Scaled experimental facility simulating a water cooled tokamak reactor
- Purpose of facility
  - Measure pressure, choked flow and wall heat transfer during loss-of-coolant accidents (LOCAs) into superheated evacuated vessels
  - Validate capabilities of fluid flow codes used by the fusion community for safety assessment of reactor designs - ATHENA, MELCOR, CATHARE, TRAC, INTRA, CONSEN

*Prepared by Brad Merrill

# Japanese Ingress of Coolant Event (ICE) Experiment



# ATHENA/RELAP5 3D ICE EXPERIMENT MODEL

## Fluid Cell Placement

Boiler
r-Θ-z - 3 x 6 x 3 (60°)

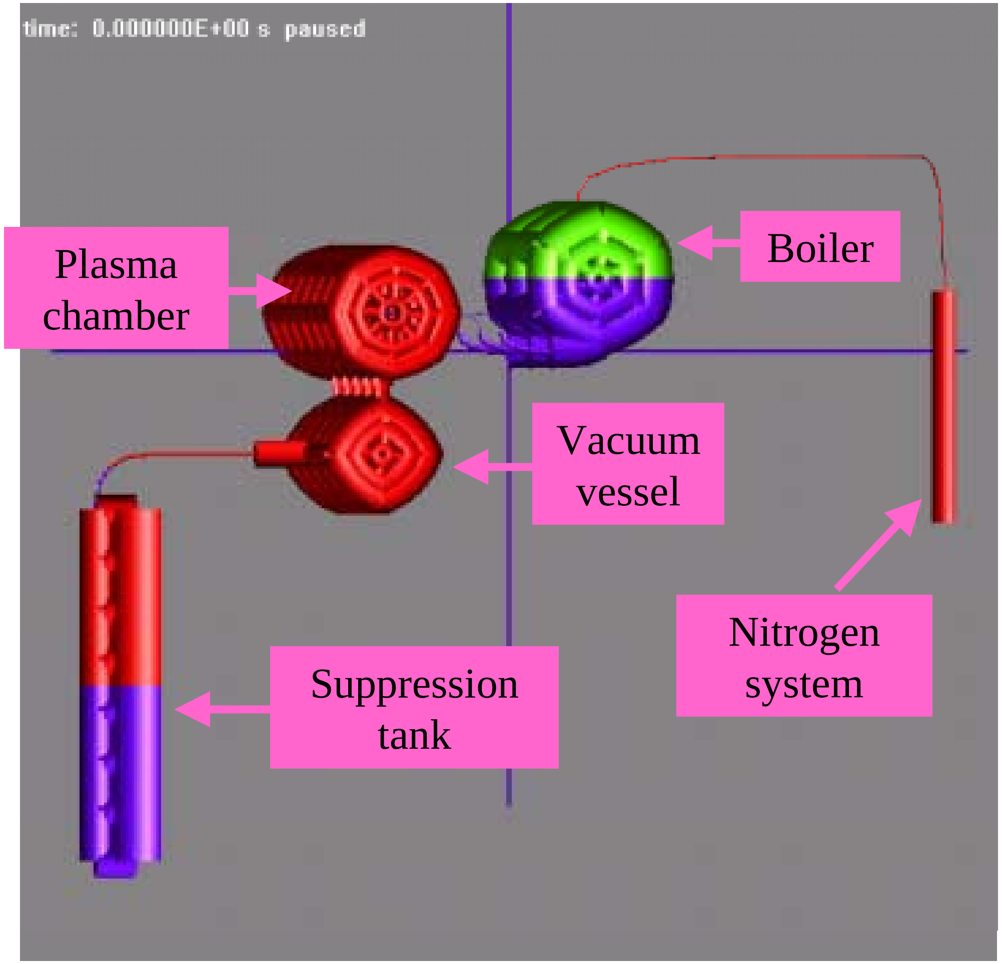
Plasma chamber heat
r-Θ-z - 4 x 8 x 7 (45°)

Divertor region divided
into five cells

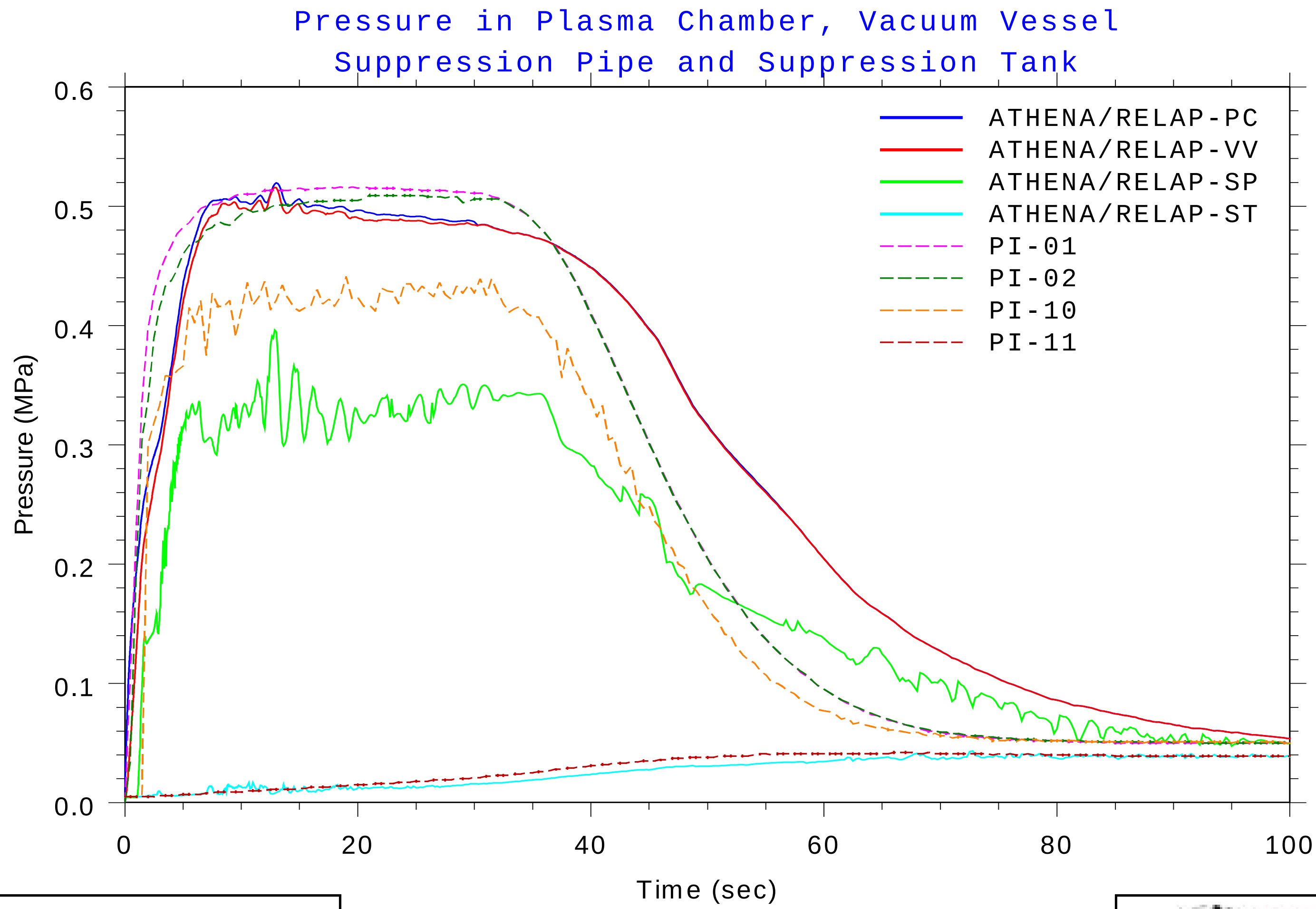
Vacuum vessel
r-Θ-z - 3 x 4 x 5 (90°)

Suppression tank
r-Θ-z - 2 x 1 x 8 (360°)

Nitrogen system, injector lines,
relief pipes, 1D components



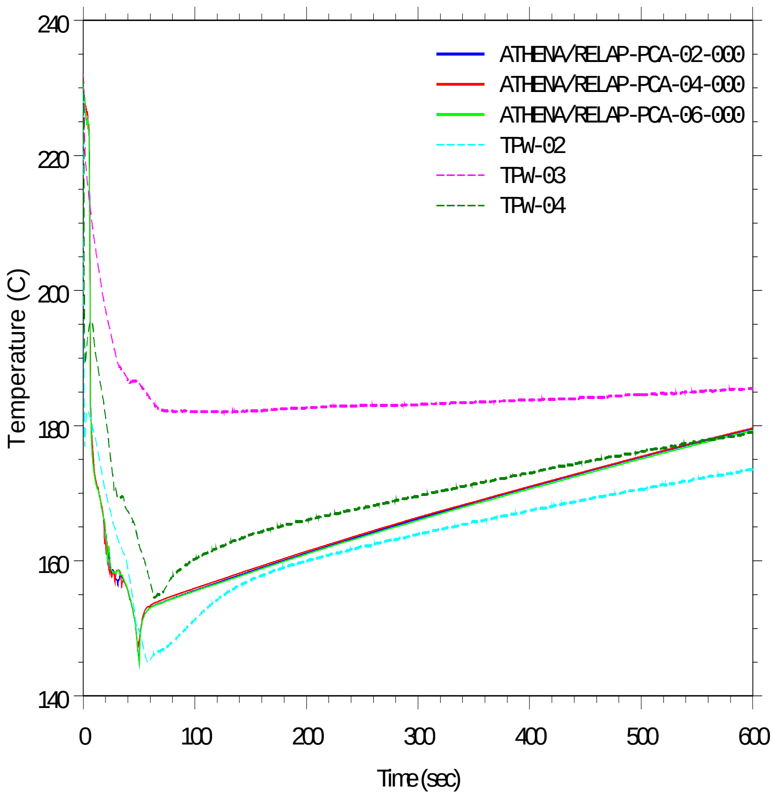
# CASE 02 RESULTS



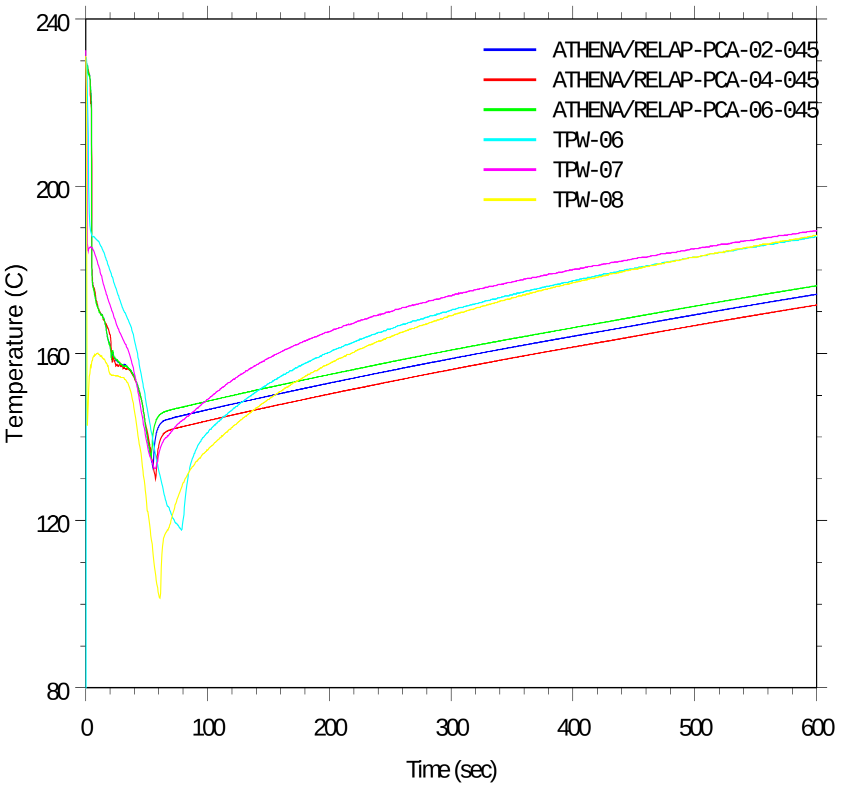

**RELAP5-3D©**

# CASE 02 RESULTS (cont)

Temperature of Plasma Chamber Wall θ=0




Temperature of Plasma Chamber Wall θ=45

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# Post-test Conclusions for ATHENA/RELAP5-3D Comparison

ATHENA/RELAP-3D compared well with ICE test data provided

- homogenous flow velocity model (equal vapor and liquid) was employed => inter-phase drag model needs to be examined
- post-CHF heat transfer correlations were enhanced by a factor of 7 to simulate droplet impingement => heat transfer models need to be added

# Future Activities*

| Task | Objective |
|---|---|
| Multi-Thread with PVM | Permit execution of RELAP5-3D in parallel when coupled to other codes using the PVM methodology |
| Improve Air Appearance Logic in RELAP5-3D | Modify logic to avoid repeat of time step |
| Allow Reflood on Left or Right of Heat Slab | Generalize reflood model for different geometries |
| FORTRAN 90: fixed commons, volume block | Convert fixed common blocks to FORTRAN 90 modules and convert the control volume block to a FORTRAN 90 module |
| Resolve BPLU Zero Bandwidth Problem | Find and correct root cause for anomalous zero bandwidth failures |
| RGUI Development | Model Builder/Editor |

*Based on projected funding