NEUTRINO-SPH Development and Assessment

IRP Meeting – Raleigh North Carolina

Topics

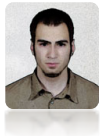
- **Introduction**
  - Team
  - Neutrino-SPH
- **Neutrino-SPH For Industry Problems**
  - Requirements
    - Flows (Flooding/High Winds)
    - Communication with PRA
  - Neutrino-SPH Current/Recent Capabilities (2016)
    - Coupled Particle Killers/Emitter (Sink/Source) Model
    - Coupled Shallow Water/SPH Model (Flood)
  - Neutrino-SPH In Development (2017 & Beyond)
    - Particle Shifting - High winds
    - Differential Flow Emitter
    - Spray and Pipe Breaks
    - Neutrino-SPH Solver in Moose

Introduction: Team

- Neutrino-SPH Developers
  - **Ram Sampath**

    - R&D Engineer: Disney Feature Animation, Digital Domain etc.
    - M.S: Computer Science – University of South Carolina.
  - **Niels Montanari**

    - M.S: Applied Mathematics - University of Grenoble.
    - Diplôme d'ingénieur: Computer Science – University of Bordeaux.
  - **Nadir Akinci**



    - Post Doctoral – MIT.
    - Ph.D – University of Frieberg.

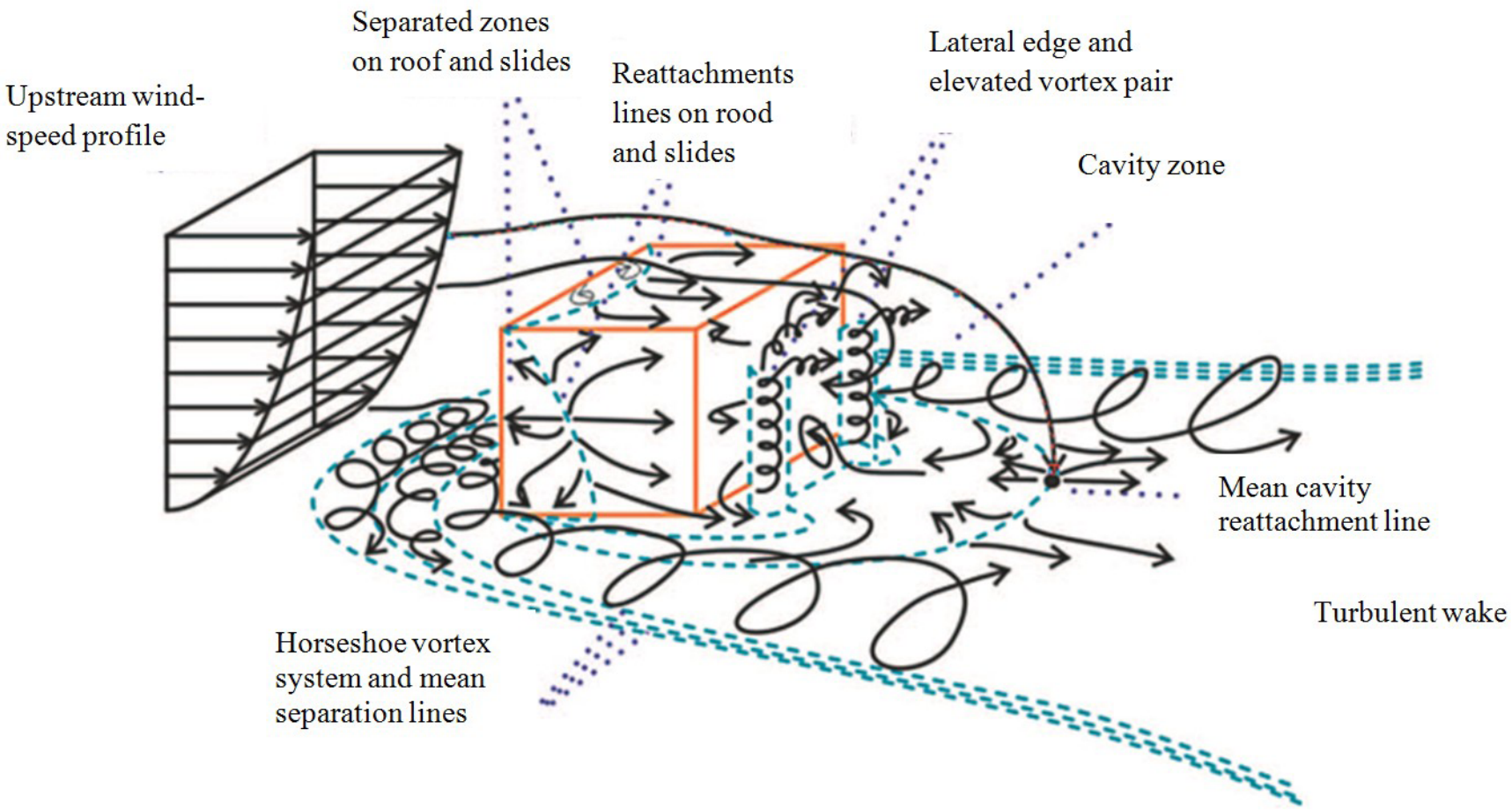
Introduction: Neutrino-SPH

- Smoothed Particle Hydrodynamics based System
- Neutrino's Boundary Implicit Incompressible SPH Solver
  - Rest Density based formulation of Incompressibility
  - Iterative Pressure Solver
  - Hydrostatic/Hydrodynamic Coupled Simulation
  - Rigid/Fluid Coupling

Requirements: Flooding

- Deal with Complex Geometry
- Robust
- Fast Realization of Simulations
- Tracking Interfaces
  - Free Surface (For Measuring Fluid Height)
  - Fluid-Structure. (Computing Forces/Pressure etc)
- Verification & Validation
- Ability to couple with PRA Simulations

Requirements: Wind

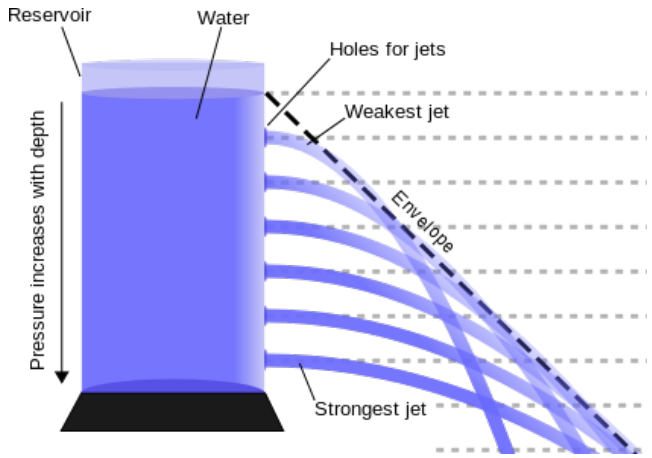


Requirements: Wind

- Deal with Complex Geometry
- Robust
- Fast Realization of Simulations
- Tracking Interfaces
  - Fluid-Structure. (Computing Forces/Pressure etc)
  - Fast moving bodies - projectiles
- Ability to handle high Reynolds number flows
  - Turbulent Motion
  - In-significant effect of gravity (Air)
  - Low Viscosity (Air)
- Verification & Validation
- Ability to couple with PRA Simulations

Neutrino-SPH: Torricelli Emitter

- Case study: rainfall-induced flooding.
  - Rainfall with the Navier-Stokes equations is overkill.
  - Use a simple fluid model based on Bernoulli's principle.
  - Solve the Navier-Stokes equations with SPH afterwards.
  - Couple the domains with an inflow boundary.

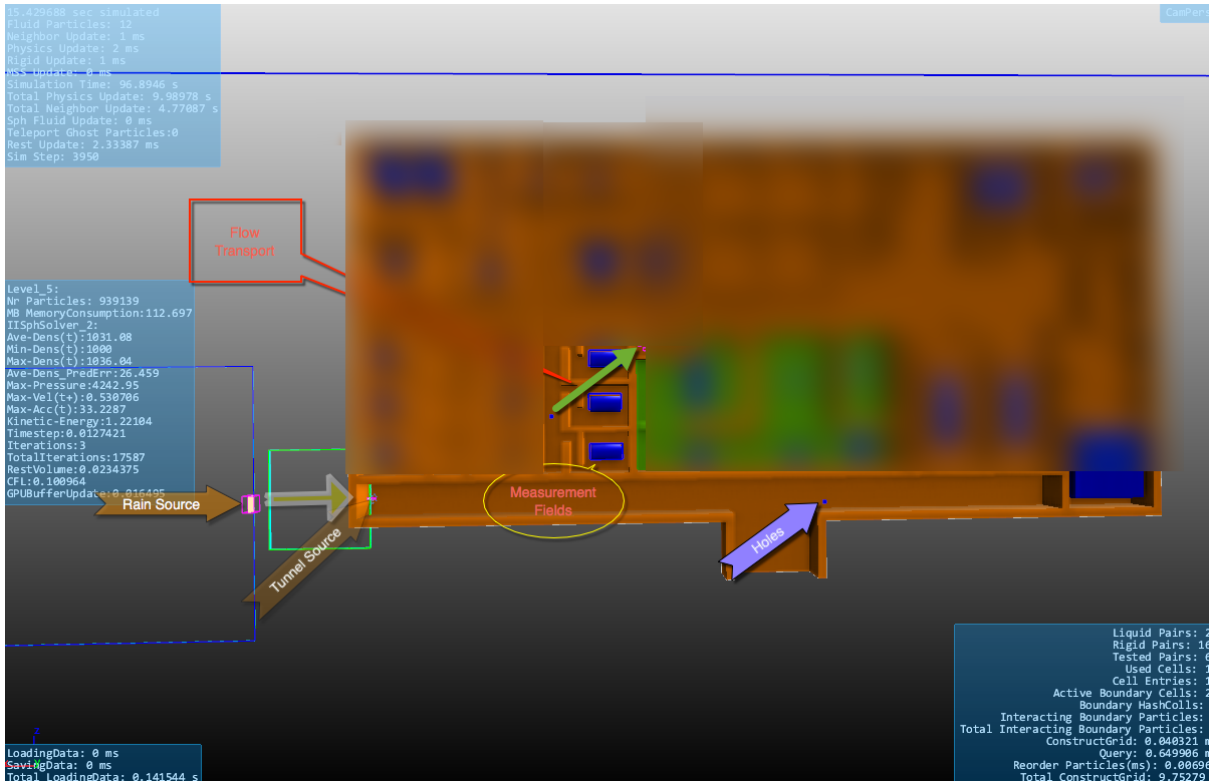


Neutrino-SPH: Emitters/Killers/Transporters

- Neutrino-SPH Emission Systems
  - Torricelli Emitter
    - Inflow
      - Rainfall etc
    - Calculated Accumulation
  - Flow Emitter
  - Rectangular Shape
  - Controlled by time varying flow rate
  - Mass Conserving
  - Emitters can be Coupled
    - Providing transport of particles across gaps
    - Emulate a virtual pipe driven flow without simulation
    - Outflow through Killer => Inflow of Emitter
    - Outflow of Torricelli Emitter => Inflow of Torricelli Emitter
    - Measurement Fields => Inflow of Emitters (Flow/Torricelli)

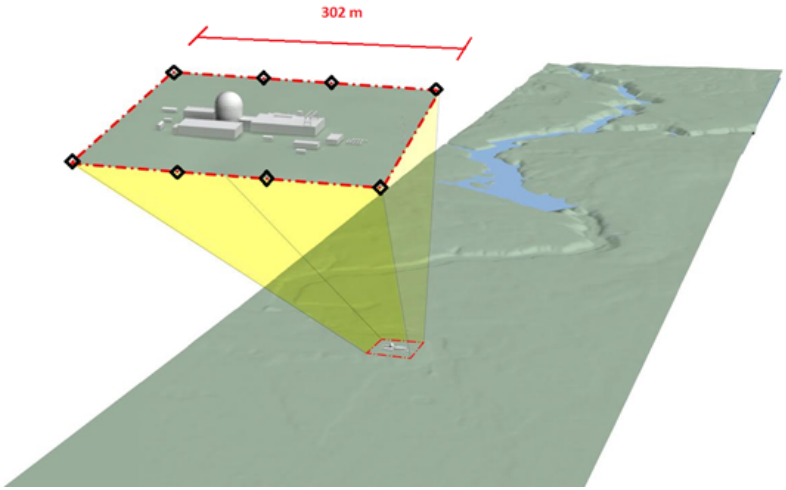
Case Study 3: Rain Induced Flooding at NPP

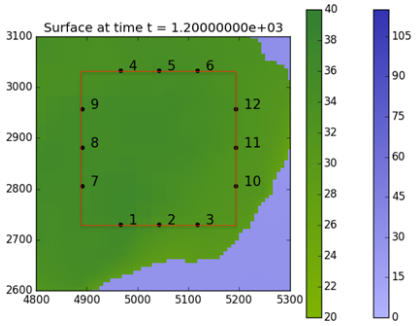
- Setup
  - Buildings
  - Levels
    - Components
    - Emitters
    - Transporters
    - Killers

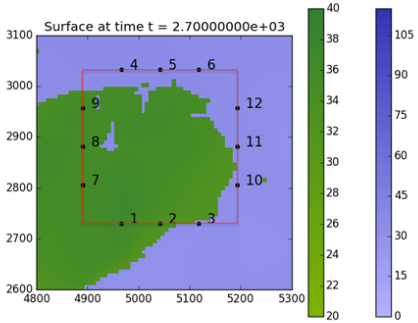


Neutrino-SPH: Coupling

- Case study: Dam Breach induced Flooding.
  - Shallow Water model for dam break until region of interest
  - Solve the Navier-Stokes equations with SPH – Flow Structure
  - Couple Domains - Inflow boundary
    - Horizontal velocity components + Height.



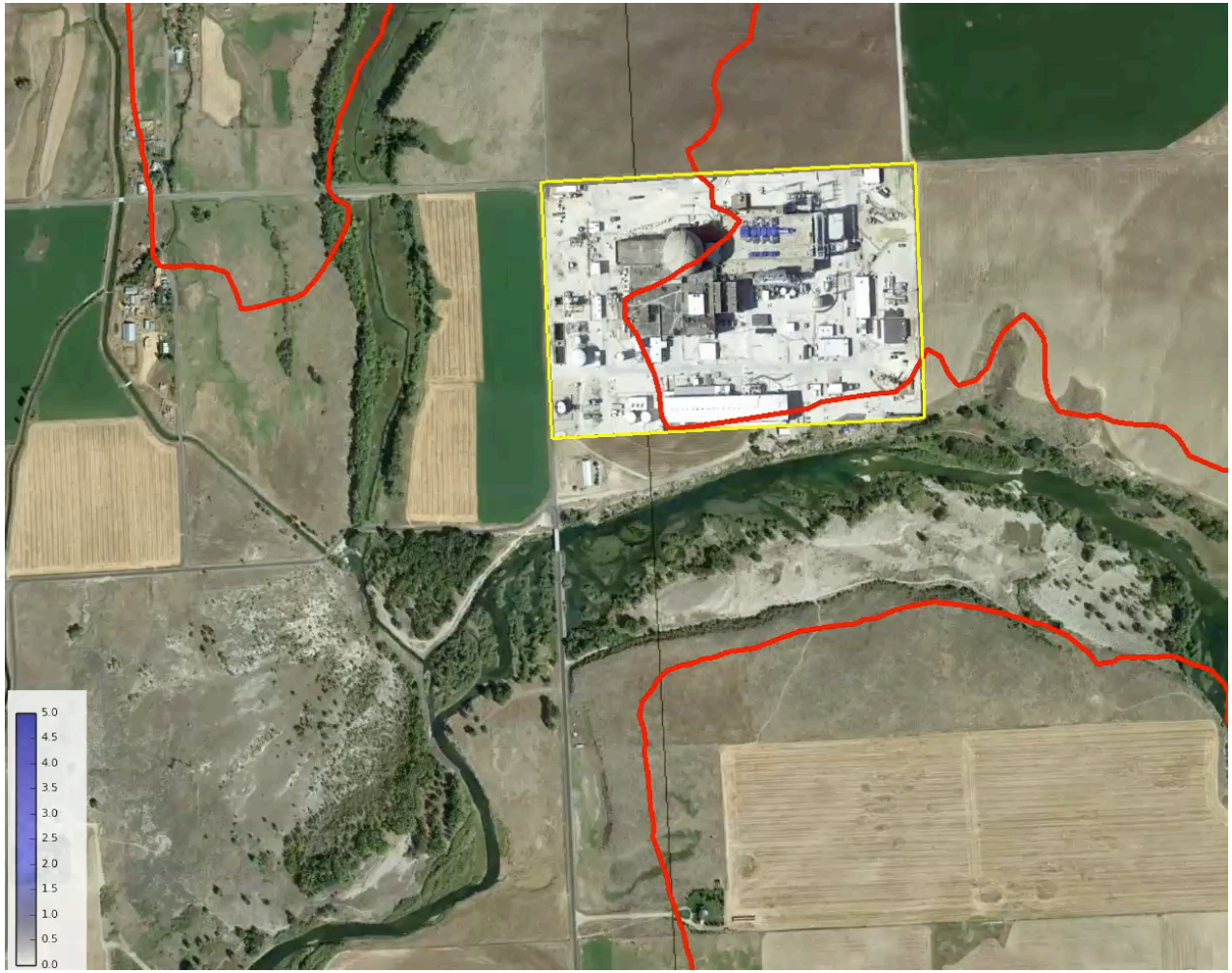




Neutrino-SPH: Coupling With SW

- Shallow Water Coupling
  - GeoClaw
    - Riemann Solver
    - Adaptive Mesh Refinement
    - Parallel
    - Setup by python script
    - Measurement Gauges
  - Domain is coupled to SPH along gauges
    - Set of gauge positions and connections.
    - Prescribe the inflow velocity, direction and height using the shallow water data.
    - Interpolate in time to synchronize the shallow water data with the SPH simulation.

Neutrino-SPH: Coupling With SW



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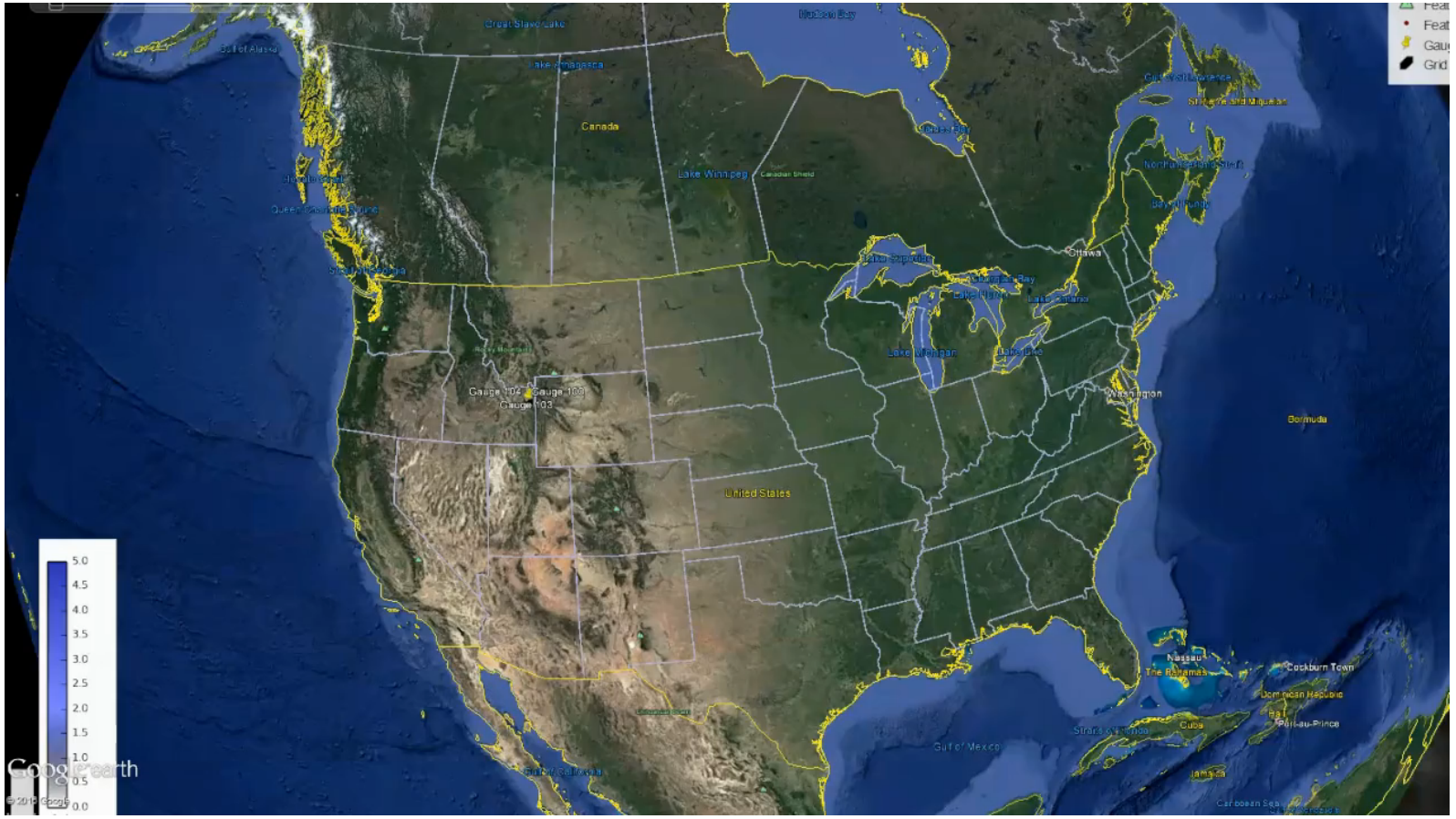
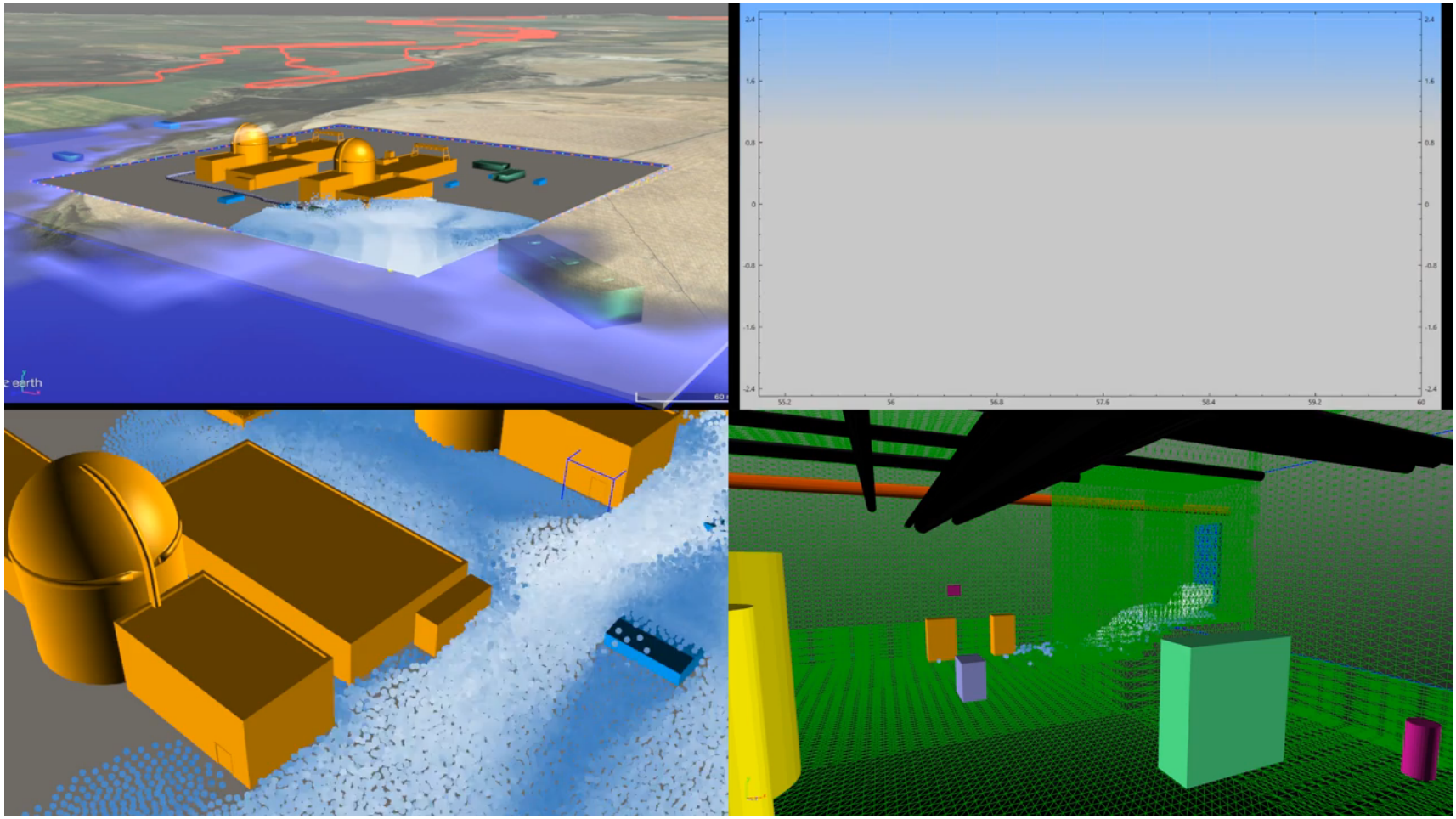
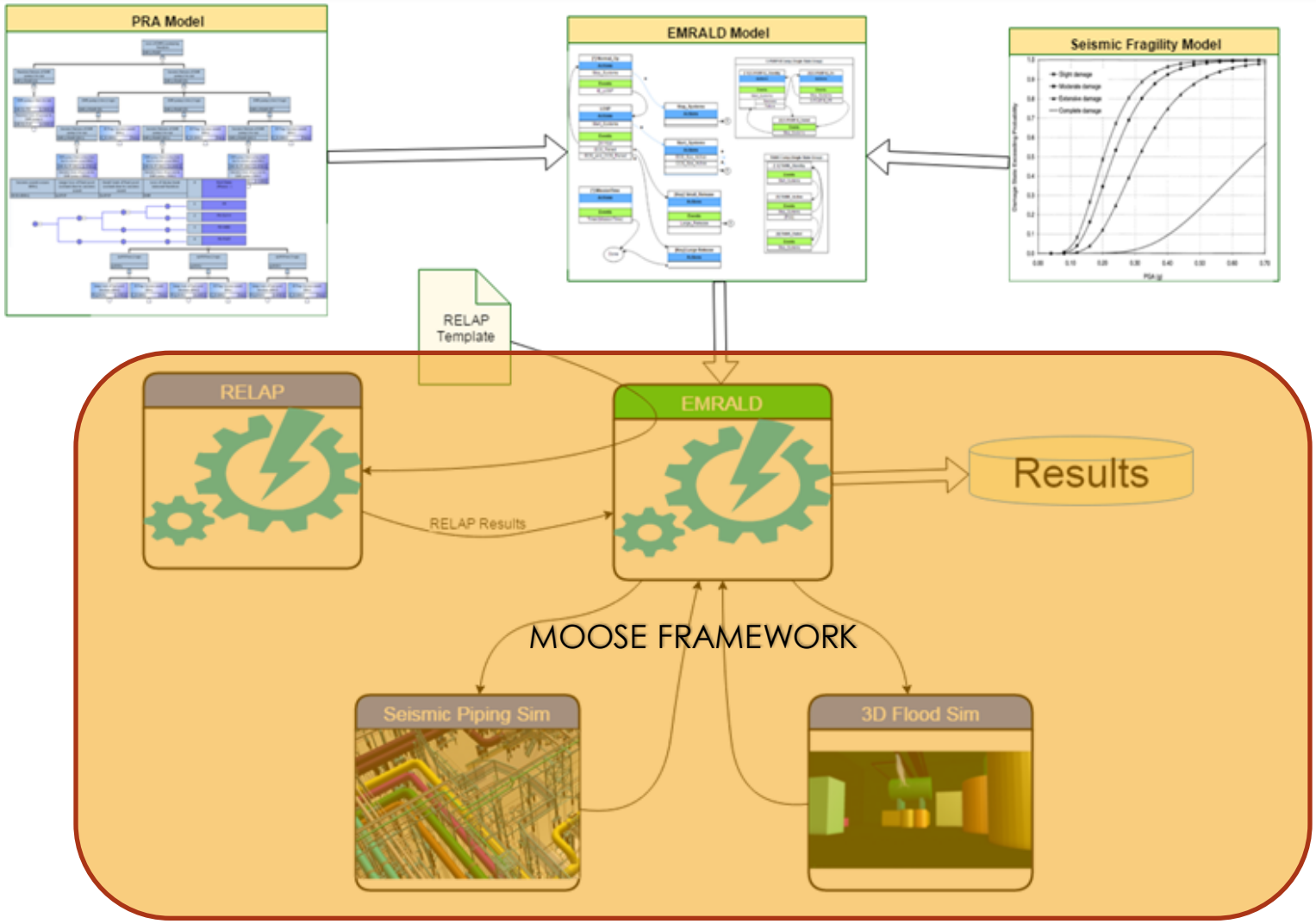


Neutrino-SPH: Coupling With SW



Neutrino-SPH: PRA System Coupling

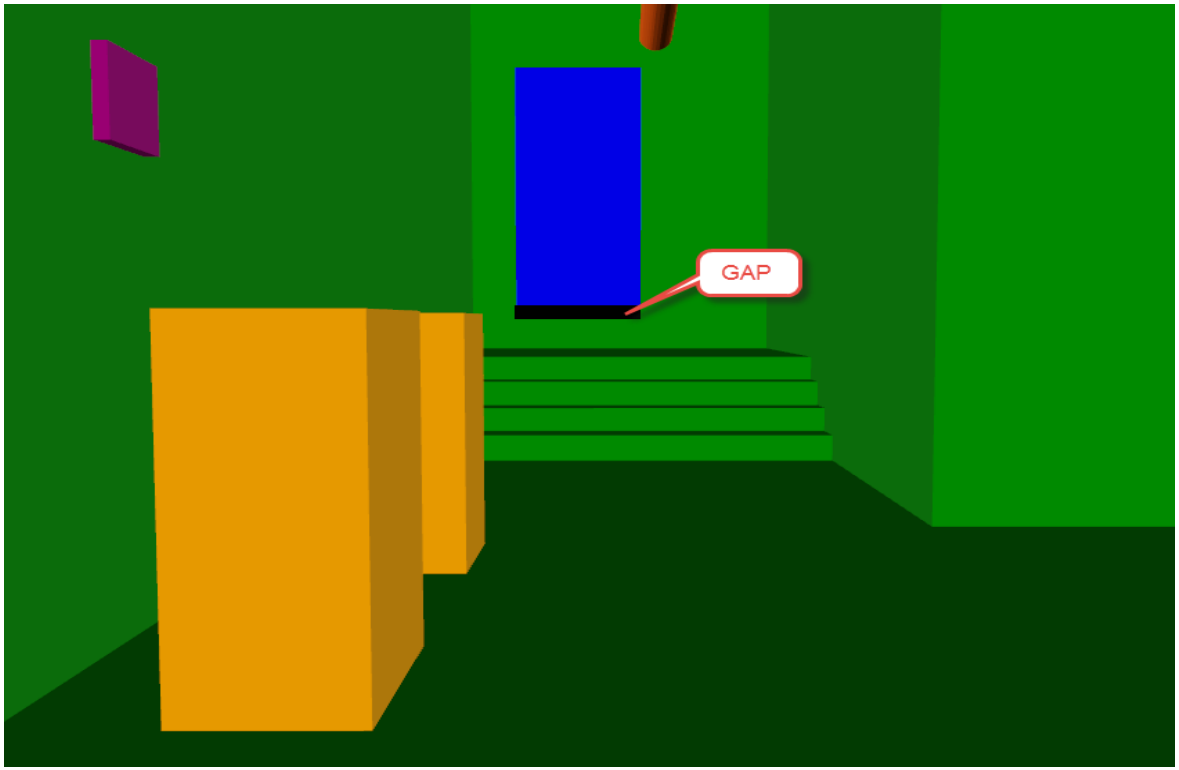


Neutrino-SPH: In Development

- Flooding Under Doors
  - Differential Flow Emitter
- High Wind
  - Particle Shifting (Handle voids)
  - SPH Turbulence Modeling
- Spray Simulation from Pipe Breaks

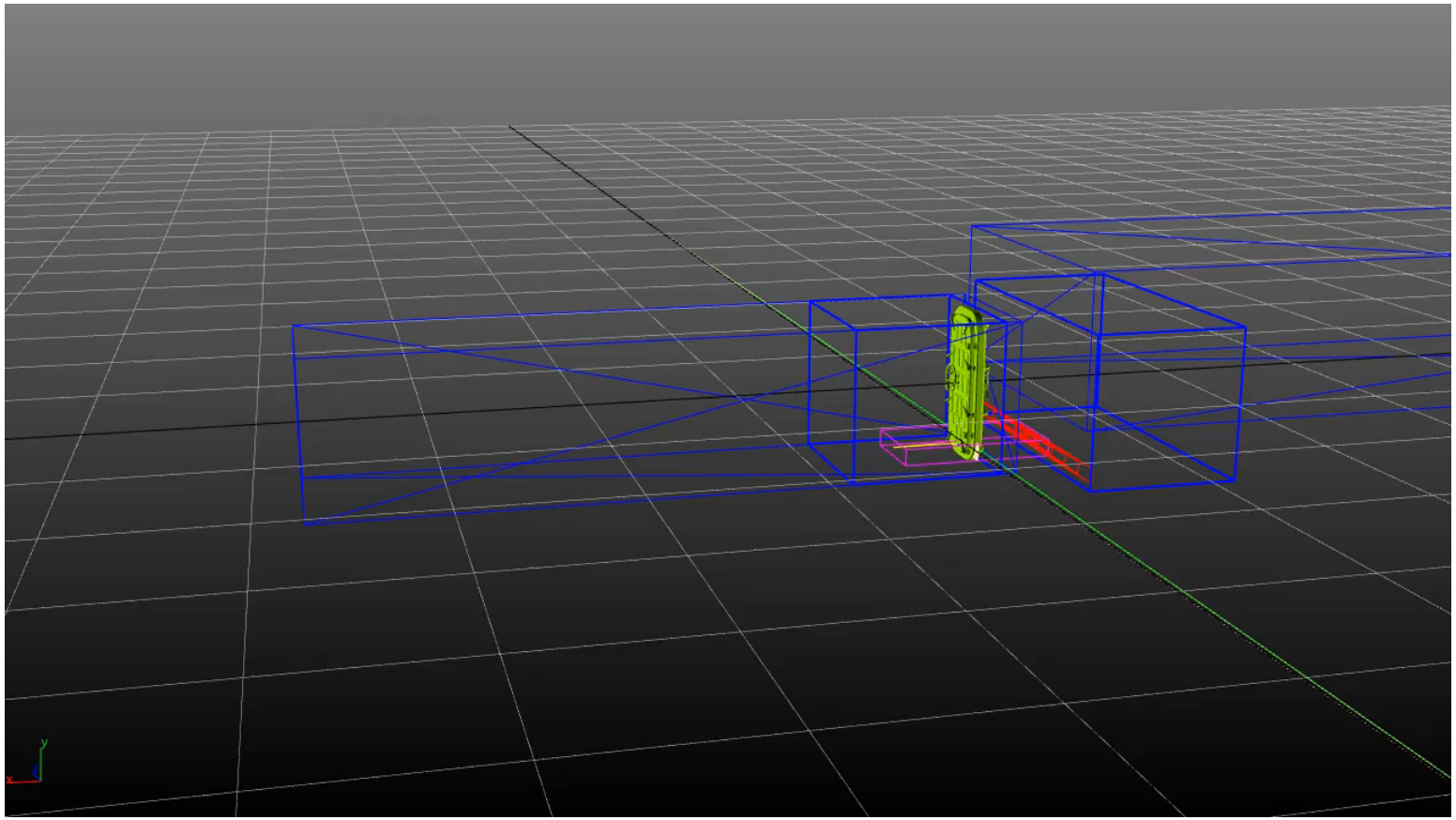
Neutrino-SPH: In Development

- Flooding Under Doors – Differential Flow



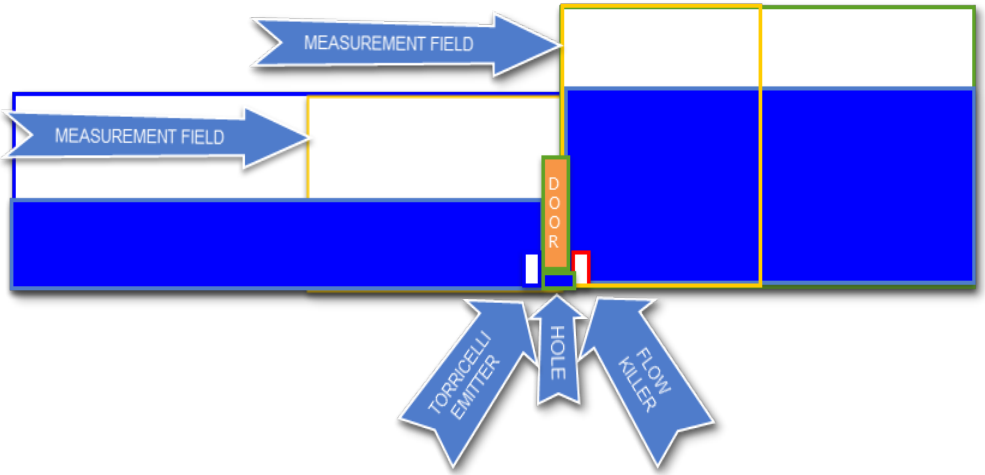
Neutrino-SPH: In Development

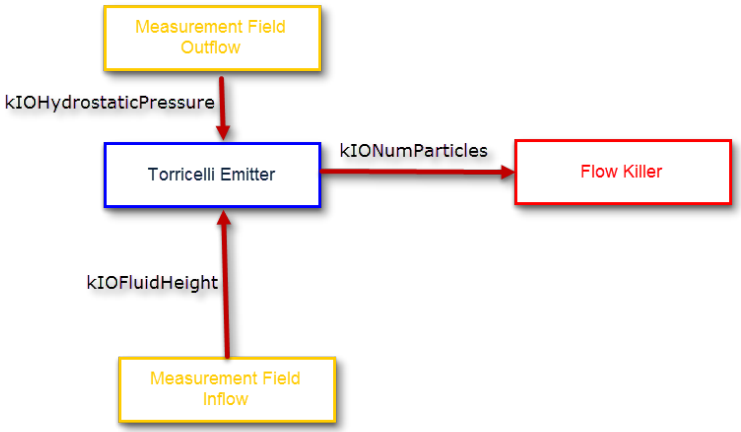
- Flooding Under Doors – Differential Flow



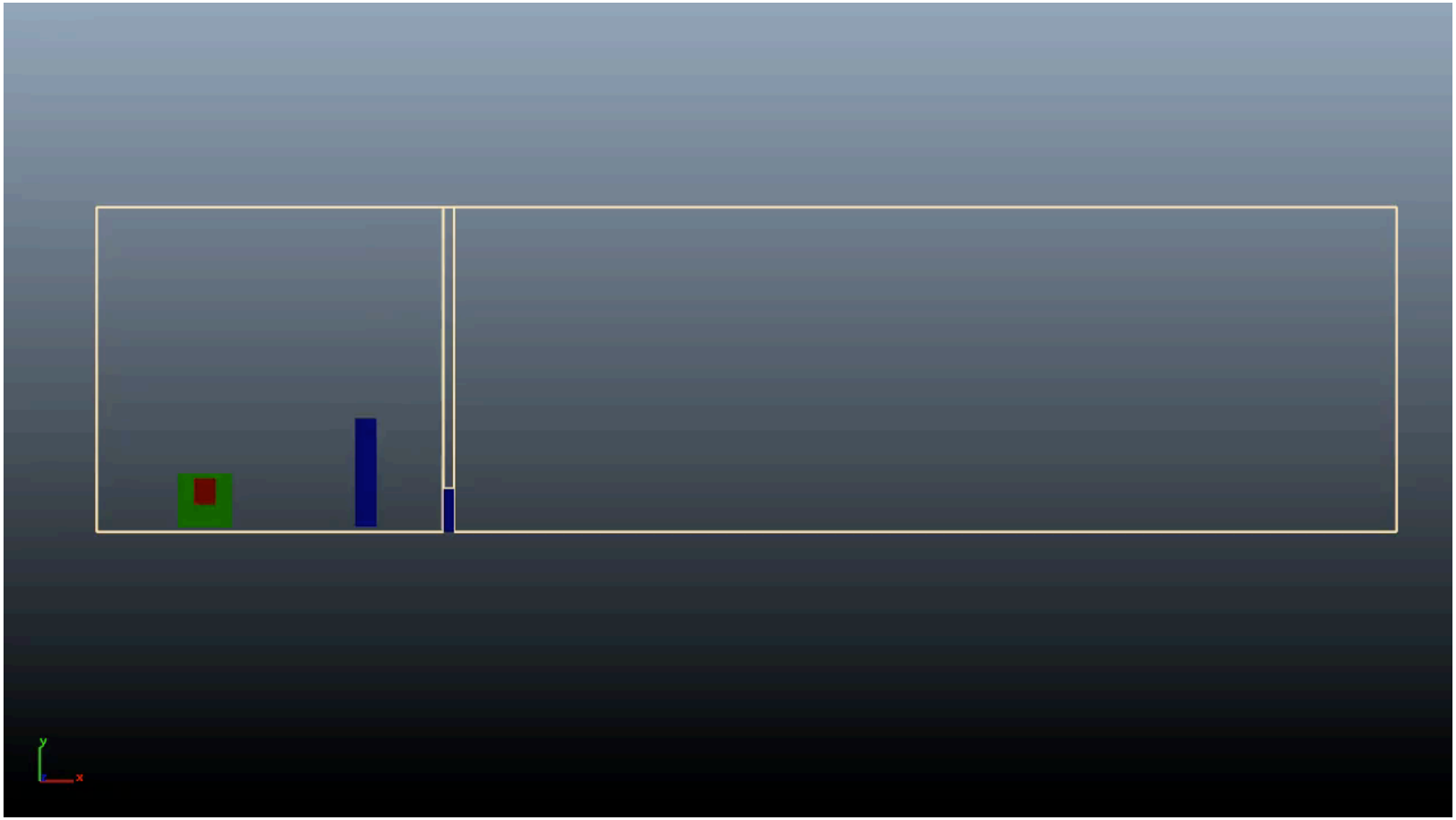
Neutrino-SPH: In Development

- Flooding Under Door Simulation



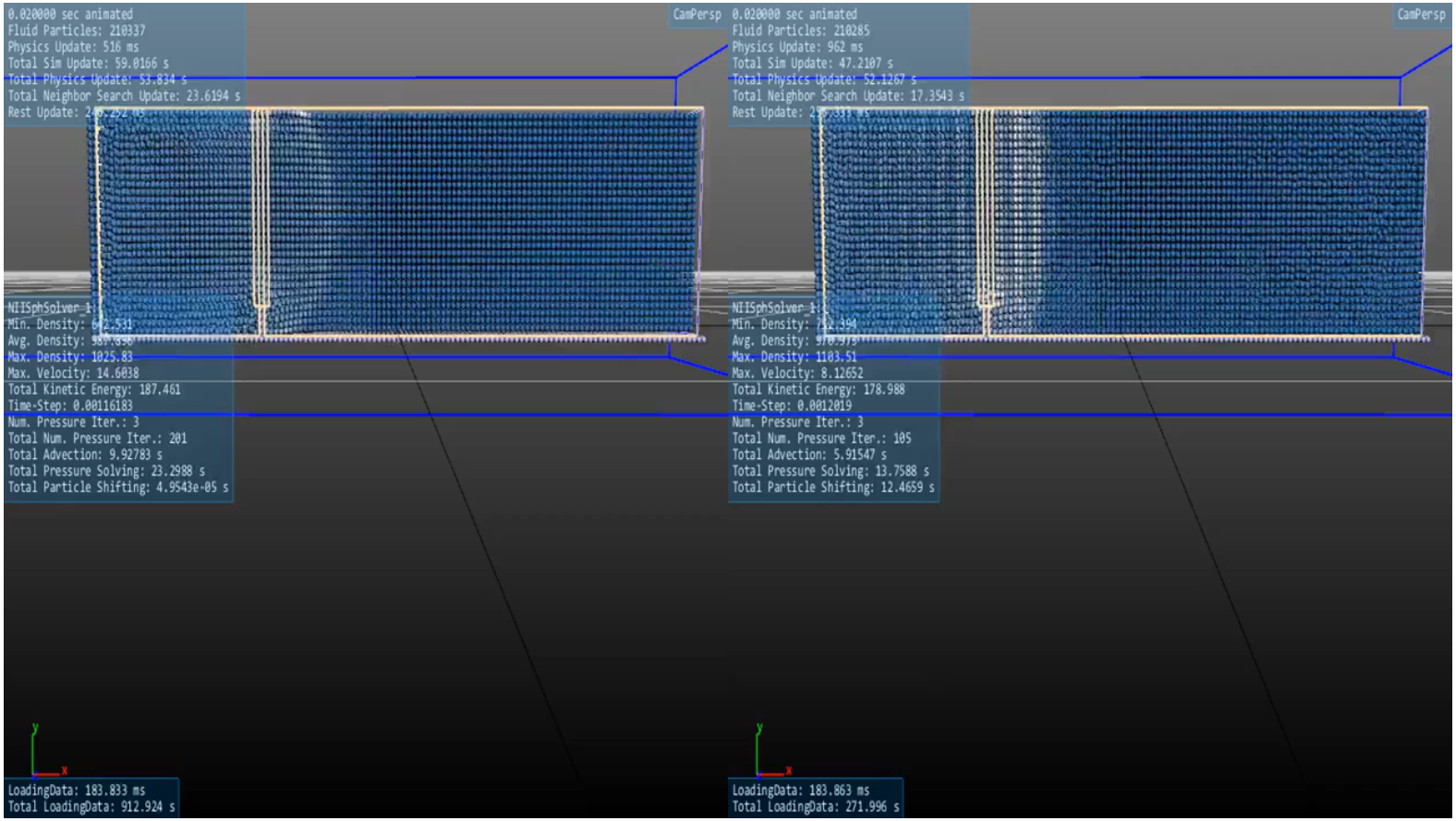


Neutrino-SPH: In Development (Wind)

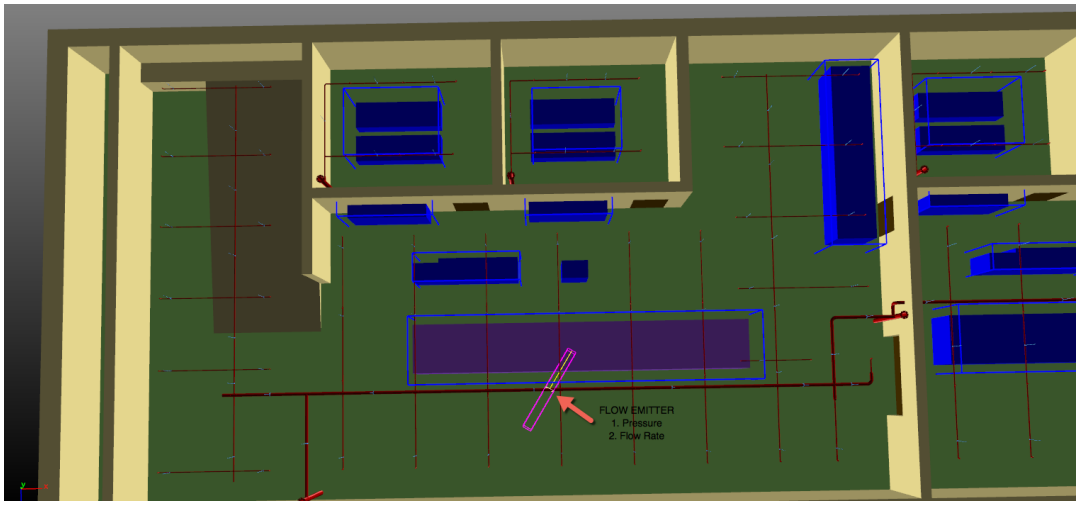


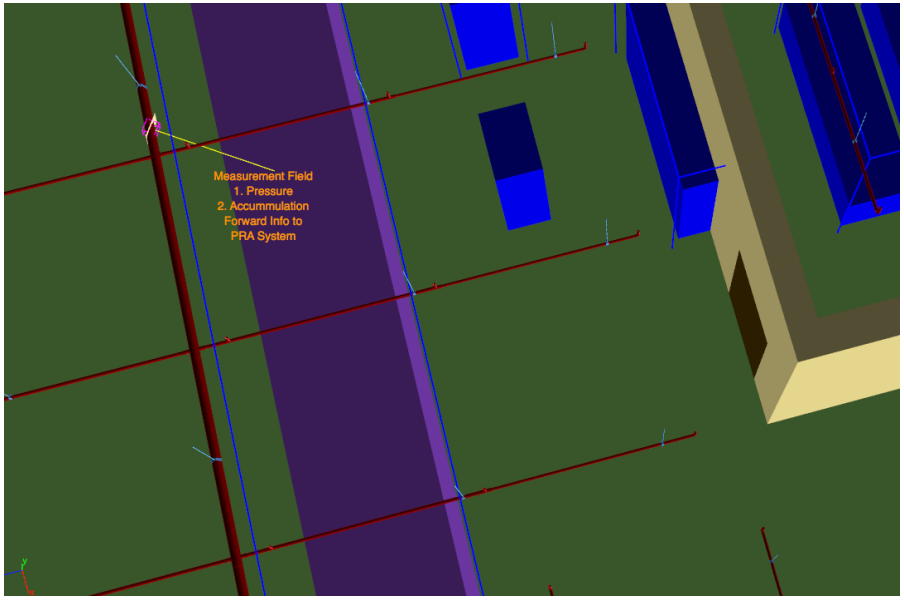
Neutrino-SPH: In Development

- Particle Shifting

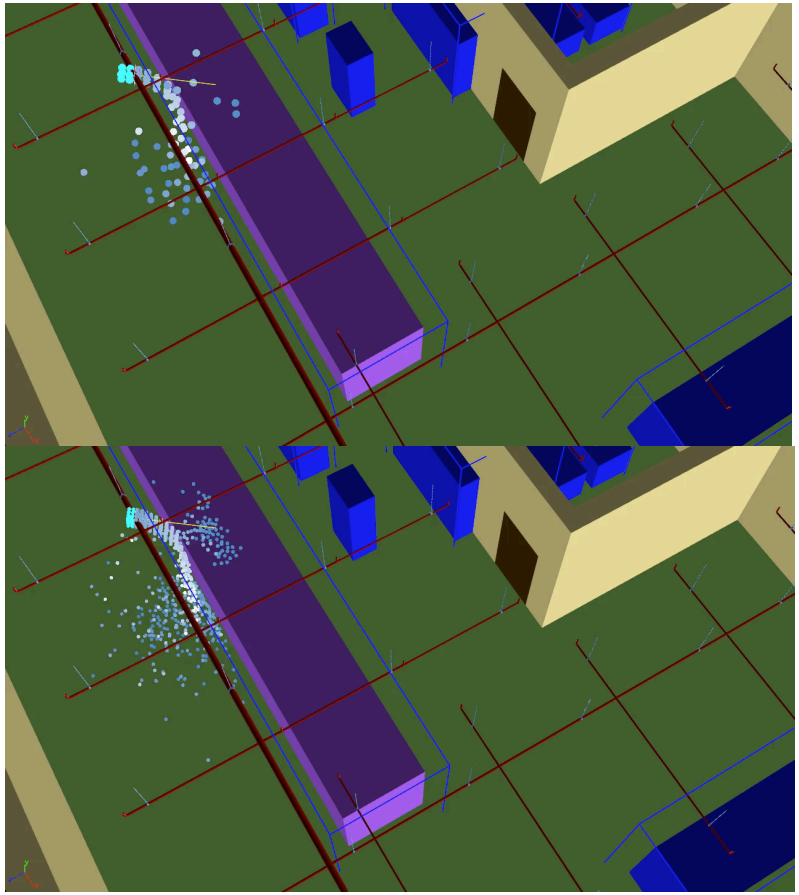


Neutrino-SPH: Pipe Break+Spray





Neutrino-SPH: Pipe Break+Spray



Neutrino-SPH: Pipe Break+Spray

- Library of spray patterns for rupture types.
- Modeler or simulation input for pressure.
- Reduce simulation runtime and error factor.

"Probability of Pipe Fracture in the Primary Coolant Loop of a PWR Plant"
NUREC CR-2189 TI85 016245

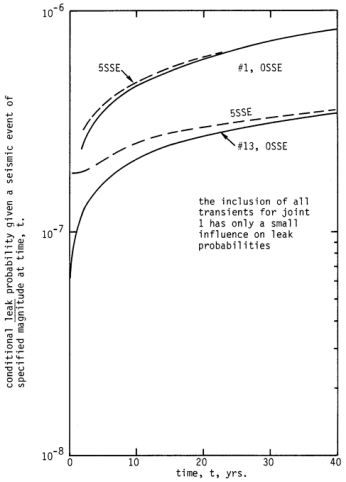
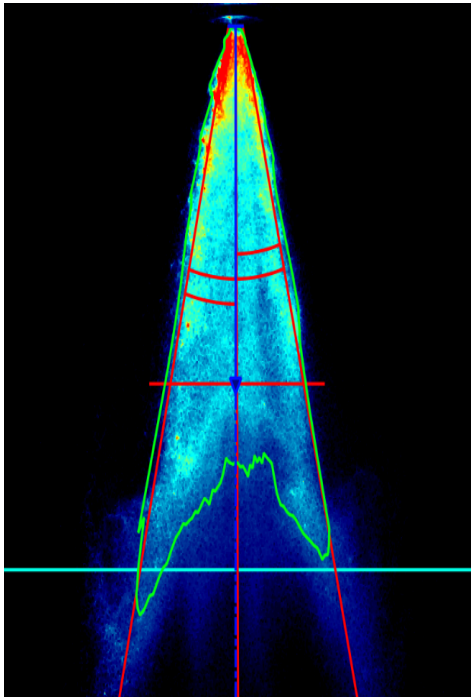
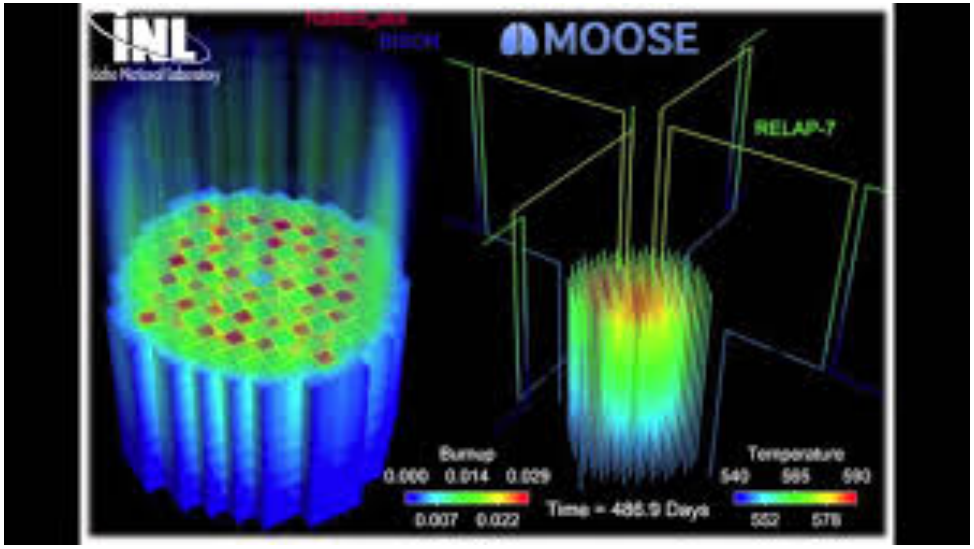


Figure 4-5. Conditional Leak Probabilities as a Function of Time for Two Representative Weld Locations Showing Influence of Seismic Events.



Neutrino-SPH+Moose

- Implement Neutrino Solve Library as a third party Moose application.
- Add API for control through Moose simulations.
- Data exchange of key events action in SPH Simulation
- Available for all Moose users.



Thank you

- Dr Curtis Smith (INL)
- Steve Prescott
- John Weglian (EPRI)
- Steven Hess, Stuart Lewis
- Dr Nam Dinh (NSCU)
- Niels Monanari (Centroid LAB)
- Nadir Akinci (Centroid LAB)