DOE NPH Meeting

Fluid-Soil-Structure Interaction Analysis of Tank for Seismic Evaluation of Nozzle Subjected to Differential Movement

October 23, 2018

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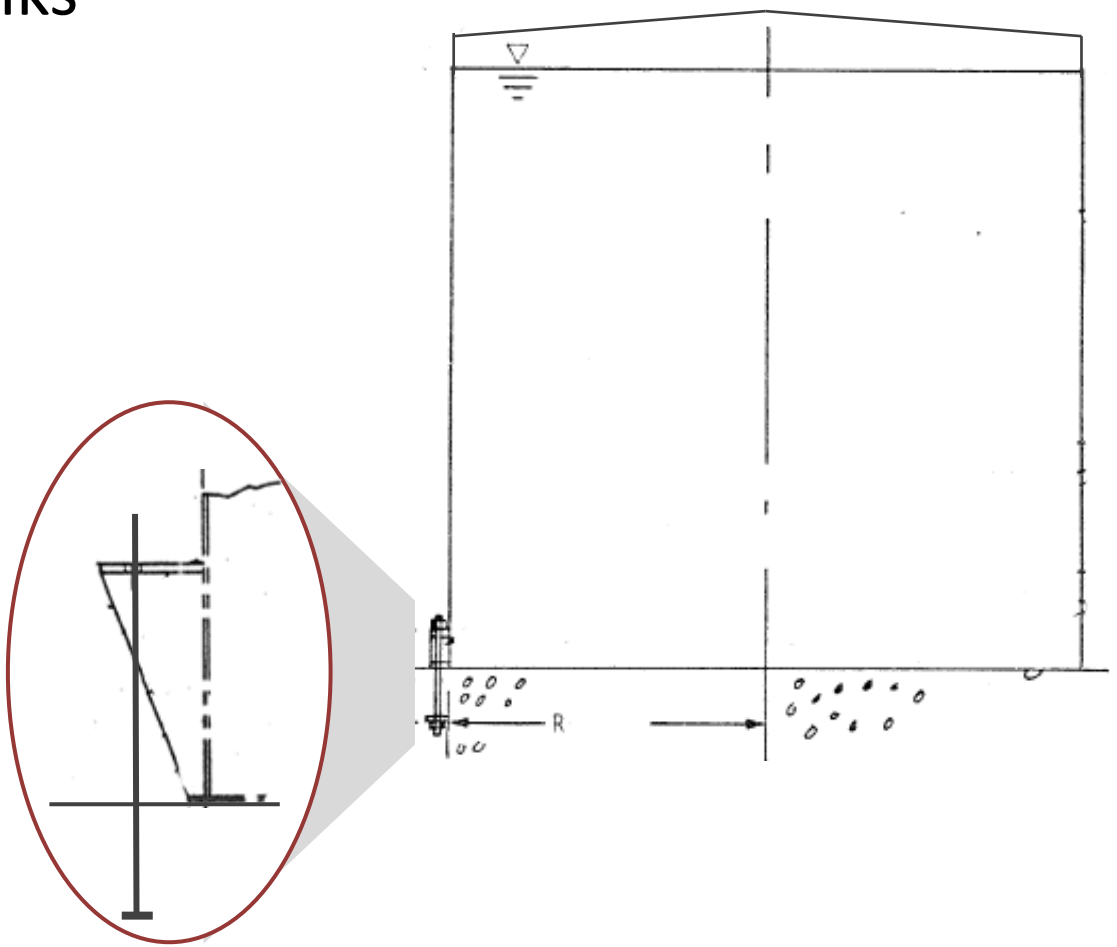
Value Through Innovation.

LA-UR-18-29880

Problem Statement

- Seismically qualified critical storage tanks
- Nonlinear anchor response
- Founded on soft soil with stiffness reversals



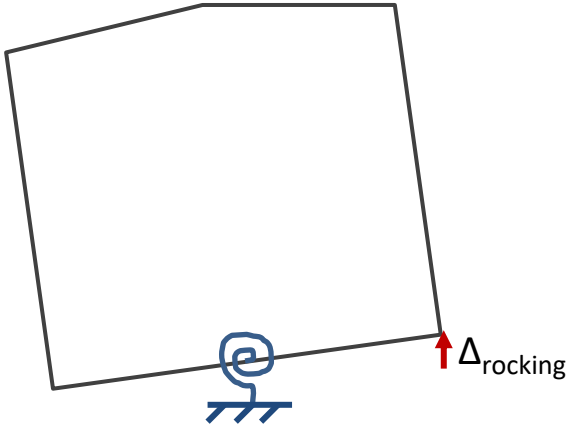
Problem Statement

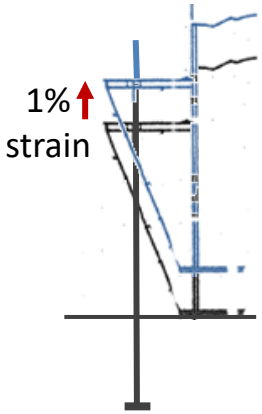
DNFSB concern:

- Over-restrained pipe-tank connection
- SAM-induced stress at connection

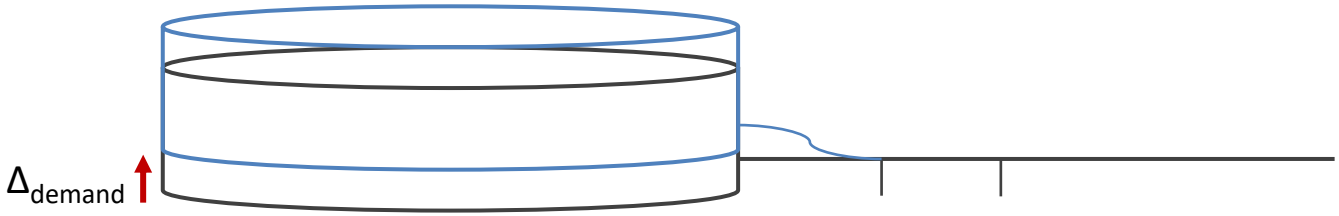
Previous Analysis

Max soil displacement + allowable anchor elongation





$\Delta_{demand} = \Delta_{rocking} + \varepsilon_{allow} \cdot l_{bolt}$ induced on tank end of system



Concluded nozzle significantly overloaded

Project Scope

Assess functionality (pressure retention) of tank and draw-off piping connection during and after DBE

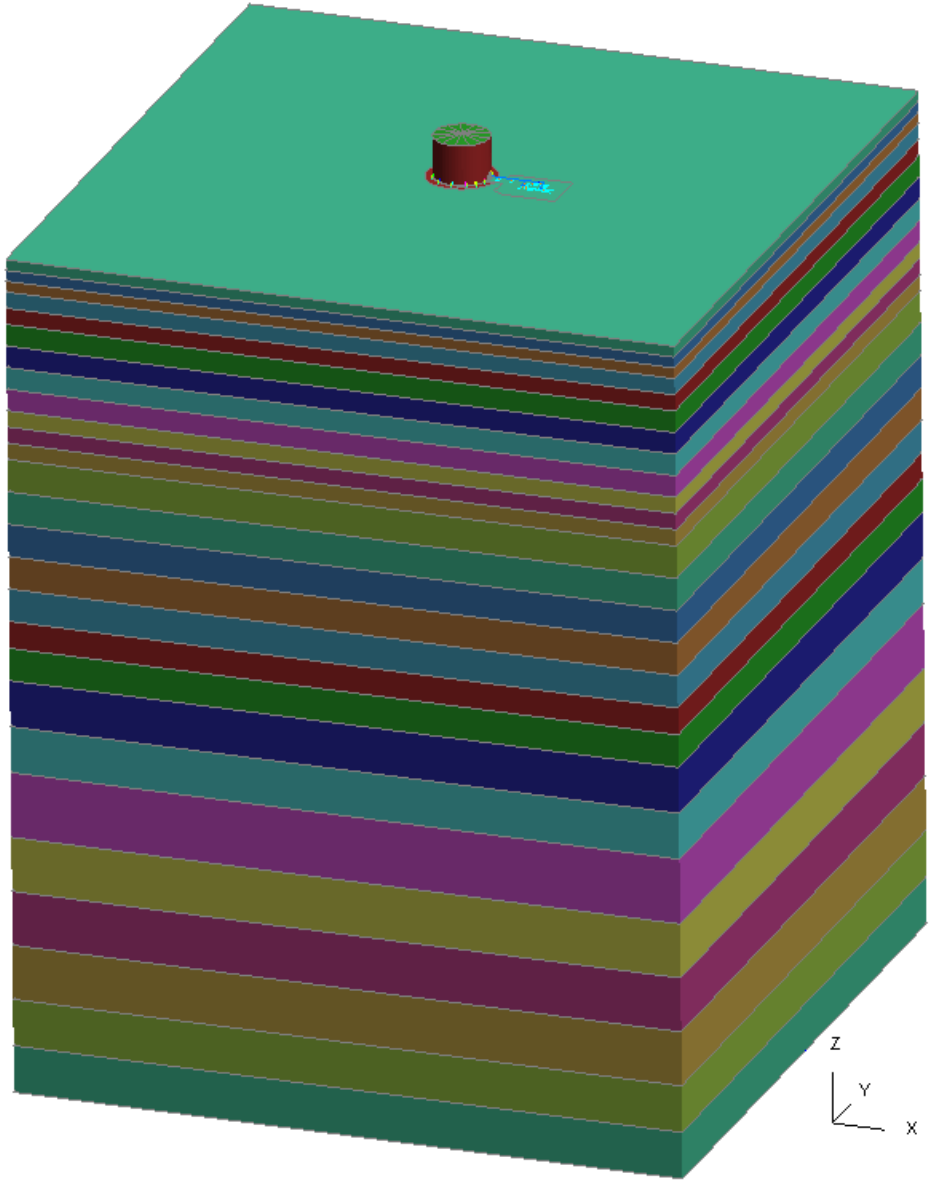
Phase 1: Determine if detailed analysis can address concern

Phase 2: Perform final analysis and documentation to full code and QA requirements for support of safety basis

Acceptance Criteria

- No failure of tank shell at piping connection
  - API 650 moment capacity
  - AWWA allowable stress
- No failure of draw-off piping at connection
  - ASME B31E
- No local tank failure caused by anchor behavior
  - SQUG GIP 3A
  - Elongation limit ~1%

Global System Model



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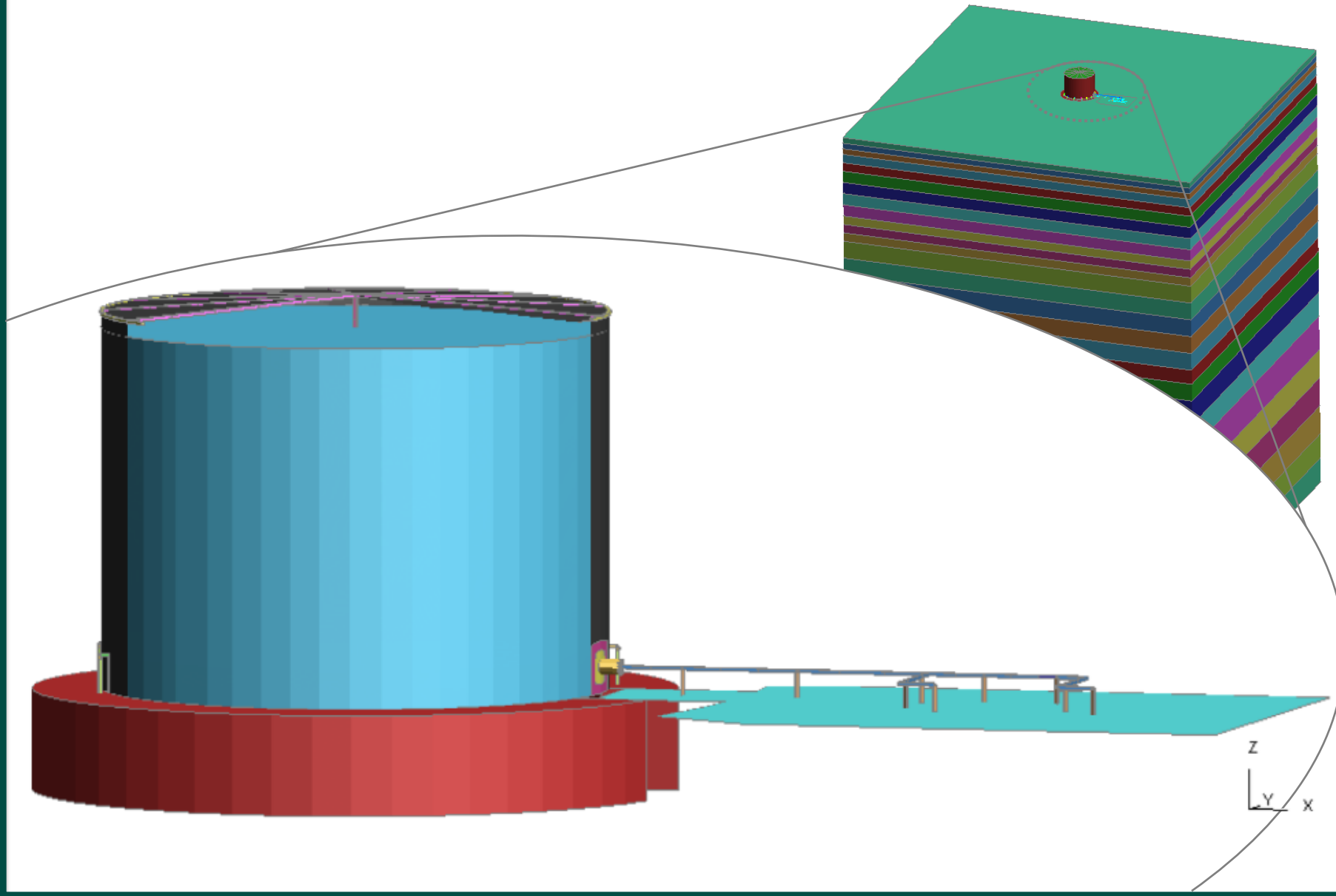
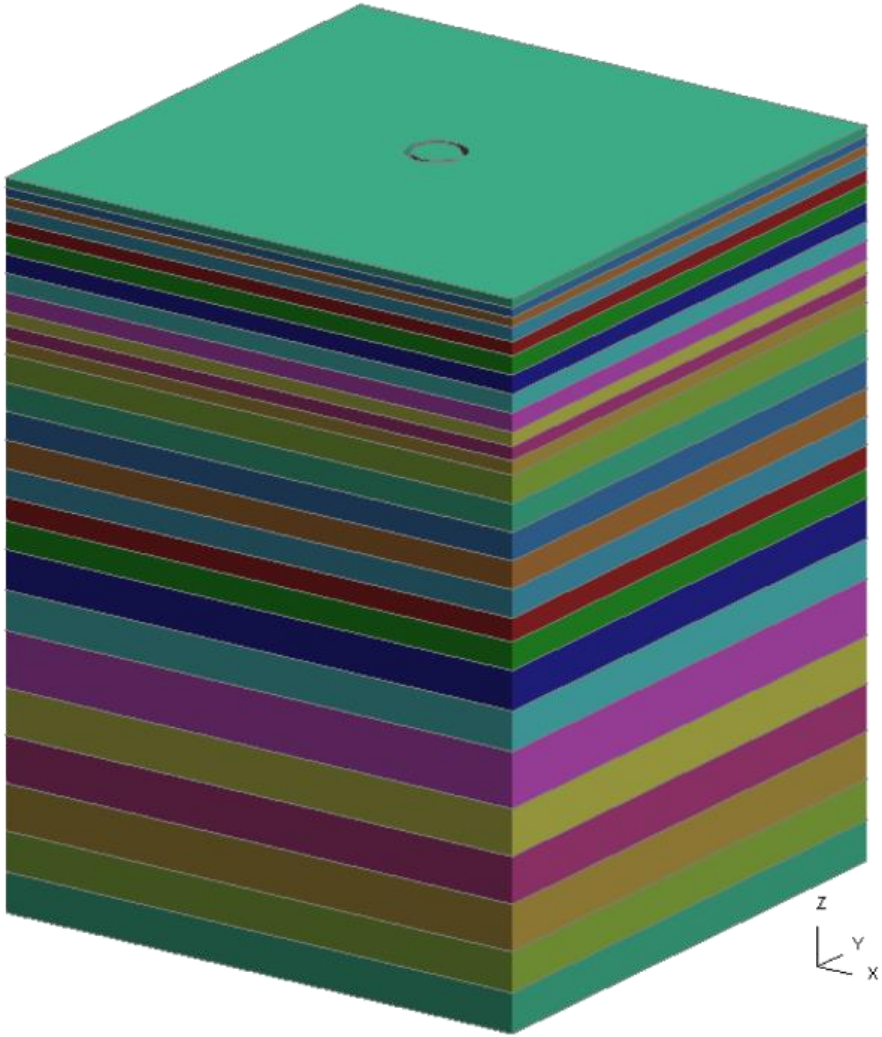
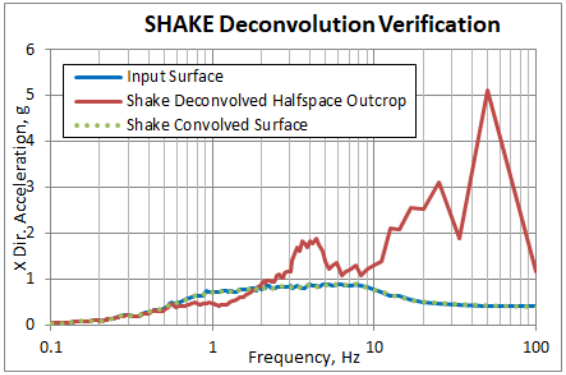


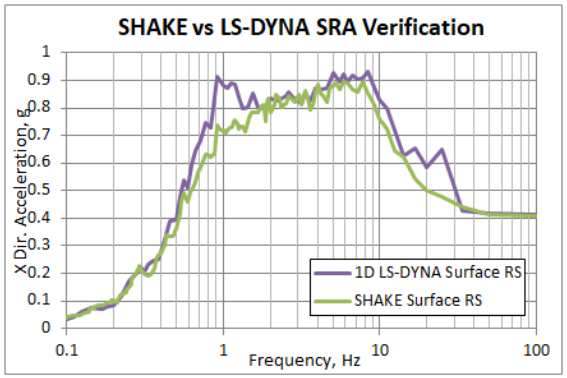
Soil Model

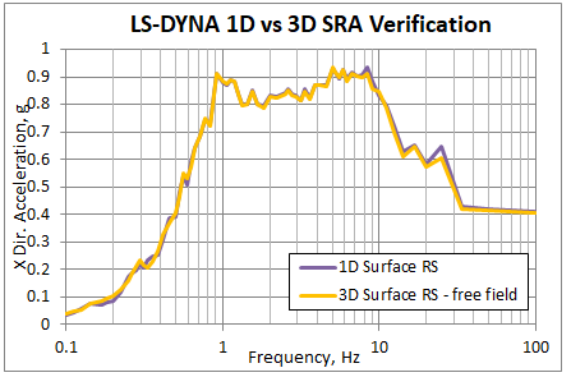


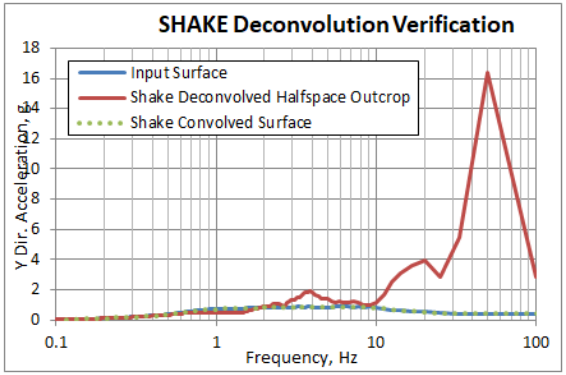
- Equivalent linear properties
- Visco-elastic material model
- 400x400x500 ft. soil domain
- Single soil profile
- Single time history
- Lysmer damper

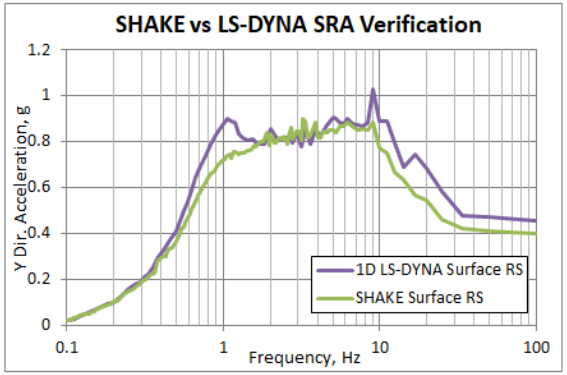
Soil Verification

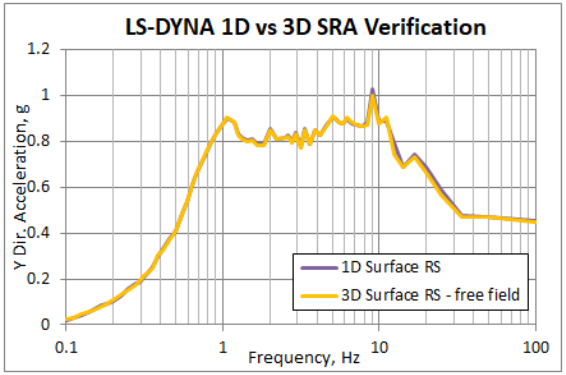


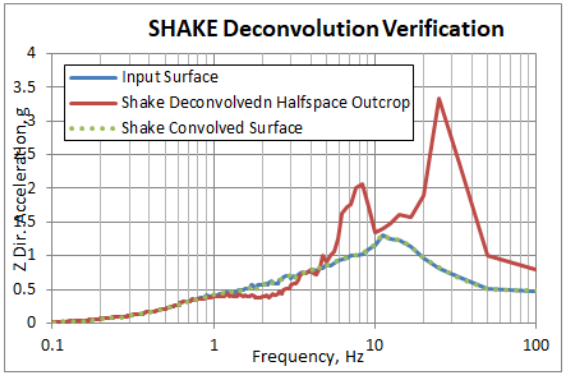


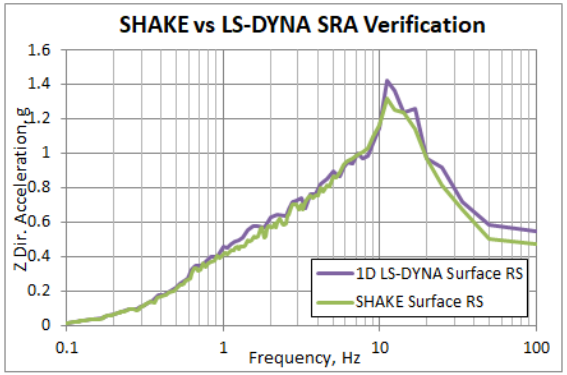


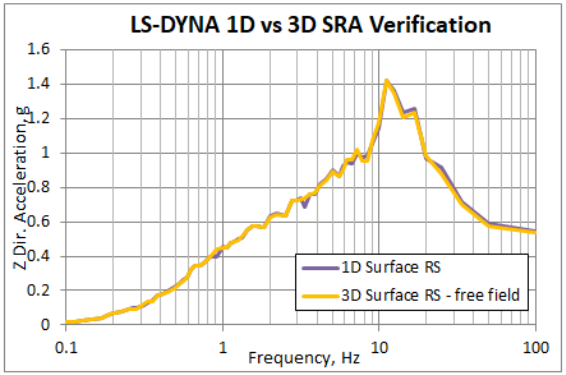






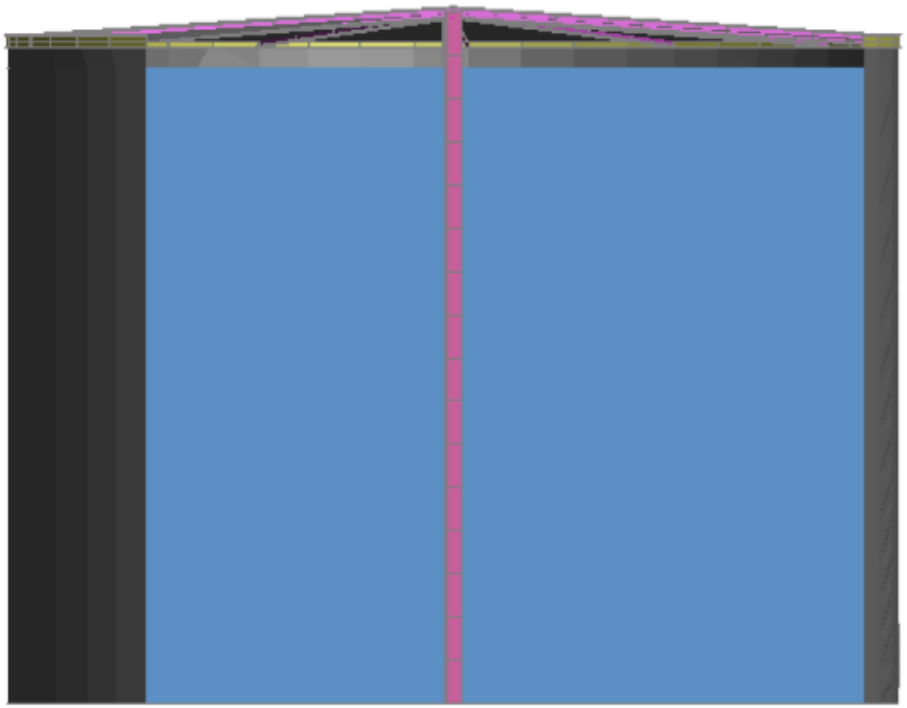




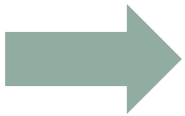


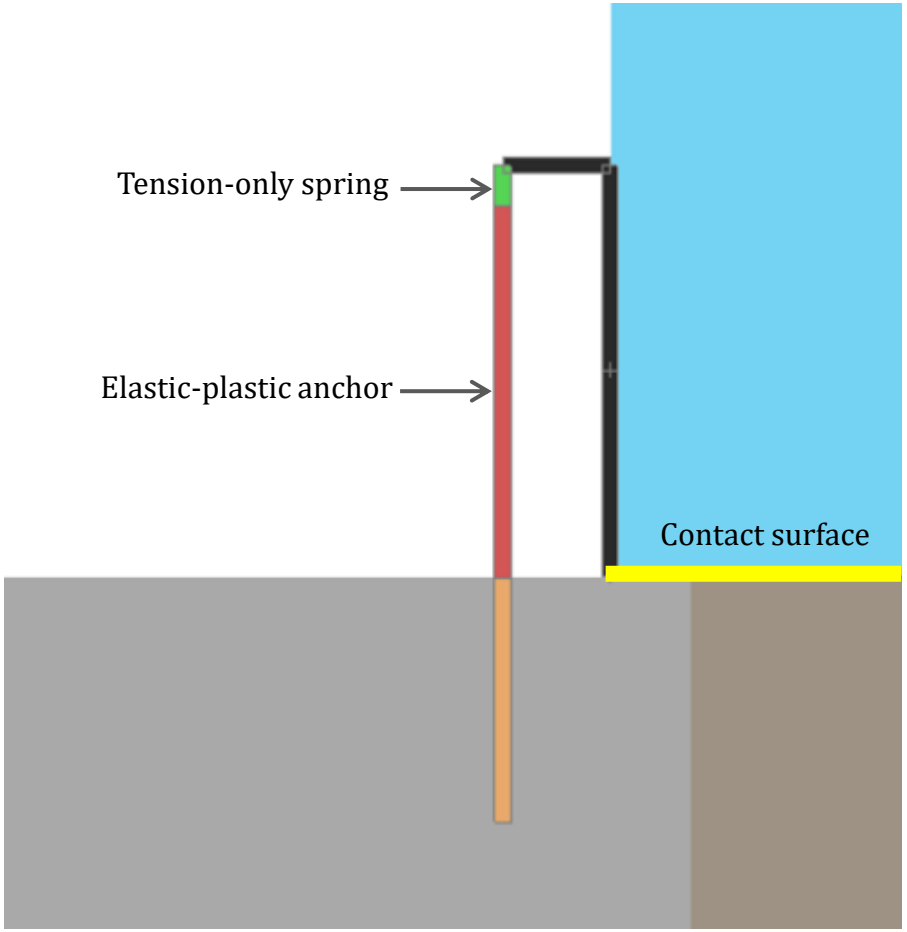
Fluid-Structure Model

- Tank shell elements (w/ beam elements)
- Fluid continuum elements
- Lagrangian fluid model
- Fluid constrained w/in tank:
  - Horizontally along wall
  - Vertically across base

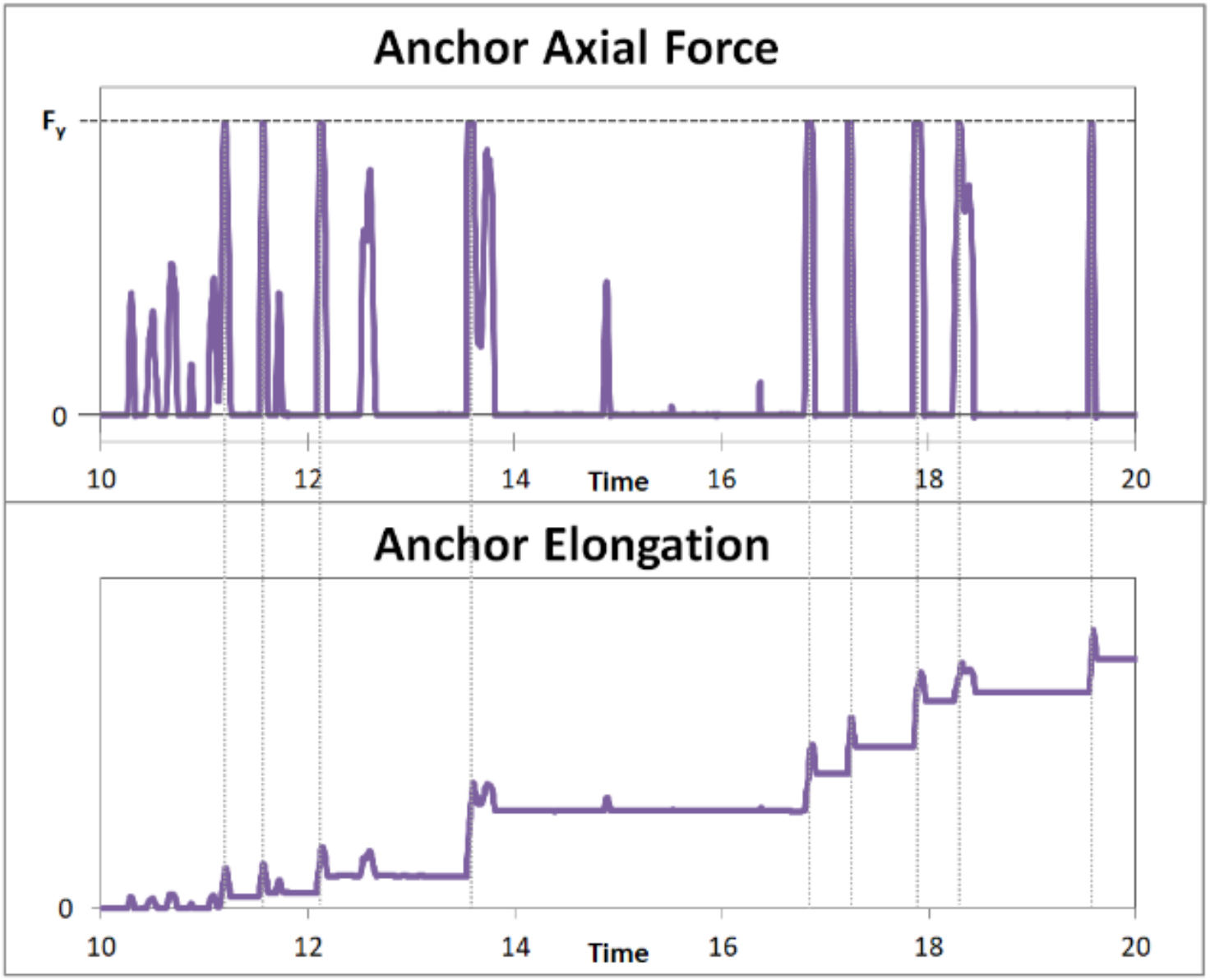


Nonlinear Anchor Model





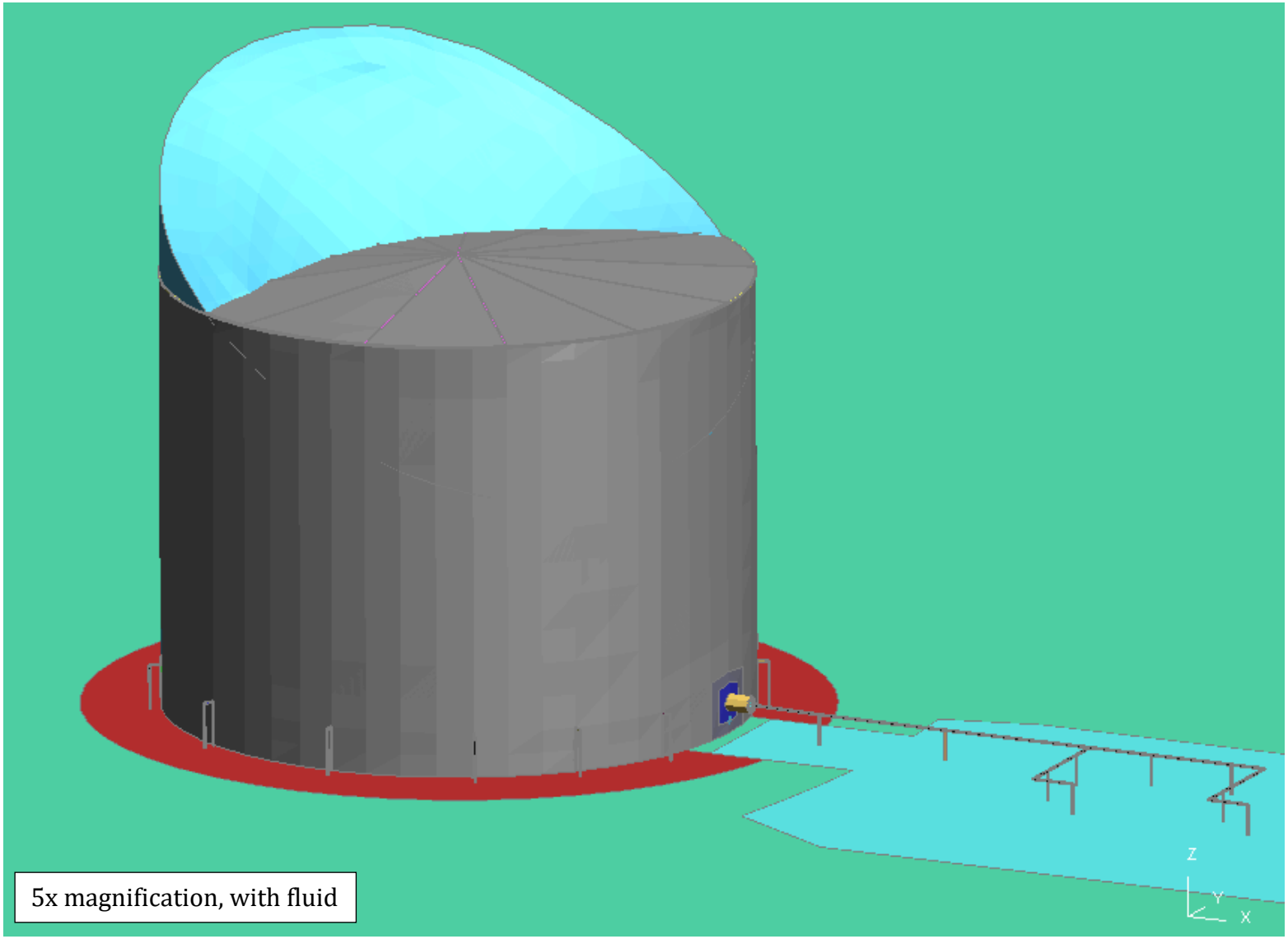
Nonlinear Anchor Response



Model Verification

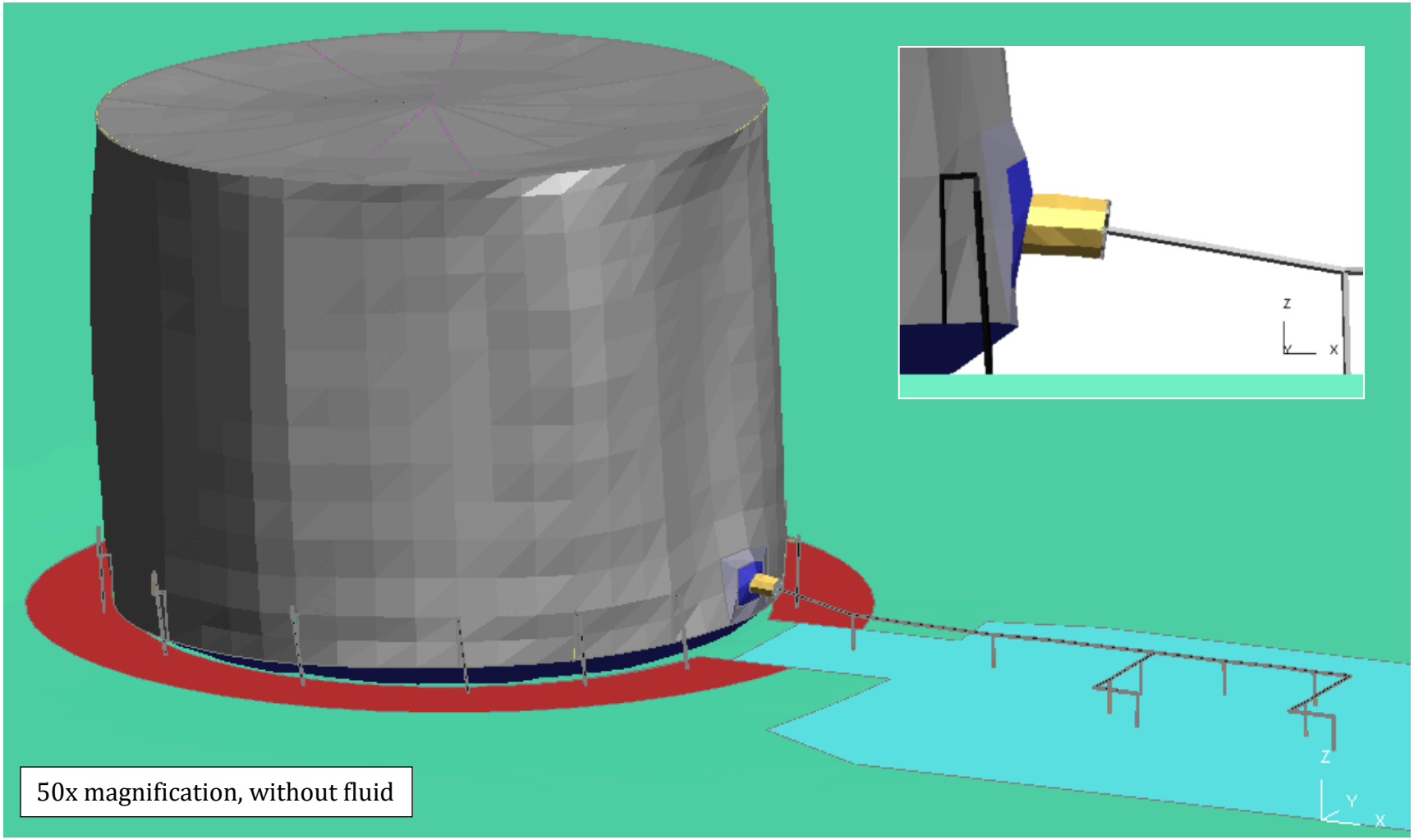
- Site response analysis deconvolution
- Finite element soil model site response
- Fluid model static and modal response
- Nonlinear anchor behavior
- Nozzle response due to uplift
- System behavior in sensitivity studies

Response at Maximum Nozzle Stress



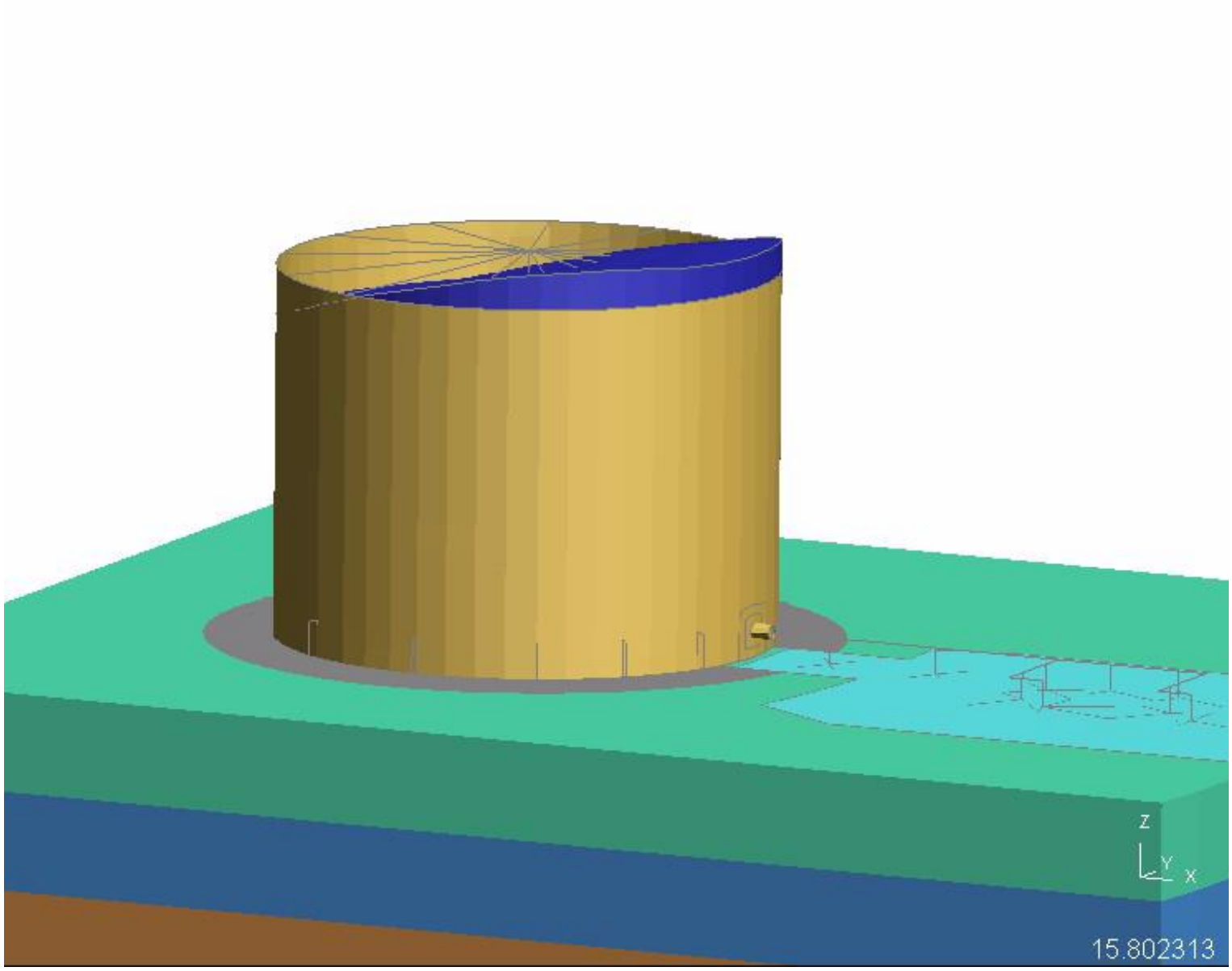
5x magnification, with fluid

Response at Maximum Nozzle Stress



50x magnification, without fluid

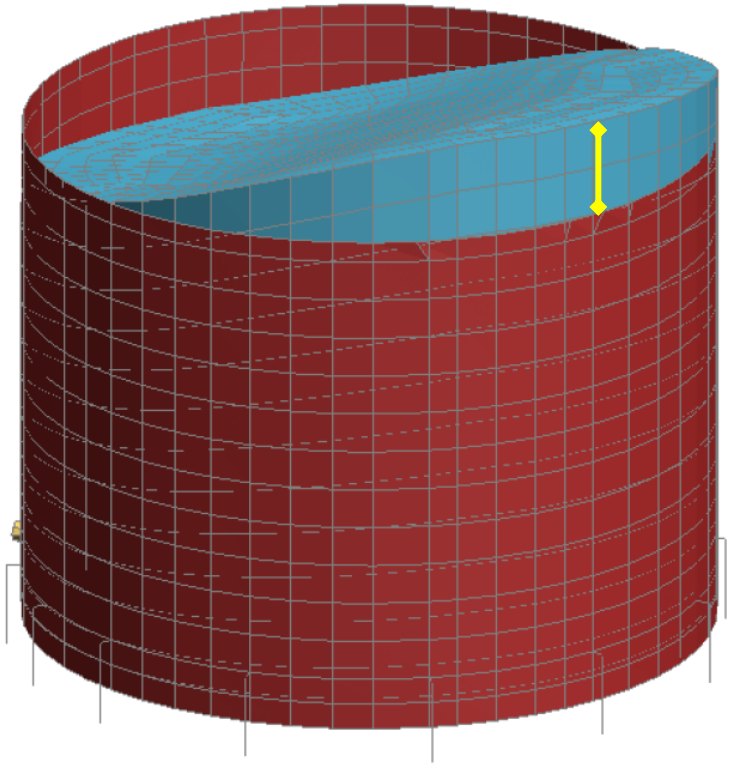
System Response



Tank Dynamic Response

Nozzle demands driven by:

- **Fluid convection**
- Fluid stress (impulse)
- Tank rocking and uplift
- Local tank – nozzle deformation



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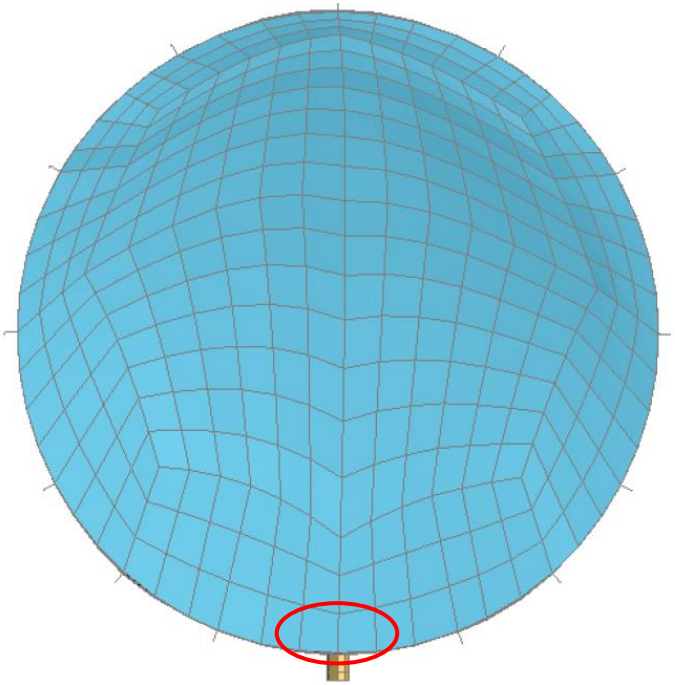

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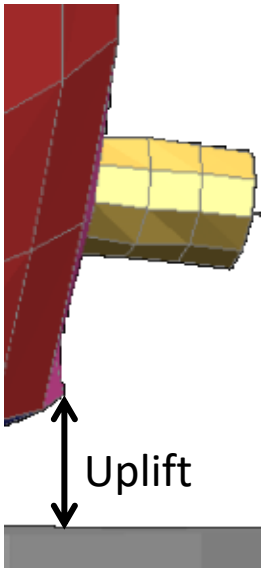

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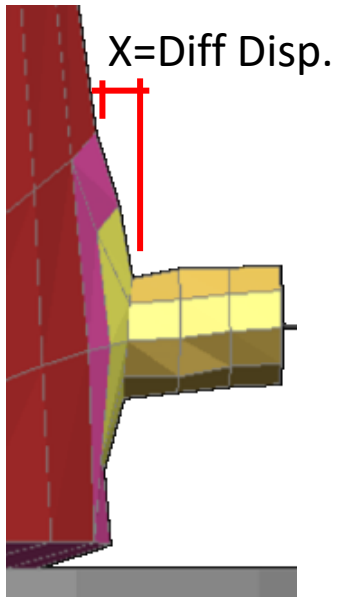
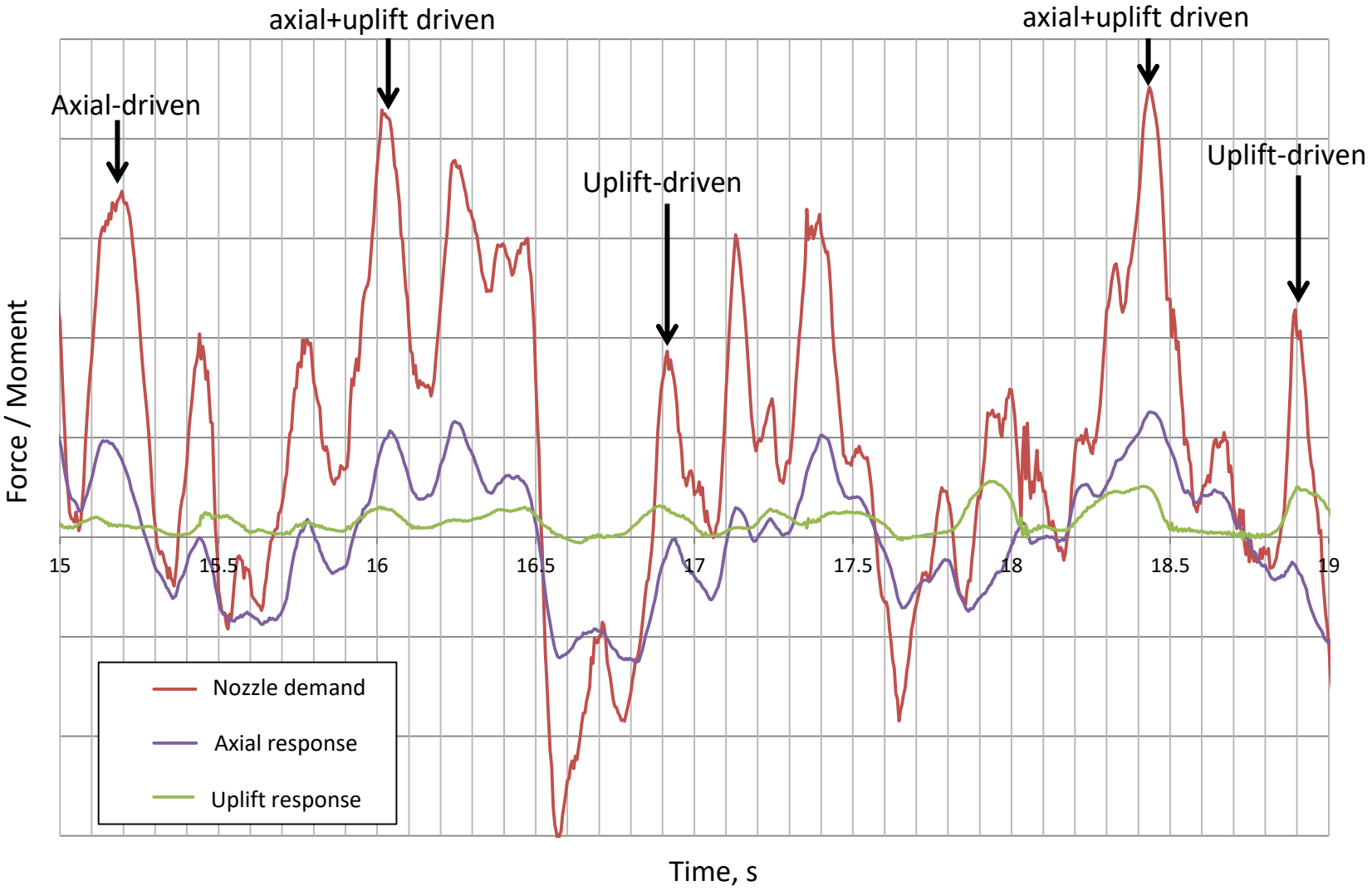


Tank Dynamic Response

Forces at Tank Wall



Tank Dynamic Response

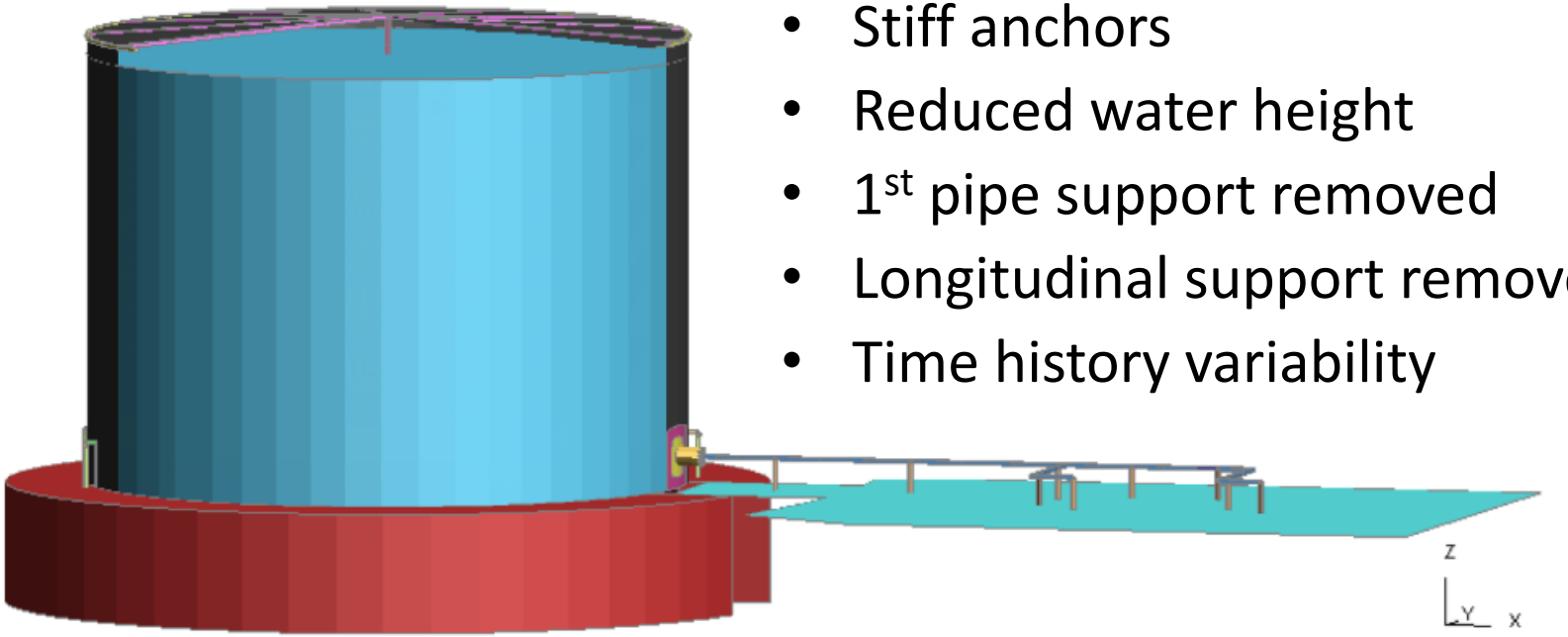
1. Tank rocking and uplift contribution weaker than anticipated

2. Local tank longitudinal differential displacement observed

3. Overall maximum stress due to combined behavior

Sensitivity Studies

Purpose: Confirm behavior, inform Phase 2



Varied Parameters:

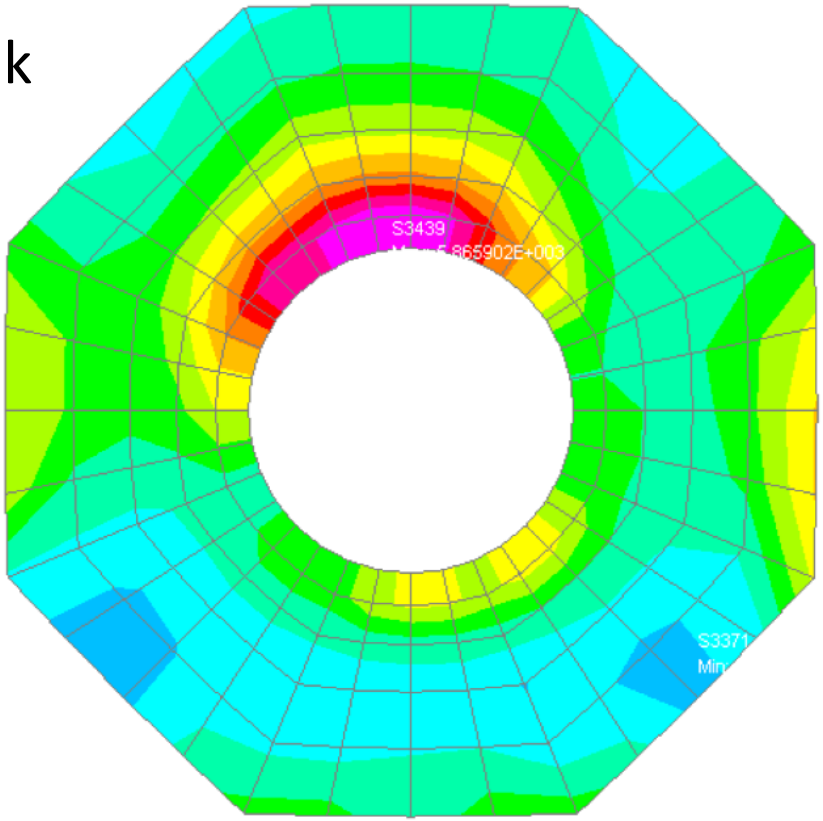
- Stiff anchors
- Reduced water height
- 1st pipe support removed
- Longitudinal support removed
- Time history variability

Benefits of Detailed Analysis

- Nozzle moments roughly 1/3
- Reduced tank displacement due to SSI rocking effect
- Combined FSI-SSI-nonlinear anchor response explicitly captured
- Local tank deformation a result of combined system response vs. imposed boundary conditions

Project Conclusion

- Functionality controlled by tank shell stress
- Anchor strain close to recommended limit
- Tank experienced minor overstress
  - ~10% above yield stress, half of tensile stress



Detailed analysis likely to address concern given acceptability of minor overstress

Questions?