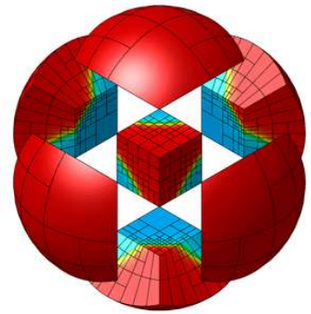


USING MFEM FOR WELLBORE STABILITY ANALYSIS

OpenSim Technology, LLC

Adolfo Rodriguez, Jorge Monteagudo and

Nathalie Nieto

Office of Advanced Scientific Computing Research

SBIR Phase I

Award #: DE-SC0022500

Development of a Cloud-based Web-App for Wellbore Stability Analysis

Our Company

OpenSim Technology, LLC is a Houston based company founded in 2016 with the objective of developing advanced multi-physics reservoir simulation software.

Our team combines more than 40 years of experience in scientific software applied to the Oil & Gas Industry.

We are specifically targeting coupled flow-geomechanics applications.

Team

Adolfo Rodriguez, Co-Founder

PhD Physics

20 years experience in Geomechanics

Past work: ConocoPhillips, UT-Austin, PDVSA

Jorge Monteagudo, Co-Founder

MSc, PhD Chem. Eng.

20 years experience in Reservoir Simulation

Past work: ConocoPhillips, Reservoir Engineering Research Institute, PetroPeru

Nathalie Nieto, IT Support

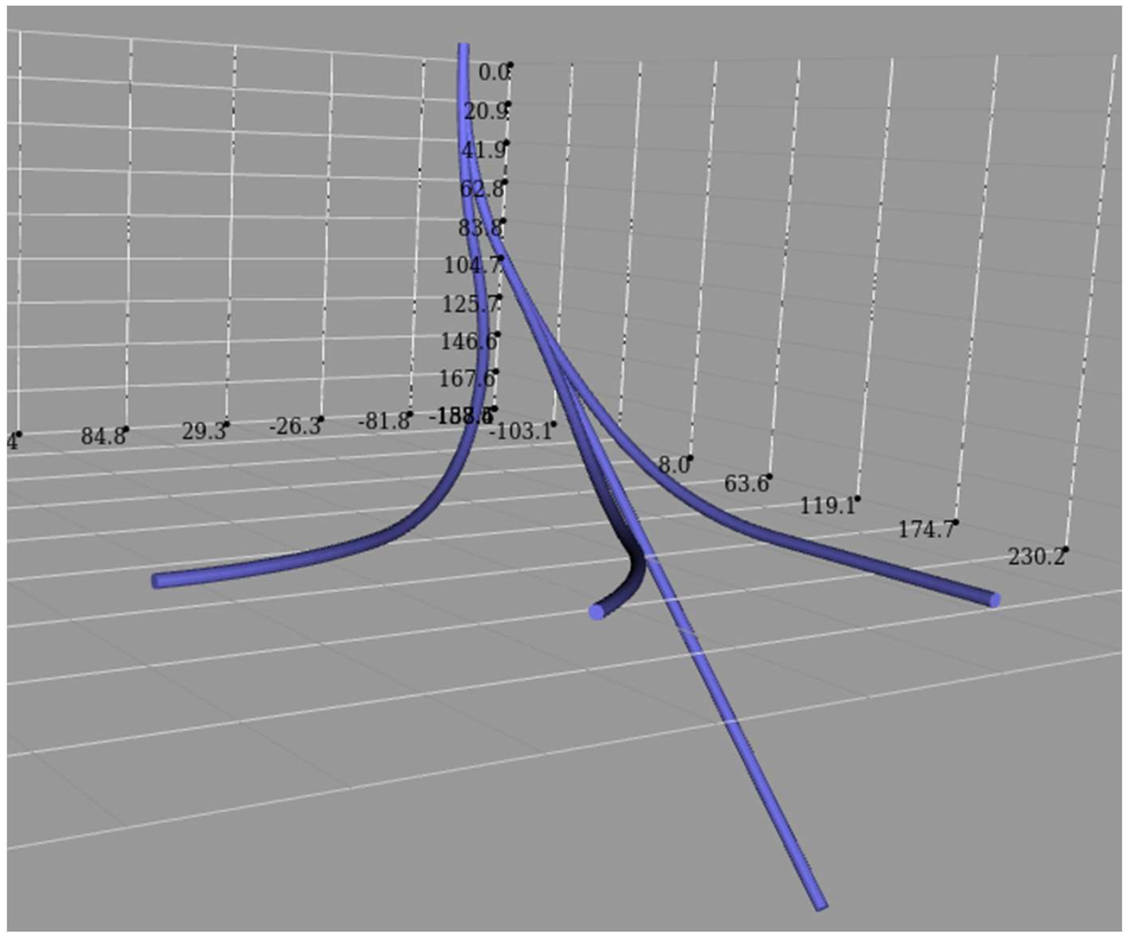
BSc Computer Science

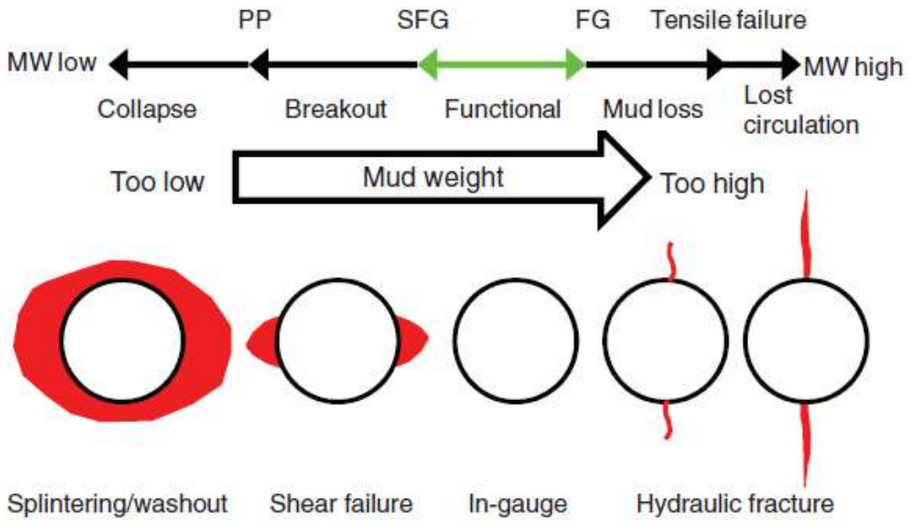
8 years experience as Java consultant

Past work: TCS Consulting Solutions, Mobile-Globe (France)

OPENSIM TECHNOLOGY

The Problem: Wellbore Stability





The Equations and BC

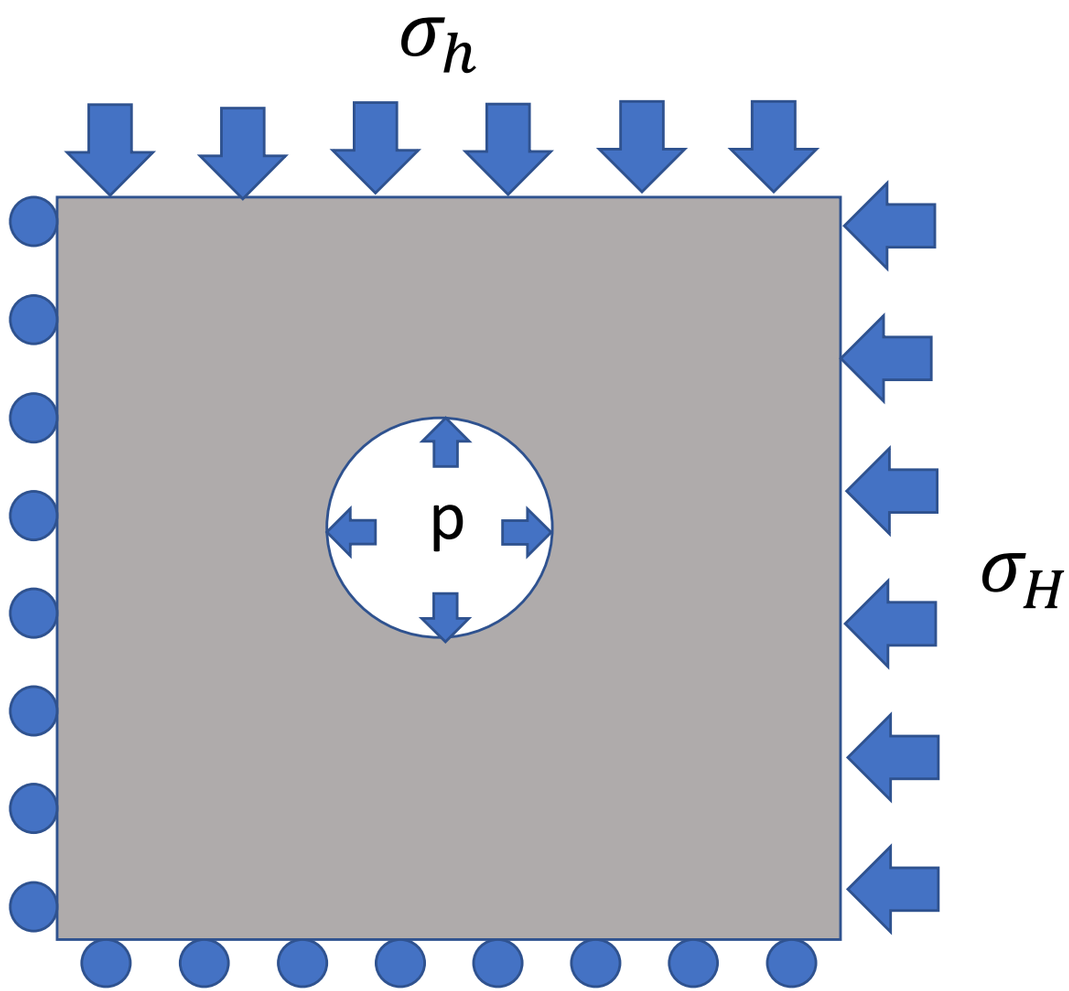
Mechanical equilibrium
Linear elasticity

$$\sigma_{ij,j} - f_i = 0$$

$$\sigma_{ij} = \lambda \delta_{ij} \varepsilon_{kk} + 2\mu \varepsilon_{ij}$$

$$\varepsilon_{ij} = \frac{1}{2}\left(u_{i,j} + u_{j,i}\right)$$

We used PYMFEM to implement the solution



Creating a Synthetic Well

Synthetic Well Trajectory

WellHead Coordinates

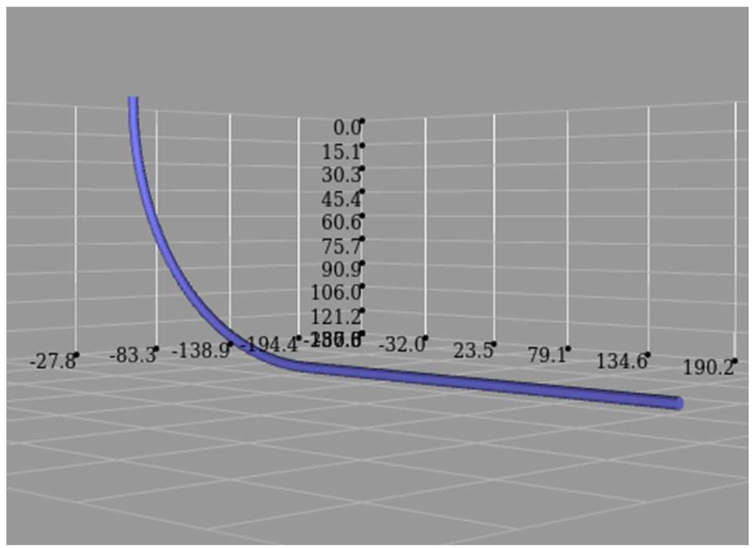
Xc:	Yc:	Zc:
100	100	0

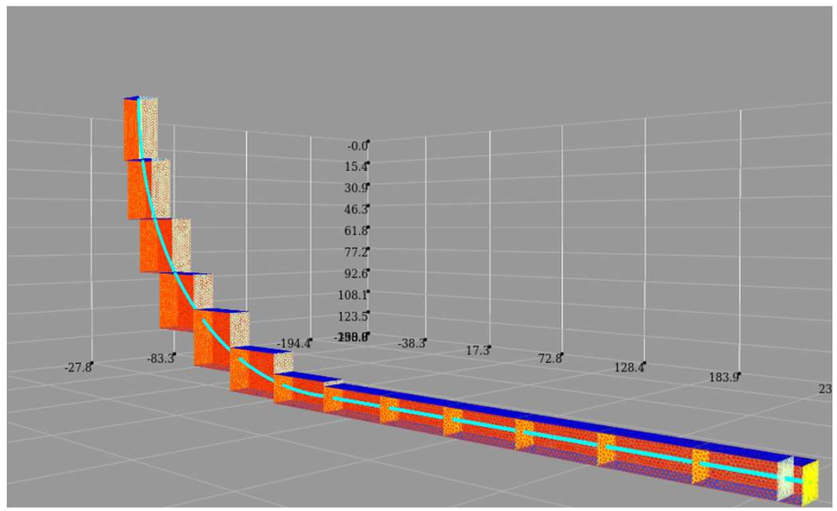
Well Drilling Design

Number of Drilling Stations:	Survey intervals (md):	Wellbore intervals (md):
5	5	30

Input per station:

index	md (m)	inc (deg)	azi (deg)	radius (m)
1	0	0	0	0.5
2	100	45	0	0.5
3	200	90	0	0.5
4	300	90	0	0.5
5	400	90	0	0.5





Meshing options

Matrix Representation: box / cylinder

Mesh type: tetra / hexa

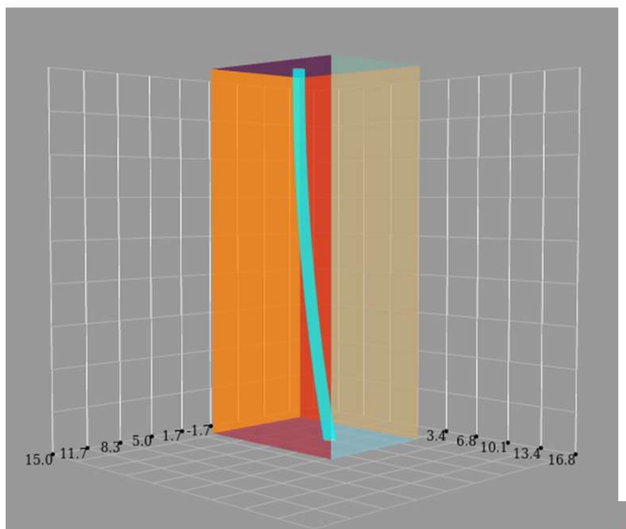
TopSide/Rwb: 20

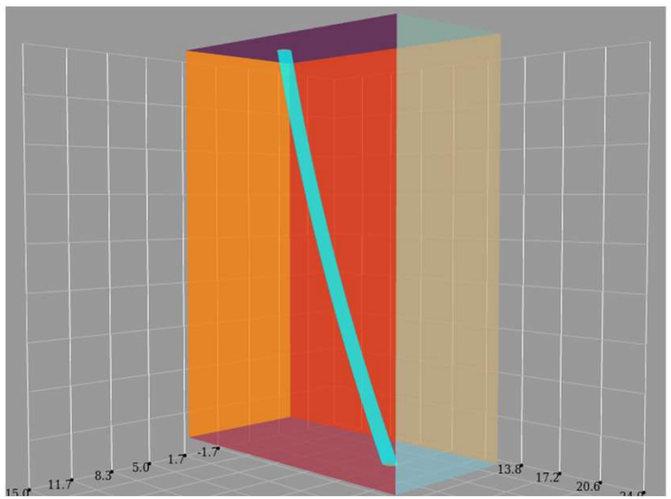
Discretization Input:

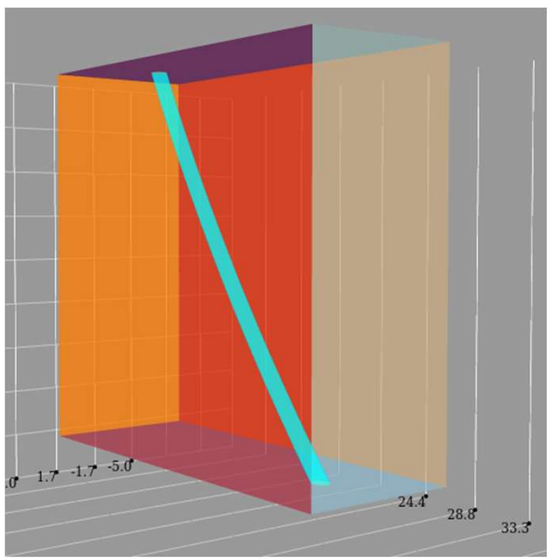
Tetrahedral discretization parameters:

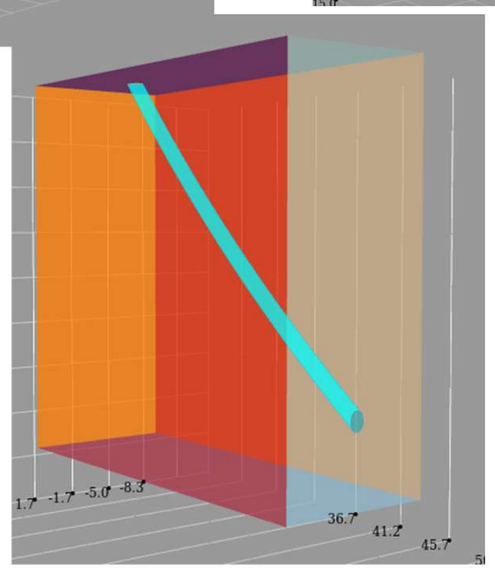
Borehole perimeter partition:	Tets max_size/min_size:	Min radius multiplier	Max radius multiplier
24	10	2	4

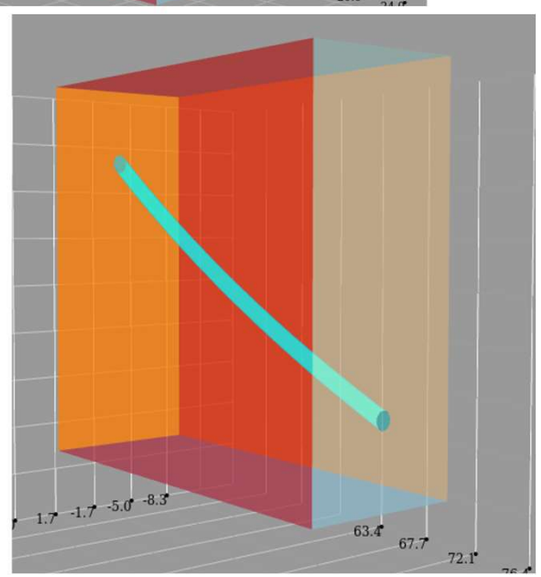
Wellbore Segments



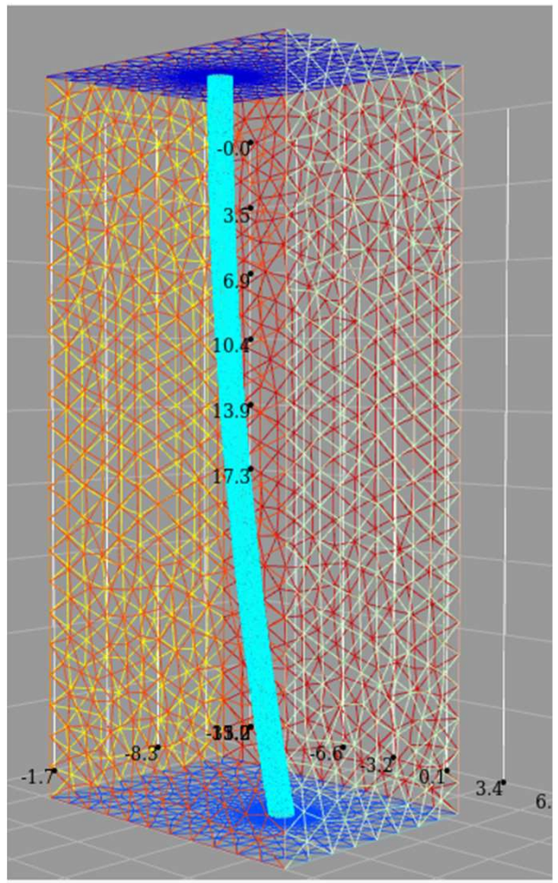


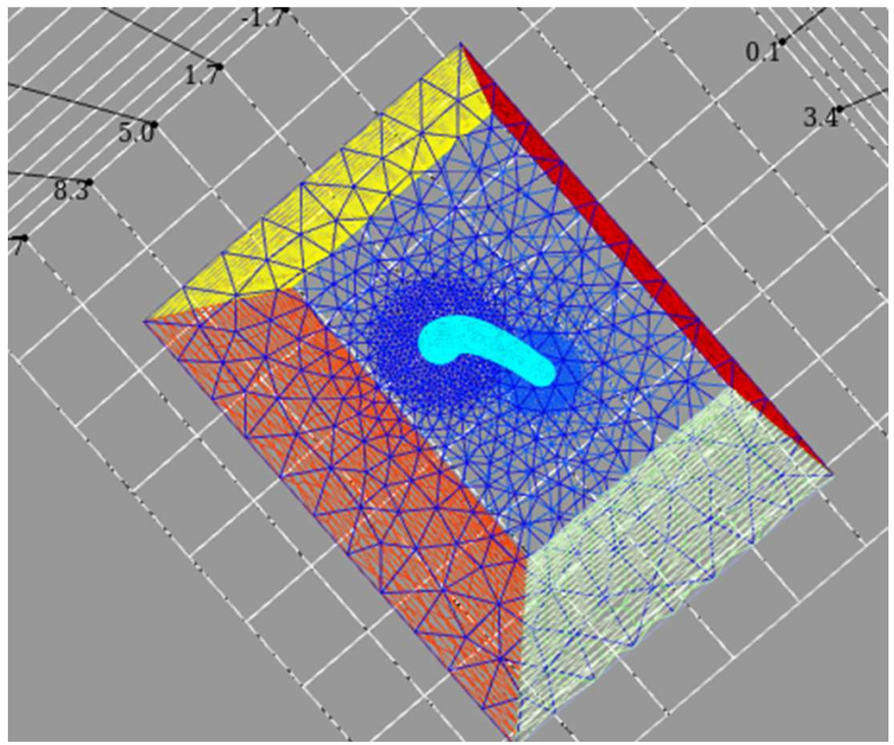




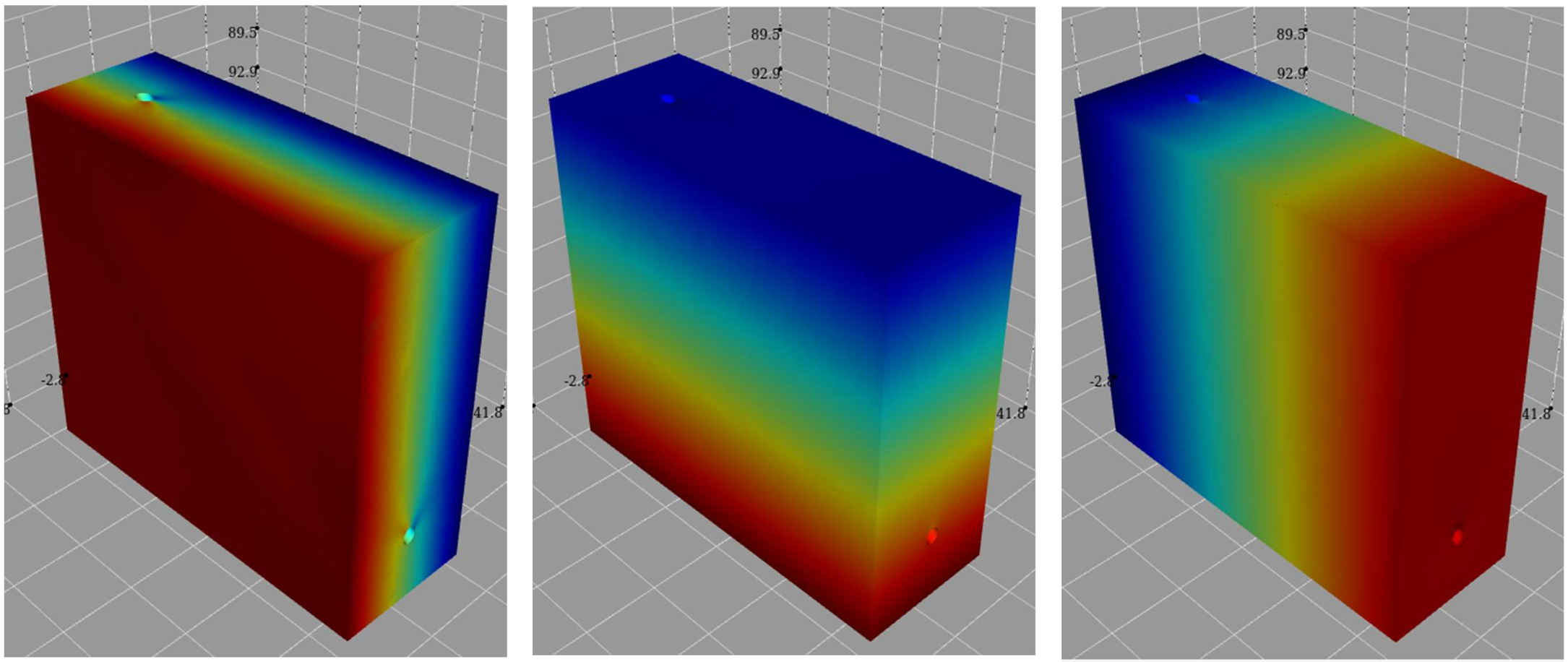


A Gridded Segment

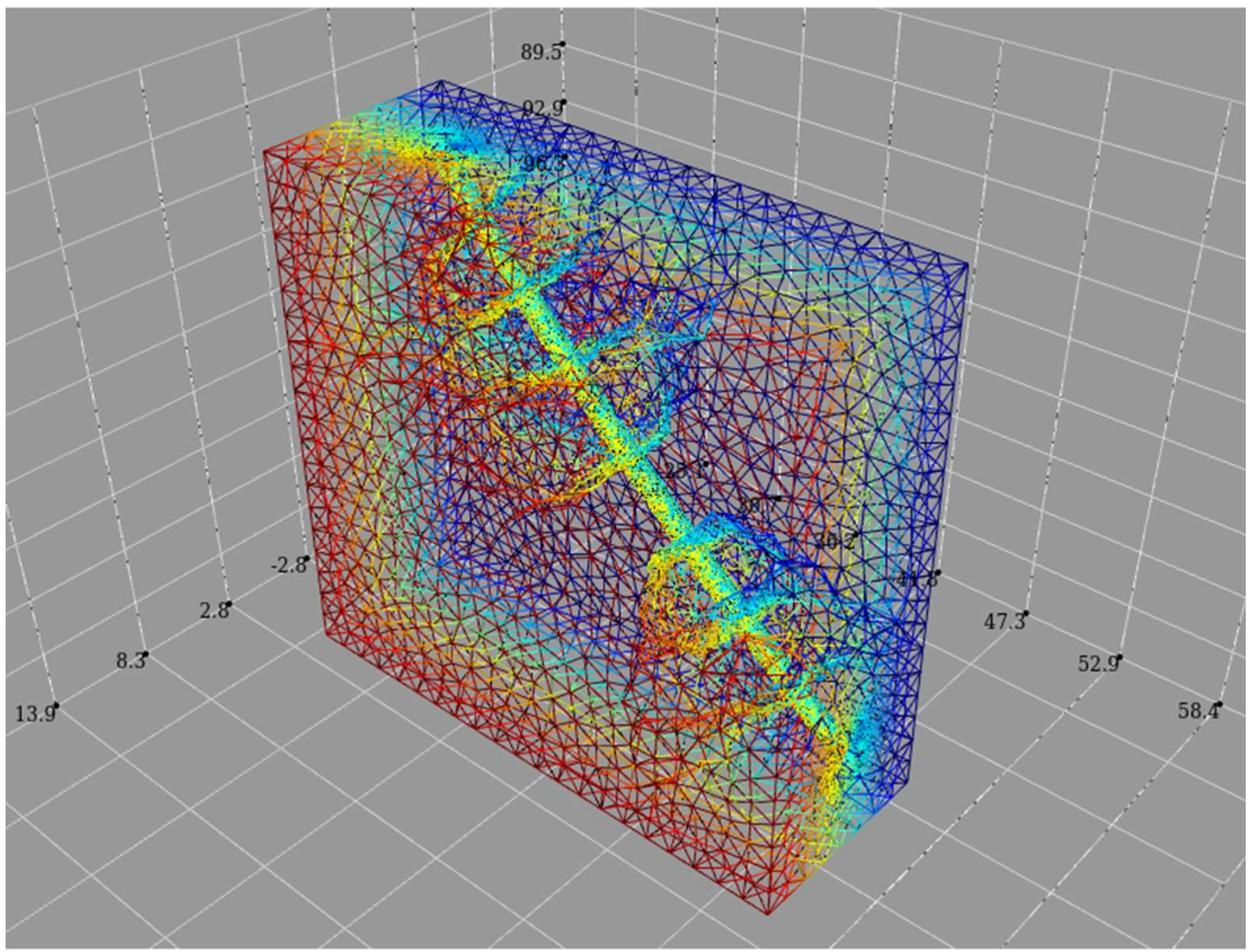


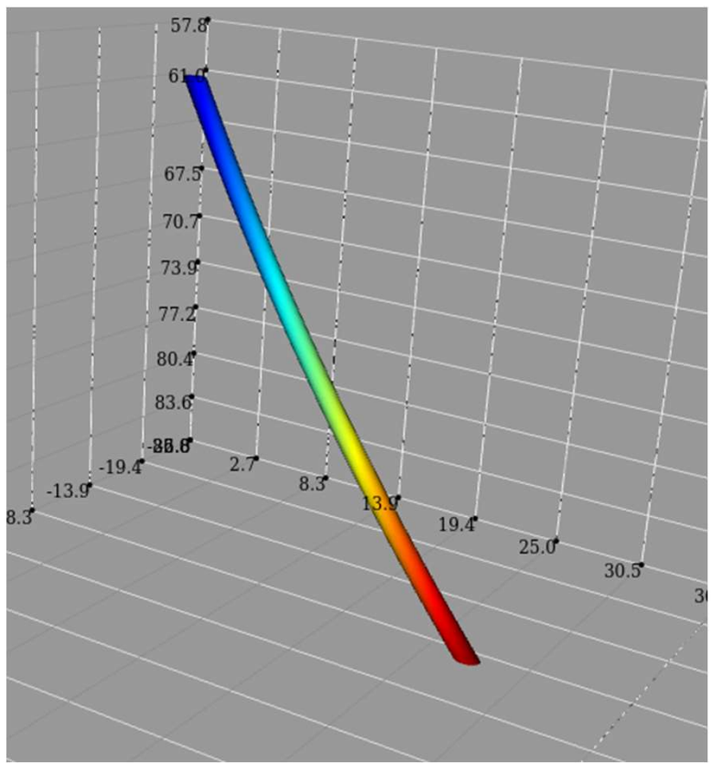


The solution: Displacements

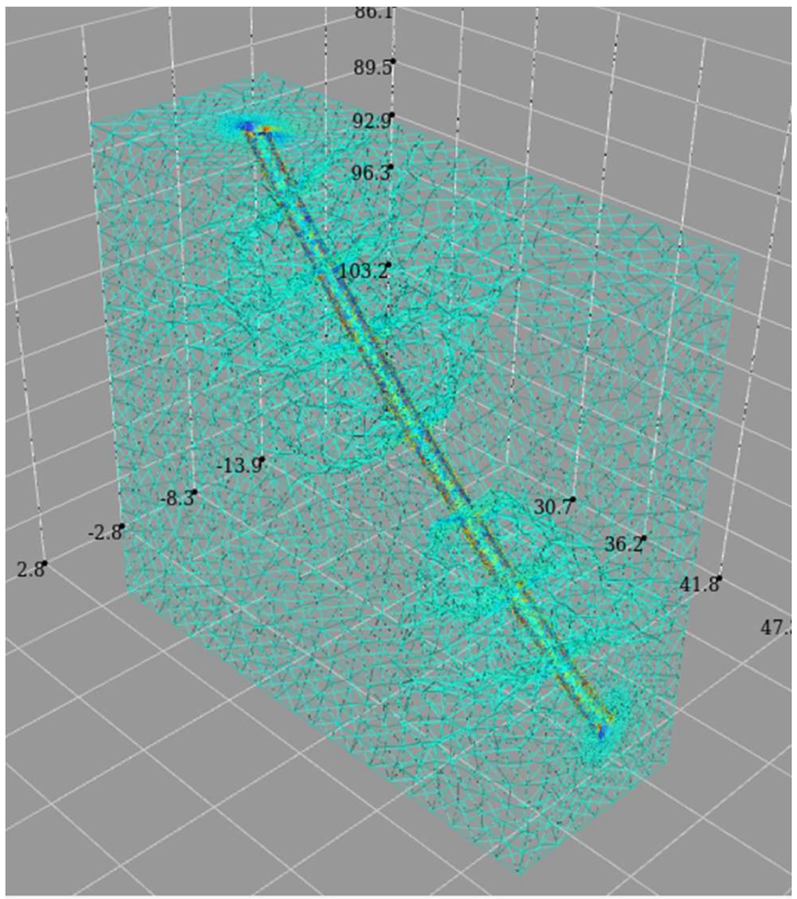


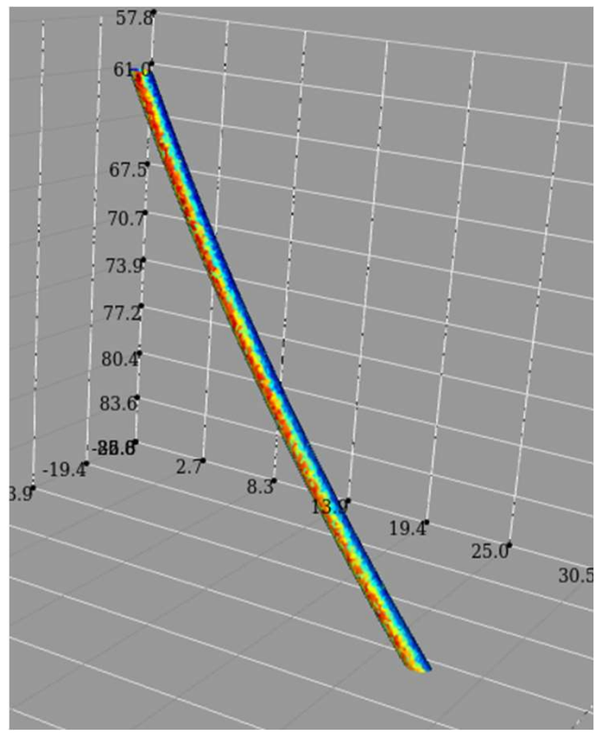
Displacement in the x-direction, wireframe





The Stress Field Calculation

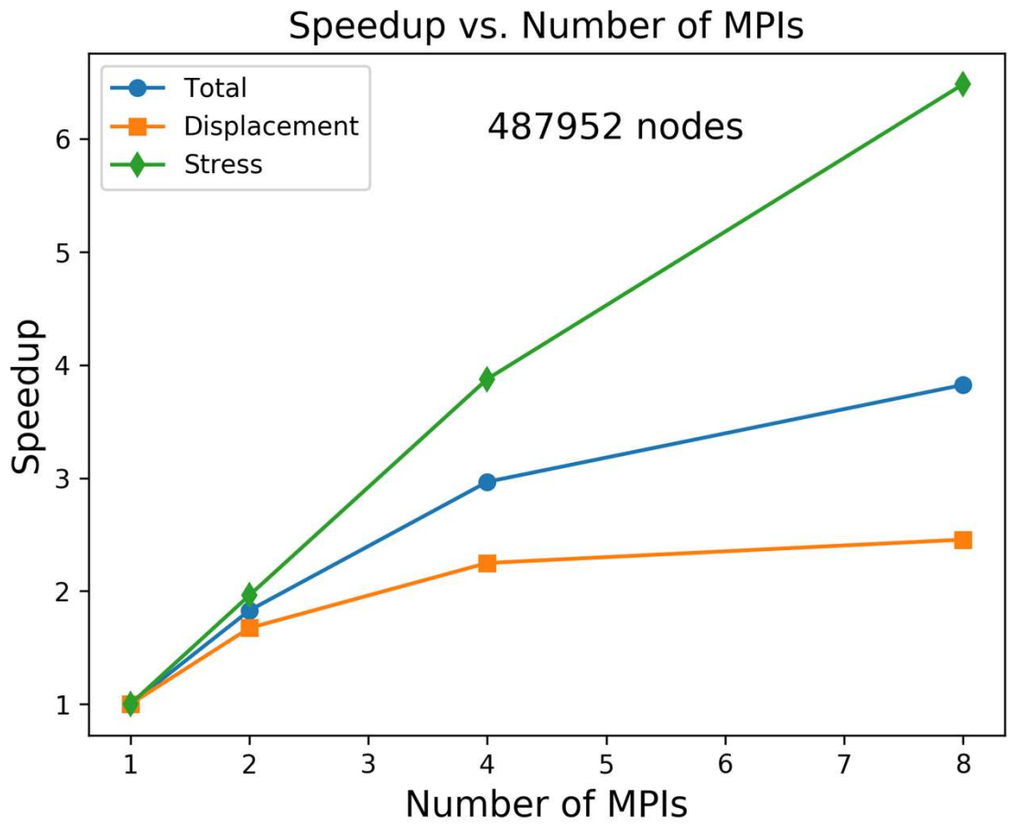




Performance and Scalability

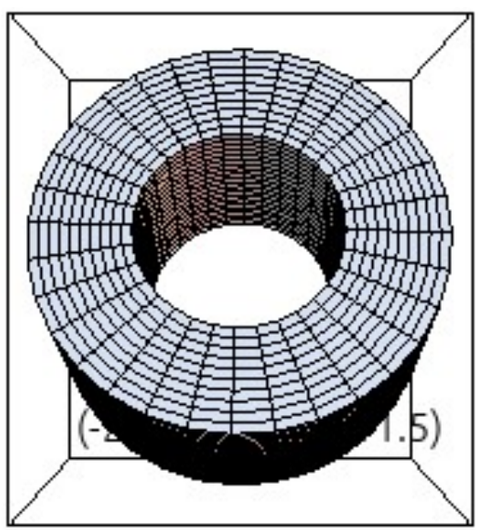
AMD Ryzen 9 4900H
8 Cores
32 GB

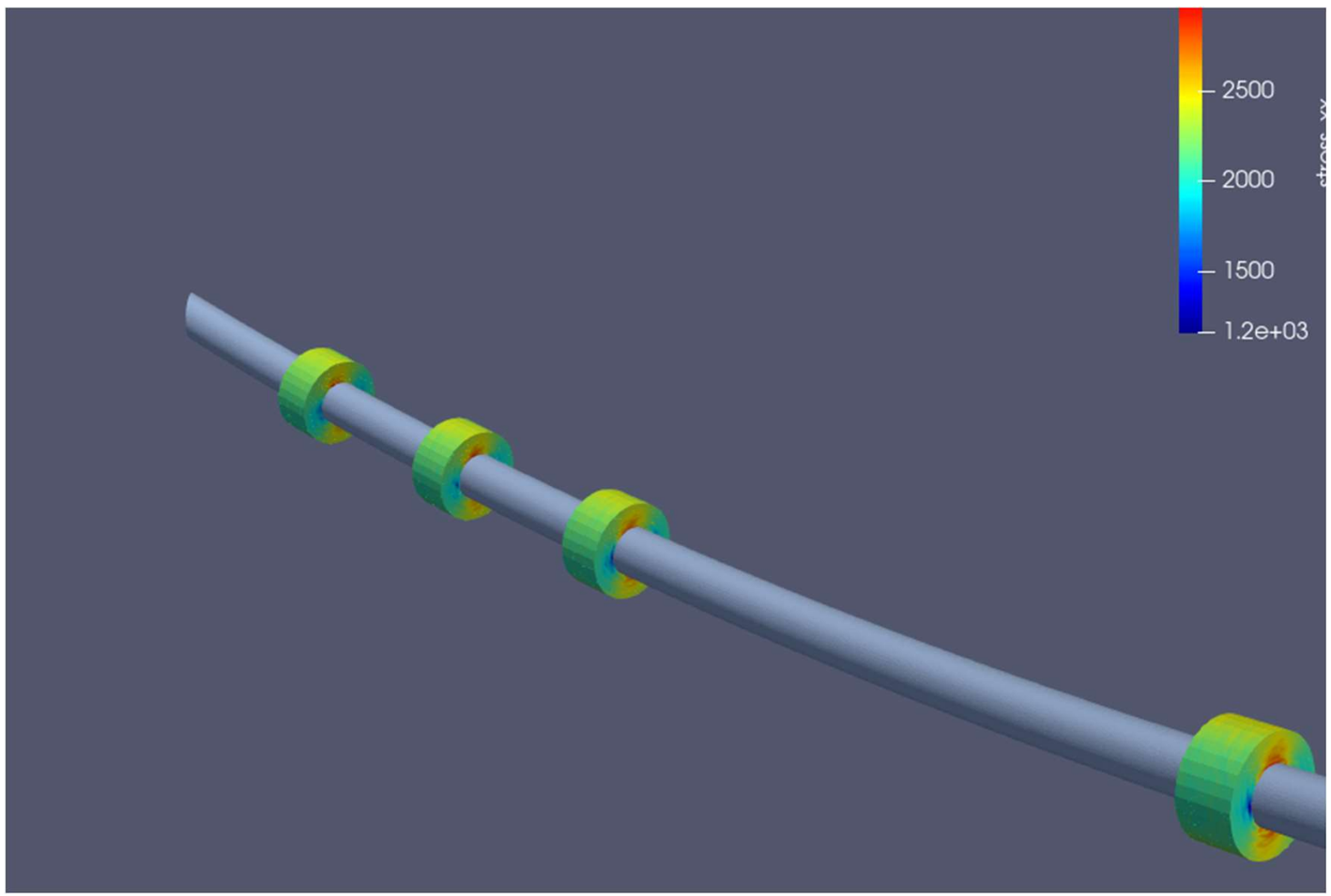
MPIs	U+Stress	U	Stress
1	906.439	384.114	522.325
2	495.697	229.528	266.169
4	305.521	170.779	134.742
8	236.9	156.42	80.48



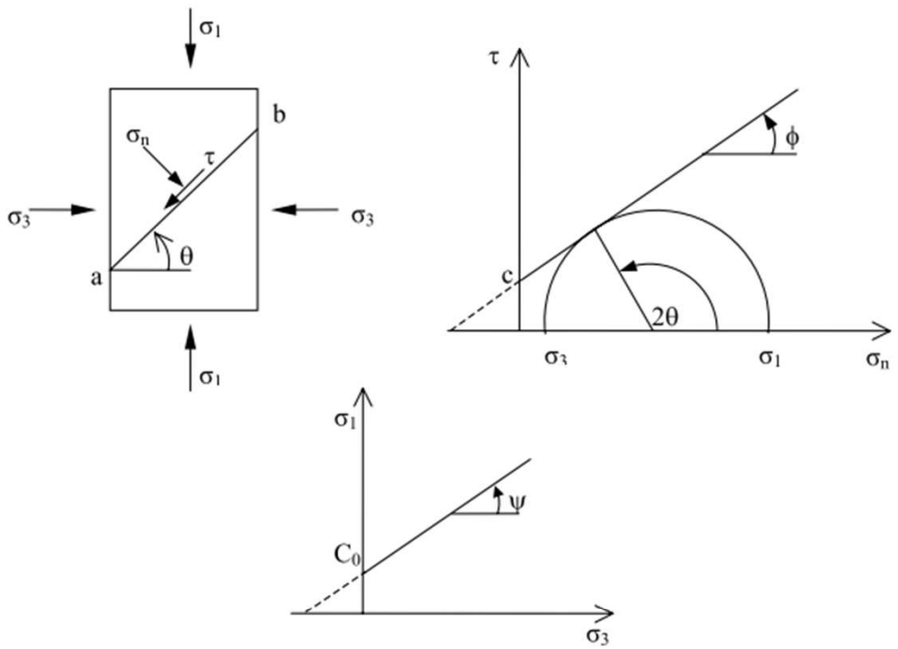
The Rings

The solution is projected on a second grid which is a cylindrical grid concentric with the well at a given position



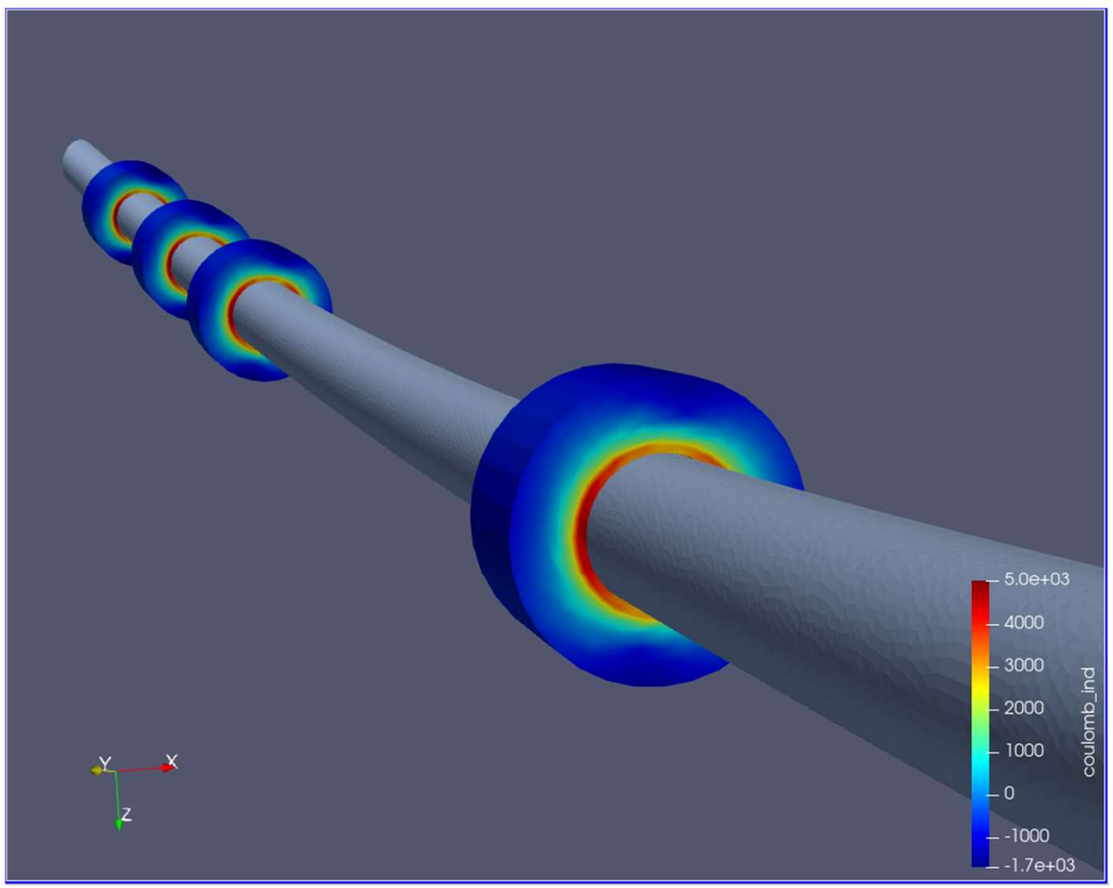


Failure Criteria: Coulomb

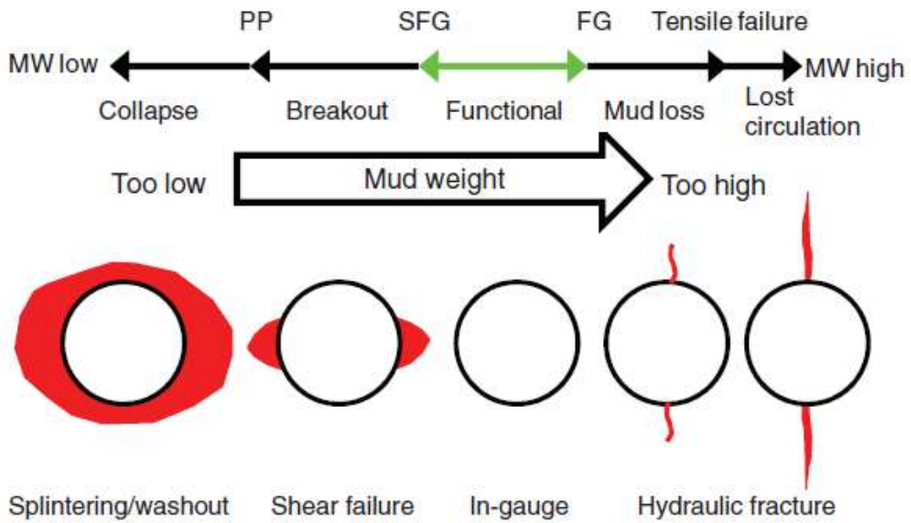


$$\sigma_1 = C_0 + q\sigma_3$$

$$s = C_0 + q\sigma_3 - \sigma_1 < 0$$



Coulomb index for different values of the mud-weight

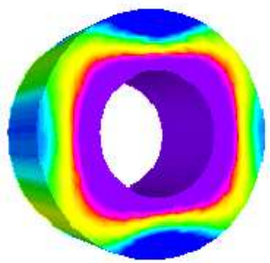


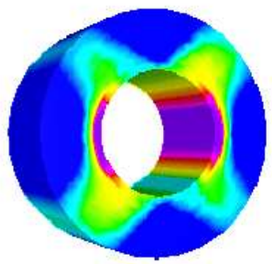
Too low

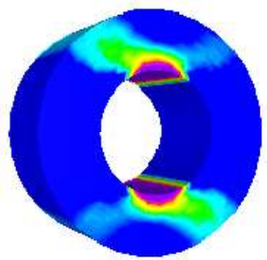
About right

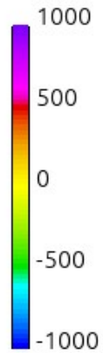
Too High

Mohr-Coulomb Index







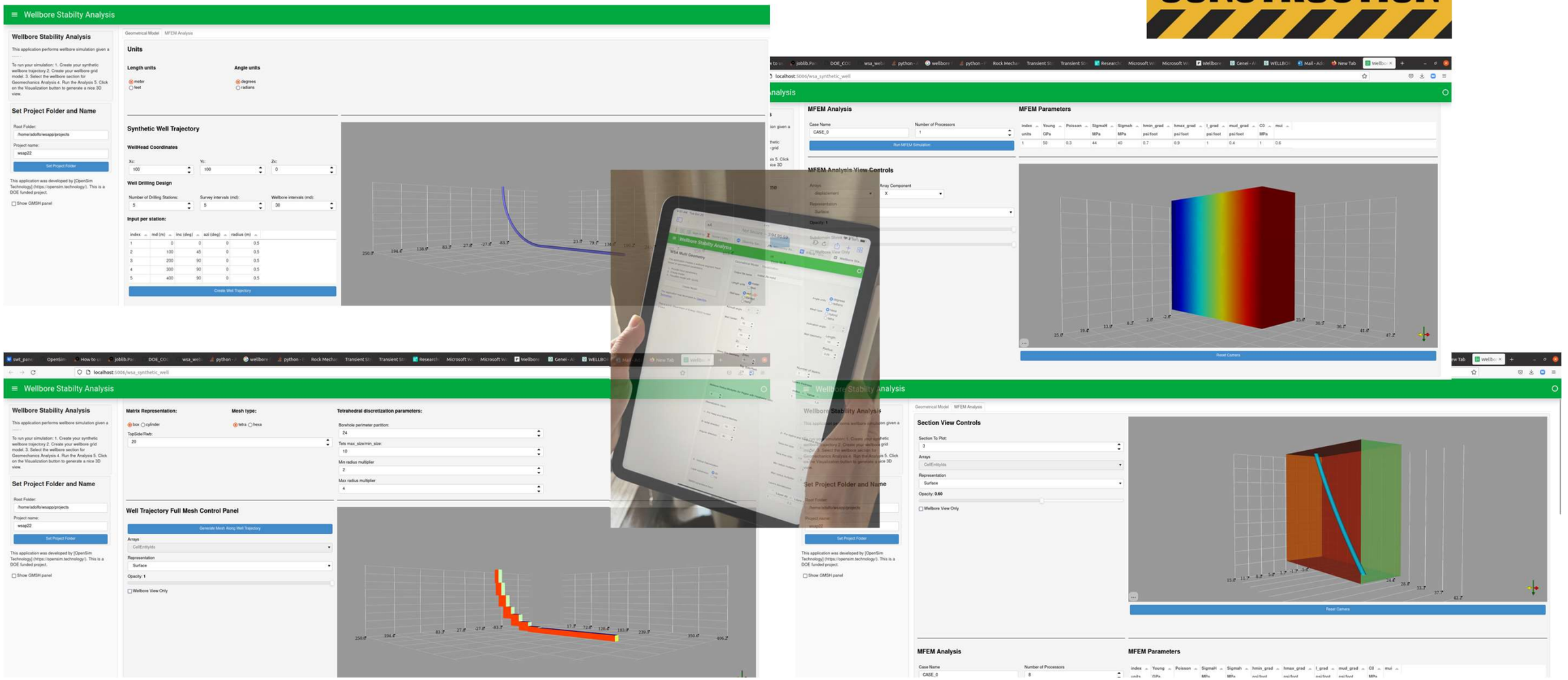


Mud weight 0.4 psi/ft

0.6 psi/ft

0.8 psi/ft

Webapp and Cloud Deployment



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  - Award #: DE-SC0022500