A Blast Model Comparison between Hydrocode and CFD

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Agenda

- Background
- Assumptions
- Problem
- The Codes
- The Models
- Results
- Observations and Differences
- Conclusions
- Recommendations

Background

- Blast or blast wave propagation modeling usually conducted using hydrocode
- CFD codes have the capability to do blast analysis
- Questions are asked
  - Are the results the same or similar?
  - Is one type of analysis superior to another?
  - Are there advantages to running one over the other?

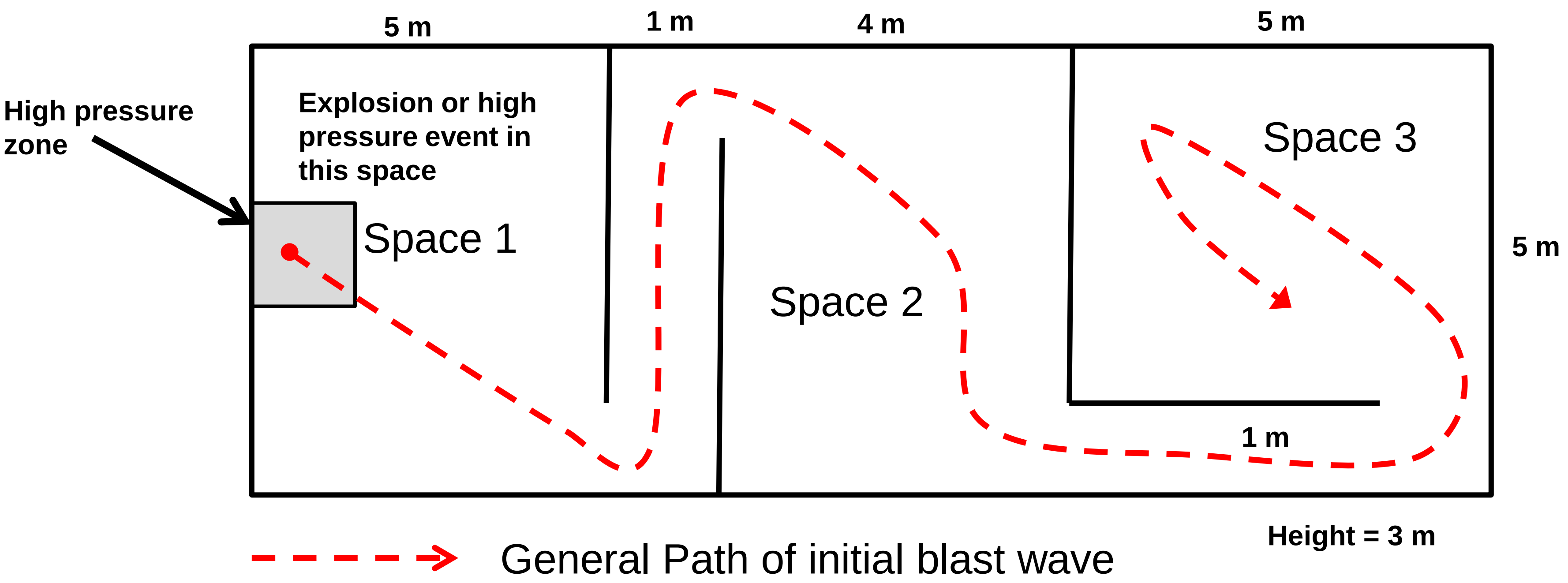
Assumptions

- “Blast” equivalent to 20 kg TNT
- Initial high-pressure volume of air to avoid complexities of HE detonation
- Several rooms or spaces to provide a meandering path for the blast
- Include hallways or corridors
- Air at STP filled remaining volume of rooms
- Walls modeled as voids
- No escape pathways or boundaries
- Codes set up for model equivalency – dimensions, mesh, etc.
- 2D proof of concept for Autodyn and Fluent was previously run

Problem

- Develop a problem that would challenge both codes
- Show differences in model, setup, run time, data analysis, accuracy
- Create models so they would be as “identical” as possible for each code
- Minimize factors that would contribute to initial differences
  - Explosion
  - Cell size

Model with Dimensions



Notes:

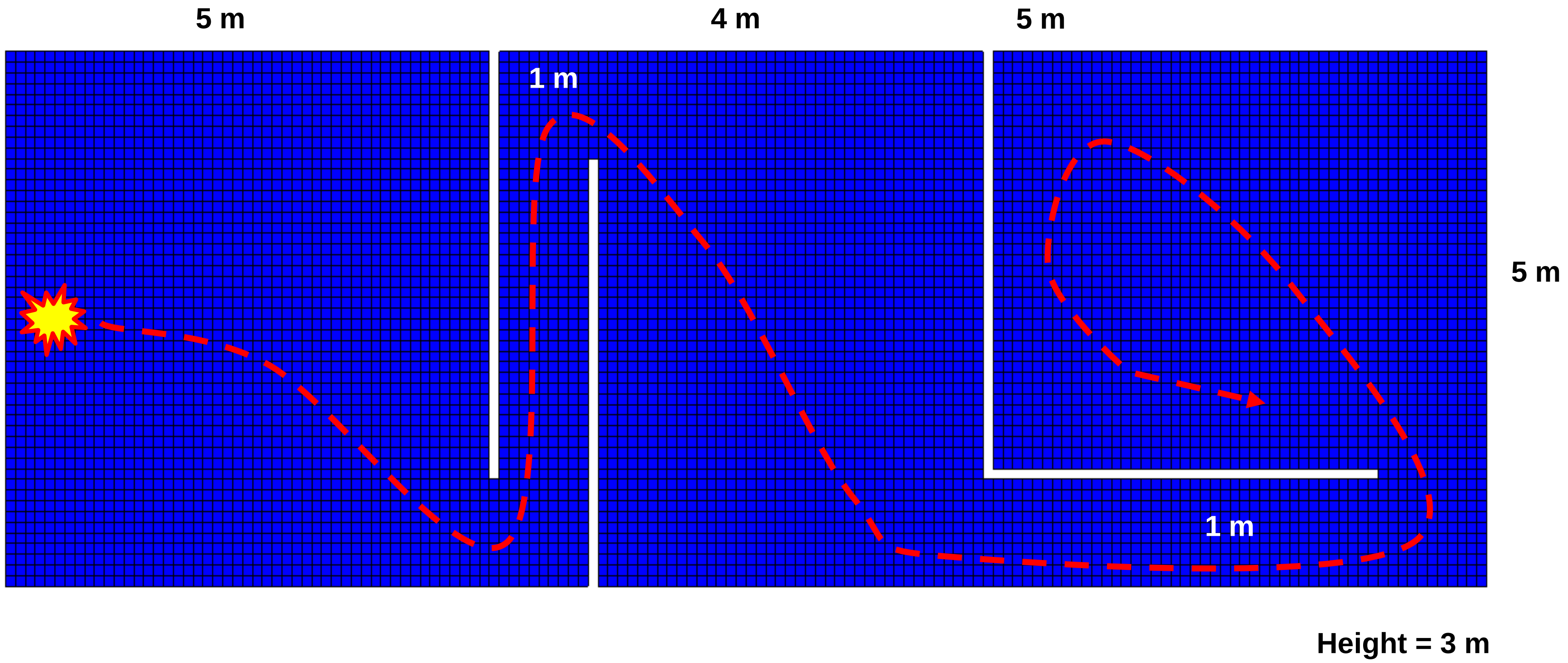
- **Several rooms or spaces to provide a meandering path for the blast.**
- **Hallways or corridors**
- **Air is medium**
- **Walls modeled as voids**
- **No escape pathways or boundaries**

The Codes

- Hydrocode
  - ANSYS Autodyn®
    - Physics-based wave propagation code
    - A fully coupled Eulerian and Lagrange explicit dynamics simulation software
    - An explicit analysis tool for modeling nonlinear dynamics of solids, fluids and gases
    - Used for solving large deformation, finite strain transient problems that occur on a very short time scale, e.g., explosions, blast, shock, impact, penetration
    - Tightly integrates the pre-processing, post-processing and analysis modules

- CFD
  - ANSYS Fluent®
    - Physics-based computational fluid dynamics simulation code
    - Subsonic to hypersonic; compressible and incompressible flow; laminar and turbulent; steady state to transient
    - Tightly integrates pre-processing, meshing, and post-processing with simulation
    - Highly parallel and scalable

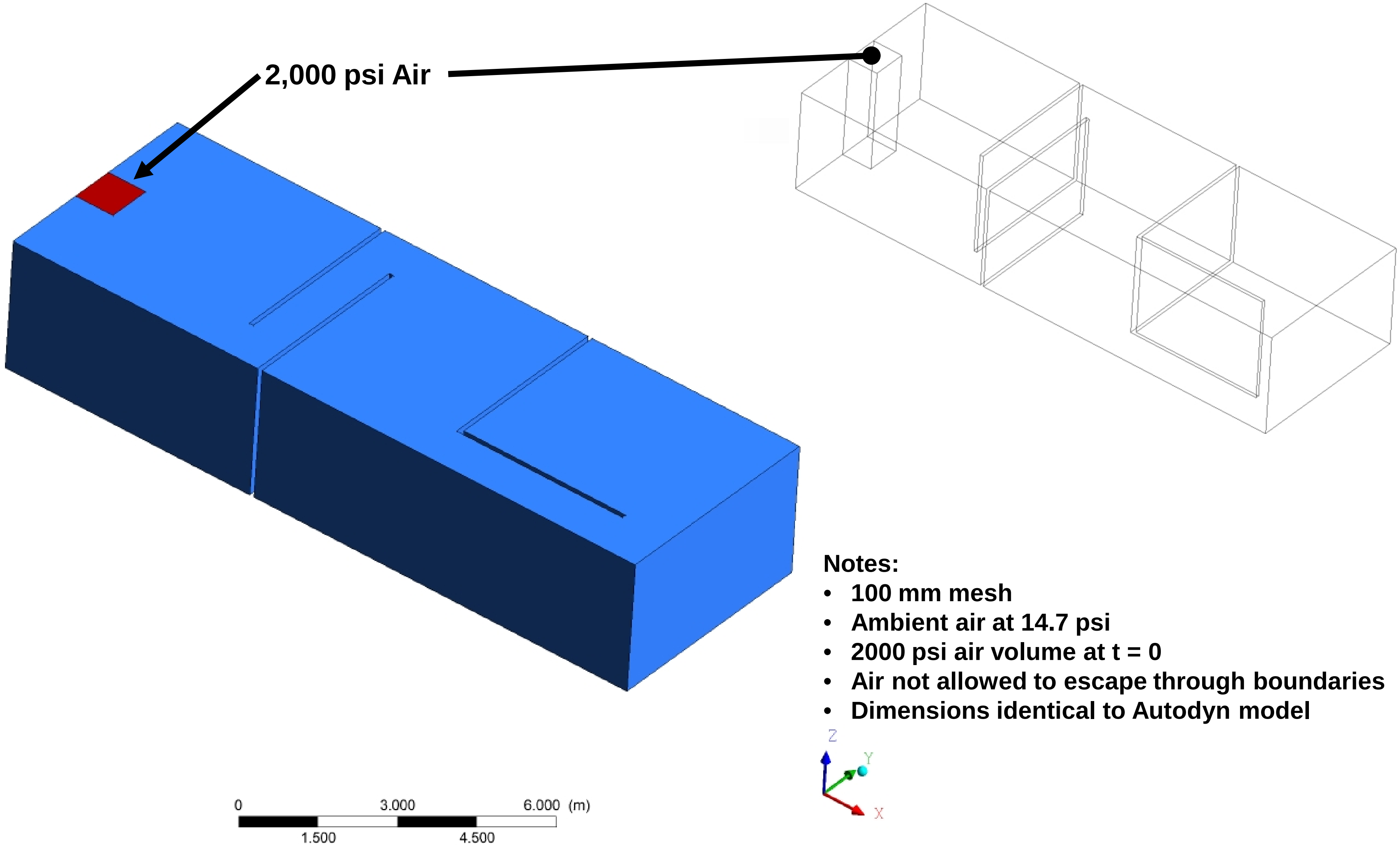
Model as Built in Autodyn



Notes:

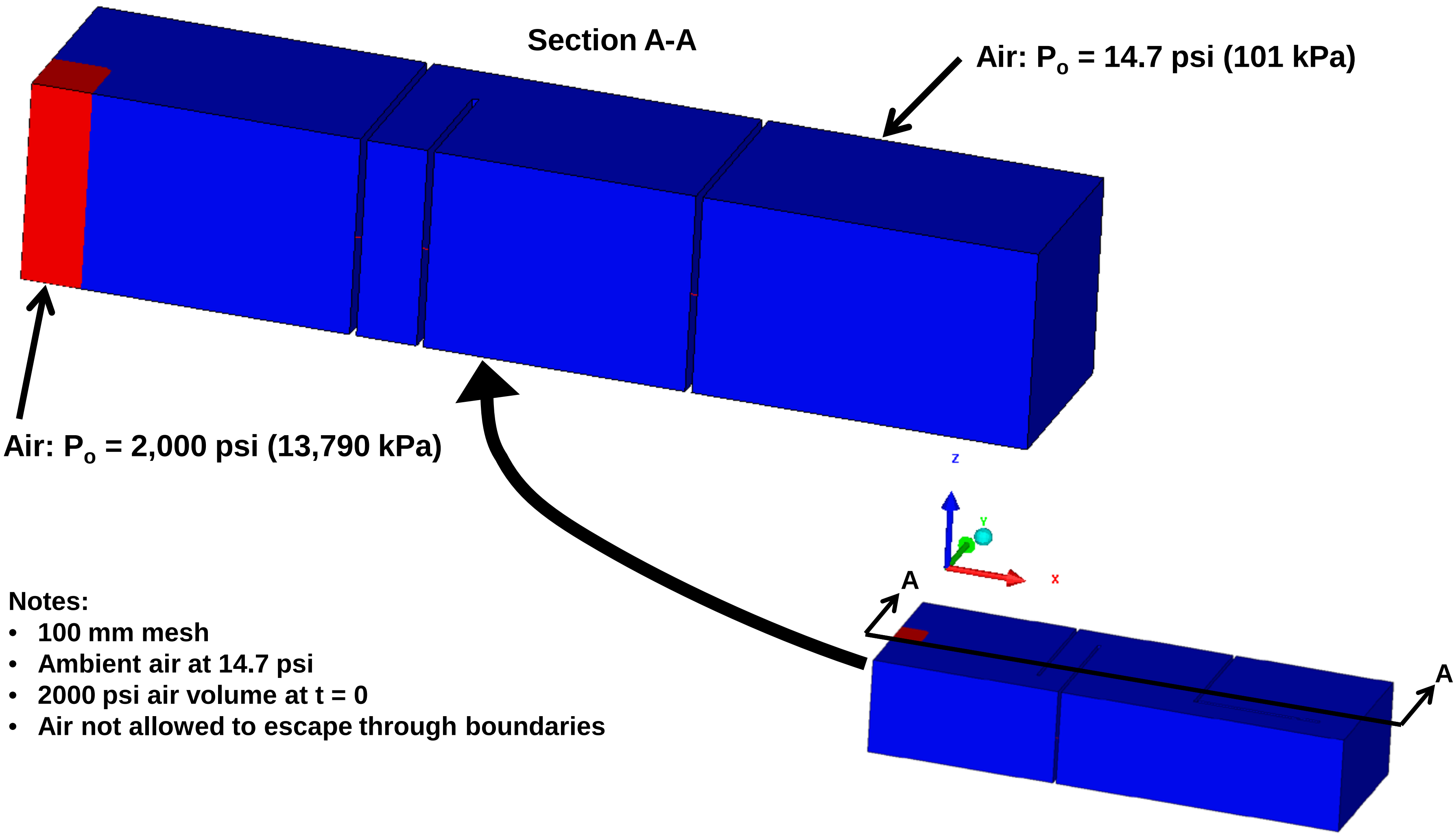
- **100 mm mesh**
- **1 m wide corridors**
- **Ambient air at 14.7 psi**
- **2000 psi air volume at t=0**
- **Air not allowed to escape through boundaries**

Fluent Model



Notes:
- **100 mm mesh**
- **Ambient air at 14.7 psi**
- **2000 psi air volume at t = 0**
- **Air not allowed to escape through boundaries**
- **Dimensions identical to Autodyn model**

Pressurized Volume



Notes:
- **100 mm mesh**
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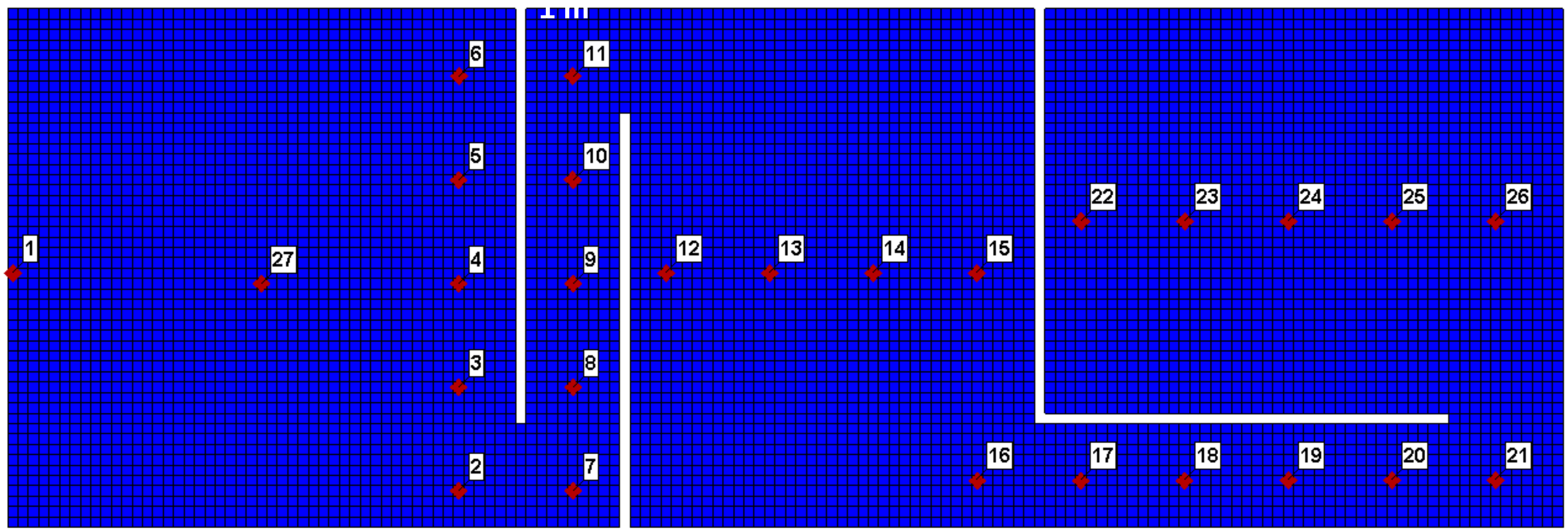
Data Collection

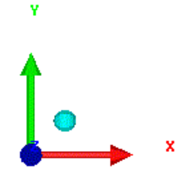
- Hydrocode
  - ANSYS Autodyn®
    - Gauges put in model to collect data while the model runs – data collected at times predetermined by user
    - Screen shots of model generated at time intervals predetermined by user
    - P-t curves generated
    - Overpressure screen shots generated

- CFD
  - ANSYS Fluent®
    - Data for model saved every 0.05 ms of flow time
    - Large data files generated that can be used to product data plots and screen shots *after* the model has completed running
    - P-t curves generated
    - Overpressure screen shots generated

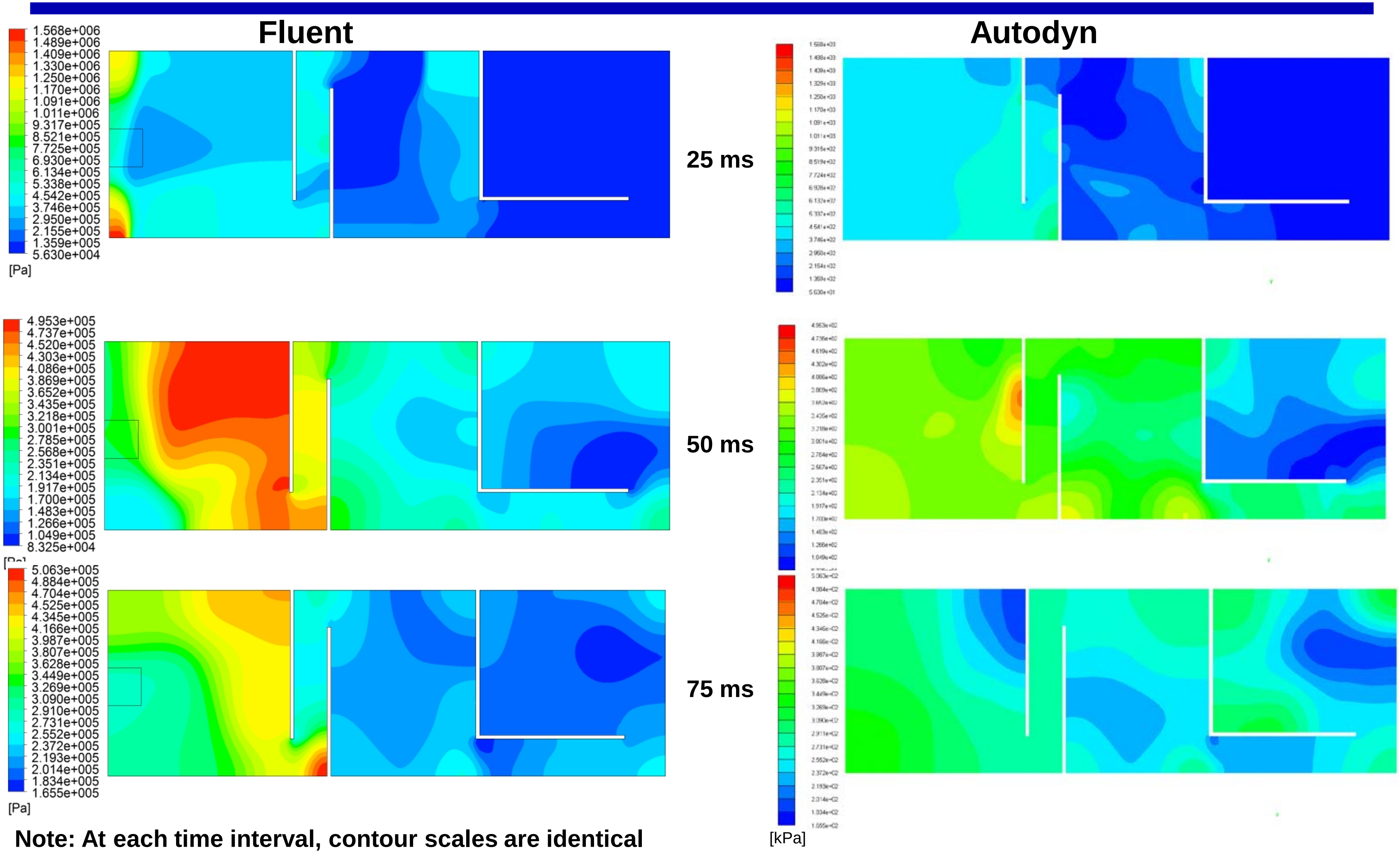
Gauge Locations



Notes:
- **Gauges at 0.85 m off floor**
- **Fluent data was collected at same XYZ locations**

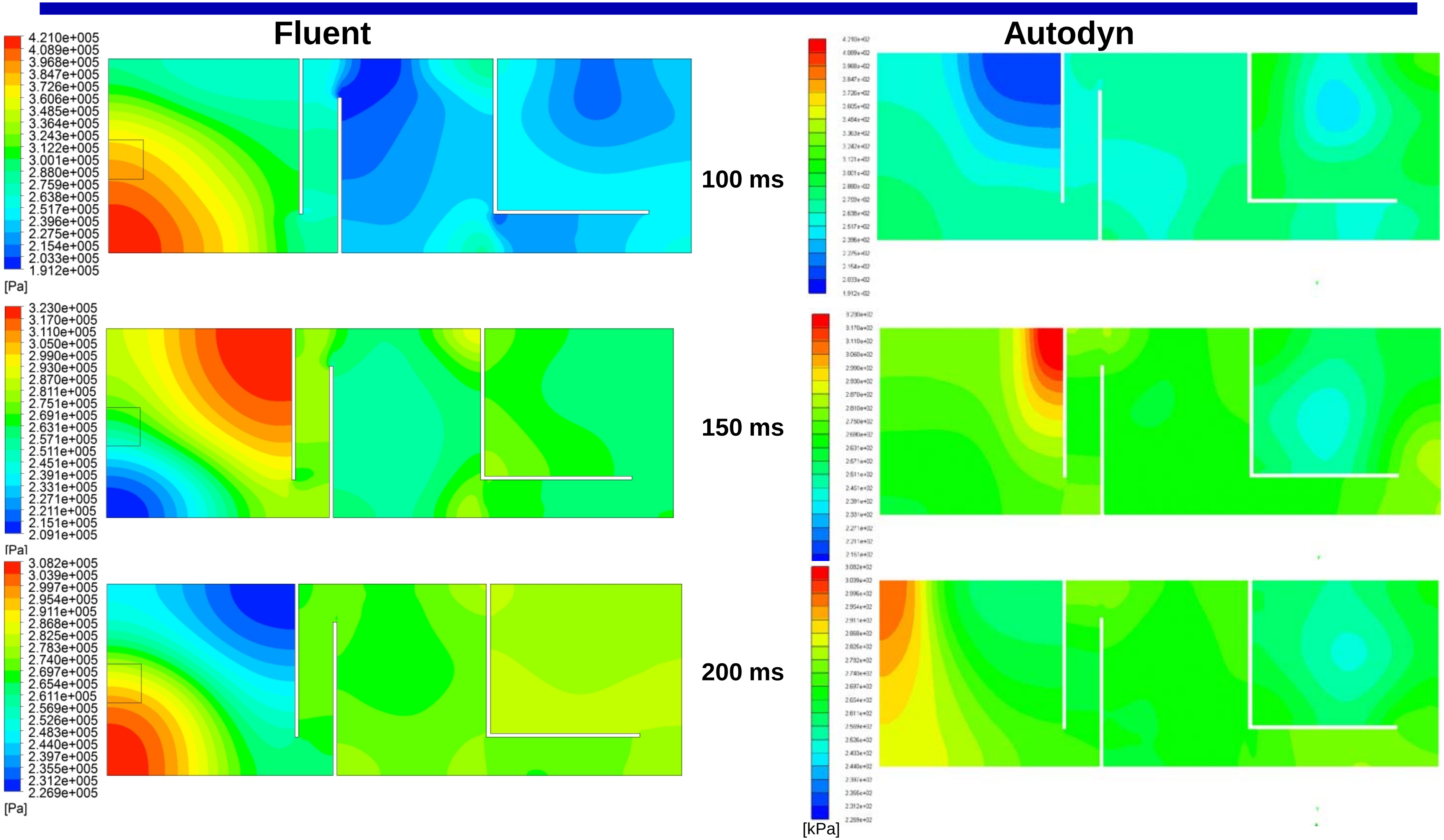


Autodyn – Fluent Comparison of Pressure Contours



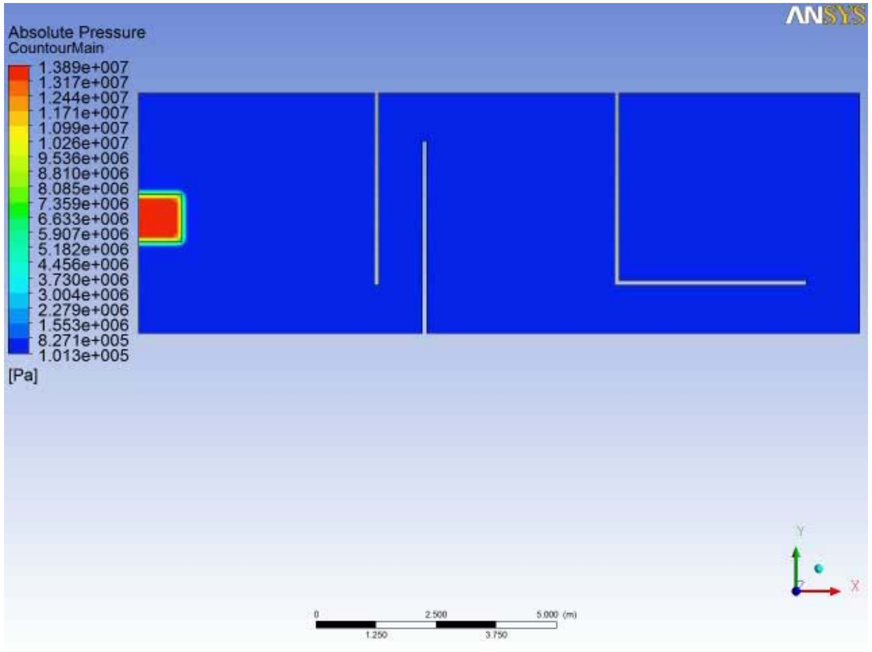
Note: At each time interval, contour scales are identical

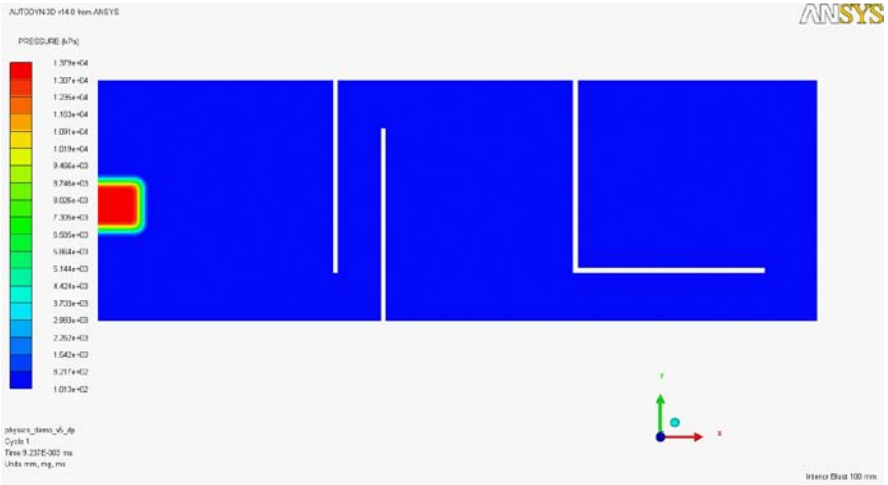
Autodyn – Fluent Comparison of Pressure Contours



Note: At each time interval, contour scales are identical

Autodyn – Fluent Animations

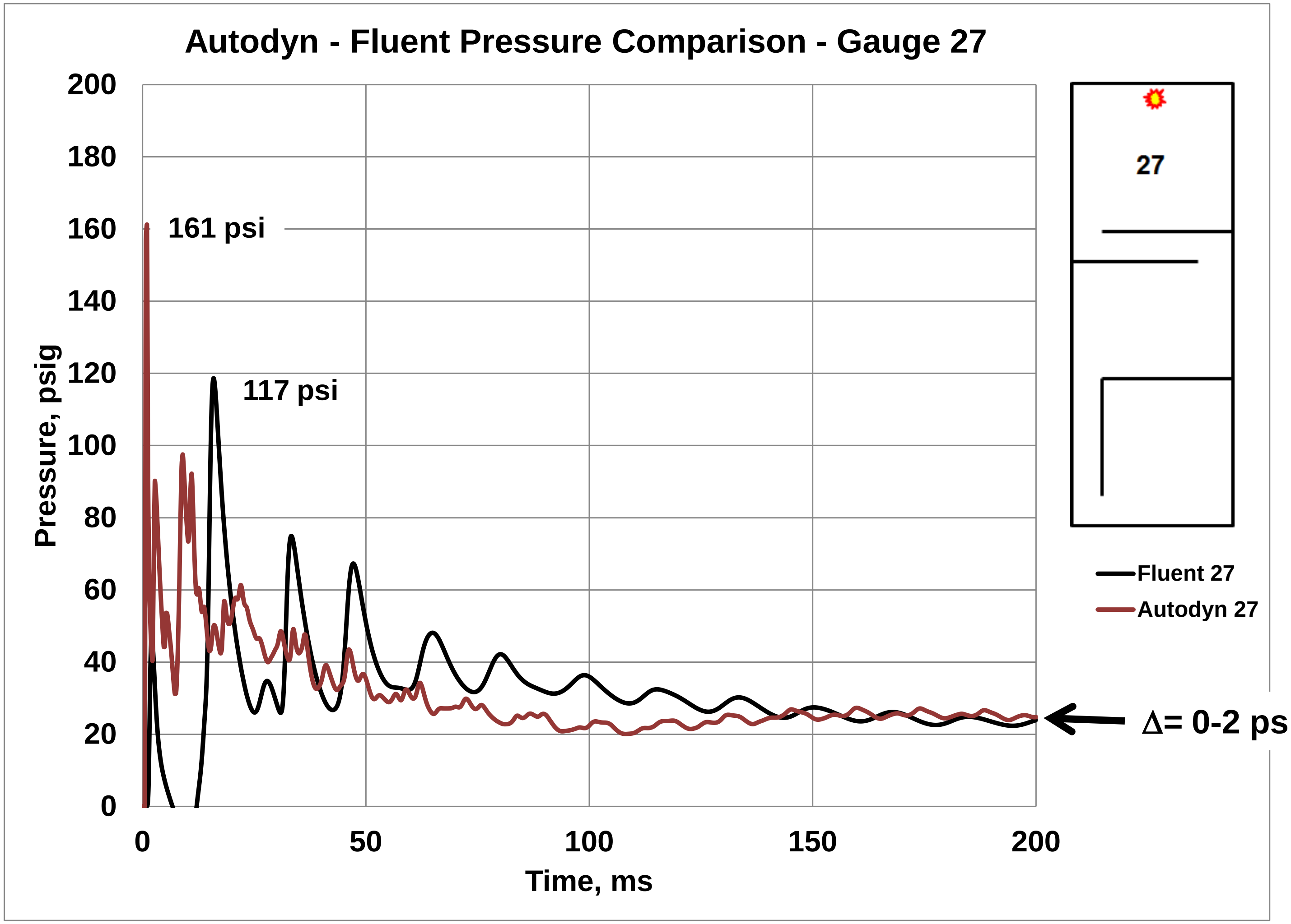




Fluent
- **0-50 ms**
- **0.05 ms**

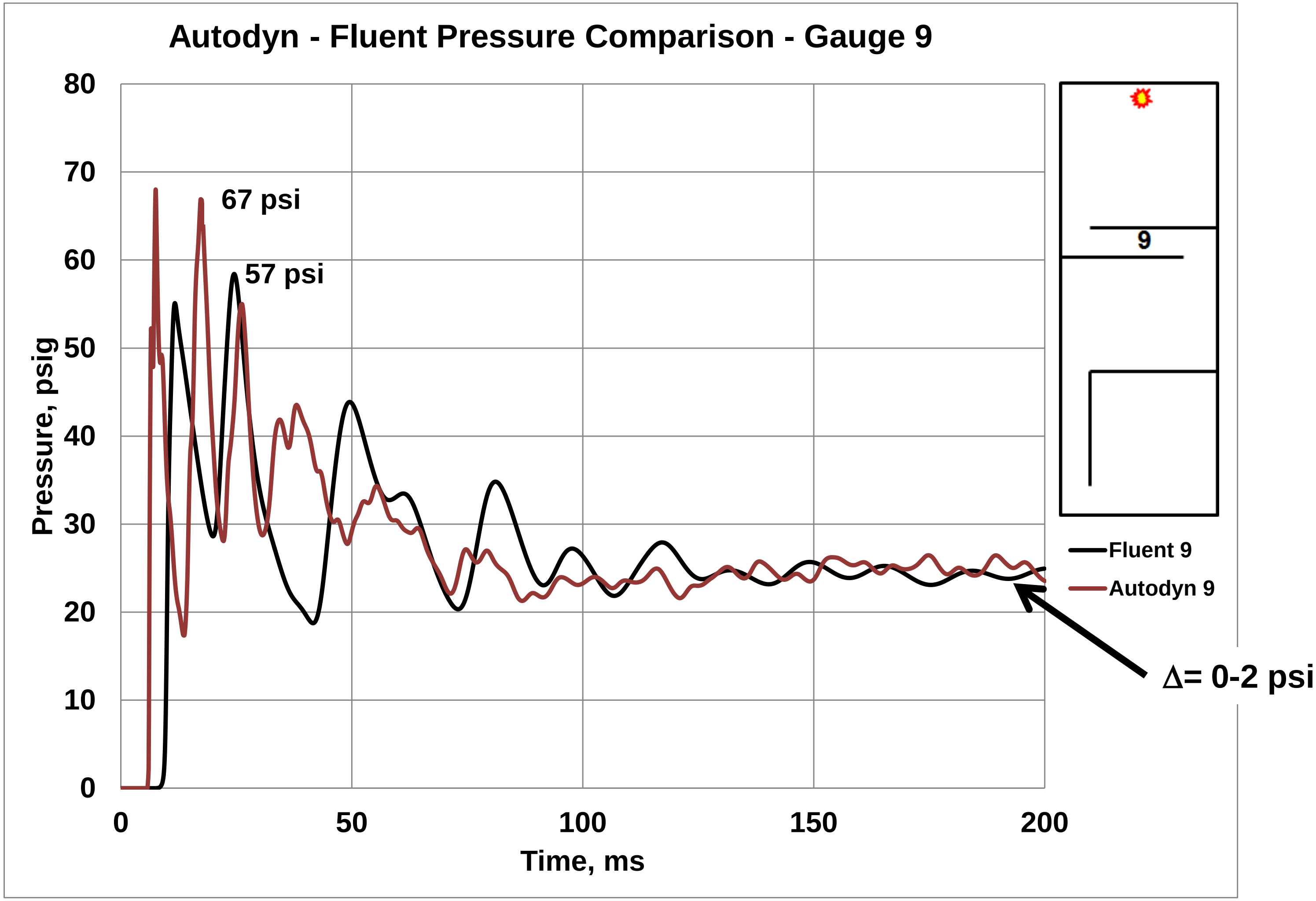
Autodyn
- **0-50 ms**
- **0.061 ms increments**

Autodyn – Fluent P-t Comparison



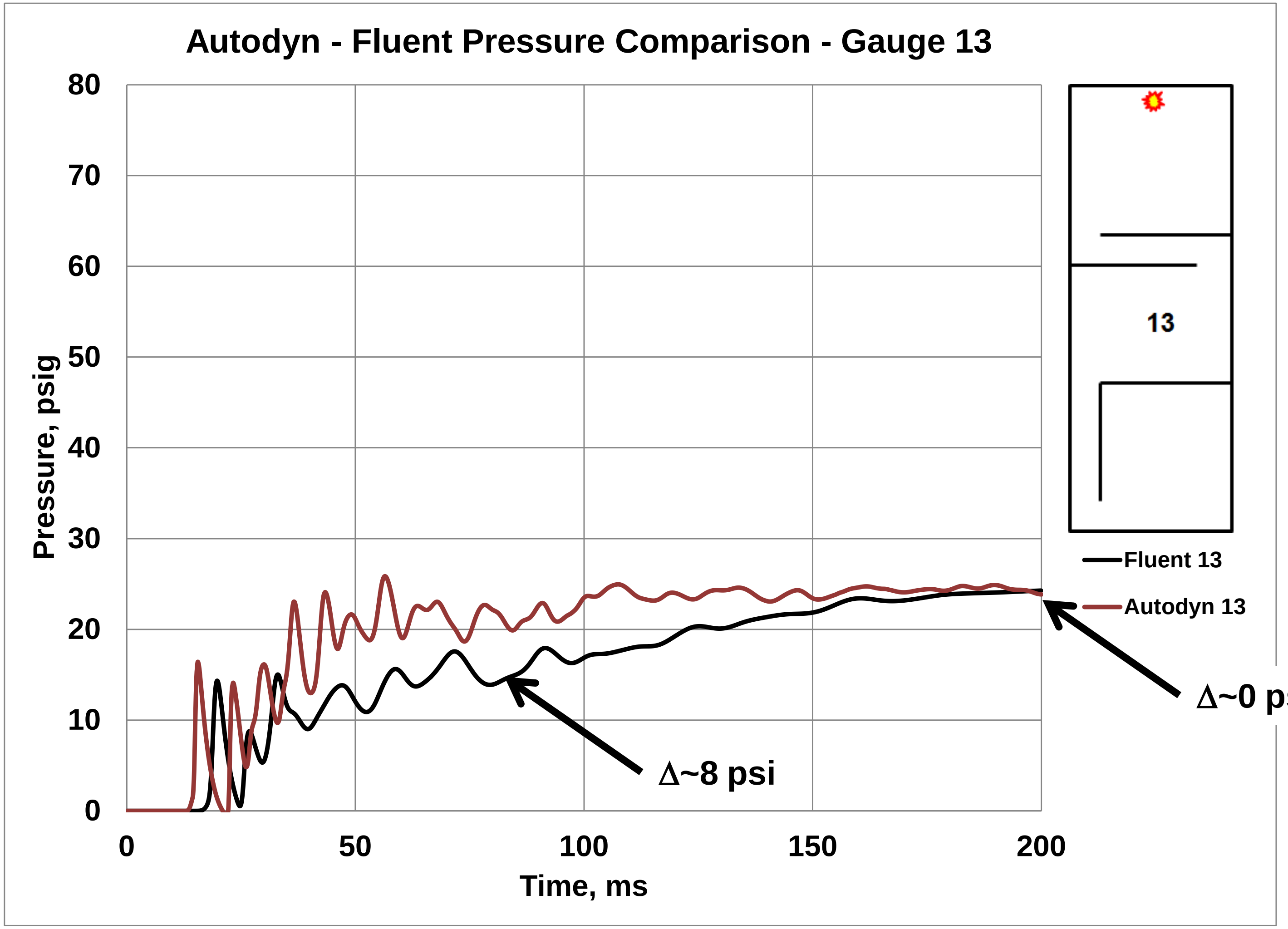
Significant P-t divergence at early times

Autodyn – Fluent P-t Comparison



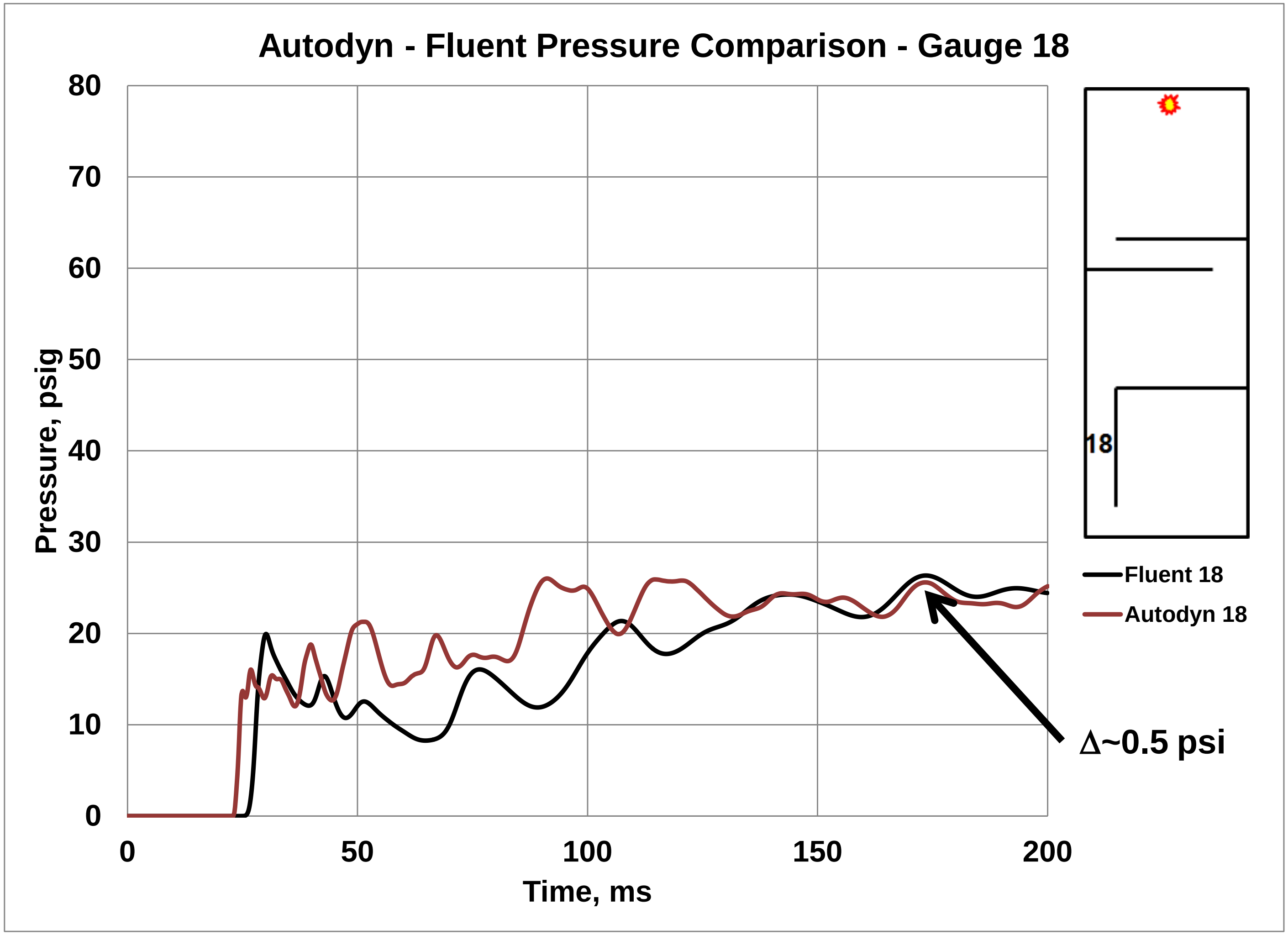
P-t convergence at late times

Autodyn – Fluent P-t Comparison



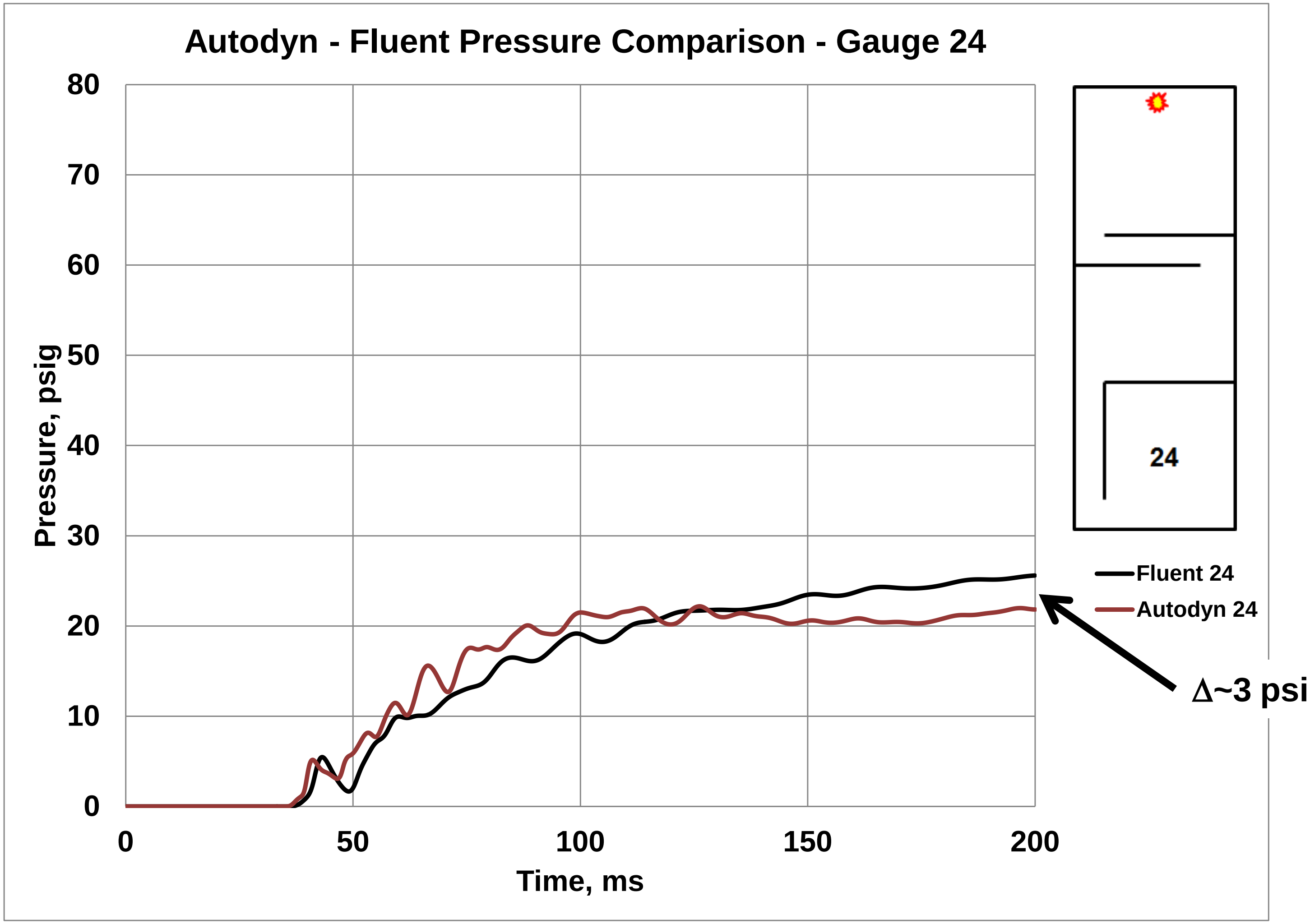
P-t convergence at late times

Autodyn – Fluent P-t Comparison



Very close P-t at late times

Autodyn – Fluent P-t Comparison



P-t behavior very similar, with late-time divergence

Observations

- Both hydrocode and CFD can handle pressure wave propagation
- General agreement in P-t, especially at longer time
- Fluent Δt was an issue, especially at early times (0-15 ms)
- Fluent runtime was about 2X longer from 15-200 ms
- Autodyn optimized for running this class of problem efficiently
- Model very easy to build in Fluent
- Fluent has a very powerful mesh generator
- Fluent produces GB++ of data
- Both Fluent and Autodyn have comparable graphics capabilities

Conclusions

- Both hydrocode and CFD can run for blast wave propagation problems
- Hydrocode (Autodyn) is optimized for this type of analysis
- CFD (Fluent) has significant advantages
  - Importing and meshing complex geometry
  - Parallelization
  - Post processing
  - Types of data captured

Recommendations

- Use hydrocode for this type of analysis
  - Unless there are compelling reasons to do otherwise
- Use CFD when
  - Runtime not a factor
  - Availability of many processors
  - Complex geometry that would be difficult to mesh and run with hydrocode
  - Analysis requirements
- Optimize Fluent variable settings
  - Timestep iteration

Questions

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Backup Slides

Runtime Comparison

Code	100 mm	
	Time, min.	# Cells
Autodyn DP (15 ms)	0.33	225,000
Fluent DP (15 ms)	6	225,000
Autodyn DP (15 – 200 ms)	2.25	225,000
Fluent DP (15 ms – 200 ms)	4	225,000

Fluent has longer run times, but is also saving massive amounts of data