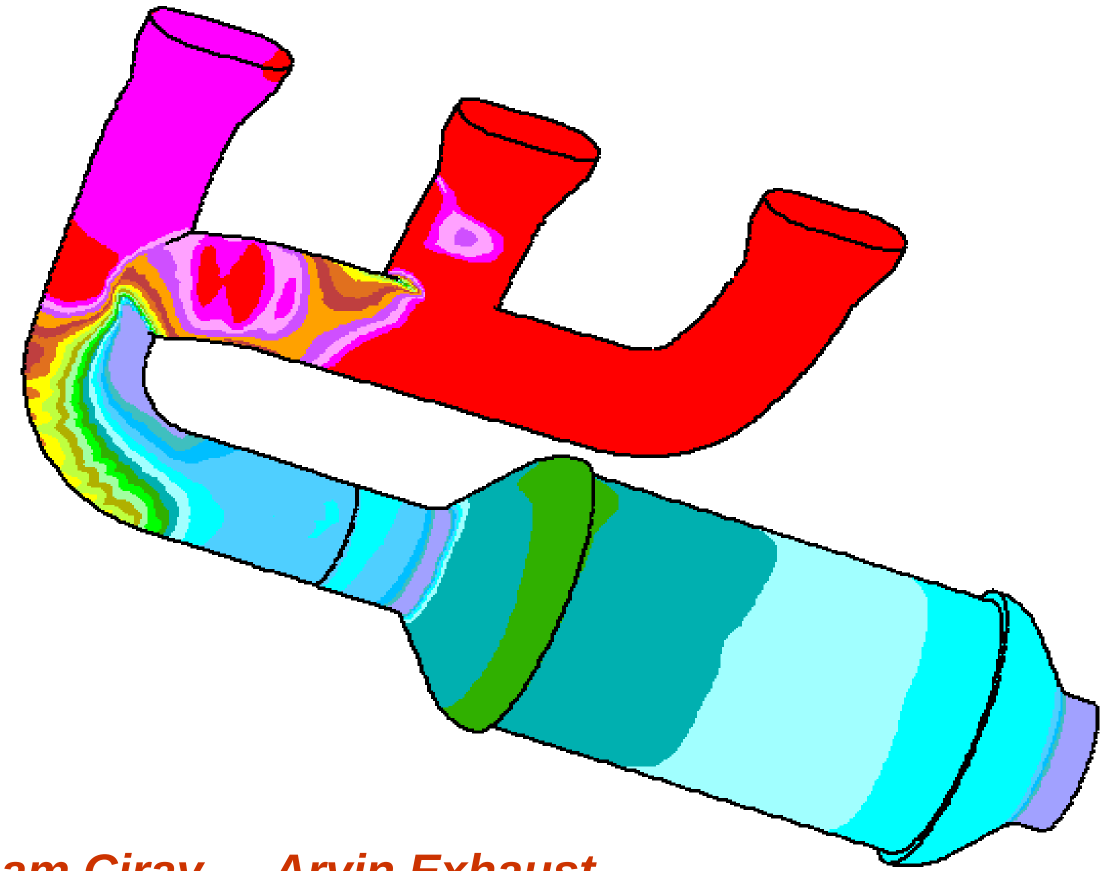
Transient Analysis of a V6 Exhaust Manifold using a Coupled 1D/3D Model



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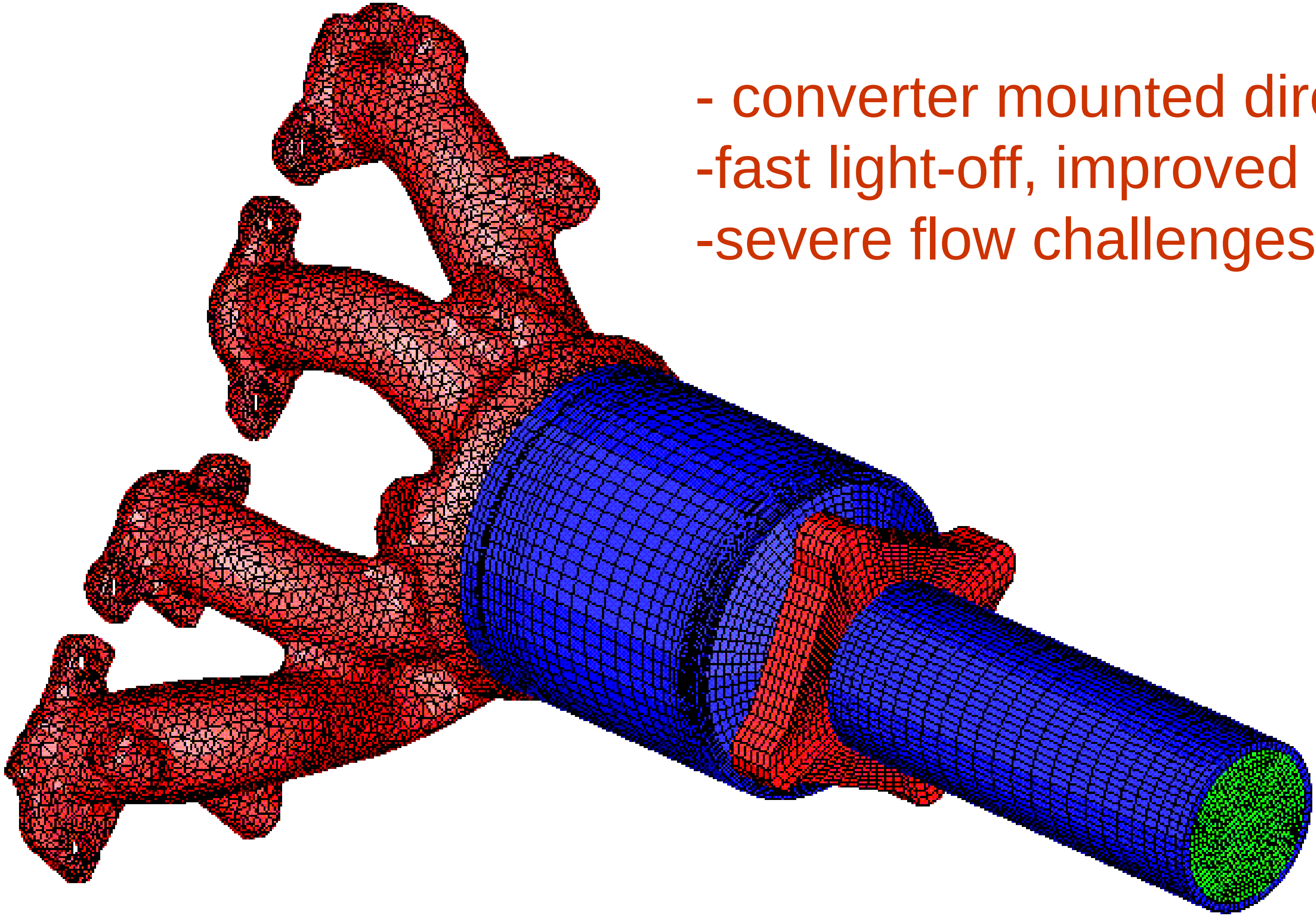
Problem Background

- Manifold & Catalytic Converter CFD
- Backpressure and Flow Distribution
- Steady vs Transient

Typical Manifold-Mounted Converter



- converter mounted directly to manifold
- fast light-off, improved emissions
- severe flow challenges

Steady Assumption

- Reasonable for underbody locations
- Less applicable for close-coupled positions
- Cases-to-case versus actual flow physics

Solution Method

- Coupled 1D/3D (Wave/Star-CD) Method
- Model full system in Wave
- Insert junctions as manifold inlets & converter outlets
- Run in fully-coupled mode, time step-by-step

Steady Cases

- Comparison purposes

- 4 cases
  - case 1,2,3: instantaneous-peak-flow from one runner
  - case 4: average flow from all runners
  - objective: compare steady results to transient

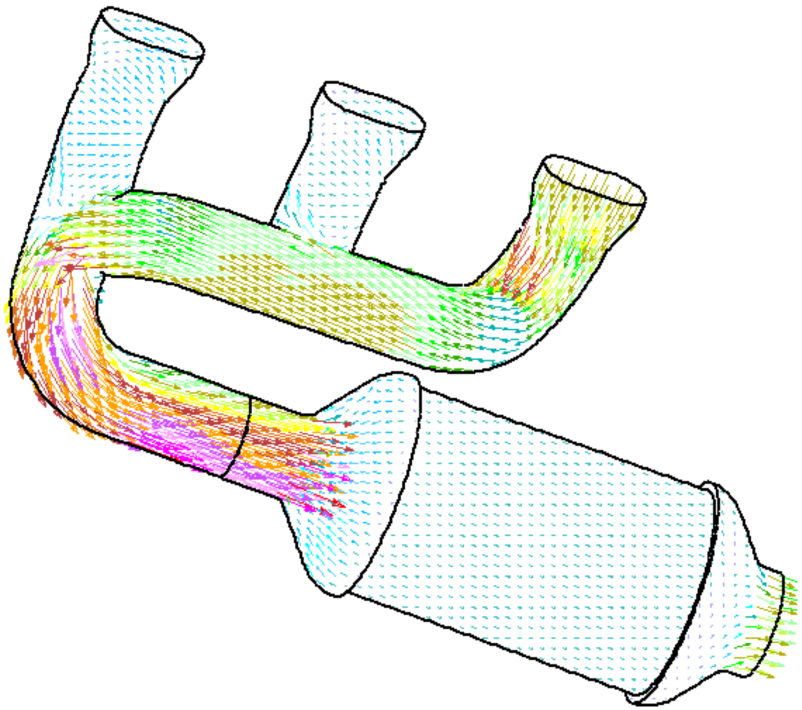
Solution Parameters:
Steady-State and Transient Cases

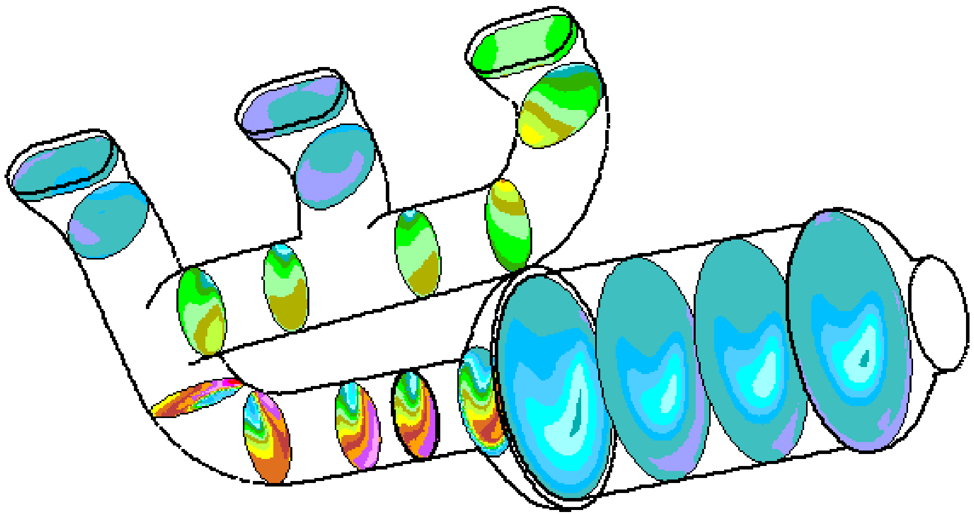
- Samm grid : 400,000 cells
- standard k-e turbulence model
- MARS discretization scheme
- inlet plane at exhaust port flange
- outlet plane downstream of covnerter outlet

Transeint 1D/3D Coupling Process

- Wave to StarCD: mass flow + all inlet info
- StarCD to Wave: pressure + all outlet info
- Variable time step controlled by Star-CD
- PISO solution algorithm
- Parallel run -- 8CPUs/400MB RAM

Steady Results: Flow Distribution

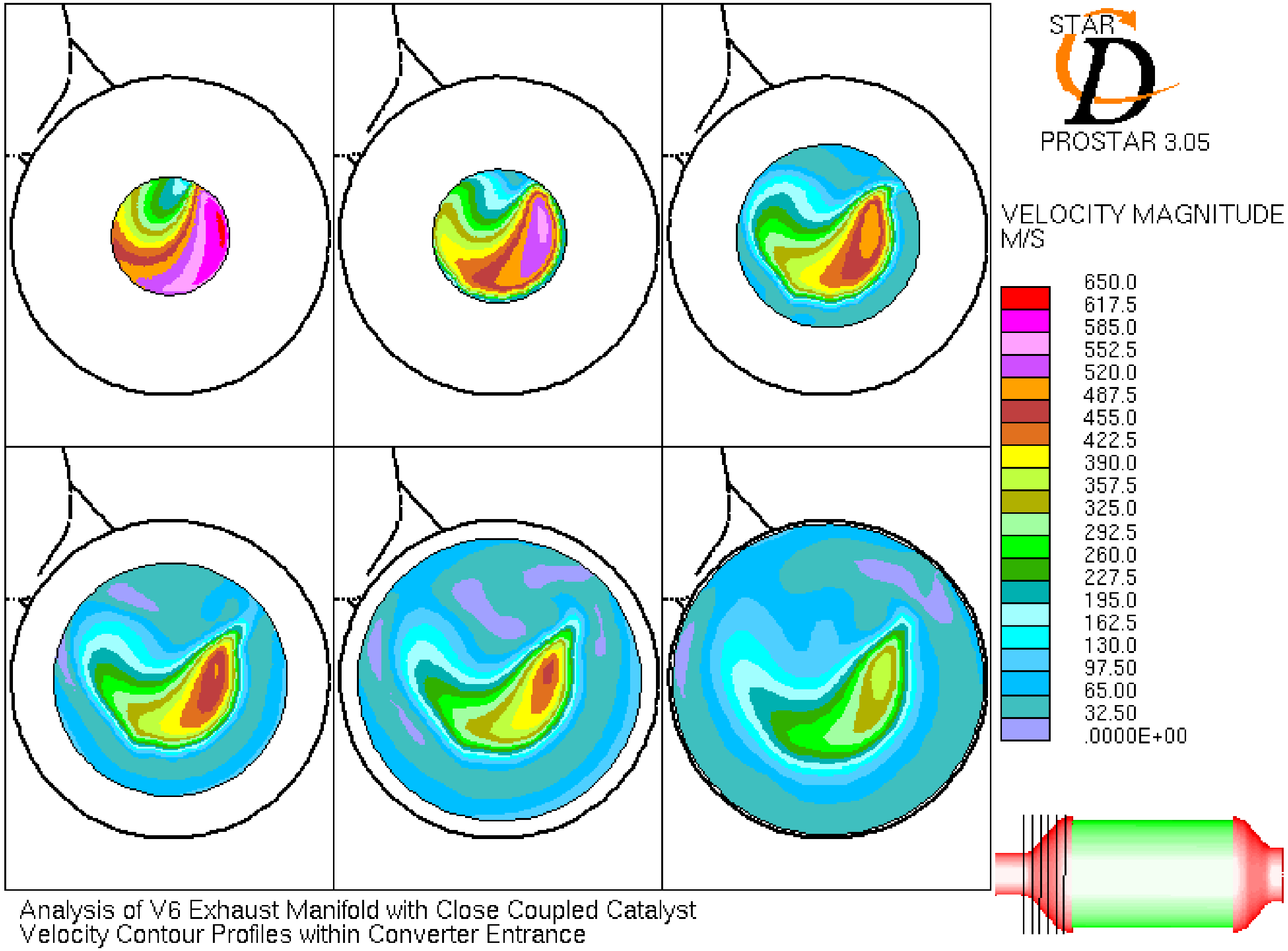




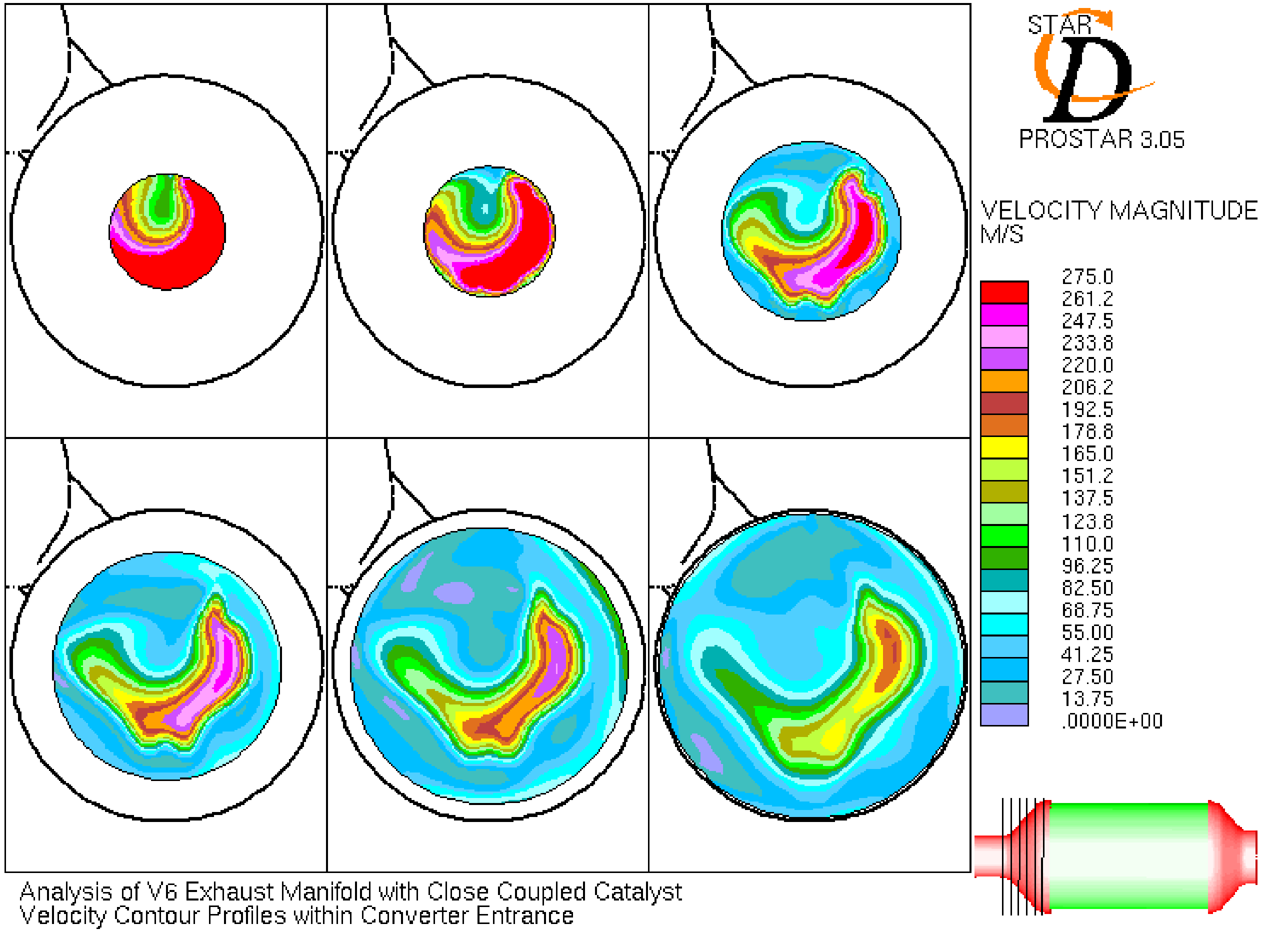
- *Flow shifts to lower wall in large U-bend*
- *Similar results for all three ports*

Steady Results: Case 2

- *‘half-moon’ flow pattern*
- *cases 1 and 3 are similar*



Steady Results: Case 4



Steady Result Comparison

Case	**Maldistribution Index (best=0)**	**Effective Area Ratio (best=1)**
Case 1	0.5311	0.6531
Case 2	0.5443	0.6475
Case 3	0.5920	0.6281
Case 4	***0.2496***	***0.8003***

- *Similar patterns; vastly differing performance indicies*
- *Which case best represents transient results*

Transient vs Steady: Flow Distribution

- *Flow shifts to lower wall in large U-bend*
- *Similar results for all three ports*

Transient vs Steady: Backpressure

Case	Pressure Drop
Case 1	53.5 kPa
Case 2	102.7 kPa
Case 3	86.3 Pa
Case 4	21.3 kPa

- *Flow shifts to lower wall in large U-bend*
- *Similar results for all three ports*

Conclusions

- For flow distribution - single-port ss case
- For Pressure loss - multi-port ss case
- Transient effects play large role in
  - flow distribution
  - flow restriction
  - port pressure levels
- Transient Case must be used where real flow physics are required