Flow Analysis of X-34 Main Propulsion System Feedlines

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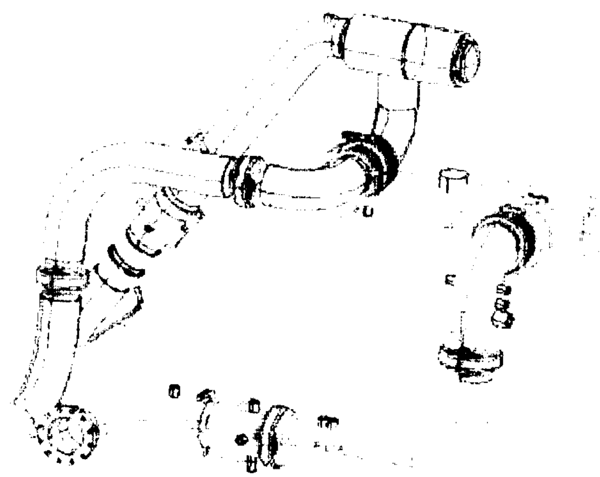
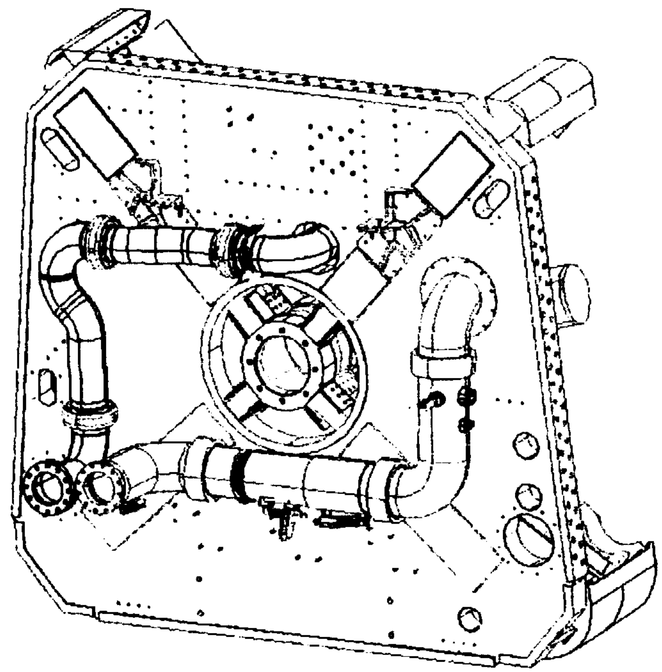
Flow Analysis of X-34 MPS Feedlines

- <u>Objective</u> - 1) Determine the flow development at the engine interface
  2) Predict the pressure drop in the feedline.



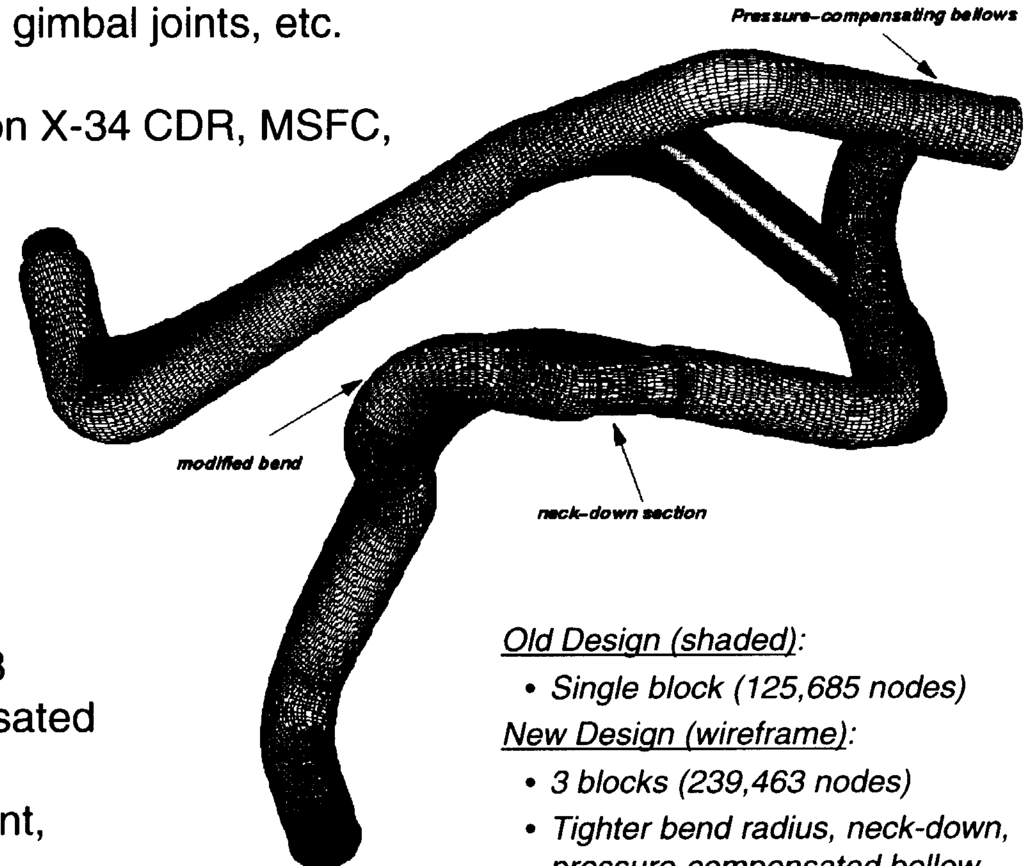
Old Configuration (MSFC's Design, Phase 2, 10/98)



New Configuration (OSC's Design, 10/99)

Computational Grids

- Assumptions -
  1) Disregard flow meters, fuel filters, gimbal joints, etc.
  2) Fully-developed flow at the inlet
  3) Reference conditions are based on X-34 CDR, MSFC, 12/15-17/97



- Method -
  1) Generate grid based on the IGES geometry provided by OSC, 10/98
  2) Model includes pressure-compensated bellows
  3) Perform single phase, 3D, turbulent, incompressible analysis

Old Design (shaded):
- *Single block (125,685 nodes)*

New Design (wireframe):
- *3 blocks (239,463 nodes)*
- *Tighter bend radius, neck-down, pressure-compensated bellow*

Numerical Methodology

- **Solve the curvilinear coordinate transport equations:**

  $$(1/J)(\partial \rho \mathbf{q}/\partial t) = \partial[-\rho U_i \mathbf{q} + \mu G_{ij}(\partial \mathbf{q}/\partial \xi_j)]/\partial \xi_i + (1/J)S_q$$

  where

  $J = \partial(\xi_i \xi_j) / \partial(x,y)$

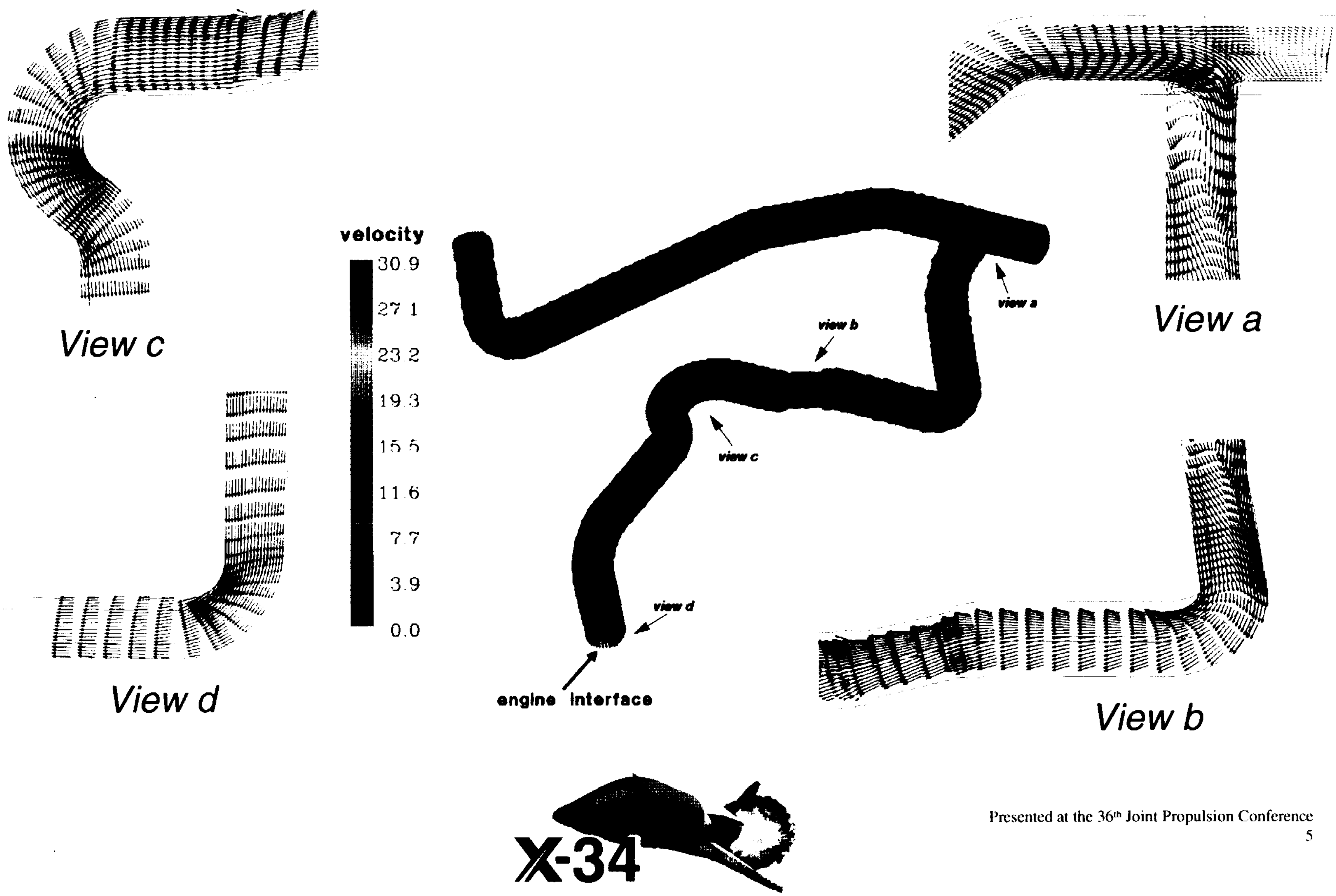
  $Ui = (u_j/J)(\partial \xi_i/\partial x_j)$

  $G_{ij} = (\partial \xi_i/\partial x_k)(\partial \xi_j/\partial x_k)/J$

- **Finite-difference approximations are used to establish a system of linearized algebraic equations**

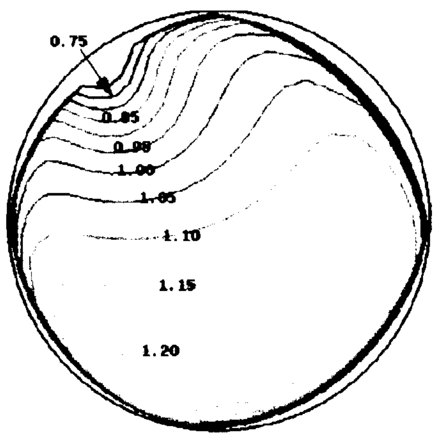
- **Relaxation schemes are based on 2nd and 4th order central differencing with artificial dissipation**

Velocity Vectors

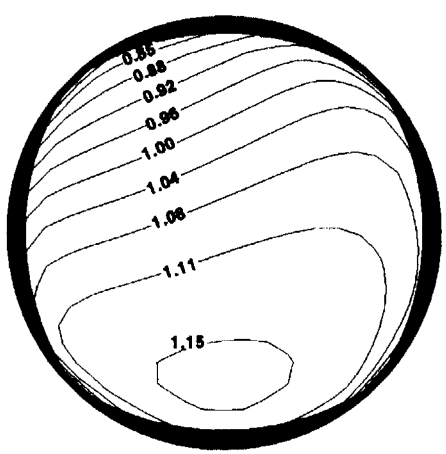


Velocity at the Engine Interface

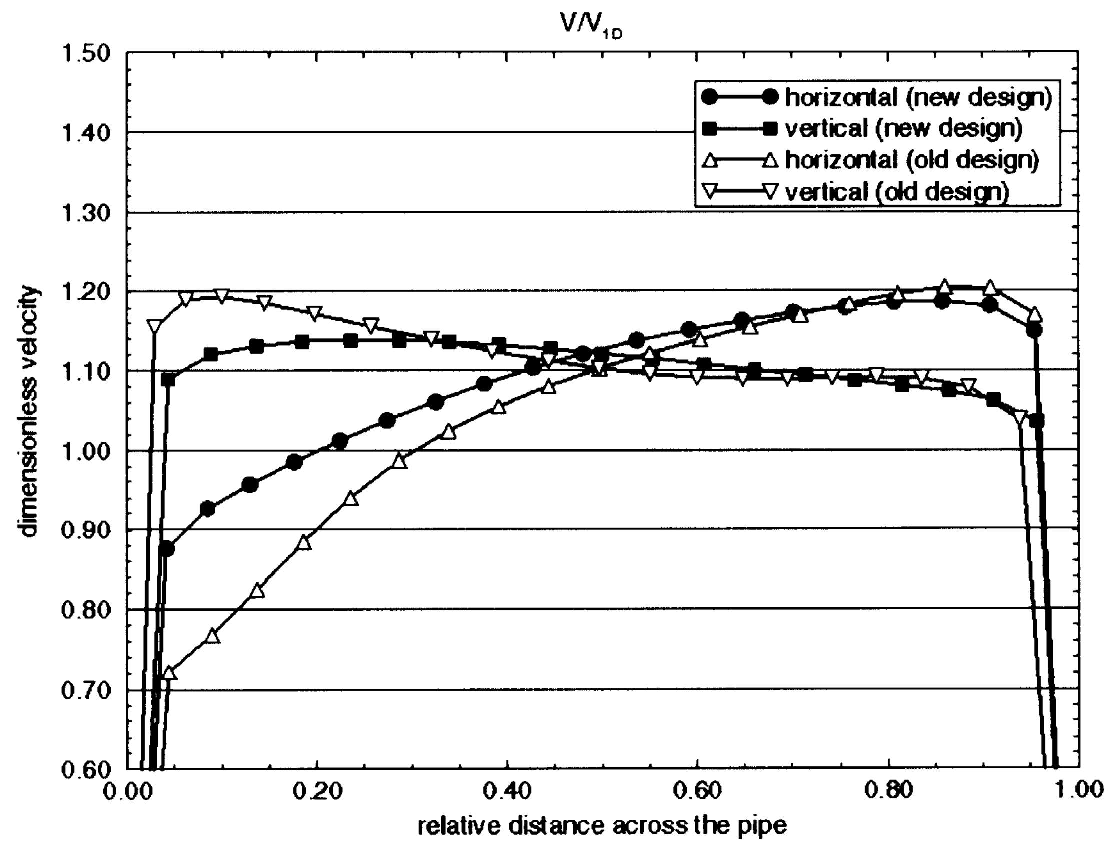
RP–1 Feedline CFD Results (MSFC's Design)
Nondimensionalized Axial Velocity



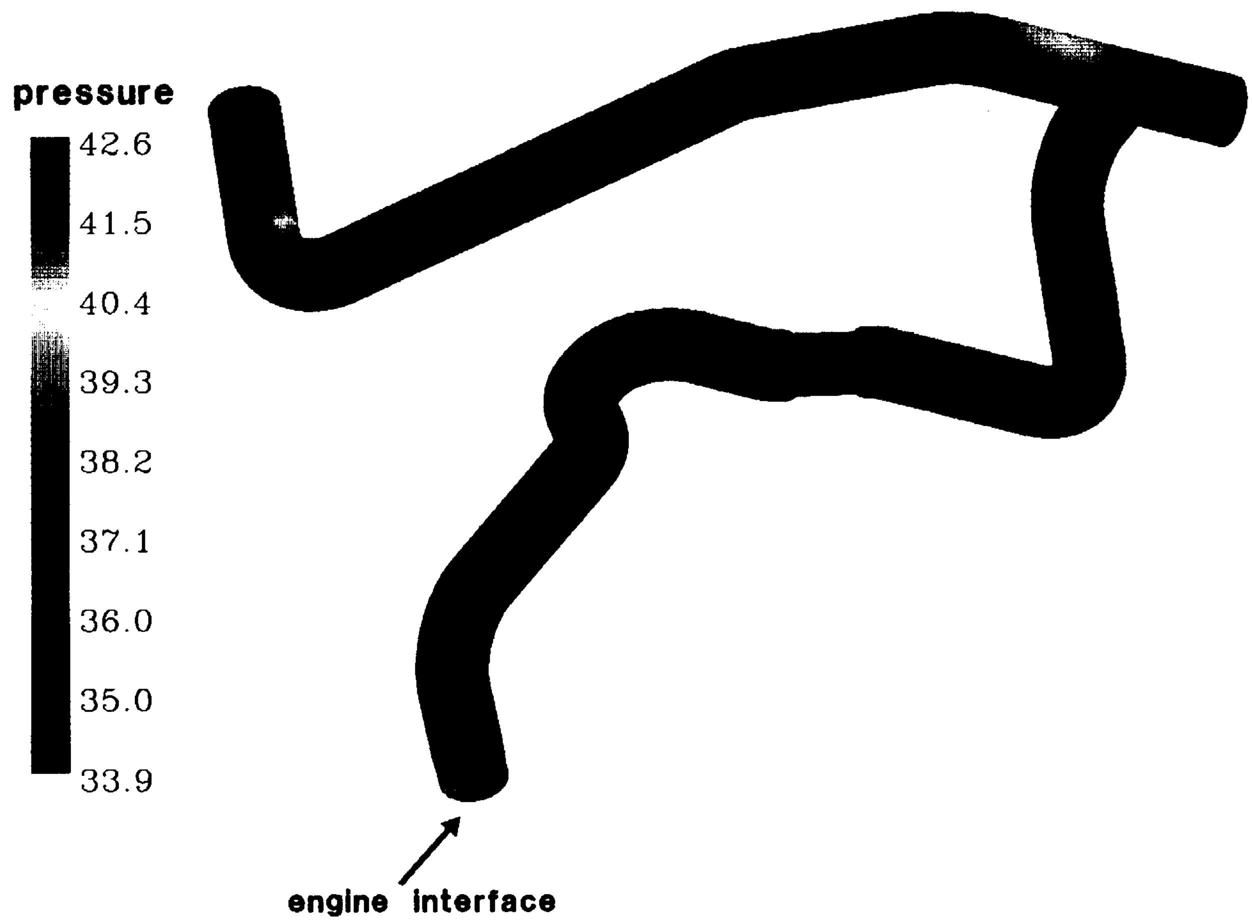
RP-1 Feedline CFD Results: Orbital's Design
Nondimensionalized Axial Velocity at the Engine Interface



X–34 RP–1 Feedline CFD Results



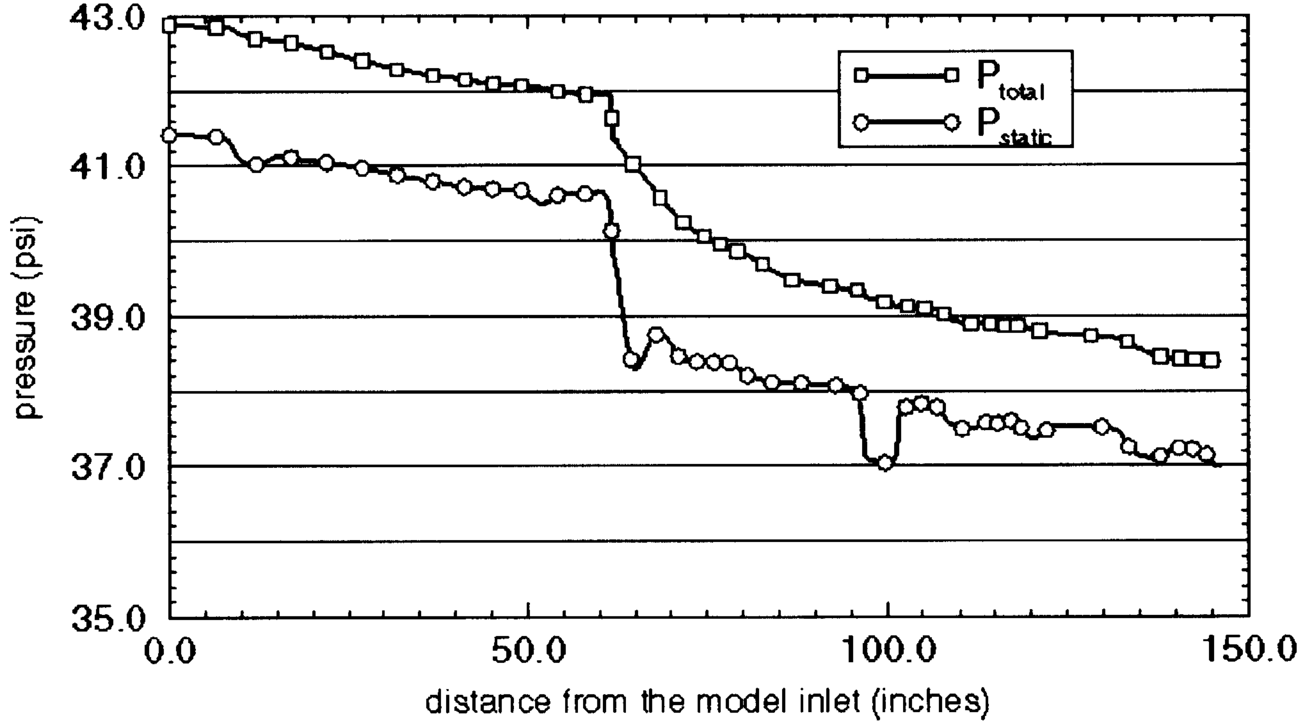
Static Pressure



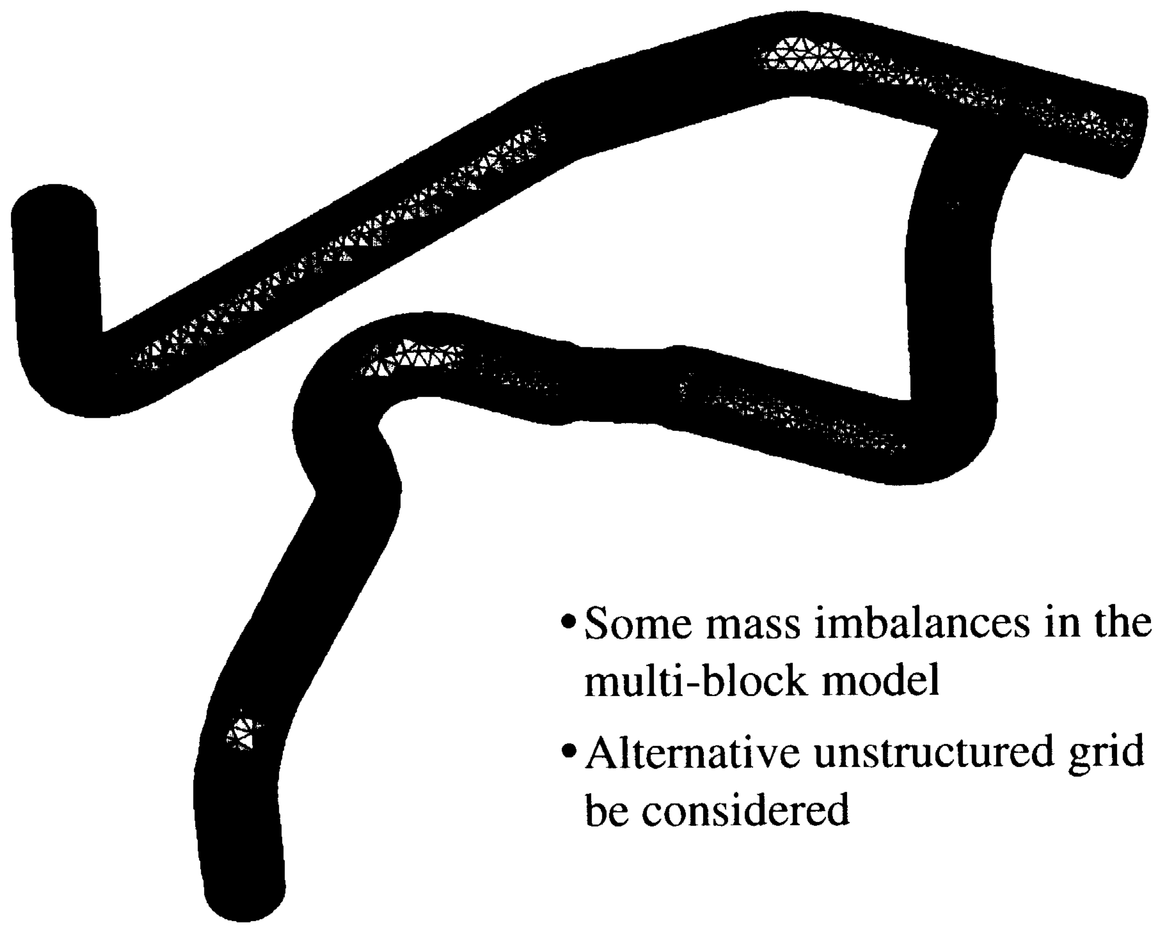
Mass-Averaged Pressure

RP 1 Feedline Mass Averaged Pressure

Referenced to 37 psi. at the engine interface



Finite-Element Model



- Some mass imbalances in the structured, multi-block model
- Alternative unstructured grid model may be considered

Results and Conclusion

Results -
1) Flow separation can be seen in the stagnation region only
2) No flow distortions at the engine interface
3) Pressure drop ($\Delta P = 4.6$ psi) is within acceptable range

Conclusion -
1) New duct design does not have significant affect on the outlet flow
2) No flow straighteners are required
3) Flow development is more favorable in new model although pressure drop is slightly higher