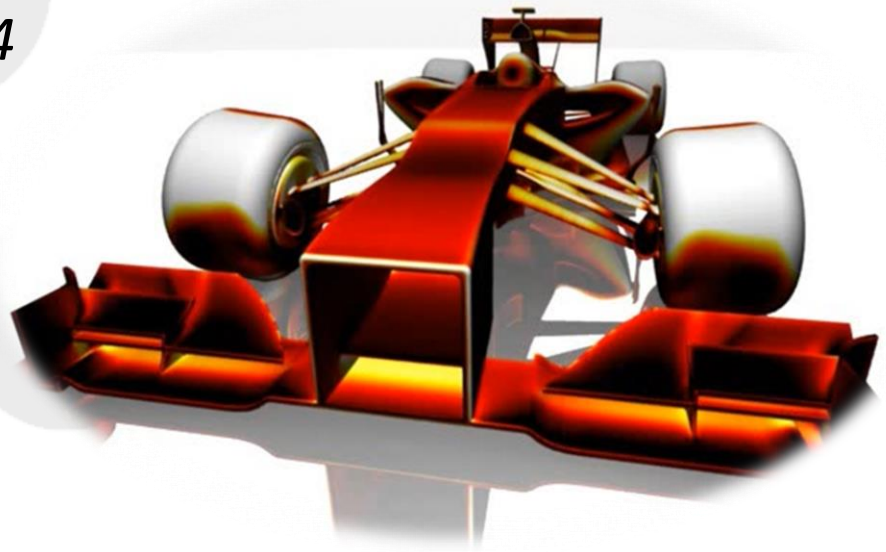
HELYX Coupled Solver

Validation and Performance Profiling

OpenFOAM Workshop 2014

23th-26th June 2014

Zagreb, Croatia

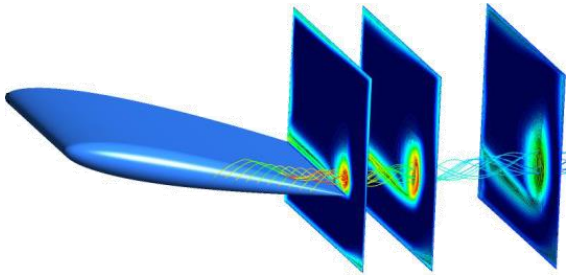


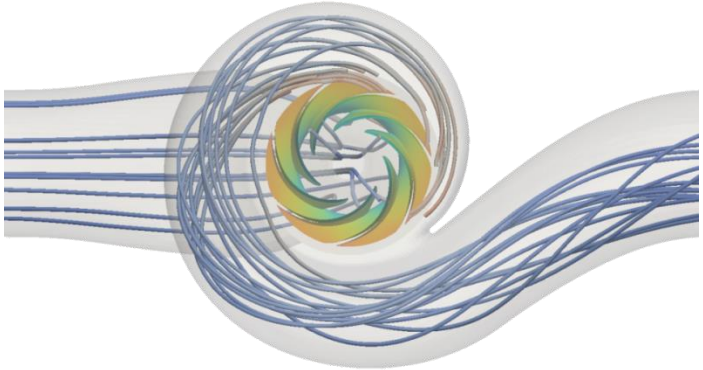
Eugene De Villiers, Engys Ltd.

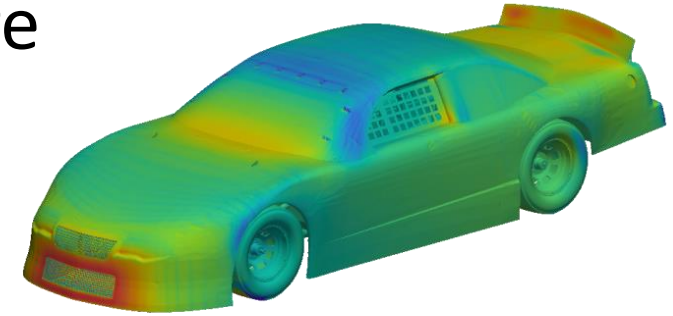
Thomas Schumacher, Engys DE.

HELYX Coupled | Features

- **Fully implicit block coupled solver**
  - Profs. L. Mangani & M. Darwish
  - Block GAMG, Block pre-conditioning, Block turbulence
  - Incompressible single phase
  - Steady/Transient
  - Mesh motion, MRF, Porous
- Fully integrated with GUI and core setup tools
  - Heavily validated and optimised
  - Verified best practices







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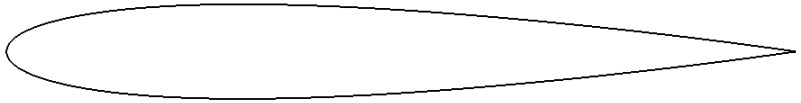
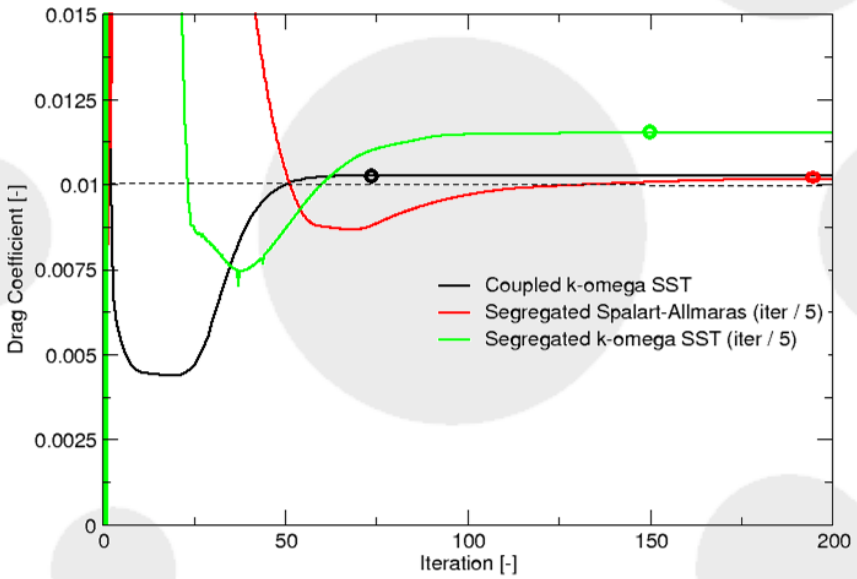
HELYX Coupled | Tripped NACA 0012

- Accuracy verification
  - 2D incompressible
  - Re = 1e6, y^+ = 11
  - 61k cells, 1 core





Solver	C_D	Time to Converge	Speed-up
Exp.	0.01 +- 0.0005		
Segreg. k-ω SST	0.0115	147	
Segreg. S-A	0.01016	176	
Coupled k-ω SST	0.01025	36.75	>4x

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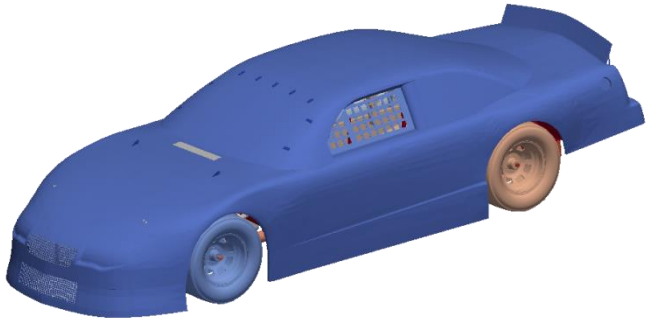
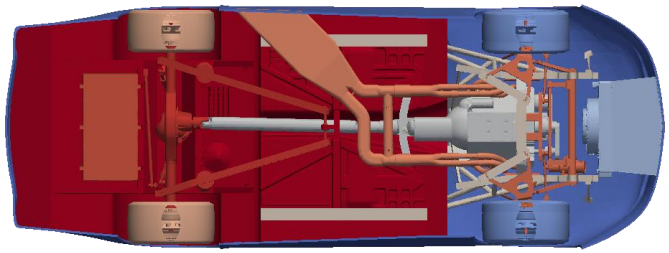
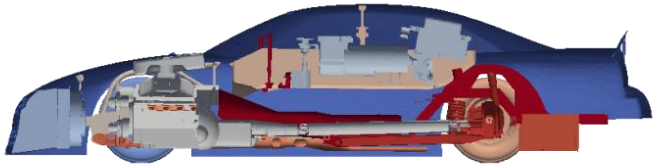
HELYX Coupled | Generic Nascar

- Parallel Scaling performance
- Case info
  - 3D incompressible
  - U = 50 m/s
  - k-ω SST
  - 37 M cells full model
  - Rotating wheels
  - Moving ground
  - Internal and external flow
  - 30, 60, 120 cores







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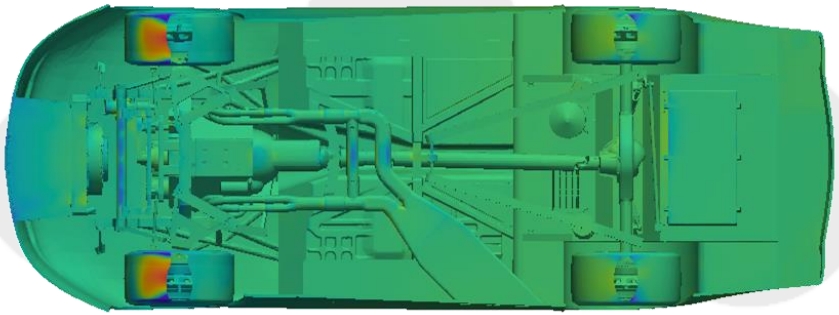
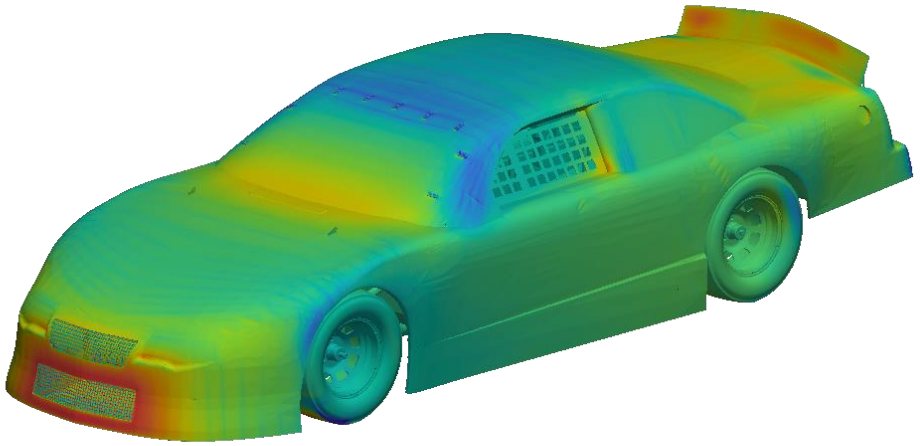
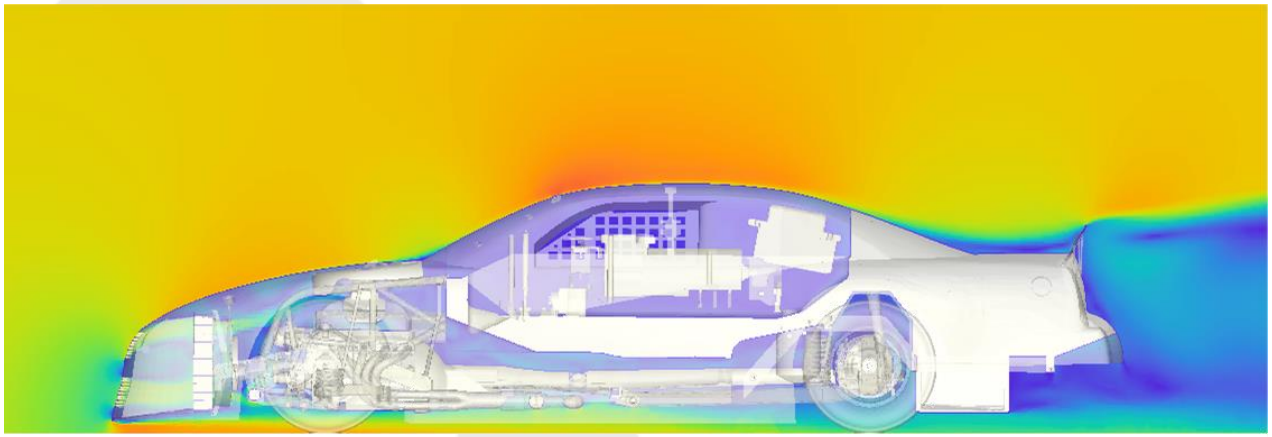
HELYX Coupled | Generic Nascar

- Typical results: C_p & U







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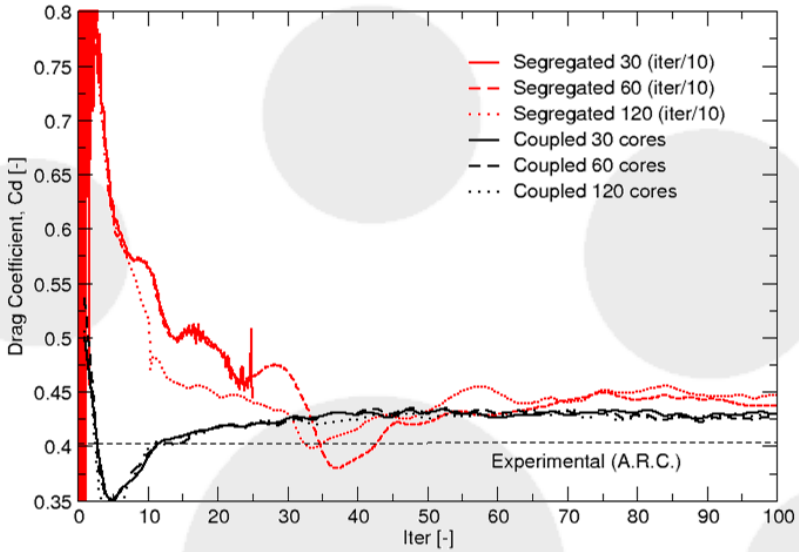
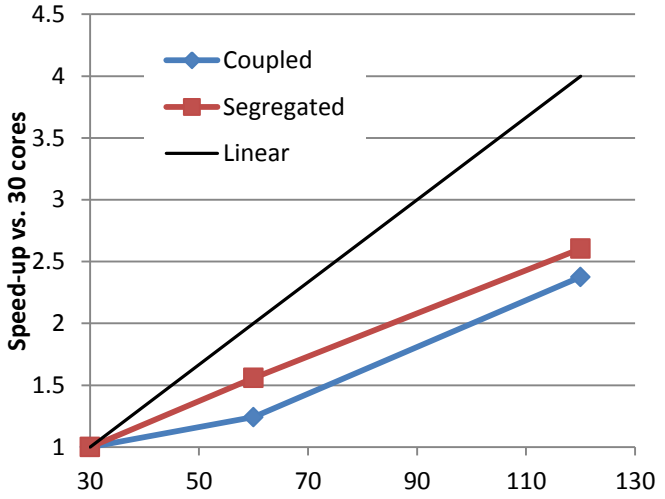
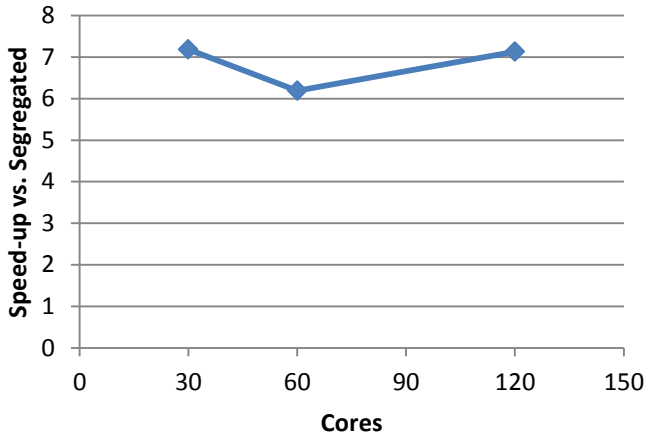
HELYX Coupled | Generic Nascar

- Parallel Scaling performance



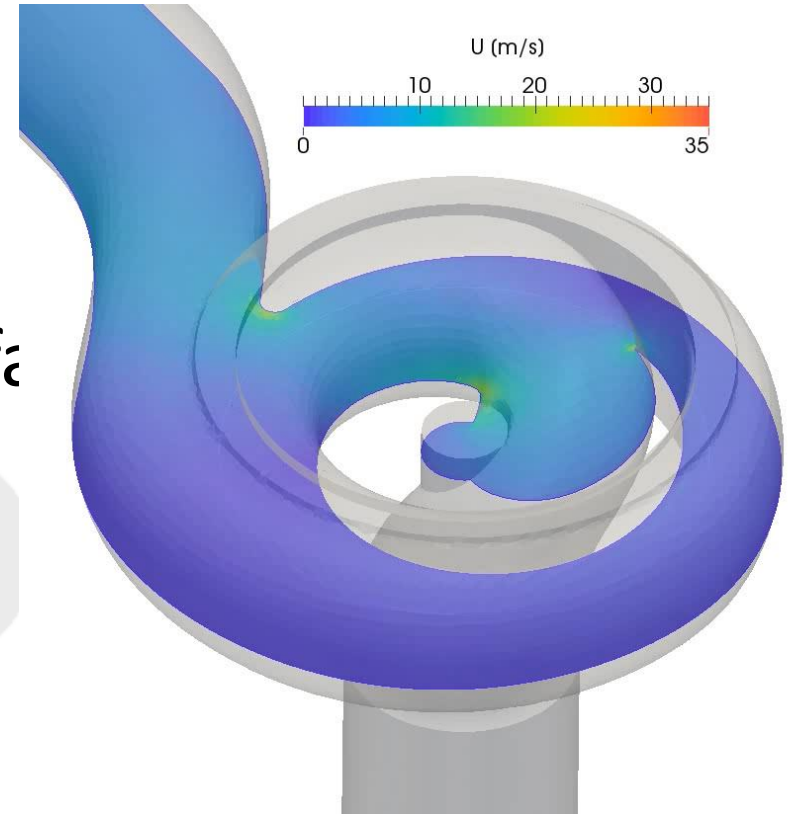




- Improved accuracy
- Slightly reduce scaling
- ~7x speed-up

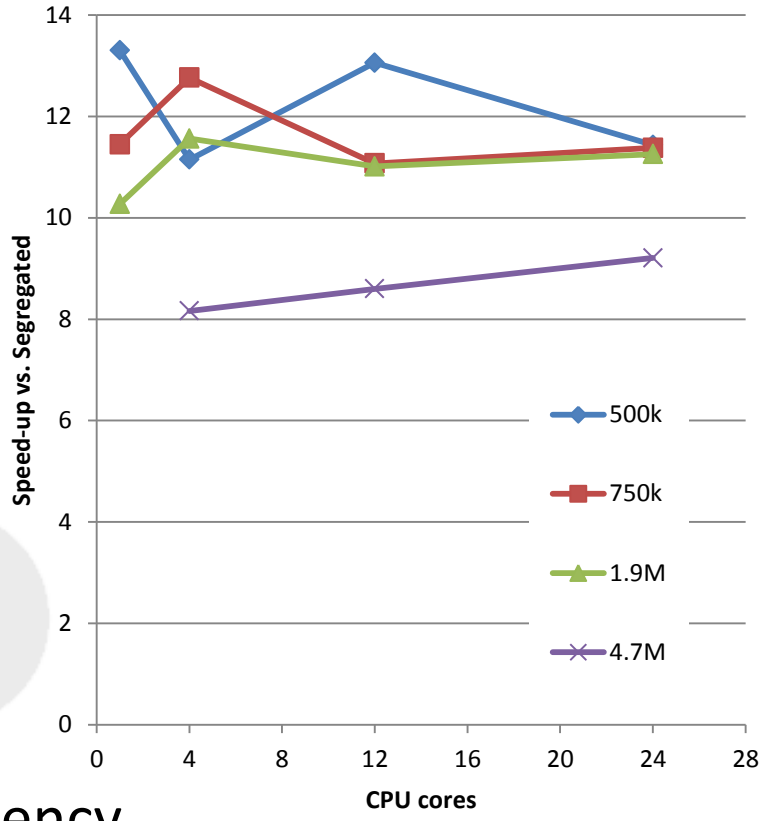
HELYX Coupled | Single Channel Pump

- Performance characterisation
- Steady state + frozen rotor
  - 4 mesh sizes
  - Parallel scaling
- Transient with sliding interfa
  - 5 time-step sizes
  - 2 rotation speeds



HELYX Coupled | Single Channel Pump

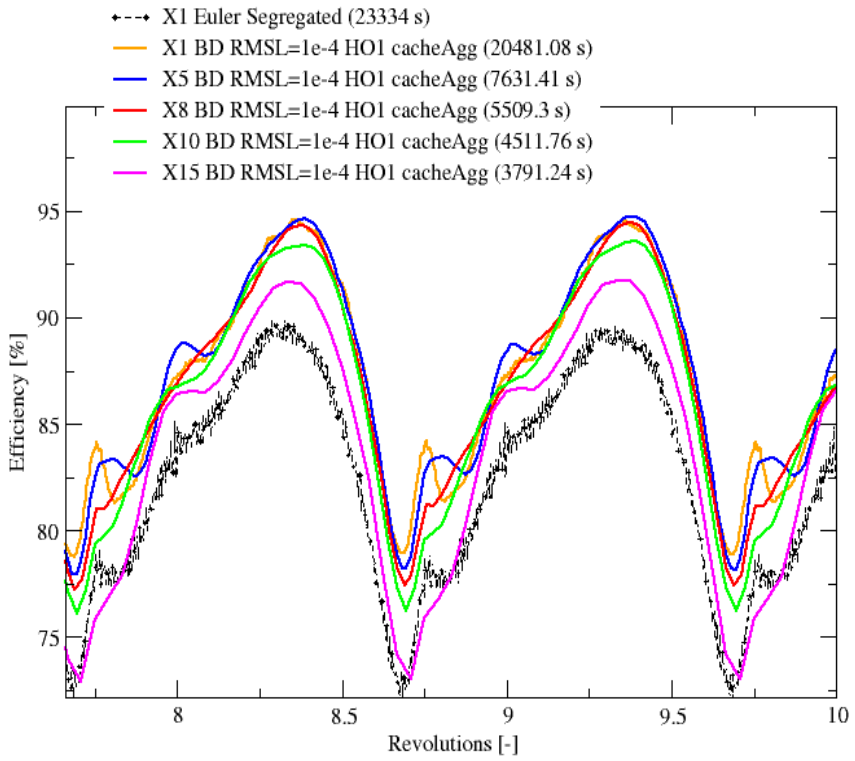
- Steady state + MRF
  - k-ω SST
  - Min scaling >8x
  - Max scaling ~13.5x
  - Mean scaling ~10x
  - Similar parallel scaling to segregated
  - Results comparable
    - 83% (S) vs. 84% (C) pump efficiency



HELYX Coupled | Single Channel Pump

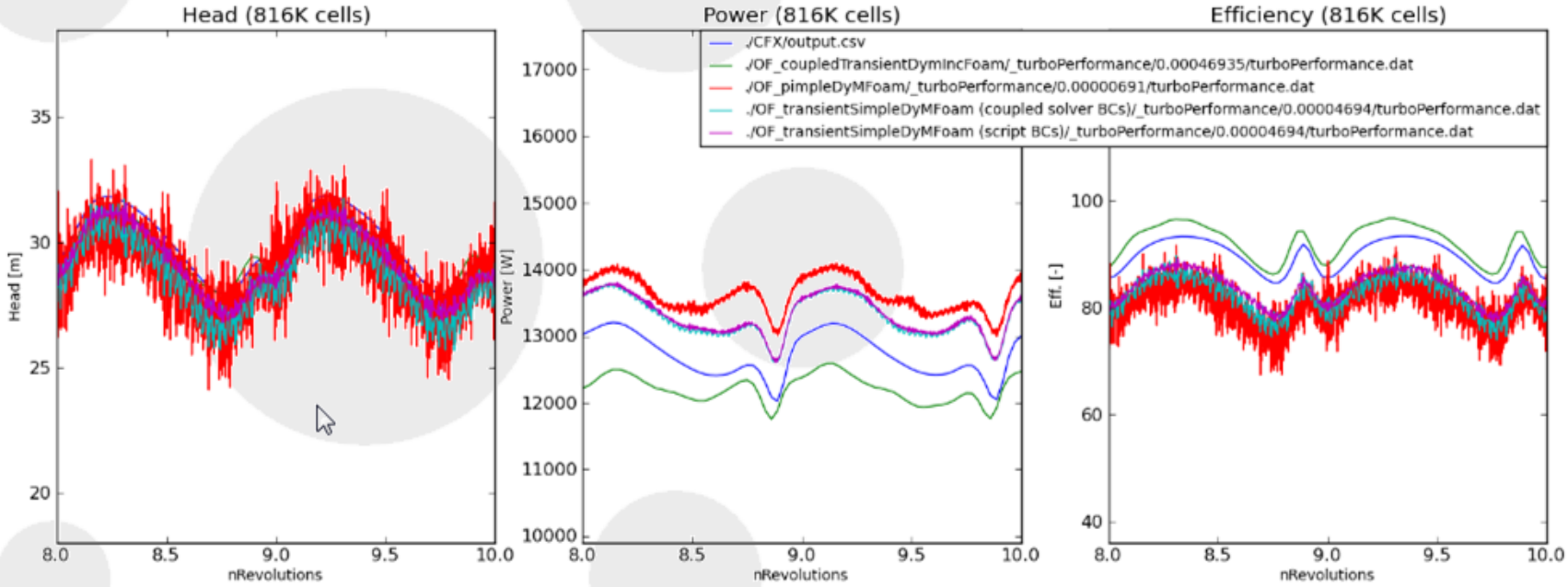
- Transient with sliding interface
  - 500k cells, 12 cores, different time step sizes
  - ω = 308.92 rads/s

Case name	$\partial\alpha$ [°]	Max Efficiency [%]	Mean Efficiency (final 3 revs) [%]	Clock Time [s]	Speed-up
Segregated X1	1	89.5	82.96	23334	-
Coupled X1	1	94.7	87.60	20481.1	1.14
Coupled X5	5	94.8	87.79	7631.4	3.06
Coupled X8	8	94.4	87.28	5509.3	4.24
Coupled X10	10	93.5	86.74	4511.8	5.17
Coupled X15	15	91.7	84.55	3791.2	6.15



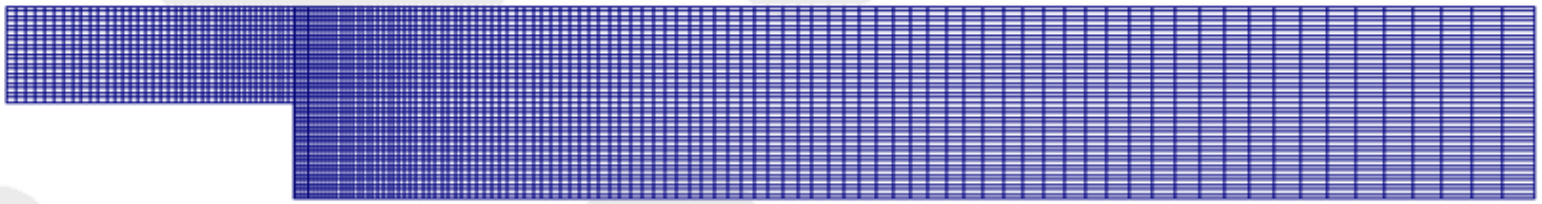
HELYX Coupled | Single Channel Pump

- Transient with sliding interface
  - 1.9 M cells
  - ω = 371.85 rads/s
  - ~accuracy and >speed vs. commercial coupled solver



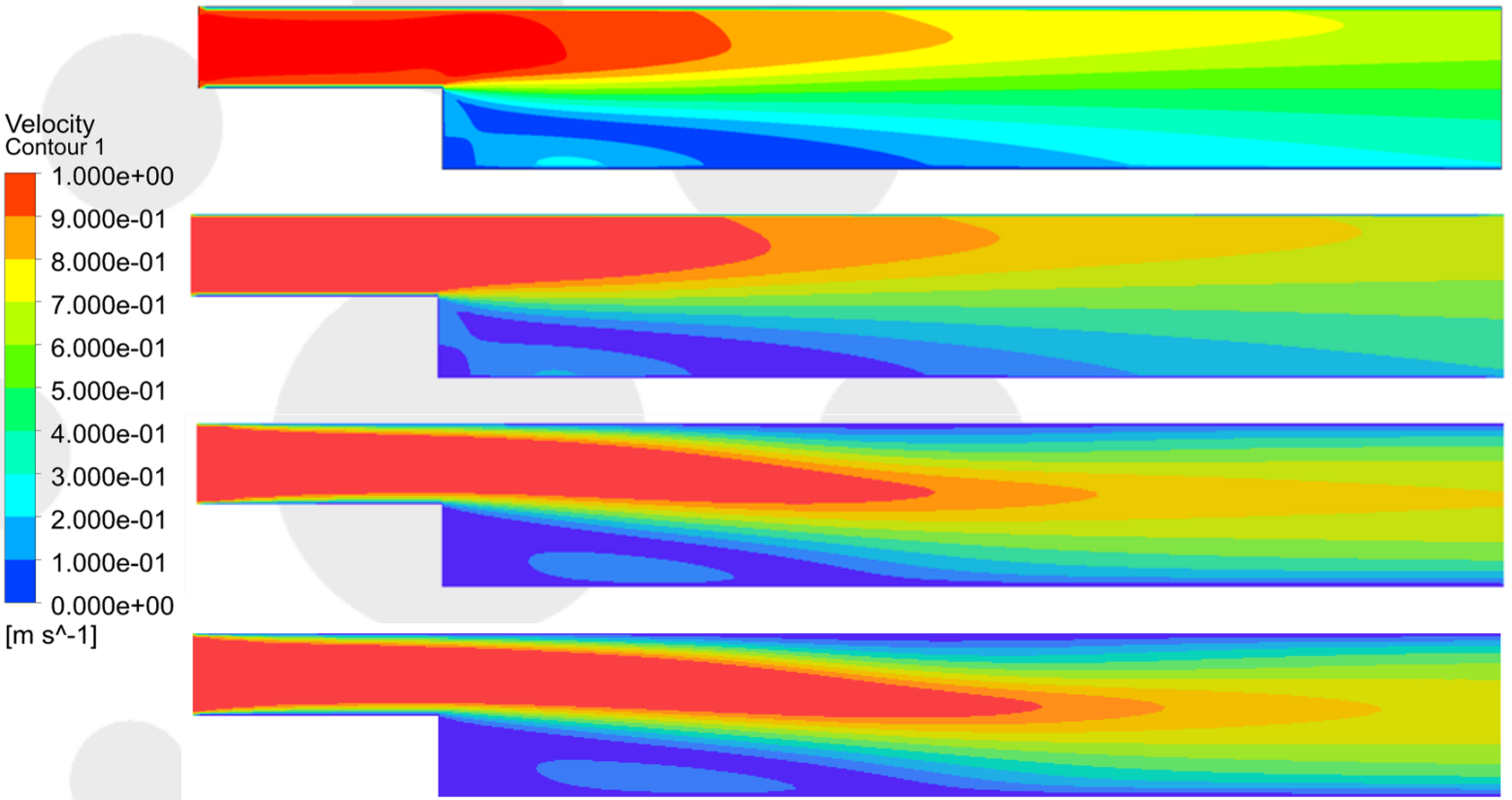
HELYX Coupled | Backward Facing Step

- Comparison with foam-extend v3.1 & CFX
  - pUcoupledFoam tutorial case
- Incompressible
  - Re = 333
  - Uinlet = 1 m/s
- Grid: 9962 cells



HELYX Coupled | Backward Facing Step

- CFX vs. HELYX vs. foam-extend vs. simpleFoam
- Velocity



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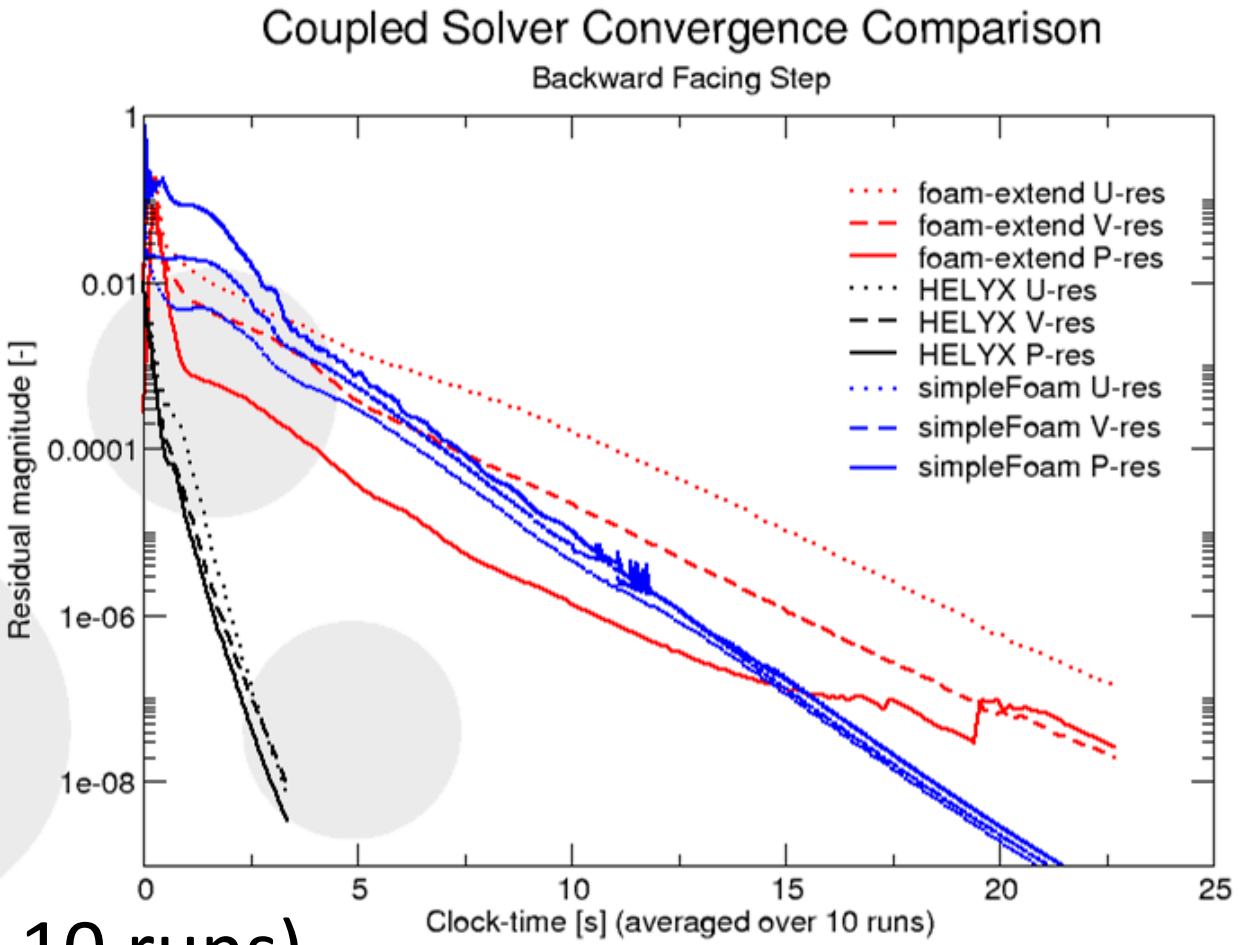
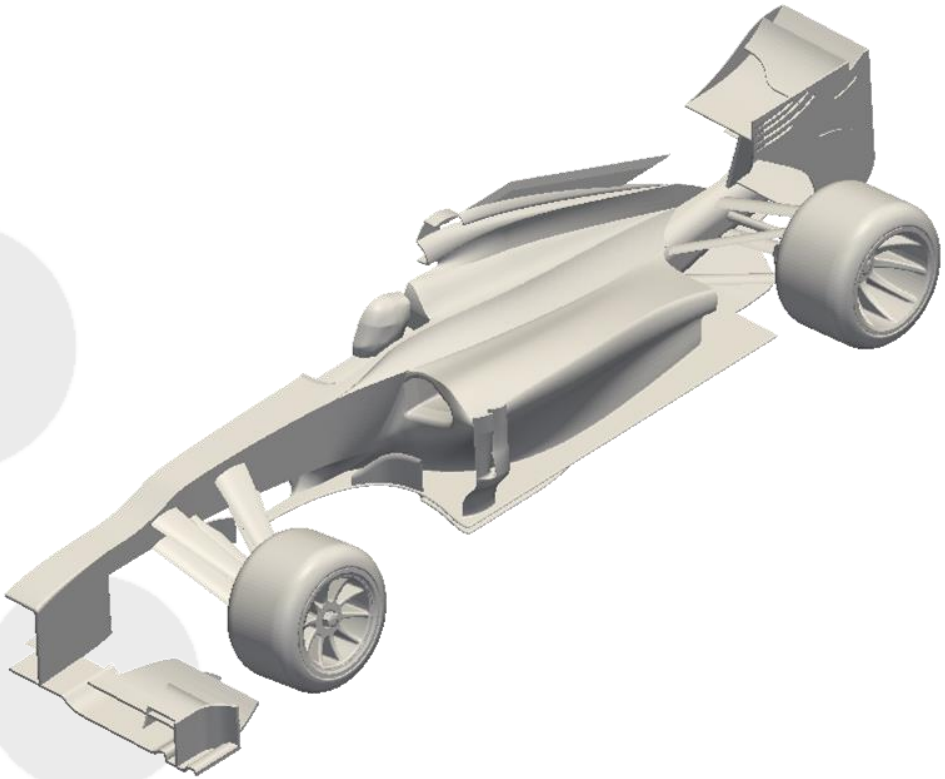
HELYX Coupled | Backward Facing Step

- foam-extend:
  - 250 iterations,
  - 22.8 s
- HELYX:
  - 75 iterations,
  - 3.4 s
  - 6.7x faster
- (averaged over 10 runs)
- Identical residual definitions



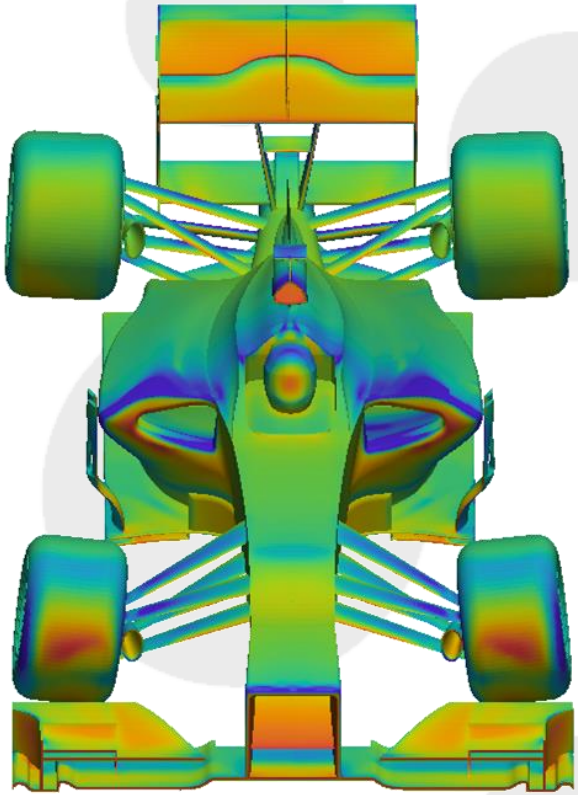
HELYX Coupled | Generic F1

- Grid size scaling
  - 3D incompressible
  - U = 70 m/s
  - k-ω SST
  - Rotating wheels
  - Moving ground
  - 16, 24, 33 & 66 M cells
  - Symmetry plane
  - 120 cores
  - Thanks to Samuel Silva for providing the model

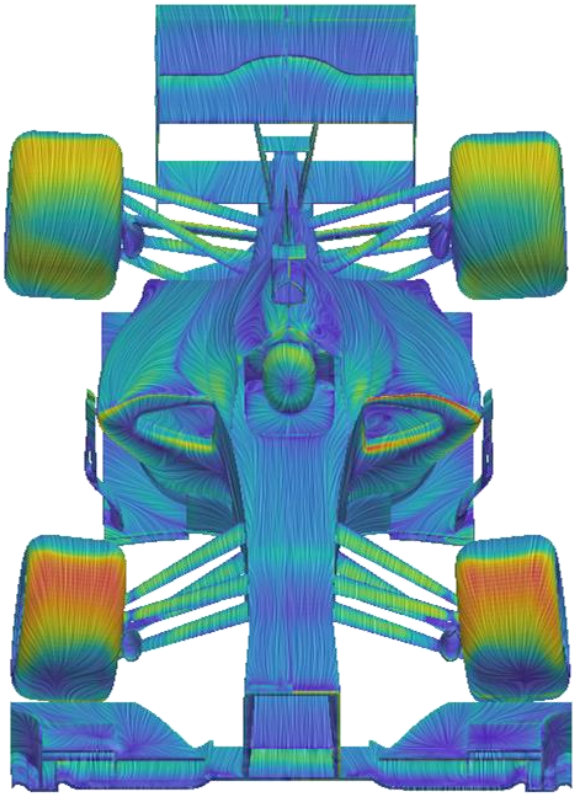


HELYX Coupled | Generic F1

- Comparative results: C_p & τ_w



Coupled



Segregated

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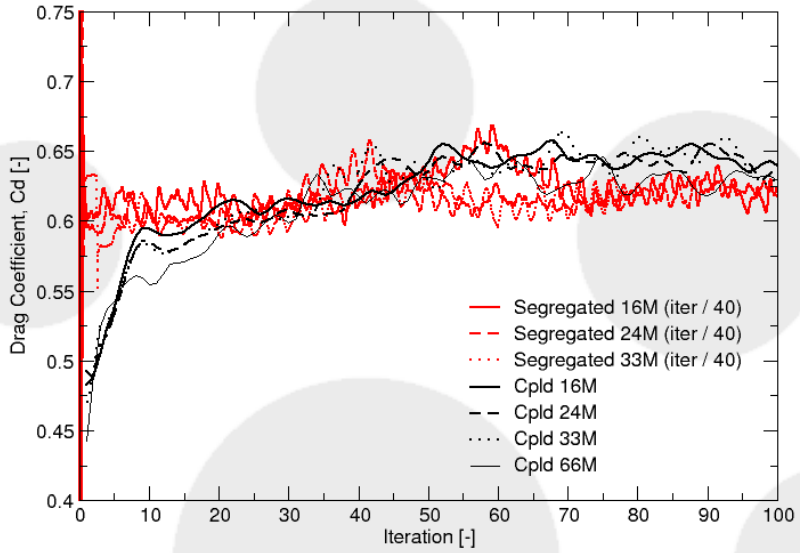
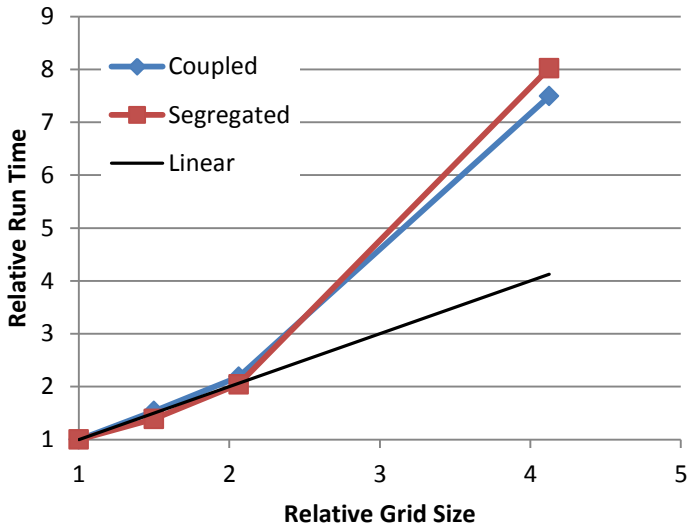
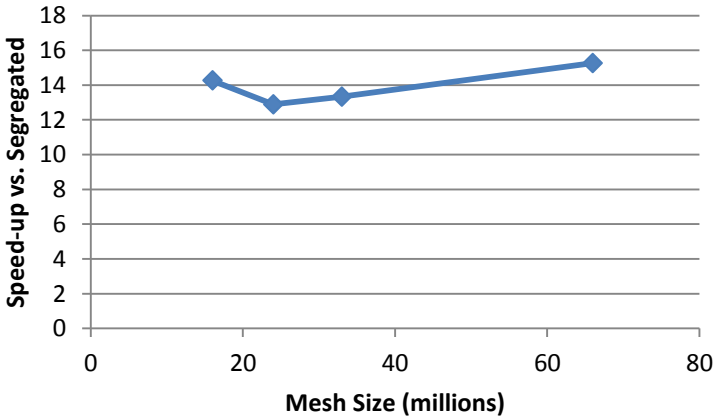
HELYX Coupled | Generic F1

- Grid size scaling





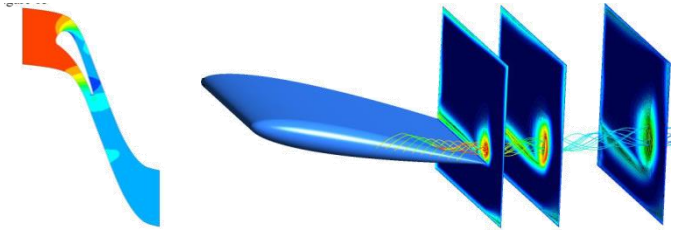


- Slightly better for large mesh
- ~13x speed-up (?)

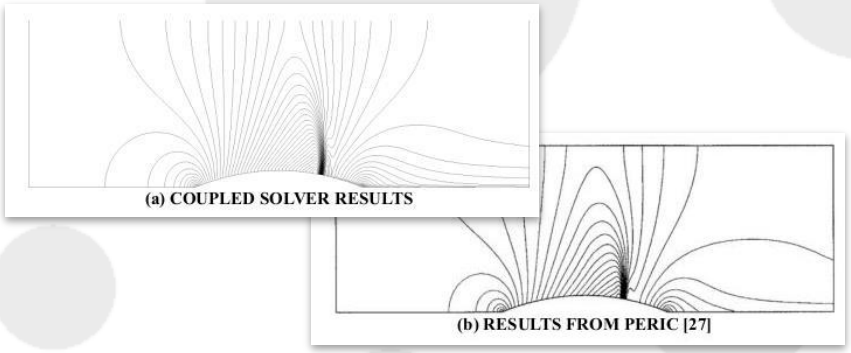
HELYX Coupled | Compressible

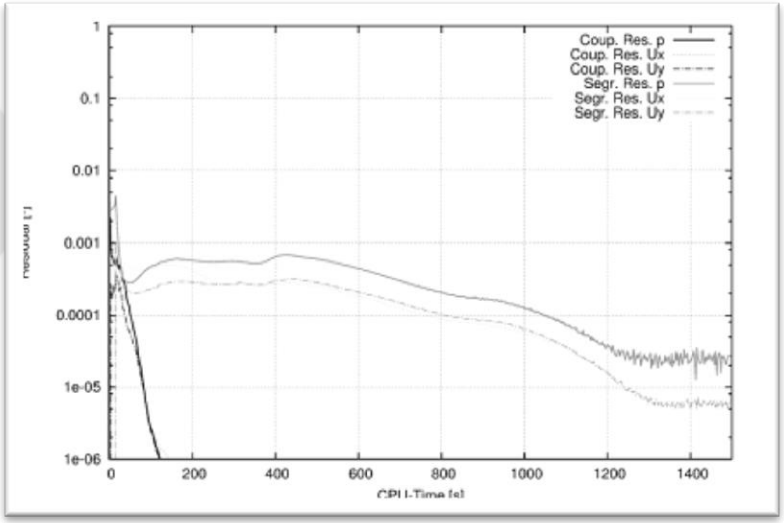
- Coming soon

Case	nCells	Speed-up
Turbine blade (C3X)	44k	21x
NACA 0012	650k	10x



- Faster residual convergence
- All Mach numbers
- Matches experiment!





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HELYX Coupled | Conclusions

- Available as plug-inn for HELYX
- Up to 15x faster convergence than segregated
- Excellent grid size and parallel scaling
- More accurate, more robust (fewer failed runs)
- Significantly faster (x7) than foam-extend coupled solver
- Competitive with best-in-class commercial alternatives

HELYX Coupled | Questions?