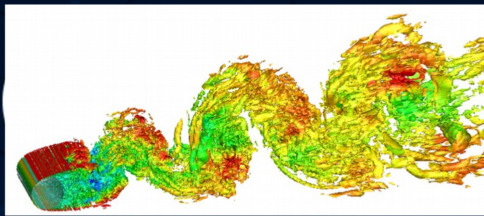
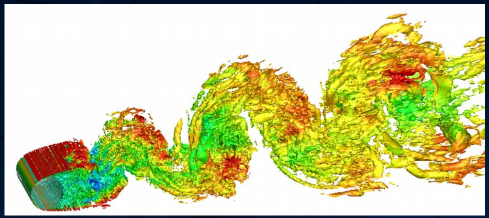


Case BI1 Vortex transport by uniform flow

Forth International High-Order CFD Workshop

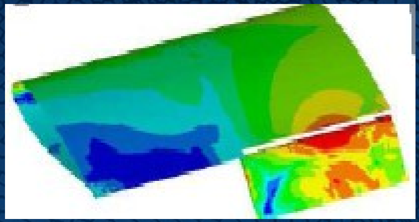
June 4th-5th 2016, Crete Island, Greece

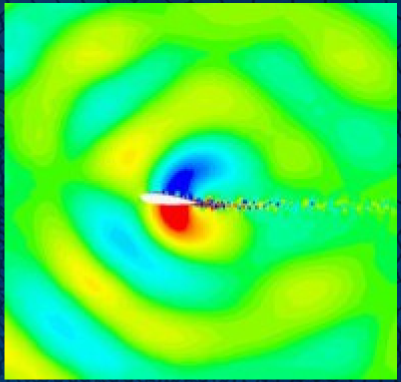
Doru Caraeni,
CD-Adapco, a Siemens business.

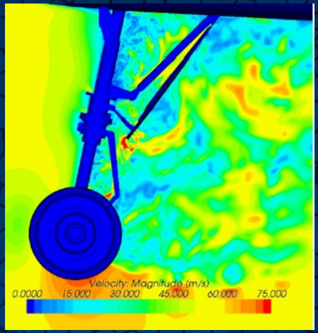


Vortex transport by uniform flow

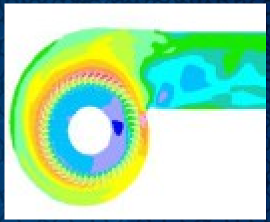
High-Order CFD targeted for high fidelity simulations

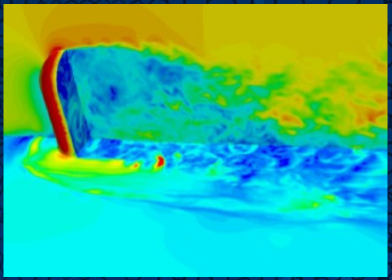




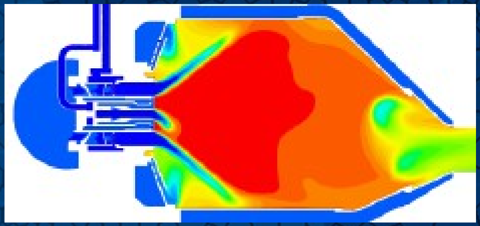


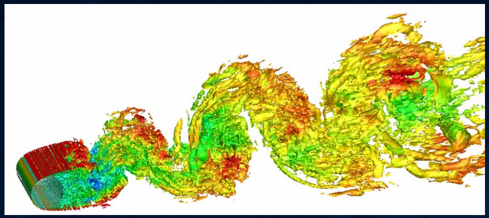
- ***Aerospace***
  - *wing transition,*
  - *high-lift devices*
  - *engine noise*
  - *landing gear aeroacoustics*
- ***Automobiles/Trucks***
  - *full vehicle aerodynamics,*
  - *mirror, window, sunroof aeroacoustics,*
  - *HVAC fans, ducts, nozzles, turbochargers*





- ***Combustion***
  - *gas turbine, reciprocating engine*
- ***Nuclear*** *(steam line/T-junctions, etc.)*
- ***Wind turbines***





Vortex transport by uniform flow

High-Order CFD targeted for high fidelity simulations

Numerical solution of (unsteady) turbulent flows requires:

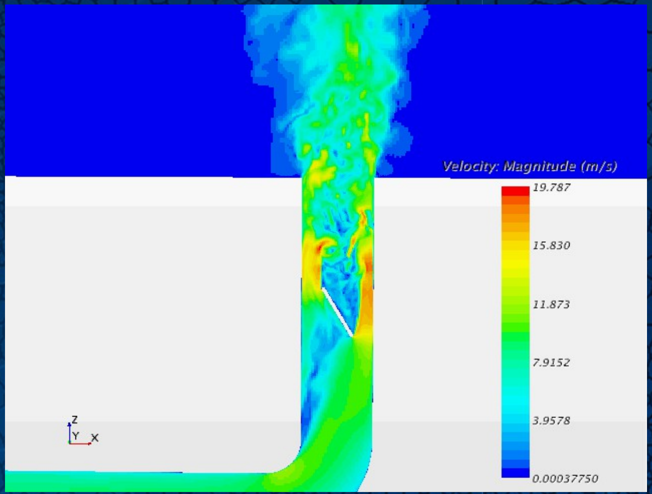
- Accuracy (+ conservation, realizability)

- Robustness (large industrial meshes)

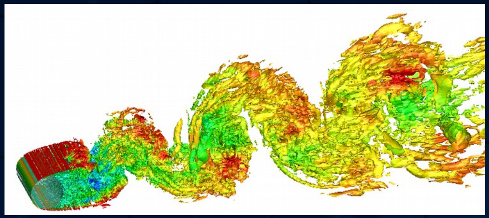
- Efficiency (CPU, 10-100 k cores)

Other characteristics:

Preserving vorticity (inviscid flow)
Preserving kinetic energy(incompressible)



HVAC WALE LES simulation ("3rd order" MUSCL/CD FVM)



Vortex transport by uniform flow

Case definition:

$$[0, L_x] \times [0, L_y] = [0, 0.1] \times [0, 0.1]$$

pressure $P_\infty = 10^5 N/m^2$, temperature $T_\infty = 300K$ and Mach number $M_\infty = 0.05, 0.5$

a vortex of characteristic radius $R = 0.005$ and strength $\beta = 0.02, 0.2$

$$(X_c, Y_c) = (0.05, 0.05)$$

$$u_0 = U_\infty (1 - \beta \frac{y - Y_c}{R} e^{-r^2/2})$$

$$v_0 = U_\infty \beta \frac{x - X_c}{R} e^{-r^2/2}$$

$$r = \sqrt{(x - X_c)^2 + (y - Y_c)^2} / R$$

$$U_\infty = M_\infty \sqrt{\gamma R_{\text{gas}} T_\infty}$$

$$T_0 = T_\infty - 0.5(\beta U_\infty e^{-r^2/2})^2 / C_p$$

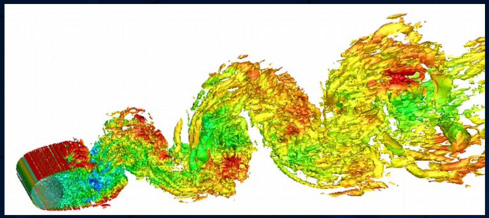
$$\rho_0 = \rho_\infty (T_0/T_\infty)^{1/(\gamma-1)}$$

$$C_p = \gamma R_{\text{gas}} / (\gamma - 1)$$

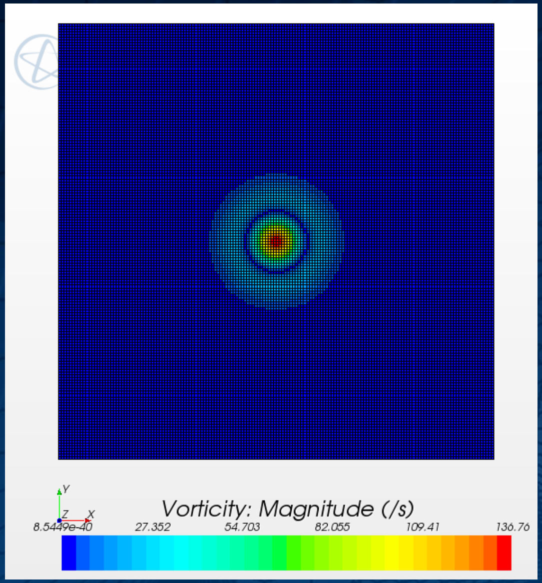
ratio of specific heats $\gamma = 1.4$

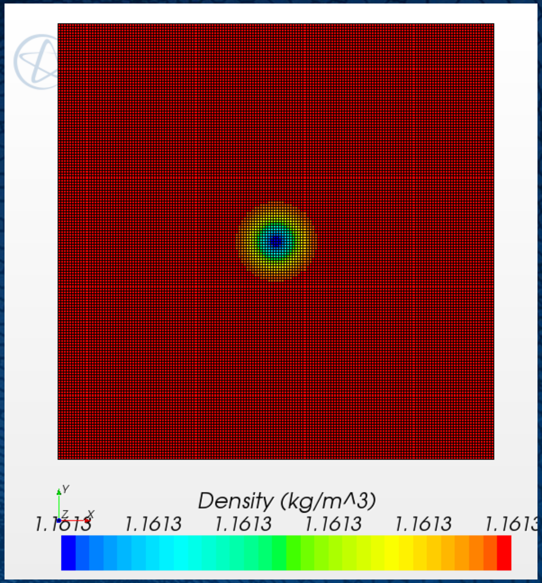
$$P_0 = \rho_0 R_{\text{gas}} T_0$$

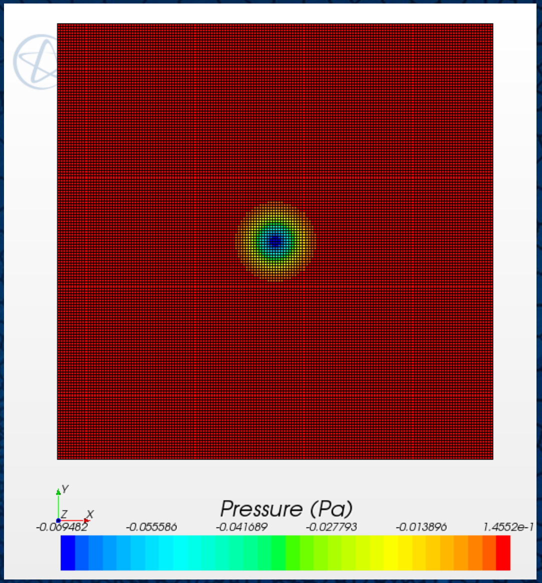
gas constant $R_{\text{gas}} = 287.15 J/kg\,K$



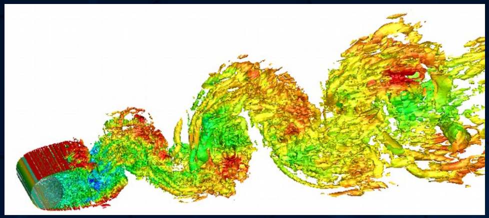
Vortex transport by uniform flow







- Very low Mach number flow (Mach = 0.05)
- Large disparity between the sound and flow speed
- Difficulties expected for explicit compressible solvers due to time-step restriction



Vortex transport by uniform flow

Participants:

- Philip Johnson (Scientific Computing and Flow Physics Laboratory, University of Michigan, Ann Arbor, USA)

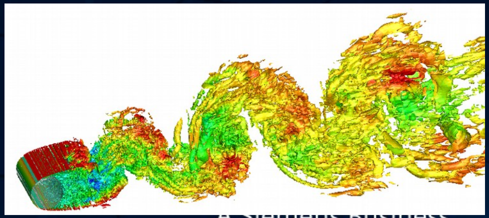
  ** P1,P2 DG (w/ compact solution enhancement), 4^{th} order explicit RK,*

- Shengye Wang, Dan Xu, Xiaogang Deng (College of Aerospace Science And Engineering, National University of Defense Technology, Hunan, People's Republic of China)

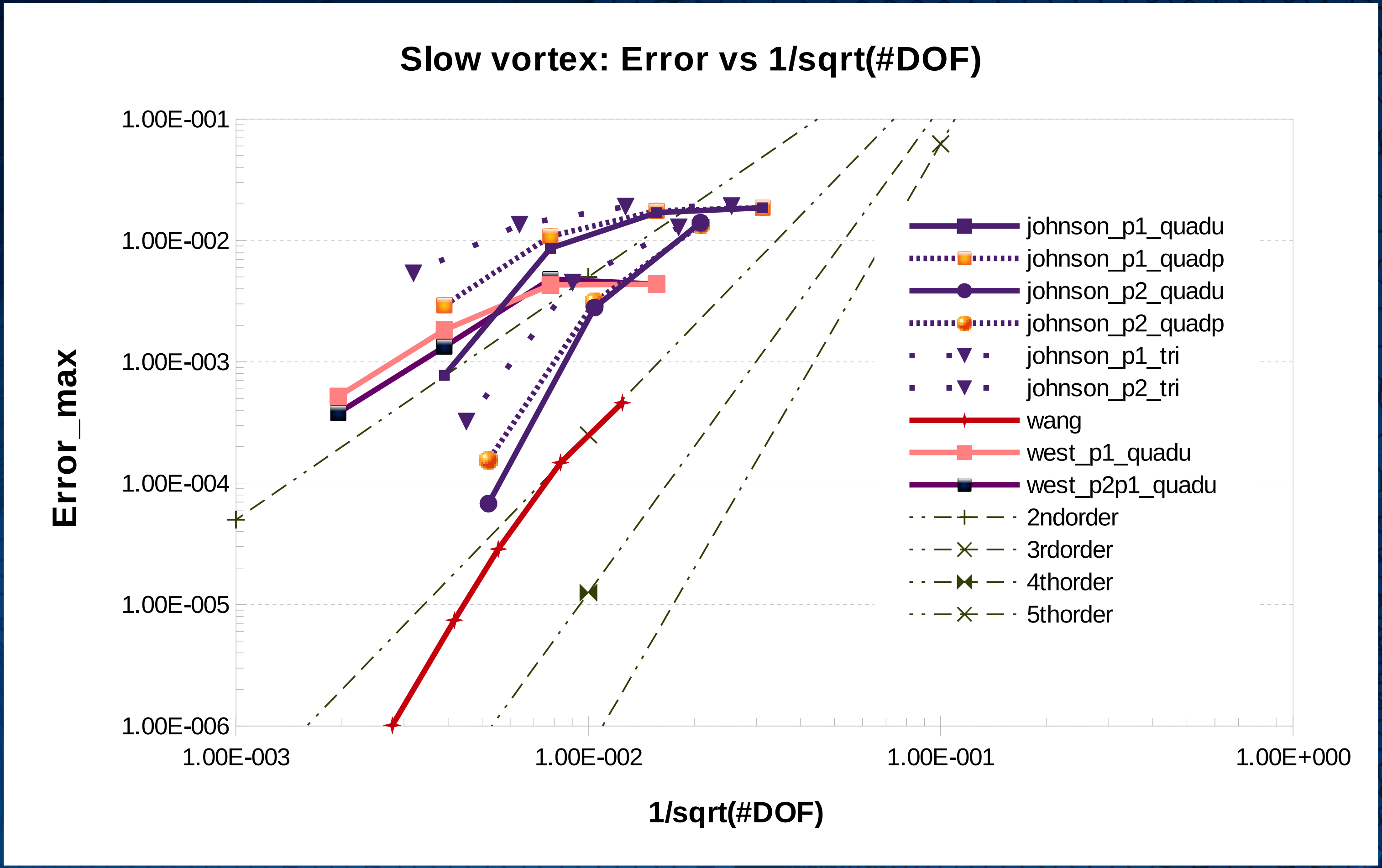
** 5th-order finitedifference scheme WCNS-E-5, w/ Roe FDS and 3-stage RK*

- Alastair West (CD-adapco a Siemens business, London, UK)

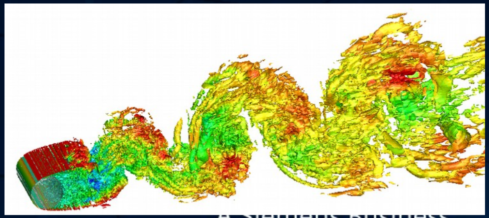
** Two 2^{nd} order schemes (p1-BCD and 'p2'-MUSCL/CD), Roe-FDS with low-Mach preconditioning, implicit dual-time stepping scheme*



Vortex transport by uniform flow

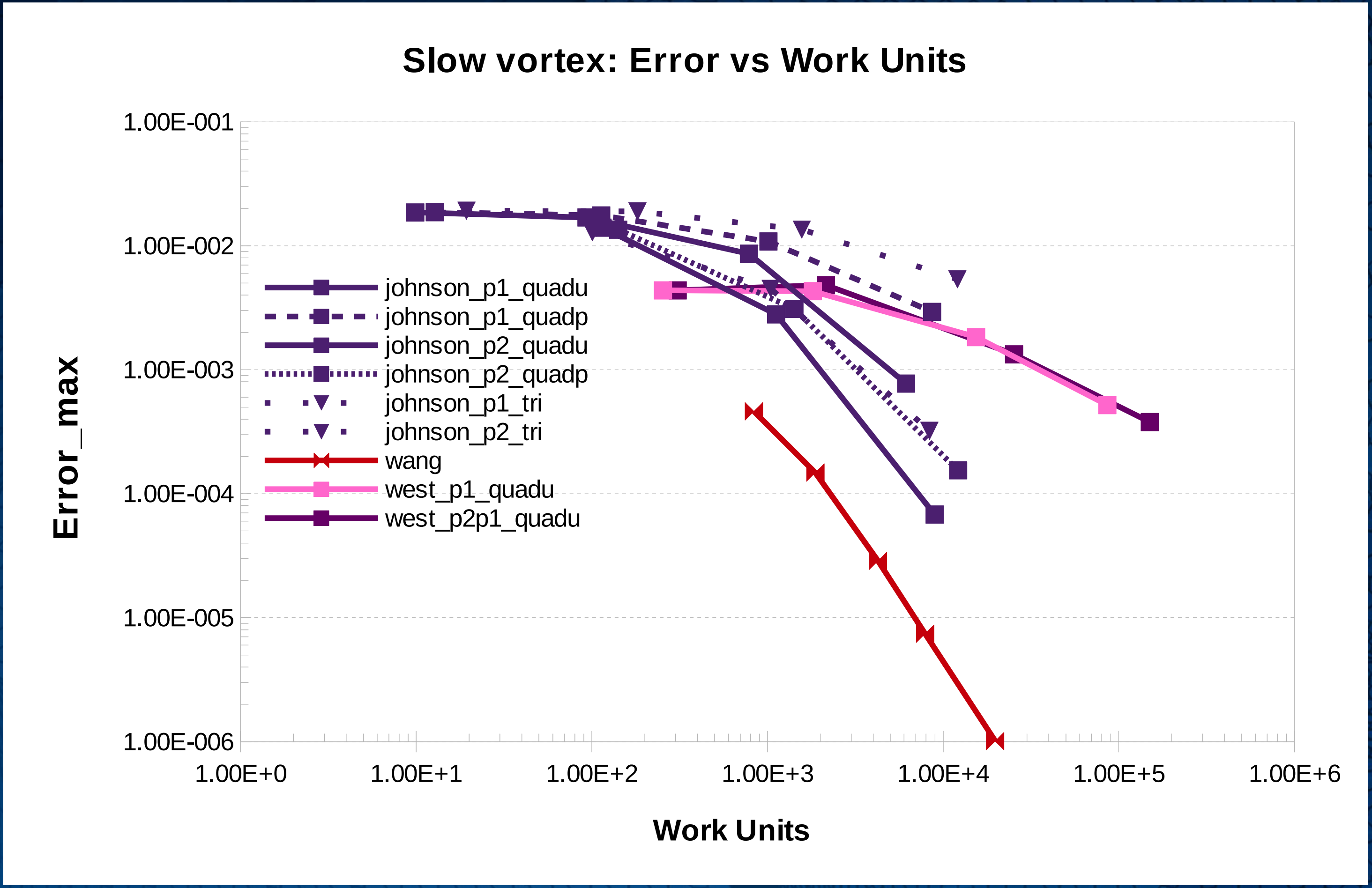


Slow vortex (Mach 0.05)

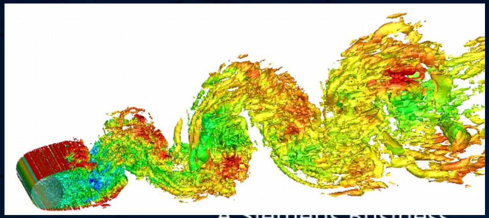


A Siemens Business

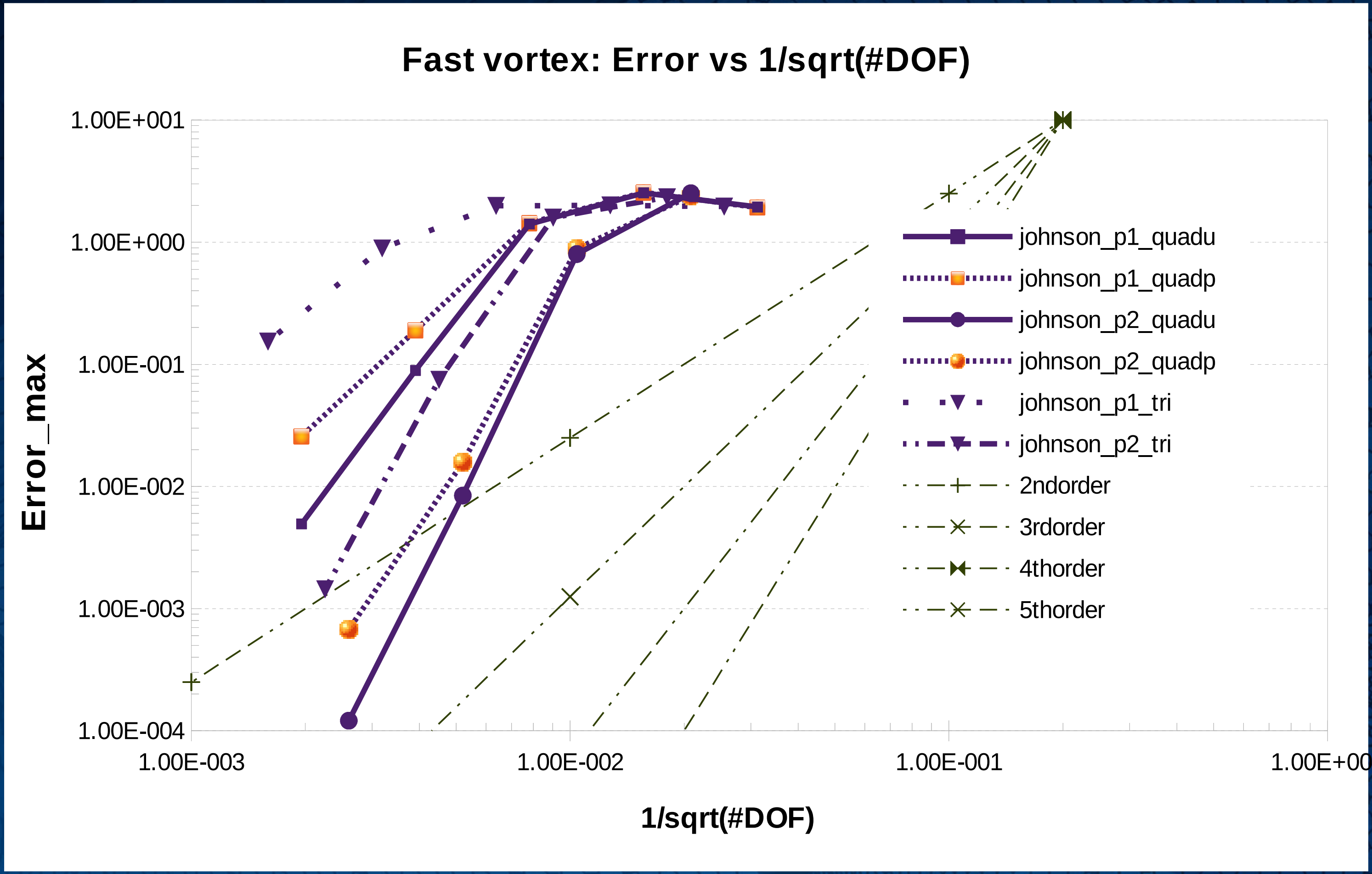
Vortex transport by uniform flow



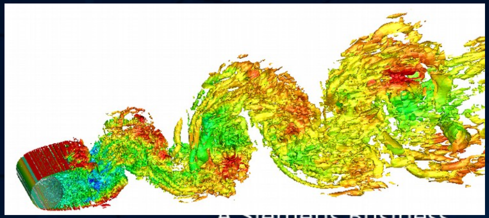
Slow vortex (Mach 0.05)



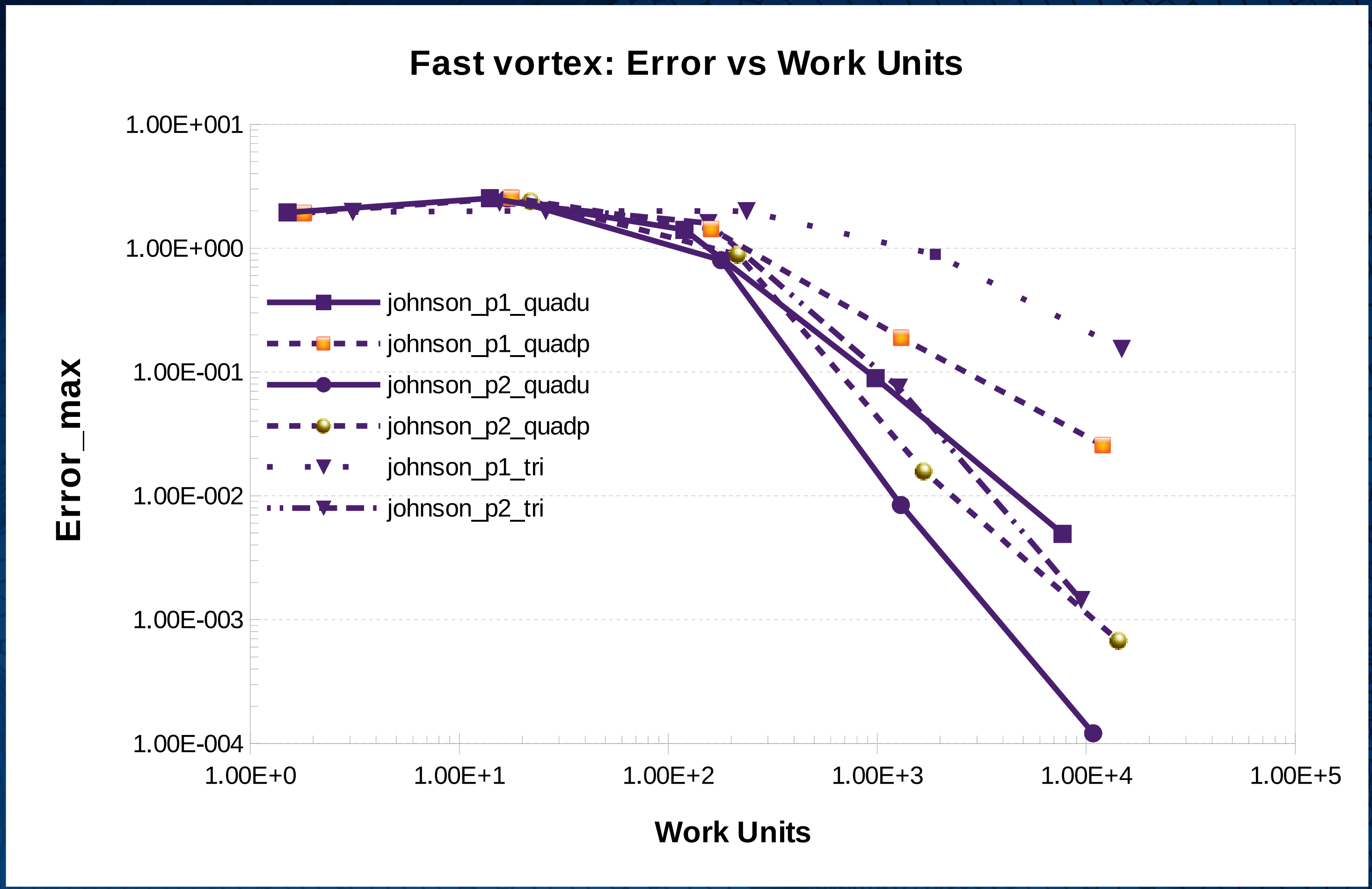
Vortex transport by uniform flow



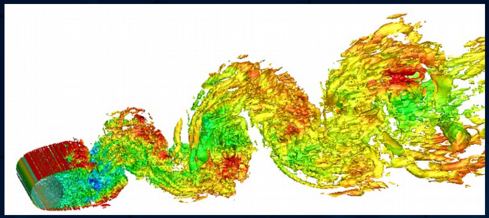
Fast vortex (Mach 0.5)



Vortex transport by uniform flow



Fast vortex (Mach 0.5)



Vortex transport by uniform flow
Summary

I

- *significant advantage of using HO time/space for high fidelity simulations*

- *FD Methods are well suited (CPU/accuracy) but not applicable to complex industrial meshes*

- *large variability of results for various low/high order methods*

Results show that HO methods have the potential to provide leap in performance, when solving unsteady turbulent flows (LES/DES)