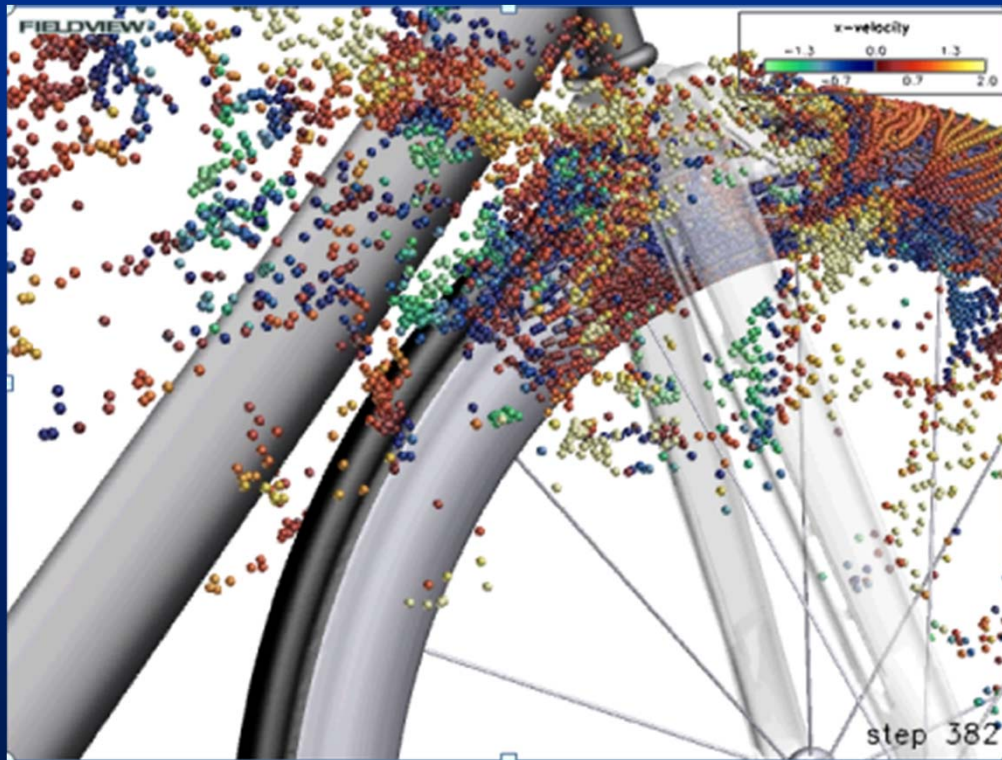


# High Performance Unsteady Workflows with STAR-CCM+



Steve M. Legensky  
Founder & Gen. Mgr.  
Intelligent Light

# Agenda

- Intelligent Light
- Background of Bike Wheel Aerodynamic Study
- Scope & Methodology of Current Work
- Results and Benefits of *XDB Workflow*
- Visualization of Unsteady Q Criterion in *FV13*

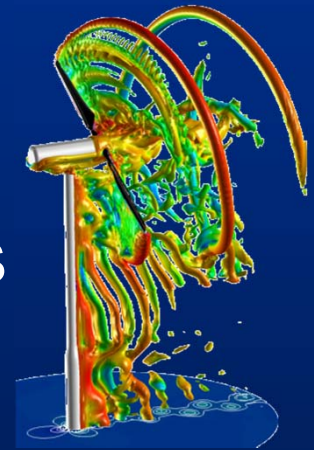
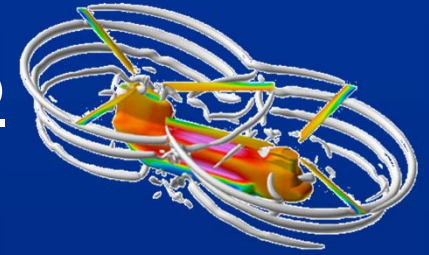
# Intelligent Light

- **Established in 1984**  
*26 years in July 2010!*  
*Global Customer Base*
- **Two components to our business:**
  - FieldView Software
  - Applied Research Group
    - Customer-driven R&D
    - CFD & Post-processing Research
    - CFD for Wind Energy



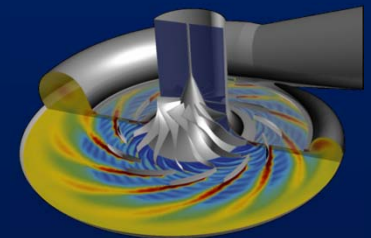
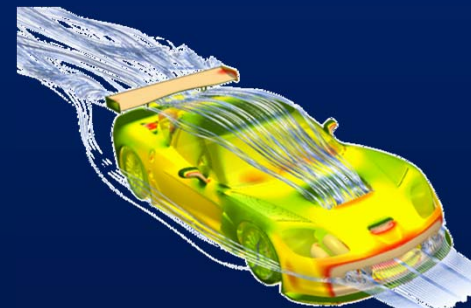
## Our Mission

To help our customers using CFD to do more with less and make better decisions



How we accomplish our mission:

- CFD post-processing products & methods
- Workflow automation
- Development of new CFD methodologies



# Serving the CFD Community

Post-processing

**FieldView Family**

Workflow

Data Management  
Automated Reports  
Pre/Solve/Post Suite

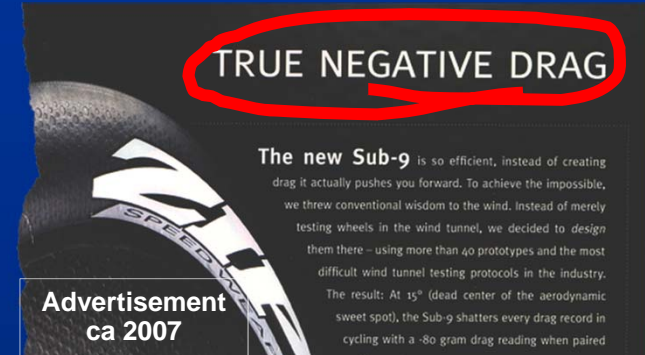
CFD Solver  
Technology

Co-processing  
Efficient File I/O  
GPGPU Accelerators  
New Algorithms

# Bike Wheel CFD Background

# Background

- Wind Tunnel testing used extensively in cycling for over 20 years
  - Typical for Zipp, 85h at \$850/h, run 3 or 4 times per year
- Benefits to cyclists from Wind Tunnels
  - Improved knowledge of positioning
  - Significant improvement in the equipment design & performance
- Current status
  - Still considerable variation in design
  - UCI rule changes & enforcement can be rapid & unpredictable
  - Wind Tunnel reaching its limit today
  - Interpretation of results 'controversial'



700C Wheels		Drag (in lbs.) @ Relative Wind Angle				
WHEEL	NO. OF SPOKES	0°	5°	7.5°	10°	15°
FiberFlite/Op4-Ult	32	0.51	0.52	0.53	0.56	0.58
GP4-Ultegra	32	0.50	0.47	0.49	0.49	0.54
Tri Spoke	3	0.57	0.54	0.48	0.45	0.36
Mavic Cosmic	18	0.48	0.46	0.48	0.44	0.46
Specialized DuPont	3	0.38	0.38	0.37	0.34	0.21
Hed J2-Sonic	24	0.30	0.31	0.34	0.37	0.35
Hed Jet-Sonic	24	0.32	0.29	0.27	0.27	0.21
Hed CX-Sonic	12	0.31	0.29	0.26	0.20	0.20
Hed Deep-Sonic	12	0.28	0.29	0.25	0.18	0.10
Hed disc	NA	0.25	0.23	0.17	0.12	-0.01

Zinn, L., "Spoked aero' wheels catching up with discs", Inside Triathlon, 1995, 10(4), p 36-37

***"In strong crosswinds in the wind tunnel, generating relative wind angles of 15 degrees, aerodynamic drag measurements along the direction of travel become negative for discs. If this is true on the road – and road tests indicate that it is – why do so few triathletes use disc wheels?"***, Zinn, L., Inside Triathlon, 1995, 10(9), p 50.

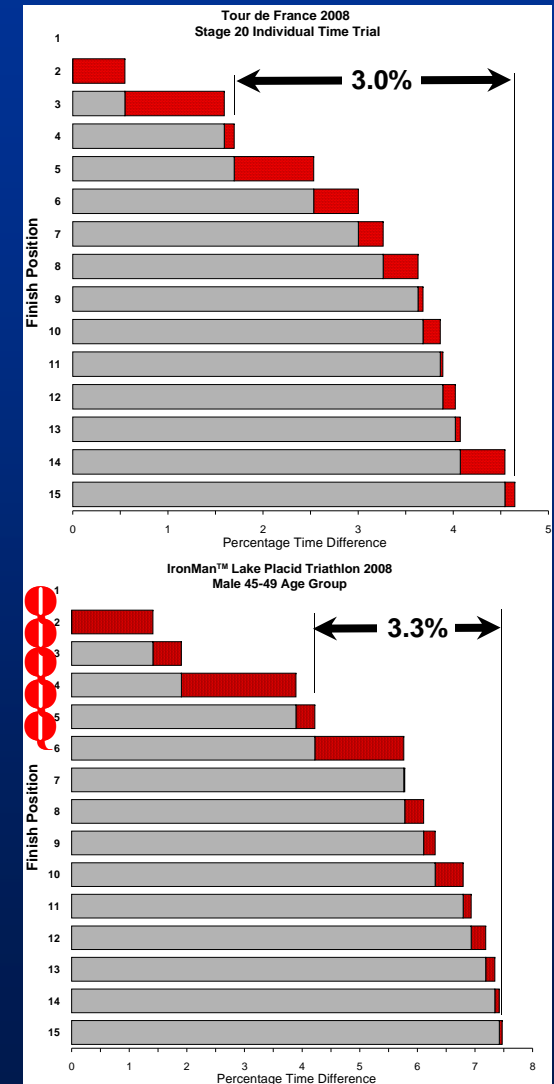
# How much does it matter?

From Greenwell et.al.

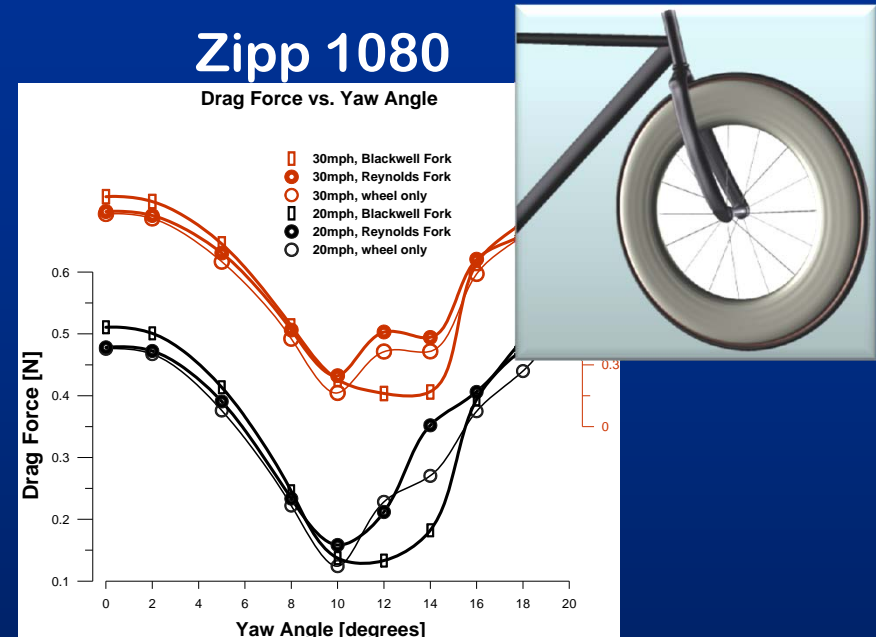
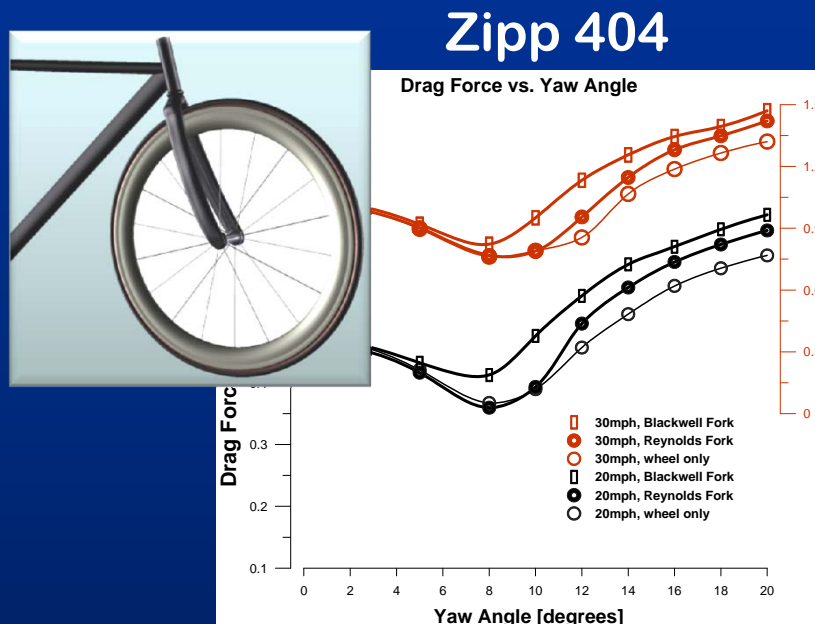
- Wheel drag is responsible for 10% to 15% of total aerodynamic drag
  - Rider makes up the majority of overall aerodynamic drag
- Improvements in wheel design can reduce drag *between wheels* by as much as 25%
- Overall reduction in drag can be on the order of 2% to 3%



*In the '05 Tour of Germany, Ullrich's Xentis front wheel was mistakenly fitted backward for the Stage 8 time trial. Although he won the trial, he finished second overall to Levi Leipheimer, behind by a final margin of 31 seconds. If the wheel had been the right way round, might Ullrich have won stage 8 by a greater margin, perhaps enough to win the race overall? Wheel manufacturer Xentis says 'Yes!'.*



# Previous Work & Current Scope



- Drag force varied significantly with yaw angle
  - Local drag minimum between 8 and 10 degree yaw angle
- Significant differences seen comparing wheel/fork combinations
  - Zipp 1080/Reynolds fork combination exhibited best overall performance
- Target for this work
  - Run DES transient at 10 degree yaw for promising fork design

# Analysis with CCM+

# Analysis Objectives

## Performance Metrics

- Resolved Forces
  - Drag & Side
- Aerodynamic Torque

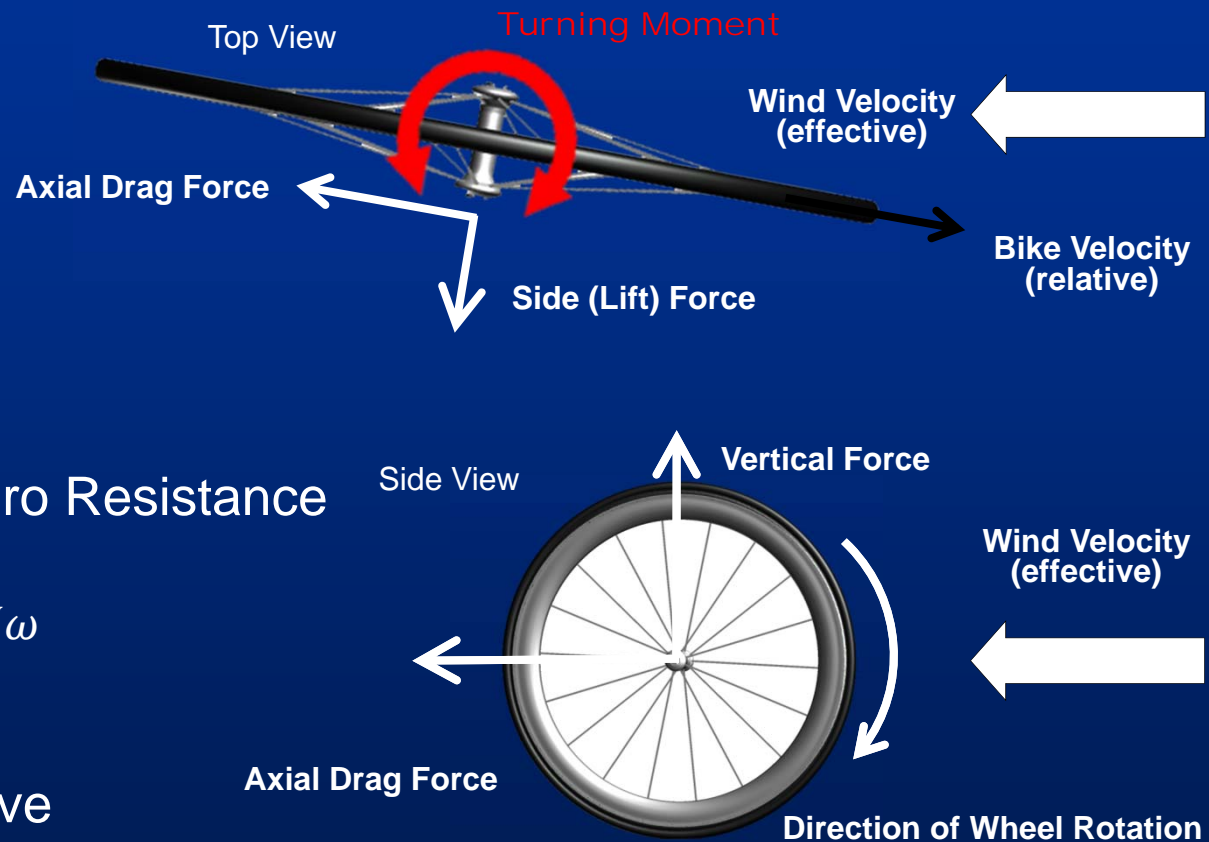
$$M = \int_0^R r \cdot T_{\theta x} dA$$

- Power to Overcome Aero Resistance

$$P = F_D V + \sum_{both\ sides} M\omega$$

## Requirements

- Quantitative & Qualitative
- Easily automated & scalable
- Batch compatible on remote clusters



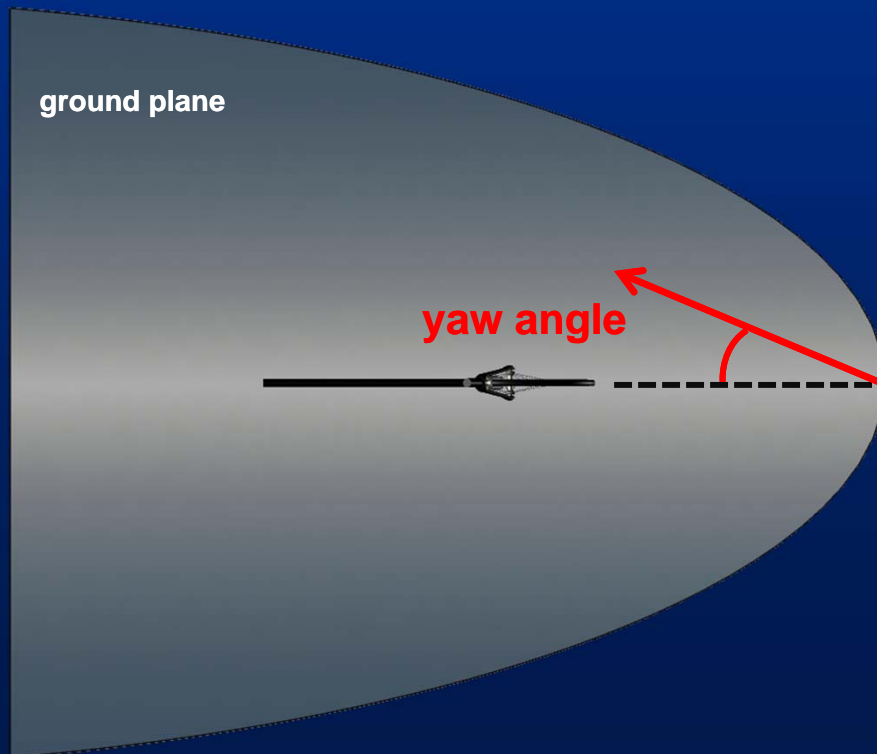
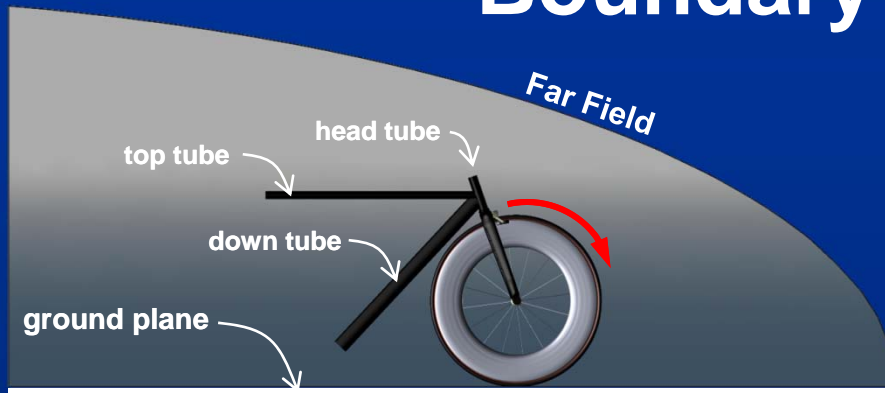
## Methodology Overview

- STARCCM+ v6.02.007
- Meshing models
  - Polyhedral Mesh, prism layers
- Physics models
  - Implicit unsteady
    - Time step = 0.00066s (2° wheel rev)
    - 360 time steps (final 80 saved for review)
  - SST (Menter) K-Omega DES
    - Used DES best practices guidelines\*
  - Low  $y^+$  wall treatment
- FieldView 13 (Intelligent Light)
  - FV-UNS exported from STARCCM+
  - Parallel export compatible with FV
  - XDB exports used in workflow

**\*Thanks to Fred Ross/CD-adapco for guidelines**

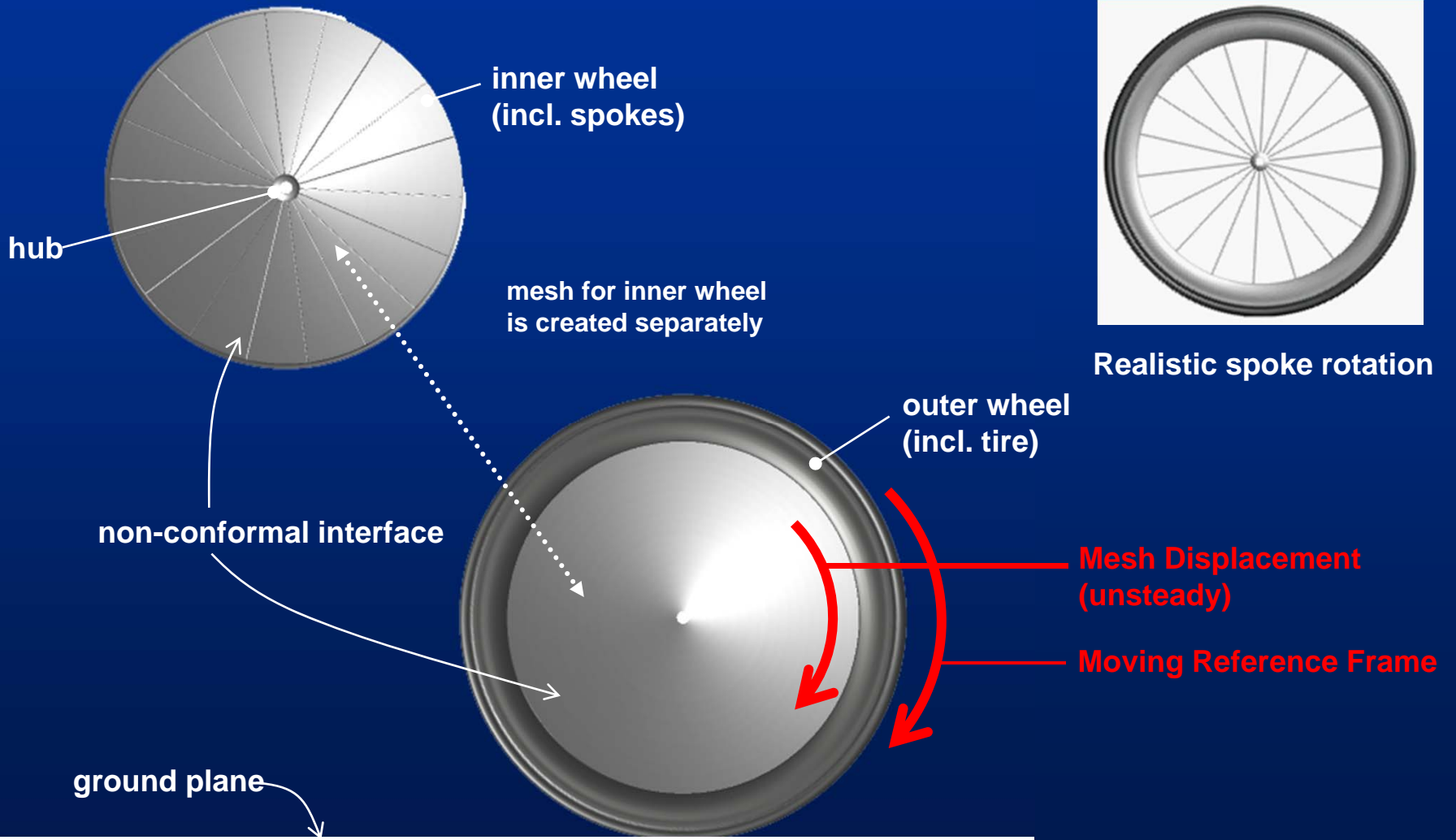


# Boundary Conditions

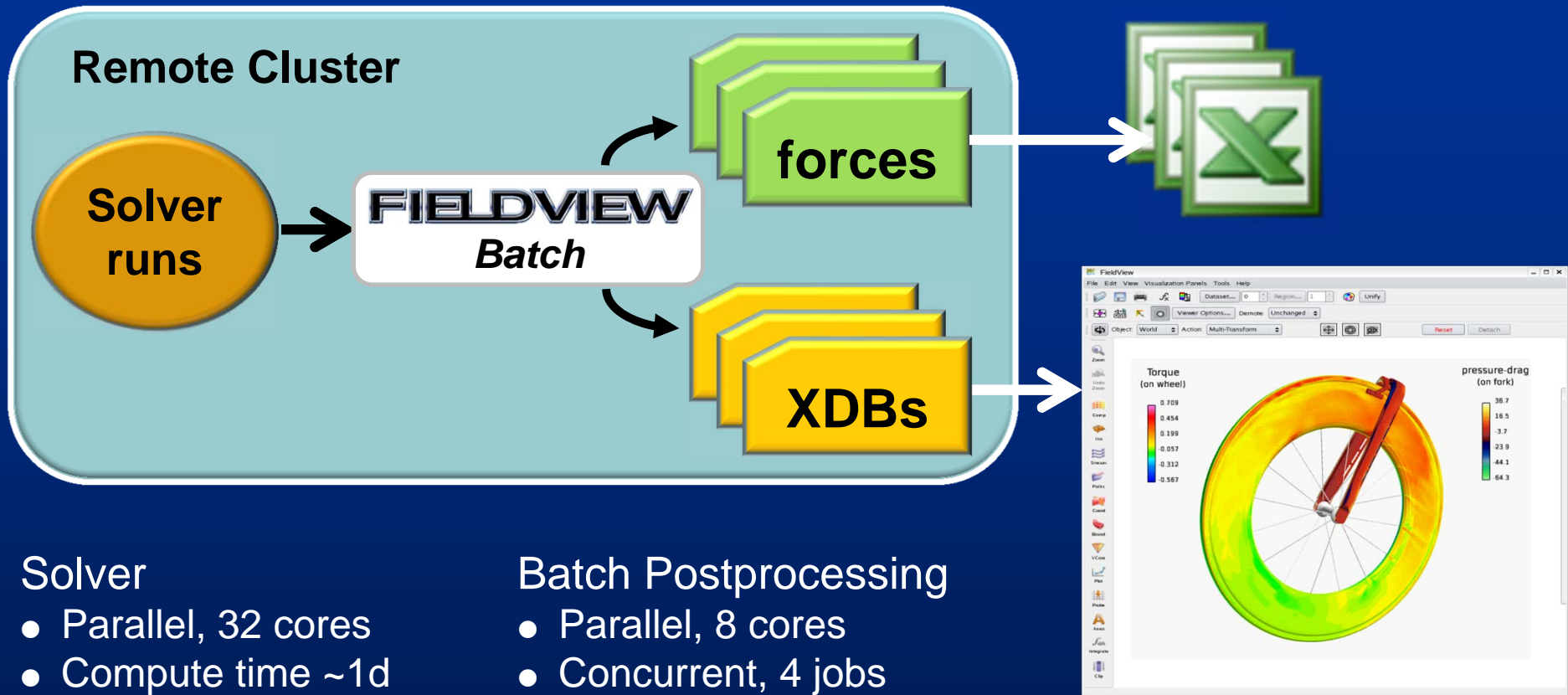


- Ground plane
  - no-slip surface
  - translational speed of 20mph
- Far Field
  - uniform velocity profile
  - yaw angle of  $10^\circ$
- Fork and partial frame
  - no slip surface
  - zero relative velocity

# Boundary Conditions (cont'd)



## Postprocessing Workflow



### Solver

- Parallel, 32 cores
- Compute time ~1d
- .sim file, 2.8GB/step
- .sim to .fvuns in batch (java macro)

### Batch Postprocessing

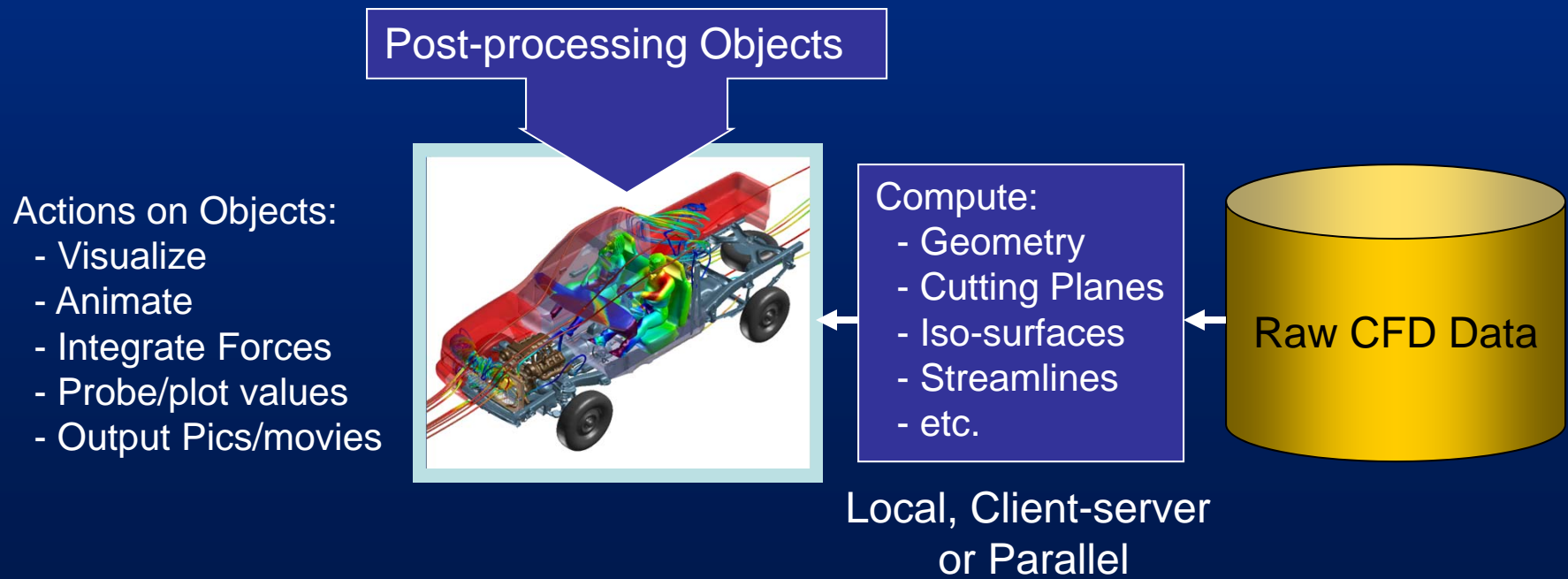
- Parallel, 8 cores
- Concurrent, 4 jobs
- FVX™ scripts used for all performance metrics

### Interactive Postprocessing

- XDB real-time review of transient data

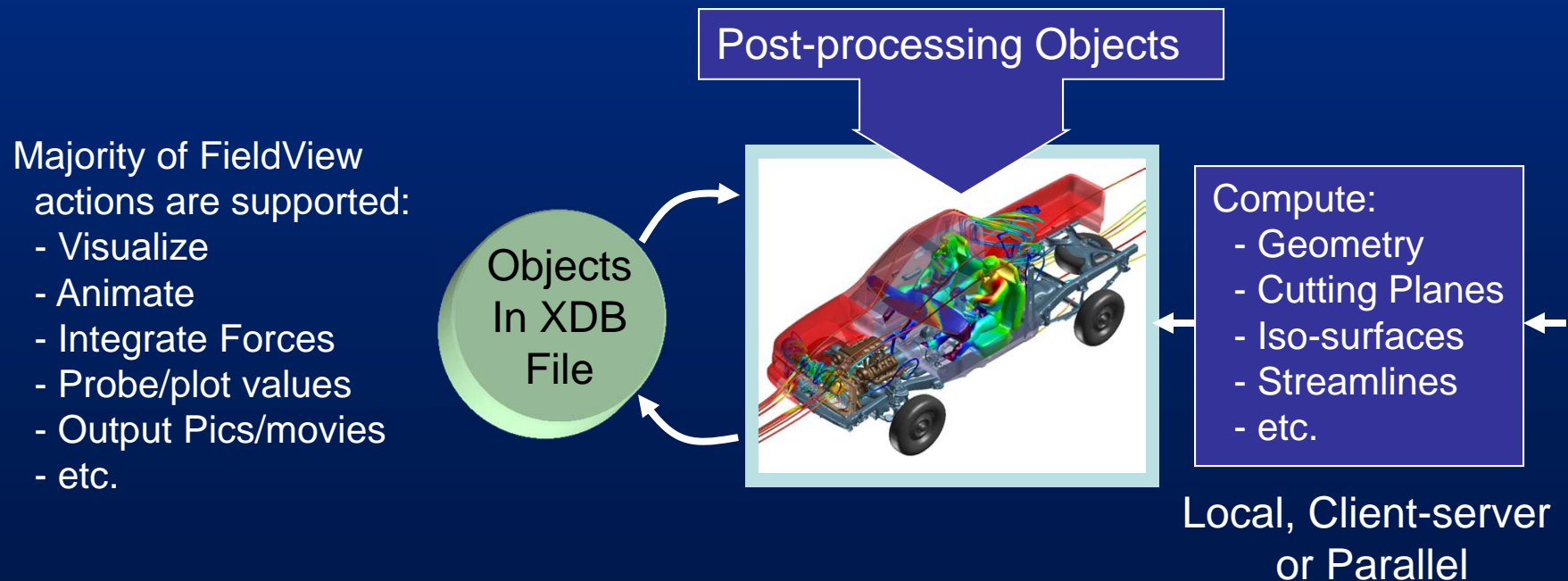
# What are XDBs?

- The usual process is to operate directly from the raw CFD in each session
  - Read data, create surface #1, surface #2, visualize...



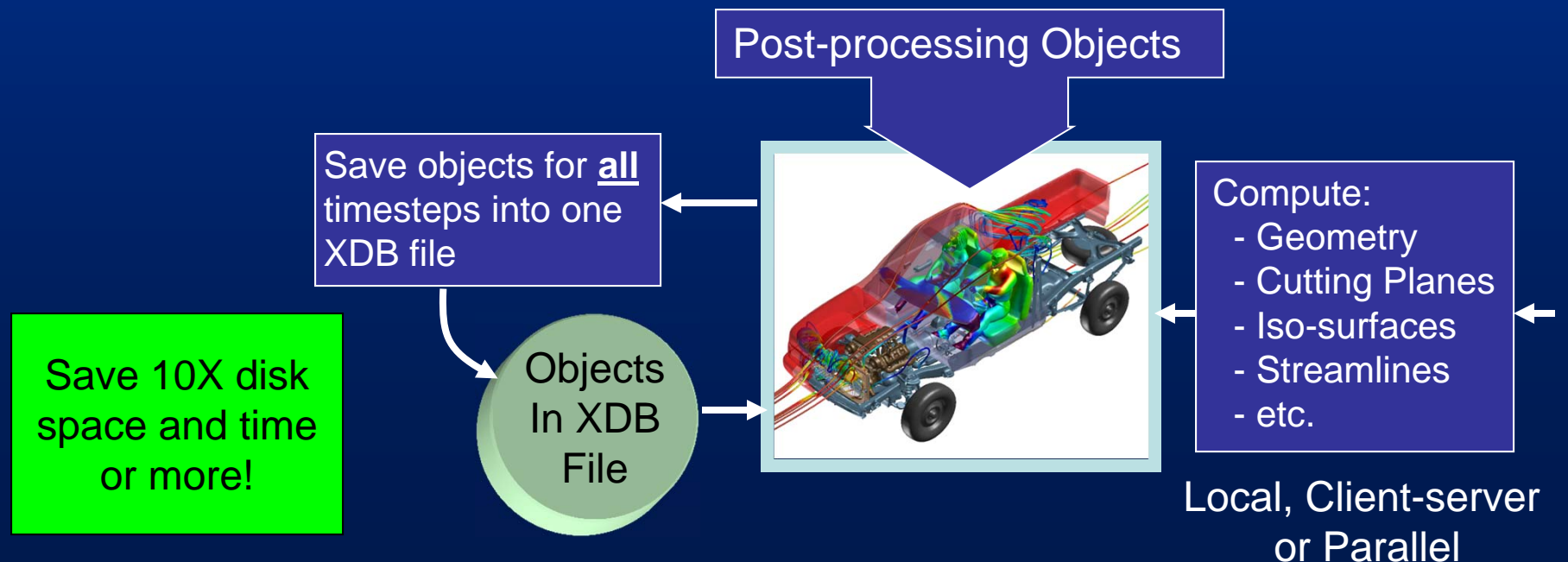
## FieldView 13 Introduces XDB Workflows

- New Process: After creating post-processing objects, save and restore from an XDB file
  - Read data, create surface #1, surface #2, visualize...
  - Next session: read XDB file, visualize, integrate forces



# XDB Workflows are great for Unsteady data

- New Process: Use FieldView in batch mode to create the XDB file for the entire unsteady run
  - Read a timestep, create surfs, etc., save a restart file
  - In batch: Use your restarts or a script to create XDB file
  - Next session: Read XDB file, use cached sweep to visualize



# XDB Workflows Save Space & Time



**.sim file**  
~2.8GB/step

**.fvuns file**  
~2.8GB/step



XDB coord plane  
~6MB/step

XDB wheel only  
~15MB/step

XDB fork & frame  
~4MB/step

XDB q crit iso  
~36MB/step

- Use Field Function in STARCCM+ for complex Torque formula on wheels
- JAVA macro controls FV-UNS export)

- Run transient sweep ~76s to read per time step, 8 cores
- Create simple .csv force reports
- Create XDB extracts in concurrent mode

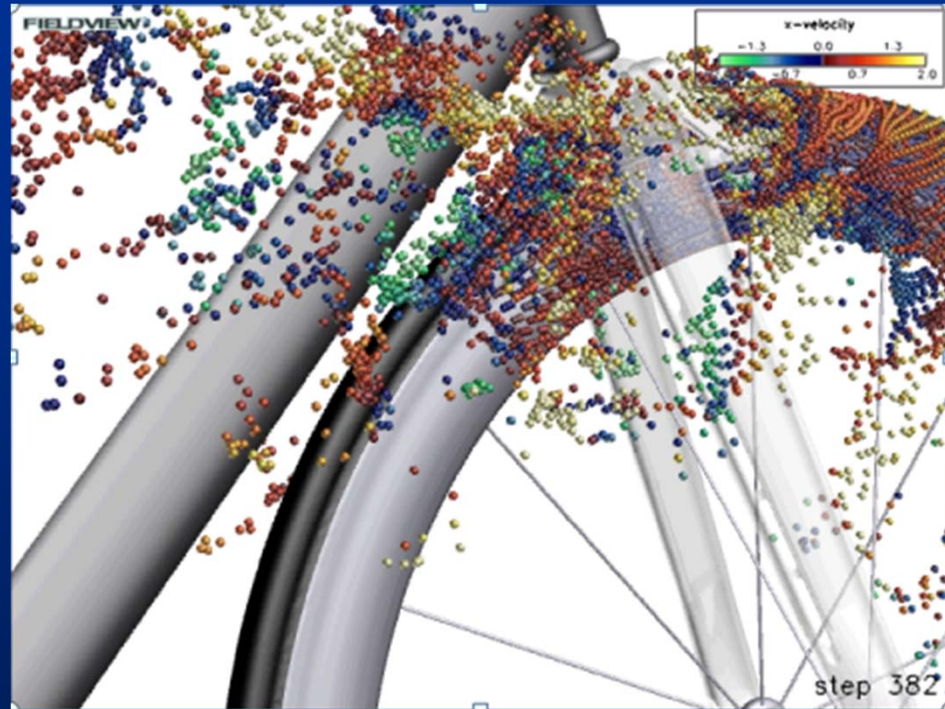
**46 to 1**  
**reduction in**  
**data size**

# XDB Workflows – Unsteady Visualization

XDB wheel only

XDB fork & frame

Particle paths

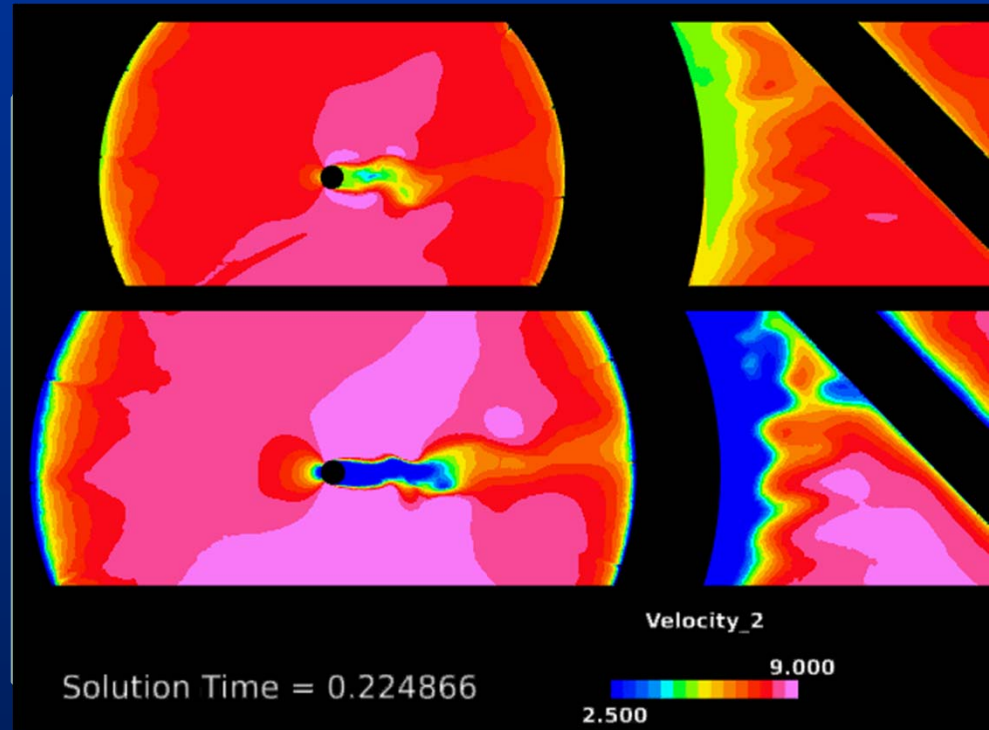


- Build up unsteady visualization one component at a time
- Time to read all components all time steps  $\ll$  time to read 1 time step

# XDB Workflows – Interactive Comparison

XDB coord plane  
zipp1080

XDB coord plane  
zipp404



To compare both configurations

Append XDBs

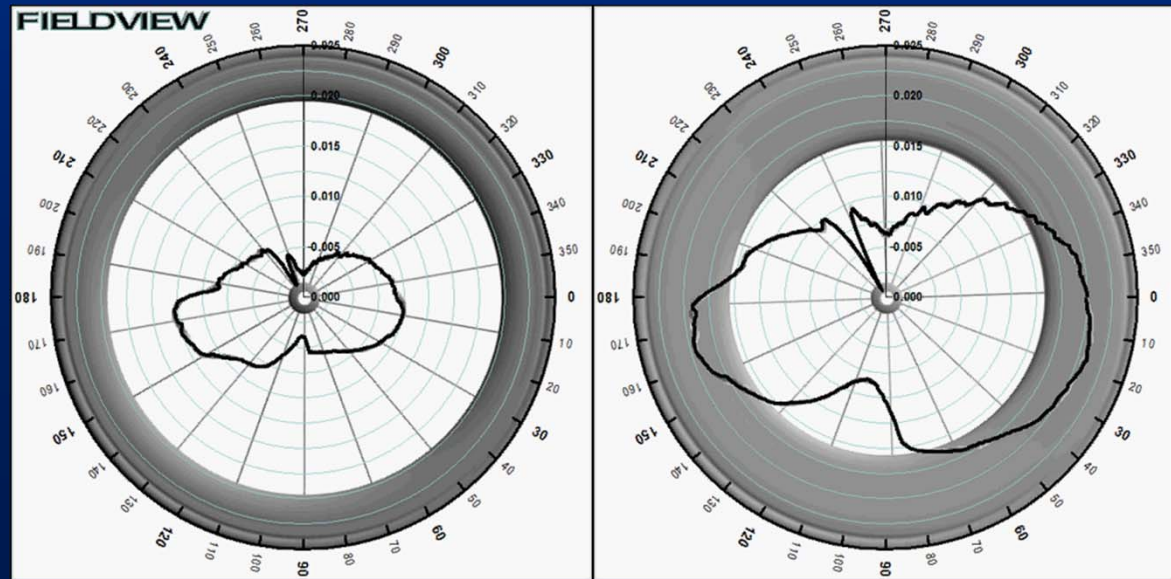
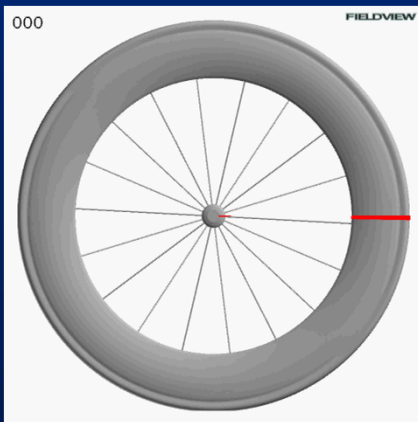
Time to read ~0.3s per timestep for coordinate surface

Time to read all XDBS << time to read one .sim time step

# XDB Workflows – Speeding Calculation



Circumferential Avg.



## Conclusions

- Moving extract production to batch processing **saves time** that the engineer spends in an interactive session
  - Benefits steady state, unsteady, DOE, Optimization
- Interaction with extracts is lighter weight, requires **less desktop compute resource**
  - Disk, memory, CPU, less need for bandwidth, etc.
- Archiving of extracts provides a **compact, accurate** way to save CAE data
  - Easy data exchange with colleagues & customers
- **Understand** unsteady data as never before

## Demonstration – Q criterion Iso-surfaces

- Last 11 times steps of simulation
- File size reduction: 78 to 1 (2.8Gb to 36Mb)
- Data read time: 159 to 1 (~350s to ~2.2s)
- Enables interaction with complex unsteady data