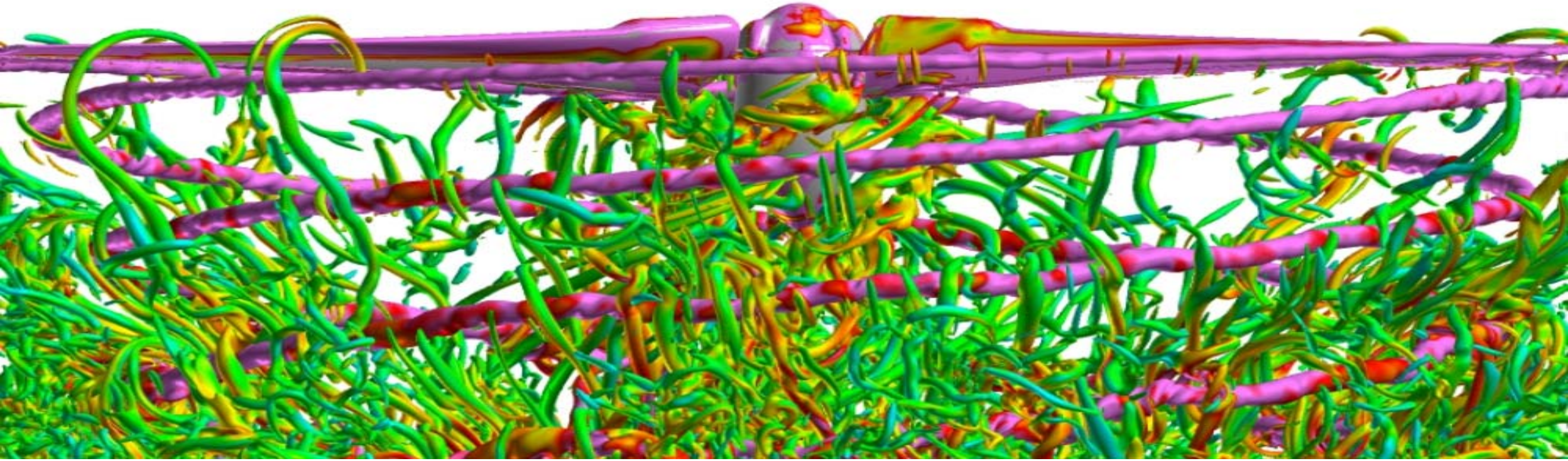
Working Towards NASA 2030 Goals for CFD

Steve M. Legensky
Founder and General Manager

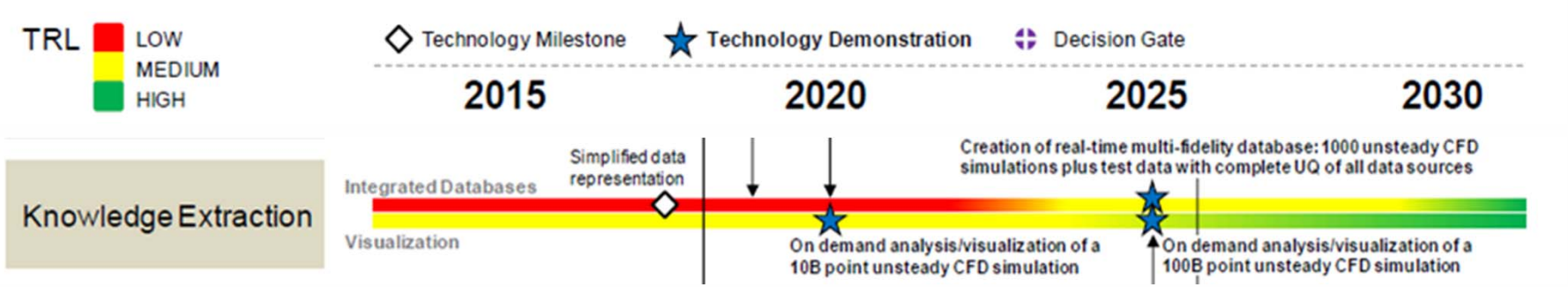
Brad Whitlock
Visualization Engineer

Intelligent Light



CFD 2030 Vision Road Map

Slotnick, J., et.al. CFD vision 2030 study: a path to revolutionary computational aerosciences," (2013).



- **Post-Processing Needs:**
  - 2020: On-demand analysis/visualization of a 10B point unsteady
  - 2025: On-demand analysis/visualization of a 100B point unsteady
  - **2030: HO Common Practice**
- Need: Data demands, **In situ analysis requirements**, coupled data storage, **interactive visualization**.



Intelligent Light

- Established in 1984
  - Three decades in the software & services business
  - **FieldView** launched in 1990
  - **VisIt/libsim** support since 2014
  - Global Customer Base
  - **Multiple CFD practitioners on staff**
- We bridge CFD & IT for customers

CFD Companies

ANSYS, SIEMENS, CORVID, newmerical, CRADLE, Metacomp Technologies, Altair, POINTWISE

IT

Microsoft, AMD, hp invent, CRAY, NVIDIA, DELL, intel

AIAA American Institute of Aeronautics and Astronautics, ASME SETTING THE STANDARD, IEEE

Aerospace & Defense

LOCKHEED MARTIN, BOEING, GE Aviation, NASA, ONERA, JAXA, DoD HPC, BETTIS, DLR, Sikorsky, Rolls-Royce, eurocopter, BAE SYSTEMS, Bell Helicopter, EADS, AIRBUS

Automotive & Transport

TOYOTA, HONDA, VOLVO, MITSUBISHI MOTORS, Visteon, Joe Gibbs Racing, LOLA, Red Bull Racing, NISSAN, JR EAST, BEHR, DENSO, Cummins, KORAIL KOREA RAIL

Consumer & Heavy Industry

Kawasaki, MITSUBISHI HEAVY INDUSTRIES LTD., P&G, HITACHI, Whirlpool, HYUNDAI, Canon, ALCOA, LEXMARK

Energy & Environmental

Vestas, LM Glasfiber, SIEMENS, ALSTOM, NALCO Mobotec, Chevron

The Historical CFD Scenario

- The ‘products’ resulting from CFD computation are results **files**
  - These files are considered to be *precious*
- Post-processing consumes the results files in the ‘analysis’ step
  - This is the ‘pay off’ from your work
- Storing and accessing these files can dominate the scope of analysis
  - ***The space of solutions you can consider can be limited by disk I/O***



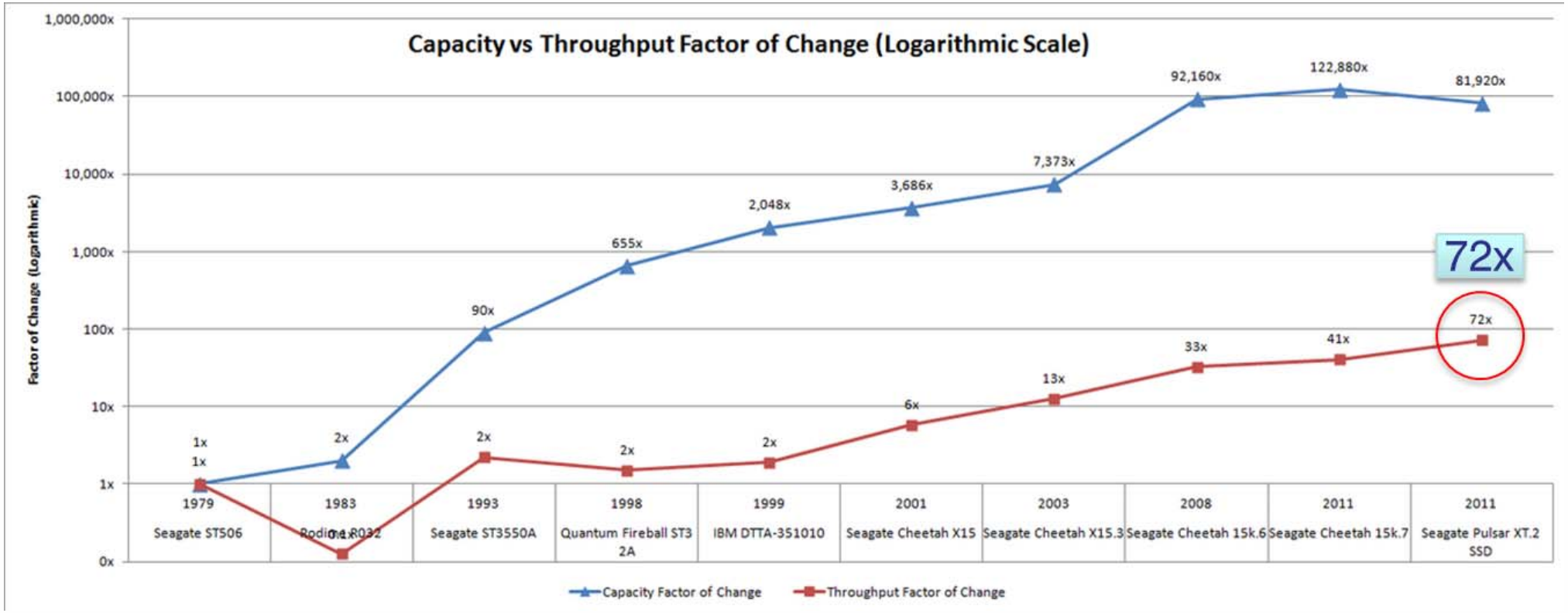


300 Mb



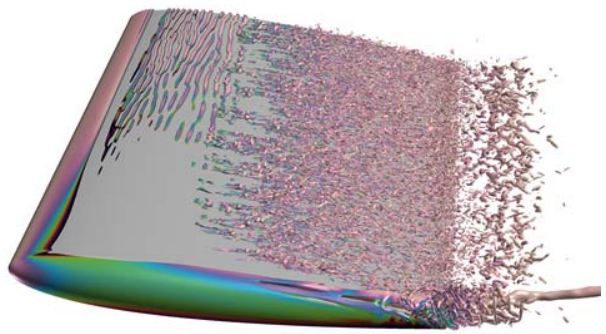
Post-processing throughput is important

- Disk throughput increase is less than 100X in about the same time that computing increased 10,000X

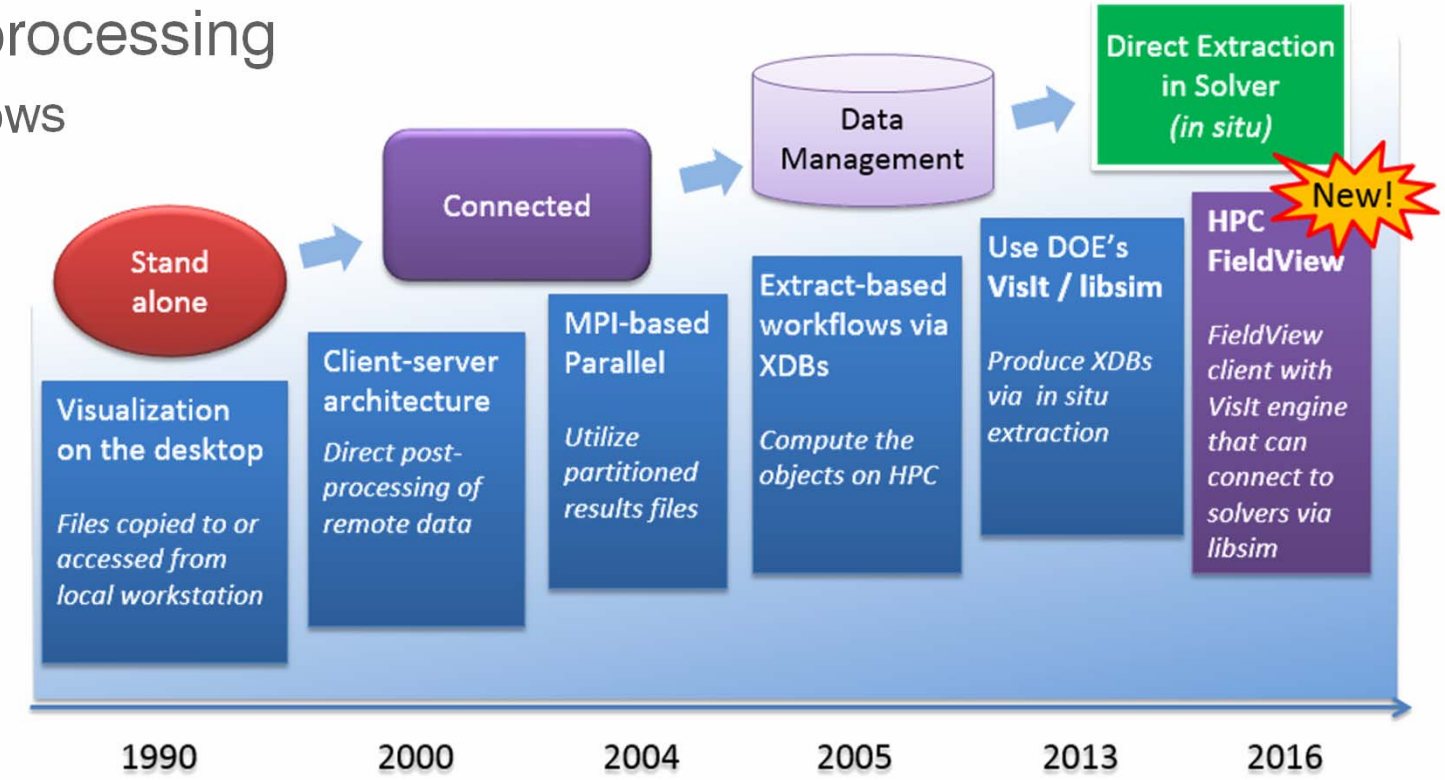


Resolving the file-based bottleneck

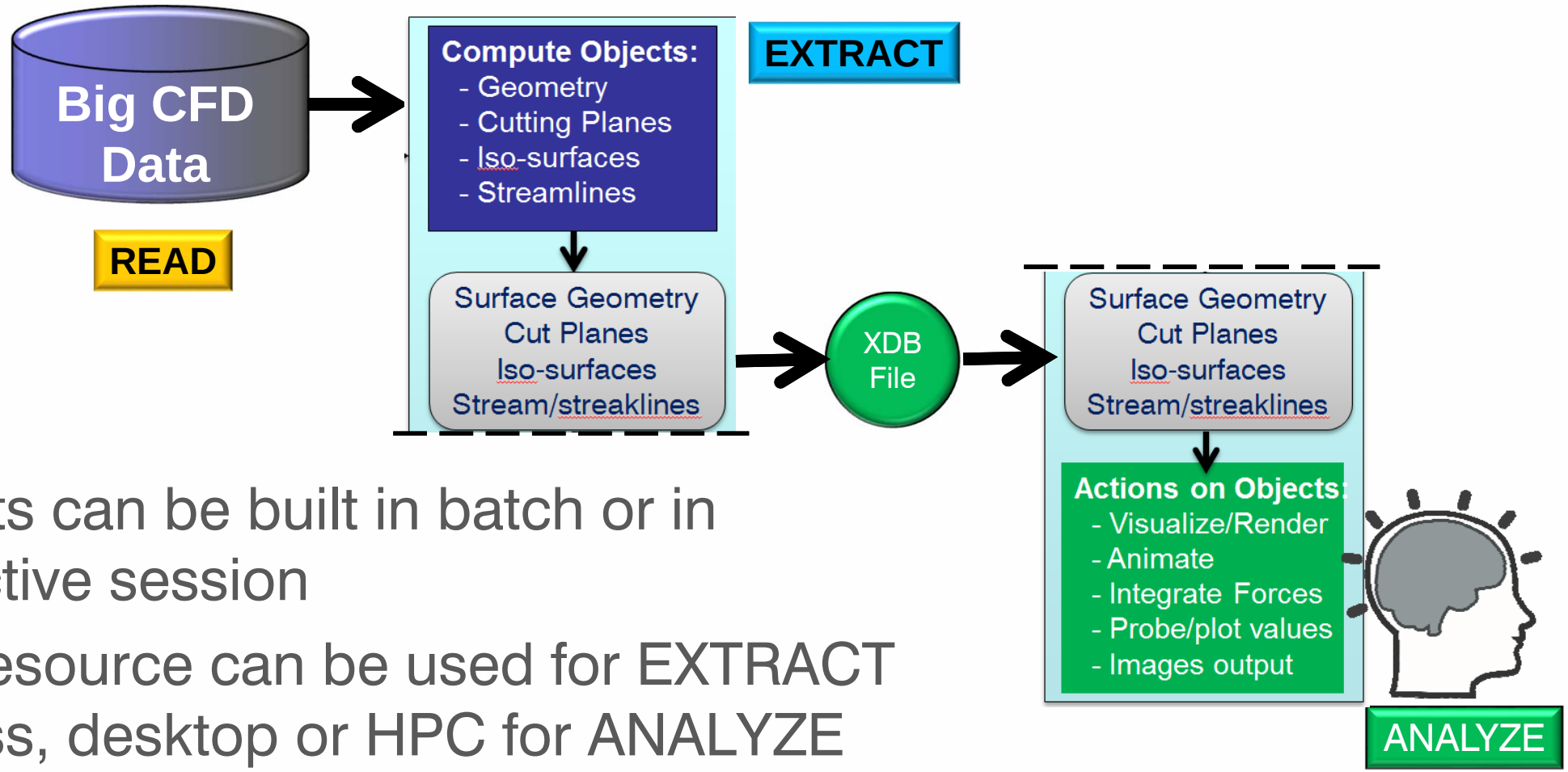
- Parallel post-processing and visualization
  - High-performance per core and Gb of RAM
- Data management for post-processing
  - Extracts integrated into workflows
- In situ extract production
  - SBIR grant from DOE for **VisIt**



FIELDVIEW



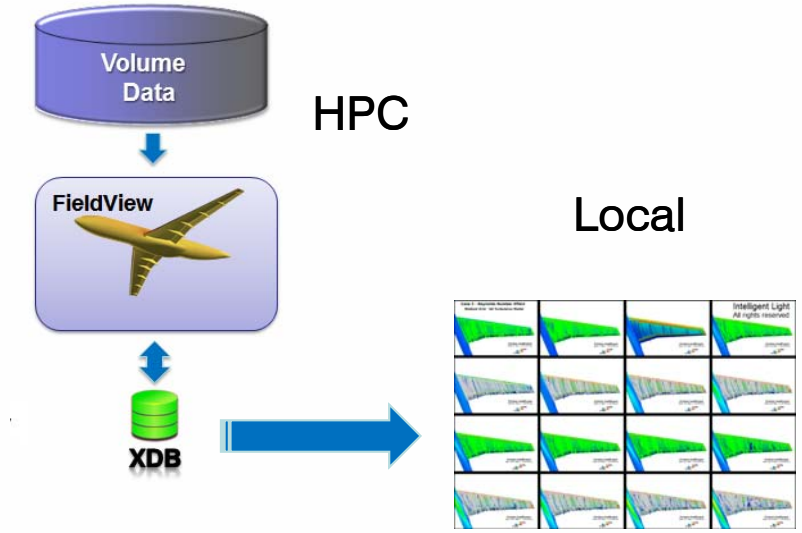
Extract Workflow: Split the Process

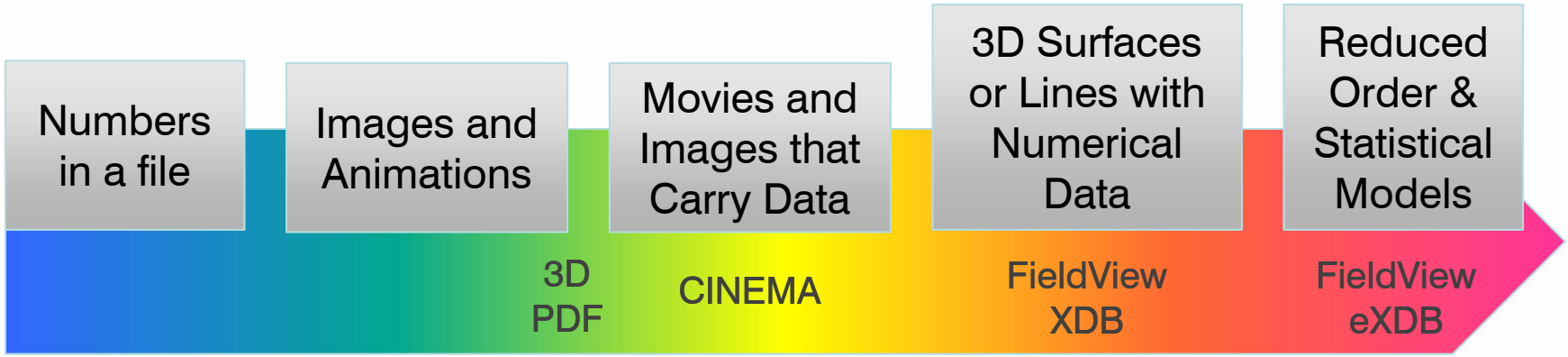


- Extracts can be built in batch or in interactive session
- HPC resource can be used for EXTRACT process, desktop or HPC for ANALYZE

Extracts are a powerful and flexible tool

- A subset of the computed results that is extracted for a specific purpose
  - Can be produced in batch, in situ & post-hoc
  - Exist on a spectrum of content and fidelity
- Can be 100's to 1000's of times smaller
  - Enables unsteady interaction



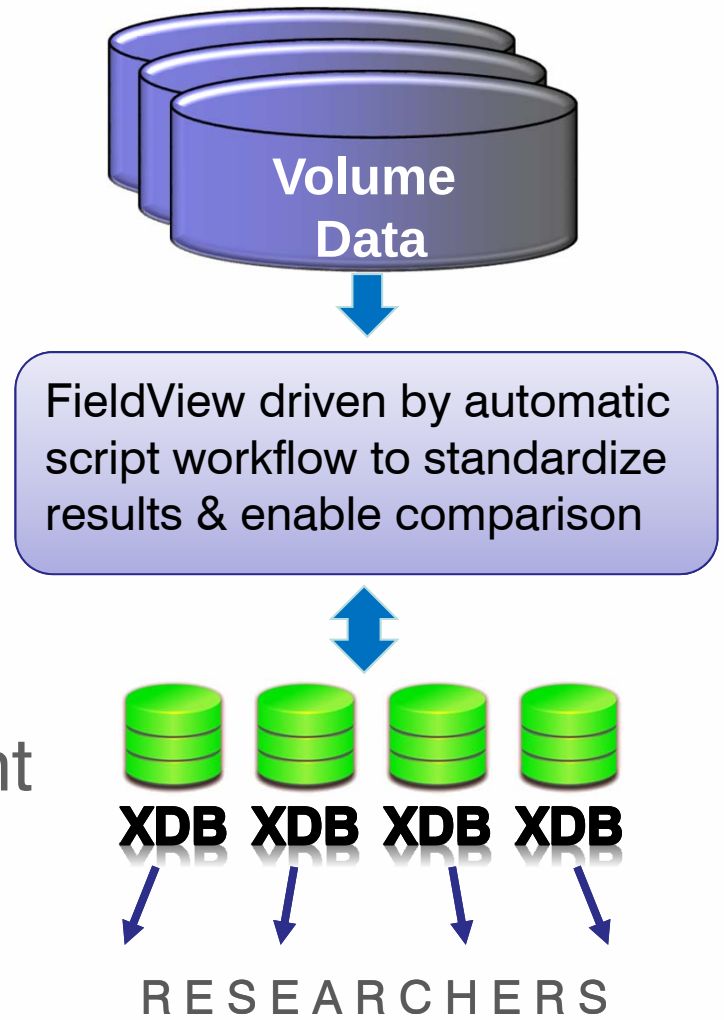




EXTRACT EXAMPLE: AIAA HOVER PREDICTION WORKSHOP

Extracts Enable Workshop Collaboration

- Generate & compare varied CFD results
  - Multiple simulations of rotorcraft in hover
- Locations in US, Korea, France
  - 3 standard blade cases
  - Durations from 1/4 - 20 revolutions
  - Grids = 6 to 6k+, elements = 8k-286k
  - 6 solvers
- A Custom Engineered extract workflow & a private cloud supplied by Intelligent Light
  - XDBs accessed via FieldView or XDBview



Examples

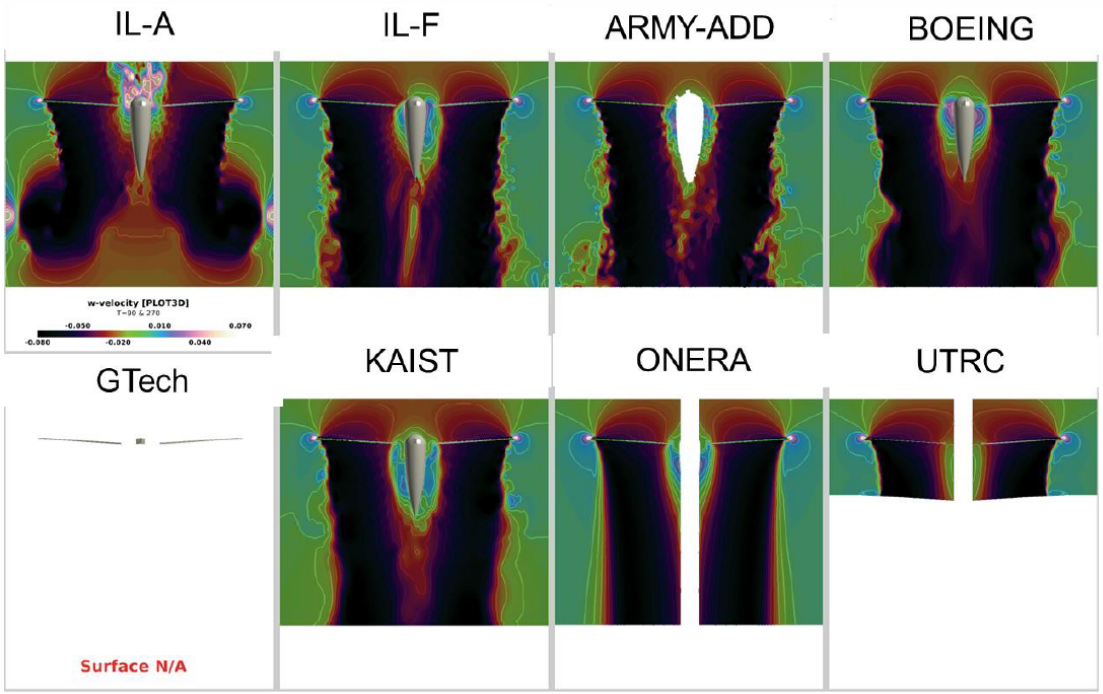


Figure 8: Comparison of w-velocity @ Coordinate Cut Plane X=0.0

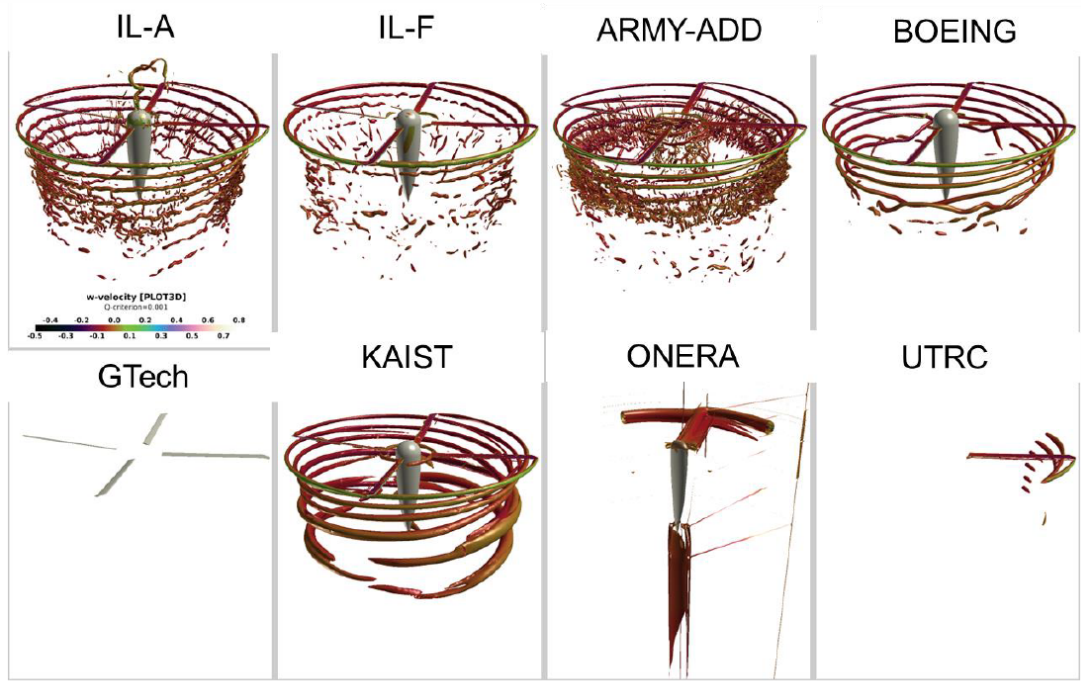
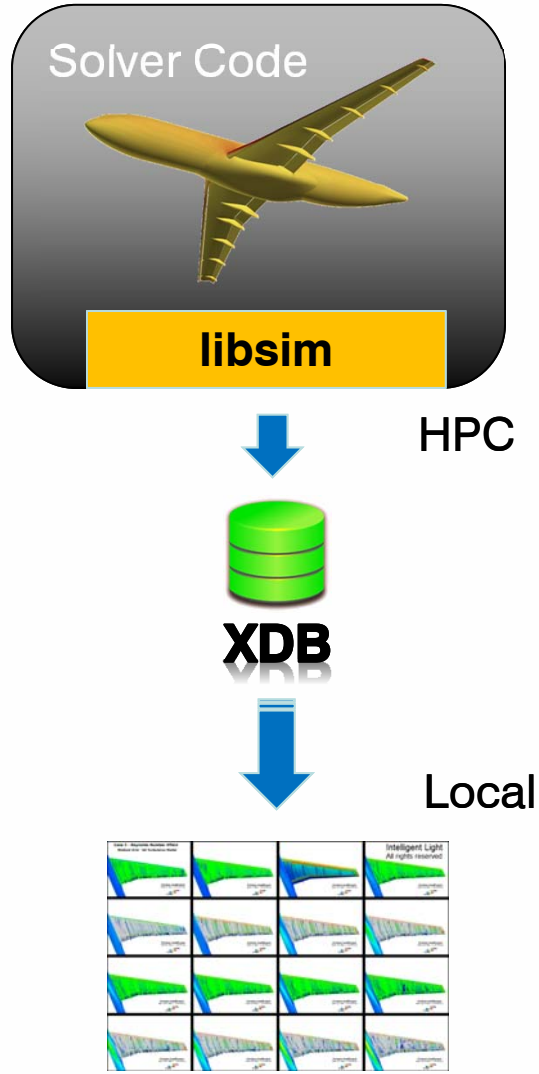


Figure 10: Iso View Comparison of Iso-surfaces of Q-Criterion =0.001 colored by w-velocity

In Situ Workflow

- Compute the visualization objects within the memory space of the solver code
  - Extracts can be saved more frequently and much faster than volume files
- Instrument the simulation so it can write out extracts
  - *VisIt libsim* interfaces to the memory of the solver and can be directed by scripts or function calls
- Every N iterations, **libsim** is called, extracts are created directly from solver memory and written to XDBs
  - The XDB workflow from in situ is the same as XDB workflow from files!

****Support from DE-SC0007548; DOE's VisIt/libsim, ADIOS*

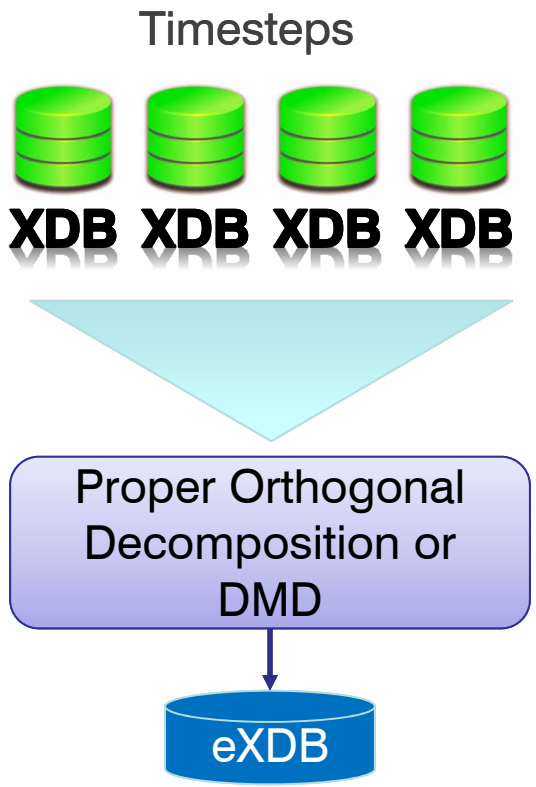




REDUCED ORDER MODELS FOR COMPRESSION & FEATURE DETECTION

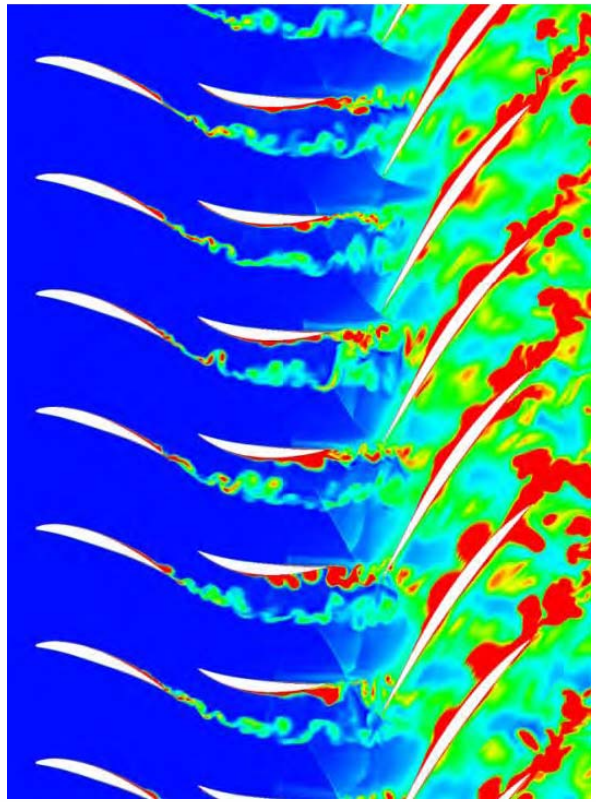
Reduced Order Models from XDBs

- Proper Orthogonal Decomposition (POD) can reveal features
  - Shocks
  - Vortices
- Physics-based compression on the HPC resource with later reconstruction
- Characterization and comparison of unsteady cases



Unsteady Turbomachinery via POD

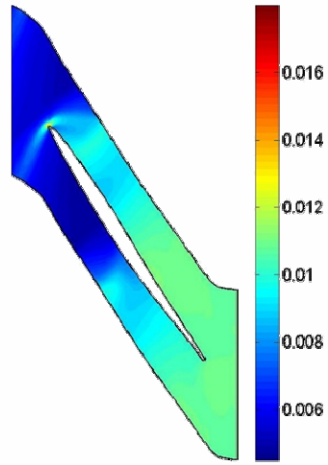
Extracts are processed into POD modes



Mode 0: Average behavior of the data

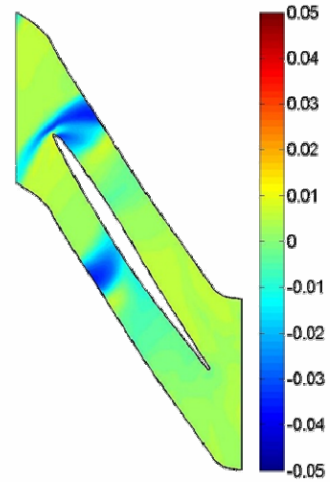
Bow shock at leading edge

Mostly stationary



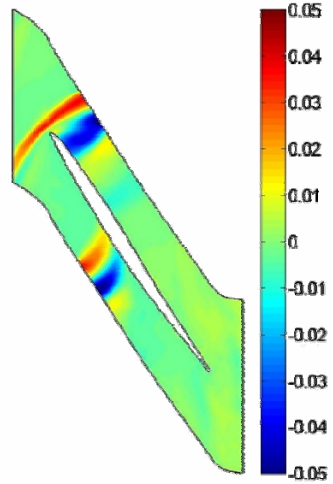
Mode 1: Variation from the average

Blue banded region is a characterization of shock movement due to 1/rev inlet distortion



Mode 3: Similar to mode 2

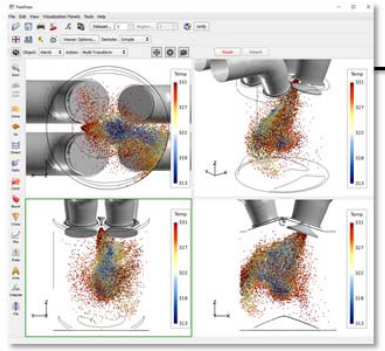
Linear combination of higher order modes reveal exact shock location for a given angular position

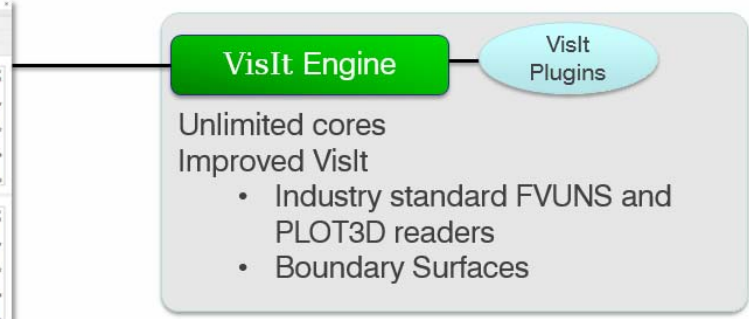


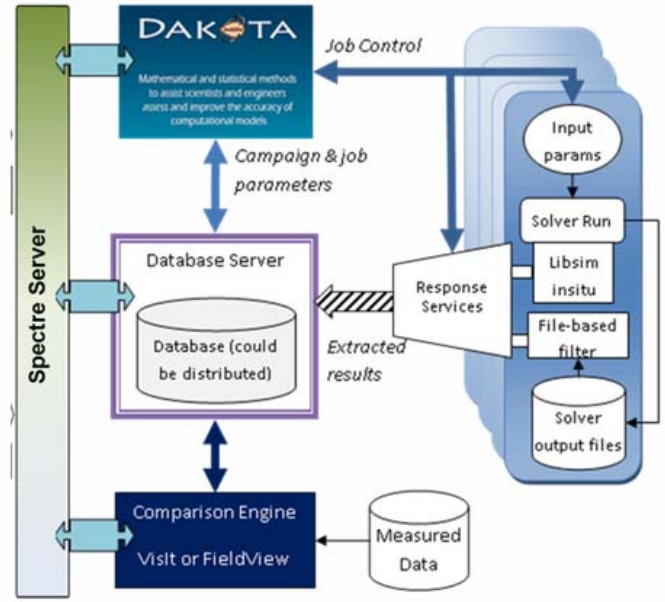


TOOLS TO ASSIST INDUSTRY WITH THE CHALLENGES OF HPC CFD

- HPC FieldView for scalable CFD
  - Combines FieldView client with VisIt
- UQ Workflows
  - DOE SBIR grant: SPECTRE
- Application-aware databasing
  - RESTful architecture, web interface
- High order elements (MFEM)
  - DOE SBIR grant, collaborate w/CEED
  - Visualization and post-processing
  - Extracts for high order (with UTK)
  - Meshing standards (with PointWise)

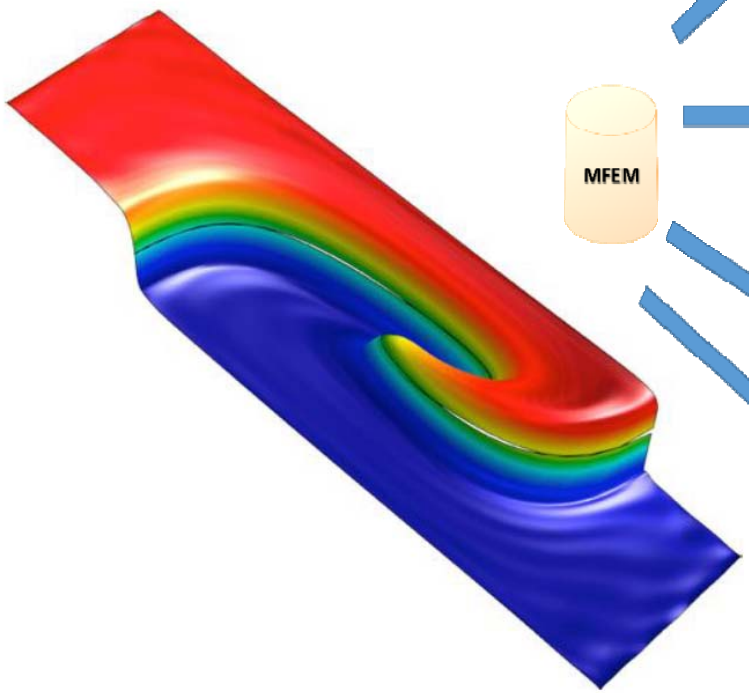




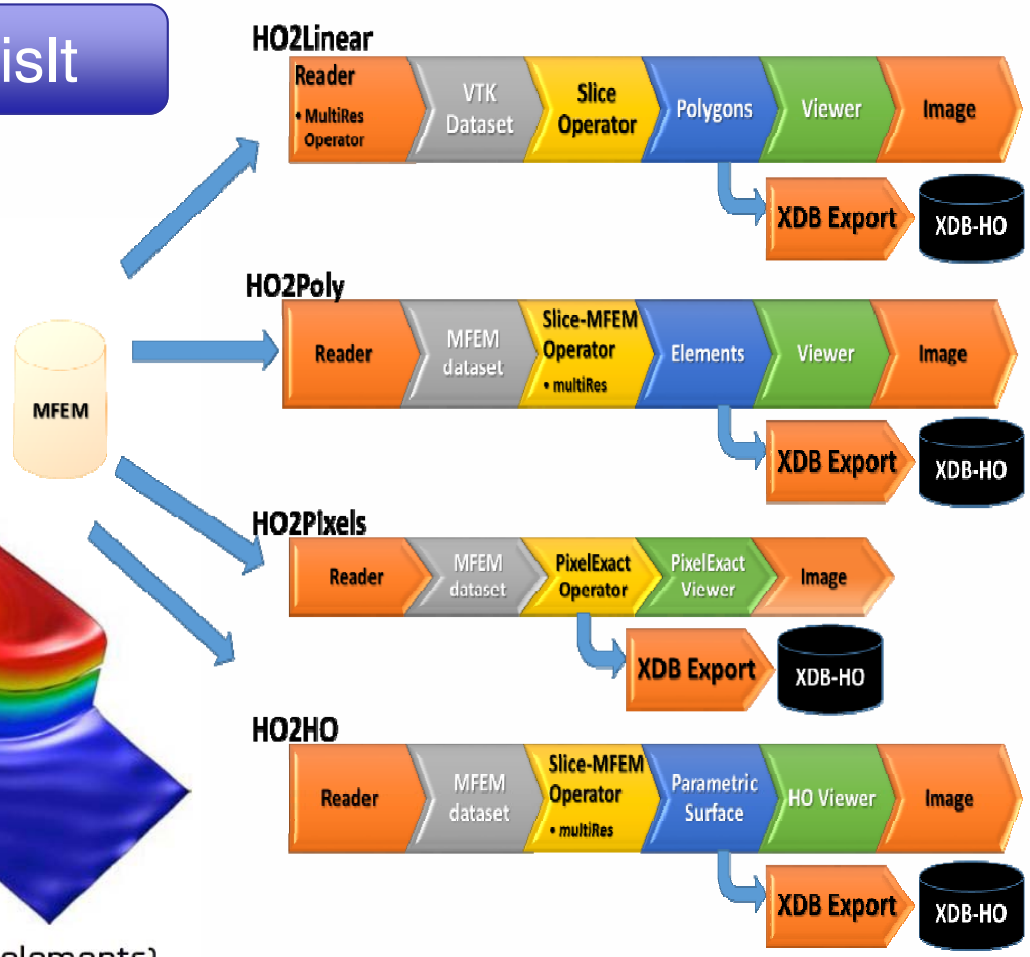


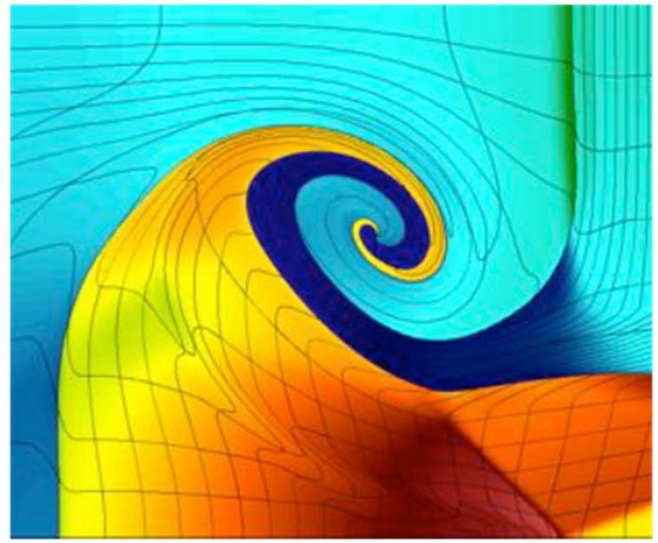
Support for higher order elements via MFEM

FieldView & VisIt



Smooth RT instability (2 elements)





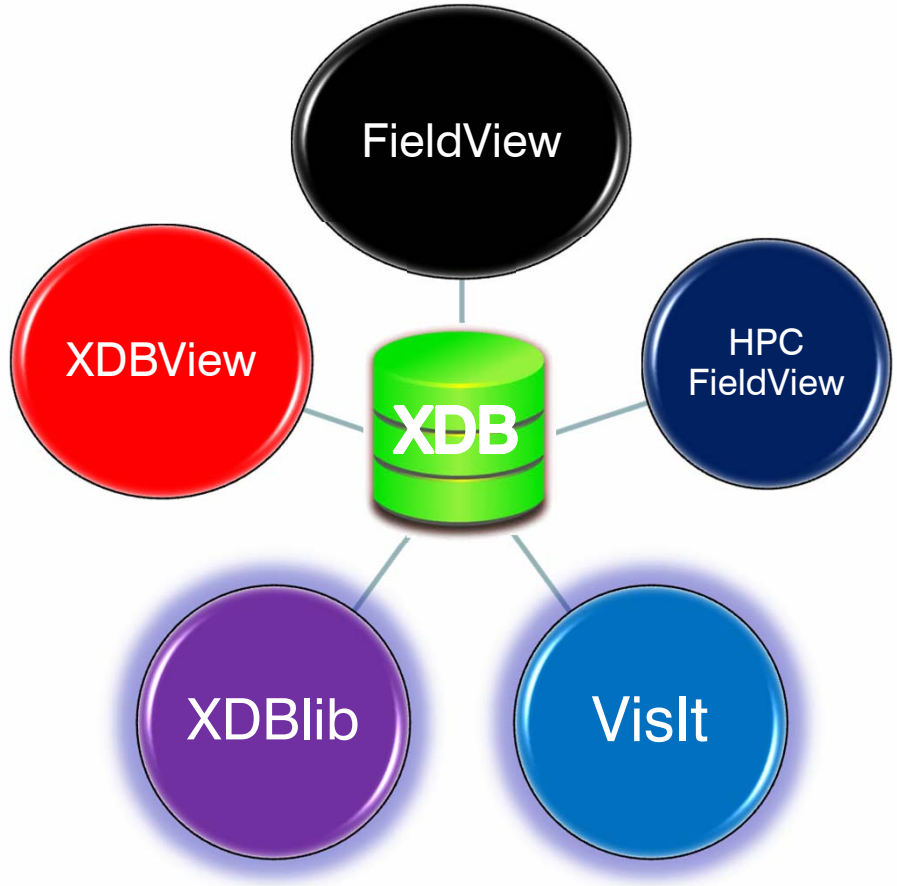
8th order Lagrangian hydro simulation of a shock triple-point interaction

Steve Karman - Pointwise
- Commercial Grid Generation Software
- Curved Elements

Ryan Glasby – UTK/JICS/ORNL
- Coffe Code
- SU/PG based Solver for Aero applications
- DOD CREATE-AV program

The Tools are Here to Break Through the Bottlenecks

- **FieldView**: Primary post-processor
  - Licensed per user or for the enterprise
- **XDB:** Extract Database
  - Compact, fast, accurate
- **HPC FieldView:** Enhanced VisIt engine with the FieldView client
- **VisIt**: In situ extraction & special purpose post-processing
  - Open source, with available support subscription from Intelligent Light
- **XDBView**: Visualize, Share, Publish
  - Open license, for customers and their partners
- **XDBlib**: Integration path for data sources





Brad Whitlock, Visualization Engineer

IN SITU + EXTRACTS