Massively Parallel simulation of combustion in Gas Turbines

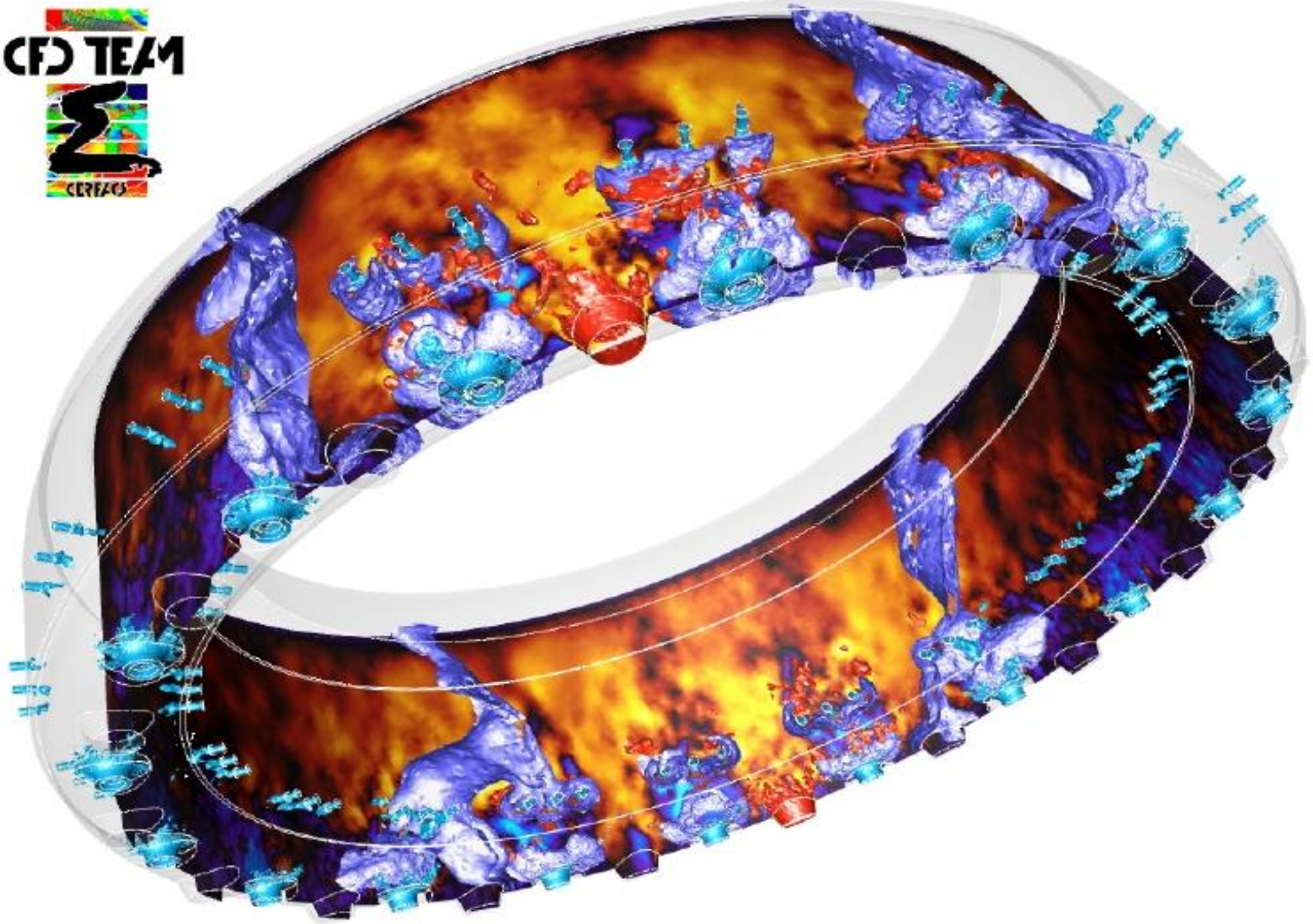
European Centre for Research and Advanced Training in Scientific Computation

- Electromagnetism
- Global Change and Climate Modeling
- Aviation and Environment
- Parallel Algorithms
- CFD :
  - Aerodynamics
  - Combustion

Objectives

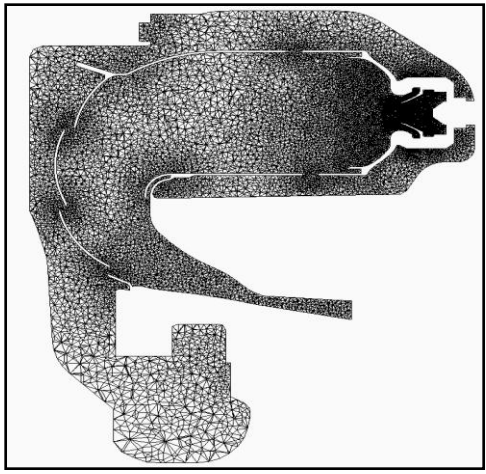
- Perform 360° full combustion chamber simulation for current R&D challenges in Gas turbines :
  - Thermo-acoustic Instabilities
  - Quenching
  - Ignition / Re-ignition

Ignition

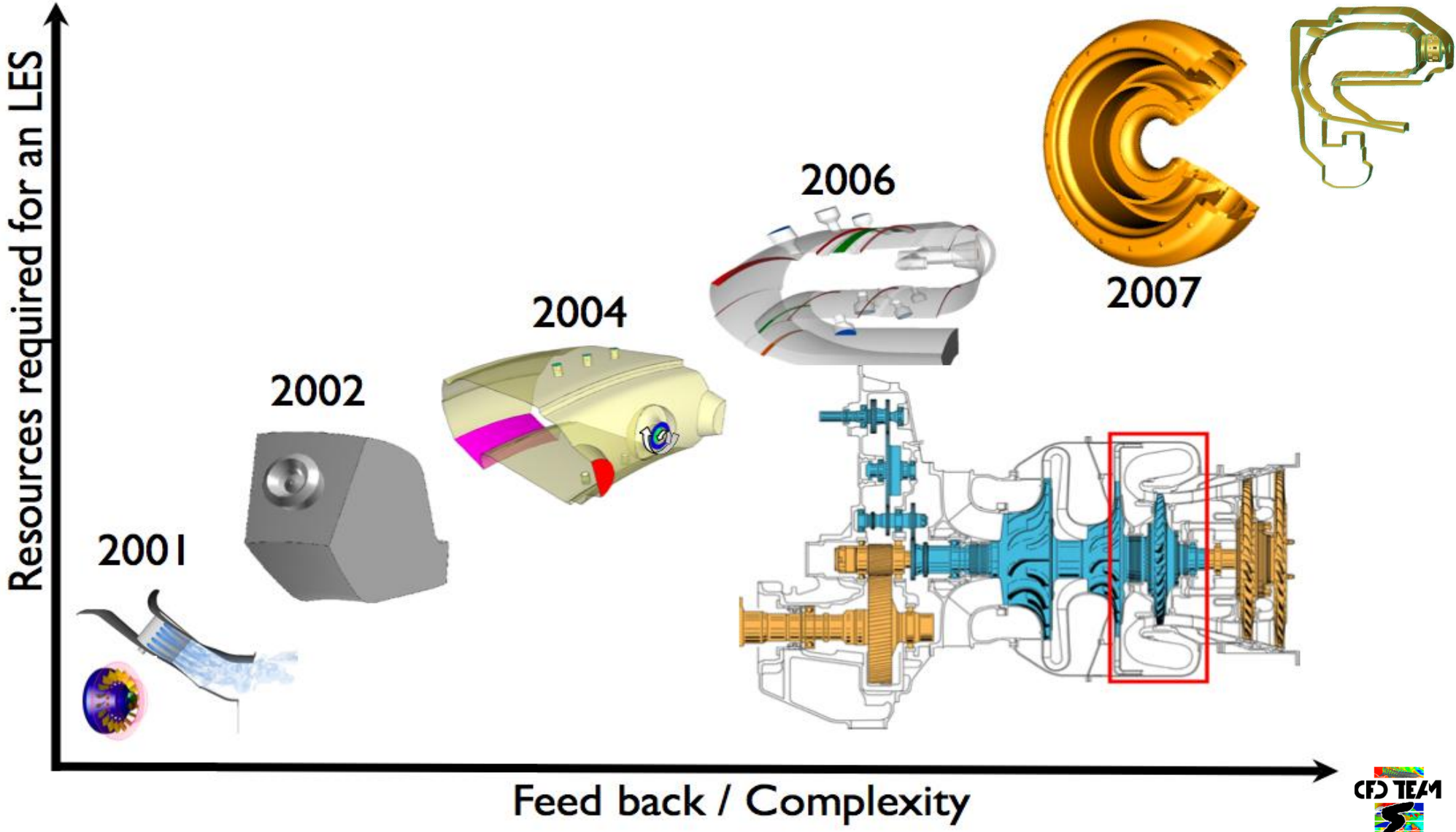


CERFACS's code : AVBP

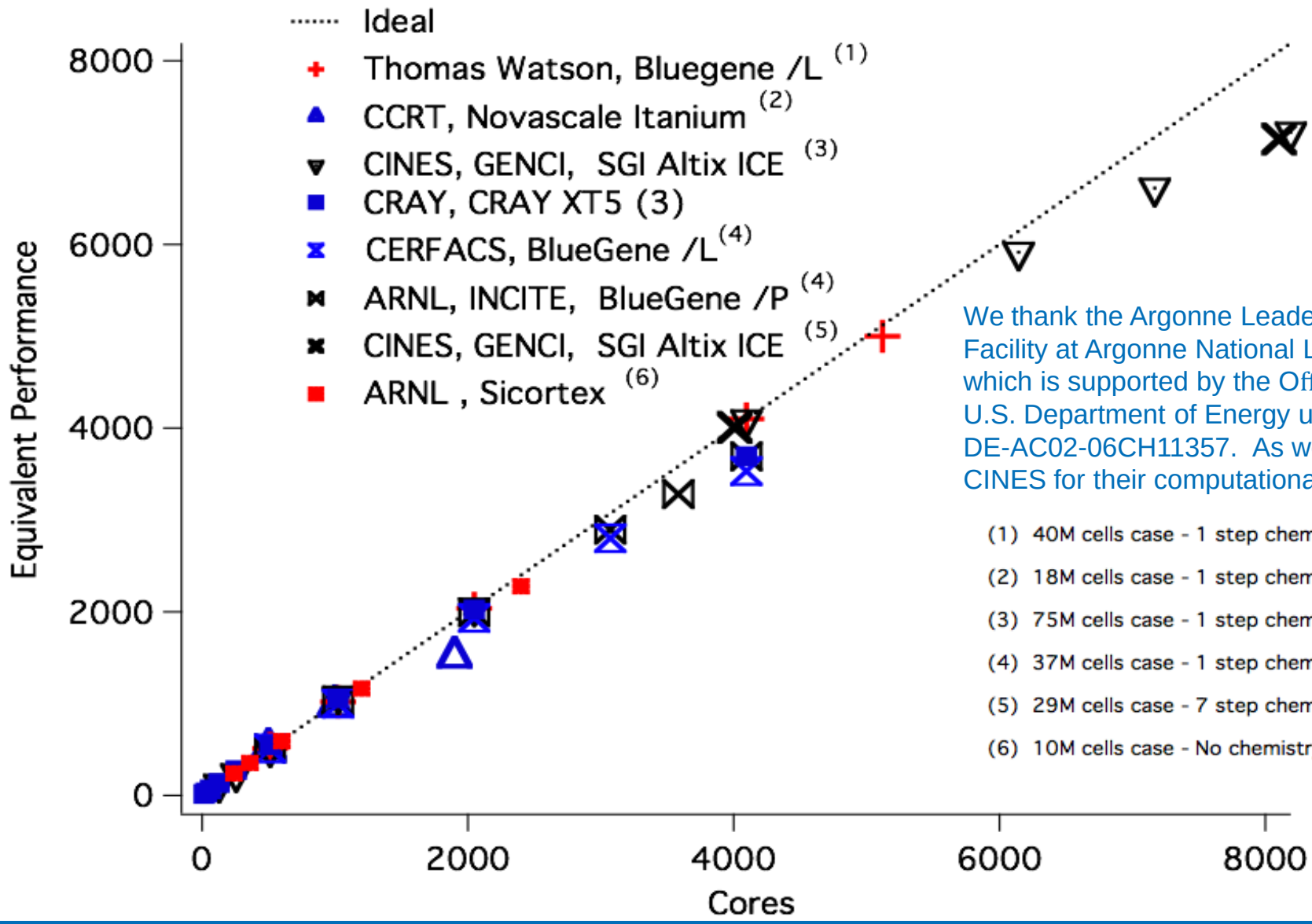
- Massively parallel : MPI / Fortran (with C allocations)
- Large Eddy Simulations approach :
  - Flow Turb and Comb 2000, J of Turb 2004, Comb. Flame 2004, 2005, 2006, 2007, 2008, JFM 2007, 2008
- Compressible
  - AIAA J. May 2004
- 3rd order space and time accuracy
  - J. Comp. Phys. 2000, J. Comp. Phys 2005
- Thickened flame model
  - Phys. Fluids 2000, Comb. Flame, 2004, J. of Turb 2004, Comb. Flame 2005, J. Fluid Mech. 2007
- Hybrid grids and unstructured meshes
  - AIAA J. 1999, J. Comp. Phys 2005



The drive towards real engine simulations



Strong scaling performance



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(1) 40M cells case - 1 step chemistry

(2) 18M cells case - 1 step chemistry

(3) 75M cells case - 1 step chemistry

(4) 37M cells case - 1 step chemistry

(5) 29M cells case - 7 step chemistry

(6) 10M cells case - No chemistry

I/O Patterns and Strategy

- Master / Slave parallel pattern:
  - I/O handled by MASTER core only (synchronisation required).
  - PHDF5 under study (limitation of parallel file systems).
- Two computing modes:
  - All process compute : Compute server mode
  - Only slaves compute / Master handles I/O only: Distinct server

I/O Patterns and Strategy

- Unsteady phenomena : A lot of snapshots allowing easy restart.

- Dynamic partitionning and a root / multiple master strategy is studied to increase I/O performance.

Performance

- Performance has been analyzed with PAPI , Tau and performanceanalyser (intel).

- Possible bottlenecks :
- Global reductions. Partition updates. I/O scheme.
- Specific sub-communicator for low memory version to use all reduce.

Status and Scalability

- Today : 10k cores, Tomorrow : 50k.
- Ideal Cells/proc ratio in BGP seems higher than in BGL.
- Global communications seem to exert a great toll on performance: communication scheme ?
- Current scalability was achieved by developing the low memory version of the code and synchronization of the processors prior to send/receive of “big” buffers on BGL (not needed in BGP).