Southeast Asia '09

Visualization and Collaboration Environment for High End Applications on Virtual Reality

1. Dec. 2009

Korea Institute of Science and Technology Information(KISTI)
Supercomputing Center

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Contents

1.1 Organization

KISTI Supercomputing Center
(National Supercomputing Center)

- Dept. of Application & Support
- Dept. of Cyber Environment Development
- Dept. of Infrastructure Technology Development
- Dept. of Computing & Networking Resources

KISTI Supercomputing Center is responsible for national cyberinfrastructure of Korea

Four departments
- ✓ Resource
- ✓ User Support
- ✓ Cyber Environment
- ✓ Technology

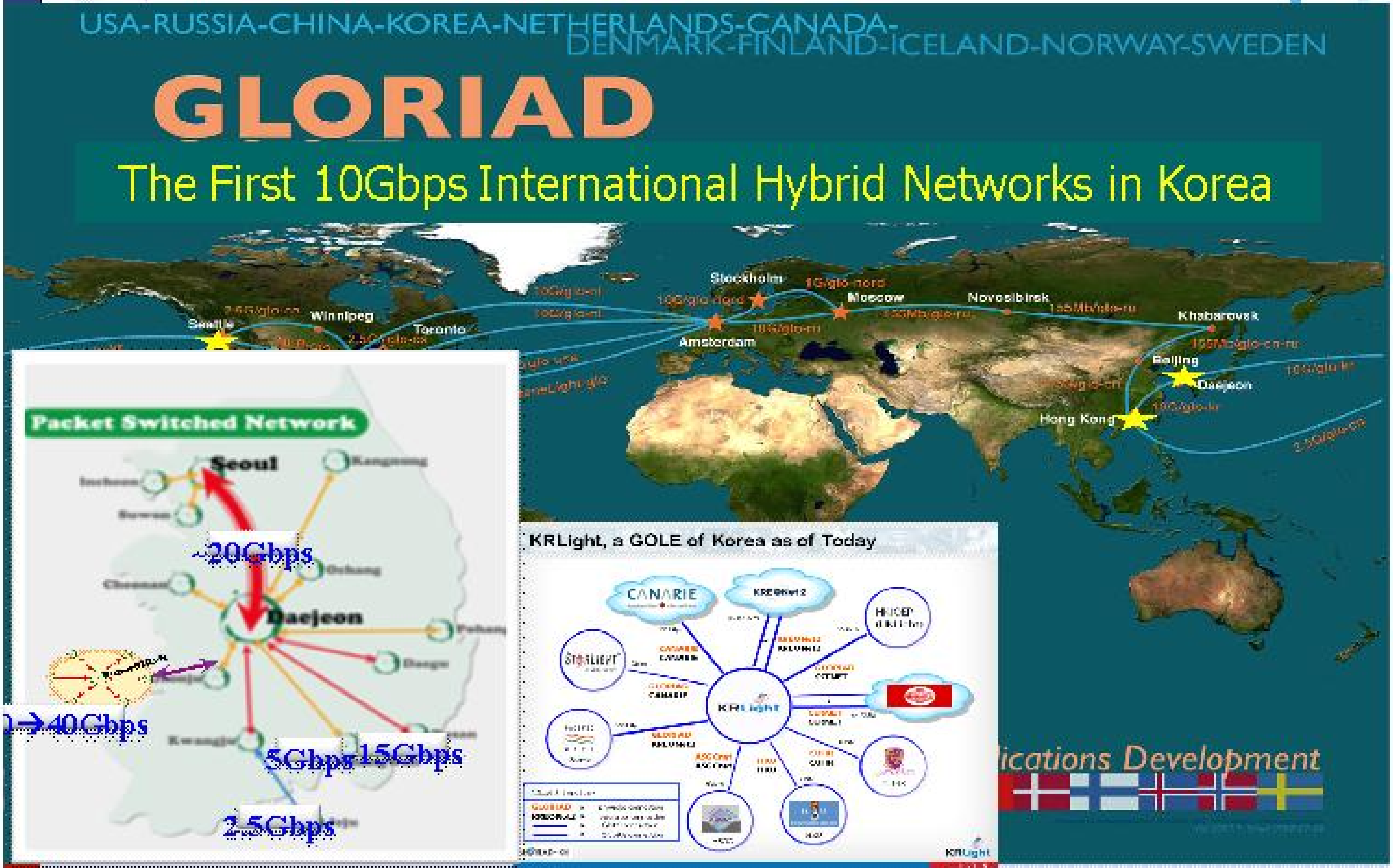
Key Statistics
- ✓ Over 150 staffs
- ✓ Budget over $ 30 million mostly government funded

Major Missions
- ✓ Supercomputing Service
- ✓ Network Service
- ✓ National e-Science

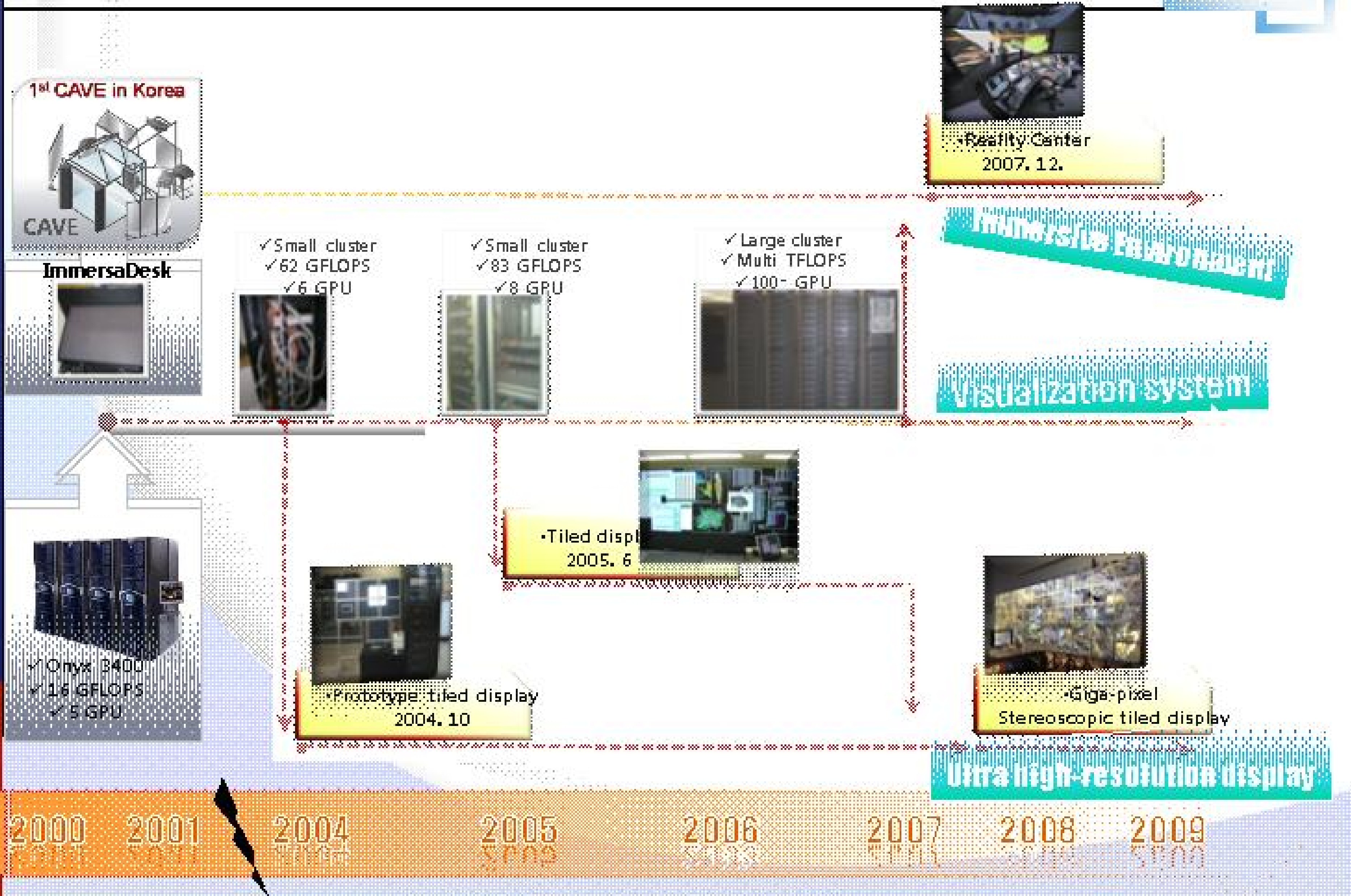
1.2 Supercomputing Resources

TOP 14('09. 11)

1.3 KREONET & GLORIAD



1.4 Visualization System(Picasso)

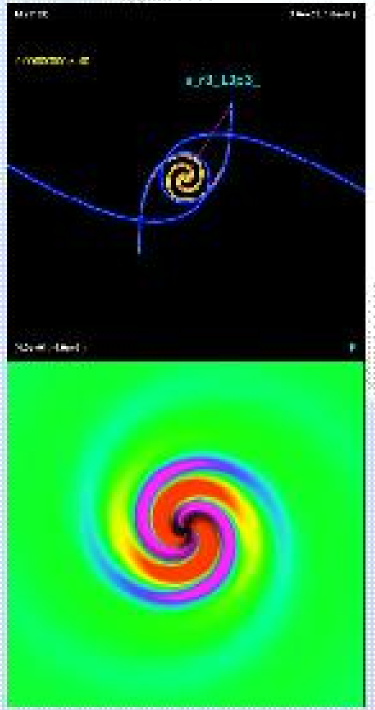


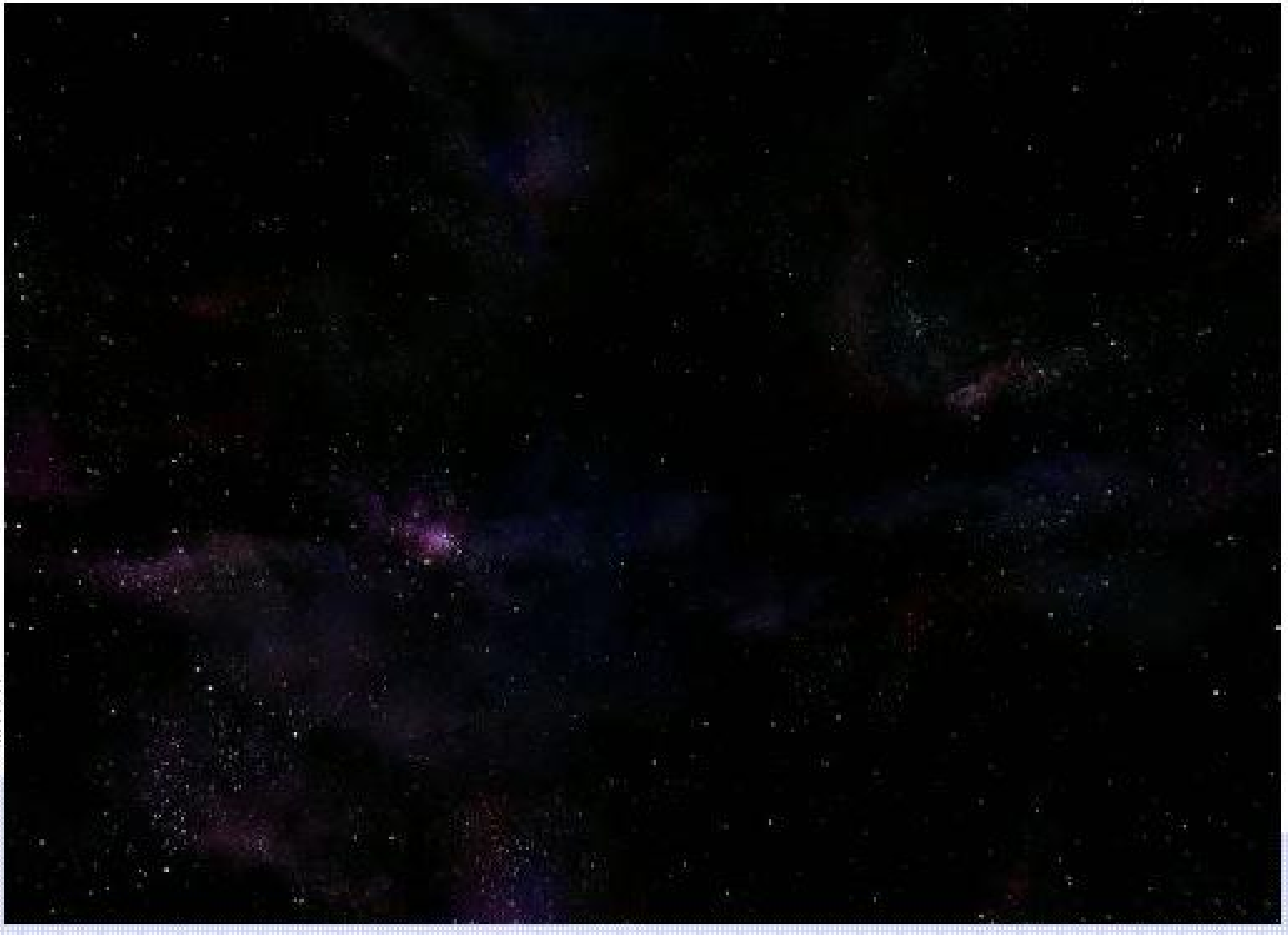
1.4 Visualization System(Picasso)

Visualization Computer		
Total number of nodes		±150
CPU	# of CPU cores	800⁻
Total memory		3.5⁻ TB
GPU	Model	NVIDIA QuadroFX 5600
	# of GPUs	96⁻
Disk	File System	Lustre
	Capacity	300⁻ TB
	Throughput	10 ~ 12⁻ GB/sec sustained
Network	Interconnection network	20 Gbps
	External network	160⁻ Gbps

2.1 Numerical Simulation Results

- Simulation of two black holes collision on KISTI supercomputer
  - 256 CPU(IBM Power 5+, 2007), ~ 60 days
  - Numerical Relativity Research Group at KISTI

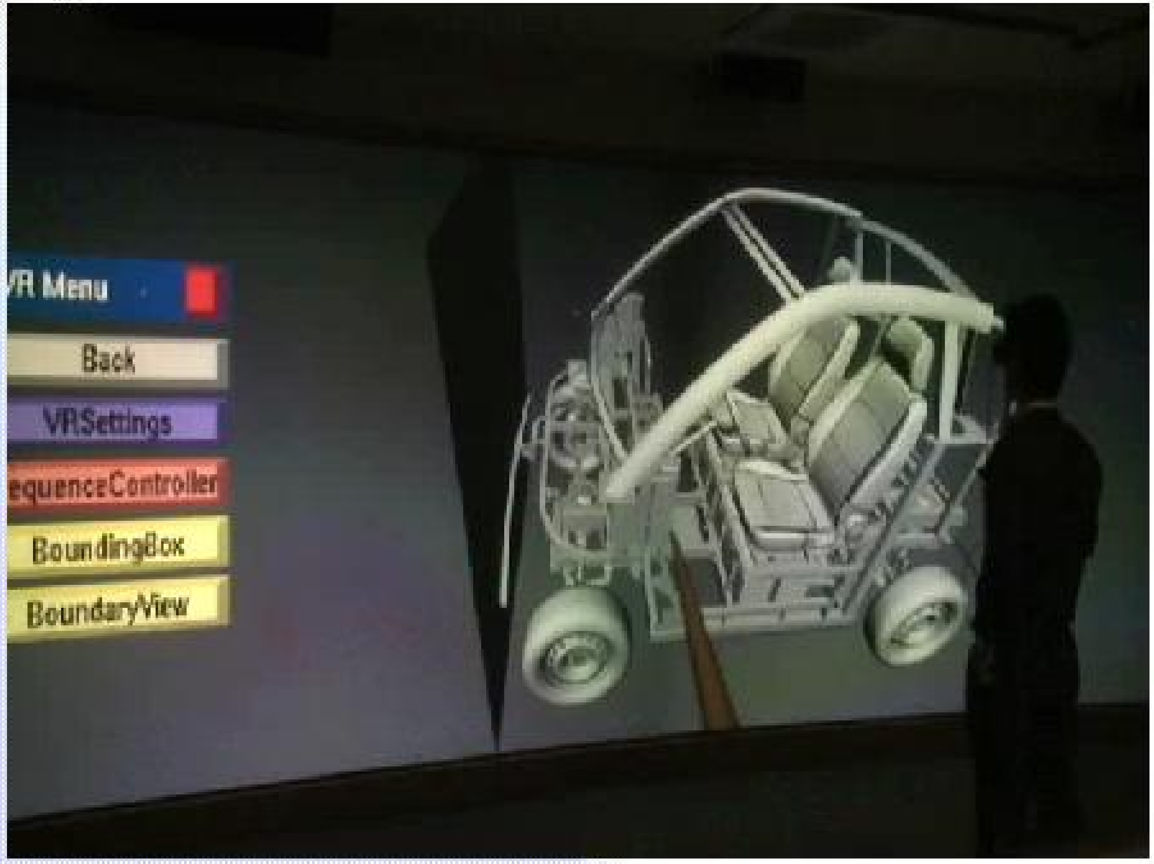


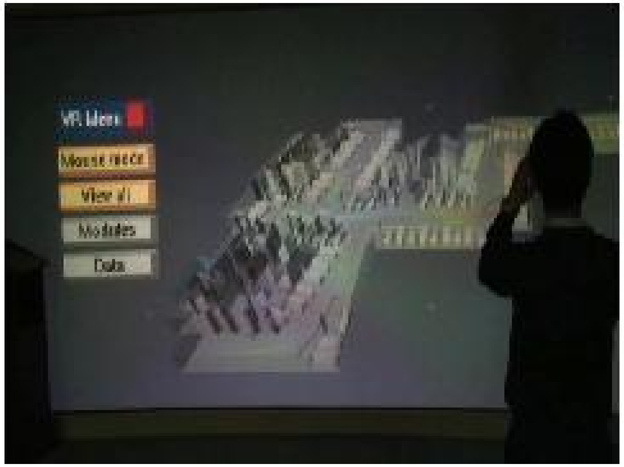


2.2 Industrial User Support

Manufacturing Company Support

- Design overview and validation using VR(Aviso S/W)
- Industrial user supporting program funded by government agency





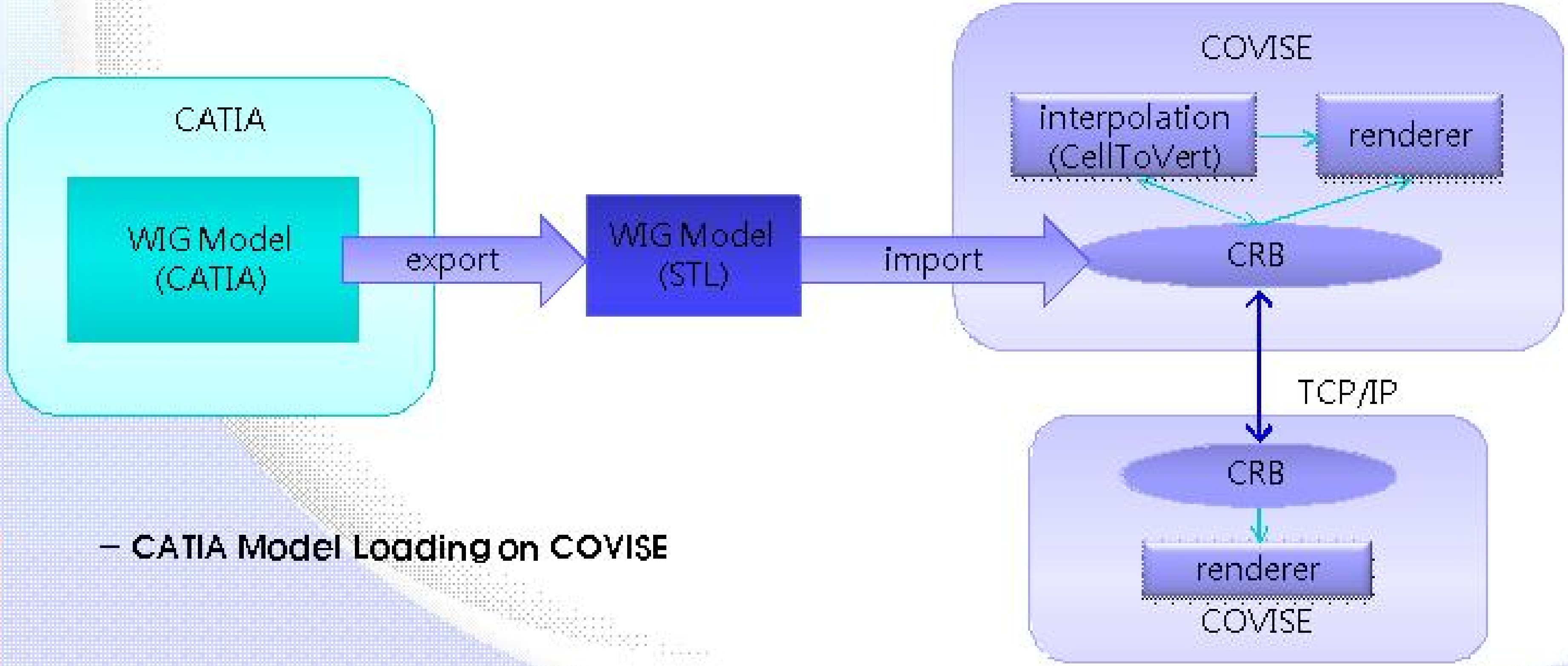
2.3 High-end Application Support

Movie Company Support

- Sports movie(title: 국가대표, The National Team)
- Rendering of sky jump

3.1 Remote Viz. Env. Using COVISE + SAGE(1/3)

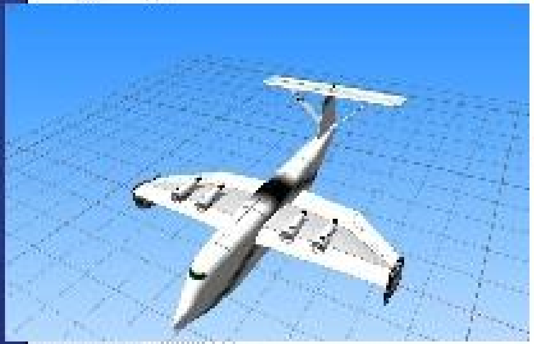
- Remote visualization env. of WIG(Wing-In-Groud effect) ship
  - Combination of COVISE and SAGE
  - CAD → Mesh → Viz → Collaboration



– CATIA Model Loading on COVISE

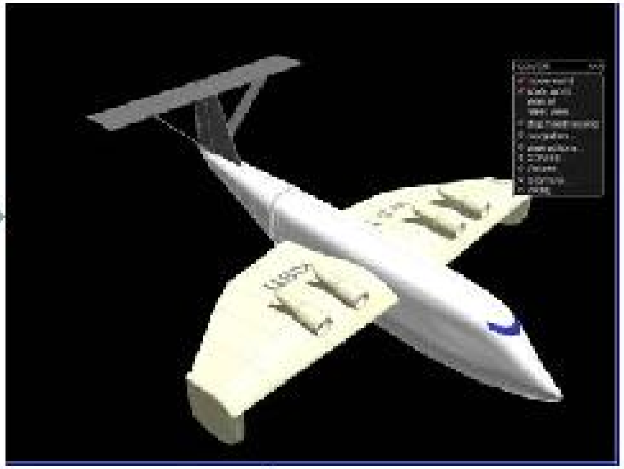
3.1 Remote Viz. Env. Using COVISE + SAGE(2/3)

- Surface data extraction from Multigen

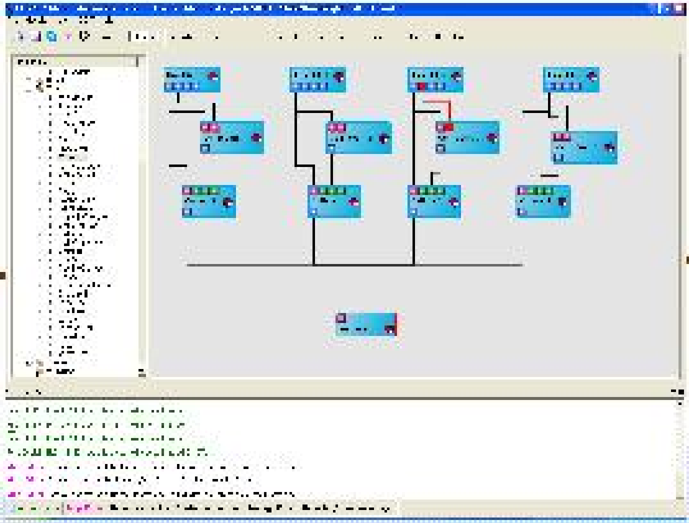


Multigen (WST)

CATIA V5

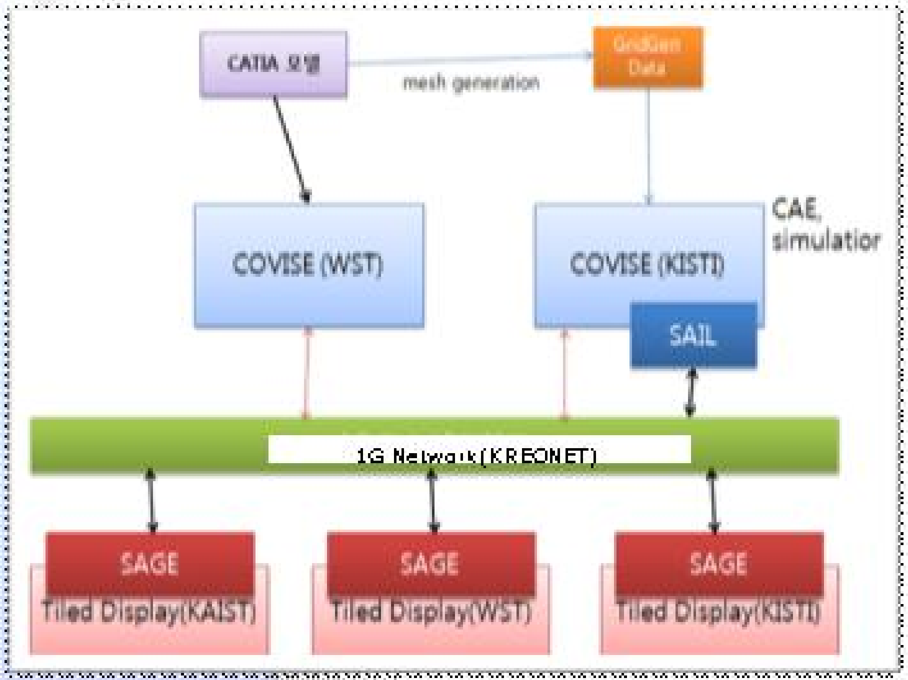


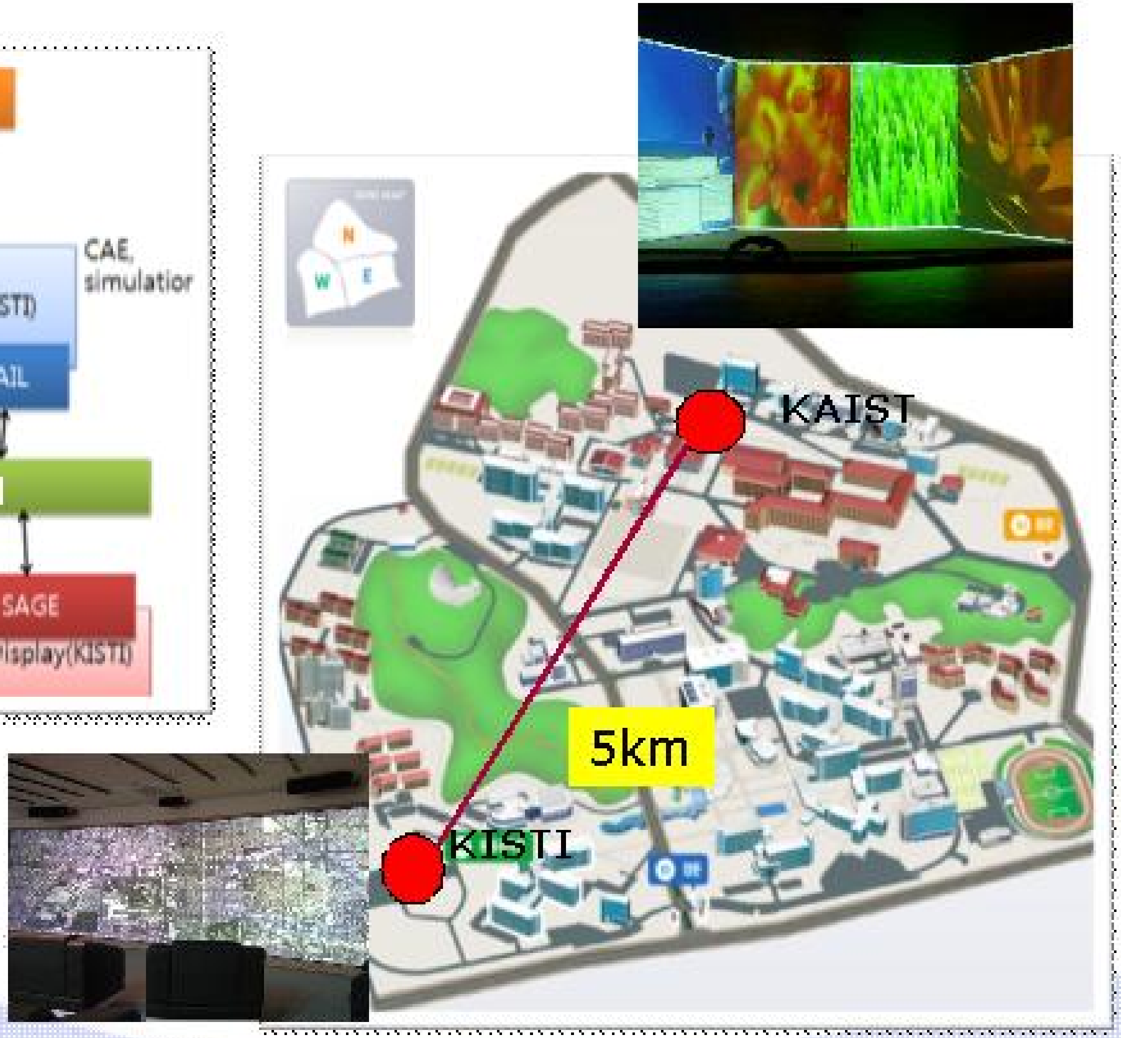
Covise / OpenCover

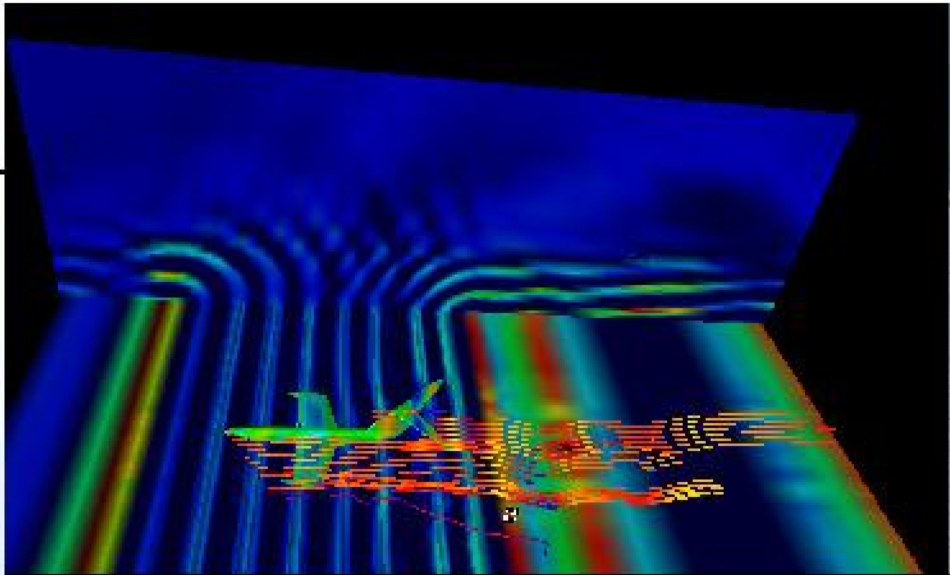


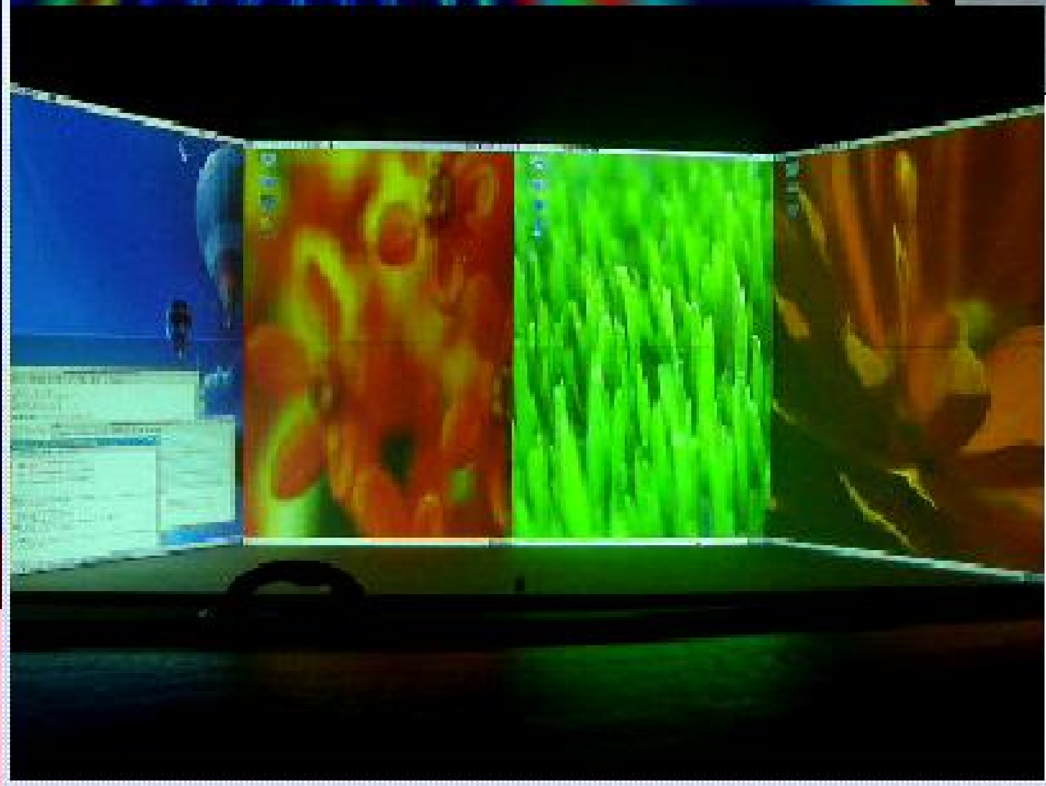
3.1 Remote Viz. Env. Using COVISE + SAGE(3/3)

➲ Testbed(KISTI-KAIST)





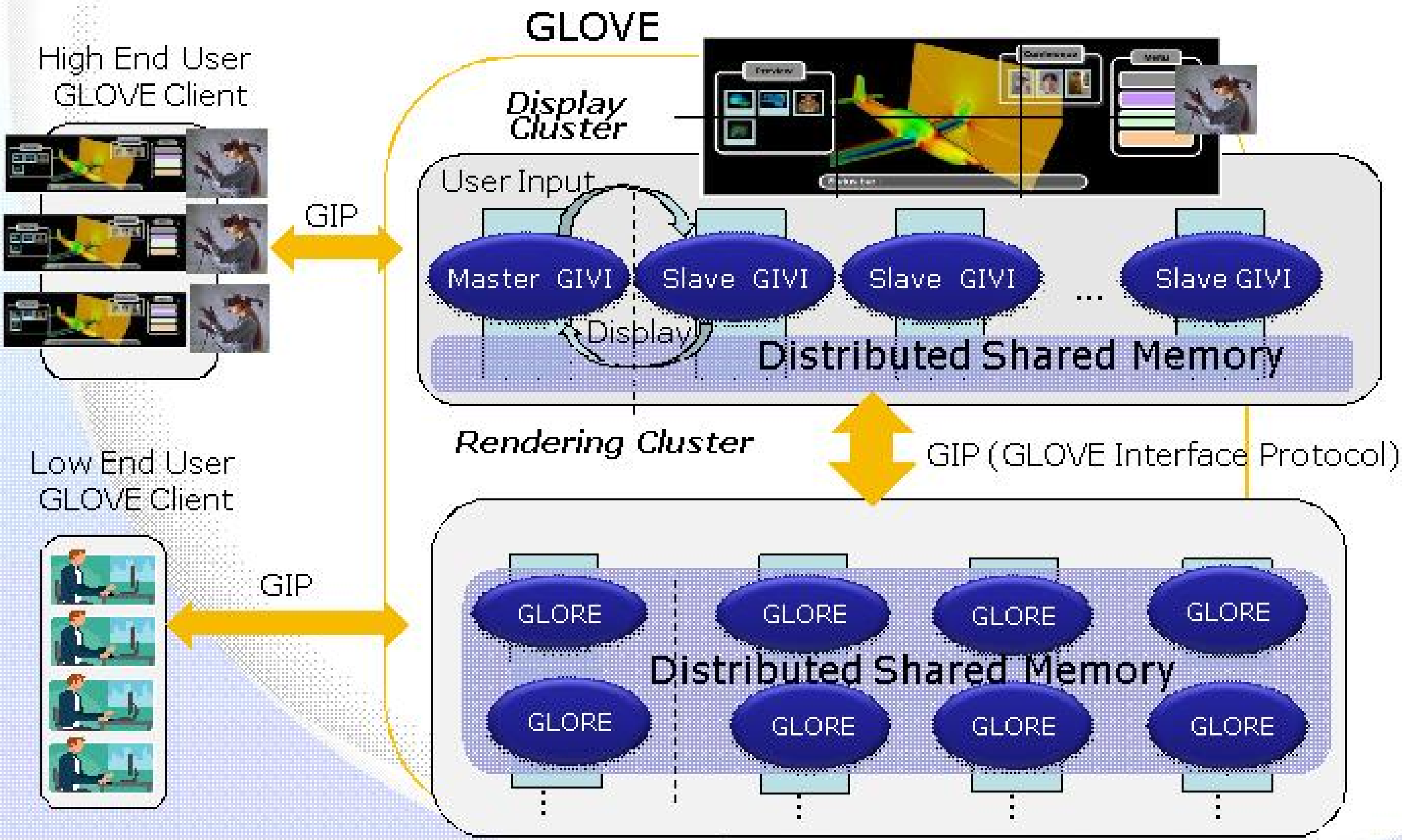




3.2 Overview of GLOVE System

➲ GLObal Virtual Environment for collaborative research

3.2 GLOVE System Architecture



GIVI : GLOVE Integrated Visualization Interface
GLORE : GLOVE Rendering Engine

3.2 Issues of Hugh Data Management(1/2)

- Parallel data I/O system
  - Synchronous file access of each display node
- Lambda RAM cash(distributed shared memory)
  - Hugh data → limitation of cash memory → Lambda RAM
  - Hugh size memory(Parallel rendering and animation) → limitation of local memory
- Example:
  - Unsteady aerodynamic simulation(helicopter)
  - Mesh size: 24.4M points
  - Required memory: 61G(90 simulation steps)

3.2 Issues of Hugh Data Management(2/2)

➲ Rotor Blade Simulation Data Loading Time

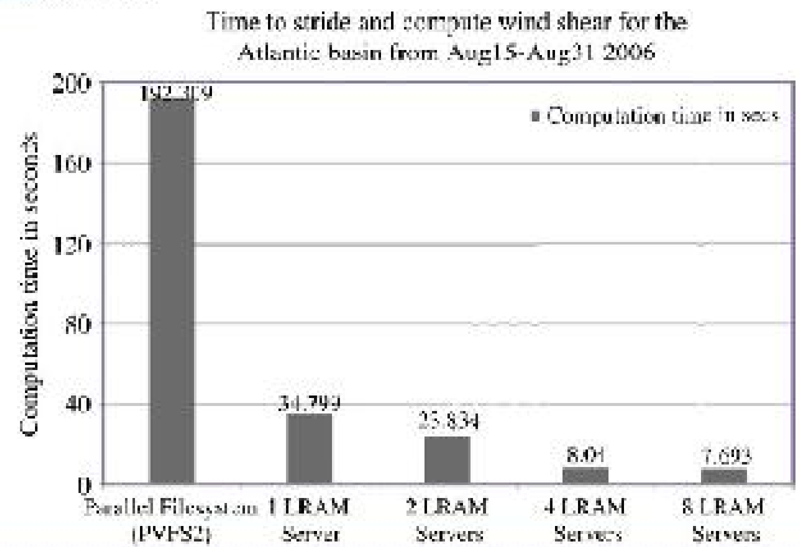
Number of vertices	Cache	Ascii	Binary
35,360	X	0.54	0.219
	O	0.16	0.016
1,208,064	X	22.84	15.345
	O	6.408	1.319

< Blade Data Loading Time in sec>

Number of vertices	Cache	Ascii	Binary
1,070,124	X	138.79	10.31
	O	134.13	3.31
218,049,216	X	1591.41	129.91
	O	1533.59	48.54

< Field Data Loading Time in secs >

➲ Computing time using LambdaRAM

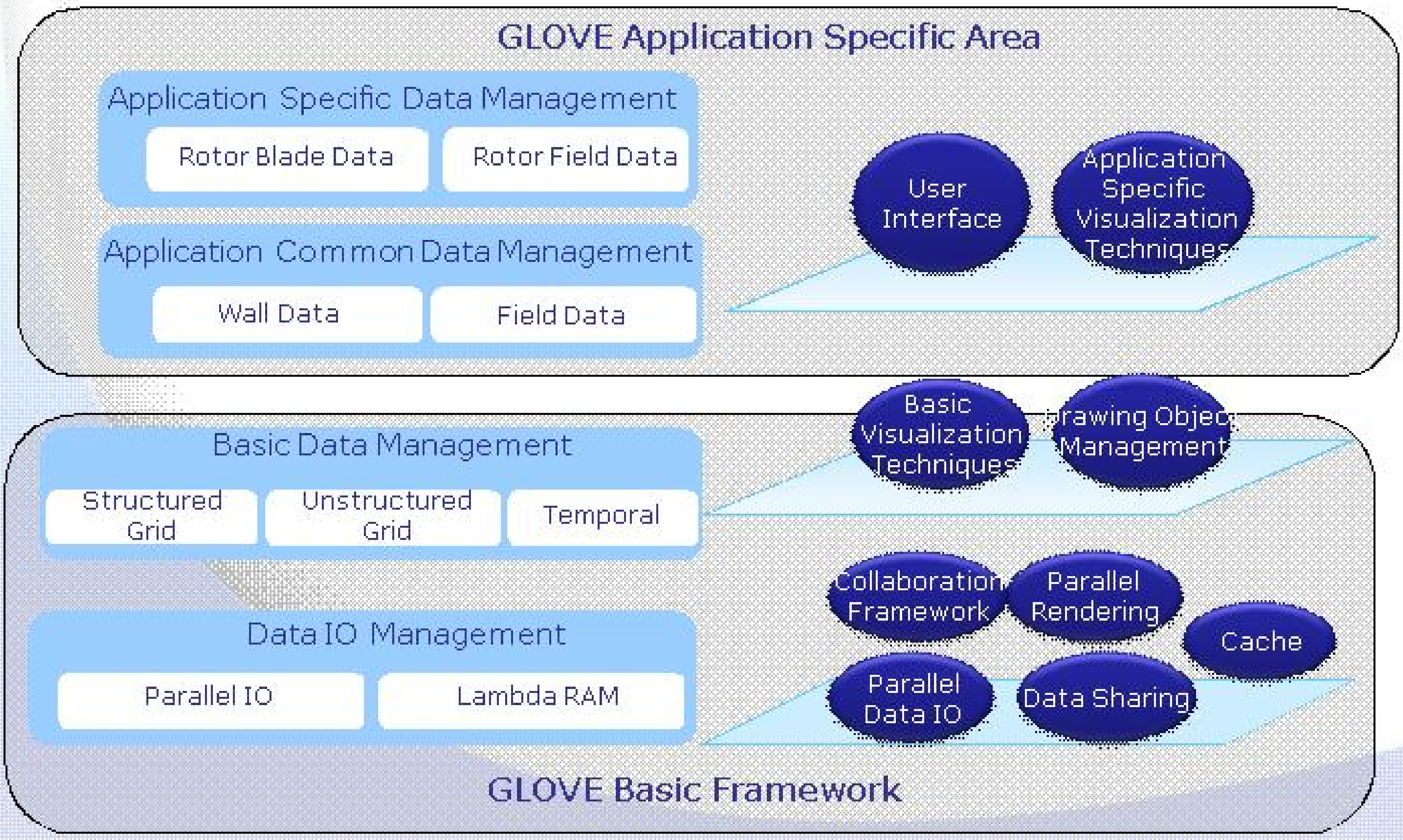


< Wind Shear Computation Time>

*source : Accelerating tropical cyclone analysis using Lambda RAM, Future Generation Computer Systems, 2008

3.2 Framework and Data Mngt Hierarchy

➲ Flexible structure to support applications



3.2 Parallel Rendering

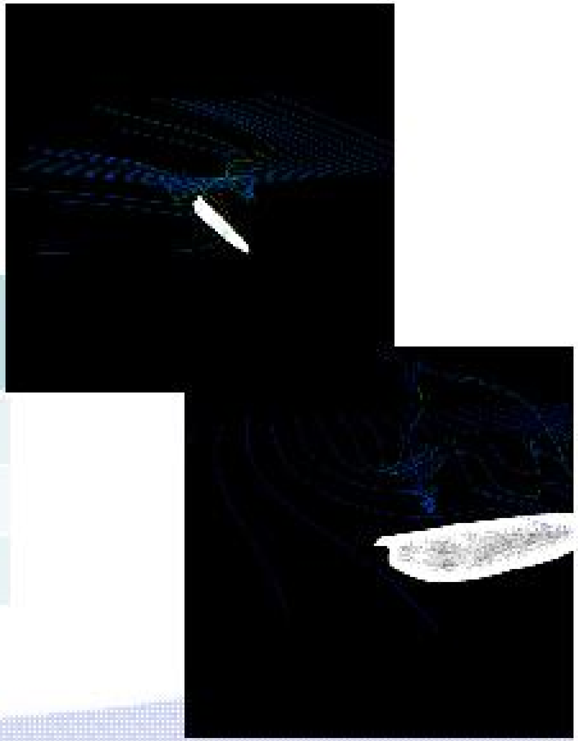
- Efficient Parallel Streamline Generation on the Massive Flow Data
  - Visualization of huge flow data bigger than local memory
    - Out-of-core, Parallelization
- Streamline generation is computing intensive task
  - Integration of flow fields
  - Random access of cell in unstructured grids
- Flow field clustering
  - Partitioning flow field by similarity of velocity vector
  - Methods
    - Hierarchical Tree, Feature based Topology
    - Vortex feature definition, Physics based Anisotropic diffusion

3.2 Parallel Rendering: Test case

- Insect Wing
  - 6M cells x 100 frames

	Vertices	Faces	Cells
Identical	6M	18M	6M
Duplicated	83K	17M	-
Total	6M	35M	6M

- 400 steps / 1,000 seed points (sec)



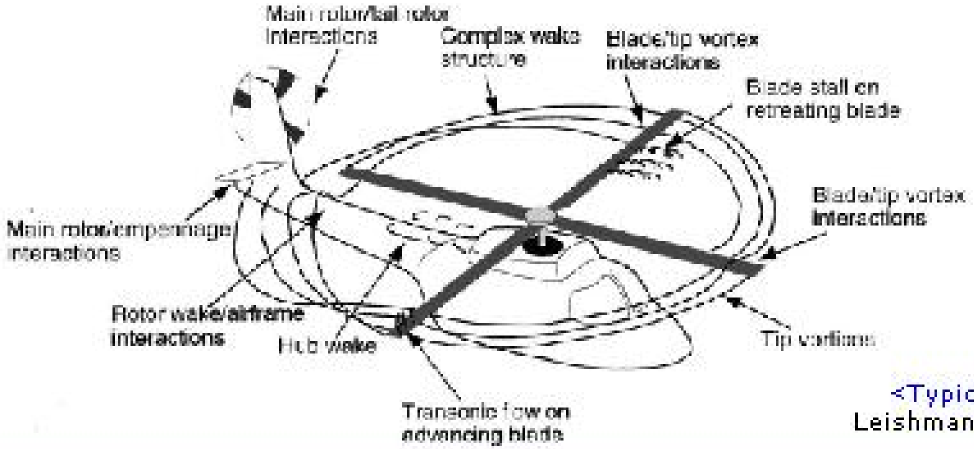
	Regular Decomposition	Clustering based Decomposition
Single Node	32.44	
16 Nodes	9.59	8.12
32 Nodes	8.61	7.55

3.2 Real Application: Rotorcraft aerodynamics

Features of rotorcraft aerodynamics

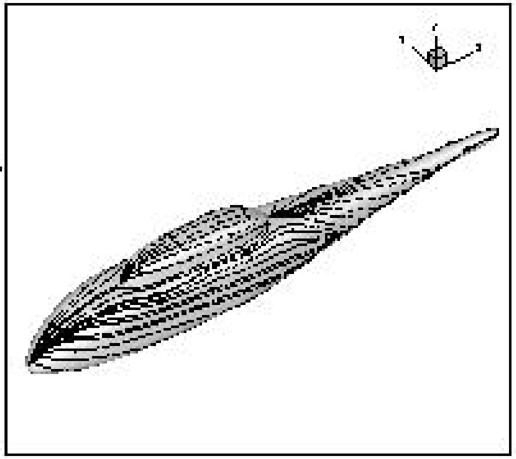
- ✓Variation of velocity and Reynolds number along the radial direction
- ✓Strong tip vortices
  - highly unsteady and nonuniform induced velocity field at the rotor disk
- ✓Blade-Vortex Interaction
- ✓Aeroelastic effects
- ✓Rotor-Fuselage Interaction
  - Mutual aerodynamic interference and the aerodynamic inharmoniousness between the rotor and the fuselage
  - Undesirable noise, air loads and vibration occurrence

For the stable operation of helicopter, elaborate aerodynamic analysis of the rotor-fuselage interaction must be preceded.



<Typical flow phenomena found on a helicopter in forward flight>
Leishman, J. G. and Bagai A., "Challenges in Understanding the Vortex Dynamics of Helicopter Rotor Wakes"

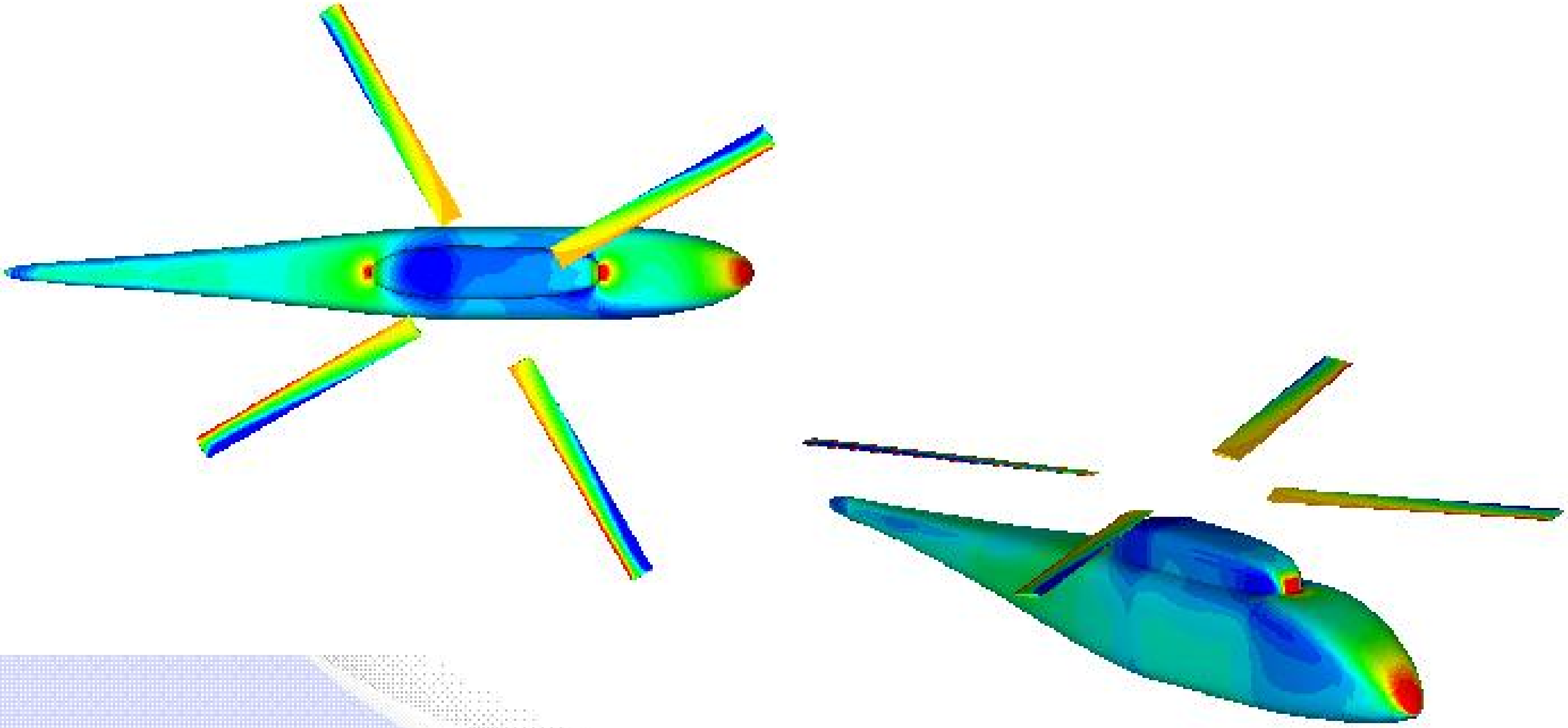
3.2.1 Numerical methods



- Governing equations
  - The 3D N-S equations
- Spatial discretization
  - 2^{nd} order Roe flux difference splitting scheme
  - 5^{th} order Weighted ENO(Essentially Non-Oscillatory scheme)
- Time advancing method
  - Dual-time stepping combined with DADI(Diagonalized ADI)
- Parametric Study for Isolated ROBIN fuselage
- To compute Rotor-Fuselage Interaction of Robin Configuration
  - Structured Chimera overset grid system
  - Rotor–Fuselage vortex interaction

3.2.1 Test case

➲ Rotor-Fuselage Configuration



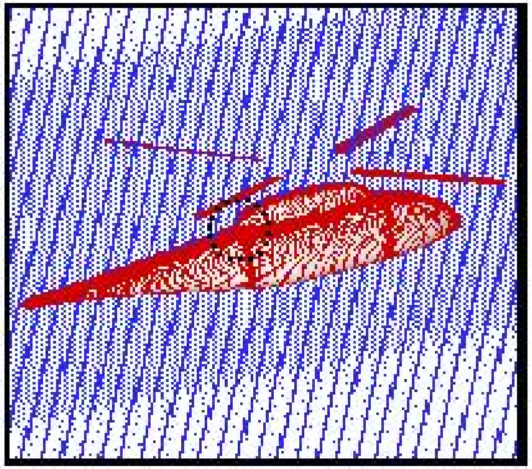
3.2.2 Experimental Setup

➲ Operating conditions and parameter

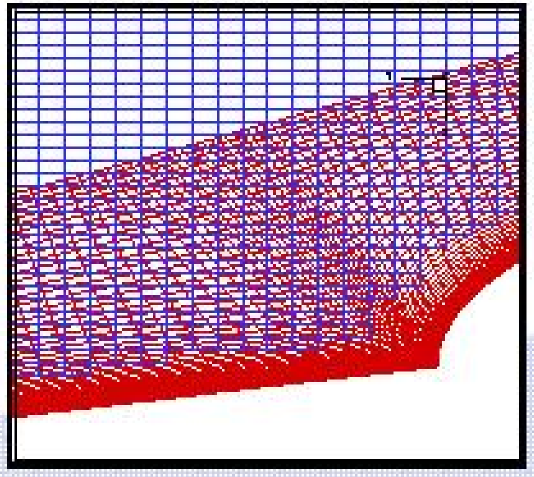
Property	Value
Blade planform	Rectangular
Radius	0.8606 meters
Root chord	0.0660 meters
Tip chord	0.0660 meters
Number of blade	4
Root cutout location	0.24R
Flap/lag hinge location	0.06R
Airfoil section	NACA0012
Twist	-8°
Nominal thrust coefficient	0.0064
Solidity	0.0977
Nominal hover M_{tip}	0.53
Approx. mean coning angle	1°
Shaft tilt	3° nose down

Grid type	Cells
Background	241 X 341 X 241
Blade X 4	21 X 101 X 169 X 4
Fuselage	129 X 549 X 49
Total	24.7M cells

✣ Rotor-Fuselage and Background Chimera grid syste

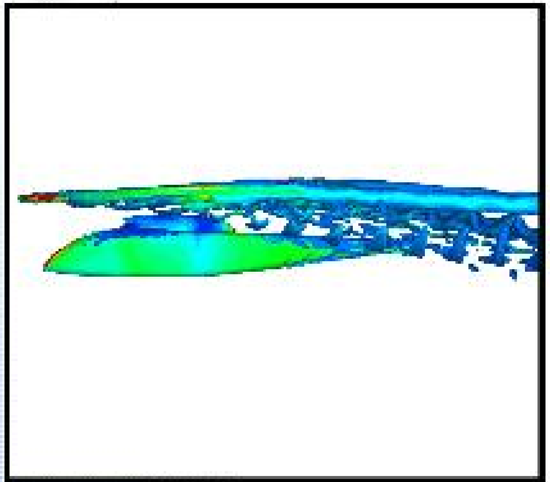


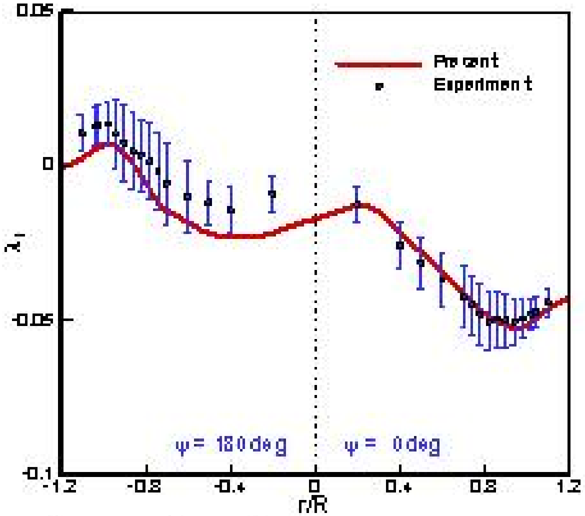
✣ Chimera Grid system at the back of Pylon shape

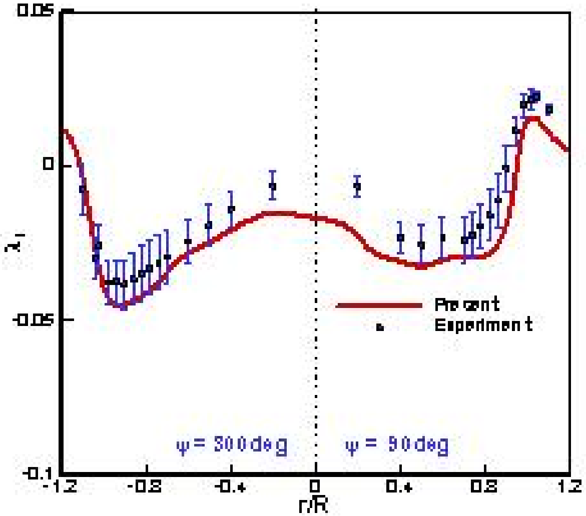


3.2.3 Time-averaged velocity distribution

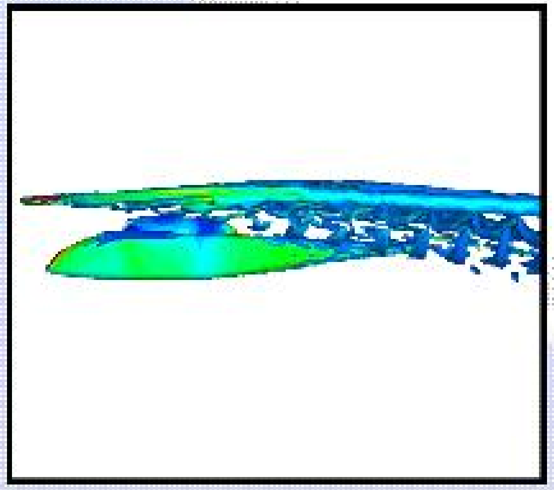
- Time-averaged downwash distribution for ROBIN configuration at 1.15c above the rotor disk

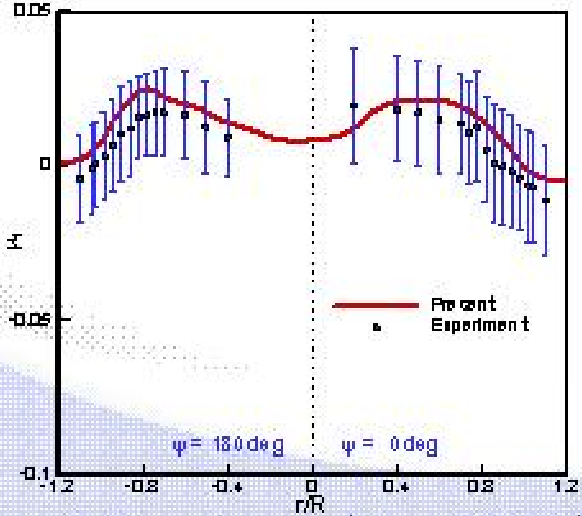


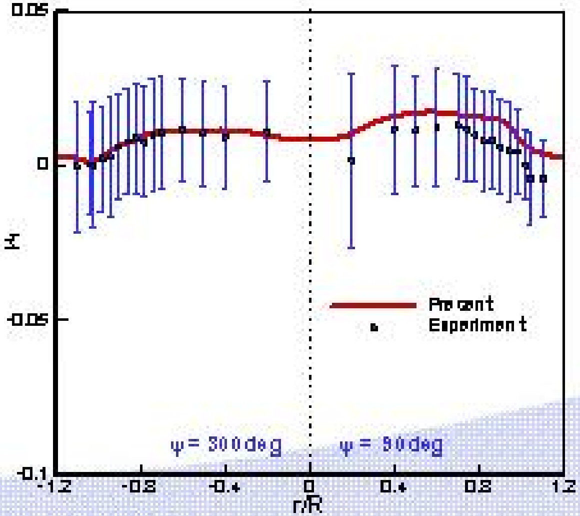




- Time-averaged stream wise velocity distribution







- Experiment data : NASA/TM-100541

3.2.3 Wake Visualization

- Wake visualization by *Q: the second invariant of velocity gradient tensor*
- Q criterion: $$Q = \frac{1}{2}(\Omega_{ij}^2 - S_{ij}^2) = -\frac{1}{2}\frac{\partial u_i}{\partial x_j}\frac{\partial u_j}{\partial x_i} = \frac{1}{2}\frac{\nabla^2 P}{\rho} > 0$$

  where

  $$\Omega_{ij} = \frac{1}{2}\left(\frac{\partial u_i}{\partial x_j} - \frac{\partial u_j}{\partial x_i}\right), \quad S_{ij} = \frac{1}{2}\left(\frac{\partial u_i}{\partial x_j} + \frac{\partial u_j}{\partial x_i}\right)$$

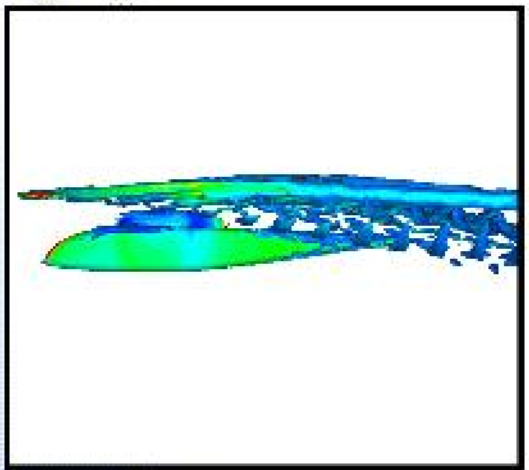
  Vorticity components — Strain rate

- *Q* represents the balance between the vorticity and the rate of strain. This leads to a representation of vortical structures.

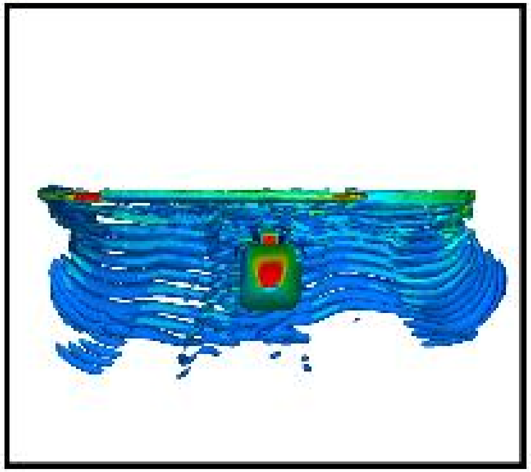
Q iso-Surfaces	: 0.0005	C_p (blade)	: -0.5 ~ 0.1
vorticity	: 0.05 ~ 0.2	C_p (fuselage)	: -0.005 ~ 0.015

3.2.3 Wake Visualization

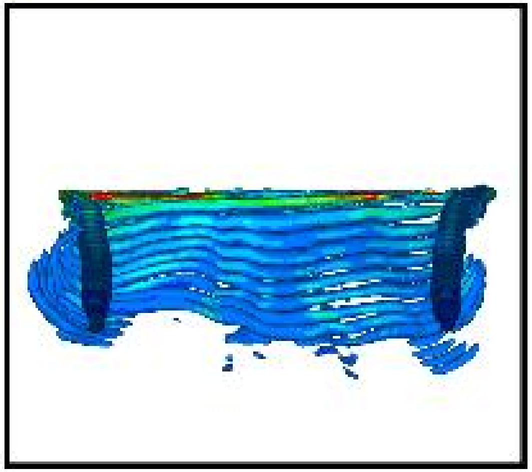
- side view



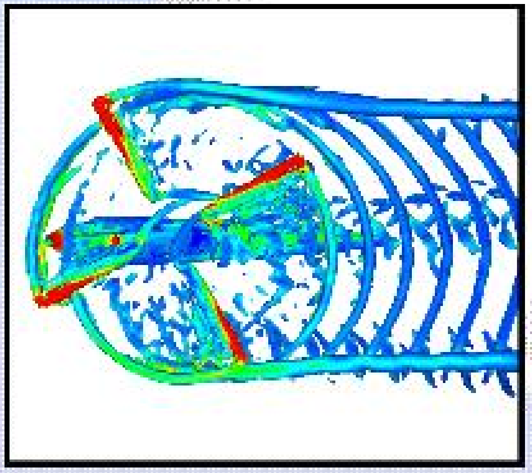
- front view

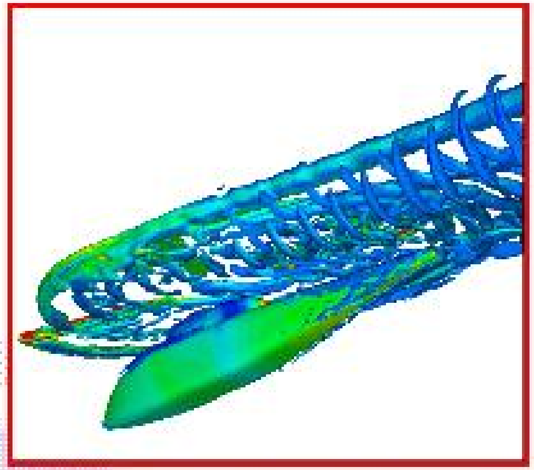


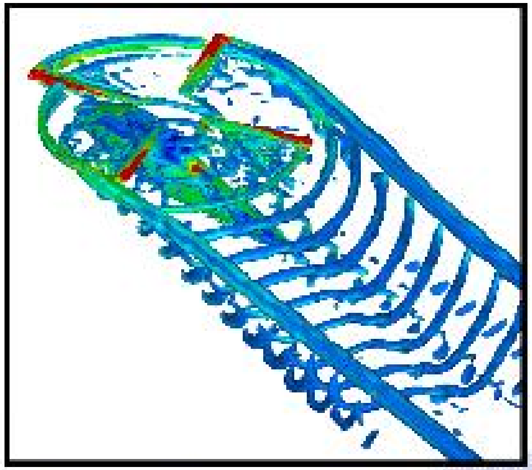
- rear view



- top view



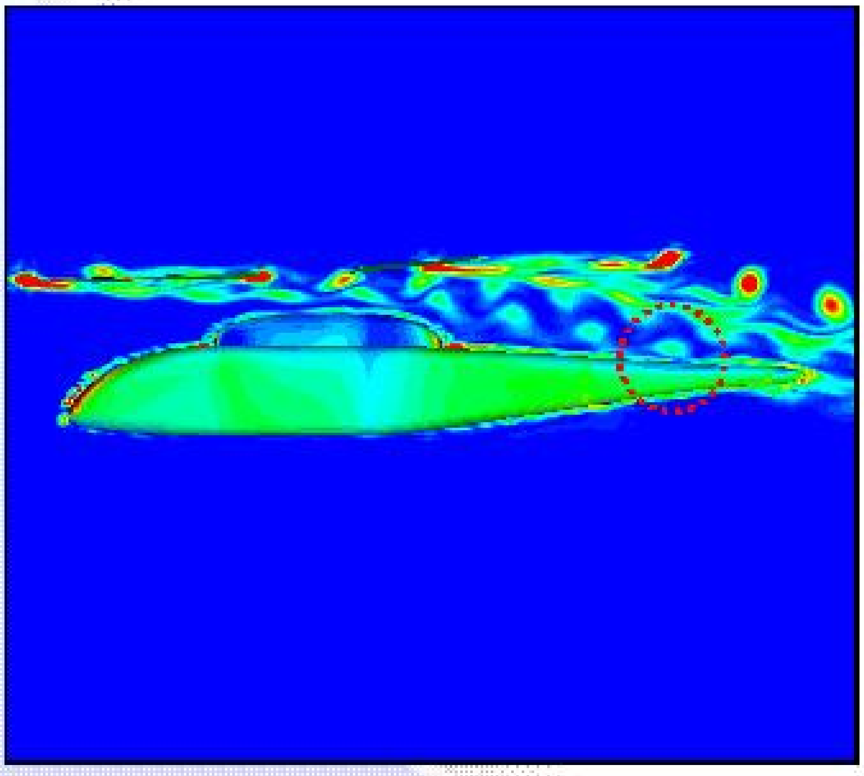




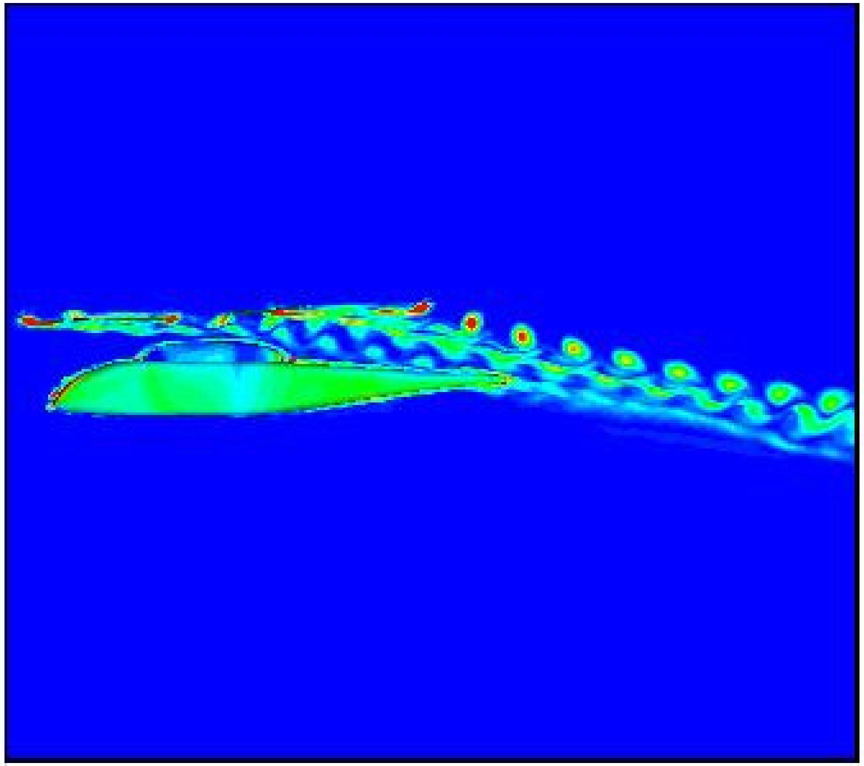
- Q criterion colored by vorticity strength

3.2.4 Vorticity contour

- Vorticity contour (0.01 ~ 0.15) at the fuselage symmetric plane :
  $\mu = 0.15$, $C_T=0.00654$, $\Psi=300°$



(a) near view

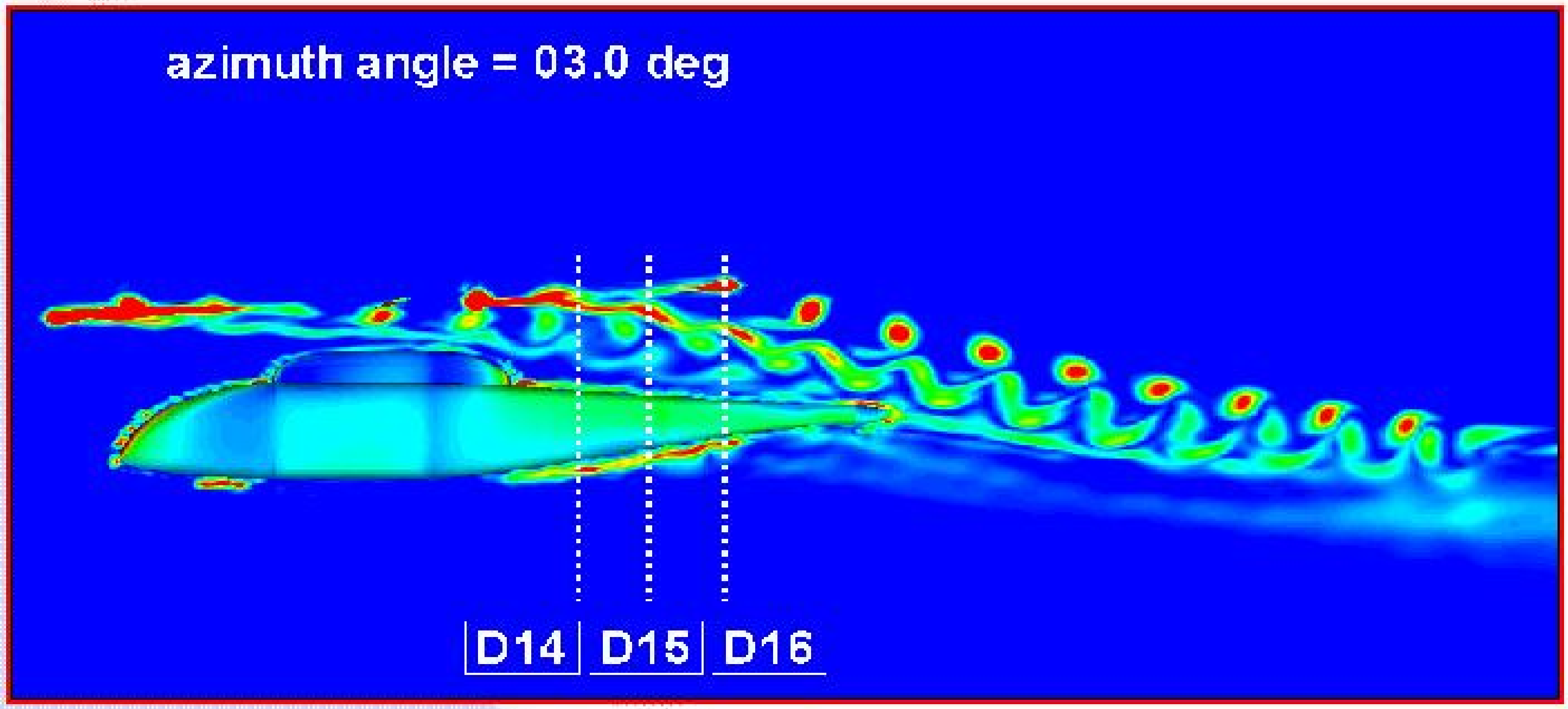


(b) far view

- Fuselage vortex interaction captured

3.2.4 Vorticity contour

- Vorticity contour at the fuselage symmetric plane :
  $\mu = 0.15$, $C_T = 0.00654$, $\Psi = 300°$

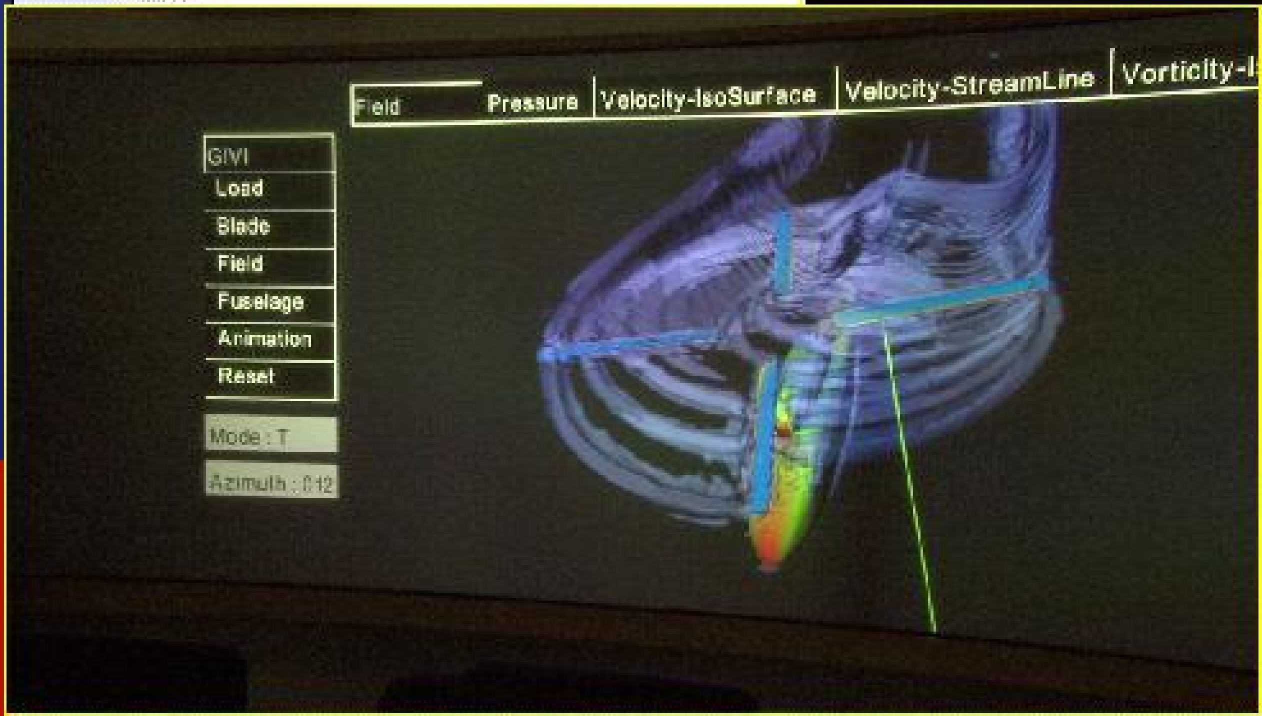


3.2.4 Blade Surface Visualization

- Pressure Distribution
- Graph
  - ✓ Pitch Angle Variation, Sectional Force (normal, chord, span)
  - ✓ Section Moment (x, y, z)

3.2.5 Field Date Visualization

- Vorticity iso-surface
- Q-criteria
- Velocity streamline
- Velocity iso-surface
- Animation



3.3 Demo

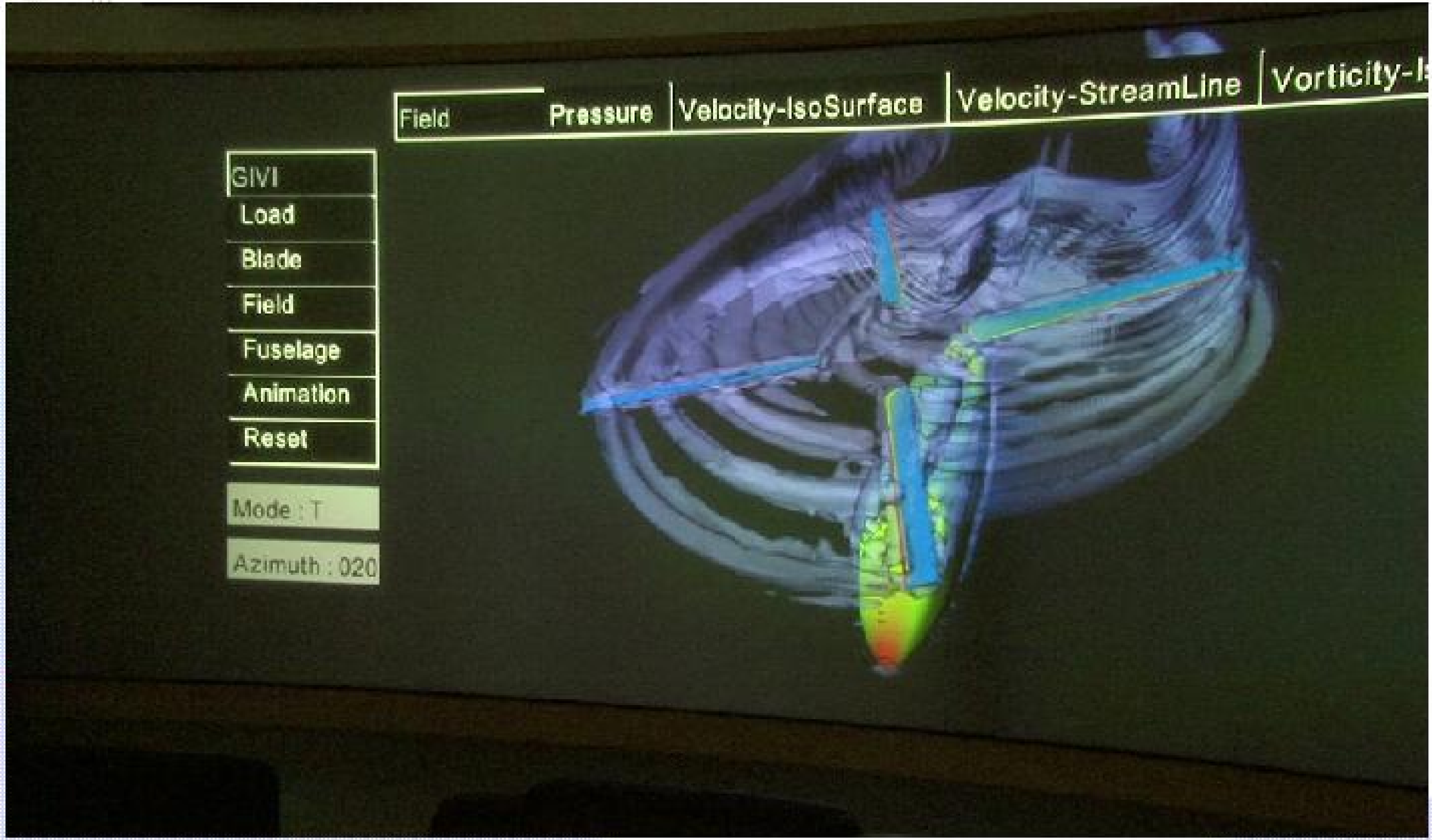
Picasso Rendering System

- No. node : 146 node(109 node graphic performance)
  - ✓ Back-end Rendering 90 node, Display 16 node
- GPU : 109 (nVidia QuadroFX5600)
- CPU Core: 8 core/node, total 872 core, real performance 8.4 TFLOPS
- Storage 450 TB
- Network : Infiniband 20Gbps, Ethernet 10Gbps
- Memory/node : 64G
- Display System :Resolution = 7300 * 2100

Development tools

- VRJuggler, vjVTK, VTK

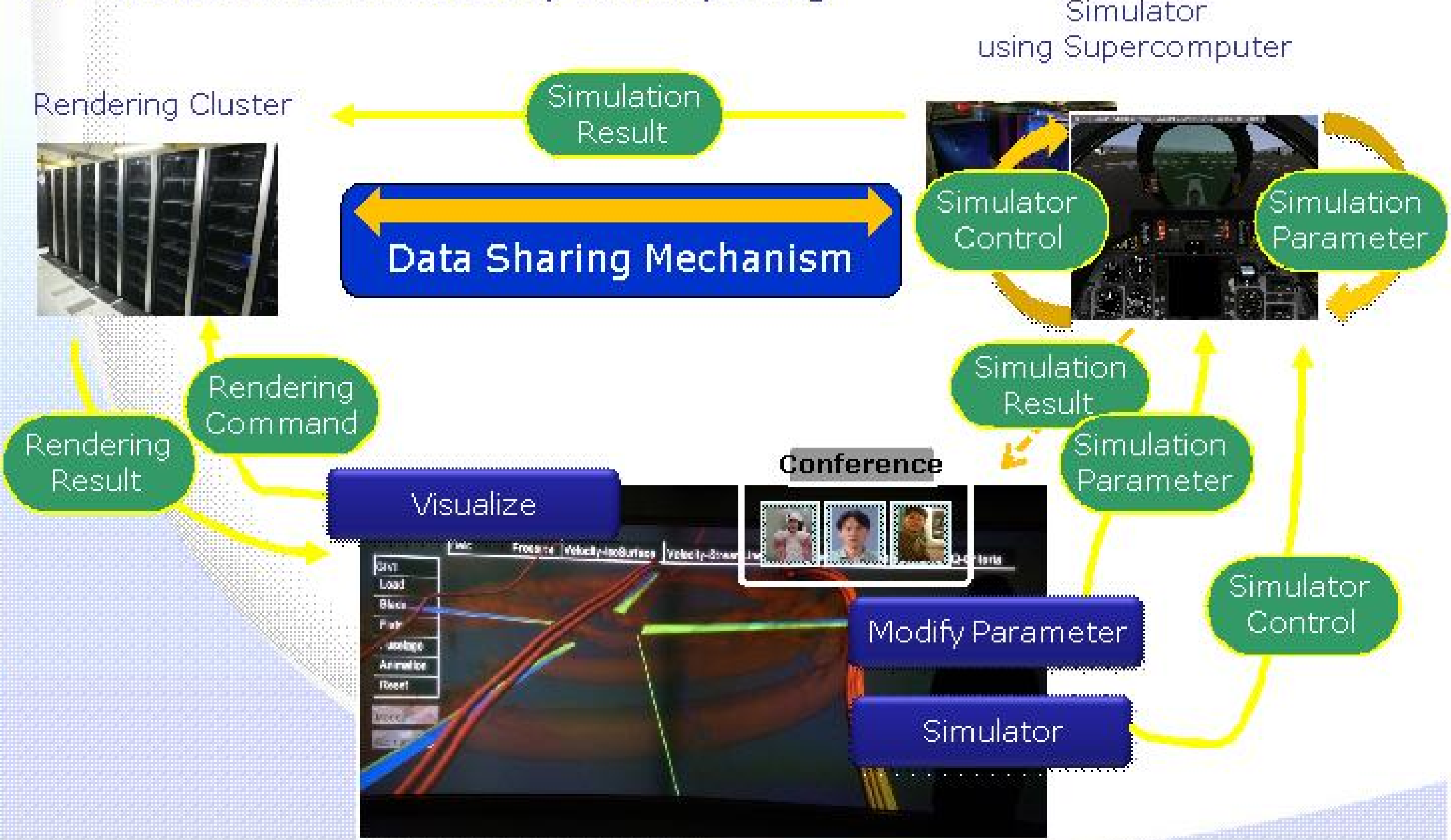
3.3 Demo



Field
Pressure
Velocity-IsoSurface
Velocity-StreamLine
GIVI
Load
Blade
Field
Fuselage
Animation
Reset
Mode : T
Azimuth : 020

4.1 Future Plan

- Visual Interactive Supercomputing



Thanks for your attention !

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