Web-Based Integrated Research Environment for Aerodynamic/Wind Simulation(e-AIRS)

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Dept. of Cyber Environment Development

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1. **Overview**

2. Web-based CFD research environment

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4. Conclusions

What is e-Science ?

Science 2.0 + Team Science

High-end cyber research environment which increases the productivity of research by integrating high-performance computing facilities, large scale data, human resources and more, though the leading edge ICT and high performance network
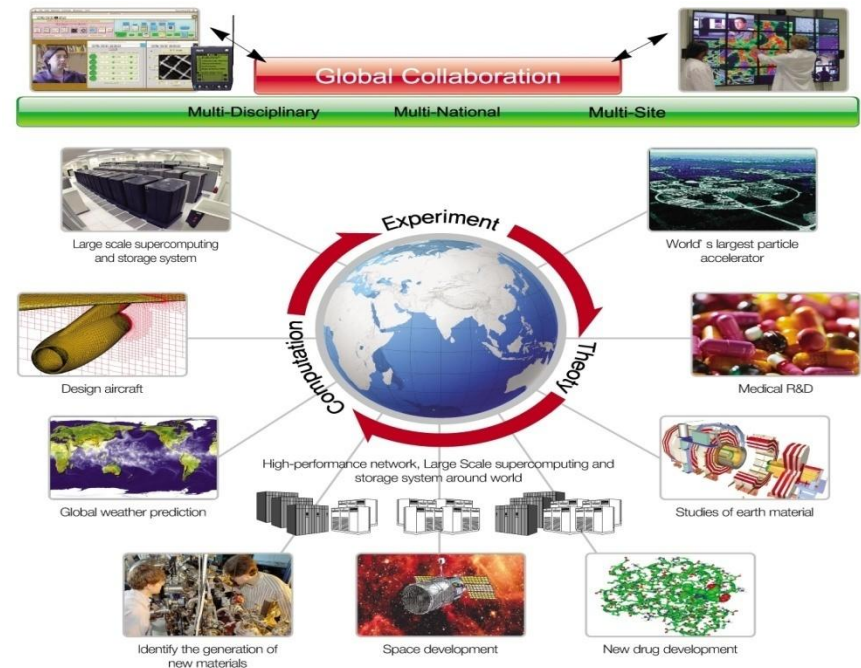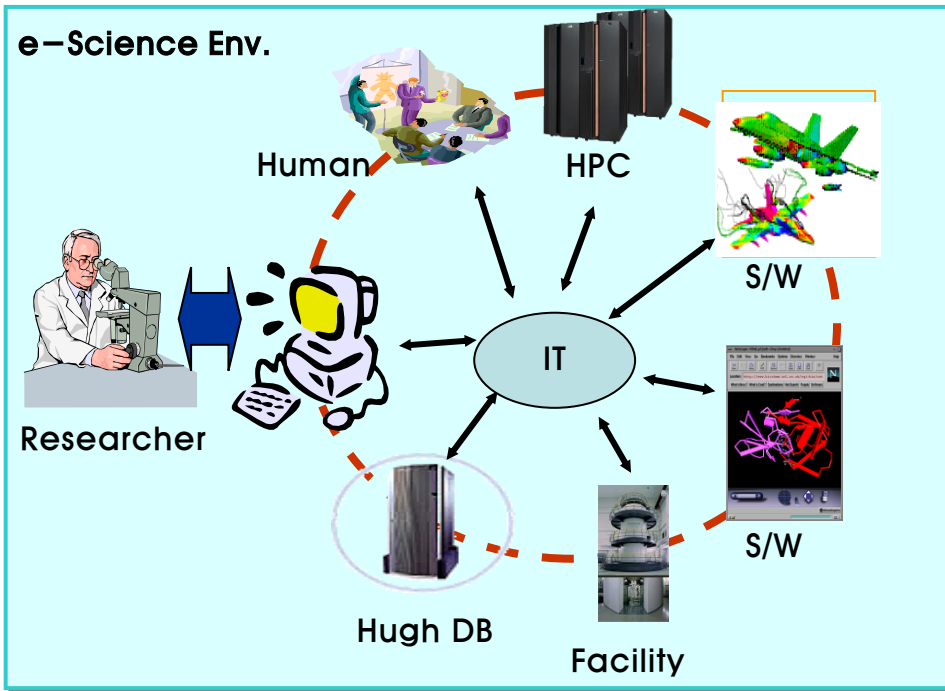
- e = electronic : enhanced : enabled
- Science 2.0(Open, Share, Collaboration), Team Science

KISTI Top Brand Project (K e-Science)

KISTI Top Brand Project (K e-Science)

e-Science Applications

Core Technology
DM/KM, Grid computing, WS

Collaboration Infra.
Viz, AG, Computing, Storage

Virtual Lab   **Cyber Education**

Global Collaboration

| Multi-Disciplinary | Multi-National | Multi-Site |

Key Words

Real World

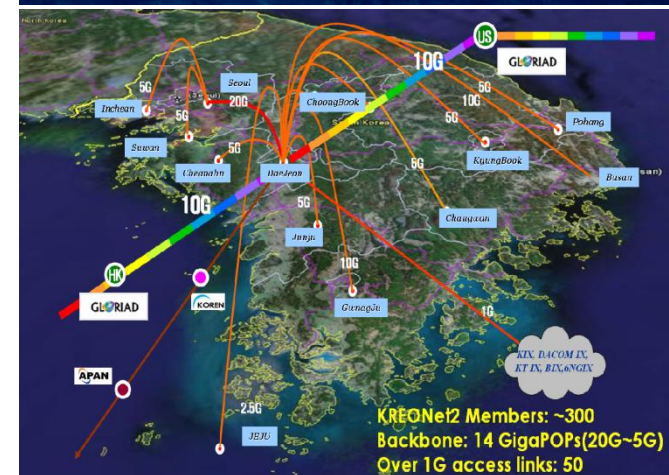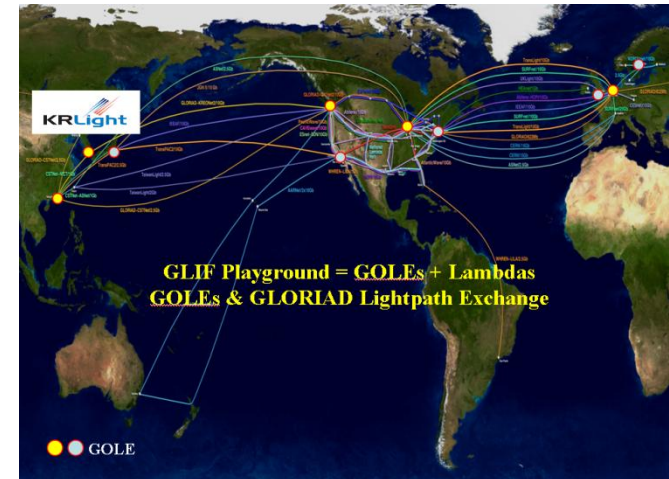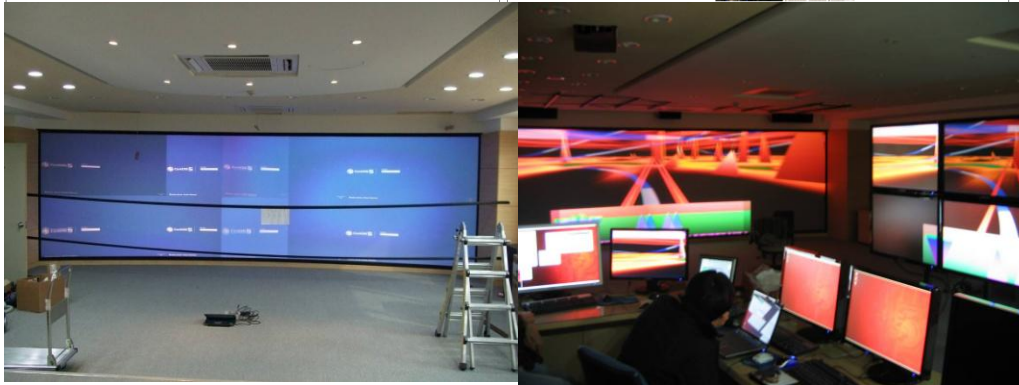GLORIAD(10G)

World-class Facilities at KISTI

KISTI's 4th Supercomputer

- **MPP System** (1st phase)
  - **SUN C48** :188 Nodes
  - Target Performance : **24 Tflops**
  - Internal Disk : 8 GB Flash or Micro Drive
  - Infiniband 4x DDR 20Gbps
  - External Storage : 200TBytes
- 2nd phase
  - **250 TFlops Target performance**
  - About 21,000 cores
  - 1.3 PBytes external storage

- **SMP System**
  - **IBM p595 & p6**: 10 (1st), 24 nodes(2nd)
  - Target Performance:**36TFlops**
  - Internal Disk : 1,17 GB
  - External Storage : 63TB(1st), 273 TB(2nd)
  - HPS(1st) interconnect network & Infiniband 4x DDR (2nd)

GLIF Playground = GOLEs + Lambdas
GOLEs & GLORIAD Lightpath Exchange

GOLE

KREONet2 Members: ~300
Backbone: 14 GigaPOPs(20G~5G)
Over 1G access links: 50

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3. EDISON Project

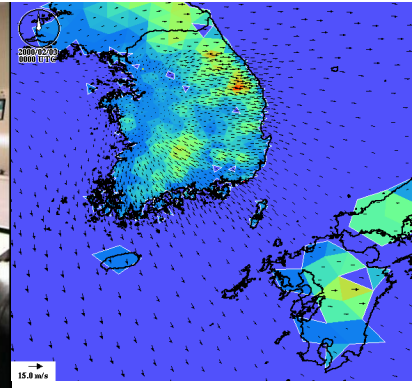4. Conclusions

e-AIRS(ICT + Fluid Dynamics)

Fluid Dynamics

- the sub-discipline of fluid mechanics dealing with fluid flow: fluids (liquids and gases) in motion
  - Calculating forces and moments on aircraft
  - Determining the mass flow rates of petroleum through pipelines
  - Predicting weather patterns, traffic engineering and etc
- The solution of a fluid dynamics problem typically involves calculation of various properties of the fluid, such as velocity, pressure, density, and temperature, as functions of space and time.

Navier-Stokes Eqn.

$$\frac{\partial Q}{\partial t} + \frac{\partial (F_j - Fv_j)}{\partial x_j} = 0$$

$$Q = \begin{bmatrix} \rho \\ \rho u_i \\ \rho E \end{bmatrix}, \quad F_j = \begin{bmatrix} \rho u_j \\ \rho u_i u_j + p\delta_{ij} \\ \rho u_j H \end{bmatrix}$$
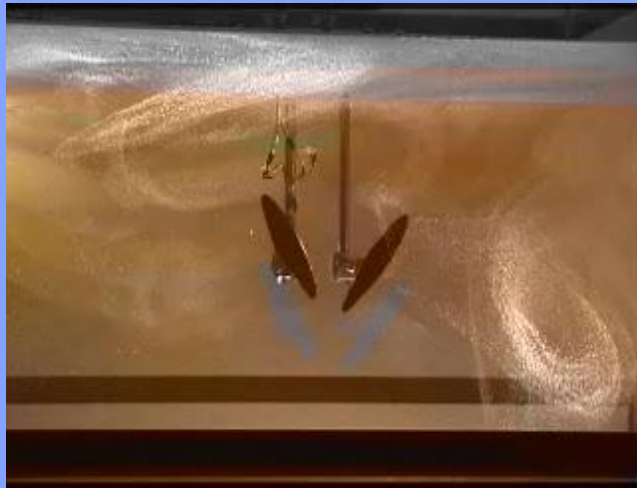
$$Fv_j = \begin{bmatrix} 0 \\ \tau_{ij} + \tau_{ij}^* \\ u_i(\tau_{ij} + \tau_{ij}^*) - q_j + (\mu_l + \sigma_k \mu_t)\frac{\partial k}{\partial x_j} \end{bmatrix}$$
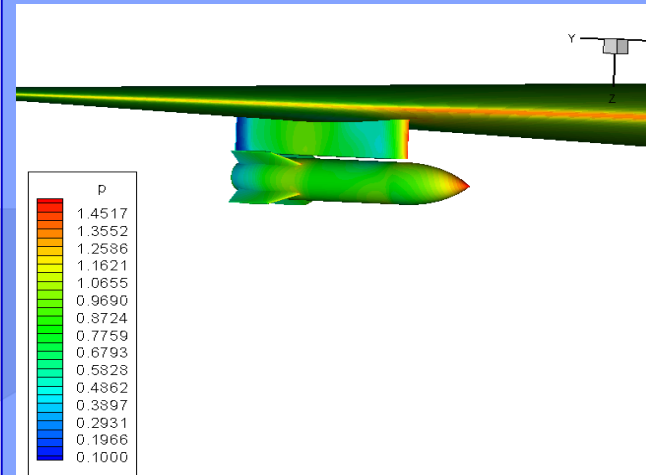
Korea Institute of Science and Technology Information
www.kisti.re.kr

e-AIRS(ICT + Fluid Dynamics)

○ How we can predict flow patterns?

Experimental method	Computational Fluid Dynamics

- Experimental method(Wind/Water Tunnel) and Computational Fluid Dynamics(CFD)
- Hugh size of computing power, visualization and data management are key items on CFD
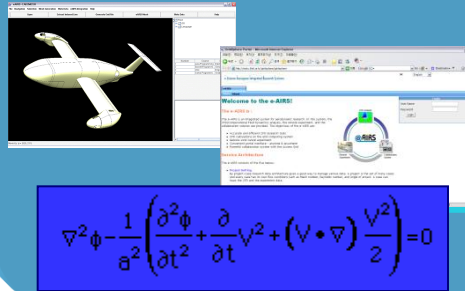- e-Science is essential environment to integrate these components and enhance competitiveness
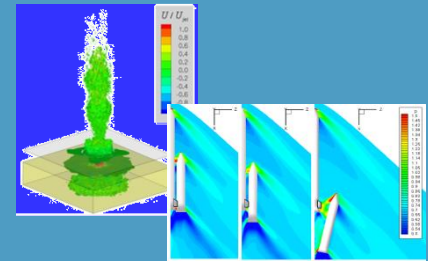
Objectives of e-AIRS

Facilities	Tools	Integrated Env.

$$\nabla^2\phi - \frac{1}{a^2}\left(\frac{\partial^2\phi}{\partial t^2} + \frac{\partial}{\partial t}V^2 + (V\cdot\nabla)\frac{V^2}{2}\right) = 0$$
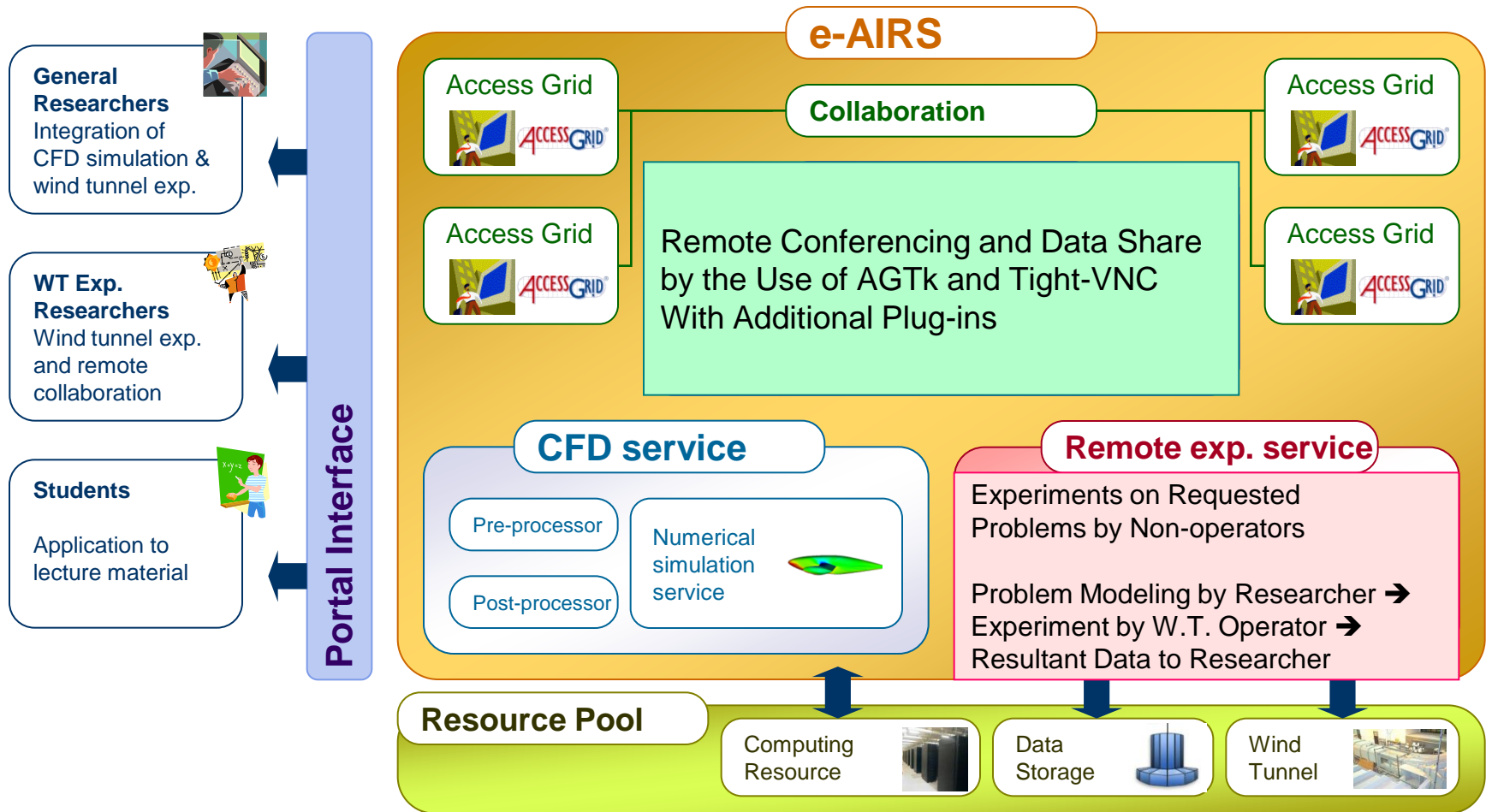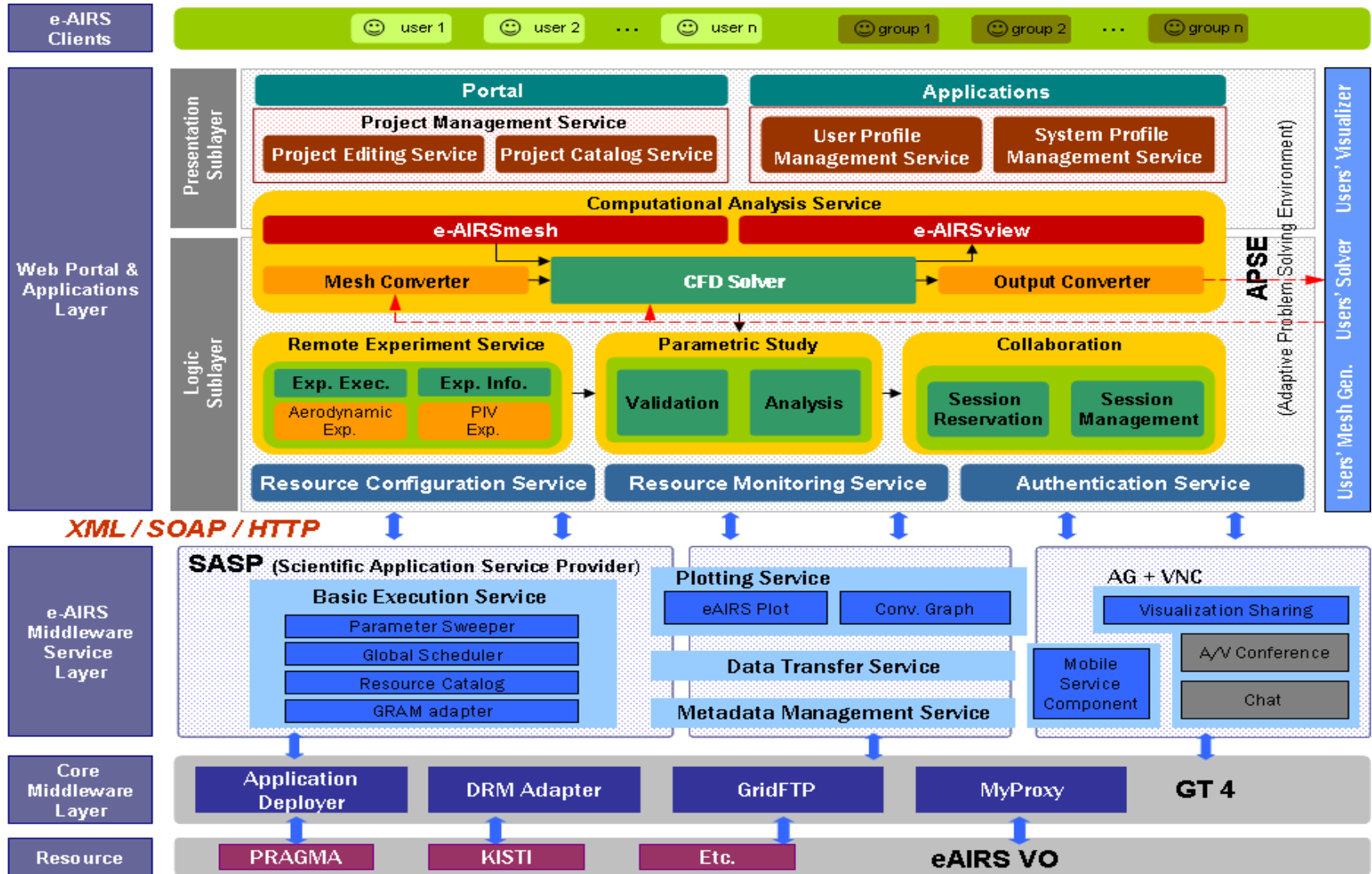
- e-AIRS(Anytime, Anyplace, Any Fluid Research)
  - Integrated Fluid Dynamics Research Environment using ICT(Information and Communication Technolofy)
  - Numerical Simulation Service (CAD, Mesh, Solver, Visualization, Data Mngt)
  - Remote Experimental Service (Wind tunnel)
  - Integrated Service (Experimental, Numerical Research and Digital Mock-up)
  - Collaboration Service (Video Conf., Remote Viz. and etc)
  - ICT: Grid computing, Web service, Networking and etc

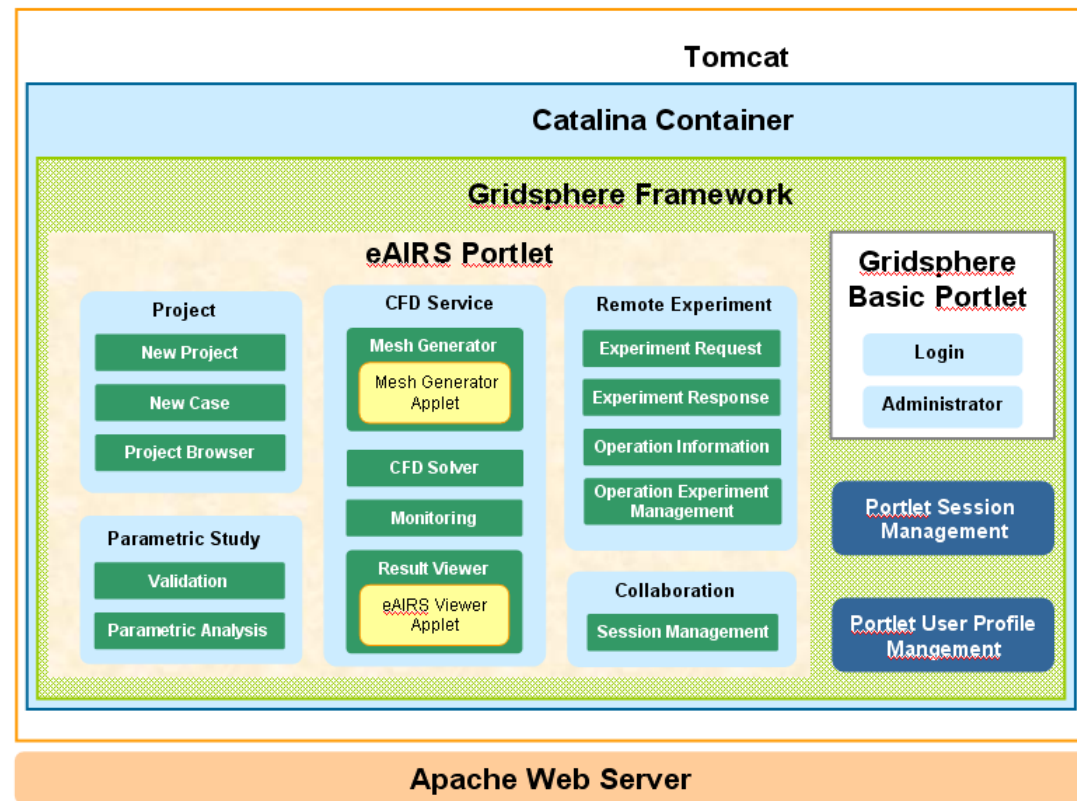# Introduction to e-AIRS

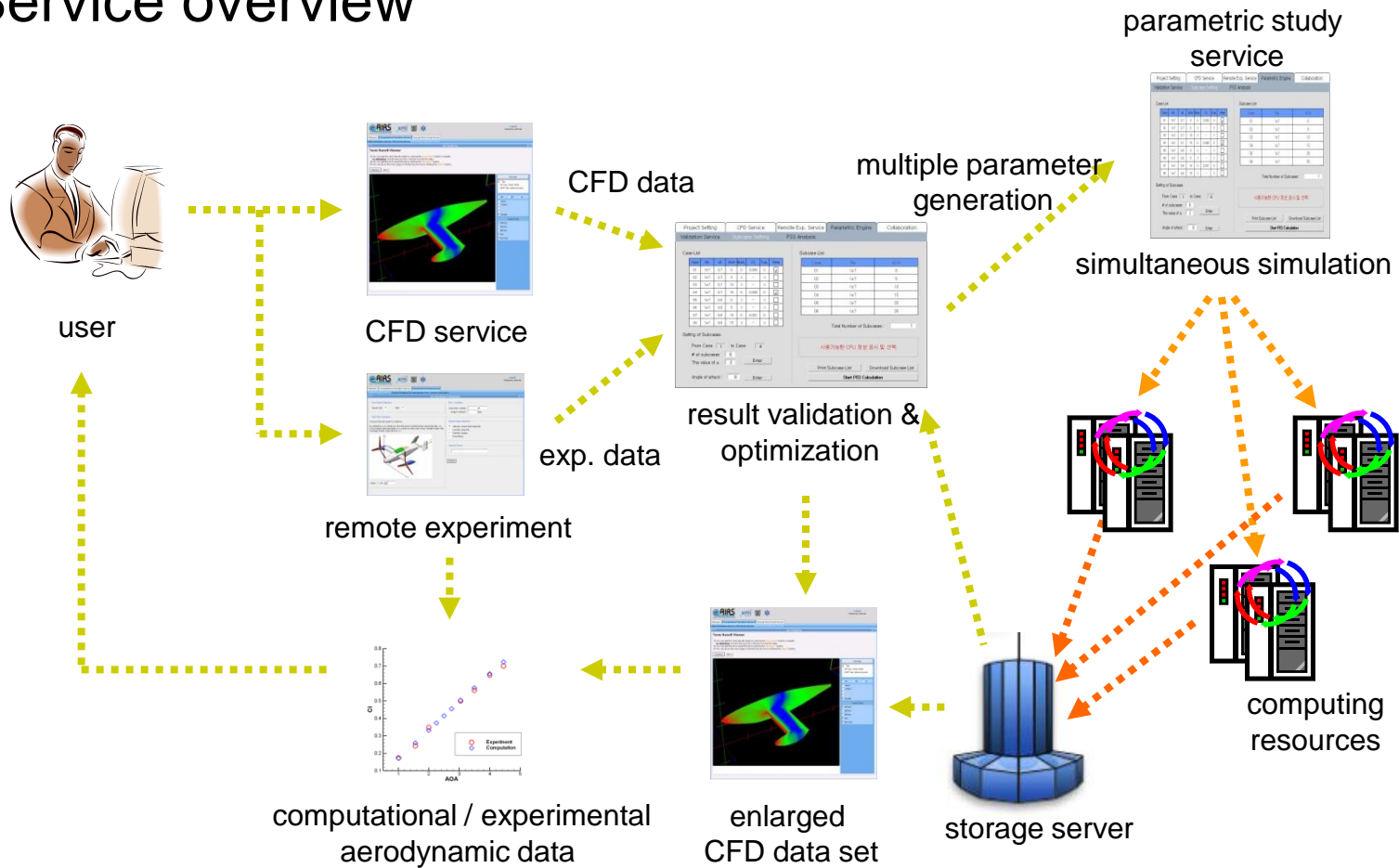- e−AIRS: an Aerodynamic Research Environment

General Researchers
Integration of CFD simulation & wind tunnel exp.

WT Exp. Researchers
Wind tunnel exp. and remote collaboration

Students
Application to lecture material

Portal Interface

e-AIRS

Access Grid

Access Grid

Collaboration

Access Grid

Access Grid

Remote Conferencing and Data Share by the Use of AGTk and Tight-VNC With Additional Plug-ins

CFD service
Pre-processor

Post-processor

Numerical simulation service

Remote exp. service
Experiments on Requested Problems by Non-operators

Problem Modeling by Researcher ➜ Experiment by W.T. Operator ➜ Resultant Data to Researcher

Resource Pool
Computing Resource

Data Storage

Wind Tunnel

e-AIRS Architecture

Construction of Web Portal

- Implement e-AIRS Web Portal based on Gridsphere Framework
  - Reusing the basic Gridsphere portlets
  - Added e-AIRS portlets

- User Session Management
  - Maintain user sessions in the portal
  - Make use of existing Portlet API

- User Data Management
  - Provides various types of data such as user's job information, result file

# Flow of Portal Services

Service overview

user

CFD service

CFD data

remote experiment

exp. data

multiple parameter generation

parametric study service

simultaneous simulation

result validation & optimization

computing resources

storage server

enlarged CFD data set

computational / experimental aerodynamic data

CFD Solver Service(1/3)

CAD2MESH & e-AIRSmesh

- **CAD2Mesh**
  - Extraction of Geometric Features from CAD Data
    - Line and Surface Information
  - Java Applet based system
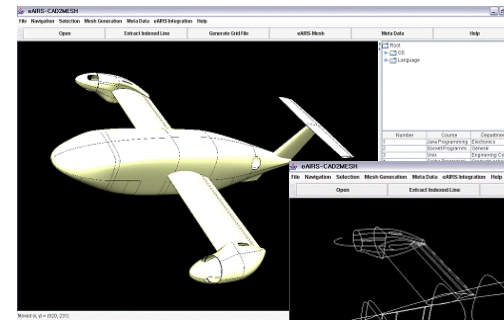
CAD2Mesh
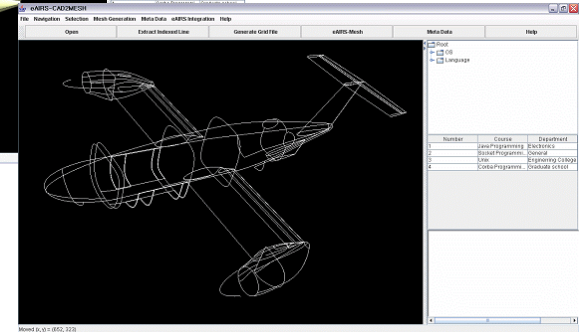
- **e-AIRSmesh**
  - Mesh Generator using Java Applet
  - Easy to Use: Icon-based Interfaces
  - Display Control by Mouse Motion and Scroll
  - PLOT3D Data Format
  - Geometry Library for Automatic Mesh Generation (NACA 4-digit Airfoils)
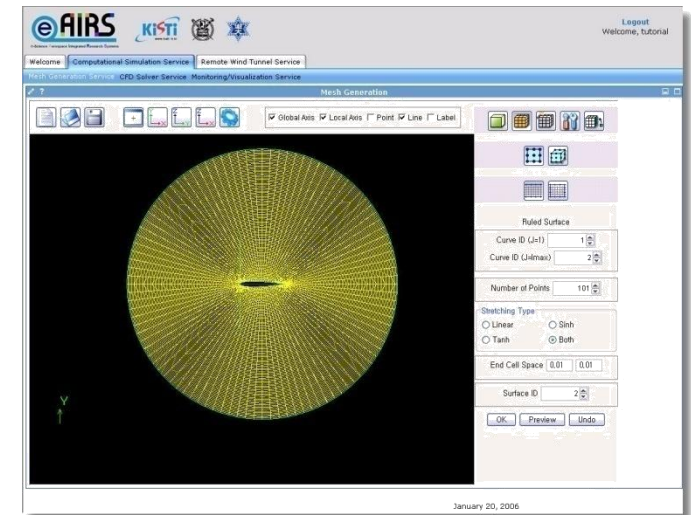
e-AIRSmesh

CFD Solver Service(2/2)

Various Levels of CFD Solvers

- **General-purpose CFD Solvers for Arbitrary Geometry**
  - 2-D / 3-D, Compressible and Incompressible Solvers

- **Specific Solvers for Killer Application**
  - Integrated Rocket Simulation Solvers
    - External Flow Analysis : Aerodynamic-dynamic Coupled Solver for Separation Simulation of Detached Rocket Booster
    - Internal Combustion Solver: Fluid-Structure-Combustion Integrated Solver for Ignition of Solid Rocket Propellant
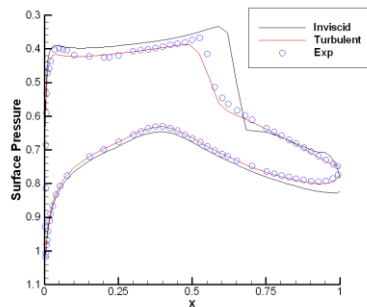
Validation :
RAE 2822 Airfoil
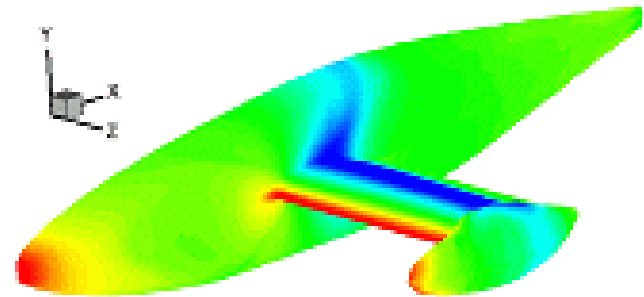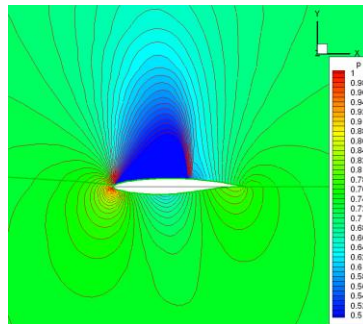
Surface Pressure around Smart UAV
(Mach No. 0.84, Angle of Attack 3.06)

CFD Solver Service(3/3)

Monitoring and Visualization

- **Monitoring on a Portal**
  - Status, Residual History

- **Visualization via e-AIRSview**
  - Java Applet Based Visualization Tool

- **Data Visualization by TecPlot**
  - Support of Tecplot (Commercial S/W) File Format for Advanced Visualization
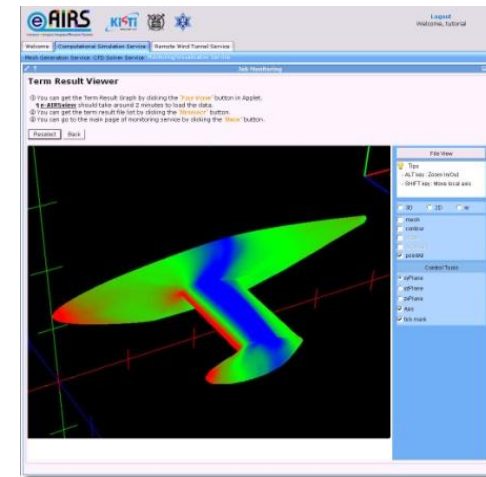
e-AIRSview
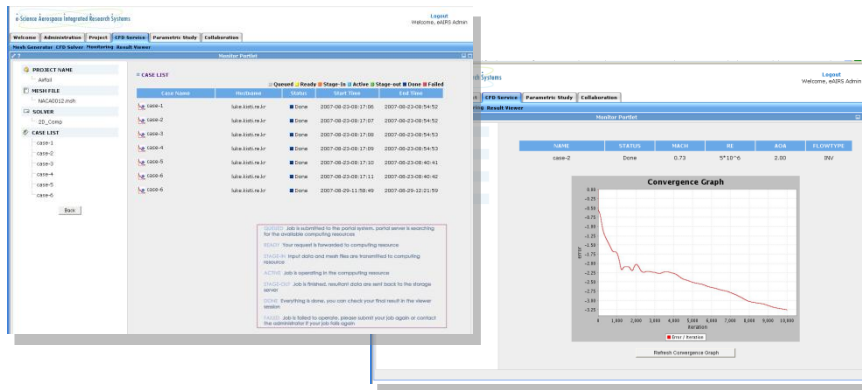
e-AIRS Monitoring Page
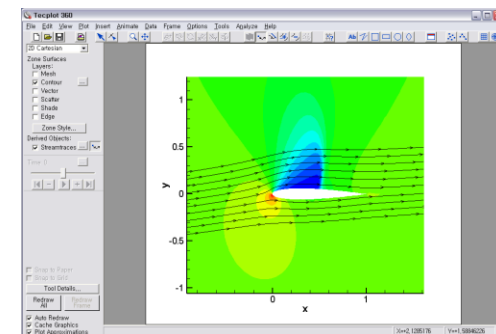
Tecplot S/W Interface

POSE: Parametric Study Service

- Various input parameters and their discrete range not a single value

- Repeated simulation for searching meaningful input conditions

- **Application Repository**
  - Container for an application and its parameter information

- **POSE UI**
  - Get application information from repository
  - Generate parametized job
 - Submit and get results into storage element

- **POSE Server**
  - Generate multiple jobs
  - Binding sub jobs to available computing resource set
  - Transfer application relevant data
 - Collect result set from computing resource
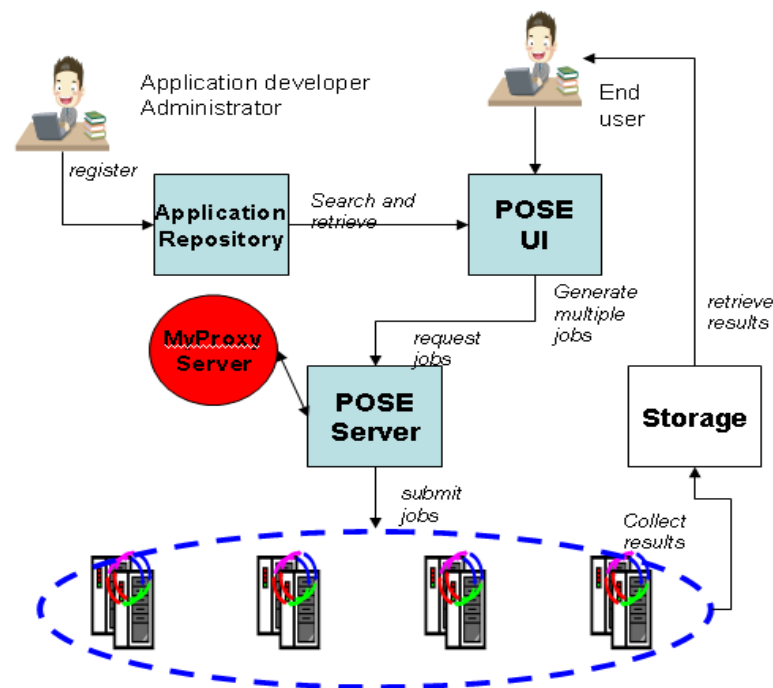
POSE: Parametric Study Service

- CFD Application : 2D_Comp
  - two-dimensional, compressible flow field around an airfoil
- Geometries (mesh) : NACA0012, NACA11412, NACA2412, NACA3412, NACA4412
- AOA : -6, -4, -2, 0, 2, 4, 6, 8, 10, 12, 14, 16, 18, 20(increment : 2)
- Total 70 jobs at a time

NACA0012

NACA1412

NACA2412

NACA3412

NACA4412
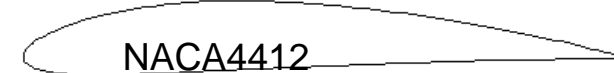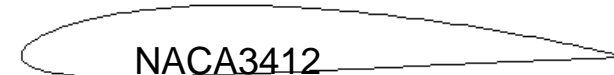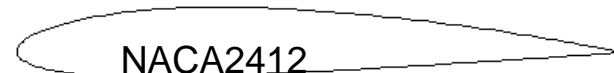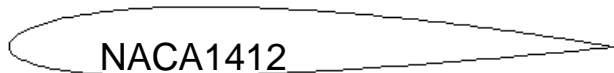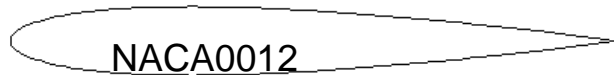
Cl-Lift coefficient
Cd-Drag coefficient
AOA – Angle of Attack

Cl VS. AOA for increasing camber
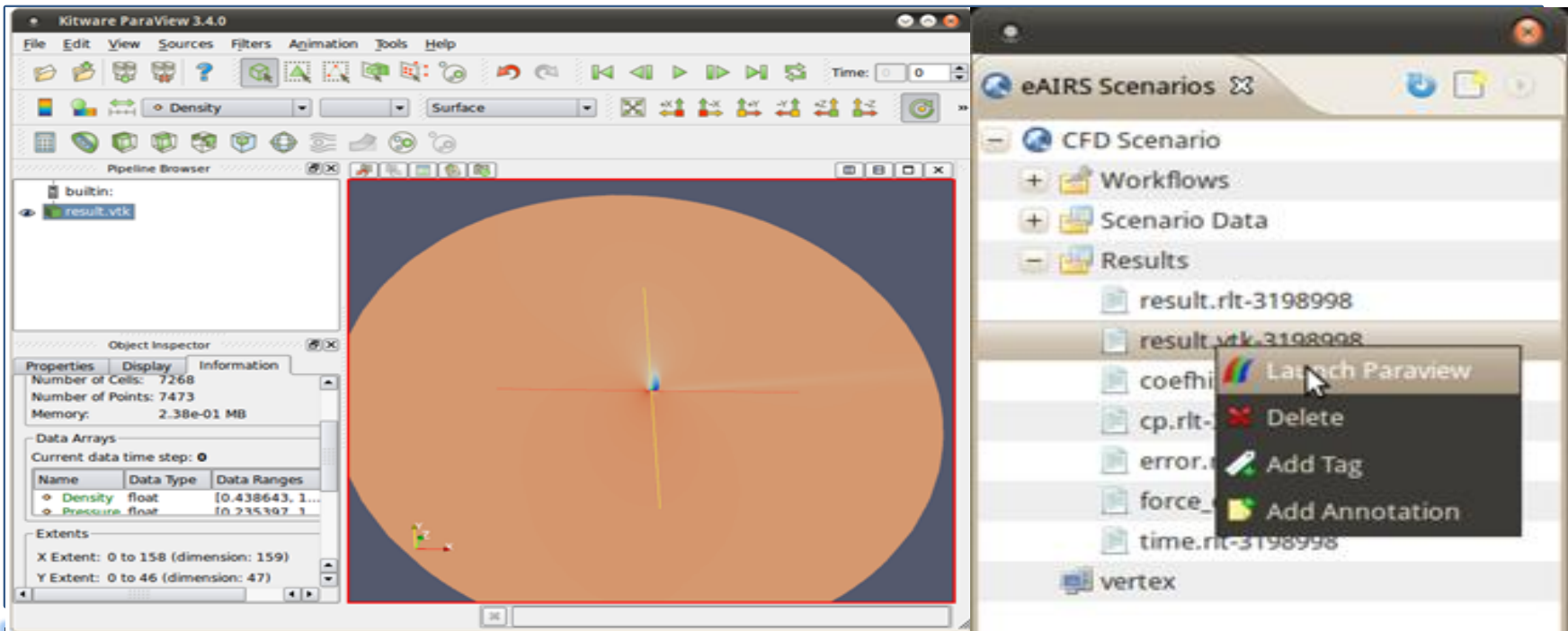

Cd vs. AOA for increasing camber
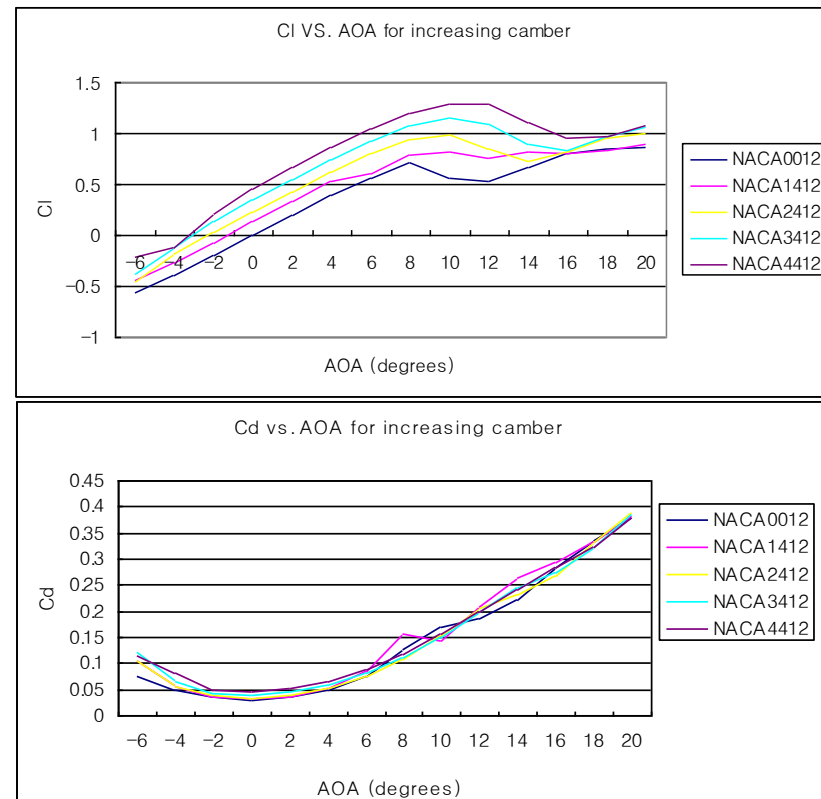
Remote Conferencing Tool

AG (Access Grid) + TightVNC

- Add Shared TightVNC Service into AG as a Shared Application

- While existing Shared Desktop shares a full screen of remote server, the Shared TightVNC provides the function that shares a specific frame on the remote screen.

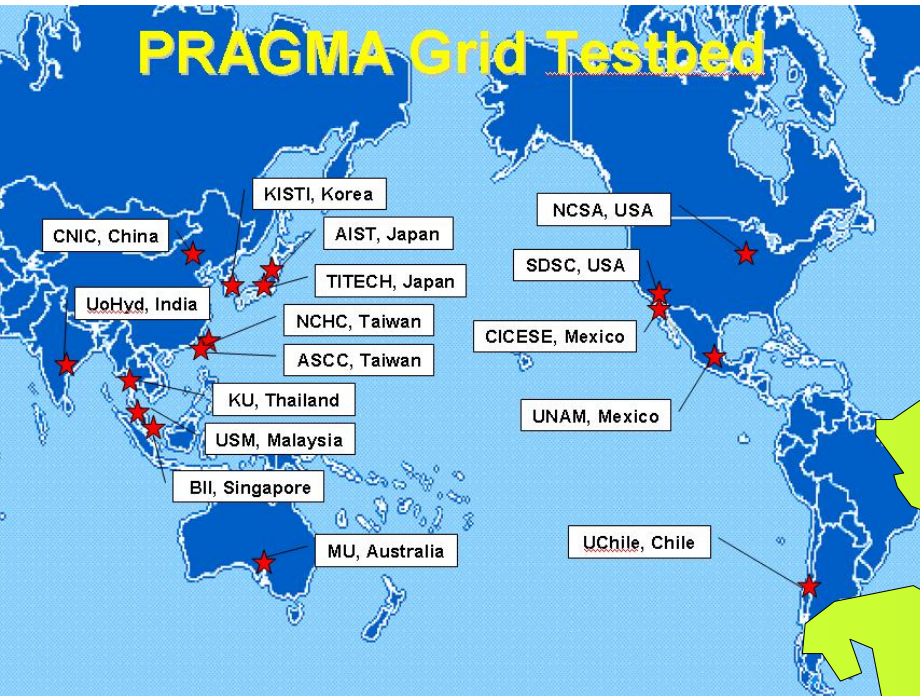- Sharing the visible results through Shared TightVNC Client
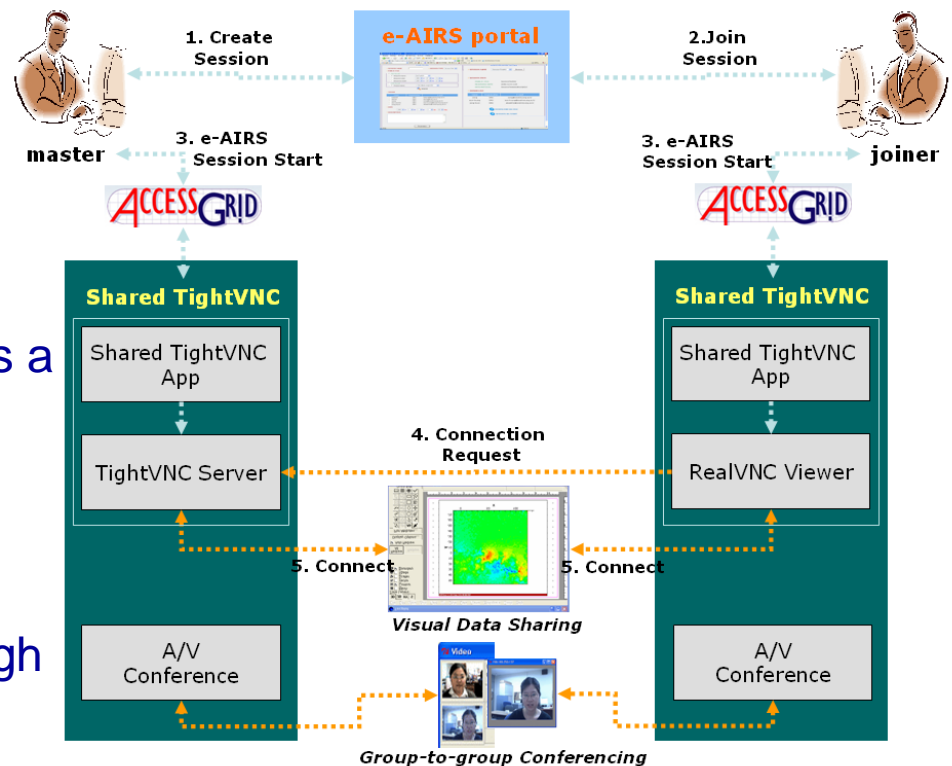
KISTI-NCSA Science Gateway

- Application Platform Development: KNSG('10 ~ '12)
  - Onse-stop Preprocessor-Simulation-Postprocessor System
  - Reuse of current technology, e-AIRS(KISTI), MAEViz(NCSA) and etc.
  - Infrastructure: TeraGrid(USA), KISTI Supercomputer, PRAGMA resources

KISTI Supercomputer	TeraGrid (USA)	PRAGMA	PLSI (KOREA)

Grid Computing Infrastructure

PRAGMA Grid Testbed

KISTI, Korea
CNIC, China
AIST, Japan
TITECH, Japan
UoHyd, India
NCHC, Taiwan
ASCC, Taiwan
KU, Thailand
USM, Malaysia
BII, Singapore
MU, Australia

NCSA, USA
SDSC, USA
CICESE, Mexico
UNAM, Mexico
UChile, Chile

PRAGMA Grid Resources

Cluster
Seoul, SNU
KREONET
Daejeon, KISTI
Storage Portal Server Cluster
DB Server
GLORIAD
KISTI, Korea
Cluster
AIST, Japan
Cluster

NCSA USA
TeraGrid

Utilization of e-AIRS Service

- Cyber Education
  - Lecture materials for students (Seoul Nat'l University and Konkuk University)
  - Lecture & demo contents
    - CFD simulation : 2-Dimensional analysis through e-AIRS portal
    - Experiment : Through AG, remote lecture on introduction of wind tunnels
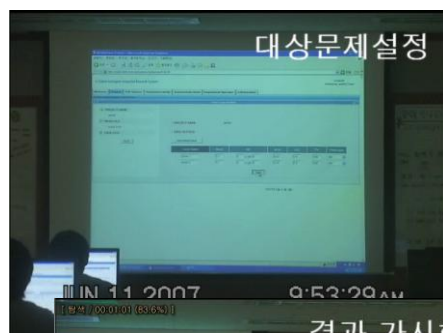
CFD analysis lecture and demo
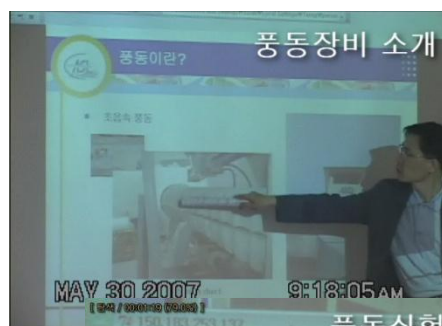
Remote experiment lecture and demo
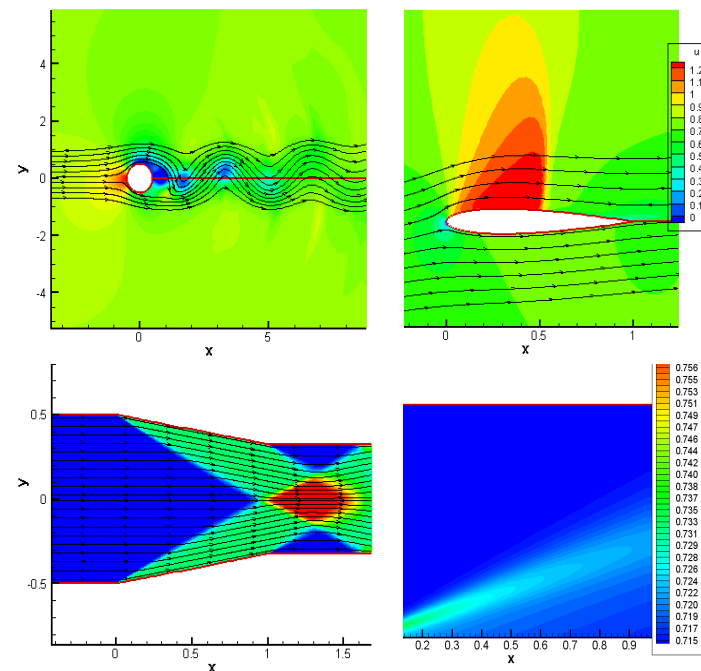
Main CFD analysis problems

Use on Research

- **Launch Vehicle / Rocket Simulation**
  - **Conventional Research : Distributed Research in Each Discipline**

https://eairs.kisti.re.kr/

Natural Freque-ncy FEM Model

Structure

Combustion

Aerodynamics and Dynamics
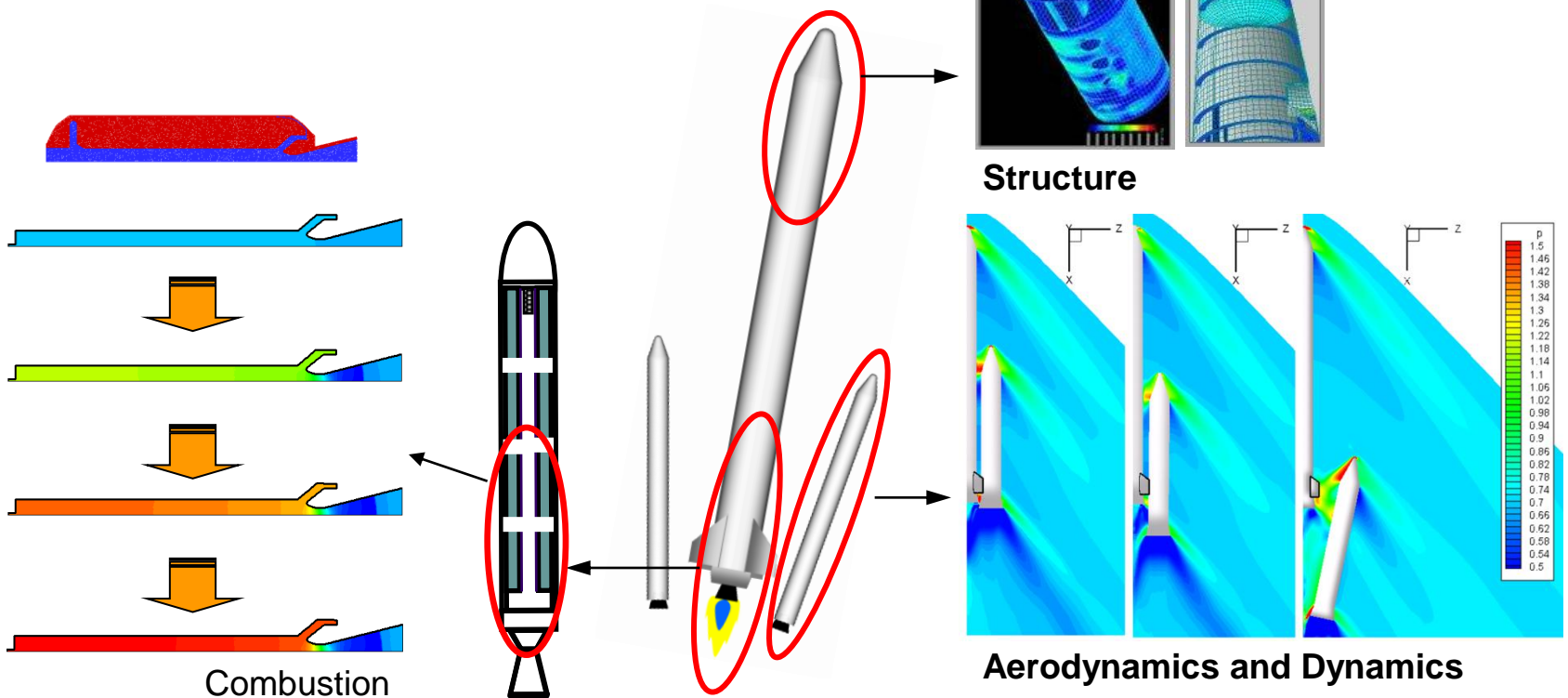
Use on Research

Integrated Analysis on Combustion and Motion

- **Necessity : Plume gas by internal combustion affects external motion of a rocket system**

- **Two Solvers in Distributed Location, Loosely Coupled**
  - Combustion Simulation Code and External Aerodynamics Code
  - Solvers remain separated, operate independently
  - e-AIRS enables integrative rocket analysis by supporting distributed computing and automatic data flow between two solvers
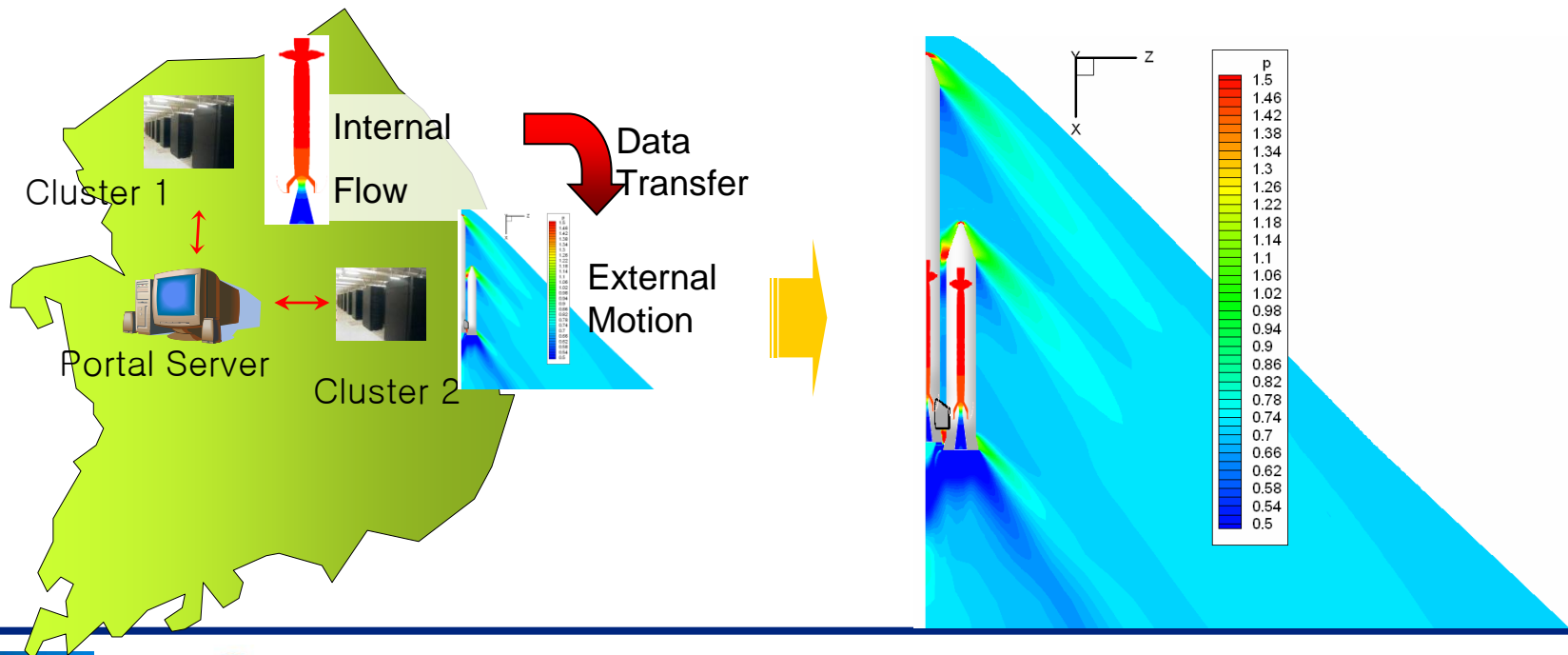
User Group

- 10 Universities use e-AIRS System in Korea
- International user and partner
  - Tohoku Univ. in Japan
  - Southampton Univ. in UK
  - NCSA in USA

Seoul National Univ.

Chungnam National Univ.

Korea Aerospace Univ.

Tohuku Univ.(Japan)

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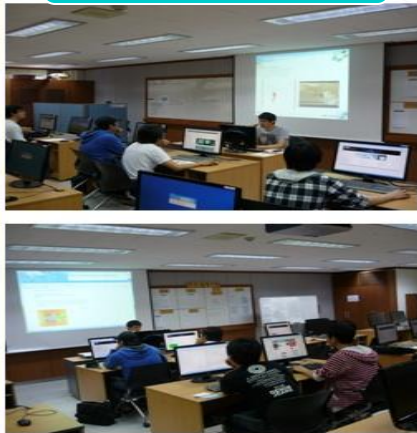
2. **Web-based CFD research environment**

3. **EDISON Project**

4. **Conclusions**

EDISON Project(1/2)

<u>E</u>ducation-hub <u>D</u>evelopment by converging high-end <u>I</u>T and computational <u>S</u>cience for providing new <u>O</u>pportunities to the <u>N</u>ext generation.

■ EDISON is a cyber environment, science gateway or portal for the research and education of the computational science communities.

■ The goals are

  - To accelerate research and advance higher education by building the converged cyber environment for the research and education with the research outcomes and developed software from the academia and research labs.

  - To help computational scientists and professors spend less time on Information Technologies and practical experiment issues, and more time on research discoveries.

EDISON Project(2/2)

- Plug-in-play simulation codes

- Sharing of information for the research and higher education

- Integration of high-end computing power

- National Project(Korea Ministry of Education, S&T): '11 ~ '20, $ 30M
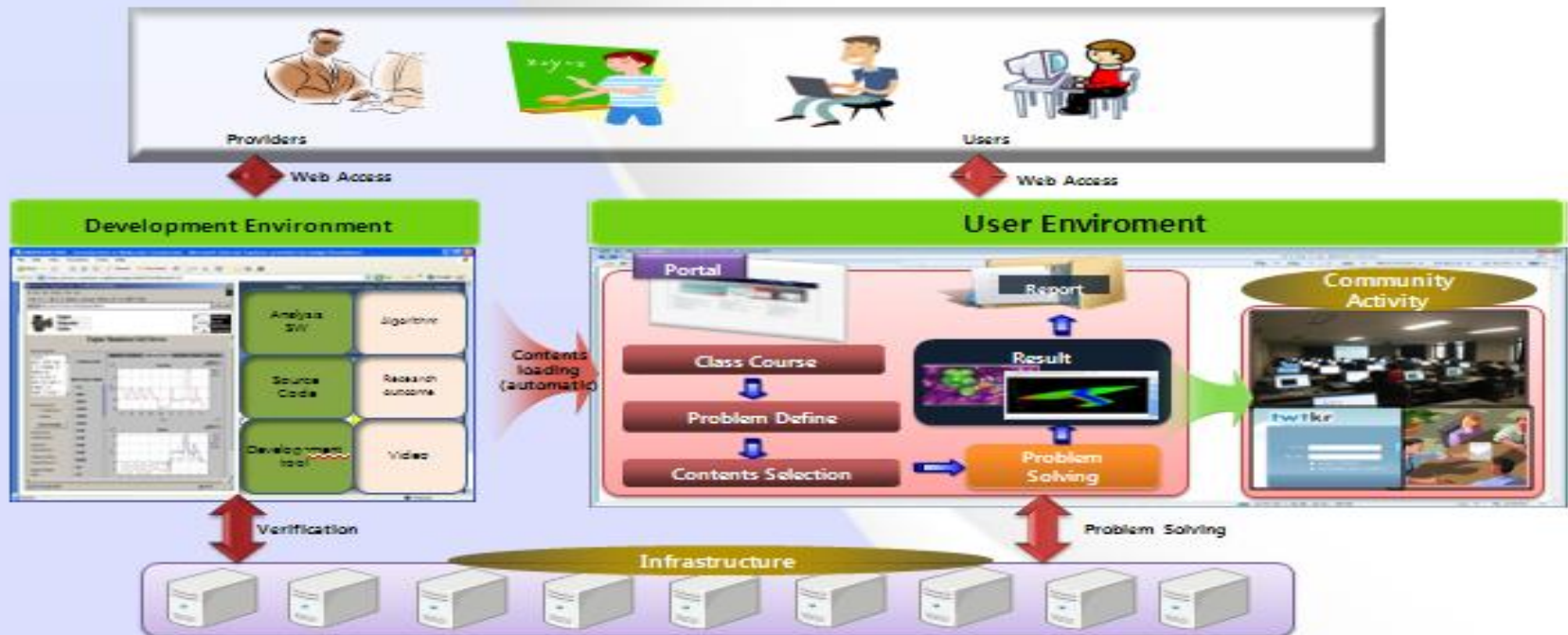
Conclusions

- **e-AIRS System**

  - **e-AIRS: An Efficient and User-friendly Research Environment**
  - **Internet-based Grid Portal Service**

- **Components of e-AIRS**

  - **CFD, Remote Experiment, Comparative (PSS) and Collaborative (AGTk) Research System**
  - **Components of CFD Service**
    - Easy-to-Use Mesh Generator
    - Accurate CFD Solver
    - Monitoring and Visualization Services

- **Utilization & Expectation**

  - **Use on University Lectures and Integrated Rocket Simulation**
  - **High Adaptability for Other Engineering and Science Fields**

Thanks for your attention !!

ckw@kisti.re.kr

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Ke Science

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