

# **Numerical simulation software integration with TENT**

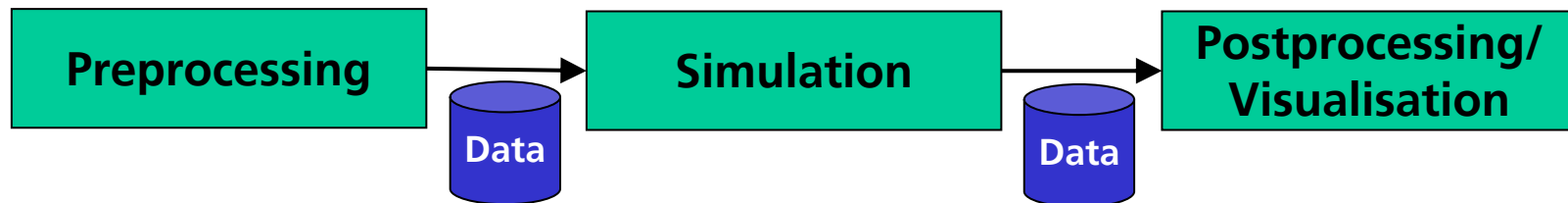
## **Software Integration and Workflow Management**

Andreas Schreiber, DLR Simulation and Software Technology  
Joint ESTEC-DLR Workshop, ESA/ESTEC, Noordwijk, May 3-5, 2006

# Introduction

## Workflows

- Today, many problems require **complex numerical simulations**.  
Examples:
  - Re-entry simulation of space vehicles
  - Aero dynamical and aeroelastical analysis of flight maneuvers
- Performing such simulations is **software technologically** complex
  - Invocation of many different codes *in correct order*
  - Usage of high performance computers
  - Transfer of data between the different codes
  - Collaboration with colleagues
- Complex simulations are **Workflows** of many codes:



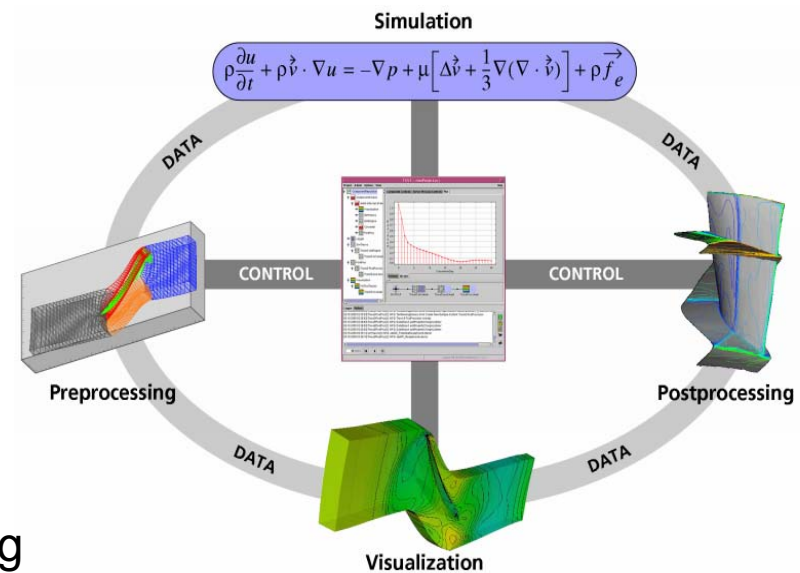
# What is TENT?

## Answer for Users

TENT is an *integration and simulation environment* for engineering applications.

Essential features:

- Easy setup and configuration of simulation workflows with **integrated applications**
- Usage of **distributed computing resources**
- **Online steering** and visualization
- Project-based **data management** with support for cooperative working
- Multidisciplinary **coupled** simulations



# What is TENT?

## Answer for Computer Scientists

TENT is an *open and extensible framework* for tool integration and workflow management.

Essential characteristics:

- Component based
  - CORBA Peer-to-peer model
- **Extensible** Java-GUI
- Distributed computing (Grids)
- Flexible integration of existing tools
  - Large development library
- Data management
  - Open solution (WebDAV & XML)



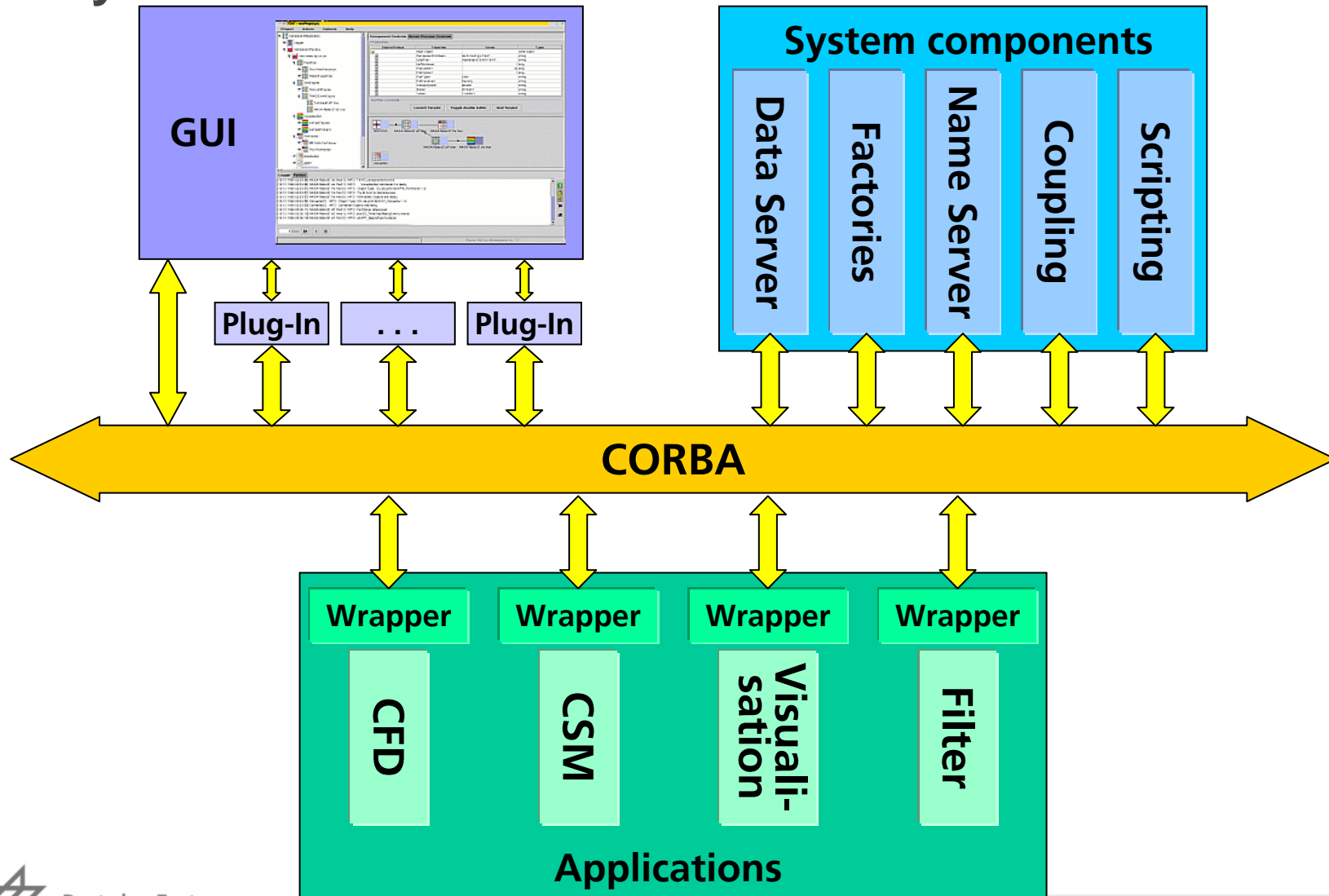
Development based only on accepted *standards*

- CORBA, LDAP, FTP, HTTP, WebDAV, XML, ...



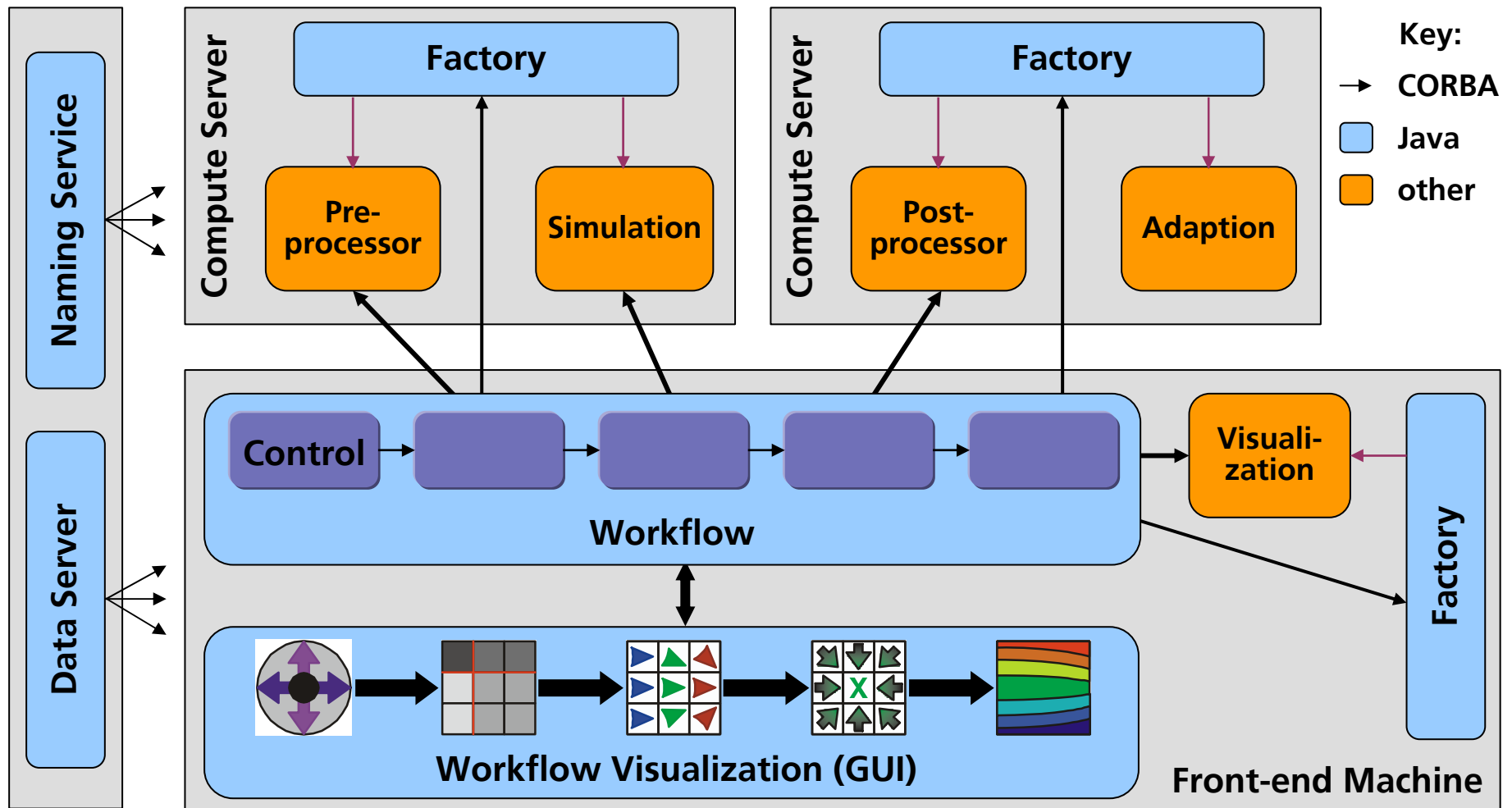


# System Architecture





# Architecture and Deployment





TENT - [fimens-demo3/ SYNCHRONIZED]

Project Simulation Workflow Component Tools View Scripting Help

**Components** Projects

- Component Repository
  - ComponentFactory
    - sbkhp18.bk.st.dlr.de
      - ActionEventSender
      - Script
    - CouplingControl
      - CouplingControl
      - CouplingControl.struct
      - AnsysCoProcess.STRU
      - CouplingControl.STRU
      - MpCCIControl
      - MpCCIControl
      - thor.sistec.kp.dlr.de
      - sif.sistec.kp.dlr.de

**Properties** Starter Properties

Name	Value	Type
Root DataObject		DataObject
ApplicationEnvironment		DataObject
MpCCIProperties		DataObject
CCIRunOpt	-xterm -log	String
CCIRunPath	/wbbk/tent/mpcc...	String
ConfigFile	cta.cci	String

**Application browser**

**Property editor and plug-ins**

**Workflow Design**

Welcome **Logger** Python

**TENT**

This page will help familiarize you with the TENT system.  
To get started, read the sections below and click on the related links.

- ▶ **Create a Simulation**  
To start, first [connect to a project](#). Next create a Simulation within that

**Control**

action 1Steps [up] [right] [pause] [stop]

Joerg Heinecke 0%



The screenshot shows the TENT software interface with several key components highlighted by blue callout boxes:

- Project browser:** Located in the top-left pane, it displays a hierarchical tree of project files and folders.
- Meta data:** A table in the bottom-left pane showing project metadata.
- Plug-In: Panel:** A panel in the top-right pane showing configuration fields for the application.
- Plug-In: Toolbar:** A toolbar in the bottom-right pane containing simulation control buttons.

The central workspace displays a workflow diagram with nodes for 'action', 'CouplingMa...', 'SimulaSIKMa2004.1.7', and 'TAUSIKMa2004.1.7', connected by 'ActionEvent' and 'CouplingEvent' arrows.

Name	Value
Description	Aerodynamics-Flig...
Engineer	T.Forkert
ModificationDate	2005-04-08
PlatformSimul	bassgi15
PlatformTAU	sikma
Project	SikMa

**Properties Panel:**

- Executable: /home3/nv/sikma/Kopplung/fluegel/Cntl/
- Host Name: bassgi15.as.bs.dlr.de
- Input Directory: /home3/nv/sikma/HAP2000/KOPPLUNG/
- User Name: sikma
- Working Directory: /home3/nv/sikma/HAP2000/KOPPLUNG/

**Simulation Parameters:**

- CouplingManager: Unsteady, Physical Time Steps: 100, Step Size [sec]: 0.0010
- TAUSIKMa2004.1.7: Unsteady, Physical Time Steps: 100, Step Size [sec]: 0.0010, Inner Iterations: 10





# Example GUI Plug-In

## 2D-Plot

Properties
Starter Properties
ParaSel
Plot

x-axis: TimeStep, Linear, Timestep

y-axis: 2, Delta / Residuum, Linear

Properties
Starter Properties
ParaSel
Plot

**x axis**

Property: TimeStep

Scale: Linear

Label: Timestep

**Special**

Show grid

Show impulses

Show fill button

**Plotmode**

Scattermode

Functionmode standard

Functionmode extended

Clear plot

Export to EPS...    Save Data

**y axis**

No. of y axes: 2

Label: Delta / Residuum

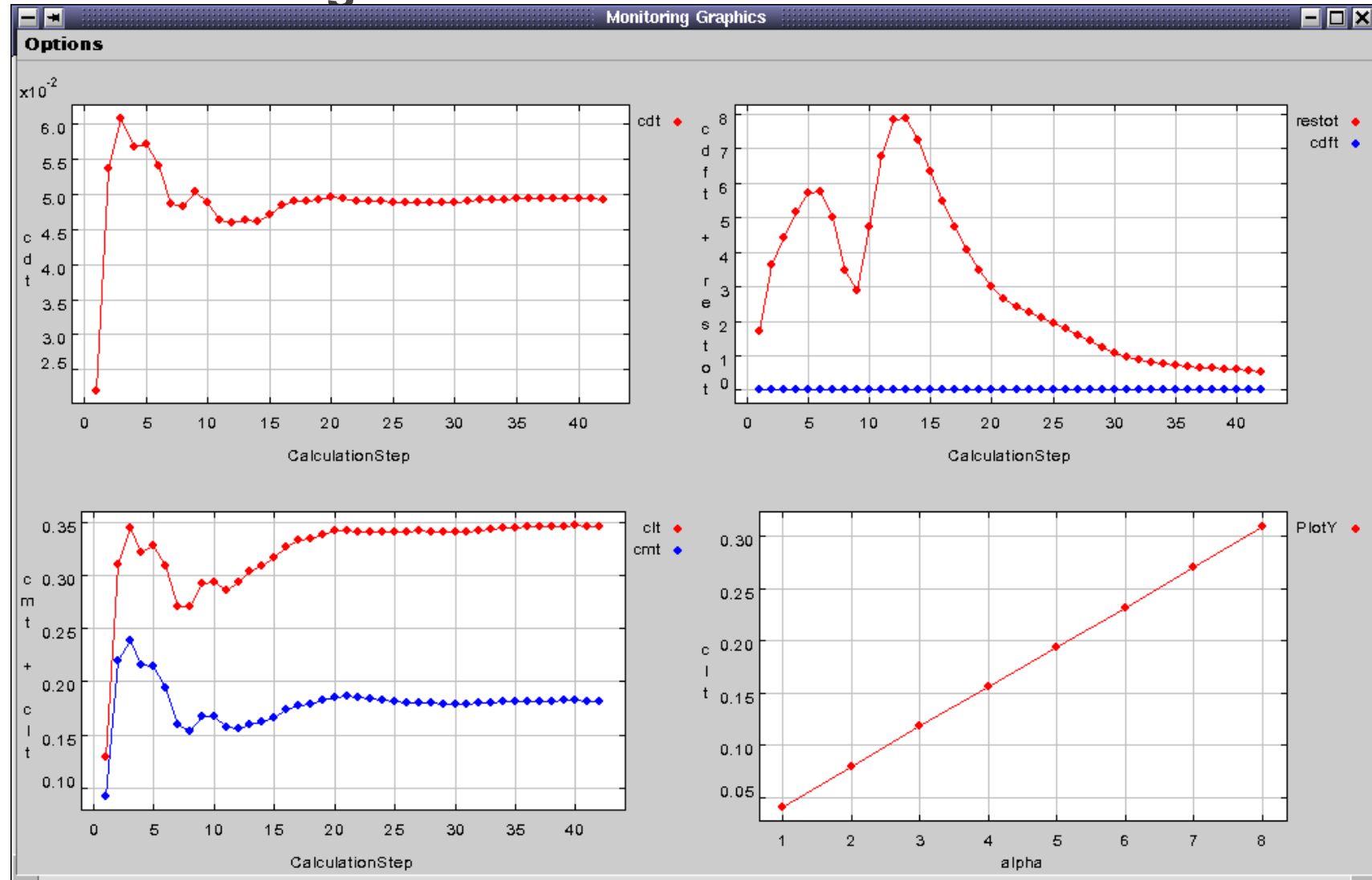
Scale: Linear

No.	Property	Marks style
1	Delta	dots
2	Residuum	various

Settings
2D plot

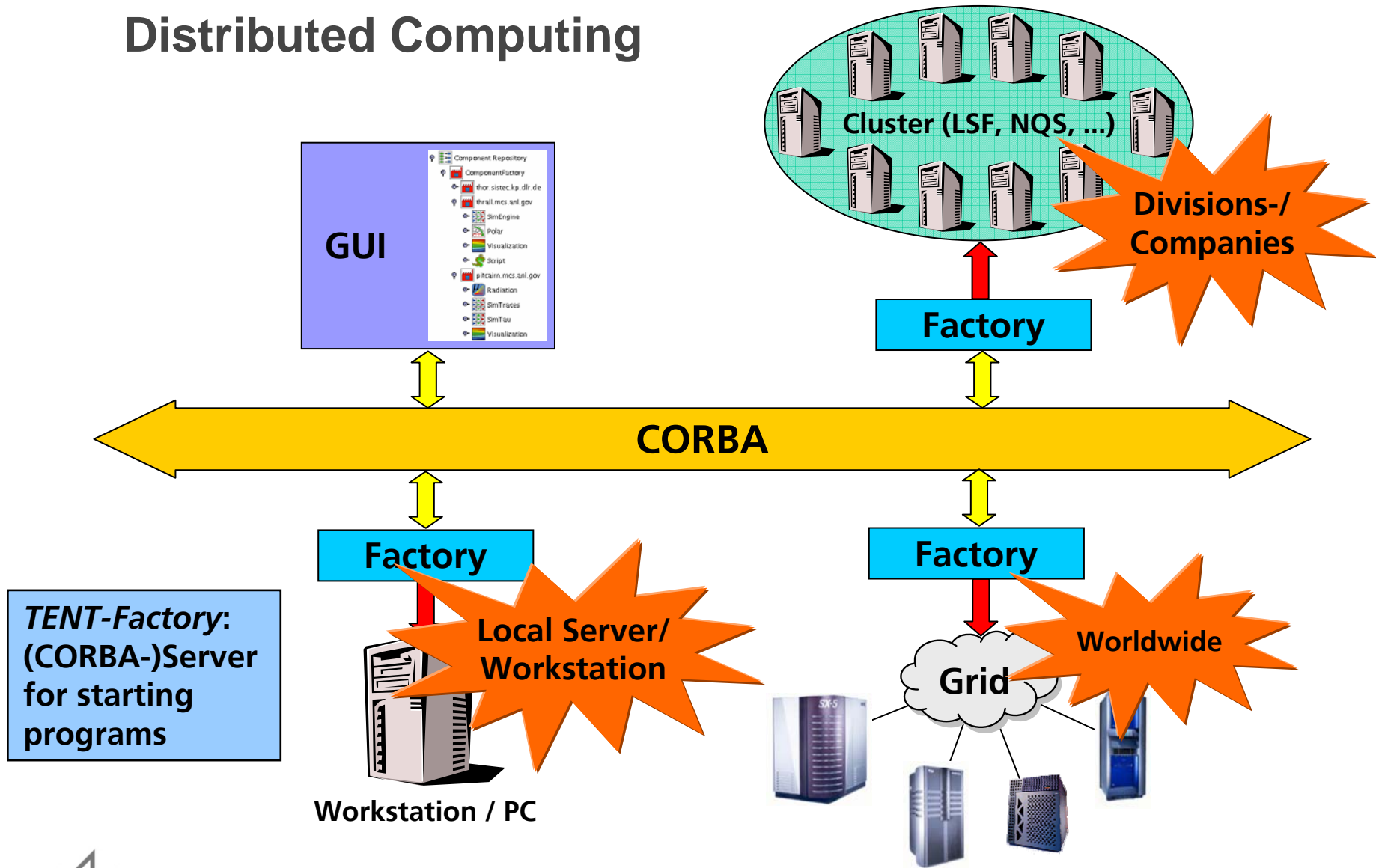


# Monitoring



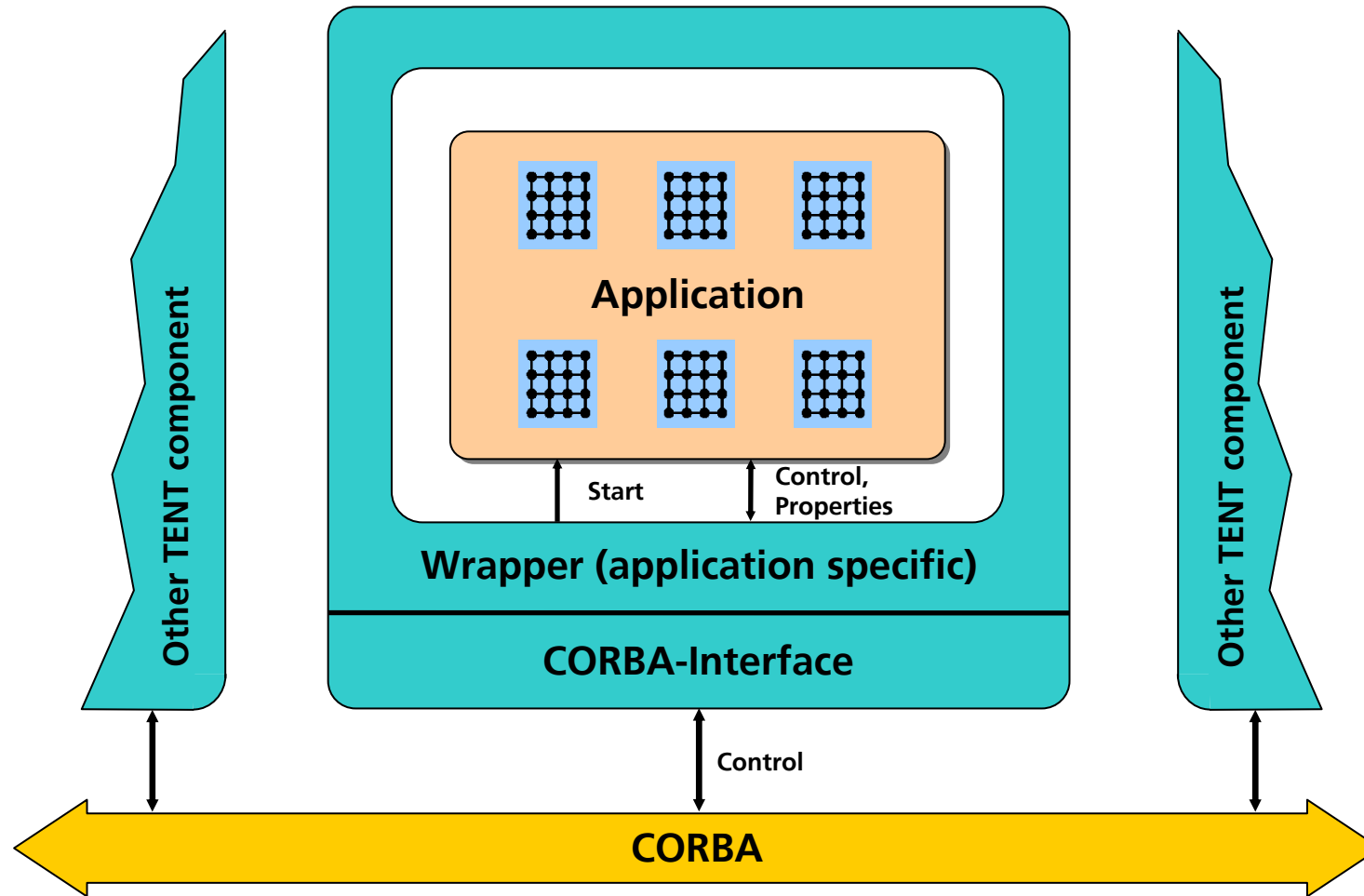


# Distributed Computing





# Integration of Applications Wrapper

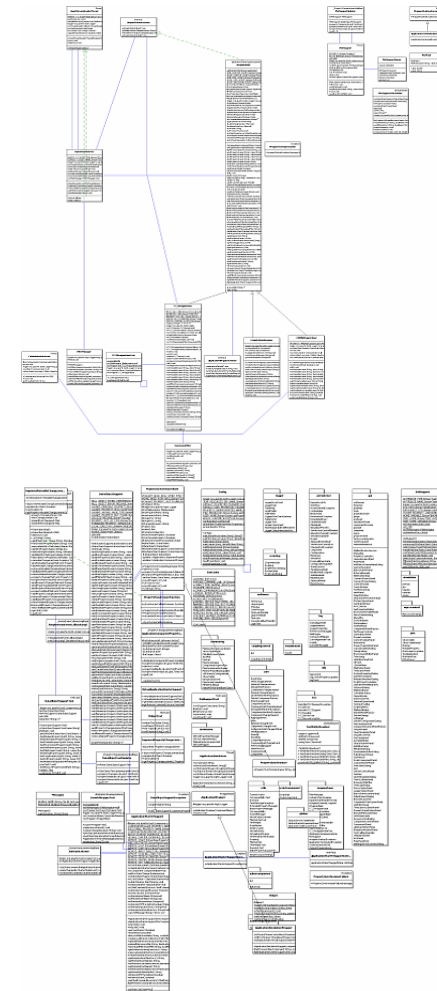




# Integration of Applications

## Wrapper Library (SDK)

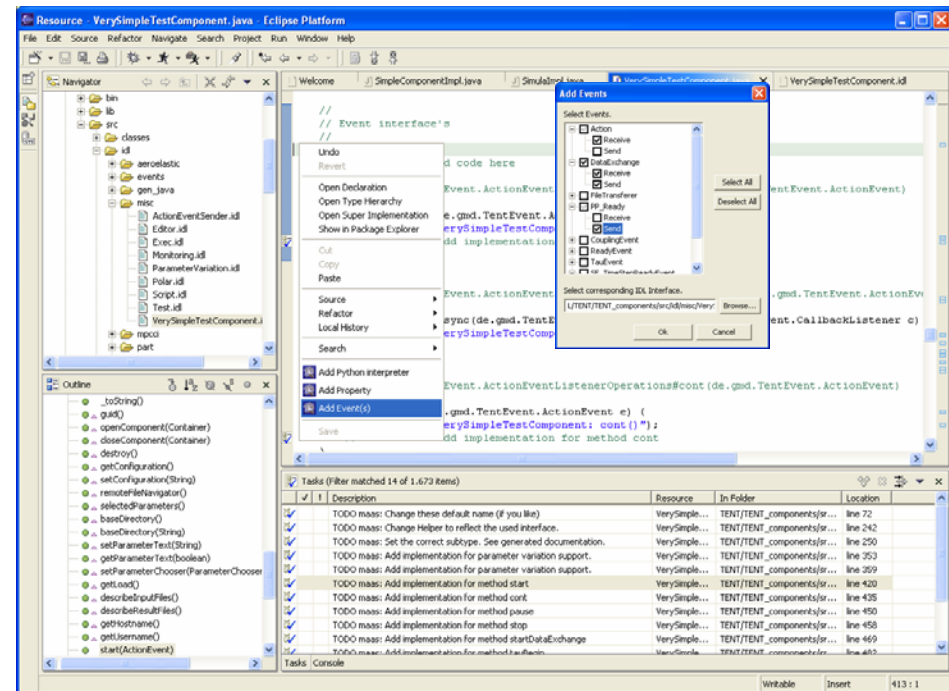
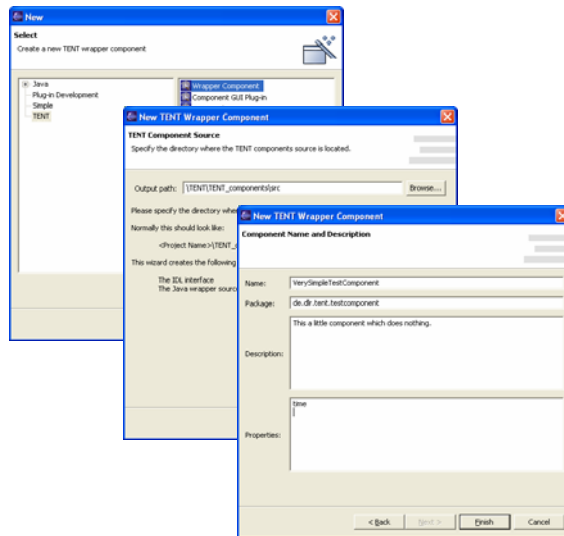
- Wrapper development in **Java** or **Python**
- Some features
  - Generation of input files
    - Templating (replacement of parameters)
  - Parsing of result files
    - Extraction of values
    - General filter mechanism
  - Execution
    - Remote execution
    - Application control via pipes, TCP/IP sockets, CORBA, ...
- **Wrapper code can be generated...**



# Integration of Applications

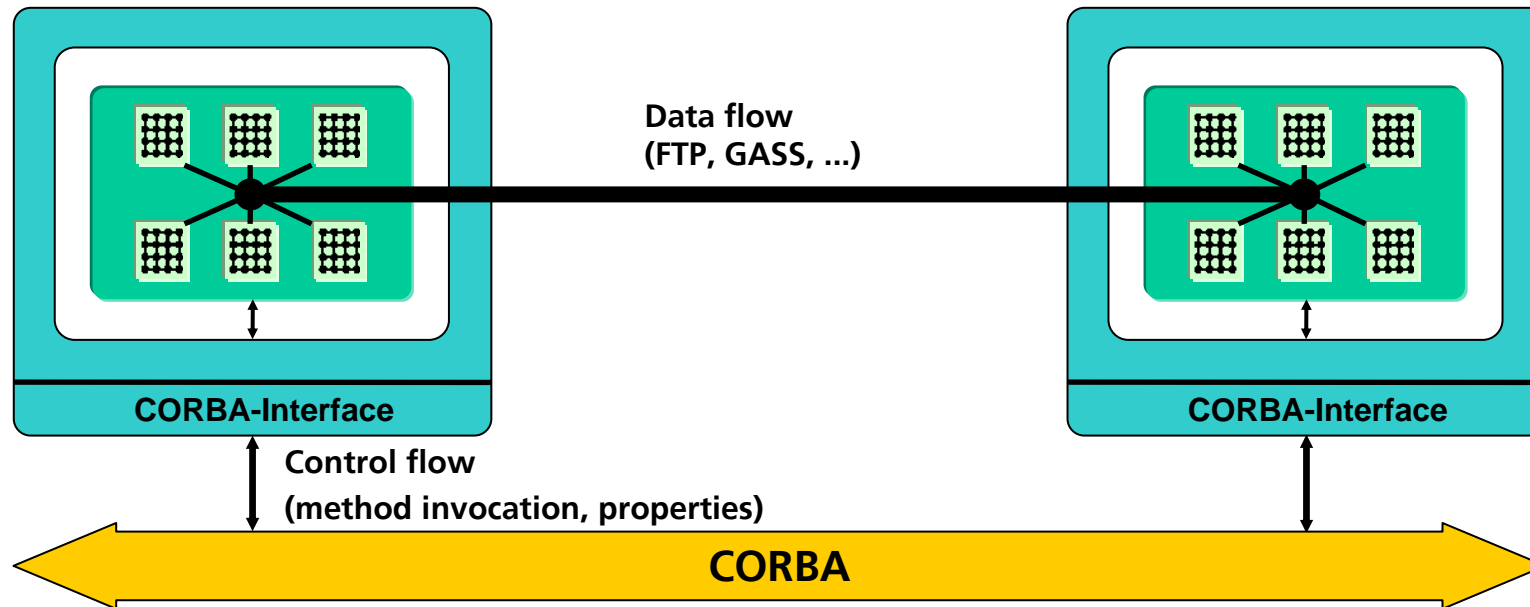
## Automatic Generation of Wrapper Code

- To **reduce the effort** and **minimize coding errors**
- TENT specific Eclipse plug-ins for:
  - Generating new wrapper code
  - Extending existing code



# Communication

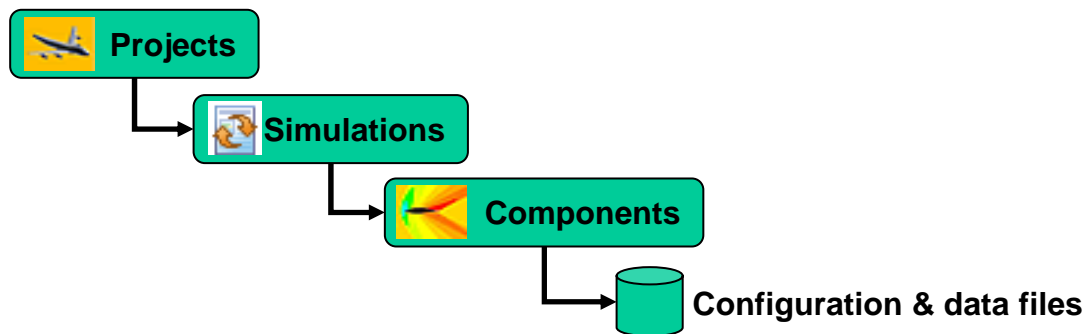
- Control flow
  - Events and method invocations through CORBA
- Data flow
  - Small data set as parameter through CORBA
  - Massive data through GASS, FTP, GridFTP, Socket, ...



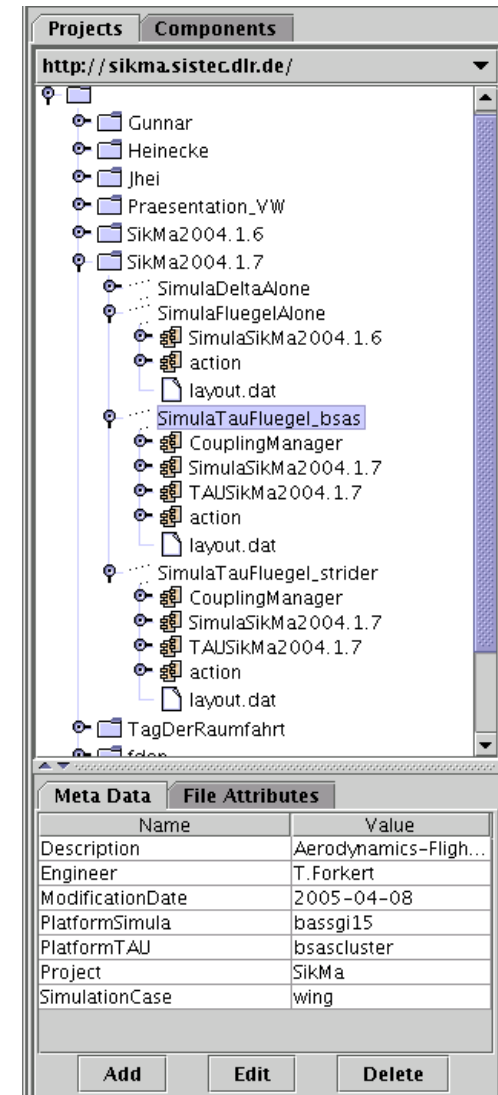
# Data Management

## Project and Workflow Structure

- Free hierarchical structure of projects and data:



- Cooperative working
  - User management and access control
  - Data exchange via data server
  - Similar to PDM systems
    - *Check-Out, Check-In*





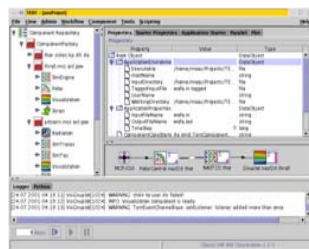


# Data Management XML & WebDAV

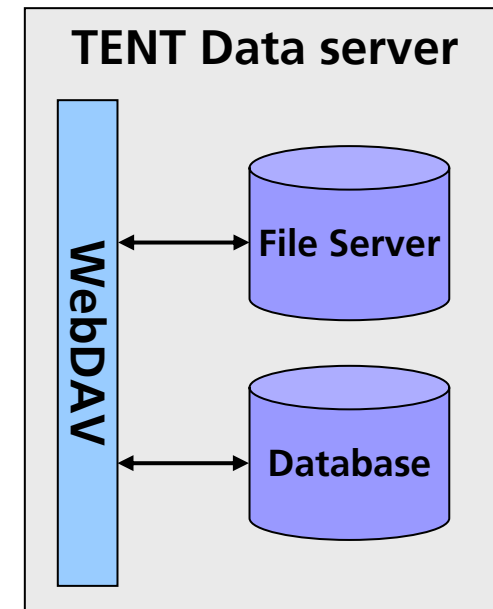
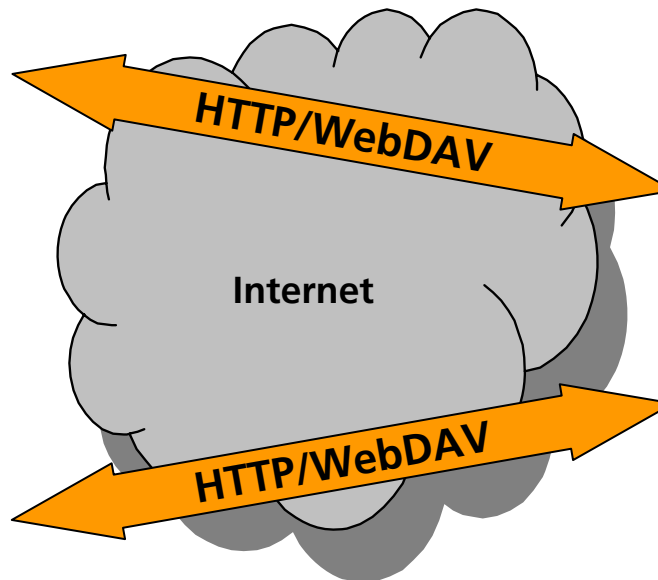
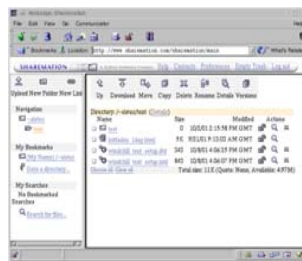
**WebDAV: *Web Distributed Authoring & Versioning***  
Extension of the HTTP protocol  
(locking, meta data, versioning, search,  
and access control)

## ➤ Concept

- Storage of project data in XML format on a server
- Access to data using the standard protocol WebDAV



TENT



## Other applications



Deutsches Zentrum  
für Luft- und Raumfahrt e.V.  
in der Helmholtz-Gemeinschaft



# Data Management

## Data Provenance

- **Provenance** is information **in addition to the standard logging** which helps answer **questions about origins of data**
- Typical such questions are
  - *Given some data item, what was the simulation case?*
  - *Given some parameter, in what simulation(s) has it been used?*
  - *What data has been recorded in a simulation with a specific parameter?*
  - *What simulations have been run using a given model (aircraft design)?*
  - *Given two/more simulations with the same setup, what is the result and the difference in provenance?*
- TENT has integrated a **provenance storing and querying service** (developed in the EU GRID PROVENANCE project)



# Scripting

## Integration, Control and Automation

**Applications do not have everything, so scripting is needed.**

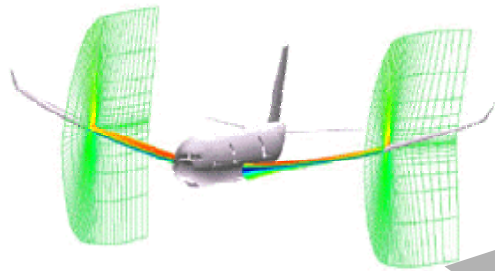
- Usage of scripting in TENT
  - **Integration of applications**
  - **Workflow control** (loop constructs, conditional constructs, coupling control)
  - Test scripts for quality assurance automation
  - **Debugging**
  - Command journaling
- Technique
  - **Embedded Python interpreter**
  - Script interpreter in the GUI
  - Script console in the GUI
  - Scripting block in workflows (control and code integration)



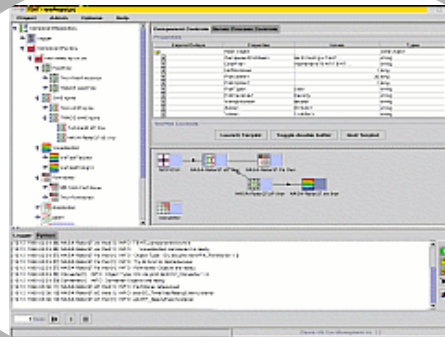


# Application Systems

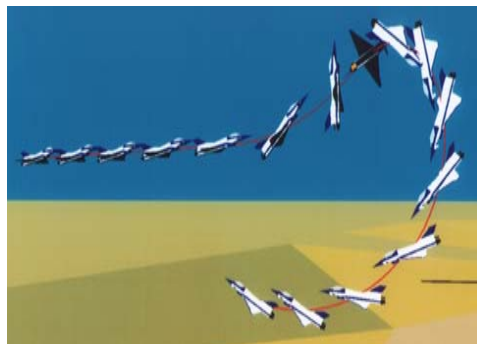
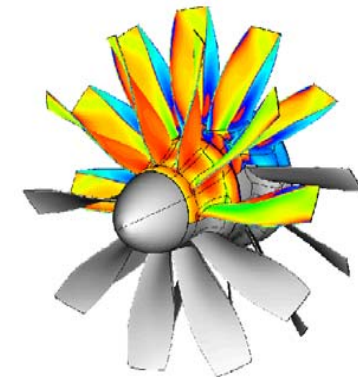
Space reentry vehicles



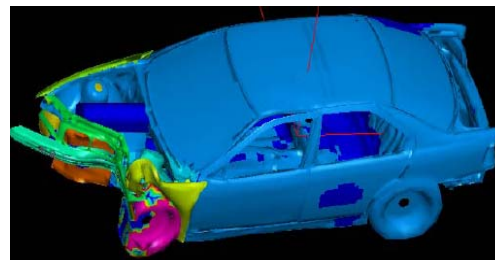
aircraft



Turbine engines



Flight maneuvers



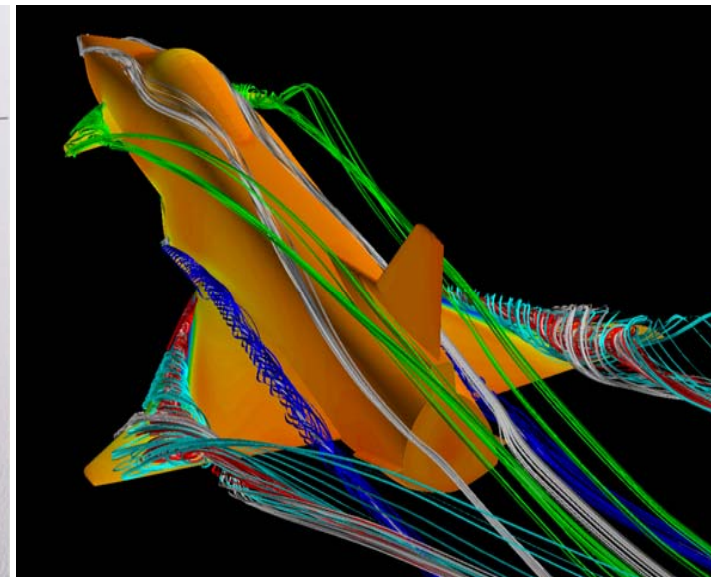
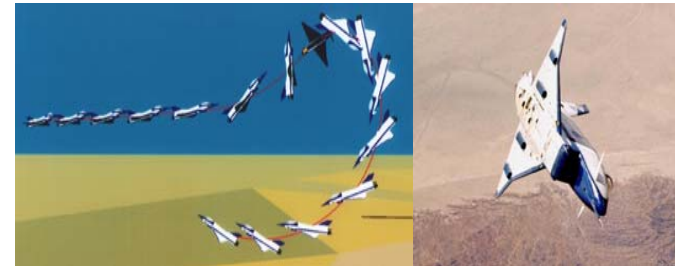
Automobile design





## Example Application 1 Flight Maneuver Simulation

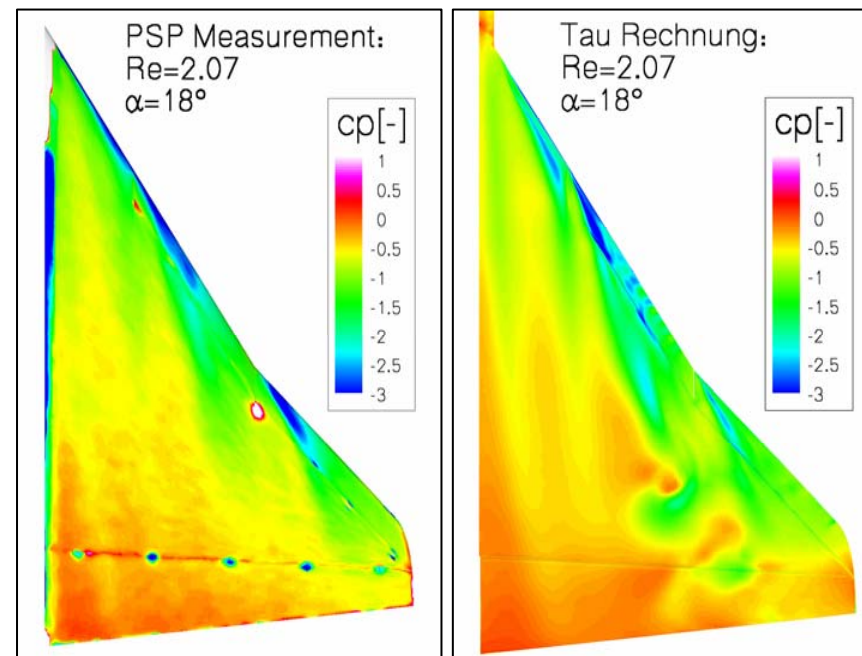
- Interactive simulation environment for the simulation of a freely flying, fully configured, elastic warplane
- Project SikMa: X-31





# Flight Maneuver Simulation Model

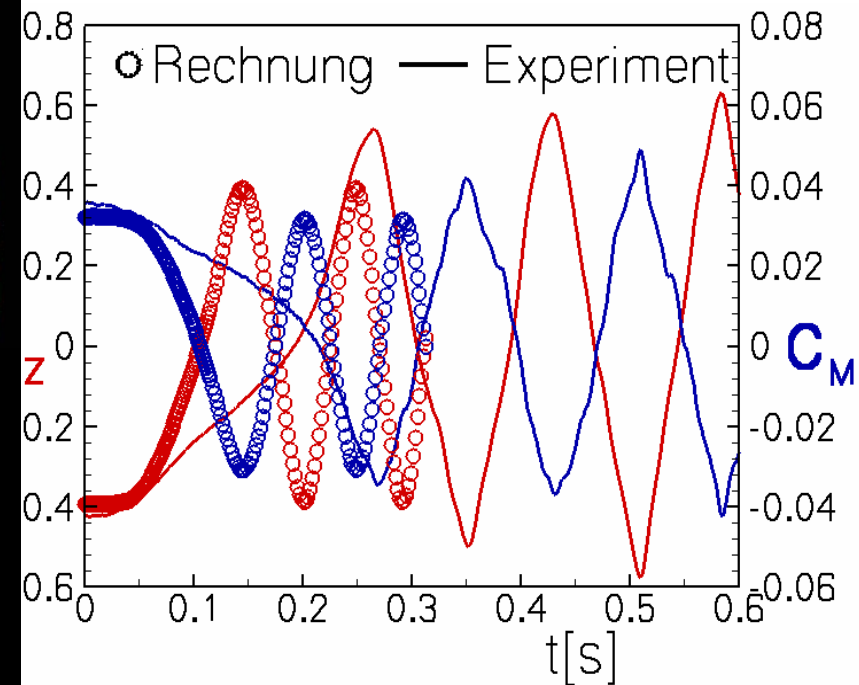
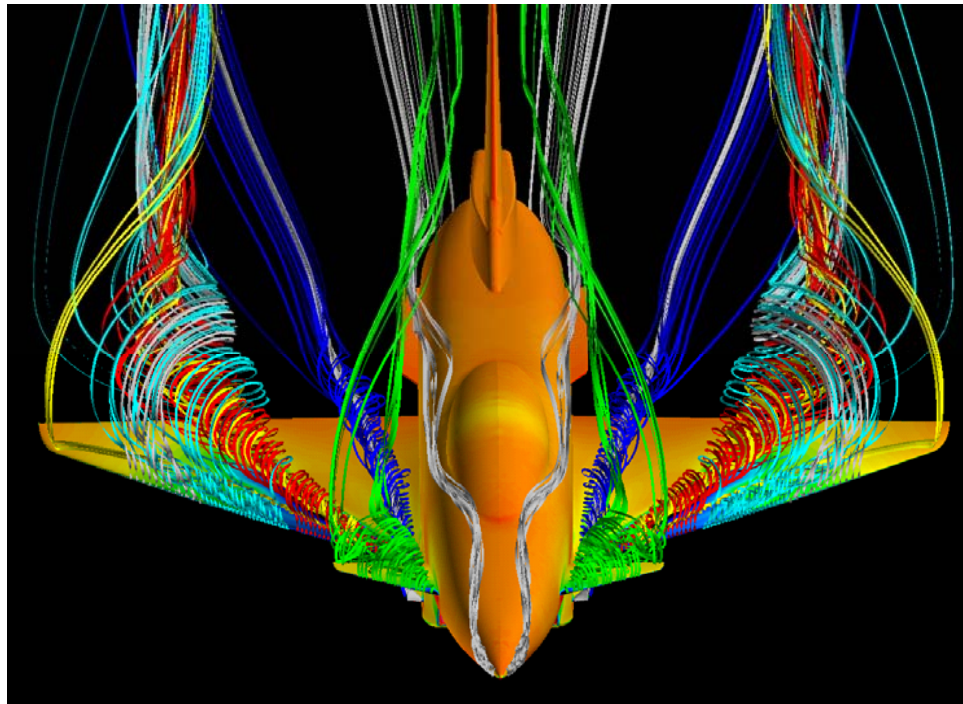
- Simplified model for wind tunnel experiments
- Simulation for validation of experiments





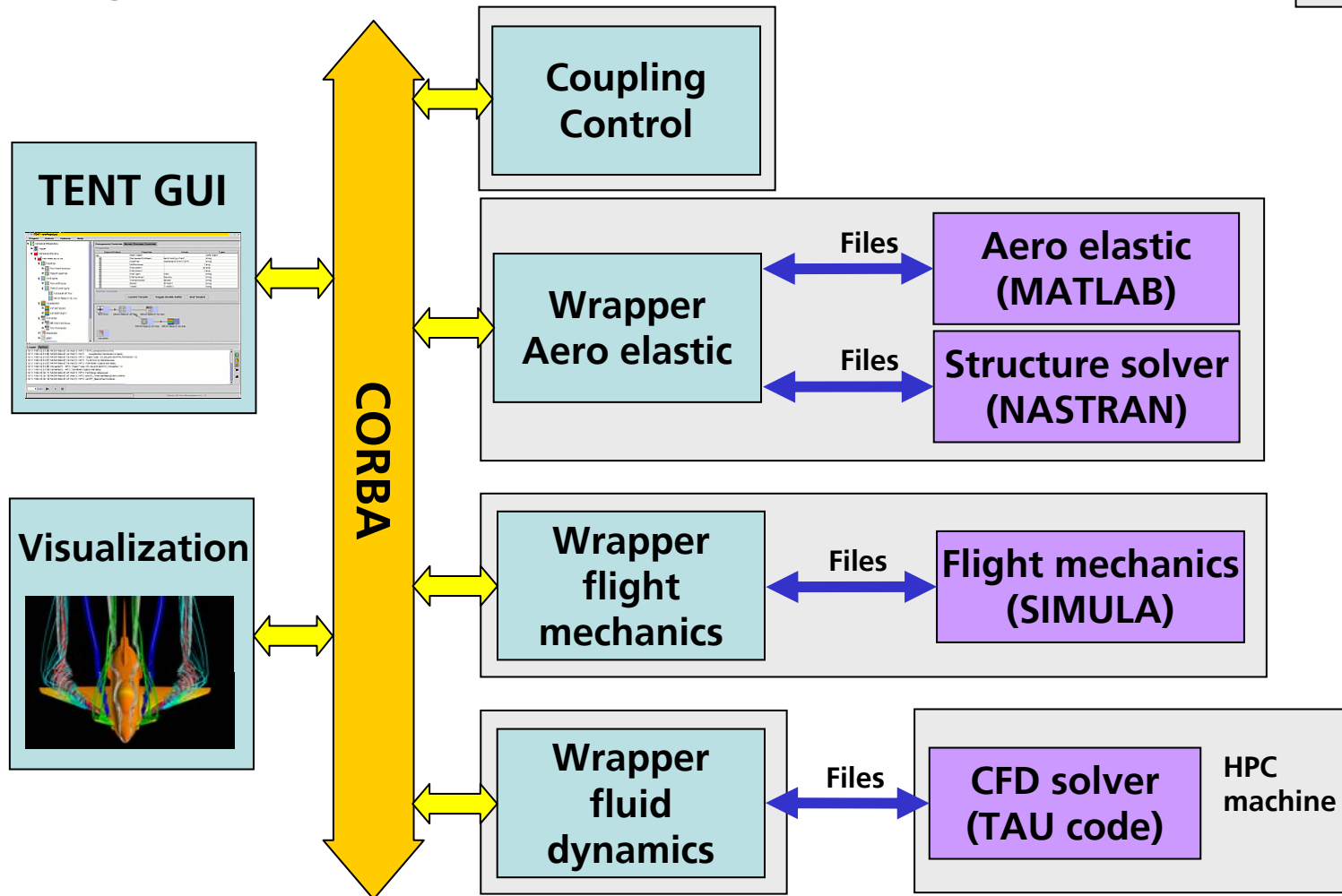
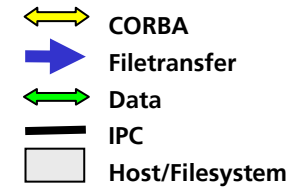
# Flight Maneuver Simulation Results

- Coupled simulation: Aerodynamic – flight mechanics – aeroelasticity
- Computing times: ~ 7 days on large computing cluster (> 64 procs.)
- Important: **Online monitoring** and **restart capability**





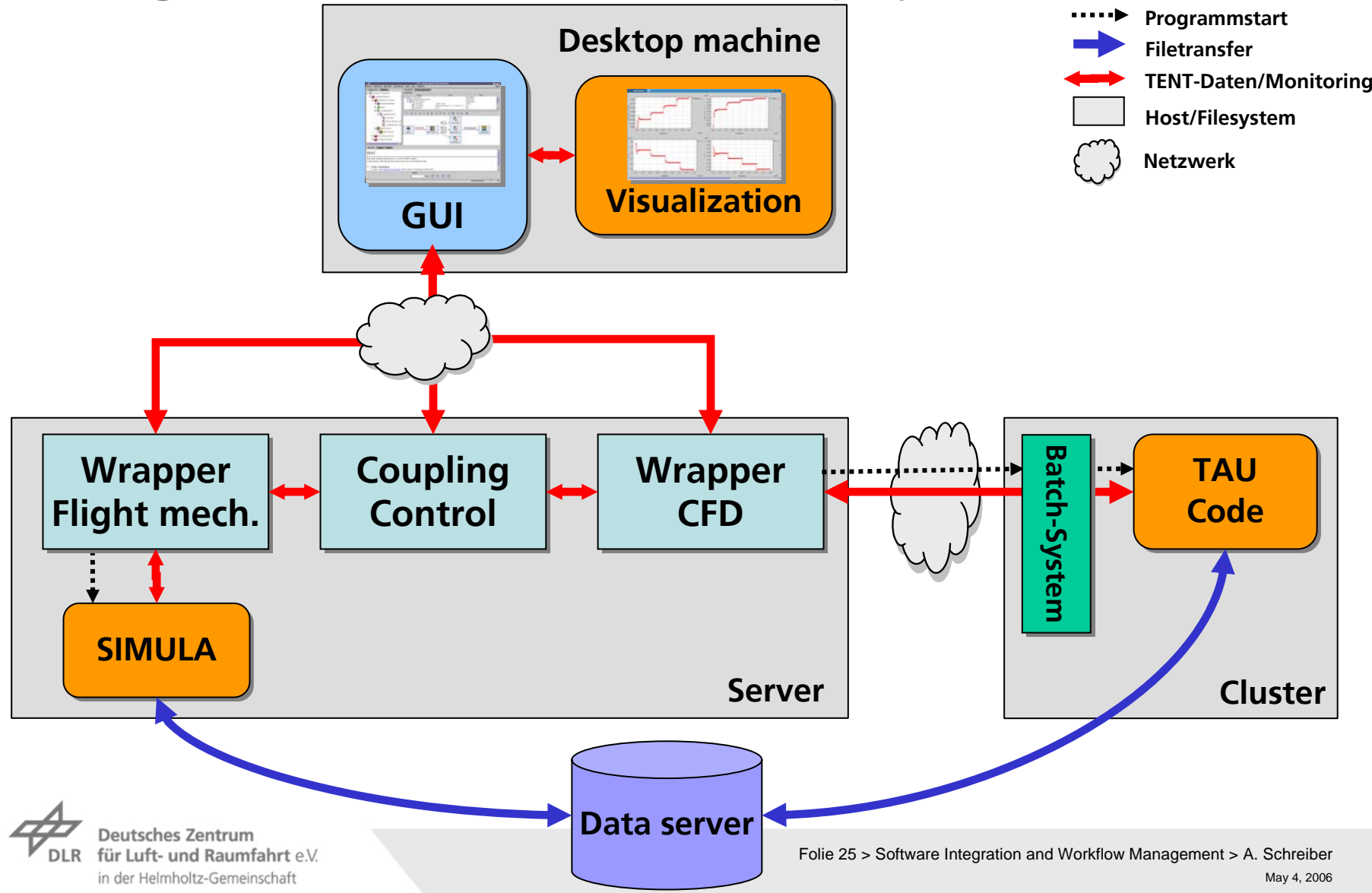
# Flight Maneuver Simulation Integration in TENT







# Flight Maneuver Simulation - Deployment





TENT - [SimulaTauFluegel\_bsas/ reserved]

Project Simulation Workflow Component Tools View Scripting Help

Projects Components

http://sikma.sistec.dlr.de/SikMa2004.1.7/

- SikMa2004.1.7
  - SimulaDeltaAlone
  - SimulaFluegelAlone
  - SimulaSikMa2004.1.6
    - action
    - layout.dat
  - SimulaTauFluegel\_bsas
    - CouplingManager
    - SimulaSikMa2004.1.7
      - TAUSikMa2004.1.7
        - action
        - layout.dat
    - SimulaTauFluegel\_strider
      - CouplingManager
      - SimulaSikMa2004.1.7
        - TAUSikMa2004.1.7

Properties Application Starter ParameterFileEditor Plot Tau TauUserScriptEditor

Local Environment Properties  
Remote Environment Properties  
Process Environment  
Application Properties

Executable: /home3/nv/sikma/Kopplung/fluegel/Cnt/|  
Host Name: bassgi15.as.bs.dlr.de  
Input Directory: /home3/nv/sikma/HAP2000/KOPPLUNG/| ...  
User Name: sikma  
Working Directory: /home3/nv/sikma/HAP2000/KOPPLUNG/| ...

Save Properties

TENT - [SimulaTauFluegel\_bsas/ reserved]

Welcome Logger Python

## TENT

This page will help familiarize you with the TENT system.  
To get started, read the sections below and click on the related links.

**Create a new Simulation**  
To start, first [select a project](#) or [create a new project](#). Next create a Simulation within that

**CouplingManager**

Unsteady Physical Time Steps 100 Step Size [sec] 0.0010 Inner Iterations 10

**TAUSikMa2004.1.7**

Unsteady Physical Time Steps 100 Step Size [sec] 0.0010 Inner Iterations 10

**action**

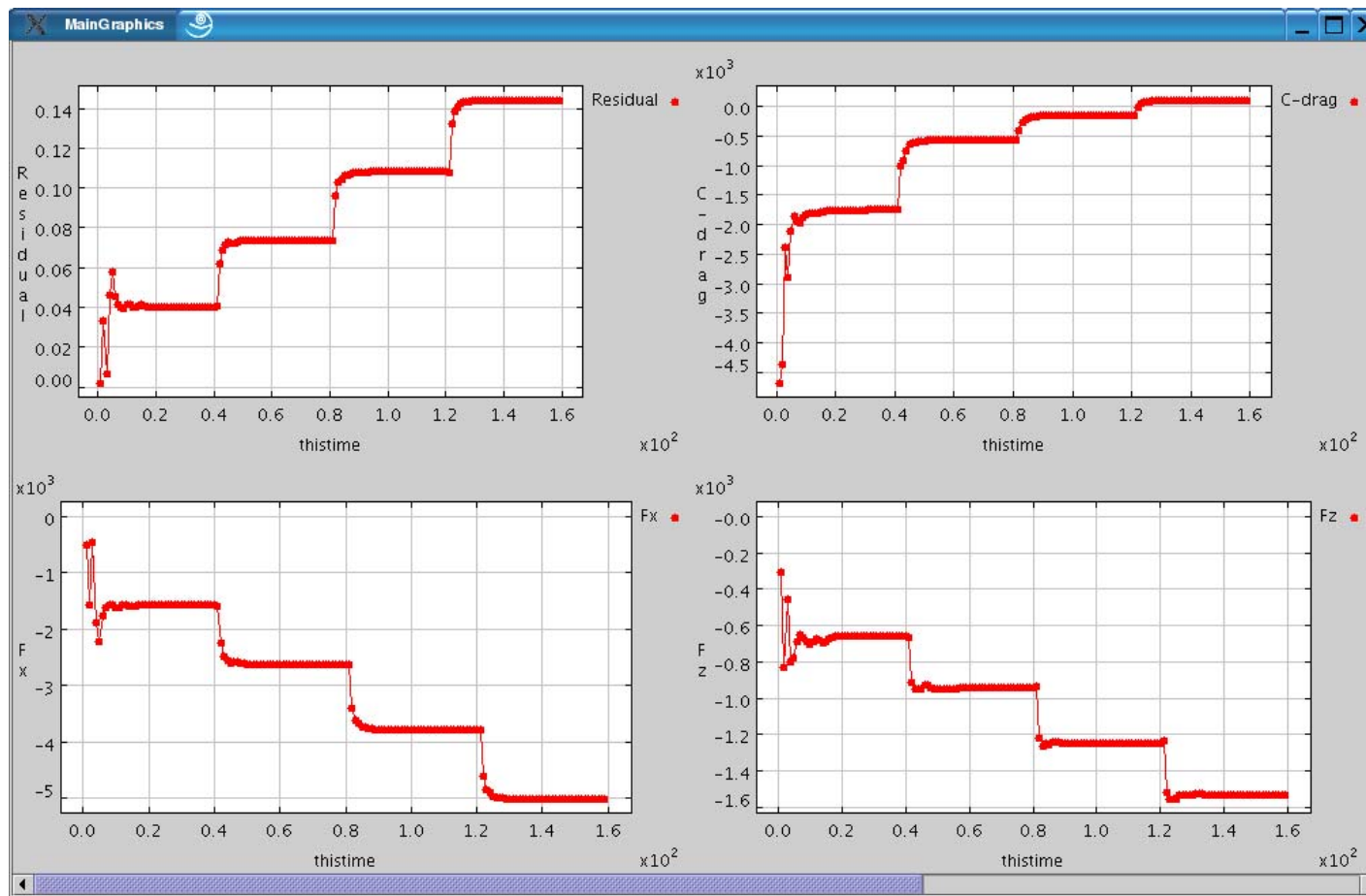
▶ || ◻ ▶▶

guest 0%



# Flight Maneuver Simulation

## Online Monitoring of Results

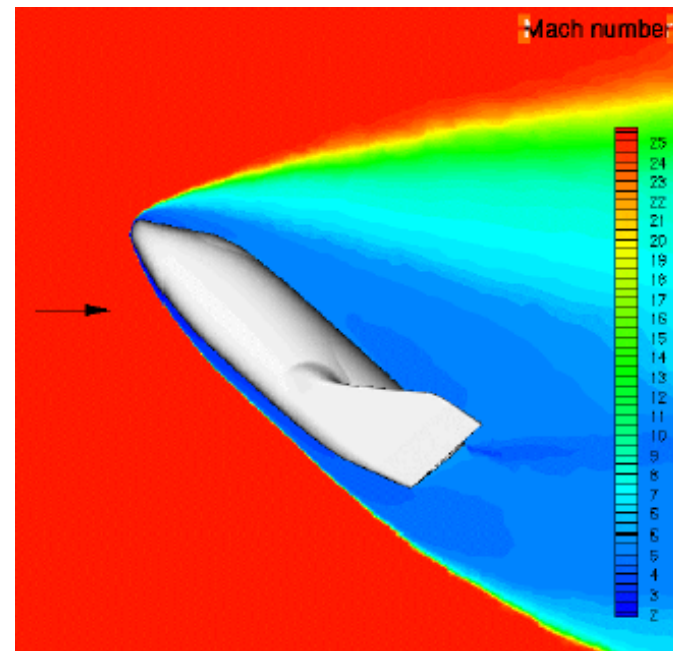




## Example Application 2

### Space Re-Entry Simulation

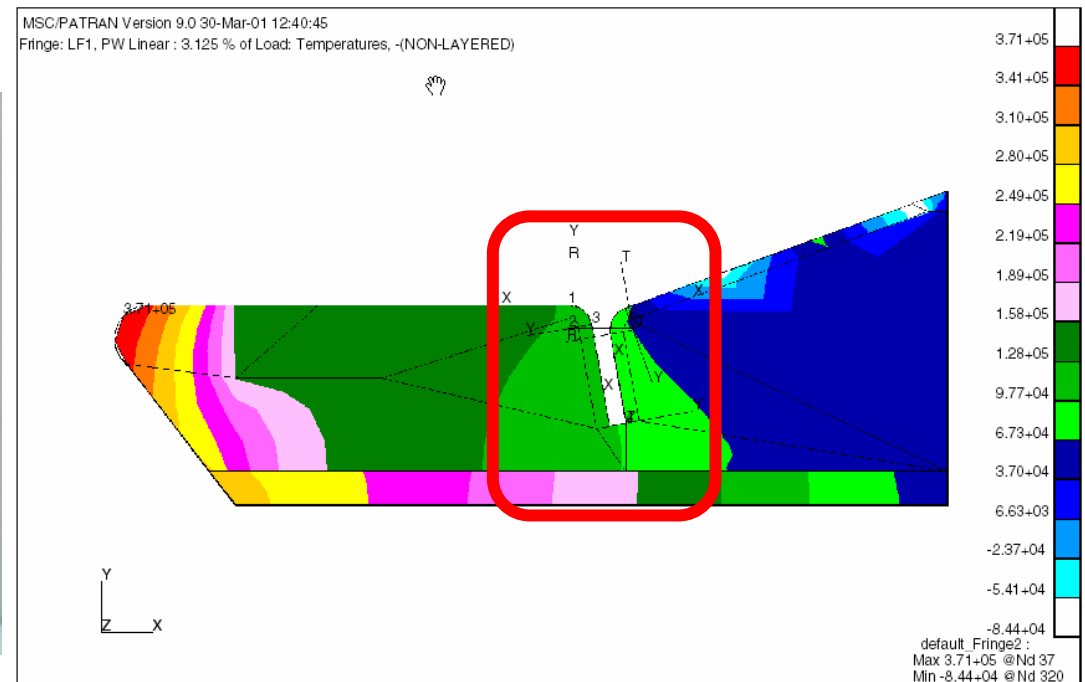
- Simulation of thermal heavily loaded parts of the X-38 space re-entry vehicle
- Fluid-Structure-Thermal coupling





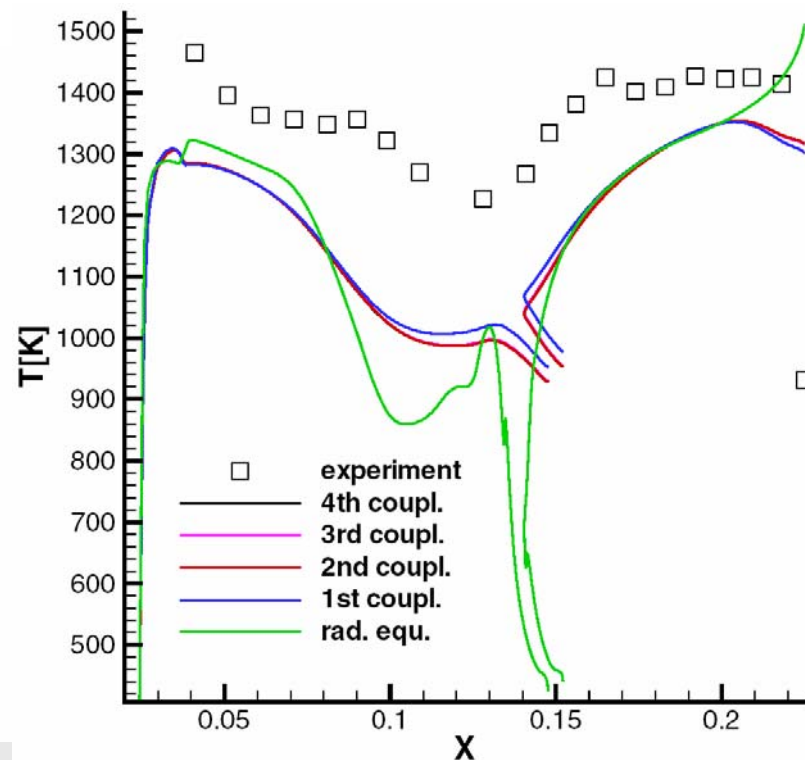
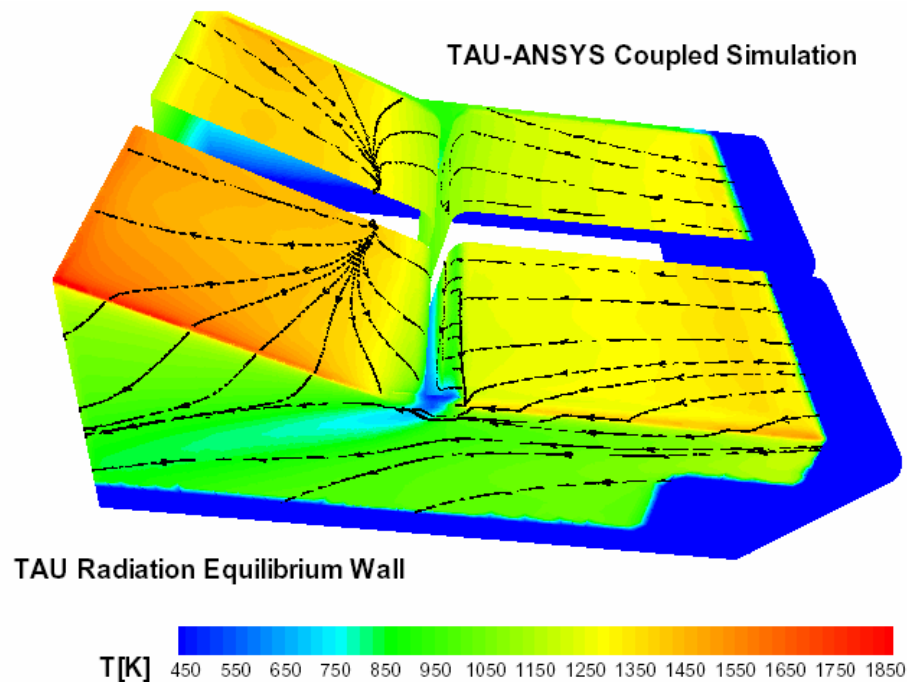
# Space Re-Entry Simulation Model

- Simplified model for wind tunnel experiments
- Simulation for validation of experiments
- Focus on flaps and gap



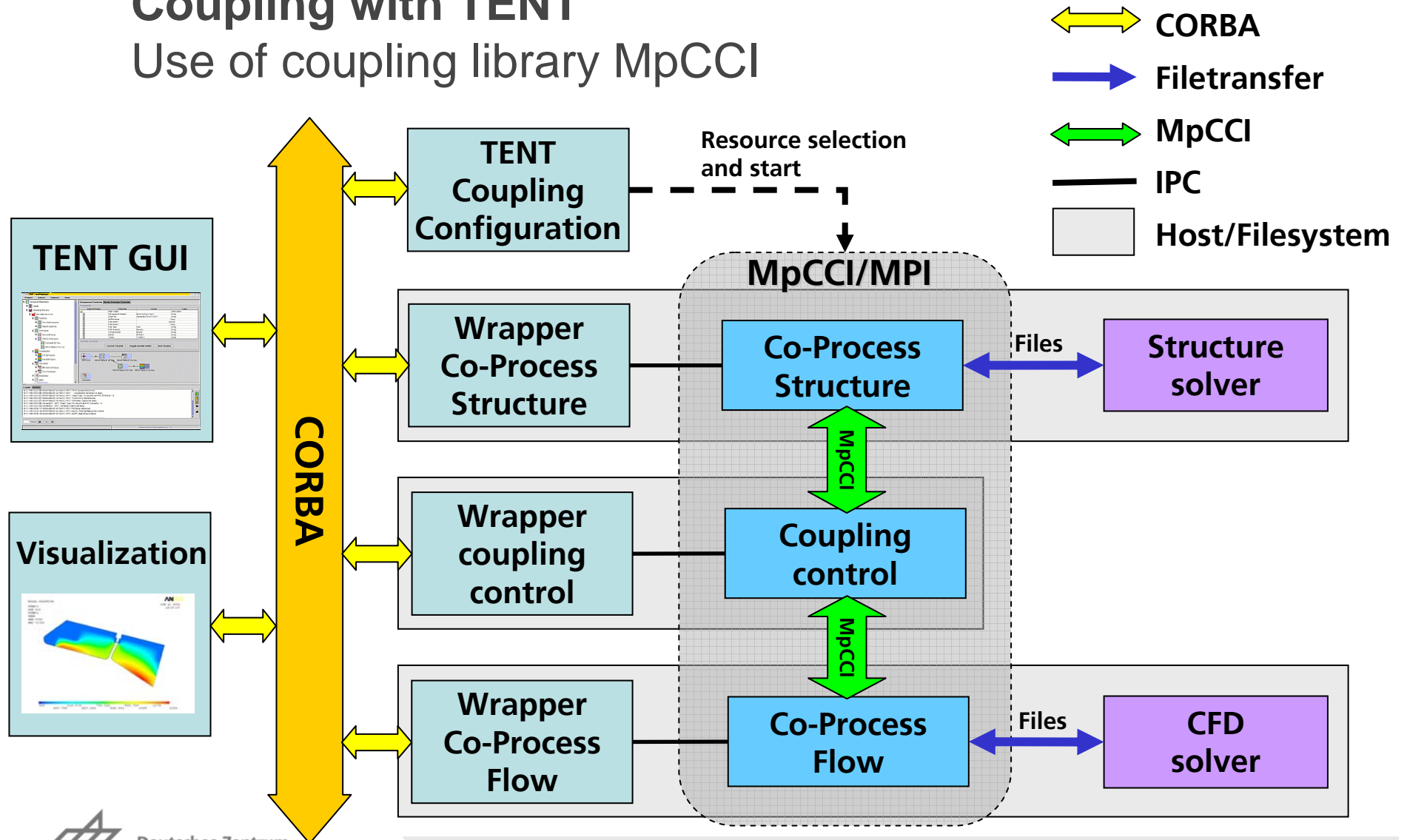
# Space Re-Entry Simulation Results

- Coupled simulation
  - DLR-TAU code for aerodynamics
  - ANSYS and MSC/NASTRAN for heat transport and deformation in the structure



# Coupling with TENT

## Use of coupling library MpCCI





TENT - [IMENS\_PLUS-SISTECDemo-2/ reserved]

Project Simulation Workflow Component Tools View Scripting Help

Projects Components

http://imens.sistec.dlr.de/fdan/

- fdan
  - IMENS\_PLUS-ASDemo-2
  - IMENS\_PLUS-ASDemo-BAK
  - IMENS\_PLUS-SISTECDemo-2
    - Action
    - AnsysCoProcess
    - CouplingControl
    - MpCCIControl
    - TauCoProcess
    - layout.dat
  - IMENS\_PLUS-SISTECDemo-BAK

Properties Starter Properties CouplingControl

UserName: fdan

HostName: luts.sistec.bs.dlr.de

StartOptions: iflsControlCode.py

StepsPerEvent: 1

Executable: ccipython /home/fdan/Devel/TENT\_HEAD, ...

WorkingDirectory: /home/fdan/Devel/TENT\_HEAD/TENT\_prd, ...

TENT - [IMENS\_PLUS-SISTECDemo-2/ reserved]

Meta Data File Attributes

Name	Value
ANSYS_host	thor.sistec.kp.dlr.de
Coupling_Scenario	
MpCCI_Version	
TAU_host	luts.sistec.bs.dlr.de
TENT_version	

Add Edit Delete

Action MpCCIControl MpCCI MpCCI MpCCI TauCoProcess AnsysCoPro... CouplingCo...

Logger Python

Global GUI TENT Factory CouplingControl AnsysCoProcess MpCCIControl

Filter:

Type	Component	ID	Time	Message
GUI	AWT-EventQueue-0		24.05.2005 - 11:01:38	Adding component control
GUI	AWT-EventQueue-0		24.05.2005 - 11:01:38	Adding component control
GUI	AWT-EventQueue-0		24.05.2005 - 11:01:39	Adding component control
MpCCIControl	RequestProcessor[2]		24.05.2005 - 11:01:46	MpCCI-Control: starting CCI

Action

guest 0%





# New Technologies

## Technology Upgrade for TENT

- **TENT used modern technologies of the past 10 years**
- **Technology upgrade for the next 10+ years in project SESIS**

TENT	Project SESIS	RCE (Project SESIS)
➤ GUI with Plug-Ins (proprietary development)		➤ GUI Plug-Ins Framework (Eclipse)
➤ Single role for all users		➤ Multiple user roles
➤ Single communication protocol (CORBA)		➤ Various protocols (Web Services, Java RMI, CORBA, ...)
➤ Authentication with user name & password		➤ Authentifizierung with certificates (single-sign-on)
➤ File-based data management		➤ Data management with complex data structure (and files)
➤ Modularity in sub systems		➤ Everything is modular

# Project SESIS

## Goals

### *Design in 7 Days* in a virtual organization

- **Early ship design** for creation of offers
- Reduction of design times
- Distributed design und simulation
  - Shipyards organizing ship building process
  - Integration of supplier in design process



Quelle: Flensburger Schiffbau-Gesellschaft mbH & Co. KG

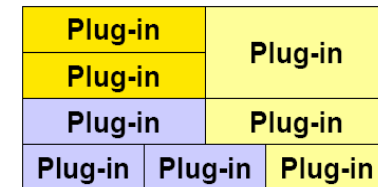


# Project SESIS

## System Design



- System designed with a **Plug-In architecture** based on the **OSGi** platform
  - RCE (Reconfigurable Computing Environment)
- Advantages
  - Consistent modularization
  - Good extensibility und scalability
  - Specificity by configuration
  - Use of many existing Plug-Ins (*see Eclipse!*)



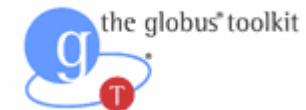


# Project SESIS

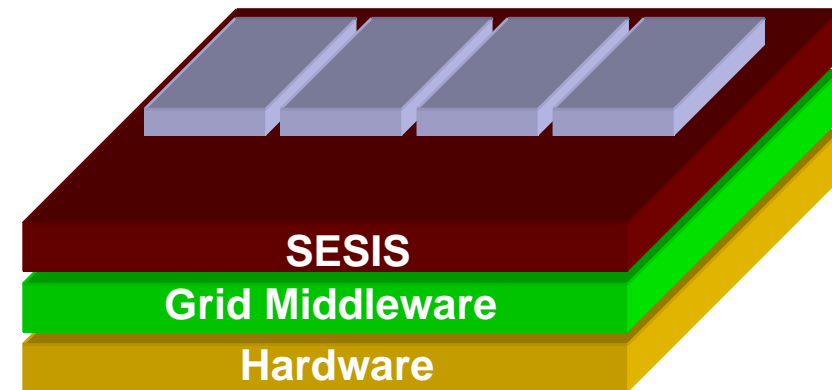
## Base-System Layer



- Usage of databases and Grid middleware solutions
- SESIS supports
  - Communication
  - Updates
  - Privilege management
  - Services discovery



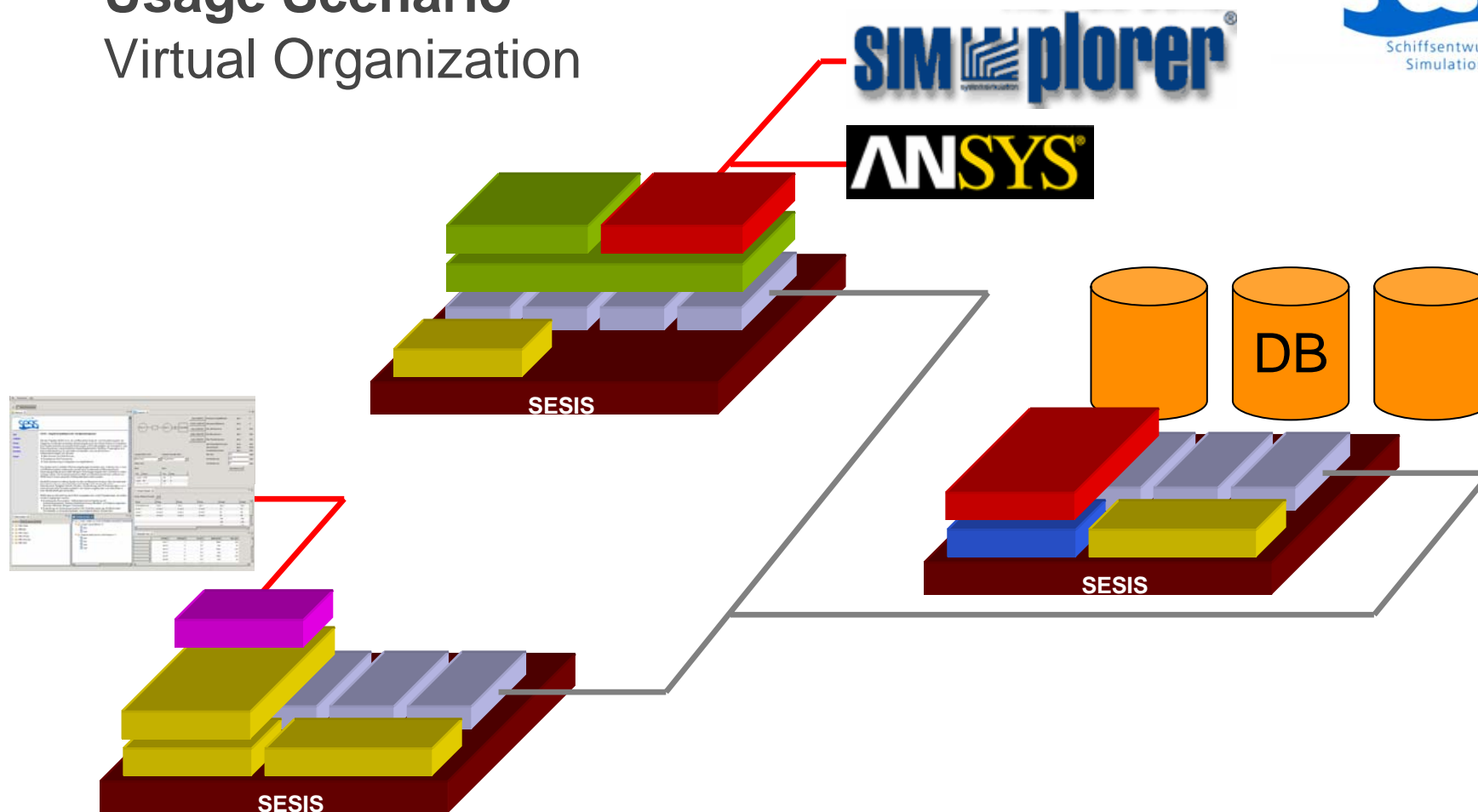
**Installation of identical base system on every machine**  
**Specificity by loading additional plug-ins**





# Usage Scenario

## Virtual Organization



# SEISIS Graphical User Interface

## Eclipse RCE w/Plug-Ins



**SEISIS - Integriertes Schiffsentwurfs- und Simulationssystem**

**Ziel**

Ziel des Projektes SEISIS ist es, ein schiffbauliches Entwurfs- und Simulationssystem als integrierte und flexibel einsetzbare Arbeitsumgebung für den frühen Entwurf zu entwickeln. Das Projekt verknüpft und erweitert Erfahrungen und Funktionalitäten aus Simulations- und Entwurfssystemen unterschiedlicher Anwendungsbereiche: Schiffbau, Flugzeugbau und Automobilentwicklung. Es setzt dabei auf aktuellen und zukunftsicheren Softwaretechnologien auf, darunter

- Web Services und Grid Services,
- Erweiterbare GUI-Frameworks,
- Code Generierung zur Integration von Applikationen.

Das System wird in verteilten Rechnerumgebungen einsetzbar sein, in denen Unix-, Linux- und Windowsysteme miteinander vernetzt sind. Existierende schiffbauspezifische Anwendungssoftware wird mittels Wrapper-Technologie eingebunden und bleibt in vollem Umfang nutzbar. Die Zusammenarbeit von Werft und Zulieferunternehmen auf Basis von SEISIS wird in einem speziellen Arbeitspaket demonstriert werden.

Mit SEISIS entsteht ein offenes System für den schiffbaulichen Entwurf. Über klar definierte Schnittstellen können neue Methodenentwicklungen (z.B. aus den Bereichen Hydrodynamik, Festigkeit, Akustik, Vibration, Visualisierung und VR-Anwendungen u.v.m.) sowie kommerzielle Simulationspakete in das System eingebunden und miteinander in einer Workflowkette genutzt werden.

SEISIS läuft von Mai 2005 bis April 2008 und gliedert sich in drei Projektschalen, die zeitlich verzahnt angegangen werden:

- Erstellung des Kernsystems - Softwaretechnische Entwicklung inkl. Anforderungsanalyse, Software-Qualitätssicherung, Workflow- und Datenmanagement, Benutzer-Interfaces, Wrapper-Technologie;
- Entwicklung von Anwendungsmodulen inkl. Produktionsplanung, Schiffsimulator, Schnittstellen zu Simulationspaketen, neue Datenstrukturen, Kooperation

**Simplorer**

Start SIMRUN Netzspannung (Mittelwert) label V  
 START SIMSTEP Motostrom (Mittelwert) label A  
 Stop SIMSTEP Max Motostrom label kWhm  
 Weiter SIMSTEP Min Motostrom label kWhm  
 Ende SIMSTEP Max Propellermoment label kWhm  
 Motorluftpaldrehmoment label kWhm  
 Motordrehzahl label RPM  
 Propellerdrehmoment label kWhm  
 Max Zeit 300 msec  
 Schrittweite max 200 usec  
 Schrittweite min 50 usec  
 Übernahme Zeit

Key	Value	Key	Value
U_gen	4700	len	5
I_gen	50	typ	A
xdraub_	0.0865	dim	2

String	String	String	String	Integer	Integer
schreibgeschuet	Typ a	Typ c	Typ h	Typ z	Typ i
z1 sp 1	z1 sp 2	z1 sp 3	z1 sp 4	15	61
z2 sp 1	z2 sp 2	z2 sp 3	z2 sp 4	25	62
z3 sp 1	z3 sp 2	z3 sp 3	z3 sp 4	35	63
				106	109
				136	139
				127	140

	STRING	INTEGER	FLOAT	BOOLEAN	YES_NO
1	Item 1	1	1.0	false	yes
2	Item 2	2	2.0	true	no
3	Item 3	3	3.0	false	yes
4	Item 4	4	4.0	true	no
5	Item 5	5	5.0	false	yes
6	Item 6	6	6.0	true	no