

Biomechanical modelling and treatment planning in a Grid environment

22.9.04

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Overview

- **A wider view... comments on virtual human modelling, treatment planning, computer-assisted interventions, ...**
(HealthGrid White Paper - Chapter 4)
- **Examples from the GEMSS project**



Genomics .. Proteomics
Bio-Informatics

Populations

Current Focus... but “in future” → Multi-scale !

Prediction

Computational Models of
The Human Body

Integration with
Data Repositories

Digital
Atlases

Eg use of Data-
mining

Integration with
Medical Imaging +
Data Repositories

Patient-specific

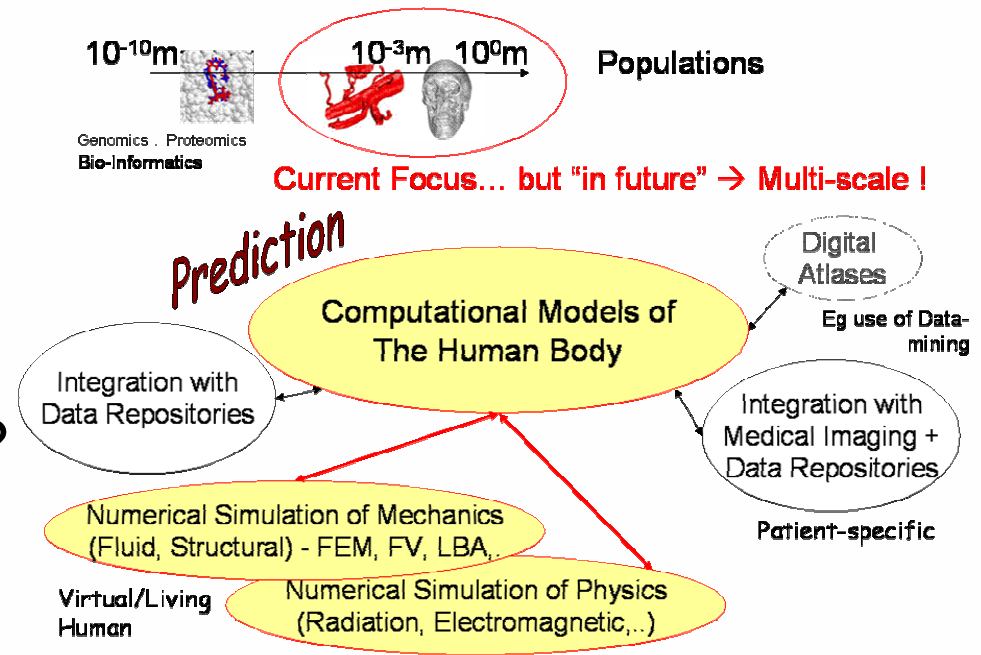
Numerical Simulation of Mechanics
(Fluid, Structural) - FEM, FV, LBA,..

Virtual/Living
Human

Numerical Simulation of Physics
(Radiation, Electromagnetic,..)

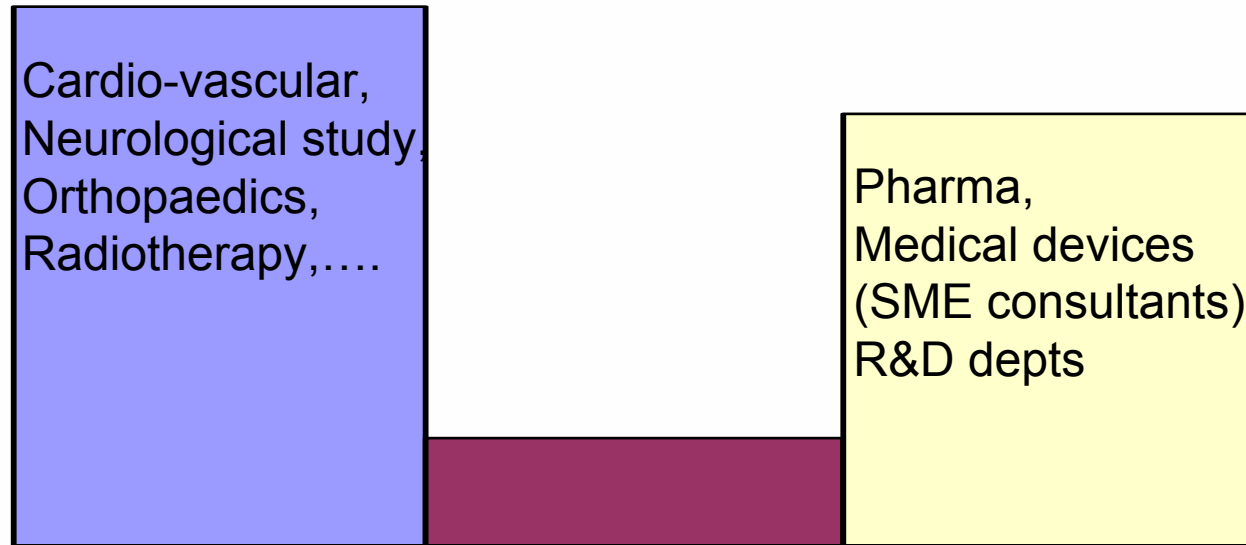
A naming problem....

- Bio-physics modelling ?
- Bio-numerics ?
- Bio-informatics ?
- Just “a part of” Medical informatics ?
- Virtual human modelling ?



Impact status of Bio-numerics in the medical community

(personal observations/estimation)



Medical Research ("understanding") Medical Practice ("clinical planning") Medical Suppliers ("design, discovery")

Requirements:

Computational platforms (HPC), data availability & access,
continued development of modelling technology

“medical + cost-saving” pilot studies to promote growth in
medical practice take-up

HPC in Hospitals ?

“A new supercomputer funded by the University of Sheffield and located within the Royal Hallamshire Hospital, will help scientists to improve their understanding of how human cells and organs work.”



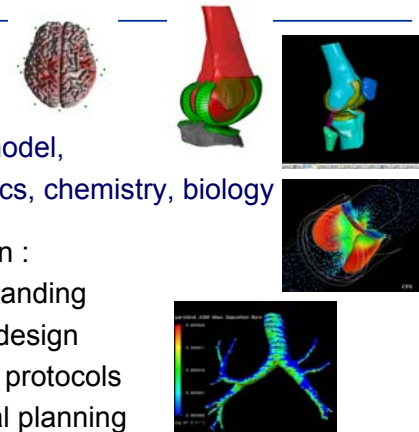
Figures courtesy of U. Sheffield



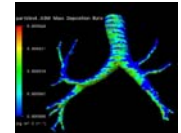
University of
Sheffield

Biomedical Simulation

We scan the patient,
..... identify the bits,
..... build a numerical model,
..... including physics, chemistry, biology



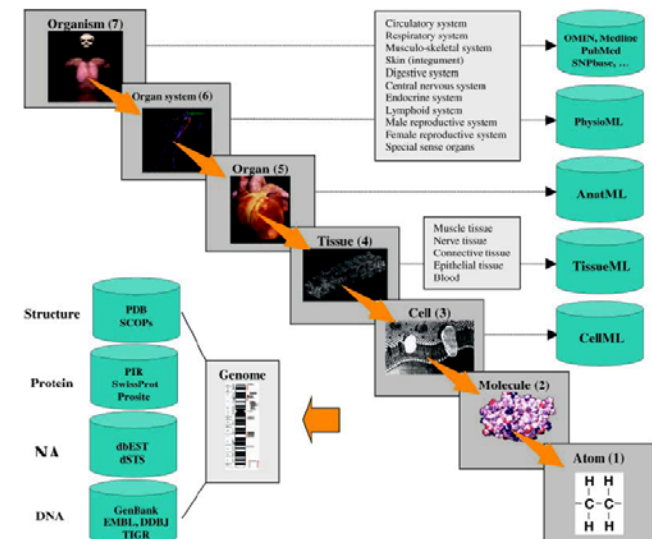
Numerical Simulation can :
.....improve our understanding
.....improve prosthesis design
.....improve therapeutic protocols
.....contribute to surgical planning



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Sheffield



www.dcs.shef.ac.uk/~rod/

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Hunter P, Robbins P, Noble D (2002) The IUPS human physiome project. Eur J Physiol 445 1-9

Grid Requirements

- Access to computational resources (simulation / compute services)[*]
- Access to distributed repositories - e.g. anatomo-functional data as basis for modelling, data mining approaches
- Extremely high network-bandwidth & guaranteed QoS for applications moving towards real-time
- Secure systems (secure transmission and control of data access)
- Virtual organisation support for SME consultants to larger medical suppliers
- Integration of (expensive, scarce) Medical imaging centres



[*] Pharma's docking, and similar, apps are appropriate for meta-computing (PC-Grids), but many others will not be suitable for that approach

A Grid scenario for radiotherapy planning & treatment

1. Ongoing research - *gene profiling* to identify patient's radiosensitivity (for individualised dose adjustment) or make treatment decisions linked to tumour's capacity for metastatic spread → (multi-scale approach), access to distributed data centres
2. Medical scanning at distributed centres, as planning support for the radiotherapy treatment → interaction between related data repositories
3. Access to Monte Carlo-based dose and targetting computations at remote HPC centre
4. Collaboration between expert centres on QA procedures, shared digital atlases and tele-consultation

GEMSS: GRID-enabled Medical Simulation Services

<http://www.gemss.de>

Project Duration: 30 months, Commencement: 1.9.2002

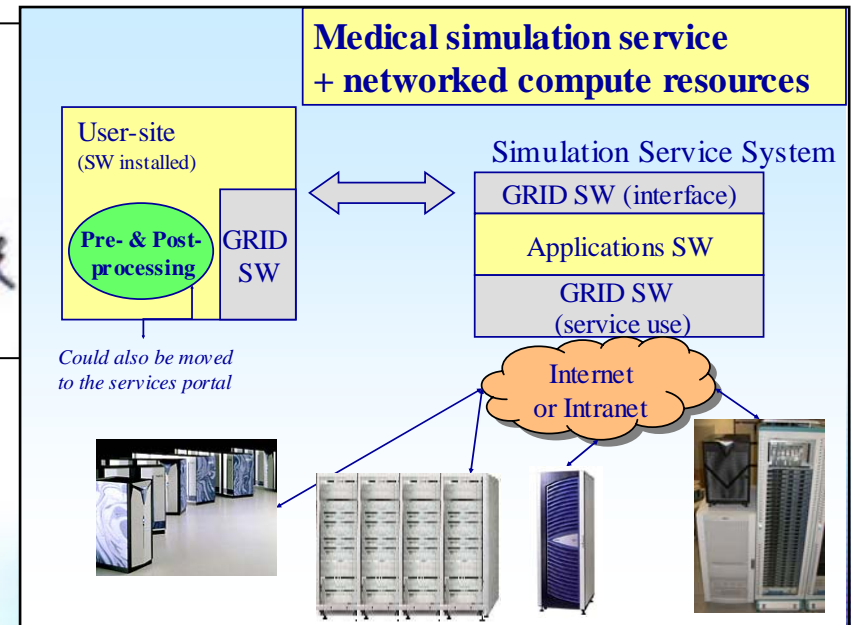
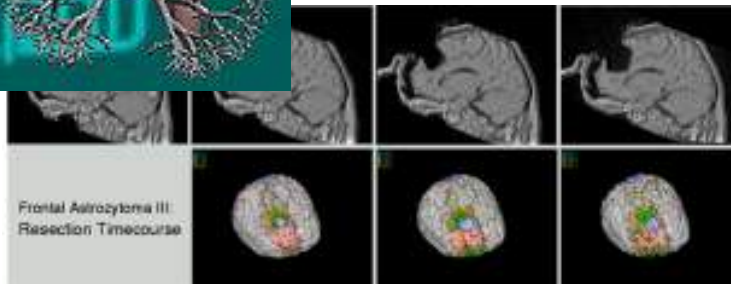
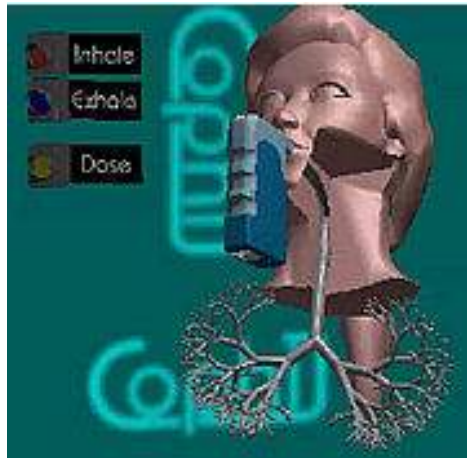
Grid
Software
/solutions

Simulation
/Imaging
Software

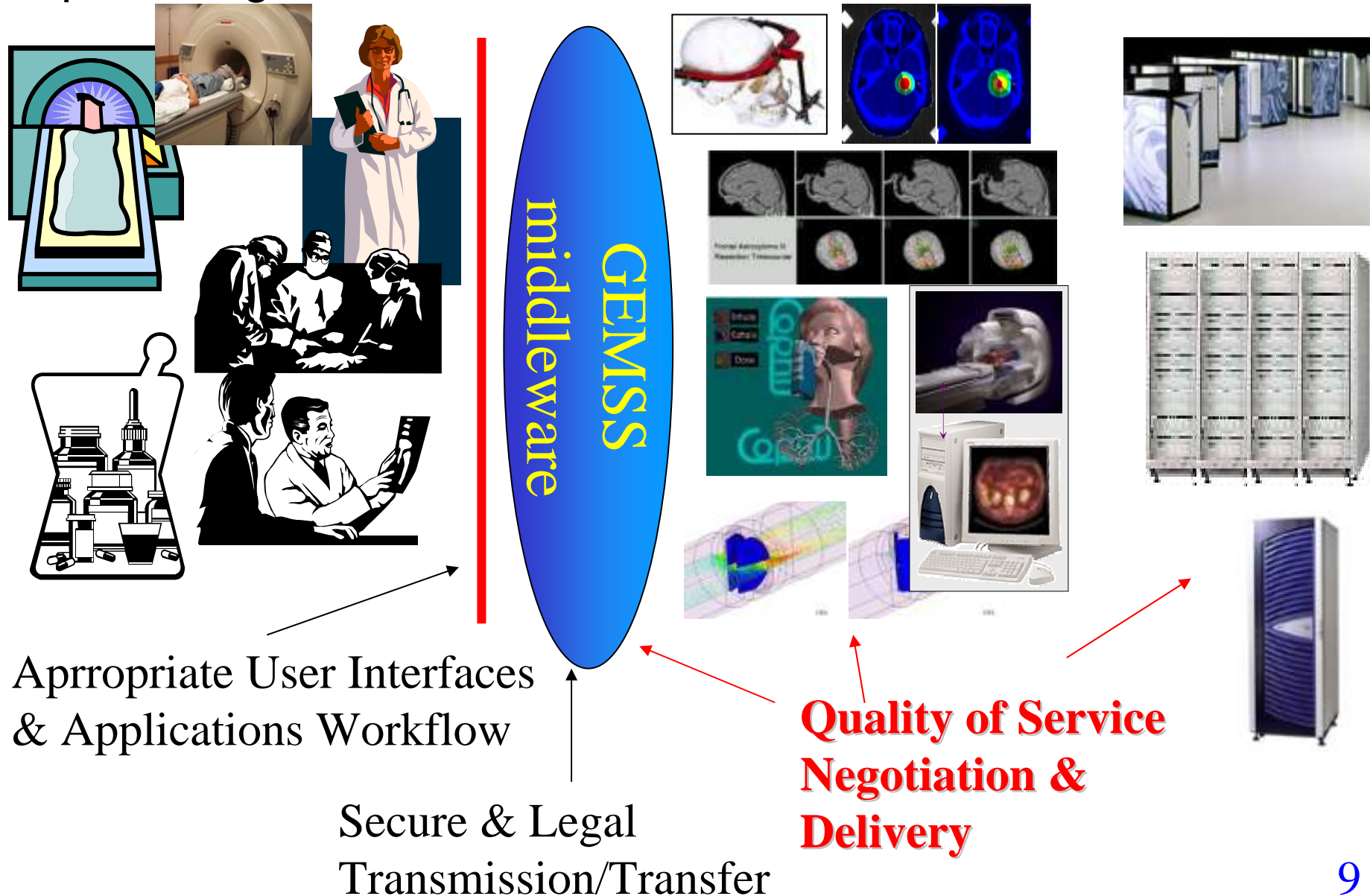
Bio-
numeric
modelling

Medical
Expertise

Legal
Aspects



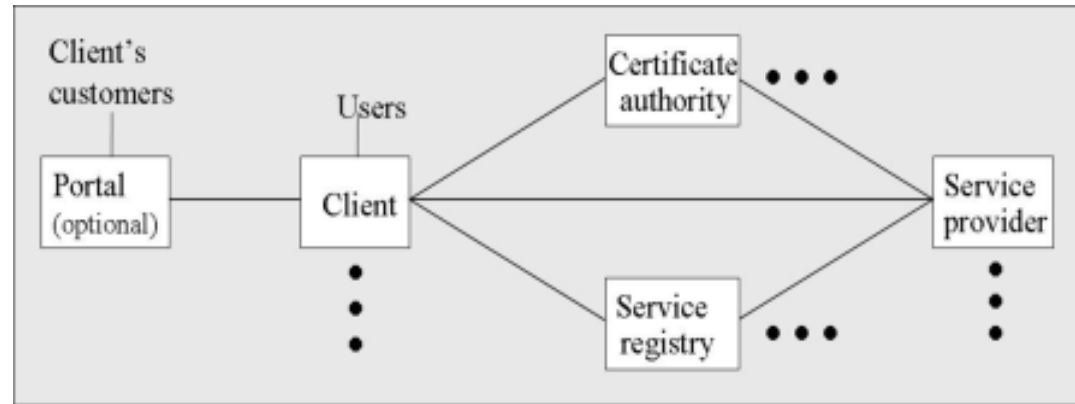
<http://www.gemss.de>



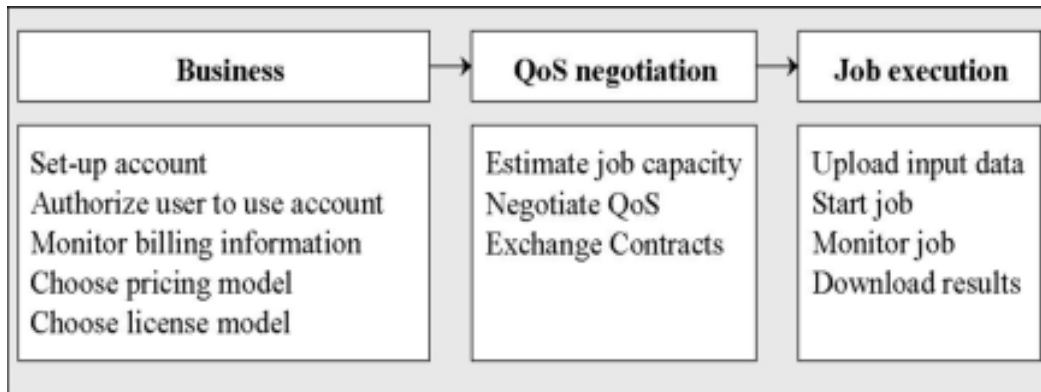
GEMSS Architecture

Grid Architecture:

- **Service oriented approach**,
- Based on Web Service technology,
- Interoperability via standards like OGSA,
- Modular component framework,
- Supports flexible workflows:
Quality of Service (QoS),
business, application workflow.



Three step process model:



- Flexible business model to allow commercial operation of Grid services.
- Flexible negotiation model: client can negotiate with service providers.
- Quality of service terms can be discussed, as well as the price involved.
- Job execution and data transfer.

Maxillo-Facial Surgery Simulation Service

- Easy to use HPC tool for planning of correction of facial malformations
- Finite Element simulation of distraction osteogenesis processes based on medical images, e.g. CT



(before)



(after)

Patient data courtesy of Dr. T. Hierl, U. Clinic Leipzig.
Figures courtesy of the GEMSS Consortium

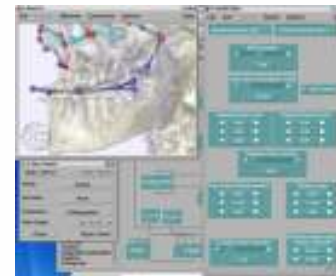
CT images



Segmentation



Bone cutting tool



Applied cuts

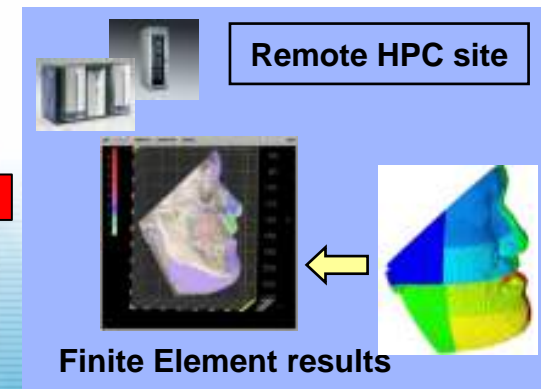


Pilot evaluation study

Dr. Thomas Hierl, Department of Oral and maxillo-facial surgery, University clinics Leipzig.

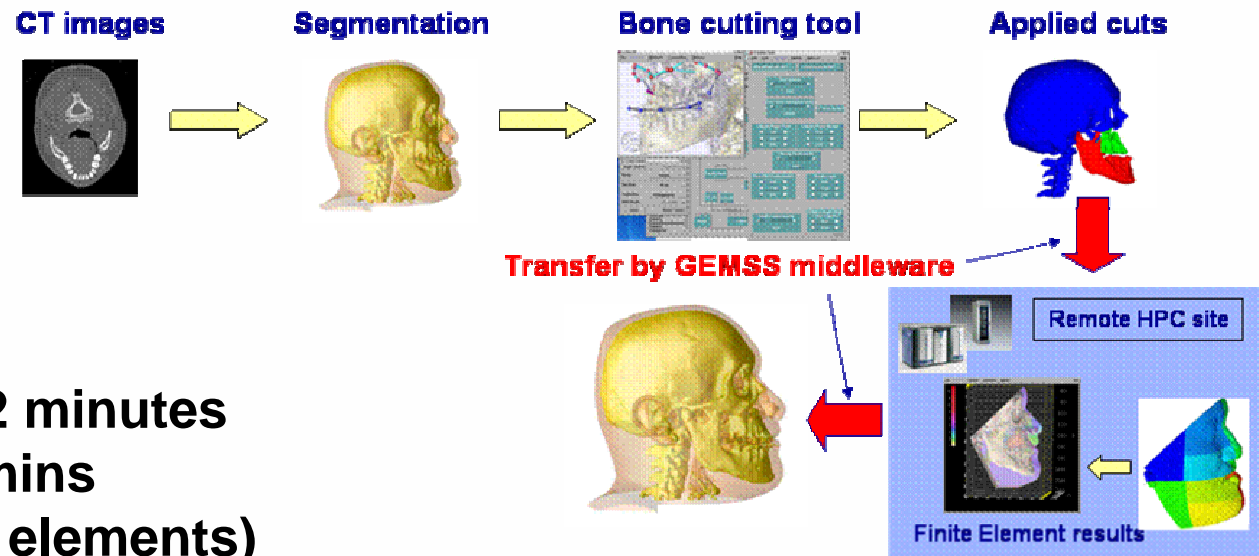
"The product greatly enhances the surgical planning process for maxillo-facial operations. GEMSS lets me access NEC's advanced high performance computing facilities with a single mouse click when I need it".

Transfer by GEMSS middleware



Maxillo-Facial Surgery Simulation Service - Approx. Times from current experience

- Model preparation (interactive), approx. 2 minutes
- Mesh generation - 3 mins (→ mesh size of 0.5 M elements)
- Simulation times on 8 processors (PC cluster), 5 minutes
- Total job time 10 minutes (excluding time for surgeon to draw cuts)



Future Nonlinear Simulation - several hours:

- should give better accuracy of soft tissue displacements + reliable force/displacement relationship (not obtainable with linear approach).
- Forces roughly correspond to pain for patients, so force peaks should not be too high. Also, could predict which forces have to be applied with halo to achieve a given displacement.

Summarising Grid Needs:

- Computational Grid Services (in addition to the use of, possibly enterprise-wide, PC-Grids for some apps) - either pre-installed software solutions or large facilities for medical researchers
- Collaborative access to distributed data repositories
- For medical practitioners: services delivered into the workplace in an appropriate, ergonomic manner
- Security, policy and legal constraints on the use of patient data

Boundary conditions:

Economic impact needs to be demonstrated and deployment of tools accepted by the funding regime of individual countries' health systems

Empowered by Innovation

NEC