Workflow on the OR: Review of Arrowhead 2004 Seminar on Imaging and Informatics

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CARS/SPIE 3rd joint Workshop
Surgical PACS
Berlin, 25 June 2005

Content

1. Motivation
2. Examples
3. Medical Imaging
4. Workflow in surgery
5. Peer-to-Peer Computing (P2P models)
6. Surgical PACS, DICOM and IHE
7. Conclusion

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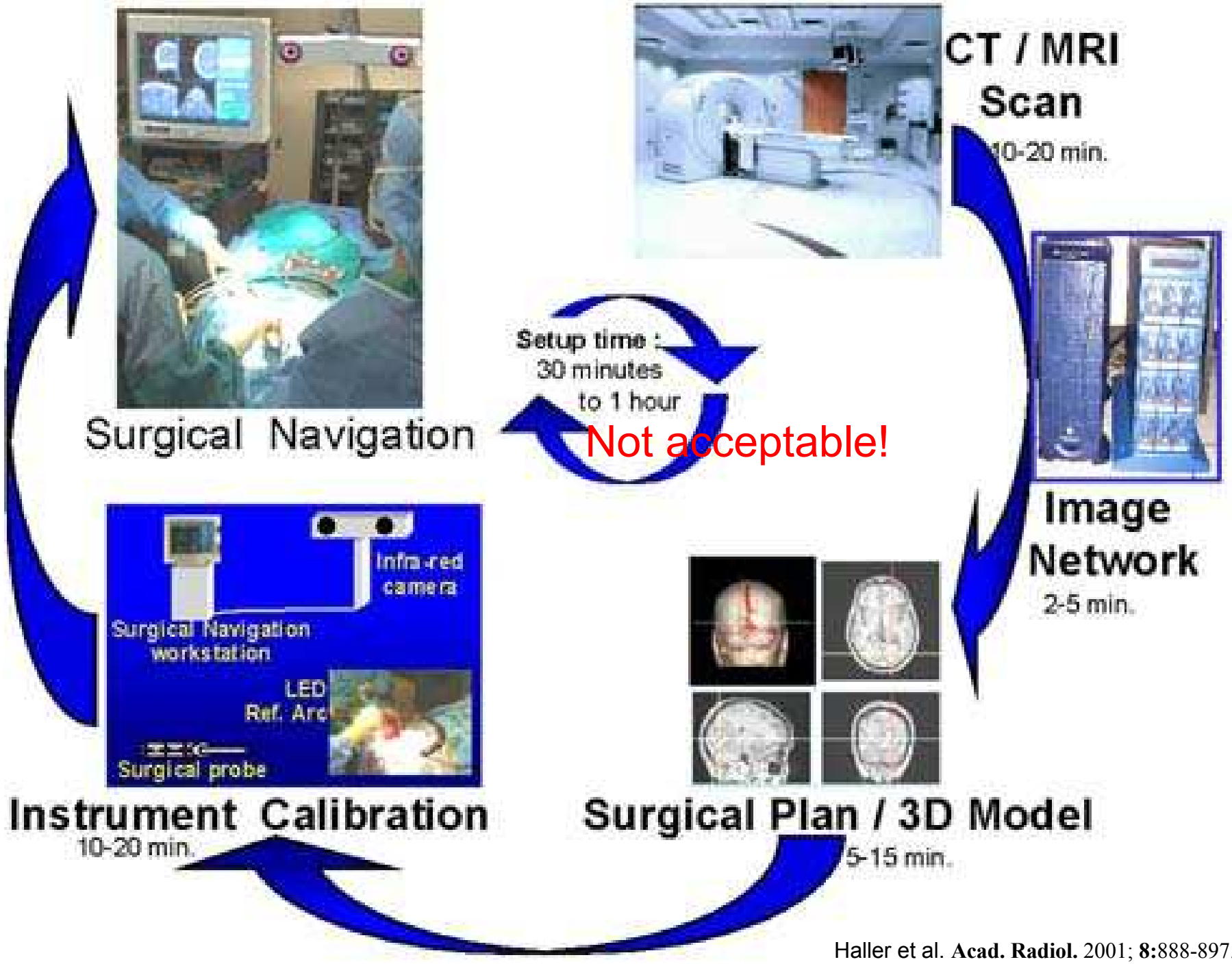
Clinical Needs, Deficiencies and Issues Workflow

- Inefficient, ineffective and redundant processes
- Inflexible "systems" of operation
- Ergonomic deficiencies which hinder the workflow
- Data (text, 1D, 2D, 3D, 4D) presentations not adequate, e.g. intraoperative and perioperative
- Soft knowledge (info+action strategy) presentation not available
- Scheduling (and tracking/RFIDing) of patients, personnel, operating rooms, equipment etc. not facilitated or coordinated (often the seeds of "busted" schedules)
- Too long set up times for robotic surgery

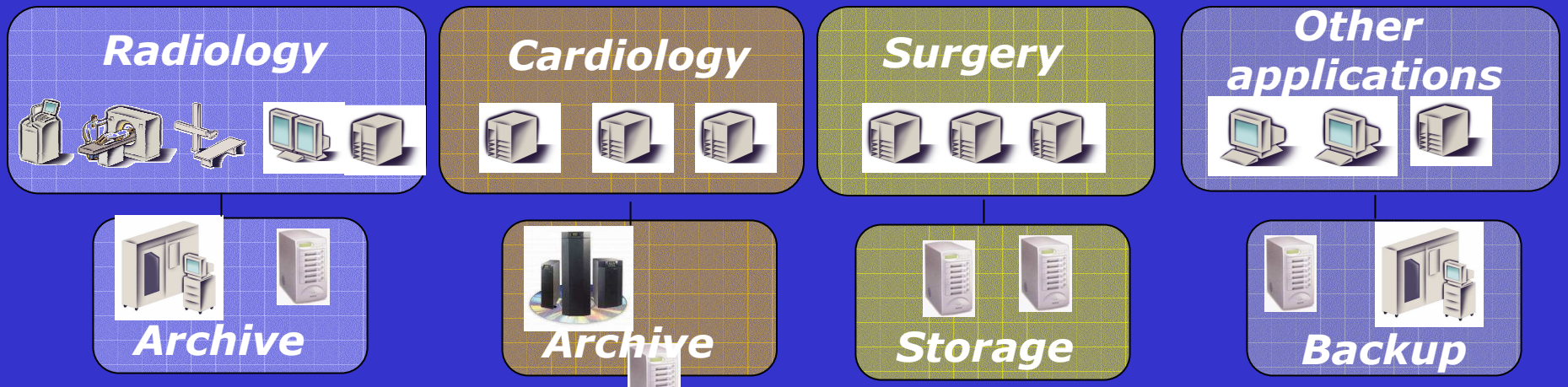


Haller et al. **Acad. Radiol.** 2001; **8:**888-897.

Clinical Needs, Deficiencies and Issues Workflow cont.

- Lack of consistent working practices/guidelines or workflows (the hospital as a high risk and high velocity "production" environment ain't scripted enough, there's too much diversity of behaviour)
- No standardised surgical devices and systems
- Lack of quantified information on work flow and error handling
- Communication across disciplines not adequate, e.g. between radiology and surgery

Medical imaging environment



- DICOM archive
- 50MB files
- First generation obsolete
- "Closed" archives
- Archive dedicated to each PACS

- DICOM or non-DICOM
- Little or no archiving (DVD)
- 500MB/1GB files
- Dedicated archive

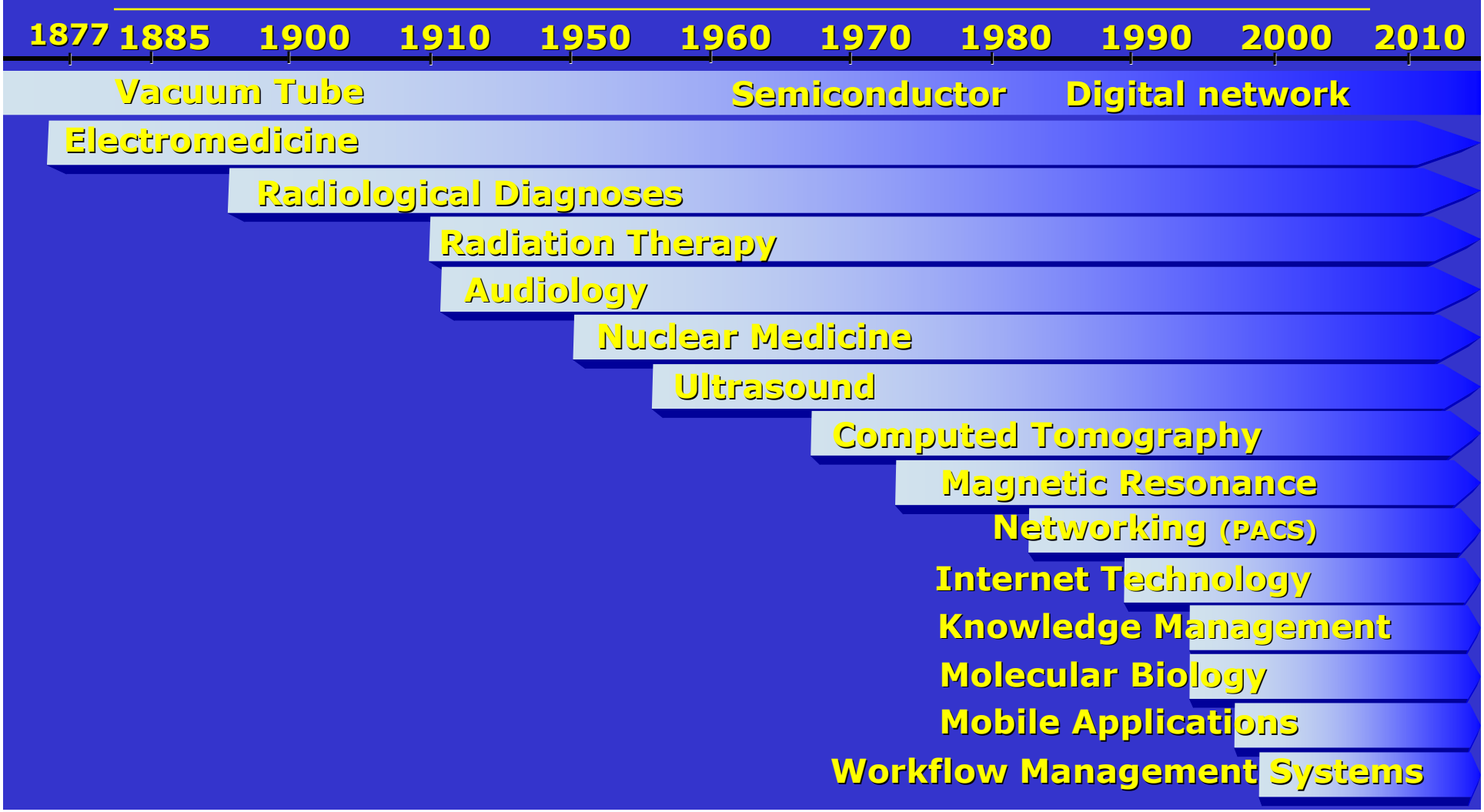
- Additional Modalities (Endoscopy, Microscopy, etc.
- Non-DICOM
- 3D/4D representations
- Real time environment
- Interactive
- Dedicated storage

- Non-DICOM
- Backup and archiving
- Small to very large files
- Dedicated tape libraries

- No sharing of infrastructure
- No sharing of information base
- No workflow integration

Continuous innovation in all technologies

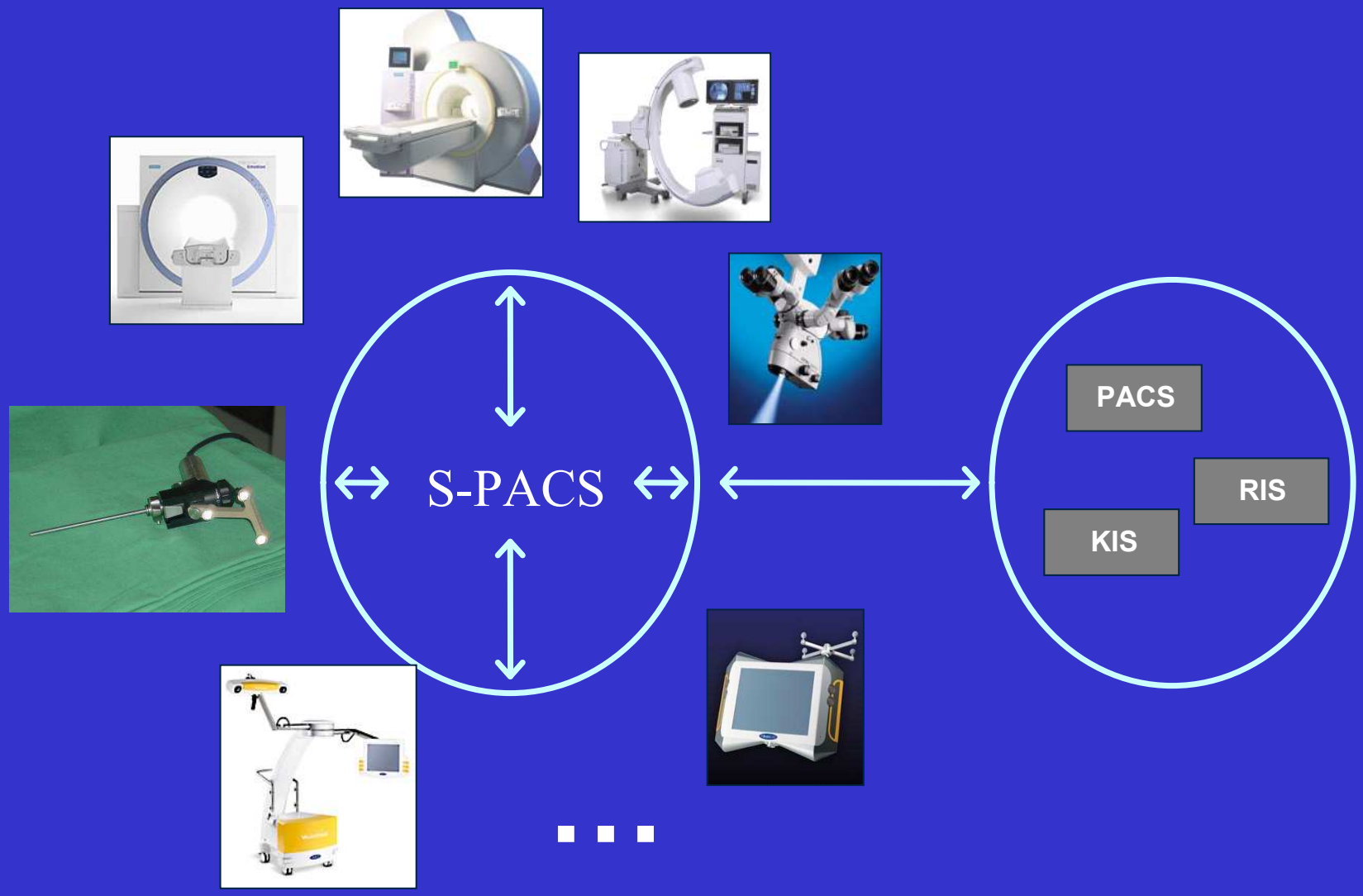
Source: W. Hruby



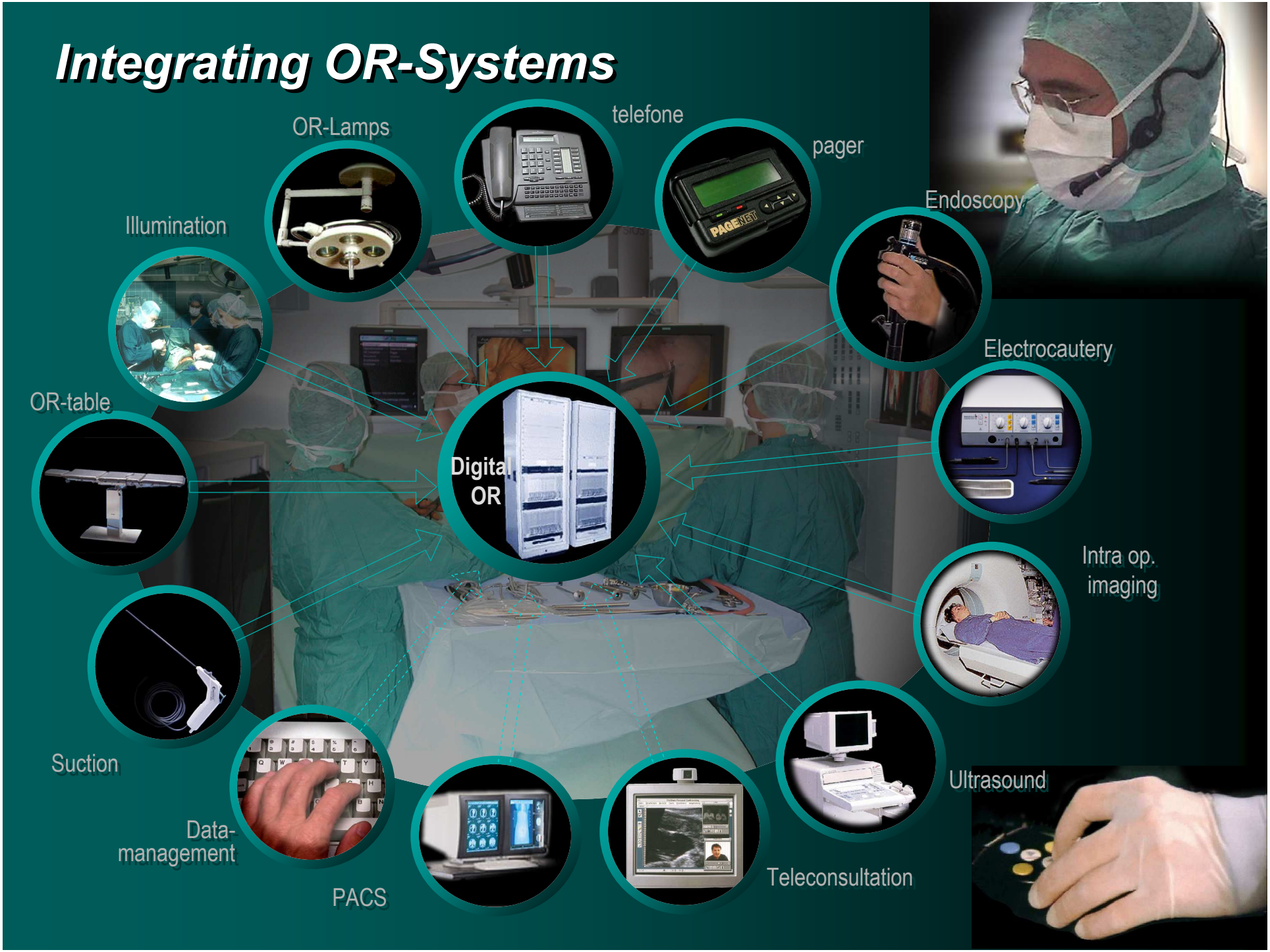
TU Berlin PACS Milestones

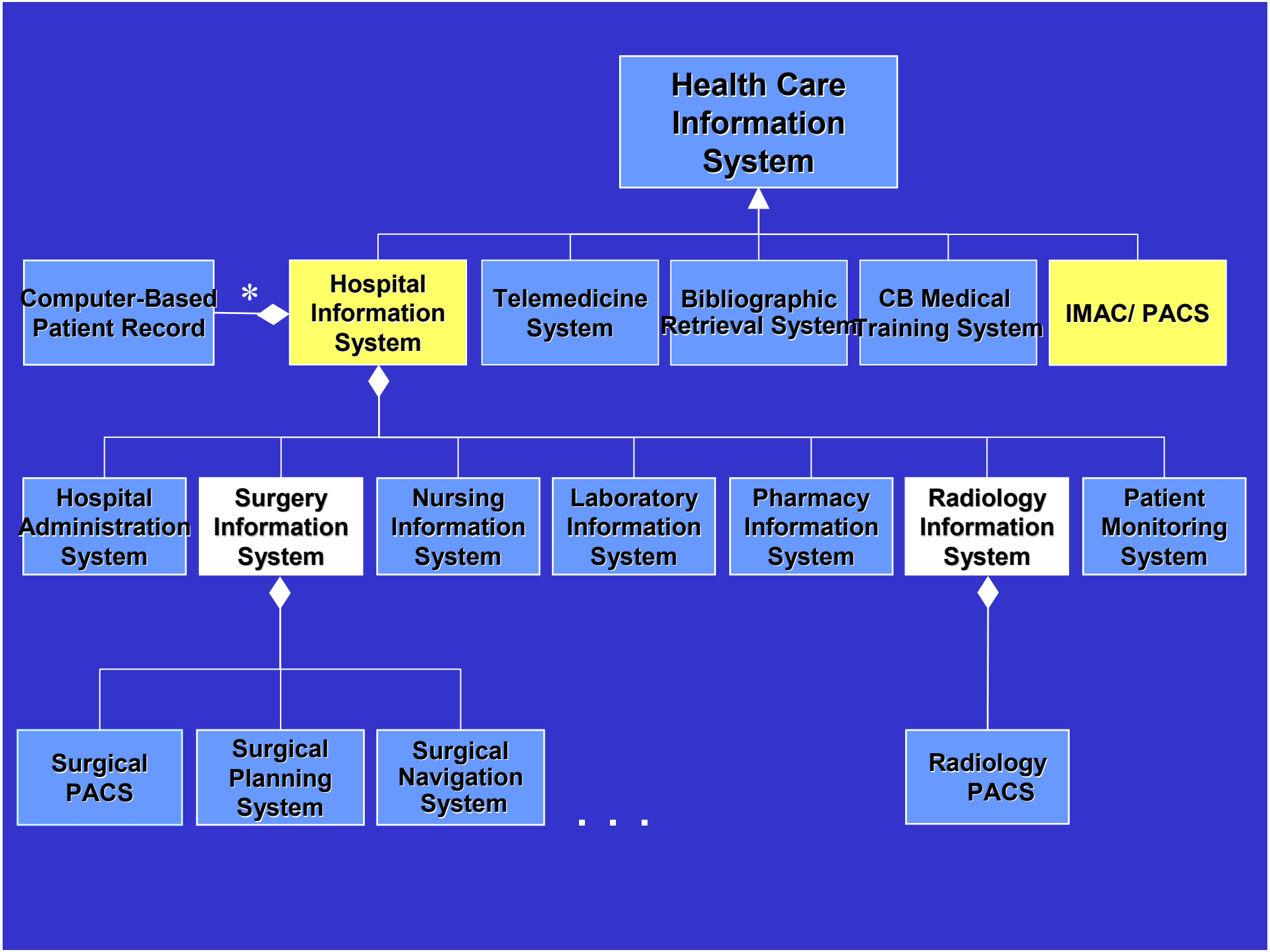
- 1975-79 PACS and MWS concept dev.
  (Publ. IEEE/ACR 1979, #1 in CPMDR)
- 1980's Rad. PACS dev. BERKOM
- 1990's MWS dev. MILORD EU project
- 2000's S-PACS TT's, S-WF's, CURAC
- 2005 ICCAS, ZiG, DICOM WG #24
  (DICOM in surgery)

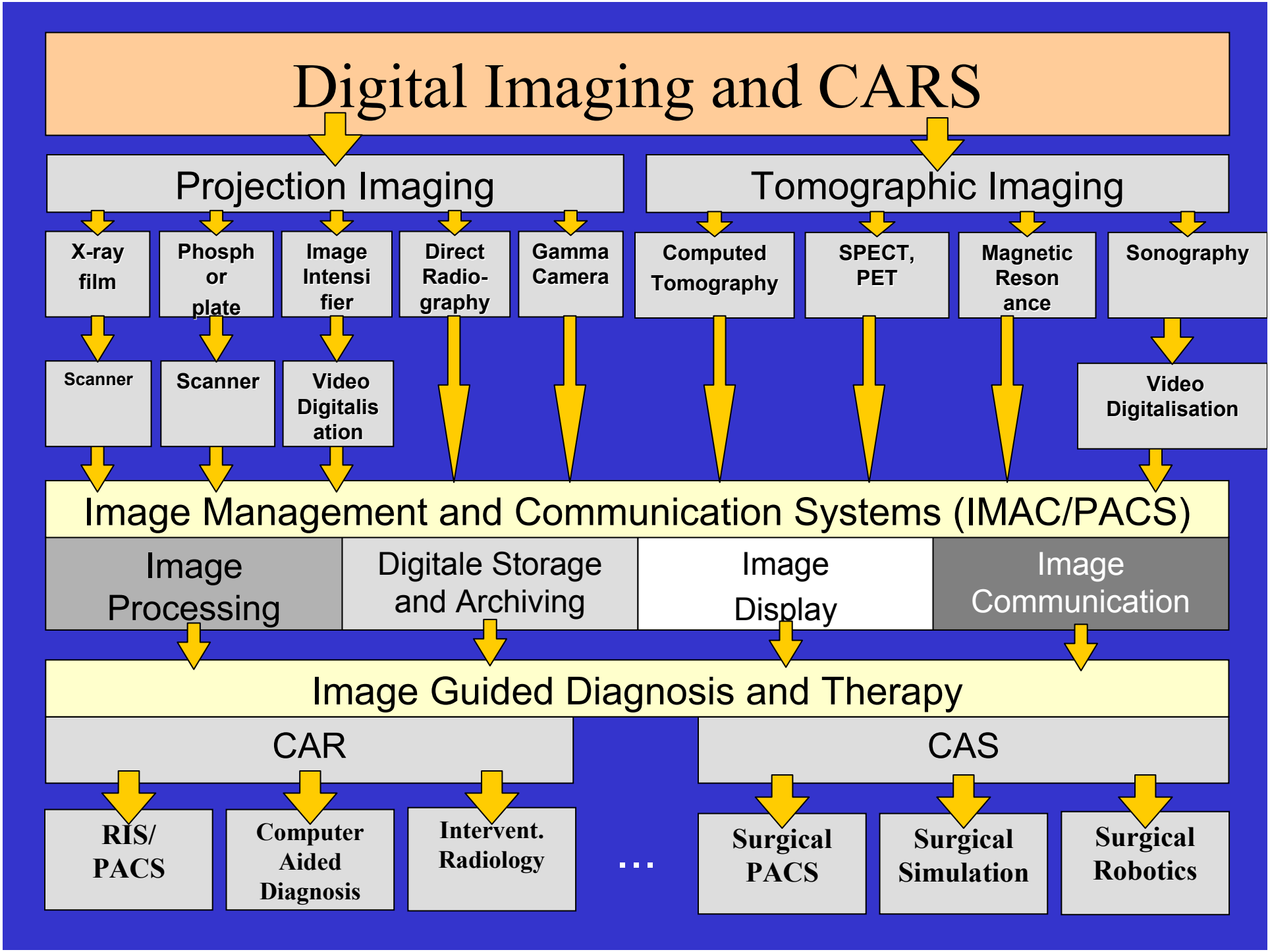
S-PACS



Integrating OR-Systems




Health Care Information System
Computer-Based Patient Record
*
Hospital Information System
Telemedicine System
Bibliographic Retrieval System
CB Medical Training System
IMAC/ PACS
Hospital Administration System
Surgery Information System
Nursing Information System
Laboratory Information System
Pharmacy Information System
Radiology Information System
Patient Monitoring System
Surgical PACS
Surgical Planning System
Surgical Navigation System
. . .
Radiology PACS


Digital Imaging and CARS
Projection Imaging
Tomographic Imaging
X-ray film
Phosph or plate
Image Intensi fier
Direct Radio- graphy
Gamma Camera
Computed Tomography
SPECT, PET
Magnetic Reson ance
Sonography
Scanner
Scanner
Video Digitalis ation
Video Digitalisation
Image Management and Communication Systems (IMAC/PACS)
Image Processing
Digitale Storage and Archiving
Image Display
Image Communication
Image Guided Diagnosis and Therapy
CAR
CAS
RIS/ PACS
Computer Aided Diagnosis
Intervent. Radiology
...
Surgical PACS
Surgical Simulation
Surgical Robotics

Steps towards a S-PACS and S-DICOM (DICOM WG 24 „DICOM in Surgery“)

1. Define a representative set of S-WF's
2. Specify a first set S-PACS functionalities to support the S-WF's
3. Derive a first set of S-DICOM functionalities
4. Expose results to an expert group

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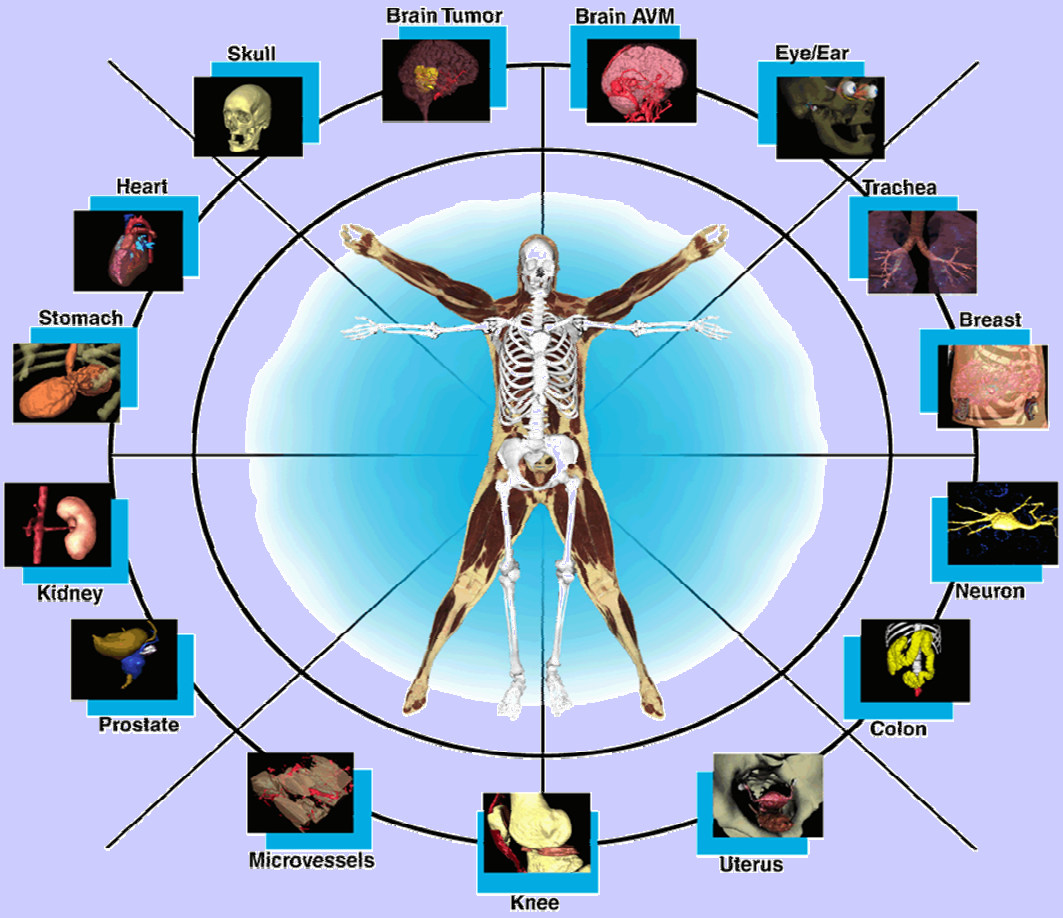
Some Medical Applications of CAS



Source: R. A. Robb

- Cranio-facial Surgery
- Brain Surgery
- Cochlear Transplant
- Laryngeal Phonation
- Heart/Coronary Disease
- Orthopedic Surgery
- Prostate Cancer
- Colon Cancer
- Special Surgeries
- Educational/Training
  - Anesthesiology
  - Narcolepsy
  - Anatomy

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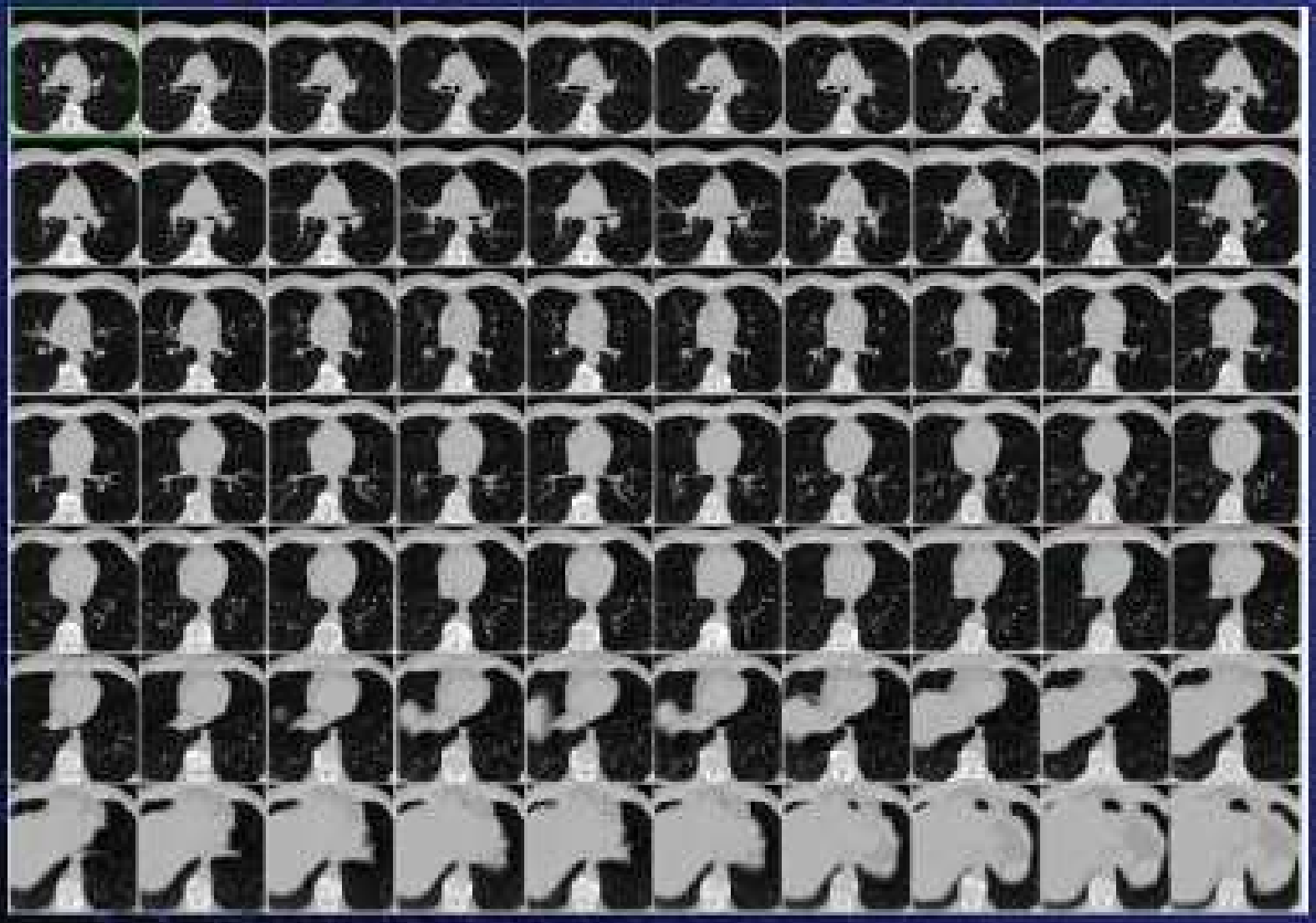
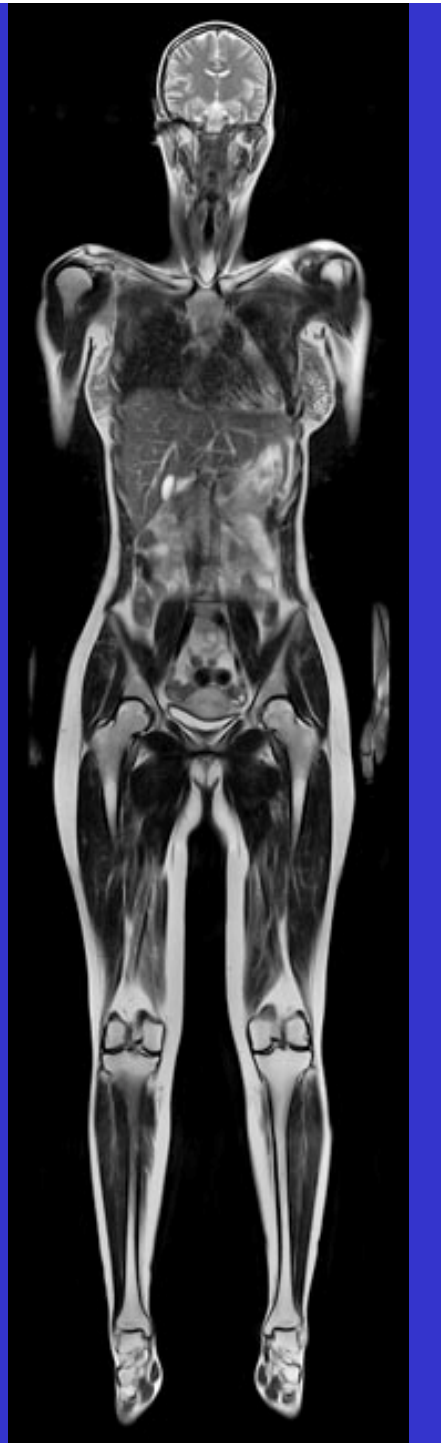
Ultrafast multi-slice CT

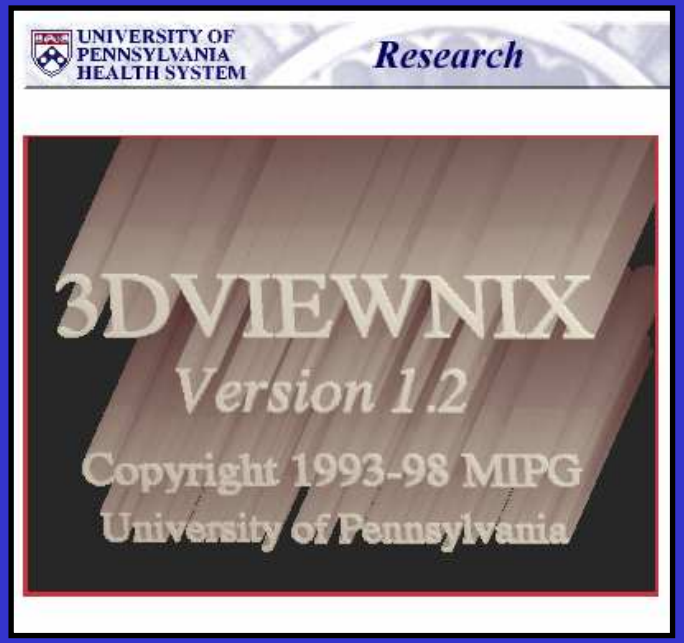


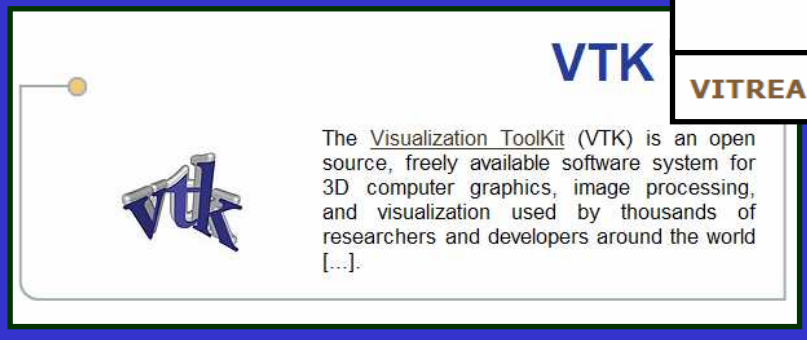
Ultrafast multi-slice CT

Whole body MRI is now feasible using massively parallel phased-arrays coils



Comprehensive Software Toolkits





Challenges

- More Images…
- More dimensions….
- Multimodality…
- Image-based interventions…

Image display and manipulation tools are lagging behind…

Navigating the 5th Dimension

- 3rd Dimension data (CT-MR volumes)
- 4th Dimension = time (Dynamic)
- 4th Dimension = modality (i.e. F
- 5th Dimension = dynamic PET-
- ...

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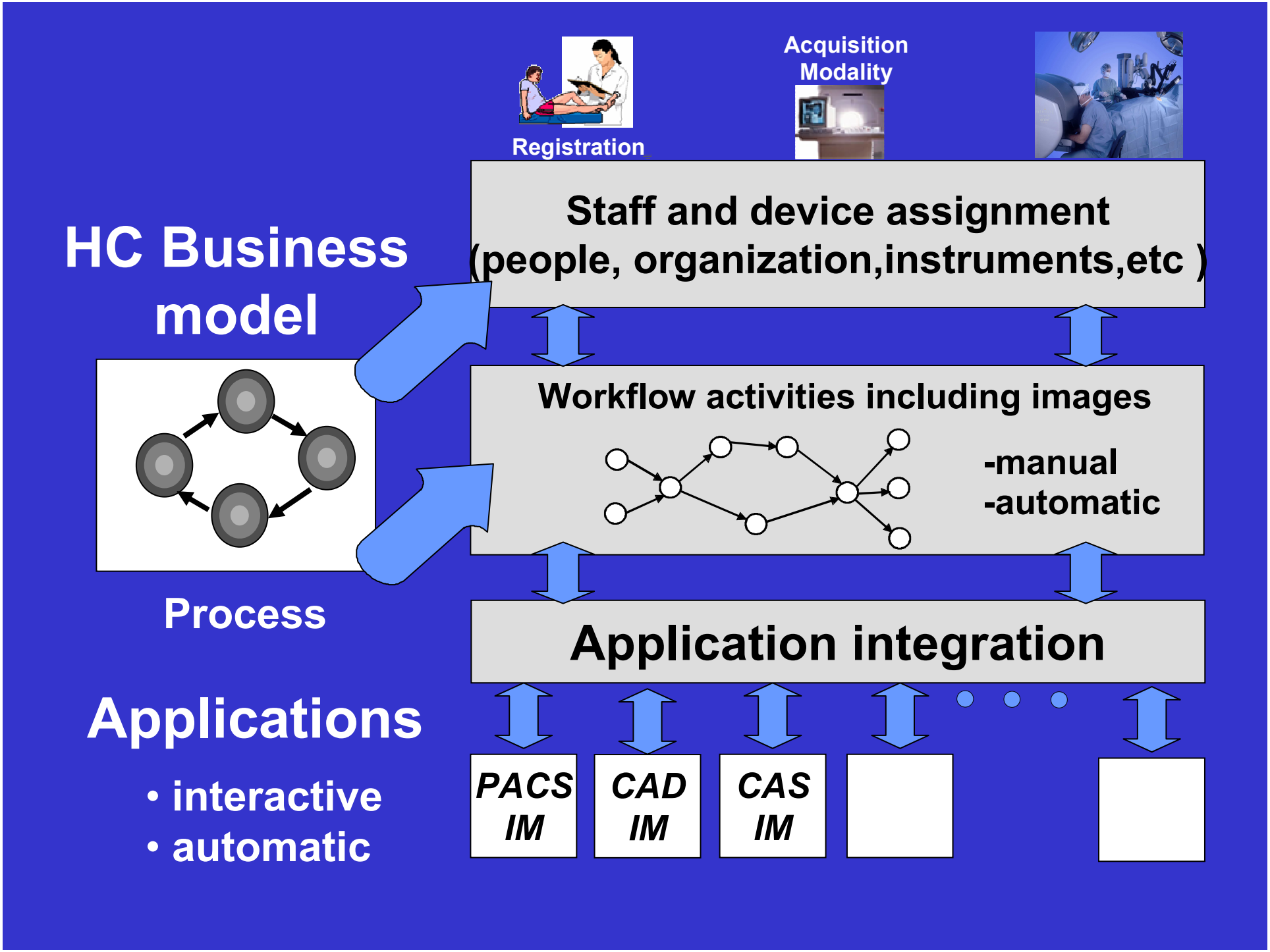
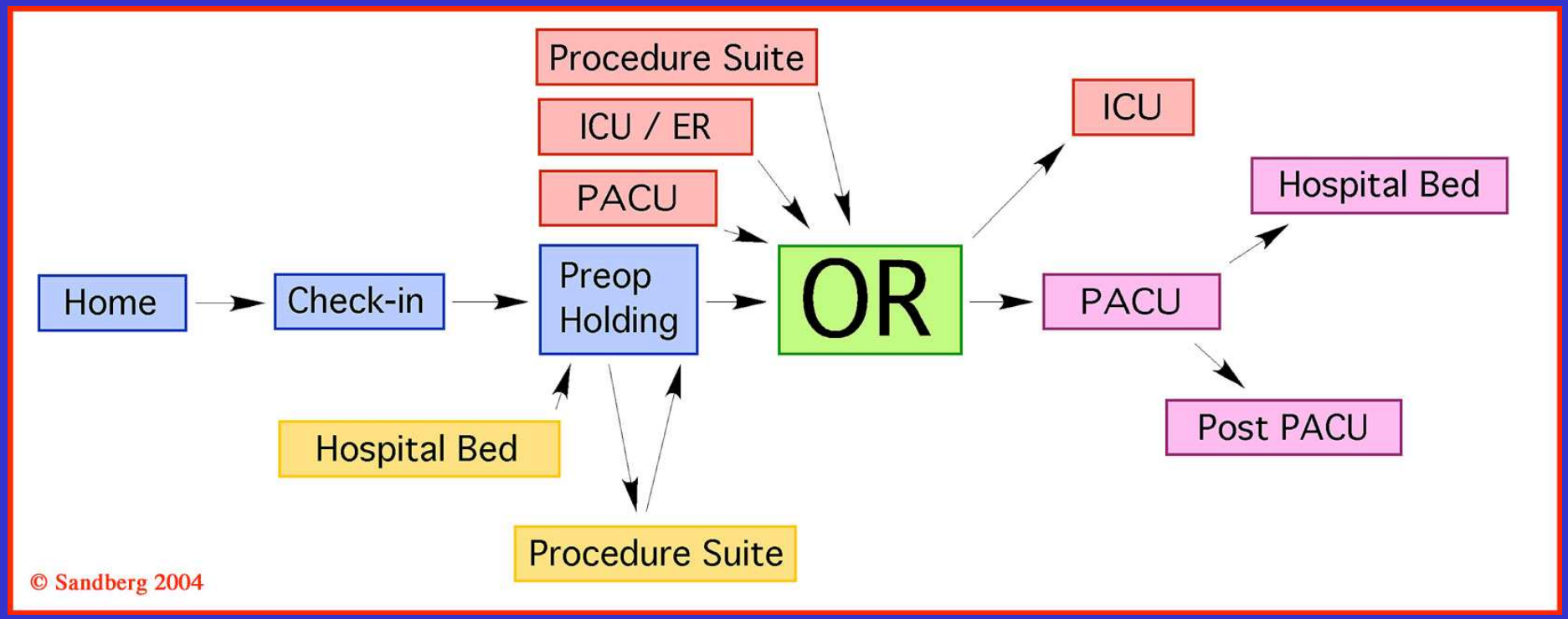
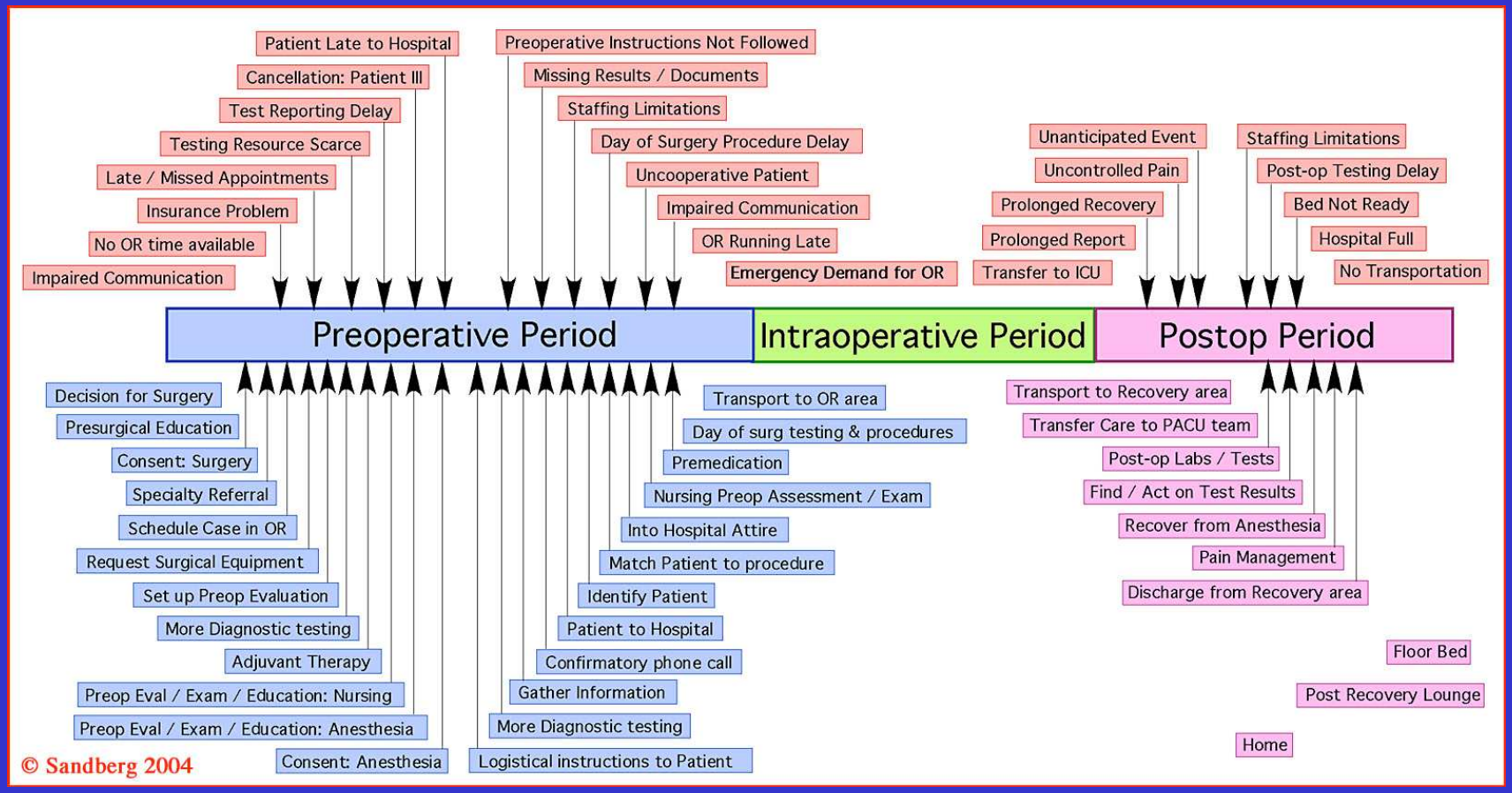

Registration
Acquisition
Modality
HC Business
model
Staff and device assignment
(people, organization,instruments,etc)
Workflow activities including images
-manual
-automatic
Process
Application integration
Applications
• interactive
• automatic
PACS
IM
CAD
IM
CAS
IM

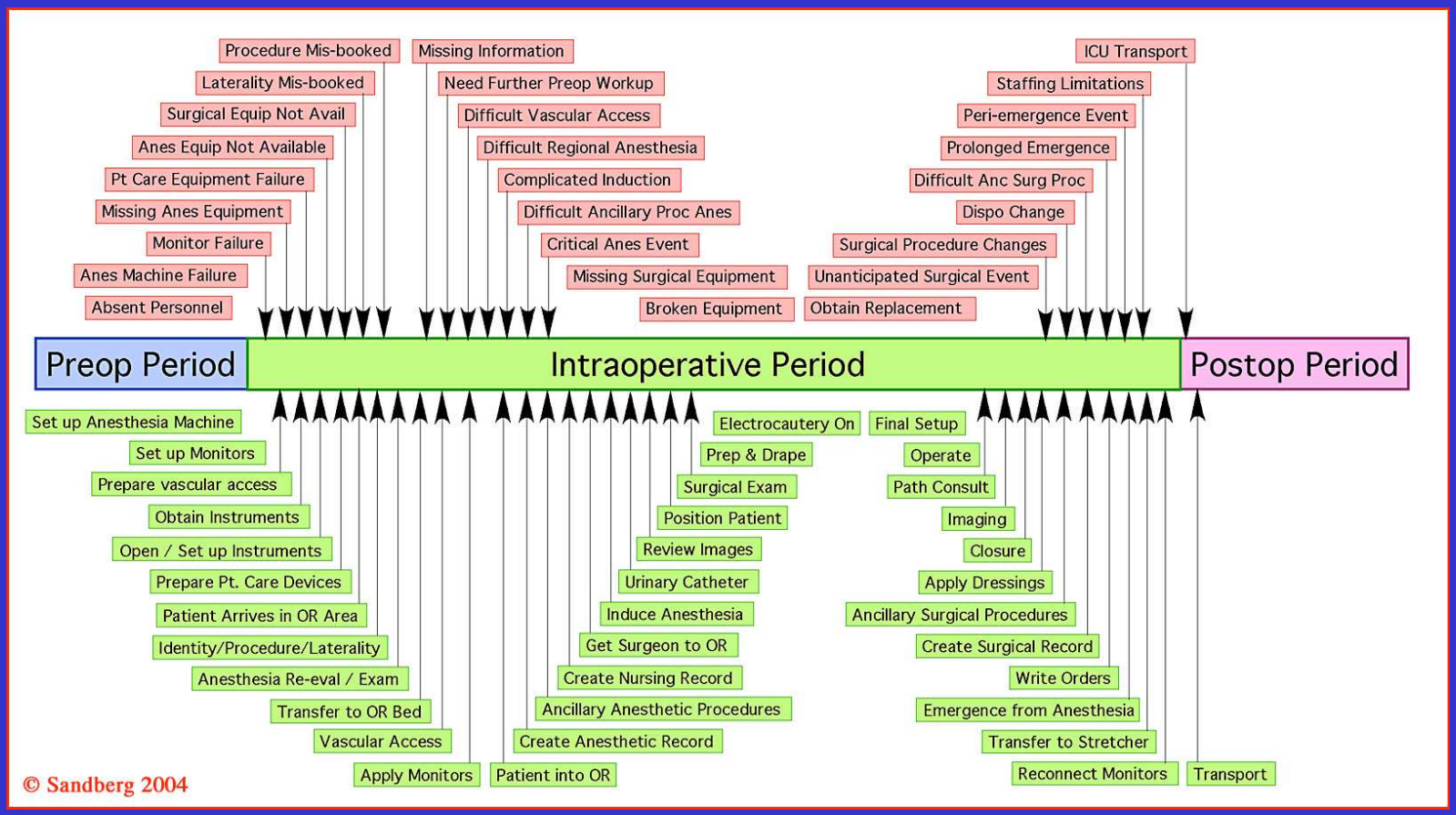
Schematic representation of a perioperative system for a single OR



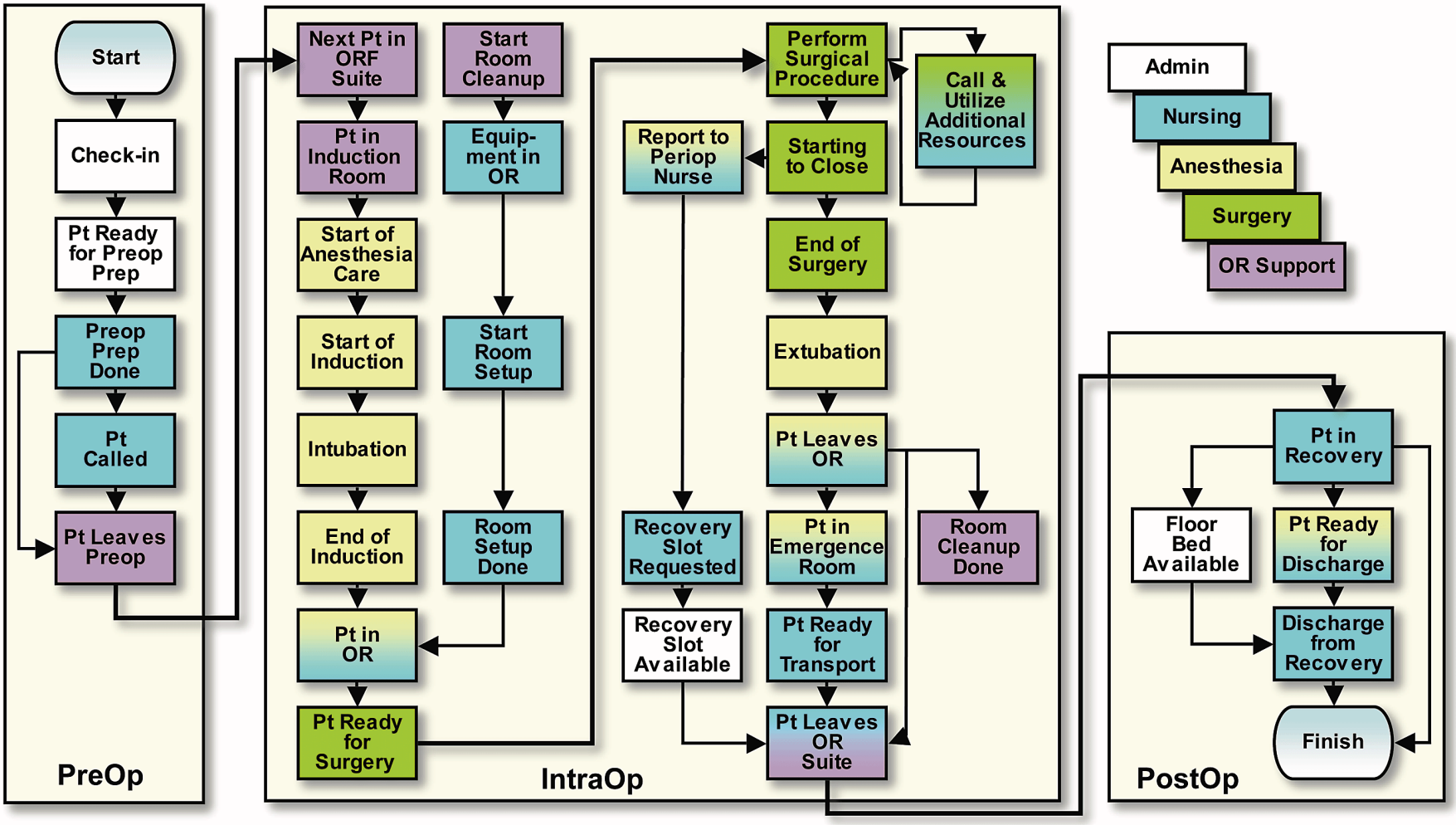
Schematic representation of the overall perioperative timeline for an elective surgery



Schematic representation of the intra-operative timeline for an elective surgery



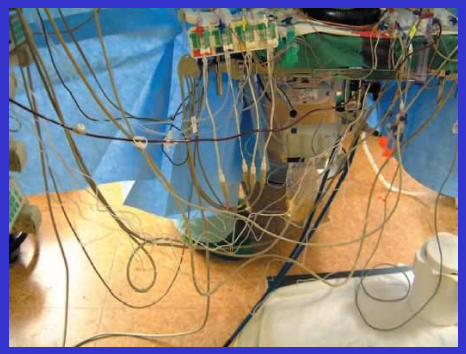
MGH ORF
Perioperative workflow that allows *ad hoc* exceptions



Motivation

- Significant ergonomic and health-economic progress in the OR through a thorough understanding of the surgical activities

- S-WF modelling and visualisation can assist the creative activity of designing surgical integration profiles (SIP)



Motivation

- Surgical process redesign can only be carried out in an environment where surgeons, radiologists, anesthesiologists and computer scientists jointly advance the field of Computer Assisted Radiology and Surgery (CARS)

- The newly founded *Innovation Center for Computer Assisted Surgery* (ICCAS) at Leipzig University is being designed to provide such an environment

University of Leipzig surgical center

University of Leipzig surgical center

Purpose of Workflow analysis

- To allow a correlation between workflows of different types of surgical procedures, e.g. to obtain a measure of similarity between workflows
- To assist in identifying parts of the same and between different workflows (Surgical Integration Profiles - SIP's) for a process redesign
- To provide concepts and data to assist in the specification, design, implementation and in-vivo usage of new Information and Communication Technology (ICT) and mechatronic (MT) systems

Methods

- A subset of the recorded workflows was modelled with Workflow Management Coalition (WfMC) tools adapted for this purpose

A S-WF definition of a surgical procedure becomes a formalized description of a coordinated set of surgical activities that are connected in a specific order

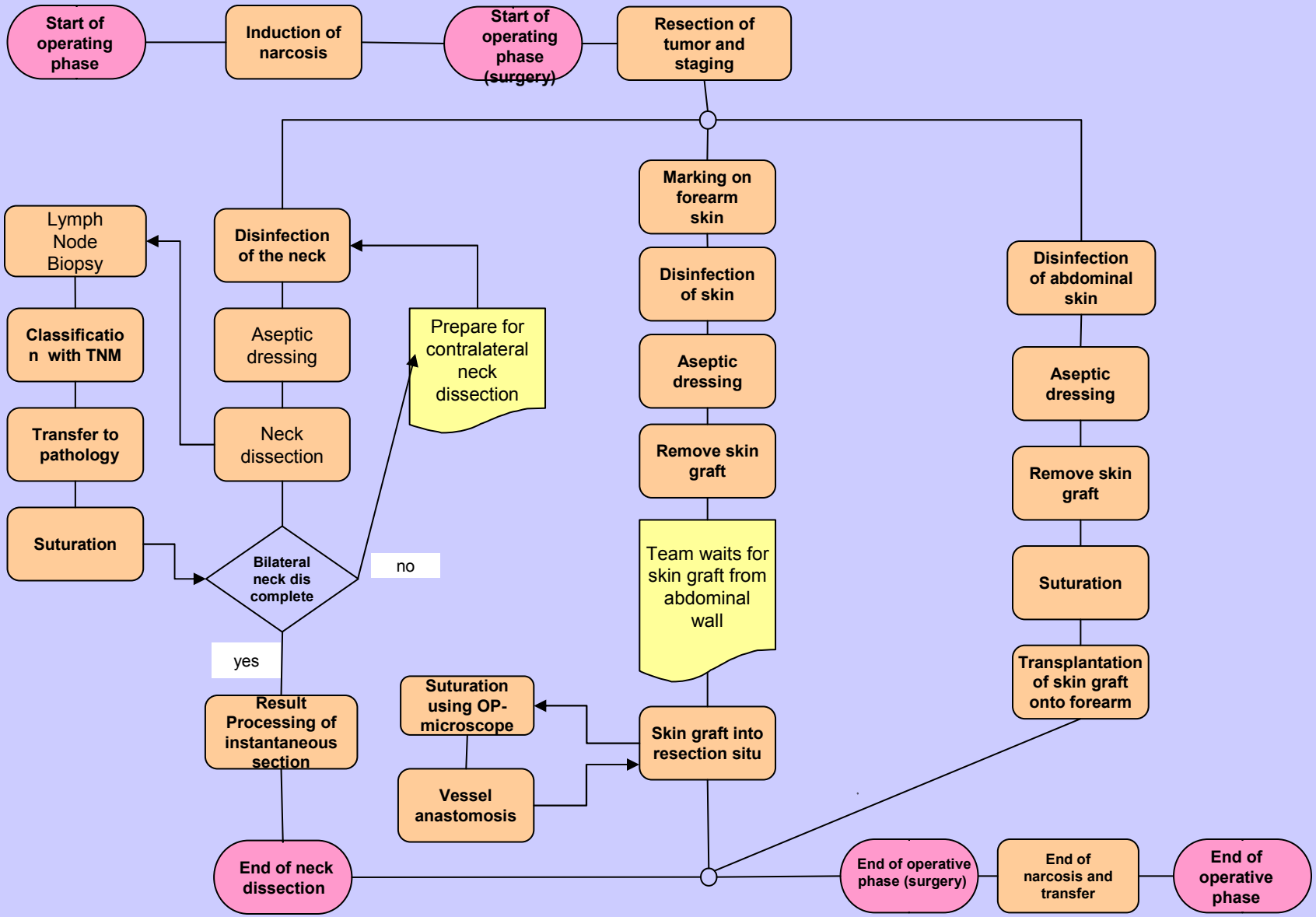
Methods

7 different head surgical procedures were selected for further workflow investigation, specifically in ENT-, Maxillofacial- and Neurosurgery:

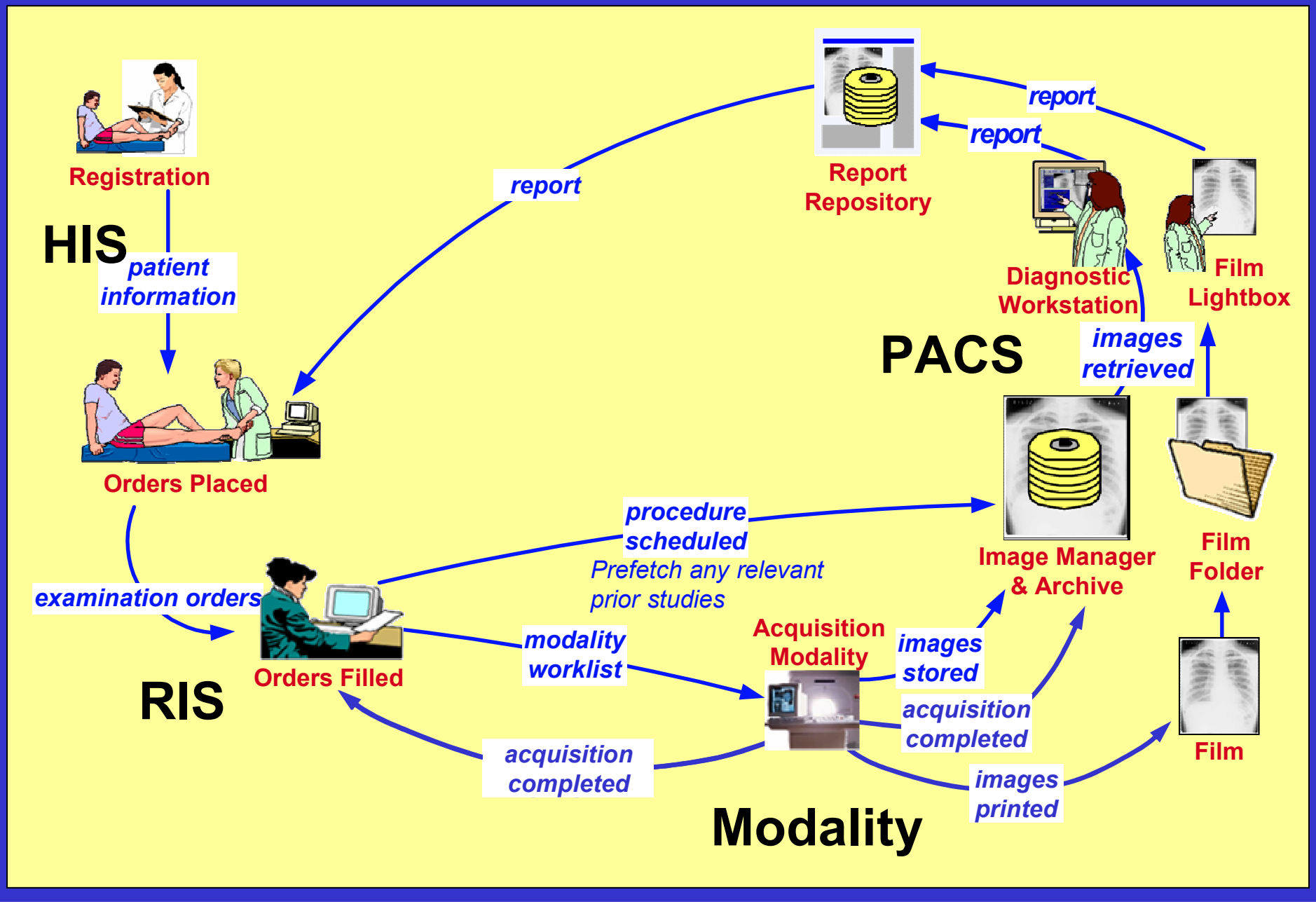
1. transsphenoidal approach to pituatiry gland
2. extranasal maxillary sinus surgery
3. functional endoscopic sinus surgery (FESS)
4. suboccipital surgery of acoustic neurinoma
5. ventriculocisternostomy
6. Microlaryngoscopy
7. tympanoplasty III.

For evaluation purposes, 3 independently recorded workflows for each surgical procedure were established as a minimum requirement

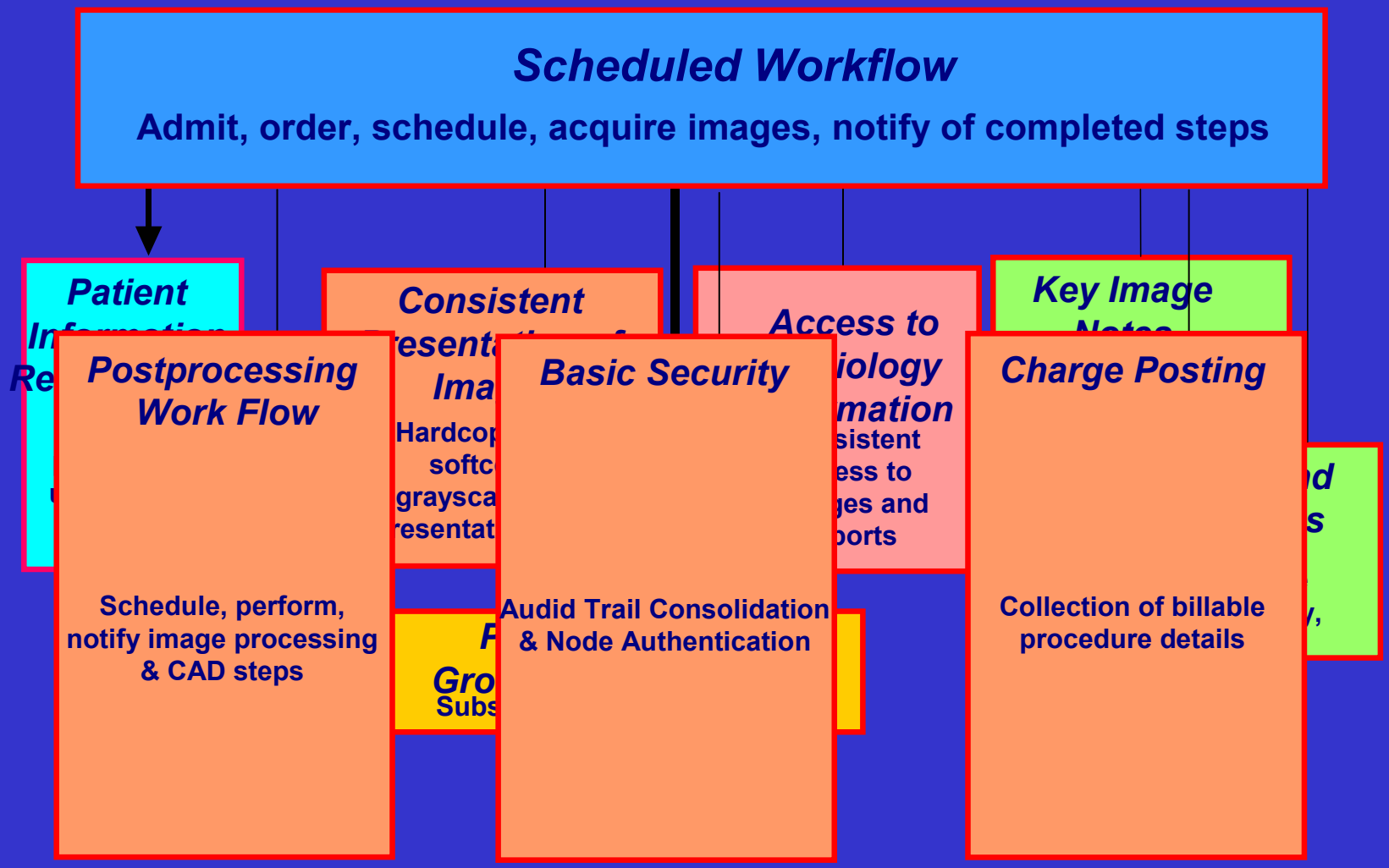
Partial and condensed workflow of "Resection of Tonsillar Carcinoma"



Scheduled Workflow Profile



10 IHE Integration Profiles

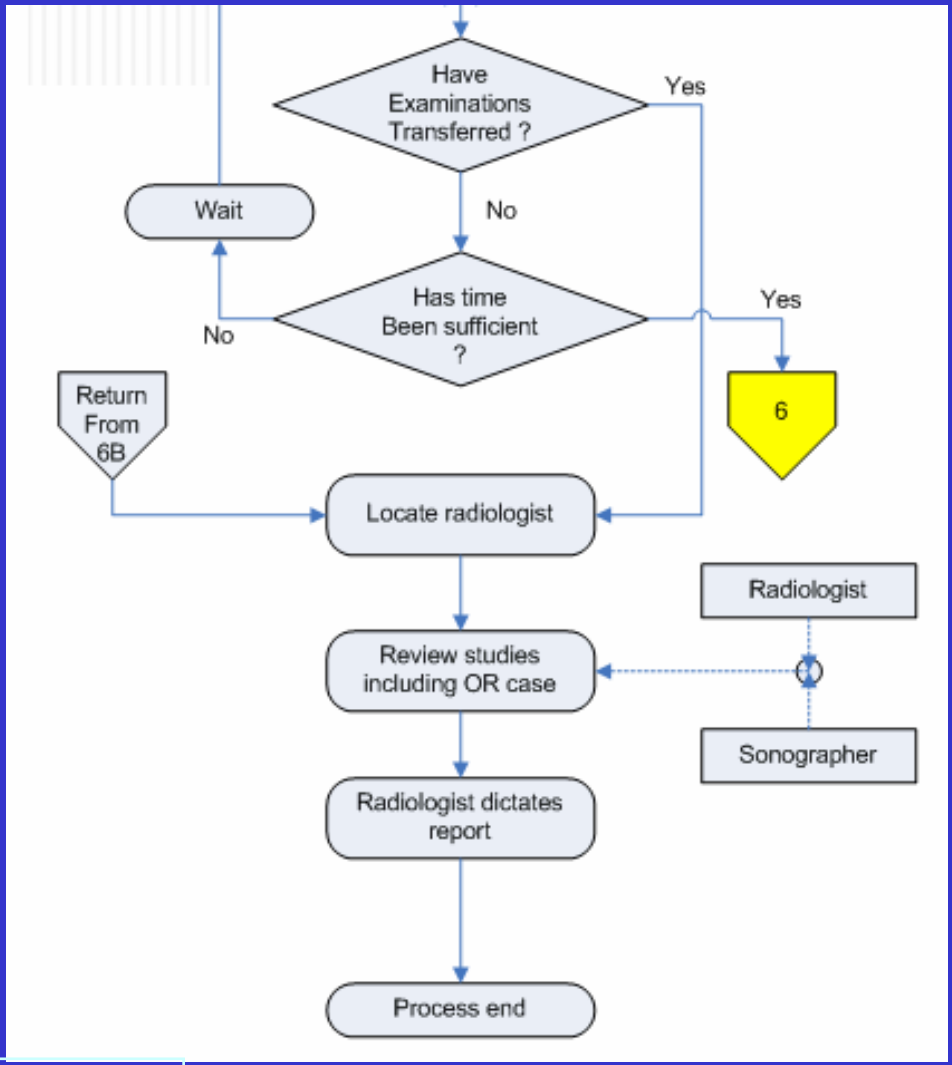


Display during intraoperative scanning

With permisson: Susan Rowling, MD, Frank Spitz, MD

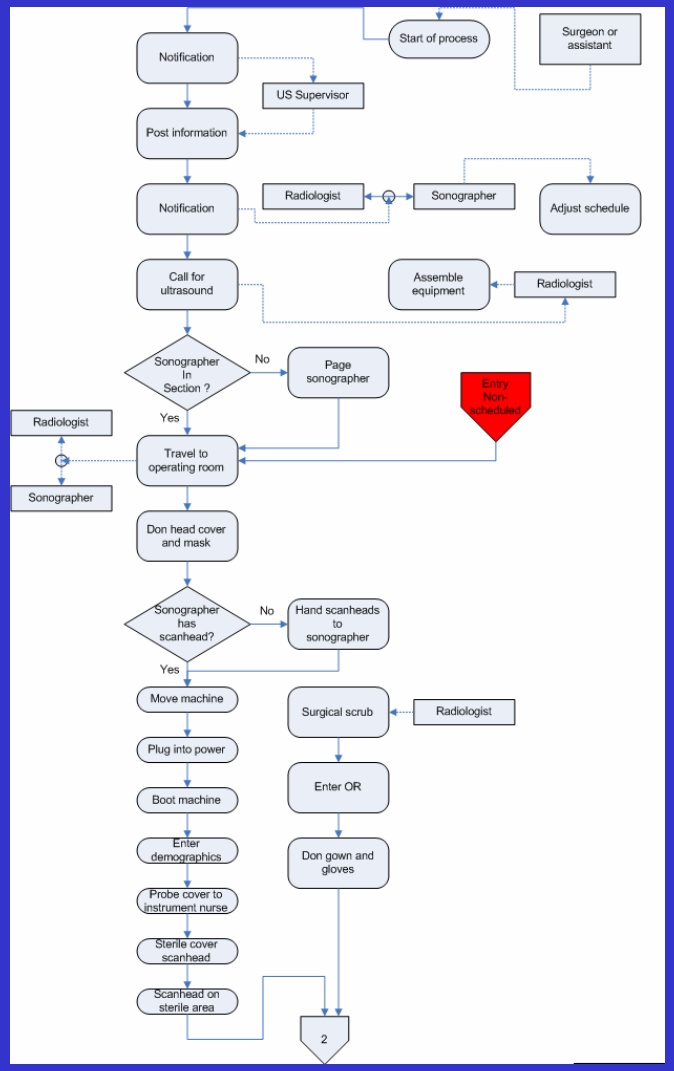
Display: the radiologist's view

Intraoperative ultrasound: transferring images

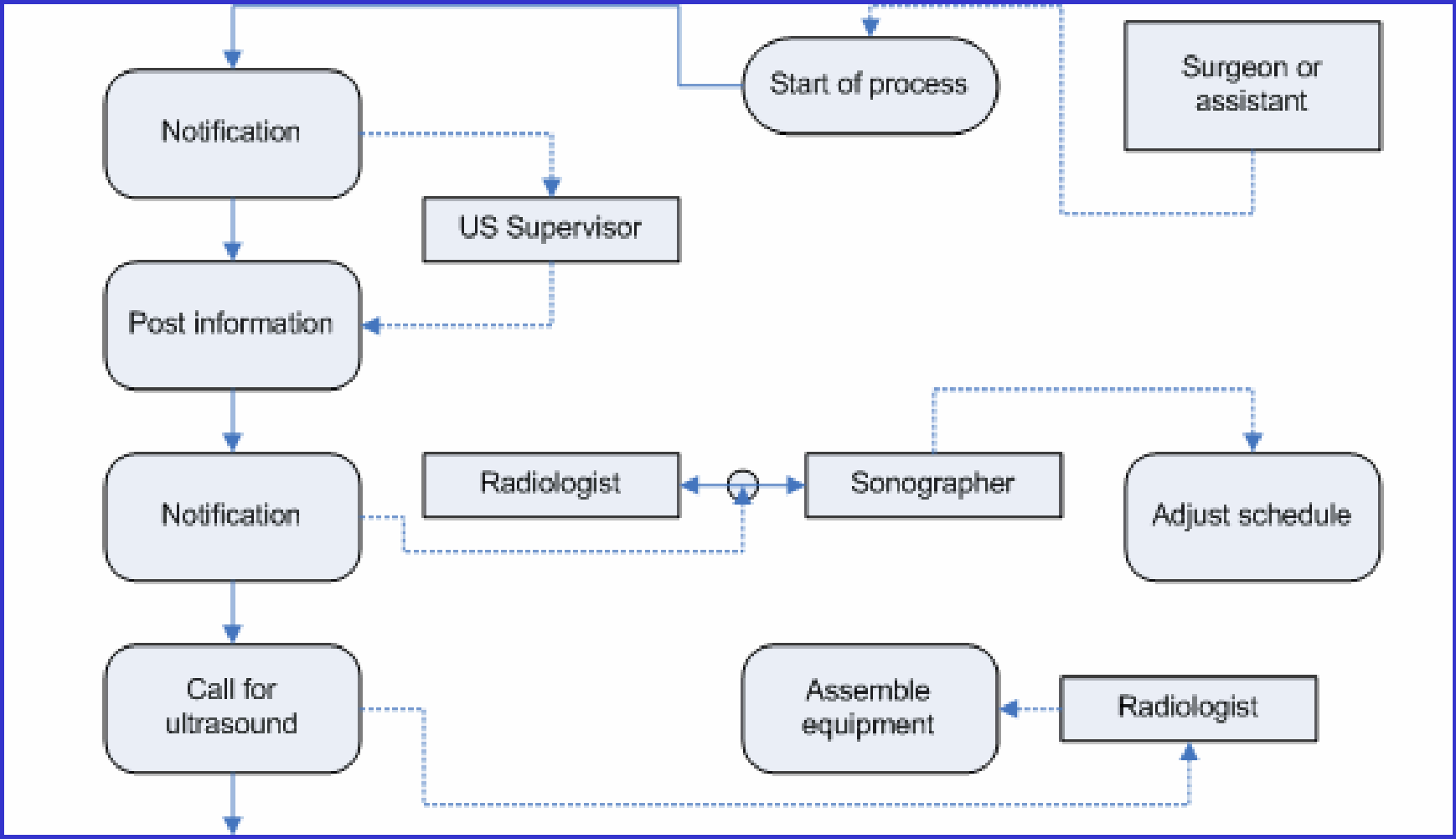


With permisson: S. Horii, MD

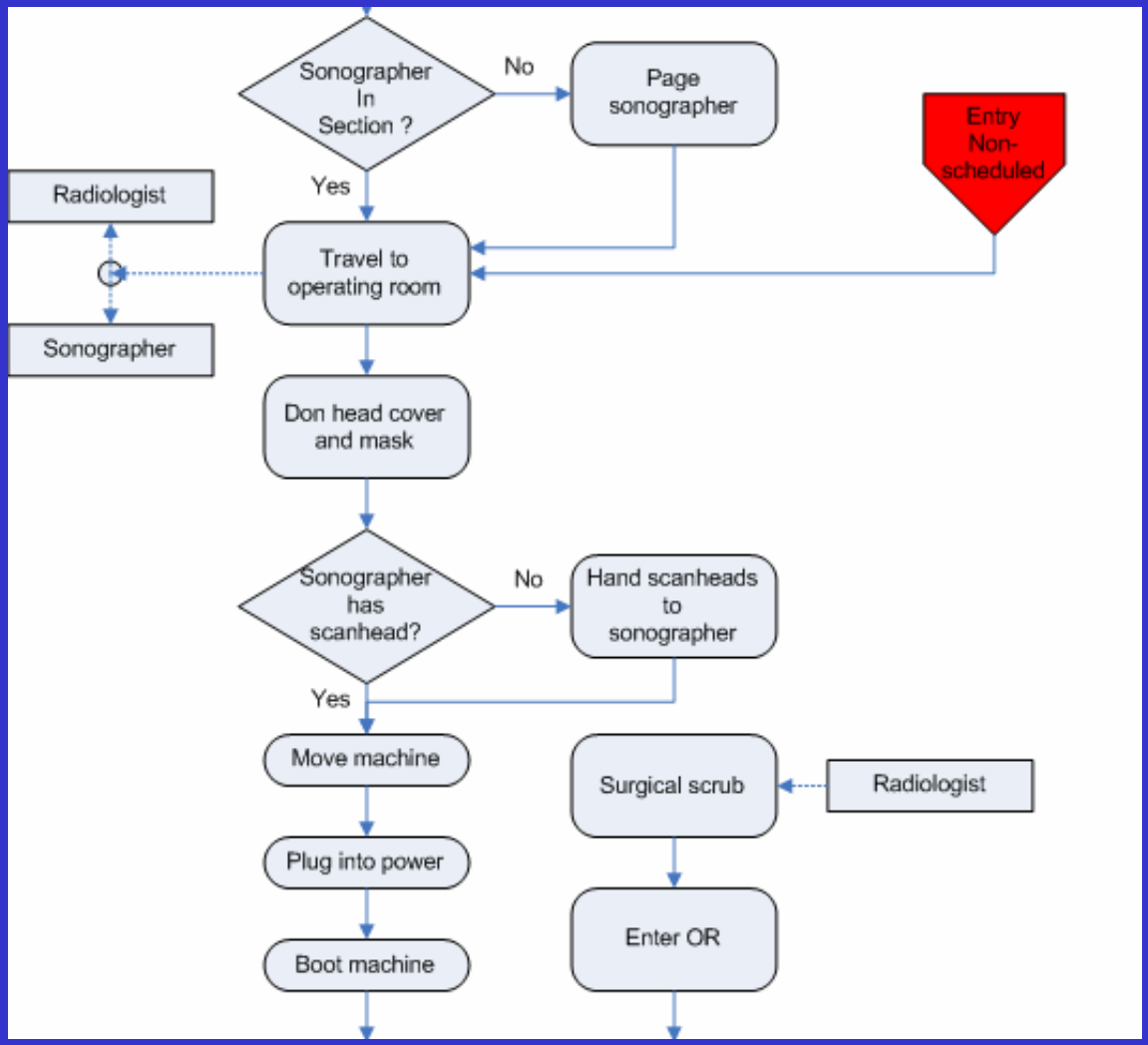
Intraoperative ultrasound: Part 1 overview



Intraoperative ultrasound: scheduled entry



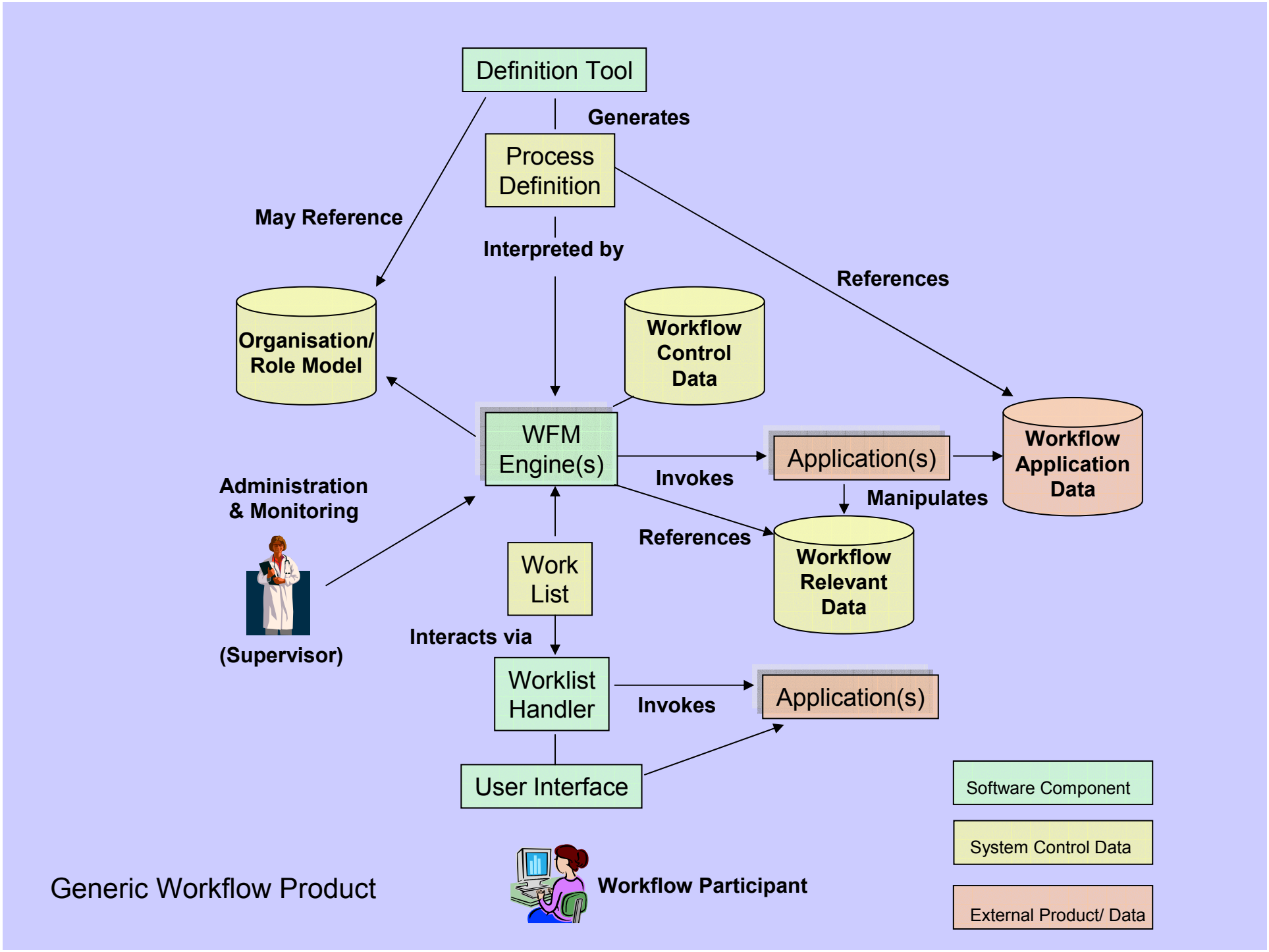
Intraoperative ultrasound: radiology to the OR



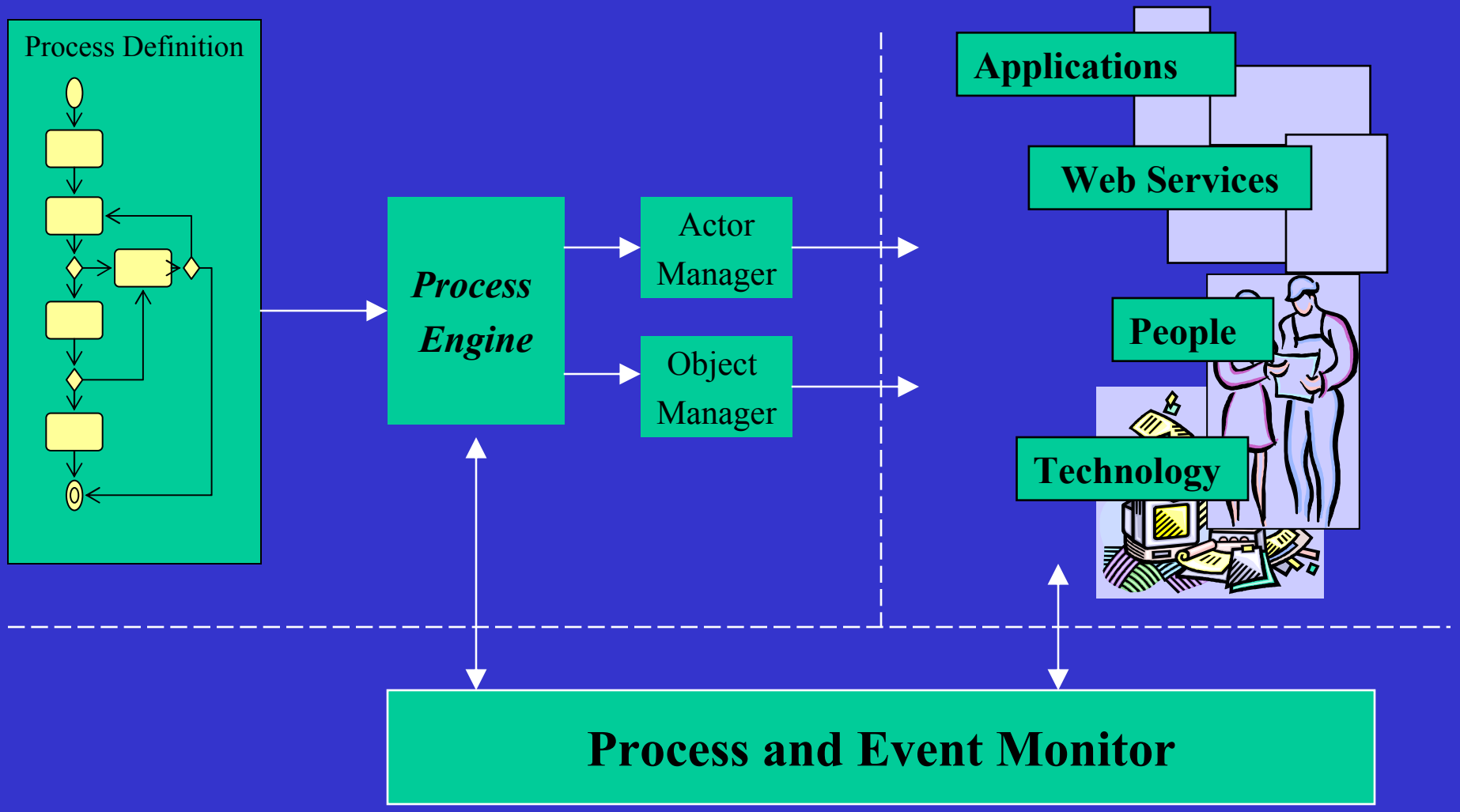
Methods (ontology)

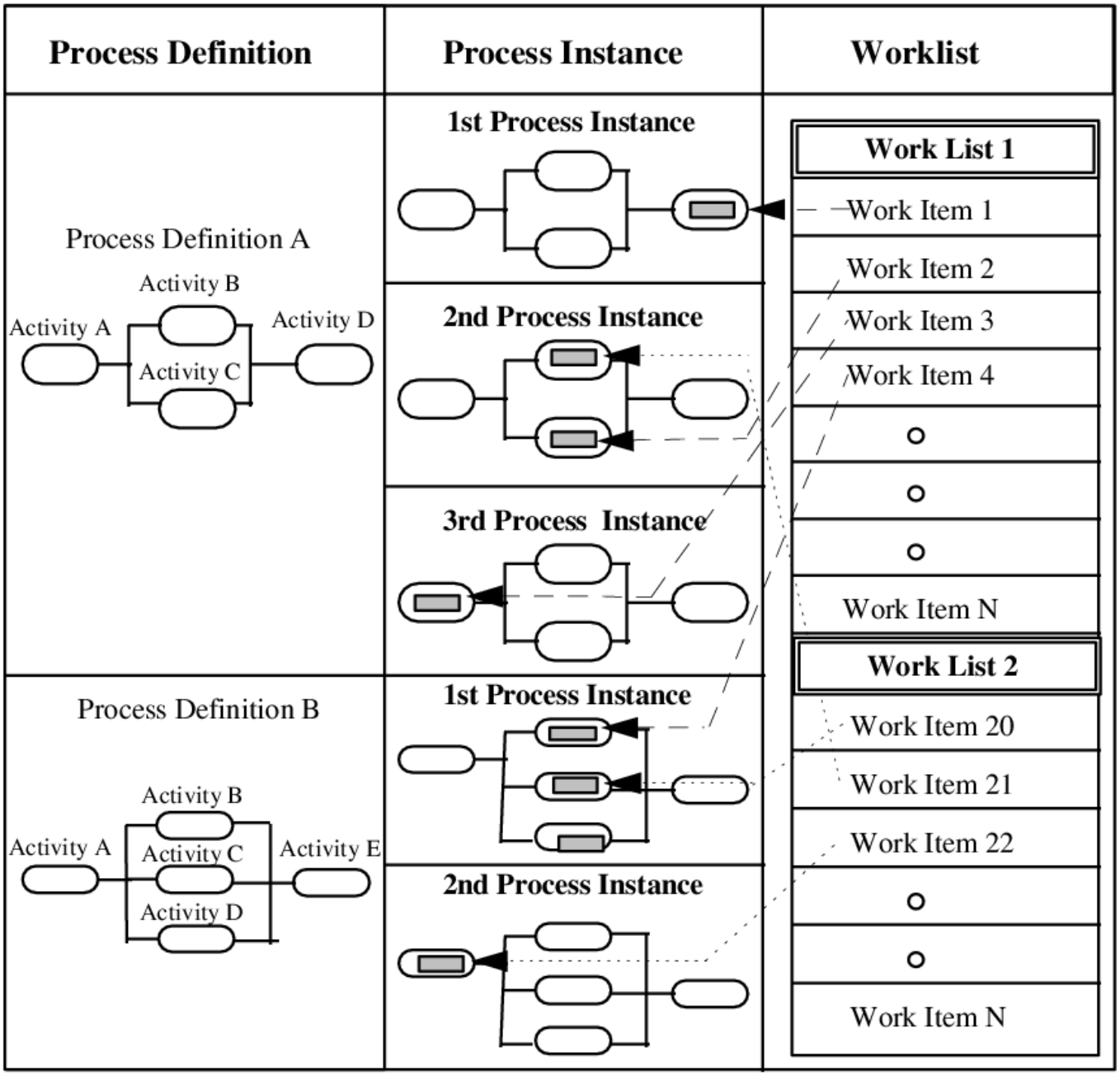
- A surgical ontology may be defined as a formal terminology for a hierarchy of concepts and their relationship in the specialized clinical context of surgical procedures and actions

- Informatic driven definitions of surgery, e.g. for terminology, GALEN, SNOMED or CEN ENV1828, and for workflow notations, UML, WfMC, and Petri-Nets

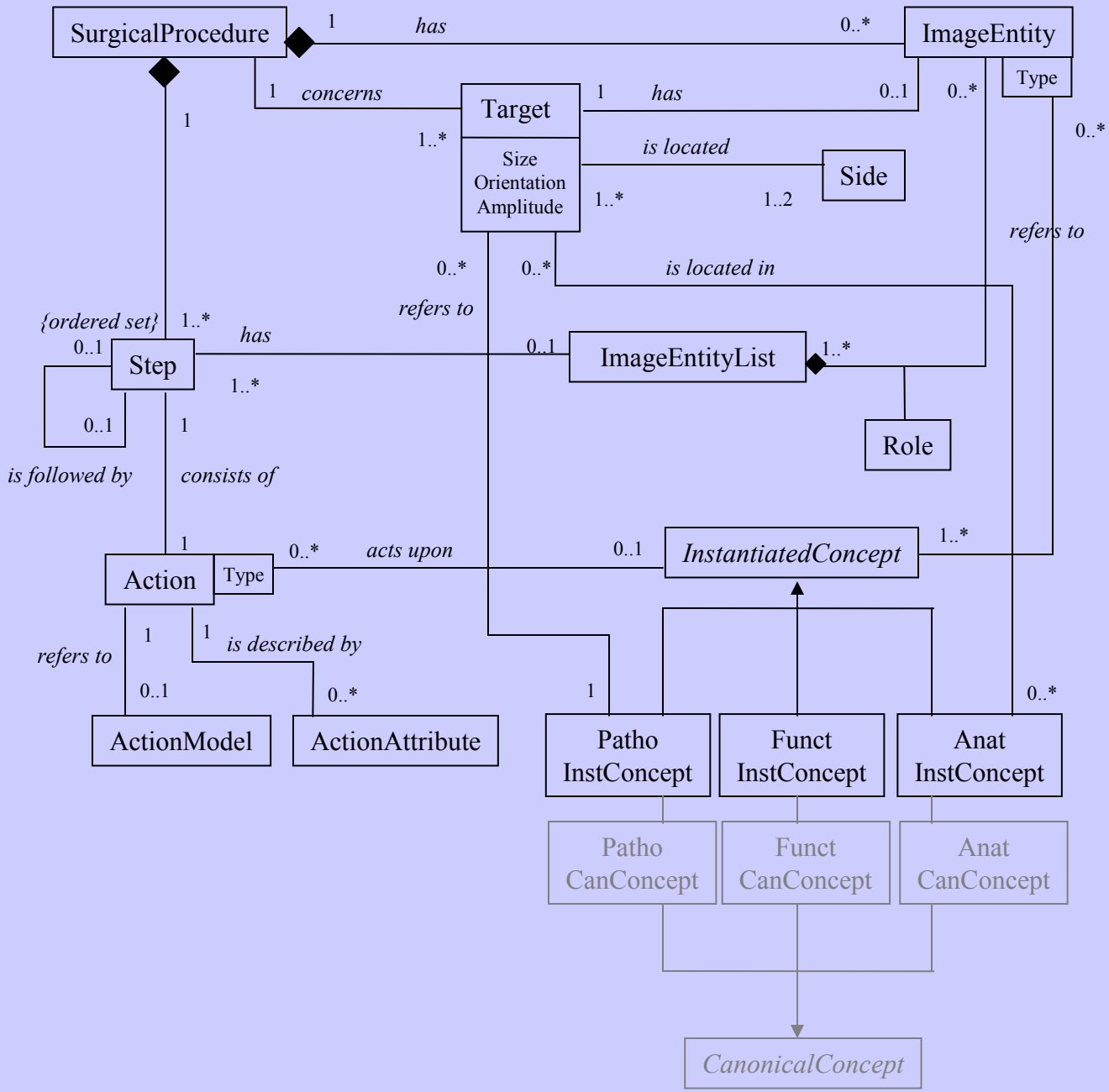

Definition Tool
Generates
Process Definition
May Reference
Interpreted by
References
Organisation/ Role Model
Workflow Control Data
WFM Engine(s)
Application(s)
Workflow Application Data
Invokes
Manipulates
Administration & Monitoring
References
Workflow Relevant Data
Work List
(Supervisor)
Interacts via
Worklist Handler
Invokes
Application(s)
User Interface
Software Component
System Control Data
External Product/ Data
Generic Workflow Product
Workflow Participant

Elements of Dynamic Workflow





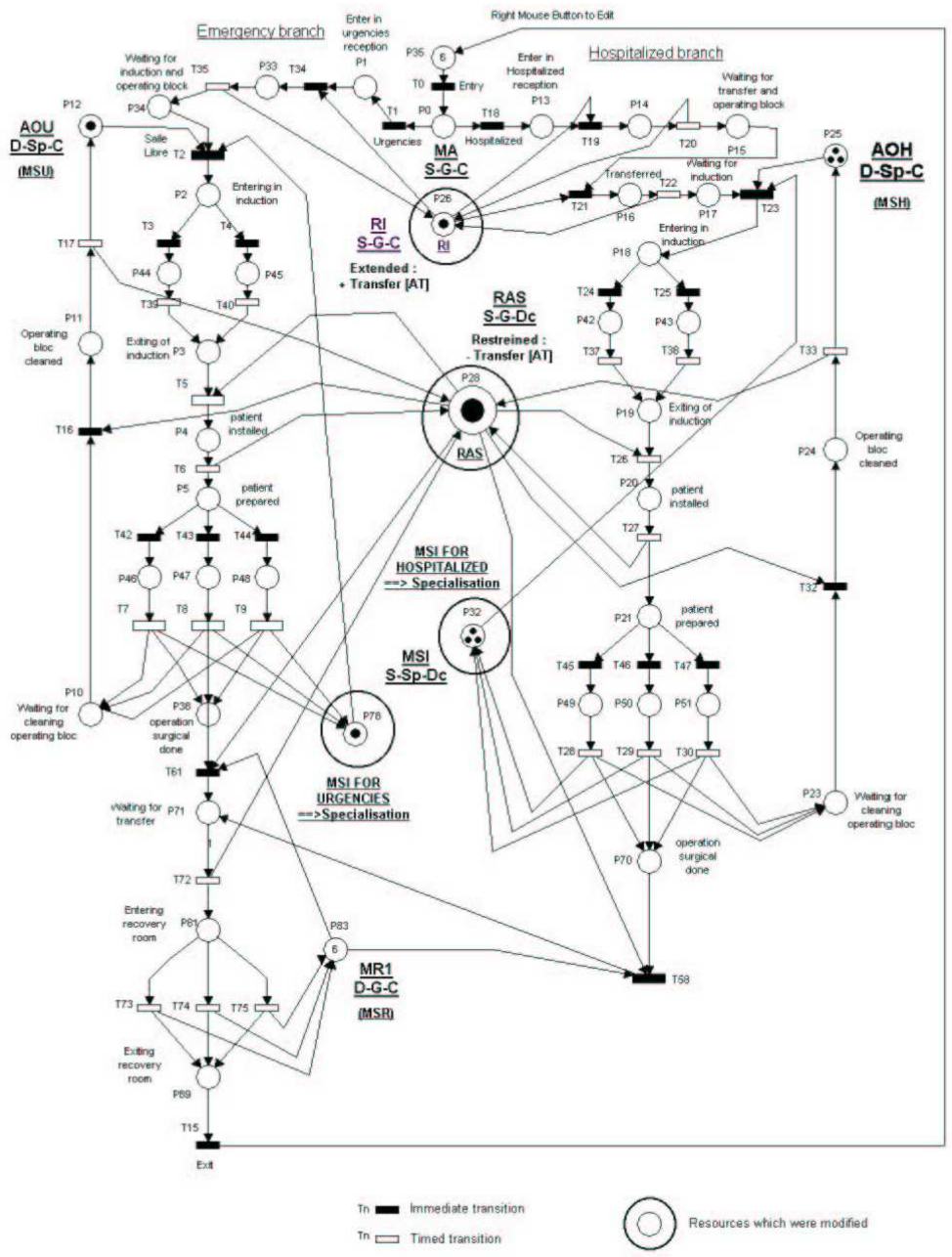
WFMC
www.wfmc.org



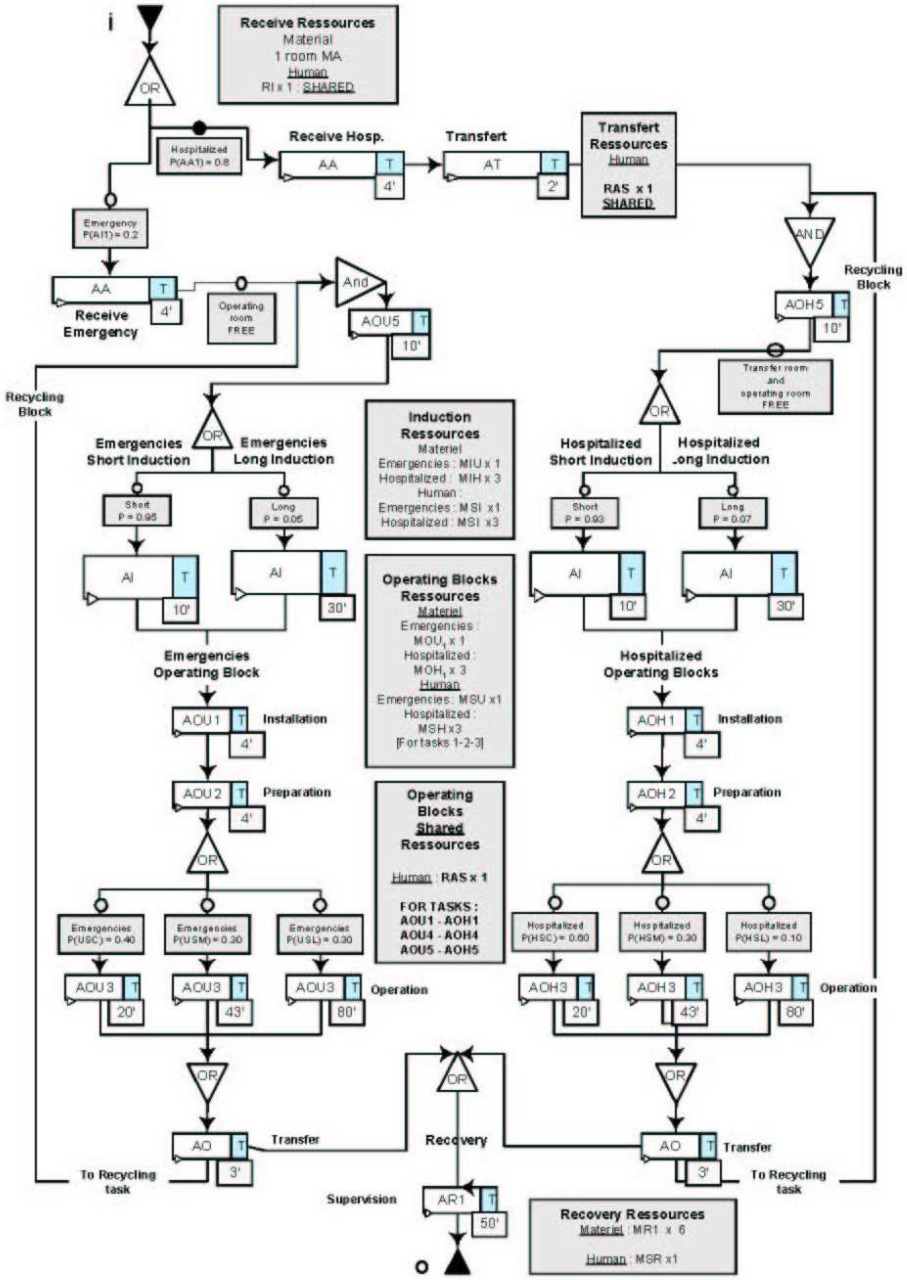
UML class diagram of multimodal image-guided craniotomies

from Jannin P., Raimbault M., Morandi X., Riffaud L., and Gibaud B. Models of surgical procedures for multimodal image-guided neurosurgery. *Computer Assisted Surgery*, Vol 8, N° 2, pp 98-106, 2003

GRAPHIC 3


Emergency branch
Hospitalized branch
Right Mouse Button to Edit
Enter in urgencies reception
Waiting for induction and operating block
Enter in Hospitalized reception
Waiting for transfer and operating block
AOU
D-Sp-C
(MSU)
AOH
D-Sp-C
(MSH)
MA
S-G-C
RI
S-G-C
Extended :
+ Transfer [AT]
RAS
S-G-Dc
Restreined :
- Transfer [AT]
MSI FOR
HOSPITALIZED
==> Specialisation
MSI
S-Sp-Dc
MSI FOR
URGENCIES
==>Specialisation
MR1
D-G-C
(MSR)
Entry
Urgencies
Hospitalized
Transferred
Entering in induction
Exiting of induction
patient installed
patient prepared
Operating bloc cleaned
Waiting for cleaning operating bloc
operation surgical done
Waiting for transfer
Entering recovery room
Exiting recovery room
Exit
Tn Immediate transition
Tn Timed transition
Resources which were modified

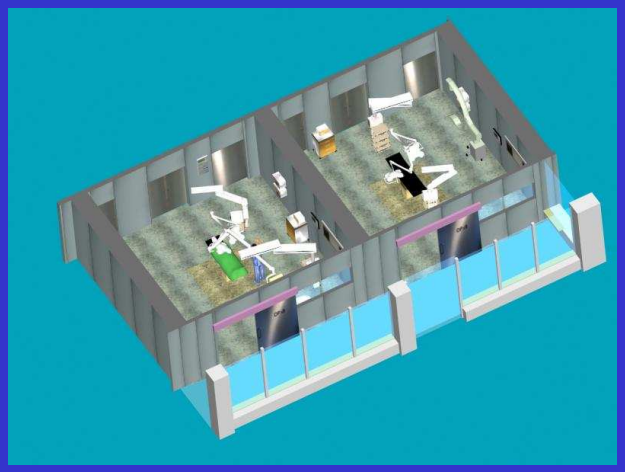
Graphic 1 : Modeling Operating-Block Workflow - Resume
Tasks, Resources and Constraints - [Probability of event P] - [WfMC extended notation]

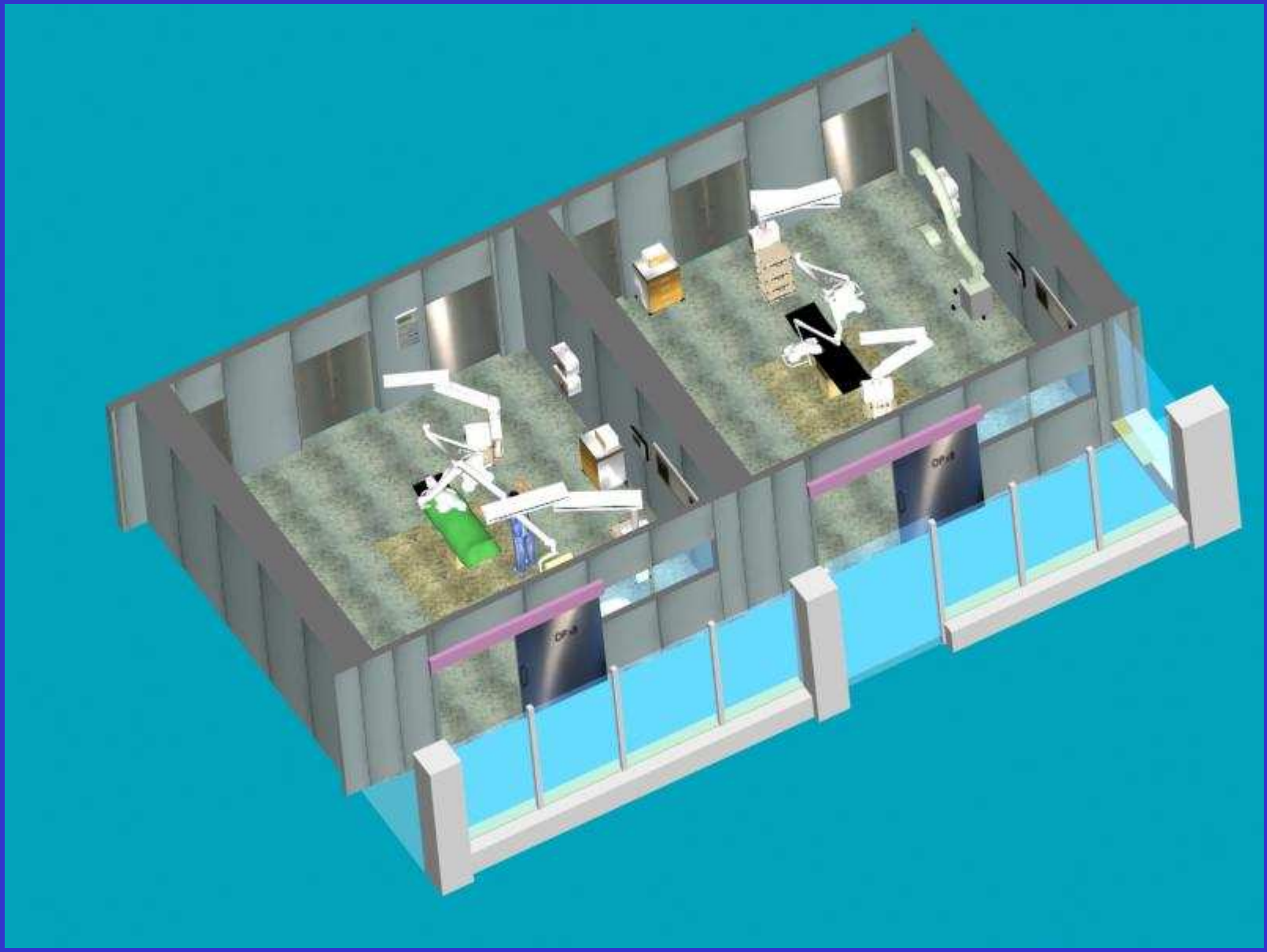


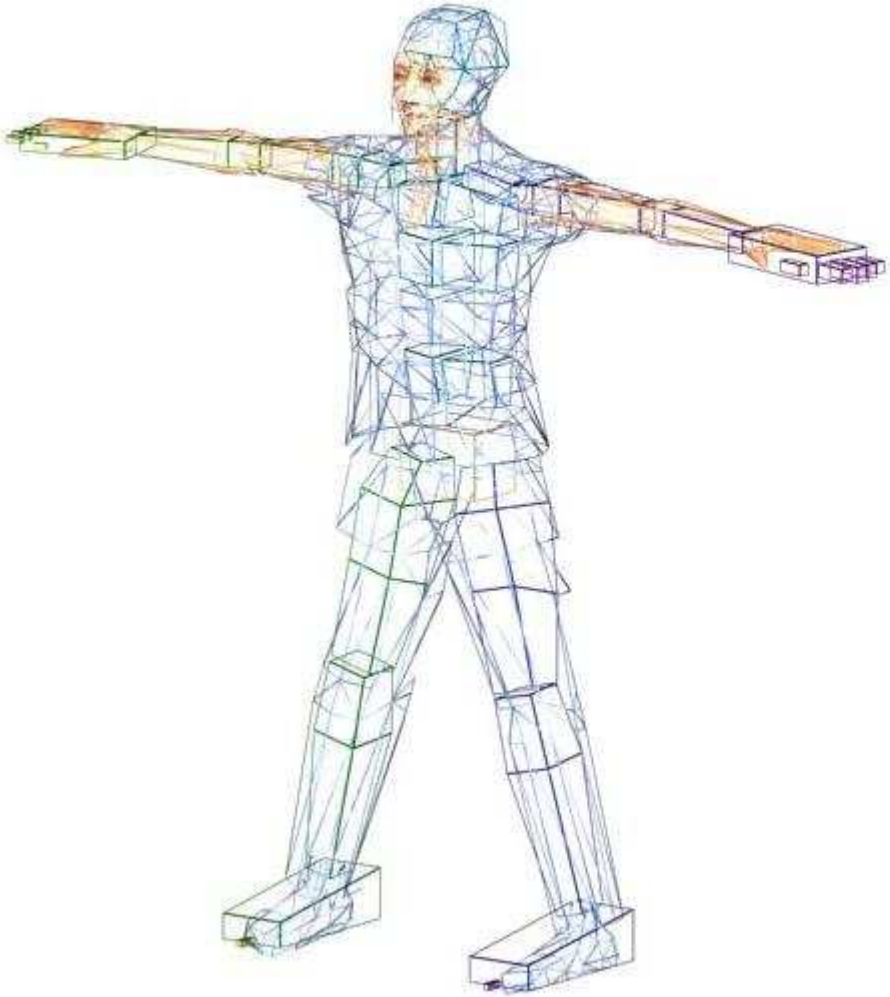
ANNEXE 2

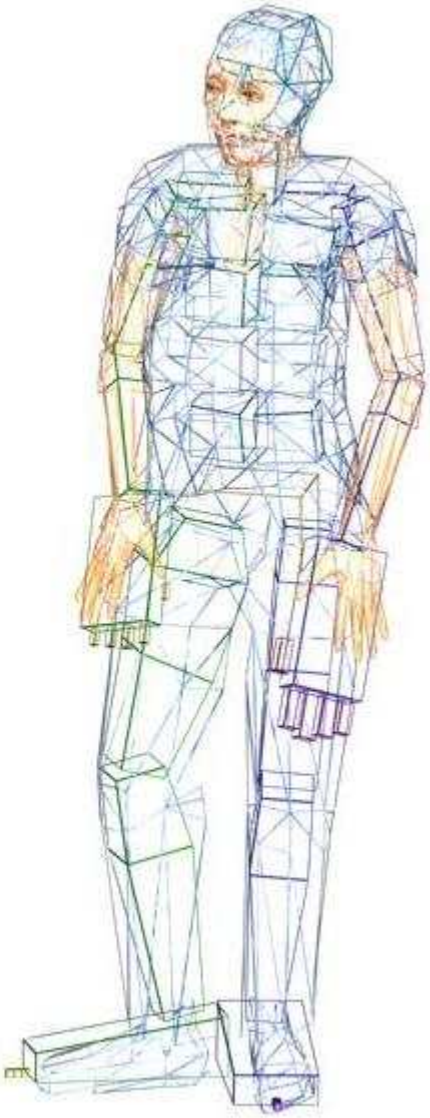
Methods

With appropriate 3D modelling, visualization and interaction tools
these S-WFs may also be represented in simulated operation room environments to provide insight into selected sequences of a surgical intervention







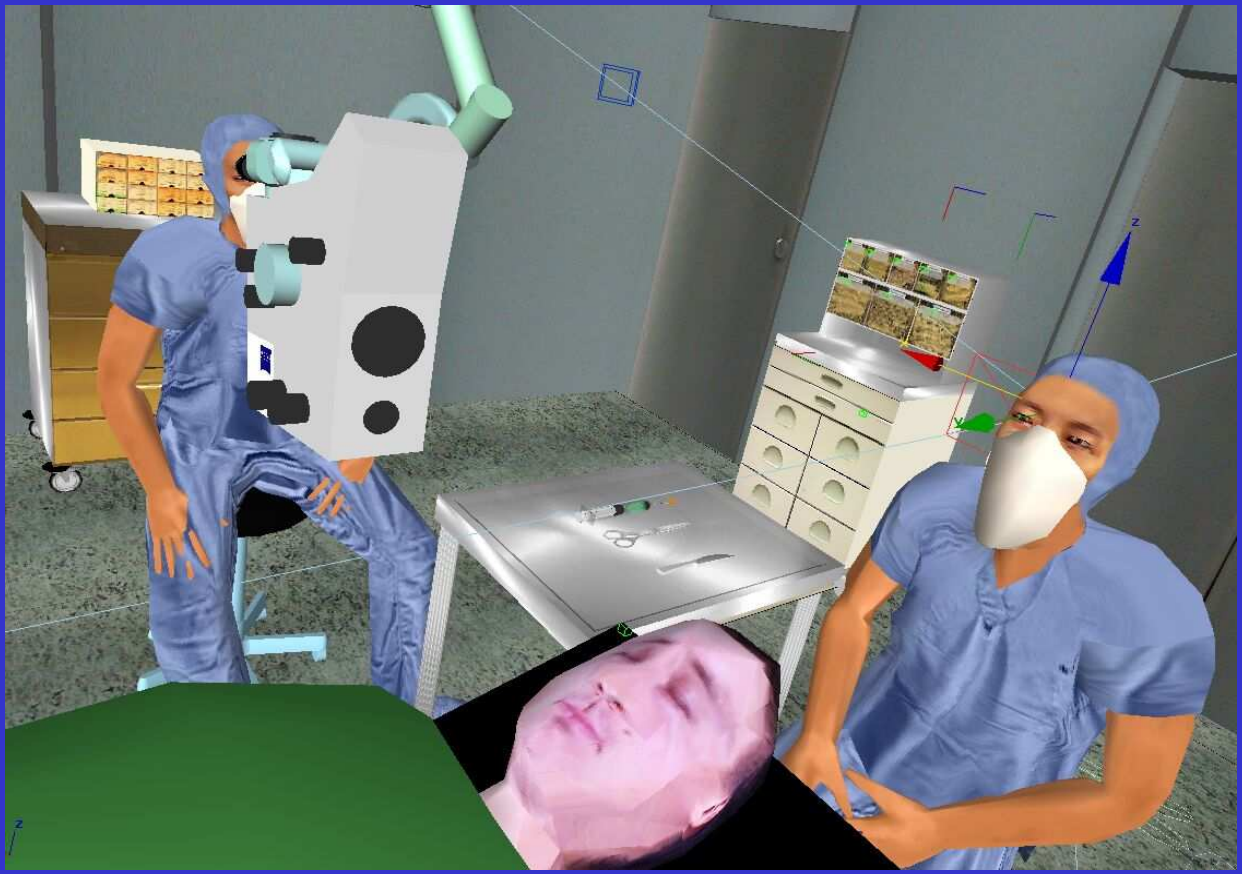



OP 89


OP 89

Volume of Vision (1)

Volume of Vision (2)



Detection of Concealment (1)

Detection of Concealment (2)

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Comparison of P2P models

A.W. Loo, The future of Peer-to-Peer computing, Comm. ACM, Sept 2003

Characteristics	Napster	Cancer Research Project	Power Server Model	Workflow Server Model
Resources shared	Music files	CPU computing power	CPU comp. pow.	WFs
Projects supported	Single project MP3 file sh.	Single project drug development	Multiple projects	Multiple projects (surgery, radiology, etc
Beneficiaries	All particip.	Organiser only	All particip.	Qualified peers
Part. new projects	No	No	Yes	Yes
Part. comp. role	Client/server	Server only	Client/server	Client/server
Platform support	Wind./Linux	Windows	All platforms	All platforms
Security	Trust	Trust	Security manag.	Security manag.

P2P „Best Practice“Workflow Repository

Reference expert knowledge

Peer Expert I

Peer Expert II

Peer Expert III

Peer Expert IV

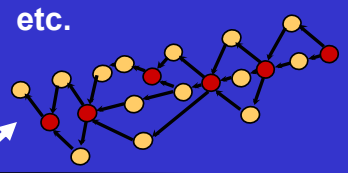
Repository of workflow

reference models (WFs, SIPs)

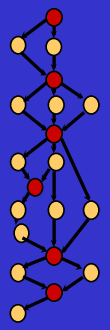
for medical techniques,

operating instructions,

etc.



WF graph



patient data

patient-spec. plan

etc.

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2. Examples
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6. Surgical PACS, DICOM and IHE
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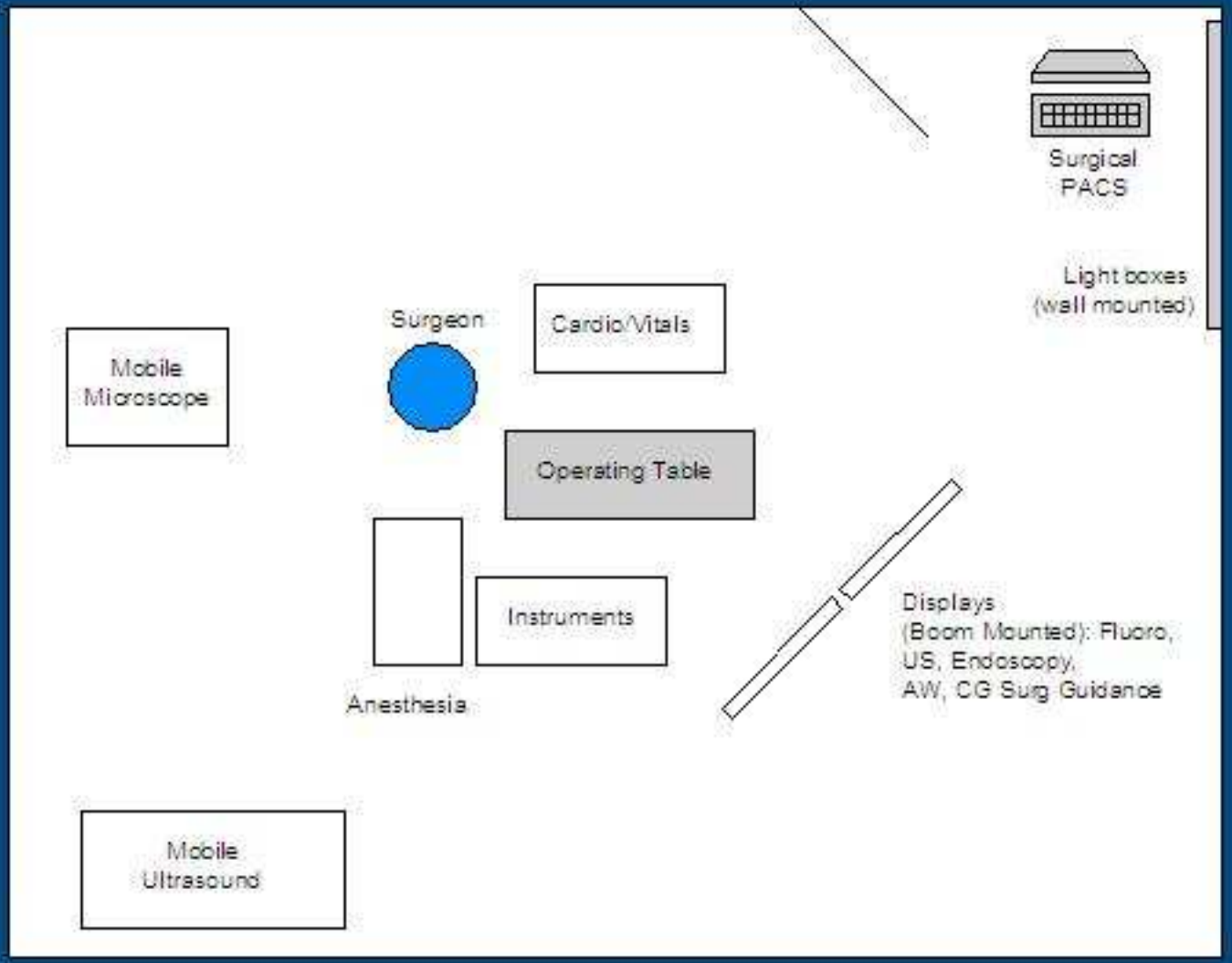
Surgical PACS, DICOM and IHE Response of Industry

1. GE
2. BARCO
3. Cedara
4. ...

Current PACS Image Review in the OR

Enterprise image reference is not convenient in the OR!



Integrated OR Concept

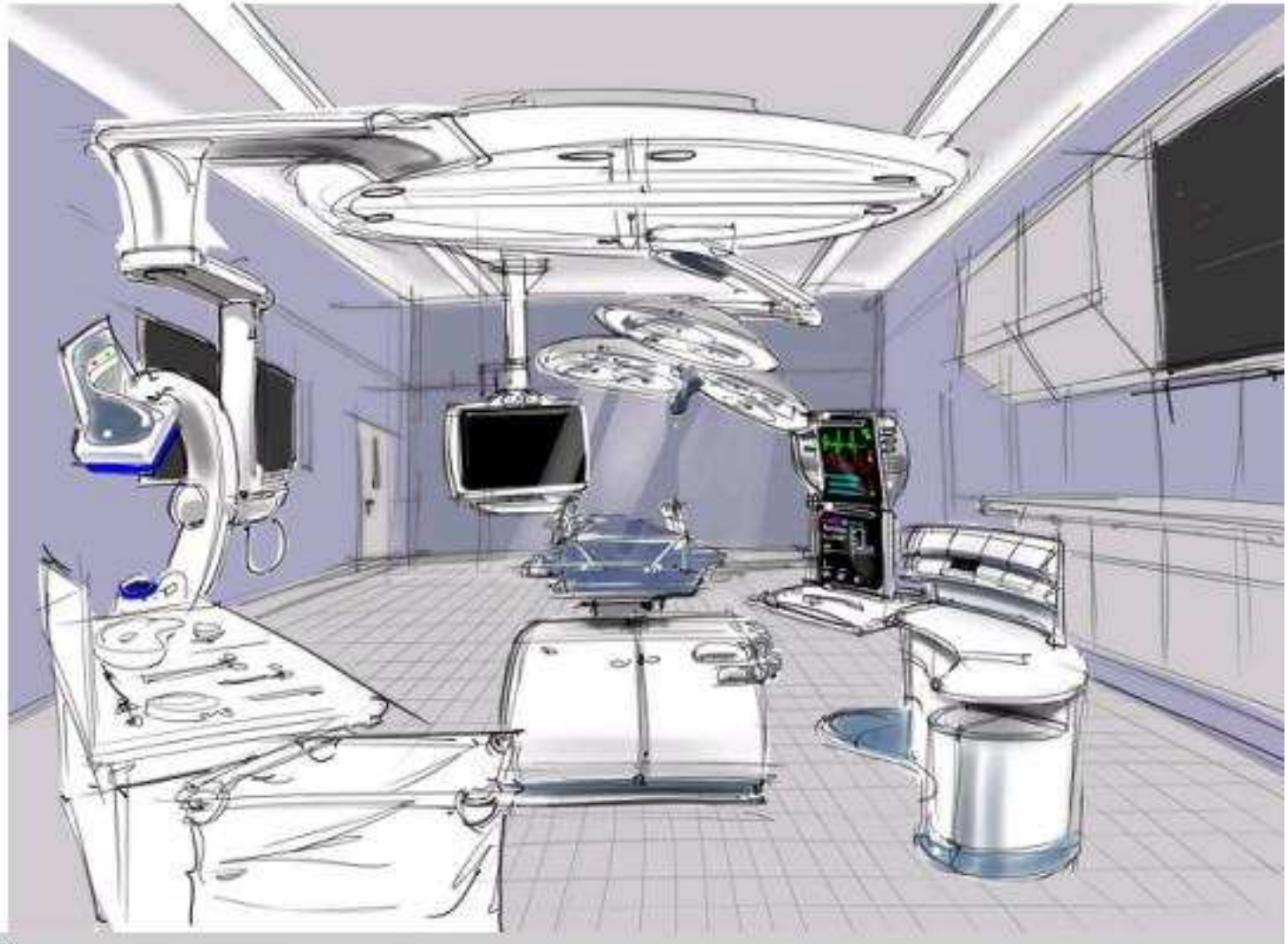
Single display

Personalized headsets

Wireless

Voice driven

All relevant patient info accessible

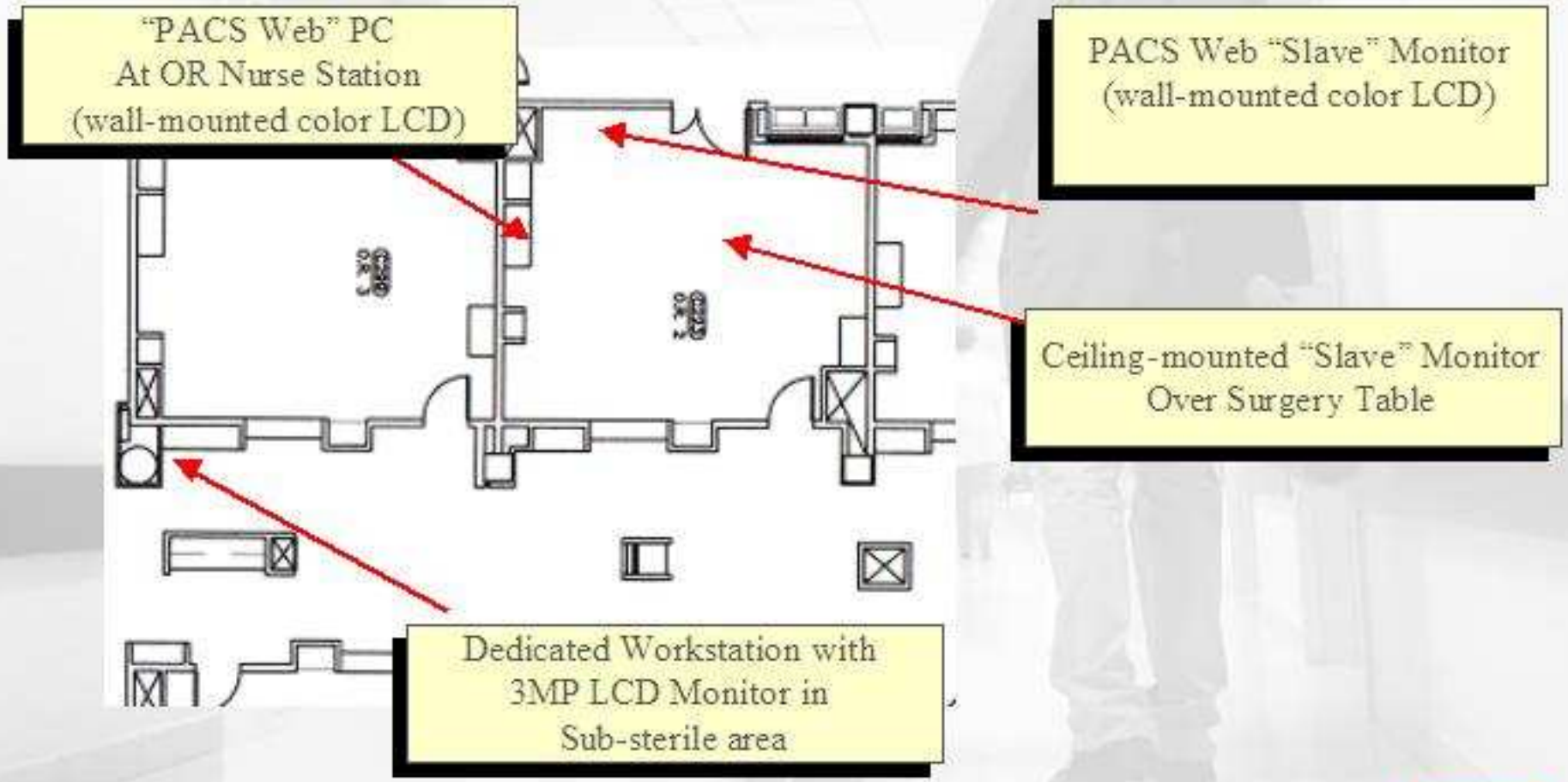


Vision

- Imaging and Information ANYTIME, ANYWHERE
- Leveraging standards like DICOM, CCOW, HL7
- Leveraging frameworks like IHE

GE Healthcare
Prakash Mahesh

PACS in the OR



BARCO
Visibly yours

Driving forces

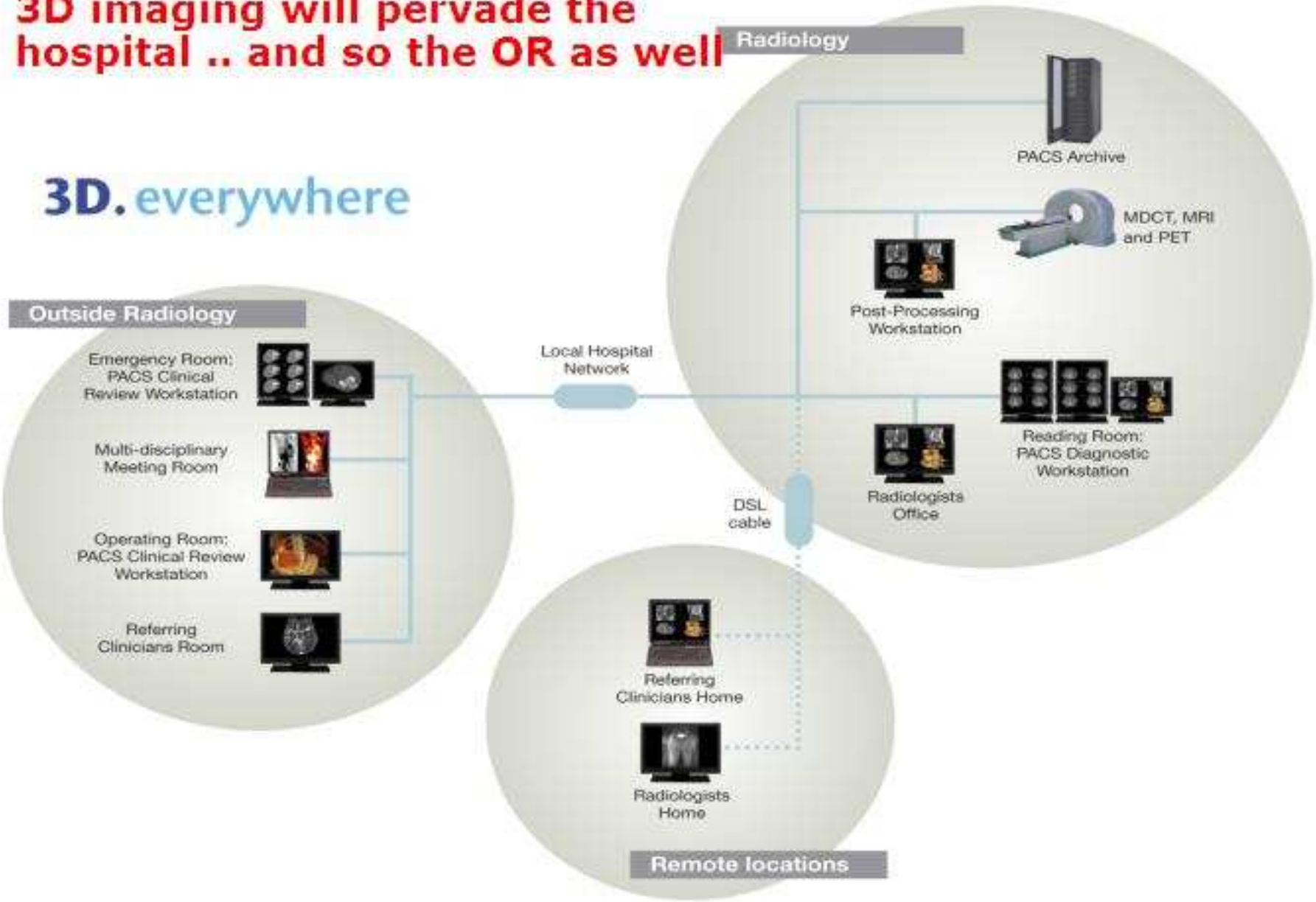
- Multiple forces are driving the digitalization of image representations
  - PACS
  - Endoscopic based surgery
  - Informatisation of patient information
- Supported by
  - new medical imaging technologies
  - Fast evolution of display technologies

Issues in today's approach

- Lack of **QA²** (Quality Awareness & Assurance) in OR
  - Awareness/importance of DICOM is low
  - Is my image representation correct? Today? Tomorrow?
  - Can impact efficiency in image judgment
- PACS in the OR not designed-in with PACS roll-out
  - OR visualisation solutions (mostly) not embraced by PACS Integrators/OEMs
  - Fuzzy exposure to what exists in the market place

3D imaging will pervade the hospital .. and so the OR as well

3D. everywhere



Workflow Automation

CEDARA

- Workflow automation is an abstraction of the workflow outside of the application
- Toolkit that is targeted not at a programmer, but rather at the business user
- Integrates technologies whether they are application, devices & people
- Provide post-execution statistics, allowing for analysis and refinement

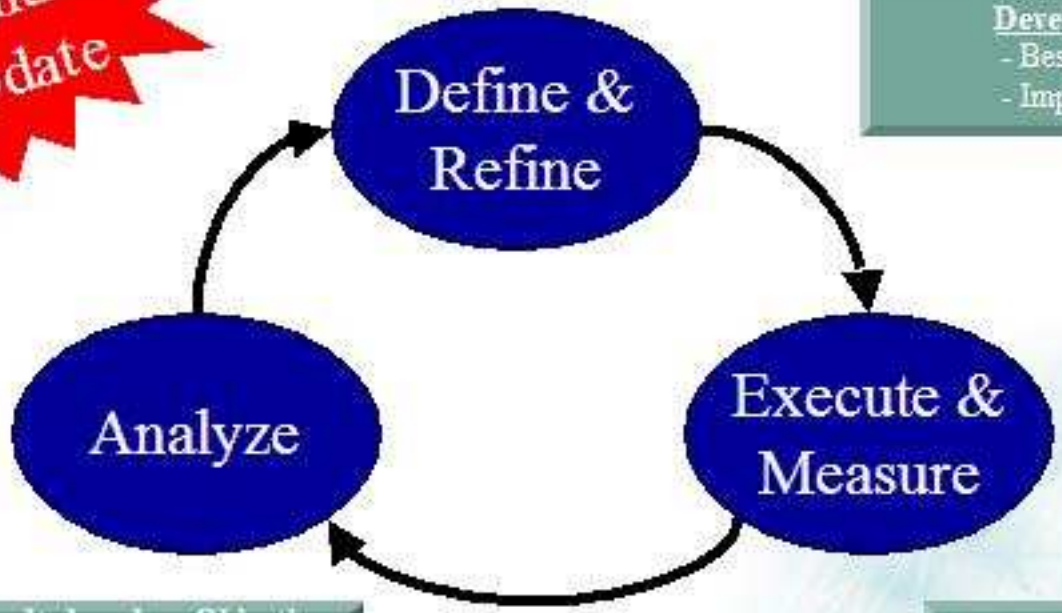
Workflow Target Applications

CEDARA

- Tools can be used to workflow-enable:
  - Clinical
  - Surgery
  - Medical Errors – Decision support
  - Single software products or applications
  - Single departments
  - Multiple departments
  - Enterprise or hospital-wide
  - Multiple enterprises

Workflow modeling in healthcare

Empowered Users

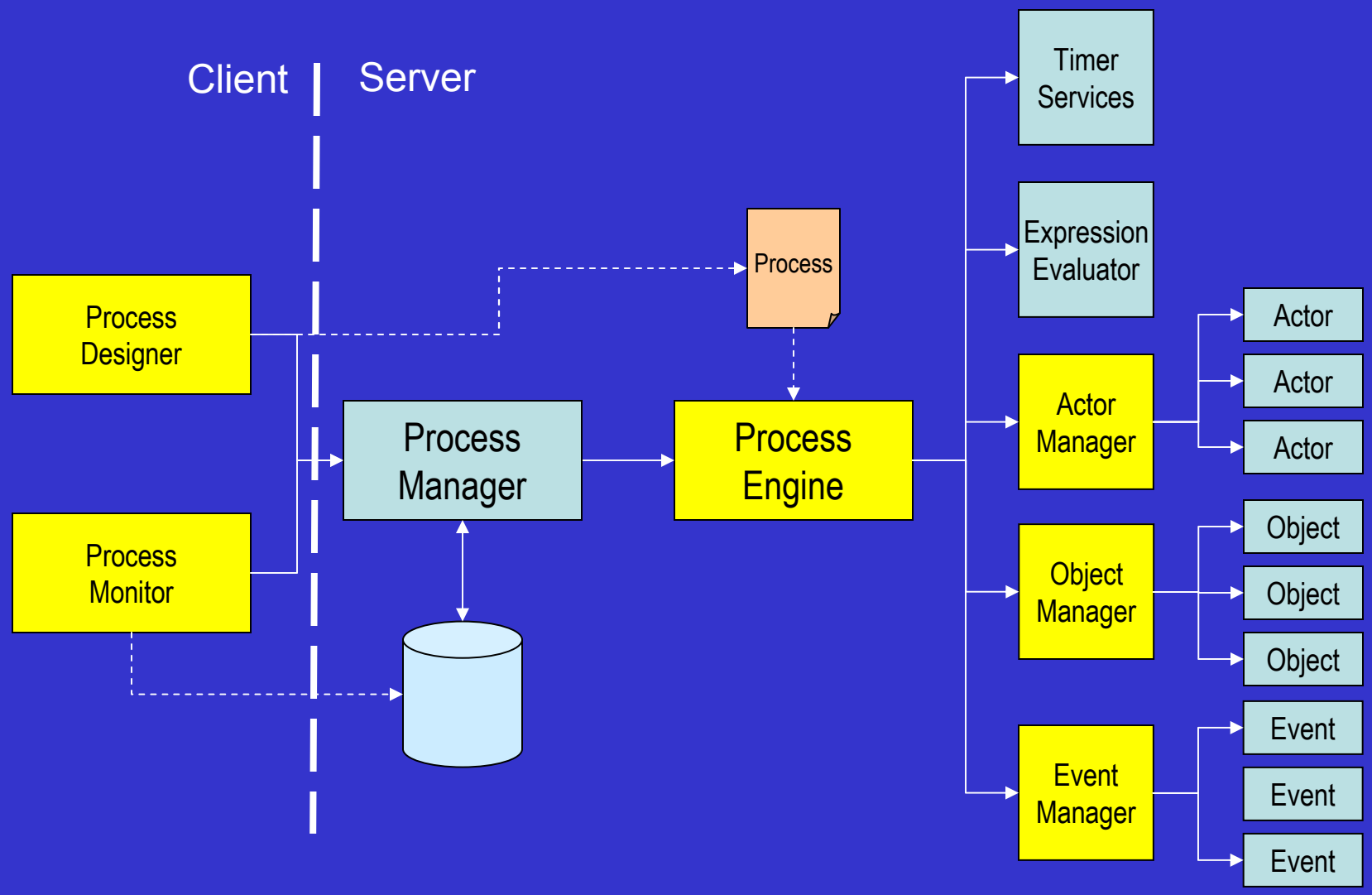


Develop Templates
- Best Practices
- Improve process

Capture Metrics
- Audit trail of all activities
- Included Start/End times, who did it

Review Results based on Objectives
- Cost Reduction
- Effectiveness
- Increase Throughput
- Collaboration

j2Flow System Architecture



Steps towards a S-PACS and S-DICOM (DICOM WG 24 „DICOM in Surgery“)

1. Define a representative set of S-WF's
2. Specify a first set S-PACS functionalities to support the S-WF's
3. Derive a first set of S-DICOM functionalities
4. Expose results to an expert group

S-PACS Cooperation Partners

- CARS Institute/Foundation (PI)
- SPIE
- UCLA
- ICCAS at the University of Leipzig (ENT, Cardio, Neuro)
- Technical University of Berlin (CG and CAM)
- USC
- Stanford University
- University of Rennes
- Japan Institute of CARS
- Industry (AGFA, SIEMENS, Philips, Cedara,...)
- CURAC (AG S-WF and S-PACS)
- University of Pisa, EndoCAS
- The Interventional Centre, Oslo
- Georgetown University
- University of Chicago
- MGH

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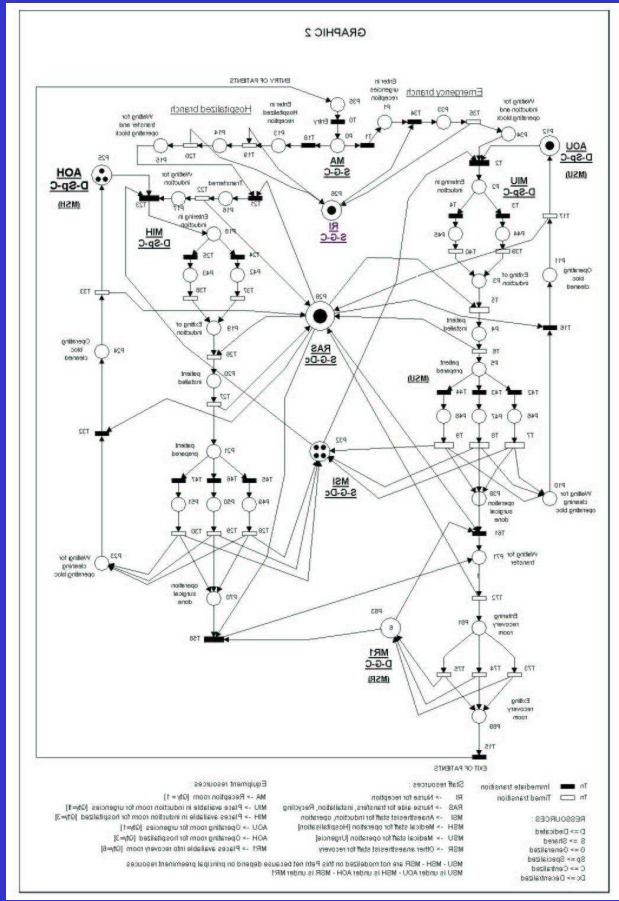
Conclusion

1. S-WFs definitions (on an appropriate granulation level) and visualizations allow surgeons and associated disciplines to understand their requirements more thoroughly when specifying and evaluating surgical PACS and CAS systems

2. Selected S-WFs defined by some standard method such as provided by the WfMC may be entered into a repository, providing a reference base for teaching and for peer-to-peer (P2P) computing on a global basis

Conclusion

3. Interdisciplinary communication between surgeons and the engineering disciplines will be enhanced through computer assisted presentation of 2D workflow models and their computer graphic 3D/4D visualization. The 2D workflow presentations may serve as a script for the animations



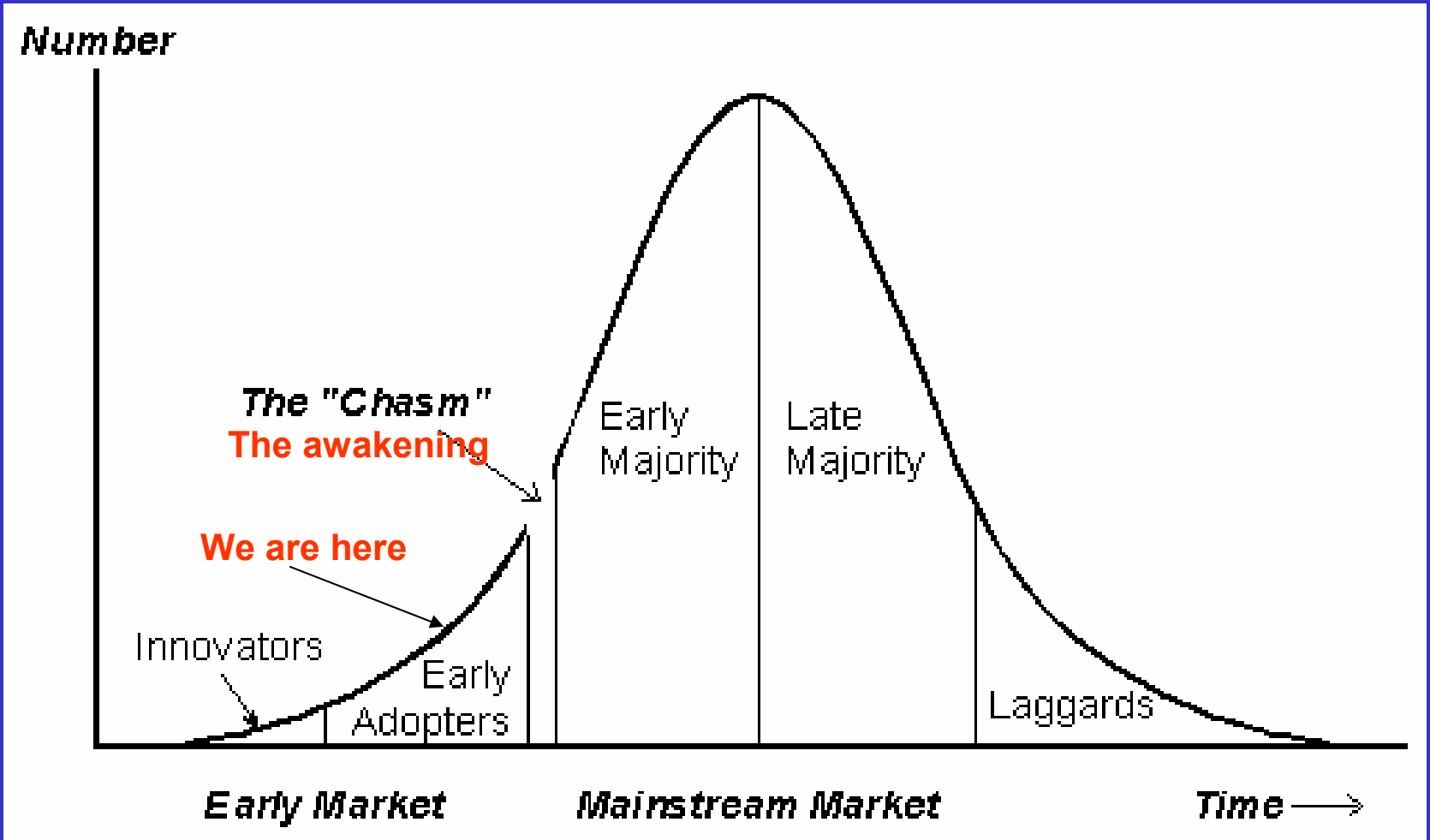
Conclusion

4. A S-PACS distinguishes itself from the classic radiological PACS by focusing on the surgical needs. These may relate to specific intraoperative imaging needs including surgical imaging modalities, real time and 3D/4D visualization as well as a high degree of interactivity between the surgeon and technologies for information presentation

5. To avoid reinventing the wheel, DICOM needs to be augmented to a surgical DICOM (S-DICOM) with the appropriate meta data in order to cover surgical interface requirements.
   The same applies to the IHE defined workflows

Innovation and IGT tools

- Adoption of new IGT tools in the "*Age of Information*" or "*Knowledge Era*"



Inaugural meeting:

DICOM WG 24 „DICOM in Surgery“

DICOM WG 24 „DICOM in Surgery“

WG24 meeting on Wednesday, 28th September 2005, 2 p.m. at the Hilton Budapest WestEnd Hotel, Room MATRAALJA. :

Agenda

1. Scope of WG24
2. Roadmap
3. Short Term Goals
4. Current Work Items
5. Relationship to other Standards and Standard Bodies
6. Election of WG24 Chair and Co-Chair
7. Miscellaneous

A first summary description of some of the agenda items be found in:
"Preliminary Strategic Summary for WG24".

The End