CTK Workshop Heidelberg, June 29/30, 2009

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X I P
Rapid and Extensible Software Development for Medical Imaging

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Challenges:
Product Integration and Interoperability

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Integrating the results of academic & clinical collaborations, software platforms of different companies and third-party applications into a unified architecture is a major challenge

Princeton University
Washington University in St. Louis
Penn
Carnegie Mellon
Rutgers
CRCG
Michigan State University
Lehigh University
University of Florida
Johns Hopkins University
Columbia University in the City of New York
University of Rochester
University of Washington

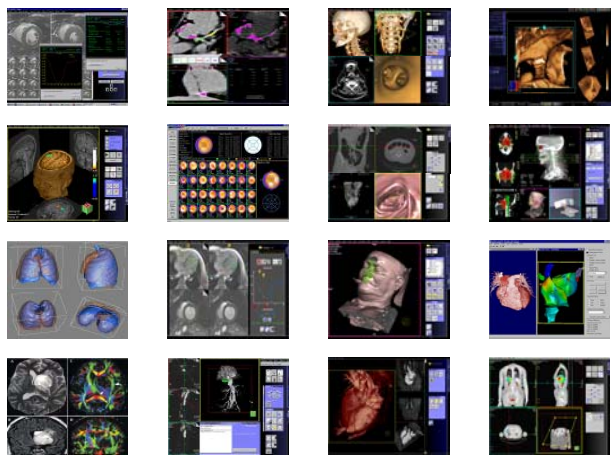
150+ students Sponsored by SCR each year

Bayer
Dade Behring
DPC
cti Molecular Technologies
Shared Medical Systems
mirada

Acquisitions of medical imaging companies

TomTec Imaging Systems
HIPGraphics
MeVis Medical Solutions
Computer Systems, Inc. Mercury
TeraRecon, Inc.

Integration of 3rd party applications



QSR-Compliant PRODUCTS

Megatrend: Imaging Biomarkers in Drug Discovery

Molecular Imaging Software Development Pipeline

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Probe / Target / CA Discovery, Animal Testing → Clinical Trials → Clinical Feasibility and Acceptance → Clinical Operations

- 10's to 100's of new disease-specific molecular imaging applications in next 10 years
- Radiologists Need:
  - Agent-customized imaging
  - More efficient development for clinical research
- Hospitals Need:
  - Agent-optimized imaging across all workstation platforms

A new model for imaging software development is needed to efficiently bring molecular agents to the clinic

Accelerating Time To Market

Rapid Transfer from Prototype to Product

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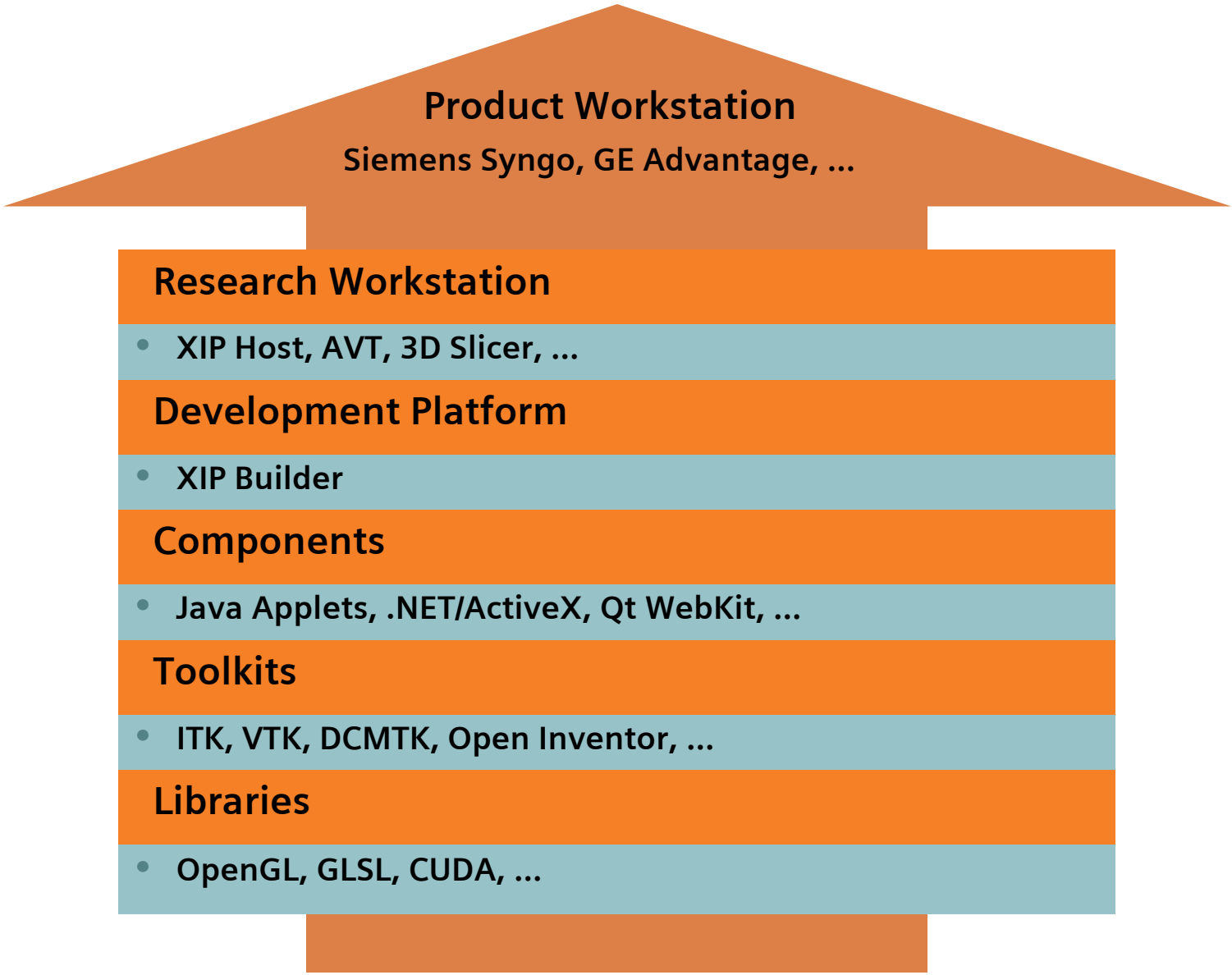

Accelerating Time To Market

Rapid Transfer from Prototype to Product

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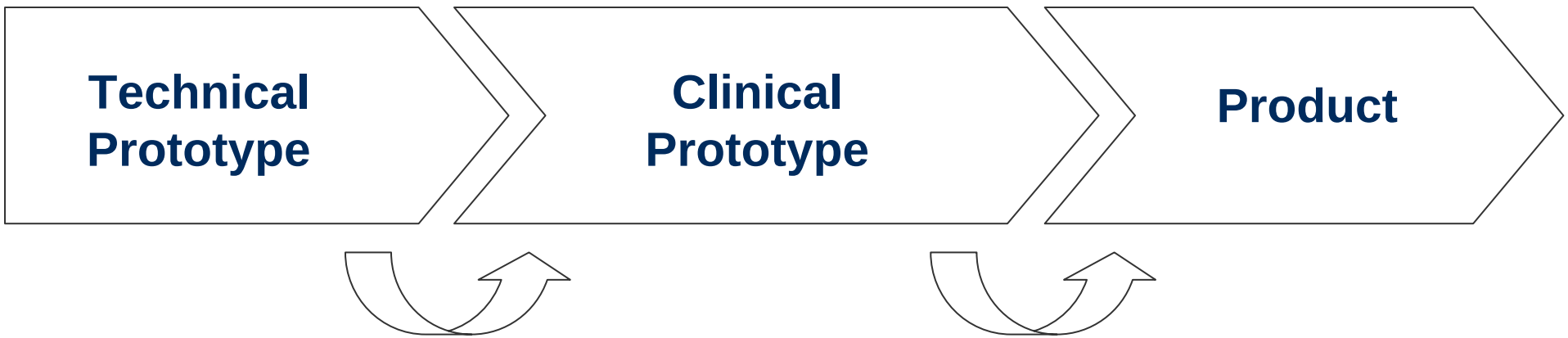
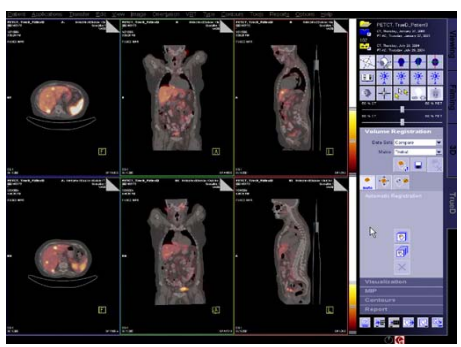
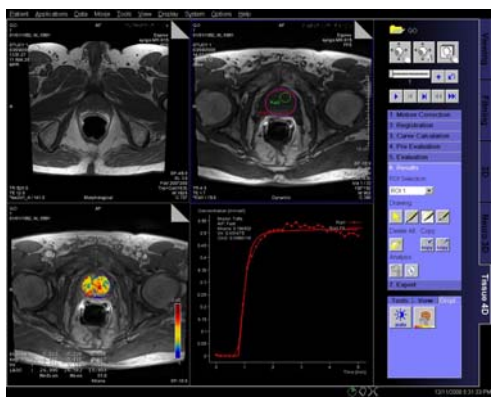


Rapid Prototyping IDE provides a graphical editor to create visualization graphs and processing pipelines

Standalone application easily deployable to clinical collaborators is used to refine workflow and algorithms based their feedback

Standardized middleware and components to ease the integration of prototyping results into product platform for clinical applications





Feedback from Pharma
Plug-in Concept

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- **Why re-implement the same image analysis software for a particular agent on each vendor's workstation?**
  - An interoperable plug-in environment can facilitate collaboration between imaging vendors and Pharma companies, enabling new business models

Market the combination of a molecular imaging agent with its disease and organ specific image acquisition & analysis

Commercial workstations are extended to execute drug-specific plug-ins

SIEMENS PHILIPS TOSHIBA AGFA

...and many other imaging vendors

Accelerating Time To Market
Standardization

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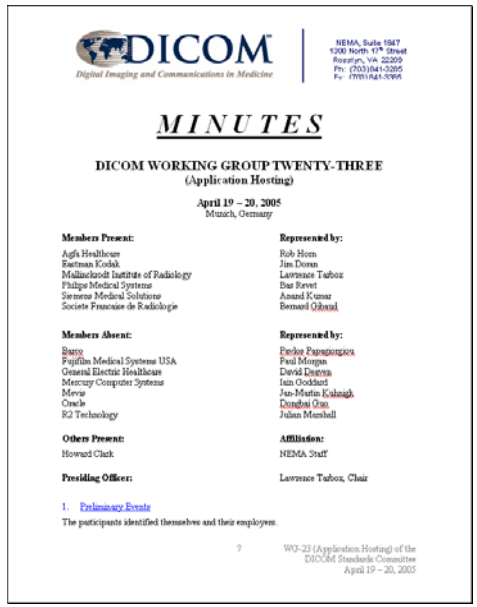
- **DICOM Working Group 23**
- Created in December 2004, with support of Siemens Corporate Research
- Chaired by **Lawrence Tarbox** (WUSTL)
- Joined by Siemens, GE, Philips, Kodak, Agfa, Barco, FujiFilm, Oracle, and many more
- Providing an "Application Hosting" reference implementation in 2009 (Supp. 118)



DICOM
Digital Imaging and Communications in Medicine

NEMA, Suite 1847
1300 North 17th Street
Rosslyn, VA 22209
Ph: (703)841-3265
Fx: (703)841-5995

MINUTES

DICOM WORKING GROUP TWENTY-THREE
(Application Hosting)

April 19 – 20, 2005
Munich, Germany

Members Present:	Represented by:
Agfa Healthcare	Rob Horn
Eastman Kodak	Jim Doran
Mallinckrodt Institute of Radiology	Lawrence Tarbox
Philips Medical Systems	Bas Revet
Siemens Medical Solutions	Anand Kumar
Societe Francaise de Radiologie	Bernard Gibaud

Members Absent:	Represented by:
Barco	Evelyn Papageorgiou
Fujifilm Medical Systems USA	Paul Morgan
General Electric Healthcare	David Pearson
Mercury Computer Systems	Iain Goddard
Mevis	Jan-Martin Kuhnigk
Oracle	Dongbai Qiao
R2 Technology	Johan Marshall

Others Present:	Affiliation:
Howard Clark	NEMA Staff

Presiding Officer: Lawrence Tarbox, Chair

1. Preliminary Events

The participants identified themselves and their employers.

→DICOM Supplement 118 is open for public comment as of Jan. 2009

ftp://medical.nema.org/medical/dicom/supps/sup118_pc.pdf

Cancer Biomedical Informatics Grid (caBIG)

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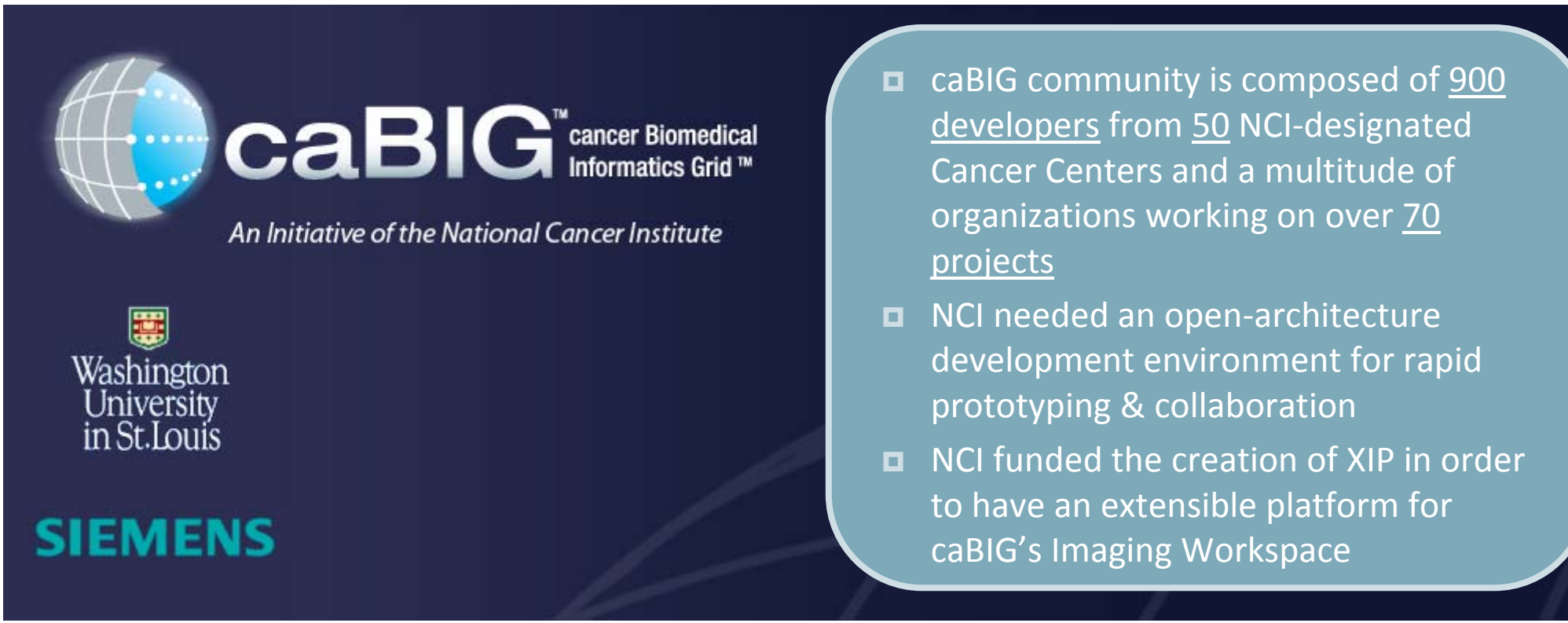

- caBIG community is composed of 900 developers from 50 NCI-designated Cancer Centers and a multitude of organizations working on over 70 projects
- NCI needed an open-architecture development environment for rapid prototyping & collaboration
- NCI funded the creation of XIP in order to have an extensible platform for caBIG's Imaging Workspace

eXtensible Imaging Platform (XIP)

eXtensible IMAGING PLATFORM

- Includes a reference implementation of WG23 emerging standard
- Collaboration with Mallinckrodt Institute of Radiology (WUSTL)
- Demonstrations at RSNA InfoRad 2006, 2007, 2008
- First release of XIP was available to caBIG community Spring 2007

XIP Builder Visual Programming Tool

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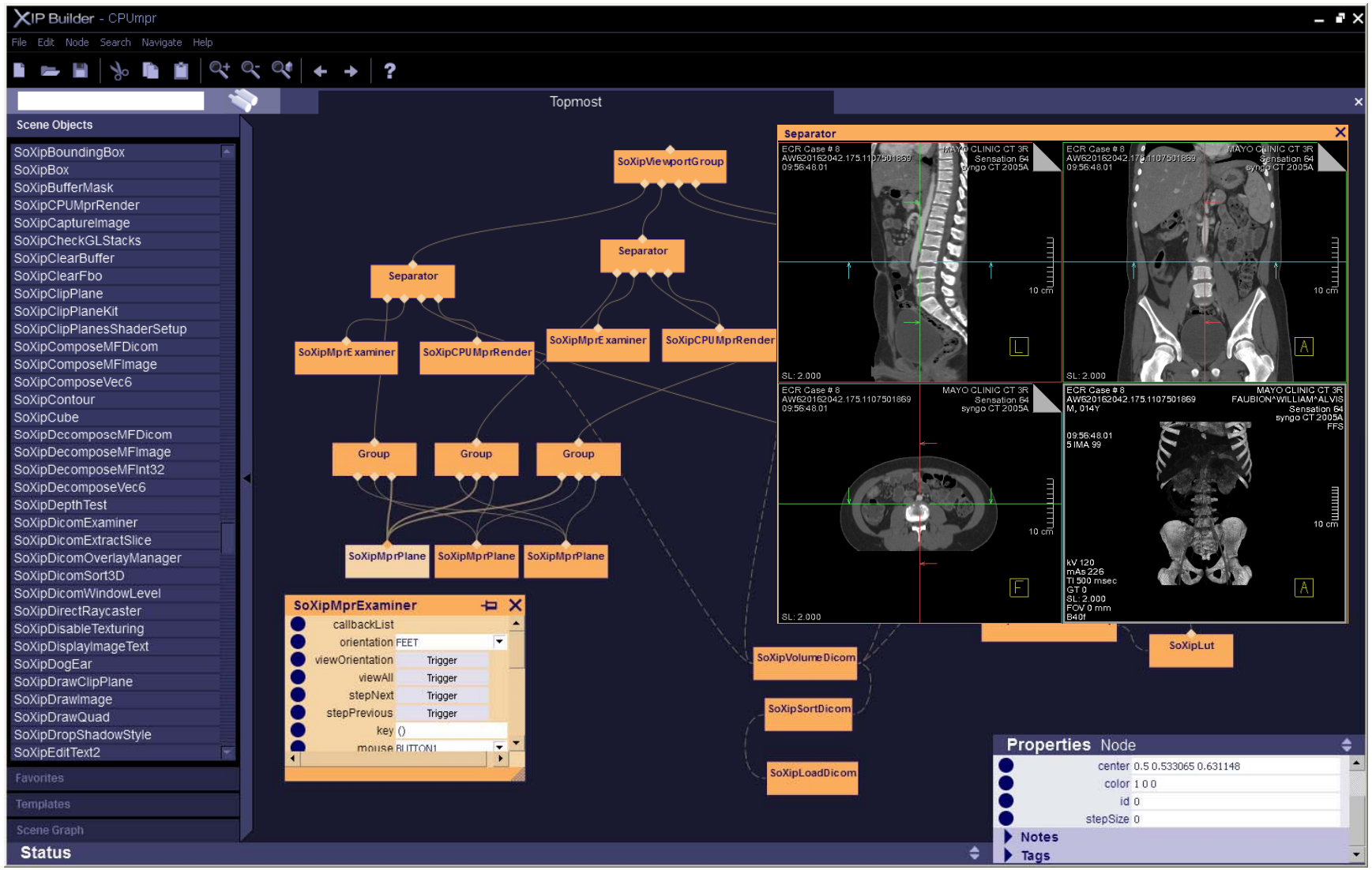
- **Interactive Design of Open Inventor Scene Graphs and pipelines**



Why Open Inventor?

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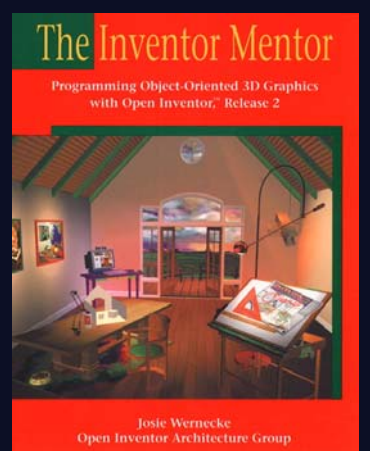
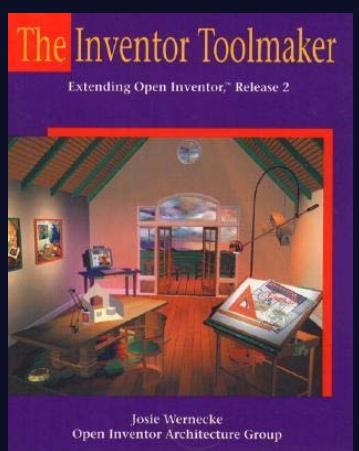
- Instead of implementing yet another library design, XIP extends Open Inventor ® (free, LGPL) with new engines, nodes, and manipulators for Medical Imaging
  - **Engines** enable the creation of processing pipelines
    → well known concept in Computer Vision
  - **Nodes** support the concept of scene graphs, which are hierarchical structures of objects describing what needs to be visualized in 2D/3D

    → well known concept in Computer Graphics
  - **Manipulators** handle input devices, measurements and coordinate transforms in response to user interaction via a simple event model
  - **Field Converters** automatically handle data conversion between different field connection types
    → facilitates interoperability between wrapped libraries
  - **Serialization** is built-in via Open Inventor's VRML standard → facilitates exchange of functionality
- Leveraging excellent Sgi's documentation for a short learning curve (Inventor Mentor/ToolMaker)

sgi Open Inventor ®





XIP Builder Visual Programming Tool

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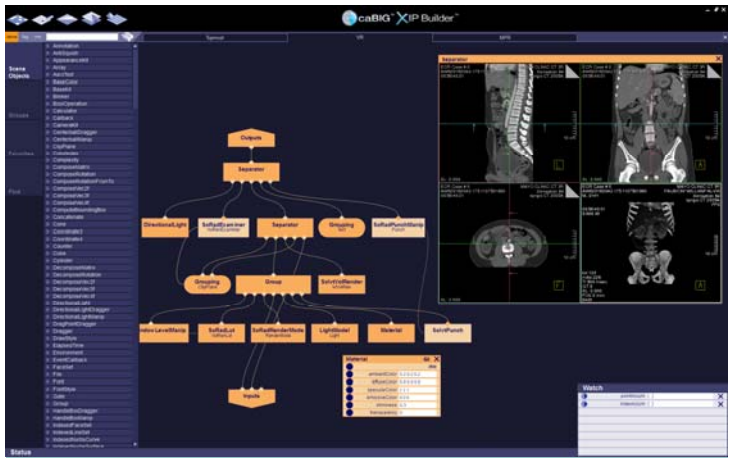
Highlights

- Makes many different open source libraries Interoperable (Open Inventor, ITK, VTK, DCMTK, GLSL, CUDA, AIM,...)
- Design can be rapidly prototyped, tested and saved to a file which can be loaded in application GUI written in C++, Java or HTML
- Ability to group sub-graphs into high level reusable packages
- Tabbed navigation facilitates navigation through large projects
- Ability to preview processing results at any stage of the graph/pipeline
- Watch window for debugging purposes
- Integrated Performance Profiling feature
- Built-in batch mode processing for automated testing/validation



XIP Builder™

XIP Host Reference Implementation

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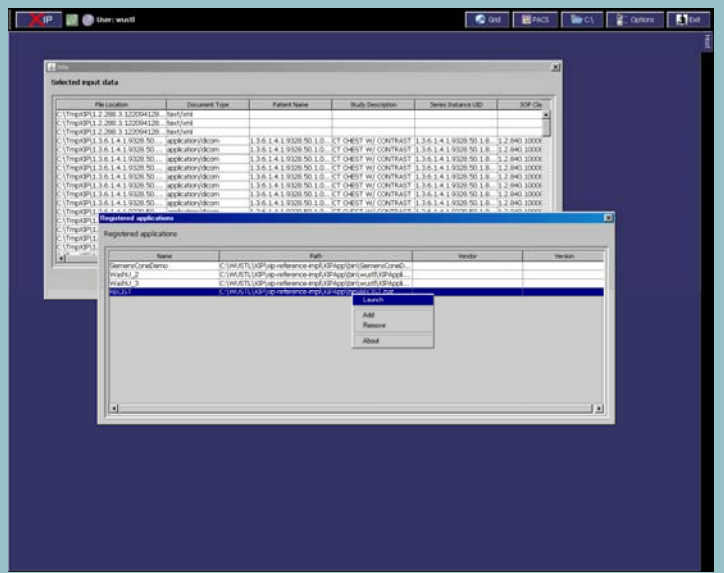
- Provides the infrastructure in which XIP or DICOM WG-23 Applications run
  - Authenticates user
  - Manages installation, launching, and termination of XIP Applications
  - Provides data and services to XIP Applications
  - Accepts status information and results back from XIP Applications
  - Deals with auditing and controls access to services and data
- Isolates the XIP application from the nature of databases, archives, networks, and possibly image data formats
  - Manages caGRID interactions and security
  - Manages access to DICOM networks, objects, and services
  - Maps images and associated meta-data between their native form and a common form useable by the XIP application
  - IHE General Purpose Worklist support



eXtensible IMAGING PLATFORM

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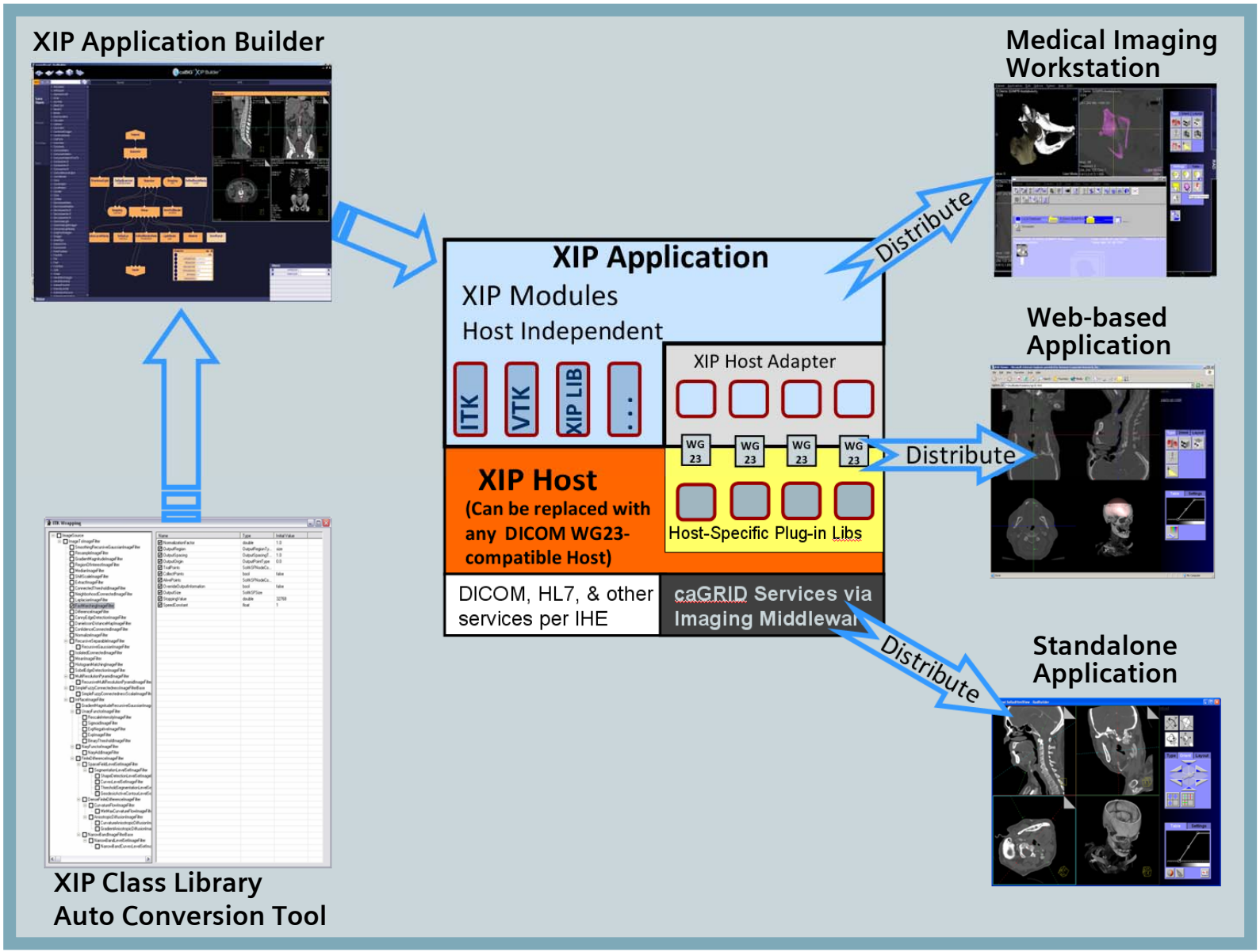

ITK Support

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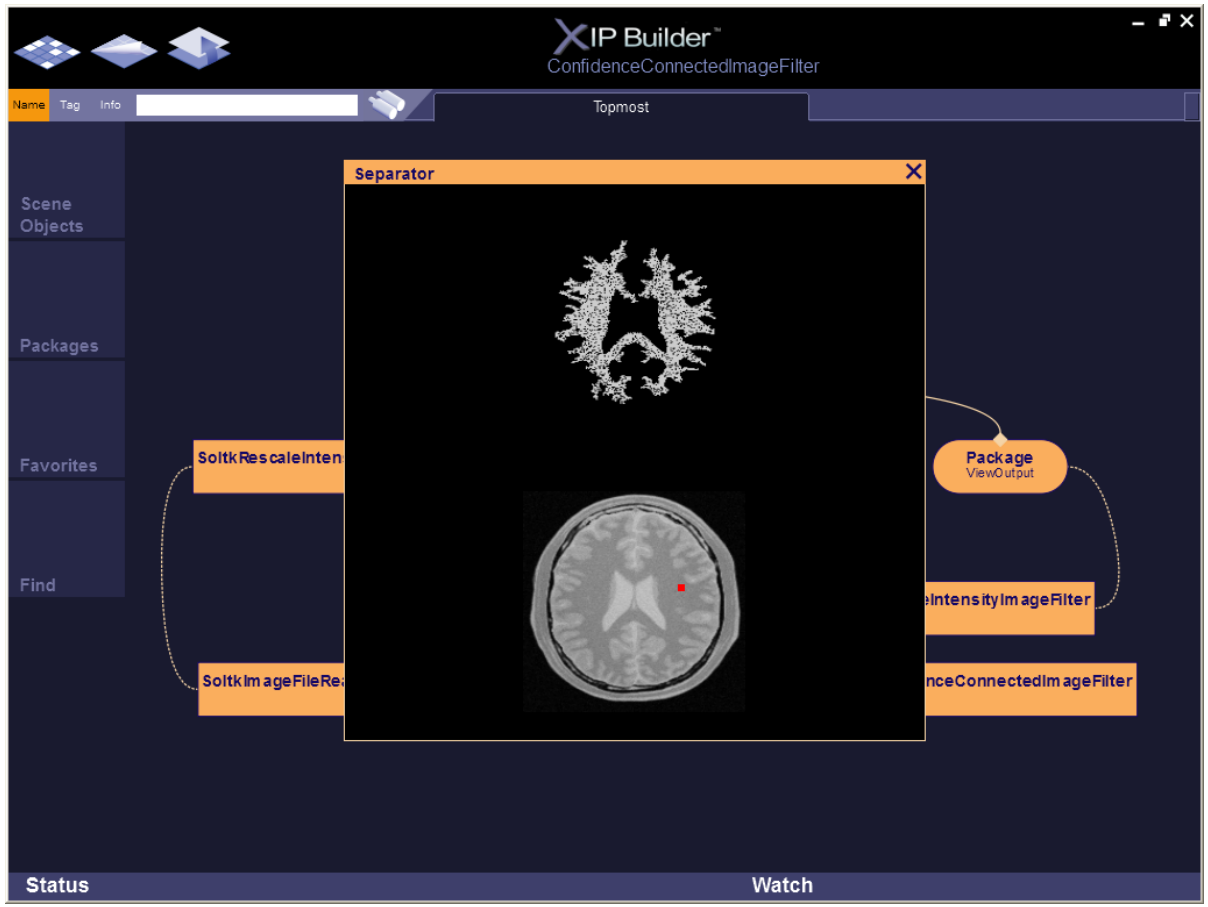
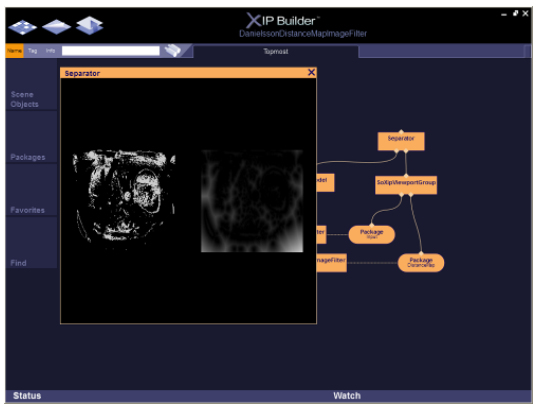
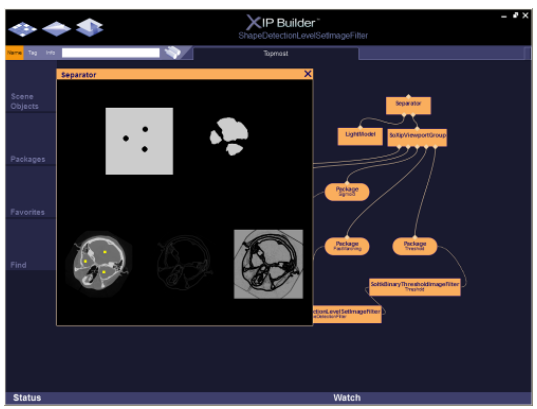
- Scripts to automatically wrap entire library (1000's of objects)
- 261 wrapped objects are fully tested
- 125 examples matching the IKT User's Guide







VTK Support

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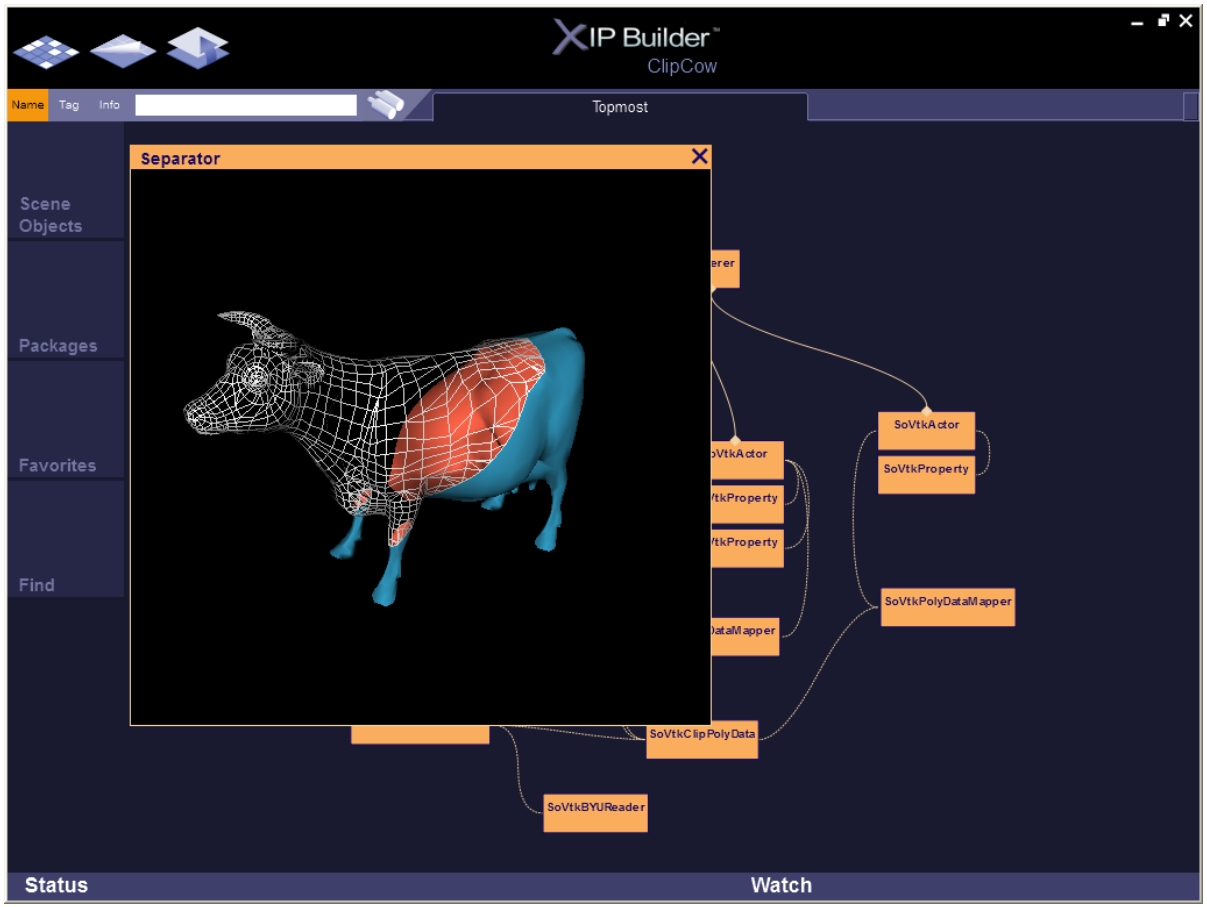
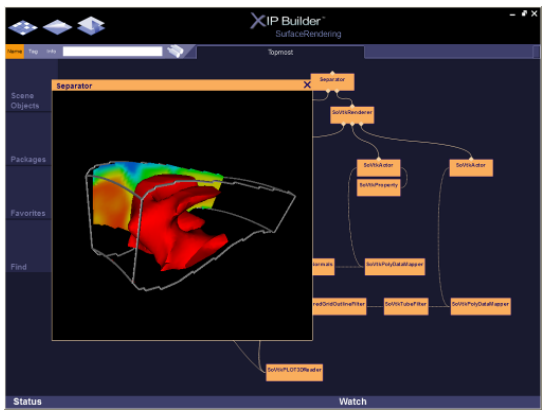
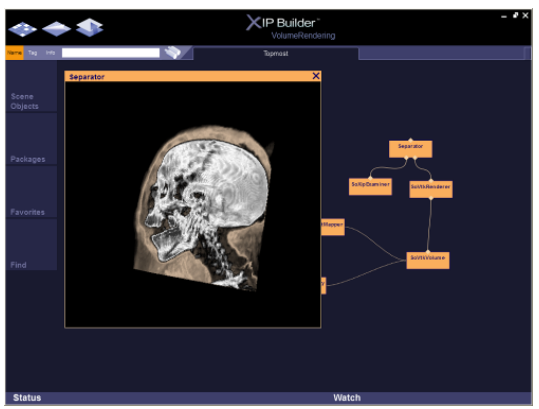
- Scripts to automatically wrap entire library (1000's of objects)
- 308 objects undergoing testing
- Various examples available (under development)







DICOM Support

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- High-level DICOM loader objects based on DCMTK
- Modular DICOM Sorting objects
- Objects for 2D on-demand-paging as well as 3D volume construction
- Flexible display of DICOM elements as overlay text information

GPU Image Processing

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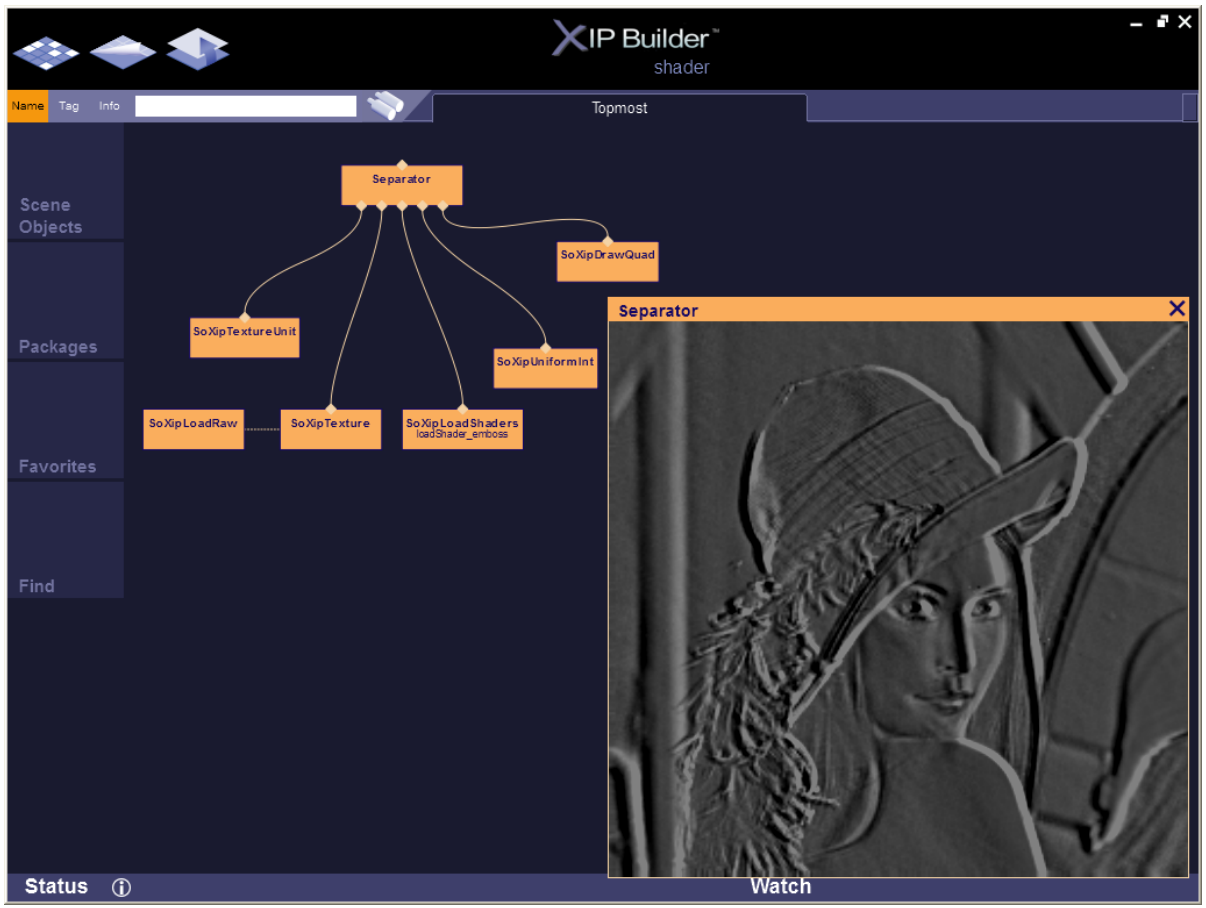
- Support for GLSL programs (C-like language)
- All underlying OpenGL 2.0 setup is taken care of
- Easy way for researchers to implement hardware-accelerated algorithms



Programmable 3D Volume Rendering and MPR

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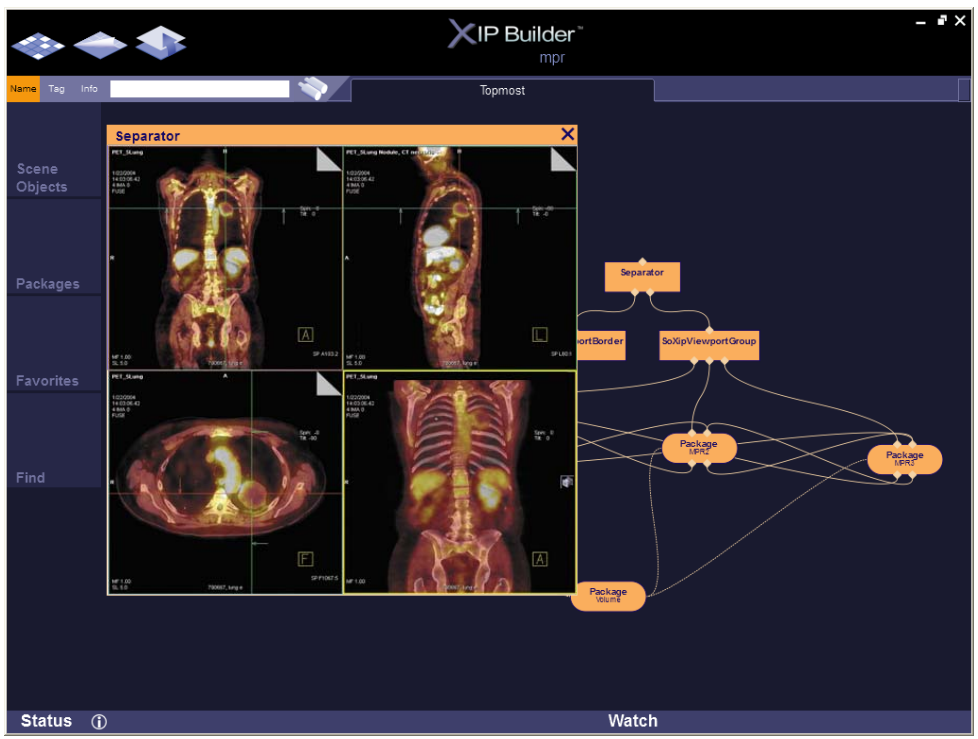
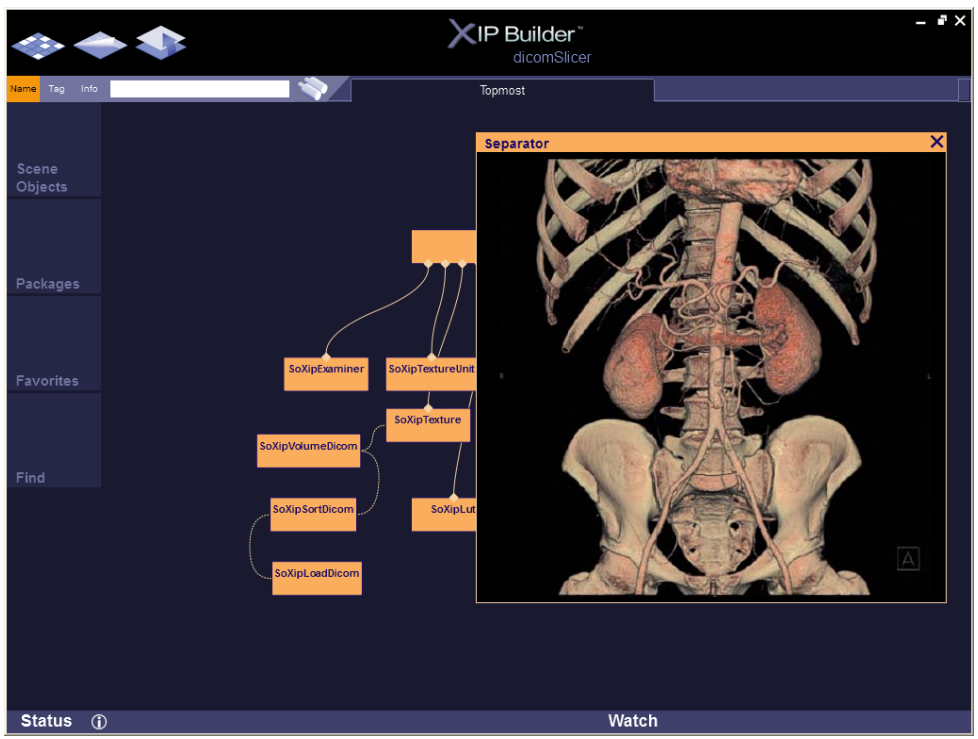
- Leverages the processing power of modern GPU graphics cards (within the constraints of the GPU card's memory, and using only standard algorithms known in the art)
- Fully programmable using the GLSL language
- Great flexibility for researchers to implement new 3D visualization ideas
- Supports multiple volumes fused in the same scene
- Synchronized 3D navigation of Oblique MPR planes





Overlay/markup graphics & Measurements

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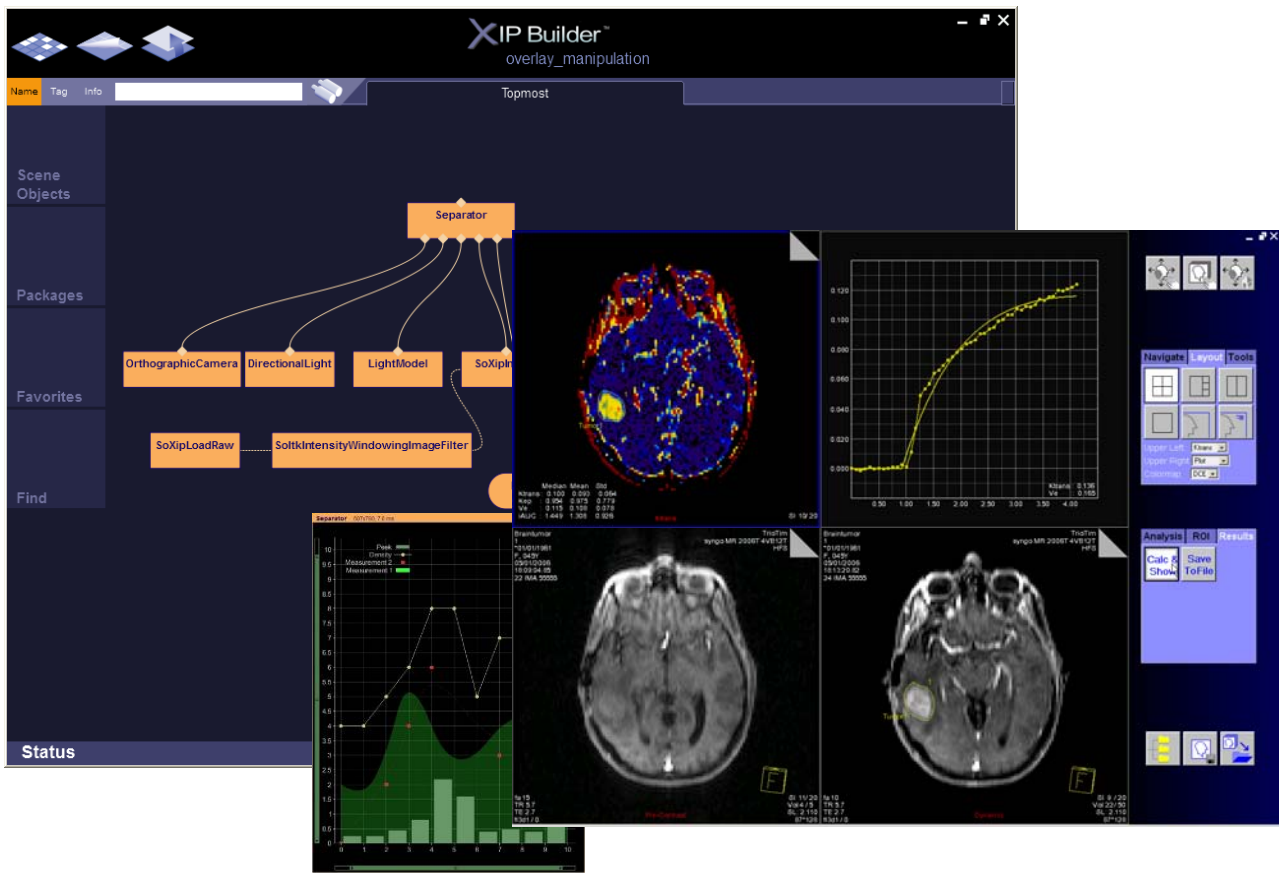
- A collection of 2D/3D shapes for a variety of image markup applications (lines, polygons, splines…)
- RECIST, WHO, area and volume measurements
- Graph plotting and charting
- Support for DICOM Presentation States



Remote Client/Server Visualization

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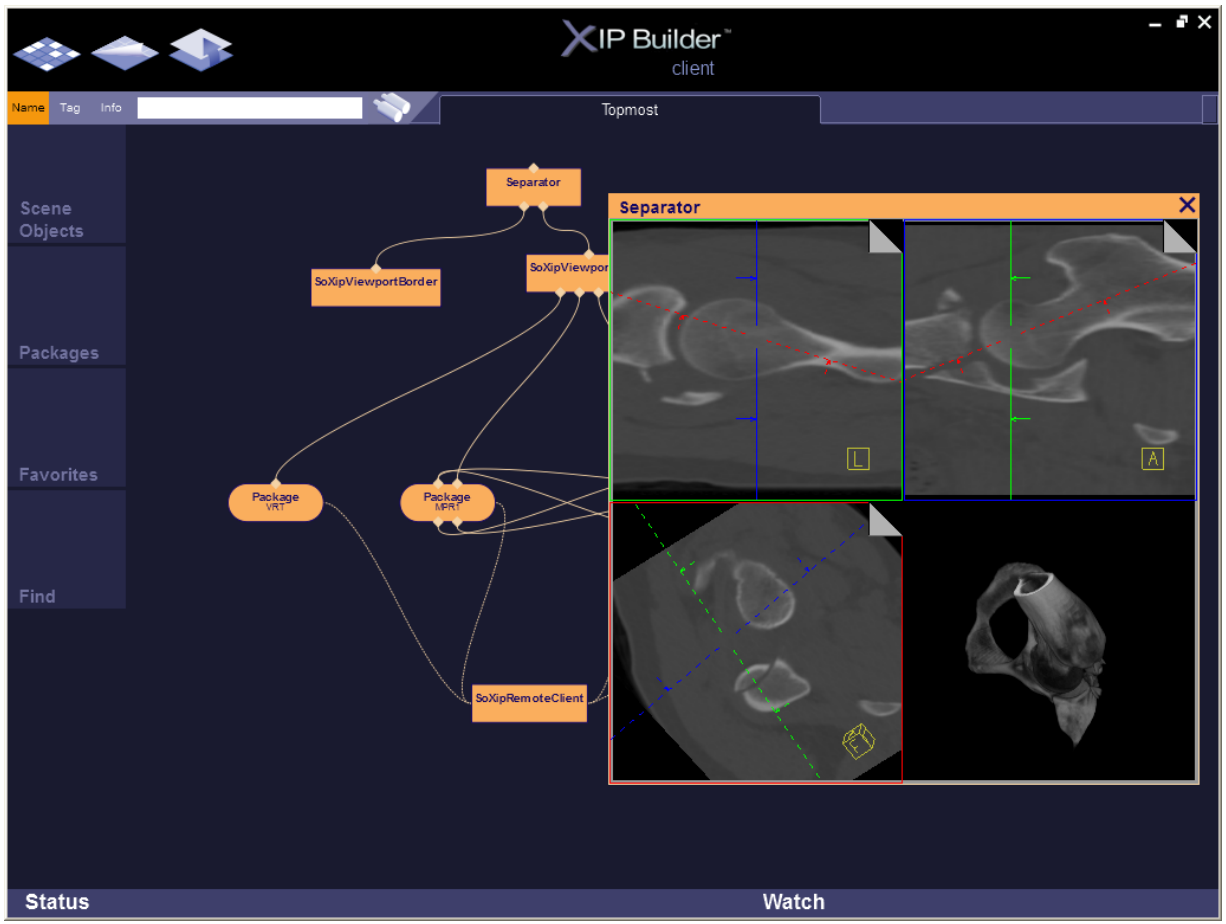
- Enables collaborative visualization over LANs, Intranets and/or the Internet
- Volume rendering and MPR fully supported
- Socket-based, it only needs the IP address of the XIP server process
- Remote loading on server is triggered by the client



Upcoming Feature:
Multi-Resolution Client/server approach

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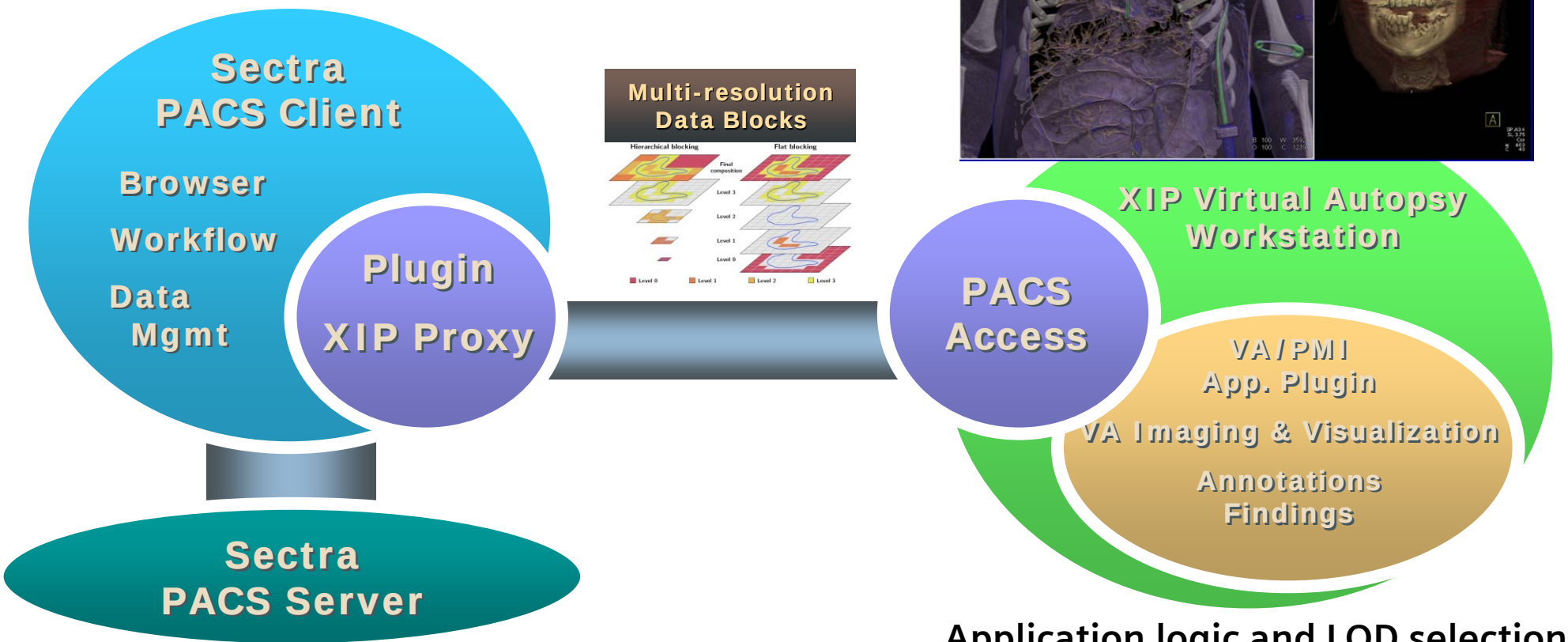
- Virtual Autopsy Workstation funded by Swedish government
- Uses full-body 0.3 mm dual-energy scans
- Linkoping Univ CMIV + Siemens + Sectra



Large data is on the back-end

Application logic and LOD selection is on the front-end

Recent New Features:
Integrated Performance Profiler

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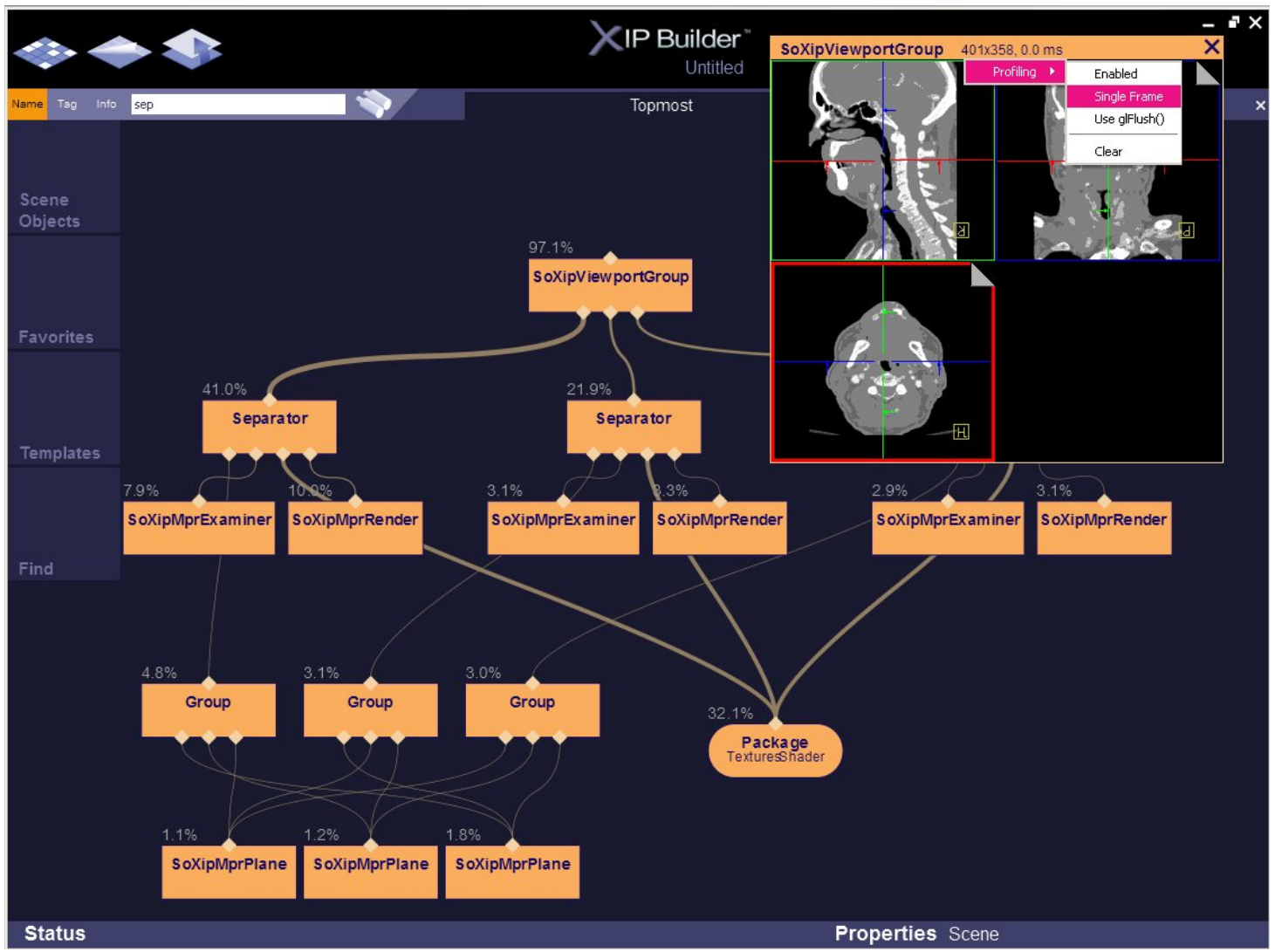
- **Visual representation of performance in order to easily identify bottleneck and optimize execution**



Recent New Features:
Automatic HTML Document Generation

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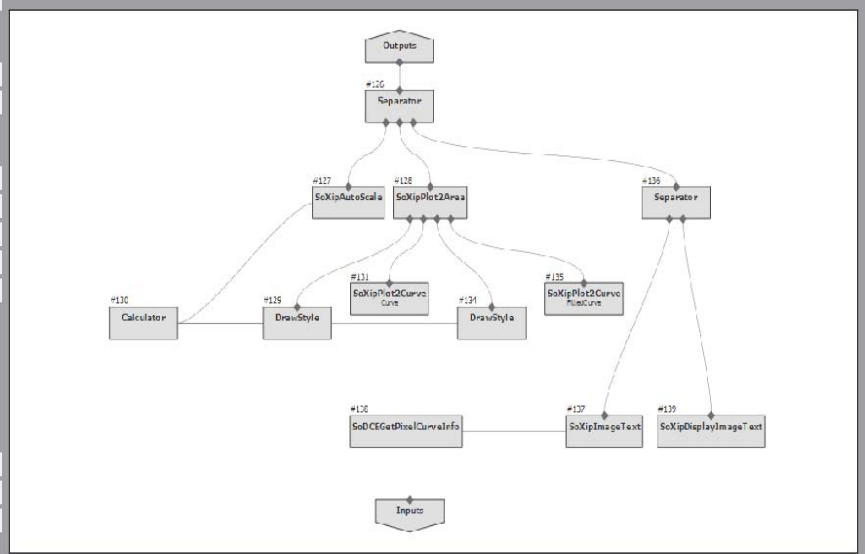
- Generates design documentation
- Can store/print requirement keys, class descriptions, connection diagrams

PLOT_ParametricPixelCurve

This package is responsible for displaying the pixel curve and corresponding fitted curve of a time series, given a coordinate. This coordinate can be either extracted via the pixel lens tool (interactive mode, uses a 1x1 kernel) or by picking (bigger kernel size allows for smoothing).

The point1 field holds the coordinate obtained via picking.

The point2 field holds the coordinate obtained via pixel lens.



#126 - Separator

The nodes #127, #128 and #136 are children of this group.

#127 - SoXipAutoScale

markerType	DIAMOND
markerColor	0 0.8 0
lineColor	0 0.8 0

#134 - DrawStyle

Field	Value
lineWidth	= *oa* @ #130

#135 - SoXipPlot2Curve "FittedCurve"

Field	Value
label	"Fit"
data	= *conc_fit* @ #132
markerColor	0 0.8 0
lineColor	0 0.8 0

#136 - Separator

The nodes #137 and #139 are children of this group.

#137 - SoXipImageText

Field	Value
position	TP_UPPER_CENTER
text	= *infoString* @ #138

#138 - SoDCEGetPixelCurveInfo

Field	Value
position	= *coordinate* @ #132
ktrans	= *ktransVal* @ #132
ve	= *veVal* @ #132
vp	= *vpVal* @ #132
chi2	= *errorVal* @ #132

#139 - SoXipDisplayImageText

PLOT_DynamicPixelCurve

Recent New Features:
CUDA-based High-Performance Computing

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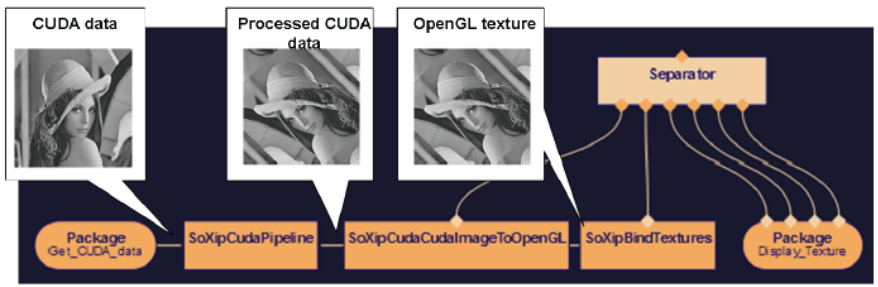
- Introduced at MICCAI HPC Workshop 2008 (V. Giden, P. Ljung, G. Paladini, T. Moeller)
- Currently adding: Global Memory Management for both CUDA and Texture memory;

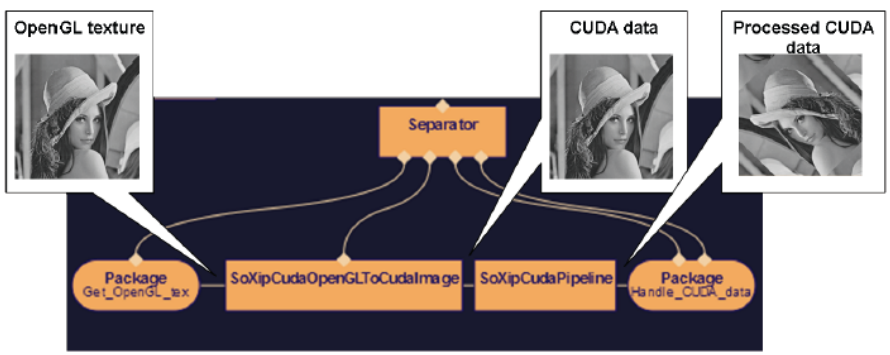
  3D texture processing; collection of CUDA-accelerated algorithms (distance transf., PDE solver, non-linear diffusion filtering, etc.)

nVidia Tesla C1060 – 0.9 TERAFLOPS

nVidia Tesla S1070 – 4 TERAFLOPS



(a) Output data from the pipeline engine is used to create OpenGL textures.



(b) OpenGL textures are used to create CUDA data which is processed by kernels in the pipeline engine.

Recent New Features:
View and Control Scene Graph with HTML/JavaScript

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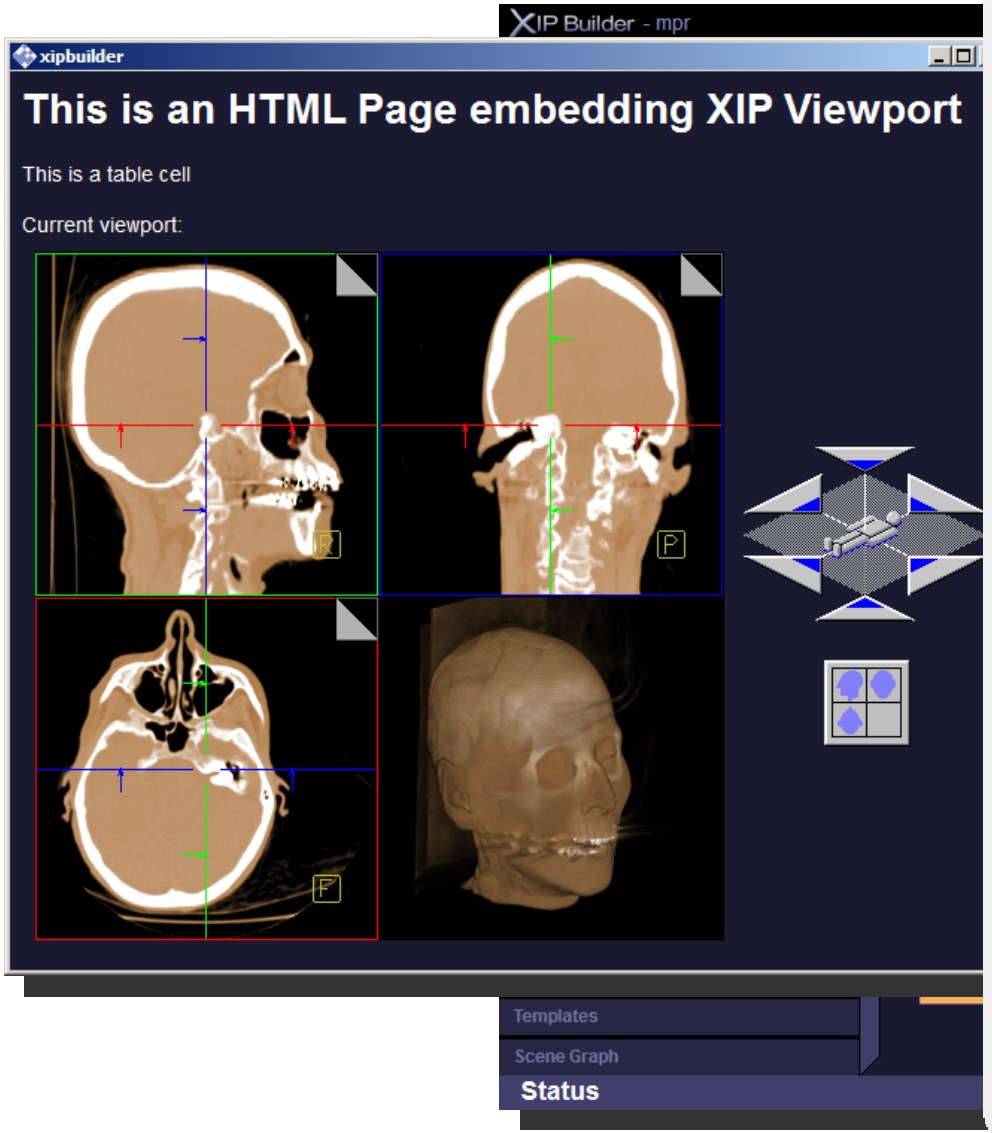


```
<script>
  widget.connectJSSlot('stateChanged(const QString &, const QSt

  window.onStateChanged = function onStateChanged(p, v)
  {
      if (v == 'RenderArea.current')
      {
          document.getElementById('output').innerText = "Current
      }
  }

  function onLoad()
  {
      setParam('AddFieldSensor', 'RenderArea.current');
  }
  function setParam(p, v)
  {
      widget.setParam(p+","+v);
  }

  function onSetOrientation(orient)
  {
      var c = widget.getParam('RenderArea.current');
      setParam('MprExaminer' + c + '.orientation', orient);
      setParam('MprExaminer' + c + '.viewOrientation', '');
      setParam('MprExaminer' + c + '.viewAll', '');
  }
  function onOrientationDefault()
  {
      setParam('MprExaminer0.orientation', 'FEET');
      setParam('MprExaminer0.viewOrientation', '');
      setParam('MprExaminer0.viewAll', '');

      setParam('MprExaminer1.orientation', 'RIGHT');
      setParam('MprExaminer1.viewOrientation', '');
      setParam('MprExaminer1.viewAll', '');
```

Recent New Features:
Support for Qt UI Designer, Qt JavaScript, Python Script

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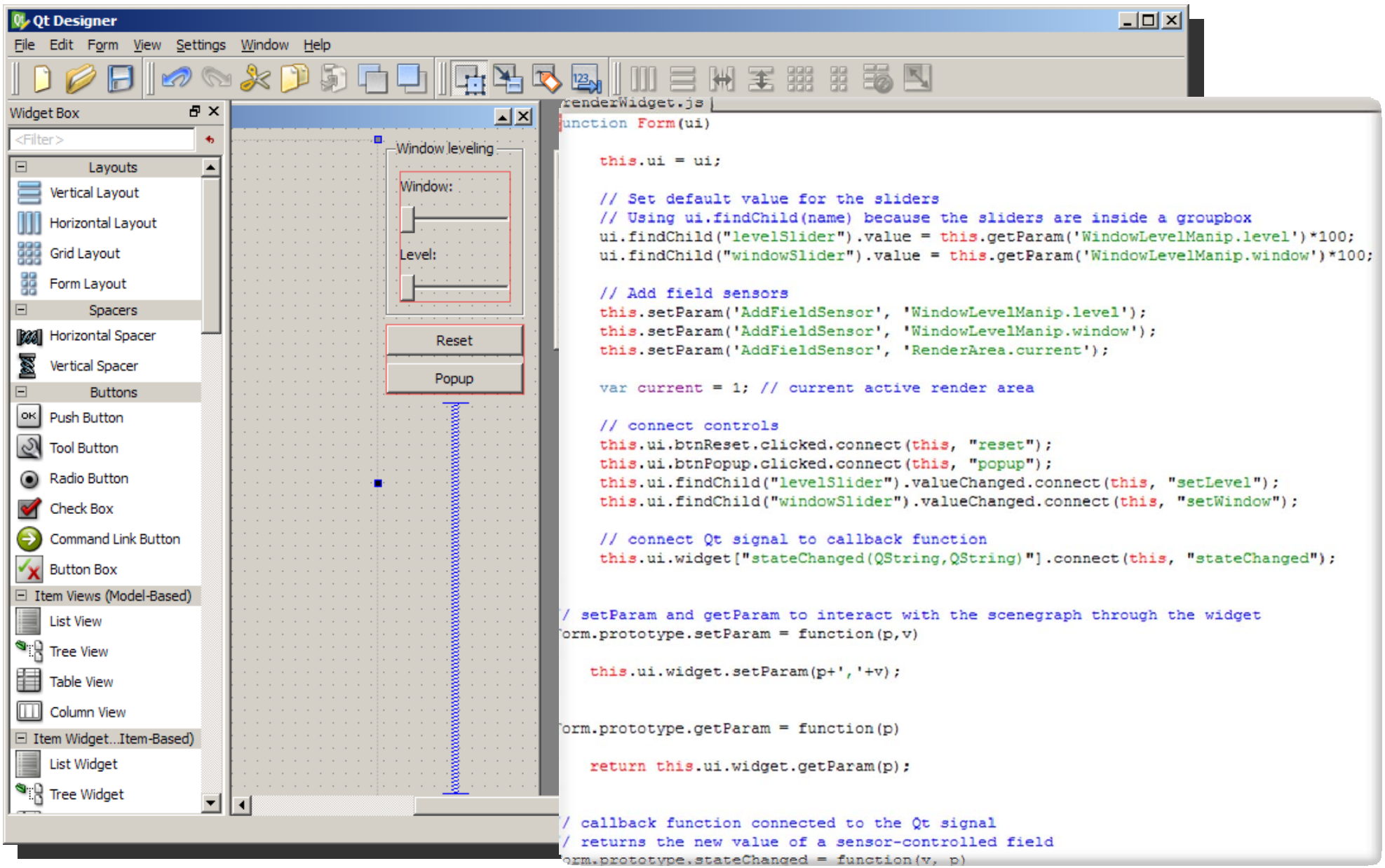

Recent New Features:
Example of XIP volume rendering inside 3D Slicer

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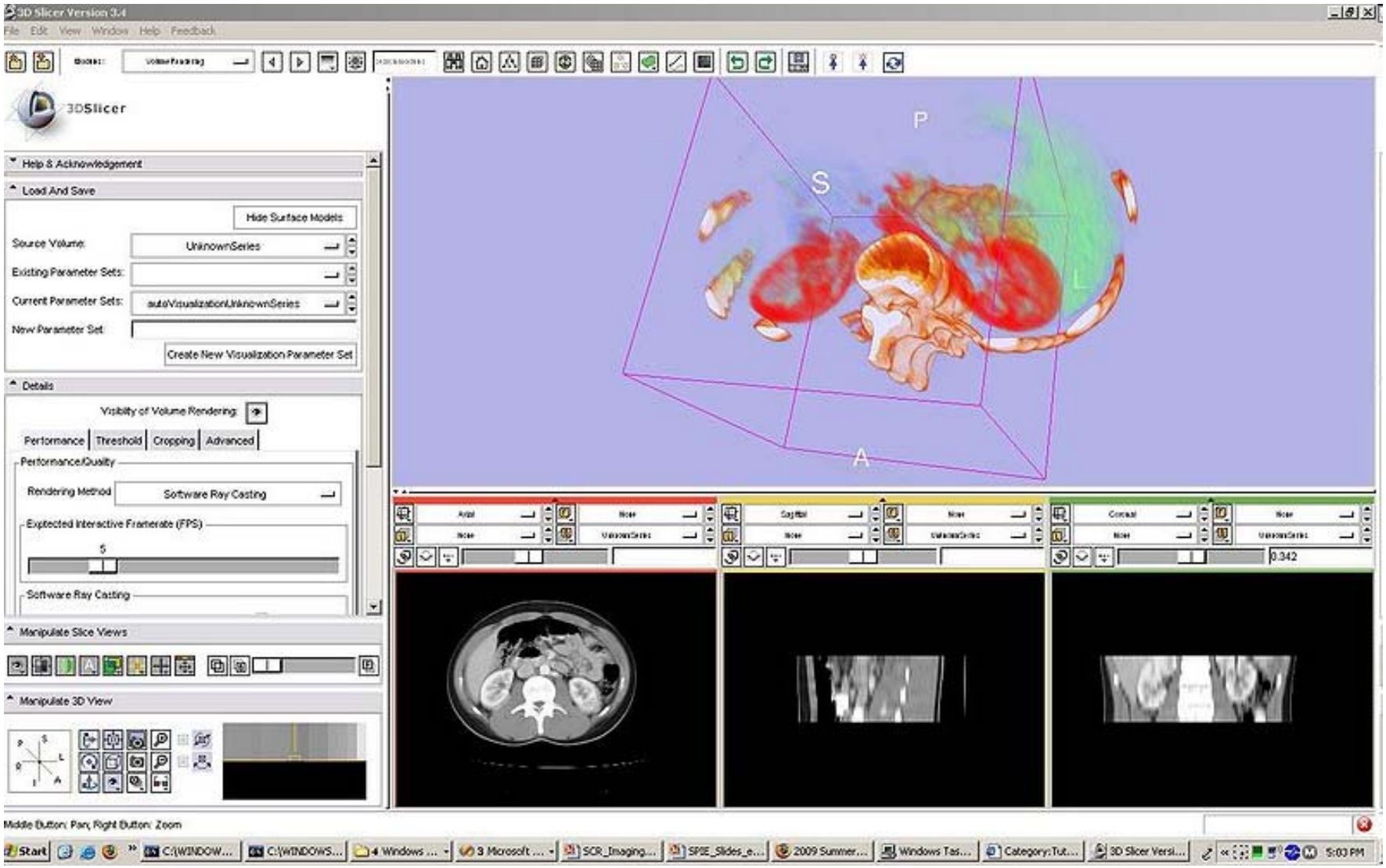

XIP Automatic Test Cases

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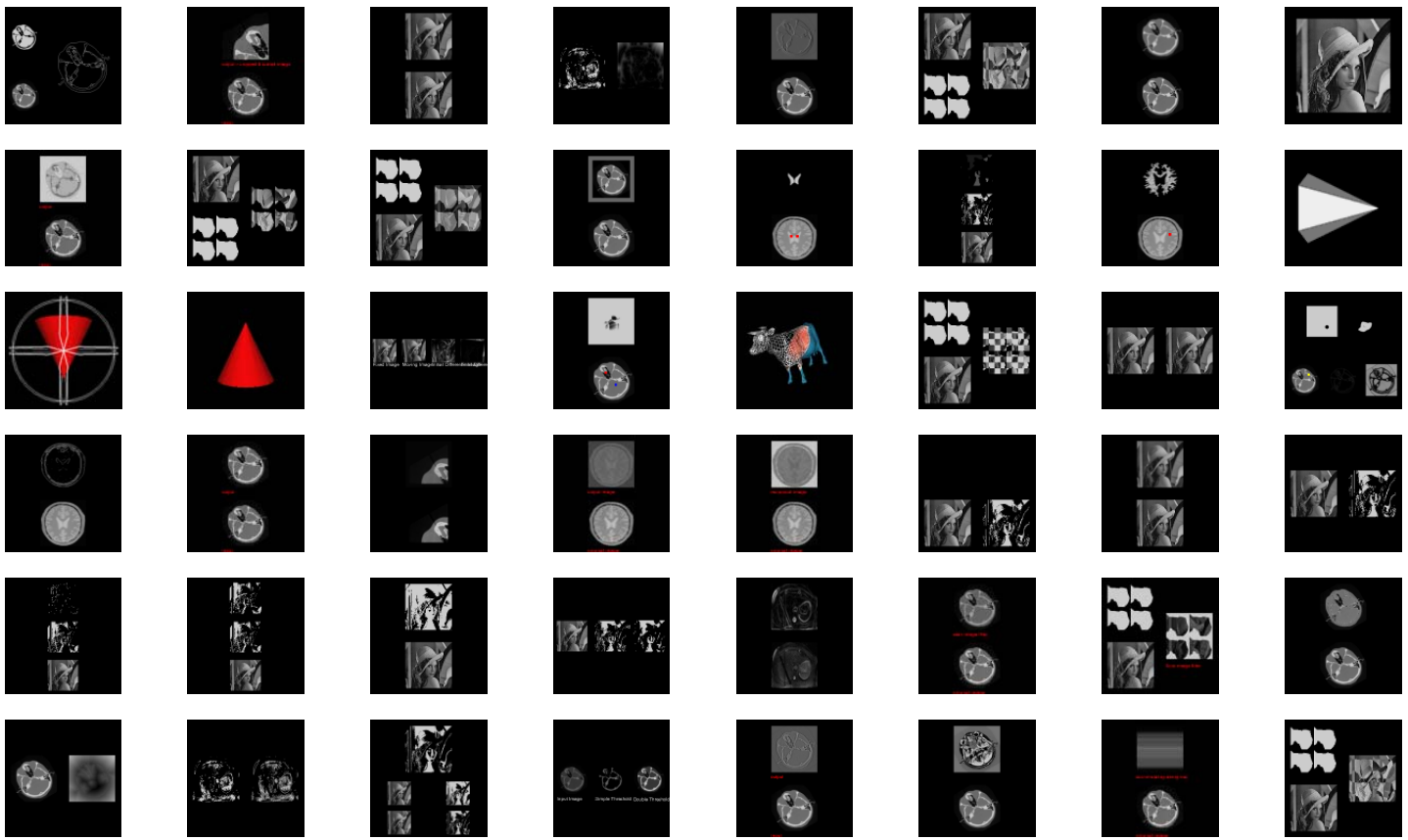
- XIP Builder tool can run and execute programs in Batch Mode
- Command Mode syntax makes it possible to vary parameter values in order to create tests that validate XIP libraries
- 100's of tests already available



XIP Wiki Site for Imaging Framework

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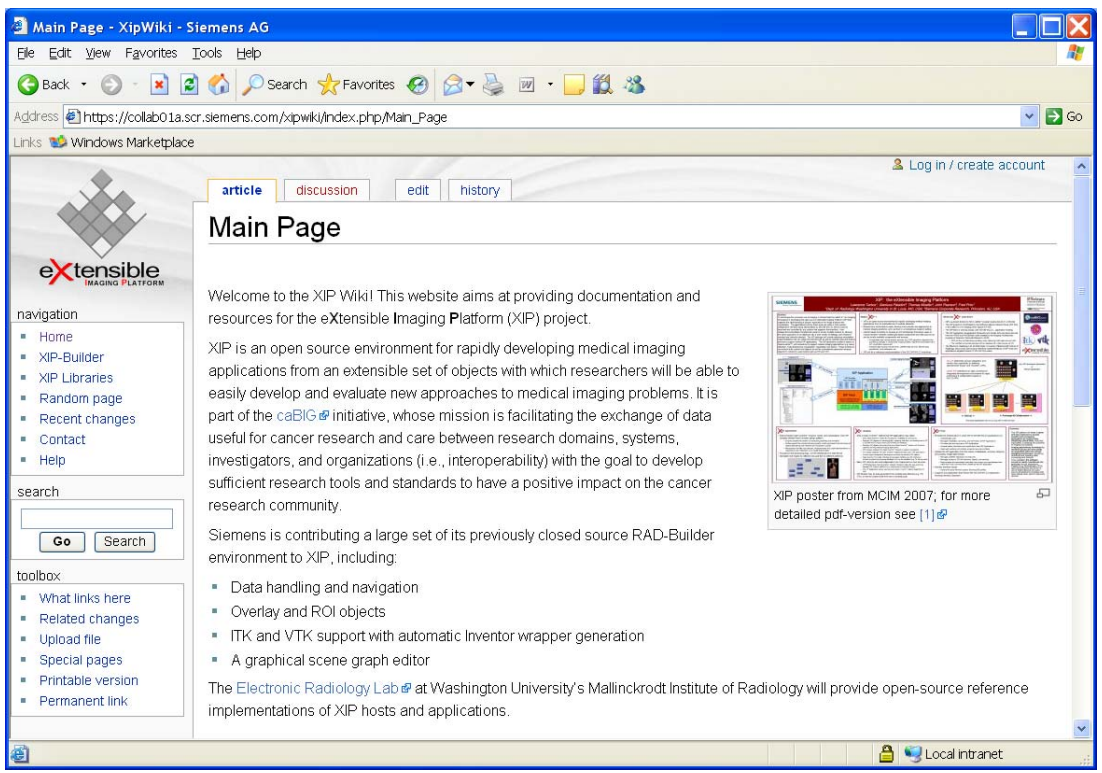
- Wiki is available at https://collab01a.scr.siemens.com/xipwiki/index.php/Main_Page
- Main web site for documentation, tutorials, reference help
- Clicking on any objects in XIP Builder and pressing F1 pop-us an online help page for such object
- Wiki allows caBIG developers to document their own objects in a central repository



XIP GForge Site

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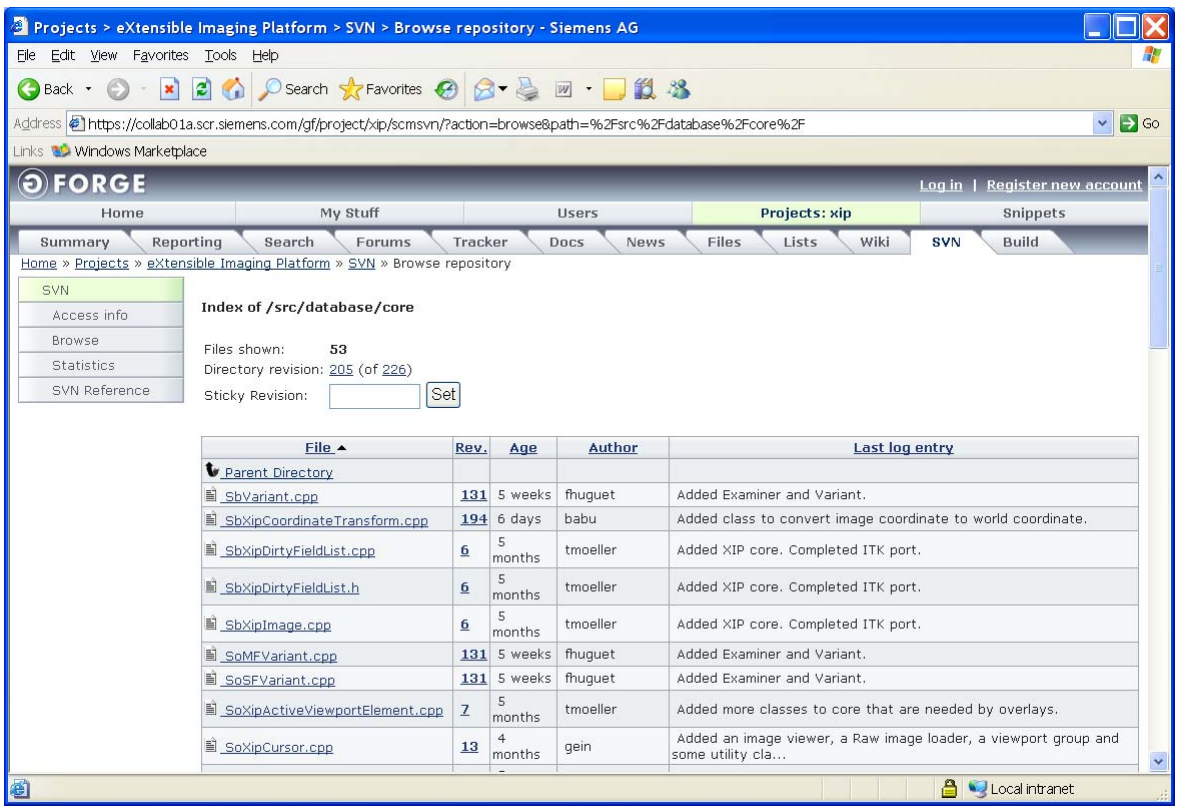
- GForge developer's site can be accessed via the XIP Wiki
- Main web site for daily source code development and latest installation packages
- Stable, frozen releases are mirrored into caBIG's GForge site
- Provides SVN-based repository, forum, bug tracking tool, Cmake automated builds, Dashboard



Boost in Productivity

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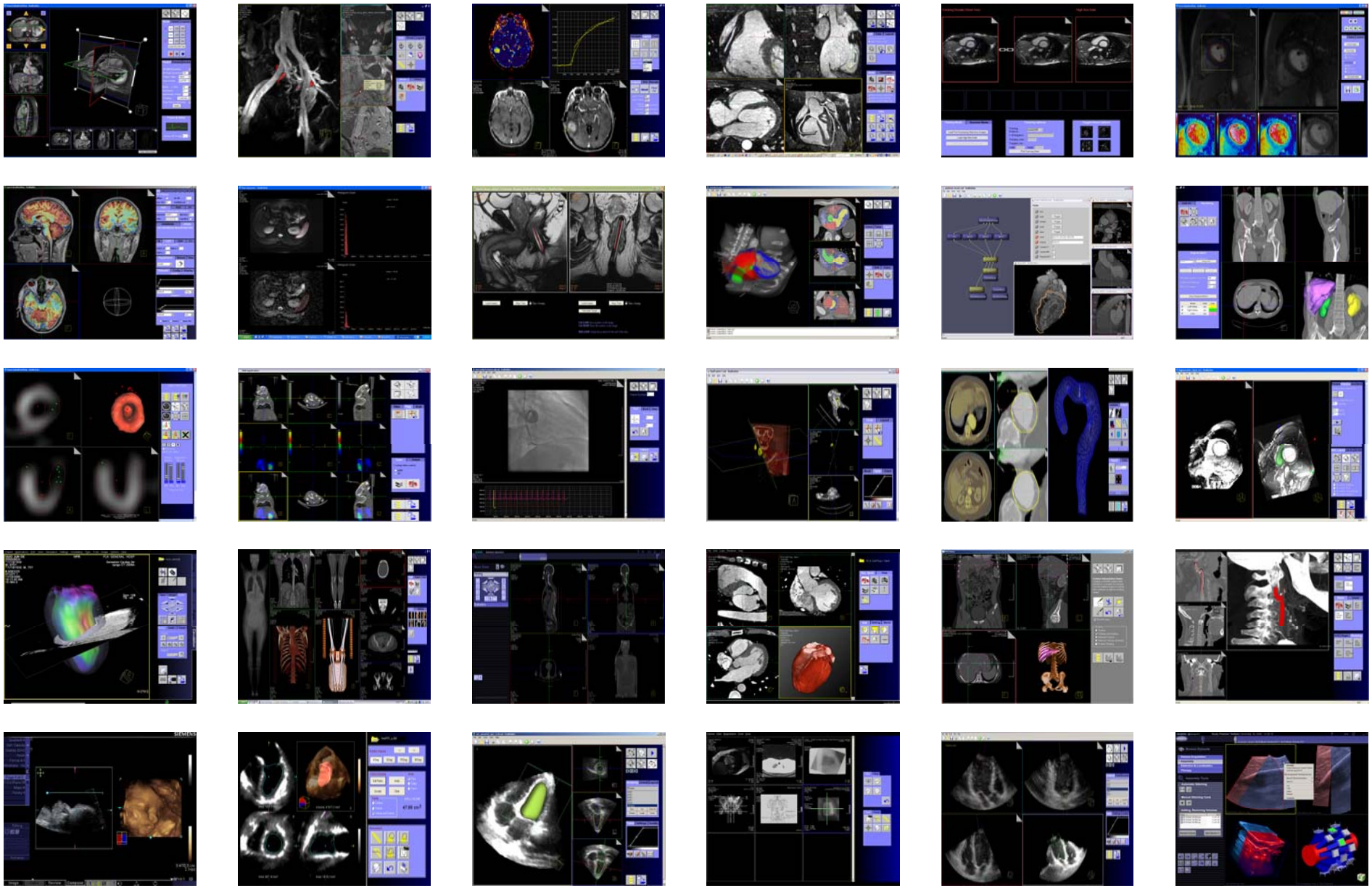
More than 30 clinical prototypes/year based on XIP Builder



Demonstrated Value of Open XIP Platform

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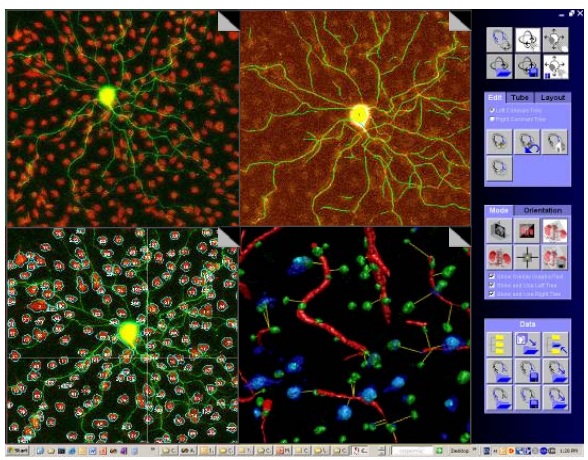
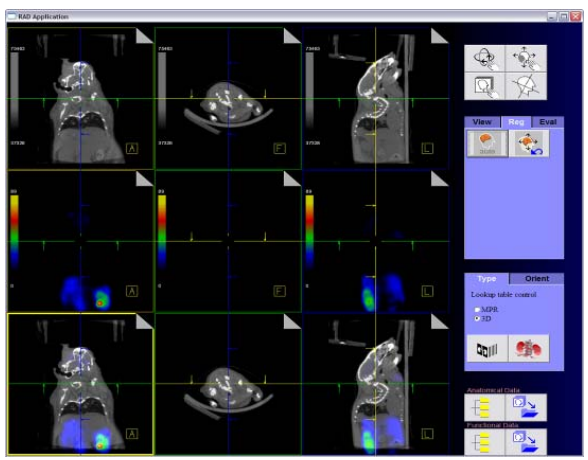
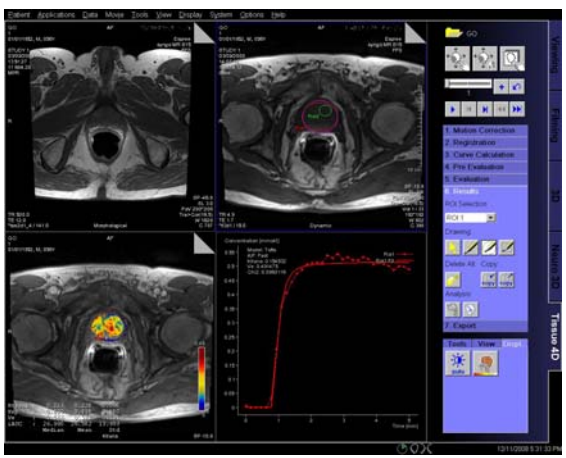
Some ongoing projects based on Open XIP – Government & Academia

- caBIG Open Source imaging libraries and XIP Builder Tool
- caBIG AVT Project (Algorithm Validation Toolkit)
- DoD TATRC/ACR's Interoperability in Medical Imaging
- DARPA deep-bleeder acoustic coagulation
- Beth Israel Intraoperative Fluorescent Imaging
- NTROI Optical Imaging for Drug Therapy Monitoring
- caBIG AIM Project (Annotation Imaging Markup based on XIP) - Northwestern Univ.
- UPENN prostate cancer multi-resolution histopathology fused with MR







In Vitro → Pre-Clinical → In Vivo

XIP for the Dept of Defense:
Congressional Project led by ACR

ACR AMERICAN COLLEGE OF RADIOLOGY

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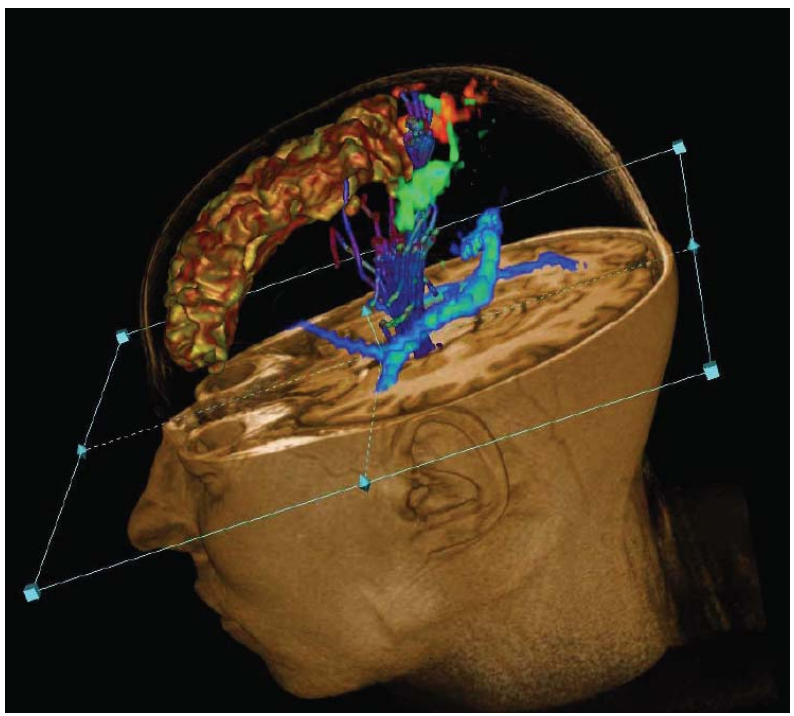
- Soldiers frequently suffer from types of injuries that are rare for civilians, e.g., Traumatic Brain Injury (TBI) from Improvised Explosive Devices (IEDs)
- DOD Healthcare needs the ability to rapidly field vendor interoperable imaging solutions for such unique problems. ACR/SCR are working with the Army (TATRC) and the Navy (NNMC) to demonstrate that XIP & WG23 can meet these needs
- This project will leverage XIP and Qt's cross-platform compatibility and will deliver a TBI application running on Mac OS X
- MR anatomy, connectivity map, diffusion tracts, fMRI activation, segmented surfaces



XIP and caBIG Algorithm Validation Tools (AVT)

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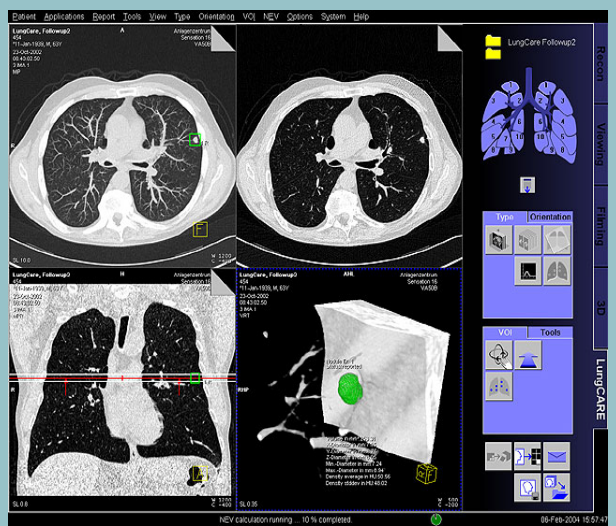
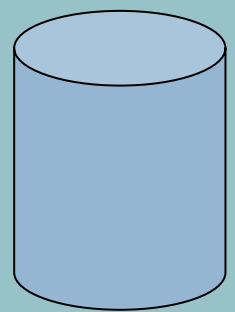
Image Analysis & Annotation



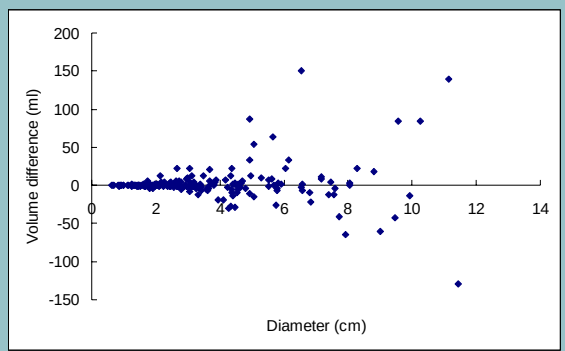
- Measure/annotate tumors with XIP

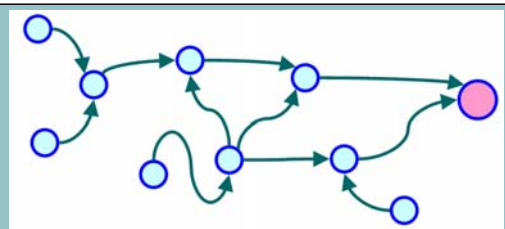
Assessment Database



- Captures Annotations & Provenance Data

Measurement Validation





- Computes measurement statistics and correlations between metrics and outcomes

- ***XIP is the foundation of other caBIG tools, including AVT, which will be used to validate tumor change quantification algorithms for clinical trials***

Enabling Imaging Support Across the Biomedical Value Chain

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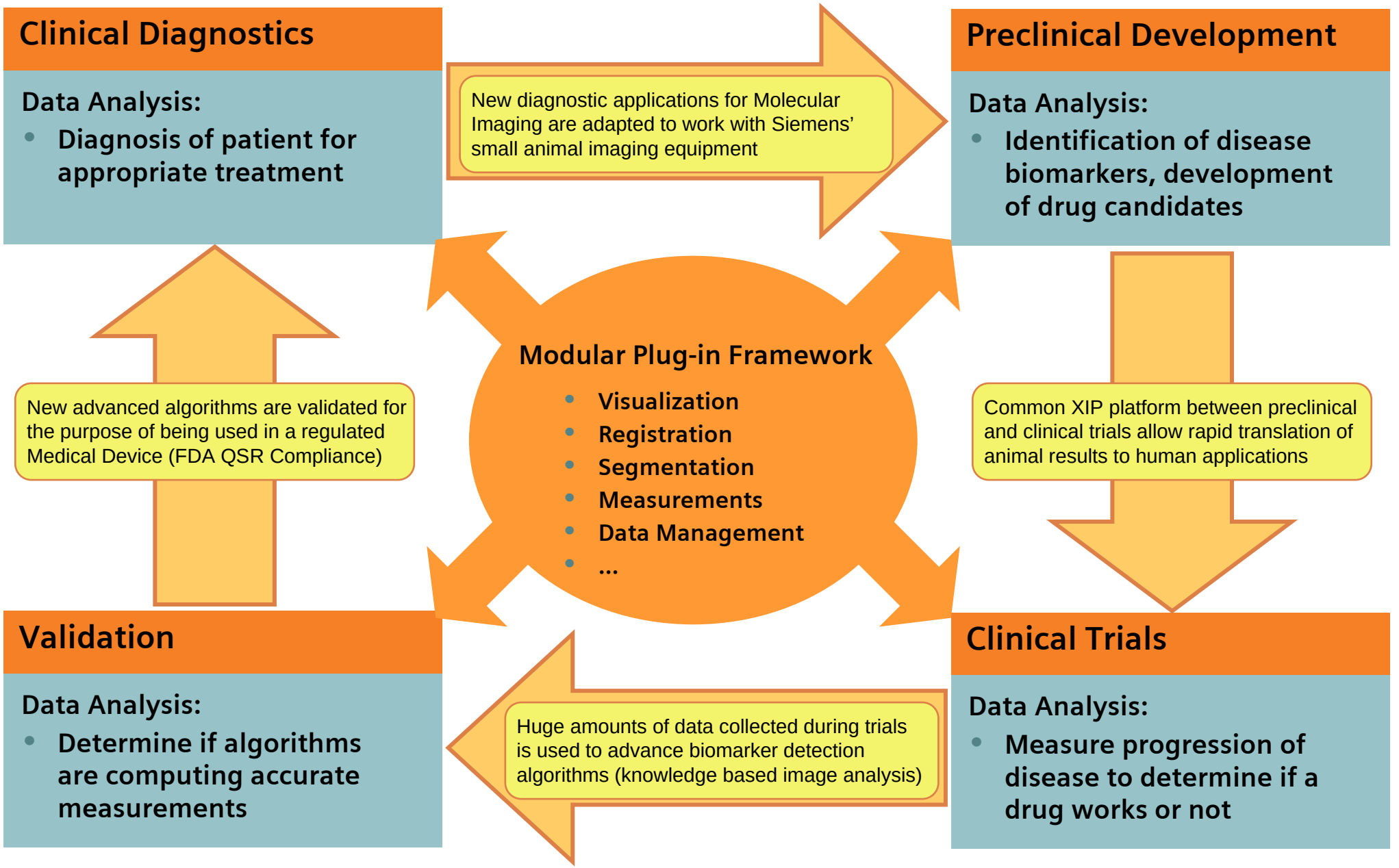

Thank you for your attention!

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