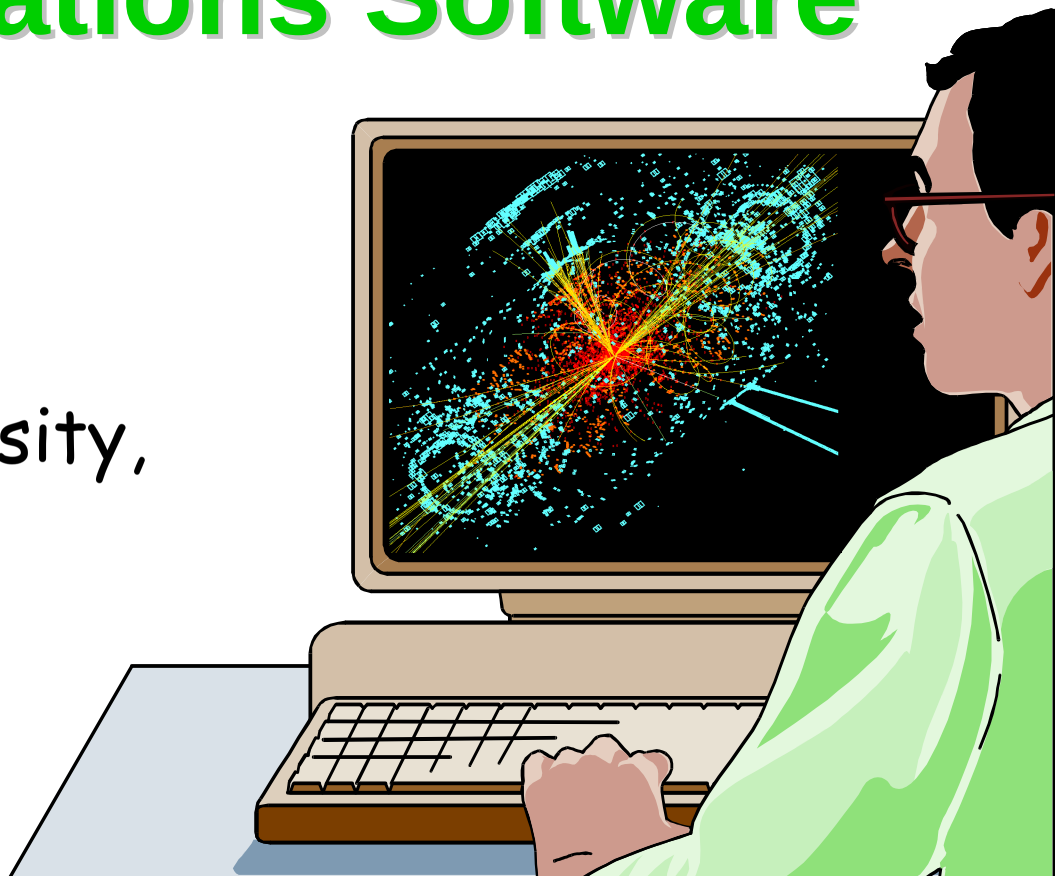
DOE / NSF Review of US CMS Software & Computing

Brookhaven National Laboratory, 14 November 2000

Breakout Session
WBS Item 2
Core Applications Software



Lucas Taylor

Northeastern University,
Boston

US CMS Core Applications Software (WBS item 2)

1	User Facility (UF)
2	⊟ Core Application Software (CAS)
2.1	⊟ Software Architecture
2.1.1	Overall Achitecture and Framework
2.1.2	⊞ Subsystem Architectures
2.1.3	⊞ CMS architecture forum and evaluation (CAFÉ)
2.2	⊟ Interactive Graphical User Analysis (IGUANA)
2.2.1	⊞ Graphical User Interface
2.2.2	⊞ Detector&Event Visualisation
2.2.3	⊞ Interactive Analysis and Presentation
2.2.4	⊞ IGUANA Infrastructure
2.3	⊟ Distributed Data Management and Processing
2.3.1	⊞ Distributed Process Management
2.3.2	⊞ Distributed Database Management
2.3.3	⊞ Load Balancing
2.3.4	⊞ Distributed Production Tools
2.3.5	⊞ MONARC
2.4	⊞ Support

Talks by: Lucas Taylor (Northeastern)

Talks by: Ian Fisk (UCSD)

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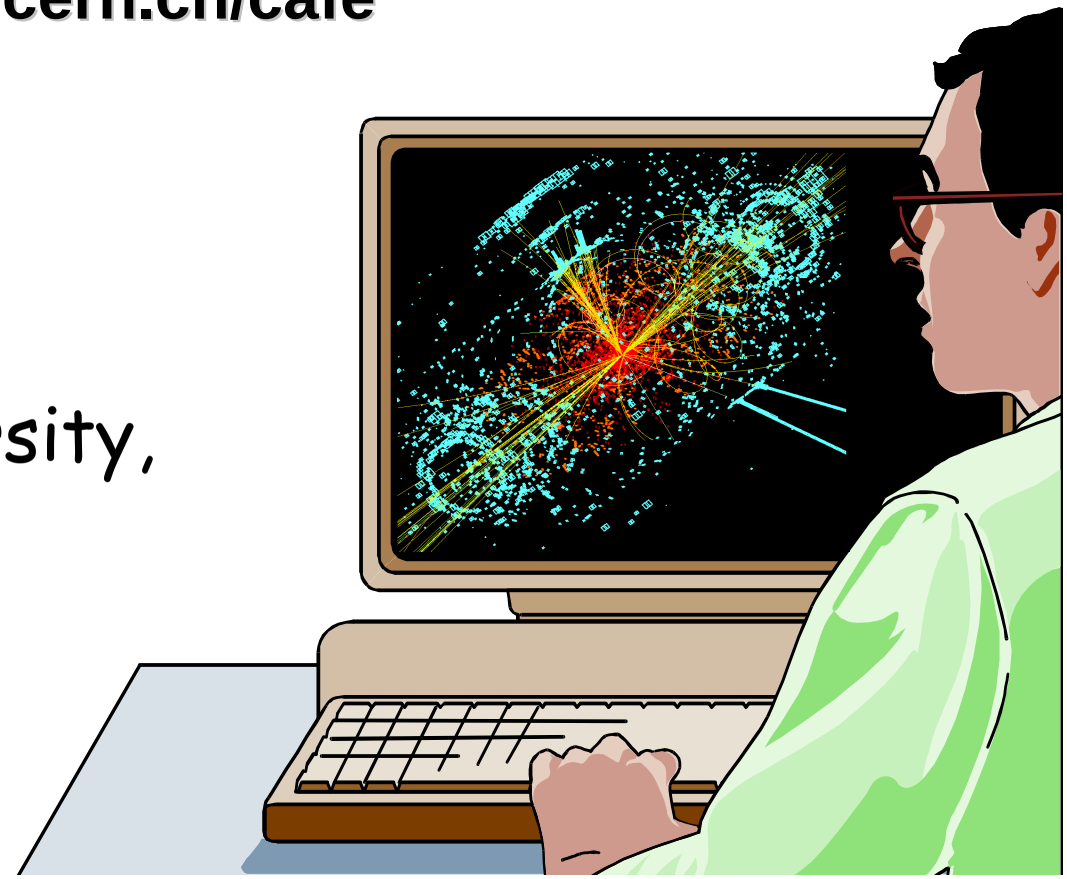
WBS Item 2.1
Software Architecture

http://cern.ch/cafe



Lucas Taylor

Northeastern University,
Boston

CAS WBS 2.1
Software Architecture

No US resources (yet) assigned

Detector Description architecture (UC Davis)

Calorimetery architecture (Caltech)

Tracking / Muon architecture (FNAL)

Analysis architecture (Northeastern)

Architectural Documentation (Northeastern)

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2.3	⊞ Distributed Data Management and Processing
2.4	⊞ Support

CAS WBS 2.1.2 Software Sub-Architectures

- **2.1.2.1 Detector Description Architecture**
  - Creation of system for single detector description for CMS
  - Must support multiple views required such as engineering (CAD), full simulation (GEANT4), fast simulation (FAMOS), reconstruction (ORCA), visualization (IGUANA)
  - Design and first prototype by March 2000
  - Will be led by UC Davis engineer
- **2.1.2.2 Simulation sub-architecture**
  - Place-holder (no core US responsibilities as yet)
- **2.1.2.3 Reconstruction sub-architecture**
  - Ensure coherence of overall designs and implementations
  - Work with physicists on ORCA
  - First step is documentation (by March 2000)
  - Participation of Caltech (Calorimetry) and FNAL (Tracker/Muon) and Quality Assurance and testing (Princeton)

These tasks will all be started by January 2001

CAS WBS 2.1.2 Software Sub-Architectures

- **2.1.2.4 Analysis sub-architecture**

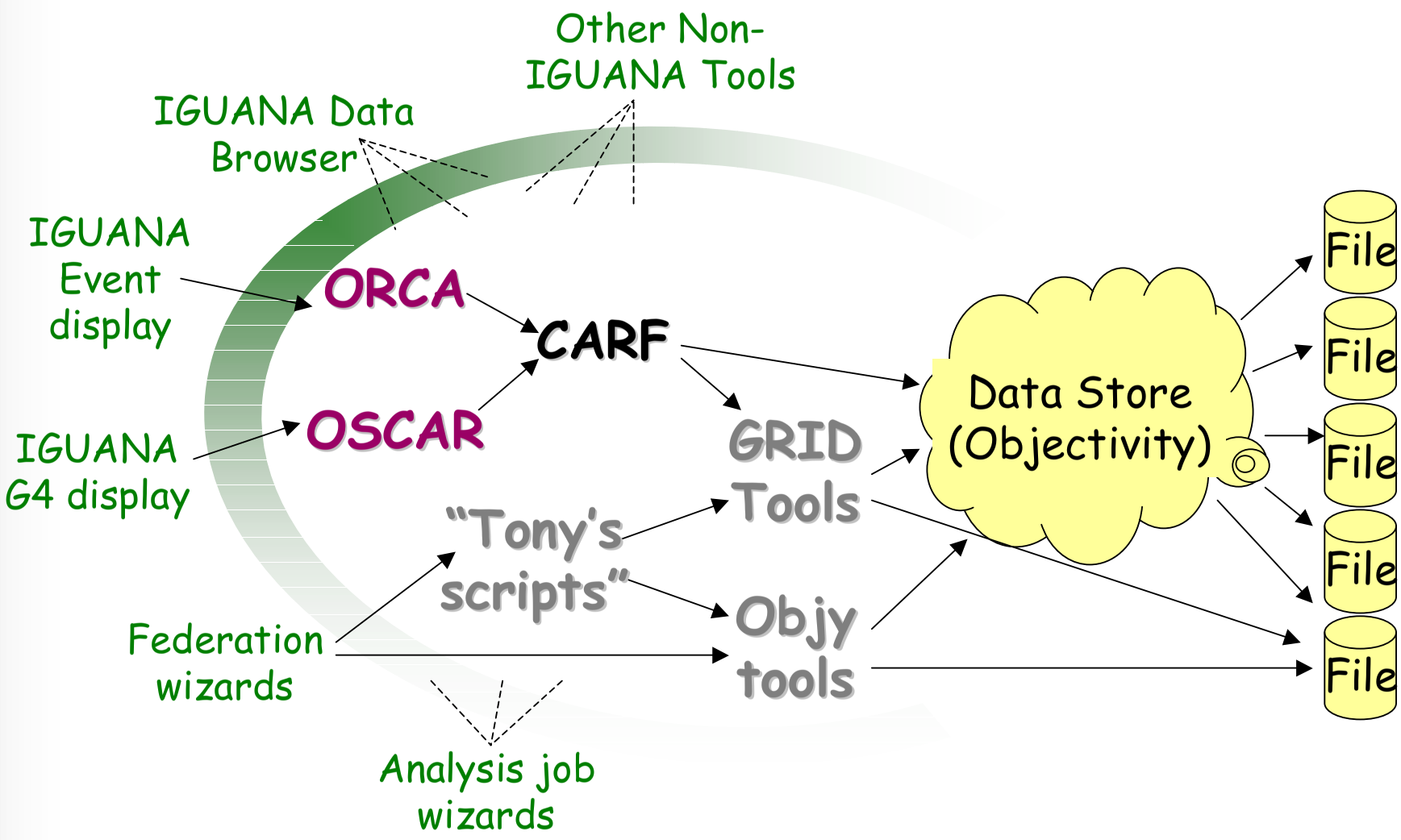
- Analysis is a lot **more than just the interactive tool**
- A great range of user activities with fuzzy boundaries beyond interactive analysis and data presentation

  Batch, interactive, scripting, setting up applications, frameworks and configuration management tools, data store operations (replicating entire data stores; copying runs, events, event parts between stores; not just copying but also doing something more complicated—filtering, reconstruction, analysis, …), browsing data down to object detail level, 2D and 3D visualisation, moving code across final analysis, reconstruction and triggers, and so on…

Today this involves (too) many tools

CAS WBS 2.1.2 Software Sub-Architectures

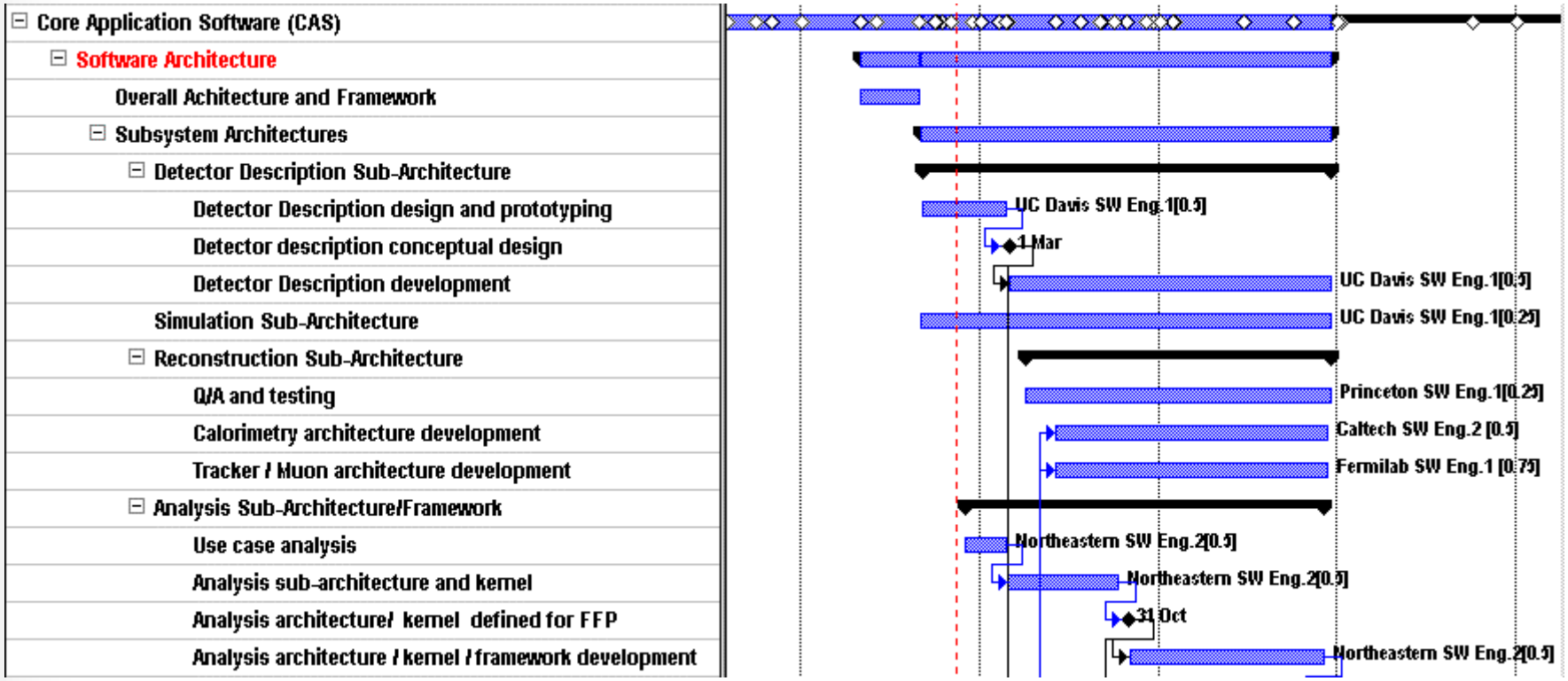
- **2.1.2.4 Analysis sub-architecture**



CAS WBS 2.1.2 Software Sub-Architectures

- **2.1.2.4 Analysis sub-architecture**
- Strategy:
  - Understand existing and new use cases and requirements (close links with Café and other CMS teams: CARF, IGUANA, ORCA,...)
  - Integrate with core frameworks (especially CARF) and grid middleware
  - Integrate with IGUANA interactive visualization and generic user analysis components
- First step:
  - Re-model some of the federation tools developed for ORCA (by US engineers) and existing IGUANA components (by US engineers) into a single coherent architecture

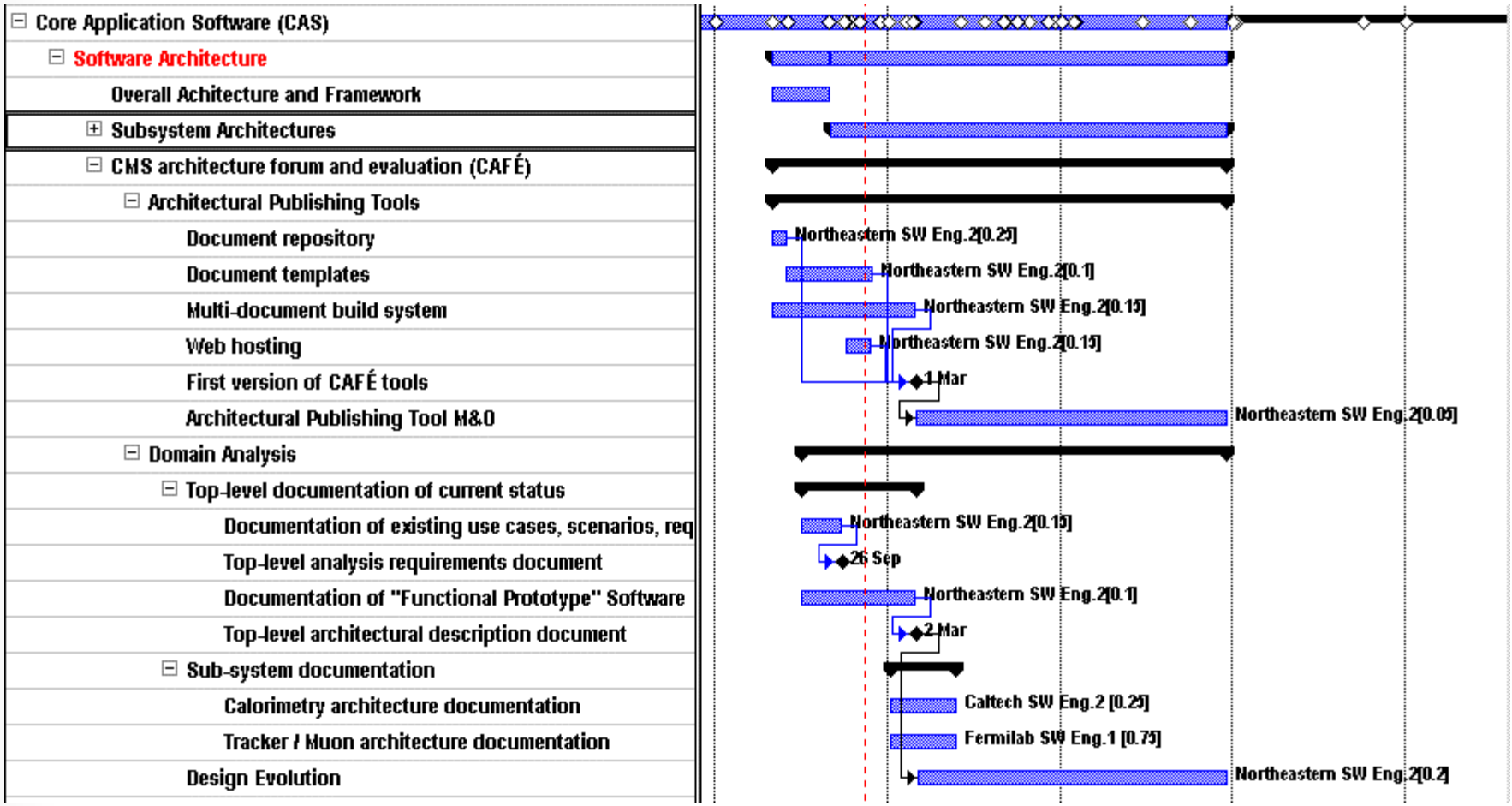
CAS WBS 2.1.2
Software Sub-Architectures



CAS WBS 2.1.3 Café project (CMS Architecture Forum and Evaluation)

- **New CMS project with US leadership (Northeastern)**
- Aims to document current CMS software architecture
  - Help to understand it and communicate to developers/users
  - Starting point for future evolution
- **First deliverable**: a set of tools to manage a complicated suite of documents
  - use-cases, requirements, technologies, choices made, designs, plans, lessons learnt, …
  - Different "views" or slices through the information
  - Complex hyper-linking problem solved with XML technologies
- Common infrastructure available to any CMS software
- **First version of the Café documents and associated system delivered by Northeastern engineer**

CAS WBS 2.1.3 Café project (CMS Architecture Forum and Evaluation)



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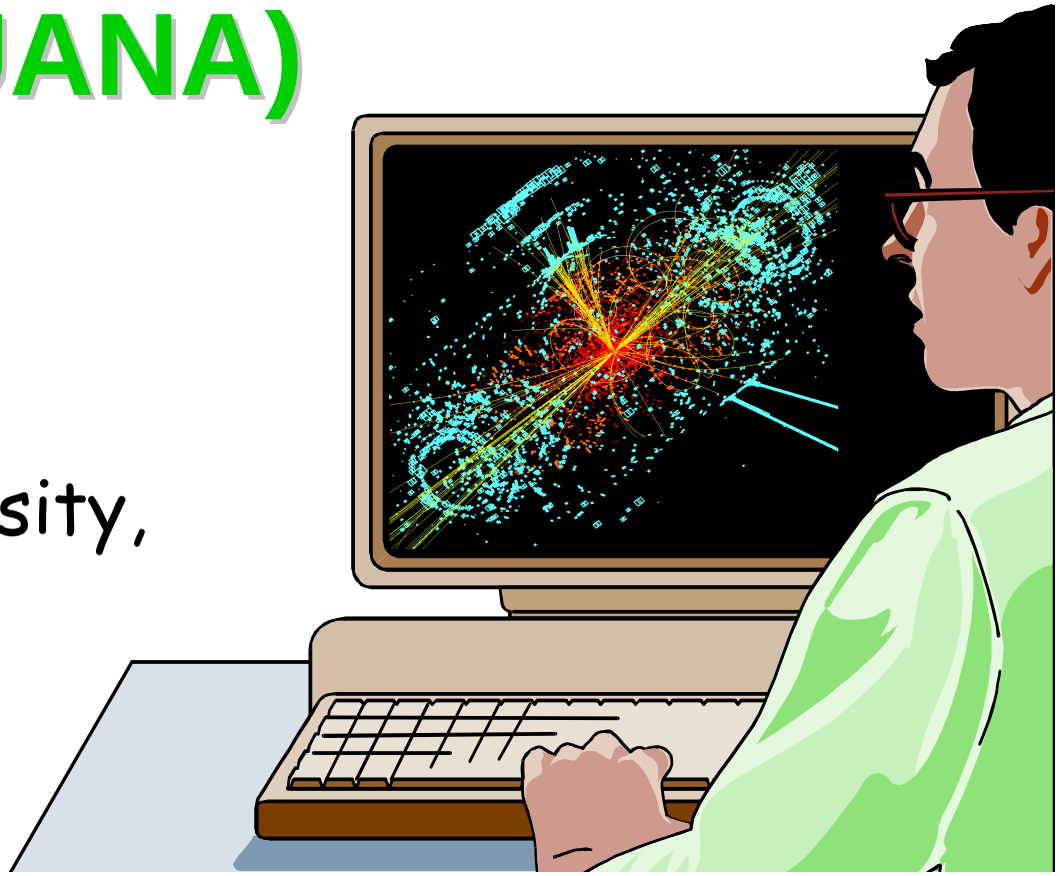
WBS Item 2.2

Interactive Graphical User Analysis (IGUANA)

http://iguana.cern.ch



Lucas Taylor

Northeastern University, Boston

CAS WBS 2.2 IGUANA Mission Statement

- The IGUANA software project addresses interactive visualisation software needs for three domains:
  - **graphical user interfaces (GUI's);**
  - **interactive detector and event visualisation**; and
  - **interactive data analysis and presentation;**

for use in a variety of areas such as offline simulation and reconstruction, data analysis, and test beams.

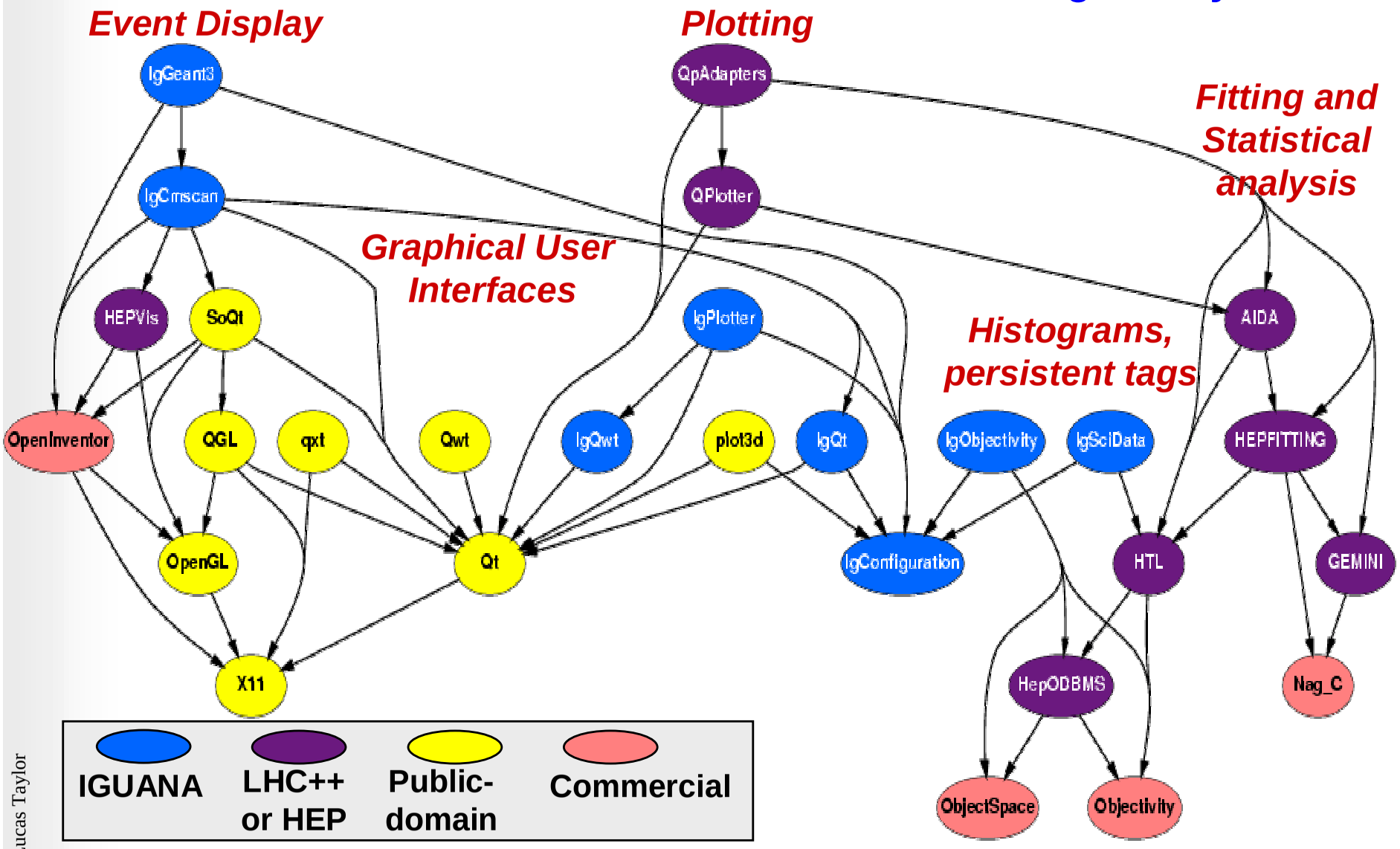
- Tasks include the assessment of use-cases and requirements and the **evaluation, integration, adaptation, verification, deployment, and support** in the CMS environment of visualization software from **HEP, academia, the public domain, and the commercial sector**.
- Pre-existing software is exploited as much as possible to optimize the use of the resources available.

CAS WBS 2.2
IGUANA General Strategy

- Focus on a **sustainable medium to long-term strategy**
- Provide a **general set of tools** (not single application)
  - for a wide variety of applications and environments
  - for both experienced developers and non-expert users
- Strong emphasis on **modularity** and use of **standards**
  - to address the issues of scalability, maintenance, deployment, support, long-term evolution,…
- Pro-actively exploit **software developed elsewhere**
  - For example…
    - HEP (e.g. HTL, HepODBMS, HEPVis, Lizard,…
    - Public domain (e.g. Qt GUI + extensions, MESA OpenGL,…)
    - Commercial (e.g. OpenInventor, NAG_C, …)
  - IGUANA work involves evaluation, integration, and support as well as developing extensions and CMS-specific software

CAS WBS 2.2 IGUANA Related Software Modules

Note: dependency analysis performed using the IGUANA Ignominy software



CAS WBS 2.2 IGUANA
Functional Prototype Milestone

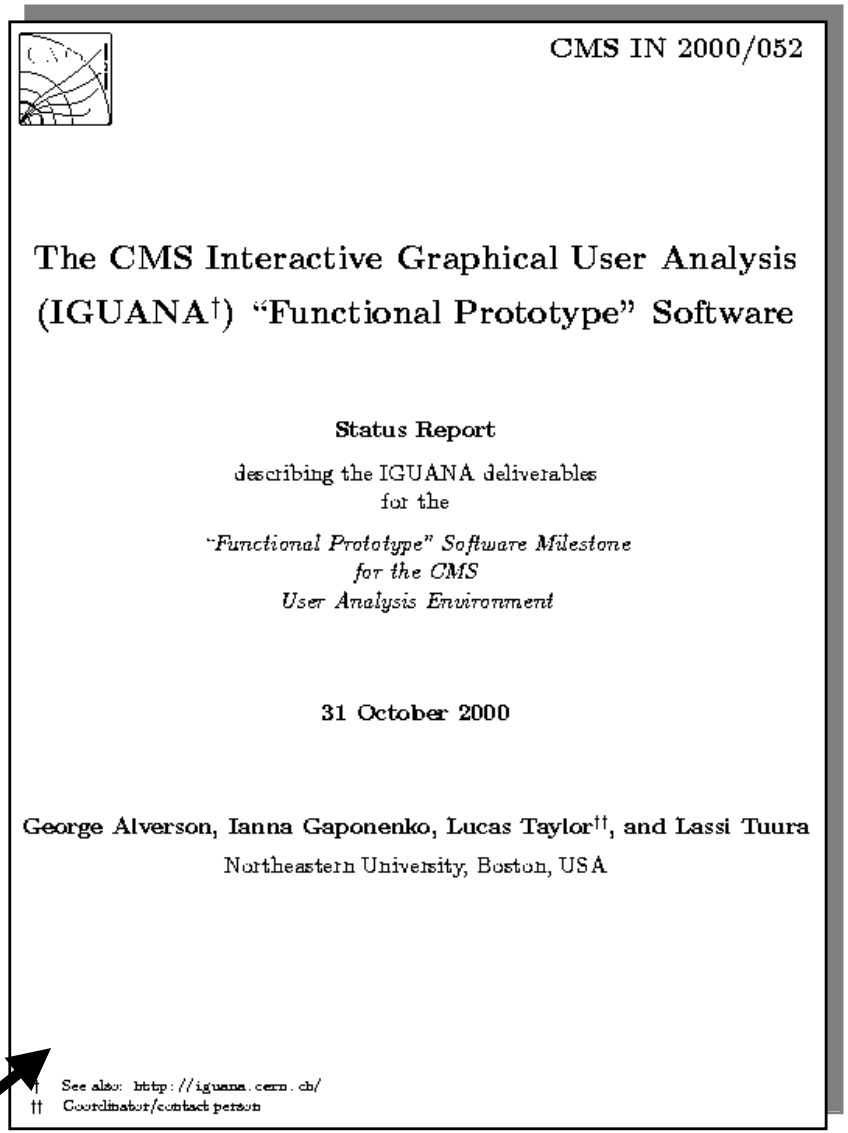
CMS MILESTONES	1998	1999	2000	2001	2002	2003	2004	2005
CORE SOFTWARE								
End of Fortran development	Jun-98							
GEANT4 simulation of CMS	1 Jun-98	2	Dec-99	3 Jun-01		4	Dec-03	
Reconstruction/analysis framework	1 Jun-98	2	Dec-99	3	Dec-01	4	Dec-03	
Detector reconstruction	1	Dec-98 2	Dec-99		3	Jun-02	4	Jun-04
Physics object reconstruction		1 Mar-99	2	Jun-00		3 Dec-02	4	Dec-04
User analysis environment	1	Dec-98	2	Jun-00		3 Dec-02	4	Dec-04

1 Proof of concept
2 Functional prototype
3 Fully functional
4 Production system

- Milestone was delayed from June 2000 to **October 2000**
  - Shortage of professional software engineering manpower
  - Alignment with 1st release of CERN Lizard interactive analysis
- This **milestone is satisfied** (imminent release of IGUANA 2.2.0)
- Now is the **time for reflection** and **future planning**
  - Document what was learned and current software (almost complete)
  - Broad discussion of where we are going, priorities,…

CAS WBS 2.2 IGUANA "Functional Prototype" Deliverables

- Documented **requirements**
- Set of Software **Prototypes, Packages, & Documentation**
- **Software Infrastructure**
  - repository, multi-platform build, release, distribution, and documentation systems.
- Proposal for a **Baseline set of Technologies**
- Proposed **Project Evolution Plan**



CMS IN 2000/052

The CMS Interactive Graphical User Analysis (IGUANA†) "Functional Prototype" Software

Status Report

describing the IGUANA deliverables for the

"Functional Prototype" Software Milestone for the CMS User Analysis Environment

31 October 2000

George Alverson, Ianna Gaponenko, Lucas Taylor††, and Lassi Tuura

Northeastern University, Boston, USA

† See also: http://iguana.cern.ch/

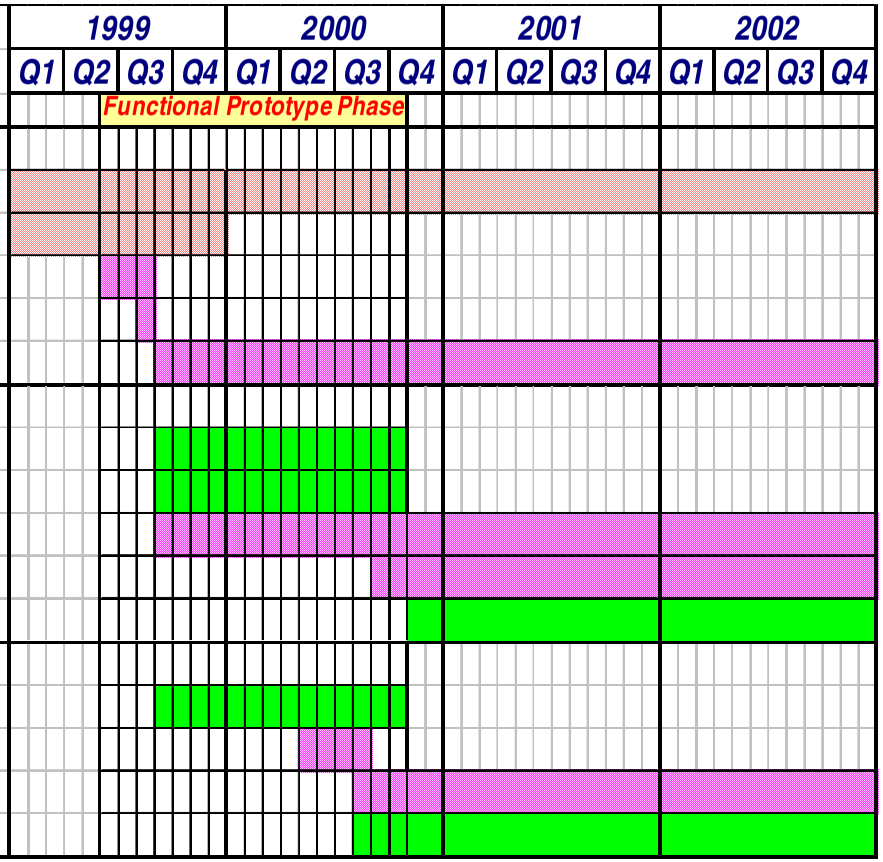
†† Coordinator/contact person

See "Additional background documentation"

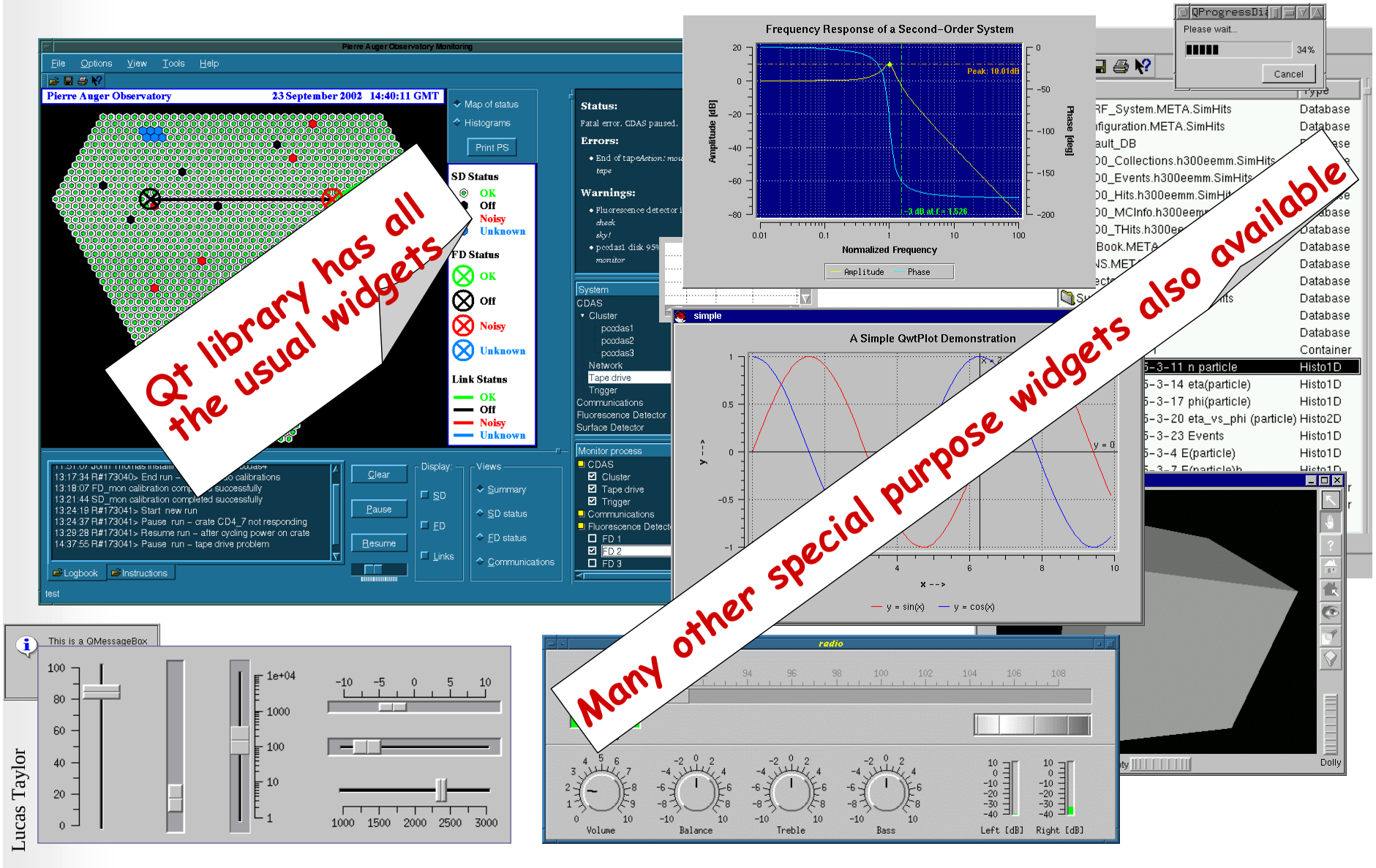
CAS WBS 2.2.1
Graphical User Interface

- IGUANA evaluation and prototyping with emphasis on
  - OO design, C++ API, and standards (facilitates integration)
  - Functionality, extendibility, widespread adoption, support,…

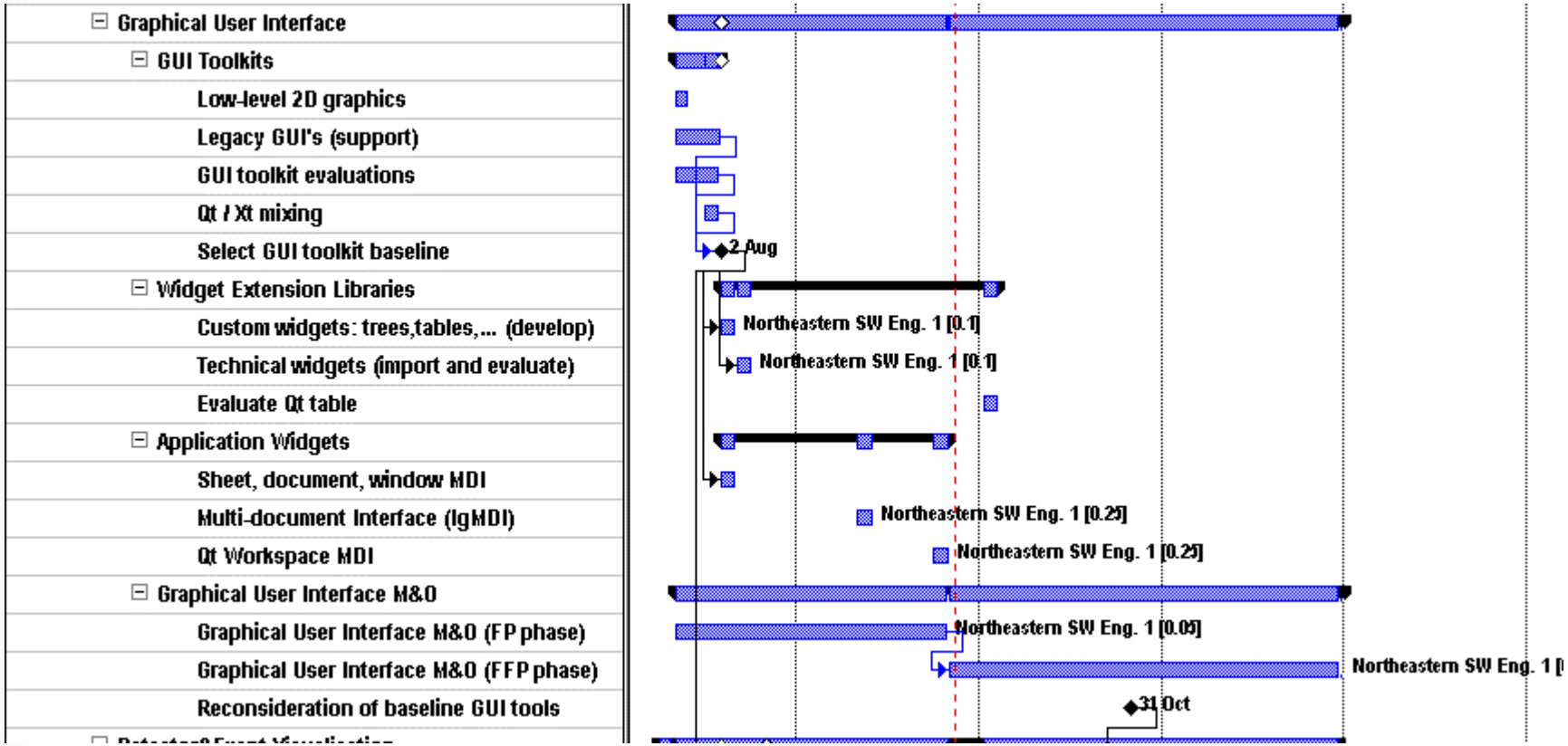
Graphical User Interface	Package(s)	Origin
2D Graphics and GUI Toolkits		
Low-level 2D graphics	X11	Vendor
Legacy GUI's	Xt / Motif	Vendor
GUI evaluations	gtk++, Qt, etc.	Public
Qt / Xt mixing	qxt	Public
GUI toolkit (+high-level 2D)	Qt	Public
Widget extensions		
Trees, tables, etc.	IgQt	IGUANA
Scene-graph controller	IgCmscan	IGUANA
Technical widgets	Qwt	Public
Flexible and editable table	Qt Table Module	Public
Widget library		IGUANA
Widget organisers		
Sheet widgets	IgQtSheet...	IGUANA
Multi-document Interface (MDI)	IgMDI	IGUANA
Multi-document Interface (MDI)	Qt Workspace	Public
Sheet, document, window MDI		IGUANA



CAS WBS 2.2.1
Graphical User Interface



CAS WBS 2.2.1
Graphical User Interface



CAS WBS 2.2.2
Detector and Event Visualisation

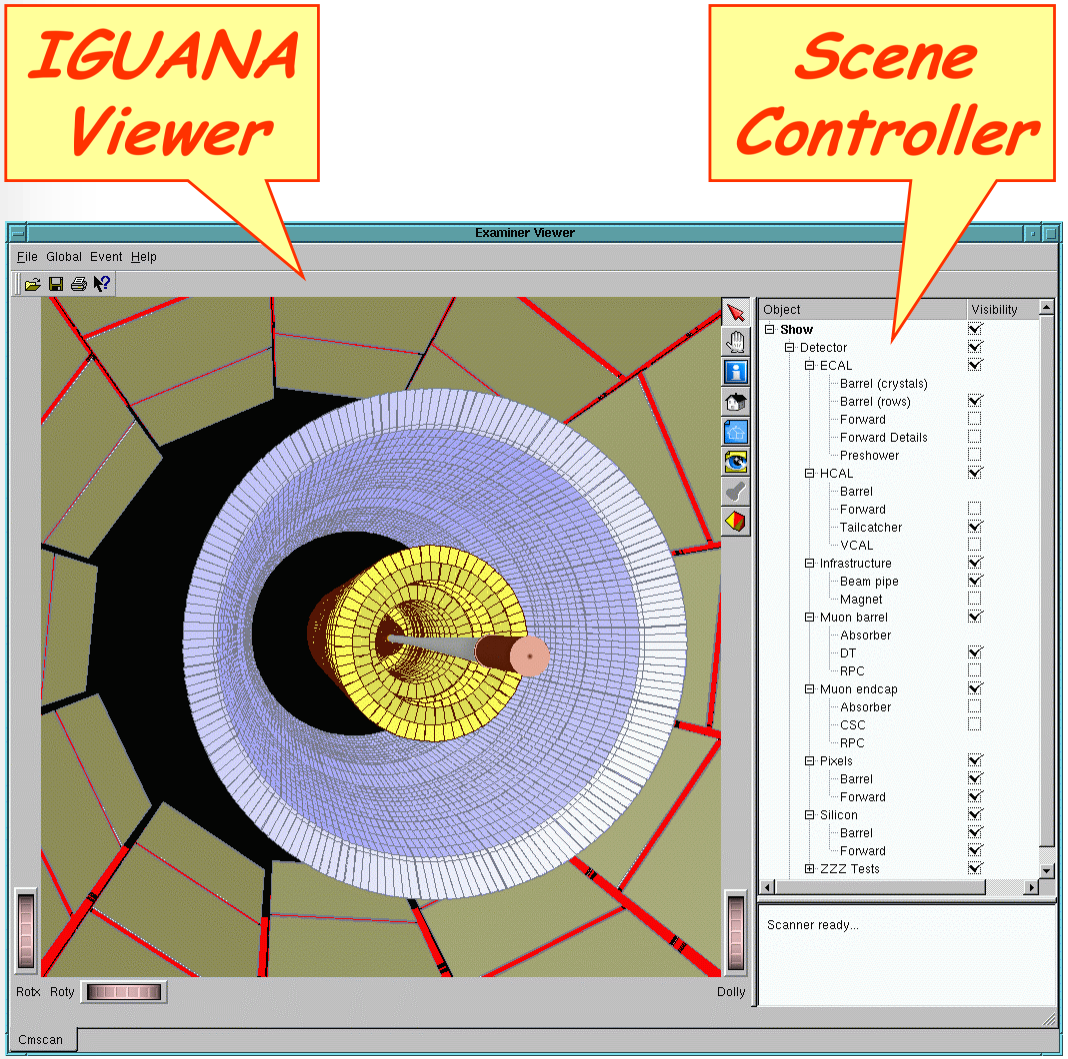
- Usual emphasis on OO design, C++ API, and standards , functionality, extendibility, widespread adoption, support,....
- Build extensions for event display based on HEP / public-domain / commercial software
- Development of specific CMS program (Cmscan with CARF & ORCA)

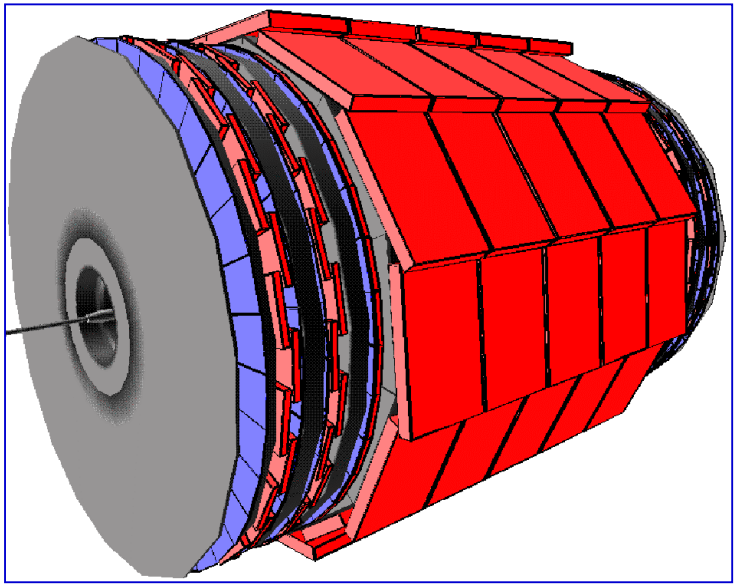
Detector and Event Visualisation	Package(s)	Origin	1999				2000				2001				2002			
			Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
				Functional Prototype Phase														
Underlying Graphics																		
Low-level 3D graphics	OpenGL	Public/vendor																
High-level 3D graphics	OpenInventor	Vendor / free									?	?	?	?	?	?	?	?
Qt / OpenGL mixing	QGL	Public																
Qt / OpenInventor mixing	SoQt	Public																
High-level 2D graphics	Qt Canvas	Public																
Detector Interfaces / Shapes																		
GEANT3 interfaces	IgGEANT3	IGUANA													?	?	?	?
HEP OpenInventor extensions	HEPVis	HEP																
GEANT4 interfaces	IgGEANT4	IGUANA																
IGUANA viewers components																		
Motif Detector / Event display	Cmscan	IGUANA																
Interactive 3D viewers	Ig3DViewer	IGUANA																
3D Detector / Event display	IgCmscan	IGUANA																
2D Detector / Event display		IGUANA																

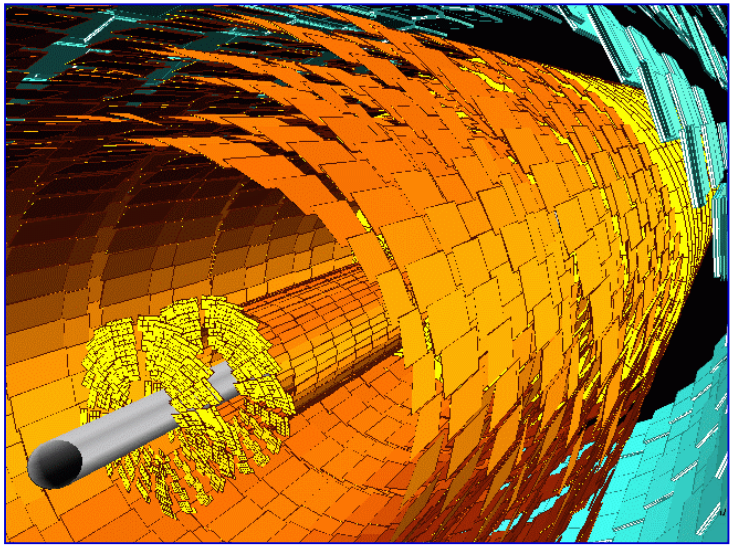
CAS WBS 2.2.2
Detector and Event Visualisation

- Basic graphics technologies
  - X11, Qt, OpenGL, OpenInventor, SoQt and QGL
- IGUANA Viewers
  - performant 3D rendering
  - rotations, translations, zoom, slicing, visibility control,...
- Interfaces to GEANT3 (CMSIM) & OpenInventor
  - Full CMS GEANT3 detector can be displayed
  - IGUANA implements sensible choices of volumes to display
- Event Visualization
  - Implemented within context of ORCA
  - Consistent with CARF action-on-demand mechanisms
  - Currently (ORCA 4.3.0) about half of the obvious reconstructed objects you would like to see are visualisable (work in progress)

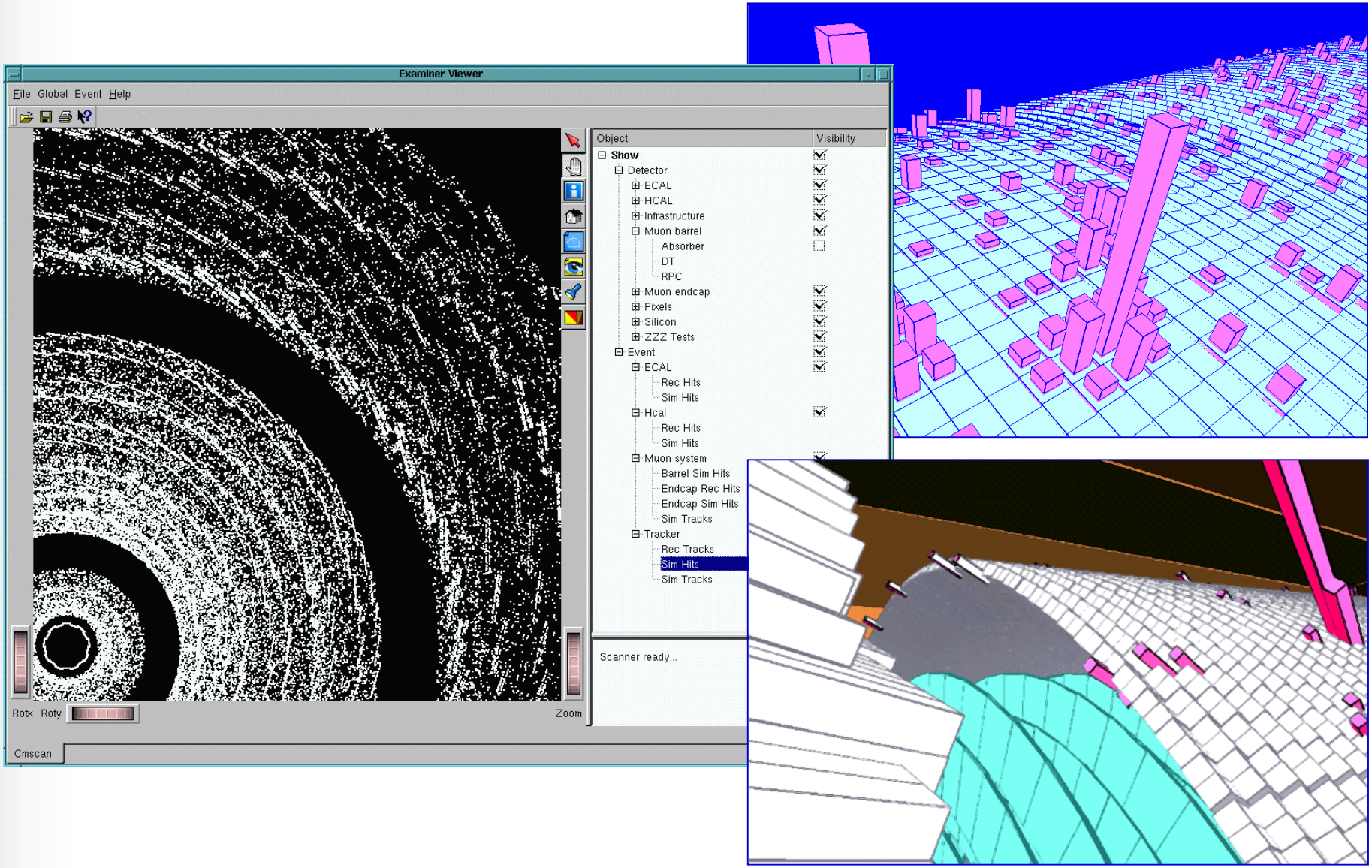
CAS WBS 2.2.2
Detector and Event Visualisation





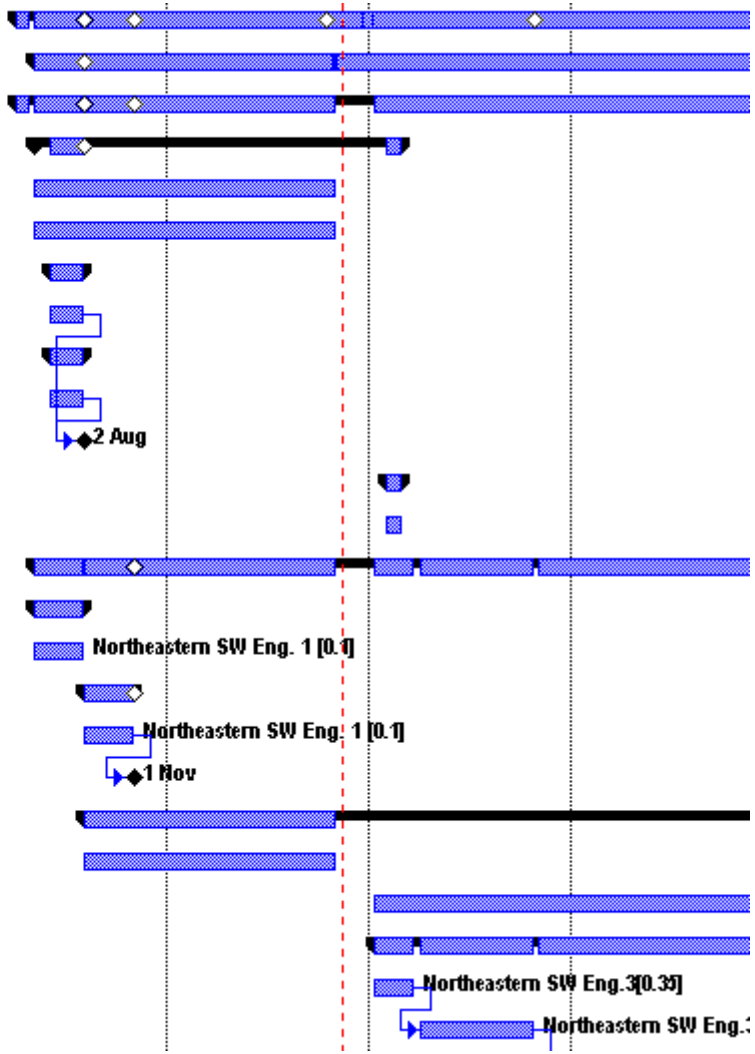


CAS WBS 2.2.2
Detector and Event Visualisation



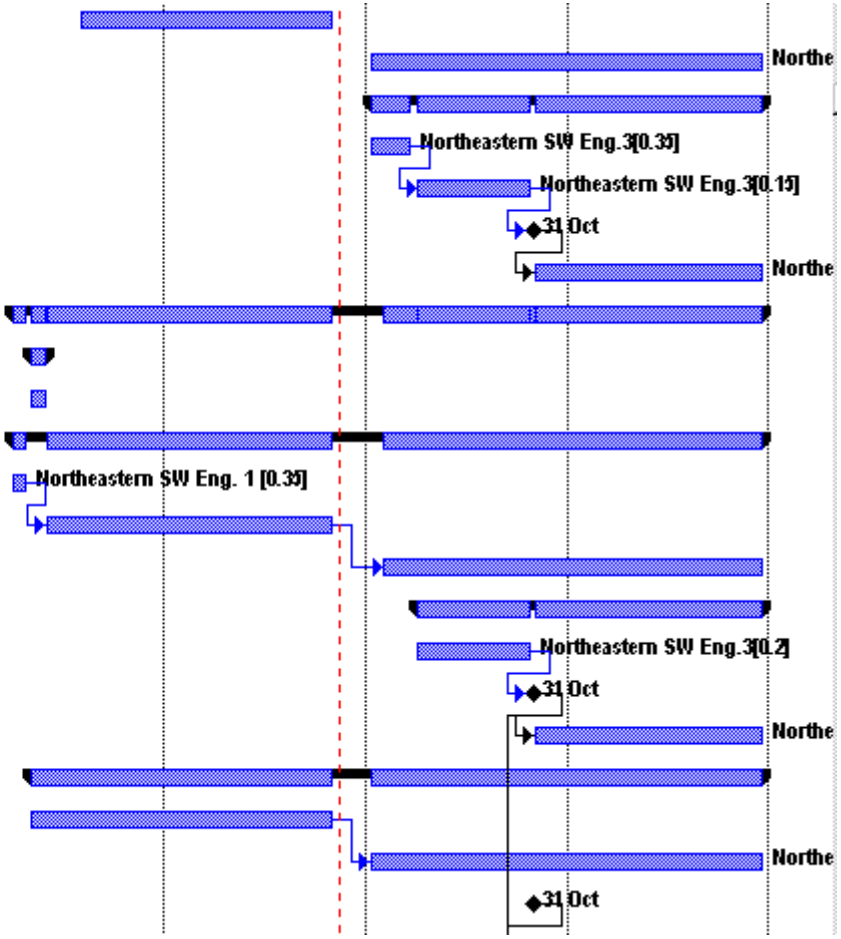
CAS WBS 2.2.2
Detector and Event Visualisation

2.2	Interactive Graphical User Analysis (IGUANA)
2.2.1	Graphical User Interface
2.2.2	Detector&Event Visualisation
2.2.2.1	Underlying Graphics
2.2.2.1.1	Low-level 3D graphics
2.2.2.1.2	High-level 3D graphics
2.2.2.1.3	Qt / OpenGL mixing
2.2.2.1.3.1	Qt / OpenGL mixing demonstration
2.2.2.1.4	Qt / OpenInventor mixing
2.2.2.1.4.1	Qt / OpenInventor mixing demonstration
2.2.2.1.5	Select 3D baseline (Functional Prototype)
2.2.2.1.6	High-level 2D graphics
2.2.2.1.6.1	Evaluation
2.2.2.2	Viewers
2.2.2.2.1	Motif Detector / Event display
2.2.2.2.1.1	Port "Cmscan Classic" controller to new GUI toolkit
2.2.2.2.2	Interactive 3D viewers
2.2.2.2.2.1	Prototype 3D viewer
2.2.2.2.2.2	Generic 3D viewer with local interactivity
2.2.2.2.3	3D Detector / Event display
2.2.2.2.3.1	Prototype Detector / Event Viewer
2.2.2.2.3.2	Benchmarking, testing, and performance enhanceme
2.2.2.2.4	2D Detector / Event display
2.2.2.2.4.1	2D Detector / event display prototyping
2.2.2.2.4.2	2D Detector / event display development



CAS WBS 2.2.2 Detector and Event Visualization (cont.)

2.2.2.2.3.1	Prototype Detector / Event Viewer
2.2.2.2.3.2	Benchmarking, testing, and performance enhar
2.2.2.2.4	⊟ 2D Detector / Event display
2.2.2.2.4.1	2D Detector / event display prototyping
2.2.2.2.4.2	2D Detector / event display development
2.2.2.2.4.3	First version of 2D browser
2.2.2.2.4.4	2D Detector / event display development
2.2.2.3	⊟ Detector Interfaces / Shapes
2.2.2.3.1	⊟ GEANT3 interfaces
2.2.2.3.1.1	Deployment from pre-existing Cmscan code
2.2.2.3.2	⊟ HEP OpenInventor extensions
2.2.2.3.2.1	Import/build system for HEPVis
2.2.2.3.2.2	Development of HEPVis classes (FP)
2.2.2.3.2.3	Development of HEPVis classes (FFP)
2.2.2.3.3	⊟ GEANT4 interfaces
2.2.2.3.3.1	GEANT4 visualization prototype
2.2.2.3.3.2	GEANT4 visualization program
2.2.2.3.3.3	GEANT4 visualization development
2.2.2.4	⊟ Detector & Event Visualisation M&O
2.2.2.4.1	Detector & Event Visualisation M&O (FP phase)
2.2.2.4.2	Detector & Event Visualisation M&O (FFP phase)
2.2.2.4.3	Review baseline GUI tool choices

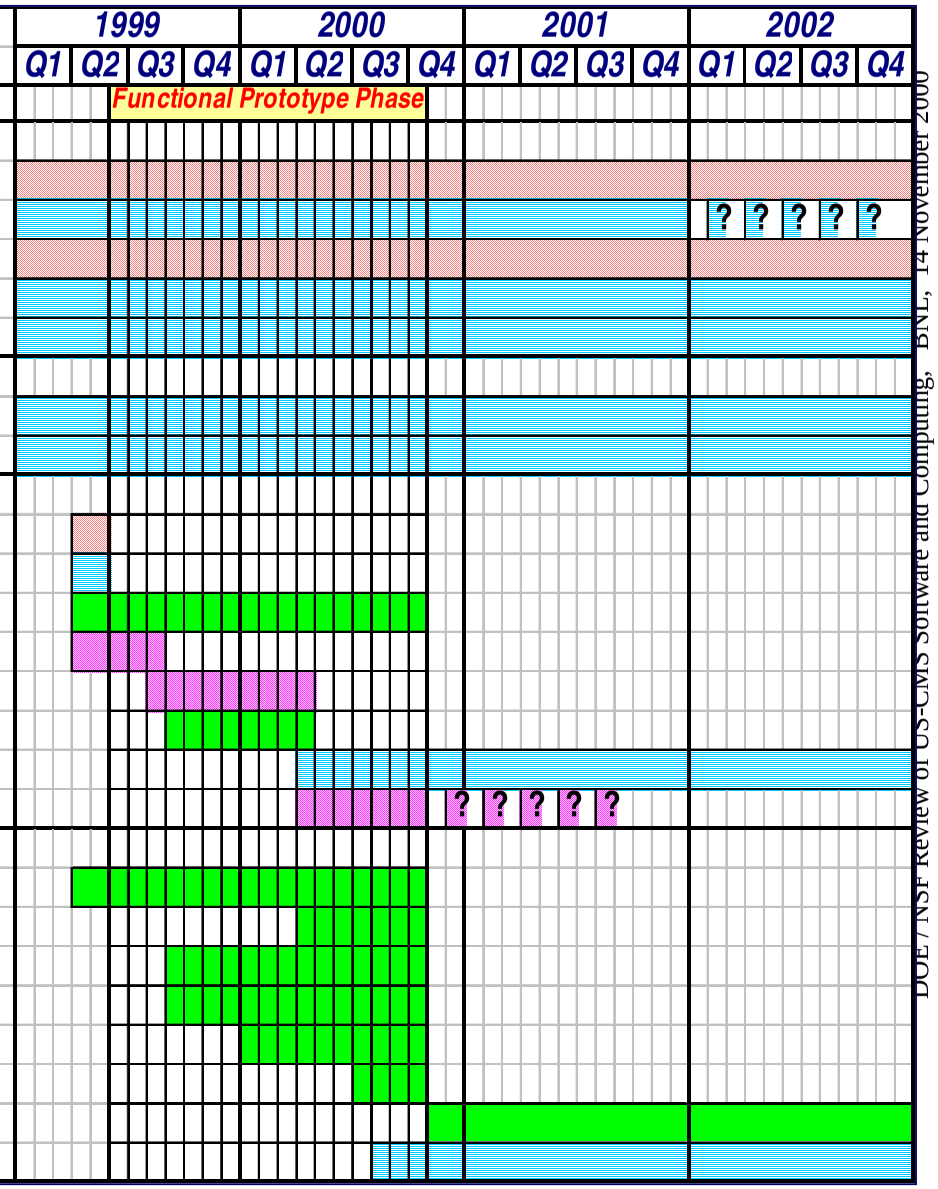


CAS WBS 2.2.3
Interactive Data Analysis & Presentation

- Statistical / Numerical Analysis
  - Responsibility of CERN/IT API group
  - Key issue is long-term support for minimization engine
    - NAG_C engine works in parallel to MINUIT w/ same C++ API
- Histograms / Tags
  - Responsibility of CERN/IT/API (HTL & HepODBMS products)
  - Extensions /variations on tags…see other talks
- Plotting
  - 1 year ago, not well covered, hence IGUANA developed a plotter
  - Same basis now adopted by CERN/IT/API for their "Qplotter"
- General Purpose Analysis
  - Many IGUANA prototypes; future emphasis on data interface
  - CERN/IT/API "Lizard" interactive analysis tool
    - First version just released: to be evaluated

CAS WBS 2.2.3
Interactive Data Analysis & Presentation

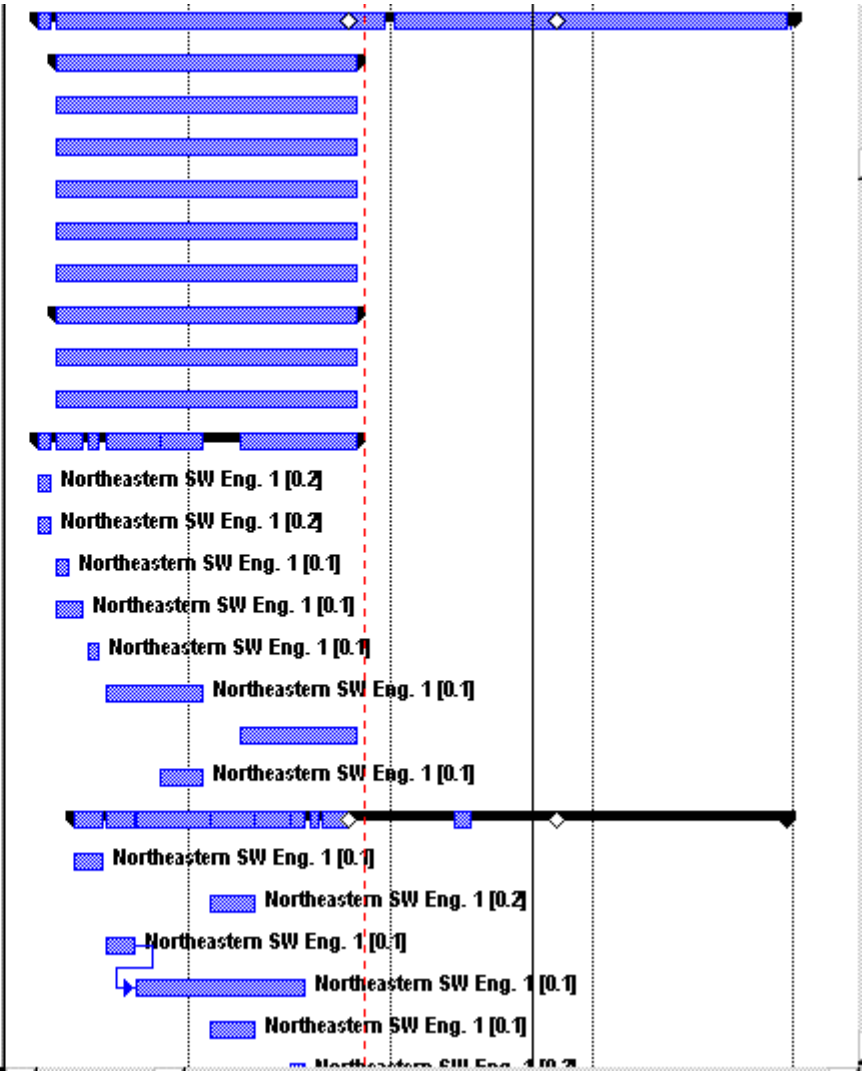
Interactive Analysis and Presentation	Package(s)	Origin
Statistical/Numerical Analysis		
Mathematical library	NAG_C	NAG
Minimiser (short/medium-term)	MINUIT	CERN/IT/API
Minimiser (medium/long-term)	NAG_C	NAG
MINUIT / NAG_C wrapper	GEMINI	CERN/IT/API
C++ Fitting API to GEMINI	HepFitting	CERN/IT/API
Histograms / tags		
Histograms	HTL	CERN/IT/API
Tags / ntuple extension	HepODBMS	CERN/IT/DB
Plotting		
1D and 2D plotting	IRIS Explorer	NAG
1D and 2D plotting	HepInventor	CERN/IT/API
Scientific vector	IgSciData	IGUANA
1D plotting	SciPlot	Public
1D plotting	Qwt	Public
1D and 2D plotting	IgQwt,IgPlotter,…	IGUANA
1D and 2D plotting	Qplotter	CERN/IT/API
Surface function plotting	plot3d	Public
General purpose analysis		
Database access modules	IgObjectivity	IGUANA
Metadata browser	Mbrowser	IGUANA
HTL browser	IgHTLBrowser	IGUANA
Generic Tag browser	IgTagPlot	IGUANA
GUI API to HepFitting	IgFitting	IGUANA
Scripting (GUI for Lizard)	IgPython	IGUANA
Data browsers / utilities		IGUANA
"PAW replacement" application	Lizard	CERN/IT/API



CAS WBS 2.2.3
Interactive Data Analysis & Presentation

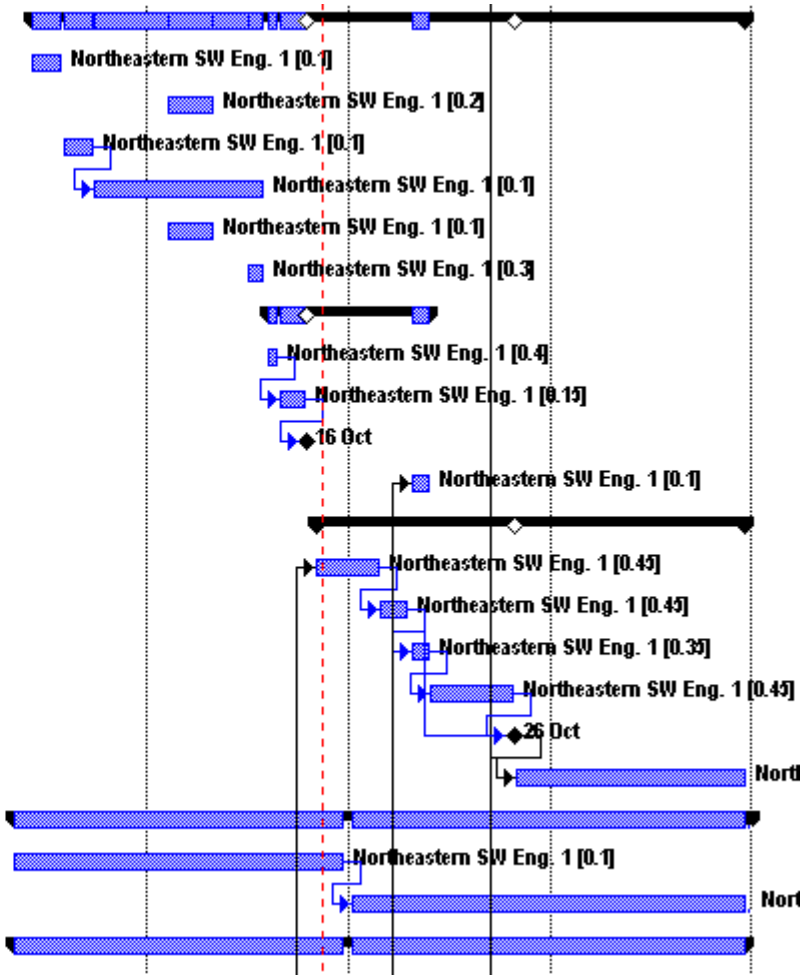
CAS WBS 2.2.3
Interactive Data Analysis & Presentation

2.2.3	Interactive Analysis and Presentation
2.2.3.1	Statistical/Numerical Analysis
2.2.3.1.1	Mathematical library
2.2.3.1.2	Minimiser (short/medium-term)
2.2.3.1.3	Minimiser (medium/long-term)
2.2.3.1.4	MINUIT / NAG_C wrapper
2.2.3.1.5	C++ Fitting API to GEMINI
2.2.3.2	Histograms / tags
2.2.3.2.1	Histograms
2.2.3.2.2	Tags / ntuple extension
2.2.3.3	Plotting
2.2.3.3.1	1D and 2D plotting (IRIS Explorer)
2.2.3.3.2	1D and 2D plotting (HepInventor)
2.2.3.3.3	Scientific vector
2.2.3.3.4	1D plotting (SciPlot)
2.2.3.3.5	1D plotting (Qwt)
2.2.3.3.6	1D and 2D plotting (IgPlotter)
2.2.3.3.7	1D and 2D plotting (Qplotter)
2.2.3.3.8	Surface function plotting
2.2.3.4	Interactive analysis
2.2.3.4.1	Database access modules
2.2.3.4.2	Metadata browser
2.2.3.4.3	HTL browser
2.2.3.4.4	Generic Tag browser
2.2.3.4.5	GUI API to HepFitting



CAS WBS 2.2.3
Interactive Data Analysis & Presentation

- Interactive analysis
  - Database access modules
  - Metadata browser
  - HTL browser
  - Generic Tag browser
  - GUI API to HepFitting
  - Scripting (GUI for Lizard)
  - Lizard "PAW replacement" application
    - Evaluation of pre-release
    - Evaluation of pre-release
    - Release of first version
    - Evaluation of Lizard "PAW functionality" release
  - Data browsers / utilities
    - Consolidation of code from "Functional Prototype"
    - Data browsers for CARF/ORCA/OSCAR
    - Data browsers for CARF/ORCA/OSCAR
    - Data browsers for CARF/ORCA/OSCAR
    - Data browsers for CARF/ORCA/OSCAR
    - Data browsers for CARF/ORCA/OSCAR
- Interactive Analysis M&O
  - Interactive Analysis M&O (FP phase)
  - Interactive Analysis M&O (FFP phase)
- IGUANA Infrastructure

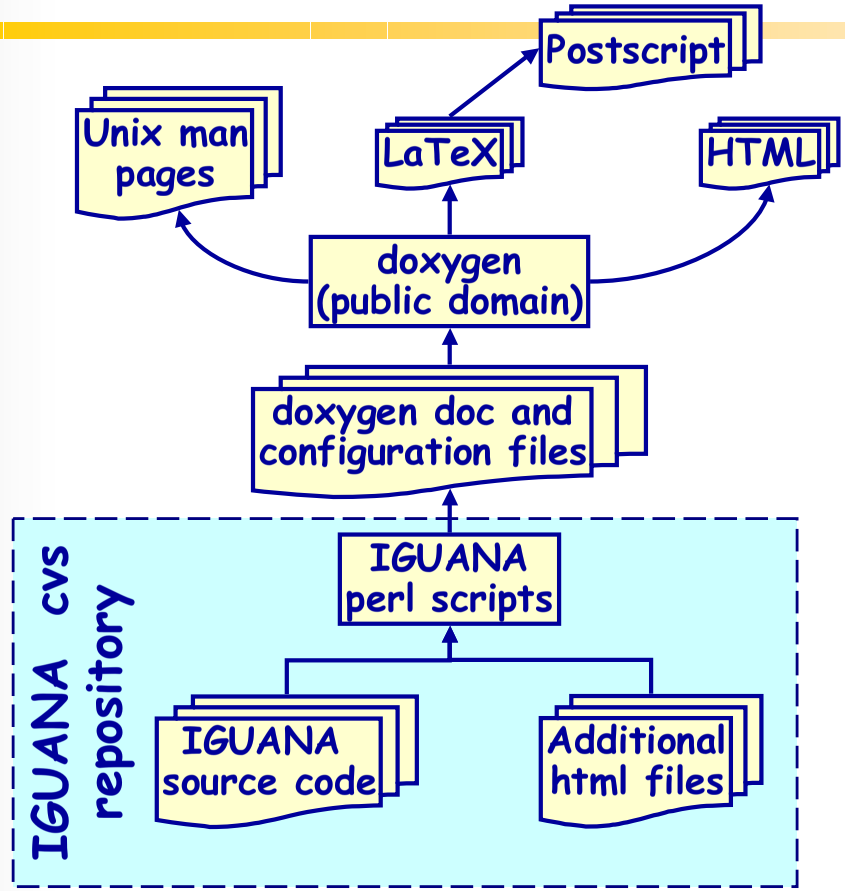


CAS WBS 2.2.4
IGUANA Infrastructure

- Runs on CMS-approved platforms: **Linux and Solaris**
  - No reason why other "Unices" and Windows should be a problem
- Software repository with version control using: **cvs**
- Build, release, and distribution system using: **SCRAM**
- Detailed dependency analysis tools developed in IGUANA and used to keep the dependencies under control: **Ignominy**
- Documentation system using **doxygen** +**IGUANA scripts**

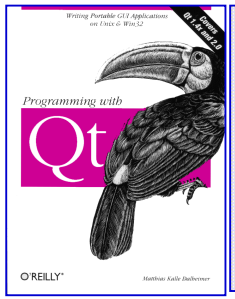
IGUANA Infrastructure / Utilities	*Package(s)*	*Origin*	*1999*				*2000*				*2001*				*2002*			
			Q1	*Q2*	*Q3*	*Q4*	*Q1*	*Q2*	*Q3*	*Q4*	*Q1*	*Q2*	*Q3*	*Q4*	*Q1*	*Q2*	*Q3*	*Q4*
				Functional Prototype Phase														
Code management																		
IGUANA repository	cvs	Public																
Build, release, distribution system	SCRAM	CMS																
Standalone remote distributor	OffsiteReleaser	IGUANA																
Code quality / checking																		
Dependency checking	dep-anal	IGUANA																
Documentation Systems																		
Reference documentation builder	doxygen	Public																
WWW pages builder	Ig_Documentation	IGUANA																
User guide builder	IgManuals	IGUANA																

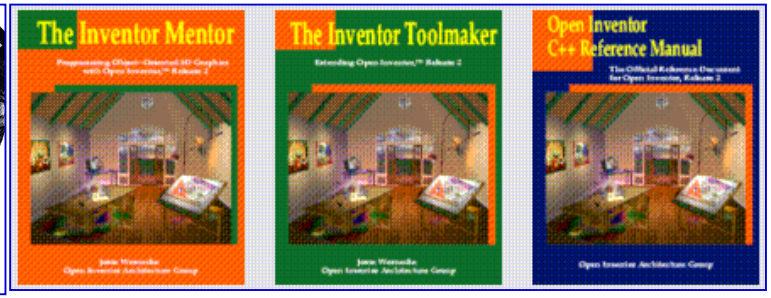
CAS WBS 2.2.4
IGUANA Infrastructure



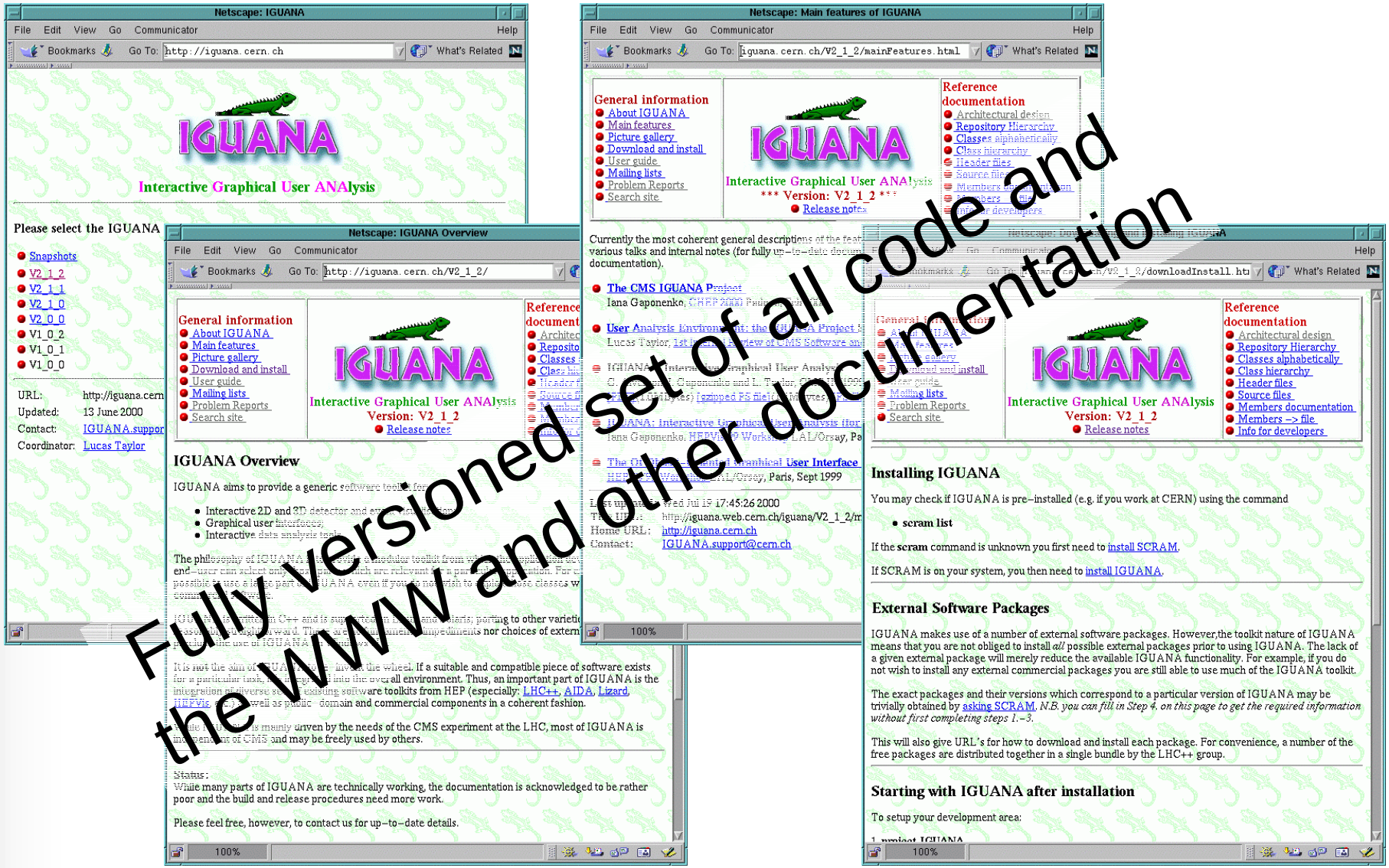
Standard packages:

Online and published documentation, examples and tutorials





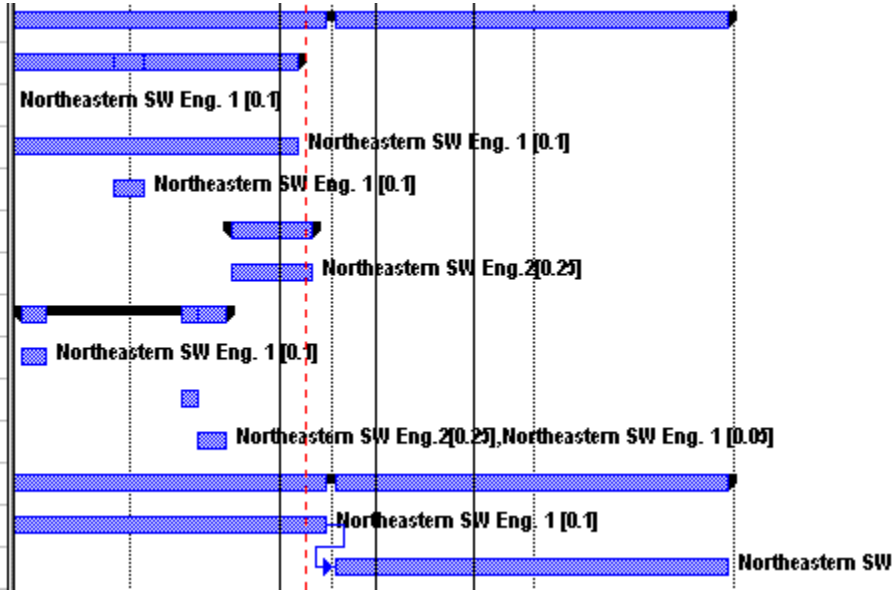
CAS WBS 2.2.4 IGUANA Infrastructure
http://iguana.cern.ch



Fully versioned set of all code and the WWW and other documentation

CAS WBS 2.2.4
IGUANA Infrastructure

2.2.4	IGUANA Infrastructure
2.2.4.1	Code management
2.2.4.1.1	IGUANA repository
2.2.4.1.2	Build, release, distribution system
2.2.4.1.3	Standalone remote distributor
2.2.4.2	Code quality / checking
2.2.4.2.1	Dependency checking
2.2.4.3	Documentation Systems
2.2.4.3.1	Reference documentation system
2.2.4.3.2	WWW pages builder
2.2.4.3.3	User guide builder
2.2.4.4	IGUANA Infrastructure M&O
2.2.4.4.1	IGUANA Infrastructure M&O (FP phase)
2.2.4.4.2	IGUANA Infrastructure M&O (FFP phase)

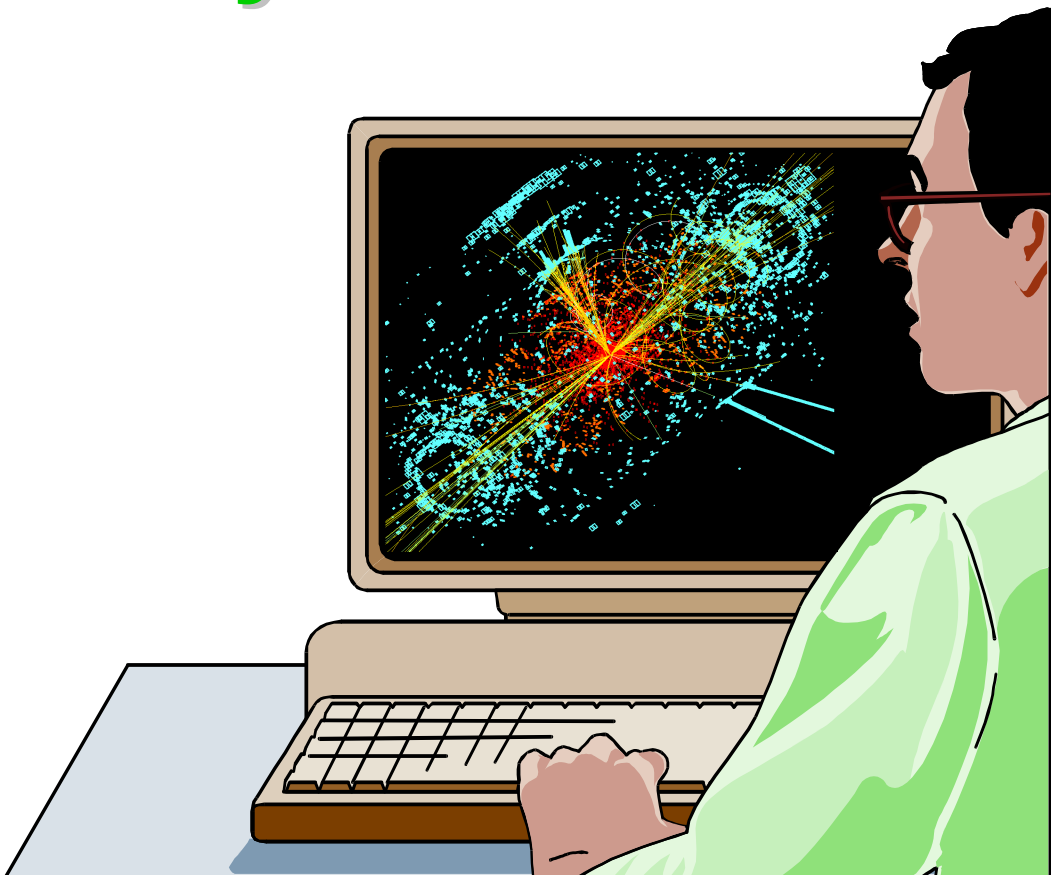


CAS WBS 2.2 IGUANA Evolution

- **Graphical User Interfaces**
  - Toolkit support, upgrades, and modest effort on development
  - Evaluation and integration of external components (Qt-based)
  - Development/support of applications (e.g. test-beams, etc.)
- **Detector and Event Visualization**
  - Steady improvements in generic 3D viewer components
  - Development of new 2D viewer components
  - Developments to keep it consistent with ORCA
  - GEANT4 / generic detector description
- **Interactive Analysis and Presentation**
  - Testing and integration of external components, e.g. HTL, HepODBMS, Qplotter, NAG_C, Lizard ("PAW-like functionality" by April 2001)
  - IGUANA focus on more CMS-specific data browsing aspects

DOE / NSF Review of US CMS Software & Computing

Brookhaven National Laboratory, 14 November 2000

WBS Item 2.3 and 2.4

See next talk by Ian Fisk