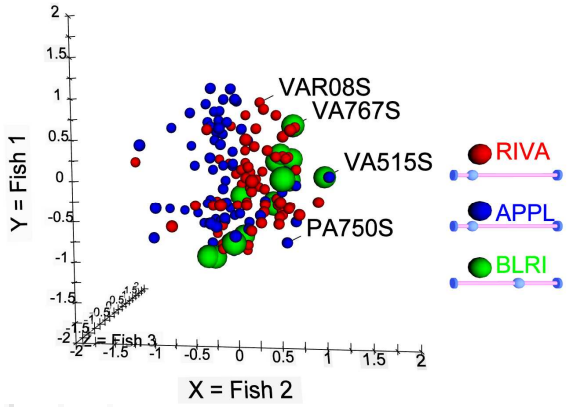
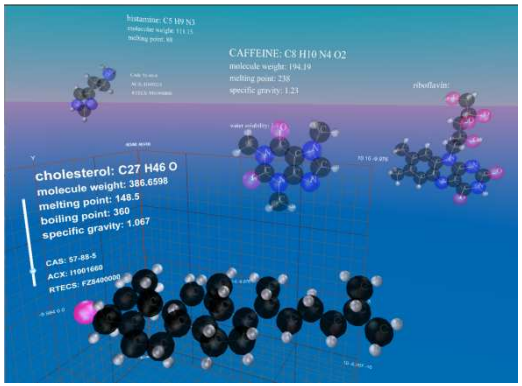
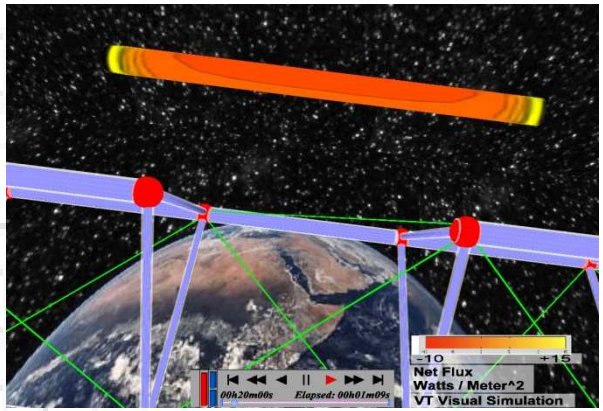
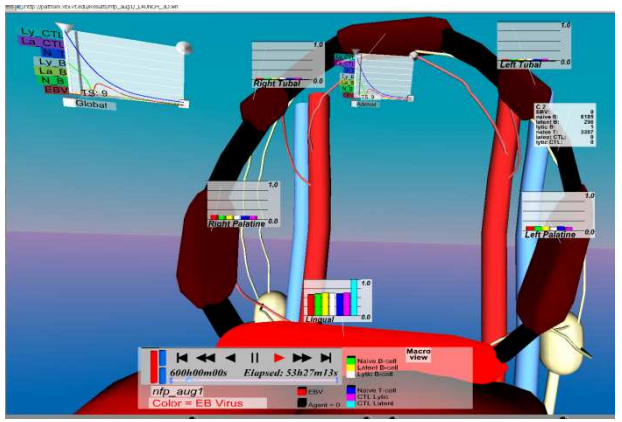




Deep Media for Research and Education



Nicholas F. Polys, Ph.D.
VT Advanced
Research Computing



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Inexorable climb

- Hardware power & speed
- Commodity platforms
- Informatics integration
- Compelling Content

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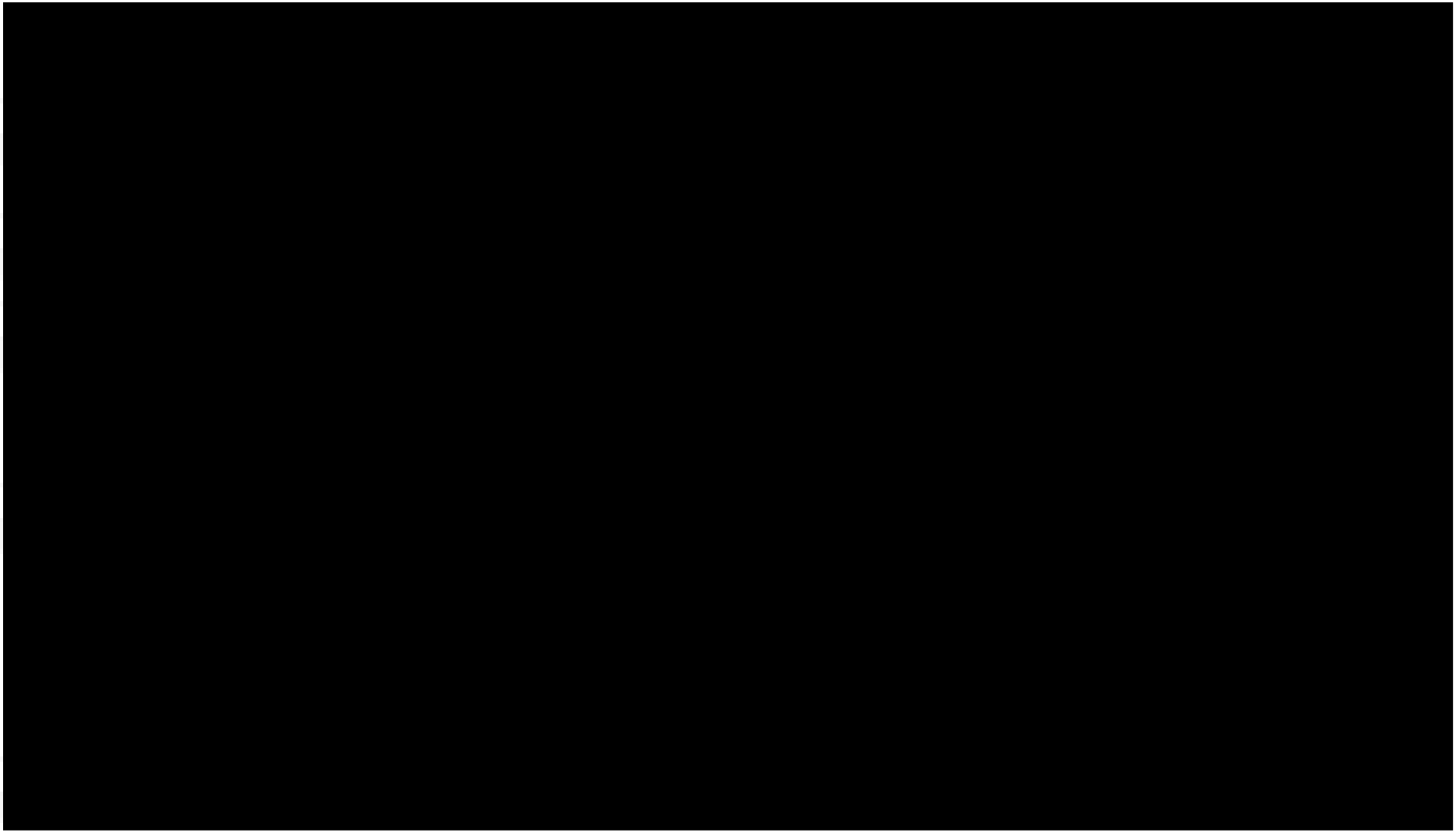
Once upon a time



4D: a first-class citizen

What's new?

- Networked 3D digital assets
  - Objects and components
  - Appearances & materials
  - Environments
- Animation and Timeseries databases
- Metadata & web-aware referencing
- Interaction semantics

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Broad-based Need

Improved visualization support is a recognized challenge:

- NSF / NIH Report - 2006
- Visual Analytics Initiative - 2006
- Many other agencies are facing the same problem: making sense of large, heterogeneous data sets

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NSF / NIH Visualization Report

A renewed funding priority for basic research-transformative technology and techniques

http://tab.computer.org/vgtc/vrc/index.html

- C. Johnson, R. Moorhead., T. Munzner, H. Pfister, P. Rheingans, and T. S. Yoo, (Eds.): (2006). NIH-NSF Visualization Research Challenges Report, IEEE Press).

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Visual Analytics R&D Agenda

A renewed initiative in visualization, recasting the problem to interactive analysis tools for large, complex data sets

http://nvac.pnl.gov/agenda.stm

- See the book (free online, *Illuminating the Path*)
- Thomas, J. J., and Cook, Kristin A. (2006). A Visual Analytics Agenda. IEEE Computer Graphics & Applications, 10-13.

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Deep Media

- Interactive spaces that evolve over time
- Contain spatially-located media resources
  - Audio
  - Video
  - Vector animations
- Hyperlinked worlds
- … approaching the vision of CyberSpace and the Metaverse!

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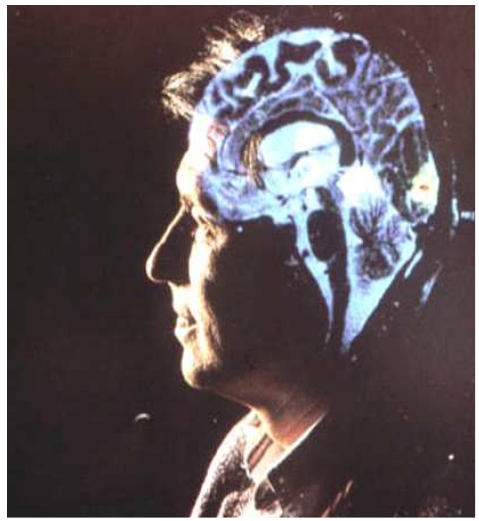
Big Picture: Convergence & Utility

Integrated Information Spaces

- Unified environment for analysis & learning
- Scalability for heterogeneous data types (spatial, abstract, temporal)
- Represent real world objects and systems
  - Reduce cognitive distance by putting information in familiar context
  - Leverage spatial abilities of users



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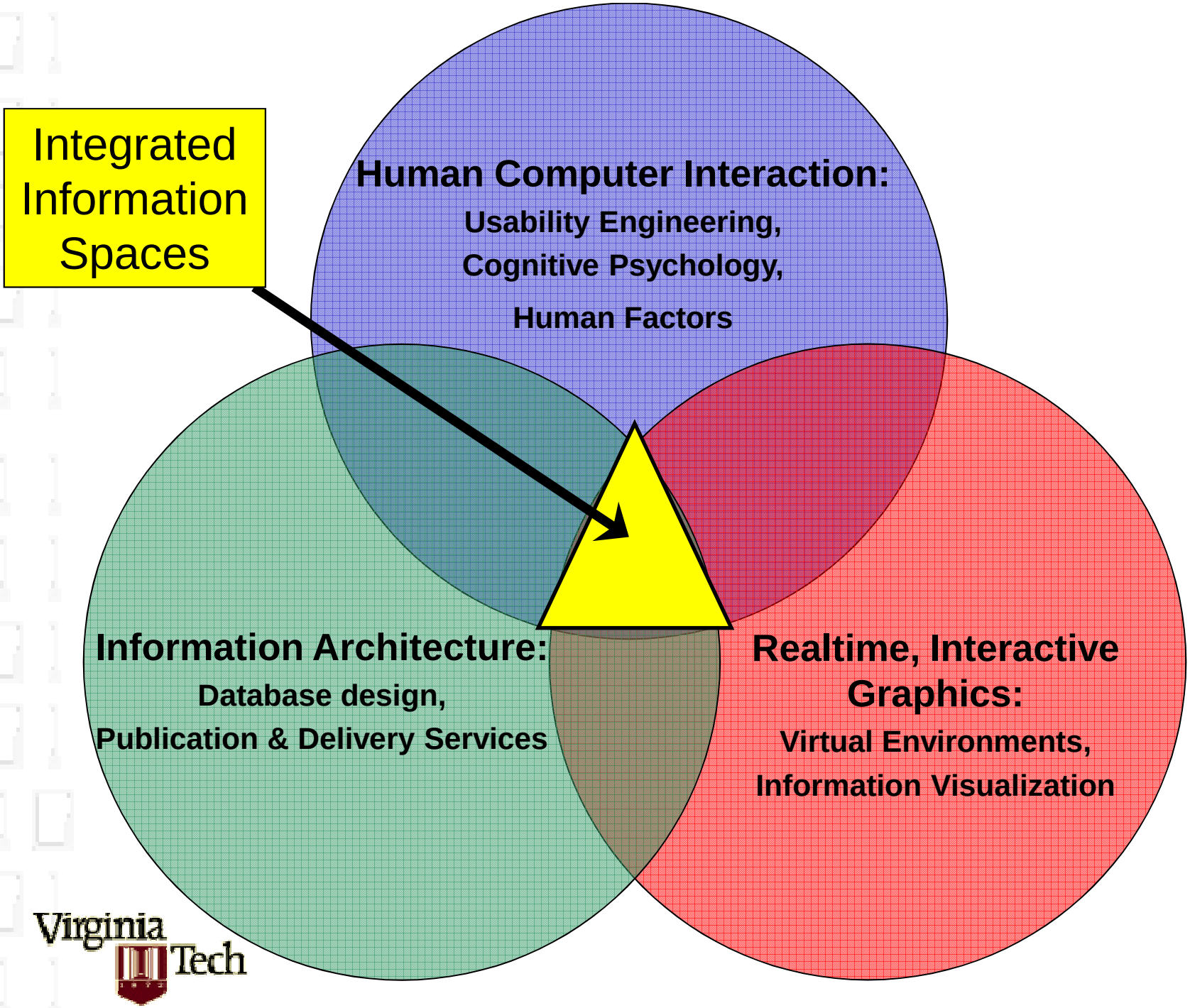

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Who am I

- CS / HCI doctorate – perception and action in information-rich virtual environments
- Environment and interface developer of deep media for research and education
- Web3D Consortium: Director, Co-author X3D Specification
- Working with Research Computing to advance visualization capabilities @ VT

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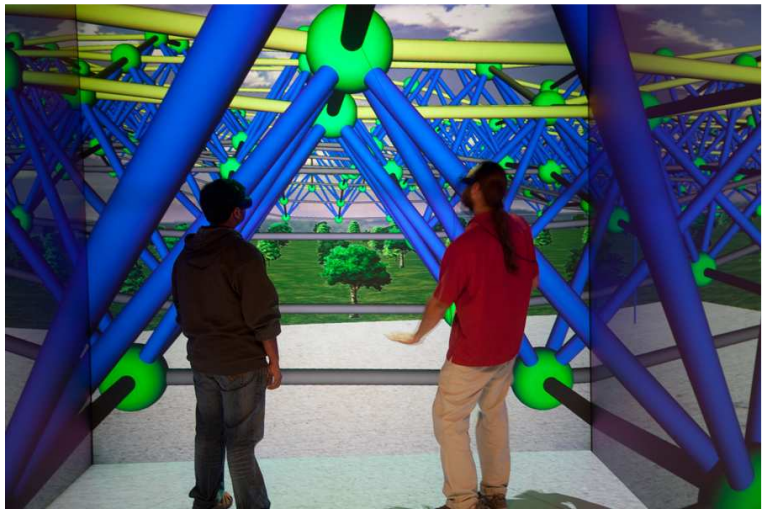
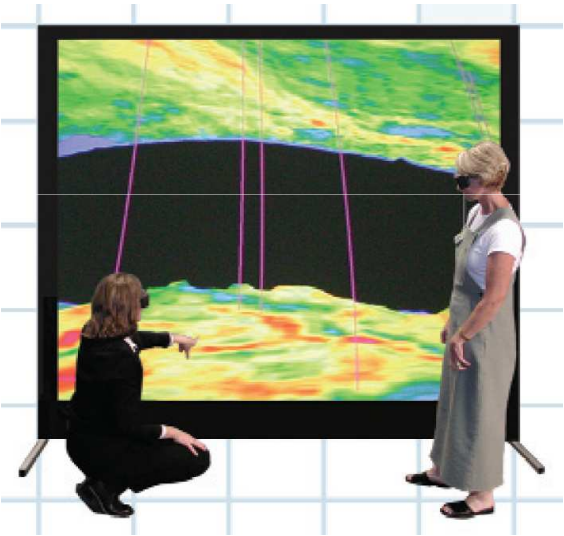
Virginia Tech IT



We have the facilities and expertise for a wide range of visualization venues and applications:



- **Visual Computing**
- **HPC / Research Computing**

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Visual Computing Group

Provide staff to:

- Consult with researchers about applications of visualization technology
- Develop visualization solutions for domain experts / HPC users
- Train faculty and students on how to use, develop, and demo visualization equipment
- Develop additional grants and funding streams with domain experts to include visualization tools and HPC

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Visual Computing Group

- Provide ‘World-Class’ visualization facilities for university researchers, faculty, and students
- Build cutting-edge software stack for domains, emphasizing content portability and ease-of-use
- Deploy visualization web services middleware to HPC systems
- Build and maintain online multi-user collaborative spaces
- Upgrade and proliferate display hardware for speed, resolution, and brightness

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VT Visualization Resources

- Infrastructure & Resources that makes VT uniquely capable of performing some research
- For research programs *and* educational purposes:
  - People & Groups
  - Facilities
  - Training
  - Collaboration

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Facilities / Labs – VT ARC

- TORG 3050: Visual Computing Lab
  CAVE, stereo wall, lab machines
- Andrews: Parallel and shared-memory supercomputers, stereo wall, lab machines
- Other depts have stereo walls (architecture, art, civil engineering, geo)

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Centralized IT Resources

Serving faculty

- System X – the big Mac
- Ithaca - iDataPlex
- Shared memory machines
- Faculty and department machines co-location / hotelling in AISB

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Athena

- The system has 42 compute nodes.
- Quad-socket AMD 2.3GHz Magny Cour 8 Core Processor
- 64 GB memory per node
- Quad-data-rate (QDR) InifniBand (40 Gb/sec)
- 8 nVidia S2050 "Fermi" x 4 GPU available on the system

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GPGPU Success Stories

- …
- Dr. Adrian Sandu: 8.5x speedup (double precision) for multi-physics meteorological forecast codes on CUDA GPUs (OMP=7.5x)

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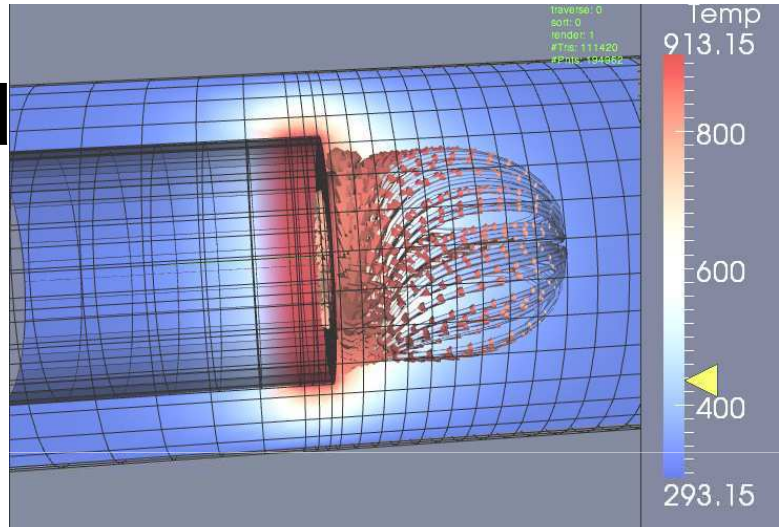
Athena Visualization

- Interactive and scripted

Vis production with :

  - Visit
  - Paraview



- Experiments and custom algorithms for cluster Volume rendering

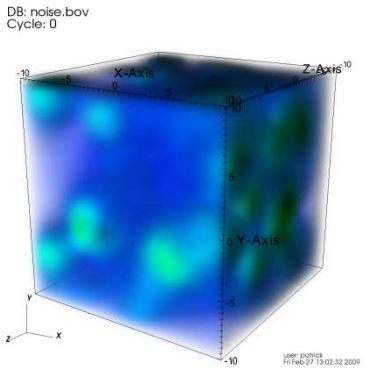


Figure 5: Visit remote rendering condition: Splatting method

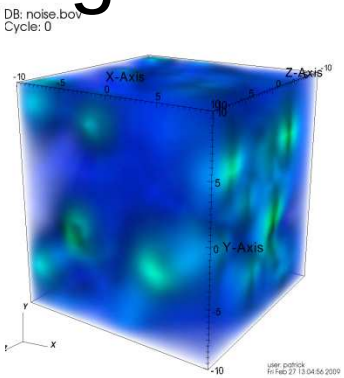


Figure 6: Visit remote rendering: 3D Texture method

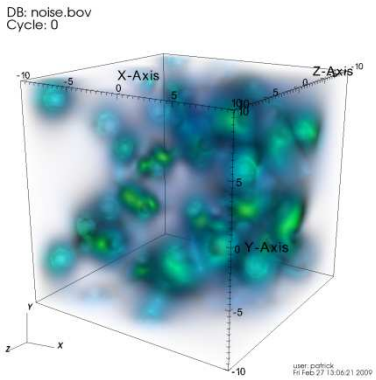


Figure 7: Visit remote rendering: Raycasting method

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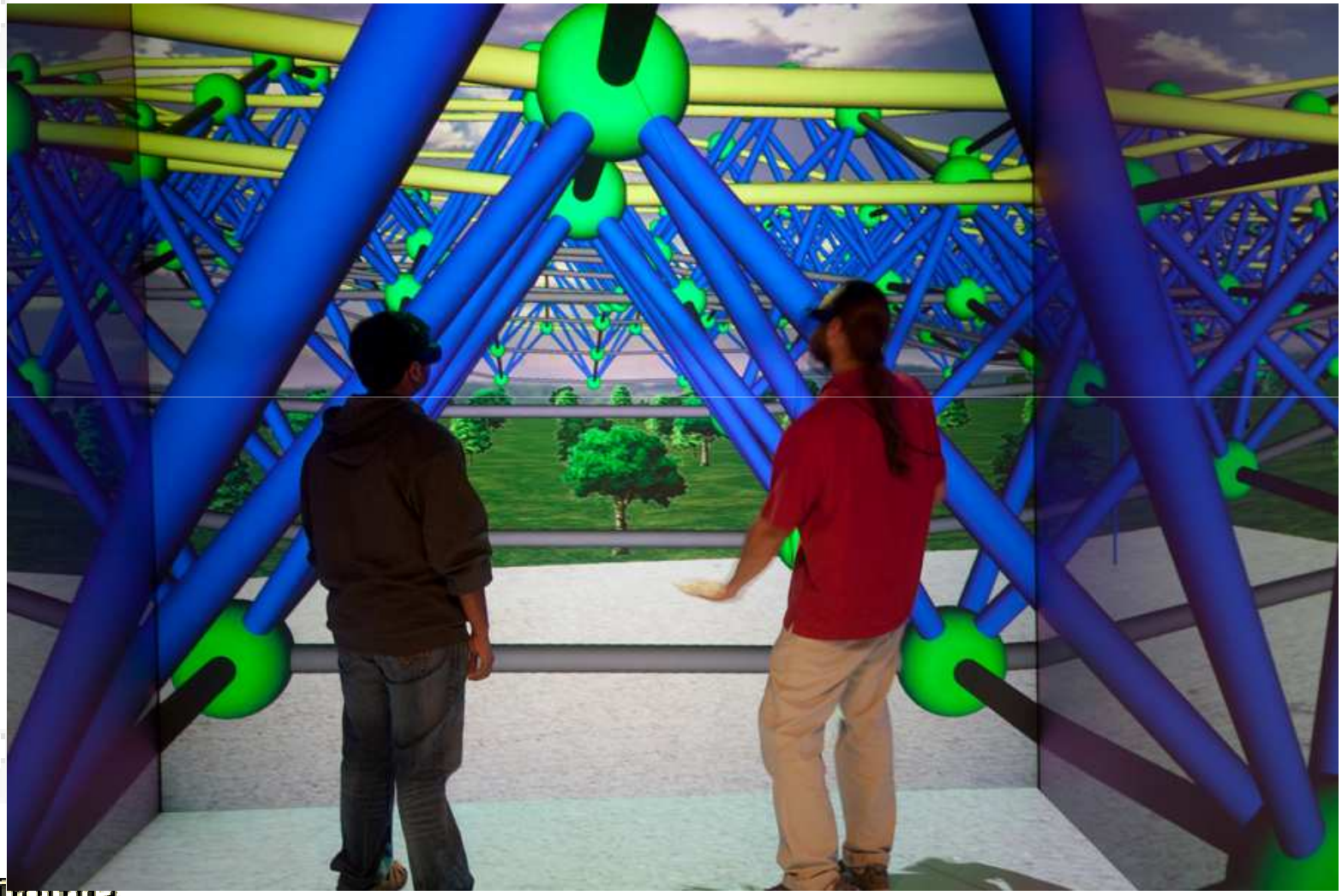
VT Visionarium

VisCube, tiled high-res display, HD multi-touch, 3D TV

VisCube



1920 x 1920 pixels per surface in Infitech passive stereo; wireless tracking
Structural design and simulation tool (NSF)

Software Stack

Support for many data & disciplines:

- CFD
- CAD
- Architecture
- Molecular Dynamics
- VRML/X3D
- DIVERSE VR (Win, Mac, Linux)
- … documentation available !

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Faculty & Student Training

- FDI classes in Visualization Technology & production skills (7 session track) run in spring, fall, and summer

- CAVE & Stereo wall training
  - Operation of, development for
  - Documentation online
  - Free, open to faculty, grad, undergrad
  - by appointment

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Who are you?

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Goals of this Workshop

Foundations of Interactive 3D development and deployment:

- Familiarity with tools and technologies
- Basic competence in authoring and production
- Pathway to utilize VT's Visualization expertise and facilities

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EXAMPLES

- Open up new worlds on the web!

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Recent Research – Display Venues

- VT Computer Science, Center for HCI show high-res and immersive display venues CAN improve task performance:
  - Analyze 22x more data in only 3x more time while maintaining accuracy
  - Reduce virtual navigation actions by 75%
  - Reduce frustration by 50%
  - Short initial learning time

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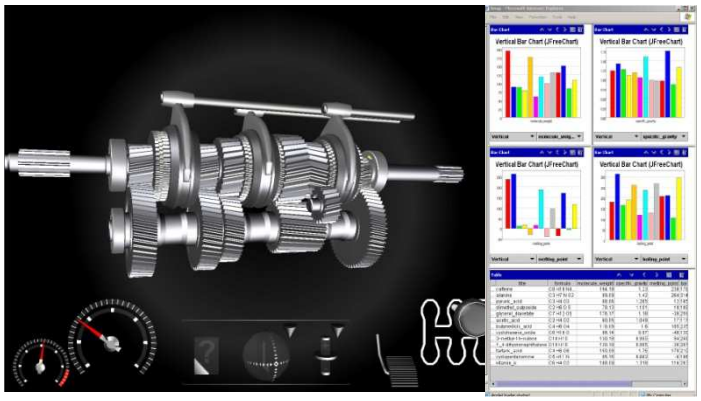
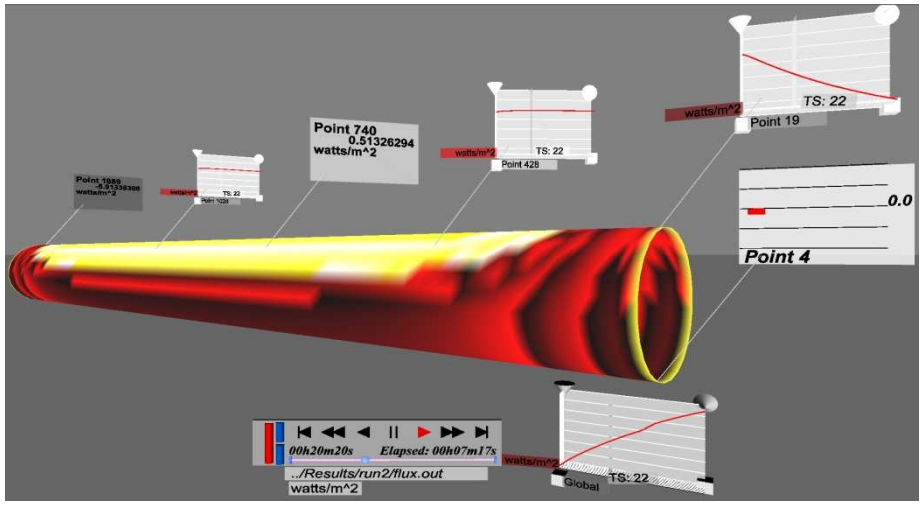
New Opportunities – Display Techniques

- Spatial, Abstract, and Temporal data can be combined, delivered and presented in an ‘integrated information space’
- Attributes and annotations plus objects and groups can be rendered with a variety of (in)consistent perceptual cues





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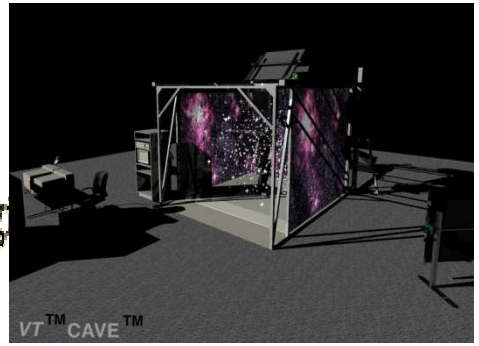
The Challenge

- The real digital divide is the last ten feet between the interface and the mind

Perception

color, shading, lines characters, squares, spatial organization

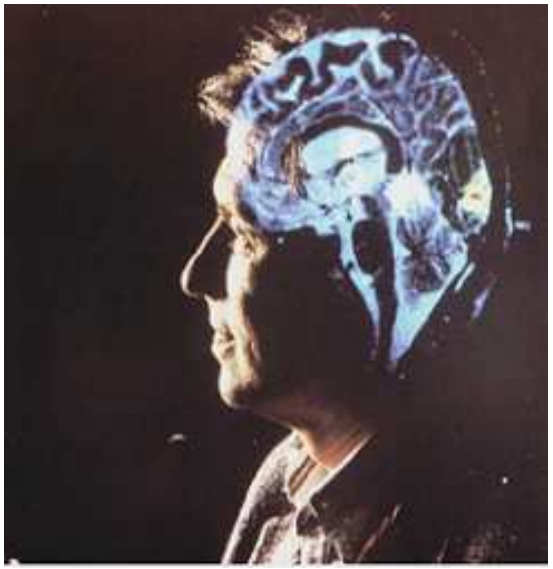


Interpretation

(Working Memory)
Excel worksheet, a part is selected, formula is displayed at top

Making Sense

Proposed design will cost too much in long term maintenance



Why Learn This?

- Integrated visualization capabilities are necessary for users to gain a full understanding of complex relationships in their heterogeneous data
- Application designers must take account of how humans build their cognitive models and what perceptual predispositions and biases are in play
- With such knowledge, designers can take steps to minimize or leverage their effect and create advantageous research, design, and decision-support applications

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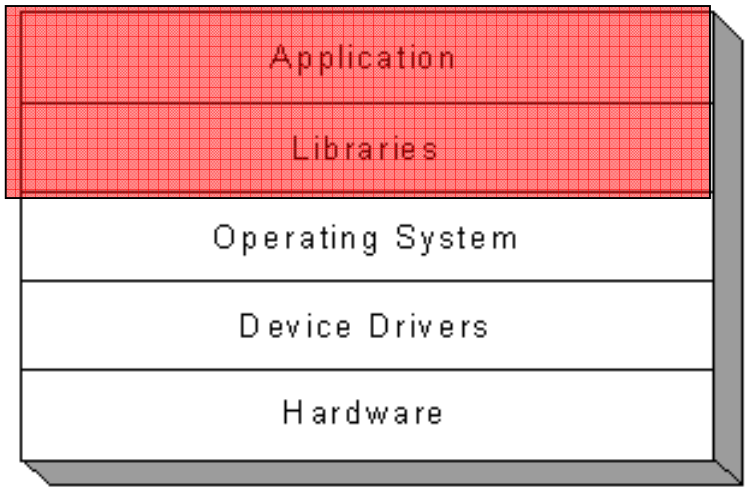
State of the Art

- Successive layers of abstraction allow developers to design and build at higher levels
- Shaders and new rendering algorithms improve realism & performance
- Concrete benefits of large format, high-res, and immersive displays



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Graphics Engines

- Games
  - e.g. Unreal, Delta3D, …
- Consumer solutions
  - e.g. Cortona, Bitmanagement, Octaga, FreeWrl, Xj3D, Flux, H3D…
- Multi-User spaces
  - e.g. ActiveWorlds, Blaxxun,BeThere, SecondLife, …
- Industrial grade tookits
  - e.g. DIVERSE, Paraview & VTK, …

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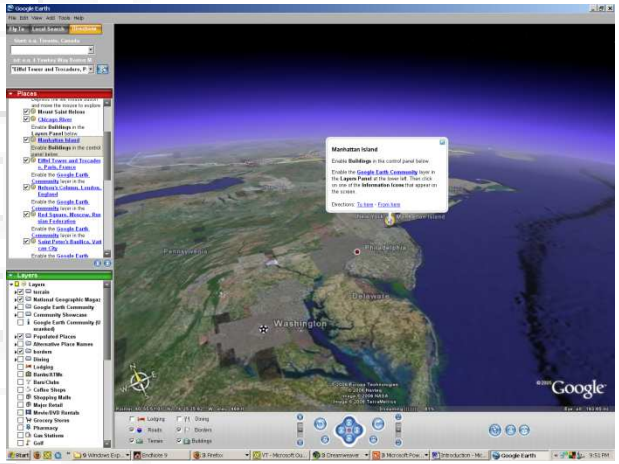
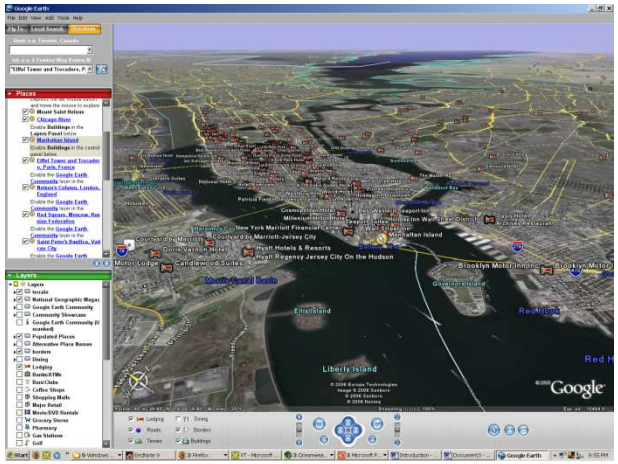
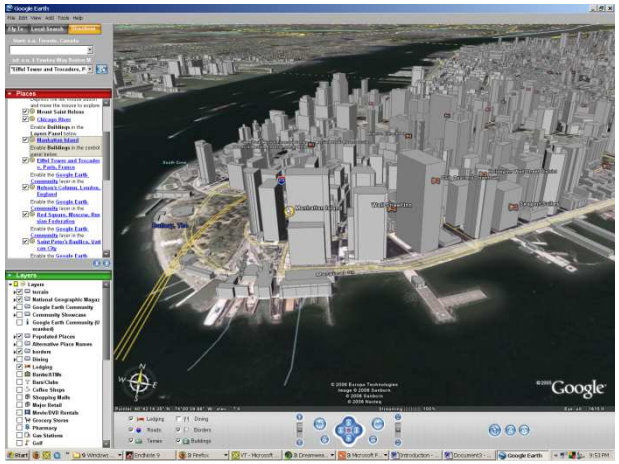
Services & Servers

- Integrated databases
- Interoperable file formats
- Referenced resources across the web
- Visualization middleware services
- Multi-user & persistent worlds







Proprietary vs. Opensource

Who owns the data?

Who owns the tools to access that data?

How are bugs/new features accomplished?

How much does it cost?

Games, Google, Second Life

vs. open standards

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Data Formats

- VRML & X3D:
  - expressive data and runtime behavior
  - Interoperation with WWW
- Import and export from many commercial and free tools
- A capable ‘common denominator’

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Open Standards

www.web3d.org

- Portability
- Durability
- IP independence
- International recognition and support

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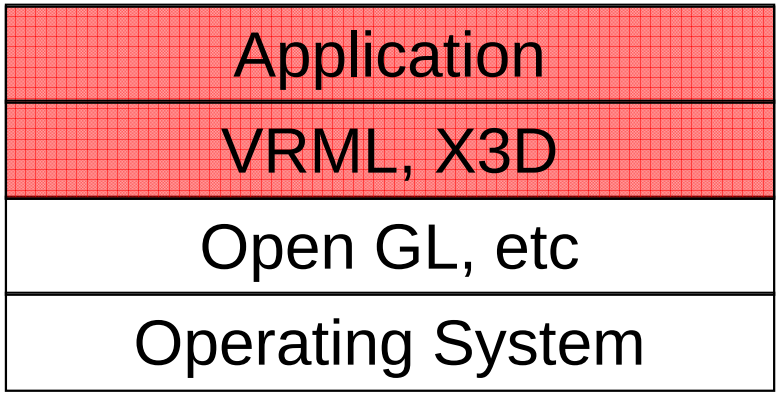
Foundations

- ISO standard, openly published
- Multiple implementations including open source codebases
- X3D includes Transformation graph and behavior graph



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Source of Specs, Models, Links, Bulleting boards, Blogs, Mailing lists, …

http://www.web3d.org

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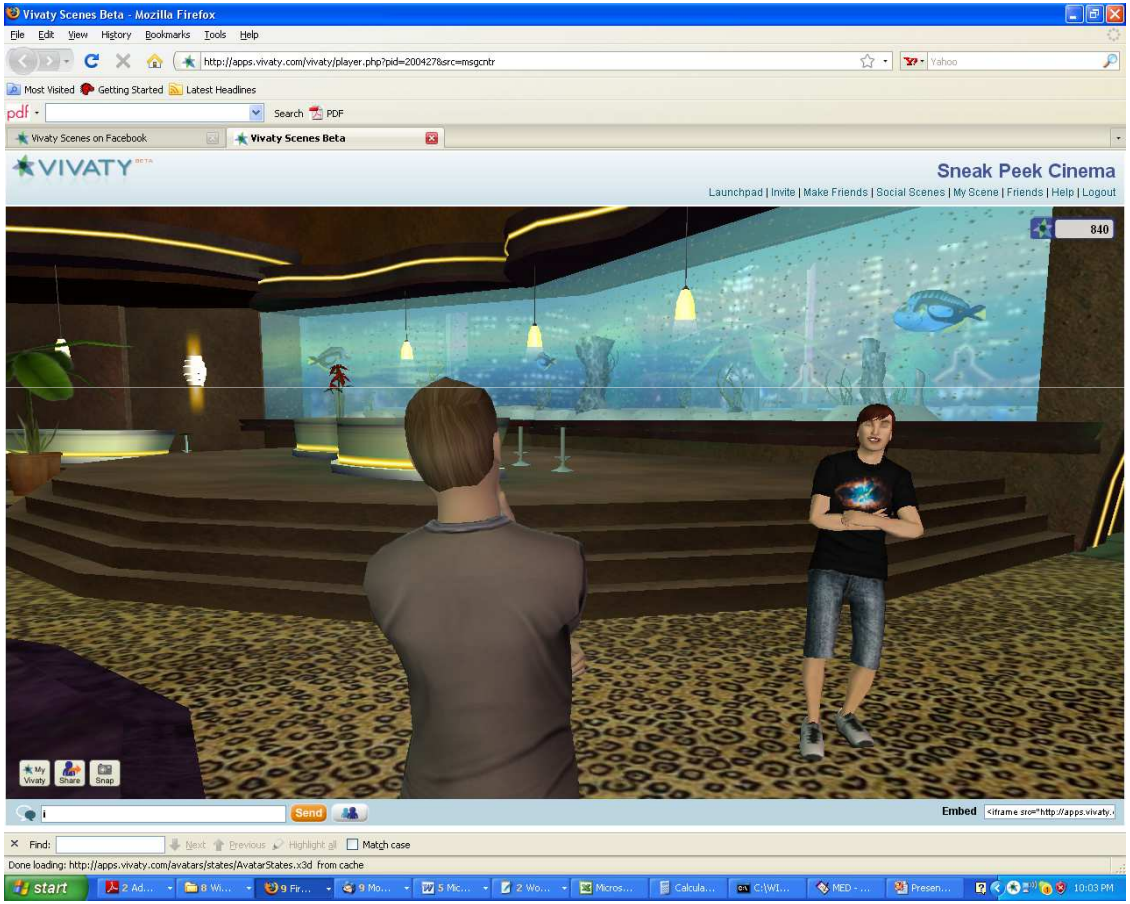
Authoring Web3D



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Many Formats but Few Standards

An Overview of X3D and related formats

- Current State of the Art
- 3D for the Web
- 3D for Documents
- 3D for Applications
- 3D Production Pipelines for web viewing
- Web3D - Get Involved

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X3D - Animated, Interactive 3D Graphics

- 3D graphics
- Animation
- User interaction-sensors allow users to interact with scene; trigger events
- Video and Spatialized audio
- Navigation-a model for navigation
- Programmable shaders - work with GPUs
- 3D and Cube Map Textures - texturing the inside of something.
- Scripting-user created code (eg. Javascript)
- User-defined extensions - prototypes

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The Web3D Consortium

X3D – Third Generation Web3D Standard

- Started in 1995 with VRML1
- VRML2 or VRML97 Second Generation
- X3D NOW and In the forseable future
  - Liaisons to other consortia encourage new ideas, concepts and features, reduce useless reinventing of the wheel

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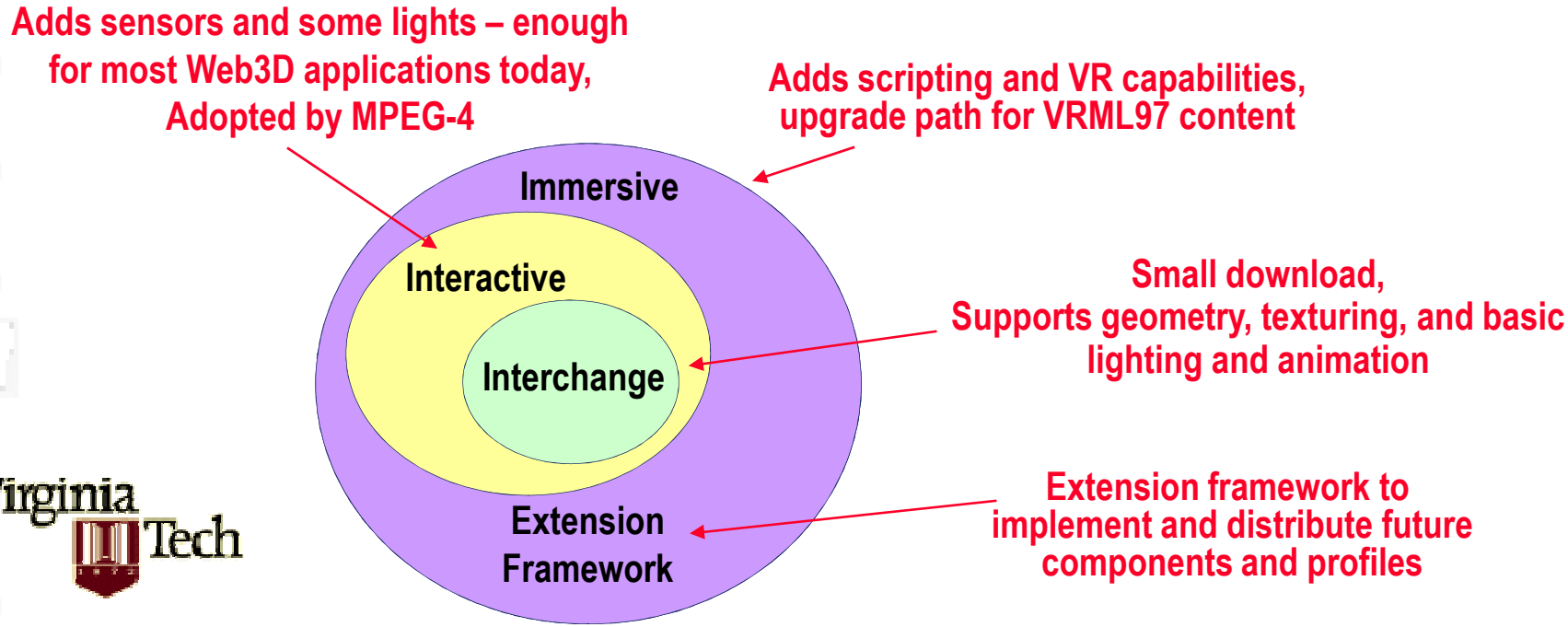
X3D – Third Generation Web3D Standard

- Extensible – profiles are adaptable in size and functionality
- Tightly integrated with XML - .wrl and .xml encodings



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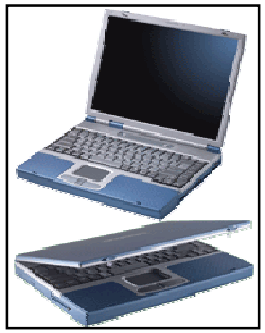
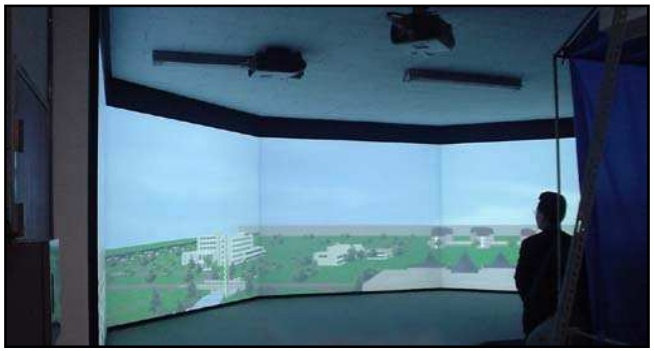
Hardware Independent





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X3D Features

XML Integrated

Componentized

Extensible

Real Time

Profiled

Conformance

ISO specified Royalty-free

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X3D Ancillary Support:

- Encodings supported
  - XML
  - VRML Classic
  - Binary compressed
- File formats supported
  - jpg, png, gif, cgm
  - wav, midi
  - GeoSpatial reference frames
- Protocols
  - http
  - Distributed Interactive Simulation (DIS)
- Languages
  - Java (optional)
  - ECMAScript (required)
  - Preliminary work on C/C++ bindings
- Graphics
  - NURBS, Shaders

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The ISO Standard for 3D on the Web

Shared world wide

Shared between applications

"X3D enables the communication of real-time 3D across networks and XML-based web services"

Lasts the Test of Time

Royalty-free Open source

Shared between systems

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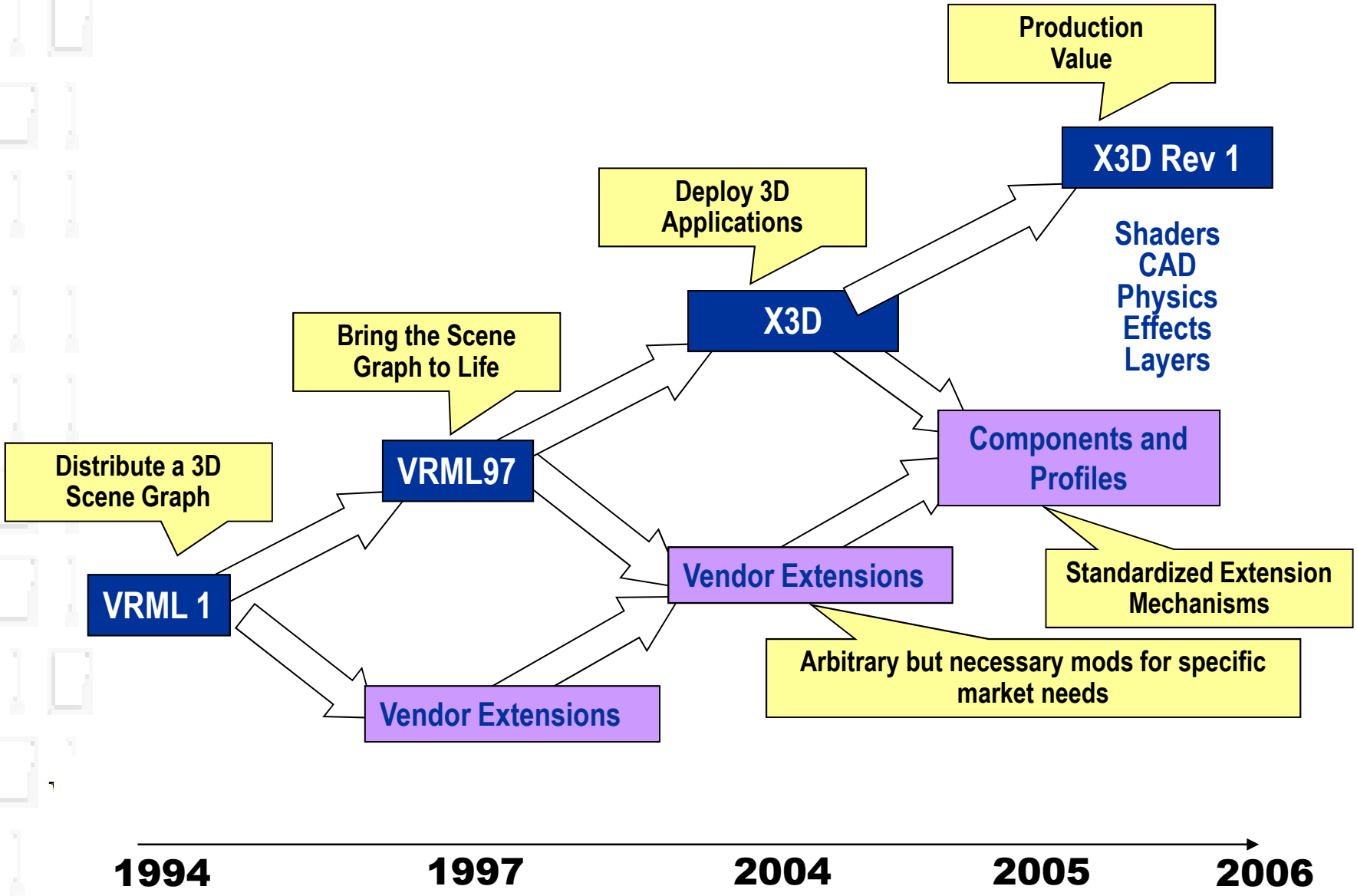
The Road to X3D



X3D - The Technology of a 3D Standard

- Real-time 3D scene graph
- Meshes, lights, materials, textures, shaders
- Integrated video, audio
- Animation
- Interaction
- Behaviors
- Scripts
- Application programming interfaces

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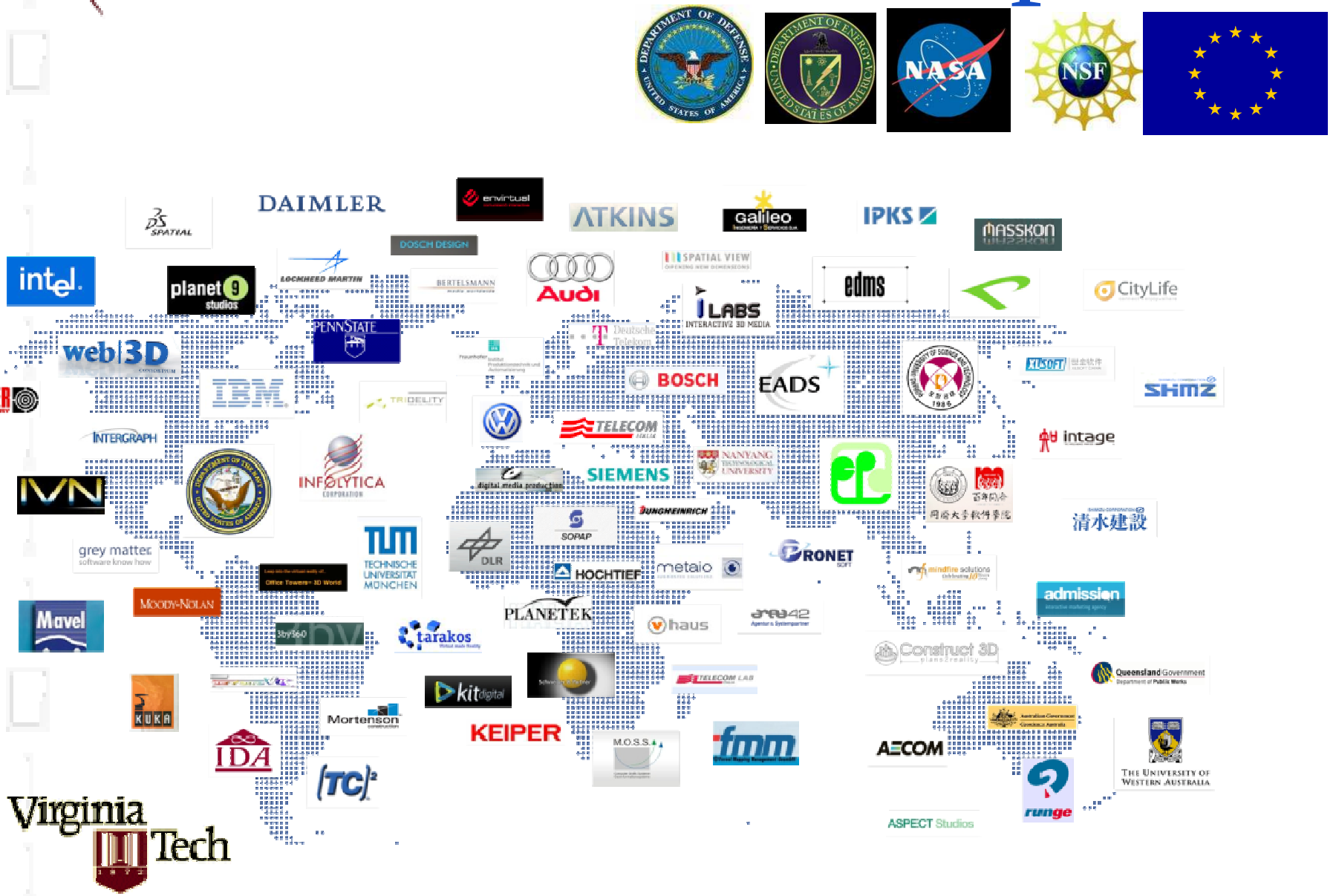
Adoption


DAIMLER
envirtual
ATKINS
Galileo
IPKS
MASSKON
DOSCH DESIGN
intel
planet 9 studios
LOCKHEED MARTIN
BERTELSMANN
Audi
SPATIAL VIEW
edms
CityLife
i LABS
INTERACTIVE 3D MEDIA
PENNSTATE
web3D
BOSCH
EADS
DRAPER
IBM
TRIDELITY
KISOFT
SHMZ
INTERGRAPH
TELECOM
intage
INFOLYTICA
NANYANG TECHNOLOGICAL UNIVERSITY
SIEMENS
digital media production
IVN
JUNGHEINRICH
清水建設
grey matter
SOPAP
TECHNISCHE UNIVERSITÄT MÜNCHEN
DLR
PRONET
HOCHTIEF
metaio
mindfire solutions
Office Towers+ 3D World
admission
Mavel
MOODY-NOLAN
PLANETEK
vhaus
area42
tarakos
Construct 3D
Queensland Government
KUKA
kitdigital
TELECOM LAB
Mortenson
KEIPER
M.O.S.S.
fmm
AECOM
IDA
THE UNIVERSITY OF WESTERN AUSTRALIA
runge
ASPECT Studios
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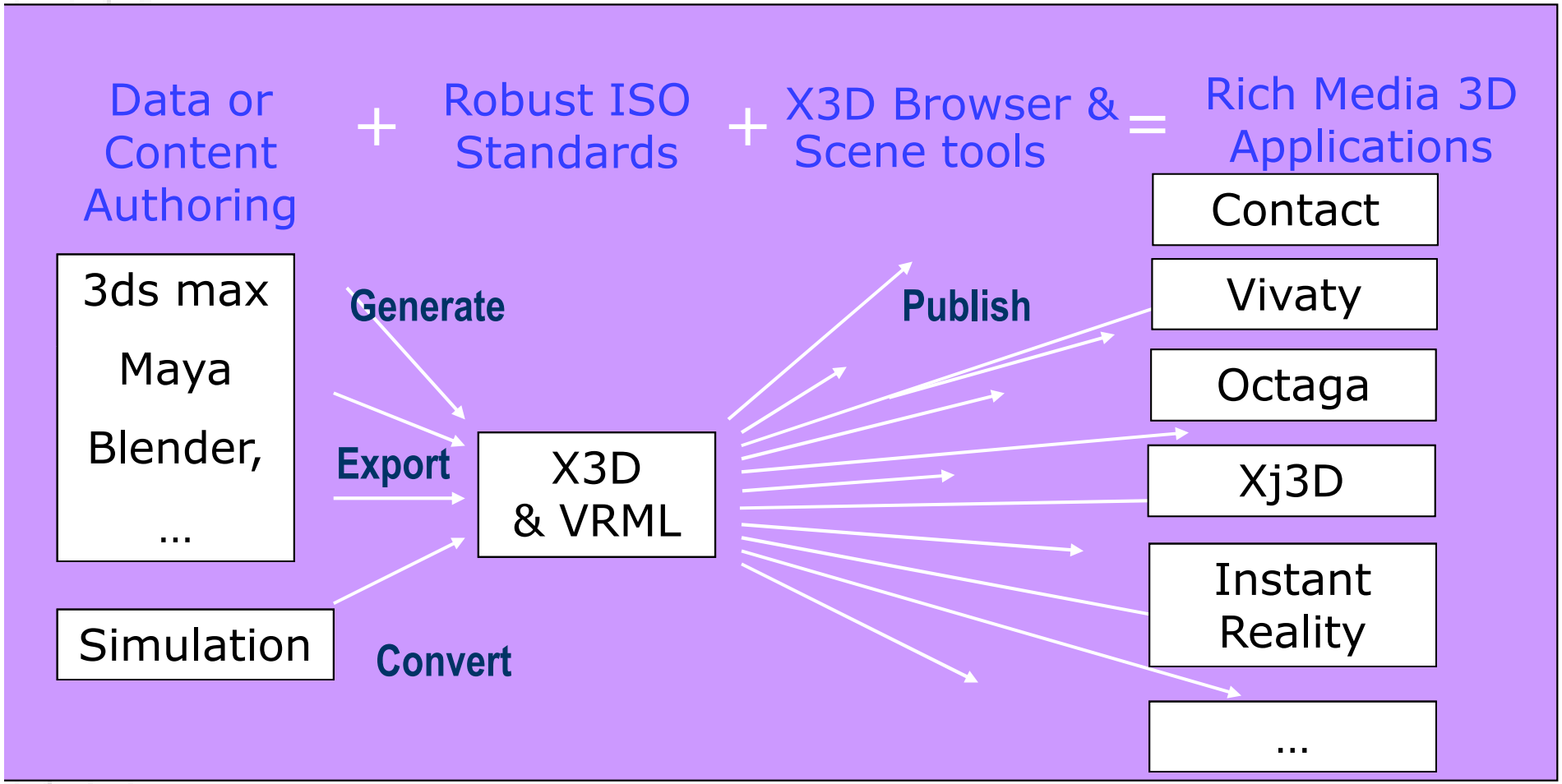
Tool Independent Workflow



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Authoring Web3D

- geometry & appearance
- animation and time
- sensors
- environments

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Resource Reminder

- Specifications, models, tutorials:
  - www.web3d.org
- VRML Reference Manual
  - http://www.cs.vu.nl/~eliens/documents/vrml/reference/BOOK.HTM

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Publishing

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Vivaty Studio

- Save (internal format)
- Import / Export
  - VRML, X3D
  - Many others roundtrip
- File -> Pull Dependent Files Local
  - Collects resources for upload/publication

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Viewers, Browsers, Players

- Plug-ins vs. Stand Alone

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Building VEs

- **Navigation** - many control options - walk, fly, examine or none (engines may also support proprietary modes)
- **Viewpoints** - pre-defined camera positions

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Building VEs

- **Models** - primitives (box, sphere, cone, cylinder), extrusions, indexed face set (mesh), line set, point set, elevation grid and text (engines may also support proprietary spline and NURBS geometry)
- **Materials** - diffuse colour, specular, emissive, ambient, shininess, transparency, colour per vertex

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Hands-on with Vivaty Studio

Visual Perception, Cameras, & Navigation

- geometry
- appearances
- lighting

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VRML & X3D
Scenegraph Basics

- Hierarchy of nodes (transformation graph)

  Nodes / Elements

- Events and attribute Data types (behavior graph)

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DAG!
(Directed Acyclic Graph)

Important nodes - (Grouping in parent/children hierarchy):

- Transform { }
- Group { }
- Anchor { }
- Switch { }
- LOD { }
- Billboard { }

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Transform Node:

- translation

  (x y z coordinates, +Y is up,

  +Z is toward the user)
- rotation around an axis

  (x y z theta; language in rads, Flux in deg)
- scale (factor in x y z)
- children (other nodes)
- Boundingbox (helps rendering optimizations)

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Shapes

Contain:

- geometry
- appearance

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geometry

- Primitives
  - Box, Cone, Cylinder, Sphere
- Extrusion
- ElevationGrid

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Indexed Faces

- `Coordinate {}`
- `coordIndex`
- `creaseAngle` : shading across polygons edges of the mesh
- `normals` (for shape-dependent lighting control)
- `solid`
- `colorPerVertex`

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Mesh editing

- Convert to IFS and select vertices, edges, polygons

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Indexed Lines

- Like faces except:
  - Use emmisive color
  - Typically not pickable
  - No creaseAngle, solid fields etc.

High order shapes

- Swept surfaces
- NURBS

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Boolean Operations

On geometry:

- Union
- Intersect
- Subtract (Extract)

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Shapes & Appearances

- **`Appearance {}`** and **`Materials {}`**: `specular, emissive, and diffuse Colors` in RGB, `shininess, transparency, ambientIntensity`
- `creaseAngle`: shading across polygons edges of the mesh
- `normals` (for shape-dependent lighting control)
- `colorPerVertex`

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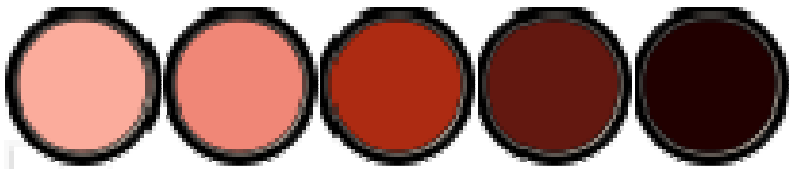
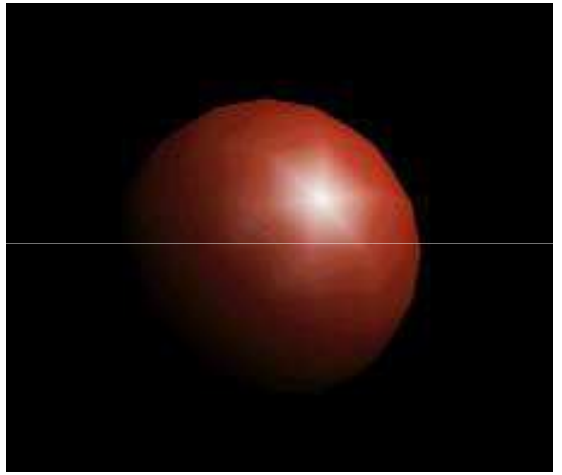
RGB

```
Material {
    diffuseColor
    0.678, 0.169, 0.07
```



specularColor



shininess

Building VEs

- **Textures** - support for JPEG, GIF, PNG and MPEG1 video. (engines may also have proprietary support for Flash, RealMedia, AVI, multi-texturing and environment mapping)
- **Lighting** - directional, point or spotlight
- **Environments** - background, and fog, hyperlinks (anchor), inlines

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Textures

- `ImageTexture {}` with (or without) alpha channels can be applied and mapped to geometry as fixed or animated maps.
  - Standard formats: .png, .jpg,
- `MovieTexture {}`
- `TextureTransform {}` …
- `PixelTexture {}`

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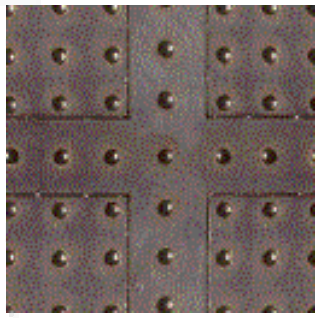
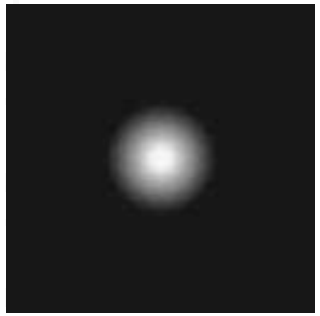
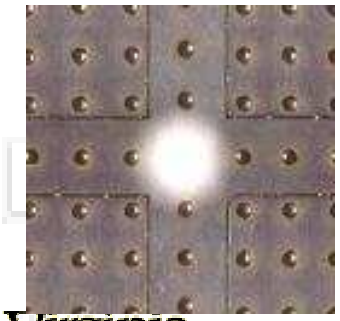
MultiTexture {}



Base Texture



+ Lightmap



= Result

Blending operations specified via `mode` field

Lighting

Lighting Nodes:
`on, intensity, ambientIntensity, color`

- `Pointlight {attenuation}`
- `DirectionalLight {}`
- `Spotlight {direction, beamWidth, cutOffAngle}`
- AMD 1: `SFBool global`

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Lighting

- Lights have color!
- Directional Lights
  - ‘ Scoped’ by scenegraph
  - sibling rule

- webfolder/vrml/lightingbasis.wrl

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Existential Perception

What is my relation to this environment?

What can I do in this world?

What do my senses tell me?

- `Viewpoint {fieldOfView}`
- `NavigationInfo {avatarSize, headlight, visibilityLimit, type, speed}`
- `Timesensor {cycleInterval }`

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Environmental effects

- `Background {}`: colors and textures give a context for the environment
- `TextureBackground {transparency}`
- `Fog {type color visibilityRange}`
- `LocalFog {} & FogCoordinate {}` (…x3d only)

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Time & Interactivity

- Keyframed animation
- Functional animation
- Events are ROUTEd between nodes

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Auditory Perception

- **`Sound {}`**
- **`AudioClip {}`**
- **`MovieTexture {}`**
  - `pitch`
  - `intensity`
  - Spatialized Audio (doppler effect)
  - Standard formats:
    .wav, .midi, .mp3, mpeg-1

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Building VEs

- **Performance** - LODs (levels of detail), visibility distance culling
- **Animation** - animate position, rotation, scale, points, colour and much more. Scope for many separate animations in one world all with different time lines and triggered by different events. Almost every attribute can be animated.
- **Sensors** - sense user activity such as touch, drag, keypress (plane, cylinder, sphere, and key sensors). Environmental sensors include time, proximity, and visibility.

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Building VEs

- **Scripting** - Interfaces directly with ECMAScript; also with Java, the web browser (DOM) and any programming language residing on the client/server
- **Routes** - scripts, animations and object properties can be "wired" together in an infinite number of ways to create any effect

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Interpolators

- Position
- Orientation
- Scale
- Others:
  - Colors
  - Coordinates

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Sensors

- TouchSensor
- Dragsensors
  - Plane
  - Cylinder
  - Sphere
- ProximitySensor
- VisibilitySensor

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Frame Rate

- Threshold for perceiving continuity:
  - flicker < 50 Hz
  - > 24 fps looks smooth & plenty interactive
- Flicker & Attention can lead to change blindness (Simmons, 2000)

- Browser.getCurrentFrameRate()
- Implementing X3DPerFrameObserverScript
  - public void prepareEvents (){}

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HTML Integration

- <EMBED SRC="vrml/composed.wrl" WIDTH="450" HEIGHT="300">
- The newer method lets you specify a classid=“” attribute <OBJECT >
- Anchor
  - url
  - description
  - parameter "target=_blank“ or some named frame

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http://www.web3d.org/x3d/content/examples/HtmlObjectTagForX3d.html

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Examples

See

- webfolder/index.html and
- embedded.html

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Characters

- H-anim
- Vivaty Studio
- Avatar Studio – Canal plus

- http://www.vrmlworlds.com/software/avatarstudio/

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New X3D technology

- Scene Access Interface (SAI)
  - Connect with external applications (eg Java, COM)
- Document Object Model (DOM)
- AJAX www.ajax3d.org

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Prototypes

- Encapsulating scenegraph branches
- For reuse
- The instance attributes are declared on the interface

- Slider example

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Scripting

Client side

- ECMA Script
  - Loosely typed
  - Non-compiled
  - Basic objects such as Math, Date, Browser
- Java
  - Fully typed
  - Compiled
  - Industrial-strength classes

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Server Side

- Internet and Local Resources
- MIME Types
- For VRML
  - x-world/x-vrml .wrl
  - Content-encoding: x-gzip .gz
- For X3D
  - AddType model/x3d+xml .x3d
  - AddType model/x3d+vrml .x3dv
  - AddType model/x3d+binary .x3db
  - AddEncoding gzip .x3dvz
  - AddEncoding gzip .x3dbz
- Anchor, Inline

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Getting online content

urlString =
'http://server.vt.edu/gateway/section_query.pl?param=yes

Browser.createVrmlFromURL(urlString,self,'isAdded');

Hexunit code example (server not live)

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