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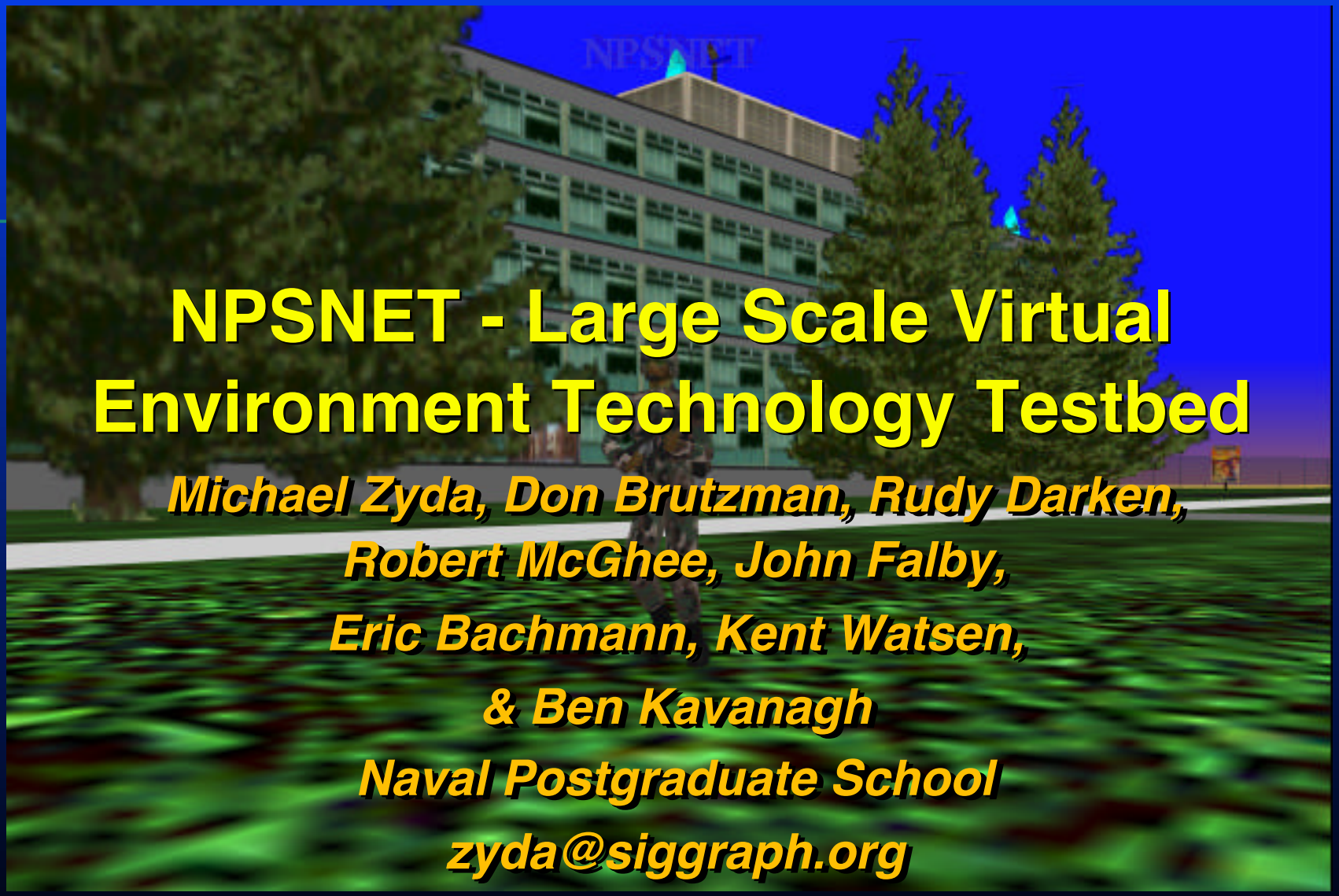
# NPSNET - Large-Scale Virtual Environment Technology Testbed (presentation to the International Conference on Artificial Reality & Tele-existence (ICAT))



# NPSNET - Large Scale Virtual Environment Technology Testbed

*Michael Zyda, Don Brutzman, Rudy Darken,*
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# Talk Outline


***NPSNET Research Group Overview***

- Techno - software technology for the networked VE.
- Interact - interaction technology for the networked VE.
- Apps - VE applications.

***Educational Infrastructure - MOVES Curriculum***

***How I spent my summer vacation ...***

# NPSNET Research Group

***The focus of the NPSNET Research Group is on the complete breadth of human-computer interaction and software technology for implementing large scale virtual environments (LSVEs).***

***In addition, we apply that research in constructing VEs useful for the DoD.***

# NPSNET Research Group


## NPSNET

### Apps
- NPSNET-V
- NPSNET-IV
- Amphibious VE

### Interact
- Inertial Motion Tracking
- Locomotion Devices
- Human Modeling in the VE
- Spatial Sound
- Wayfinding

### Techno
- LSVE Network Software Arch.
- Web-Based Interoperability
- Bamboo - VE Toolkit
- World-Building

# LSVE Network Software Architecture


***LSVE - large scale virtual environment -***

- a networked virtual environment with greater than 1,000 players in it.
  - When we say this large a number of players, we mean both live/interactive and autonomous/ computer-generated characters.

# LSVE Network Software Architecture


***Network Software Architecture (NSA) -***

- the combination of the network protocol used for the LSVE and the software architecture that supports that protocol within the confines of available bandwidth and processor cycles.
  - There are many protocol-only and software architecture-only solutions. There are few full NSA solutions.

# NSA for the VE Research Directions


## *Web-Based VE Interoperability*

- What are the issues?
  - What types of information need to be transferred between web-based networked VEs?
  - How do we transfer that information on the Internet (protocol)?
  - What is the NSA for this?

# Web-Based VE Interoperability


***What types of information need to be transferred between networked VEs?***

- State changes/entity interactions (peer-to-peer).
- Heavy-Weight Objects (http client/server requests).
- Network pointers (URLs).
- Real-time streams (Mbone audio/video).

# Web-Based VE Interoperability


***How do we transfer that information (protocol)?***

- Projects
  - Dial-a-protocol project (peer-to-peer).
  - virtual reality transfer protocol - vrtp (the applications-layer protocol used to wrap together dissimilar application layer protocols).

# Web-Based VE Interoperability


## *Dial-a-protocol project*

- Development of tools/methods for the rapid generation of peer-to-peer VE applications layer network protocols.
  - How do we formally specify the state change and entity interaction information?
  - How do we embed semantics in syntax **in general? How do we do this on-the-fly**?

# Web-Based VE Interoperability


## *Dial-a-protocol project*

- How do we formally specify the state change and entity interaction information?
  - Formal BNF specification of DIS.
  - PDU specification editor and code generator for DIS readers/writers.
  - HTML combo-form PDU specification editor.

# Web-Based VE Interoperability


## *Dial-a-protocol project*

- How do we formally specify the state change and entity interaction information?
  - DIS-Java-VRML
    - There is a working group working on how we provide DIS-like interoperability for the web. This is a fast-track effort with early success (1500 PDUs per second).

# Web-Based VE Interoperability


## *Dial-a-protocol project*

- How do we embed semantics in syntax **in general? How do we do this on-the-fly**?
  - What we are looking at very much has the flavor of Internet agents.
    - Behavior is encoded in a packet.
    - Syntax is (identifier type, number of bits).
    - Semantics is Java object & methods.

# Web-Based VE Interoperability


## General Entity Model

Objects are anything you want.

VRML
Java3D
OpenGL

Rendering

Bamboo
Java
C++

Computation & Network Access

Shared Data/Interaction

Internet

# Web-Based VE Interoperability


***How do we transfer that information (protocol)?***

- The dial-a-protocol project looks at a very small piece of the peer-to-peer, light-weight entity interaction problem in networking VEs.
- If we go back and look at our list of types of information to be transferred between VEs, we see there are other types of data in our VE ...

# Web-Based VE Interoperability


## *virtual reality transfer protocol - vrtp*

- the application-layer protocol used to wrap together dissimilar application layer protocols.
- vrtp will support:
  - Light-weight entity interactions (peer-to-peer).
  - Network pointers (URLs).
  - Heavy-weight objects (http client/server request).
  - Real-time streams (Mbone audio/video).

## vrtp & http


HTML

http

VRML 2.0

vrtp

# vrtp - a full spectrum application layer protocol


client
server

peer
peer

http
web browser
multi-user worlds

audio
video
DIS behaviors

group-cached http servers (NCSA)

"reliable" multicast

# Web-Based VE Interoperability


***The primary problem we are trying to solve is how to optimize available bandwidth and available processor cycles for our LSVE.***

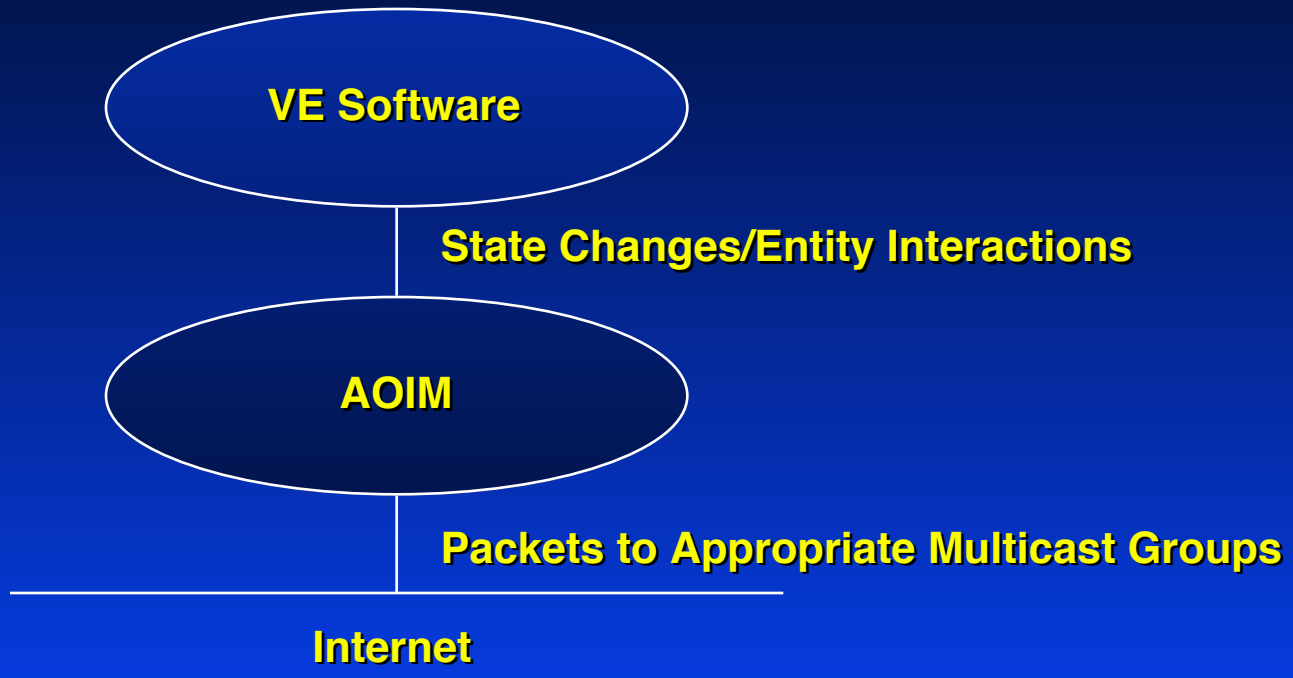
- We don't want to bury the CPU in processing packets at the applications layer of the operating system.
- We don't want to flood the network with unnecessary packets.

# Area of Interest Management


***We have done a lot of software experimentation and systems testing to get a good understanding of the software architecture issues.***

- We are now focusing on a layer of software we call the Area of Interest Manager (AOIM).

# Area of Interest Management



# Area of Interest Management


## *State Changes/Entity Interactions*

- instead of being broadcast to everyone, are assigned to particular multicast groups (groups are interested parties, spatial partitioning, functional partitioning, temporal partitioning, ...).

# Area of Interest Management


## *Packets to Appropriate Multicast Groups*

- Multicast groups are subscribed to by appropriate parties.
- Packets not part of subscribed multicast groups are killed off at the network interface unit rather than at the applications layer in the CPU!
- So your VE only gets packets from groups formally subscribed to.

# Area of Interest Management


## *Research Issues in AOIMs*

- How do we program **in a general way** an AOIM?
- AOIMs are application dependent. How do we design such systems for dynamic AOIM replacement?
- In a distributed fashion, how do we dynamically assign information to a particular set of multicast groups?

# DoD Standards for Interoperability


***The NPSNET Research Group has always been on the leading edge in the development and utilization of DoD standards for interoperability.***

- NPSNET-IV is SIMNET and DIS compliant.
- We are currently evaluating HLA for its utility in interactive LSVEs.

# Bamboo - An Extensible Framework for Networked VEs


***Motivation:***

- A general-purpose, cross-platform, high-level toolkit providing a framework facilitating VE application research and development.

# What is Bamboo?


- Core mechanisms common to networked VEs.
  - an API toolkit for serious programmers.
- Dynamically extensible runtime environment.
  - an application which puts it all together.
- Based on OpenGL++.
  - which implies OpenGL, C++, STL.

# What is OpenGL++?


***Multi-platform (SGI, Windows NT, BeOS, Linux, etc.)***

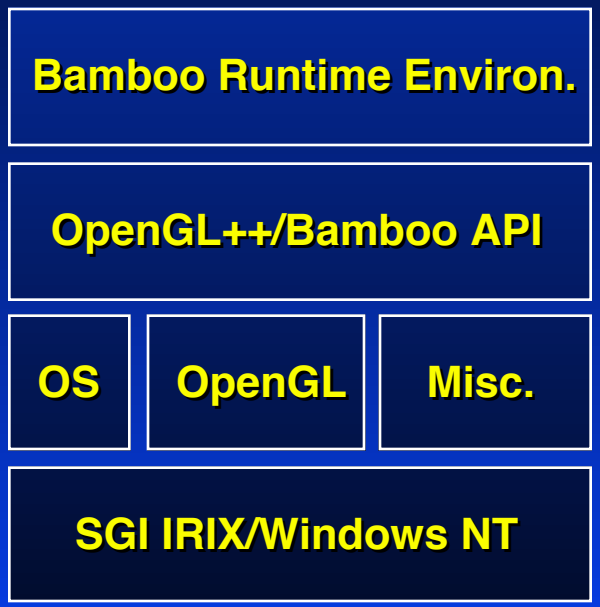
***Visualization toolkit (Performer + Inventor)***

- Mechanisms:
  - RTTI, linear math routines, scene graph, construction and manipulation, draw/probe/sound actions (traversals), engines (spline, morph), fields, routes, and some extensibility.

# How to extend OpenGL++?


***Bamboo sits along-side rather than on top of OpenGL++ ...***

***Based on Plug-ins***



# Bamboo's Mechanisms


- *Extensibility*
- *Networking*
- *Security*
- *Process Management*
- *Inter-Process Communication*
- *Remote Procedure Calls*
- *Callbacks*
- *Event Handling*
- *Device Manager*
- *Database Handling*
- *Statistics Manager*
- *Graphical User Interface*
- *Undo/Redo*
- *Physically-Based Modeling*
- *Friendly OpenGL++ Abstractions*

# VE World Building

# VE World Building

# VE World Building

# Interact


- *Inertial Motion Tracking of Humans in a Networked VE*
- *Locomotion Devices*
- *Human Modeling in the VE*
- *Spatial Sound*
- *Wayfinding*

# Inertial Motion Tracking of Humans in a Networked VE


***Current technologies are unable to provide a natural and intuitive interface for inserting a human into a large scale networked virtual environment.***

# Inertial Motion Tracking of Humans in a Networked VE


*Advances in the design of micromachined accelerometers and angular rate sensors and 3D spatial positioning using RF, present the possibility of tracking human body motion inertially in a manner similar to that of an inertial navigation system (INS).*

# Inertial Motion Tracking of Humans in a Networked VE


***Current human motion capture systems suffer from numerous limitations:***

- User encumbrance
- Restricted Range
- Susceptibility to Interference
- Latency
- Shadowing

# Inertial Motion Tracking of Humans in a Networked VE


*The hybrid inertial tracking system is essentially sourceless and does not suffer from these limitations.*

*Inertial body tracking is based upon same algorithms as inertial navigation of missiles, aircraft and ships.*

*Physics resemble those of the human vestibular system.*

# Inertial Motion Tracking of Humans in a Networked VE


***Proposed tracking system advantages:***

- High data rates without perceptible lag.
- Tolerant to environmentally induced errors.
- Will produce consistent registration between physical and virtual worlds.
- Allow multiple users in a large working volume simultaneously.

# Inertial Motion Tracking of Humans in a Networked VE


## *Basic Concept:*

- Instrument the Human body with 15 micromachined inertial sensors.
- Each sensor contains:
  - Three-axis accelerometer.
  - Three-axis rate sensor.
  - Three-axis magnetometer.

# Inertial Motion Tracking of Humans in a Networked VE


*Complementary filtering would correct for sensor errors and drift.*

*The sensors would provide an orientation vector for each body segment.*

*RF positioning of a single point on the body would accurately place the articulated human within the VE.*

# Inertial Motion Tracking of Humans in a Networked VE

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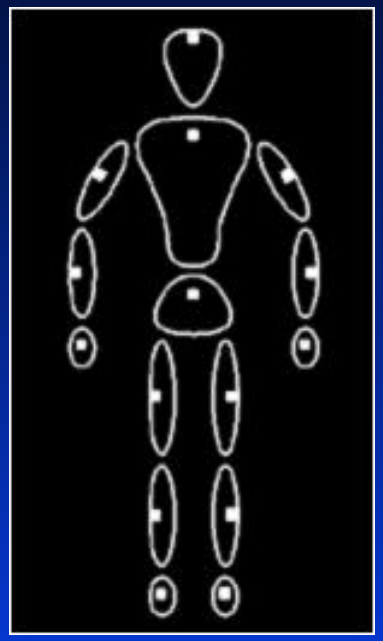
***Human Body Tracking Sensor Configuration***



# Locomotion Devices


*Most of our work in locomotion devices has been to integrate other people's locomotion devices into the NPSNET-IV software platform.*

*Two of our most successful demos ...*

# AUSA 95 Treadport

***Joint project with Sarcos Engineering, UPENN & NPS.***

- NPS role was to integrate treadport into NPSNET-IV.

# AUSA 96 Omni Directional Treadmill (ODT)

# Human Modeling in the VE

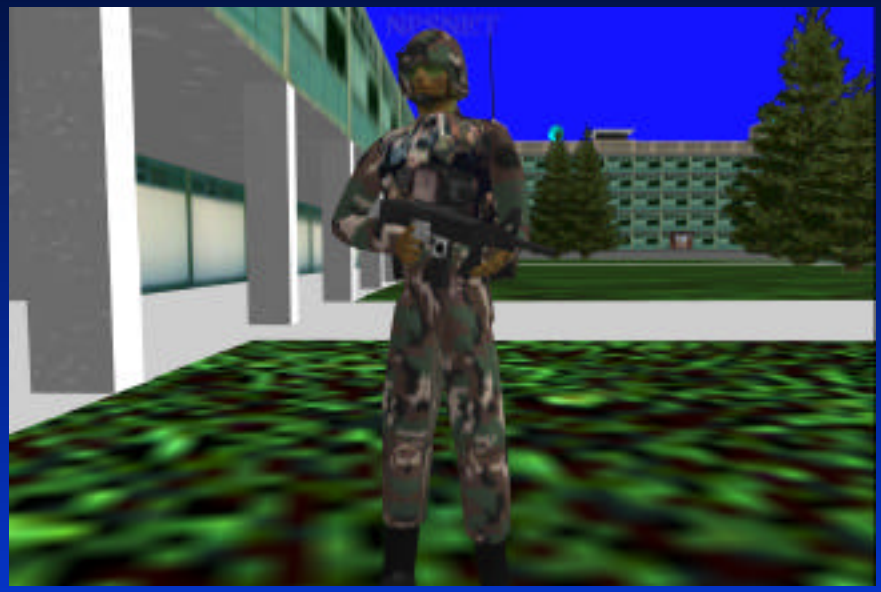

***We have explored commercial solutions for animating articulated humans in the VE.***

- UPENN Jack-ML
- BDI DI-Guy
- All of these solutions are too slow once you get above about 5 to 10 humans in view.

# Human Modeling in the VE

***Low-cost, articulated humans.***

- We want to develop articulated human support software capable of displaying 100 to 150 humans in the NPSNET-V VE.



# Spatial Sound for the VE


## *Virtual Environment Auditory & Visual Intersensory Modality Issues*

- Measuring performance & immersion during wayfinding and target acquisition tasks in a VE.
  - Are manipulating both auditory & visual display fidelities.
  - Want to find out the effects of both modalities on performance & immersion.

# Wayfinding in the VE


## *Training Spatial Knowledge Acquisition Using Virtual Environments*

- The goal of the work is to show that VEs can be used to acquire spatial knowledge of a specific real space (training transfer).

# Wayfinding in the VE


- Future work will involve the investigation of environmental features and perceptual stimuli and their role in navigation and wayfinding so that we may understand how to degrade the fidelity of a VE without substantially degrading navigation performance.
- We will then extend these concepts to training general navigation skills, including map usage (perspective transformation) and landmarking abilities.

# Applications of VE Technology


***NPSNET-IV Completion***

***NPSNET-V***

***An Amphibious VE***

# NPSNET-IV Completion


## *NPSNET-IV Capabilities*

- Building walkthroughs.
- Articulated humans - mounting/dismounting capability.
- Networking - play across the multicast backbone of Internet.
- Terrain database integration, terrain paging (70km x 70km).
- Any vehicle capability - air, ground, articulated human.
- Testbed for VE NSA issues.
- Interoperability - SIMNET/DIS
  - Constructive model integration - Janus World Modeler
  - ModSAF

# NPSNET-ODT Press Conference & AUSA 96


NPSNET


NPGNET

# NPSNET-V


## *Features & Plans*

- Redesigning the network software architecture of NPSNET.
- Plug & play VE where additional modules of capabilities (networking, human models, terrain models, walkthroughs, mounting/dismounting of humans, general interaction ...) can be developed with a uniform, published API.

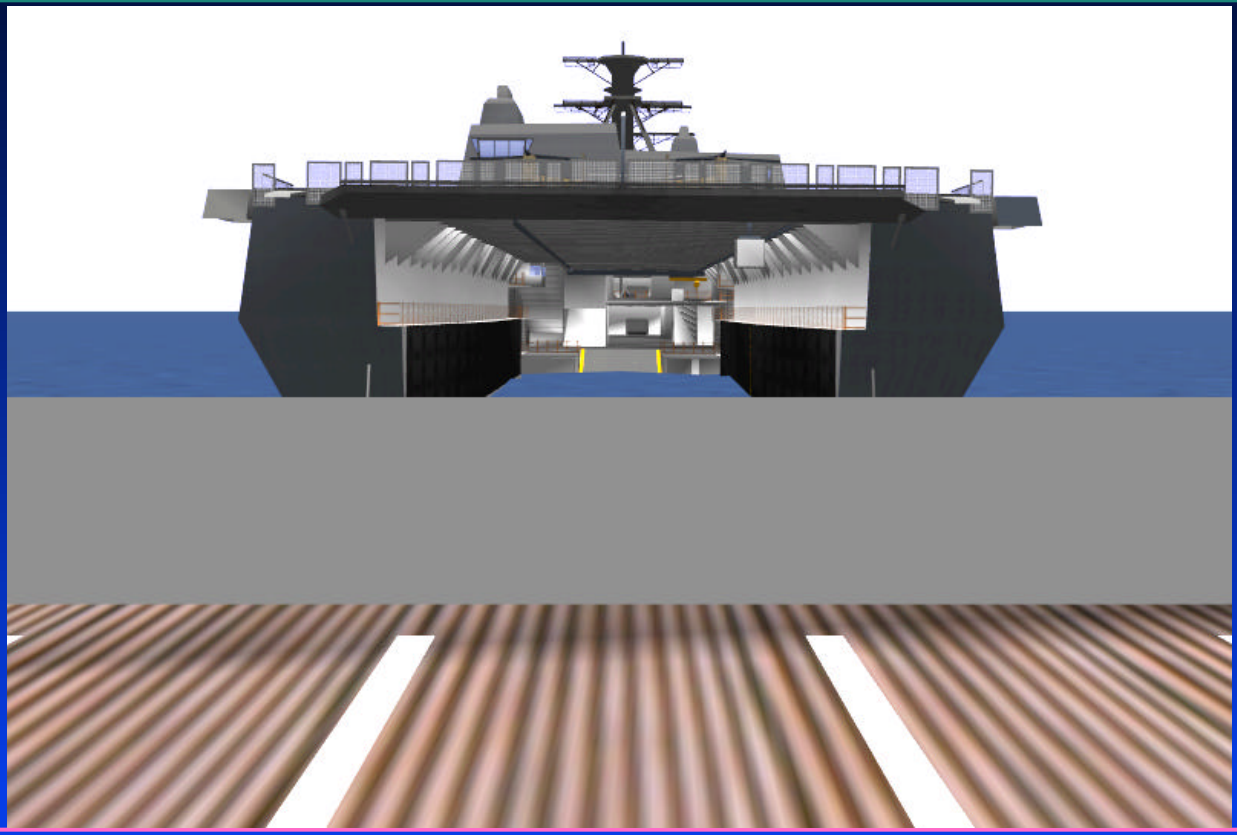
# NPSNET-V


## *Technologies for NPSNET-V*

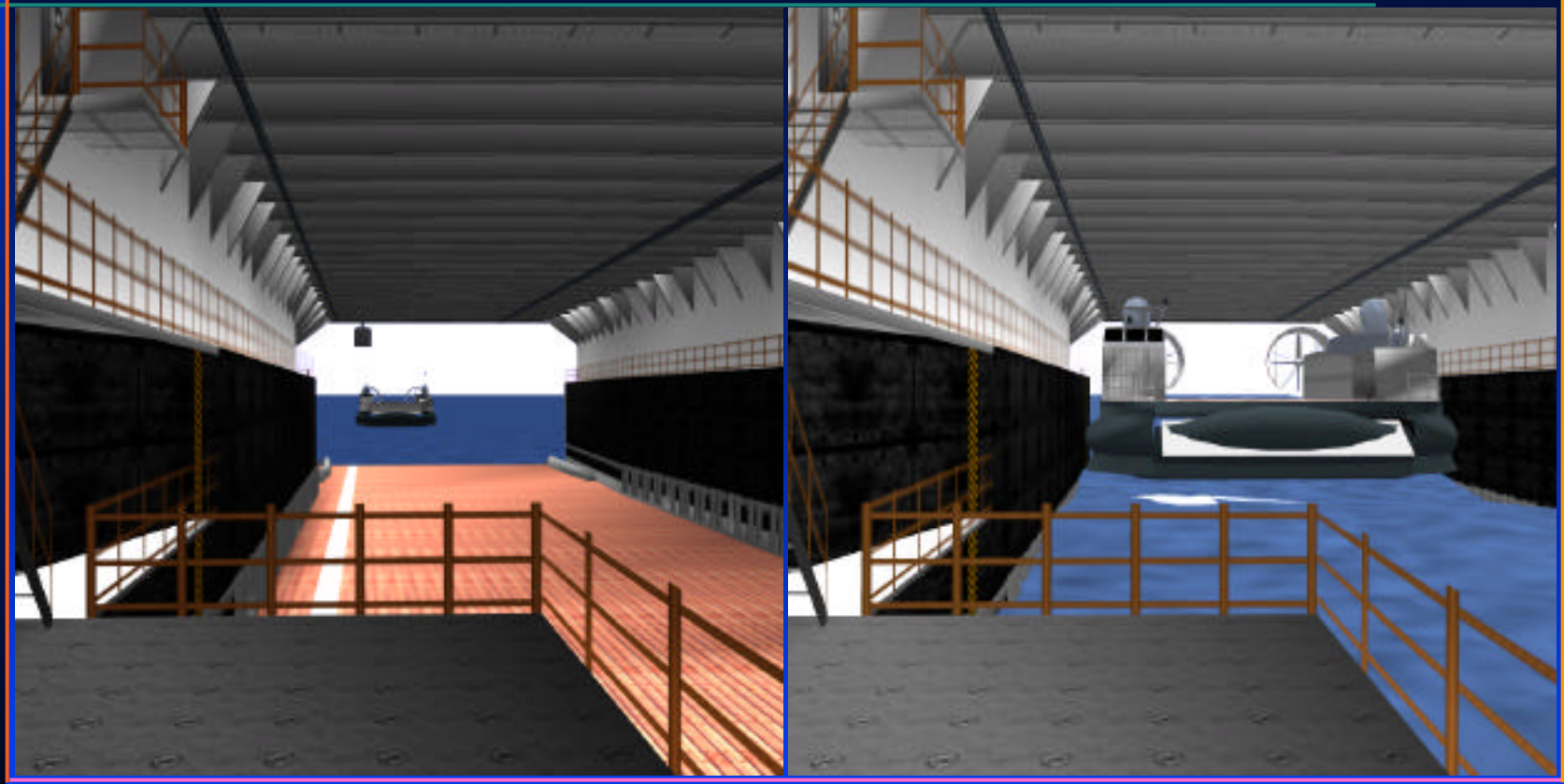
- Bamboo - Next Generation Toolkit
  - OpenGL++
  - C++/Java
  - vrtp & HLA

# An Amphibious VE

# An Amphibious VE



# An Amphibious VE



# An Amphibious VE

# Educational Infrastructure


***MS & PhD Program in Computer Science, with specialization in Computer Graphics & Visual Simulation***

# Educational Infrastructure - MOVES Curriculum


## *Modeling, Virtual Environments & Simulation Curriculum*

- The MOVES Curriculum provides the MS and Ph.D. student both fundamental & specialized courses in applied computer simulation technology & the application of quantitative analyses to human-computer interaction in simulation technology.

# Educational Infrastructure - MOVES Curriculum


- There are two tracks that support the curriculum's research efforts, the Visual Simulation Track and the Human-Computer Interaction Track.
  - The Visual Simulation track is focused on developing the technolgy for VEs.
  - The Human-Computer Interaction track is focused on evaluating human performance with the developed technology.

# NRC CSTB - Modeling & Simulation Linking Entertainment & Defense

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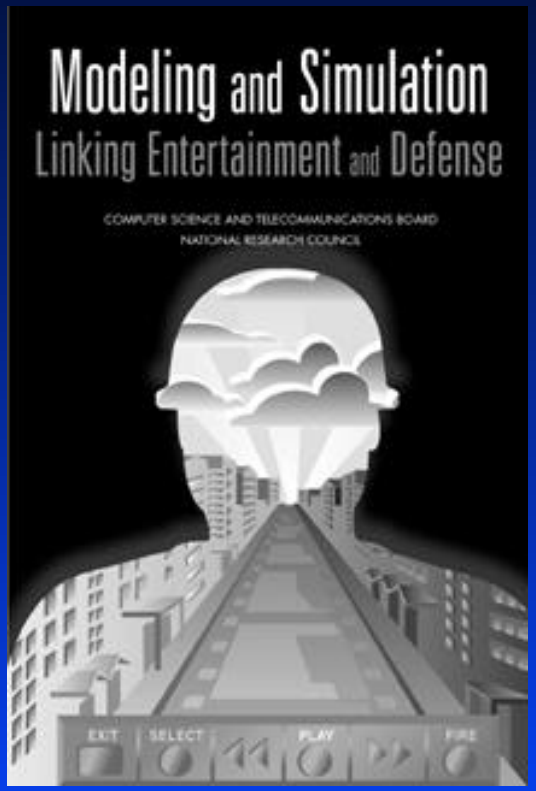
***Modeling & Simulation: Linking Entertainment & Defense***

ISBN 0-309-05842-2

National Academy Press

http://www.nap.edu/readingroom



# Mobile Agents - Explanations & Examples


***Mobile Agents - Explanations & Examples***

William R. Cockayne & Michael Zyda

ISBN 1-884777-36-8

Available from Manning Press

http://www.manning.com

# Networked Virtual Environments


***Networked Virtual Environments***

Sandeep Singhal &
Michael Zyda

- ACM Press

# NPSNET Research Group Sponsors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# NPSNET Web Sites


***NPSNET Page***

http://www.npsnet.nps.navy.mil/npsnet

***Interact Page***

http://www.npsnet.nps.navy.mil/interact

***Michael Zyda***

http://www.cs.nps.navy.mil/people/faculty/zyda