

---

# Distributed Virtual Environments

## Introduction

Richard M. Fujimoto  
Professor

Computational Science and Engineering Division  
College of Computing  
Georgia Institute of Technology  
Atlanta, GA 30332-0765, USA

<http://www.cc.gatech.edu/~fujimoto/>

# Outline

---

- What are they?
- DVEs vs. Analytic Simulations
- DIS
  - Design principles
- Example

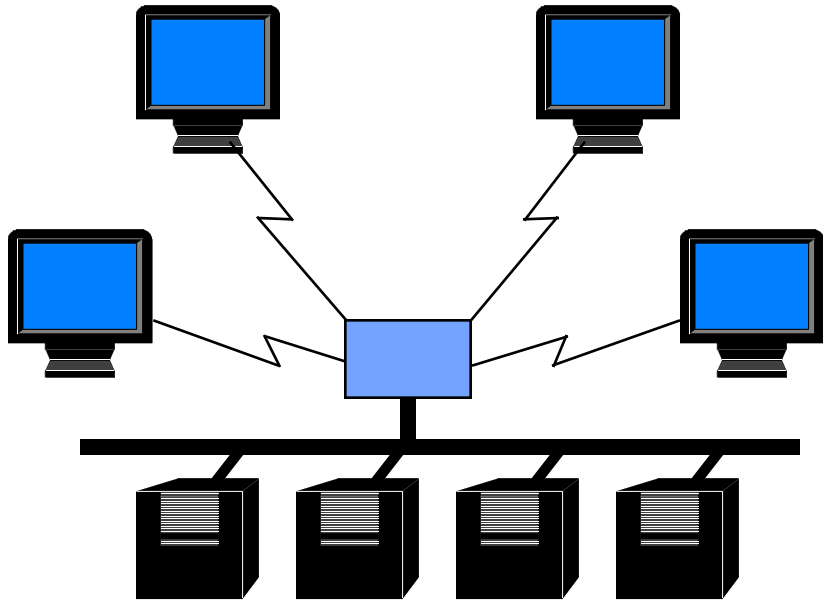
# Distributed Virtual Environments (DVE)

- A synthetic world into which humans and/or physical devices are embedded
- Interaction between embedded humans/devices and simulated elements
- Involves humans, devices, computations at different locations
- Examples
  - Military training (SIMNET, Distributed Interactive Simulation, HLA)
  - Multiplayer video games
- A key issue is to ensure different participants have consistent views of the DVE
  - Consistent in time and space
  - “Fair fight” issues
  - Latency, limited communication bandwidth

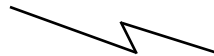
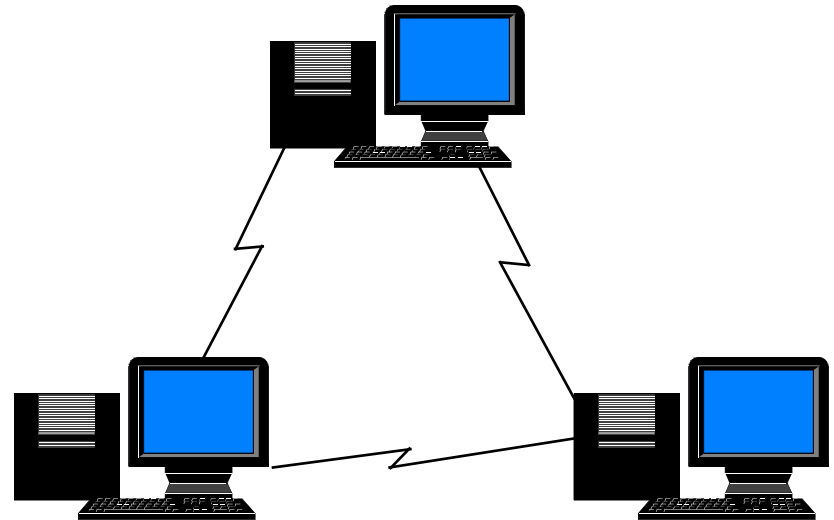
# DVE Architectures

---

## Server architecture



## Distributed architecture



WAN interconnect



LAN interconnect

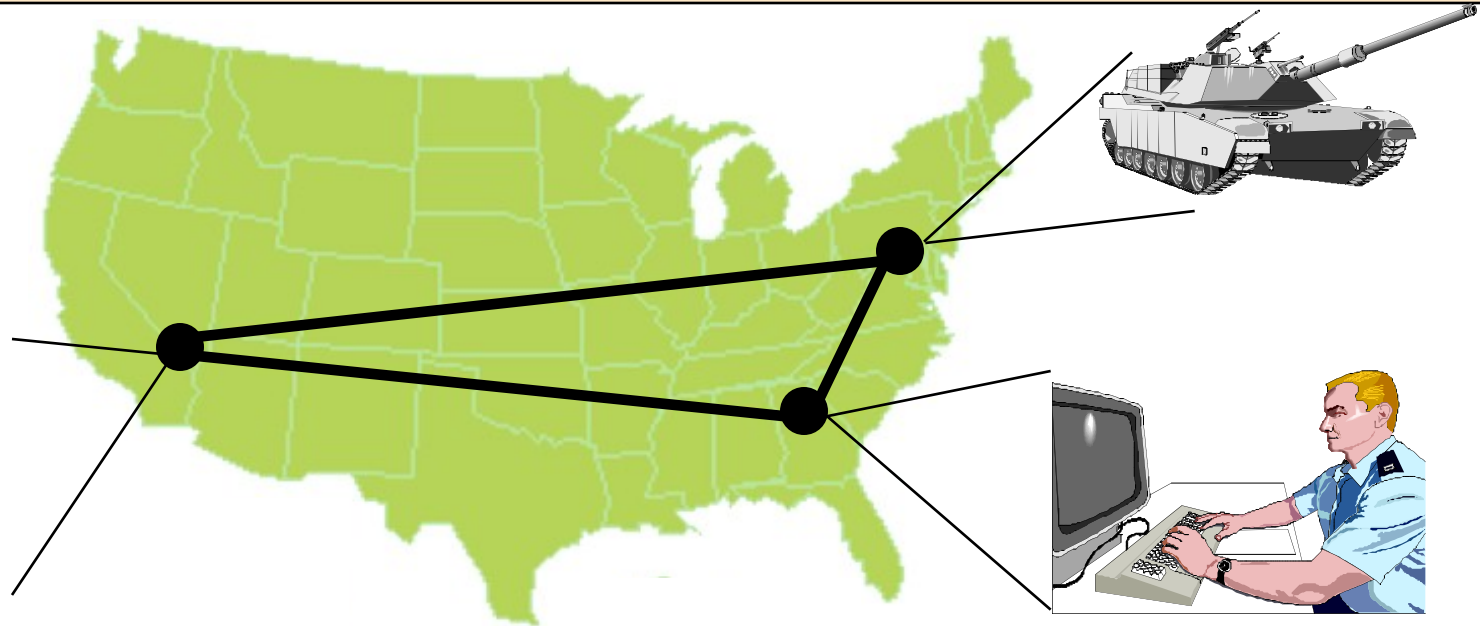
# Analytic vs. Training

---

	Analytic	DVE
Communication	Often point-to-point Reliable Multiprocessor/LAN OK w/ Arbitrary latency	Broadcast/multicast Best effort LAN/WAN Latency bounds, low jitter
Simulation Model	May be non-interactive	Interactive
Time Management	Time stamp order Synchronization protocol	Receive order No synchronization protocol
Performance	As-fast-as-possible Speedup	Real-time Realism
Typical Applications	Design, analysis	Training, entertainment
Issues (selected)	Efficient execution Ease of use	Scalable execution

# Distributed Interactive Simulation (DIS)

“The primary mission of DIS is to define an infrastructure for linking simulations of various types at multiple locations to create realistic, complex, virtual ‘worlds’ for the simulation of highly interactive activities” [DIS Vision, 1994].



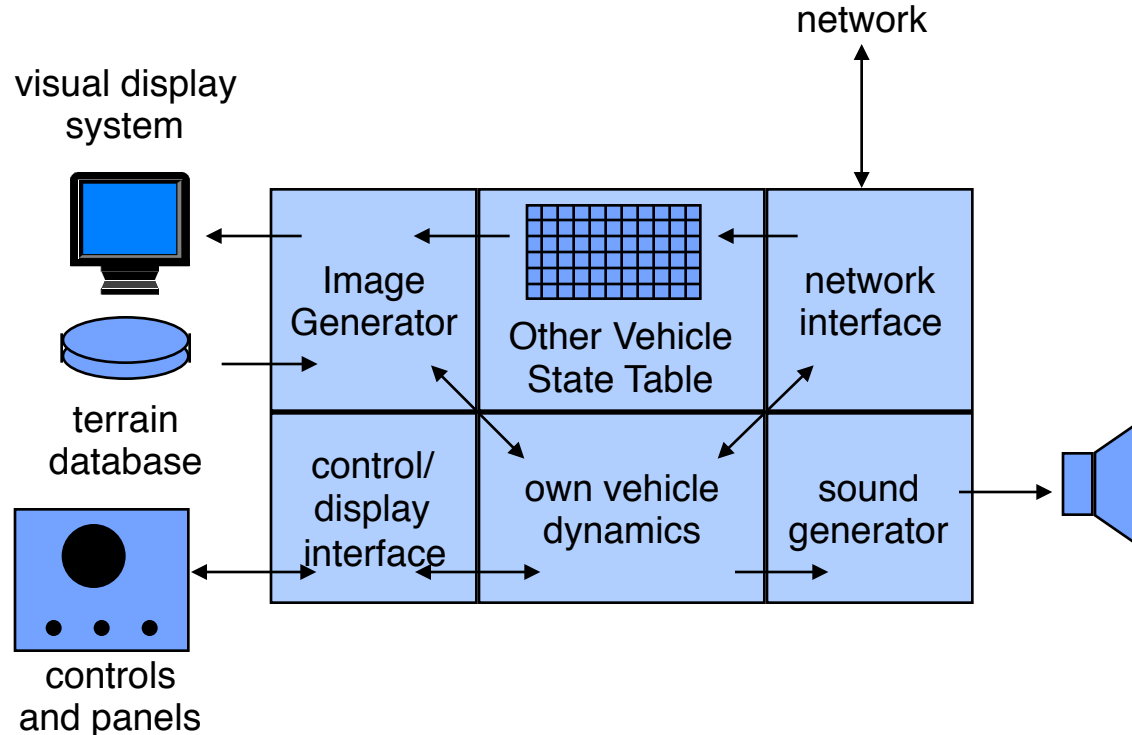
- developed in U.S. Department of Defense, initially for training
- DVEs widely used in DoD; growing use in other areas (entertainment, emergency planning, air traffic control)

# DIS Design Principles

---

- **Autonomy of simulation nodes**
  - simulations broadcast events of interest to other simulations; need not determine which others need information
  - receivers determine if information is relevant to it, and model local effects of new information
  - simulations may join or leave exercises in progress
- **Transmission of “ground truth” information**
  - each simulation transmits absolute truth about state of its objects
  - receiver is responsible for appropriately “degrading” information (e.g., due to environment, sensor characteristics)
- **Transmission of state change information only**
  - if behavior “stays the same” (e.g., straight and level flight), state updates drop to a predetermined rate (e.g., every five seconds)
- **“Dead Reckoning” algorithms**
  - extrapolate current position of moving objects based on last reported position
- **Simulation time constraints**
  - many simulations are human-in-the-loop
  - humans cannot distinguish temporal difference  $< 100$  milliseconds
  - places constraints on communication latency of simulation platform

# A Typical DVE Node Simulator

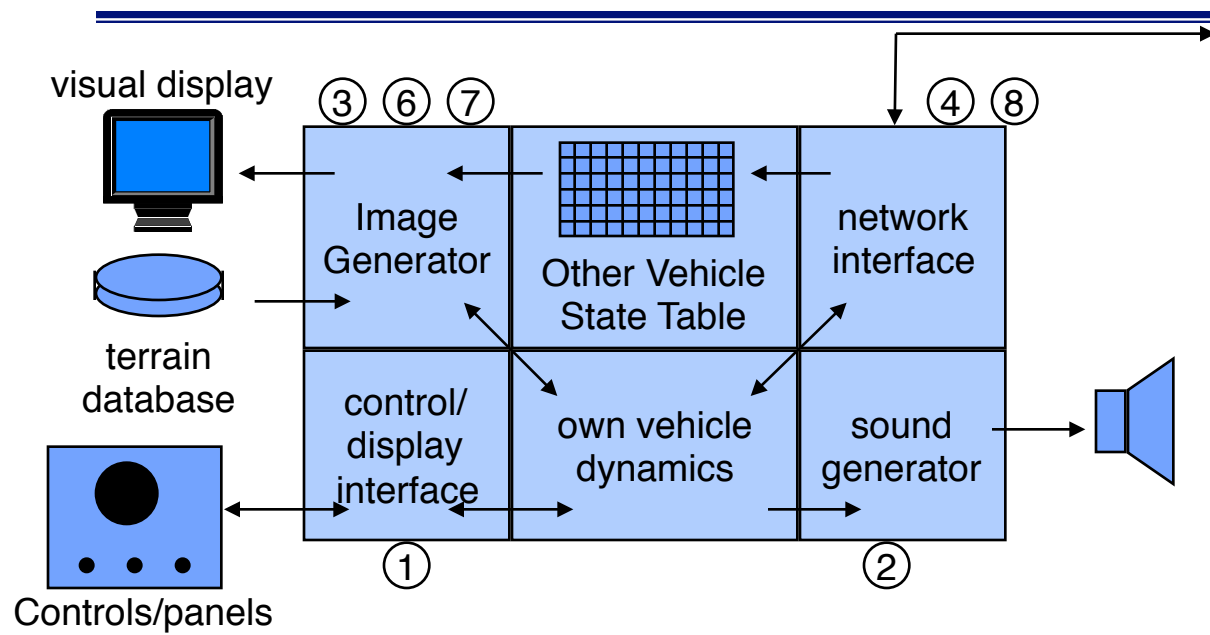


Execute every 1/30th of a second:

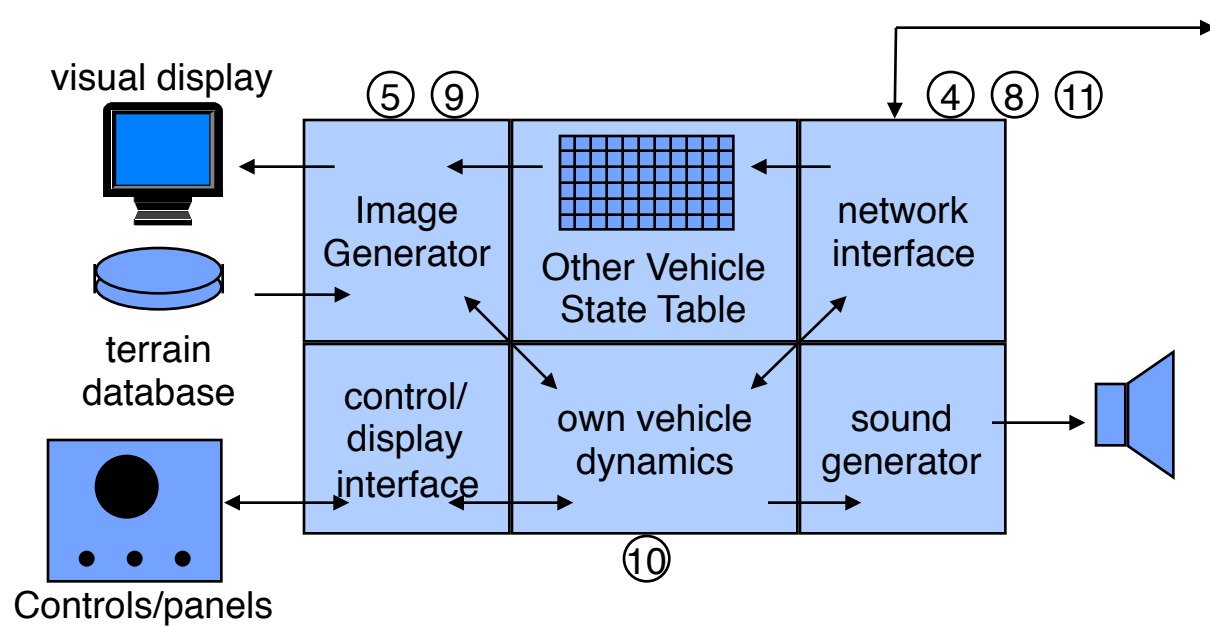
- receive incoming messages & user inputs, update state of remote vehicles
- update local display
- for each local vehicle
  - compute (integrate) new state over current time period
  - send messages (e.g., broadcast) indicating new state



# Typical Sequence



1. Detect trigger press
2. Audio "fire" sound
3. Display muzzle flash
4. Send fire PDU
5. Display muzzle flash
6. Compute trajectory, display tracer
7. Display shell impact
8. Send detonation PDU
9. Display shell impact
10. Compute damage
11. Send Entity state PDU indicating damage



# Summary

---

- Distributed Virtual Environments have different requirements compared to analytic simulations, leading to different solution approaches
  - May be acceptable to sacrifice accuracy to achieve better visual realism
  - Limits of human perception can often be exploited
- Distributed Interactive Simulation (DIS) representative of approach used in building DVEs