AGENDA

VR Meets Virtualization

Background and Motivation

Enterprise VR

Use Cases
Business Needs
Proposed Solution

Building a Multi-User Virtualized VR System

Design Requirements
Hardware
Software

Initial Results

Future Research

Q&A
BACKGROUND

What was our Motivation?

Location Based Entertainment

- Density problem
- Management of multiple PCs across separate venues

Our own tradeshow setup experience

- Multiple Rooms and Demo Staff,
- Long Setup times, cabling, Systems in Sync, latest updates,
VIRTUAL REALITY MEETS VIRTUALIZATION
Why not push pixels over the network?

Multiple full-featured VR experiences on one server?

NVIDIA GeForce NOW

Games streaming From Global Datacenters
VIRTUAL REALITY MEETS VIRTUALIZATION

Latency... the silent killer

Latency demands of VR vs Gaming

NVIDIA GeForce GRID Latency

**VR PERFORMANCE DEMANDS**

Ultra-Low Latency

Motion to Photon: ≤ 20 ms

**GeForce GRID Latency**

- **CLIENT**
  - Render
  - Decode

- **SERVER**
  - NIC
  - CPU
  - Encode
  - Render

**Network**

- GeForce GRID: 30-60 ms
- Network: 30 ms
- GeForce GRID: 60 ms

2 Frames

4 Frames
VIRTUAL REALITY MEETS VIRTUALIZATION

GPU Pass-Through to the rescue

NVIDIA GRID Technology

GPU Pass-Through

Hypervisor Support for Quadro

Bypass the Pixel streaming

Direct output from Quadro display connector to VR HMD
QUADRO PASCAL
Next Generation Quadro VR-Ready Platform
ENTERPRISE VR
ENTERPRISE VR MARKET

Anticipating Growth

Experimenting
Finding valid uses for VR

Struggling with deployment
  • Scalable
  • Practical
  • Maintainable
  • Affordable

NVIDIA VRWorks Puts the ‘Reality’ in VR for Application Developers
VR USE CASE CATEGORIES

HMDs

SINGLE-HMD

SINGLE-HMD

MULTI-HMD

PHYSICAL SPACE

PLAYERS

VIRTUAL SPACE

SINGLE-PLAYER

MULTI-PLAYER

SINGLE-PLAYER

MULTI-PLAYER
## VR USE CASES

### SINGLE-HMD SINGLE-PLAYER
- Individual HMD in one Physical Location
- One user playing a Single-Player VR Game or Experience

Examples:
- Single-Player Gaming
- Self Training Experience
- Designer/Developer

### SINGLE-HMD MULTI-PLAYER
- Individual HMDs at each of several physical Locations
- Multiple Players competing or collaborating in a shared VR Environment

Examples:
- Multi-Player Gaming
- Instructor Led Training
- Team Meetings
- Collab Design/Review

### MULTI-HMD SINGLE-PLAYER
- Multiple HMDs within tether range of each other
- Each user playing a separate Single-Player VR Game or Experience

Examples:
- Gamers at an event
- Self Training Center VR Theater
- Designers/Developers

### MULTI-HMD MULTI-PLAYER
- Multiple HMDs within tether range of each other
- Multiple Players competing or collaborating in a shared VR Environment

Examples:
- Team Gaming
- Team Training
- Group Experience
- Collab Design/Review

* Excluding Mobile Smartphone-based solutions due to power and positional tracking limitations
MULTI-USER TEMPORARY DEPLOYMENTS

Setup / Teardown - cycle can be time consuming

4 users in 4 single room scale volume configuration at a single location

* Image provided courtesy of Mass Virtual

Source: © Mass Virtual, Used by Permission
DEPLOYMENT PLATFORM OPTIONS

PC or Mobile VR

HW Platform

# VR Rigs

Use Case

Single PC

Multiple PCs

Single-User Single-Player

Single-User Multi-Player

Multi-User Single-Player

Multi-User Multi-Player
DEPLOYMENT PLATFORM OPTIONS

Solving the VR at Scale Problem

HW Platform

# VR Rigs

Use Case

Deployment Platforms

PC

Multi-User VR System

Single PC

Multi-PCs

1:4 (1:8)

Single-User Single-Player

Multi-User Single-Player

Multi-User Multi-Player

Multi-User Multi-Player

Multi-User Single-Player

Multi-User Multi-Player
COMPLEXITY PROBLEM
Consumer VR Kit

Premium VR Headsets such as the HTC Vive, include a lot of parts to setup.

For multi-user Enterprise uses in temporary locations, setup time can be considerable.
# CONSUMER VS ENTERPRISE VR CHARACTERISTICS

## CONSUMER

- **VR Inside the Home**
  - Single VR rig remains fixed in a Dedicated Space
  - Single User is also Owner, Maintainer and Operator who controls facility access.
  - No User or Content conflict
  - No Tracking System interference
  - Parts and cable management designed for one-time setup of single systems.

## ENTERPRISE

- **VR outside the Home, VR at Scale**
  - Multiple VR rigs setup in Dedicated Spaces or moved in and out of Multi-Purpose Shared-Use Collaborative Meeting Spaces
  - No specific user, Company-Owned, IT-Managed, shared access to VR facility.
  - Multiple Simultaneous Users in limited volumes. Possible Tracking interference.
  - Integrated cable management, complexity reduction, design for rapid setup/teardown.
ENTERPRISE VR BUSINESS NEEDS:
VR Platform Requirements

1. Multiple Users in a common shared physical space
2. High Density - small footprint consuming minimal floorspace
3. Rapid Setup / Teardown by users with minimal knowledge of VR equipment
4. Rugged/Relocatable/Shippable - self contained as much as possible
5. Remotely Manageable by Enterprise IT
6. Logically Identical to Individual Networked PCs
7. Performance Equivalence (or better) to standalone PCs
PROPOSED CONCEPT
Multi-User Virtualized Virtual Reality System
PROPOSED SOLUTION:
Highly Integrated Packaging

Integrated Base Stations mounts
Integrated Power Distribution, Network, Charging, Storage
Integrated PC - Link Box cabling inside case

Requires only a single external power receptacle
(Optional) Integrated Optical Isolation Pipe & Drape
PROPOSED PACKAGING:
Density, Mobility, Simplicity - Varies by Use Case

Shippable tradeshow rackmount cases on wheels

2-man portable ruggedized stackable hard cases for remote locations

Non-shippable rolling half-racks for deployment between conference rooms within office buildings
MULTI-USER VR CONCEPT

- Vive hardware concept
- 4 users
- Shared single VR experience
- 4 room scale volume configuration

Source: © Mass Virtual, Used by Permission
MULTI-USER LOCAL COLLABORATION

- Vive hardware
- 4 users
- Single VR experience

Source: © Mass Virtual, Used by Permission
MULTI-USER DISTANCE COLLABORATION

4 Users at location: Tampa, Florida

1-4 Users at location: Little Rock, Arkansas
ADDITIONAL CONCEPT HARDWARE CONFIGURATION

4 users in 4 single room scale volume configuration at a single location

Source: © Mass Virtual, Used by Permission
VIRTUAL ATTAIN MULTI-USER DEMONSTRATOR

Helicopter Pilot
PC Station 1

Marshaller
PC Station 2

Instructor View
PC Station 3

Source: © Mass Virtual, Used by Permission
MULTI-USER DEMONSTRATOR

Diorama view experience

Ground view experience

Source: © Mass Virtual, Used by Permission
MULTI-USER VR IN LIMITED SPACE

Source: © Mass Virtual, Used by Permission
BUILDING A MULTI-USER VR SYSTEM
MULTI-USER VR
MACHINE DESIGN REQUIREMENTS
Specific to the Machine

Two or more HMDs connected to a single machine. Target 4 HMDs from a 4U machine.

DisplayPort 1.2 and/or HDMI 2.0/2.1 video output capable of 4K resolution at 90 FPS delivered to each HMD

USB 3.0 root hub data interconnect to each HMD

HMD agnostic (enough USB ports to handle different HMDs and Tracking Systems)

3200W redundant power limit (two 110 or 220 kVA circuits to maintain redundancy)

Run Independent of Monitors
HARDWARE
CHASSIS AND MOTHERBOARD
Supermicro 4028GR-TR Barebones Server

4U Chassis, Two CPU Sockets

Eight Doublewide x16 PCIe slots distributed evenly between CPU Sockets to isolate PCIe traffic and reduce latency.

Room for Four Virtual Machines (4 Users).
2 slots needed per VM (GPU + USB 3.0 card)
CHASSIS AND MOTHERBOARD
Supermicro 4028GR-TR PCIe Slot Layout
QUADRO PROFESSIONAL GPUs
Enterprise Grade Reliability and Features

Must dedicate one physical GPU to each VR user

Quadro GPUs support **NVIDIA Multi-OS technology** which allows them to operate in passthrough mode on a Virtual Machine.

Quadro VR-Ready Driver runs on each Virtual Machine to ensure compatibility with standard VR Software

Quadro supports Forced EDID function to let the Windows OS believe there is a monitor attached to the primary display out. This allows Multi-User VR system to run with headset displays only.

Quadro is designed to run continuously at lower power.
QUADRO GPU OPTIONS
Different sizes to meet cost, performance, and density goals

GPU Comparison

<table>
<thead>
<tr>
<th>GPU</th>
<th>Family</th>
<th>CUDA Parallel-Processor Cores</th>
<th>GPU Memory</th>
<th>Max Power Consumption</th>
<th>VM System Memory</th>
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<tbody>
<tr>
<td>QUADRO GP100</td>
<td>Pascal</td>
<td>3584</td>
<td>16 GB</td>
<td>235 W</td>
<td>24GB</td>
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<tr>
<td>QUADRO P6000</td>
<td>Pascal</td>
<td>3840</td>
<td>24 GB</td>
<td>250 W</td>
<td>24GB</td>
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<tr>
<td>QUADRO P5000</td>
<td>Pascal</td>
<td>2560</td>
<td>16 GB</td>
<td>180 W</td>
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<tr>
<td>QUADRO P4000</td>
<td>Pascal</td>
<td>1792</td>
<td>8 GB</td>
<td>105 W</td>
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<tr>
<td>QUADRO M6000 24GB</td>
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<td>3072</td>
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<td>250 W</td>
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<td>Maxwell</td>
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<td>12 GB</td>
<td>250 W</td>
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<tr>
<td>QUADRO M5000</td>
<td>Maxwell</td>
<td>2048</td>
<td>8 GB</td>
<td>150 W</td>
<td></td>
</tr>
</tbody>
</table>
USB 3.0 CONTROLLERS

Key to Low Latency

With current Hypervisors, each Virtual Machine requires passthrough of a dedicated USB 3.0 card to meet latency requirements.

Some VR Headsets require multiple USB ports per user.

**CAUTION:** USB PCIe Controller cards are not currently on the hardware support list for VMware vSphere ESXi or Citrix XenServer.

Our sample build uses the Inateck KTU3FR-5021 5-Port USB 3.0 PCIe Controller Card
MEMORY AND STORAGE

Recommended System Memory per virtual machine \( \geq \) GPU memory
Hypervisor needs it’s own System Memory as well.

Our Sample build uses 256GB of DDR4 1600Mhz ECC SDRAM installed
48GB per Virtual Machine (1.5x Quadro P6000 memory capacity)
64GB Leftover for Hypervisor.

Storage for our sample build consists of
- one 256 GB disks for cache and boot
- four 256 GB disks each dedicated to a single VM guest machine.

For enterprise builds that depend on fault tolerance it would be important to
combine drives into a RAID5 array for VM storage and separate 256GB SSD RAID0
Mirror set to serve as the system boot drive.
With current Hypervisors, each Virtual Machine requires passthrough of a dedicated USB 3.0 card to meet latency requirements.

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# System Component Summary:

## Sample System As Built

<table>
<thead>
<tr>
<th>Item</th>
<th>QTY</th>
<th>Manufacturer</th>
<th>Mfg Part Number</th>
<th>Description</th>
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<tbody>
<tr>
<td>System</td>
<td>1</td>
<td>SuperMicro</td>
<td>4028GR-TR or 4028GR-TRT</td>
<td>SuperMicro SuperServer Barebones X10DRG-O+-CPU Motherboard, X9DRG-O-PCIE Daughter Board in CSE-418GTS-R3200B Chassis with redundant 1600W power supplies</td>
</tr>
<tr>
<td>CPU</td>
<td>2</td>
<td>Intel</td>
<td>BX80660E52640V4</td>
<td>Xeon E5-2640 2.4 GHz v4 10-core LGA 2011 Processor</td>
</tr>
<tr>
<td>Memory</td>
<td>128GB total</td>
<td>Kingston</td>
<td>KVR21R15D4K4/64</td>
<td>Kingston 64GB RAM Kit (4x16GB) 2133MHz DDR4 ECC Reg CL15 DIMM DR x 4 with TS Server Memory</td>
</tr>
<tr>
<td>SSD Drives</td>
<td>4</td>
<td>Samsung</td>
<td>MZ-7KE1T0BW</td>
<td>Samsung 850 PRO - 1TB - 2.5-Inch SATA III Internal SSD, usable with Linux.</td>
</tr>
<tr>
<td>GPU</td>
<td>4</td>
<td>NVIDIA</td>
<td></td>
<td>Quadro M6000, P4000, P5000, or P6000</td>
</tr>
<tr>
<td>USB Cards</td>
<td>4</td>
<td>Inateck</td>
<td>KTU3FR-502I</td>
<td>5-port USB 3.0 controller</td>
</tr>
</tbody>
</table>
INITIAL RESULTS
RESULTS

Anecdotal Qualification

Successful Tradeshow deployments with VMware

- No user complaints
- Multi-User Single-Player mode

Tested by several VR software developers

Demos available in the GTC Exhibit Hall

- HTC Vive  
  booth 700  
  MonsterVR  4 user collaborative +1
- CAVRNUS  
  booth 934  
  CAVRNUS  4 user collaborative
- Super Micro Computer  
  booth 111  
  Static System

Give it a try and tell us what you think.
MULTI-USER VR SYSTEM

**STRENGTHS**

- Dense, Tight Packaging possible
- Rapid Setup
- 4-Users per 4U system (6U Rack)

**LIMITATIONS**

- Currently limited to a Single GPU per User. VR-SLI not supported.
- Commercial Hypervisors do not officially support USB passthrough
- Tethers
- Density limited by USB passthrough requirement
FUTURE RESEARCH
FUTURE WORK
Additional Areas of Research

Expanded Configurations:
- 2-way workstation
- 8-way P4000 dense system.

Varied Topologies:
- Shared & Separate gaming areas
- Stacked systems working together
- Theater Row Seating

Wireless Multi-User solutions such as TPCAST (see demo at NVIDIA VR Village)

Multiple Hypervisors: VMware, Xenserver, ???
FUTURE WORK

Additional Areas of Research

IT management scenarios
- Cloned Virtual Machines
- Remote System management
- Shared Storage

Packaging concepts optimized for:
- Datacenter Density
- Ruggedized Portability,
- Self-containment
- Rapid setup.
## MORE INFORMATION

### Useful Links

<table>
<thead>
<tr>
<th>Name</th>
<th>Role</th>
<th>Email</th>
</tr>
</thead>
<tbody>
<tr>
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</tr>
</tbody>
</table>

Session: [S7171 - MULTI-USER VIRTUAL REALITY SOLUTIONS FOR ENTERPRISE DEPLOYMENT](#)

Blog: [If You Build It, They Will Come: Multi-User VR Environment Showcased at GTC](#)
REQUEST THE BUILD GUIDE
System Integrators and Partners

http://info.nvidia.com/vrsystem.html
QUESTIONS?