MULTI-USER VR SOLUTIONS FOR ENTERPRISE DEPLOYMENT

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AGENDA

Background and Motivation

- Virtual Reality Meets Virtualization

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 complexity, space required, keeping multiple systems in Sync with latest updates,





VIRTUAL REALITY MEETS VIRTUALIZATION

Why not push pixels over the network?

Multiple full-featured VR experiences on one server?



NVIDIA GeForce NOW

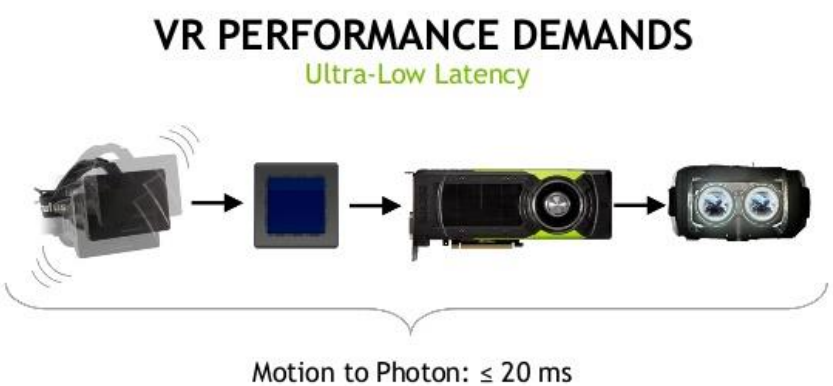


Games streaming
From Global Datacenters

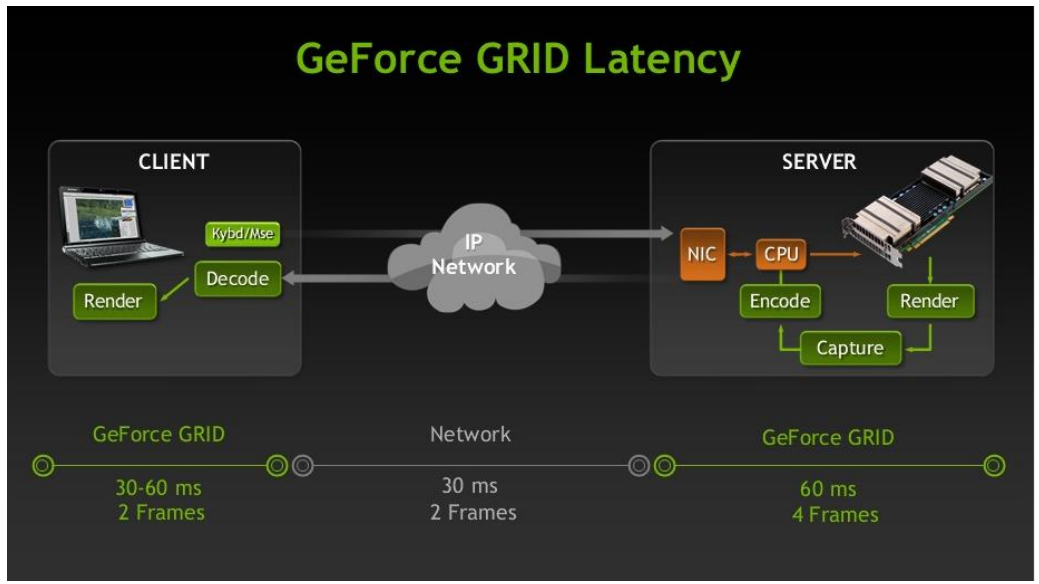
VIRTUAL REALITY MEETS VIRTUALIZATION

Latency… the silent killer

Latency demands of VR - 20ms



NVIDIA GeForce GRID Latency – up to 150ms



VIRTUAL REALITY MEETS VIRTUALIZATION

GPU Pass-Through to the rescue

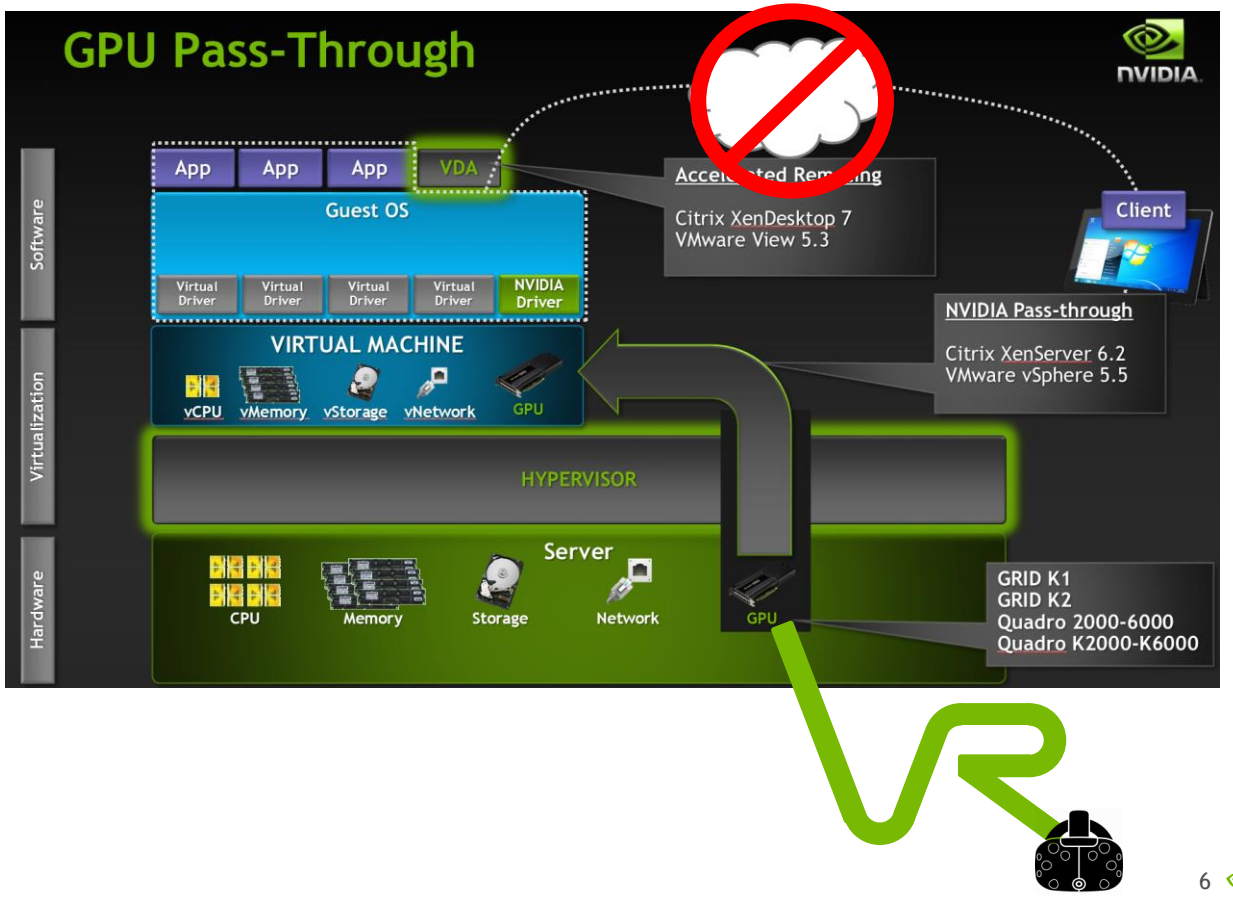
NVIDIA GRID Technology

GPU Pass-Through

Hypervisor Support for Quadro

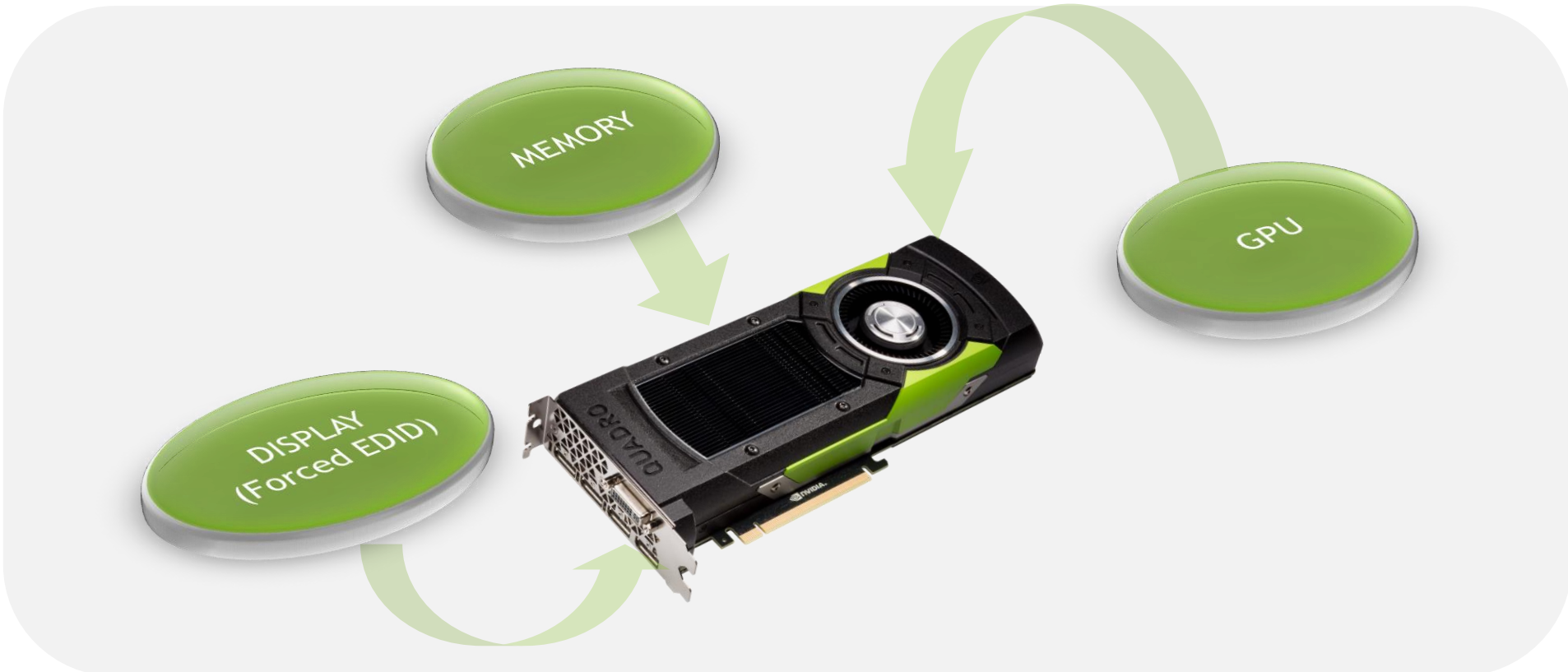
Bypass the Pixel streaming

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
- Reliable
- Maintainable
- Affordable

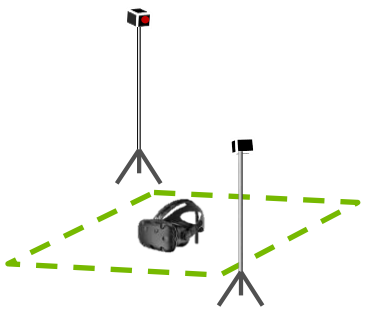


VR USE CASE CATEGORIES

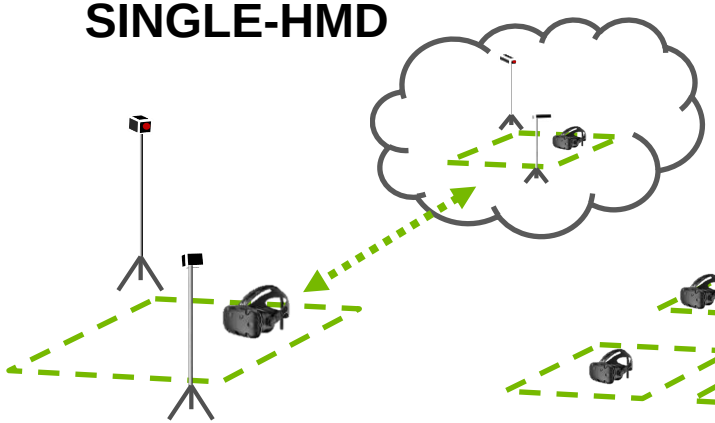
HMDs

PHYSICAL SPACE

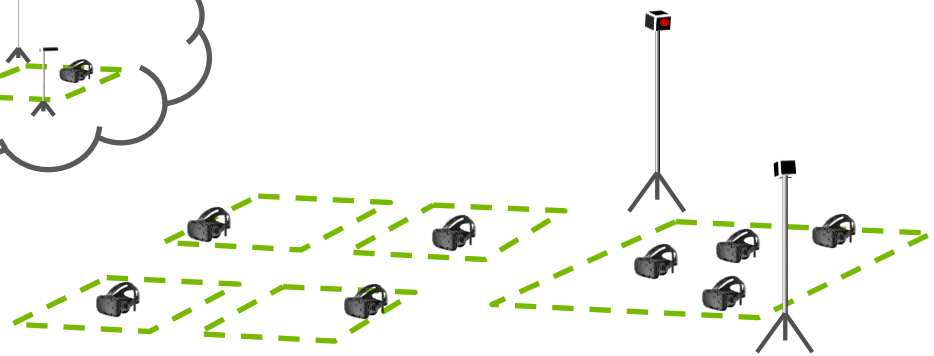
SINGLE-HMD



SINGLE-HMD



MULTI-HMD



PLAYERS



VIRTUAL SPACE

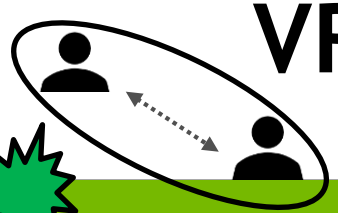
SINGLE-PLAYER

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

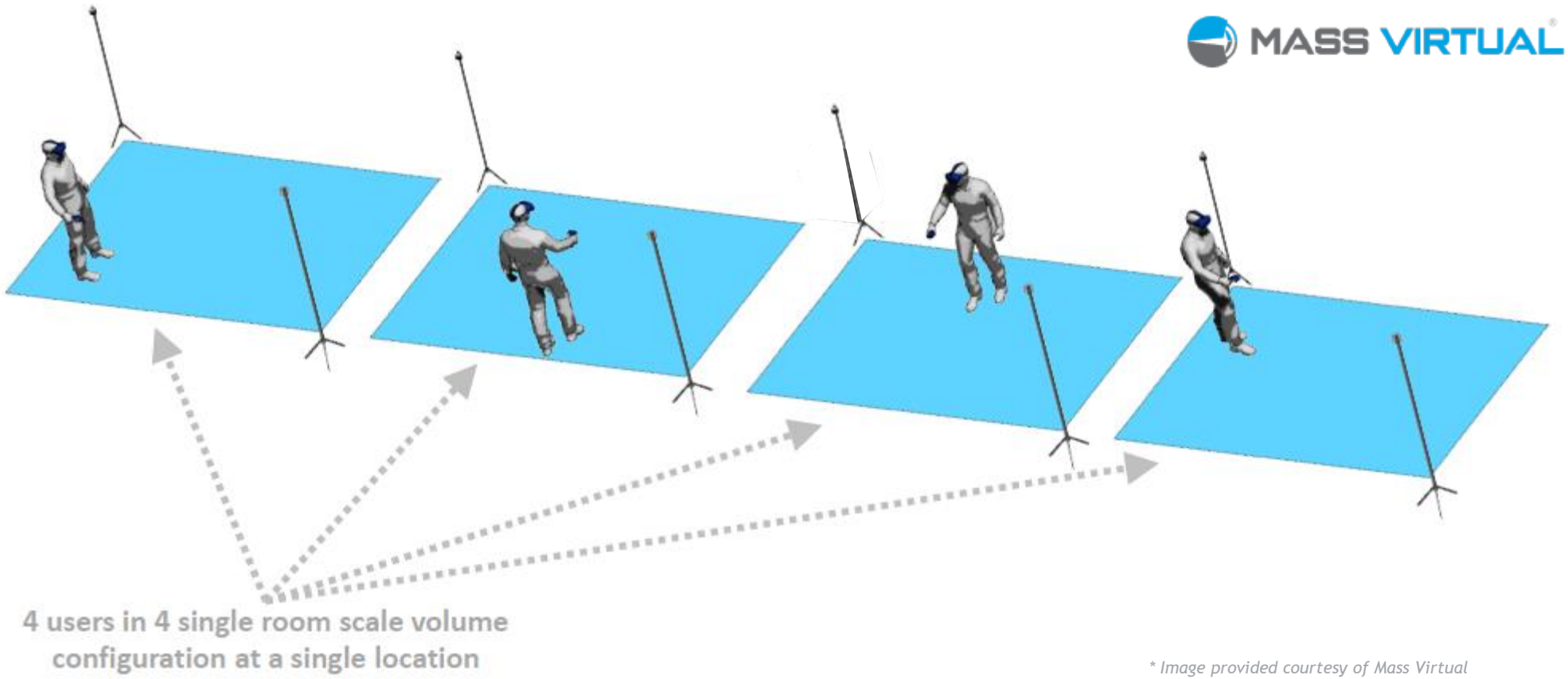
Examples:

- 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

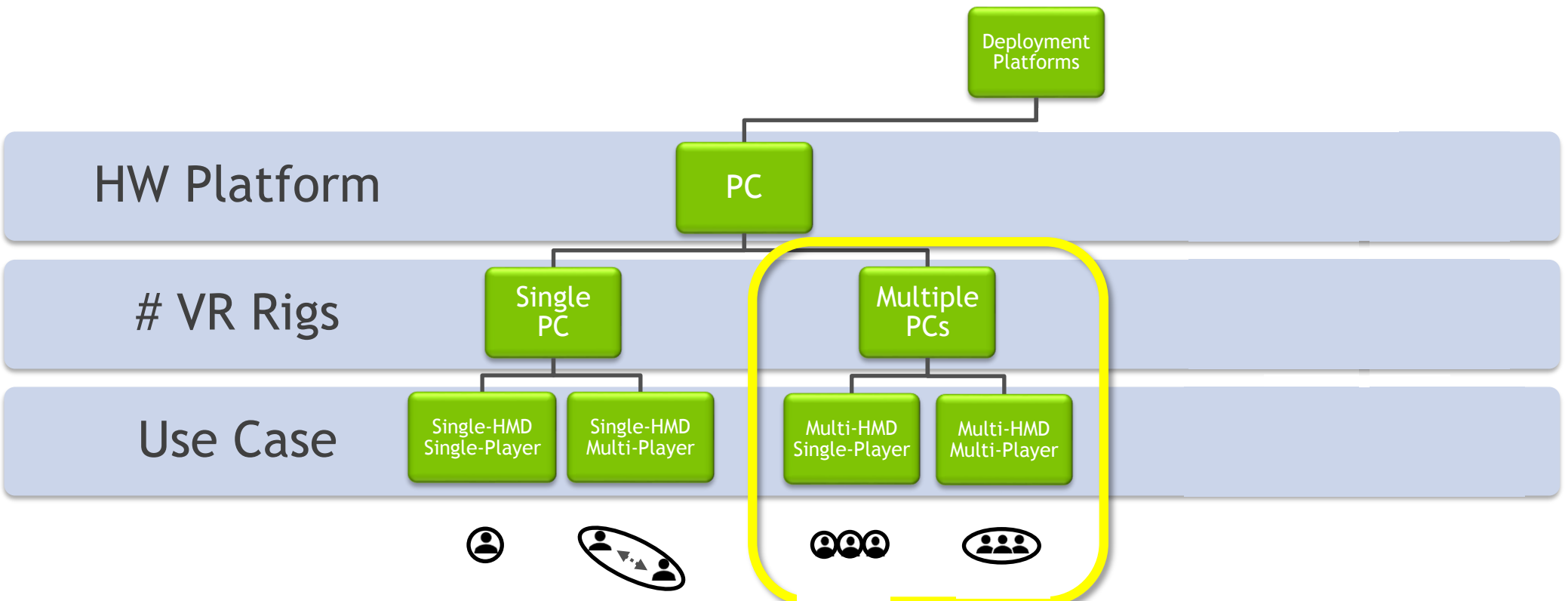


** Image provided courtesy of Mass Virtual*

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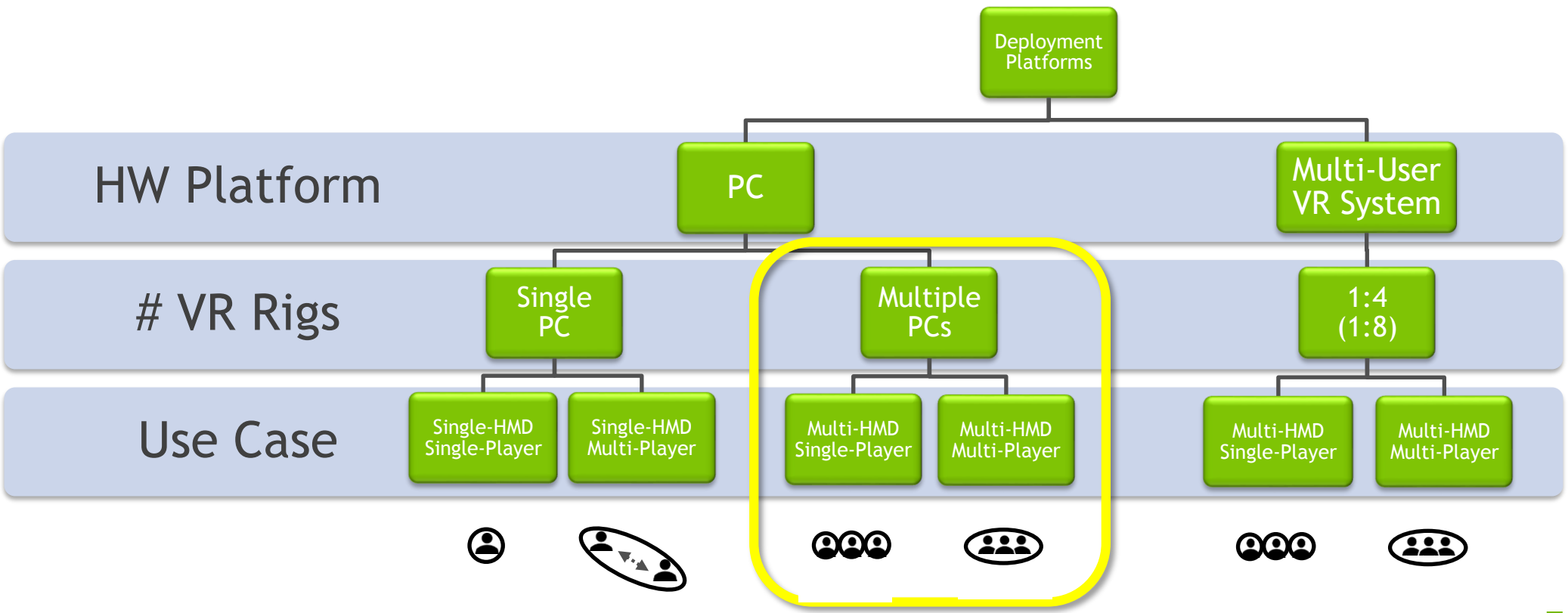
DEPLOYMENT PLATFORM OPTIONS

PC or Mobile VR



DEPLOYMENT PLATFORM OPTIONS

Solving the VR at Scale Problem



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.





** Image from PC Perspective*

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, Remote IT-Management, shared access to VR equip.

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

TOTAL COST OF OWNERSHIP

Setup / Teardown Time… Recurring Expense on Every Deployment



Separate PCs or VR Notebooks introduce additional recurring costs when relocated.

- **Total Cost** - more than just the cost of Hardware
- **Setup Time** - manpower cost
  - loss of room
  - idled systems
  - SW update time
- **Inaccessible Venues** - which are unusable due to limited setup time?
- **Maintenance and Troubleshooting** – lost or damaged parts, incorrect hookups, accidental OS changes, on-site IT staff
- **Spares Cost -** higher failure rates

PROPOSED CONCEPT

Multi-User Virtualized Virtual Reality System

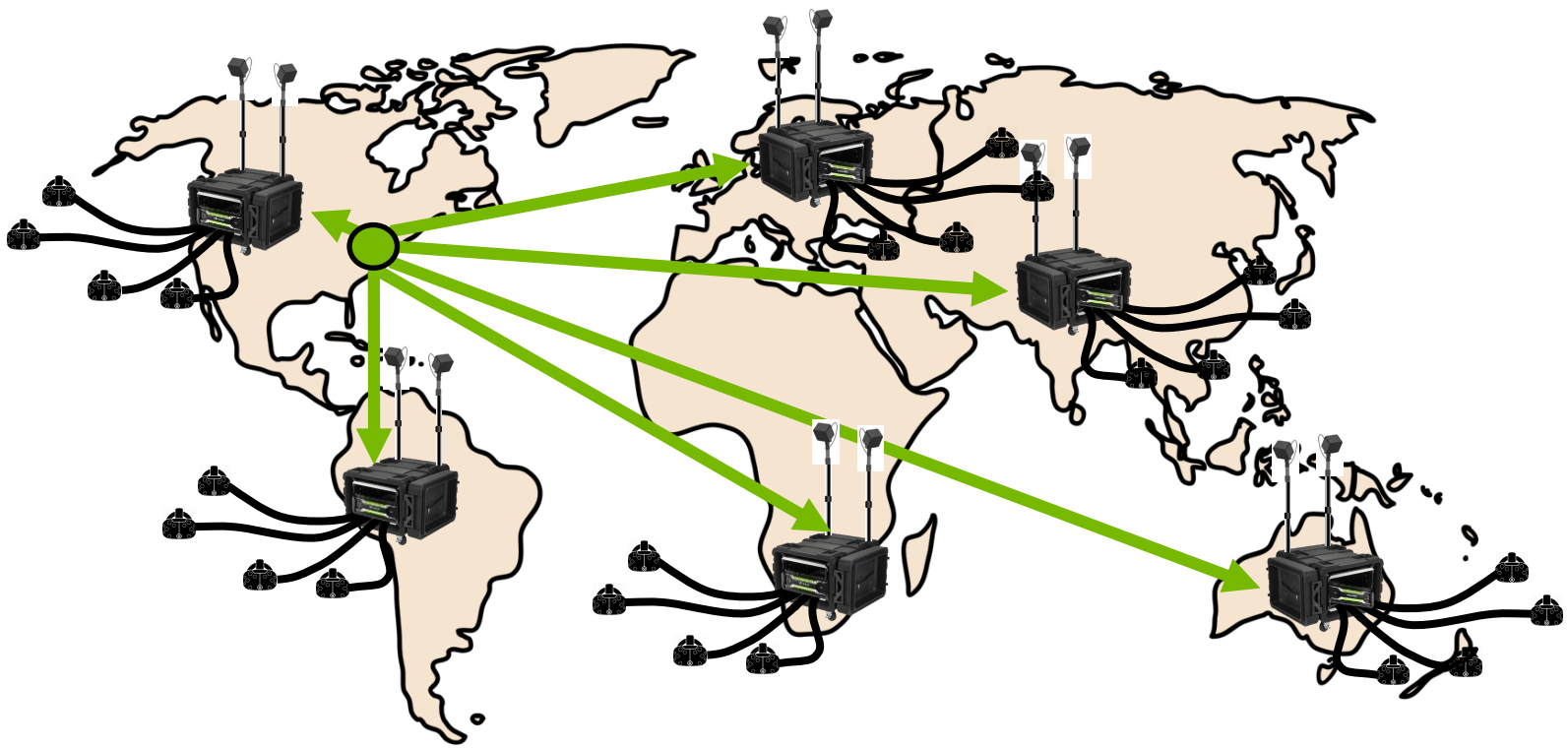




Rapidly Deployable Multi-User VR systems could service more users over their lifetime than the comparable number of standalone VR-Ready Notebooks

CENTRALIZED IT-MANAGMENT

Virtualization technologies enable IT management savings



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)

OPTIMIZATIONS

Field Replaceable Units and Spares





Field Replaceable HMD/Link Box combo,
Front-Loading, Integrated Tether Strain Relief



Integrated Hand Controller Charging Station
Designed into Shipping Container

PROPOSED PACKAGING:

Density, Mobility, Simplicity – Varies by Use Case

Shippable tradeshow rackmount cases on wheels



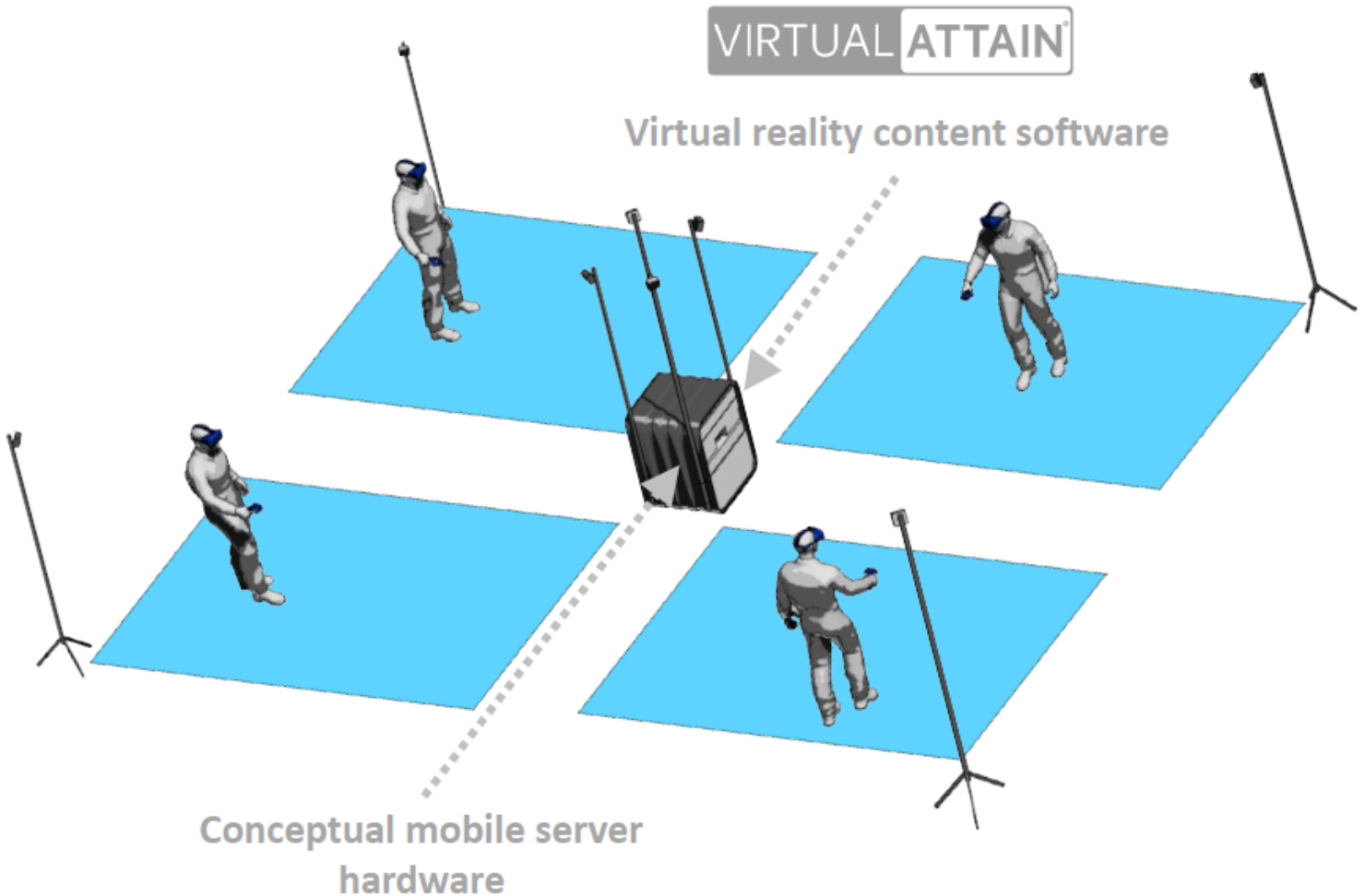
2-man portable ruggedized stackable hard cases for remote locations



Non-shippable rolling half-racks for deployment between conference rooms within office buildings



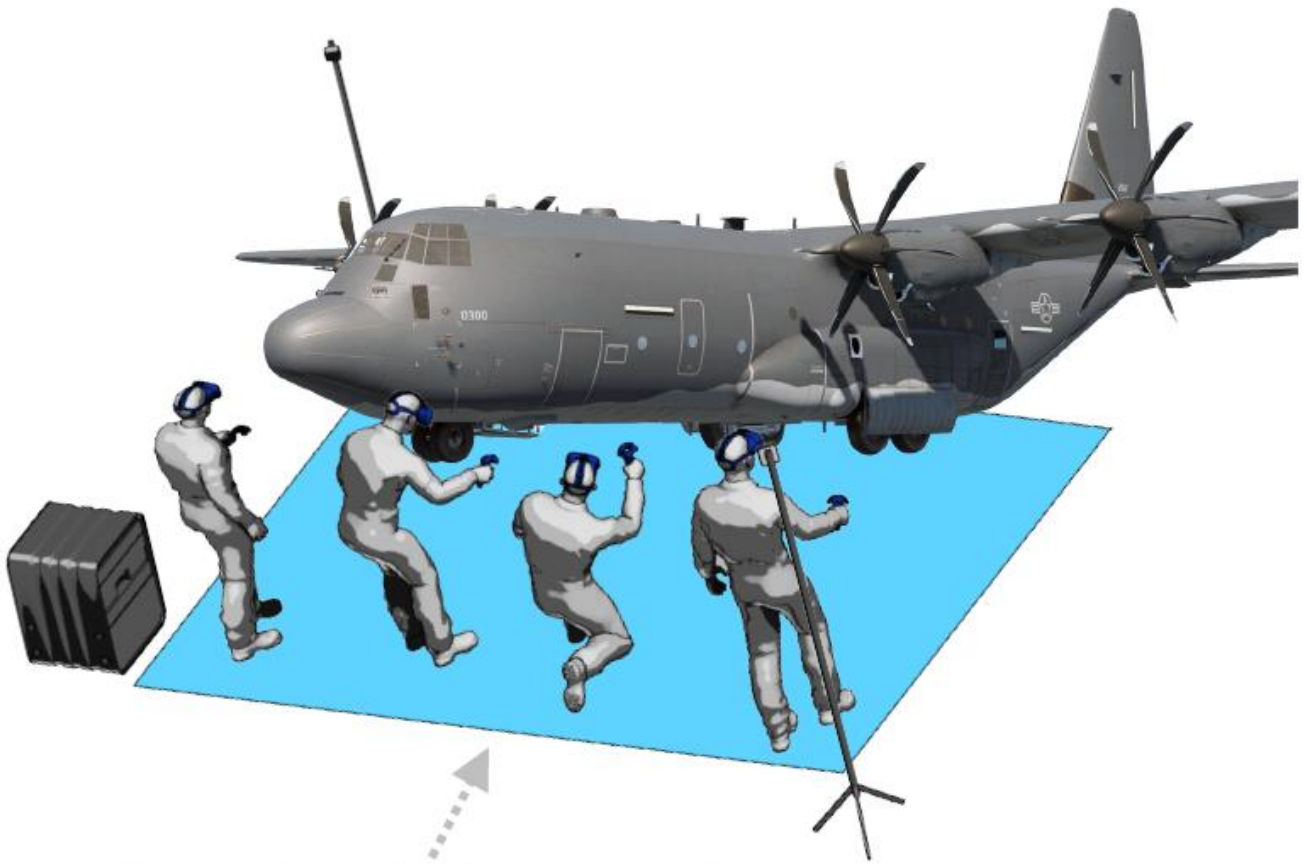
MULTI-USER VR CONCEPT



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

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MULTI-USER LOCAL COLLABORATION

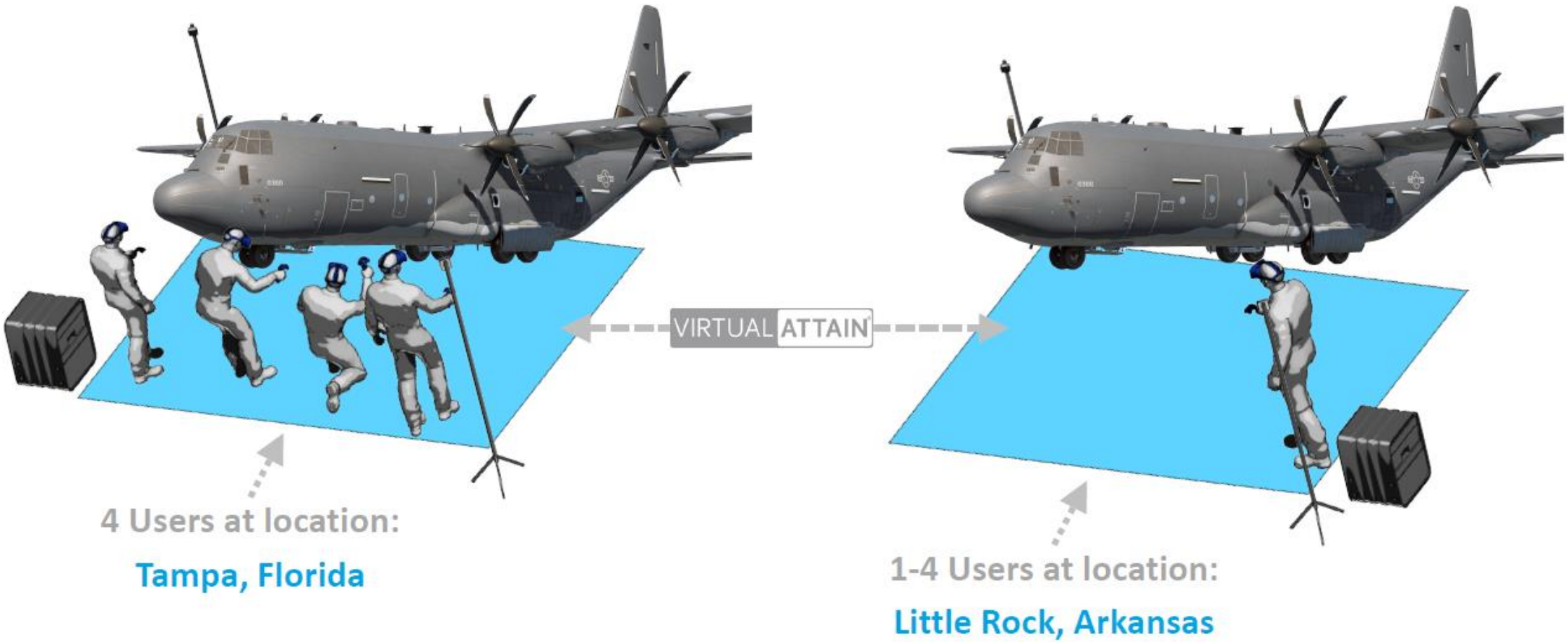


4 users in a single room scale volume configuration

- Vive hardware
- 4 users
- Single VR experience

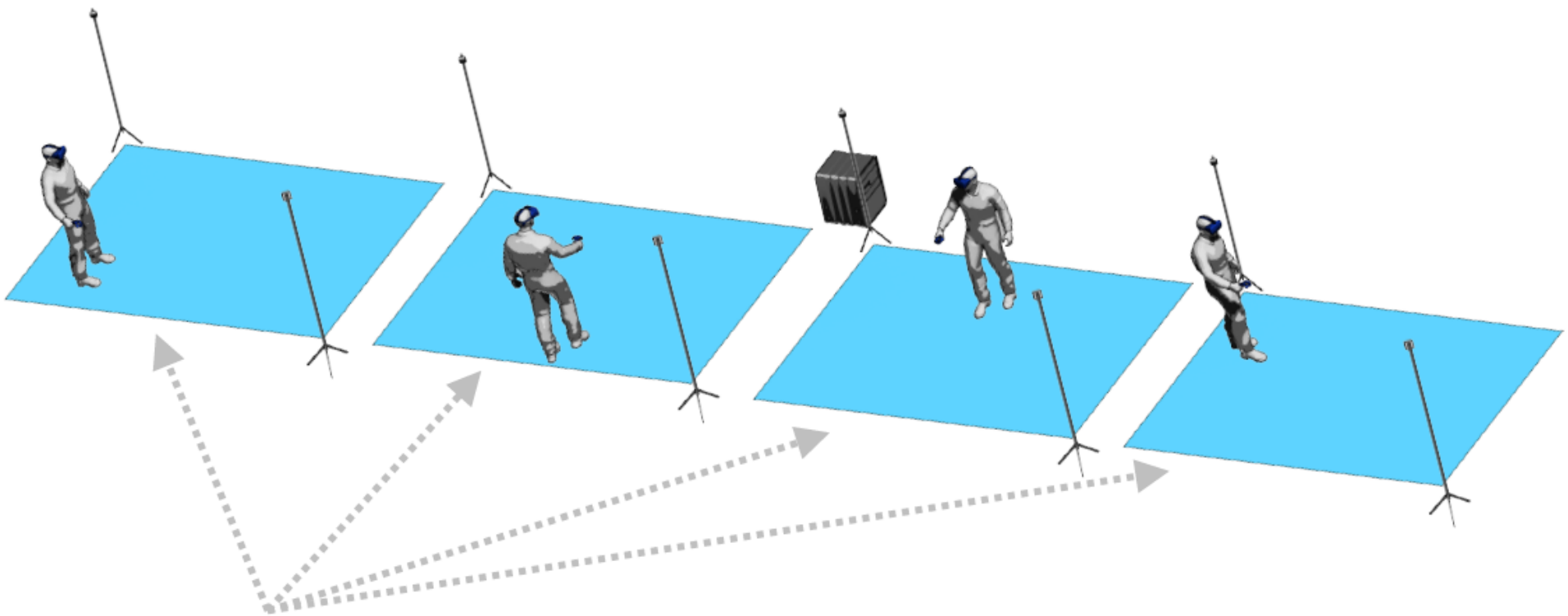
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MULTI-USER DISTANCE COLLABORATION



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ADDITIONAL CONCEPT HARDWARE CONFIGURATION



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VIRTUAL ATTAIN MULTI-USER DEMONSTRATOR



oculus





VIVE



Helicopter Pilot

PC Station **1**

Marshaller

PC Station **2**



Instructor View

PC Station **3**

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MULTI-USER DEMONSTRATOR



Diorama view experience

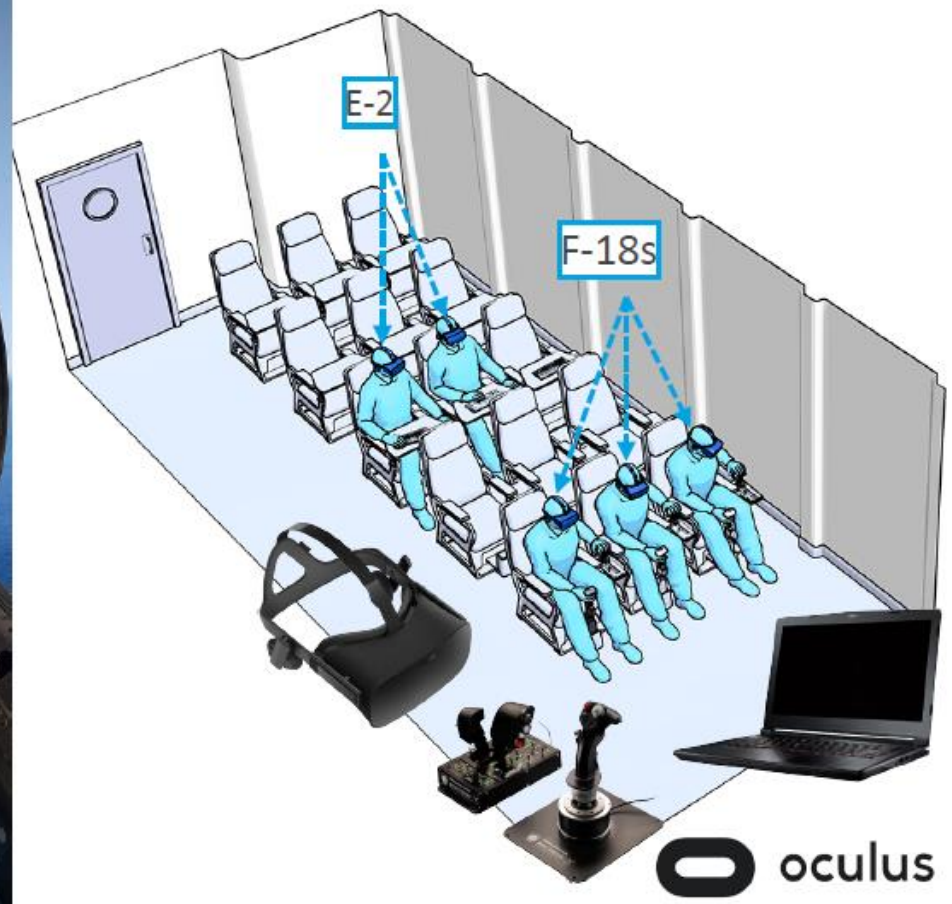


Ground view experience

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MULTI-USER VR IN LIMITED SPACE





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THE MOST AWARDED VR SYSTEM ON THE MARKET

Source: © HTC Vive, Used by Permission

ABOUT VIVE

BUILT TO SCALE



Seated → Standing → Room-scale

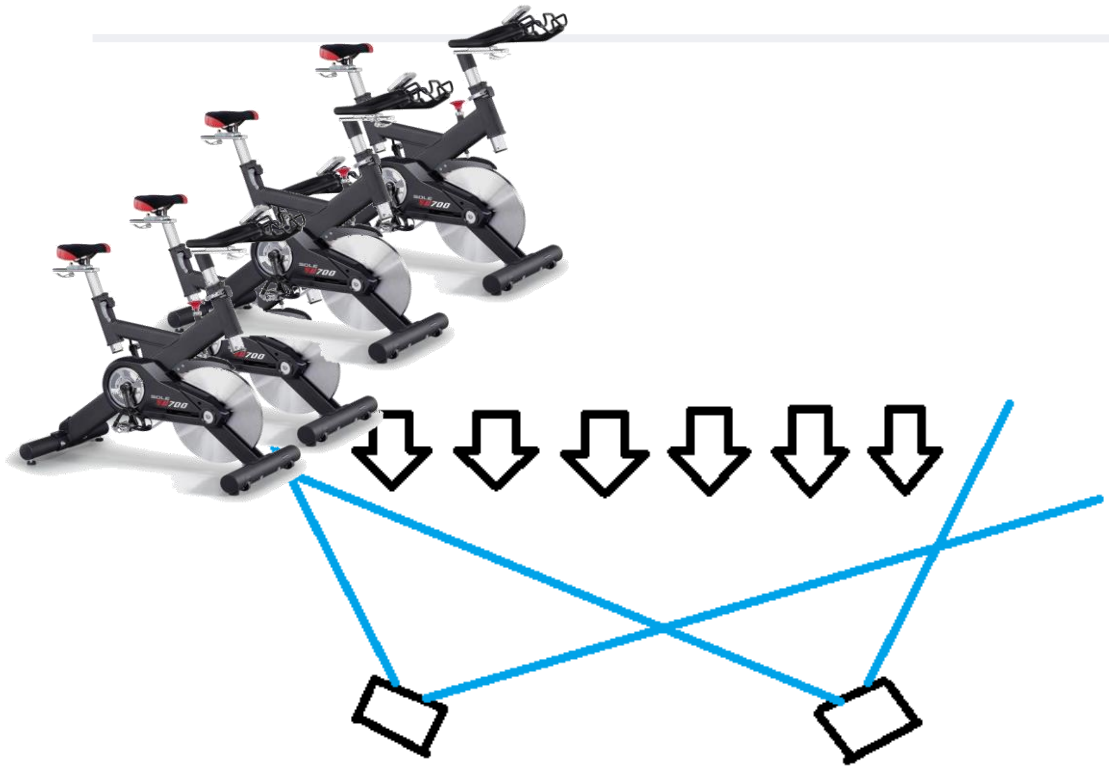
VIVE

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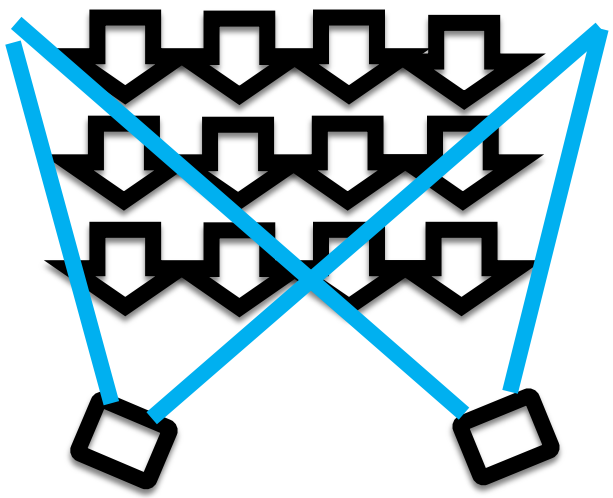


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FLEXIBLE TRACKING





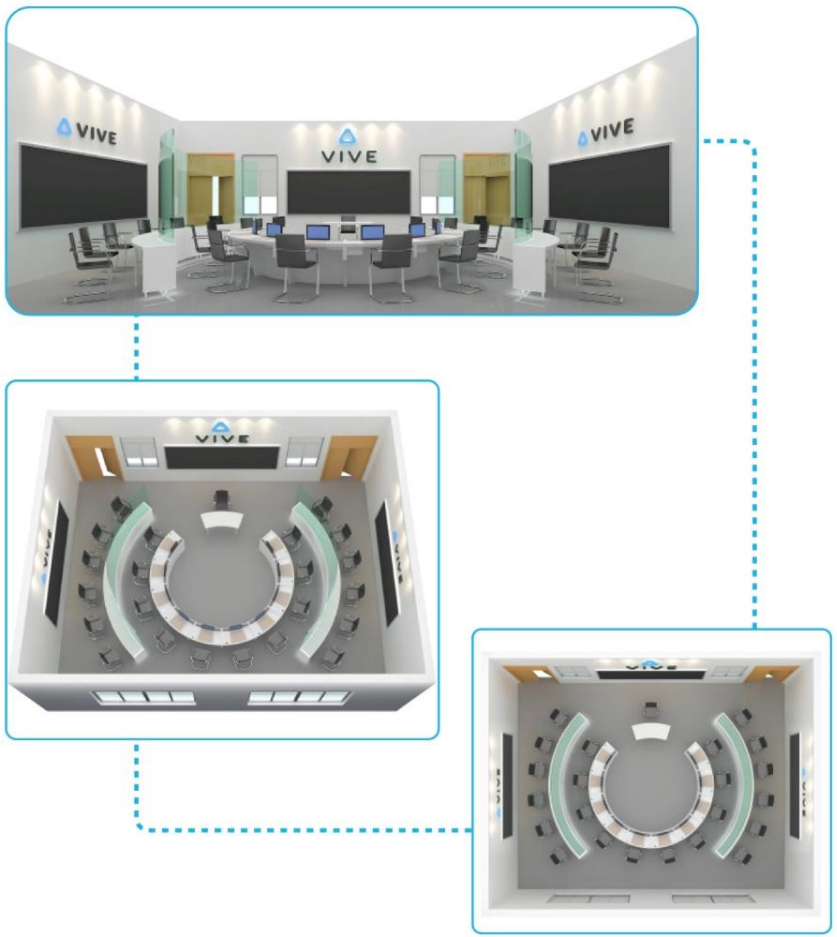


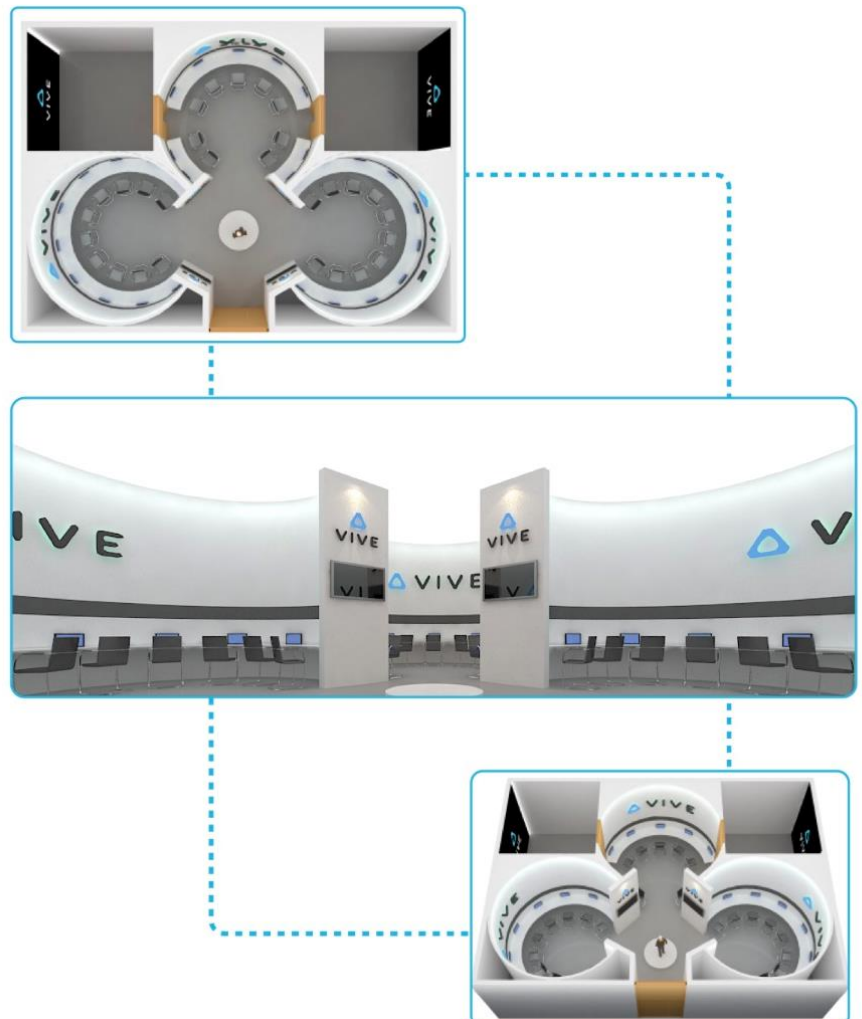
Multi-user Seated or Standing Configurations

VIVE

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CLASS ROOM & TRAINING

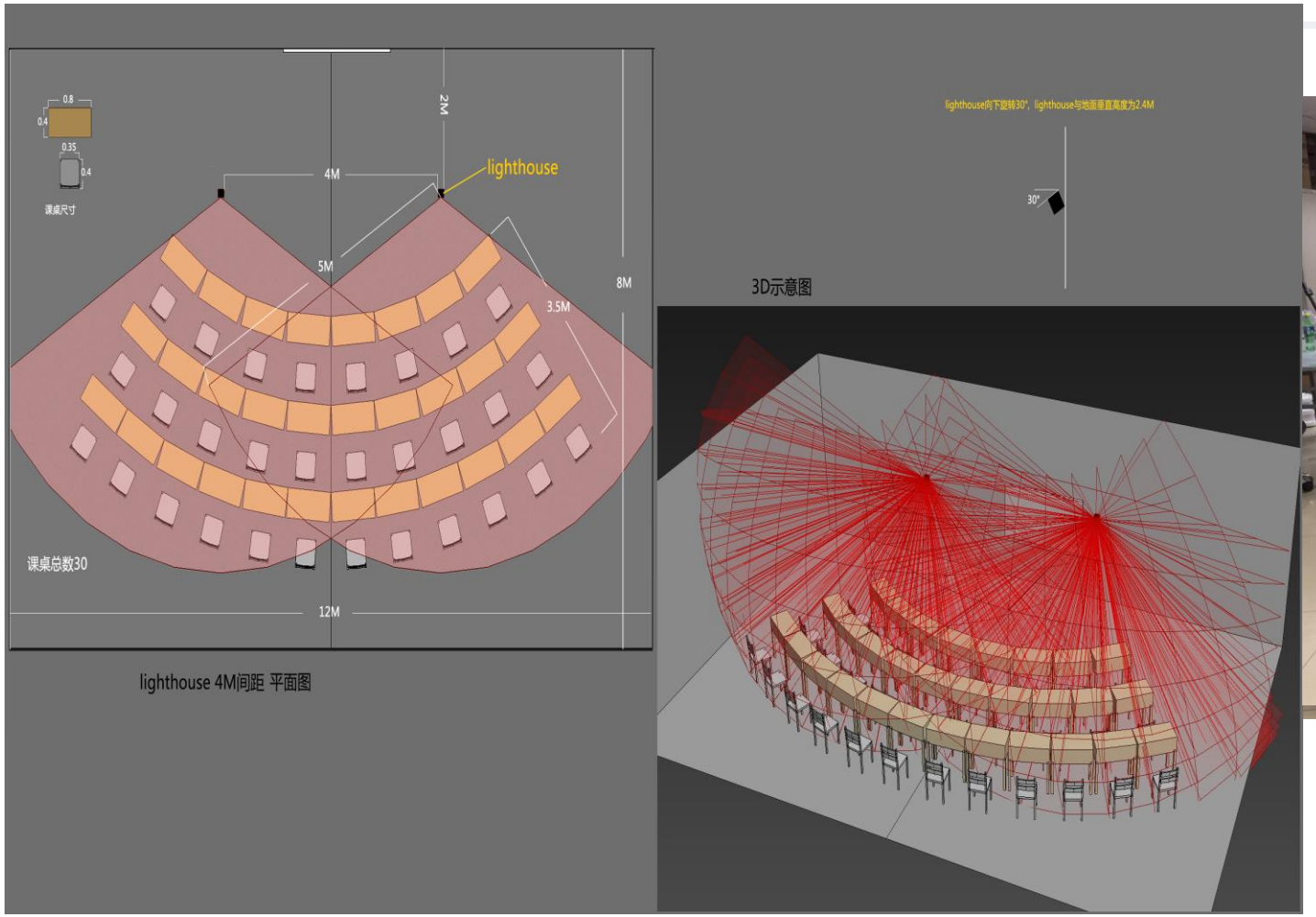




VIVE

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EDUCATION LAYOUT





Source: © HTC Vive, Used by Permission



Source: © HTC Vive, Used by Permission

VIVE Consumer Edition



$799

- 2160 x 1200, 90fps, 110 degree fov
- Comfortable Head-strap
- Eye Relief
- IPD Adjustment
- Built-In Microphone
- Front Facing Camera
- Narrow | Wide Gasket Cushion

VIVE Business Edition



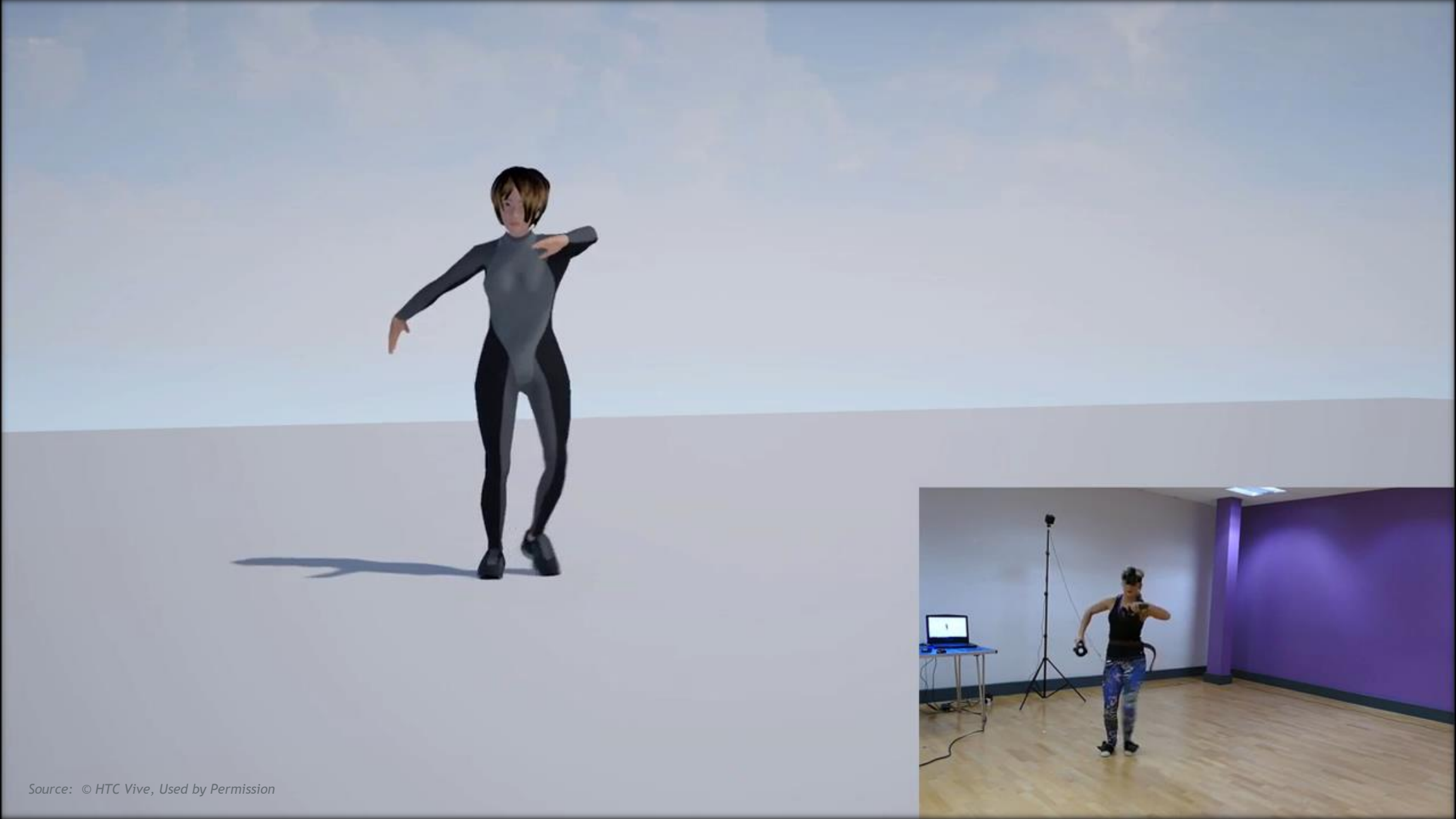
$1,200

- Deluxe Audio Strap
- 5 Meter HMD Cable Extension
- 2 Additional Wide and Narrow Face Plates
- Commercial Warranty
- Enterprise EULA
- Dedicated Phone Line Support
- Software distribution & management utilities



A NEW ECO SYSTEM OF TRACKABLE DEVICES

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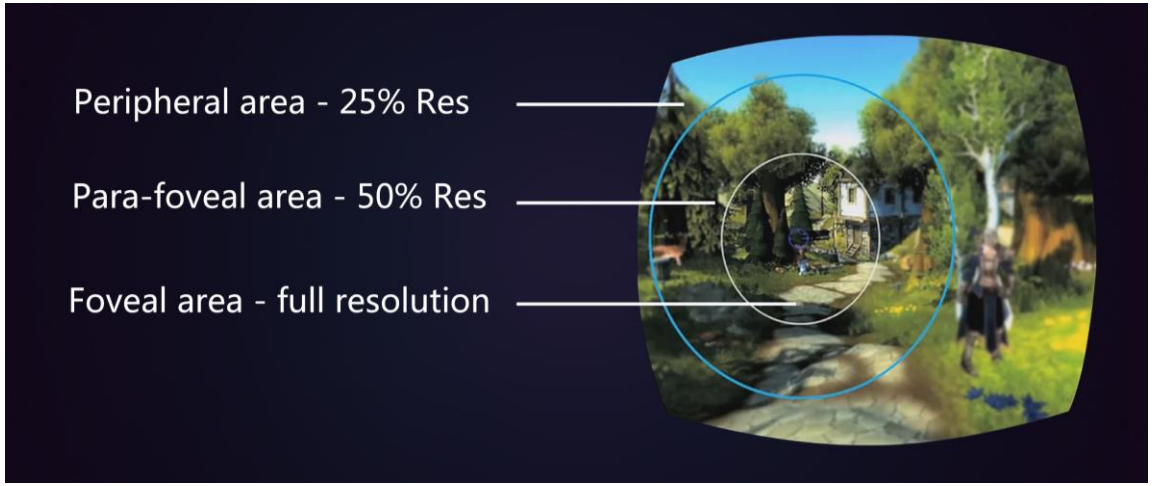


7INVENSUN

Connect the world with your eyes

EYE TRACKING

US/EMEA Availability Q3





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TPCAST
传 送 科 技

WIRELESS IS COMING

AVAILABLE Q3, 2017

Business Edition

44

4-6 Users Single Environment



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COTS

VR

ECOSYSTEM

TRACKER

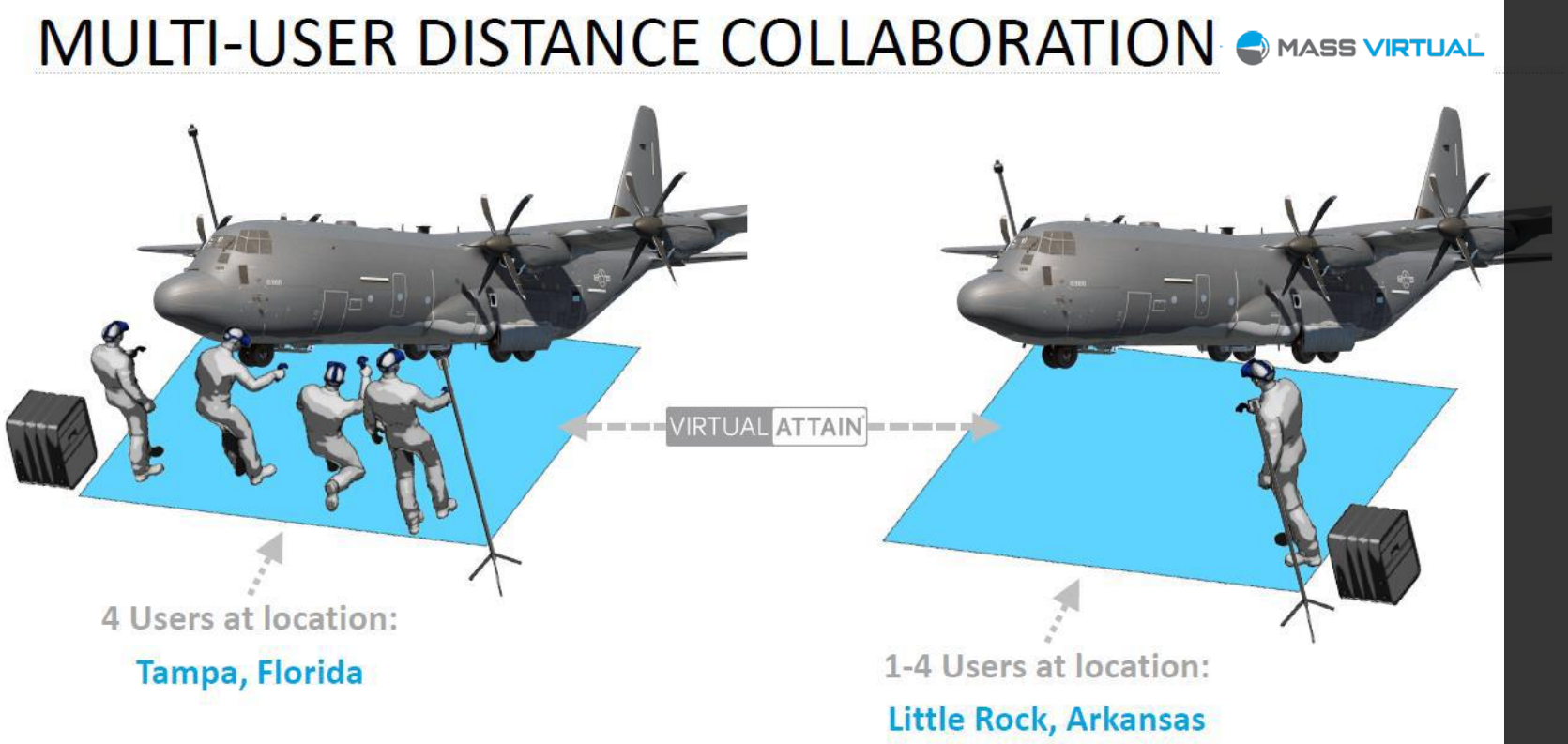
HAPTICS

EYE TRACKING

WIRLESS

MULTI-USER

ULTIMATE DEVELOPER PLAYGROUND



Lets build the future of VR together!

COTS

VR

ECOSYSTEM

TRACKER

HAPTICS

EYE TRACKING

WIRLESS

MULTI-USER

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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

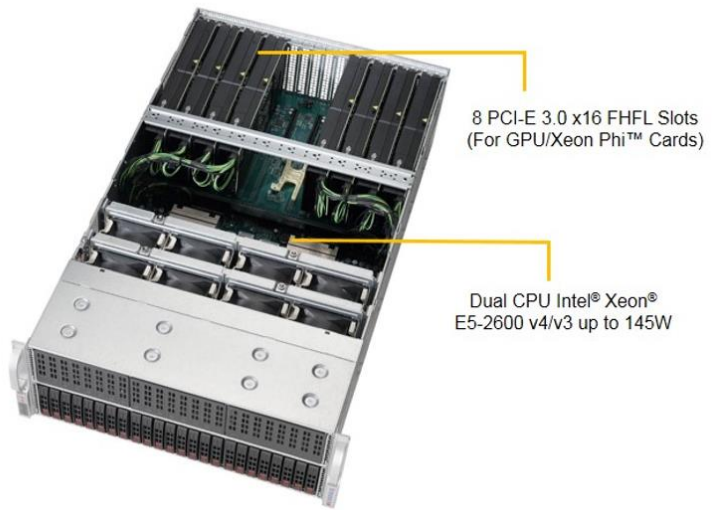
CHASSIS AND MOTHERBOARD

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)



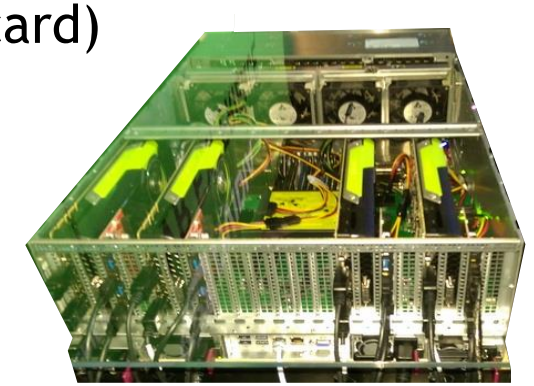
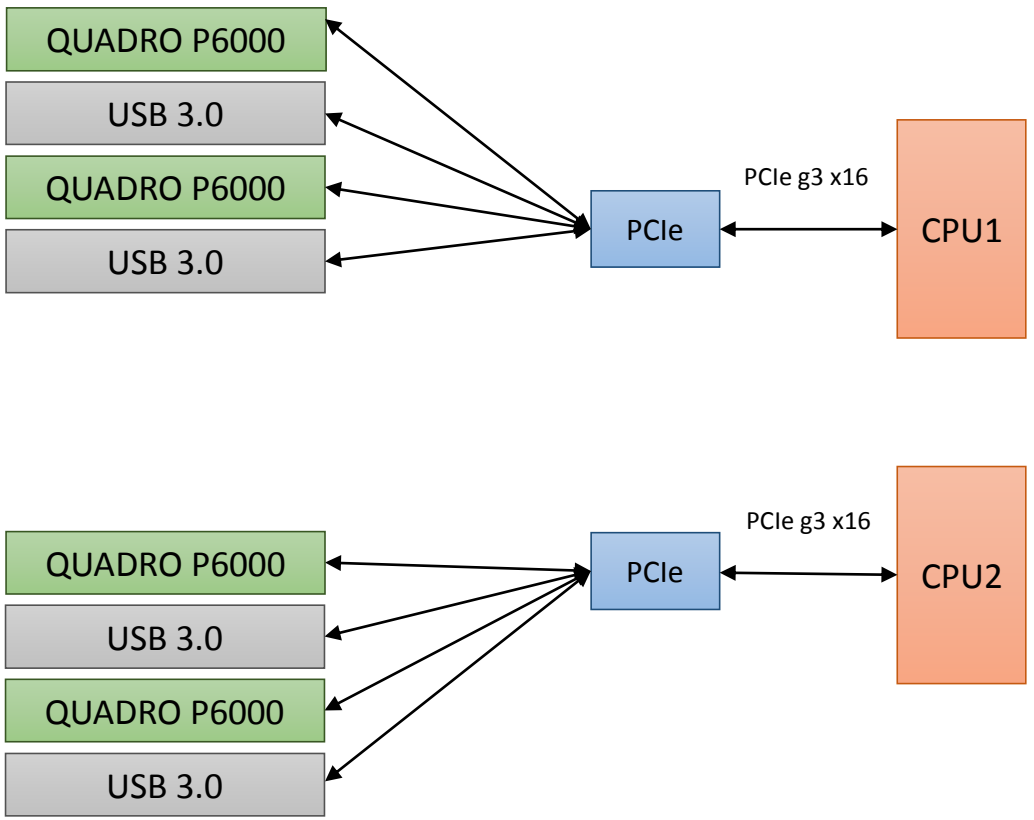


Image Source: © SUPERMICRO Superserver 4028GR-TR User Guide

CHASSIS AND MOTHERBOARD

Supermicro 4028GR-TR PCIe Slot Layout



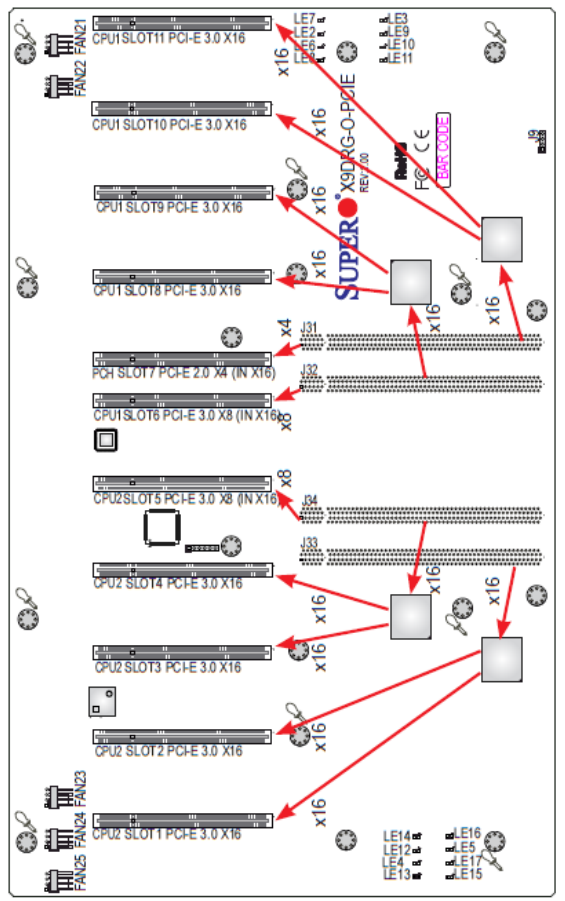


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QUADRO PROFESSIONAL GPUS

Enterprise Grade Reliability and Features

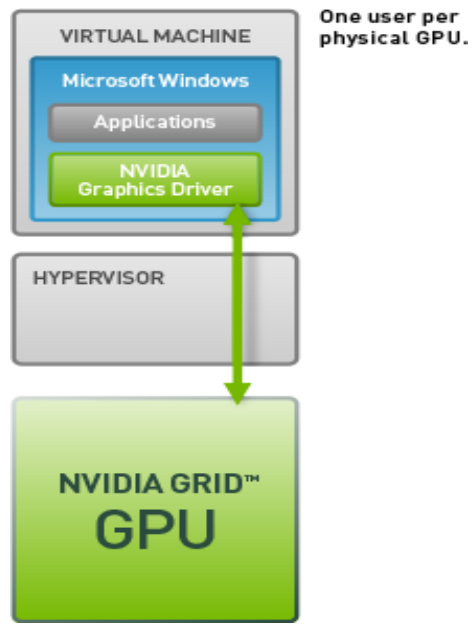
Must dedicate one physical GPU to each VR user

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

GPU	Family	CUDA Parallel-Processor Cores	GPU Memory	Max Power Consumption	VM System Memory
QUADRO GP100	Pascal	3584	16 GB	235 W	24GB
QUADRO P6000	Pascal	3840	24 GB	250 W	24GB
QUADRO P5000	Pascal	2560	16 GB	180 W	
QUADRO P4000	Pascal	1792	8 GB	105 W	
QUADRO M6000 24GB	Maxwell	3072	24 GB	250 W	
QUADRO M6000	Maxwell	3072	12 GB	250 W	
QUADRO M5000	Maxwell	2048	8 GB	150 W	

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 >= 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 left 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.

POWER

Redundant Power Supplies

Our sample system has four 1600W redundant power supplies, only two power supplies are required to operate the system at full power with four HMDs in session. This provides a fully redundant power configuration that is enterprise ready and fault tolerant.

It also helps keep noise levels down as the power supplies need not run at full capacity during normal operation.

Opportunities exist to further refine each system by powering internal integrated HTC link boxes from the system power supplies. With internal USB ports on Inateck USB PCIe cards, it is possible to keep most of the HTC wiring inside the chassis.

External power may still be desired to allow selective power-cycling of link boxes via remote controlled power distribution devices.

SYSTEM COMPONENT SUMMARY:

Sample System As Built

Item	QTY	Manufacturer	Mfg Part Number	Description
System	1	SuperMicro	4028GR-TR or 4028GR-TRT	SuperMicro SuperServer Barebones X10DRG-O+-CPU Motherboard, X9DRG-O-PCIE Daughter Board in CSE-418GTS-R3200B Chassis with redundant 1600W power supplies
CPU	2	Intel	BX80660E52640V4	Xeon E5-2640 2.4 GHz v4 10-core LGA 2011 Processor
Memory 128GB total	2	Kingston	KVR21R15D4K4/64	Kingston 64GB RAM Kit (4x16GB) 2133MHz DDR4 ECC Reg CL15 DIMM DR x 4 with TS Server Memory
SSD Drives	4	Samsung	MZ-7KE1T0BW	Samsung 850 PRO - 1TB - 2.5-Inch SATA III Internal SSD, usable with Linux.
GPU	4	NVIDIA		Quadro M6000, P4000, P5000, or P6000
USB Cards	4	Inateck	KTU3FR-5O2U	7-port USB 3.0 controller (2 ports are internal facing)

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 ESXi, Citrix 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

Tom Kaye	Sr. Solution Architect, NVIDIA	tkaye@nvidia.com
Fred Devoir	Sr. Solution Architect, NVIDIA	fdevoir@nvidia.com
Sean Wagstaff	Enterprise Tech Marketing, NVIDIA	swagstaff@nvidia.com
Frank Black	Director of Enterprise Sales, HTC-Vive	Frank_Black@htc.com

Session: S7171 - MULTI-USER VIRTUAL REALITY SOLUTIONS FOR ENTERPRISE DEPLOYMENT

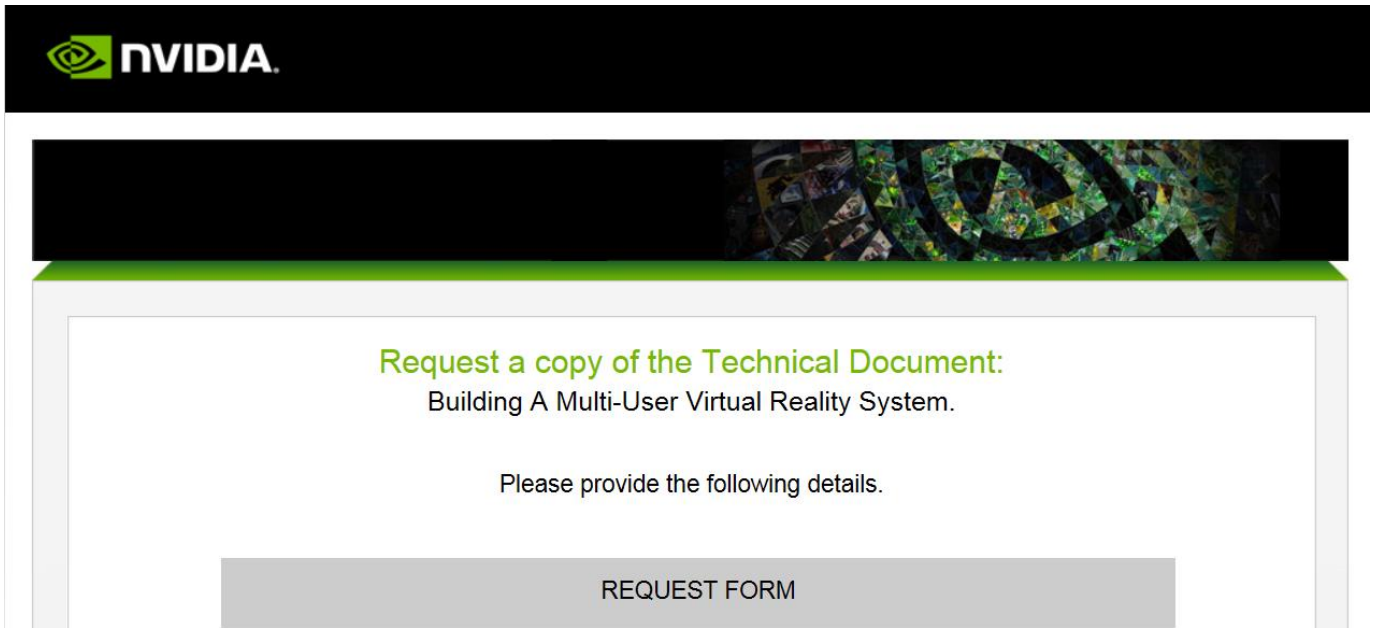
Slides: PDF version of Presentation (Access limited to GTC attendees for 30 days)

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?

