

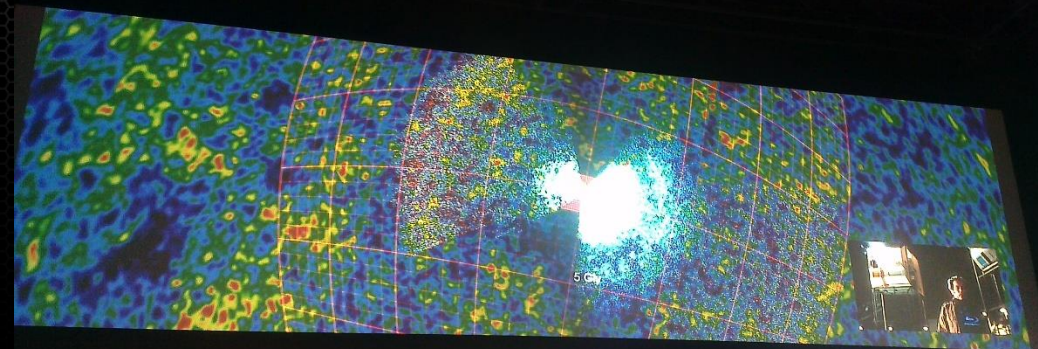
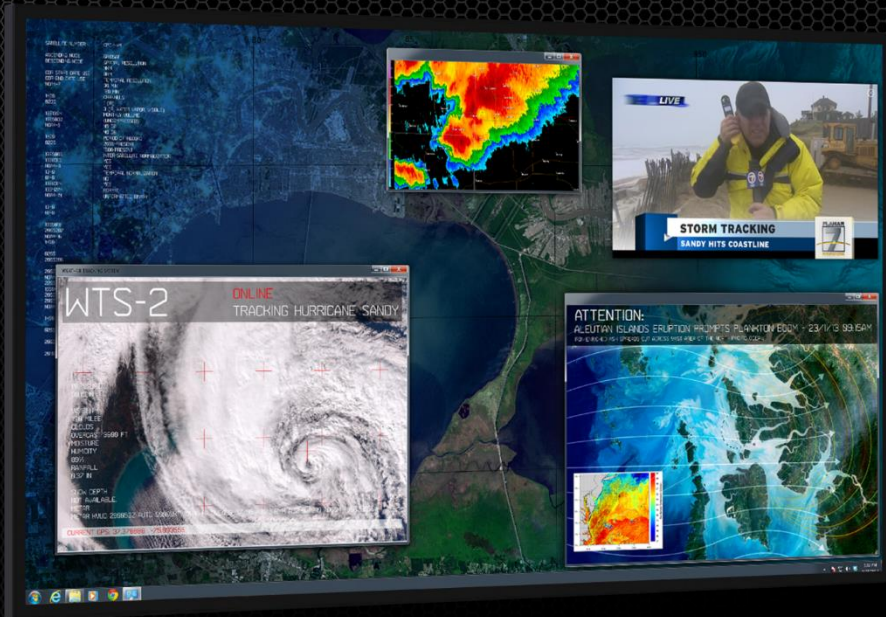


**SIGGRAPH 2013**  
Shaping the Future of  
Visual Computing

**High Performance Graphics for 4K & Ultra  
High Resolution Displays**

Doug Traill, Senior Solutions Architect -  
[QuadroSVS@nvidia.com](mailto:QuadroSVS@nvidia.com)





4K SXRD Large Venue Projector Prototype





# Things I want you to learn



- NVIDIA Quadro K5000/K6000<sup>new</sup> + Quadro Sync

- MOSAIC to create a unified Desktop

10 years of experience of Sync NVIDIA's 1<sup>st</sup> Sync card was launched at SIGGRAPH03



# Quadro Features for Display Walls

## Custom Resolutions

- GTF, DMT, CVT, CVT-RB + Custom Timings

## MOSAIC

- Seamless Desktop across multiple GPUs

## Stereo

- Active Stereo support
- OpenGL/DirectX
- Passive or Dual Pipe Stereo

## 10bit Color

- Support for High Dynamic range displays

## ManageEDID

- Capture + Read EDID from file

## Premium MOSAIC

- Overlap Support to match projector edge-blending
- Stereo support
- Warp + Blend

## Ultra High resolution Desktop

- 16K by 16K

## HDMI 1.4a

- 4K resolution support
- Stereo support

## 3D Vision Pro

- Active stereo glasses

## GPU Direct for Video

- Picture in Picture

## External or Internal Sync

- Quadro Sync supports:
  - Genlock
  - TTL sync
  - Internal sync

## Warp + Intensity API

- NV-WARP
- Auto-calibration

## Vertical Sync

- Syncs graphics swap-buffer to Projector refresh

## NVAPI + NV-WMI

- Programmatic Interface to NVIDIA driver



# Windows on its own

- Independent Desktops





# Windows on its own

- Independent Desktops





# Windows on its own

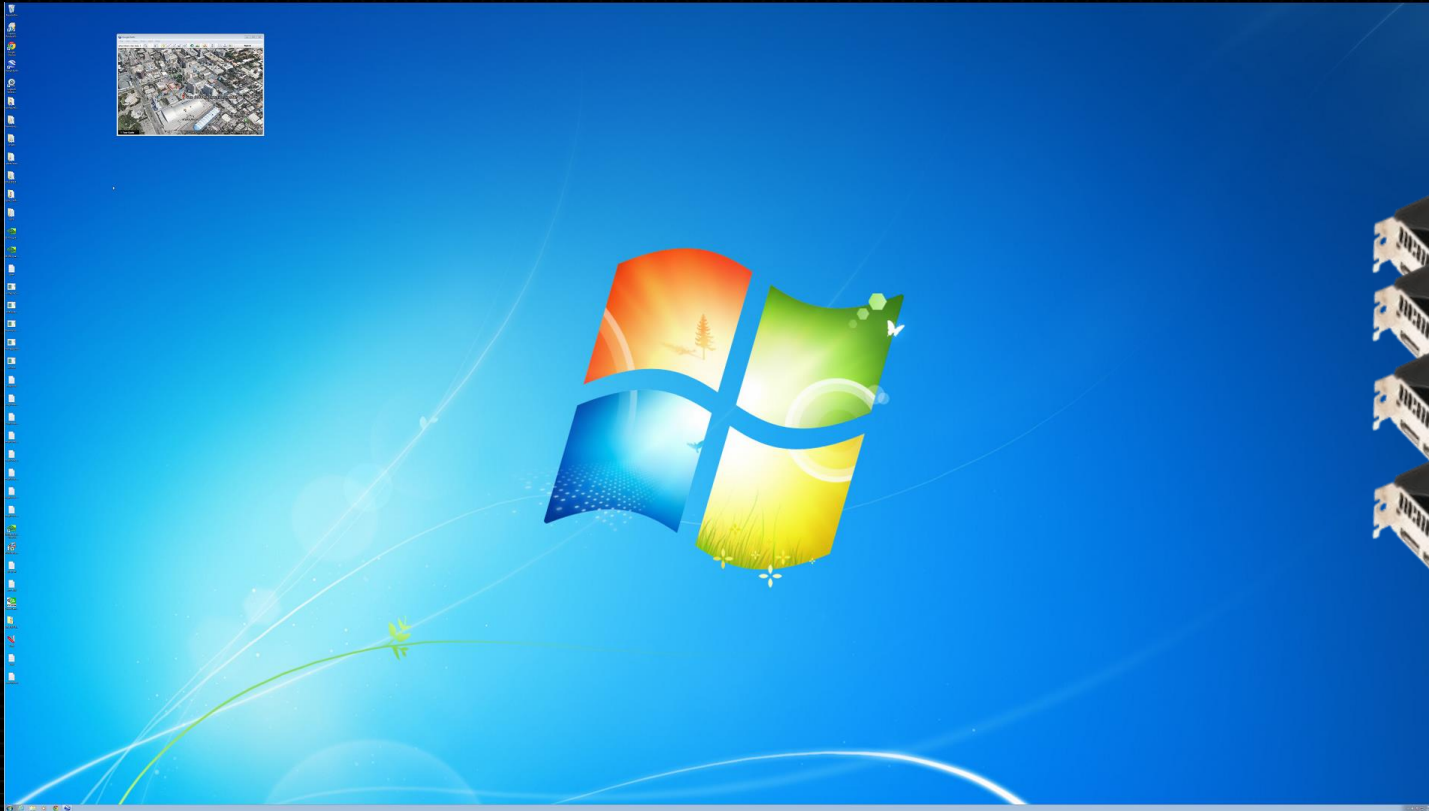
- Independent Desktops





# With MOSAIC

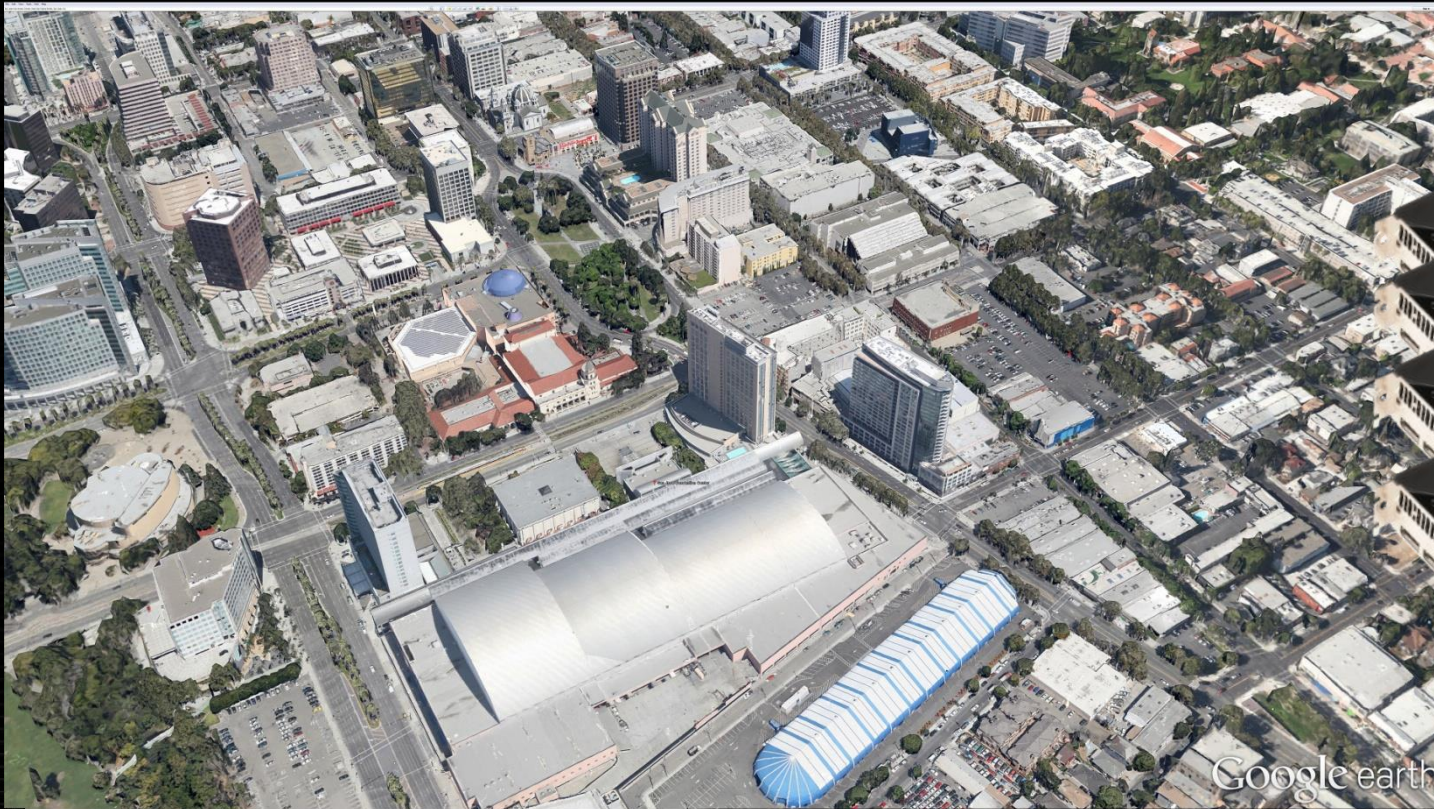
- One large Desktop





# With MOSAIC

- One large Desktop





# Mosaic Features

## Scale with Quadro and NVS Solutions

### Key Features

- Easy Configuration
- Unified Desktop (up to 8 display devices\*)
- Application Spanning
- Taskbar Spanning
- Bezel Correction
- Windows 7/8 + Linux Support



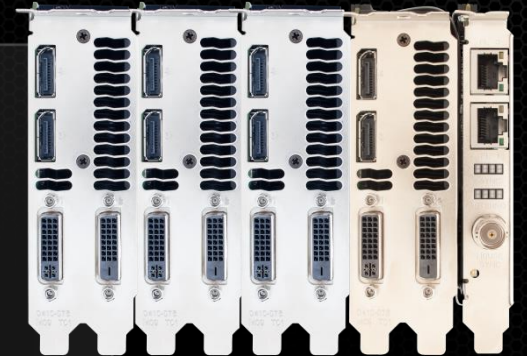
\* All displays require matching timings and resolution



# MOSAIC with Sync (Premium Mosaic) Features

## Additional Premium Features

- Unified Desktop (Up to 16 Displays\*)
- Seamless Display
- Projector Overlap
- Stereo Support
- Quadro Sync Support
- Linux and Windows Vista, XP and 7/8 Support
- API Support for Warp + Intensity Correction



Single or SLI:  
Quadro K6000<sup>new</sup>/K5000, 5000, 6000



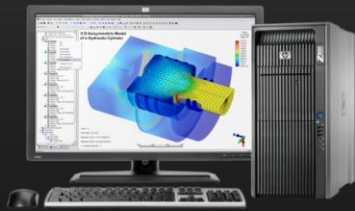
# Mosaic with Sync - Compatible cards

	Number of Synchronized displays/projectors from a single system with MOSAIC				
GPU Options	Up to 2	Up to 4	Up to 8	Up to 12	Up to 16
K6000 <sup>new</sup> /K5000	1 GPU	1 GPU	SLI (2GPUs) or 2GPUs + Quadro Sync	3GPUs + Quadro Sync	4GPUs + Quadro Sync
Q5000	1 GPU	SLI (2GPUs)			
Q6000	1 GPU	SLI (2GPUs)			
Quadro Plex 7000	1 System	1 System	2 Systems + DHIC		

- Seamless, Tear-Free Displays
- Projector Overlap
- Warp & Blend Engine
- Active and Passive Stereo Support
- Windows 7 & Linux
- XP support limited to 2 displays per GPU



# Certified Platforms for Dual QUADRO K5000/5000/6000 Premium MOSAIC



*Z800  
Dual Quadro5000/6000*

*Z820 / Z620  
Dual Quadro K5000*



*T7500  
Dual Quadro5000/6000*

*T7600/T5600/T3600  
Dual Quadro K5000*



*D20/C20  
Dual Quadro5000/6000*

*D30/C30  
Dual Quadro K5000*



*Fujitsu R670/R570  
Dual Quadro5000/6000*

*R920  
Dual Quadro K5000*



# Quadro Sync

- Synchronize up to 4 Quadro K6000s or K5000s GPUs and up to 16 displays or projectors per system
- Enable Advanced Quadro Mosaic on up to 16 displays or projectors in any system
- Windows Management Instrumentation (WMI) configuration and management for Windows based visualization clusters\*





# Systems that Support 4 K5000s + Sync



*Cubix Expander Elite  
Four Quadro K5000 +  
Sync in Expansion  
chassis*



*3DBoxx - 8950  
Four Quadro K5000 +  
Sync*



*7047GR-TPRF  
Four Quadro K5000 +  
Sync*



*Spectrum TXR410-512R  
Four Quadro K5000 + Sync*



*Workstation ProViz W60  
Four Quadro K5000 + Sync*

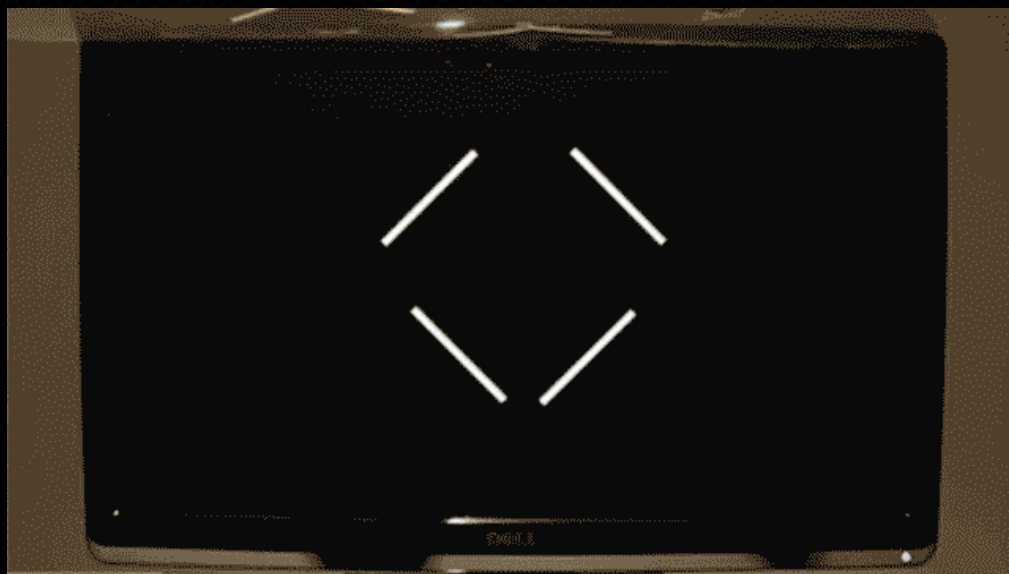


# Synchronization

- Focus on the image and not the artifacts



# Why Sync is important



Bezel's hide sync issues !!!

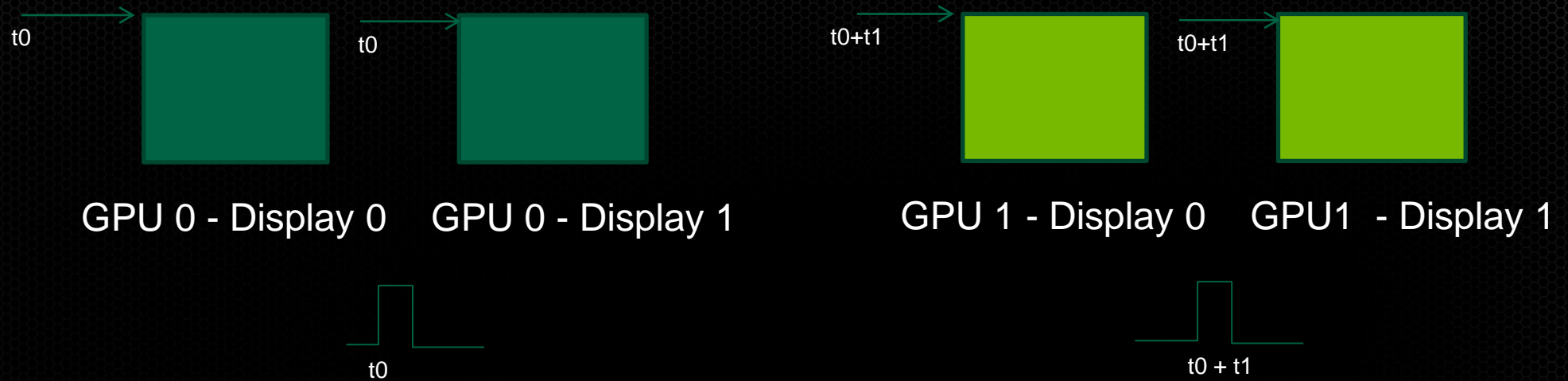


# Differences between Premium Mosaic + Mosaic

- Frame Synchronization
  - **Vertical Sync** - to a common timing - without a physical connection between cards there is no method for having a common sync
    - Effect is tearing
  - Stereo
    - **Without** frame sync there is no method for sync left/right eye between GPUS
  - Overlap
    - **Without** frame sync tearing would be most noticeable in a blend region.
    - We disable this feature so tearing is not shown.



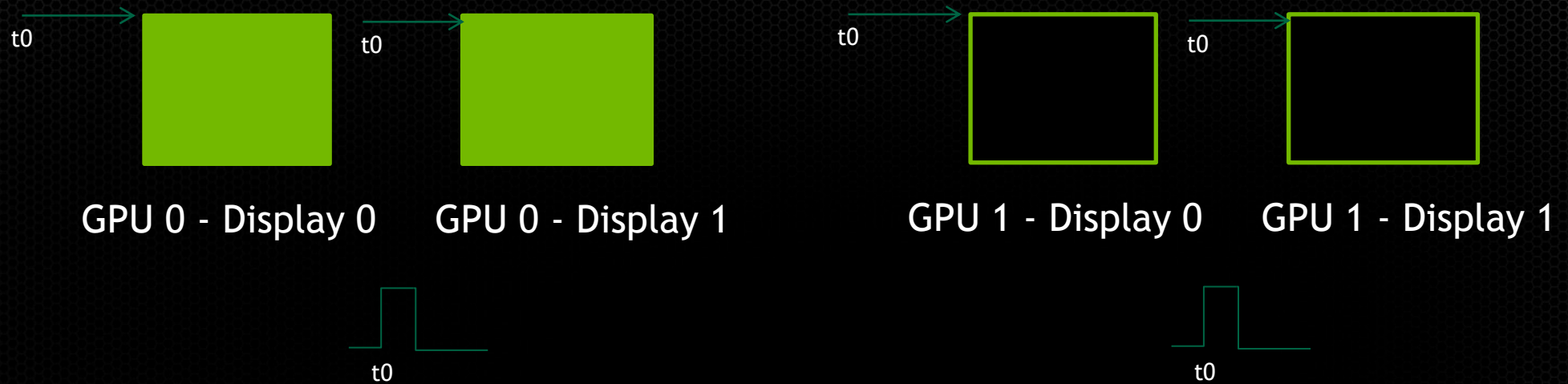
# No Frame Sync



- **Vertical Sync** is the pulse that indicates the start of the display refresh.
- To avoid **tearing** on a single screen the application swap buffers are synced to **vertical sync**.
- Although all four displays may have the same refresh rate - **vertical sync** start between 2 GPUs will be different.
- This can result in **tearing** between displays.



# Frame Sync - on Mosaic with Sync

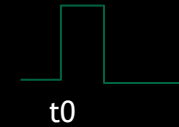


- **Frame Lock** provides a common sync signal between graphics cards to insure the vertical sync pulse starts at a common start.
- This is commonly referred to as **Frame Synchronization**
  - On **SLI workstation** - Framelock signal is provided across the SLI Bridge.
  - Between **Dual Quadro Plex's** framelock signal is provided over the CAT5 cable
  - On **K5000/K6000 with Quadro Sync** - framelock signal is provided by the Quadro Sync card



# Frame Sync - on Mosaic with Sync

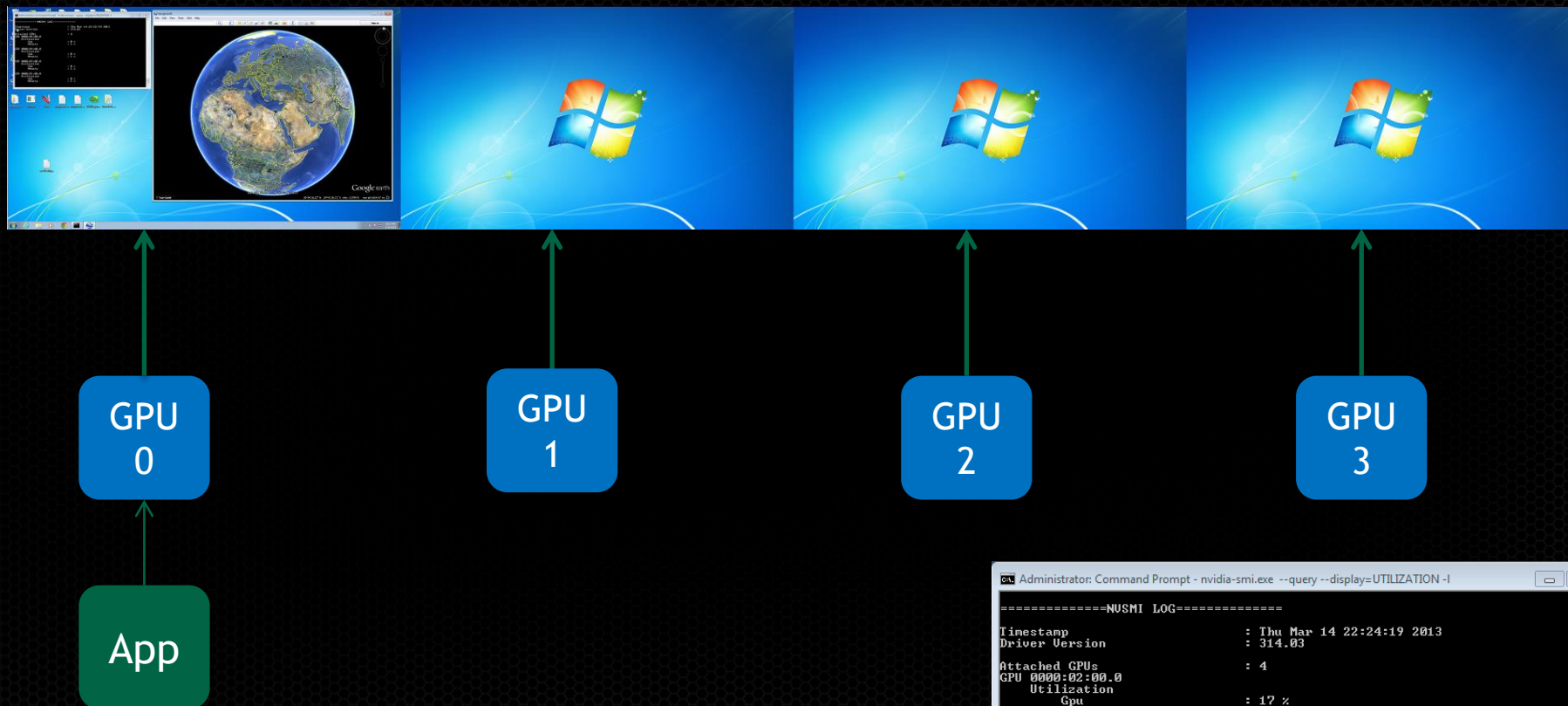
All 3 examples there is a physical connection between the GPUs.



- **Frame Lock** provides a common sync signal between graphics cards to insure the vertical sync pulse starts at a common start.
- This is commonly referred to as **Frame Synchronization**
  - On **SLI workstation** - Framelock signal is provided across the SLI Bridge.
  - Between **Dual Quadro Plex's** framelock signal is provided over the CAT5 cable
  - On **K5000/K6000 with Quadro Sync** - framelock signal is provided by the Quadro Sync card



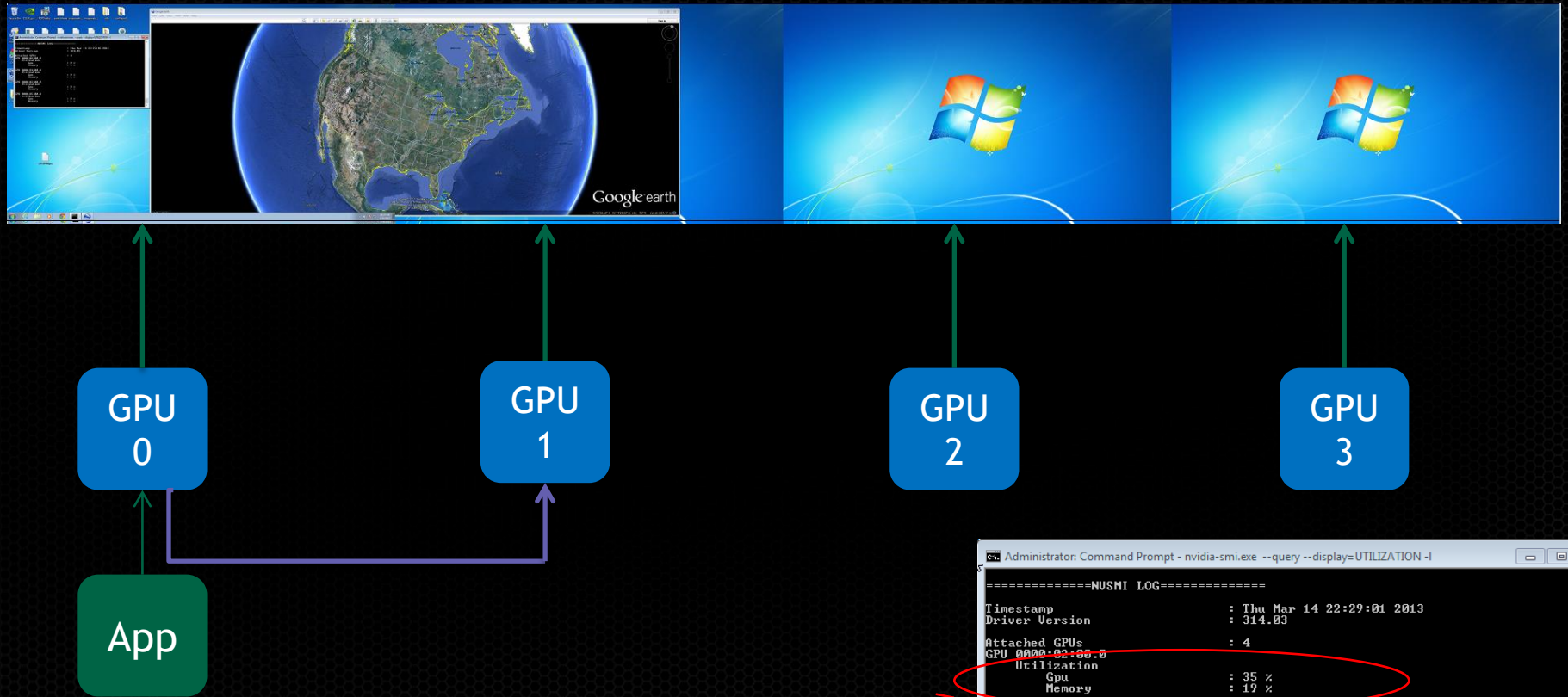
# Let the OS manage multiple displays



```
Administrator: Command Prompt - nvidia-smi.exe --query --display=UTILIZATION -l
=====NUSMI LOG=====
Timestamp           : Thu Mar 14 22:24:19 2013
Driver Version      : 314.03
Attached GPUs       : 4
GPU 0000:02:00.0
  Utilization
    Gpu              : 17 %
    Memory           : 20 %
GPU 0000:84:00.0
  Utilization
    Gpu              : 0 %
    Memory           : 5 %
GPU 0000:03:00.0
  Utilization
    Gpu              : 0 %
    Memory           : 5 %
GPU 0000:85:00.0
  Utilization
    Gpu              : 0 %
    Memory           : 5 %
```



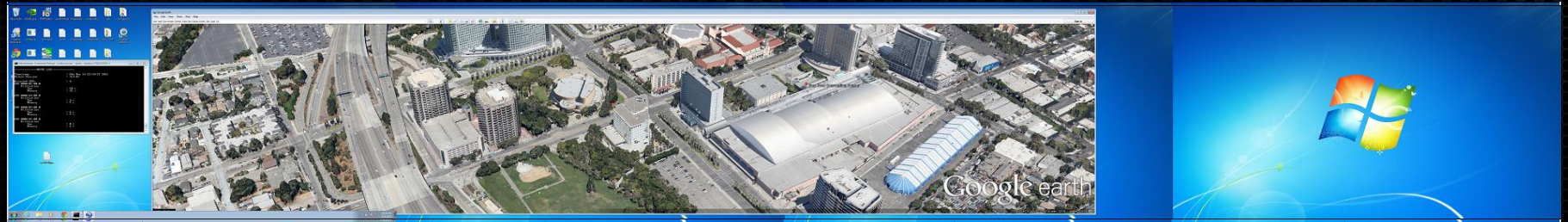
# Let the OS manage multiple displays



All rendering occurs on one GPU 0



# Let the OS manage multiple displays



GPU 0

GPU 1

GPU 2

GPU 3

App

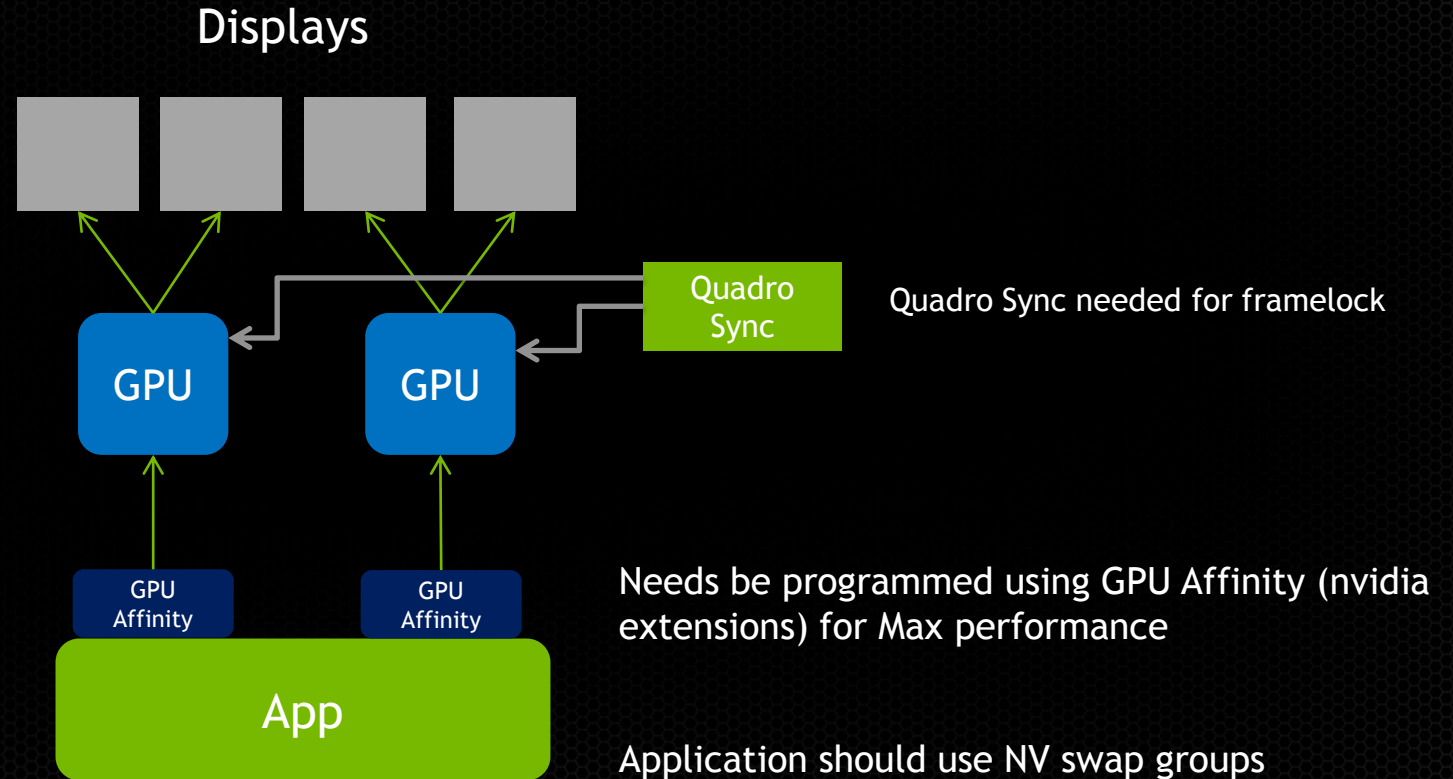
Pixels are copied across PCIe bus

All rendering occurs on one GPU 0

```
Administrator: Command Prompt - nvidia-smi.exe --query --display=UTILIZATION -l
=====NUSMI LOG=====
Timestamp           : Thu Mar 14 22:35:18 2013
Driver Version      : 314.03
Attached GPUs       : 4
GPU 0000:02:00.0
  Utilization
    Cpu              : 53 %
    Memory           : 39 %
GPU 0000:84:00.0
  Utilization
    Cpu              : 5 %
    Memory           : 7 %
GPU 0000:03:00.0
  Utilization
    Cpu              : 6 %
    Memory           : 7 %
GPU 0000:85:00.0
  Utilization
    Cpu              : 0 %
    Memory           : 5 %
```



# Application with GPU Affinity

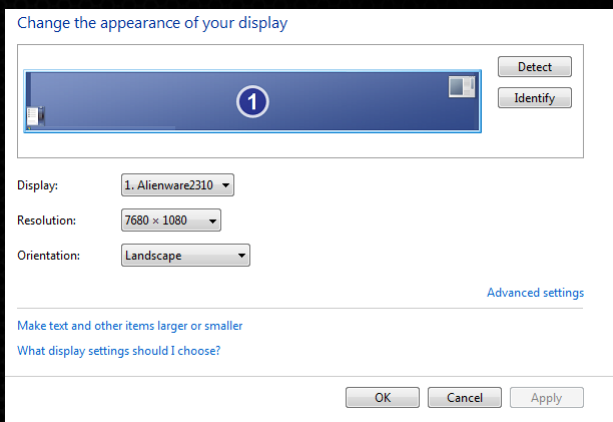
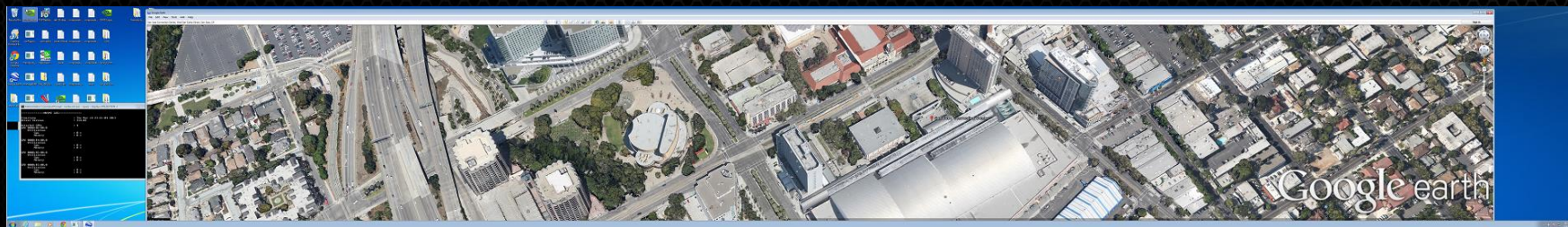


Application needs to be multi-threaded  
(4 Draw threads)

Application should use NV swap groups  
to sync swap buffer between GPUs



# MOSAIC hides the complexity



Logical GPU

App

```
Administrator: Command Prompt - nvidia-smi.exe --query --display=UTILIZATION -I
=====NUSMI LOG=====
Timestamp                               : Thu Mar 14 23:22:54 2013
Driver Version                           : 314.03
Attached GPUs                             : 4
GPU 0000:02:00.0
  Utilization
    Gpu                                    : 10 %
    Memory                                 : 7 %
GPU 0000:84:00.0
  Utilization
    Gpu                                    : 10 %
    Memory                                 : 7 %
GPU 0000:03:00.0
  Utilization
    Gpu                                    : 10 %
    Memory                                 : 7 %
GPU 0000:85:00.0
  Utilization
    Gpu                                    : 10 %
    Memory                                 : 7 %
```



# What does Sync do

## Synchronize Multiple Displays

- Align the scan out of multiple displays, GPU's, and systems
- Maintain Stereo alignment between multiple systems
- Synchronize to an internal or external timing source

## Co-ordinate Buffer Swaps

- HW based swap synchronization within a node or between clusters
- Prevent tearing and image misalignment

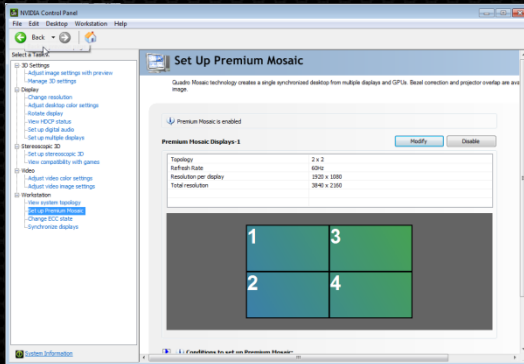


# MOSAIC

- Setup and configuration

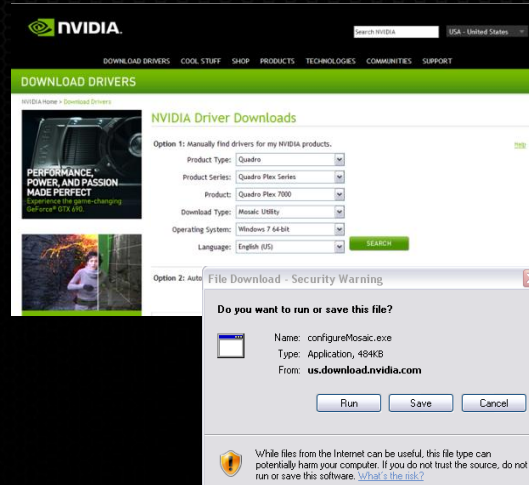


# Setting up MOSAIC



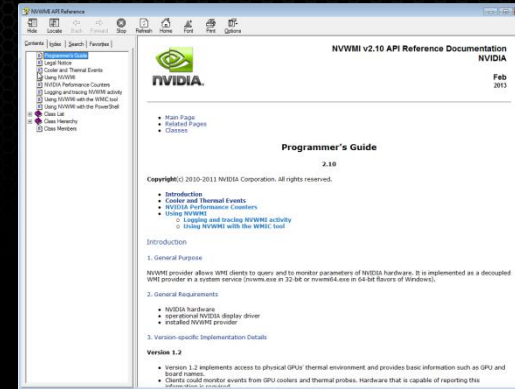
Control Panel

Best for up to 4 displays



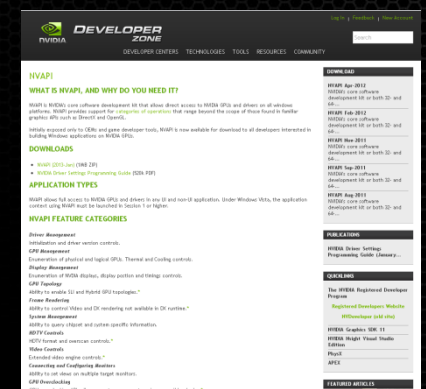
Configuremosaic

Large display walls



NVWMI

Setup from a remote machine  
Powershell scripts  
Program directly



NVAPI

Incorporate MOSAIC  
setup into your own  
application

Driver Install

Download from NVIDIA  
driver section

Install with Driver -  
under advanced  
options

Registered  
Developer for NDA  
access NVAPI



# 4K Displays + MOSAIC

## Prosumer



LG 4K 84" TV  
(Single HDMI input)

24Hz/30Hz

## Professional



Christie 4K 84" panel  
(four HDMI input)

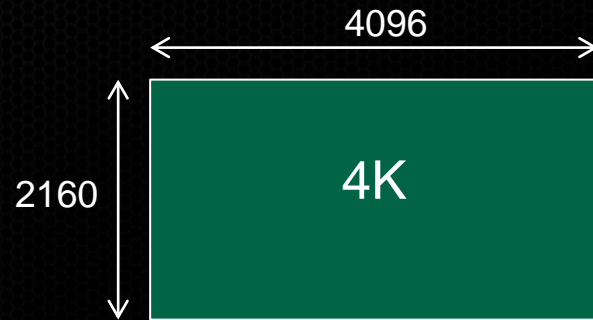
60Hz



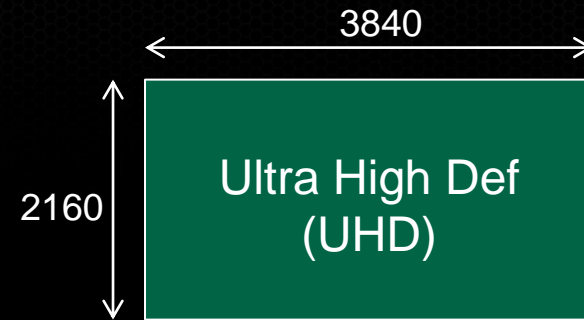
Sony 4K SXRD VPL GT-100  
(Dual DP inputs)



# What is 4K ?



Video Bandwidth  
~567MHz @ 60Hz



Video Bandwidth  
~533MHz @ 60Hz

## Video Connection Bandwidth

SL-DVI = 165MHz

DL-DVI = 330MHz

DP1.1 ~330MHz

HDMI\* ~340 MHz

DP1.2\*\* K5000 ~540MHz

DP1.2\*\* K6000 ~592 MHz

\* HDMI 1.4 supports 4k/UHDTV at 24 & 30 Hz for single cable

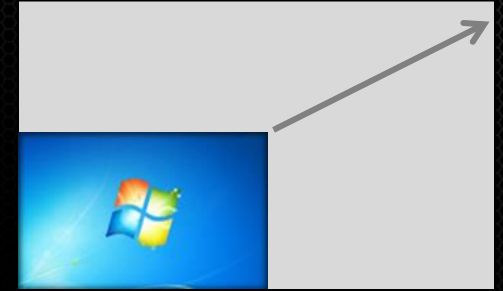
\*\* DP1.2 can drive 4K but implementation will vary per Graphics card.



# Driving 4K - single connection

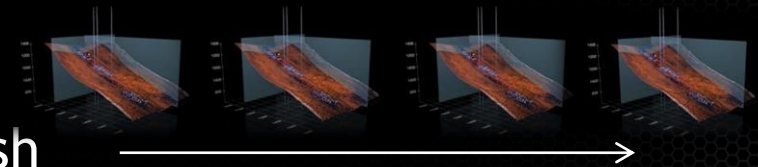
- Scale Resolution

- Single input at 1920x1080 @60Hz
- Scaled to 3840x2160@60Hz



- Scale Refresh rate

- HDMI 1.4a - 3840x2160@30Hz
- Display will scale to 60Hz or 120 Hz refresh
- Disadvantage for Computer graphics is latency/lag

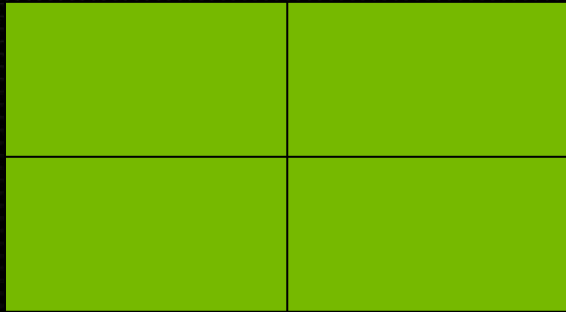


Each image is repeated 4 times

There are no DP1.2 capable 4K displays yet!!



# Driving 4K - multiple connections



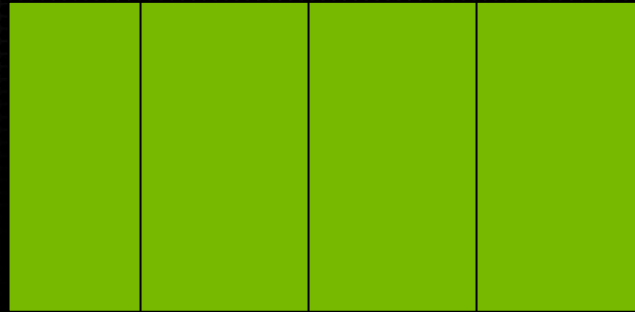
## Quadrants

4 DVI or HDMI/DP

Each input is

4K – 2048 x 1080@60Hz

UHD – 1920x1080@60Hz



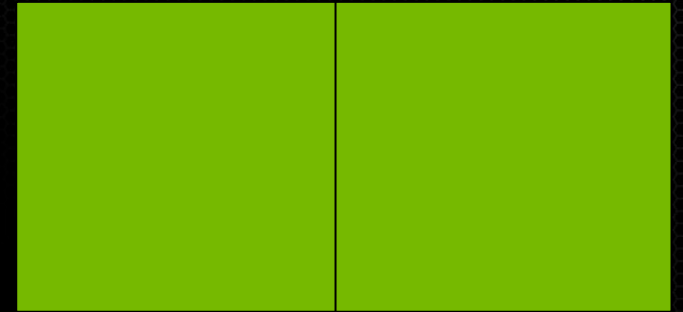
## Stripes

4 DVI or HDMI/DP

Each input is

4k - 1024x2160@60Hz

UHD – 960x2160@60Hz



## Side by side

2 DL-DVI/DP

Each input is

4k – 2048x2160@60Hz

UHD -1920x2160@60Hz

Display Port can support higher color depth desktop



# Quadro K5000 Display Out

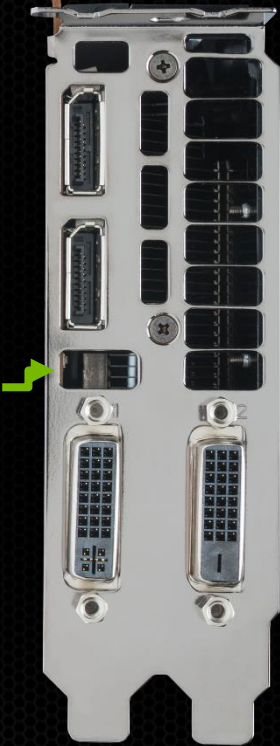


- **4 Display Connectors → 4 Displays\***
  - 2 DVI-DL, 2 DP 1.2
    - Only one VGA output on DVI
  - DP 1.2 support High Bit Rate 2 (HBR2) and Multi-Stream
    - Total of 4 independent heads
    - High Bit Rate 2 -> 3840x2160 30bit @ 60Hz on a single connector
  - Stereo through an optional Stereo Bracket - same as Quadro 4000

\* Win XP limited to 2 displays



# Quadro K6000 Display outputs

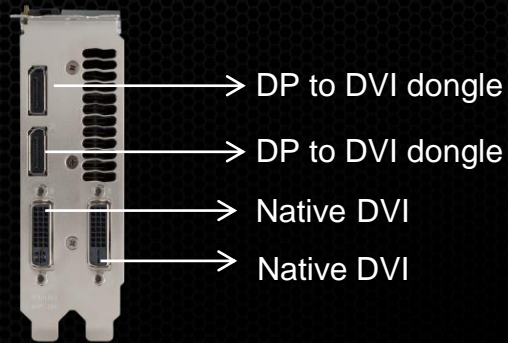


LED indicates  
Master GPU in  
Multi-GPU systems

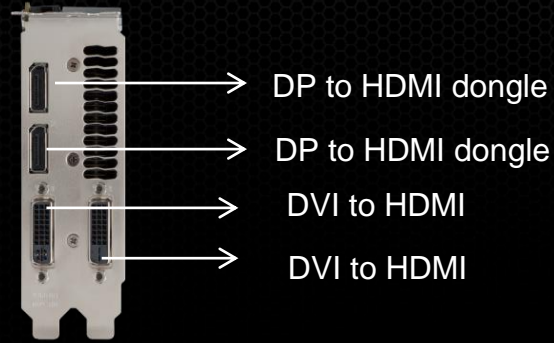
- 4 Display Connectors → 4 Displays\*
  - 2 DVI-DL, 2 DP 1.2
    - Only one VGA output on DVI
  - DP 1.2 support High Bit Rate 2 (HBR2) and Multi-Stream
    - Total of 4 independent heads
    - High Bit Rate 2 -> 4096x2160 30bit @ 60Hz on a single connector
  - Stereo through an optional Stereo Bracket - same as Quadro 4000



# K5000/K6000 - Supported Outputs



Up to 4 Single link  
or Dual Link\* DVI



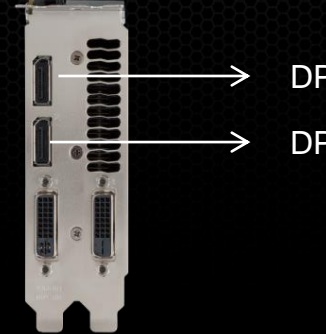
4 HDMI



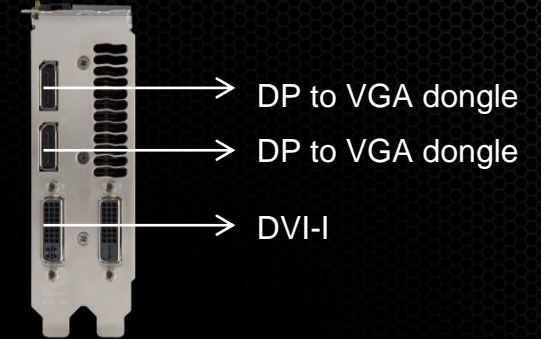
DVI to HDMI adaptor



DP to HDMI adaptor



2 Display Port displays or  
4 Display Ports using MST\*\*.



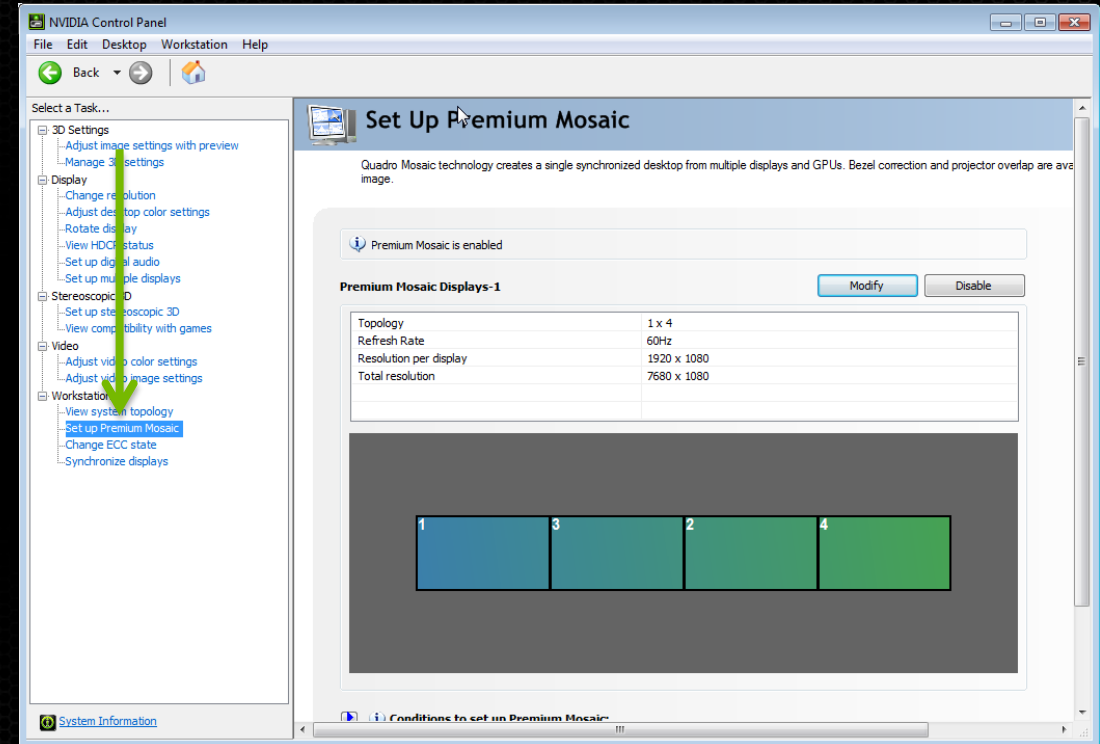
3 VGA ports

- Dual link requires active dongle for DP connectors
- \*\*MST allows for DP to be daisy-chained. Support 4 displays per card



# NVIDIA Control Panel

- Order in which commands are applied can matter
  - (1) Manage 3D Settings
    - Profile
    - Stereo
    - Vsync etc
  - (2) Set Resolution
  - (3) Set MOSAIC and/or Synchronization





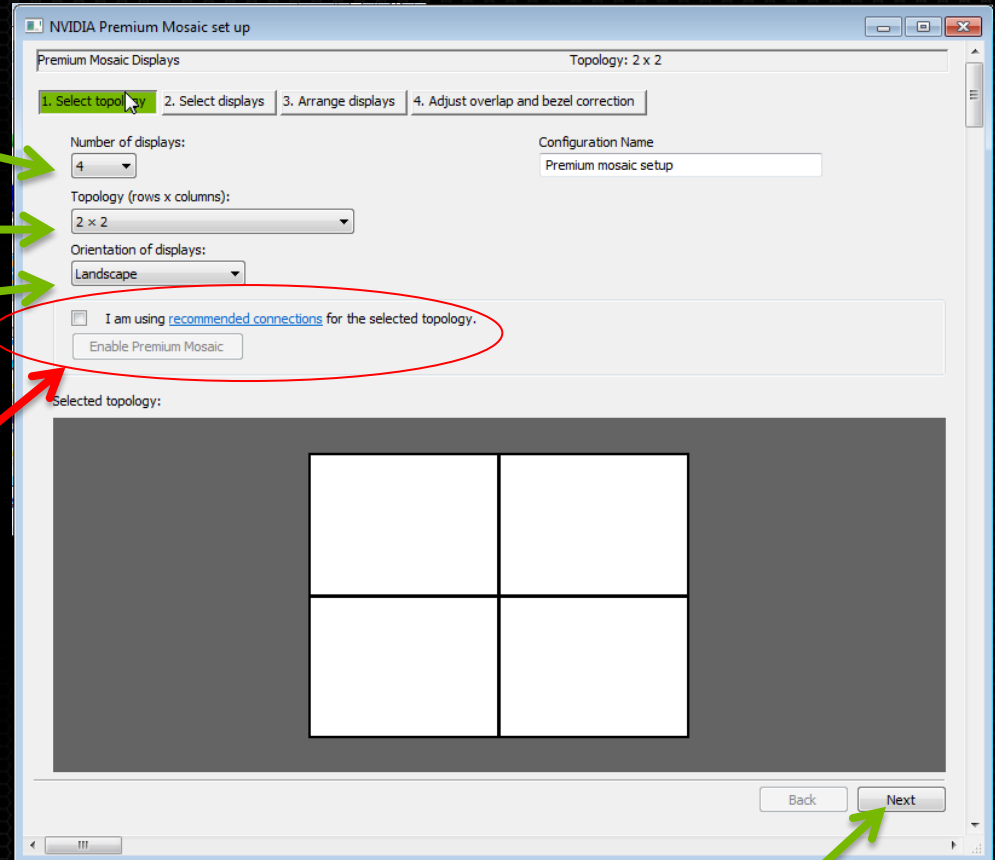
# MOSAIC Wizard

Select Number of displays

Select Topology

Set Rotation

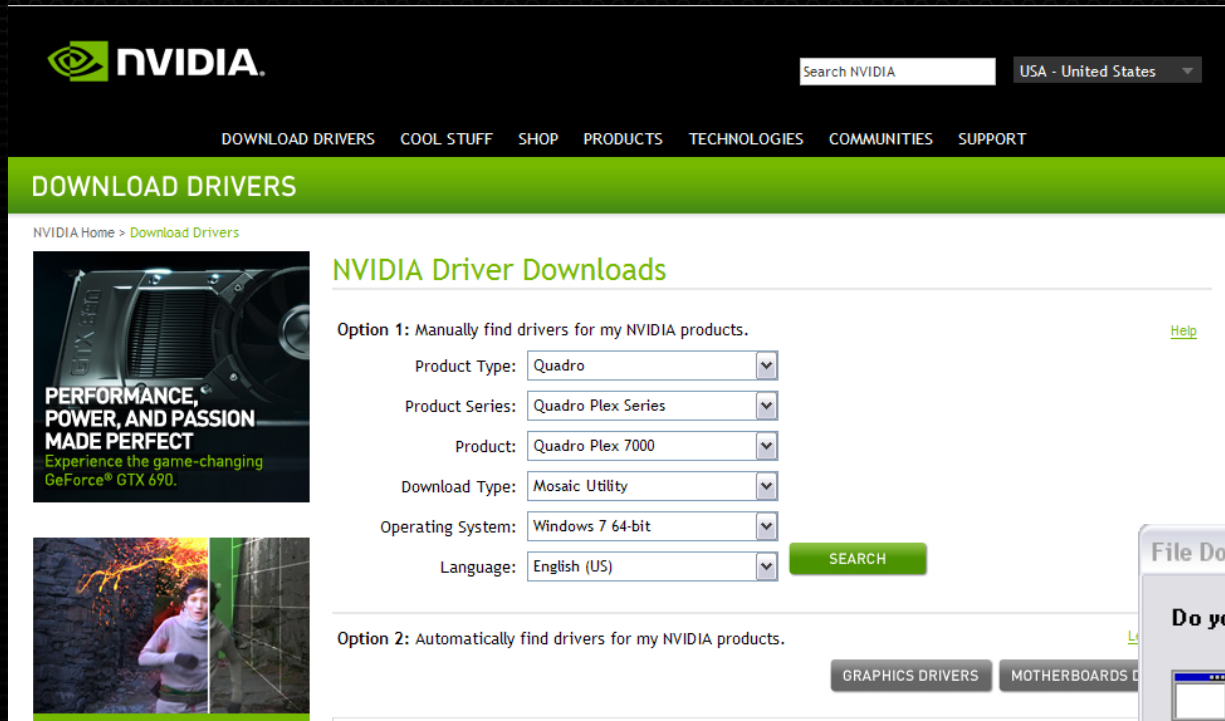
Bypass Wizard and apply MOSAIC



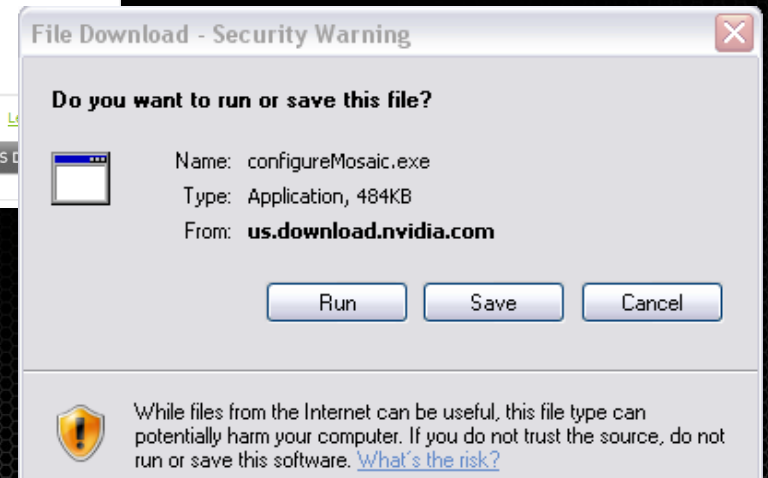
For next page



# Configure Mosaic



The screenshot shows the NVIDIA website's 'Download Drivers' page. At the top, there is the NVIDIA logo, a search bar, and a dropdown menu for 'USA - United States'. Below this is a navigation menu with links for 'DOWNLOAD DRIVERS', 'COOL STUFF', 'SHOP', 'PRODUCTS', 'TECHNOLOGIES', 'COMMUNITIES', and 'SUPPORT'. The main heading is 'DOWNLOAD DRIVERS', with a sub-link 'NVIDIA Home > Download Drivers'. The page title is 'NVIDIA Driver Downloads'. There are two options for finding drivers: 'Option 1: Manually find drivers for my NVIDIA products.' and 'Option 2: Automatically find drivers for my NVIDIA products.'. Option 1 includes a form with the following fields: Product Type (Quadro), Product Series (Quadro Plex Series), Product (Quadro Plex 7000), Download Type (Mosaic Utility), Operating System (Windows 7 64-bit), and Language (English (US)). A green 'SEARCH' button is located below the form. To the left of the form is a promotional banner for the GeForce GTX 690 with the text 'PERFORMANCE, POWER, AND PASSION MADE PERFECT' and 'Experience the game-changing GeForce® GTX 690.'. Below the banner is a small image of a person in a game. At the bottom of the page, there are buttons for 'GRAPHICS DRIVERS' and 'MOTHERBOARDS D'.



The screenshot shows a Windows security warning dialog box titled 'File Download - Security Warning'. The dialog asks 'Do you want to run or save this file?'. It displays the following information: Name: configureMosaic.exe, Type: Application, 484KB, and From: us.download.nvidia.com. There are three buttons: 'Run', 'Save', and 'Cancel'. At the bottom, there is a warning icon and text: 'While files from the Internet can be useful, this file type can potentially harm your computer. If you do not trust the source, do not run or save this software. [What's the risk?](#)'



# Understanding Topologies

ROWS



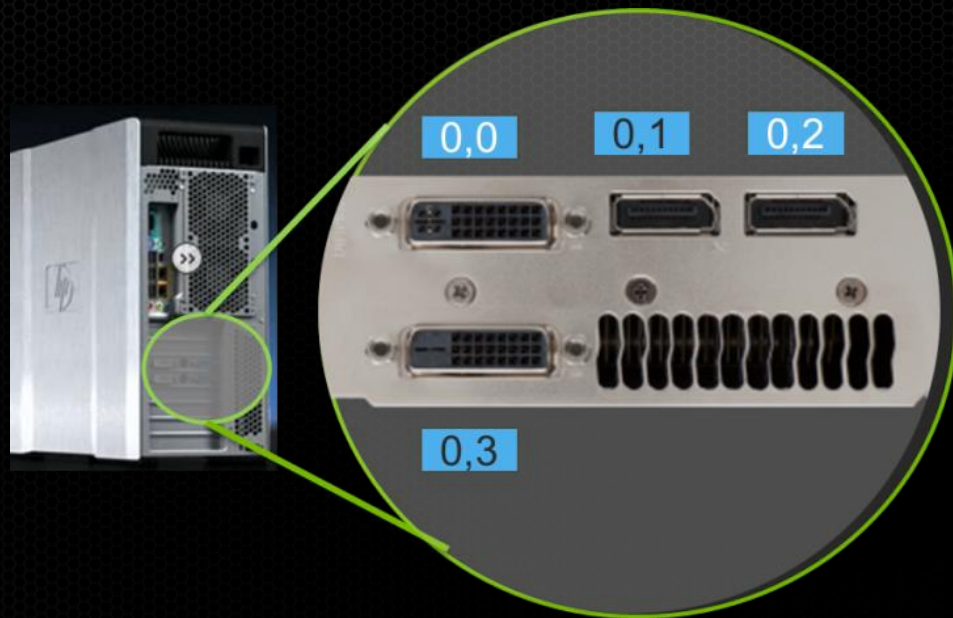
columns



columns



# Relating Ports to Grid - single GPU

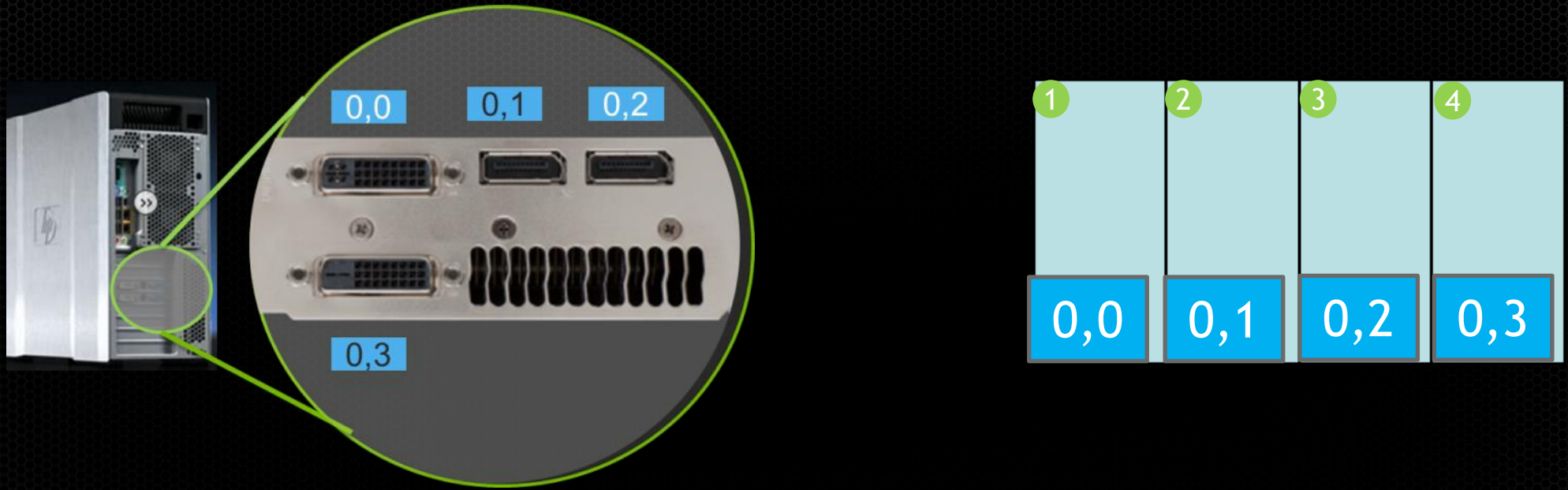


`configureMosaic.exe set rows=2 cols=2`

`configureMosaic.exe set rows=2 cols=2 out=0,0 out=0,1 out=0,2 out=0,3`



# Relating Ports to Grid

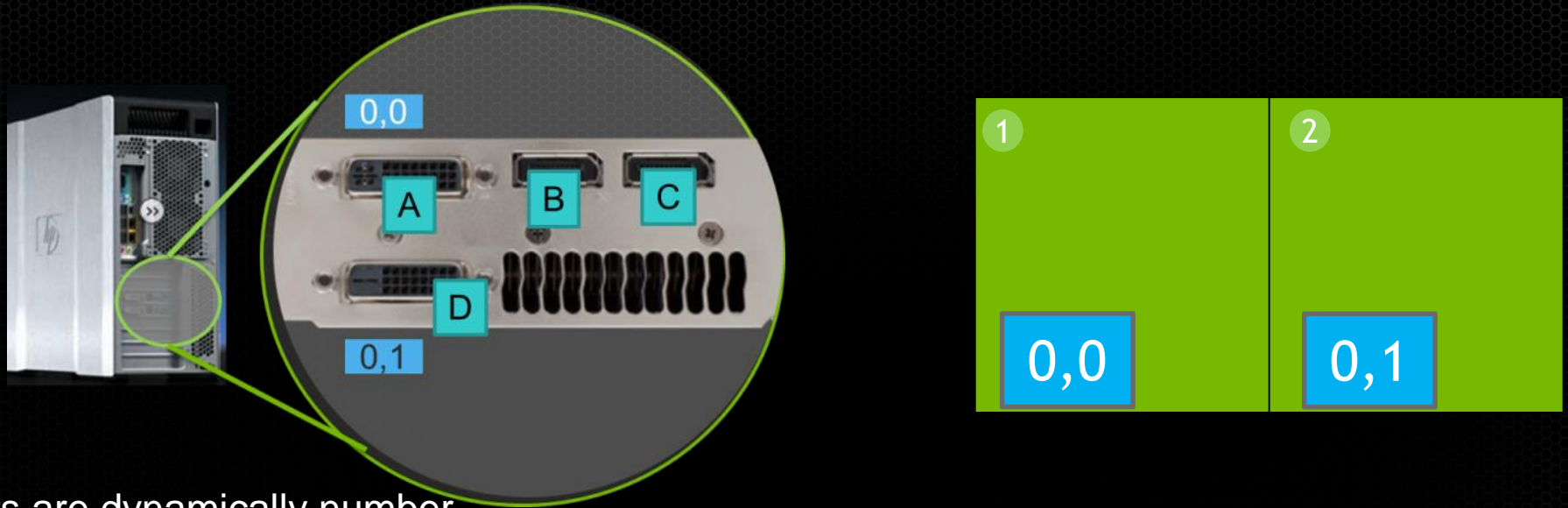


`configureMosaic.exe set rows=1 cols=4 res=1024,2160,60`

`configureMosaic.exe set rows=1 cols=4 out=0,0 out=0,1 out=0,2 out=0,3`



# Relating Ports to Grid

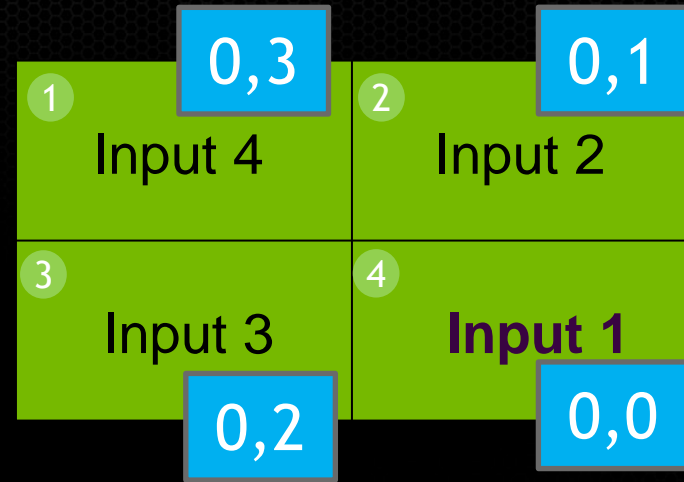
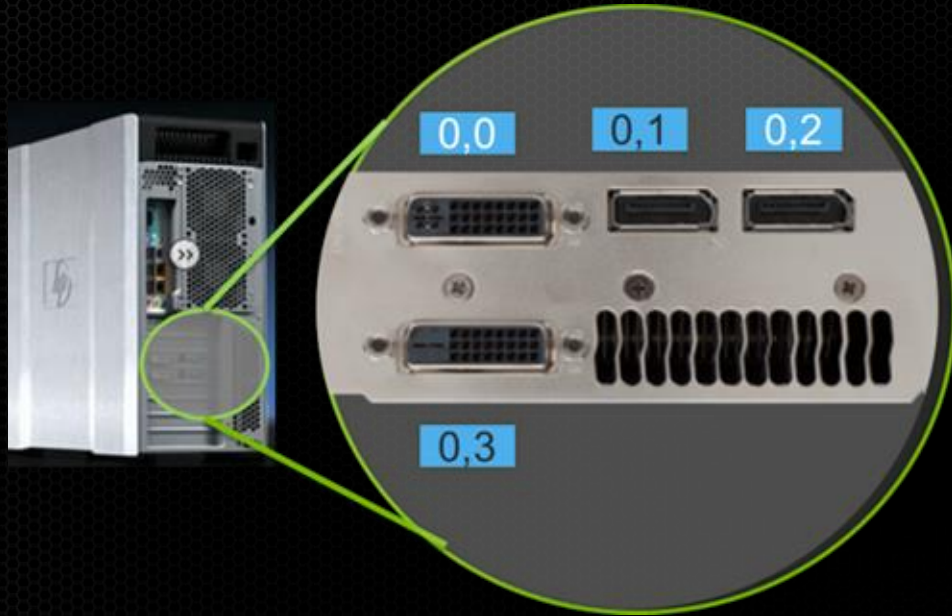


Note: Ports are dynamically number  
– if only using DVI ports will be as shown

```
configureMosaic.exe set rows=1 cols=2 res=2048,2160,60  
configureMosaic.exe set rows=1 cols=2 out=0,0 out=0,1
```



# Reordering displays



Some 4K displays will only work if its primary input is active  
Primary input may be bottom left.

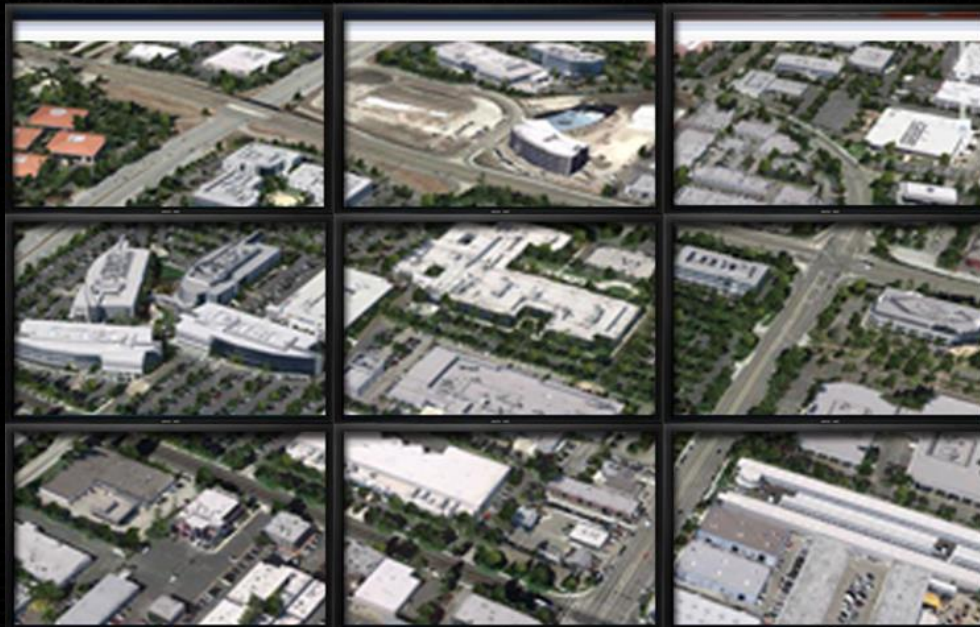
- 1
- 2
- 3
- 4

`configureMosaic.exe set rows=2 cols=2 out=0,3 out=0,1 out=0,2 out=0,0`



# 3x3 Layout

## 3 K5000s with Quadro Sync





# Boxx Technologies 8950 Workstation

## Example workstation

- 4 PCIe Gen 3 slots
- Supports 4 K5000s with Quadro Sync



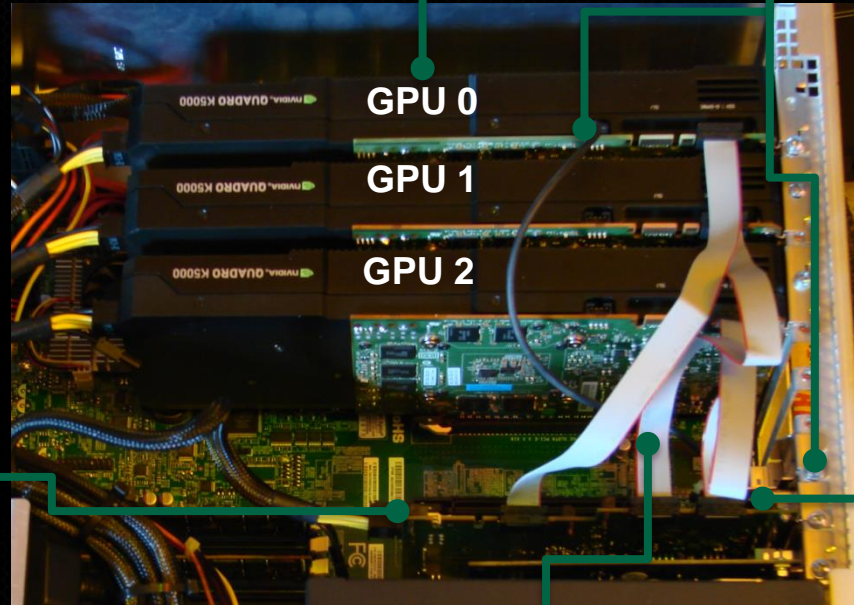


# 3 K5000 configuration

PCIe bus order will determine GPU numbering

VESA stereo header - connected to VESA bracket

Slot 2  
Slot 4  
Slot 6  
Slot 8



Quadro Sync card power

Quadro Sync card  
Up to 4 GPUs

sync cables



# PCIe bus enumeration



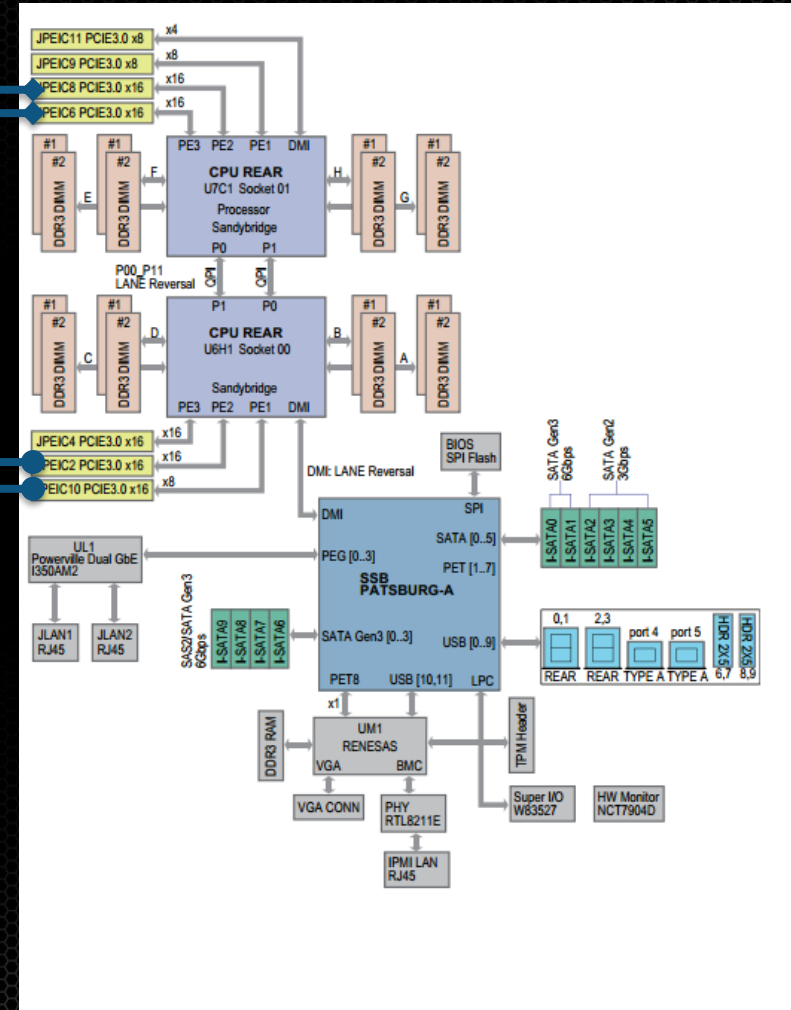
CPU1 – PE2 – Slot 8

CPU1 – PE3 – Slot 6

CPU0 – PE3 – Slot 4

CPU0 – PE2 – Slot 2

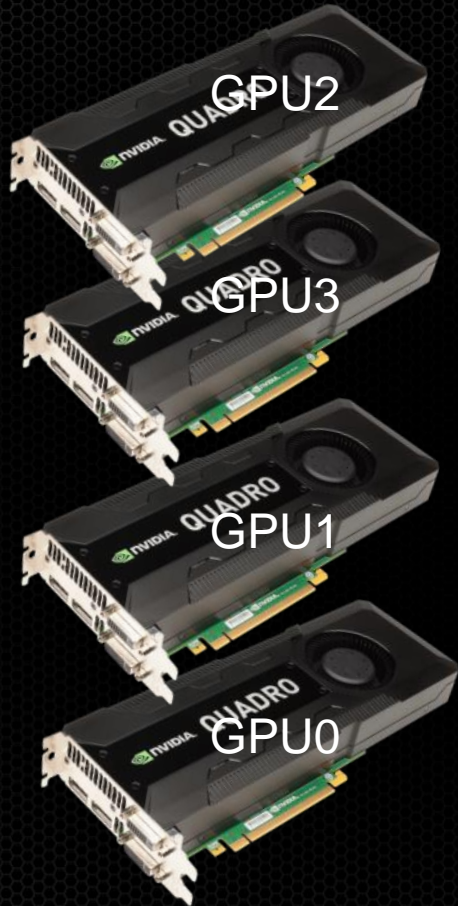
3 GPU Example



Quadro Sync card slot is not important.



# PCIe bus enumeration

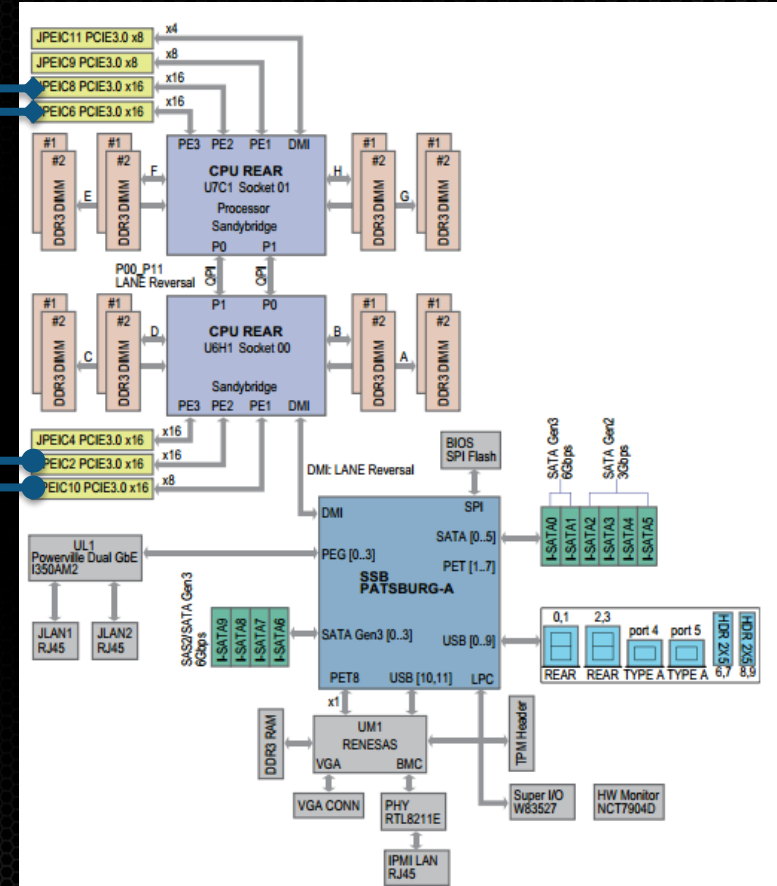


CPU1 – PE2 – Slot 8

CPU1 – PE3 – Slot 6

CPU0 – PE3 – Slot 4

CPU0 – PE2 – Slot 2



4 GPU Example – **note** GPU # doesn't follow slot number

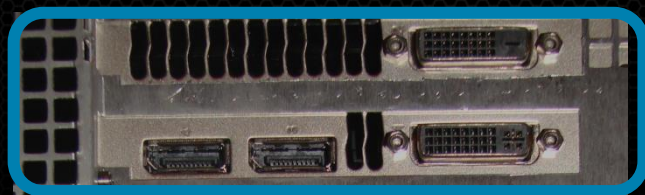
Quadro Sync card slot is not important.

Layout will vary based on motherboard



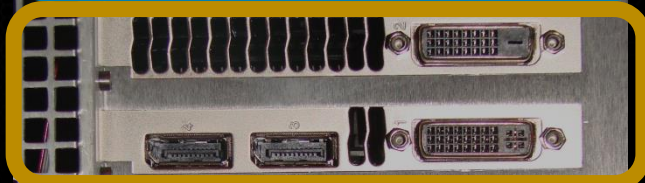
# Rear panel

GPU 0



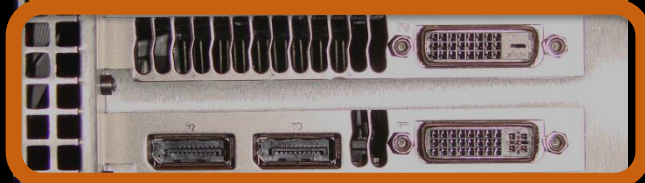
Slot 2

GPU 1



Slot 4

GPU 2



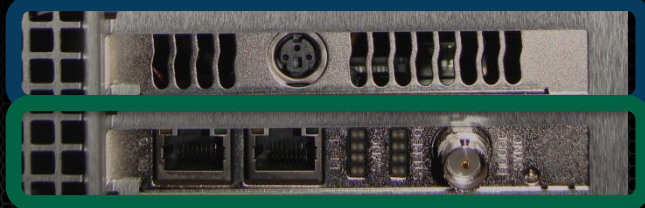
Slot 6

Slot 8

VESA Stereo Bracket



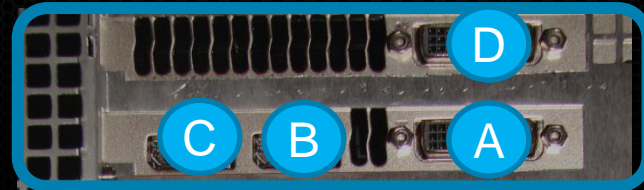
Quadro Sync



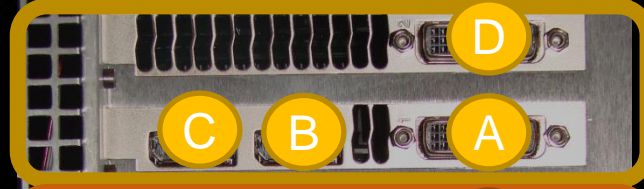


# Port Numbering

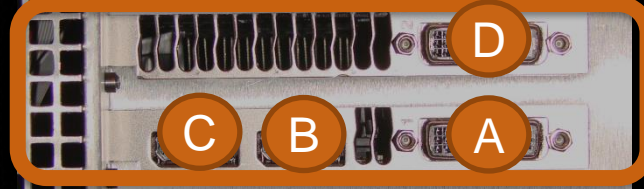
GPU 0



GPU 1



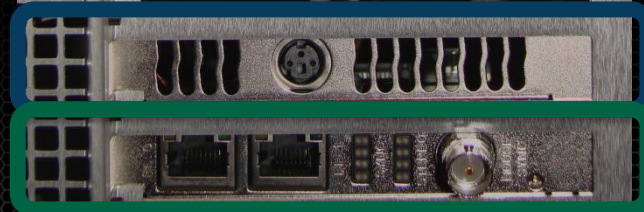
GPU 2



VESA Stereo Bracket



Quadro Sync



Ports auto enumerate depending  
what is attached –

i.e. A + D are attached

A = 0,0

D = 0,1

A + B + D are attached

A = 1,0

B = 1,1

D = 1,2

A + B + C + D are attached

A = 2,0

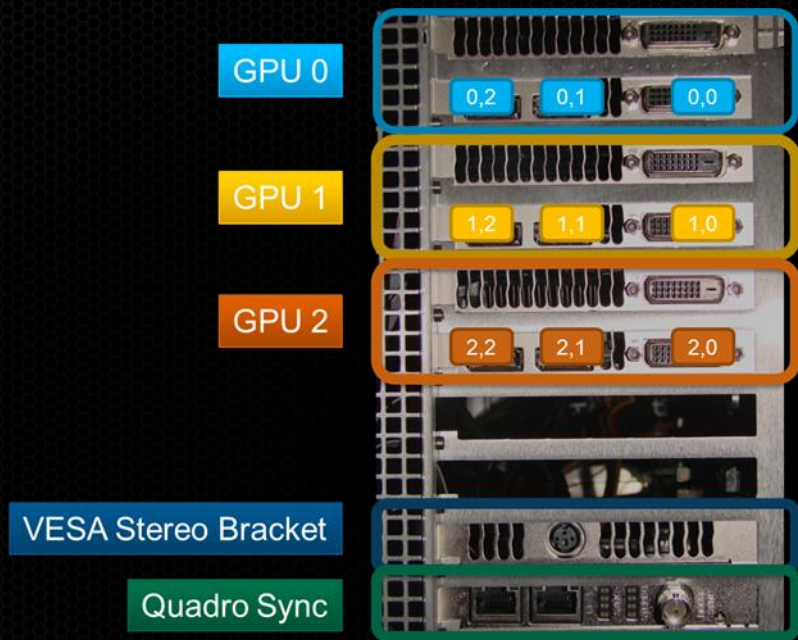
B = 2,1

C = 2,2

D = 2,3



# Relating Ports to Grid



`configureMosaic.exe set rows=3 cols=3`

`configureMosaic.exe set rows=3 cols=3 out=0,0 out=0,1 out=0,2 out=1,0 out=1,1 out=1,2 out=2,0 out=2,1 out=2,2`

1

2

3

4

5

6

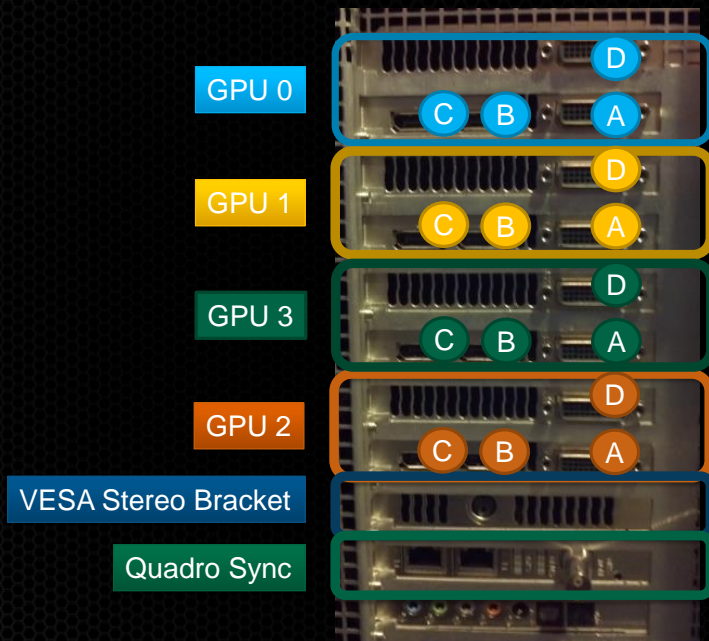
7

8

9

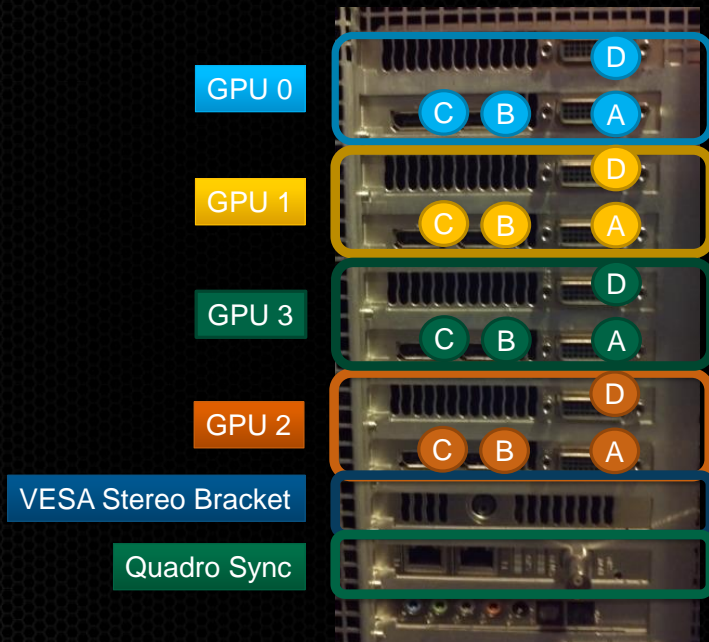


# 4 GPU Example





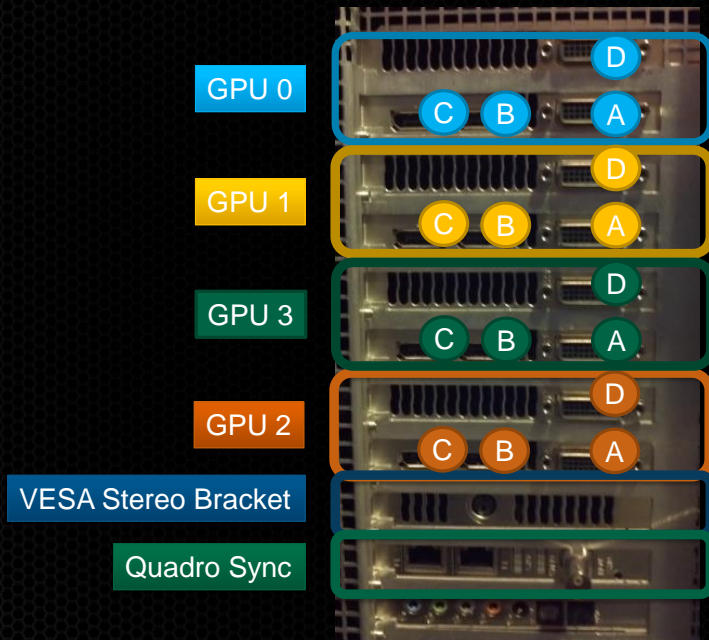
# 4 GPU Example



Windows Display Properties can only identify 10 unique displays



# 4 GPU Example



Windows Display Properties can only identify 10 unique displays



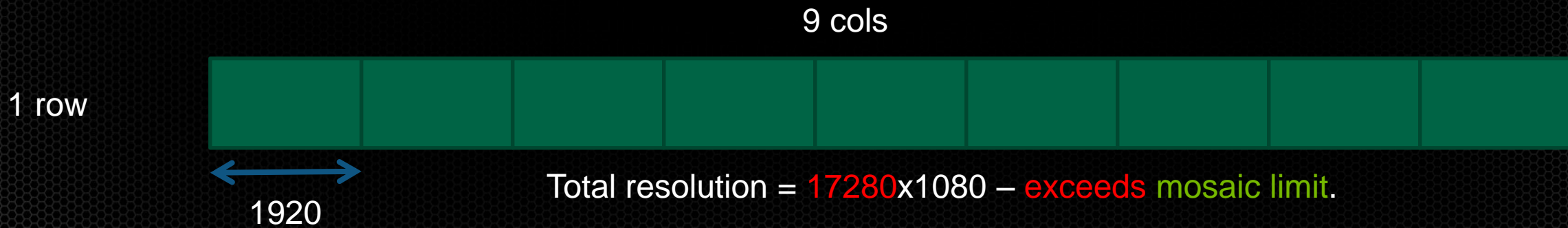
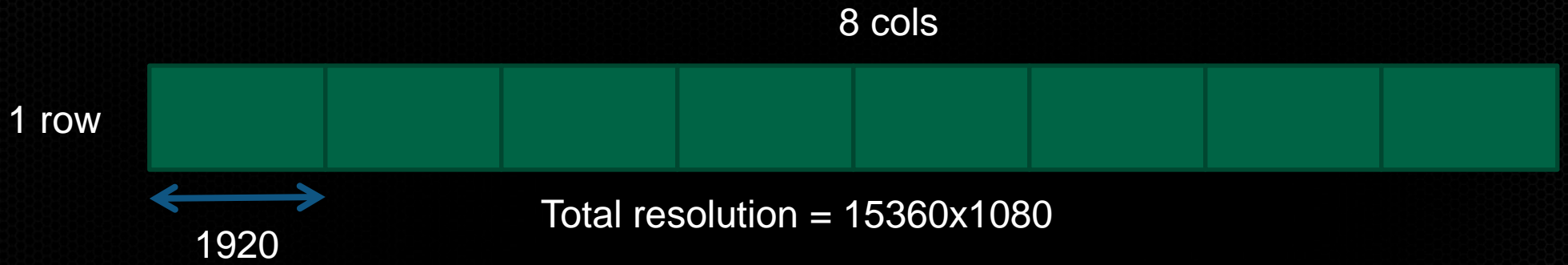
# University of South Florida - Tampa





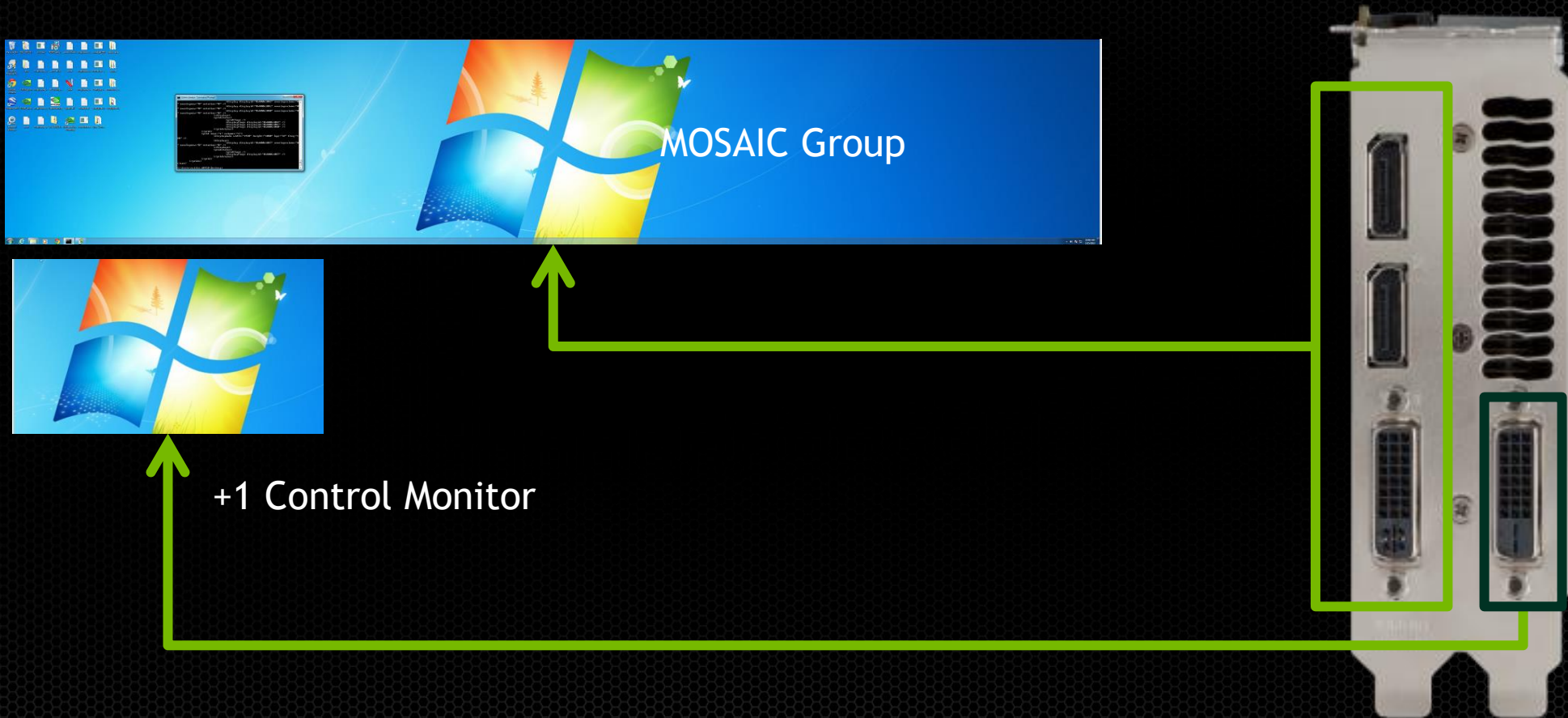
# MOSAIC limits

- Max horizontal or vertical pixels - 16384 (16k)





# MOSAIC + 1 - Single GPU



Spare ports are only available for +1 when MOSAIC does not cross GPUs



# MOSAIC + 1 - Single GPU

The image shows the NVIDIA Control Panel window in the 'Set Up Multiple Displays' section. The window title is 'Set Up Multiple Displays' and it contains the following text: 'NVIDIA nView technology allows you to specify how you would like to use multiple displays.' Below this, there are two main steps:

- 1. Select the displays you want to use.** A list of displays is shown under the 'Quadro K5000' section:

Display	Count
<input checked="" type="checkbox"/> Dell Alienware2310 (1 of 4)	4
<input checked="" type="checkbox"/> Dell Alienware2310 (2 of 4)	
<input checked="" type="checkbox"/> Dell Alienware2310 (3 of 4)	3
<input checked="" type="checkbox"/> Dell Alienware2310 (4 of 4)	
- 2. Drag the icons to match your display configuration.** A visual representation of the display configuration is shown with four icons: a green icon with the number '4', a blue icon with the number '3', a green icon with the number '1', and a green icon with an asterisk '\*'. Below this is a link for 'Mosaic options'.

Below the configuration area, there is a 'Description:' section with the text: 'Drag the icons so they match the physical configuration of your displays. Right-click on an icon for additional options.' and a 'Typical usage scenarios:' section with a bulleted list:

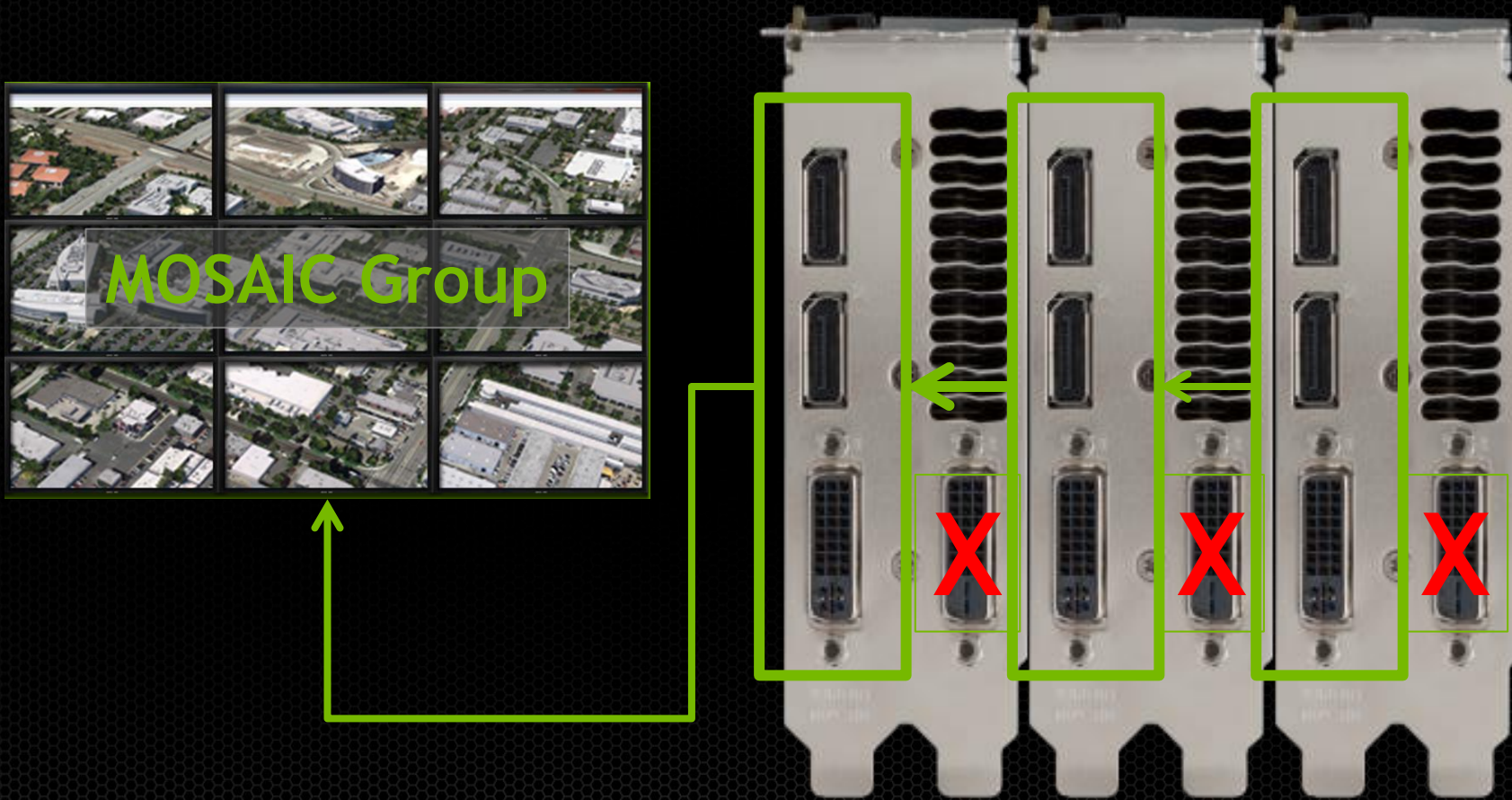
- Matching the desktop to the physical configuration of the displays
- Changing the primary display
- Cloning displays

On the right side of the image, a GPU back panel is shown with several ports highlighted by green boxes: two DVI ports, one VGA port, and one DisplayPort port. A green arrow points from the 'Set up multiple displays' option in the NVIDIA Control Panel to the GPU back panel.

Spare ports are only available for +1 when MOSAIC does not cross GPUs

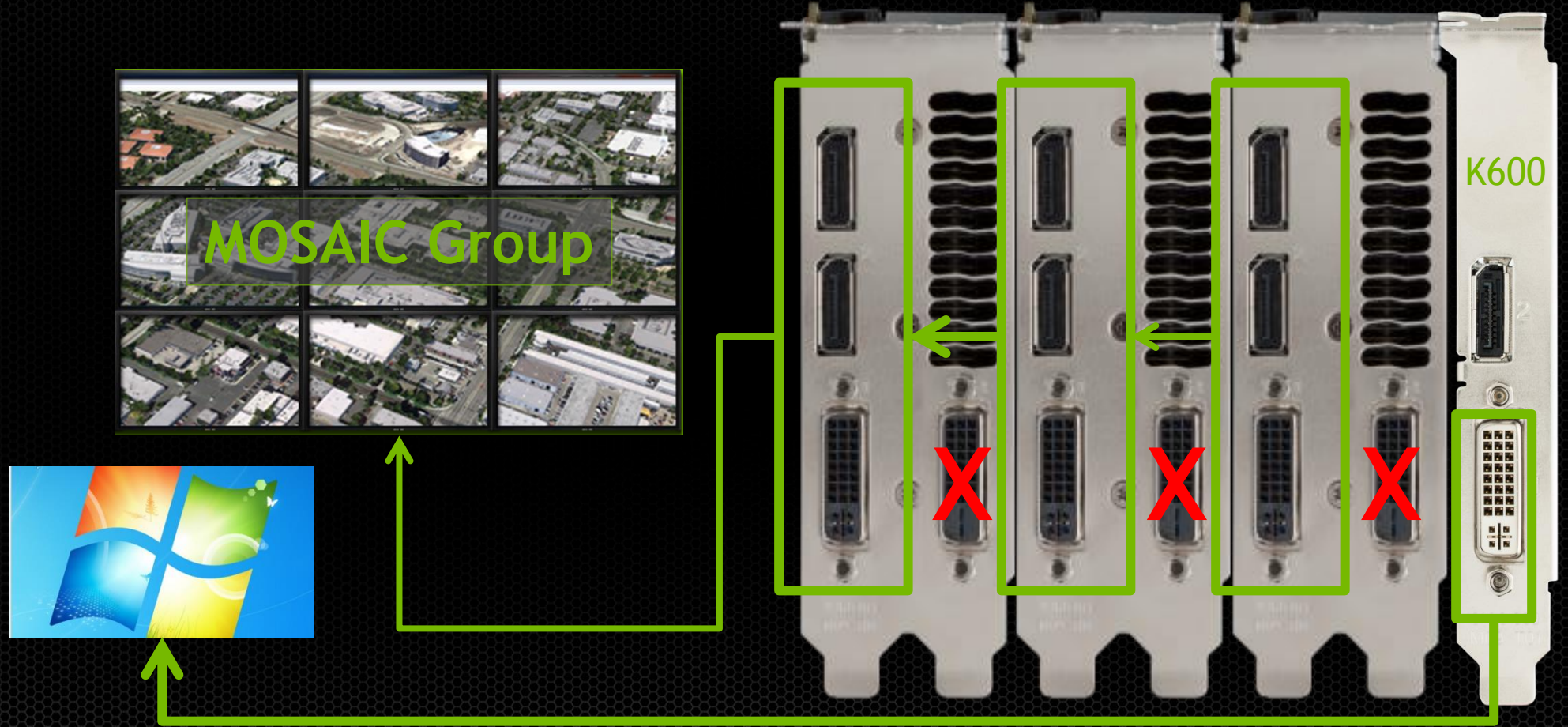


# MOSAIC across multiple GPUs + 1



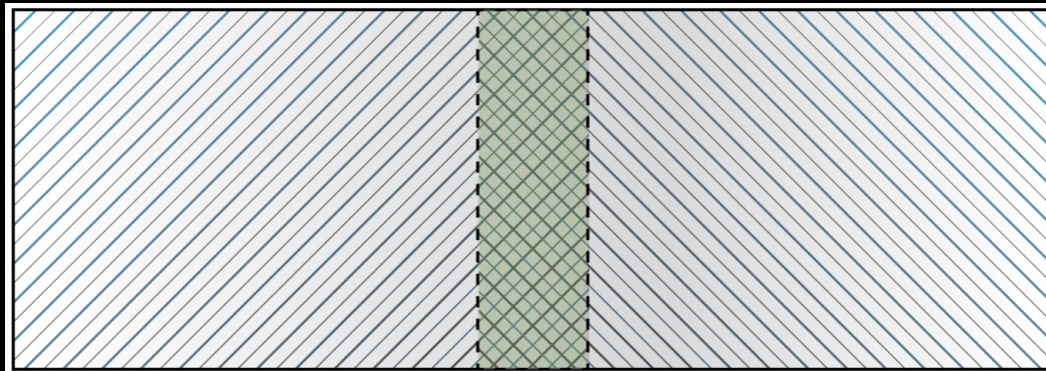


# MOSAIC across multiple GPUs + 1





# 2 Channel Overlap

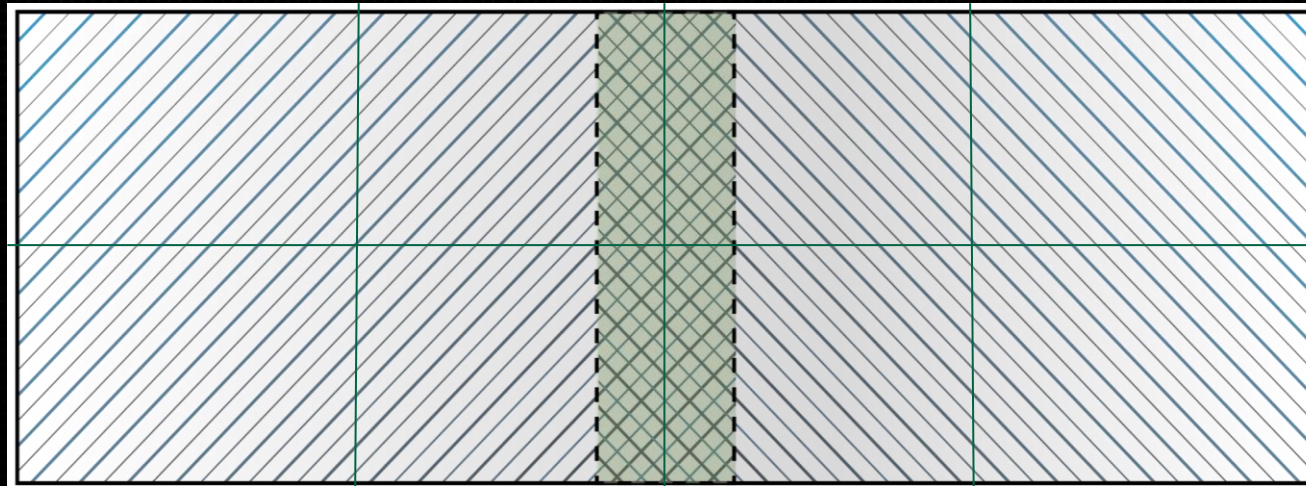


180 pixel overlap

`configureMosaic.exe set rows=1 cols=2 overlap=180,0`



# Overlapping 4K Projectors



0 pixel  
overlap

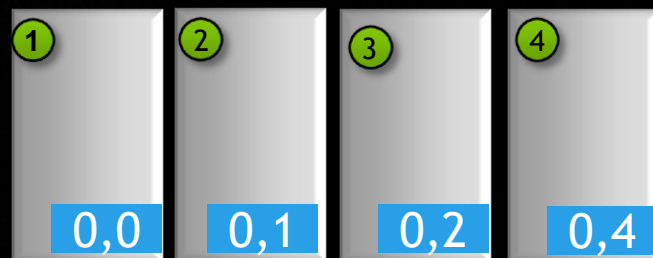
180 pixel  
overlap

0 pixel  
overlap

`configureMosaic.exe set rows=2 cols=4 overlapcol=0,180,0`



# Portrait Mode - Win 7/8 only



Rotate values

90

180

270

`configureMosaic set rows=1 cols=4 rotate=90`



# **WARP + Intensity Adjustment**

- Not all screens are flat !!



# NV-WARP - Warp + Intensity API



Image courtesy of Joachim Tesch  
- Max Planck Institute for Biological Cybernetics

## SDK - Available to Registered Developers

- ✓ Sample SDK
- ✓ Three function calls
- ✓ NVAPI
- ✓ Win7/8 + Linux<sup>new</sup>



## 3<sup>rd</sup> party applications

- ✓ Full Auto-calibration system
- ✓ Premium MOSAIC support
- ✓ Win 7 only



## Projection Mapping using NV-WARP

Developed by Christie Digital

One fifth model car

RTT Delta Gen software

Demo on NVIDIA Booth





# Projection Mapping using NV-WARP



Images courtesy of Christie Digital

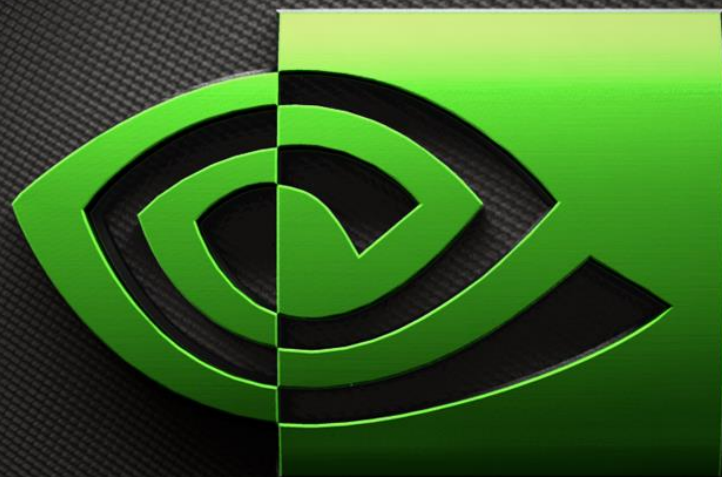


# Summay

- MOSAIC- Allow you to create large unified Desktop
  - Any application can scale
- K5000/K6000 with Sync creates a tear-free display
  - 4K tiles
  - Overlapped projectors
  - Ultra-thin bezel displays
- Warp + Intensity API
  - Opening new possibilities for displays configurations.

Contact us at: [QuadroSVS@nvidia.com](mailto:QuadroSVS@nvidia.com)





**nVIDIA**

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Thank you