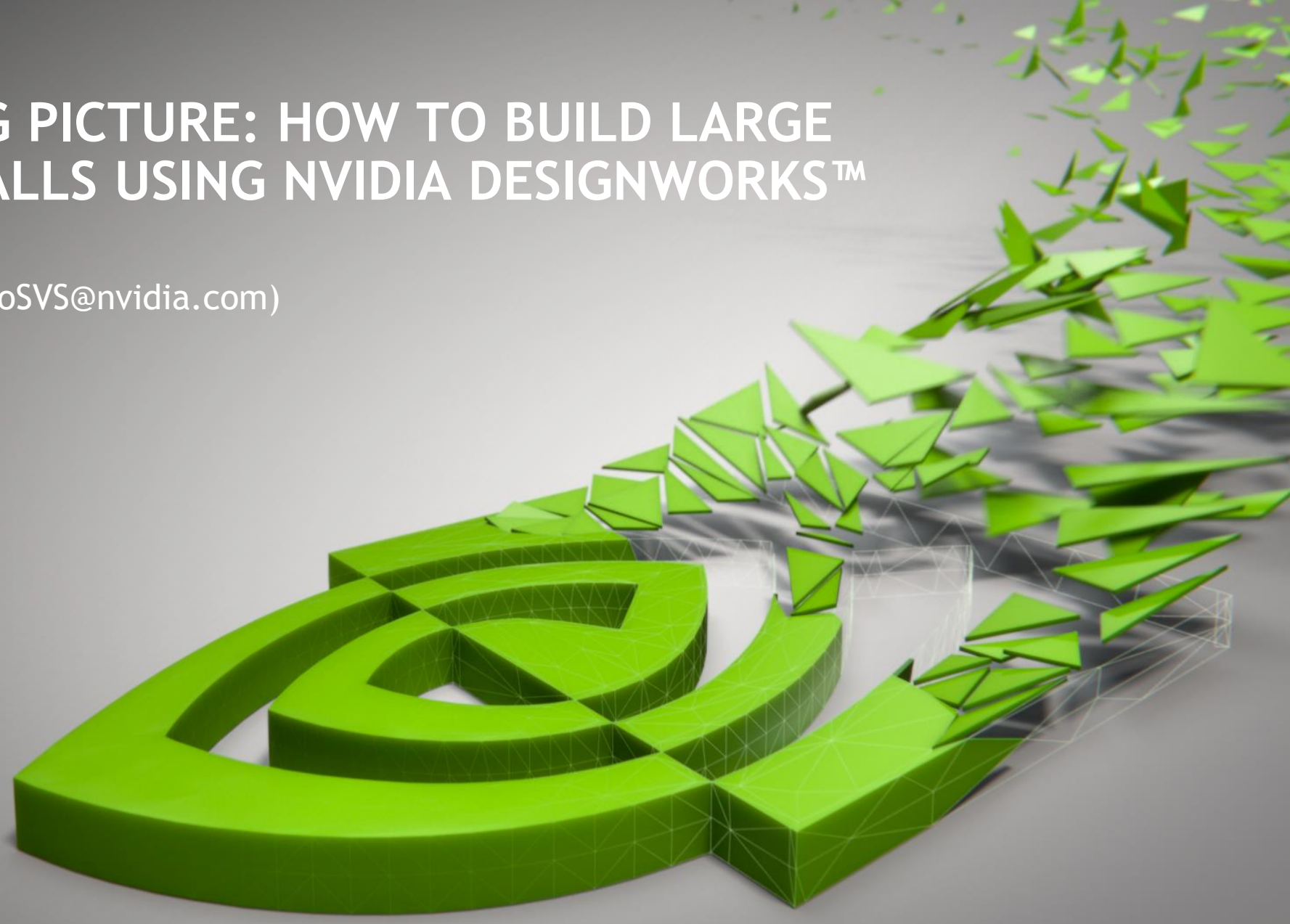
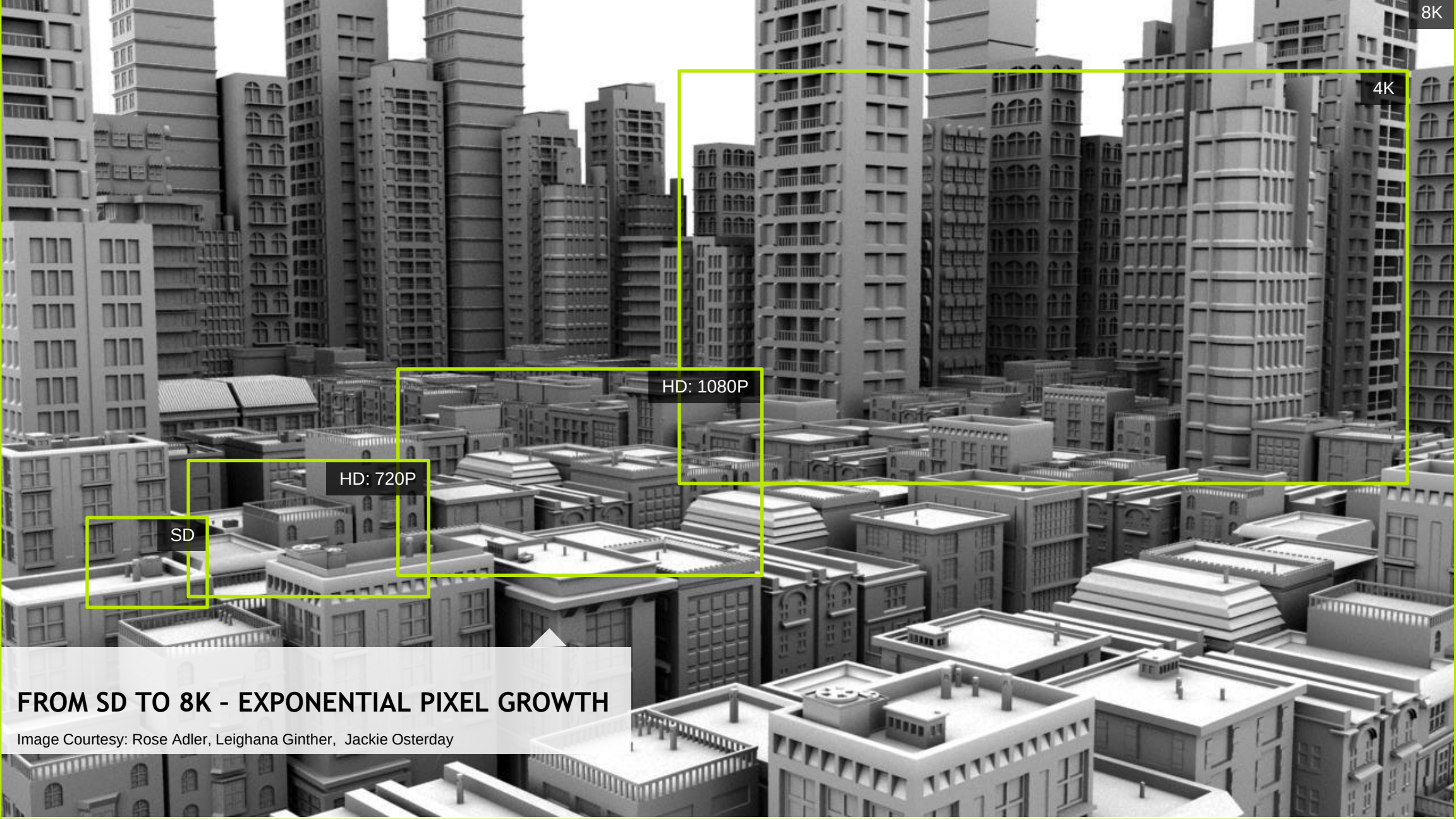
SEE THE BIG PICTURE: HOW TO BUILD LARGE DISPLAY WALLS USING NVIDIA DESIGNWORKS™ APIS/TOOLS

Doug Traill (QuadroSVS@nvidia.com)





FROM SD TO 8K – EXPONENTIAL PIXEL GROWTH

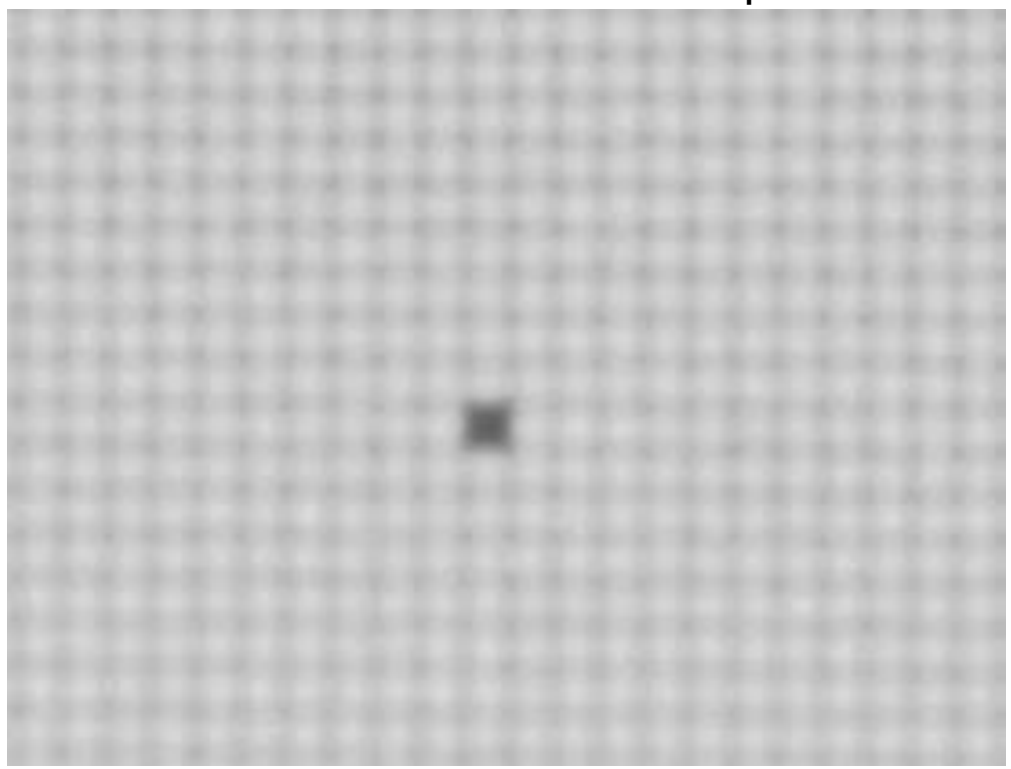
Image Courtesy: Rose Adler, Leighana Ginther, Jackie Osterday

4K VERSUS HD

Perceptual Performance of GPU based warp & anti-aliasing

Stim Level: 3.5
Pixel Pitch: .5 arcmin/pixel

Stim Level: 3.5
Pixel Pitch: 1.78 arcmin/pixel



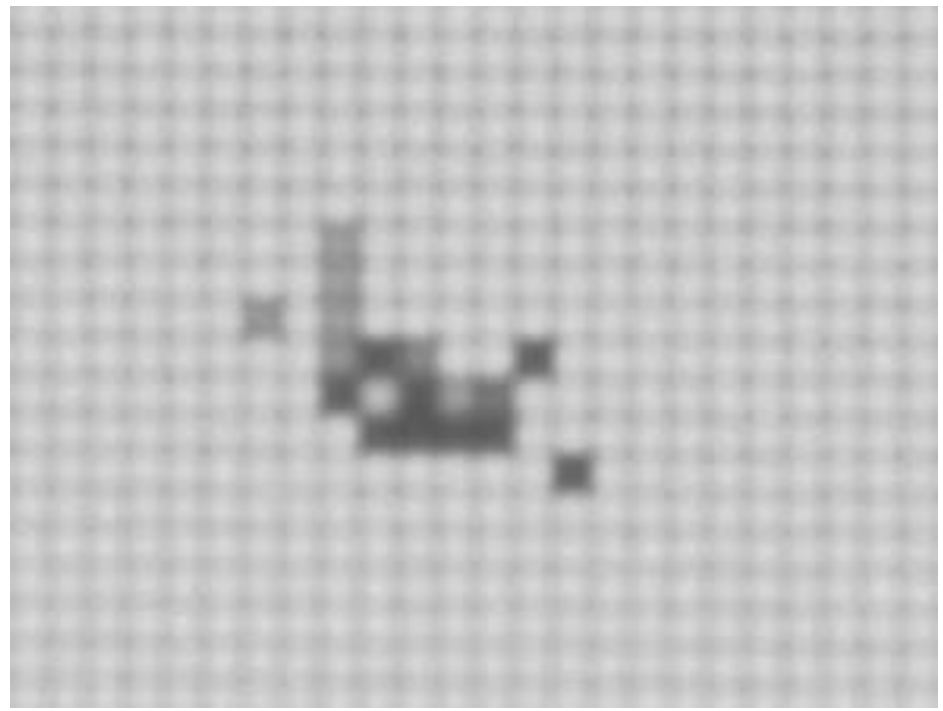
Images courtesy of USAF – School of Aerospace Medicine

4K VERSUS HD

Perceptual Performance of GPU based warp & anti-aliasing

Stim Level: 3.0
Pixel Pitch: .5 arcmin/pixel

Stim Level: 3.0
Pixel Pitch: 1.78 arcmin/pixel



Images courtesy of USAF – School of Aerospace Medicine

DRIVING ULTRA HIGH RES DISPLAYS

MAX SINGLE CABLE BANDWIDTHS/RESOLUTIONS

Connector	Version	Max pixel clock	Color depth	Max resolution for single cable
Display Port	1.4**	~	12bpc	Up to 4K (UHD)@120Hz (DSC) 8K@60Hz (DSC)
	1.3	~	12bpc	Up to 5K by 3k @ 60Hz Up to 8K @30Hz
	1.2	~592 MHz	12bpc	Up to 4K @ 60Hz
	1.1a	~330 MHz	10bpc	Up to 4k @ 30Hz
HDMI	2.0*	~600 MHz	12bpc	Up to 4K @ 60Hz
	2.0	~330 MHz	6bpc (YUV 4:2:0)	Up to 4K @ 60Hz
	1.4b	~330 MHz	10bpc	Up to 4k @ 30Hz
	1.0 to 1.3			Does not support 4K
DVI	Dual Link	330 MHz	8bpc	Up to 4K @ 30Hz
	Single link	165 MHz		Does not support 4K

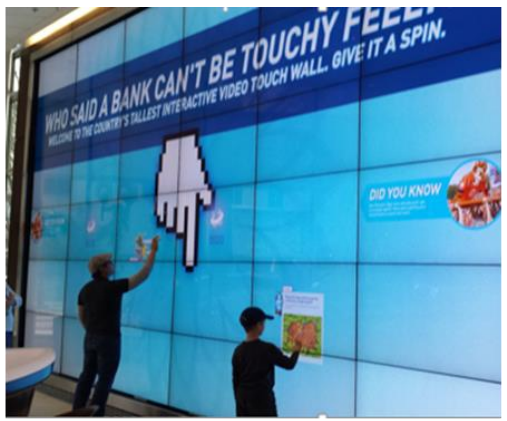
Color - Windows Desktop 8bit, OpenGL Apps – 10/12bit, DirectX??

NOTE: Displays, extenders, switches may not implement full speed connections

*High bandwidth HDMI2.0 supported on M6000 using DVI to HDMI adaptor
** DP1.4 support added to Pascal GPUs -

LARGE SCALE VISUALIZATION

See the big Picture



Clockwise from upper left images courtesy of Vislogix, Prysm, Inc., Visbox, Christie Digital, IMMERSIVE DESIGN STUDIOS, Elbit Systems.

Ultimate performance & Interactivity
Dual slot FF with Sync support

Quadro M6000-12GB

Quadro M6000-24GB

Demanding 3D content & Interactivity
Dual slot FF with Sync support

Quadro M5000

Performance 3D content
Single slot FF with Sync support

Quadro M4000

Video and basic 3D content
Low profile for SFF systems

Quadro K1200

Video and basic 3D content
Single slot FF with 8 display outputs

NVS 810

2-way SLI support

Quadro Sync Support – 4 GPUs

Digital Signage

Interactive Displays, Conference Rooms

Product Design Reviews

Specialty Applications

MULTI-GPU MOSAIC WITH SYNC

Sync requires a physical connection between GPUs

Two-way SLI (requires bridge)

- 2 Quadro cards (8 displays)
- Certified OEM workstations
  - Dell/HP/Lenovo
- SLI Motherboards
  - New – R361/R364 driver
  - Quadro now supported in GTX cert motherboards.

Quadro Sync

- 2 to 4 Quadro cards (16 displays)
- Any motherboard or expansion chassis
- Support for external Sync sources.
  - House Sync
  - Sync from another Quadro Sync card.

Note: Same performance level

NVIDIA DESIGNWORKS™

Display Management Technologies

MOSAIC

WARP & BLEND

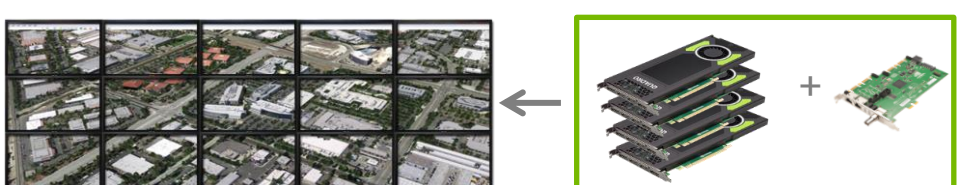
DISPLAY MANAGEMENT APIS

Monitoring + Setup tools

NVAPI

NVWMI

SYNC



developer.nvidia.com/designworks

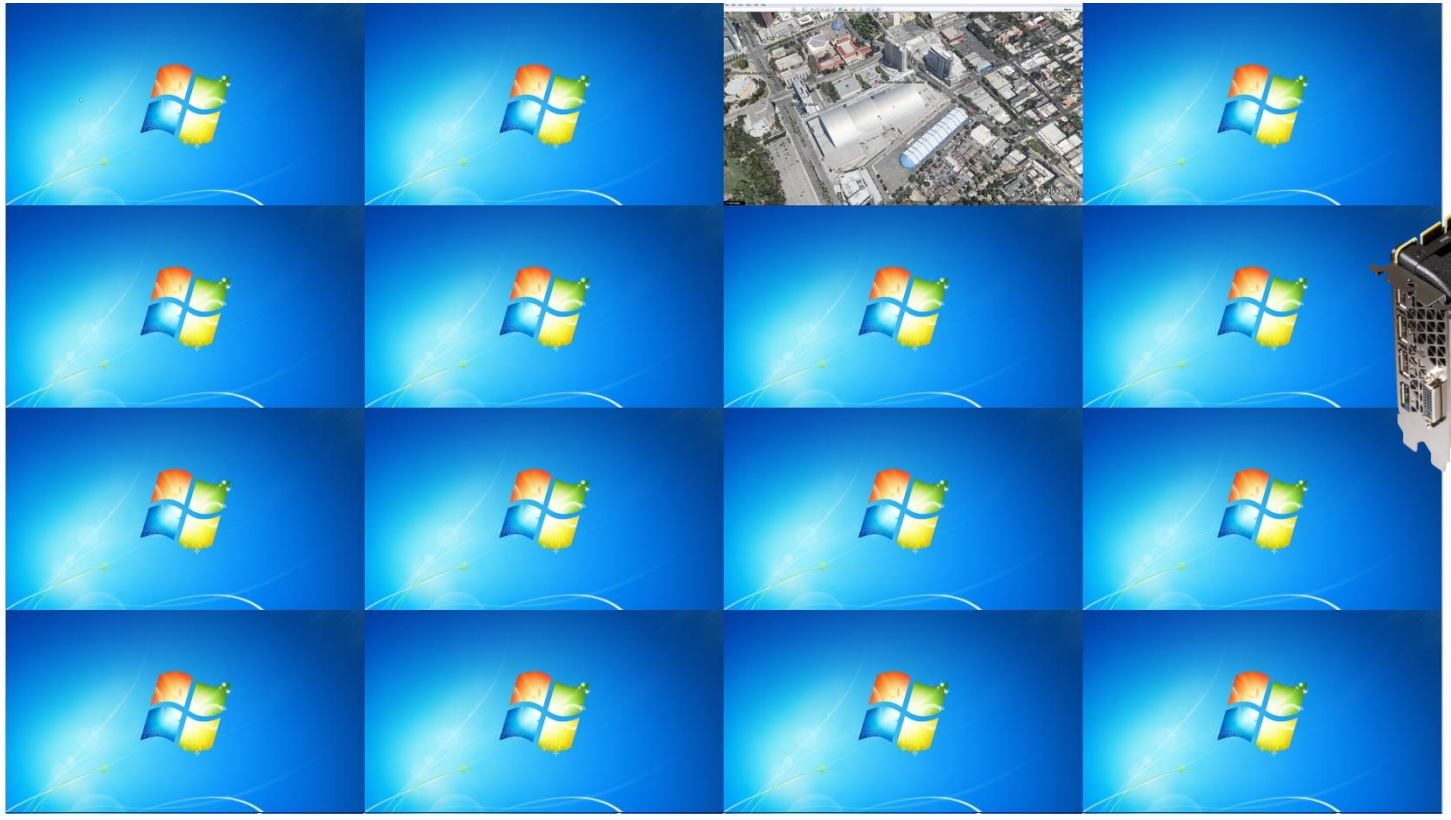
MOSAIC – SETUP & CONFIGURATION

MOSAIC – WHY IS IT NEEDED?

– Windows on its own - Independent Desktops

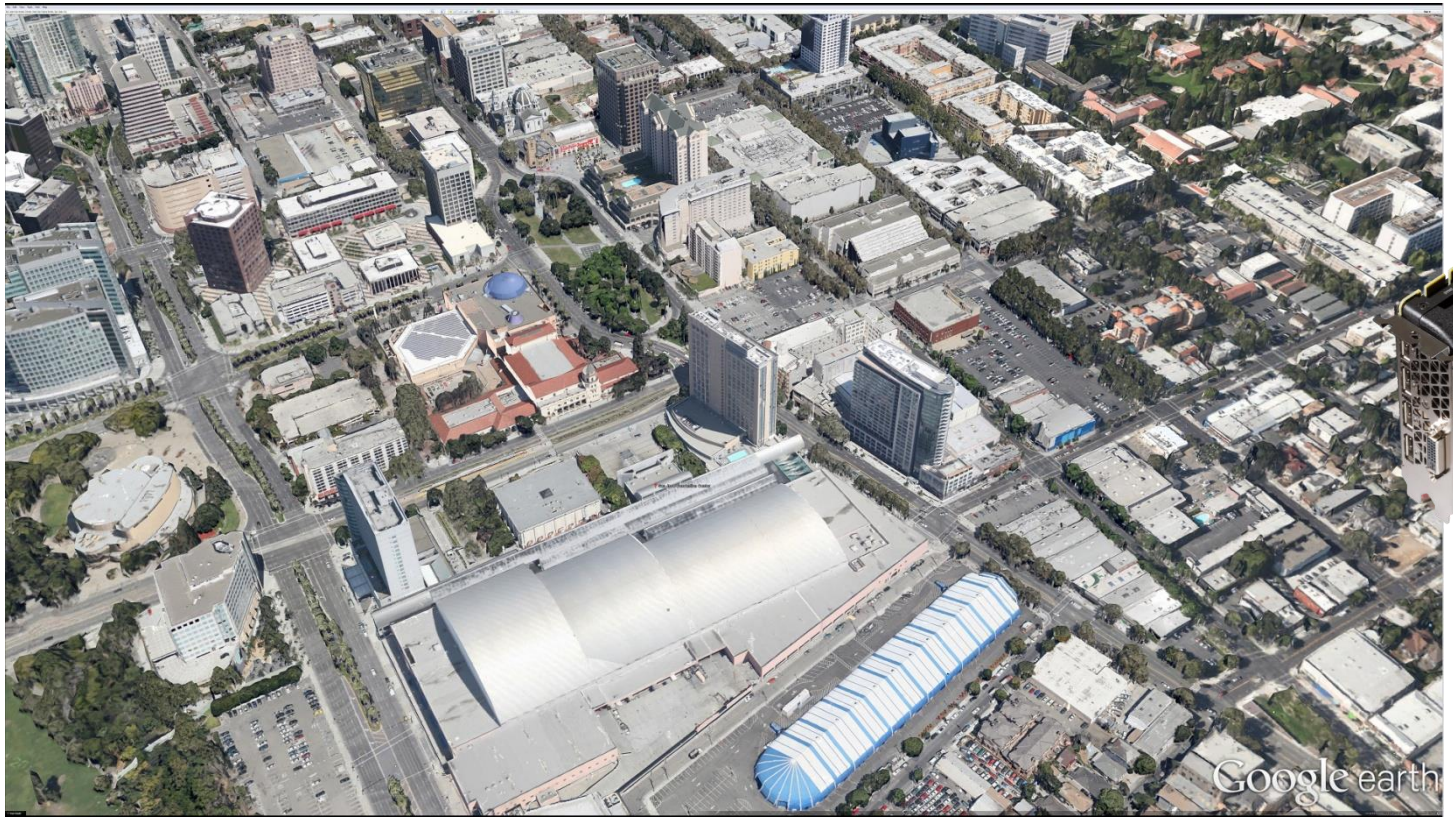
WINDOWS ON ITS OWN

- Independent Desktops

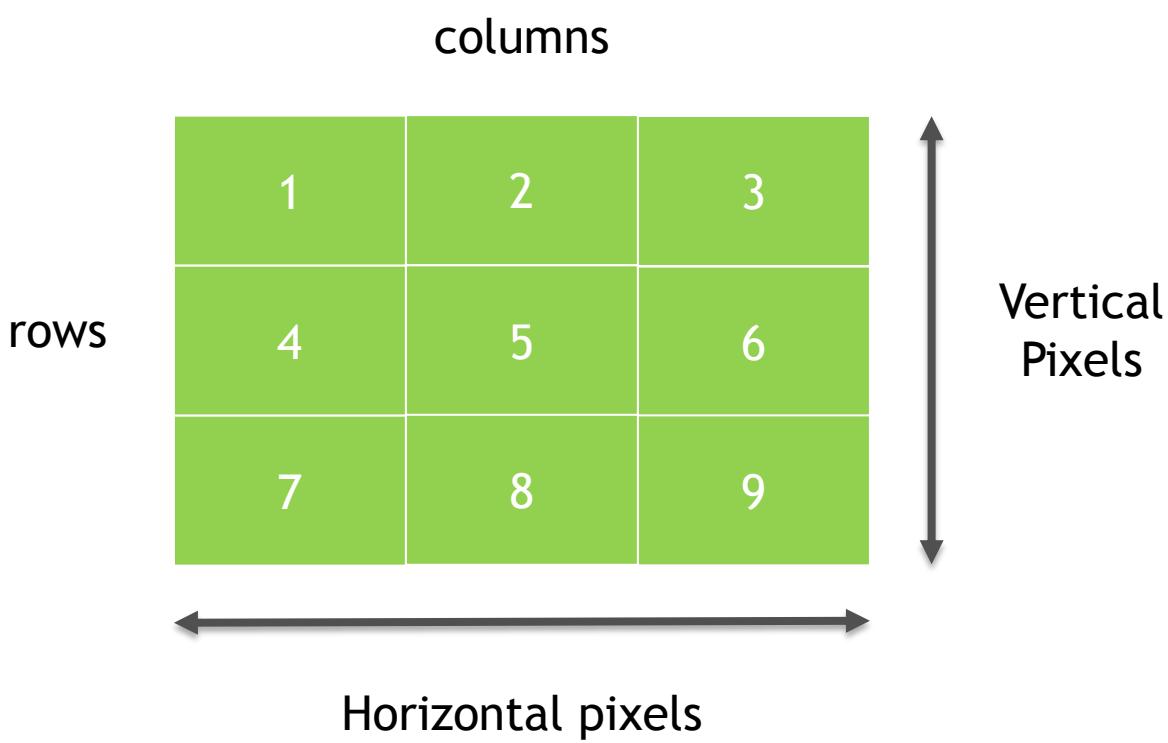


WITH MOSAIC

- One large Desktop



MOSAIC GRIDS



Rows x columns <= 16
Max Horizontal or vertical Pixels <= 16384

Enumeration of the Grid always starts top left and goes left to right

BEZEL AND OVERLAP CORRECTION

Bezel Correction

Will make the image look continuous as we render ur

Bezel Correction

No Bezel Correction

Projector Overlap

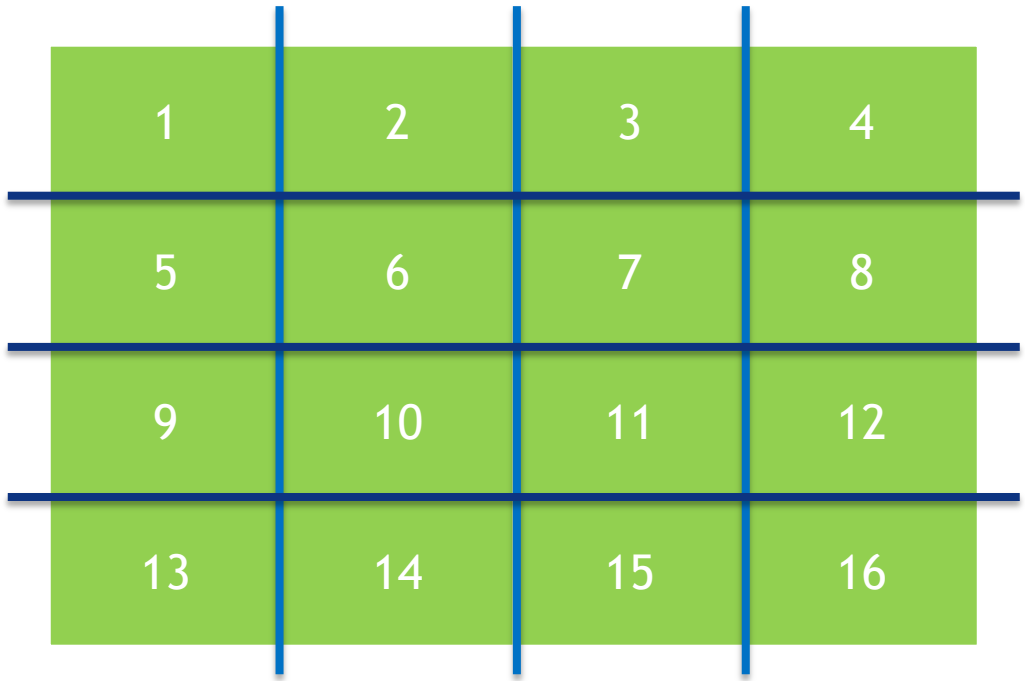
No Projector Overlap

Overlap Correction

For projectors it maintains the aspect ratio of the display.

UNDERSTANDING TOPOLOGIES

Row Overlap/Bezel correction



Column Overlap/Bezel correction

Bezel correction will increase overall pixel size

i.e. each display is 1920x1080
Bezel per column is 100

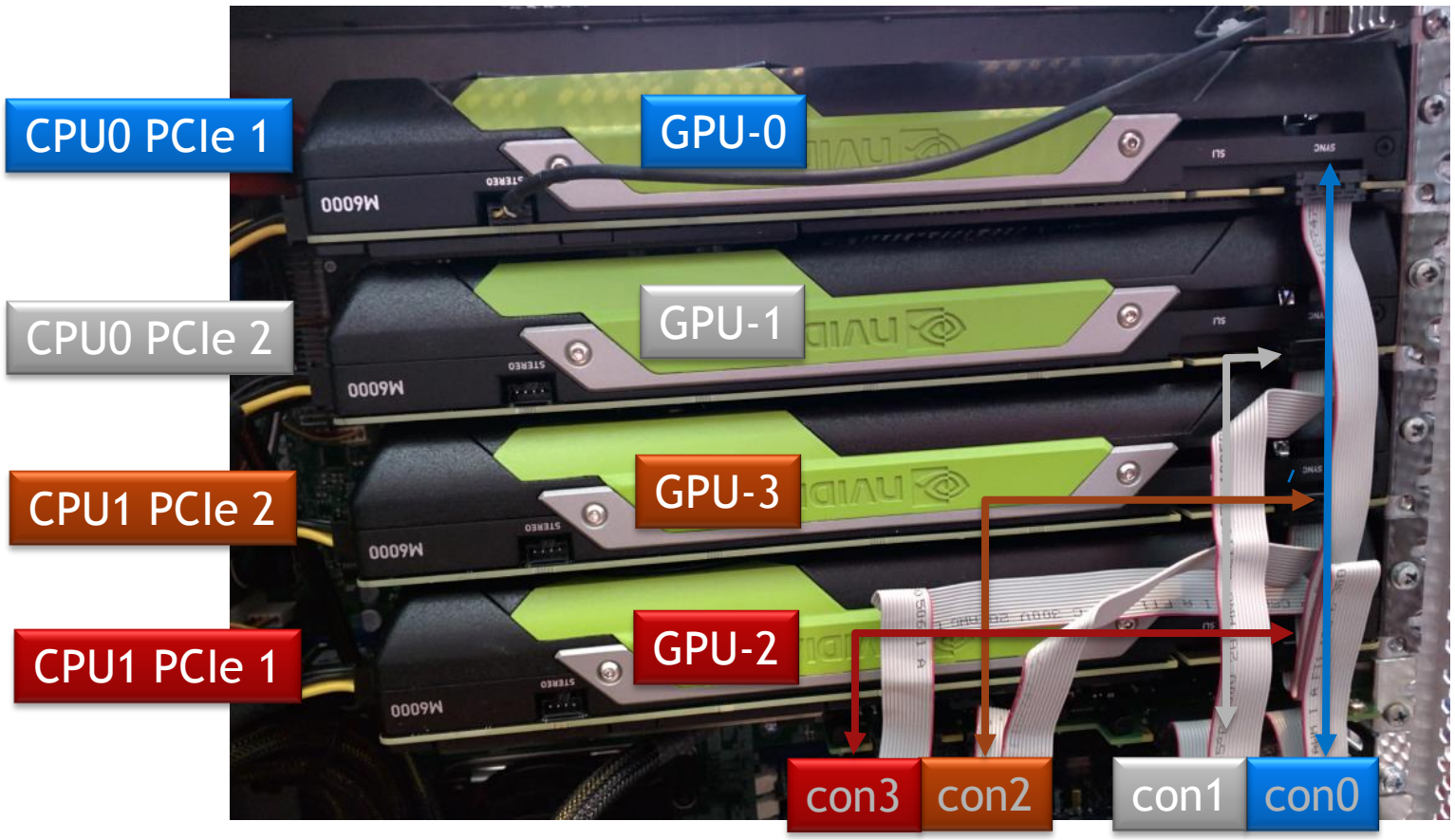
Total horizontal width
= 1920*4 + 100*3 = 7980

Overlap correction will decrease overall pixel size

i.e. each display is 1920x1080
overlap per column is 100

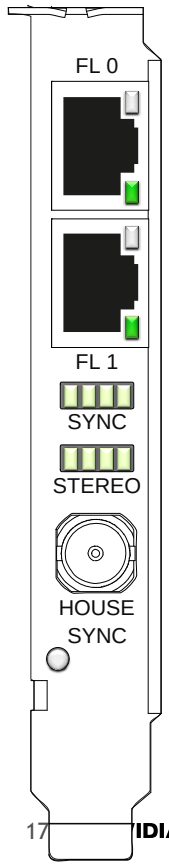
Total horizontal width
= 1920*4 - 100*3 = 7380

ANATOMY OF A SYSTEM



stereo sync bracket

Quadro Sync card



REAR PANEL - 4 M6000S

VESA Stereo Bracket

GPU 0

GPU 1

GPU 3

GPU 2

Quadro Sync

VESA stereo – only one per system required
Doesn't require PCIe slot – just a blank

Connect to all 4 GPUs.
At boot-up LEDs will be amber showing GPU connected

PORT NUMBERING

VESA Stereo Bracket

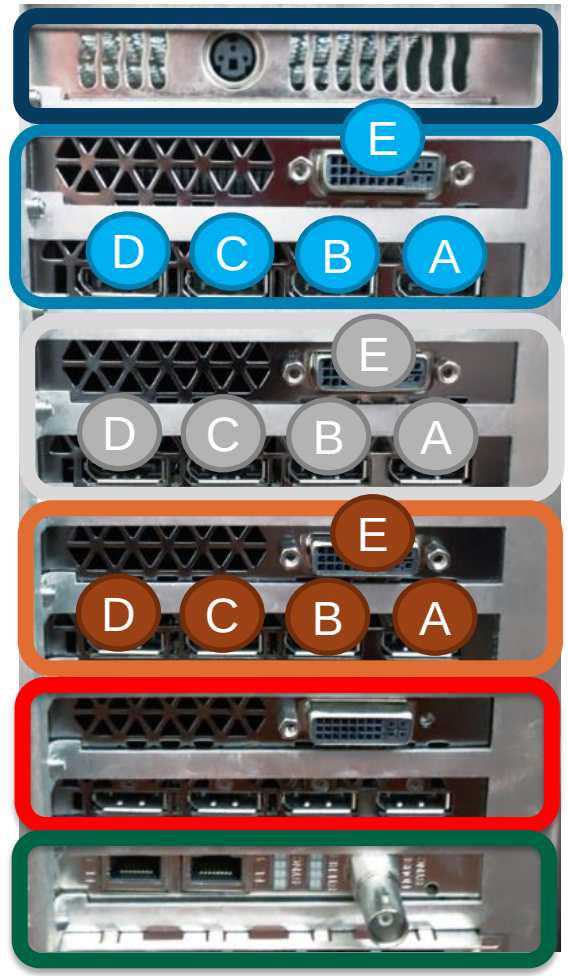
GPU 0

GPU 1

GPU 3

GPU 2

Quadro Sync

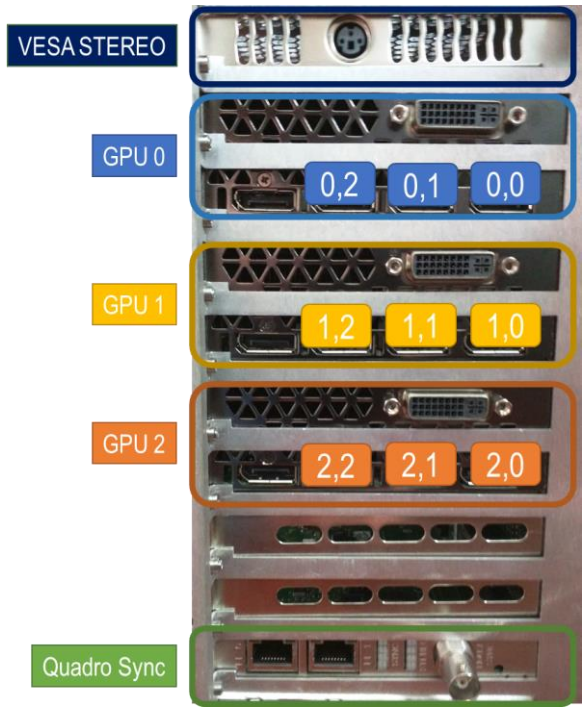


i.e. only E is attached
E = 0,0

A + E are attached
A = 1,0
E = 1,1

A + B + C + D are attached
A = 3,0
B = 3,1
C = 3,2
D = 3,3

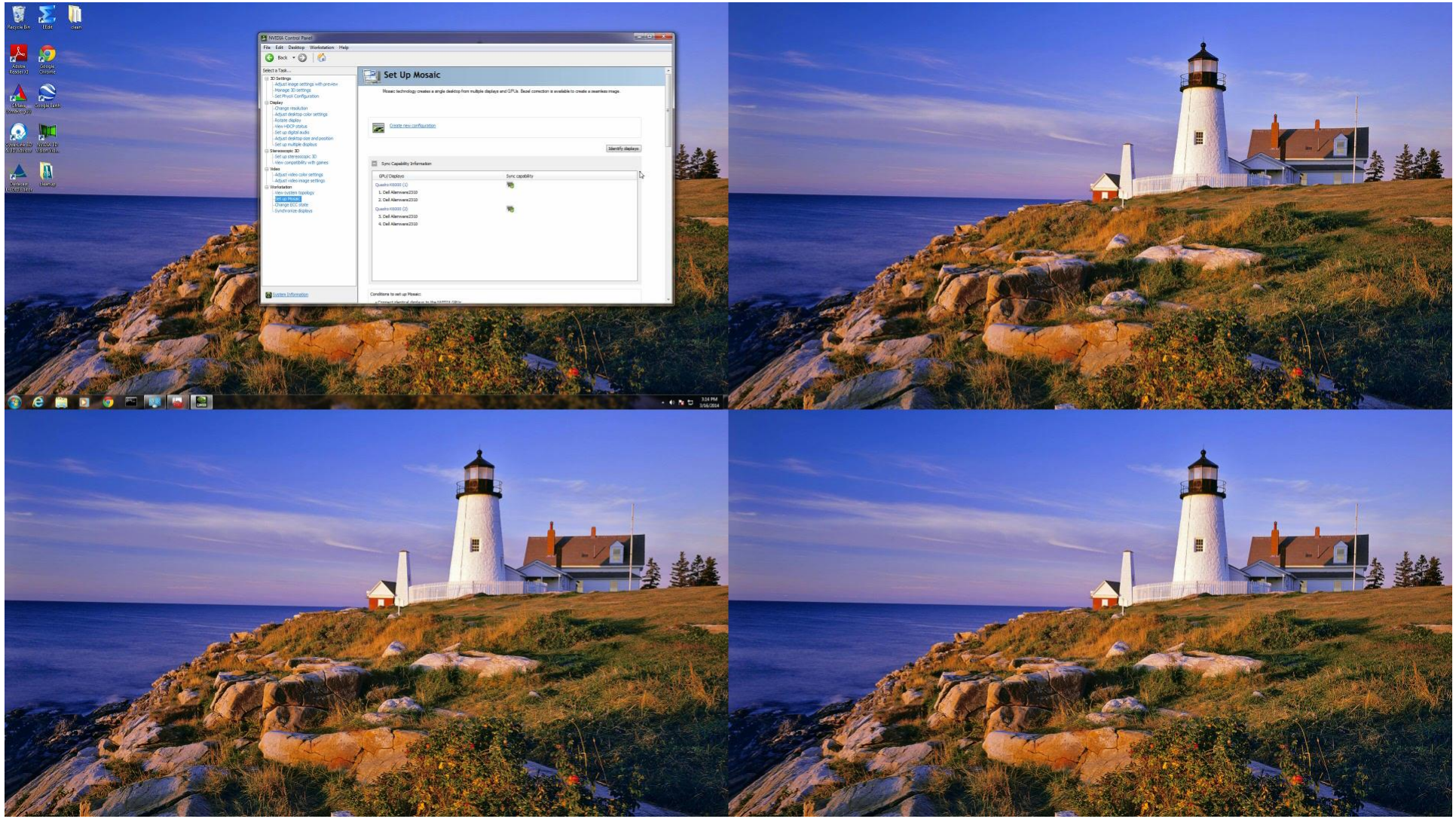
RELATING PORTS TO GRID



configureMosaic-x64.exe set rows=3 cols=3

configureMosaic-x64.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

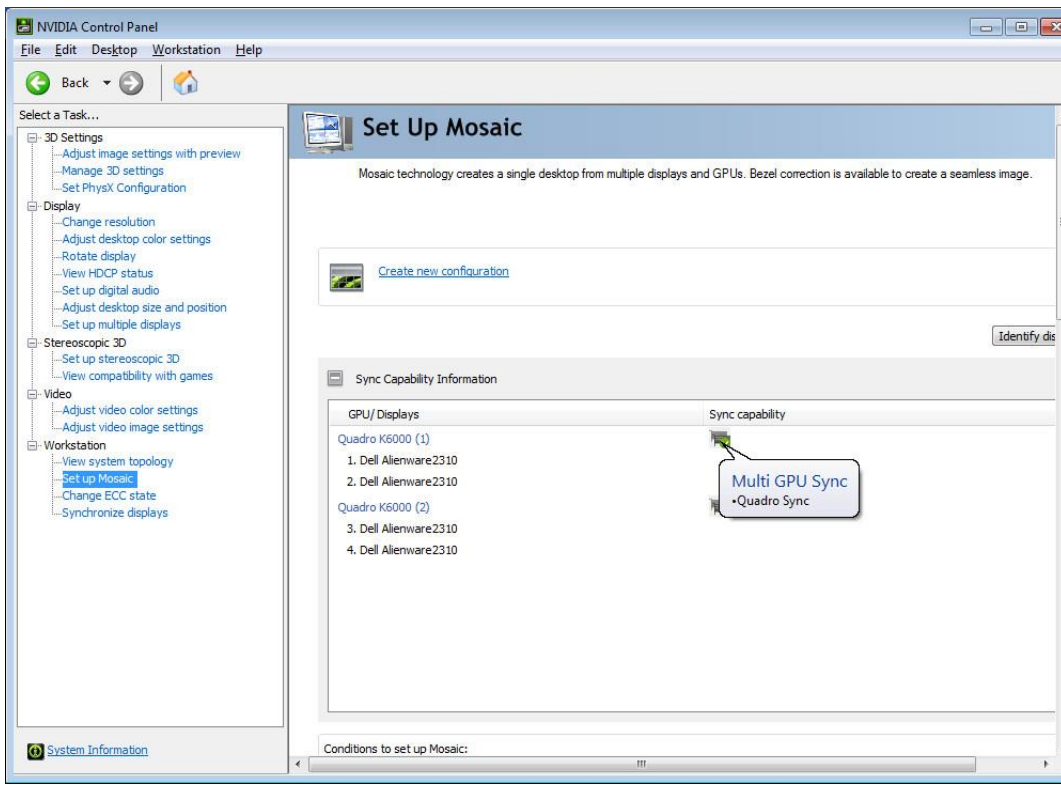

NVIDIA Control Panel
File Edit Desktop Workstation Help
Back
Select a Task...
3D Settings
Adjust image settings with preview
Manage 3D settings
Set PhysX Configuration
Display
Change resolution
Adjust desktop color settings
Rotate display
View HDCP status
Set up digital audio
Adjust desktop size and position
Set up multiple displays
Stereoscopic 3D
Set up stereoscopic 3D
View compatibility with games
Video
Adjust video color settings
Adjust video image settings
Workstation
View system topology
Set up Mosaic
Change ECC state
Synchronize displays
System Information
Set Up Mosaic
Mosaic technology creates a single desktop from multiple displays and GPUs. Bezel correction is available to create a seamless image.
Create new configuration
Identify displays
Sync Capability Information
GPU/ Displays
Sync capability
Quadro K6000 (1)
1. Dell Alienware2310
2. Dell Alienware2310
Quadro K6000 (2)
3. Dell Alienware2310
4. Dell Alienware2310
Conditions to set up Mosaic:
3:34 PM
3/16/2014

MOSAIC WITH SYNC

MOSAIC with Sync = Premium MOSAIC = SLI MOSAIC

Setup MOSAIC Menu

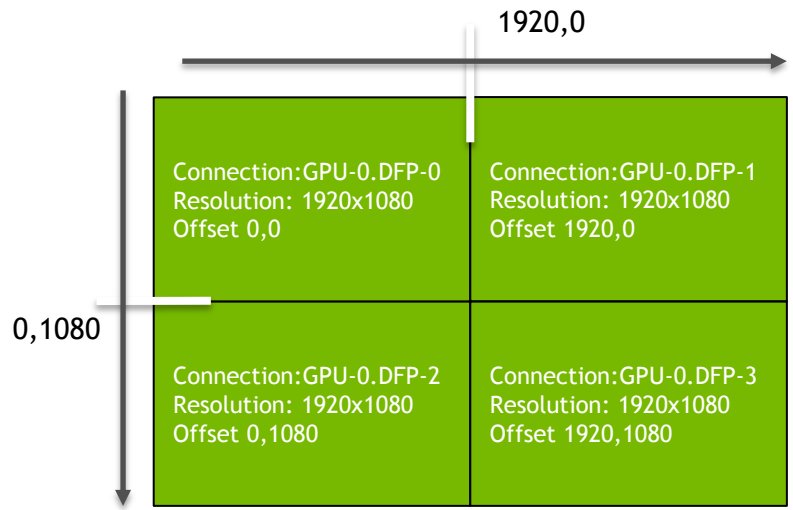
- Roll over icon under “Sync capability”
- Indicates whether card can be sync’d
  - Multi-GPU Sync “Quadro Sync” –multi-GPU sync via Quadro Sync card
  - Mutli-GPU Sync “SLI Bridge” – 2-way GPU sync via SLI bridge
  - Single GPU Sync - outputs on single card can be framelocked.



LINUX

Single GPU (4 outputs) – MetaModes only

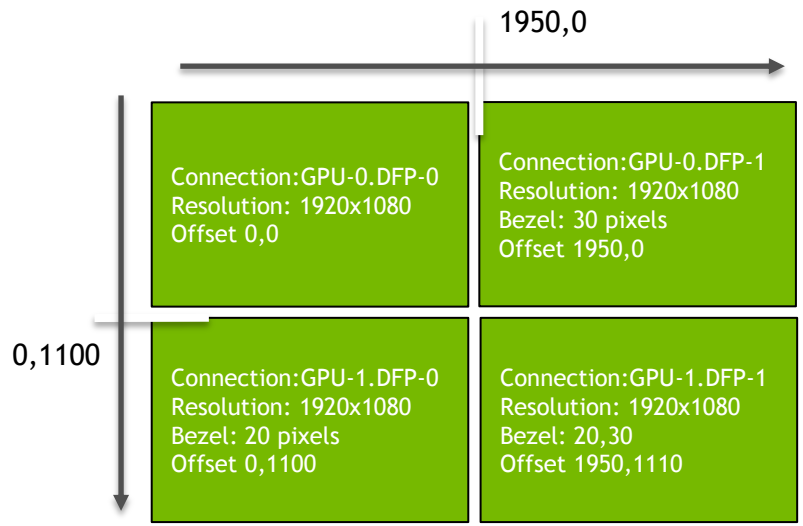
```
Section "Screen"
    Identifier     "Screen0"
    Device         "Device0"
    Monitor        "Monitor0"
    DefaultDepth    24
    Option         "MetaModes" "1920x1080 +0+0,
1920x1080 +1920+0, 1920x1080 +0+1080, 1920x1080
+1920+1080"
    Option         "nvidiaXineramaInfo" "FALSE"
    SubSection     "Display"
        Depth       24
    EndSubSection
EndSection
```



LINUX

2 GPUs example – Use BaseMOSAIC (No SLI or QUADRO SYNC)

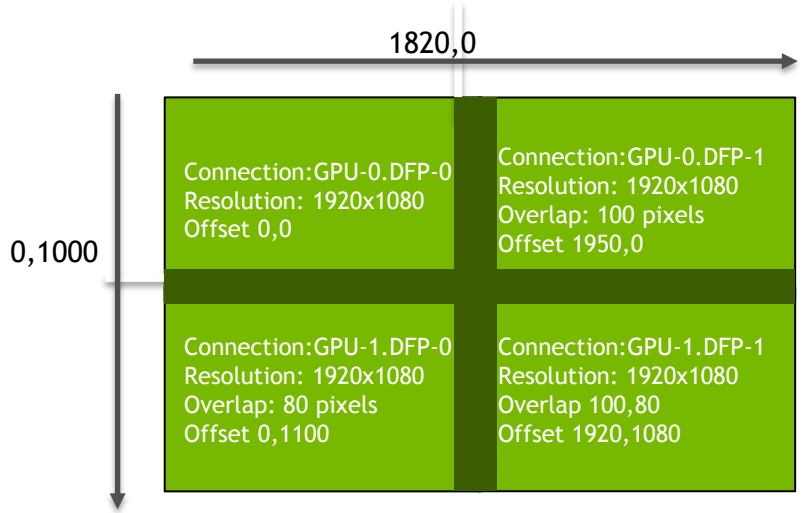
```
Section "Screen"
    Identifier     "Screen0"
    Device         "Device0"
    Monitor        "Monitor0"
    DefaultDepth    24
    Option        "BaseMosaic"   "TRUE"
    Option        "MetaModes" "GPU-0.DFP-0:
1920x1080 +0+0, GPU-0.DFP-1:  1920x1080 +1950+0,
GPU-1.DFP-0: 1920x1080 +0+1100, GPU-1.DFP-1:
1920x1080 +1950+1100"
    Option         "nvidiaXineramaInfo" "FALSE"
    SubSection     "Display"
        Depth       24
    EndSubSection
EndSection
```



LINUX

2 GPUS with Quadro Sync or SLI connector – Use “SLI” “MOSIAC”

```
Section "Screen"
    Identifier     "Screen0"
    Device         "Device0"
    Monitor        "Monitor0"
    DefaultDepth    24
    Option        "SLI"   "MOSAIC"
    Option         "MetaModes" "GPU-0.DFP-0:
1920x1080 +0+0, GPU-0.DFP-1:  1920x1080
+1820+0, GPU-1.DFP-0: 1920x1080 +0+1000, GPU-
1.DFP-1: 1920x1080 +1820+1000"
    Option         "nvidiaXineramaInfo"
"FALSE"
    SubSection     "Display"
        Depth       24
    EndSubSection
EndSection
```



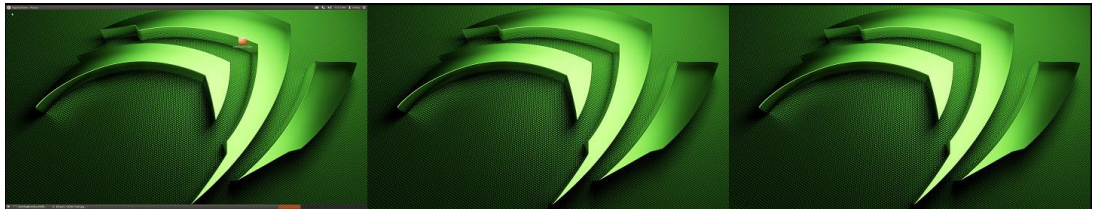
NVS810 – Use this mode

LINUX TIPS

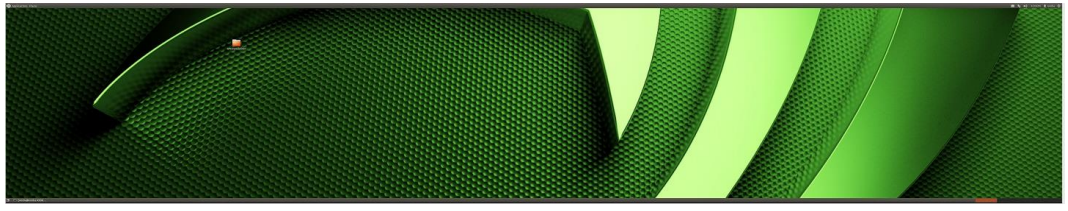
Window Manager (GNOME, Unity, KDE etc) may over-ride MOSAIC settings.

```
Section "Screen"
    Identifier     "Screen0"
    Device         "Device0"
    Monitor        "Monitor0"
    DefaultDepth    24
    Option         "MetaModes" "1920x1080 +0+0, 1920x1080 +1920+0, 1920x1080 +3840+0"
    Option         "nvidiaXineramaInfo" "False"
    SubSection     "Display"
        Depth       24
    EndSubSection
EndSection

Section "Extensions"
    Option         "Composite" "Disable"
    Option           "RANDR" "Disable"
EndSection
```



1x3 MOSAIC – but three separate Desktops
MOSAIC is running – i.e. Windows should open full screen



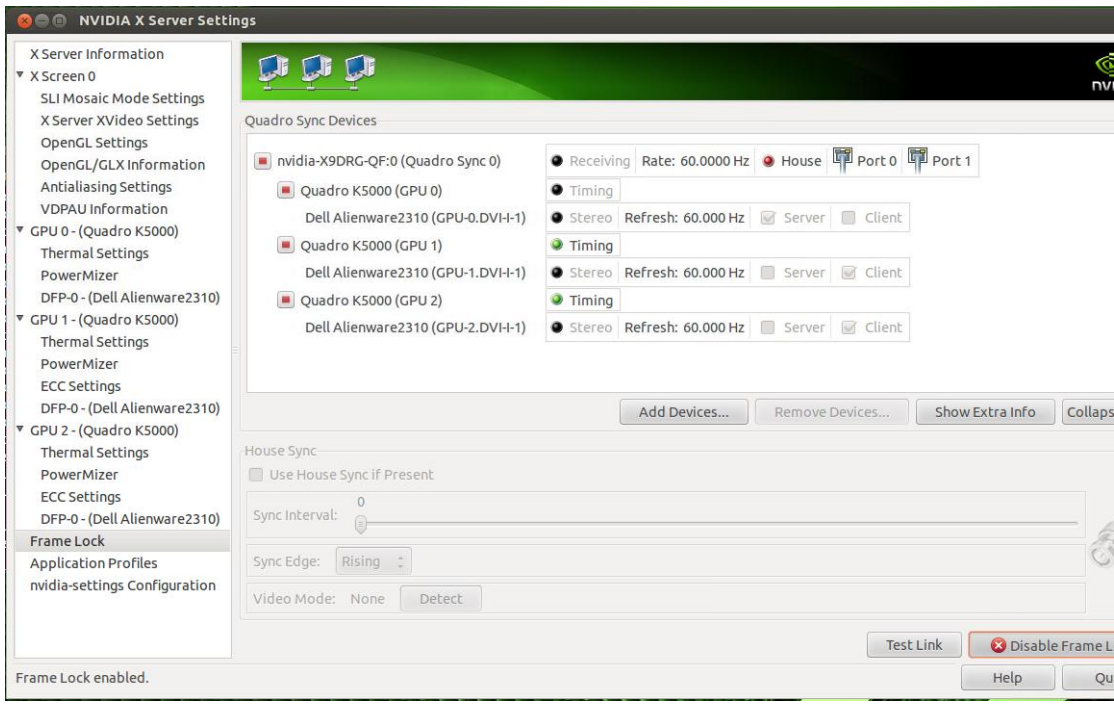
1x3 MOSAIC – Single Desktop

LINUX TIPS

MOSAIC with Quadro Sync

Set SLI MOSAIC in xorg.conf

After restarting X - Enable Framelock (Not automatic)



CLIP MOSAIC

Load balance Pixel fill rate on multi-GPU MOSAIC

Benefits

- Divides pixel fill between GPUs – improves perf on large res displays

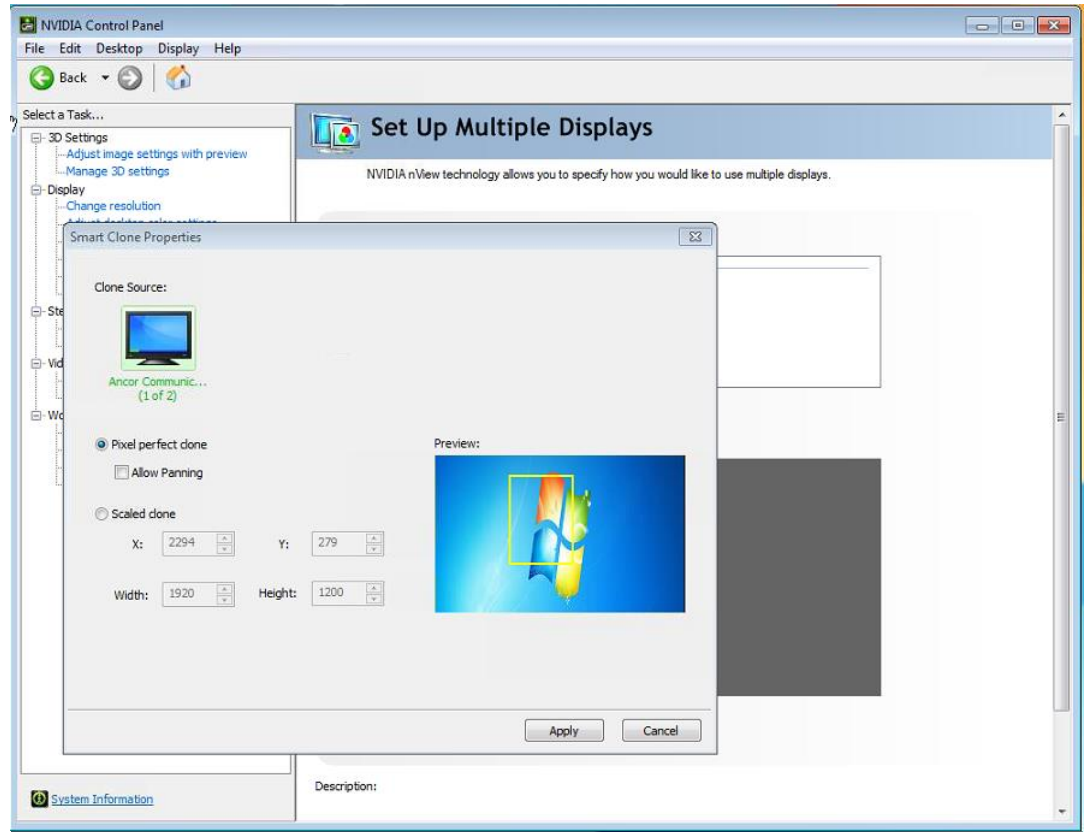
Requirements

- Full screen OGL or DirectX app
- Supported on Windows + Linux
  - Windows – command-line utility - send email to QuadroSVS@nvidia.com
  - Linux – environment variable. `__GL_MOSAIC_CLIP_TO_SUBDEV=1`

SMART CLONE

Single GPU MOSAIC only

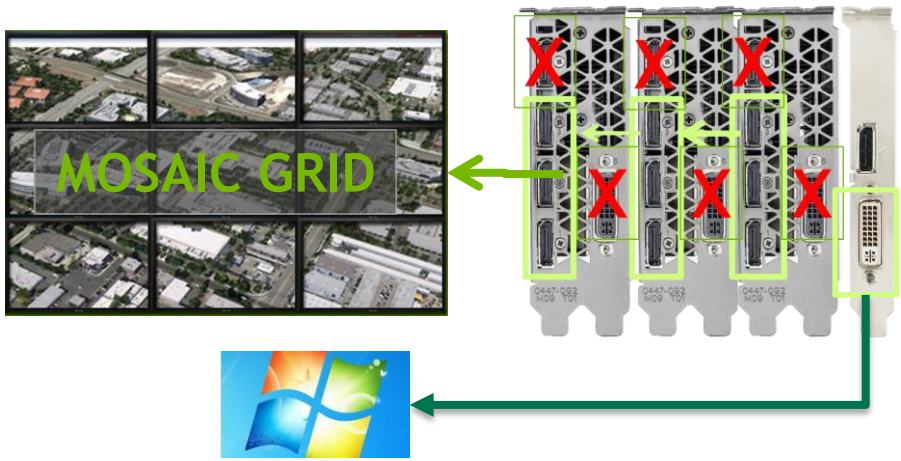
- Pan and Scan
  - Clones the area around mouse
- Select area to clone
  - Yellow box shows clone are
- Scaled clone



MOSAIC +1

Across multiple GPUs

- Windows
  - GRID spans multiple GPUs
    - Spare ports on GPU cannot be used for additional displays
    - Add a Quadro K620
    - New display is like a new grid
- Linux
  - Not officially supported
    - Use Option “MOSAICplusOne”



MEMORY PRE-ALLOCATION

Force Stereo shuttering

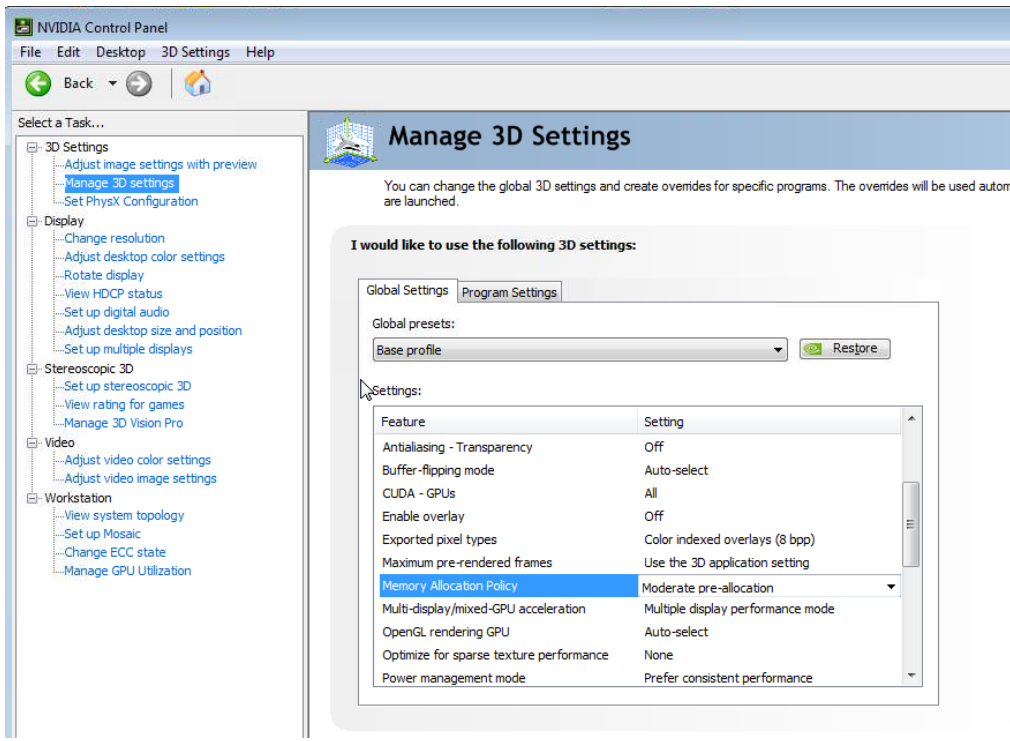
Memory Allocation Policy

Moderate Pre-allocation

Set Stereo to enable

VESA stereo (3-pin) port will now be active – even if no stereo app is running.

- AERO desktop will always be disabled
- 3D Vision Pro hub will be always enabled.



Windows 7 only – not supported on Win8.1/Win10

MEMORY PRE-ALLOCATION

Mode Set Reduction

"mode-sets" (SCREEN FLASH) reduction during setup for:

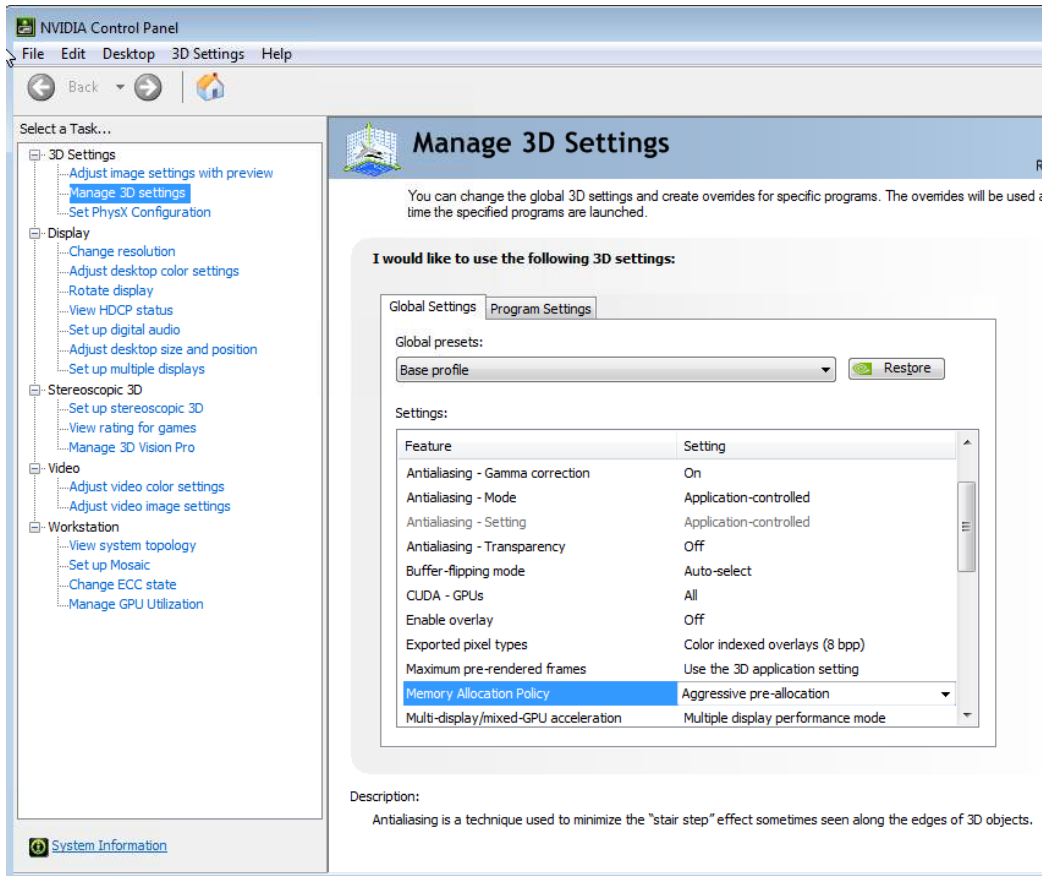
- "Swap Groups"
- "tear free" mode – i.e. Video Edit Profile

Memory Allocation Policy

- Aggressive Pre-allocation

Note:

- force stereo will also be enabled
- AERO is disabled
- Doesn't affect MOSAIC setup – ie. Still screen flash



Windows 7 only – not supported on Win8.1/Win10

JVC 4K/8K E-SHIFT PROJECTOR

Native support in NVIDIA Windows driver (Linux support planned)

- 8k Projector
  - Similar to active stereo – scans alternate odd/even frames (1200x2400)
  - Automatically detected by driver
    - EDID is seen at 2400x4800 resolution per input (project has 4 inputs)
    - VESA stereo (3pin) port is used to identify odd/even frame.

- 4k Projector
  - Similar to passive stereo – separate odd/even frames
  - Enabled using configuremosaic tool.

```
configuremosaic set rows=1 cols=1 pixelshift
out=0,0,tl out=0,1,br res=1920,1080,60
```

WARP + INTENSITY ADJUSTMENTS

PROJECTION BLENDING

Warp + Blend Engine

3rd party software available from

scalable DISPLAY TECHNOLOGIES

VIOSO

play-out.com

Fraunhofer FOKUS

CHRISTIE

Pixelwix Inovative Media Solutions

coolux A CHRISTIE COMPANY

IMMERSAVIEW

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

WARP AND BLEND

API for geometry and intensity adjustments for seamless projection environments

WARP NOT JUST FOR PROJECTORS

NVS810 – 8 outputs on 1 card

WARP 2.0

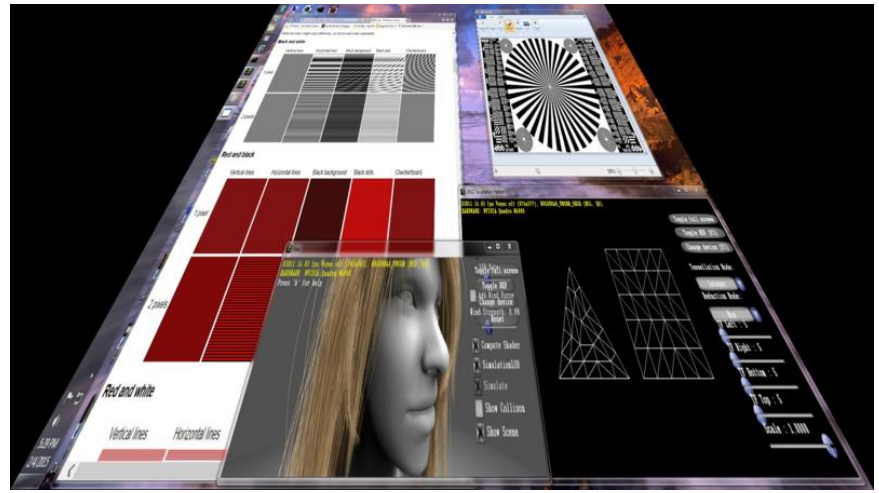
New filtering methods

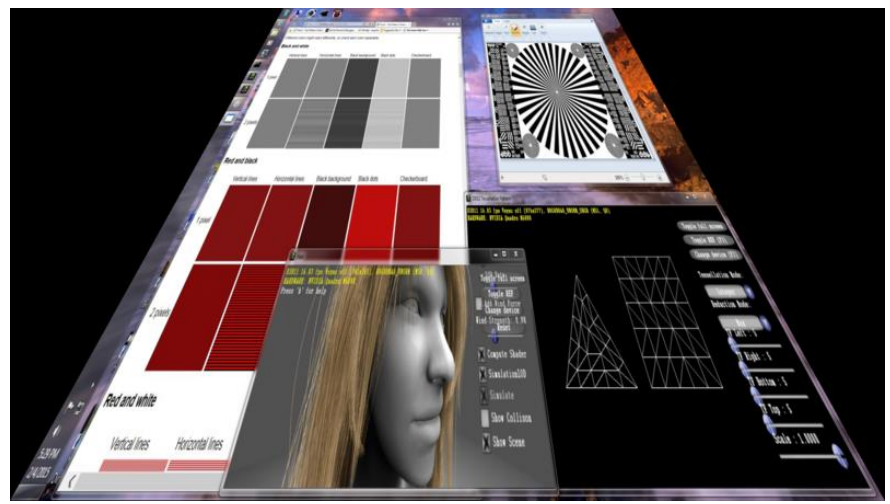
`NvAPI_GPU_SetScanoutCompositionParameter`

Selectable via NVAPI

- Bilinear
- BI-CUBIC Triangular
- BI-CUBIC Bell Shaped
- BI-CUBIC Bspline
- BI-CUBIC – Adaptive Triangular
- BI-CUBIC – Adaptive Bell Shaped
- BI-CUBIC Adaptive Bspline

Bi-linear filtering – WARP 1.0





Bi-cubic triangular filtering

IMPLEMENTING WARP

Links to past talks/info

Windows

- S5143 - Architectural Display Walls Using NVAPI – Doug Traill, GTC 2015
- S2322 - Warping & Blending for Multi-Display Systems – Shalini Venkataraman GTC 2012
- Sample code - DesignWorks developer pages

Linux

- Sample code - nv-control-warpblend. Shipped with driver. Tar ball can be downloaded here: ftp://download.nvidia.com/XFree86/nvidia-settings/
- Go to samples directory.

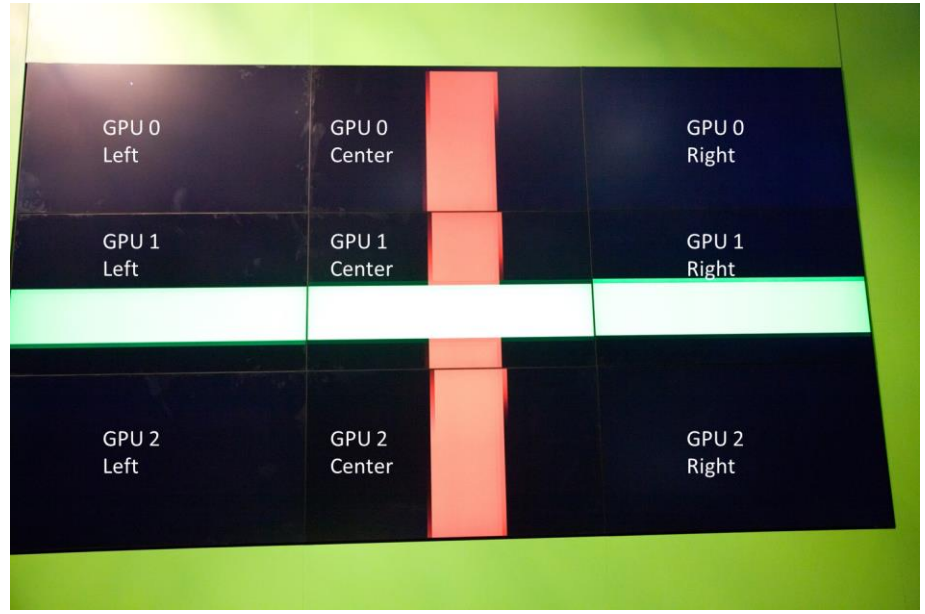
LCD TILE WALLS

MOSAIC + WARP

Solves issues with sync on LCD panels

Tearing between each row

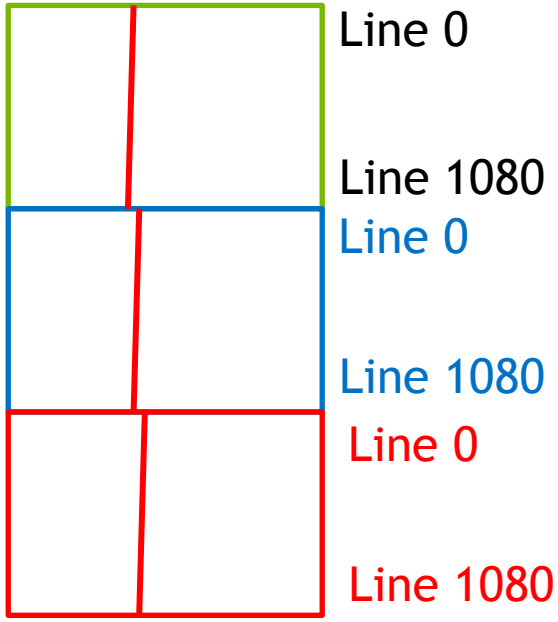
- Appears with fast moving video or interactive content
- Display wall is framelocked – but response time of LCD panels results in this optical effect



LET’S TAKE A CLOSER LOOK

What’s happening

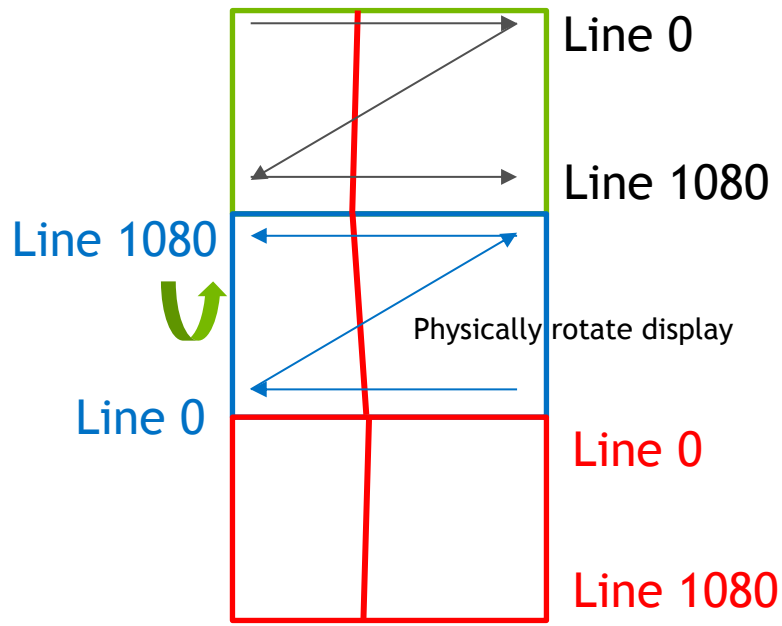
- Progressive scan-out from line 0 to line 1080
- Each lower row appears to be rendering ahead
- Columns within a row appear to be sync’d



SOLVING THIS PROBLEM

Use WARP API + rotated row

- Progressive scan-out from line 0 to line 1080
- Rotate every other row
  - Line 1080 -> Line 1080
  - Line 0 -> Line 0
- WARP API
  - Rotate Desktop image so looks correct to the viewer



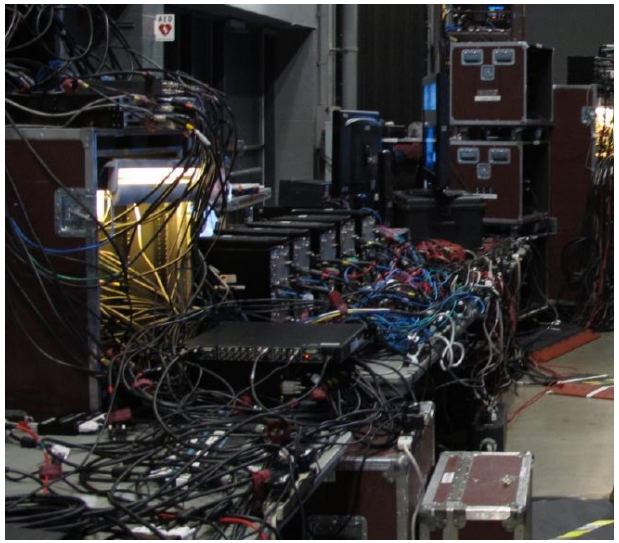
DISPLAY MANAGEMENT APIS

NVWMI TOOLKIT & NVAPI

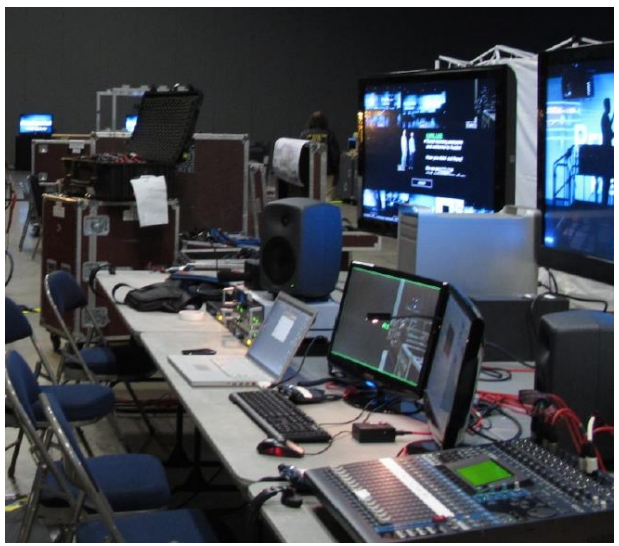
Remote management and NVIDIA control panel APIs manage complexity

NVWMI remote management API	
▪	Monitor and manage NVIDIA graphics from anywhere
▪	Do everything the control panel can do and more
▪	Plugs into Microsoft's WMI
▪	Perfmon support
▪	Scriptable | wmic | powershell | C# support

NVAPI for the NVIDIA control panel	
▪	Custom resolutions
▪	EDID management
▪	Warp + Blend API (Quadro only)
▪	MOSAIC API
▪	Reskinning the NVIDIA control panel (build your own)



Without NVIDIA Technology



With NVIDIA Technology

Image courtesy of Immersive Design Studio

NVAPI FUNCTIONS

Selection of different features

Custom Resolutions	MOSAIC	Sync Management	EDID Management
GFT, DMT, CVT, CVT-RB, Manual timing	Seamless desktop across multiple GPUs	Genlock/TTL sync, framelock (internal sync)	Capture and read EDID from file
EDID Management	**WARP + Intensity API**	**Driver Profiles**	**Driver Settings**
Capture and read EDID from file	Edge-blending, projection mapping on Windows or Linux	Global and nView profile management	Manage 3D settings selection
Display Setup	**GPU Direct for Video**	**Color Management**	**GPU Utilization**
Clone mode, display position	Picture-in-picture support	Color space conversion via NVAPI SDK	GPU utilization, memory etc.

NVAPI BASICS

Public & NDA Version

Public – developer.nvidia.com

Most functions available – MOSAIC, WARP etc NO Custom Resolution.

NDA – registered developer with NDA. NVIDIA provides access to partner network for download

All functions available – including custom resolution

More SDK examples

Structure versions

Each structure in NVAPI contains a version field that must be set.

NV_XXX.version = NV_XXX_VER;

displayIds – unique identifier for each display attached. Includes GPU info.

NVWMI

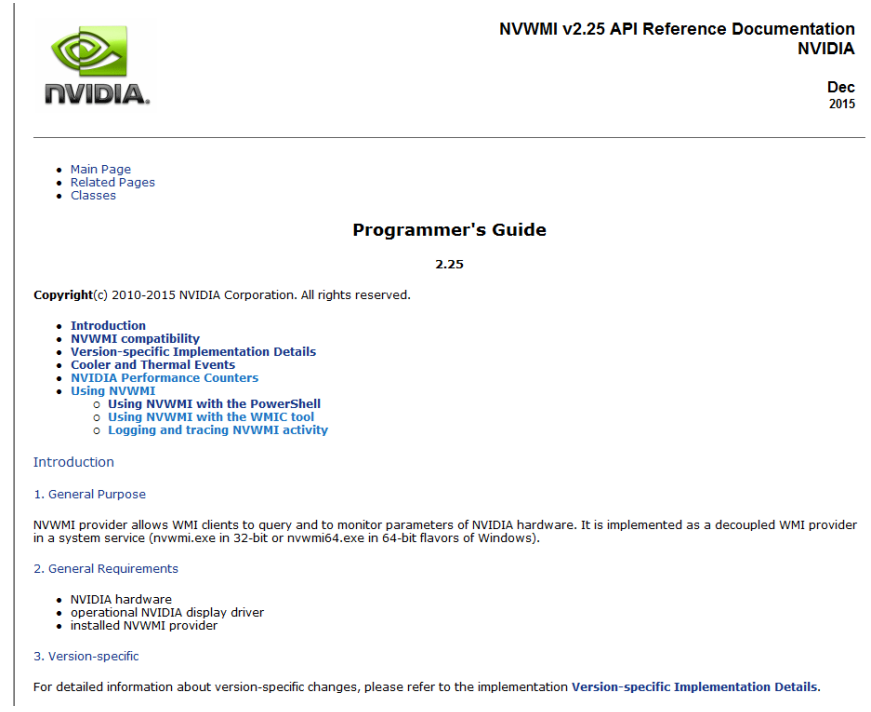
Plug into Windows Management Infrastructure

Accessible using:

- WMIC – command line
- Powershell
- C#

developer.nvidia.com/nvwmi

- SDK samples
- White paper



NVWMI v2.25 API Reference Documentation
NVIDIA

Dec
2015

- Main Page
- Related Pages
- Classes

Programmer's Guide

2.25

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- **Introduction**
- **NVWMI compatibility**
- **Version-specific Implementation Details**
- **Cooler and Thermal Events**
- **NVIDIA Performance Counters**
- **Using NVWMI**
  - **Using NVWMI with the PowerShell**
  - **Using NVWMI with the WMIC tool**
  - **Logging and tracing NVWMI activity**

Introduction

1. General Purpose

NVWMI provider allows WMI clients to query and to monitor parameters of NVIDIA hardware. It is implemented as a decoupled WMI provider in a system service (nvwmi.exe in 32-bit or nvwmi64.exe in 64-bit flavors of Windows).

2. General Requirements

- NVIDIA hardware
- operational NVIDIA display driver
- installed NVWMI provider

3. Version-specific

For detailed information about version-specific changes, please refer to the implementation **Version-specific Implementation Details**.

Installed with the driver - C:\Program Files\NVIDIA Corporation\NVIDIA WMI Provider

MOSAIC SETUP

NVWMI – adds remote setup support

- Class – DisplayManager
- Function – createDisplayGrids
- Input parameters – string containing grid information i.e.

  "rows=2;cols=2;stereo=0;layout=1.1 1.2 1.3 1.4;mode=1920 1200 32 60"

- Layout – numbering starts at "1". Different than control panel

```
ObjectGetOptions Options = new ObjectGetOptions();
ManagementPath Path = new ManagementPath("DisplayManager");
ManagementClass ClassInstance = new ManagementClass(Scope,
Path, Options);
ManagementBaseObject inParams =
ClassInstance.GetMethodParameters("createDisplayGrids");

string[] grid_input_params = { "rows=1;cols=2" };
inParams["grids"] = grid_input_params;

ManagementBaseObject outParams =
ClassInstance.InvokeMethod("createDisplayGrids", inParams,
null);
```

C# code snippet

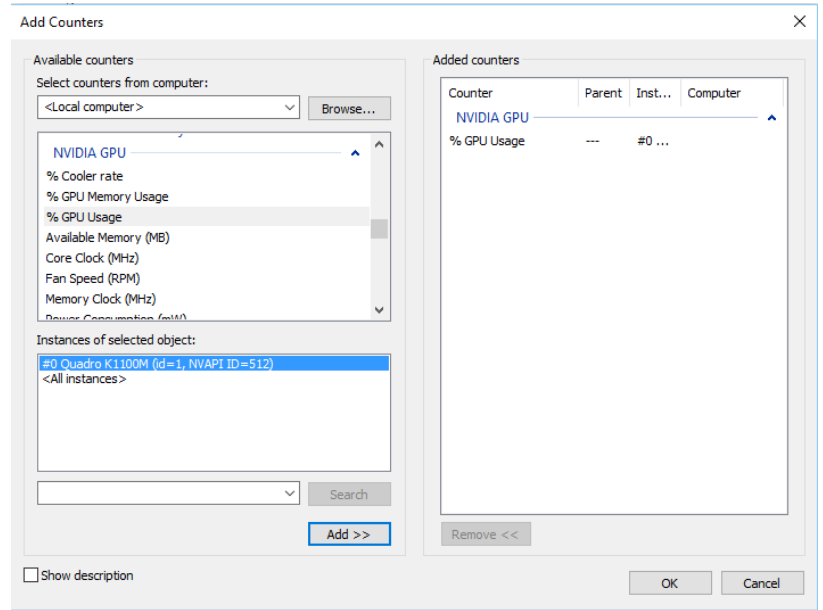
PERFORMANCE MONITOR

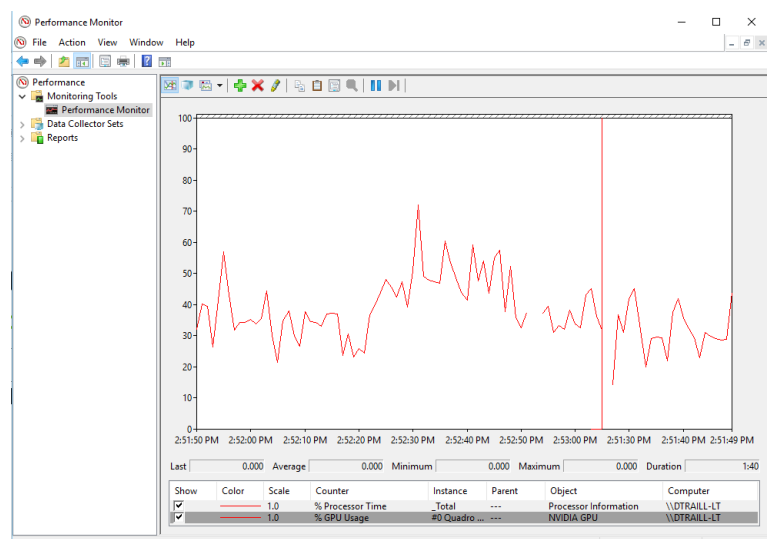
Performance Counters

- monitor utilization
- Temperature/power

Event monitor

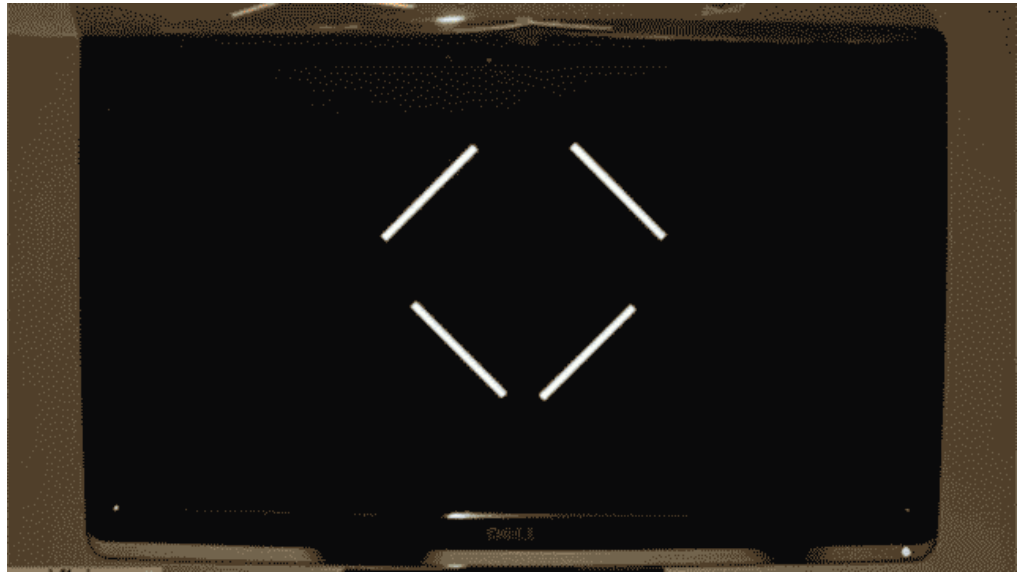
- Quadro Sync events
  - Changes in sync status reported without polling.





QUADRO SYNC

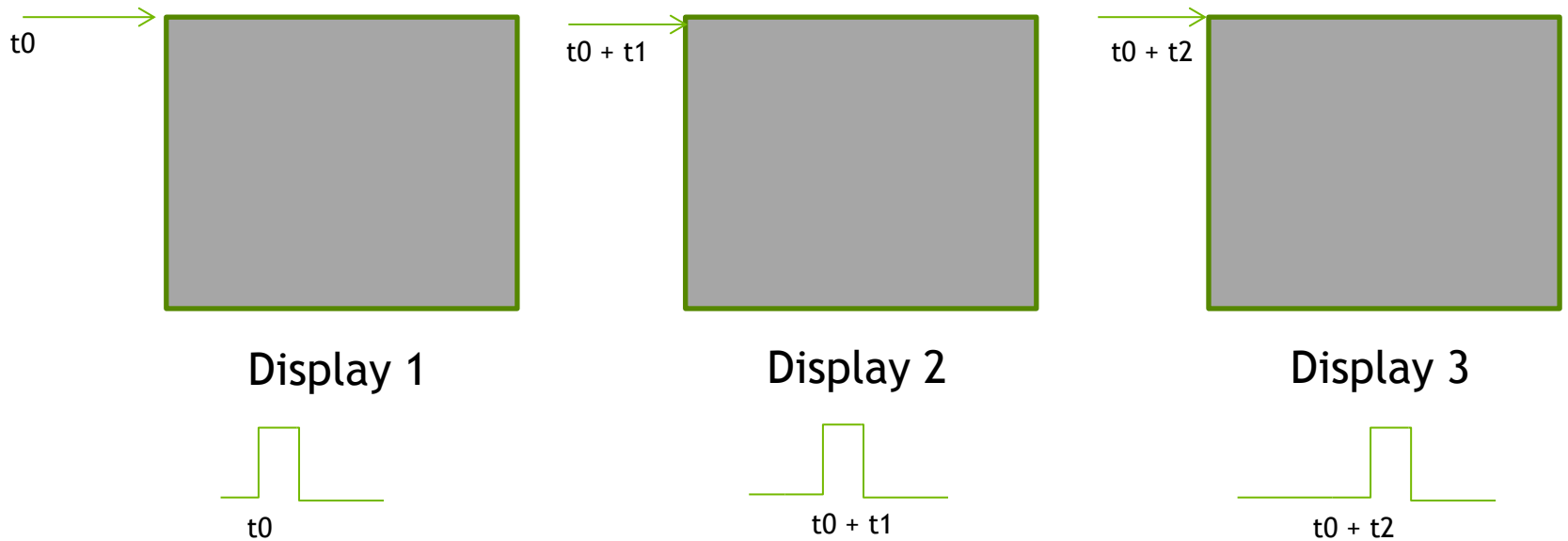
WHY IS SYNC IS IMPORTANT?



Bezel’s hide sync issues !!!

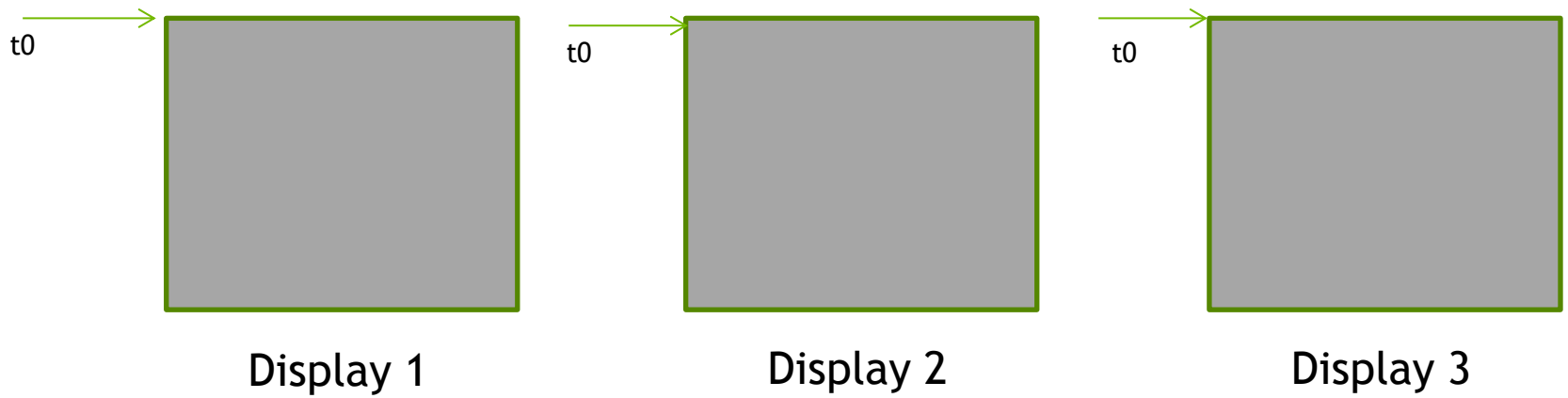
Image from gizmodo.com

VERTICAL SYNC



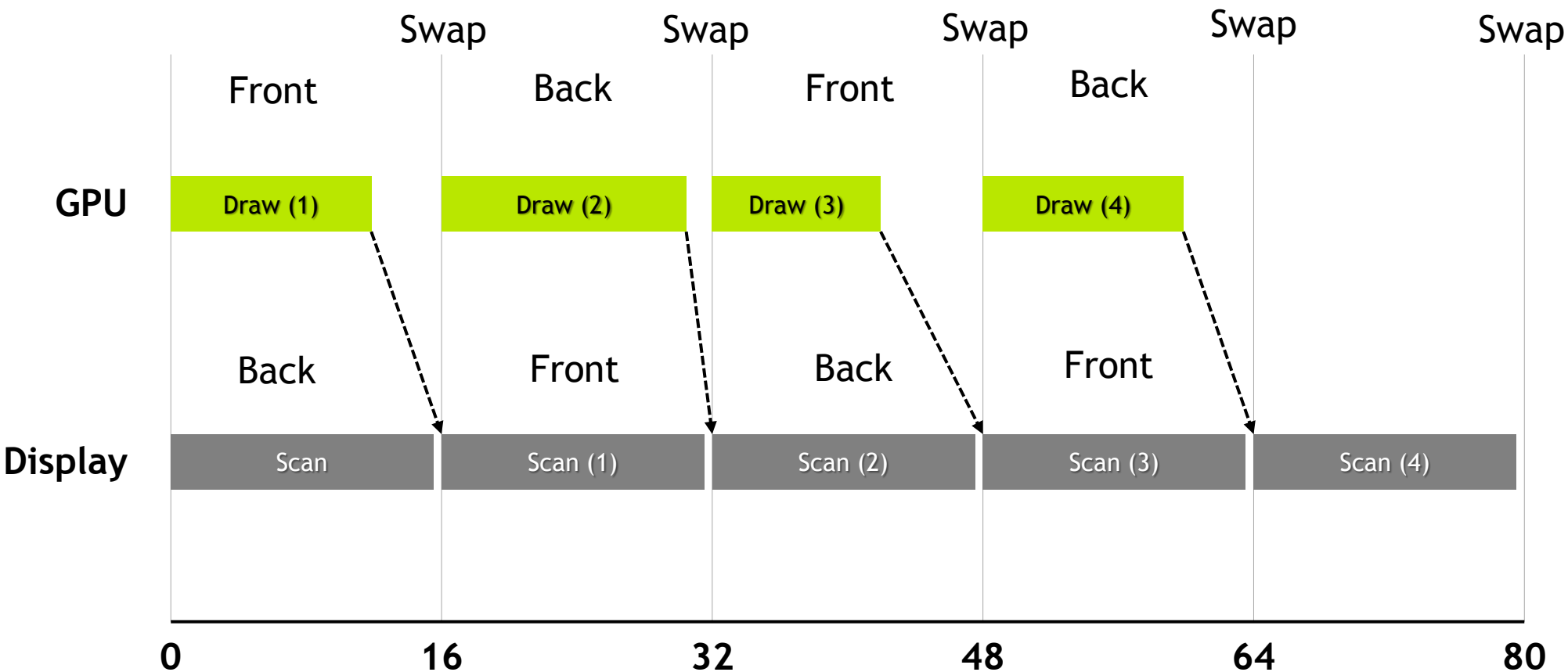
- *Vertical Sync* is the pulse that indicates the start of the display refresh.
- To avoid *tearing* on a single screen the application swap buffers are synced to *vertical sync*.
- Although all three displays may have the same refresh rate – *vertical sync* start may be different.
- This can result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

FRAMELOCK/GENLOCK

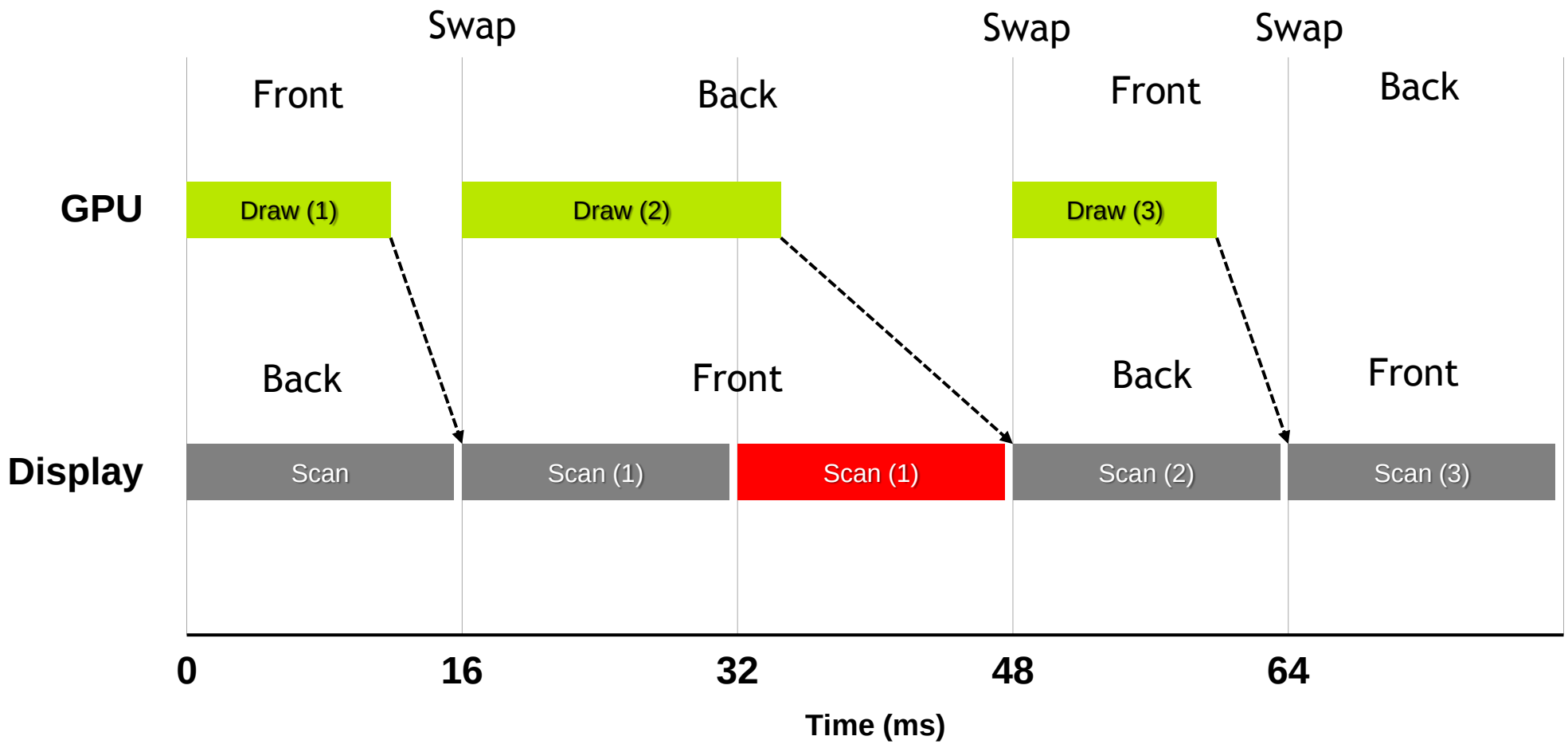


- *Framelock/Genlock provides a* common sync signal between graphics cards to insure the vertical sync pulse starts at a common start.
- This is commonly referred to as *Frame Synchronization*
- *Framelock* – Synchronization is generated from a master node. All other nodes would be sync to this.
- *Genlock* – synchronization is from an external sync generator (house sync). Each node attached to the genlock signal is synced from that signal.
- *Framelock & Genlock* can be mixed in the cluster. With the master node being synchronized from the genlock pulse.

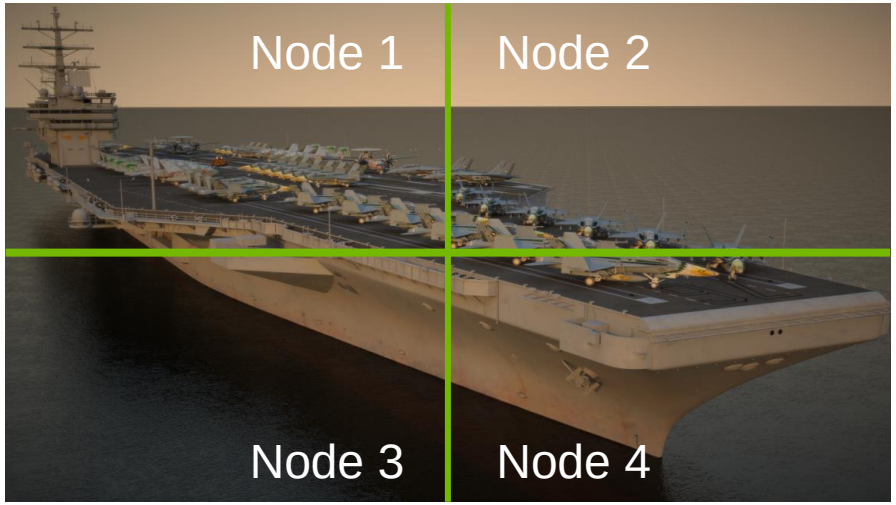
SWAPBUFFERS



SWAPBUFFERS



SWAPBUFFERS IN A CLUSTER



Each node is now rendering a scene with different complexity i.e from least to highest we get:

1. node 3 ~ 16ms = 60fps
2. node 4 ~ 36ms = 30fps
3. node 2 ~ 53ms = 15fps
4. node 1 ~ 99ms = 10fps

- With each node running at a different rate the user would perceive tearing on the screen.
- We need a mechanism to ensure that each node will *swap* at the same time.

SWAPBUFFERS IN A CLUSTER

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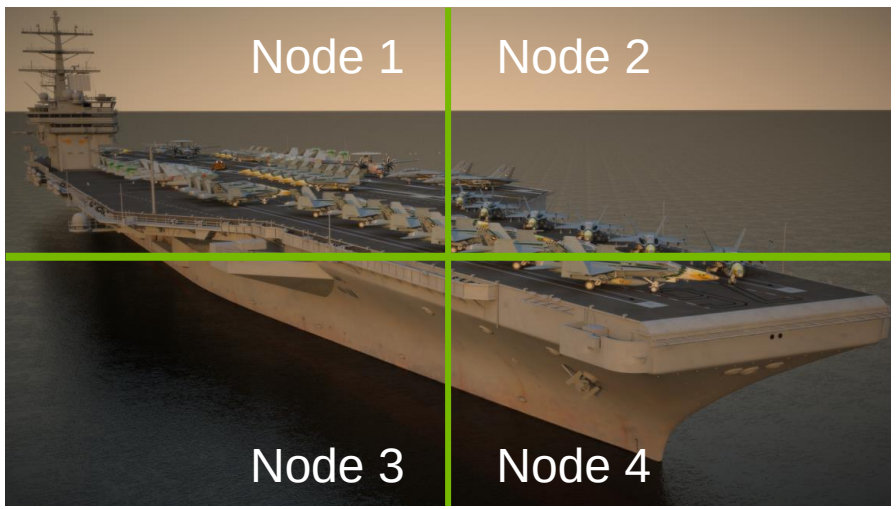
SWAP GROUP AND SWAP BARRIER

NVIDIA Extensions to OpenGL /DirectX (via NVAPI)

- Swap Group – provides synchronization multiple GPUs in a single host
- Swap Barrier – provides synchronization of GPUs across multiple nodes.
- Use RJ45 (framelock) connection on Quadro Sync – so faster than sync over a network



With Swap Barrier each node will wait until all nodes have completed their render

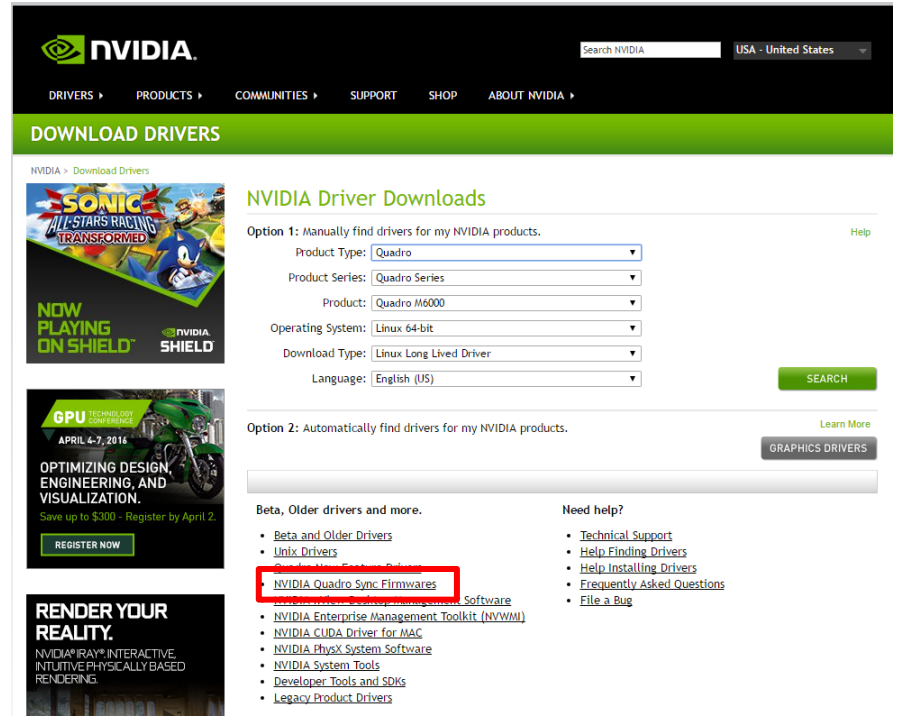
1. node 3 ~ 16ms = 10fps
2. node 4 ~ 36ms = 10fps
3. node 2 ~ 53ms = 10fps
4. node 1 ~ 99ms = 10fps

QUADRO SYNC FIRMWARE

Version 0x57

Fixes

- Issues with 50Hz house sync signals
- Start delay and Sync offset functions
- Mosaic as part of cluster – each node is running MOSAIC locally.
- General stability related to Maxwell generation of GPUs.



If your system isn't broken – don't fix it.
i.e. please only upgrade if one of the issues above applies to you

BUILDING CLUSTER AWARE SOFTWARE

CLUSTER SOFTWARE

3rd party/Open Source

Toolkits

eon reality

getReal3D FOR UNITY

CAVELib SIMPLIFIED PROGRAMMING

unity

worldviz where virtual becomes reality

OpenSceneGraph

Middle Ware

Conduit FROM DESKTOP TO VIRTUAL REALITY

TechViz

Equalizer

THANK YOU

Questions - dtraill@nvidia.com or QuadroSVS@nvidia.com

twitter @dougtraill