See the Big Picture: Scalable Visualization Solutions for High Resolution Displays

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From SD to 8K – Exponential Pixel Growth
Scaling Detail

Realism requires Resolution

- **MOSAIC** - scale any application across up to 16 displays from just one computer using 4 Quadro cards and Quadro Sync

- **Cluster** - Scale even further with a visualization cluster of systems built upon Quadro Sync
Scaling Detail

Realism requires Synchronization

• **MOSAIC** - scale any application across up to 16 displays from just one computer using 4 Quadro cards and Quadro Sync

• **Cluster** - Scale even further with a visualization cluster of systems built upon Quadro Sync

Brown University - YURT
69 projectors powered by a cluster of K5200 + Quadro Sync
From HD to 4K & Beyond
Increasing Display Resolutions

4K UHD - 4 times HD res
8K UHD - 16 times HD res

Professional 4K projectors
4096x2160
4096x2400

8k Projectors
JVC - 8192x4800 (e-shift)
(4 * 4K)
Scale from 4k UP....

**MOSAIC**
Single workstation  
Single Desktop  
Up to 4 GPUs - 16 display heads  
*Application independent*

~142 Mpixels  
(16 * 4K)

**GPU Affinity**
Single workstation  
Multiple - desktops/GRIDs  
Up to 8 GPUs - 32 display heads  
*Application dependent*

~284 Mpixels  
(32*4k)

**Cluster solution**
Multiple workstations  
Multiple - desktops/GRIDs  
Up to ~200 GPUs - 800 display heads  
*Application dependent*

~7,078 Mpixels  
(800x4K)
Project on to any surface...

Image Courtesy of IMMERSIVE DESIGN STUDIOS
WARP + Intensity API
Windows + Linux

Projection Blending & Mapping software available from:

- Scalable Display Technologies
- VIOSO
- play-out.com
- coolux A Christie Company
- IMMERSAVIEW
- CHRISTIE
- Fraunhofer FOKUS
- Pixelwix

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

Image courtesy of Christie Digital
WARP not just for projectors
Arbitrary display layouts
## Quadro Driver Display Features

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<th>Tiled Displays</th>
<th>10/12 bit Color</th>
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<td>Automatic MOSAIC setup on tile displays using Display ID</td>
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</table>

- **EDID Management**: Capture and Read EDID from file
- **4K resolution**: DP1.2 per connector or HDMI1.4b
- **Warp + Intensity API**: Edge-blending, projection mapping, Windows + Linux
- **8K e-shift support**: Native support for 8k e-shift projector

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**Quadro Driver Display Features**

- **MOSAIC**
  - Seamless Desktop across multiple GPUs
- **Tiled Displays**
  - Automatic MOSAIC setup on tile displays using Display ID
- **10/12 bit Color**
  - Support High Dynamic Range Displays
- **3D Stereo**
  - OpenGL/DirectX, active, passive, pixel packed
- **Display Port MST**
  - Support multi-streaming devices
- **GPU Affinity**
  - Multi-GPU support and Swap Groups
- **Color Management**
  - Color Space Conversion - NVAPI SDK

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- **Custom Resolutions**
  - GTF, DMT, CVT, CVT-RB, Manual timing
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  - Color Space Conversion - NVAPI SDK
MOSAIC - WHY IS IT NEEDED?
- WINDOWS ON ITS OWN - INDEPENDENT DESKTOPS
WINDOWS ON ITS OWN
- INDEPENDENT DESKTOPS
WITH MOSAIC
- ONE LARGE DESKTOP
<table>
<thead>
<tr>
<th></th>
<th>1 GPU</th>
<th>2 GPUs</th>
<th>3 GPUs</th>
<th>4 GPUs</th>
</tr>
</thead>
<tbody>
<tr>
<td>QUADRO M6000</td>
<td>4</td>
<td>8</td>
<td>12</td>
<td>16</td>
</tr>
<tr>
<td></td>
<td>Overlap + bezel correction</td>
<td>Overlap + bezel correction SLI (2) or Quadro Sync</td>
<td>Overlap + bezel correction Quadro Sync</td>
<td>Overlap + bezel correction Quadro Sync</td>
</tr>
<tr>
<td>QUADRO M5000</td>
<td>4</td>
<td>8</td>
<td>12</td>
<td>16</td>
</tr>
<tr>
<td></td>
<td>Overlap + bezel correction</td>
<td>Overlap + bezel correction SLI (2) or Quadro Sync</td>
<td>Overlap + bezel correction Quadro Sync</td>
<td>Overlap + bezel correction Quadro Sync</td>
</tr>
<tr>
<td>QUADRO M4000</td>
<td>4</td>
<td>8</td>
<td>12</td>
<td>16</td>
</tr>
<tr>
<td></td>
<td>Overlap + bezel correction</td>
<td>Overlap + bezel correction SLI (2) or Quadro Sync</td>
<td>Overlap + bezel correction Quadro Sync</td>
<td>Overlap + bezel correction Quadro Sync</td>
</tr>
<tr>
<td>QUADRO K1200</td>
<td>4</td>
<td>8</td>
<td>12</td>
<td>16</td>
</tr>
<tr>
<td></td>
<td>Overlap <em>now</em> (1) bezel correction</td>
<td>bezel correction</td>
<td>bezel correction</td>
<td>bezel correction</td>
</tr>
</tbody>
</table>

(1) Overlap support on single GPU
(2) SLI must be certified platform - [http://www.nvidia.com/object/quadro_sli_compatible_systems.html](http://www.nvidia.com/object/quadro_sli_compatible_systems.html)

Multi-GPU Overlap requires SLI or Quadro Sync card.

MOSAIC is supported on Windows 7, 8.1, 10 + Linux

Unified Display heads - 4 DP1.2 connectors per card
Synchronization

Why Sync is important
Framelock + Genlock
Swap barriers + Groups
WHY IS SYNC IS IMPORTANT?

Bezel’s hide sync issues !!!
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** 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

<table>
<thead>
<tr>
<th>GPU</th>
<th>Display</th>
</tr>
</thead>
<tbody>
<tr>
<td>Draw (1)</td>
<td>Scan</td>
</tr>
<tr>
<td>Draw (2)</td>
<td>Scan (1)</td>
</tr>
<tr>
<td>Draw (3)</td>
<td>Scan (2)</td>
</tr>
<tr>
<td>Draw (4)</td>
<td>Scan (3)</td>
</tr>
<tr>
<td>Front</td>
<td>Front</td>
</tr>
<tr>
<td>Back</td>
<td>Back</td>
</tr>
<tr>
<td>Front</td>
<td>Front</td>
</tr>
<tr>
<td>Back</td>
<td>Back</td>
</tr>
<tr>
<td>Front</td>
<td>Front</td>
</tr>
<tr>
<td>Back</td>
<td>Back</td>
</tr>
</tbody>
</table>

0 16 32 48 64 80
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.
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

**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
MOASAIC

Setup/Configuration
Display GRIDS
Overlap/Bezel Correction
Linux Setup
Setting up MOSAIC

Control Panel
- Wizard tool

Configuremosaic
- Large display walls
- Command-line
- Batch files

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
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.

Rows:
- 1
- 4
- 7

Columns:
- 1
- 2
- 3
- 4
- 5
- 6
- 7
- 8
- 9

Horizontal pixels:

Vertical Pixels:
Bezel and Overlap correction

Bezel Correction
Will make the image look continuous as we render under the bezel

Overlap Correction
For projectors it maintains the aspect ratio of the display.
Understanding Topologies

Column overlap or bezel correction

Bezel correction will increase overall pixel size

\[ \text{i.e each display is } 1920\times1080 \]

Bezel per column is 100

Total horizontal width
\[ = 1920\times4 + 100\times3 = 7980 \]

Overlap correction will decrease overall pixel size
Anatomy of a System

Stereo sync bracket
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

Slot 2

Slot 4

Slot 6

Slot 8

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

Ports auto enumerate depending what is attached –
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.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
Portrait mode

Command line or Control panel

configureMosaic set rows=2 cols=4 rotate=90

Control Panel - Portrait mode requires that GUI starts in Landscape mode - it’s a feature ;-)
Multiple MOSAIC GRIDs

Only one GRID can cross multiple GPUs

- 12 Projectors, driven by 3 K5000s
- Floor and Front wall - 4 projectors
- Side walls are 2 projectors
- 4th GPU used a console output
- After configuring MOSAIC set Sync.
- Dual boot - works with Linux.

```
configureMosaic.exe set rows=1 cols=1 out=0,0 nextgrid rows=2 cols=2 overlap=384,240 out=1,0 out=1,1 out=1,2 out=1,3 nextgrid rows=2 cols=2 overlap=0,240 out=3,0 out=3,1 out=3,3 out=3,2 nextgrid rows=2 cols=2 overlap=384,480 out=2,0 out=2,1 out=2,2 out=2,3
```
MOSAIC across multiple GPUs + 1
MOSAIC across multiple GPUs + 1
MOSAIC Confidence Monitor

Aimed at 4K projectors with dual inputs.

- Scale
- Area or interest
- Pan + Scan mode

All displays on single GPU.
Clone to a single monitor.

R352 Driver and above
SVS Features

Premium MOSAIC is now MOSAIC with Sync

- Sync Capability
  - Single GPU - overlap support on single card only
  - Multi GPU Sync
    - Quadro Sync card
    - SLI bridge present

Indicates whether or not card or system can be sync’d.
New SVS features - R346
Force Stereo Shuttering - Win 7

Memory Allocation Policy
 Moderate Pre-allocation

Set Stereo to enable

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

Notes:
1. AERO desktop will always be disabled
2. 3D Vision Pro hub will always be enabled.
New SVS Features - R346

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:

1. force stereo will also be enabled
2. AERO is disabled
3. Doesn’t affect MOSAIC setup - ie. Still screen flash
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)

Example Showing Bezel correction.
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
```

Note SLI connector only works on Quadro SLI certified workstations
**LINUX tips**

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

```
Section "Screen"
   Identifier     "Screen0"
   Device         "Device0"
   Monitor        "Monitor0"
   DefaultDepth  24
   Option         "SLI" "Mosaic"
   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 Sync

Set SLI MOSAIC in xorg.conf

After restarting X - Enable Framelock (Not automatic)
Display Connectors

Pixel Bandwidth
Display Port
HDMI support
DP MST
Driving Ultra high res Displays
Max single cable bandwidths/Resolutions

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

Resolution per cable is a function of the connection bandwidth and color depth.

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
** DP1.3 support has not been announced
Display Port to DVI

Pixel Clock - 165MHz, 270MHz, 330MHz

Passive Single-link DVI (165)
- Max res - 1920x1200@60 (CVT_RB)
- Active single link DP to DVI is not supported

Active - Dual-link DVI (270)
- Max res - 2560x1600@60Hz
- No sync with native DVI
- No Stereoscopic support

Active - Dual-link DVI (330)
- Full DVI bandwidth
- Sync with native DVI
- Stereoscopic support
HDMI Cables DONGLEs

DVI to HDMI

DVI to HDMI is **pin compatible**

HDMI signaling over single-link DVI cables (3840x2160@60Hz)

HDMI 2.0 / HDMI1.4b support

**“good” quality cables**

Adaptors tend to have more leakage - don't support high resolution

HDMI 2.0 (4:2:0) support added in R340 - Kepler cards + above
HDMI 2.0 (4:4:4) supported on Quadro M6000 (Note - probably only through DVI port - not sure the DP to HDMI dongles support it)

DP to HDMI

DP (Type 2) to HDMI passive dongle

HDMI 2.0 / HDMI1.4b support

Marketed as supporting 4K HD, stereoscopic
RGB Color
YCbCr - Bringing Color to a Black and White TV

Y = Luminosity

Cb = “Blue-ness”

Cr = “Red-ness”
½ the Data Size

4:4:4 4:2:0
What’s the Impact?
Getting help

NVIDIA Customer help
developer.nvidia.com
QuadroSVS@nvidia.com
http://nvidia.custhelp.com/
SDKs + Utilities - developer.nvidia.com

- OGL/DirectX Swap Group examples
  - QuadroSVS@nvidia.com
- GPU Affinity
  - QuadroSVS@nvidia.com
- Warp + Blend API SDK
  - QuadroSVS@nvidia.com
- NVAPI Sync samples
  - Developer.nvidia.com
- NVAPI MOSAIC samples
  - QuadroSVS@nvidia.com
- NVWMI examples
  - Developer.nvidia.com
  - QuadroSVS@nvidia.com
    - Sync, event monitors, EDID examples

- Configuremosaic
  - Nvidia.com - driver downloads

- Nvtimingdiag.exe
  - QuadroSVS@nvidia.com

- Clip MOSAIC - perf enhancement
  - QuadroSVS@nvidia.com

- ManageEDID
  - Command line EDID management
  - QuadroSVS@nvidia.com
Thank you

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