GPU TECHNOLOGY CONFERENCE

S5143 - ARCHITECTURAL DISPLAY WALLS USING NVAPI

"HOW TO MAKE A FUNKY DISPLAY WALL ;-)"

DOUG TRAILL – SENIOR SOLUTIONS ARCHITECT, NVIDIA

ARCHITECTURAL DISPLAYS

Image courtesy of Planar – MOSAIC Walls

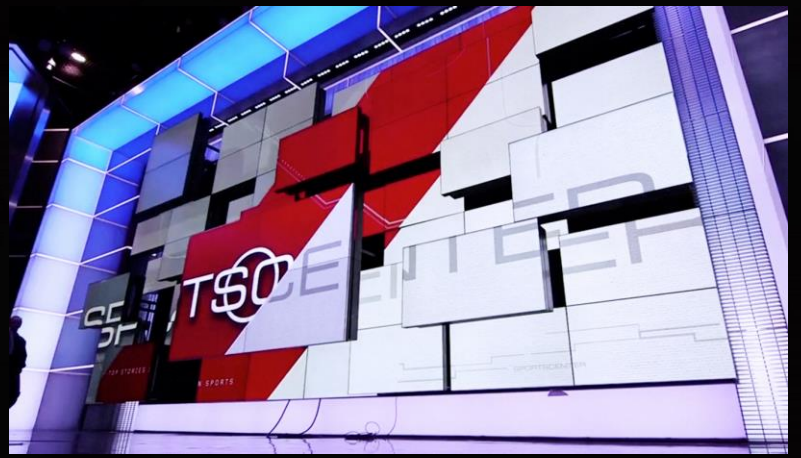


Image courtesy of Christie Digital – Micro Tiles

Non-linear displays – don’t fit into standard MOSAIC GRID

NVAPI WARP + INTENSITY API

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

Image courtesy of Christie Digital

Projection Blending & Mapping software available from:

scalable DISPLAY TECHNOLOGIES

VIOSO

play-out.com

domeprojection.com

coolux A CHRISTIE COMPANY

Fraunhofer FOKUS

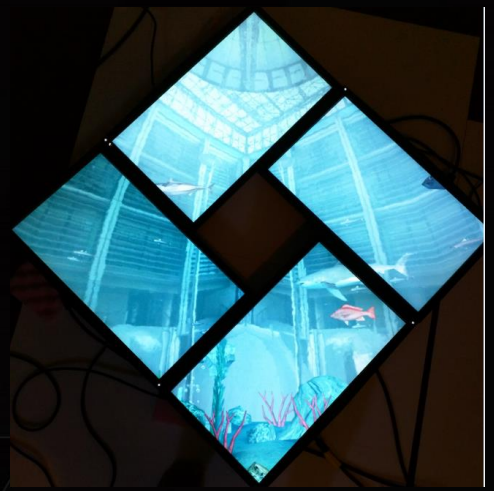
IMMERSAVIEW

Pixelwix Inovative Media Solutions

CHRISTIE

CAN WE USE NVAPI TO CREATE THIS ?

WE CAN SUPPORT UP TO 16 DISPLAYS

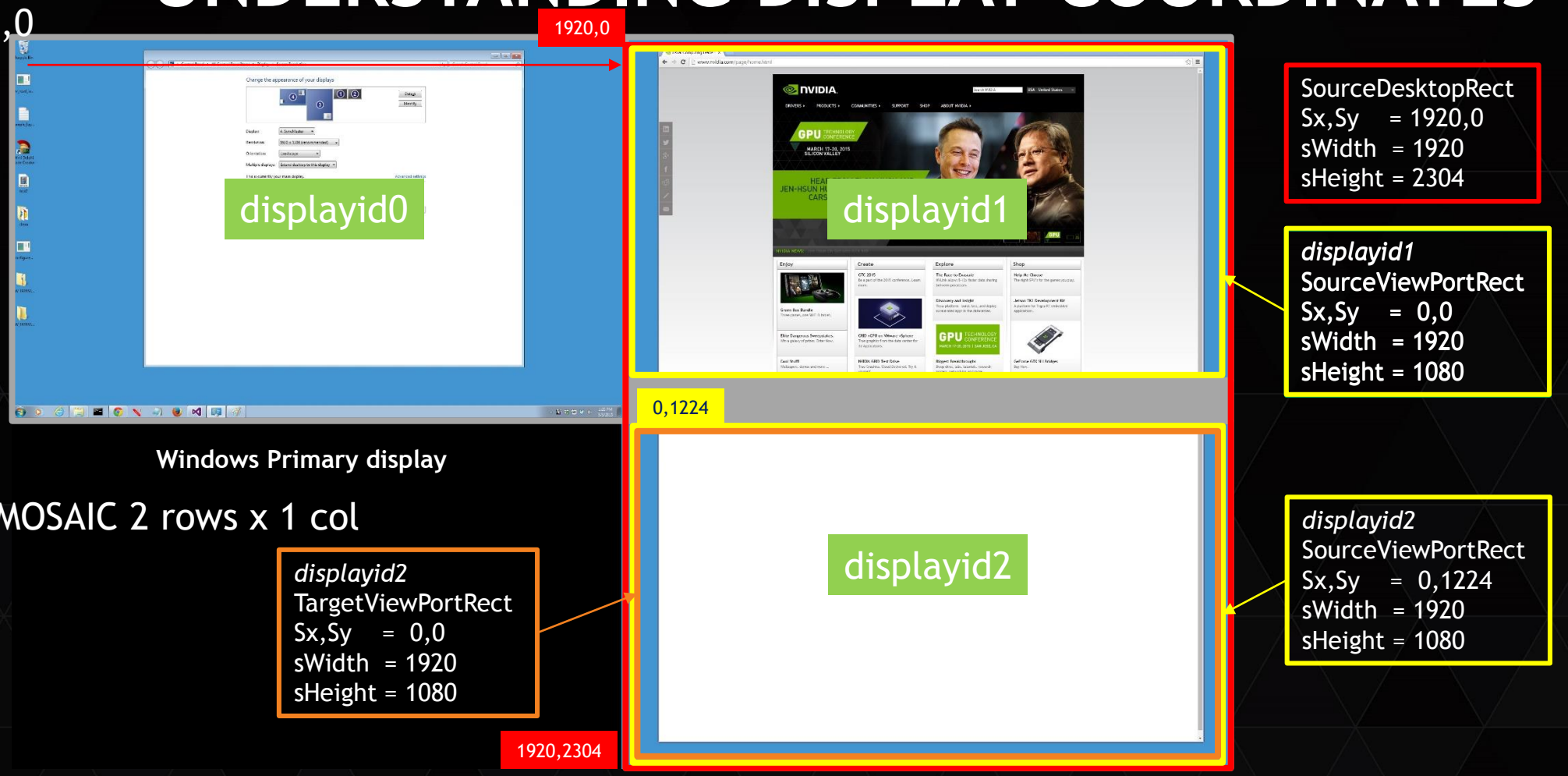


This technique allows us to have arbitrary layouts.

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.

UNDERSTANDING DISPLAY COORDINATES



Windows Primary display

MOSAIC 2 rows x 1 col

TWO STEP PROCESS

For this example need a desktop of 3984x3984 pixels
This is size of two 1920 monitors + bezel correction

- Create Custom Windows Desktop
  - Needs to cover the resolution of the display
  - SourceDesktopRect – 3984x3984 pixels
- Warp the scanout to match the physical location of the monitors
  - Physical monitor is the targetViewPortRect and we are going to warp the SourceViewRect to match the location of the monitor
    - Top Left - 2064,2064
    - Top Left - 3984,3984
    - Bottom Left - 2064,3144
    - Bottom Right - 3984,3144

CREATE A CUSTOM WINDOWS DESKTOP

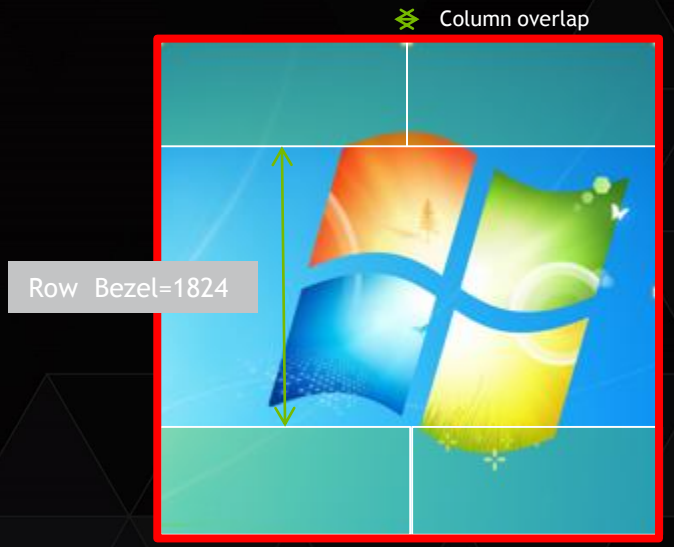
- MOSAIC
  - Creates a new SourceDesktopRect based on individual displays.
    - Bezel correction – increase the size of the Desktop
    - Overlap decreases it
  - 2x2 MOSAIC
    - Width = 3840 + 144 bezel = 3984
    - Height = 2160 + 1824 bezel = 3984

Extended Desktop

4 x4 GRID - 1920x1080

MOSAIC

1 GRID - 7680 x 4320



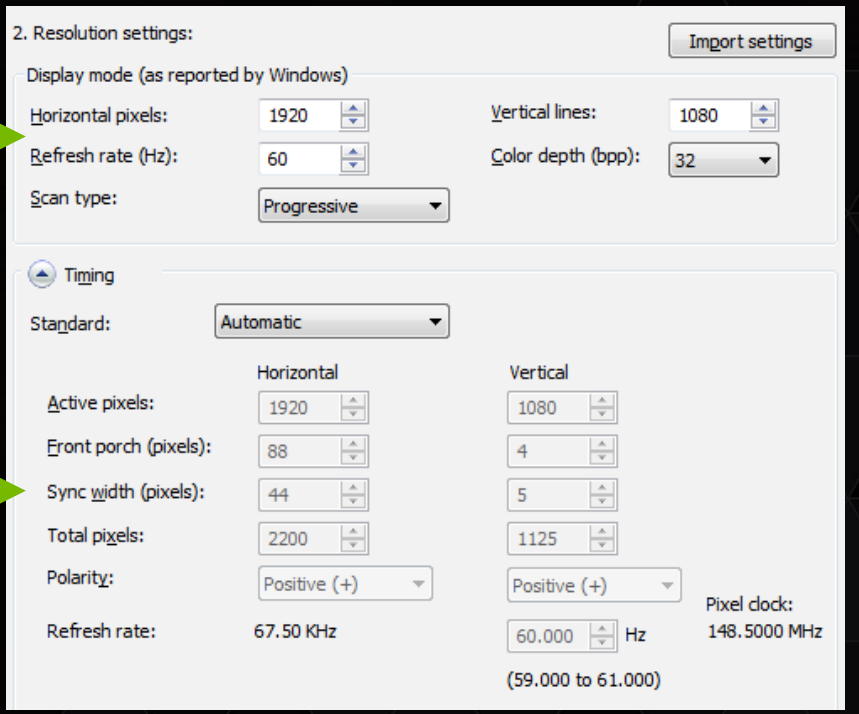
Unfortunately this does not work – Max bezel = half of display size = 520
Would also limit us to the layout

DISPLAY RESOLUTION 101

Display Mode (front end timing)
what is set by Windows

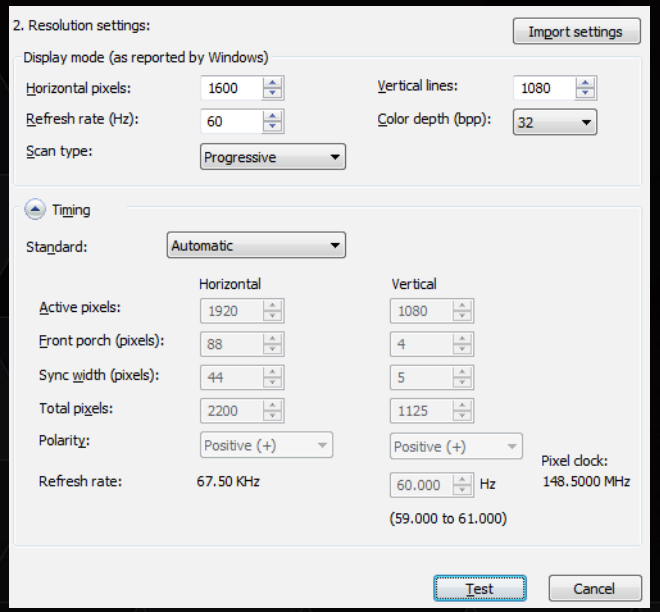
Generally speaking
these values should match

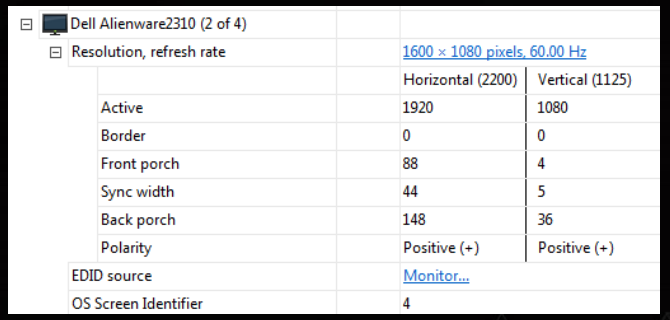
Display Timings (back-end timing)
what the display supports



DISPLAY RESOLUTION 101

- If you request a timing that is not in the Display EDID + Select Automatic
  - NVIDIA Driver will create new timing that uses the closest native display timing in the EDID, but with a modified Display mode.

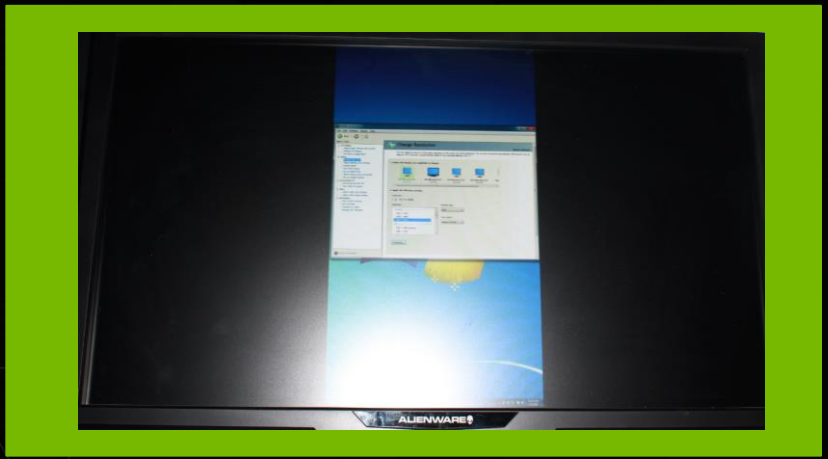




Monitor reports it is getting 1920x1080

INSIDE

THINKING ~~OUTSIDE~~ OF THE BOX!!



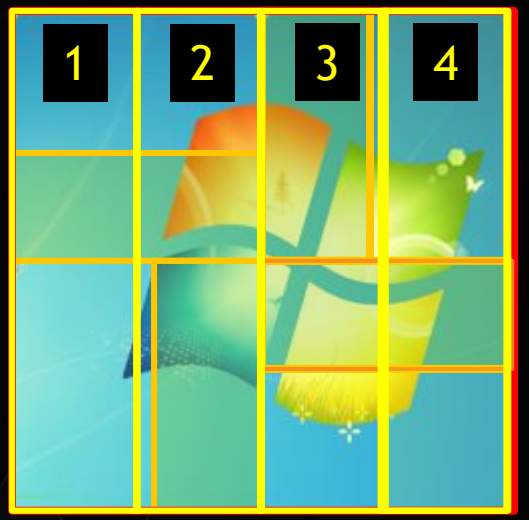
1080x1920

1920x1920

We can create almost any “arbitrary” desktop resolutions

You can do this using the control panel – set 1920x1080 – Automatic first.
Then change to “Manual”
Then modify the scanout – not all desktops will show – depends on your monitor

CREATING CUSTOM DESKTOP



- MOSAIC
  - Rows 1 x Columns 4
  - Custom resolution – 996x3984
  - Creates SourceDesktopRect – 3984x3984 pixels
- SourceViewRect – 4 stripes (this is what we warp)
  - Width – Height - 996 x 3984
  - 1 – 0,0 2 – 996,0
  - 3 – 1992,0 4 – 2988,0
- targetViewPortRect – 4 physical monitors
  - Want to map the warped desktop to these.

GPU TECHNOLOGY CONFERENCE

WARNING - THE FOLLOWING MAY CONTAIN CODE

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#GTC15

SOME PSEUDO CODE

- [1] Read coordinates from file (physically measure or work out by hand)
  - This is what we warp the SourceViewPortRect to.
- [2] Calculate the co-ordinates
- [3] Get all displayIds for attached displays
- [4] Find targetViewPortRect displayIds
- [5] Enable all displays
- [6] Clean up - delete any old custom resolutions, disable warp if still applied
- [7] Create custom resolutions
- [8] Set MOSAIC
- [9] Apply Warp
- [10] Clean-up

CONFIG FILE

- Displays – number in MOSAIC GRID
- Resolution – per display
- Units – pixels
  - RFE - add option for “inches” or “cm”
- 1 +0+840 +Landscape
  - “1” Match to MOSAIC OSD – when hit identify displays
  - +Sx+Sy – offset relative to 0,0.
    - 0,0 top left of the Desktop
  - Landscape/Landscape-flipped/Portrait/Portrait-flipped/rotate=45
    - Orientation of the display – used to calc all 4 corners.

```
// Example
//     (0,0)              ----------X2 - (3144,0)
//                        |         |
//                        |         |
//      X1----------------|    2    |
//      |                 |         |
//      |       1         |         |
//      ----------------X3-X4----------------
//              |         |                 |
//              |         |        4        |
//              |    3    |-----------------
//              |         |
//              |         |
//             -----------
//   X - marks top left of each monitor
//   coords are relative to Desktop 0,0


// Grid 1
Displays=4
Resolution=1920x1080@60
units=pixels
1 +0+840
2 +3144+0 +Portrait
3 +1920+2064 +Landscape
4 +2064+2064 +Portrait

//Grid 0
Console=5
```

HELPER FUNCTIONS

- These are in the NVAPI SDK NDA Samples
  - Info.cpp (EDID Locking sample)
    - Function: `getInfo`
    - Returns a list of all connected DisplayIds, active displays, port names and GPU names etc.
  - DisplayConfiguration.cpp (Display Configuration sample)
    - Function: `AllocateAndGetDisplayConfig`
      - Returns the current resolution of all active displays. Use DisplayID to match to display you are working on
  - CustomTiming.cpp (Custom Timing sample)
    - Shows correct usage to create custom timing.

CUSTOM RESOLUTION

- Pseudo Code
  - AllocateAndGetDisplayConfig – gets current timing
  - Match DisplayIds
  - Copy current timing into Custom resolution structure
  - Modify desktop scanout values
  - TryCustom timing
  - Save Custom timing

```
NV_DISPLAYCONFIG_PATH_INFO *pathInfo = NULL;
NvU32 pathCount = 0;
ret = AllocateAndGetDisplayConfig(&pathCount, &pathInfo);
if (ret != NVAPI_OK)
{
printf("AllocateAndGetDisplayConfig failed!\n");
getchar();
exit(1);
}

NV_CUSTOM_DISPLAY cd[NVAPI_MAX_DISPLAYS] = { 0 };
copy_nvtiming_custom(&pathInfo, cd[0]);
cd[0].width = layout.hCustom;
cd[0].height = layout.vCustom;

printf("\nNvAPI_DISP_TryCustomDisplay()");
for (int i = 0; i < noDisplays; i++)
{

ret = NvAPI_DISP_TryCustomDisplay(&displayIds[i], 1, &cd[0]);

printf("NvAPI_DISP_SaveCustomDisplay()");
ret = NvAPI_DISP_SaveCustomDisplay(&displayIds[i], 1, true,
true);

}
```

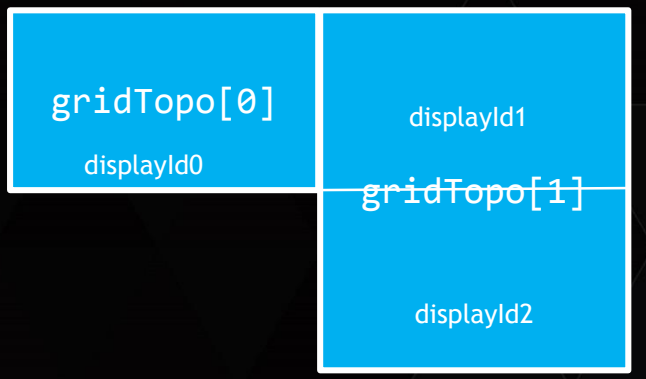
MOSAIC ENUMERATING DISPLAY GRIDS

Get Number of Grids

```
NvU32 gridcount
NvAPI_MOSAIC_EnumDisplayGrids (NULL, &gridcount)
```

Get Grid Topology

```
NV_MOSAIC_GRID_TOPO *gridTopo = new NV_MOSAIC_GRID_TOPO[16];
gridTopo->version = NV_MOSAIC_GRID_TOPO_VER;
NvAPI_Mosaic_EnumDisplayGrids(gridTopo, &gridCount);
```



console MOSAIC 2x1

console

```
gridTopo[0].displayCount = 1
gridTopo[0].rows=1
gridTopo[0].columns =1
gridTopo[0].displays ={displayId0}
 - per display is overlap settings
gridTopo[0].displaysettings = 1920,1200,60, 8bpp
```

MOSAIC 2x1

```
gridTopo[1].displayCount = 2
gridTopo[1].rows=2
gridTopo[1].columns =1
gridTopo[1].displays ={displayId1, displayId2}
 - per display overlap settings
gridTopo[1].displaysettings = 1920,1080,60, 8bpp
```

MOSAIC – PSEUDO CODE

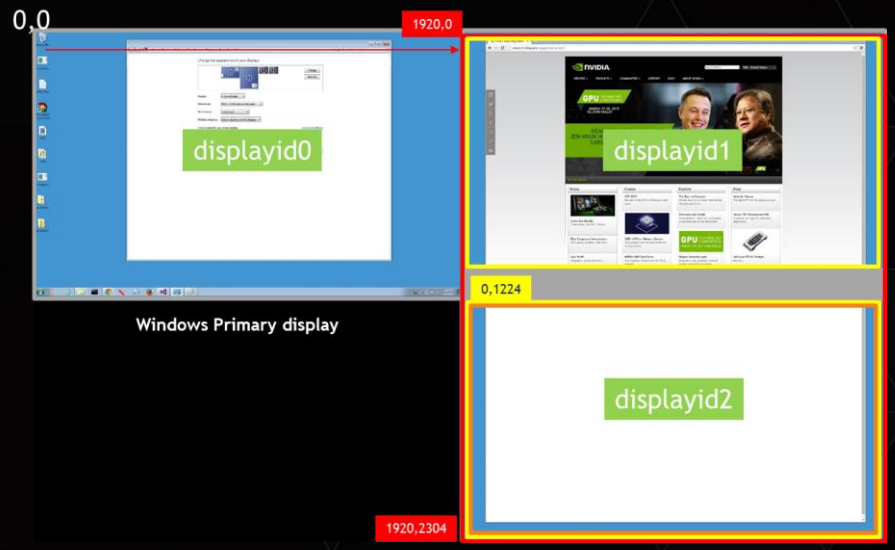
- Enumerate current grids
  - Helpful to populate info
- no_grid =2
- Console display – Grid[0]
  - Create a 1 by 1 grid
  - Choose default timings
- Grid[1] – this is MOSAIC layout
  - rows/columns i.e. 4 rows 1 cols (choose based on layout)
  - Set resolution based on custom timing
- `NvAPI_Mosaic_SetDisplayGrids(grid, no_grid, 0);`

MOSAIC TIPS

- Sort the GPUs based on PCIe slot info
  - Enumeration of the GPUs returned by NVAPI is just a list – doesn't indicate position.
  - Enumeration position can change based on configuration.
  - For PCIe info
    - `NvAPI_GPU_GetBusId` & `NvAPI_GPU_GetBusSlotId`
- Validate the display Grid –returns list of failure codes
  - `NvAPI_Mosaic_ValidateDisplayGrids`
- Check for non-mitigating applications
  - Apps that are likely to crash when - Multi-GPU MOSAIC is set – general apps running OGL context.
    - Includes Chrome browser etc.
  - `NvAPI_GPU_QueryActiveApps` & `NvAPI_QueryNonMigratableApps`

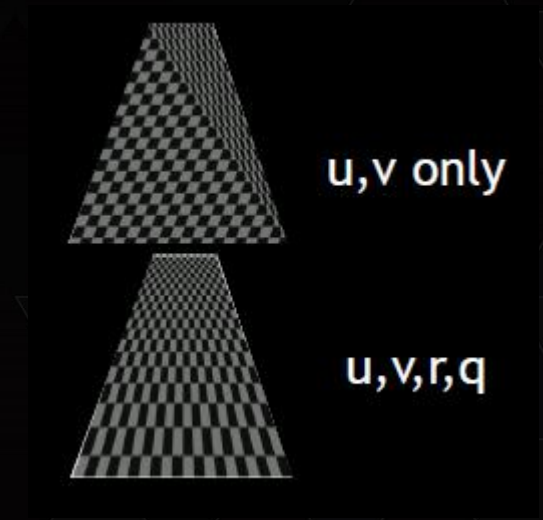
UNDERSTANDING DISPLAY COORDINATES

- NvAPI_GPU_GetScanoutConfigurationEx (displayId, scanInfo)
  - scanInfo.sourceDesktopRect – Sx, Sy, sWidth, sHeight
    - All displayId that are part of MOSAIC grid will return same sourceDesktopRect.
  - scanInfo.sourceViewPortRect – Sx, Sy, sWidth, sHeight
    - *Gives the values related to the Desktop size.*
  - scanInfo.targetViewPortRect – Sx, Sy, sWidth, sHeight
    - *Gives the values related to the physical monitor.*



WARPING DATA STRUCTURE

- NV_SCANOUT_WARPING_DATA
  - VertexFormat : strip or triangle list
  - Vertices: array of 6 float vertex
    - x,y : mesh coordinates per-display rectangle
      - `scanInfo.targetViewPortRect`
    - u,v : texture coordinates in desktop space
      - Co-ordinates from our config file
        - Plus offset from sourceDesktopRect
    - r,q : perspective mapping to simulate 3D warp
  - textureRect
    - Pass in `scanInfo.sourceDesktopRect`

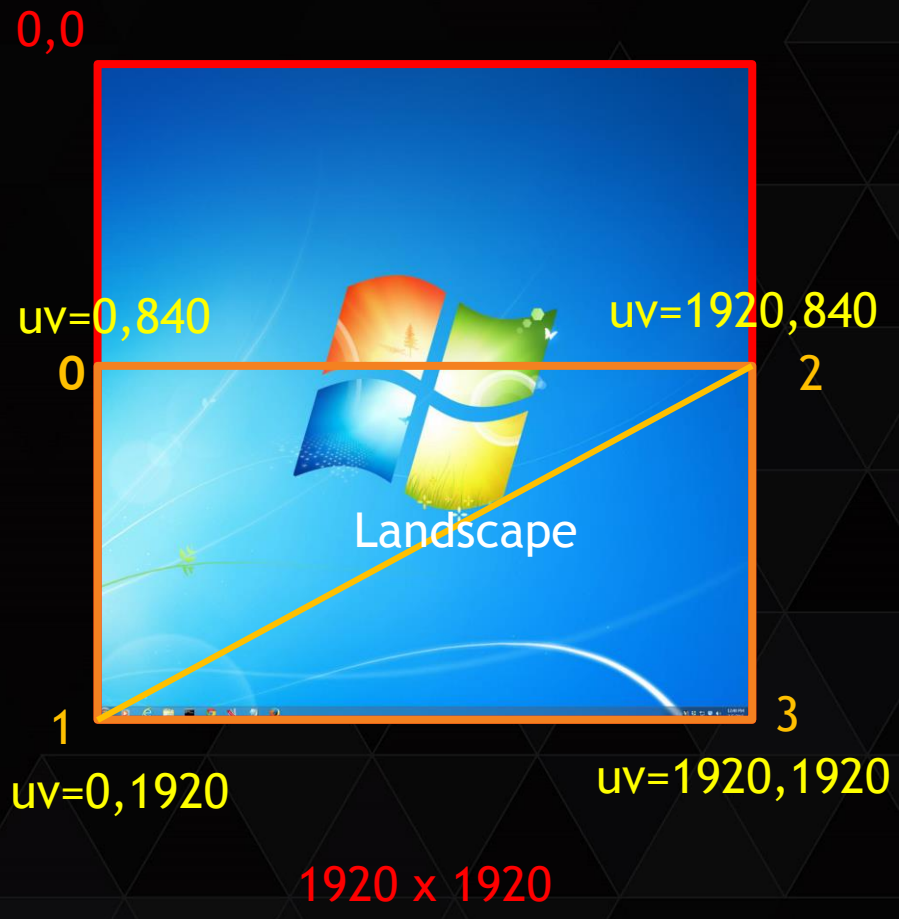


MAP 1920X1920 TO HD DISPLAY

- Sample mapping

```
//x       y     u     v     r     q
{
  0,      0,    0,    840,  0.0f, 1.0f,      // 0
  0,      1080, 0,    1920, 0.0f, 1.0f,      // 1
1920,     0,    1920, 840,  0.0f, 1.0f,      // 2
1920,     1080, 1920, 1920, 0.0f, 1.0f  // 3
};
```

- targetDesktopRect is the monitor – this is physical co-ordinates relative to the top left of the monitor – i.e we can't warp the physical hardware.

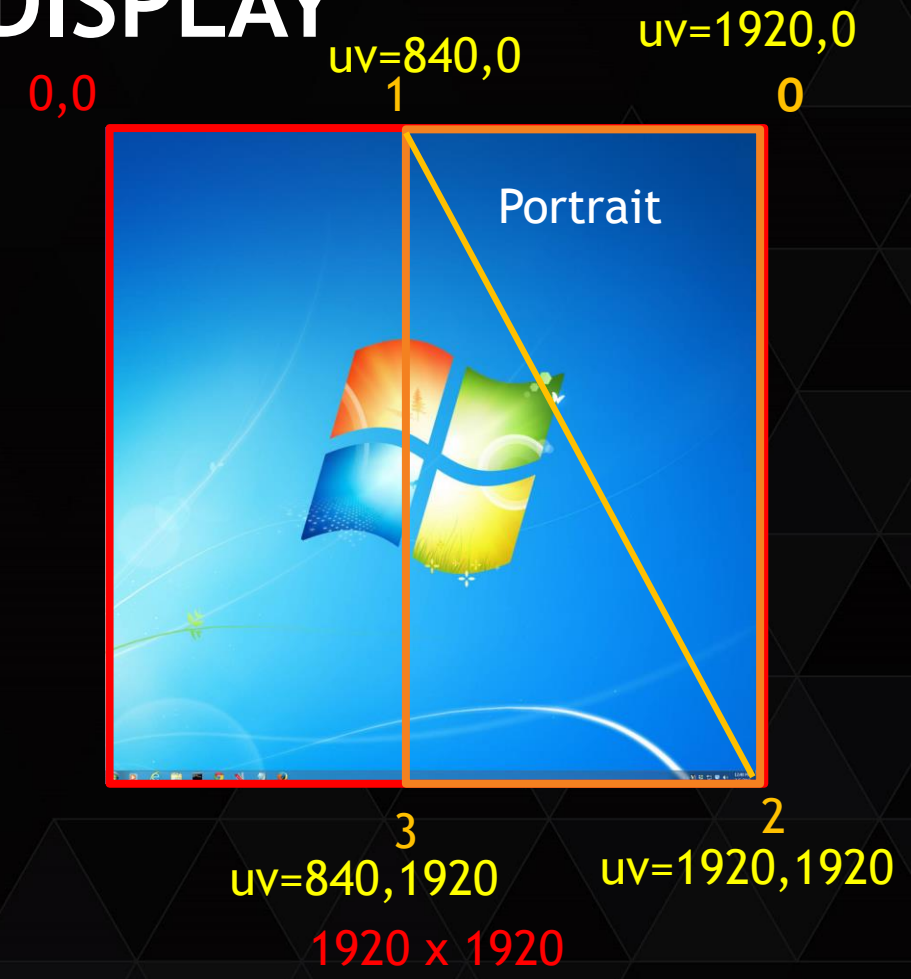


MAP 1920X1920 TO HD DISPLAY

- Sample mapping

```
//x       y     u     v     r     q
{
  0,      0,    1920, 0,    0.0f, 1.0f,     // 0
  0,      1080, 840,   0,   0.0f, 1.0f,     // 1
1920,     0,    1920, 1920, 0.0f, 1.0f,     // 2
1920,     1080, 840,  1920, 0.0f, 1.0f  // 3
};
```

- targetDesktopRect is the monitor – this is physical co-ordinates relative to the top left of the monitor – i.e we can't warp the physical hardware.



PSEUDO CODE

- NvAPI_GPU_GetScanoutConfigurationEx
  - scanInfo.targetViewPortRect
  - scanInfo.SourceDesktopRect
- Set target coordinates
- Set Offset
  - scanInfo.sourceDesktopRect.Sx
  - scanInfo.sourceDesktopRect.Sy
- Apply warp to each display in MOSIAC GRID.
  - Coordinates are read from file.

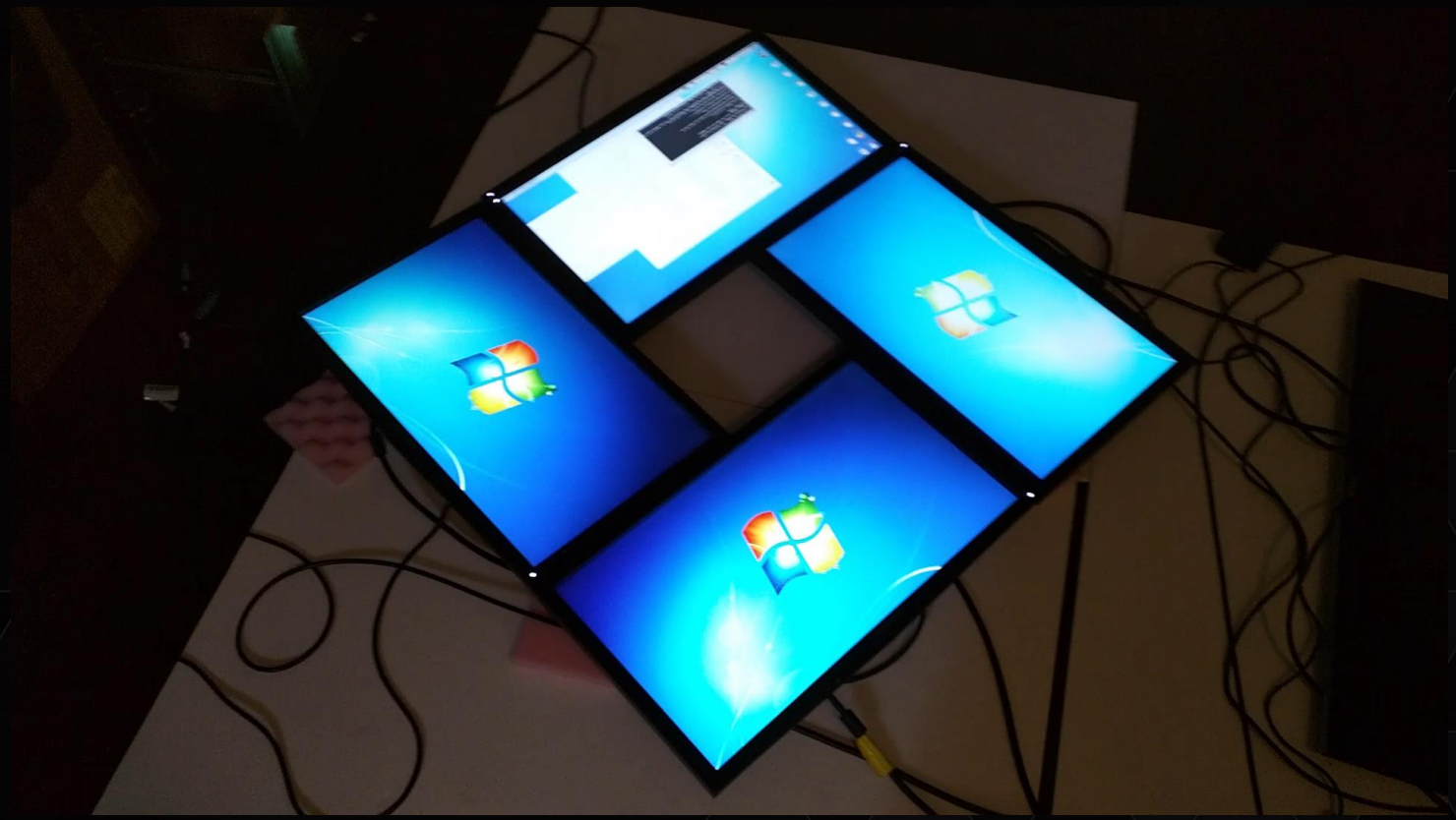
```
for (int i = 0; i < layout.number_displays; i++)
{
topleftSx = layout.displays[i].coords[0].x;
topleftSy = layout.displays[i].coords[0].y;

bottomleftSx = layout.displays[i].coords[1].x;
bottomleftSy = layout.displays[i].coords[1].y;

topRightSx = layout.displays[i].coords[2].x;
topRightSy = layout.displays[i].coords[2].y;

bottomRightSx = layout.displays[i].coords[3].x;
bottomRightSy = layout.displays[i].coords[3].y;

float vertices[] =
//      x y     u          v           r                      q
              {
(float)target[0].x, (float)target[0].y, topleftSx + offsetX, topleftSy + offsetY,
0.0f, 1.0f,     // 0
(float)target[1].x, (float)target[1].y, bottomleftSx + offsetX, bottomleftSy +
offsetY, 0.0f, 1.0f,     // 1
(float)target[2].x, (float)target[2].y, topRightSx + offsetX, topRightSy + offsetY,
0.0f, 1.0f,     // 2
(float)target[3].x, (float)target[3].y, bottomRightSx + offsetX, bottomRightSy +
offsetY, 0.0f, 1.0f,     // 3
              };

int maxnumvert = 4;
warpingData.version = NV_SCANOUT_WARPING_VER;
warpingData.numVertices = maxnumvert;
warpingData.vertexFormat = NV_GPU_WARPING_VERTICE_FORMAT_TRIANGLESTRIP_XYUVRQ;
warpingData.textureRect = &scanInfo.sourceDesktopRect;
warpingData.vertices = vertices;
// This call does the Warp
error = NvAPI_GPU_SetScanoutWarping(layout.displays[i].display_Id, &warpingData,
&maxNumVertices, &sticky);
```

TO DISABLE WARP

- Set Vertices to NULL
- numVertices =0

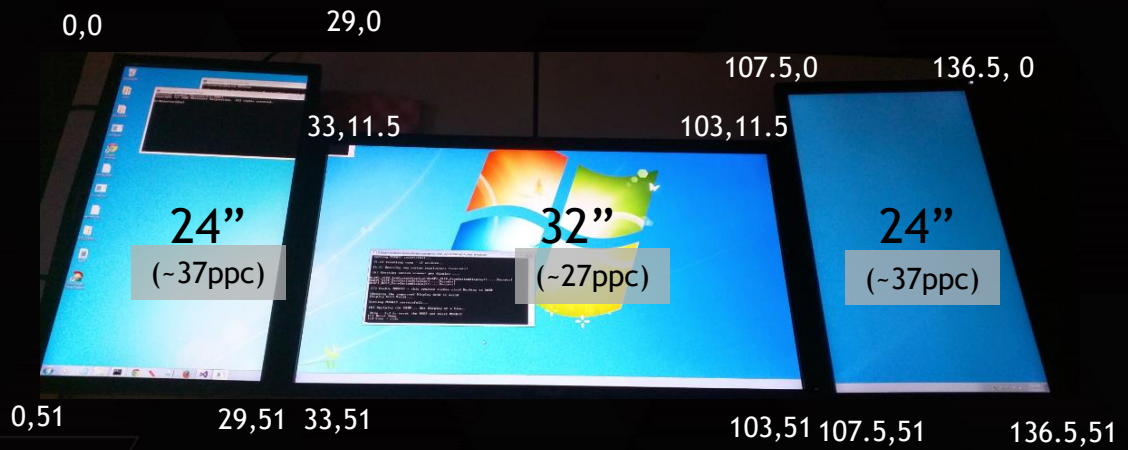
- NvAPI_GPU_SetScanoutWarping

HOW IT LOOKS ON THE DISPLAYS

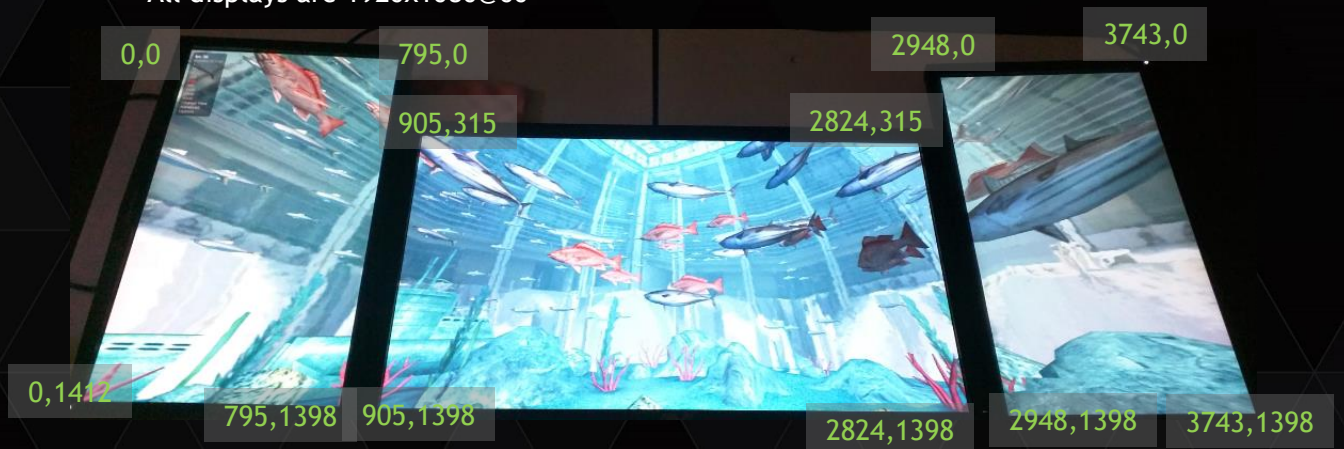


WE CAN PLAY ANY CONTENT

MIXING DISPLAYS OF DIFFERENT SIZES



All displays are 1920x1080@60



- Coordinates in cm (from top left)
- ppc – pixels per cm
- Need to select at common ppc for all displays
  - 32” display – 27.42 ppc

  (this gives 1:1 pixel mapping for 32” display)

- Coordinates in pixels
- based on common ppc

- 1398-315 = 1083 (1080)
- 2824-905 = 1919 (1920)

THIS IS WEBGL EXAMPLE APP

SUMMARY

- MOSAIC + NVAPI WARP
  - Up to 16 displays across 4 GPUS.
  - 16k by 16k resolution
  - Mixed display sizes
- Future enhancements
  - Support for mixed display resolutions.
  - Create a confidence monitor – across multi-GPUS
- Some “features”
  - Hardware cursor was disabled – turn on mouse trails as a workaround.
  - Some custom resolutions failed to be created.
    - My test code tested ~700 custom resolutions in 30sec
    - Compensate with bezel correction.
- Contact us at QuadroSVS@nvidia.com
  - Will make the source code available
  - Need to have access to NDA NVAPI.

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