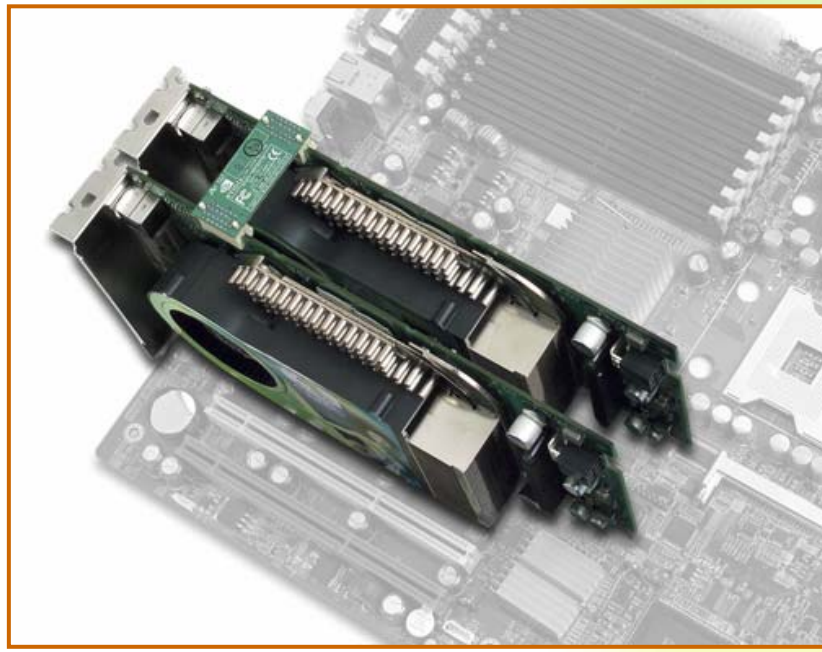
NVIDIA

Matthias M Wloka

NVIDIA Corporation

SLI: Scalable Link Interface

- Plug 2 identical GPUs into PCI-E motherboard
- Driver still reports only one (logical) device
  - Renders up to 1.9x faster
- Video memory does NOT double



Don't Care For High-End Niche Markets

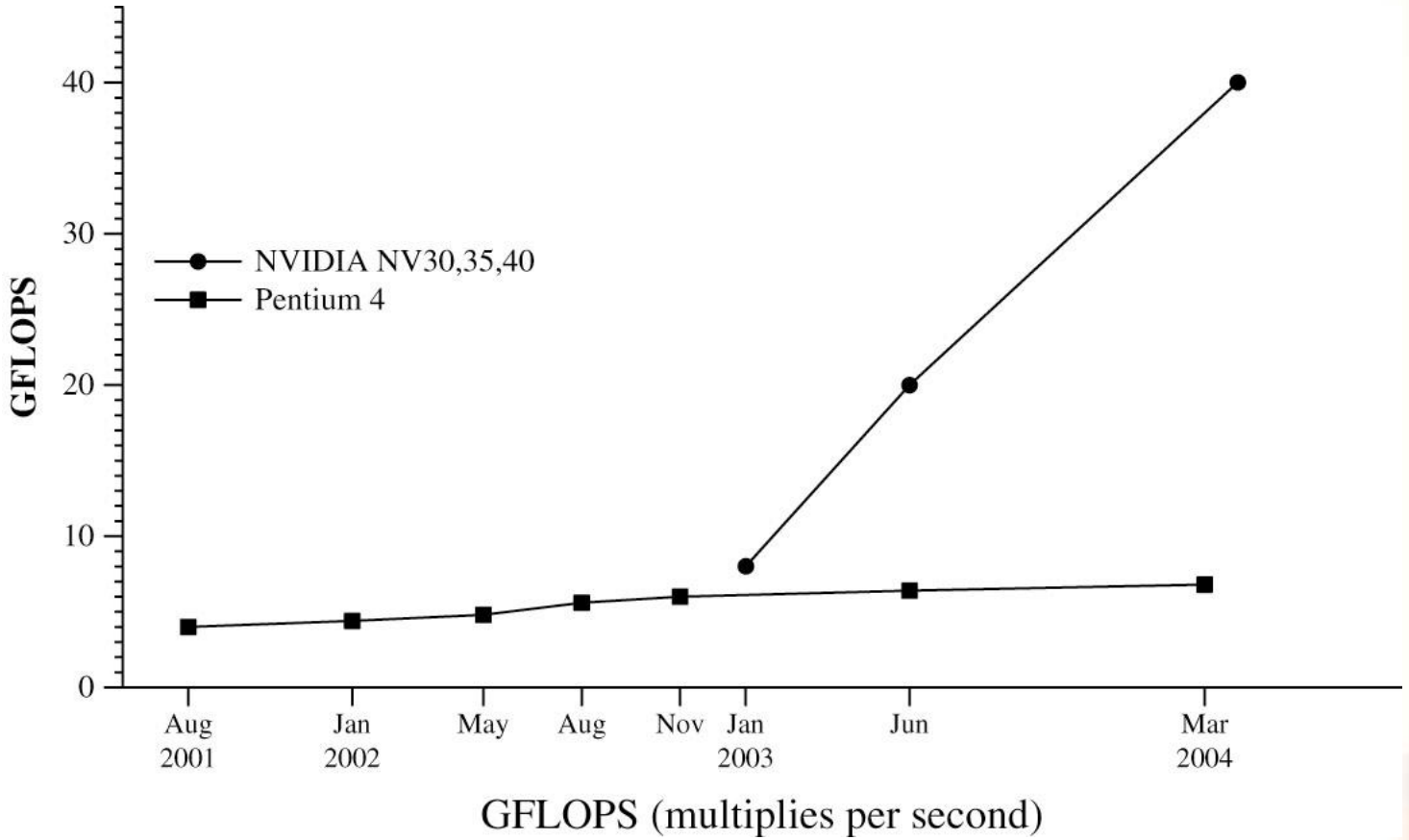
- SLI becoming mainstream:
  - GeForce 6600 GT SLI
  - In addition to 6800 GT and 6800 Ultra
- Dual core boards
  - Gigabyte 3D1: Dual 6600 GT

- SLI motherboards sold to date: > 350,000 units
  - That's > 25% of total nForce 4

Game Development Cycle

- 2 years (or more)
  - CPU performance doubles (or less)
  - GPU performance quadruples
- CPU/GPU balance shifts!
  - Worse: CPU-hungry modules come later: AI, physics, full game play
- SLI hints at future GPU vs. CPU balance
  - For target ‘mainstream’ spec

The Last Couple of Years



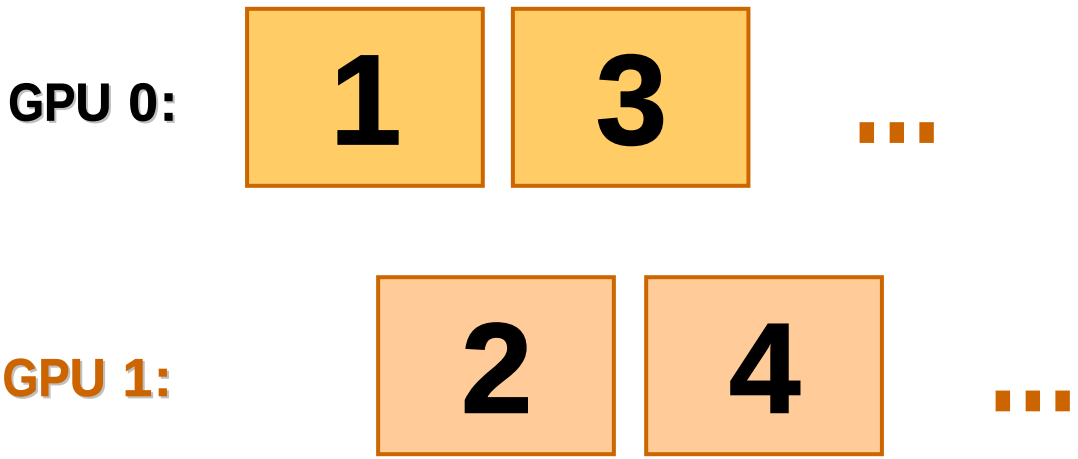
Courtesy Ian Buck, Stanford University

Ok, How Does SLI Work?

- **Compatibility mode:**
  - **Only uses one GPU**
  - **No SLI benefits**
- **Alternate frame rendering (AFR)**
- **Split frame rendering (SFR)**

AFR

- Each GPU works on its own frame



- Scan-out toggles where to read framebuffer from

General Rendering Case for AFR

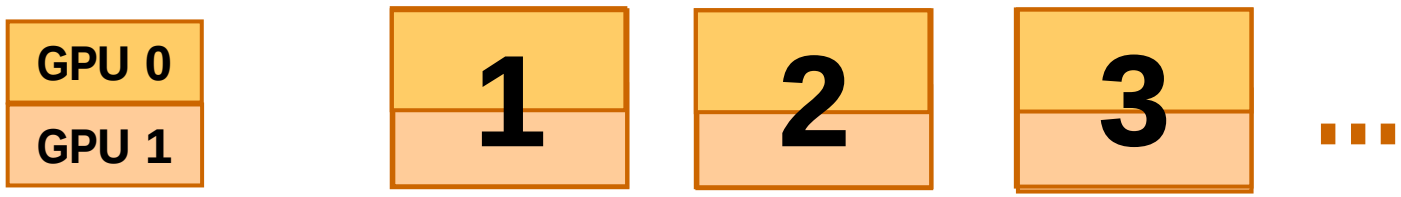
- If frame not self-contained:
  - Push necessary data to other GPU
  - E.g., updating render-to-texture targets only every other frame
- Pushing data to other GPU is overhead
  - Hence not 2x speed-up

AFR Advantages

- All work is parallelized
  - Pixel fill, raster, vertex transform
- Preferred SLI mode
- Works best when frame self-contained
  - No prior work is re-used
  - No communications overhead between GPUs

SFR

- Both GPUs work on the same frame
  - GPU 0 renders top portion
  - GPU 1 renders bottom portion



- Scan-out combines framebuffer data

General Rendering Case for SFR

- Load-balance ‘top’ vs. ‘bottom’
  - If one GPU took longer to render
  - Adjust load accordingly (make it work less)
- Clip vertices to top/bottom portions
  - Avoids both GPUs processing all vertices
  - But not perfect
- Still requires data sharing:
  - E.g., render to texture

SFR Compared to AFR

- SFR works even when limiting number of frames buffered
  - Or when AFR otherwise fails
- In general, SFR has more communications overhead
- Applications with heavy vertex load benefit less from SFR

How Do I Detect SLI Systems?

- **NVCpl API:**
  - **NVIDIA-specific API supported by all NV drivers**
- **Function support for:**
  - **Detecting that NVCpl API is available**
  - **Bus mode (PCI/AGP/PCI-E) and rate (1x-8x)**
  - **Video RAM size**
  - **SLI**

NVCpl API SLI Detection

- SDK sample and full documentation available

```
HINSTANCE hLib = ::LoadLibrary("NVCPL.dll");

NvCplGetDataIntType NvCplGetDataInt;
NvCplGetDataInt =
  (NvCplGetDataIntType)::GetProcAddress(hLib,
                        "NvCplGetDataInt");

long    numSLIGPUs  = 0L;
NvCplGetDataInt(NVCPL_API_NUMBER_OF_SLI_GPUS,
                                &numSLIGPUs);
```

Forcing SLI Support In Your Game

- **Use NVCpl**
  - **NvCplSetDataInt() sets AFR, SFR, Compatibility mode**
  - **See SDK sample**
- **Modify or create a profile:**
  - **http://nzone.com/object/nzone_sli_appprofile.html**
  - **End-users can create profiles as well**

Overview: Things Interfering with SLI

- CPU-bound applications
  - Or vsync enabled
- Limiting number of frames buffered
- Communications overhead

CPU-Bound Applications

- SLI cannot help
- Reduce CPU work or better:
- Move CPU work onto the GPU
  - See http://GPGPU.org
- Don't throttle frame-rate

VSync Enabled

- Throttles frame-rate to monitor refresh
- Enabling triple-buffering does NOT offset enabling vsync:
  - If render-rate faster than monitor refresh,
  - Then vsync still gates GPU
- Worse, triple-buffering
  - Increases lag
  - Consumes (much) more video-memory

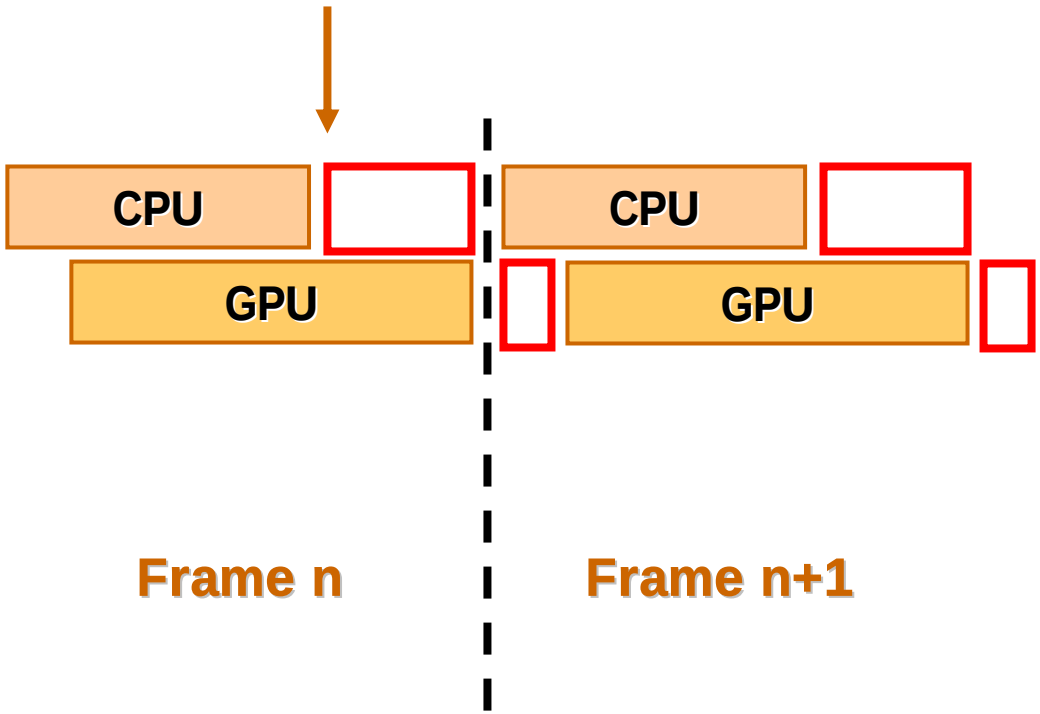
Limiting Number of Frames Buffered

- Some apps allow at most one frame buffered
  - To reduce lag
  - Via event queries
  - Don't lock/read back-buffer: Causes CPU stall!
- Disables AFR SLI speed-up
- But SLI is up to ~1.9x faster
  - I.e., SLI systems ~1.9x less lag

Why Locking the Back-Buffer Is Bad

Back-buffer lock:

wait for GPU to finish rendering



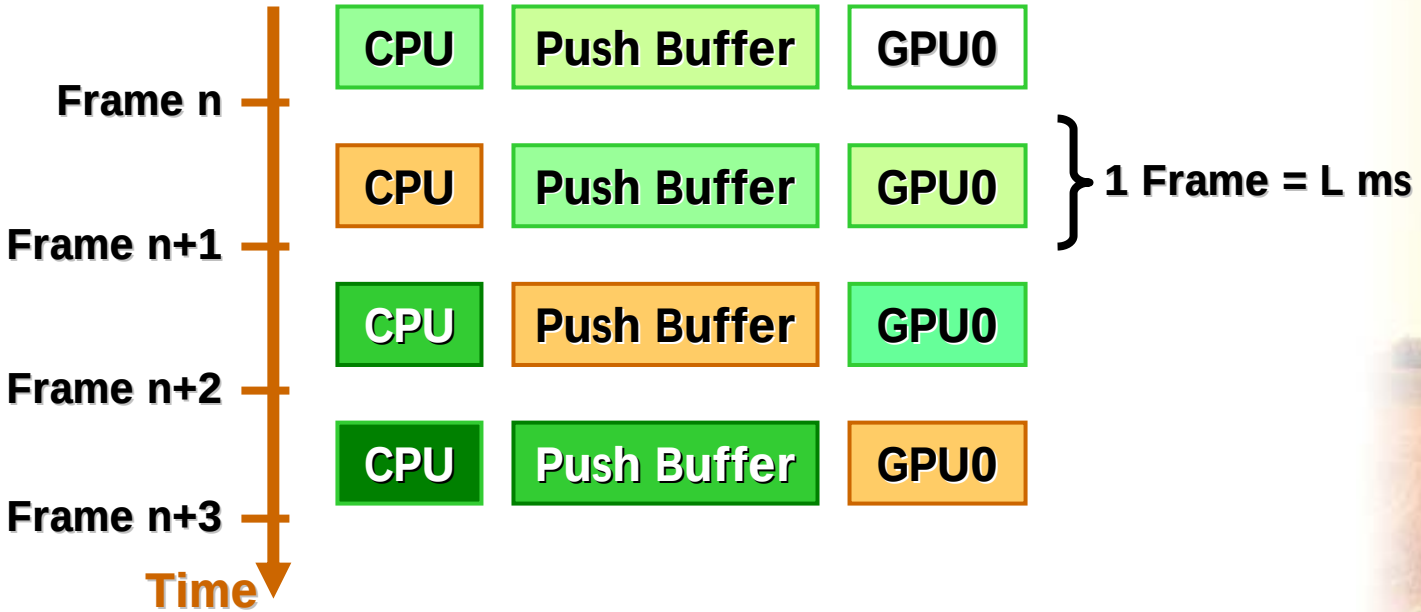
Limit Frames Buffered to Number of GPUs

- **Single GPU system:**
  Buffer at most 1 frame

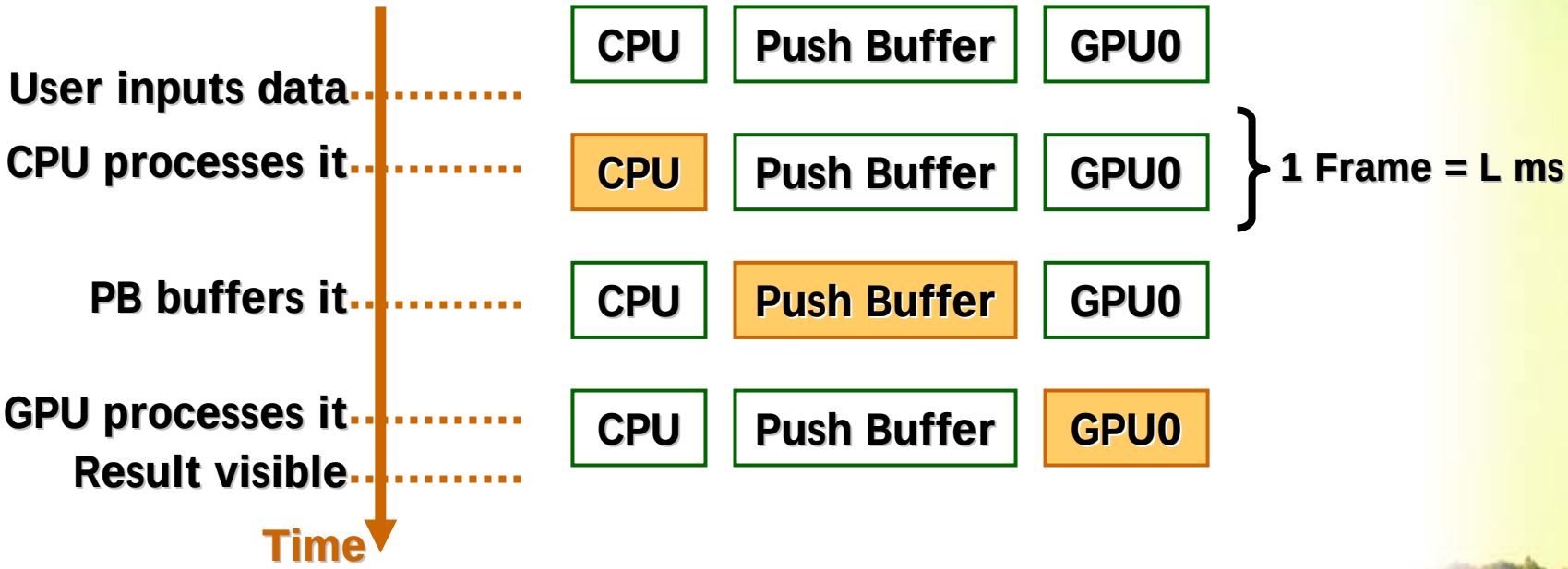
- **When detecting SLI system:**
  Buffer at most 2 frame

The Basic Pipeline

Frames flow through pipe over time:



Single GPU Latency

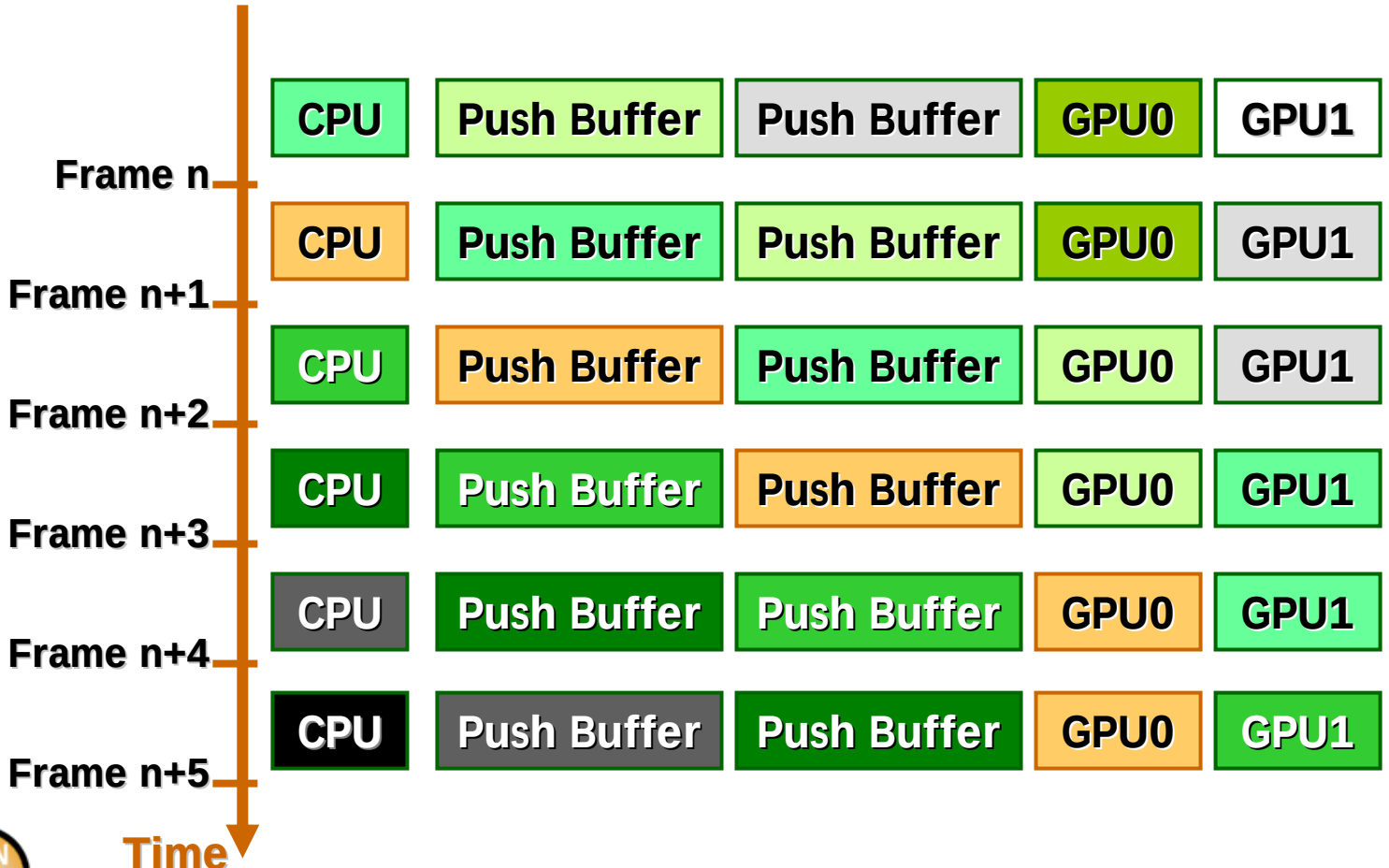


Total latency: 3L ms

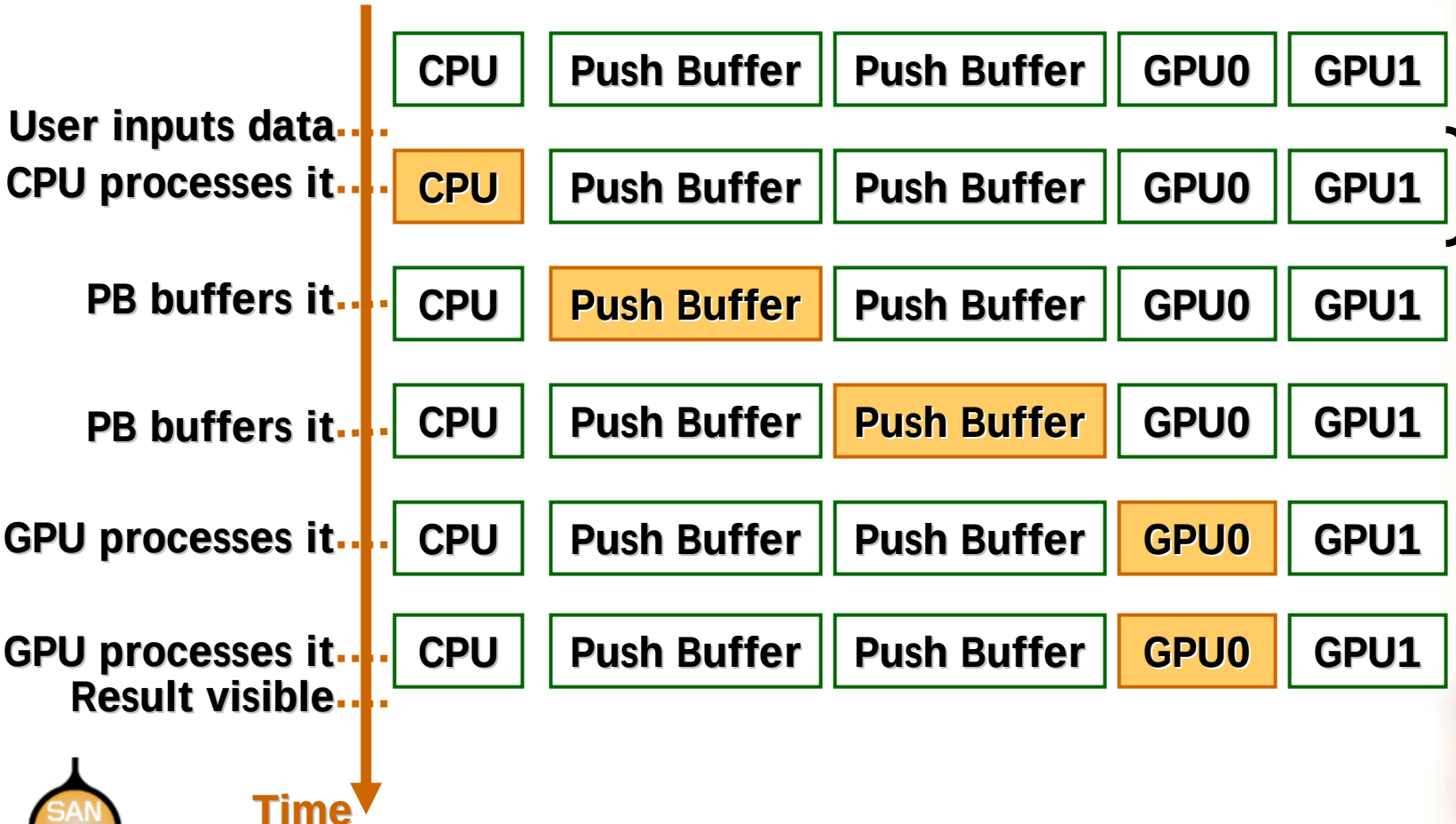
Latency Assumptions

- GPU limited
  - If not, then push buffer contains <1 frame
  - No point in limiting push buffer
- SLI is 2x faster
  - Can relax this later!
- Increase frames buffered to 2:

Frames Flowing Through AFR SLI



AFR SLI Latency



Total latency: 5·L/2 ms

Latency Comparison: Single vs. AFR

- **Single GPU latency: 3L ms**
  - 3 frames of length L ms
- **AFR SLI GPU latency: 5 L/2 = 2.5L ms!**
  - 5 frames of length L/2 ms (i.e., double frame rate)
  - Despite buffering twice as many frames
- **SLI speed-up only needs to be 1.66!**
  - $3L = 5L/x \rightarrow x = 5L/3L = 1.66$
  - Most games speed-up by ~1.8

SFR Latency?

- SFR unaffected by buffering one frame
- SFR speed-up directly reduces lag
  - If SFR 2x faster,
  - Then latency 2x shorter

Even Better: Limit Lag Based on FPS

- If your game runs at over 100 fps
  - Reasonable to buffer 3 frames
- If your game runs at less than 15 fps
  - Only allow one frame to buffer
- Faster SLI system gets automatic benefit
- Our drivers already do that
  - > 15 fps buffer 3 frames as usual
  - < 15fps reduce number of frames buffered

Overview: Things Interfering with SLI

- CPU-bound applications
  - Or vsync enabled
- Limiting number of frames buffered
- **Communications overhead**

Communications Overhead

- Peer to peer SLI memory transfers
  - Transfer itself costs bandwidth and time
  - GPU stalls waiting for transfer to complete
- Or replicate operations on both GPUs
  - For example, render to texture
- Relevant resources:
  - Vertex/index buffers
  - Textures
  - Render targets

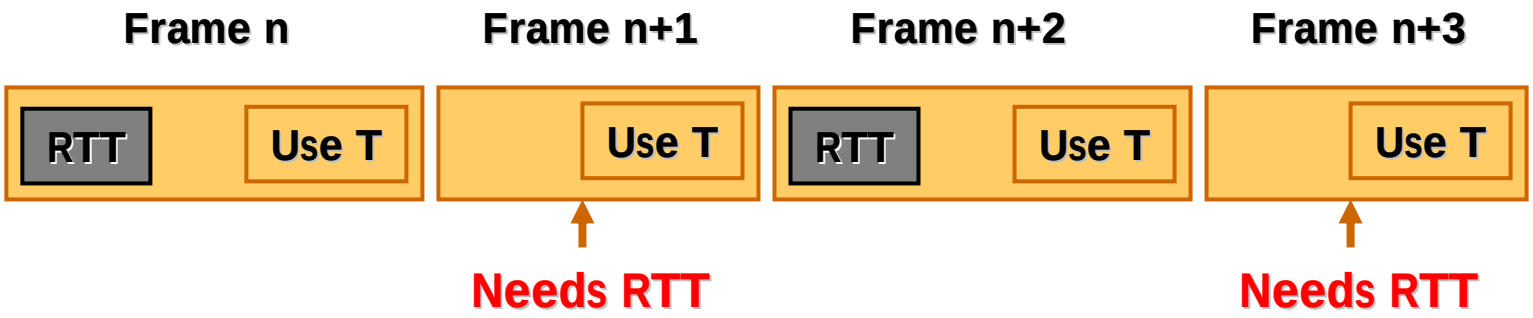
Uploading Resources On the Fly

- Remember video RAM is duplicated
- Need to transfer to both video RAMs
- Not much developers can do to avoid this
  - Oh well

Render Targets

- Clear Z
  - Always clear Z!
- Clear color when detecting SLI
  - Tells driver that the old data is irrelevant
  - No need to transfer old data across GPUs
- Don’t reuse data across frames
  - Make frames self sufficient, i.e., independent from one another

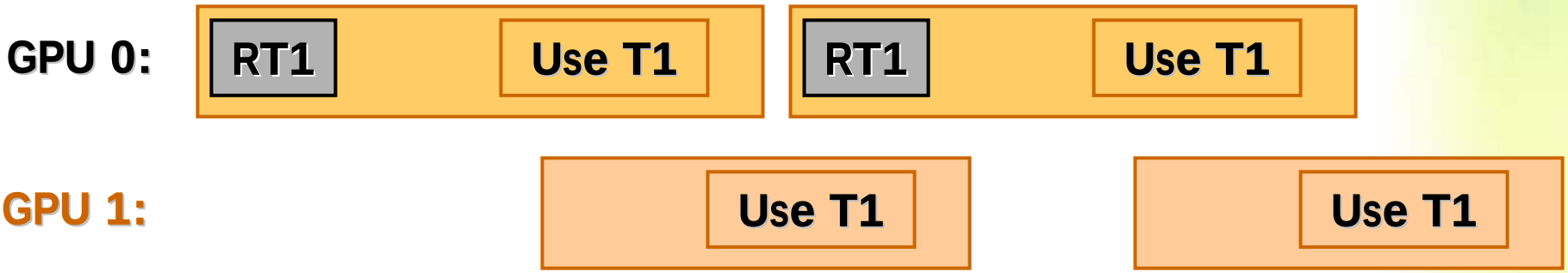
Update-Skipping "Optimization"



- **Added SLI overhead:**

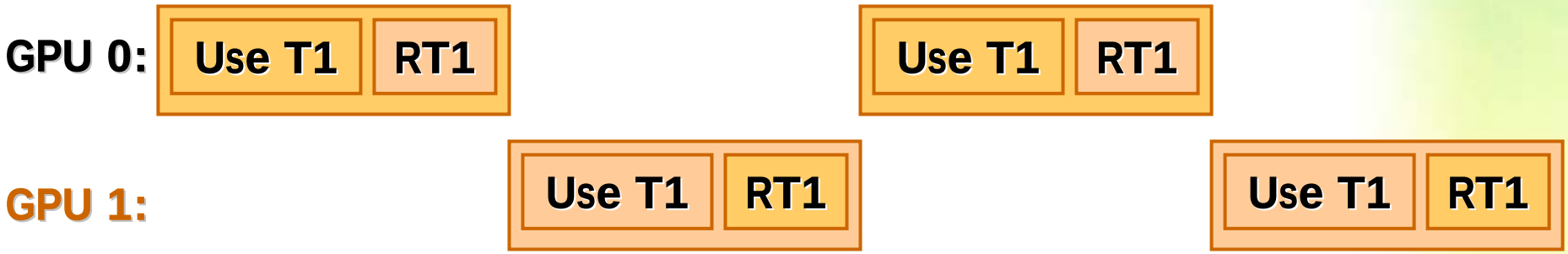
  - GPU 1 stalls until GPU 0 RTT finishes and transfers
  - Or GPU 1 duplicates RTT operation
  - Might as well do right thing when on SLI

Render Early, Use Late!

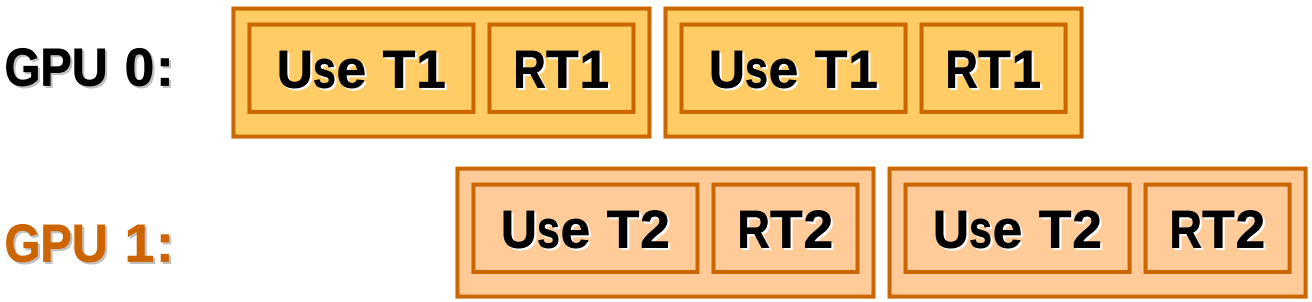


- Avoid sync-stalls
  - In AFR SLI as shown
  - And in single GPU mode
  - But still has communications overhead

Really Bad: Use Early, Render Late



Instead: Ring-buffer textures when on SLI!



SLI Performance Debug Support

- SLI support in NVPerfKit:
  - Pluggable hardware and driver signals for
  - PIX
  - perfmon.exe
  - pdh (your game, VTune…)

- "NVIDIA Performance Analysis Tools"
  Today, 2:30pm - 3:30pm

Supported SLI Performance Signals

- Total SLI peer-to-peer bytes
- Total SLI peer-to-peer transactions

- Above originating from
  - Vertex/index buffers: bytes and transactions
  - Textures: bytes and transactions
  - Render targets: bytes and transactions

Questions?

- GPU Programming Guide, Chapter 8
  http://developer.nvidia.com/object/gpu_programming_guide.html
- http://developer.nvidia.com
  The Source for GPU Programming
- mwloka@nvidia.com
- Slides available online

GPU Gems 2

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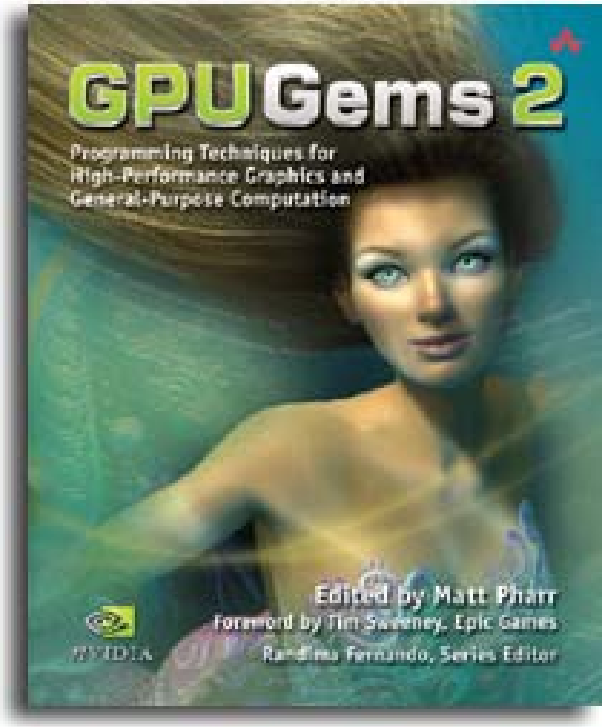

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