

Ultra Low Latency Dataflow Renderer

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Motivation for Low Latency in Virtual Reality

Latency is the delay between a user's input, and a computer's response to this input

- Virtual Reality (VR) is confounded by latency
- Virtual Environments (VEs) emulate physical systems
- Users of VEs expect them to respond accordingly
- When a VE's reactions are delayed:
 - The illusion is destroyed
 - User behaviour deteriorates¹

Computer systems have unavoidable latencies that must be compensated for

- Graphics Processing Units (GPUs) provide high throughput, but their architecture suits only a small subset of rendering techniques
- Dataflow Computing provides new opportunities for low latency algorithms designed for VR

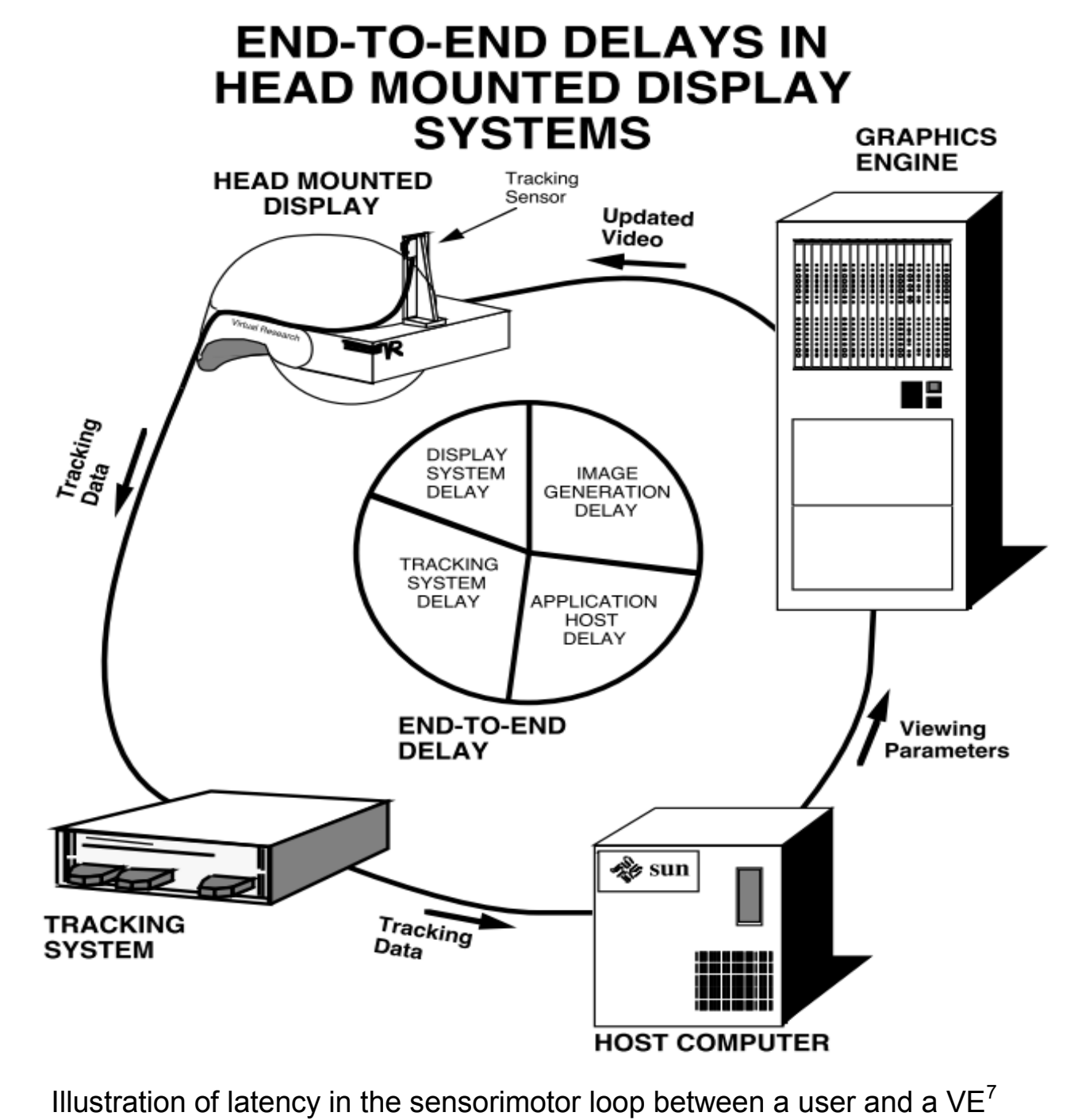
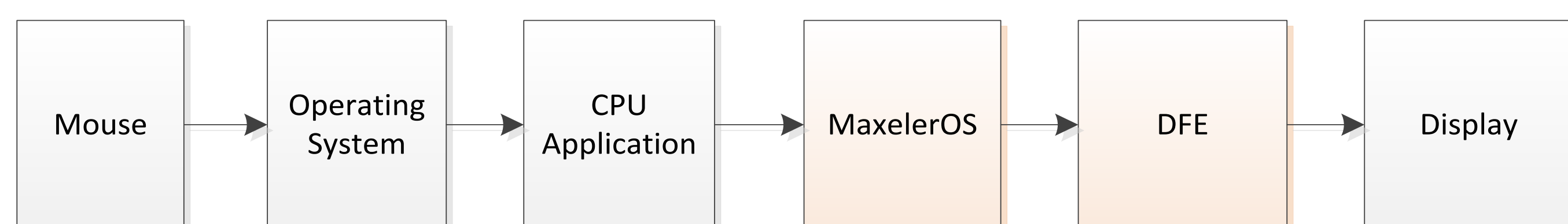
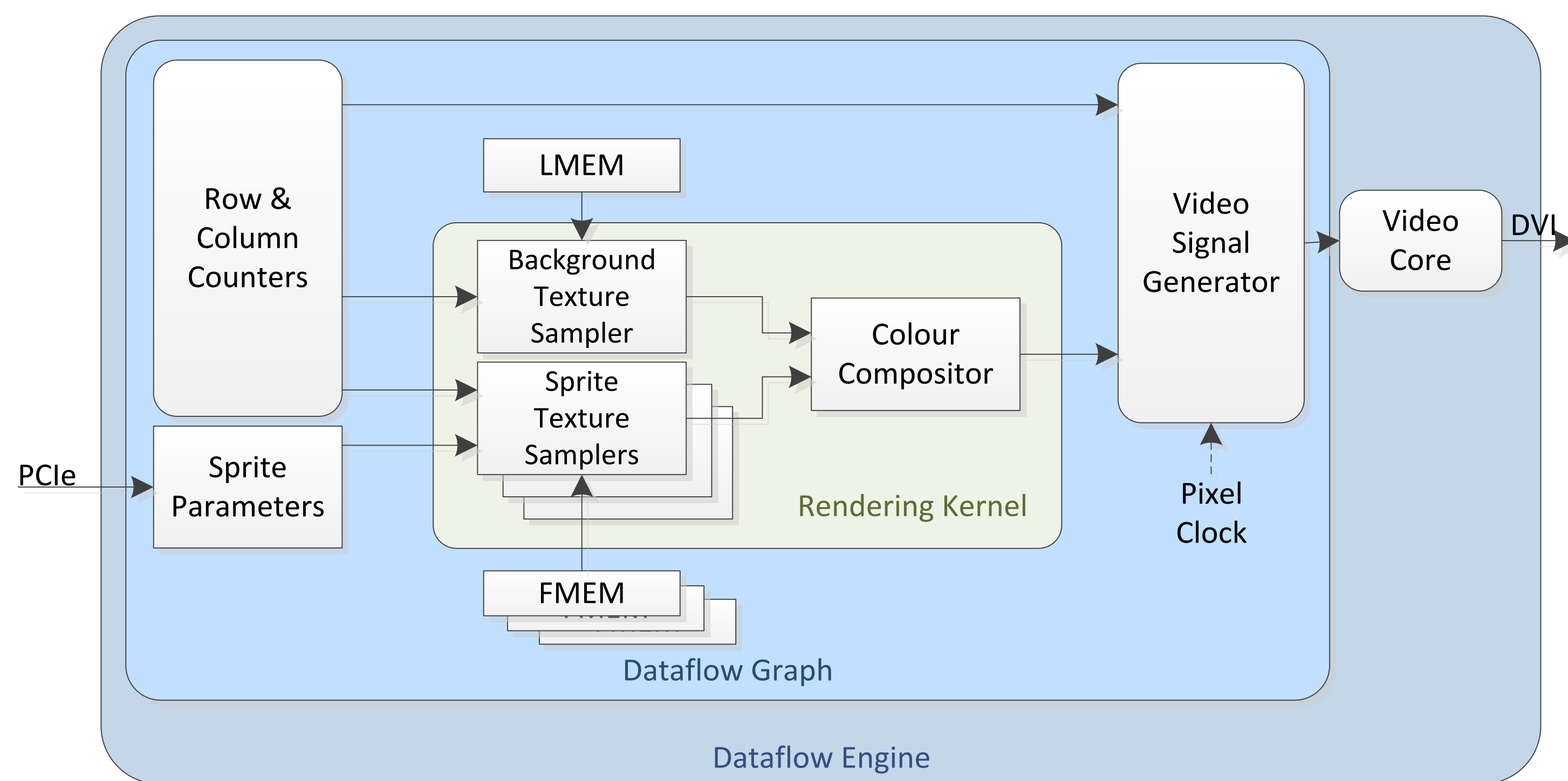


Illustration of latency in the sensorimotor loop between a user and a VE⁷



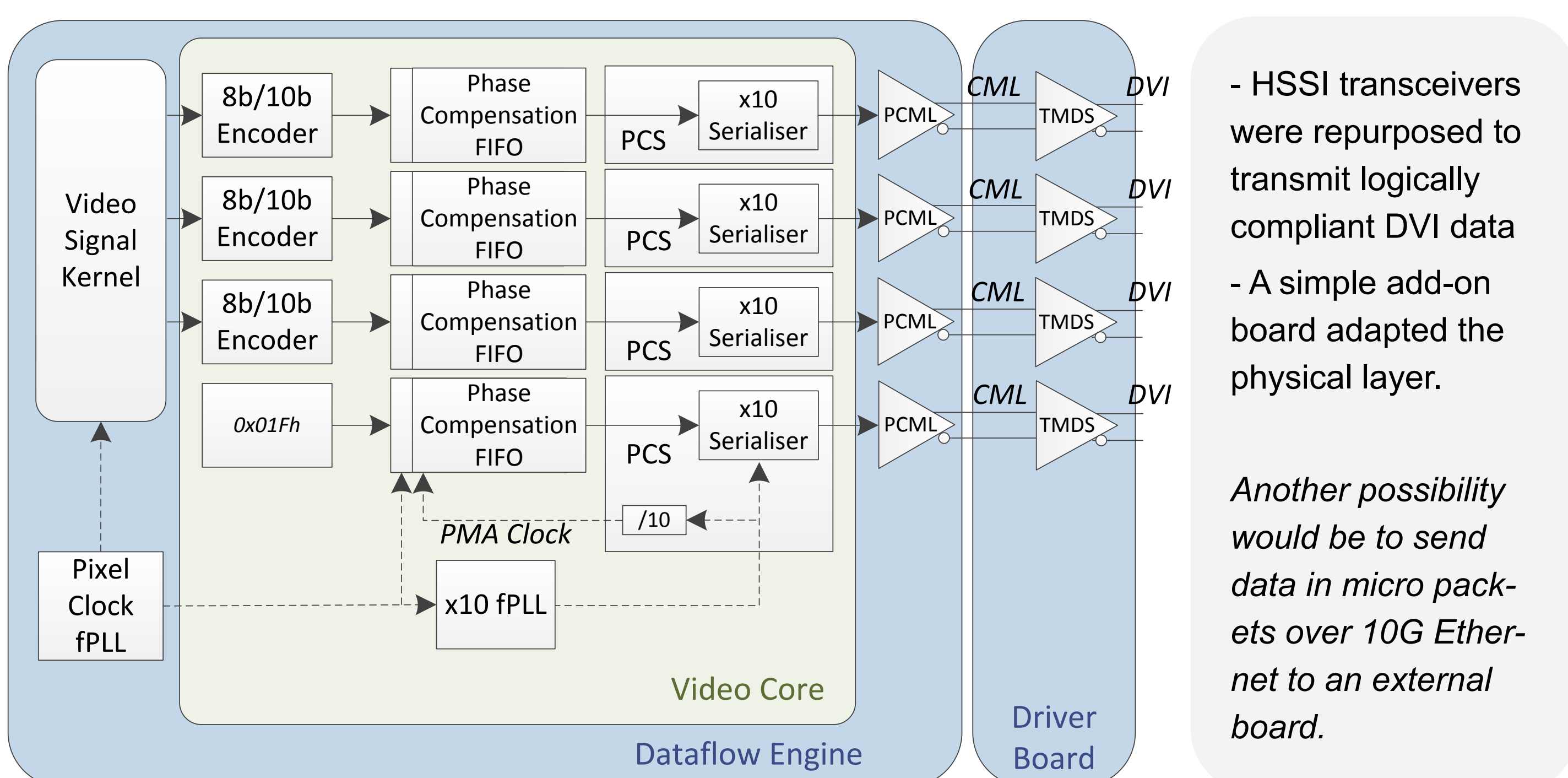
Ultra Low Latency Dataflow Renderer

We constructed a Dataflow Engine (DFE) based renderer with ultra low latency

- Pixel values are computed atomically just in time that results in:
 - 1 ms for the renderer
 - 6 ms for the entire apparatus (predominantly the scan-out time of the display)

Mouse	Operating System	CPU Application	MaxelerOS	PCle	DFE	Display
			Operating System	Parallel Port		
1 ms			< 1ms		5 ms	

- We achieve one of the lowest latency systems reported
- Comparable systems, e.g. Jota et al², typically use novel display technologies such as DMDs with a tight coupling between the renderer and the display
- Our renderer took the place of a typical GPU and directly drove a full HD display
- DFEs integrate well into the host system allowing maximal reuse of existing libraries and components

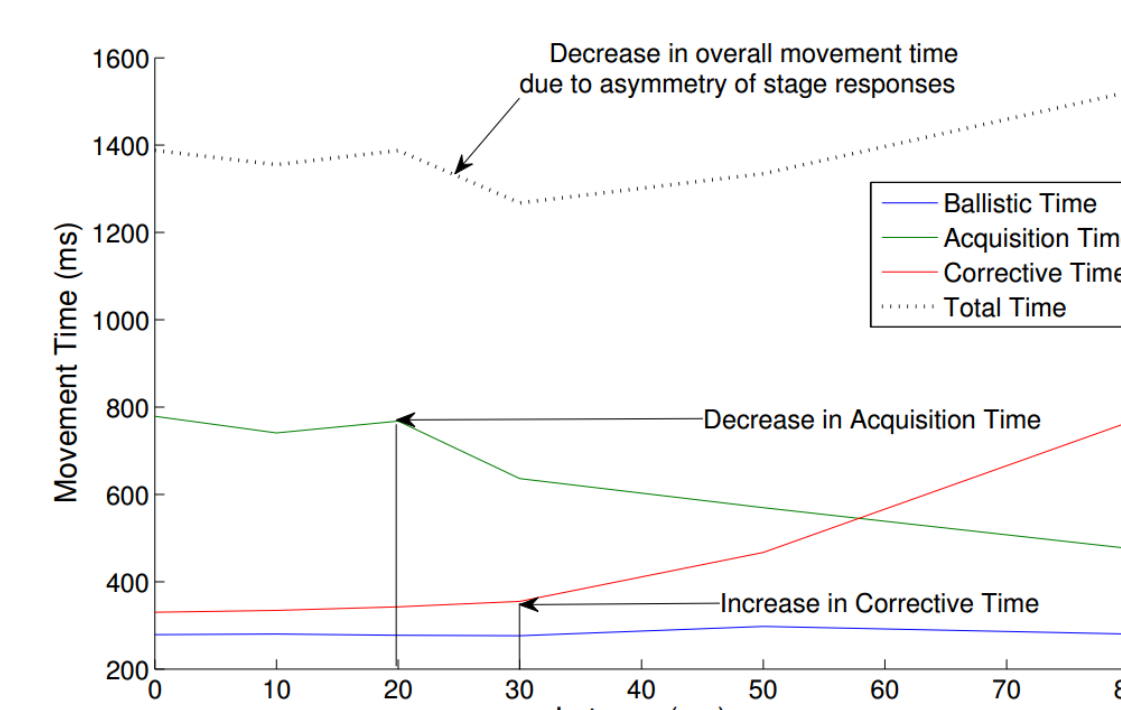


- HSSI transceivers were repurposed to transmit logically compliant DVI data
- A simple add-on board adapted the physical layer.

Another possibility would be to send data in micro packets over 10G Ethernet to an external board.

The Effects of Low Latency on Pointing and Steering Tasks

We conducted a study: *The Effects of Low Latency on Pointing and Steering Tasks*⁶. In this study users completed simple tasks requiring high dexterity on a typical LCD.



Latency had a non-linear effect on the human motor system. This has significant implications for researchers conducting user performance tests.

Future Work

The Effects of Low Latency on Presence in Virtual Reality

A real-time ray casting renderer is already implemented

- It can render a 3D virtual environment within a head mounted display without approximations.

We aim to re-create the pit-room experiment performed at SIGGRAPH 2002³:

- Users will be put in a stressful virtual environment while physiological cues are measured
- The stronger the reaction, the more believable the environment is



Images: (Left) The current state of our environment, rendered with our real-time ray caster. (Right) The VE from the original 2002 experiment³.

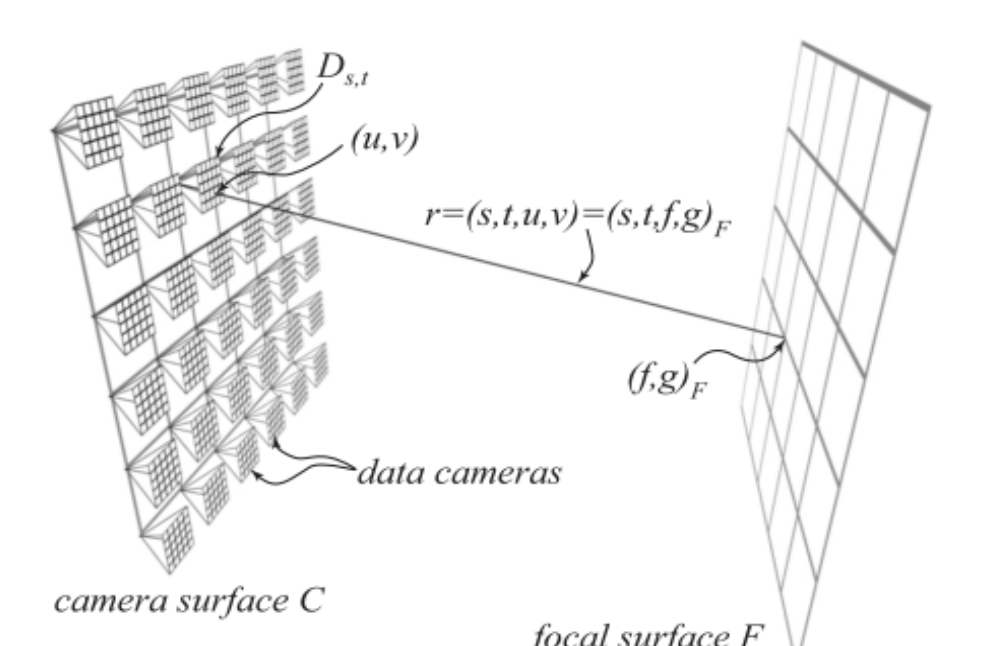
Our real-time ray caster can be seen on Demo Night, Wednesday 2nd

Light Field Rendering

We will extend our ray caster to render from light fields

- Light fields take a long time to synthesise
- But sampling is a straightforward, highly localised operation
- This will enable the ultimate combination of low latency and high fidelity
- Hardware light field renderers have been built before⁴
 - But were limited by memory technology

We aim for a system capable of displaying a large, highly detailed virtual environment.



Images: (Top) Image of Regan et al's hardware light field renderer in use. It had a latency of microseconds⁴. (Bottom) Diagram of one possible light field parameterisation. This shows a view plane, each point containing a set of views of the destination point for all view directions⁵.

References

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