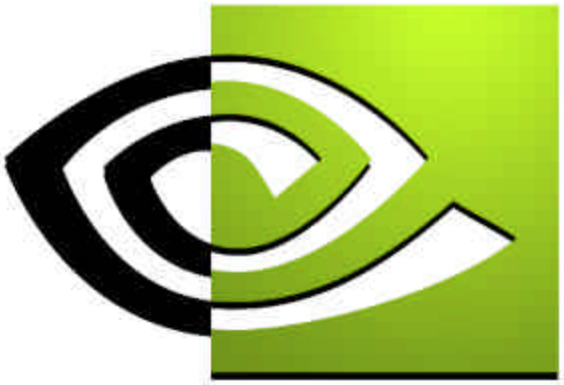
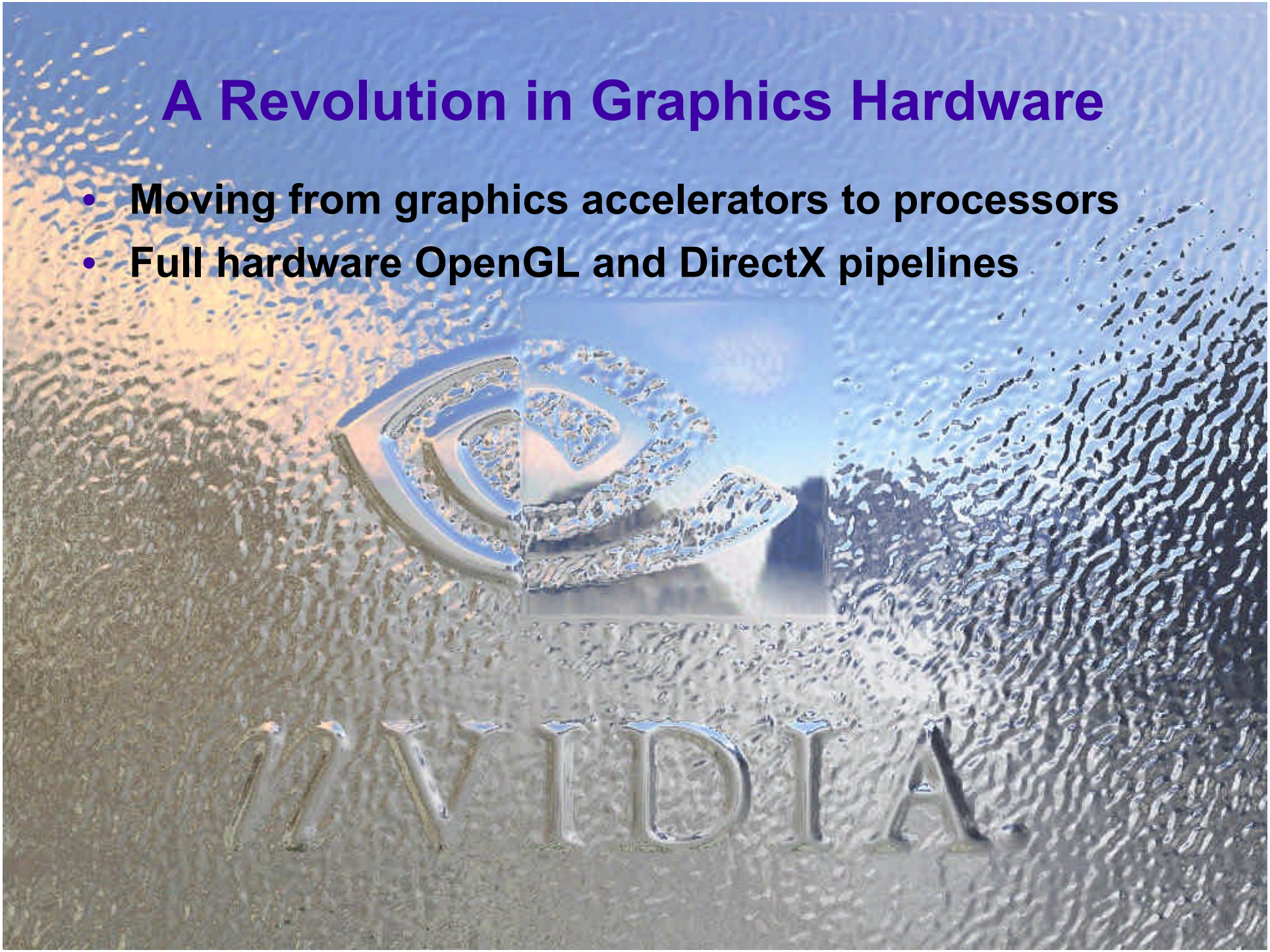


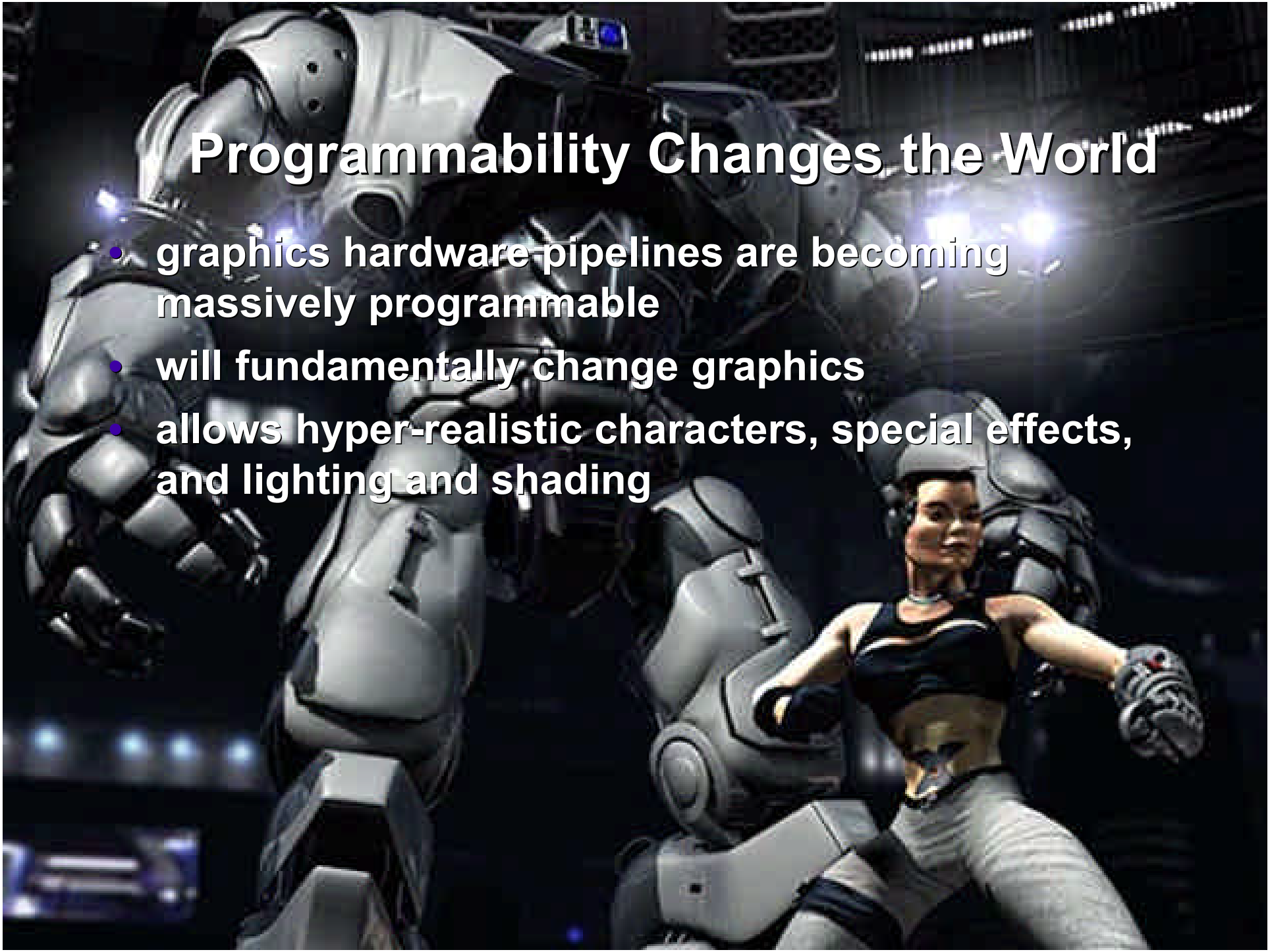
NVIDIA™

Programmability - a New Frontier in Graphics Hardware

A Revolution in Graphics Hardware

- Moving from graphics accelerators to processors
- Full hardware OpenGL and DirectX pipelines





Programmability Changes the World

- graphics hardware pipelines are becoming massively programmable
- will fundamentally change graphics
- allows hyper-realistic characters, special effects, and lighting and shading

3D Graphics is about

- Animated films (Bug's Life, Toy Story, etc.)
- Special Effects in live action movies (The Matrix)
- Interactive Entertainment (Video games)
- Computer Models of real world objects
  - Or, objects that haven't been invented yet

- Making reality more fantastic
- Making fantasies seem real

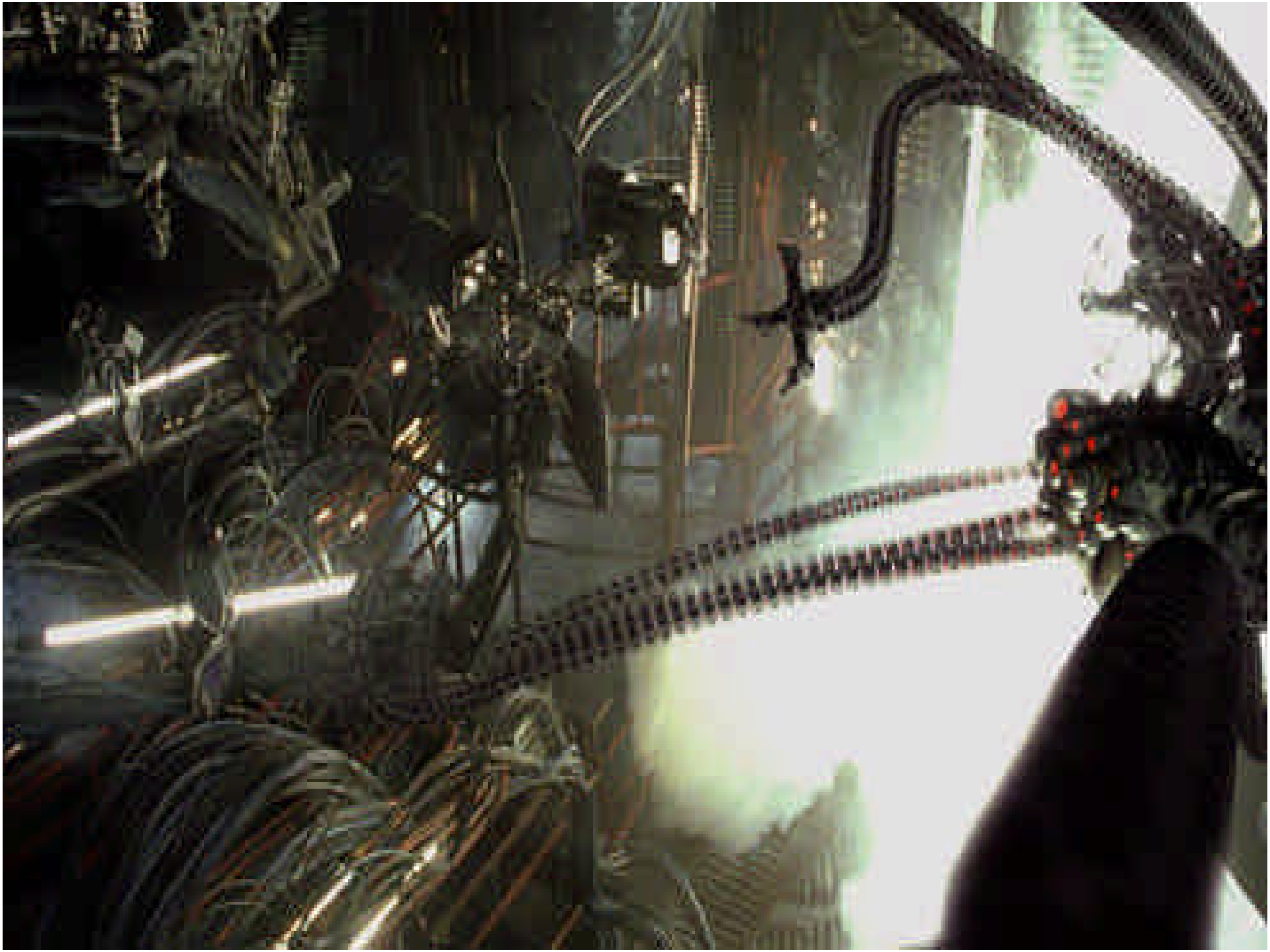
NVIDIA.


LIGHTYEAR

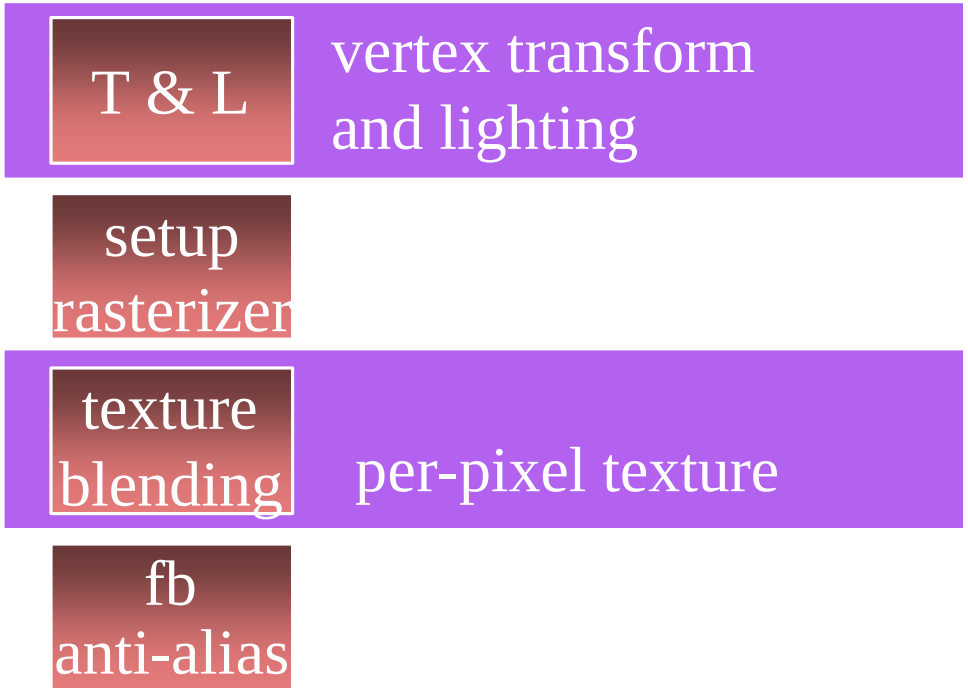
Why are Movie Special Effects Exciting and Interesting?

- Suspension of Disbelief
  - Something amazing is happening
  - But, you believe it, because it is “real”
- Realistic and detailed characters
  - Motion, and emotion
- Realistic and recognizable materials
  - Chrome looks like chrome
  - Skin looks like skin
- Action!

NVIDIA.



The Year 2000 Graphics Pipeline



NVIDIA

Pixar's Geri – A Believable Old Man

- Not a real person
- Geri is built from Curved Surfaces
- Curved surfaces are broken down into triangles
- Each triangle is transformed into position
- Each pixel in each triangle is shaded
- Every frame
  - 24 (movie) or 60 (PC) times per second

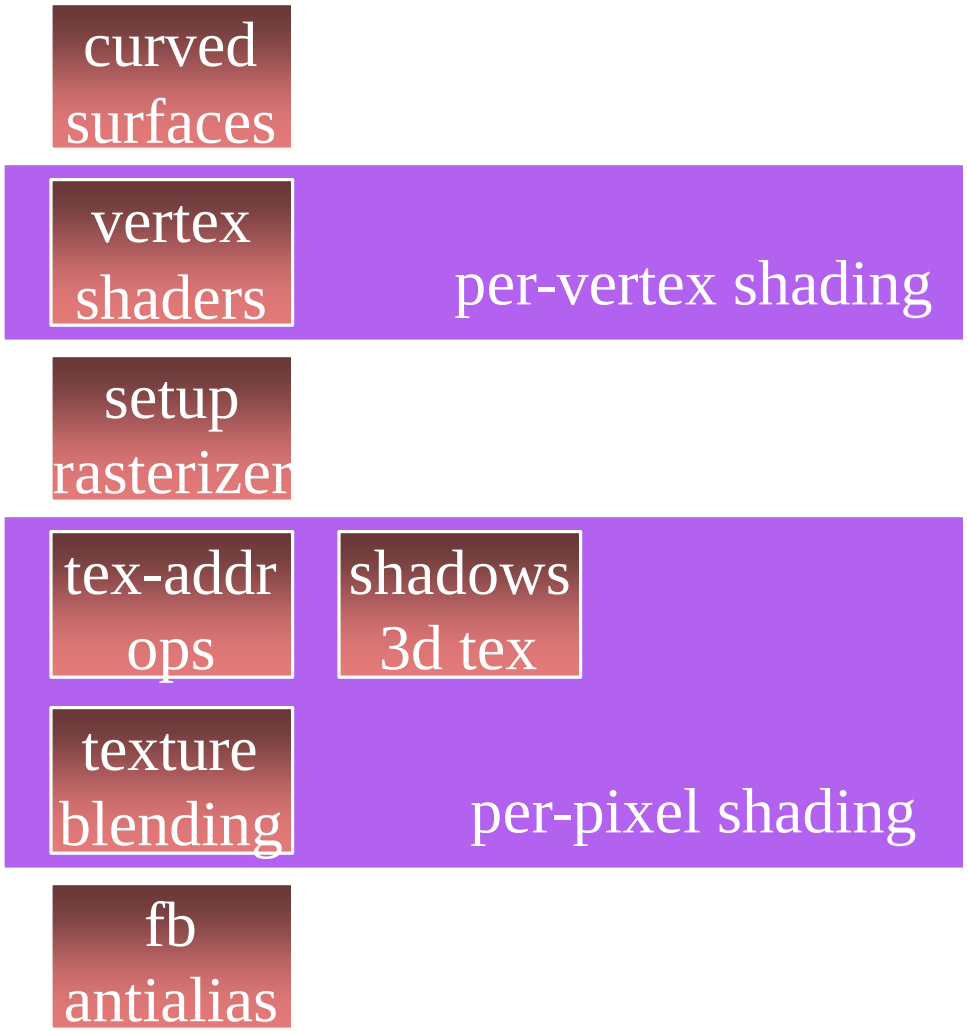
NVIDIA.

3D Movie Special Effects Come to PC and Console Graphics

- Lots of Geometry – lots of stuff going on
  - Geforce does this – hardware Transform & Lighting
  - The next generation makes the pipeline programmable
- Lots of Lighting and Shading
  - Geforce (year 2000)
    - Hardwired vertex lighting
    - Little “shader programs” run for every pixel
  - Taking Shading to the next level (year 2001)
    - Powerful “vertex programs” run for every vertex
    - Powerful “shader programs” run for every pixel

NVIDIA.

The Year 2001 Graphics Pipeline

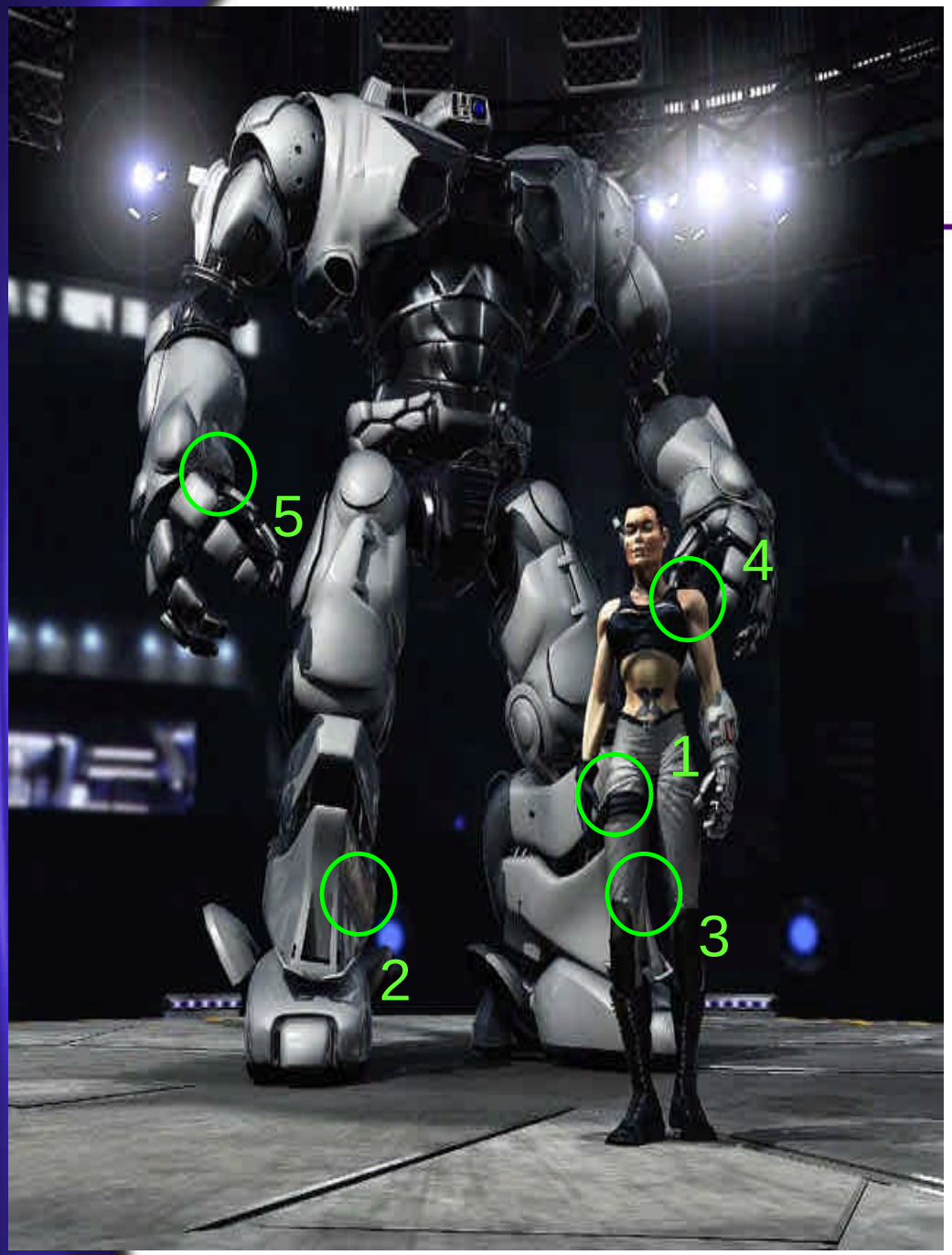


NVIDIA

Microsoft *xbox Powered by NVIDIA*

- **Next-Generation GPU from NVIDIA**
  - 10X Graphics performance Playstation2
  - World's First Tera-Op Processor
    - Over one Trillion Operations Per Second (1.2TOPS)
  - World's first Programmable Shading Engine
- **NVIDIA Custom Media/Communication Processor**
  - Broadband
  - Unparalleled 3D Audio Capabilities
- **Additional features include:**
  - 733MHz x86 compatible CPU
  - 64MB of RAM (Unified memory architecture)
  - 8GB hard drive
  - 4X DVD drive with movie playback
  - Four game controller ports
  - Expansion port

NVIDIA.



Effects Explained

- (1) Shadows
  - Raven's arm casts a shadow on her body
- (2) Reflections
  - Robot reflects Raven and the world
- (3) Lighting, shading and materials
  - Raven's clothing looks like cloth with wrinkles and shape
- (4) Programmable Vertex Shading
  - Raven's arms and body bend smoothly, like real arms
- (5) Anti-aliasing
  - Edges are smooth, not jagged

NVIDIA.

Programmable Vertex Processing

- GeForce family introduced hardware T&L to the PC
  - Transform and Lighting
- Next generation makes T&L user programmable
  - Vertex programs
- Developers can write custom
  - Vertex Transformation
  - Vertex Lighting
  - Special effects (layered fog, volumetric lighting, morphing…)

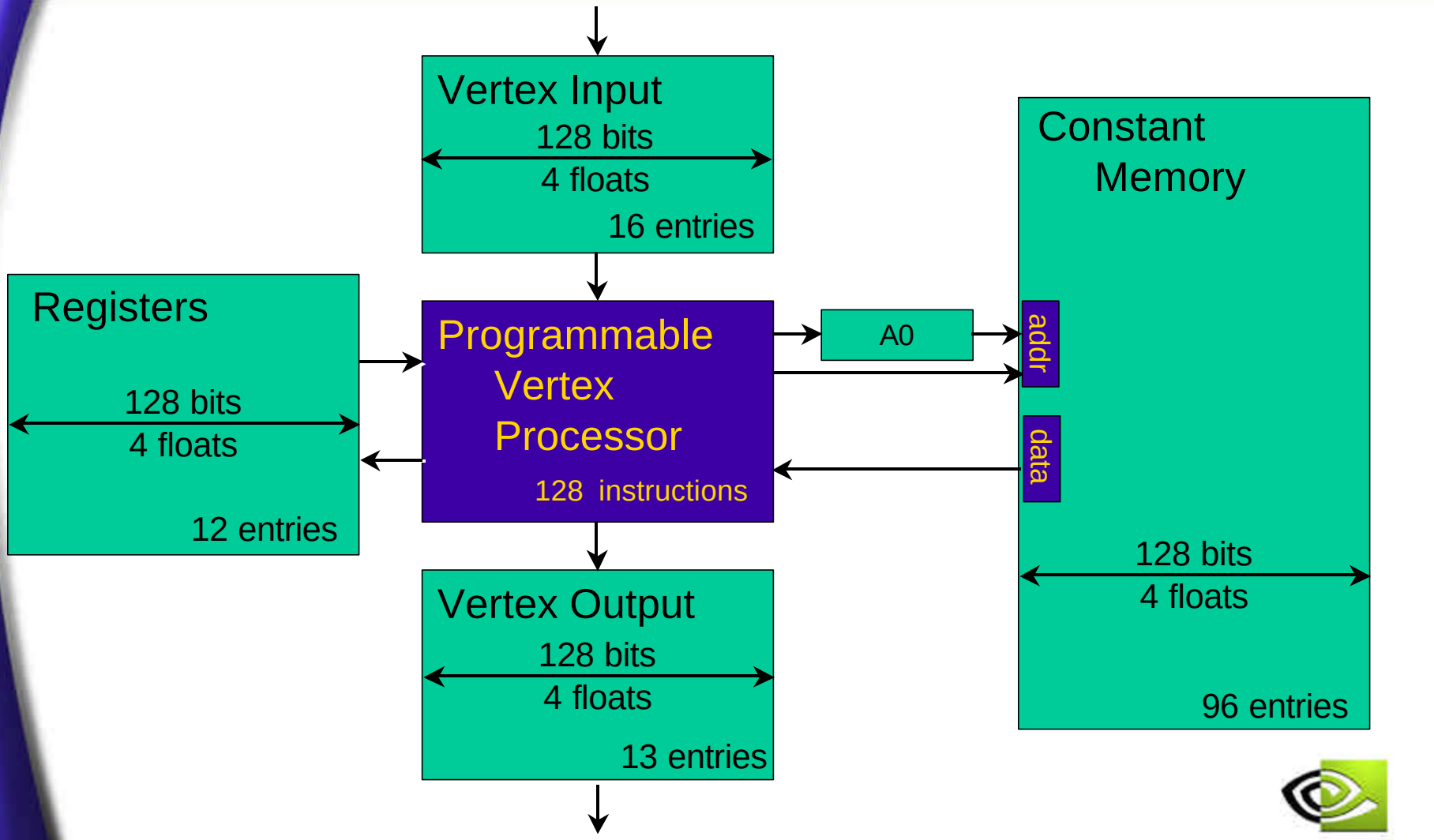
NVIDIA.

Developers Have Been Asking For…

- Complete control of the transformation and lighting hardware
- Complex vertex operations performed in hardware
- Custom vertex lighting
- Custom skinning and blending
- Custom texgen
- Custom texture matrix operations
- <your request goes here>

NVIDIA.

Custom Substitute for Standard T&L



NVIDIA.

What does it do?

- Per *vertex* calculation
- Processing of:
  - Colors – true color, pseudo color
  - 3D coordinates - procedural geometry, blending, morphing, deformations
  - Texture coordinates – texgens, set up for pixel shaders, tangent space bumpmap setup
  - Fog – elevation based, volume based
  - Point size
- Vertex program accepts one input vertex, generates one output vertex

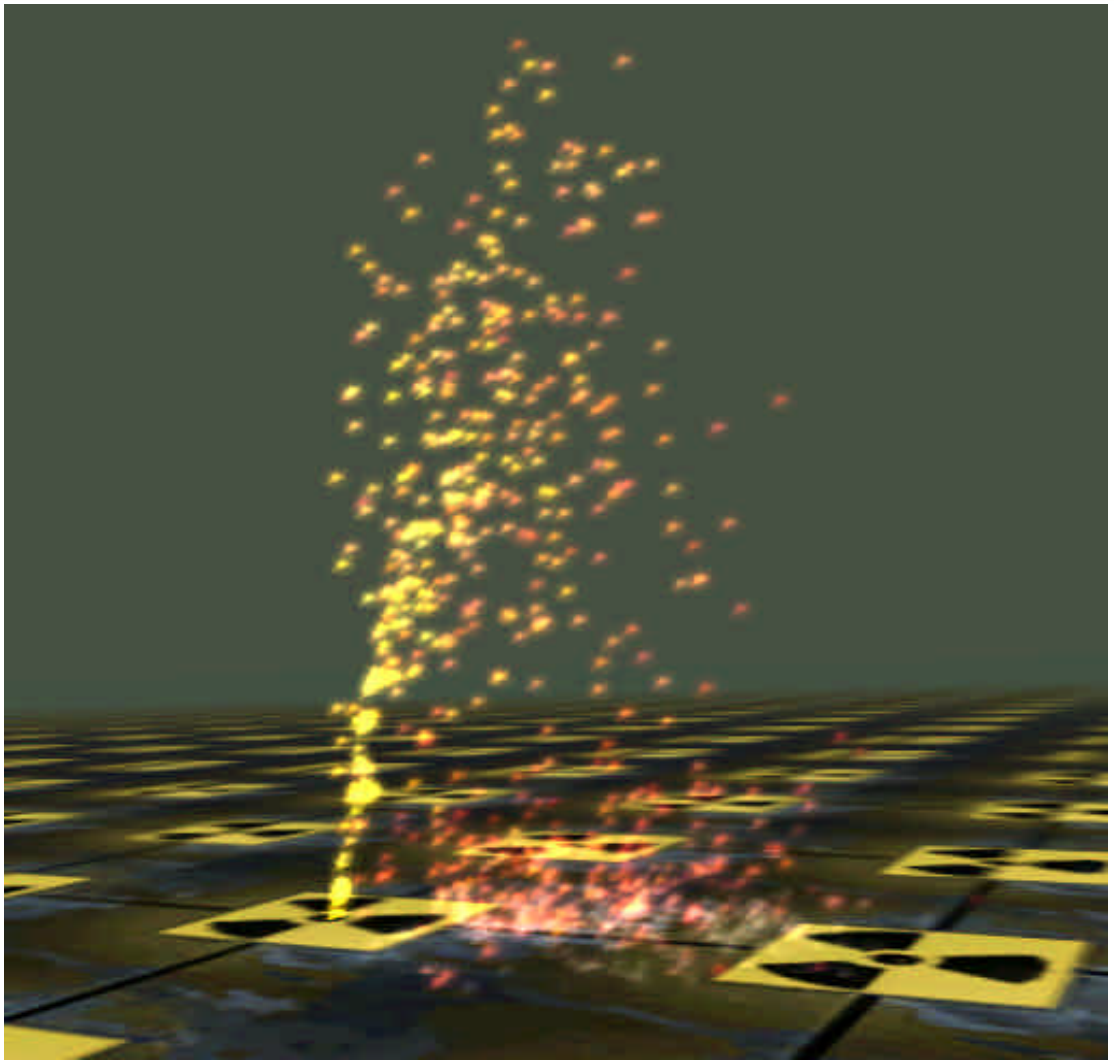
NVIDIA.

Plus: Novel Effects… (Demos Later!)

- Irregular view transformation
  - Fish-Eye lens, …
- Novel texture coordinate calculations
  - Projected textures
- Paletted skinning with 20 or more bones!
  - Now you can be much more efficient than with DirectX7™
- Geometry morphing
  - Blending multiple meshes
- Procedural Geometry Deformations

NVIDIA.

Vertex Programs
Physics on the GPU

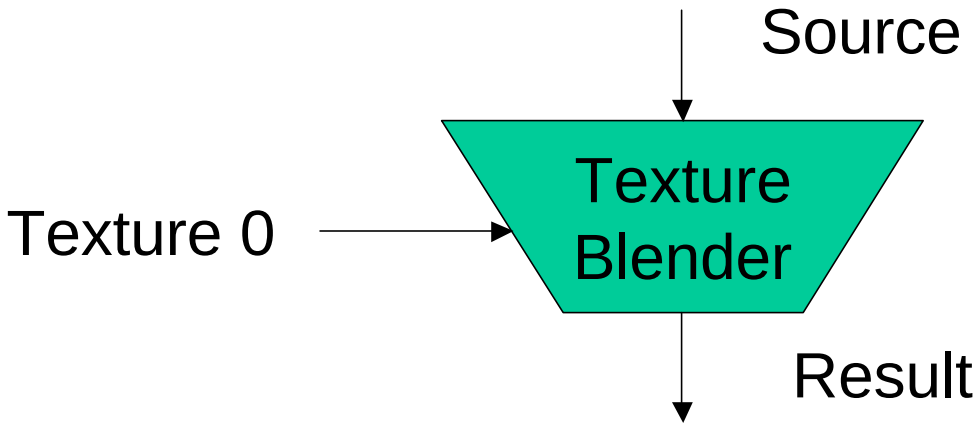



Programmable Shaders
make possible
materials
lighting
reflections
shadows

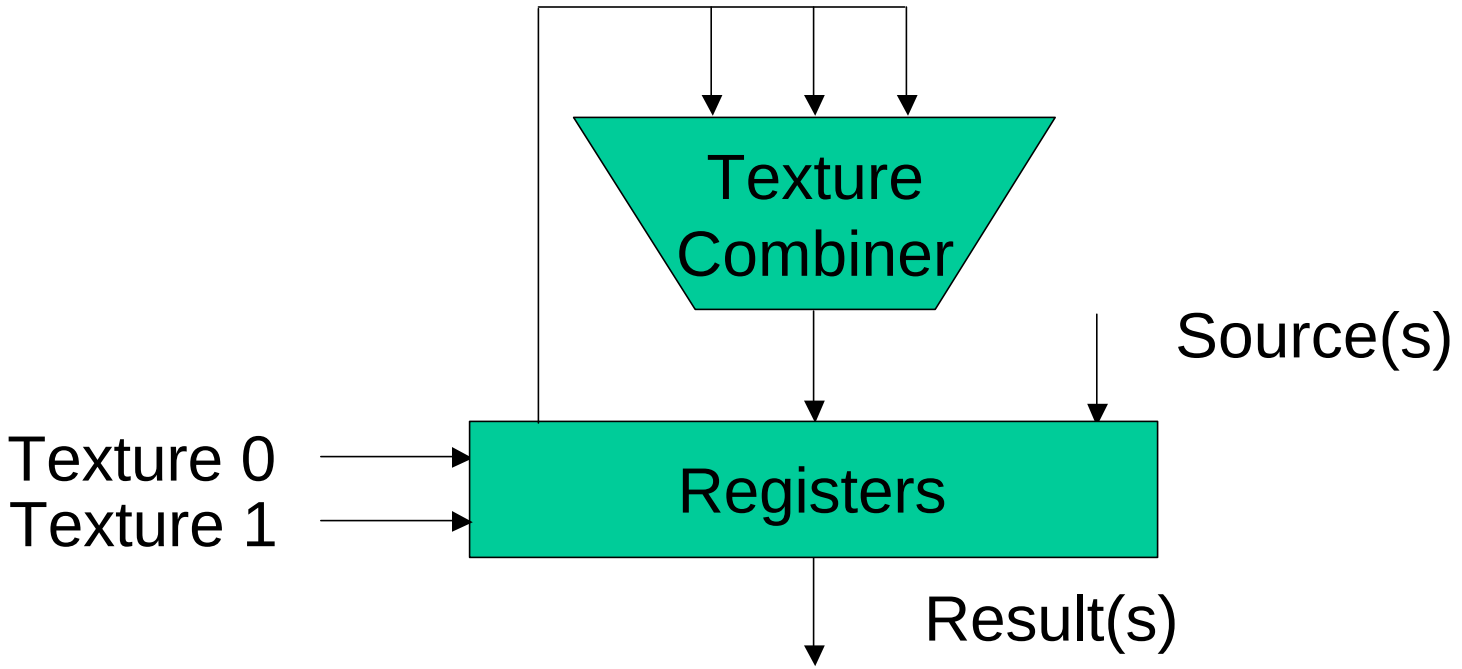
Evolution of Hardware Shading

- Hardware Rasterizers and perspective-correct texture mapping (RIVA 128)
- Single Pass Multitexture (TNT / TNT2)
- Register Combiners: a generalization of multitexture (GeForce 256)
- Per-pixel Shading (Geforce 2 GTS)
- Programmable Hardware Pixel Shading

Single Texture Programming Model

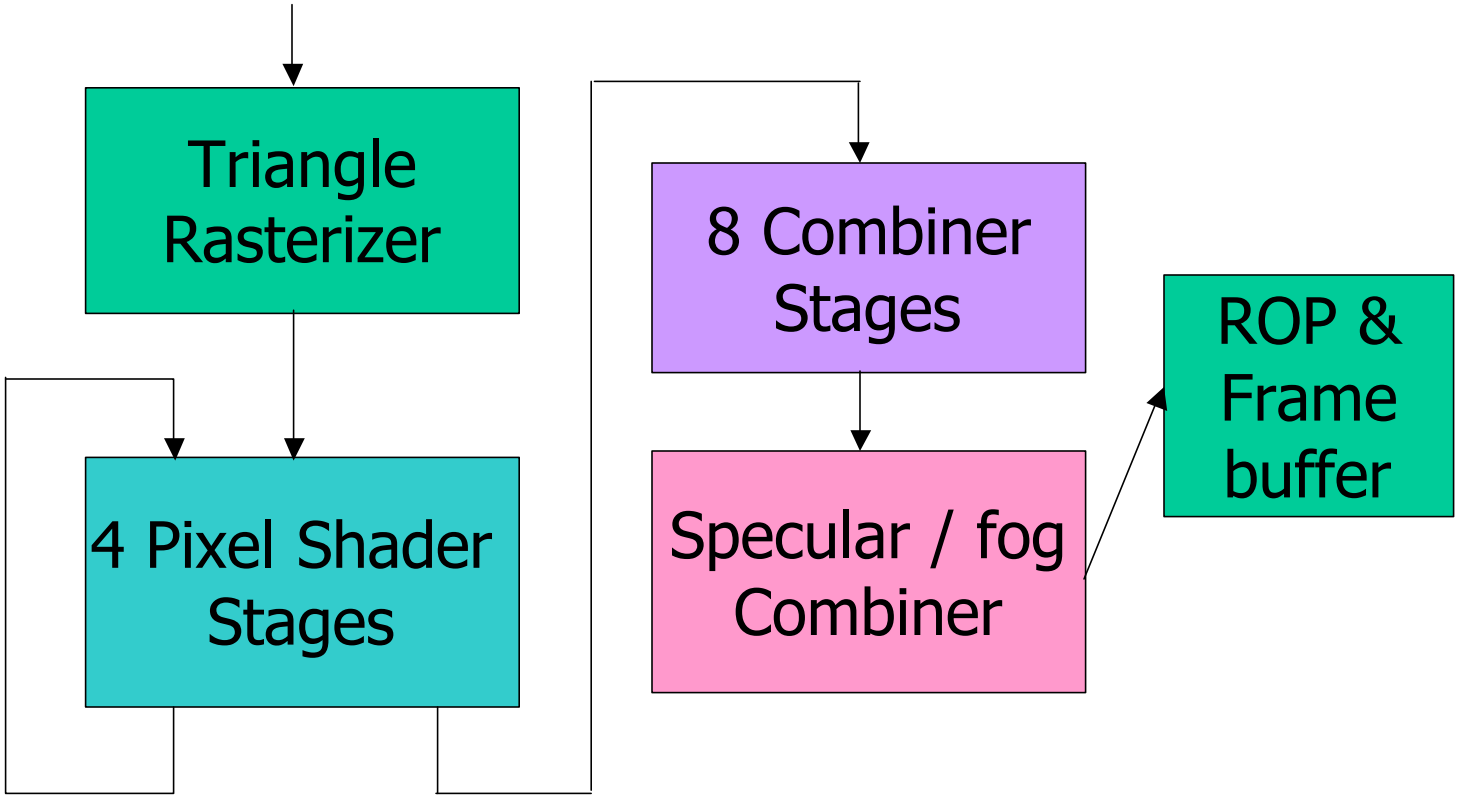


Register Combiner Programming Model



NVIDIA

Pixel Shading Pipeline



NVIDIA.

Pixel Shaders

A pixel shader converts a set of texture coordinates (*s*, *t*, *r*, *q*) into a color (ARGB), using a shader program.

Pixel shaders use:

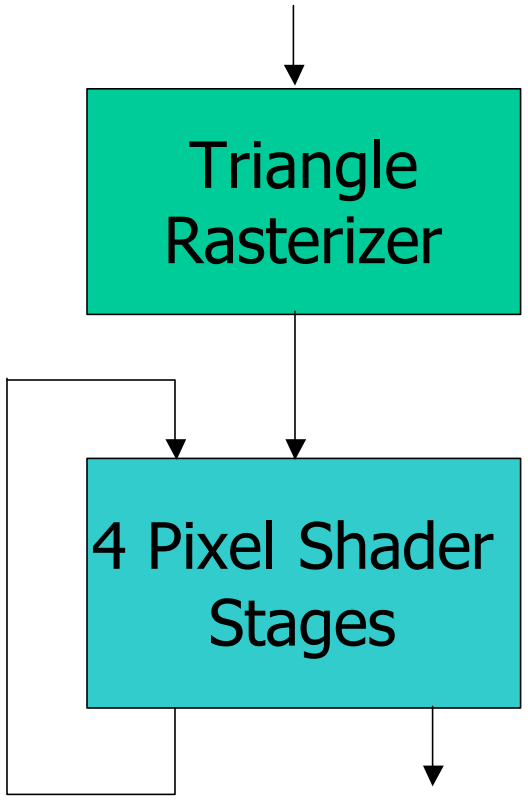
- **Floating point math**
- **Texture lookups**
- **Results of previous pixel shaders**

Simple Dependent Textures

The results of one shading program can be interpreted as the texture coordinates for a subsequent texture lookup.

- **AR ® (s, t)**
- **GB ® (s, t)**

Texture lookups become arbitrary functions.



NVIDIA.

Register Combiners / Texture Blending

- Strict superset of framebuffer alpha blending capabilities
  - a*b+c*d
- Register-based programming
  - All textures and colors available for each and every texture blending stage
  - 8 Stages
  - Signed color arithmetic

NVIDIA.

A “processor model” for Per-pixel Shading

- Computation primitives:
  - Texture addressing
  - Cube maps
  - Volume textures
  - Comparison & muxery
  - Register combiners
  - Vector math (dot3, reflection, etc)
- Hardware shading is now
  - Programmable
  - Extensible

NVIDIA.

Bumpy Shiny Patch

- The bumpy_shiny_patch demo illustrates three key new extensions working together
  - NV_evaluators
  - NV_vertex_program
  - NV_texture_shader
- The goal of bumpy_shiny_patch is to render a bumpy, mirrored, and deformable patch -- with an RGB glossmap to boot

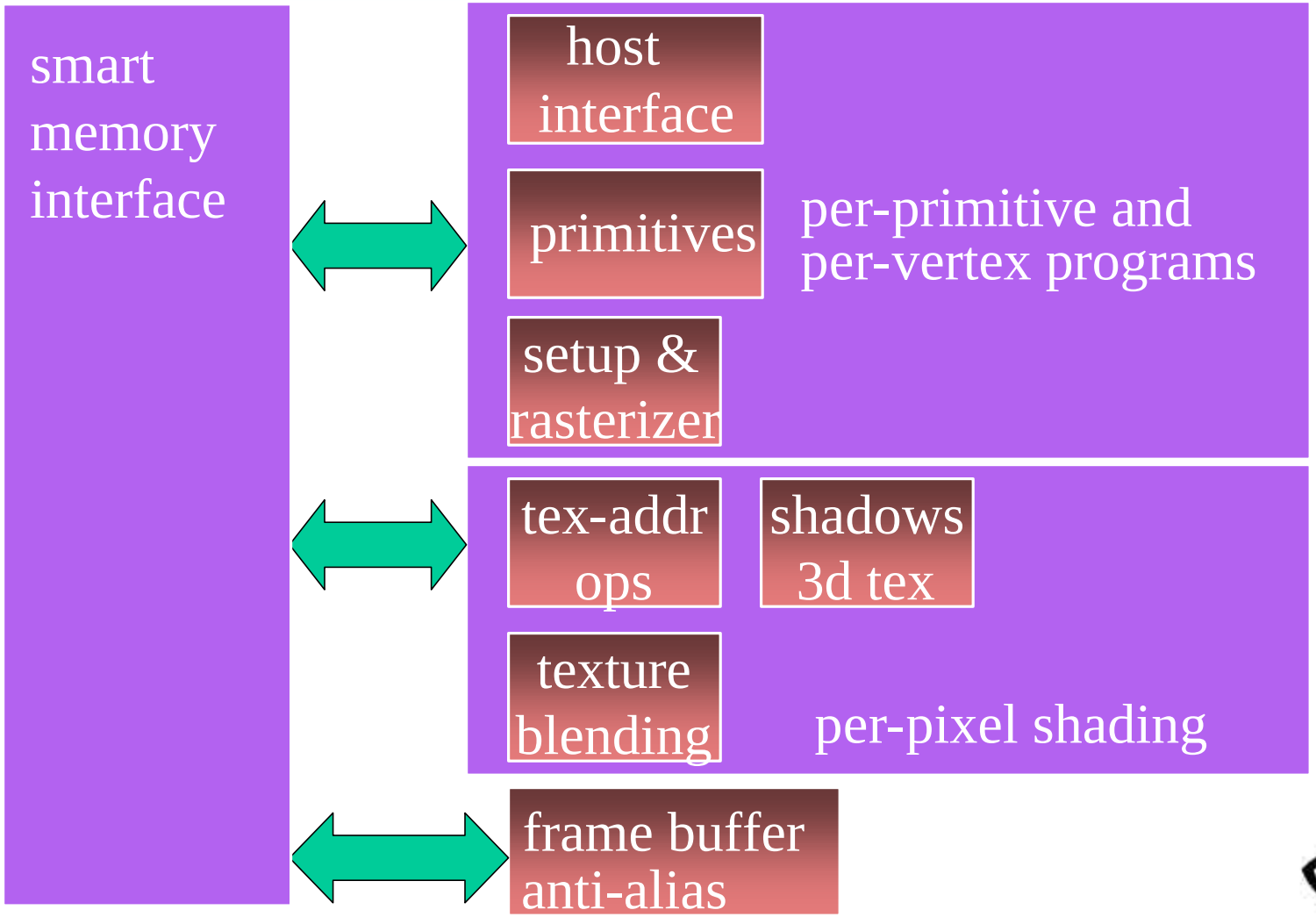
The Bump Map and Gloss Map

The Environment Map

The Results

NVIDIA.

Future Graphics “Pipeline”



NVIDIA.

Acknowledgements

- **Thanks to Mark Kilgard, Sim Dietrich, Matthew Papakipos, Simon Green, Cem Cebonoyan, Erik Lindholm, Doug Rogers, Cass Everitt, and other NVIDIA wizards for contributing slides, demos, and images.**

NVIDIA.