GPU Ray Tracing at the Desktop and in the Cloud

Phillip Miller, NVIDIA

Ludwig von Reiche, mental images

Ray Tracing – has always had an appeal

Ray Tracing Prediction

The future of interactive graphics is ray tracing....

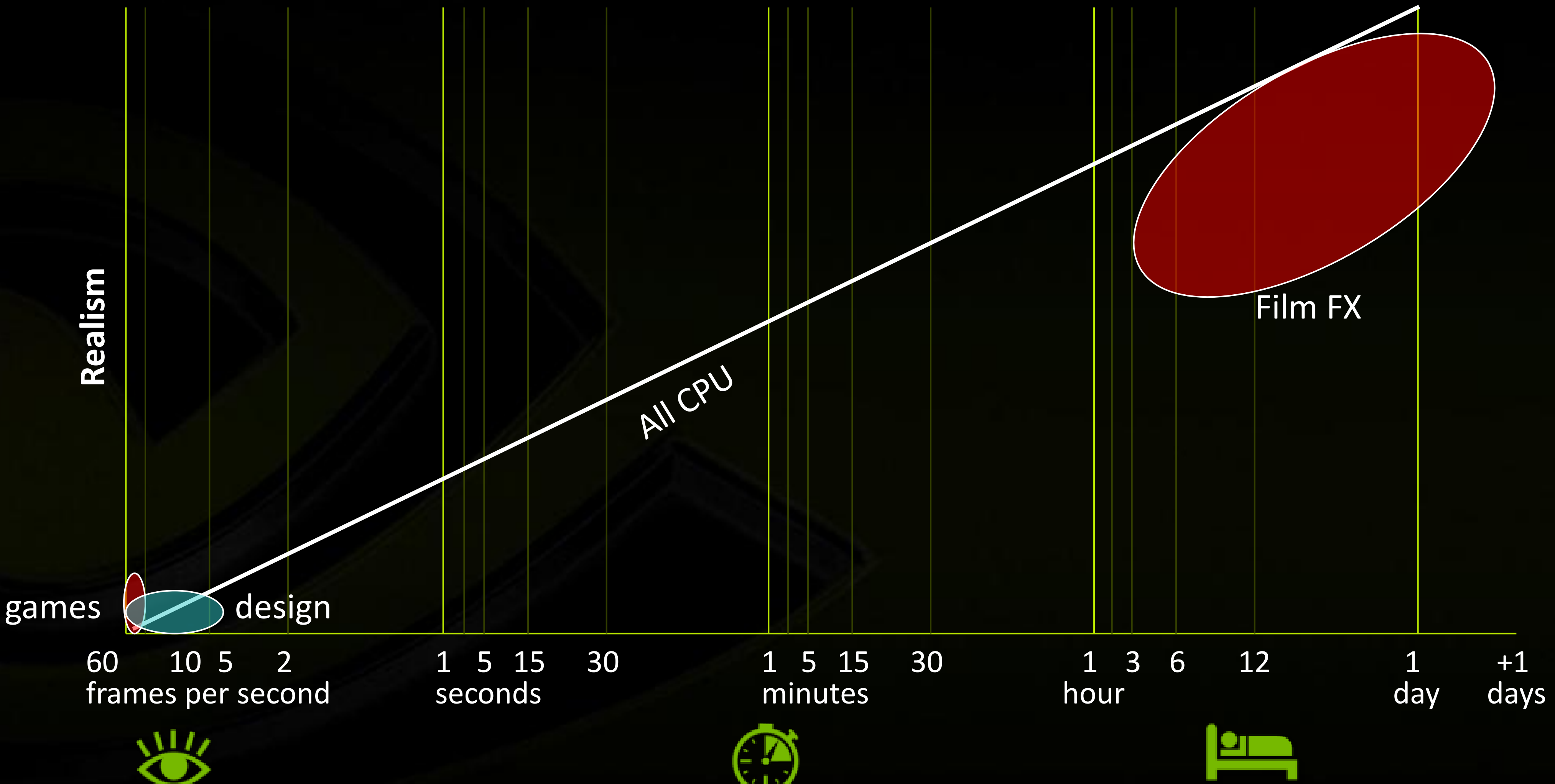
And it ***always*** will be   :)

GPUs are making that “future” look ***much*** closer...

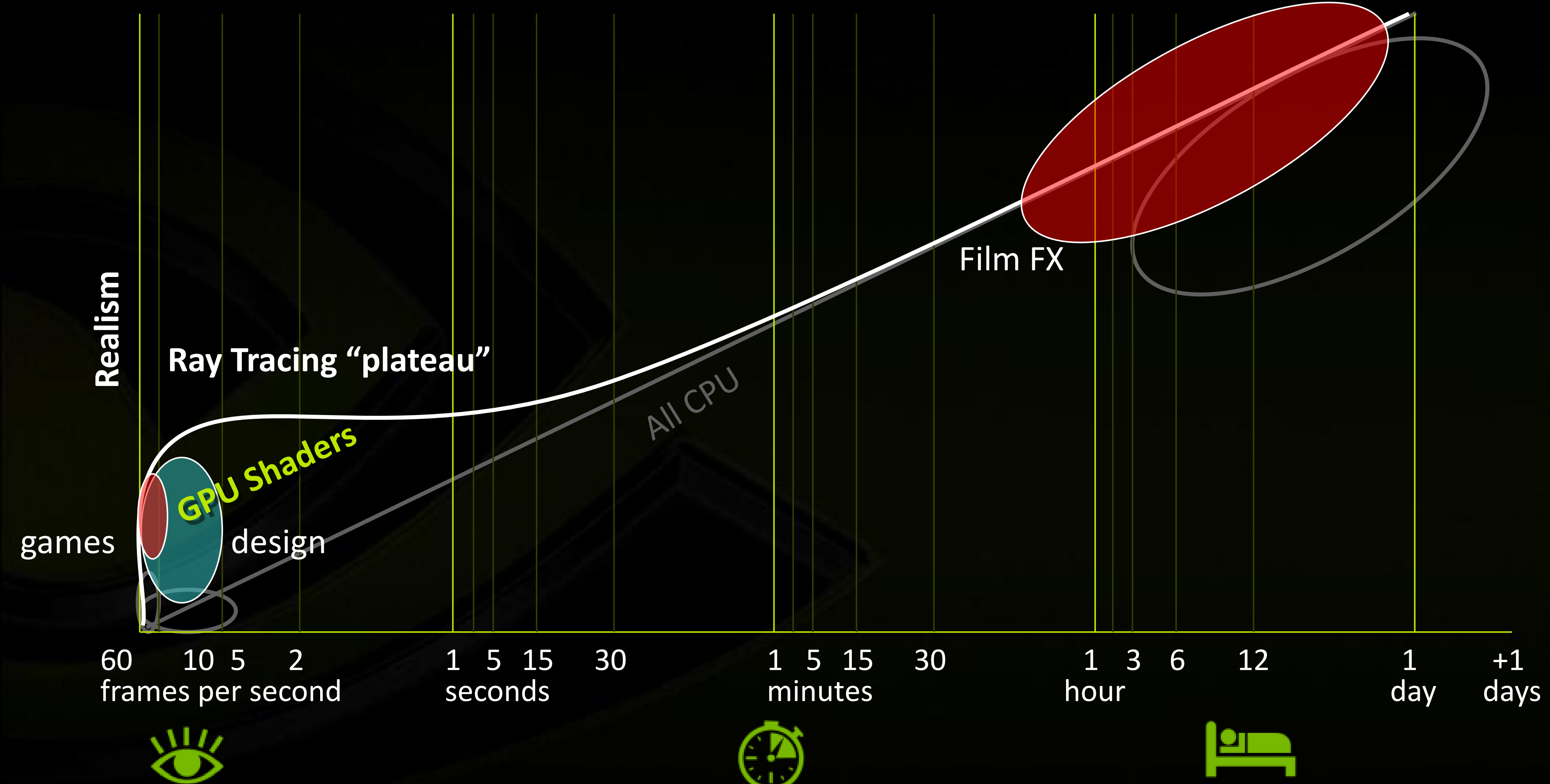
Realism versus Interaction – a Constant

- For all visual industries, realism is most often the goal
- In Film FX – realism typically more important than time
  - **Innovation decreases time**
  - **Increasing realism most often consume time gains**
- In Games and Design – time more important than realism
  - **Realism increases as real-time is maintained**
  - **Design requires at least 5 to 10 FPS**
  - **Games requires 30 or 60 FPS (now 120 FPS in stereo)**

Realism/Time Speed/Node: Baseline



Realism/Time Speed/Node: GPU & Shaders



Real-Time State of the Art

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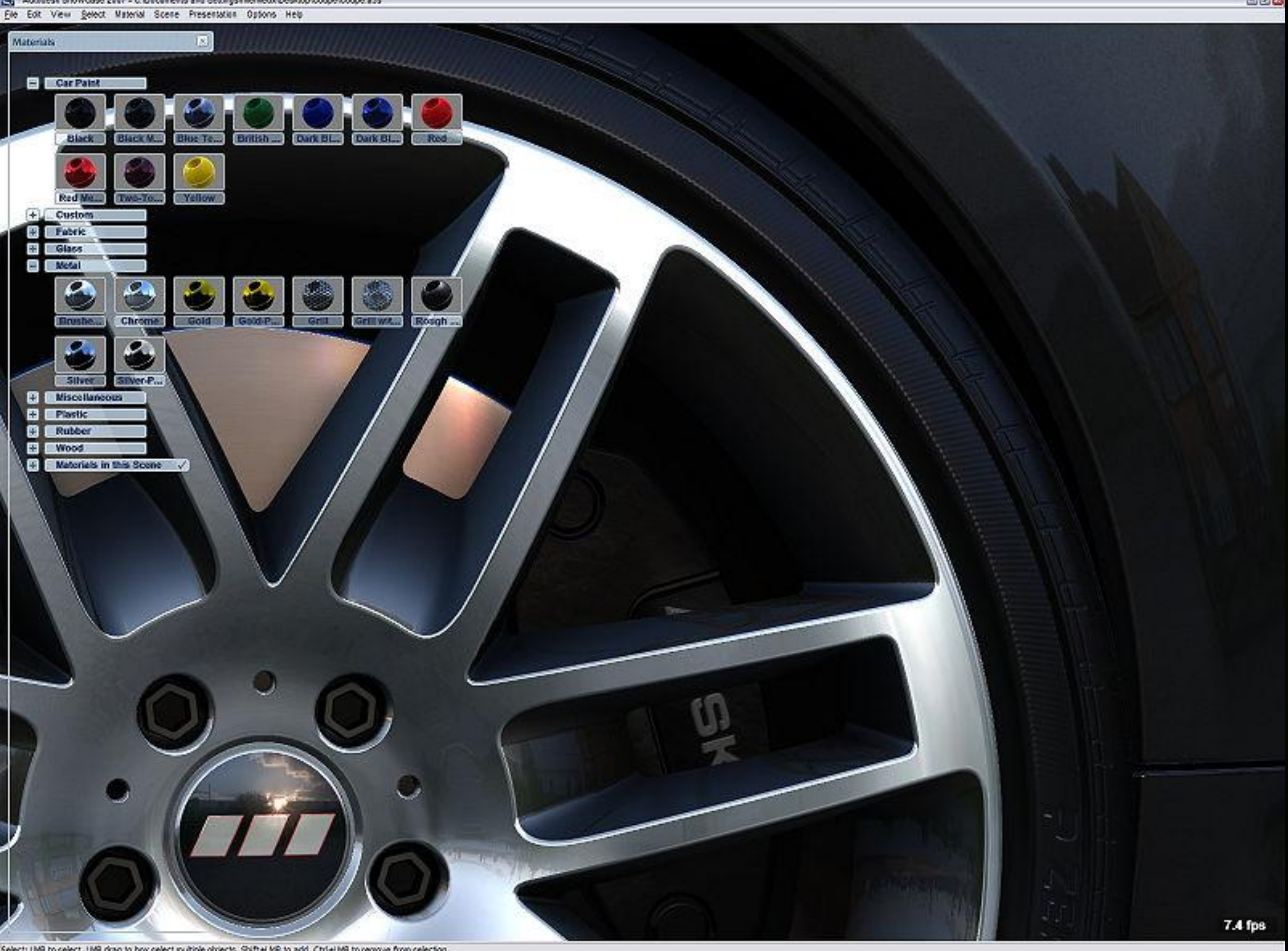


Select: LMB to select. LMB drag to box select multiple objects. Shift+LMB to add. Ctrl+LMB to remove from selection.

Real-Time State of the Art

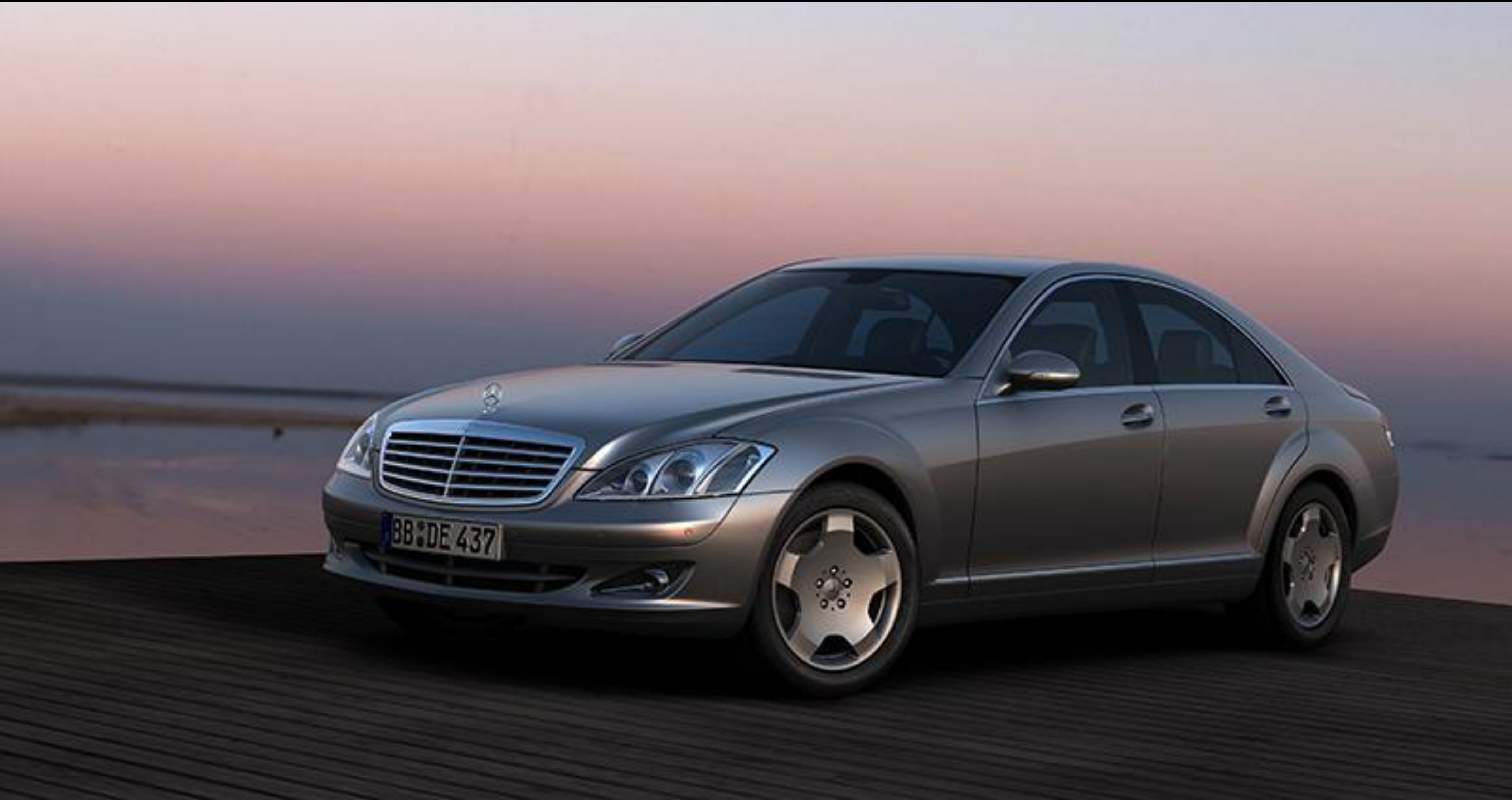
Real-Time State of the Art

Real-Time State of the Art

What’s behind this level realism

- A **lot** of talent (and **time**)
- using great tools
- powered by top end GPUs
- with custom shaders (CgFX, HLSL, GLSL)
- managed by a real-time scene graph

No Self Reflection



No Global Illumination

Careful Compositions

DeltaGen image courtesy of RTT

Raster
Showcase Image courtesy of Autodesk

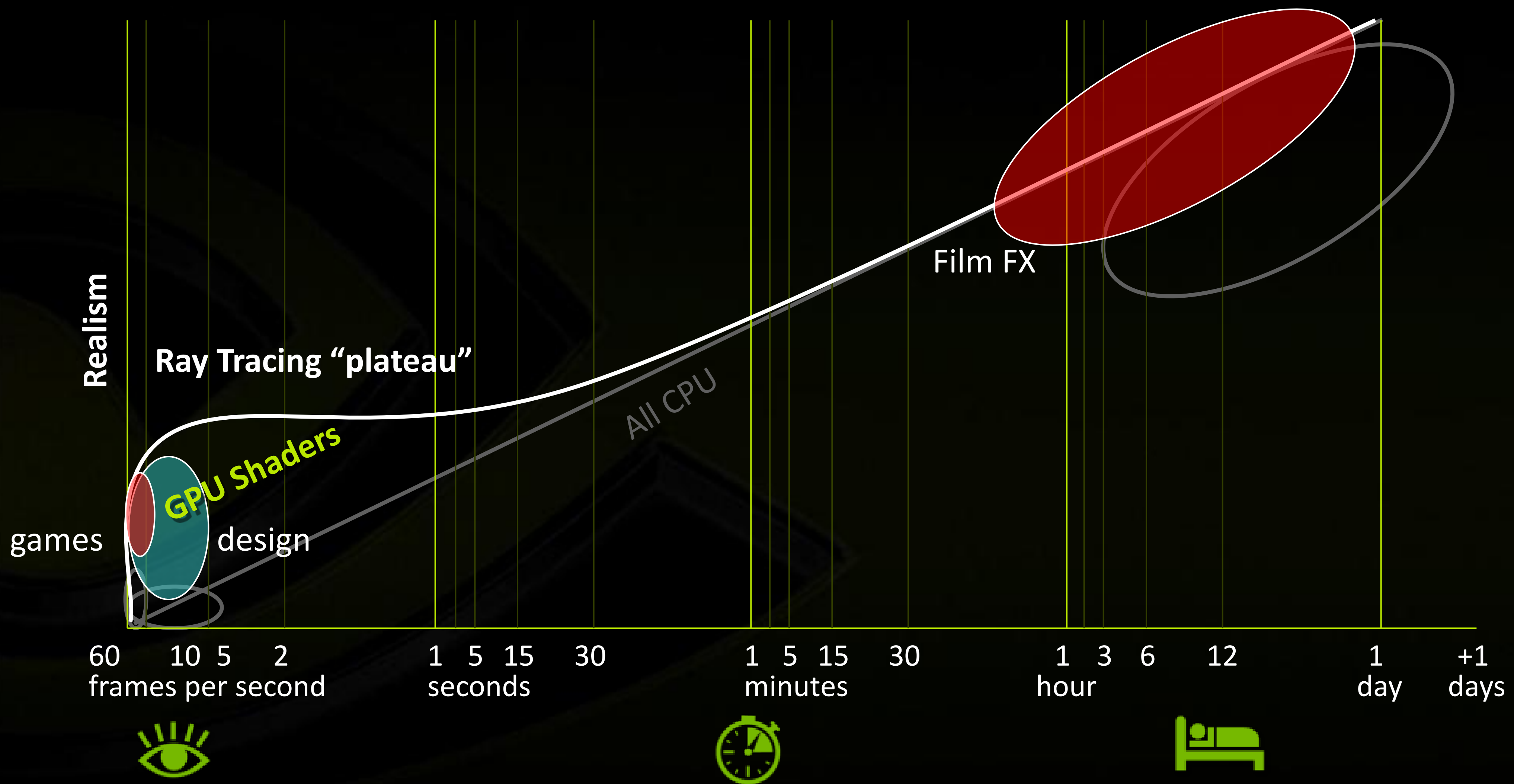
Today

- Limited to Raster Capabilities
- Result is tied to the scene
- High training & cost
- **Intense art time**

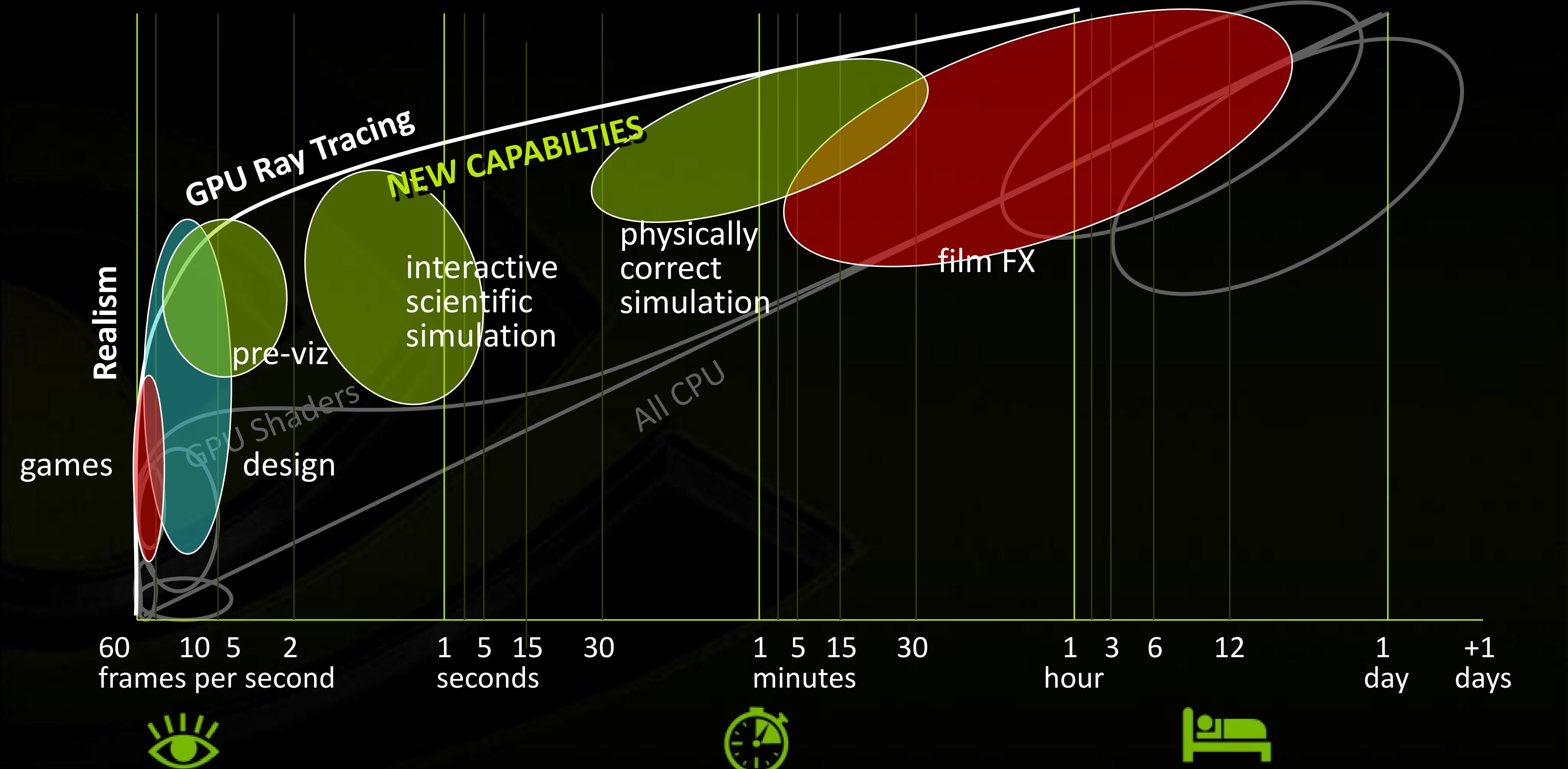
Tomorrow

- Physically correct
- Result works any where
- Far less training and cost
- **Intense computations**

Realism/Time Speed/Node: GPU Shaders



Realism/Time Speed/Node: GPU Ray Tracing



Interactive Ray Tracing Leadership

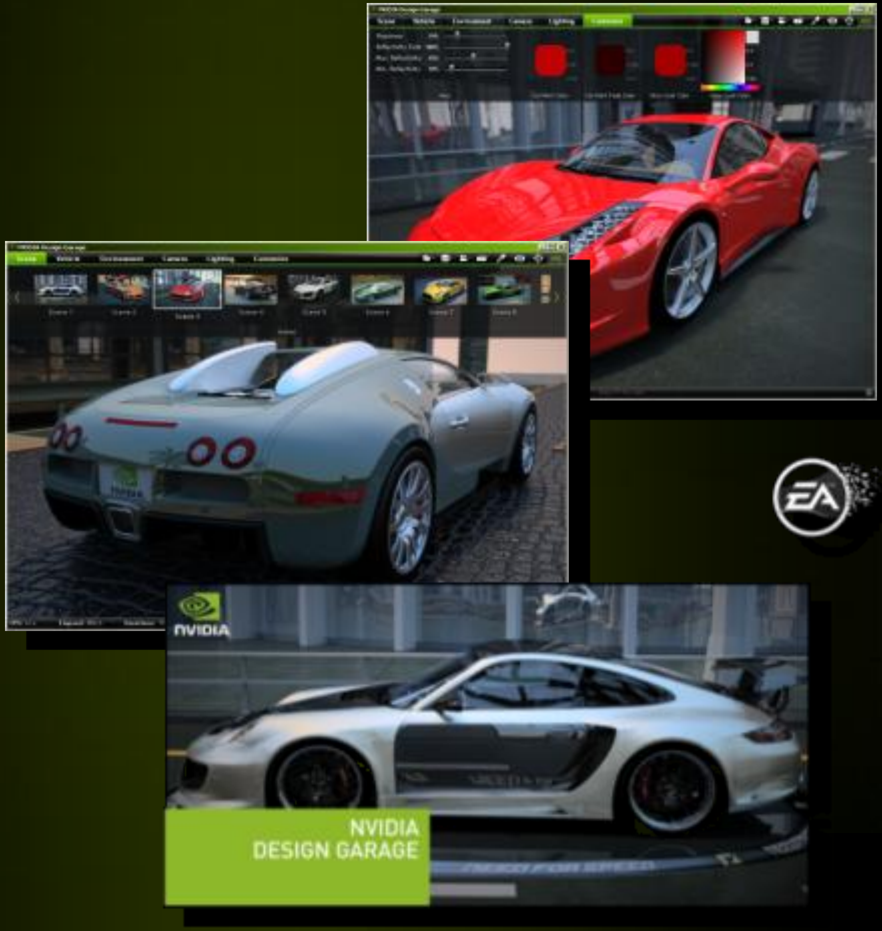
- **SIGGRAPH 2008**
  - 30 FPS proof of concept, on shipping hardware
  - Later published papers on approaches
- **SIGGRAPH 2009**
  - Debuted the OptiX engine and the iray renderer
  - **OptiX, iray, RealityServer 3** released 3 months later
- **Early 2010**
  - Design Garage demo in 5 weeks w/ OptiX & SceniX
- **SIGGRAPH 2010**
  - Numerous GPU rendering solutions on display
  - iray in Bunkspeed **Shot,** OptiX a v2
- **Now**
  - iray in Autodesk **3ds Max 2011**, and DS **Catia v6**
  - OptiX in **Lightworks** and numerous private applications
  - Cloud rendering with iray ready to deploy

Public Views on GPU Ray Tracing

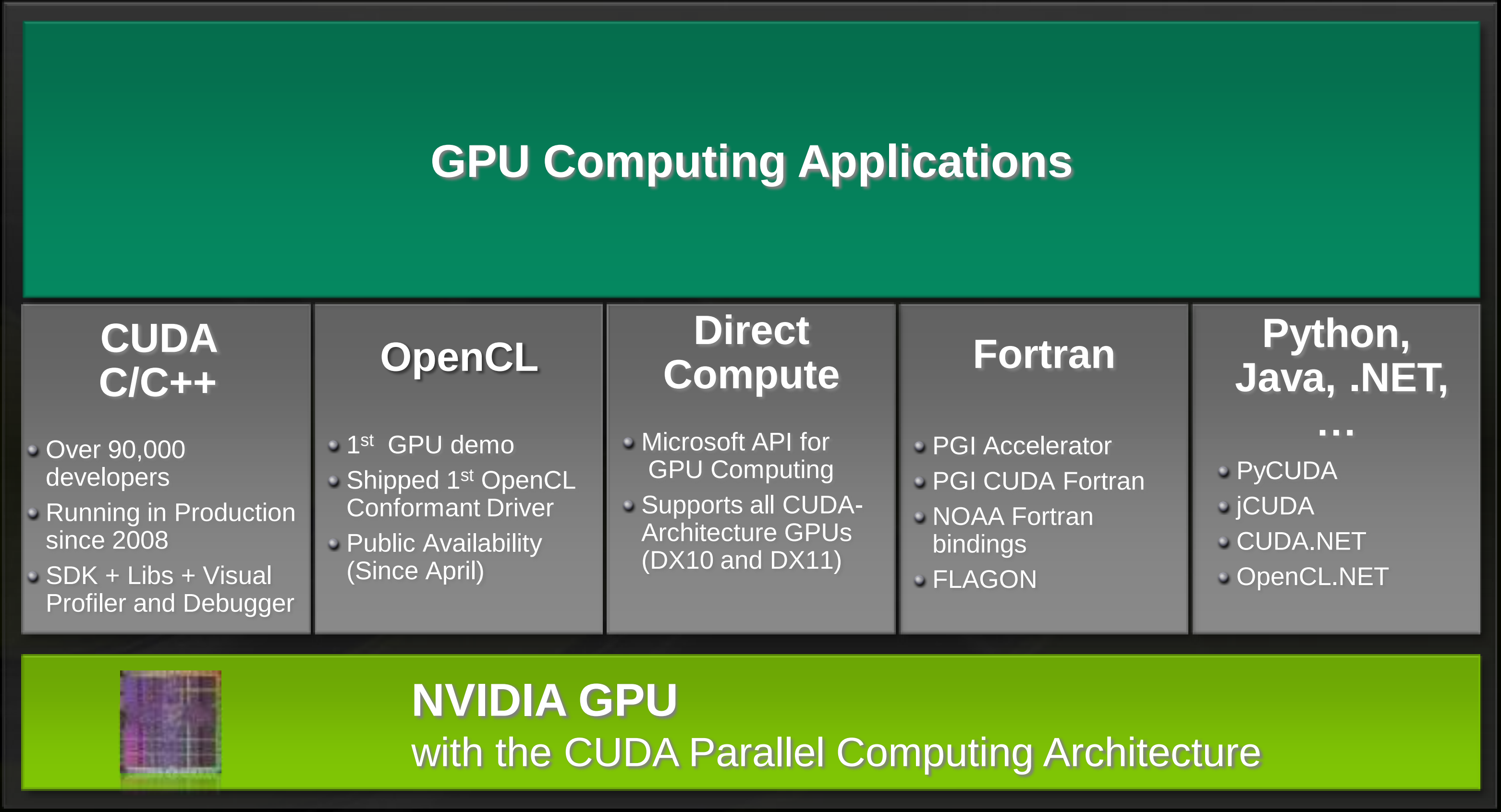
3 years ago –	A GPU ***can't*** ray trace
2 years ago –	NVIDIA can, but we ***can't***
1 year ago –	Now everyone ***can***
This year –	Now many ***are***
Next year –	You can do it ***anywhere***

NVIDIA Design Garage Demo

- Photorealistic car configurator in the hands of millions of consumers
- Uses pure GPU ray tracing
  - Est. 40-50X faster vs. a CPU core
  - 3-4X faster on GF100 than on GT200
  - Linear scaling over GPUs & CUDA Cores
- Built on SceniX with OptiX shaders – similar to other apps in development
- Rendering development speed – 5 weeks



GPU Computing Overview



GPU Computing Applications

CUDA C/C++
- Over 90,000 developers
- Running in Production since 2008
- SDK + Libs + Visual Profiler and Debugger

OpenCL
- 1st GPU demo
- Shipped 1st OpenCL Conformant Driver
- Public Availability (Since April)

Direct Compute
- Microsoft API for GPU Computing
- Supports all CUDA-Architecture GPUs (DX10 and DX11)

Fortran
- PGI Accelerator
- PGI CUDA Fortran
- NOAA Fortran bindings
- FLAGON

Python, Java, .NET, …
- PyCUDA
- jCUDA
- CUDA.NET
- OpenCL.NET

NVIDIA GPU
with the CUDA Parallel Computing Architecture

Broad Adoption

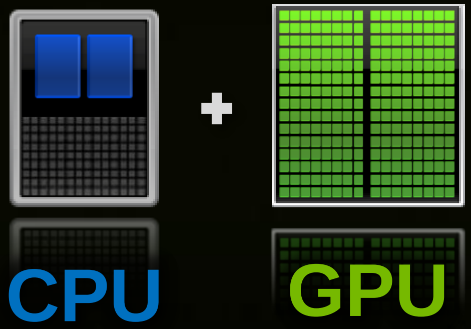
- Over 250,000,000 installed CUDA-Architecture GPUs
- Over 100,000 GPU Computing Developers
- Windows, Linux and MacOS Platforms supported
- GPU Computing spans HPC to Consumer
- 250+ Universities teaching GPU Computing on the CUDA Architecture

Many Programming Approaches in Use

iray	CUDA C, C Runtime
finalRender	CUDA C, C Runtime
Furry Ball	CUDA C, C Runtime
Arion	CUDA C, driver API
Octane	CUDA C, driver API
V-ray RT GPU	OpenCL
OptiX	CUDA C, driver API with PTX stitching
Lightworks, etc.	CUDA C, OptiX API

Solutions Vary in their GPU Exploitation

- Speed-ups vary, but a top end Fermi GPU will typically ray trace 6 to 15 times faster than on a quad-core CPU
- A GPGPU programming challenge is to keep the GPU “busy”
  - Gains on complex tasks often greater than for simple ones
  - Particularly evident with multiple GPUs, where data transfers impact simple tasks more
  - Can mean the technique needs to be rethought in how it’s scheduling work for the GPU
  - OptiX 2.1 example – first tuned for simple, now tuned for complex, with a 30-80% speed increase

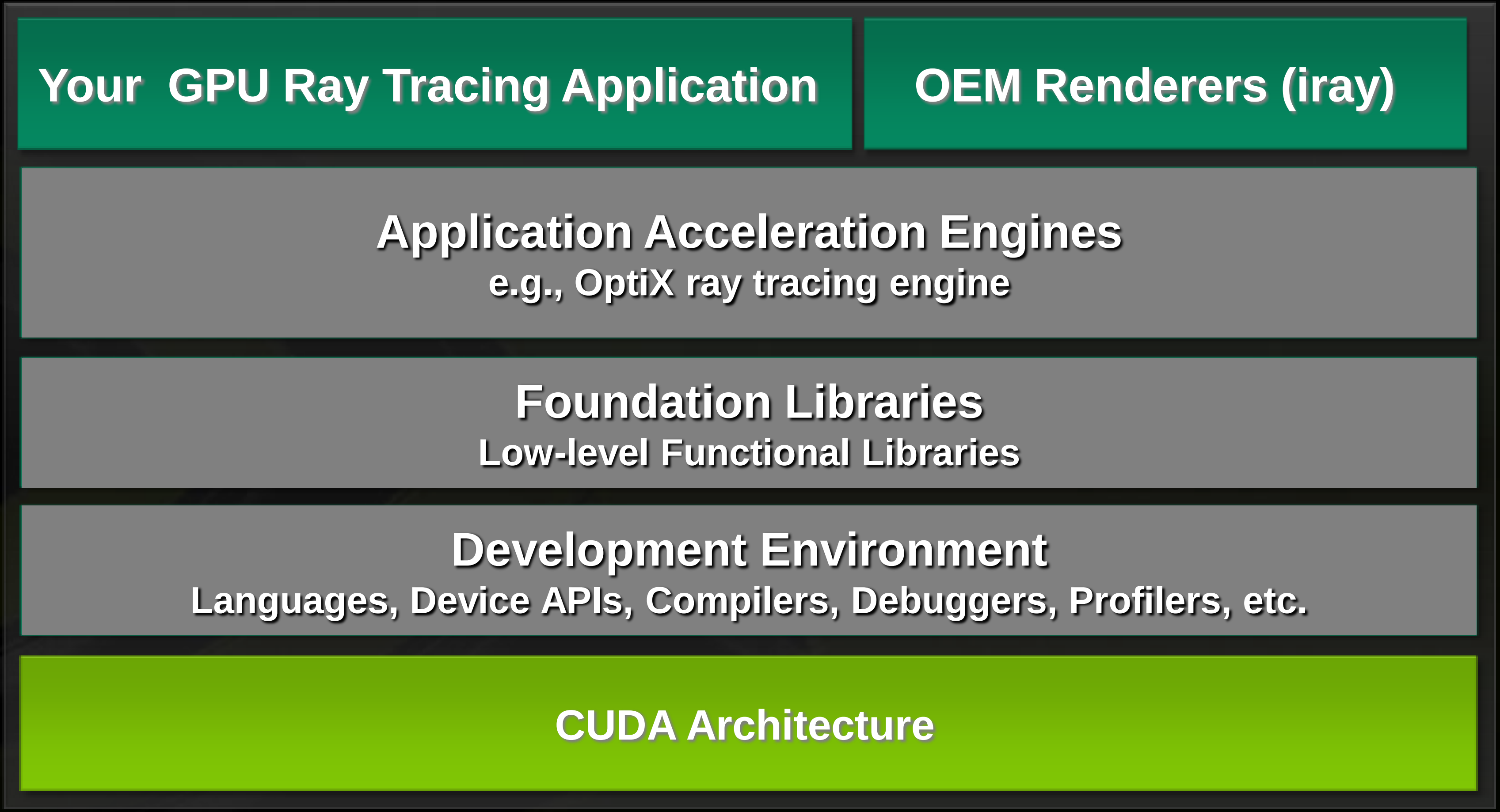


Similarities for today's GPU Ray Tracing

- Performance tends to scale linearly with GPU cores and core clock for a given GPU generation
- Gains between GPU generations will vary per solution
- Most scale well across system GPUs, with no need for SLI.
- Most solutions can "distribute" rendering, but only some support "cluster" rendering
- Scaling efficiency will vary per solution and/or technique
- Entire scene must fit onto the GPU's memory* – geometry, textures, and acceleration structures

*__not__ a permanent situation

GPU Computing Application Development


Your GPU Ray Tracing Application
OEM Renderers (iray)
Application Acceleration Engines
e.g., OptiX ray tracing engine
Foundation Libraries
Low-level Functional Libraries
Development Environment
Languages, Device APIs, Compilers, Debuggers, Profilers, etc.
CUDA Architecture

Accelerating Application Development

App Example: Auto Styling

1. Establish the Scene
   = ScenIX

2. Maximize interactive quality
   + CgFX + OptiX

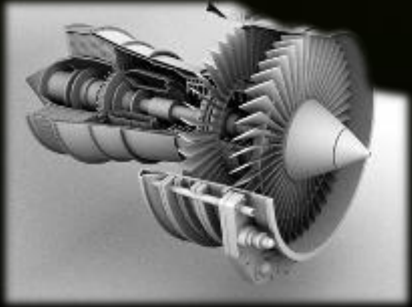
3. Maximize production quality
   + iray

App Example: Ray Tracing Task

1. Prepare your Scene
   = **your art production path**

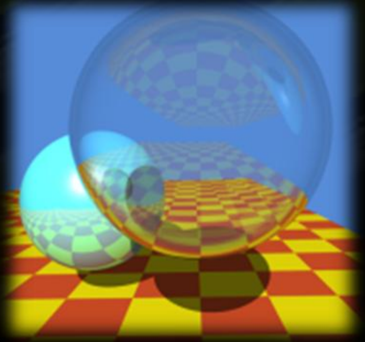
2. Identify a ray tracing bottleneck
   + **OptiX**

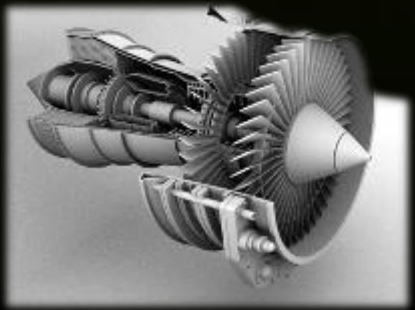
3. Process the task and merge
   e.g., ambient occlusion
   e.g., light maps



What Ray Tracing techniques are possible?

- **Answer: What ever you'd like.**
- Unbiased rendering is currently a popular approach in commercial renderers but ***by no means the only approach***
- For example:



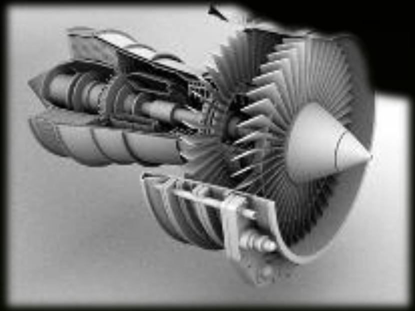


NVIDIA® OptiX™

the world's first interactive ray tracing engine

A programmable ray tracing pipeline for accelerating interactive ray tracing applications – from complete renderers, to functions, to tasks (collision, acoustics, signal processing, radiation reflectance, etc.)

- You write the ray tracing techniques
  – OptiX makes them fast

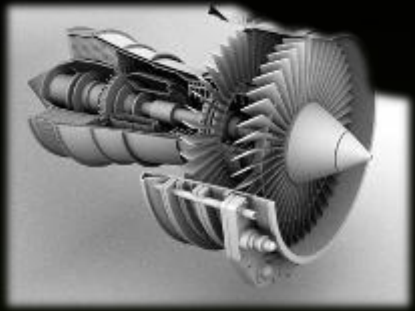


OptiX

for faster and easier ray tracing development

Faster development

- Ray calculations are abstracted to single rays
- State of the art acceleration structures & traversers
- Programmable shaders, surfaces and cameras
- Tight coupling with OpenGL & Direct3D
- GPU issues like load balancing, scheduling, parallelism are all handled.



Flexible use

- Ray payloads can be custom
- Custom intersection goes well beyond triangles
- Not tied to a rendering language, shader model or camera model

Greatly lowers the barrier to entry

- For creating high performance ray tracing
- Developers often saving 50-75% on base effort
  – with much higher performance results

Hybrid – Increasing Interactive Realism

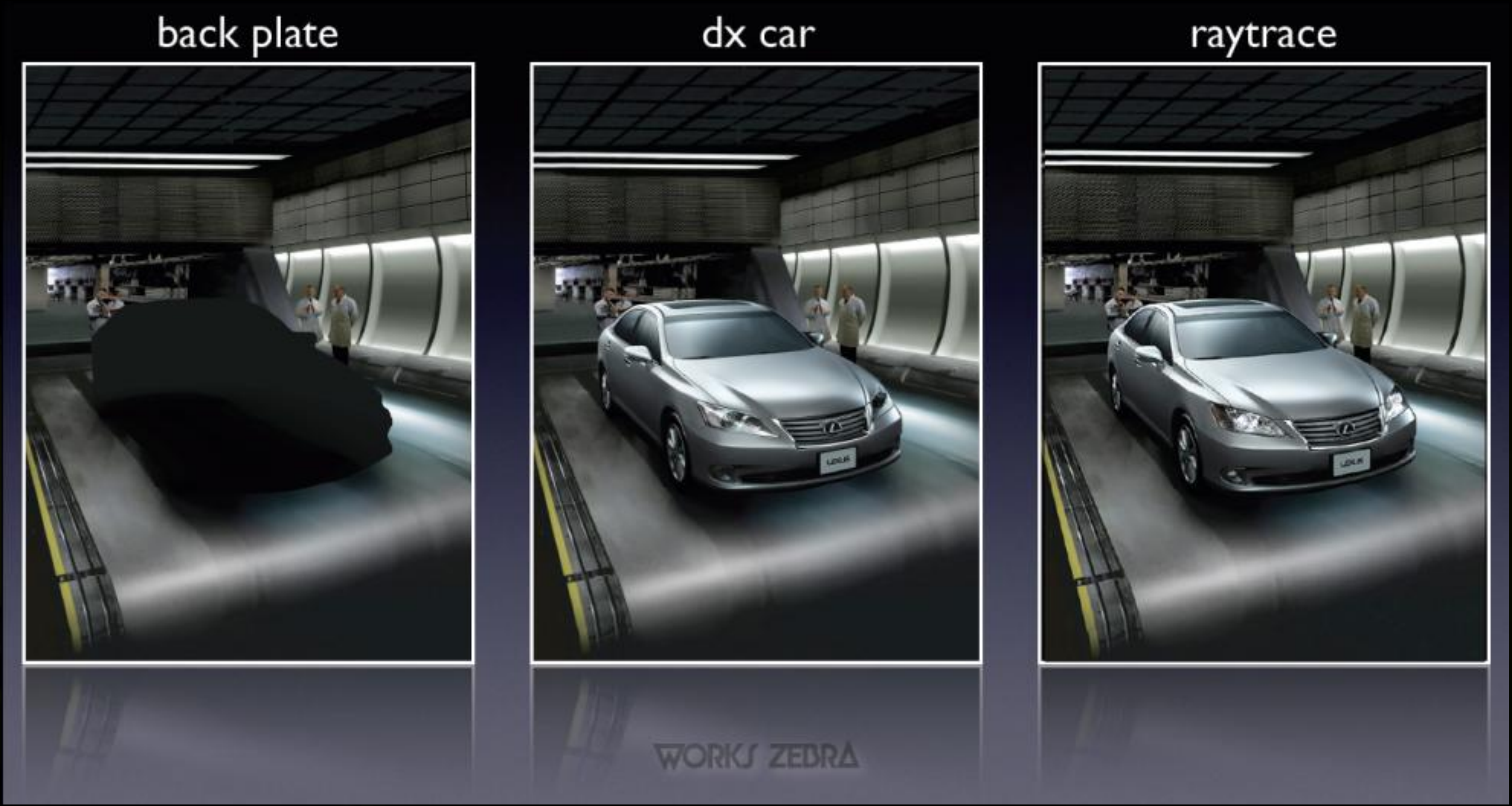
- Combined as a Scene Effect with OGL or D3D

+ Glossy Reflections

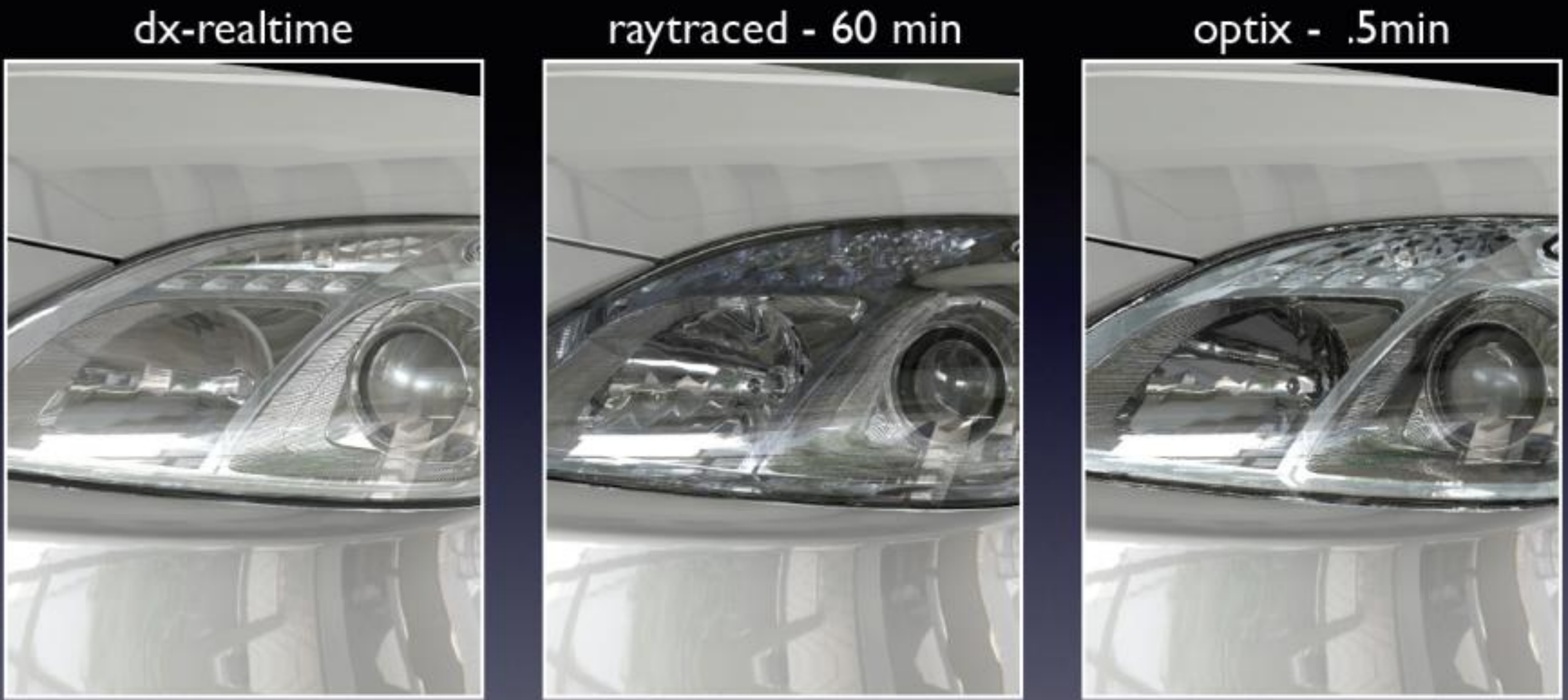
+ Soft Shadows

+ Ambient Occlusion, etc…

Example: Works Zebra workflow



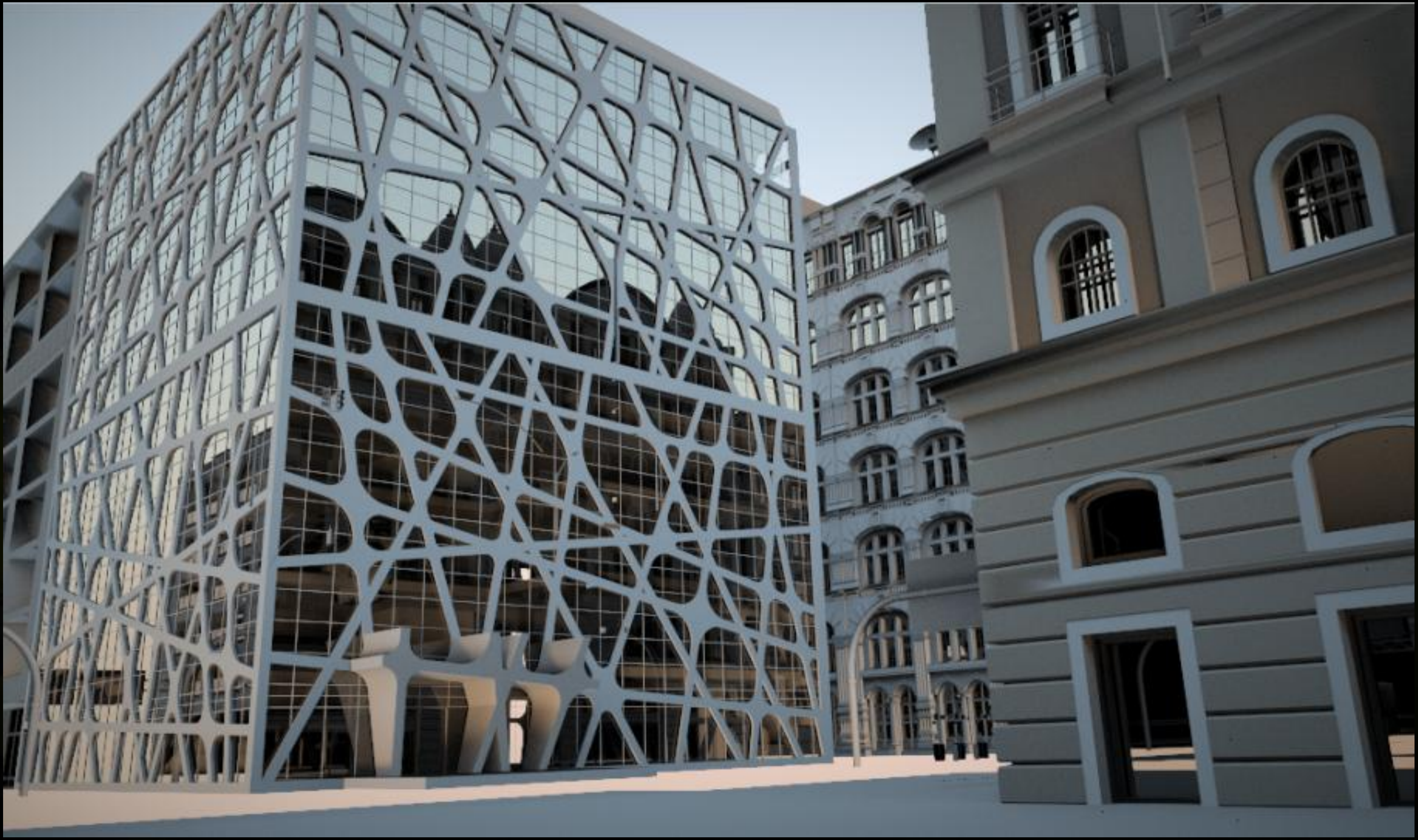
Example: Works Zebra using the GPU



"on screen, I can see the difference between real-time and offline, but not between OptiX and offline"

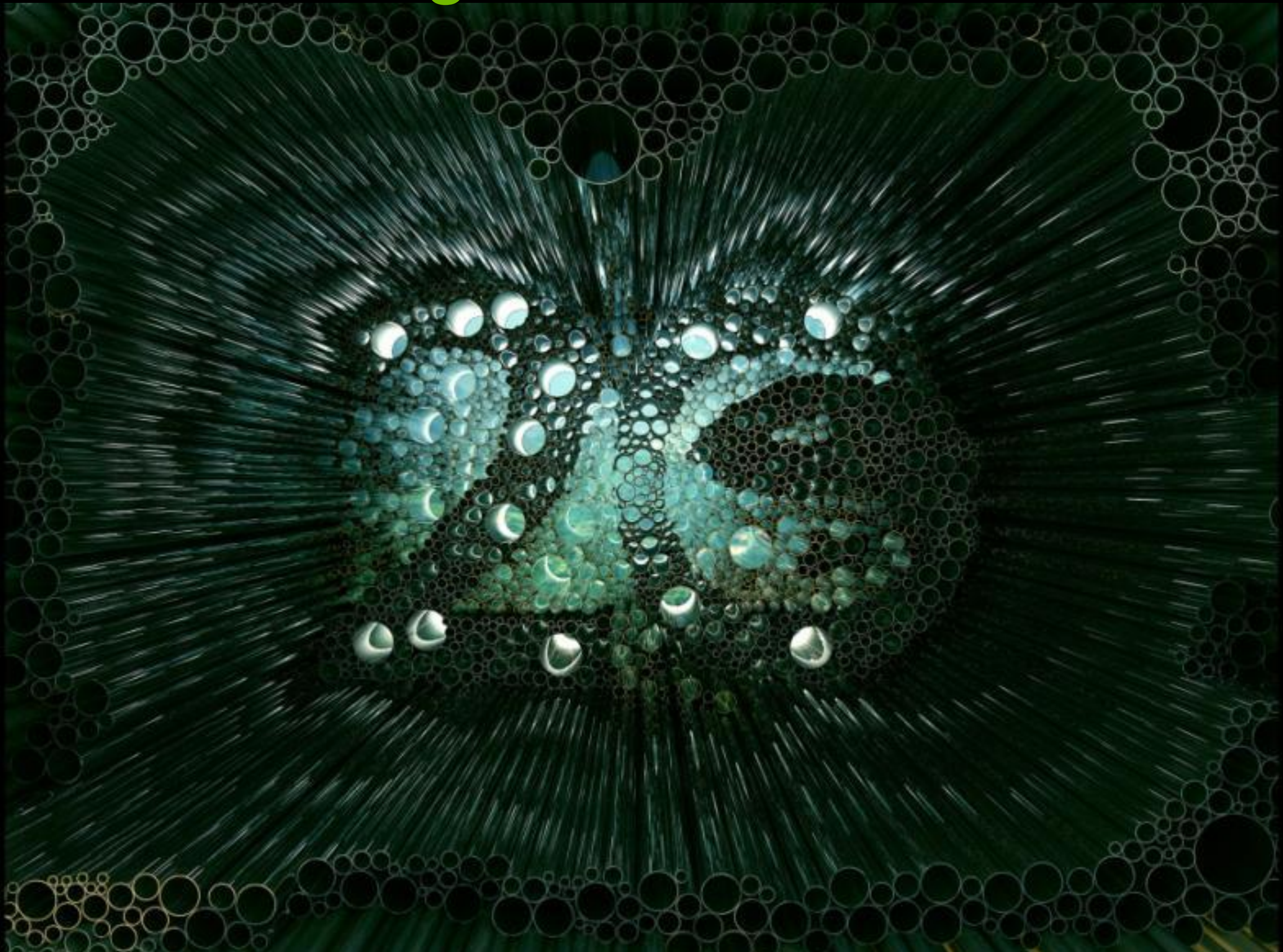
Manager, Toyota Marketing Japan

Interactive Ray Tracing: Lightworks



Interactive Ray Tracing: Bunkspeed Shot™

3ds Max Rendering Revolution Contest



3ds Max Rendering Revolution Contest

AUTODESK® 3DS MAX®

3ds Max Rendering Revolution Contest

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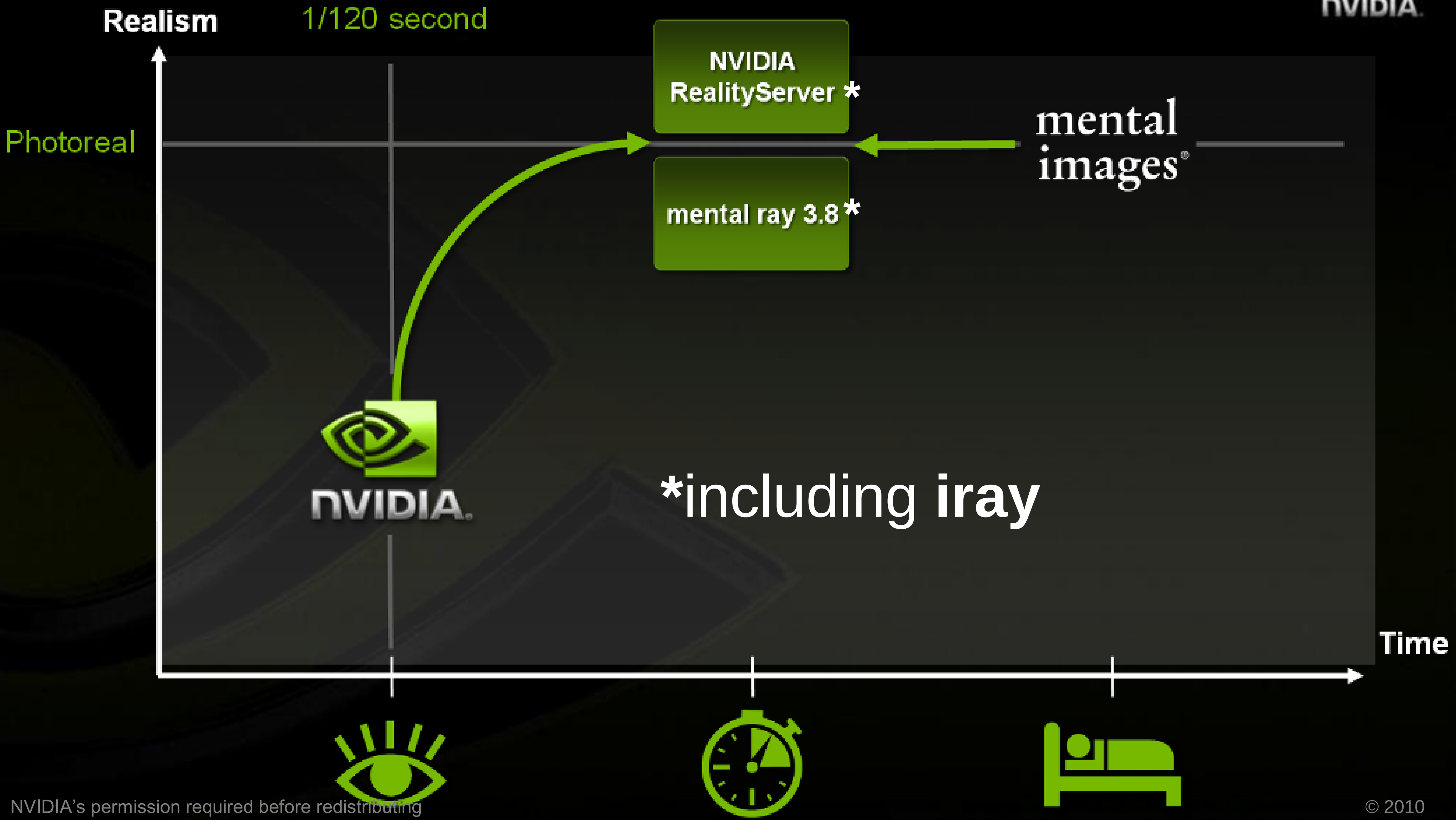

*including **iray**

End

iray® from mental images

bringing photoreal ray tracing to a product near you

A physically correct and interactive global illumination renderer.

The perfect choice for those relating to the real-world (designers, consumers,…)

- CUDA-based w/ CPU fallback (massive delta – not interactive)
- Scalable across GPUs & nodes (DICE)
- Inclusion Options:
  - w/ current mental ray and RealityServer
  - Integrator Edition (for those w/o mental ray)
  - Option for SceniX (later this year)
  - Coming to numerous products in 2010

iray – in action

GPU Technology Conference (GTC 2010)

September 20-23, 2010 San Jose, CA

Now taking Submissions:

http://www.nvidia.com/object/call_for_submissions.html

NVIDIA

iray and OptiX

together addressing the spectrum of rendering needs

- **With iray, you add or replace a renderer.**
  Ideal when you want a ready-to-integrate/use photorealistic solution

- **With OptiX, you accelerate or build a renderer.**
  OptiX is ideal when you want to accelerate hybrid & custom solutions

Ongoing Focus:

iray –	quality, complete solution, perf
OptiX –	interaction, flexibility/generality, perf
NVIDIA -	assisting GPU ray tracing development **wherever** it's desired