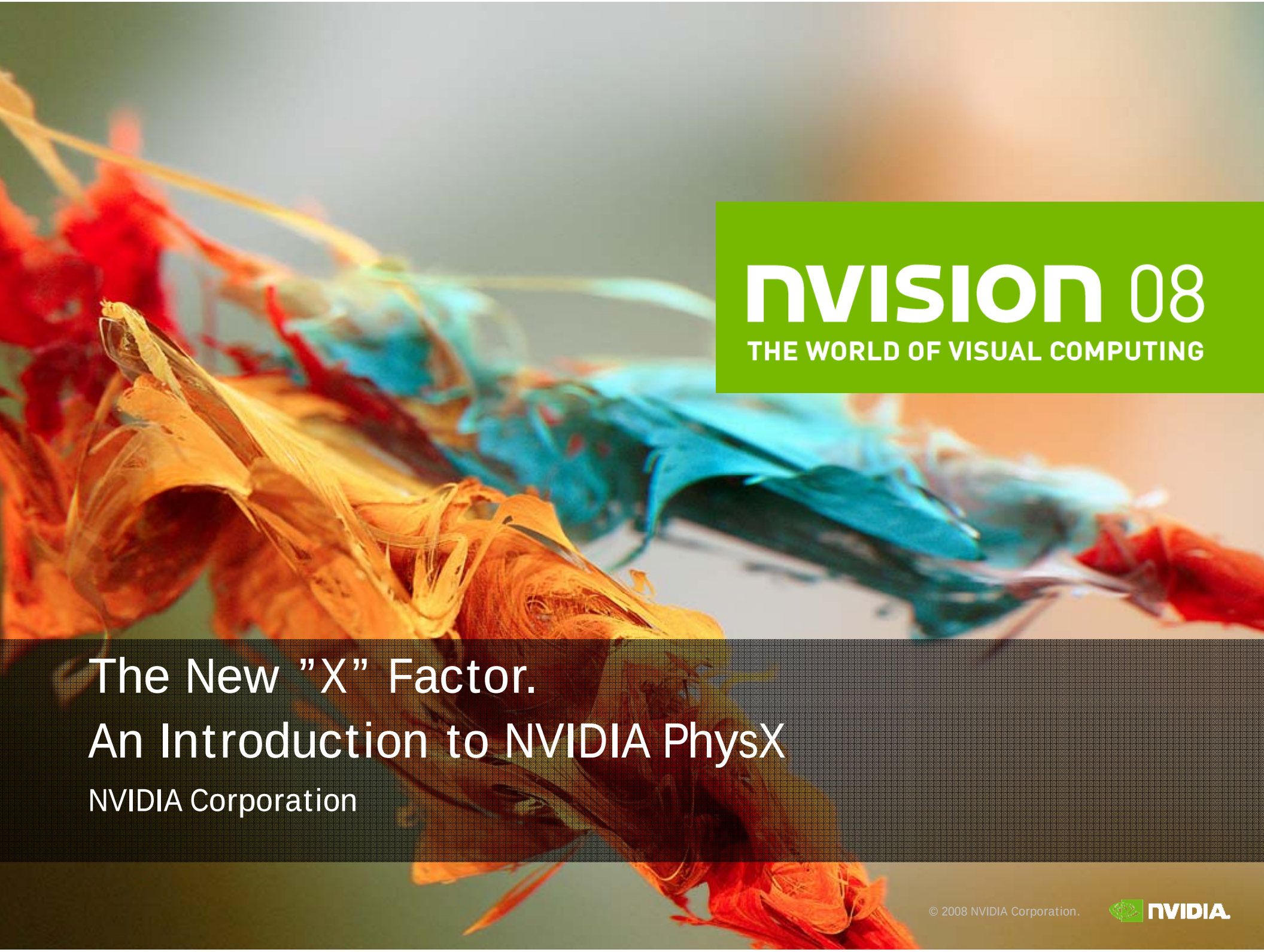

The New "X" Factor.
An Introduction to NVIDIA PhysX

NVIDIA Corporation

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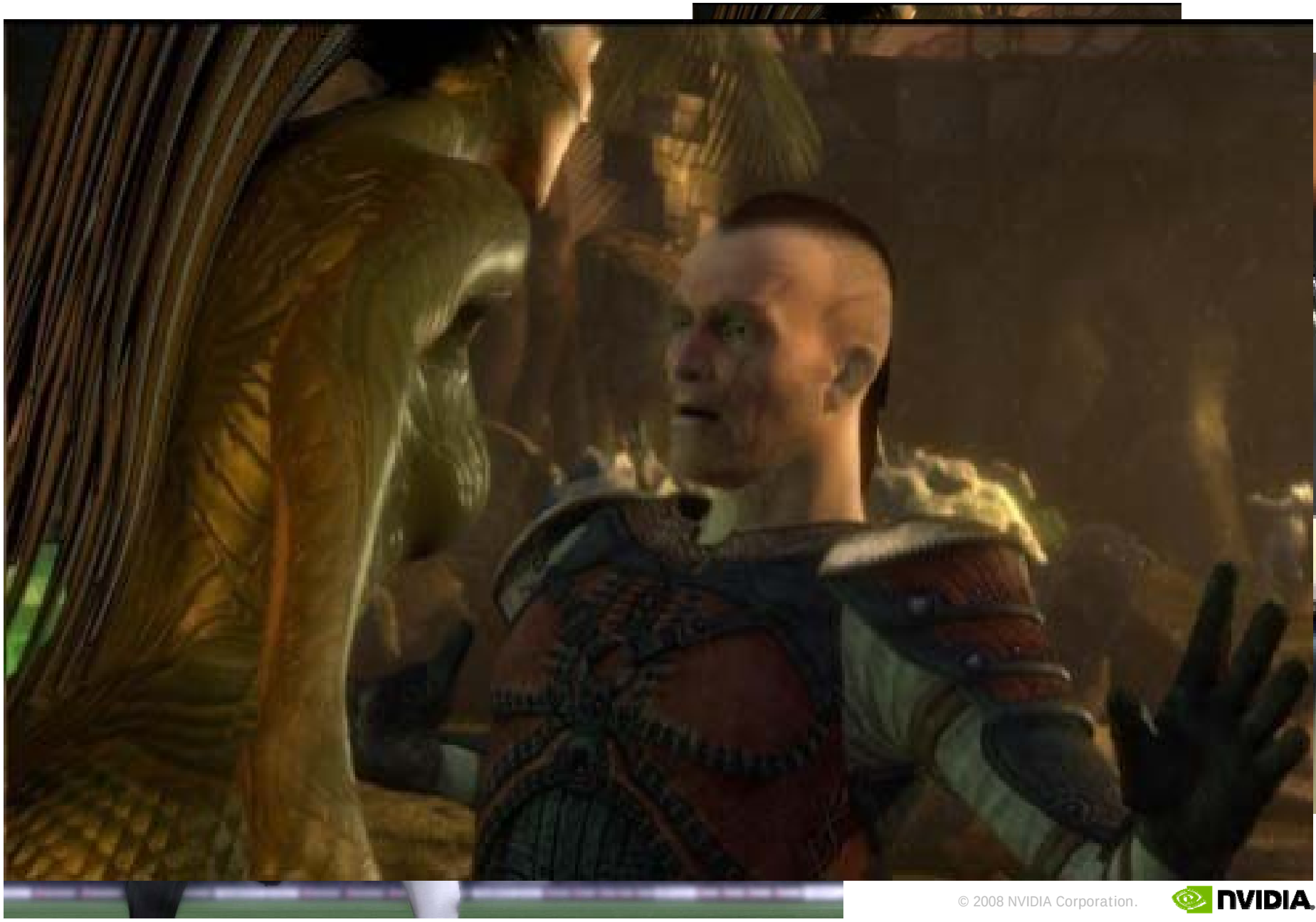
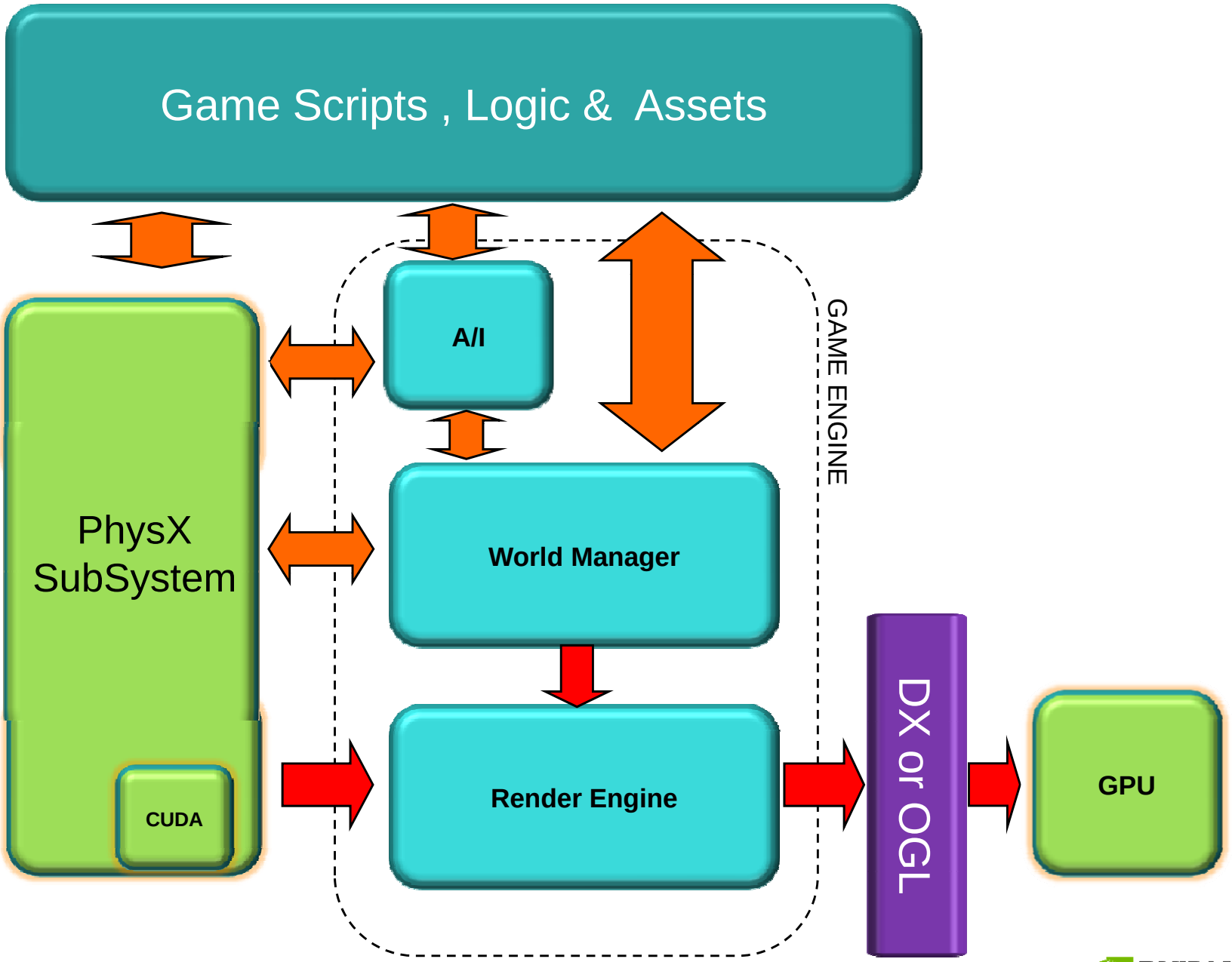
What is Gaming Physics?



Simplified Game Pipeline



XBOX 360

PhysX™
by NVIDIA

PLAYSTATION 3

Wii

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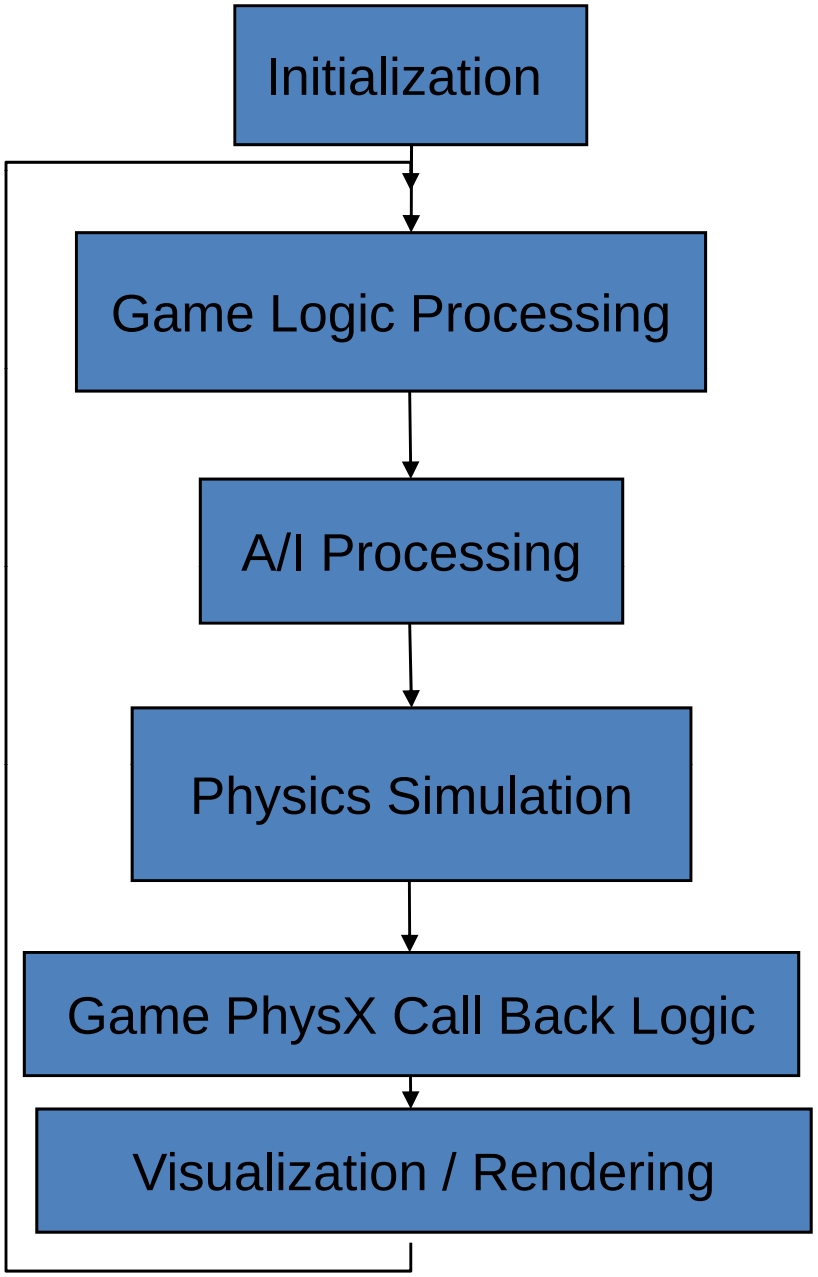
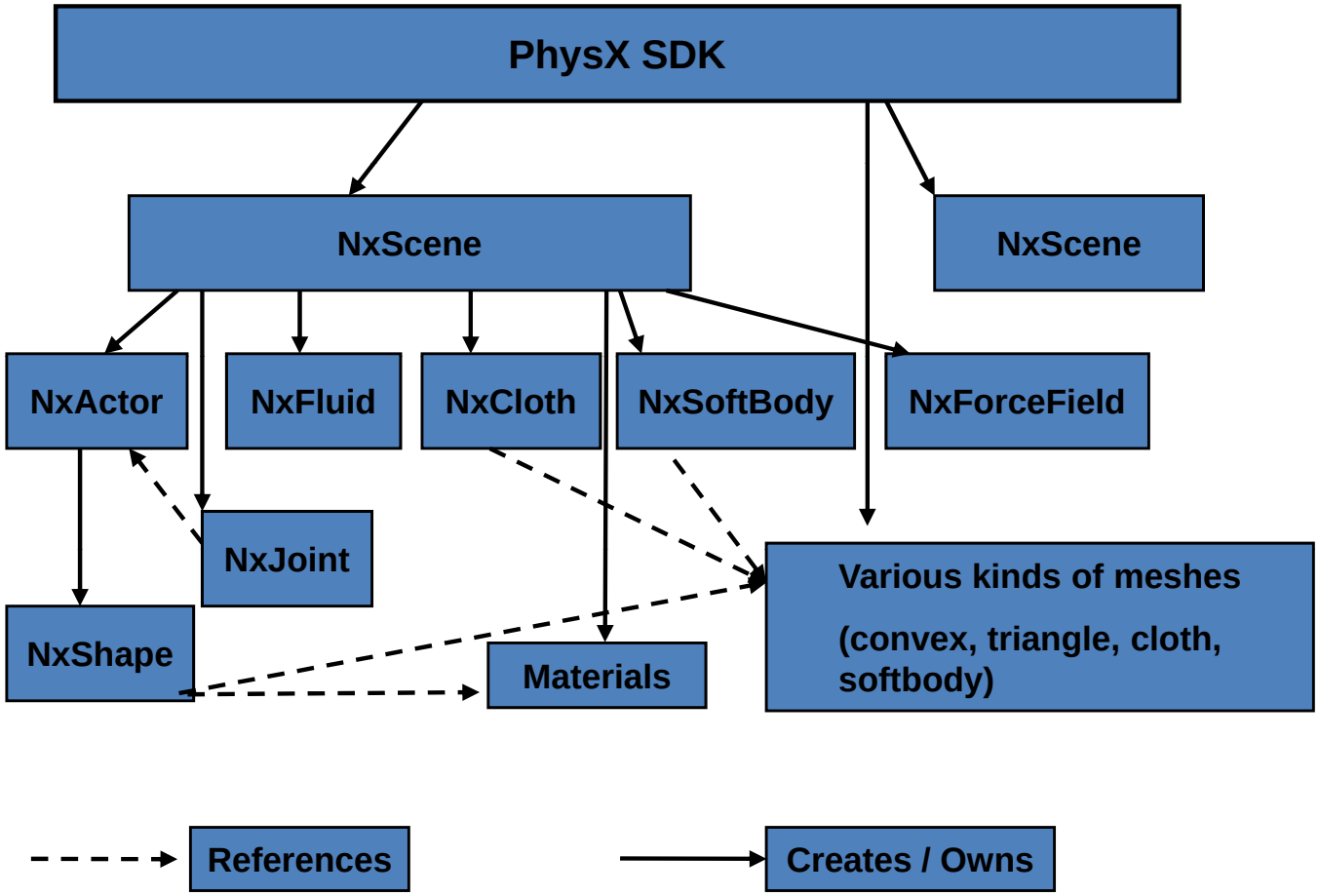
NVIDIA PhysX SDK Overview

- PhysX SDK is a complete Physics Solution
  - Comprehensive API
  - Library of auxiliary methods (Cross platform)
  - “Cooking” Library
  - Development Tools
  - Multi-Media Documentation
  - Multi-Tiered Support
  - Extensive Industry Eco-System

Simplified Game Flow With PhysX

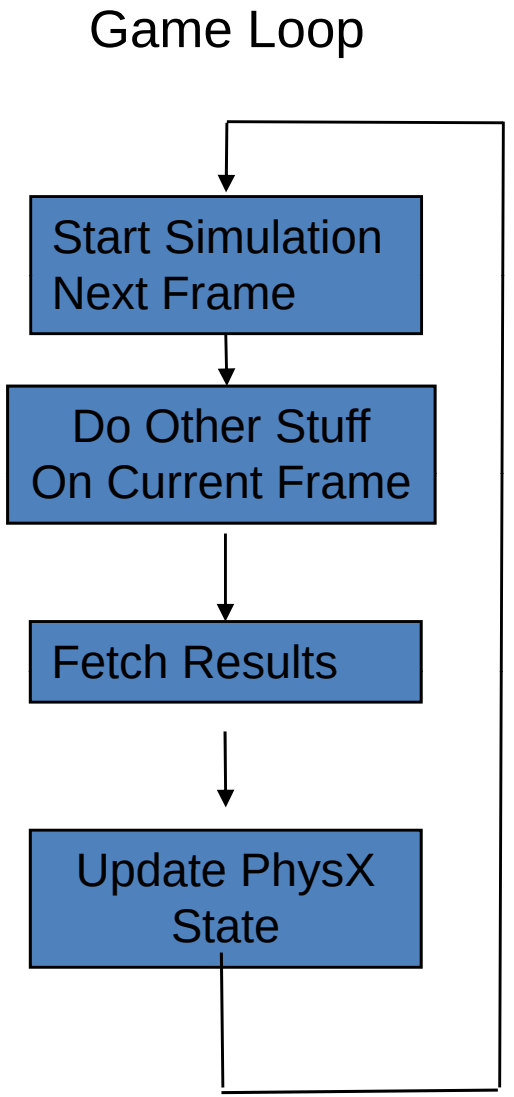


PhysX Object Model



PhysX Runtime

- Asynchronous Simulation Core
  - Rigid Body
  - Fluid
  - Cloth
  - Soft Body
  - Force Field
- Additional Functions
  - Scene Query
  - Character Controller
  - Vehicle Controller

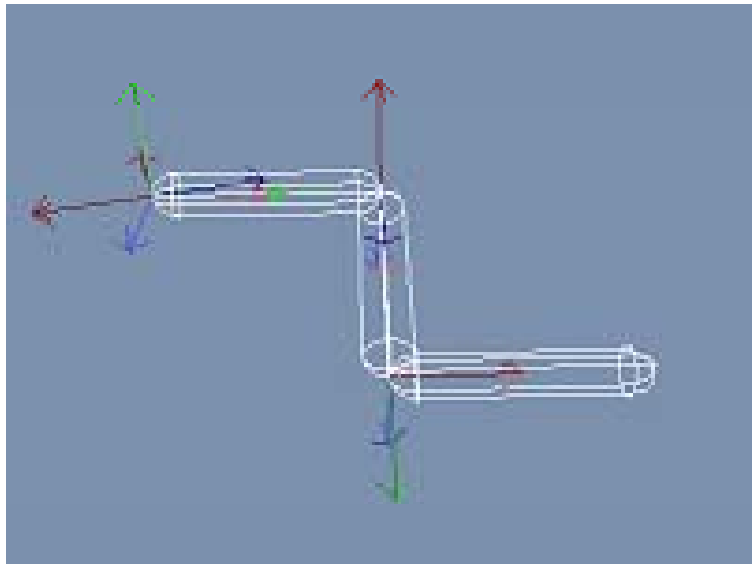


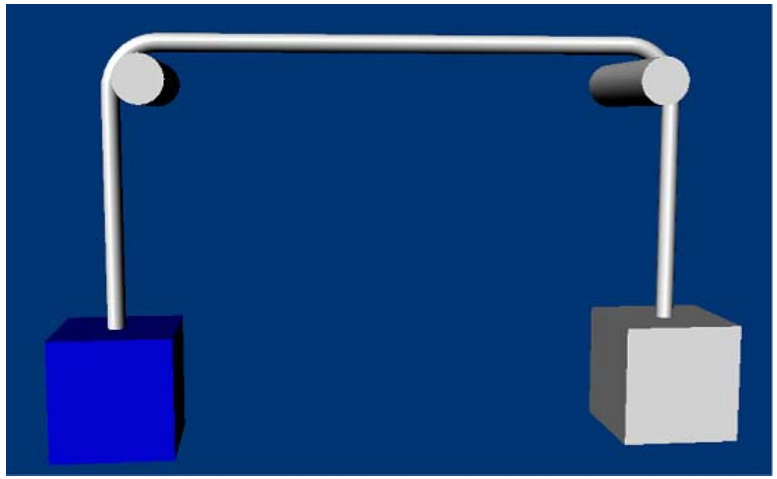
Rigid Body

- **Actor**
  - Static – fixed in world space
  - Dynamic – and have ‘body’
  - One or more Shapes
    - Geometry
    - Relative Transform
    - Material
- **Dynamic - Body**
  - Velocity (linear & angular)
  - Mass properties
  - Sleep properties
  - Can form mechanisms

Rigid Body

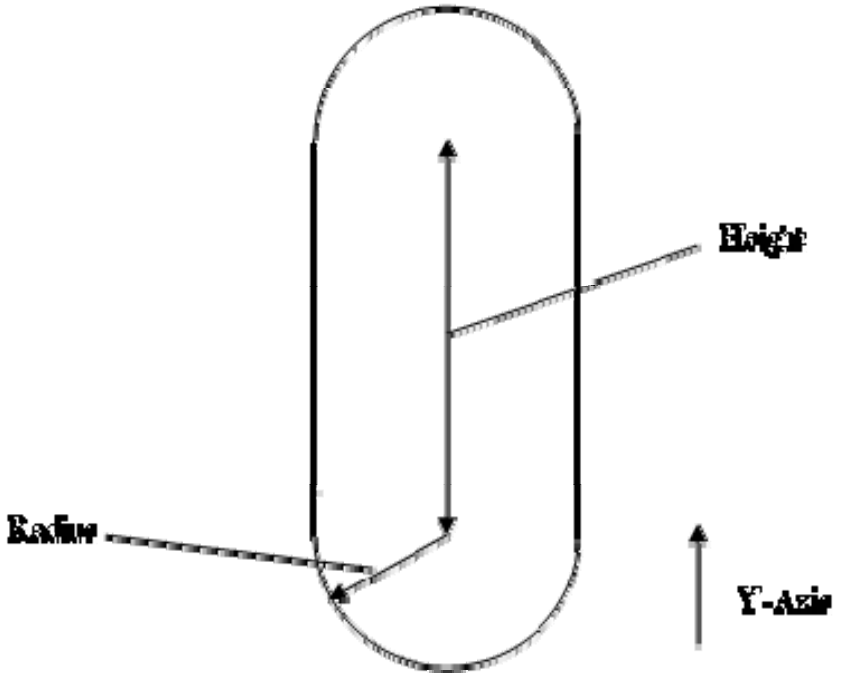
- Joints
  - a frame in each actor
  - constraints on those frames
- D6 and 8 additional types
- Includes support for
  - Motors
  - Springs
  - Limits
  - Pulleys





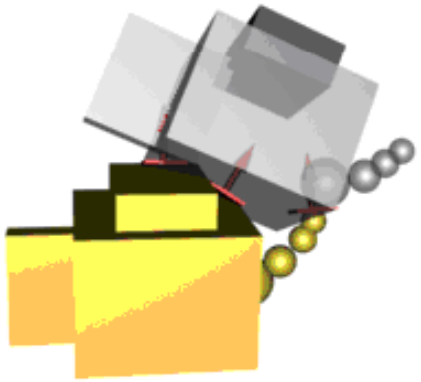
PhysX Shapes

- Single or Meshes
  - Capsule
  - Sphere
  - Box
  - Convex Mesh
  - Triangle Mesh



Physics Shape

Graphics Representation



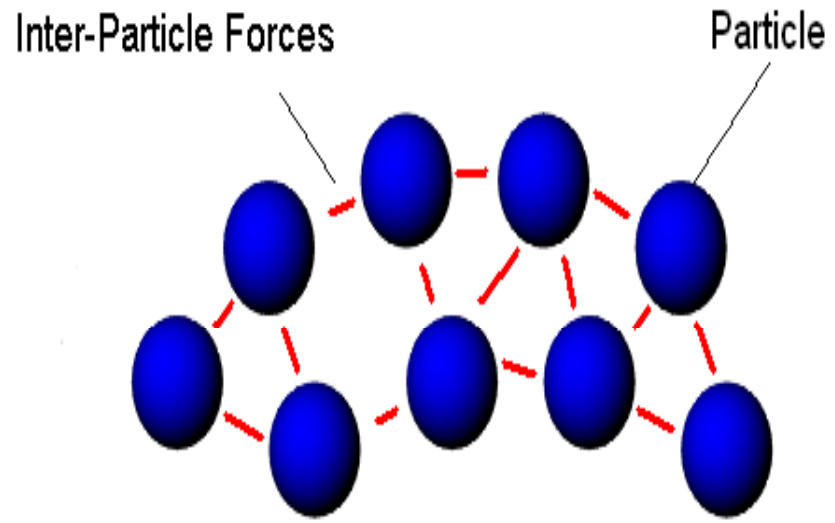
Bounding Box Representation

The Kinematics of any rigid body can be represented by a tensor and point.

Physics representation does not need to be same of the graphical mesh.

Fluid

- Colliding particle system
  - Position, velocity, lifetime, density, …
- Interaction Modes
  - SPH
  - Non-interacting
  - Mixed

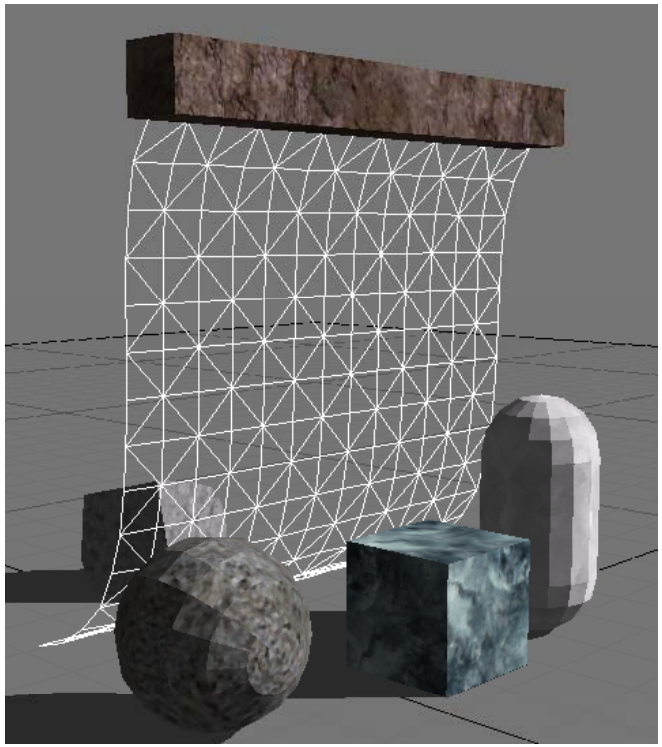


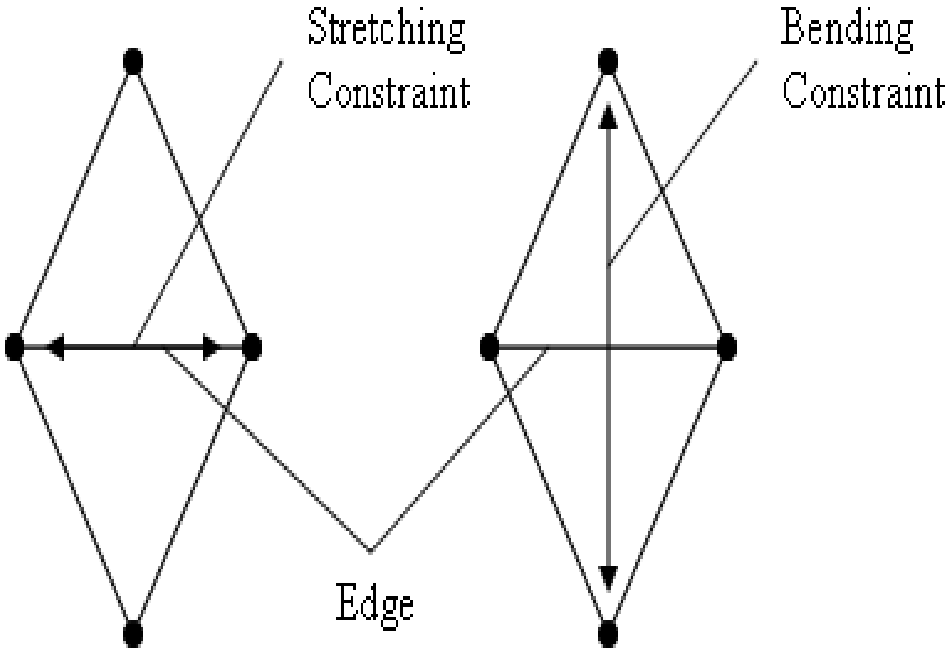
Fluid

- Particle Manipulation
  - add, update, remove particles
- Packet-based culling
- Emitter (Source)
  - can attach to shapes
- Drain (Sink)
  - NX_SF_FLUID_DRAIN flag on shape
- Event Notification

Cloth

- Mesh of particles
- Stretching and bending constraints





Cloth Parameters

NxCloth class parameters

- *Bending Stiffness*
- *Stretching Stiffness*
- *Density*
- *Thickness*
- *Damping*
- *Solver Iterations*
- *Attachment Response Coefficient*
- *Collision Response Coefficient*
- *Friction*
- *External Acceleration*
- *Wind Acceleration*
- *Valid bounds*

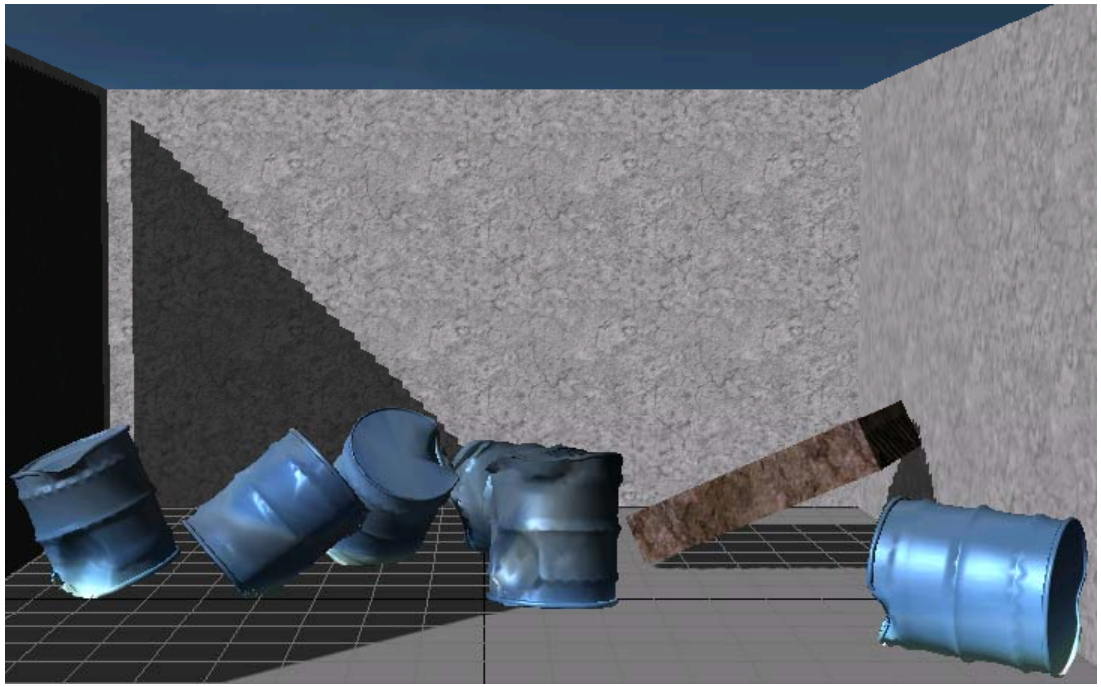
- *+ Selection of Flags to enable various affects*

Cloth

- Attachment
  - Attach vertex to fixed points or shapes
  - Detach vertex
- Tearing
  - automatic or explicit
  - tearable attachments
- Pressure
  - Closed meshes only
- Collision
  - Self-collision
  - Collision with rigid bodies

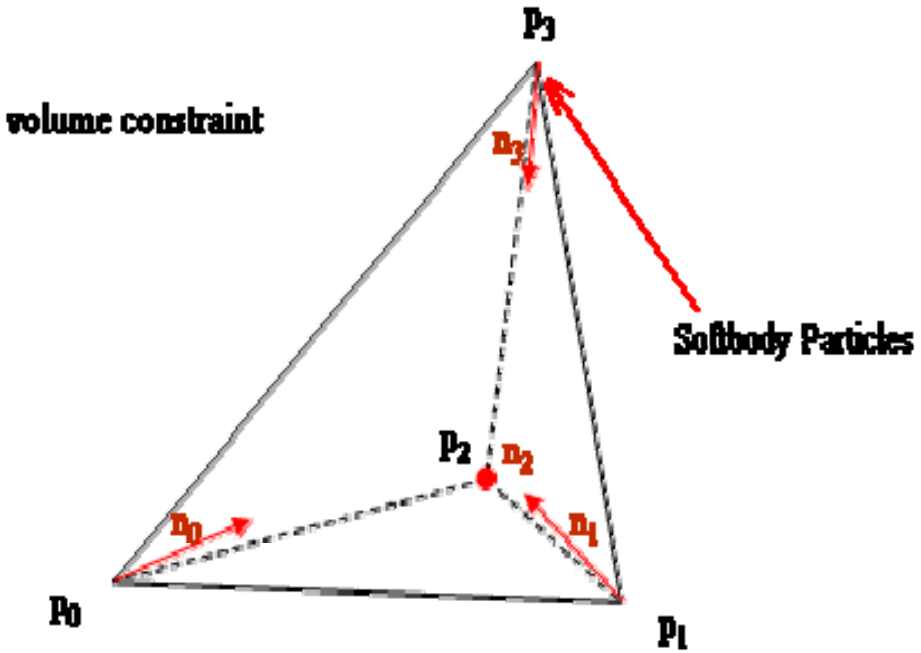
Metal Cloth

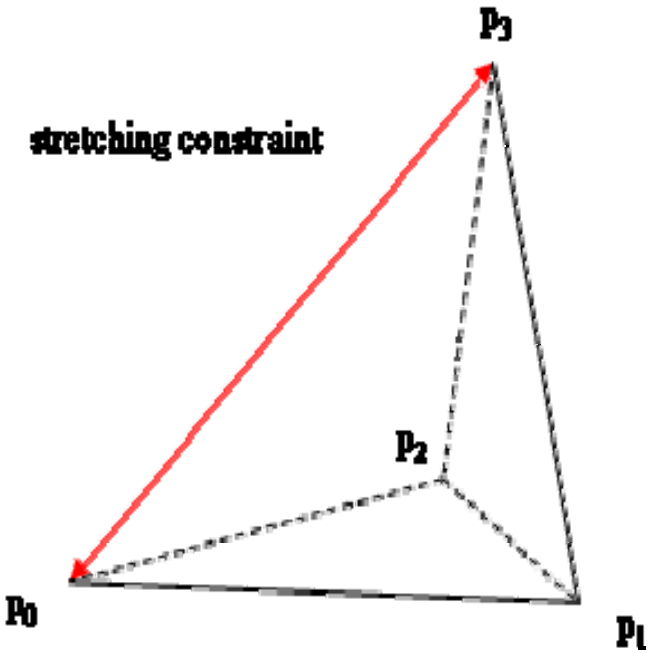
- Derivative of Cloth Feature
  - Plastic deformation of sheet metal
  - Cloth mesh around a rigid body core
  - On impact deform the mesh & adjust RB collision



Soft Bodies

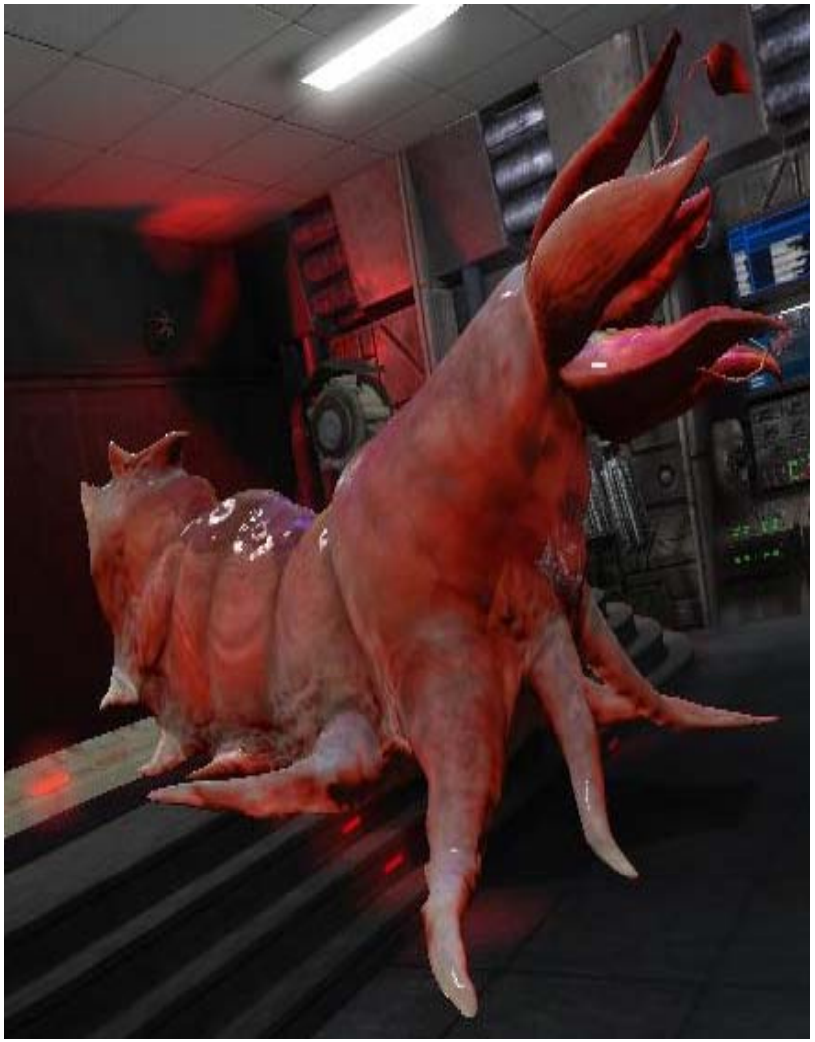
- Mesh of particles
- Volume-preserving tetrahedral constraints
- Uses cloth Solver





Soft Bodies

- Creation
  - Requires Tetrahedralization
  - Tetra-maker in PhysXViewer!
- Attachments & Tearing



Volumetric Force Fields

- Enables procedural insertion of energy into the system
- Activity volume
  - ‘Include’ & ‘Exclude’ volumes
- Data-driven Fixed-function Kernel
- Custom Kernel
  - Procedural shaders compiled at compile time and runtime

Tornado example FF provided in SDK

Other SDK Functionality

- Scene Query
  - Raycast
  - Swept Volume: Box/Capsule/Actor
  - Batching & Sweep Cache for performance
- Character Controller
  - A box- or capsule- shaped actor
  - Sweep tests for ease of walking
  - Ships with source
- And More ..

Cooking

- Offline Asset Preprocessing
  - AABB Trees for Triangle Meshes
  - Convex Hull from point set, plus acceleration cube map
  - Cloth from tri-mesh, soft body from tet-mesh
- All assets cook to binary stream
- Conditioning
  - Vertex welding
  - Optional inflation and edge beveling for thin/sharp objects

PhysX Development Infrastructure

- APEX
- AgPerfmon
- PhysX Visual Debugger (VRD)
- SoftImage PlugIns
- Max PlugIns
- Maya PlugIns
- PhysXViewer
- TetMaker
- Video Tutorials

APEX Overview

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APEX Mission:
Solve 3 Big Game Physics Problems

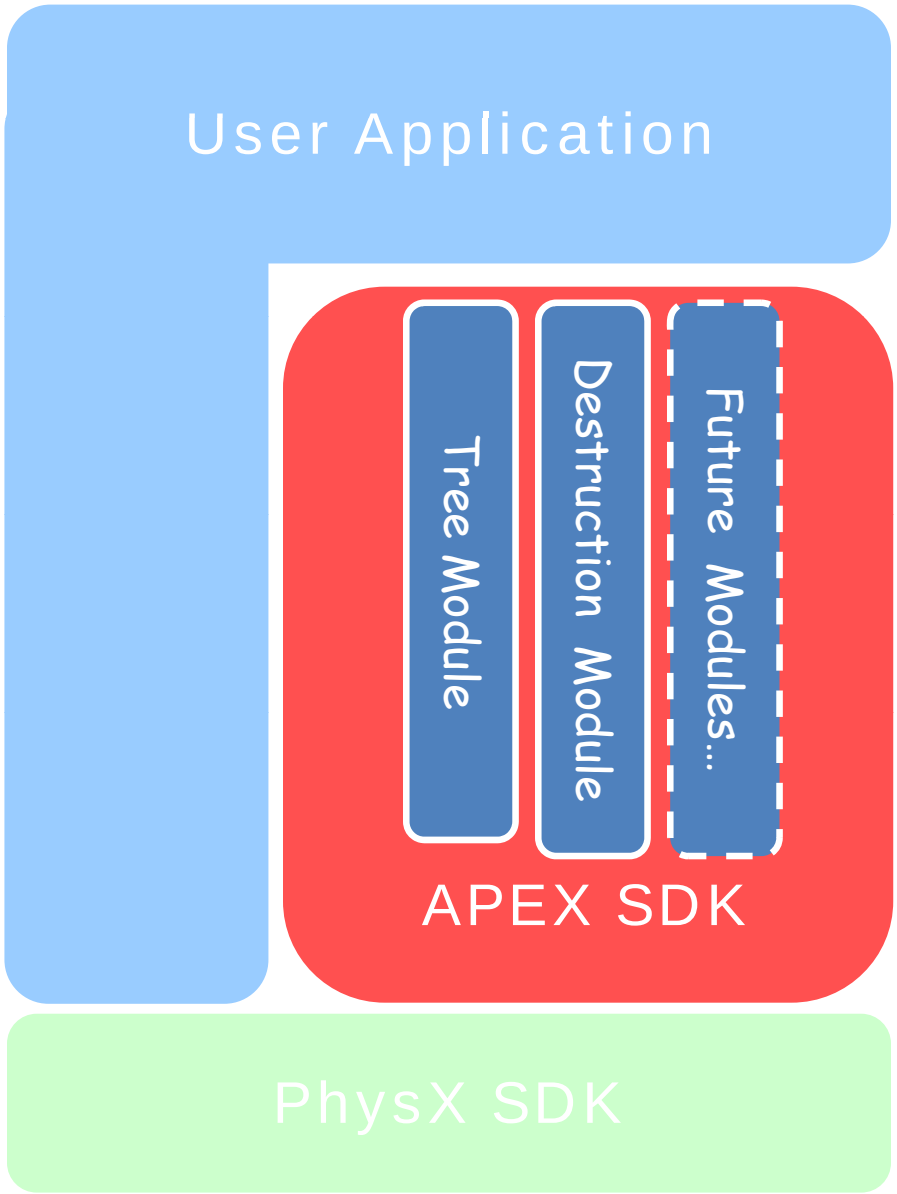
1. Significant programmer involvement

2. Content designed to “min spec”

3. Game engine limitations

Basic Design

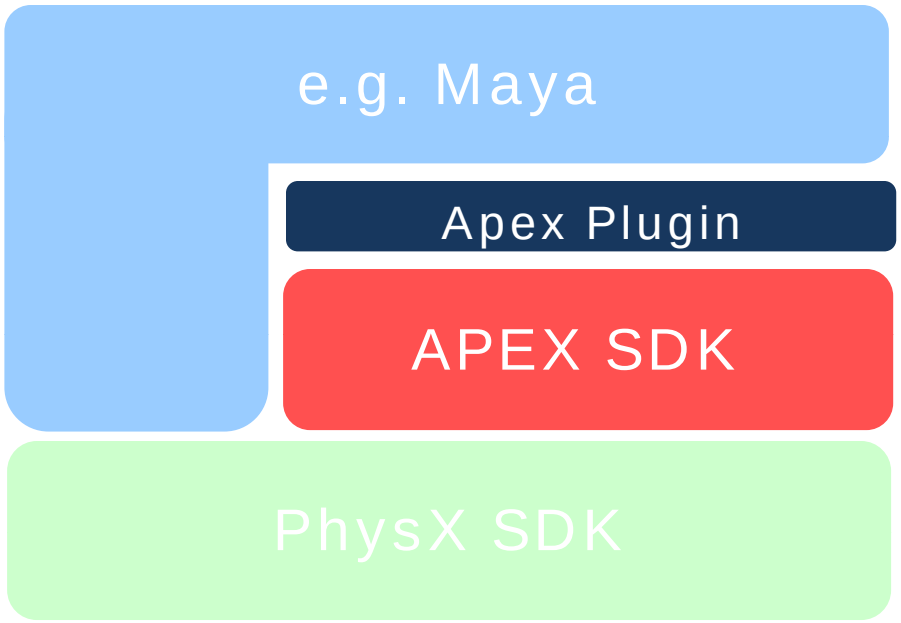
- A collection of “modules”
- Shared interfaces
- Built on top of the PhysX SDK
- User Application:
  - Game (runtime)
  - Authoring tools
  - Level editor

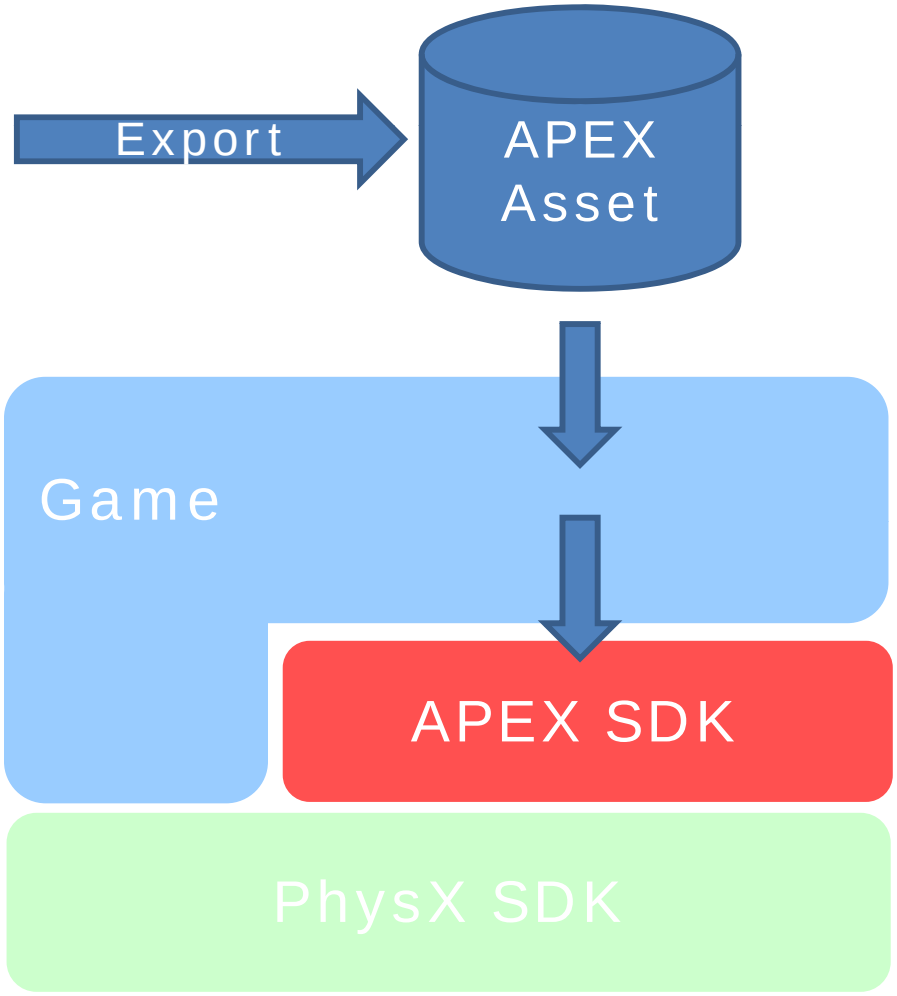


Modules

- **Implement intuitive, specific purpose, high-level physics technology**
- **Level of abstraction appropriate for content creators**
  - **Low SDK level of abstraction: rigid body, joint, cloth, fluid**
  - **High APEX level of abstraction (modules): vegetation, character, destructible mesh**
- **Manage multiple physics elements and simulation types**

Authoring





- **Modules are provided with authoring tools**
- **SDK has asset file serialization support built-in (load/store)**

Problem 1

- **Significant programmer involvement**
- **APEX Solution: Provide a “high-level” interface to the artists**
  - **Reduces the need for programmer time**
  - **Add automatic physics behavior to familiar objects**
  - **Leverage multiple SDK features**

Scaling

- Scaling graphics was easy…
  - Scaling physics, not so much!
- All modules provide load-time and/or run-time scalability mechanisms
  - E.g. Number of APEX objects to have active, total number of debris to keep around
- APEX assets are authored once
  - … to reduce work
  - But the developer still has control over scaling and LOD

Problem 2

- Content designed to “min spec”
- APEX Solution: scalable modules
  - Variable physics “quality” for each physical system
    - Static: hardware capability, player preference
    - Dynamic: visibility, distance from player, etc.

Interface to Rendering System

- APEX has a unified API for sending data directly to the rendering engine
  - Shared by all modules
  - Bypass game logic whenever possible
  - Efficient, but flexible

- Application implements a few interfaces
  - APEX objects ask the game to allocate buffers
  - APEX streams rendering data to the buffers
  - Application renders the buffers with appropriate materials, shaders, etc…

Problem 3

- Game engine limitations
- Solution: Create a rendering “fast path”
  - Bypass the inefficient, fully generic path
  - PhysX objects in an APEX asset are scriptable / networkable / etc. as a group, not individually

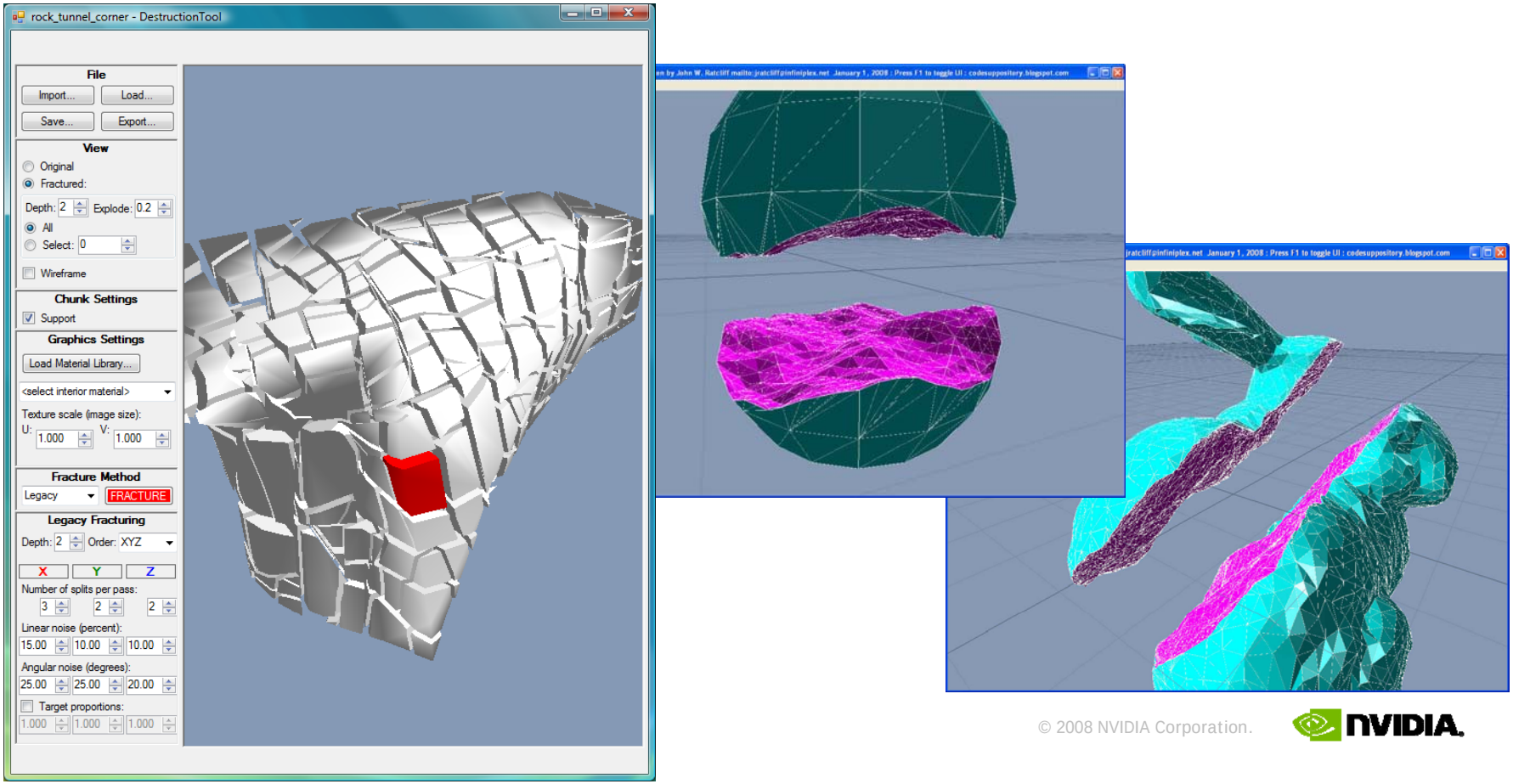
Destruction Module

- Arbitrary meshes are pre-fractured at authoring time
- In real time as they take damage, pieces get blasted away
- Meshes can be initially static or dynamic
- “Support” system for static meshes
- Automatic small debris effect using particles


0
1st / 0
+100
100

Destruction Authoring

- **Standalone tool, easily integrated into 3dsmax, Maya, or XSI**
  - **Hierarchical splitting with random fracture surface generation**



Destruction Scalability

- **At authoring time:**
  - **# of pieces the original asset is split into**
- **At runtime:**
  - **Whether to fracture down all the way to the finest level of pre-fracture, or only to a coarser level**
  - **Option to scale amount of particle meshes**
  - **Size adjustable global debris FIFO**
- **The game can change runtime APEX parameters based on LOD.**

Tree Module

- Lets us create trees with physical behaviors
- Works with SpeedTree trees
- Full physical interactions
- Tree destruction
- Leaf dropping effect

Tree Physics

- Trees skeletons are automatically generated
- Skeletons are only simulated when trees are being interacted with (LOD)
- Emitters are automatically created to spawn leaves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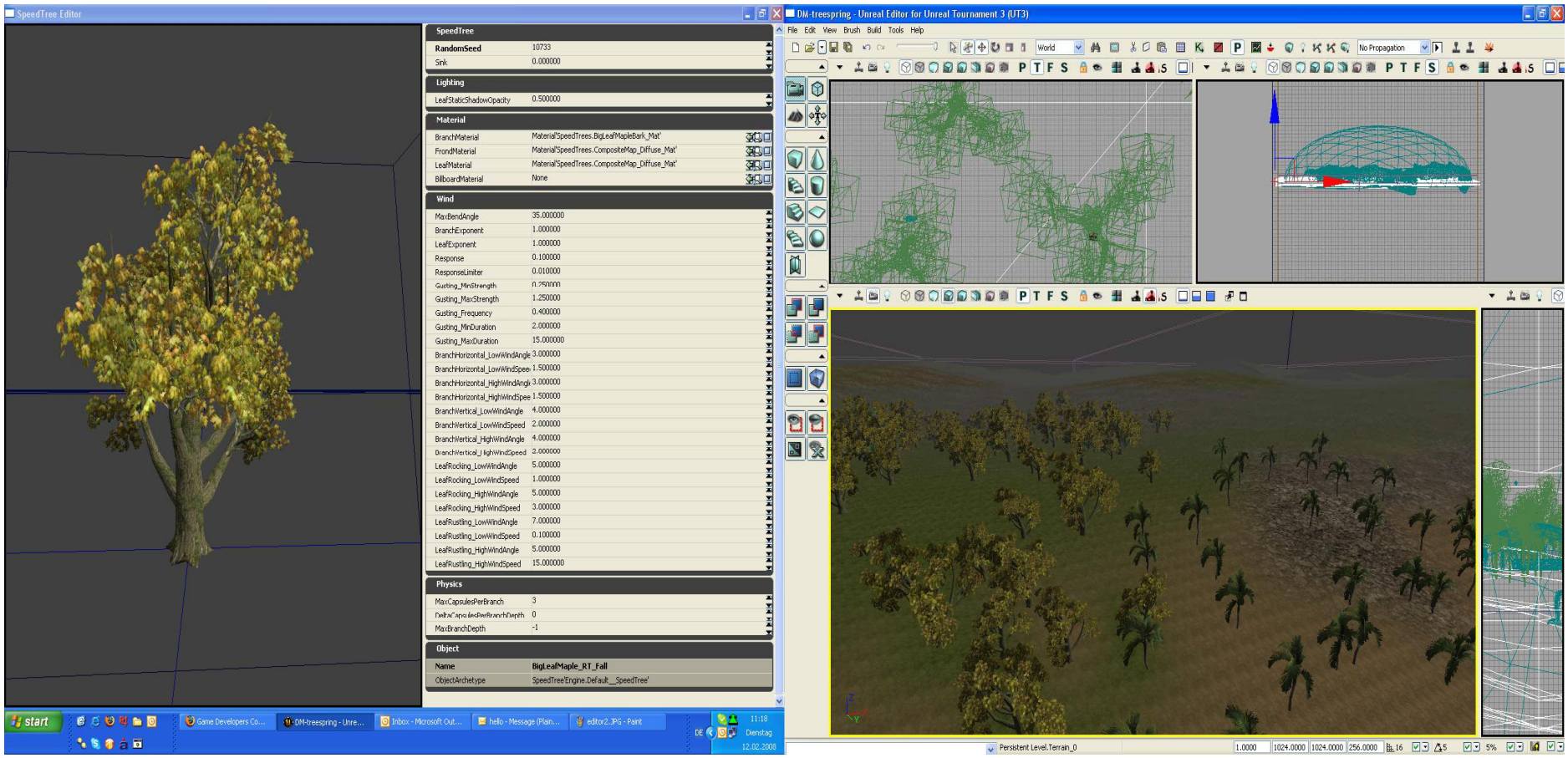
Tree Authoring

- **Authoring process same as for normal trees, except for a few simple physics parameters**
  - **Capable of directly loading SpeedTree format files**



Tree Scalability

- **At load / authoring time:**
  - **A particular tree asset can have variable detail RB skeleton generated**
- **At runtime:**
  - **A large forest can have more or less of its trees become physically active at any one time, in response to interactions**
    - **Tree actor FIFO for fast activation**
  - **Leaf emitters can emit more or less leaves**

More modules…

- **Actively seeking great ideas**
  - **and partners to work with…**
- **What would <u>you</u> like to see?**

AgPerfMon & VRD

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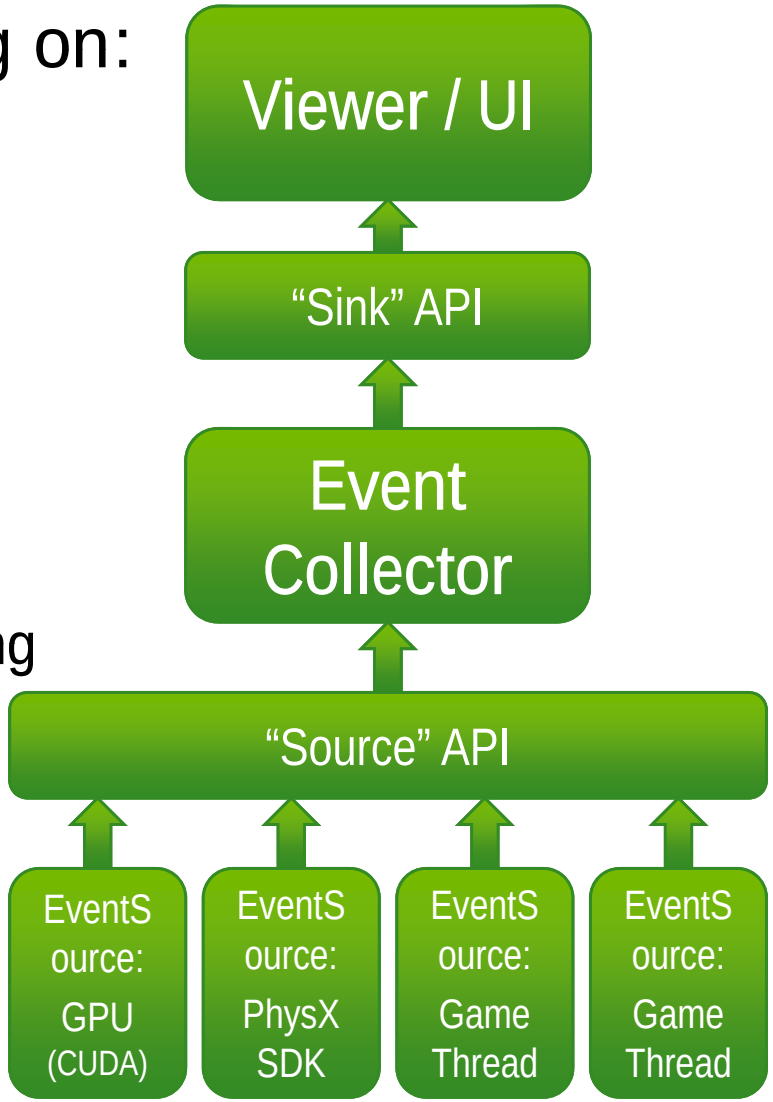
Problem Statement

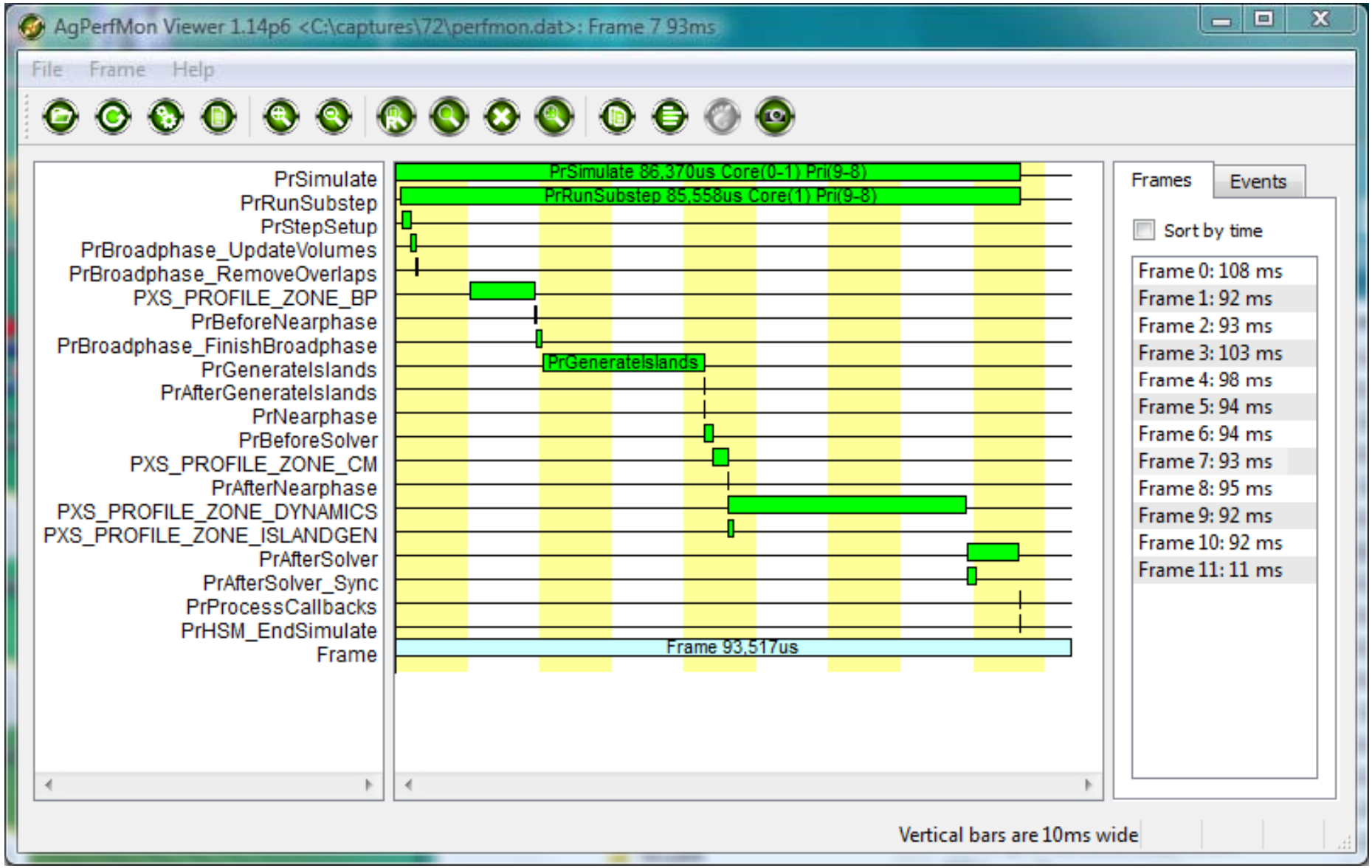
- Identifying system-wide bottlenecks is very challenging
  - Many asynchronous processes running in parallel on different processing cores
  - Can't just analyze who's using the most cycles: dependencies matter
  - Visualizing "what happens when" is critical

AgPerfMon Overview

- Supports simultaneous profiling on:
  - CPU Threads: PhysX / APEX SDKs, game / application threads
  - GPU: CUDA Kernels, Warps
- Event-logging architecture
  - Synchronized time stamps
  - Configurable source-based filtering
  - Configurable event triggers
  - Periodic event generation
  - Source & sink API's
  - VERY lightweight



Event Viewer



Source API – Initialization

YourCode.cpp:

```
#include “AgPerfMonEventSrcAPI.h”

// Initialization code
AgPerfUtils *gPerfUtils = new AgPerfUtils;
```

```
// Shutdown code
delete gPerfUtils;
```

Source API – Event Generation

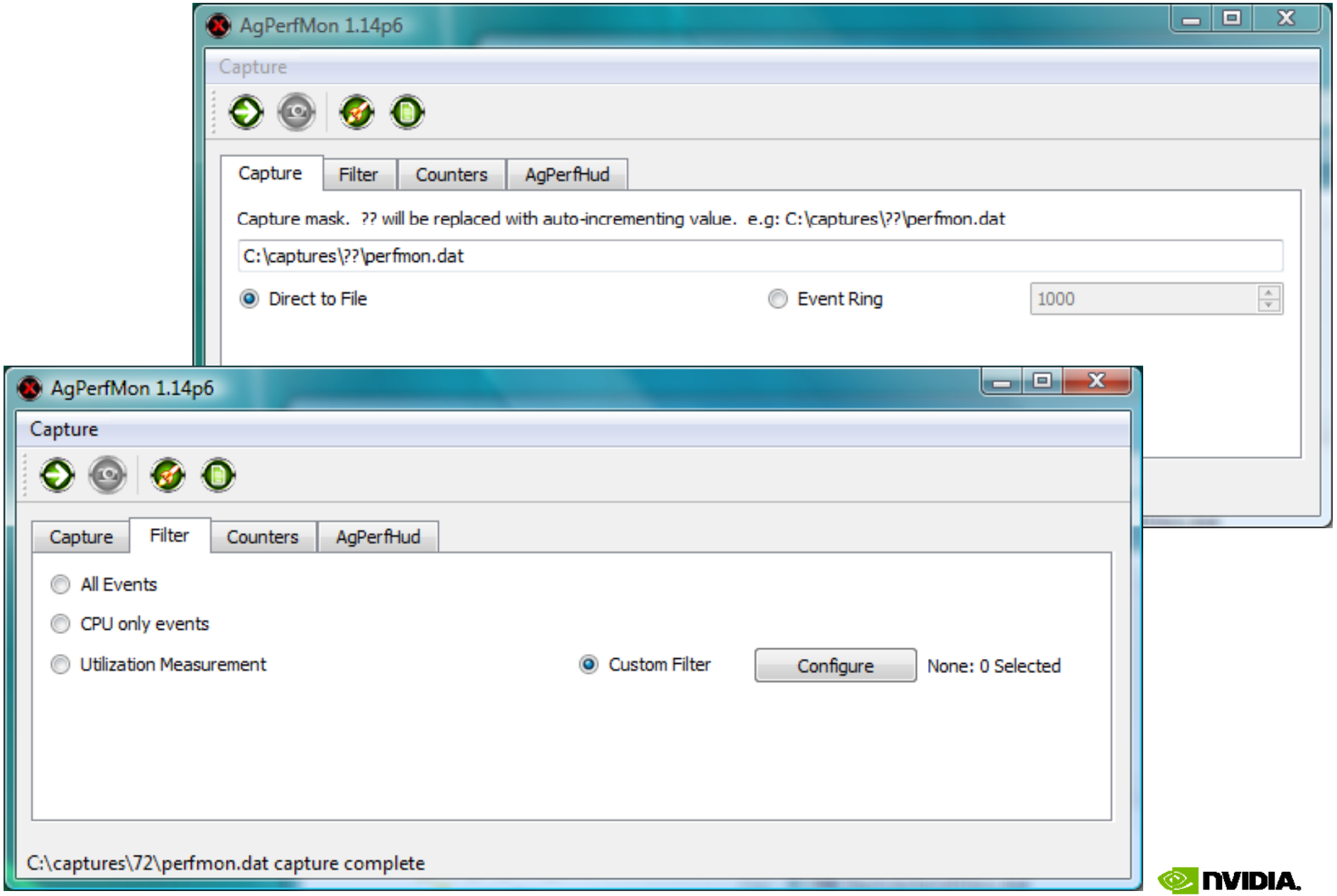
AgPerfMonEventDefs.h:

```
DEFINE_EVENT(Foo)
```

YourCode.cpp:

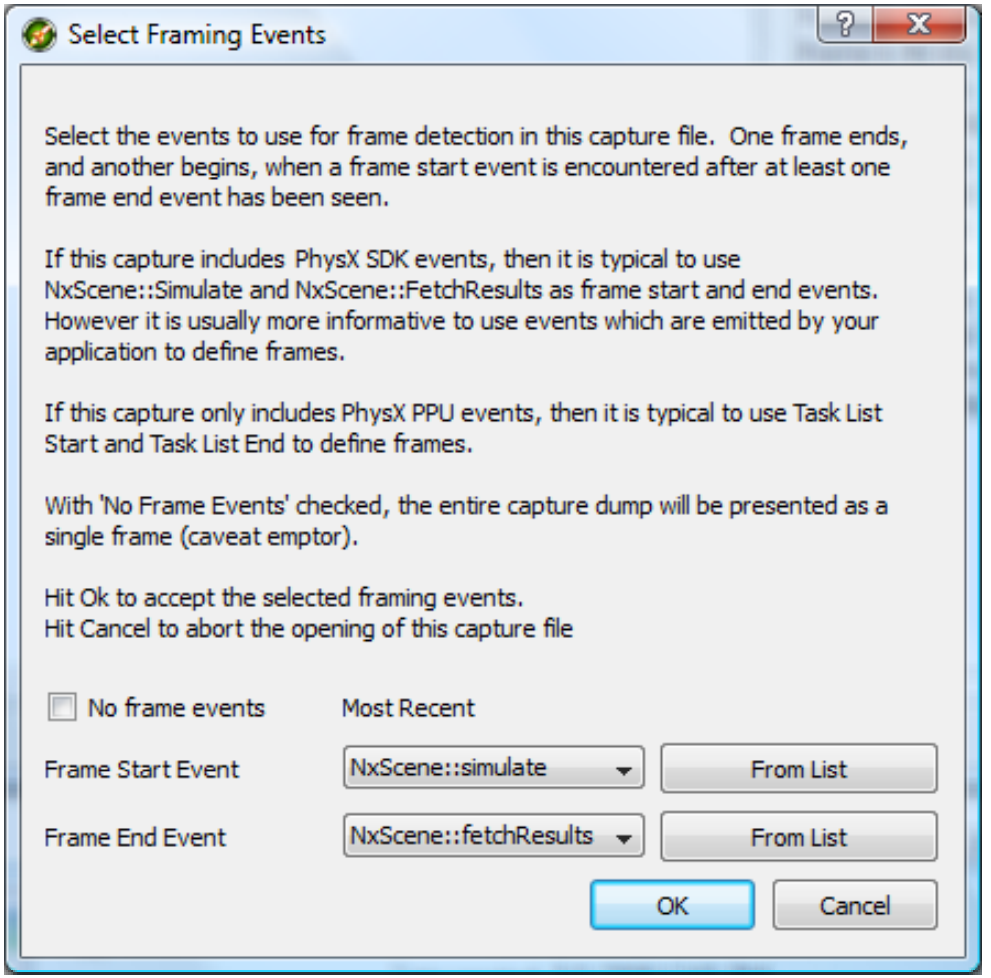
```
{
   AgPerfScope s(Foo);
   // do something
}
```

AgPerfMon GUI

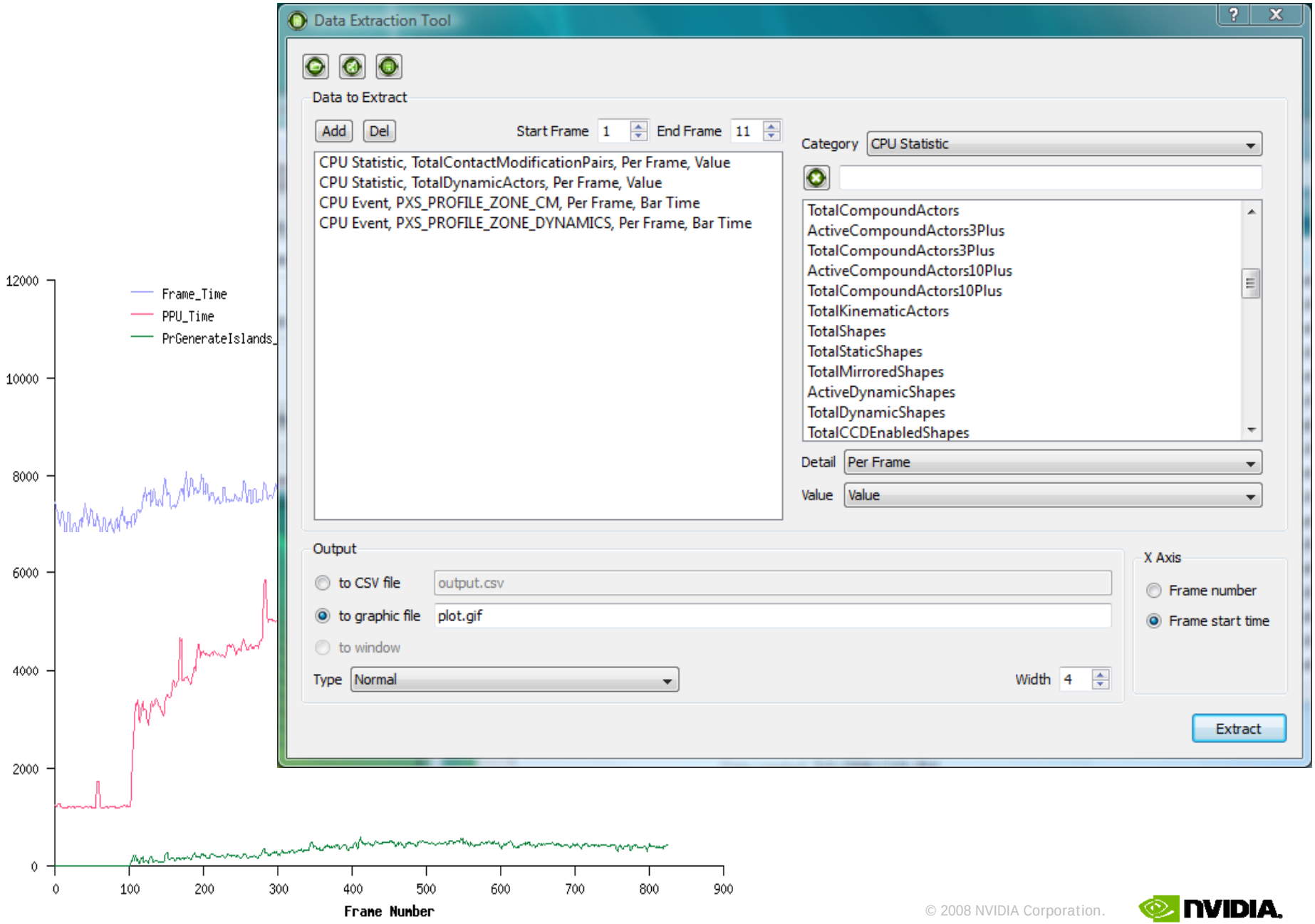


AgPerfMon Viewer

- Frame events
  - Define frame boundaries
    - Frame Start Event marks the start of frame…
    - … only if a Frame End Event has been seen since last start of frame
  - No frame events
    - View entire file as a single frame
    - Only works for small files
  - Index cache
    - Viewer builds an index cache to accelerate finding frames in large data files (*.fdx)

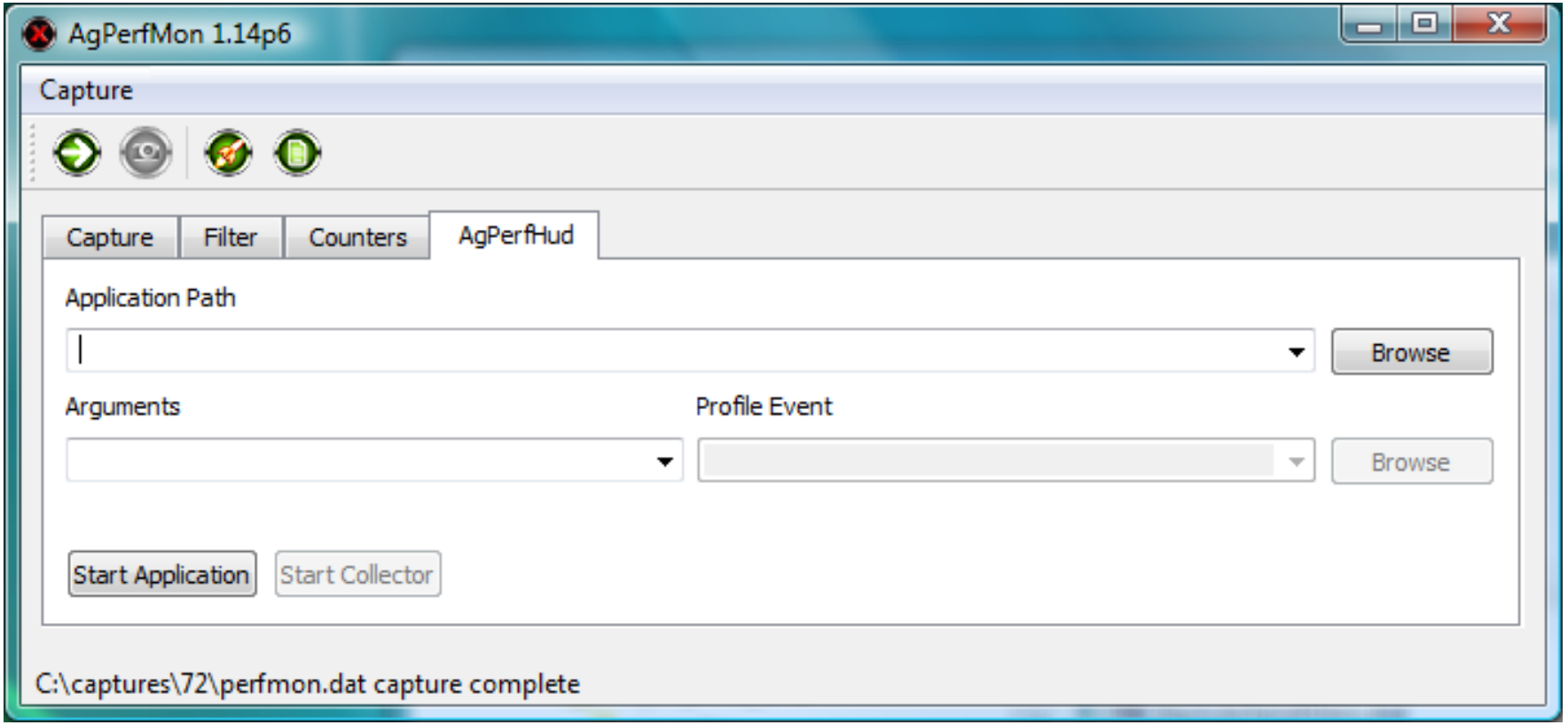


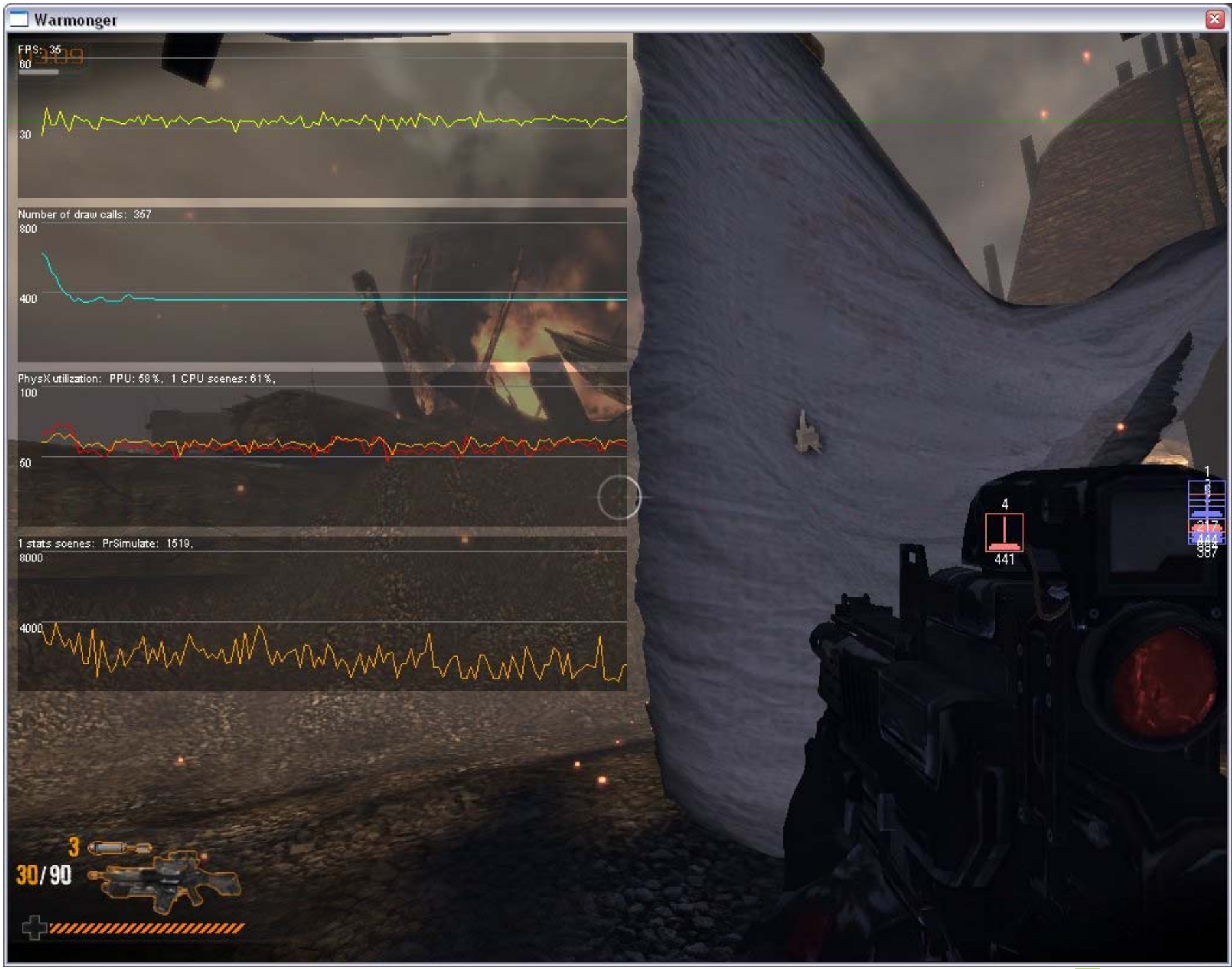
Data Extraction Tool



AgPerfHud

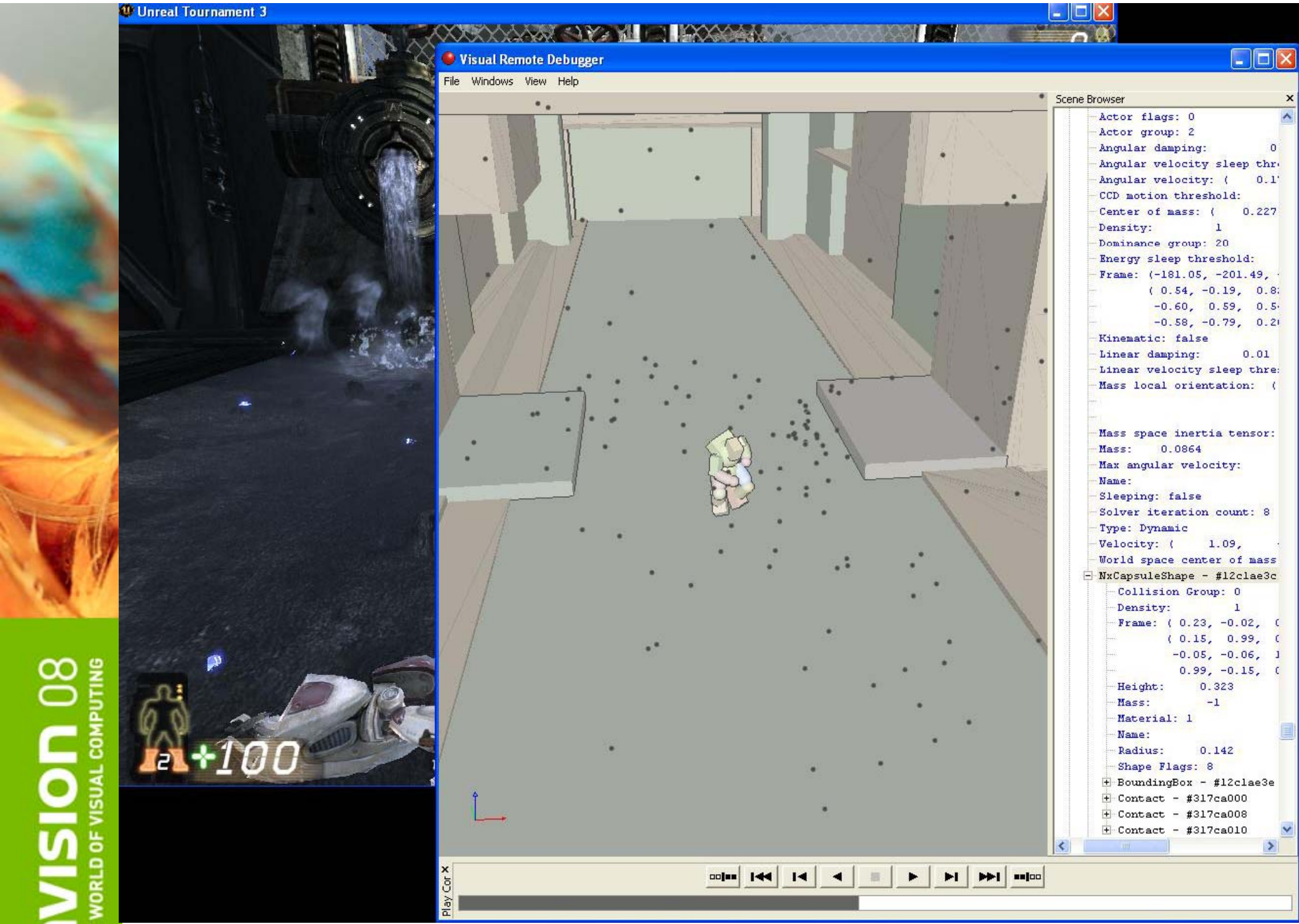
- Simple utility to overlay AgPerfMon performance data on any D3D application window





Visual Remote Debugger (VRD)

- Connects to a running PhysX SDK through a network socket
- Provides access to all simulation state data
  - Live visualization
  - Record / playback / save to file
- Full visualization of physics scene
  - Shapes / bounding boxes / particles
  - Contacts / joints
  - Velocities
- Data editing
  - Click on an object to view / modify state in “Scene Browser” window



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PhysX SDK Licensing and Support

NVIDIA Corporation

NVIDIA

Platform Coverage

	PhysX™ by NVIDIA	Competitor's Solution
PC Support - CPU only	YES Multi-Threaded Support for Multi-Core x86 Products	YES
PC Acceleration	YES! GPUs (CUDA): Mobile + Desktop	NO
Xbox 360	YES	YES
Playstation3	YES	YES
Wii	YES*	YES

PhysX License Fees

Per Game License Fee	PC[3]	PS3[1]	Xbox 360	XBLA	Wii[2]	Wii-Ware
Binary	Free	Free	Free	Free	Free	Free
Source	**$50K**	**$50K**	**$50K**	**$50K**	**$50K**	**$50K**

1 The PS3 PhysX SDK has been maintained and supported by Sony. If you are a PS3 registered developer, you can find the PhysX SDK on Sony's online download site. NVIDIA will soon take direct ownership of licensing.

2 Wii SDK in Beta

3 Linux Driver Support Available

PhysX License Fees

Binary SDK

- SDK – Unified PhysX API for both PC and Console Platforms
- PC Binary SDK Free for both Commercial **AND** Non-Commercial use
  - No License Fee Required
  - Over 30,000 Downloads
- Console SDK's Free for Registered Developers for both Commercial **AND Non-**Commercial use
  - EULA covers terms

Source SDK

- Individual Game License for each Platform
  - Multi-title flexibility on terms
- Source Code SDK includes HL source code to facilitate debugging process

Developer Support

- **Multi-language documentation on the way:**
  - Japanese, Chinese, and Korean
- **Two Levels of Support:**
  - Free forum support always available via NVIDIA's developer website

    developer.NVIDIA.com/forums
  - Ticket-based support and staffed in local time-zones worldwide
  - Paid Support Model - $8k annual/game/platform