Game Programming: The BIG Picture

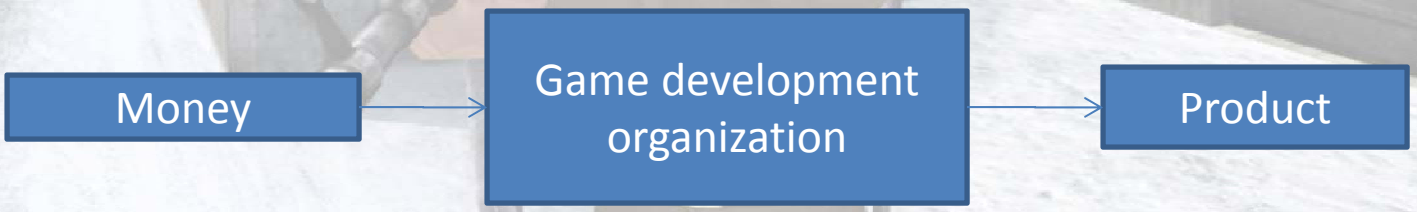
Dan White
Studio Technical Director
Pipeworks
danw@pipeworks.com

The very old days…

30 years ago, a game might have 1 programmer, and maybe 1 artist

View from the CEO's chair…

- Games are big business
  - Current AAA titles: $30 million budget, 2+ year time frame
  - Project completion date is very important
    - Particularly for licensed properties, sports, holiday launches, or anything with advertising



This means we make games differently…

When I first noticed change…

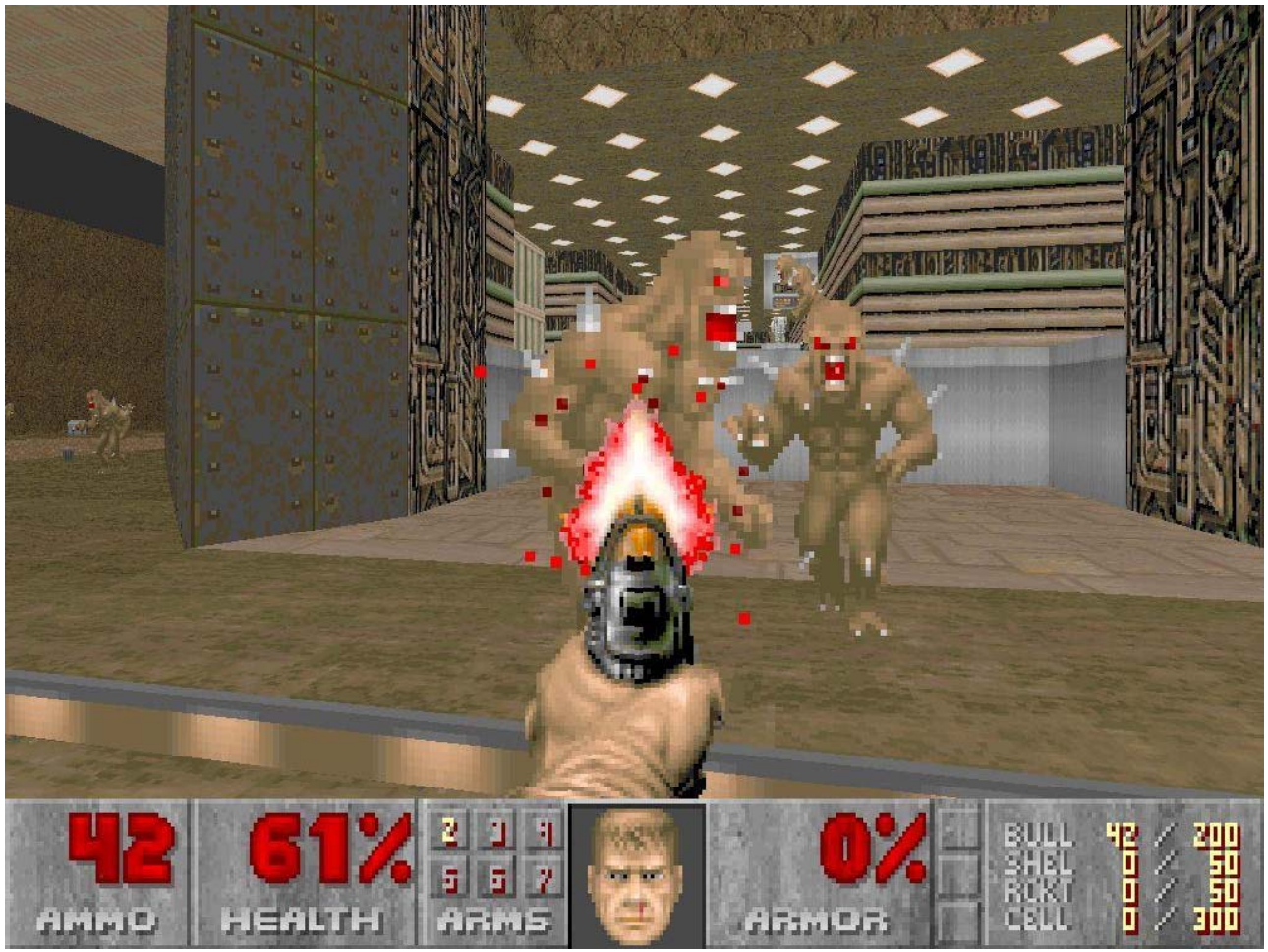
Jumpman
Atari 800
circa 1983:

This game had an EDITOR!
At the time, this seemed revolutionary to me.

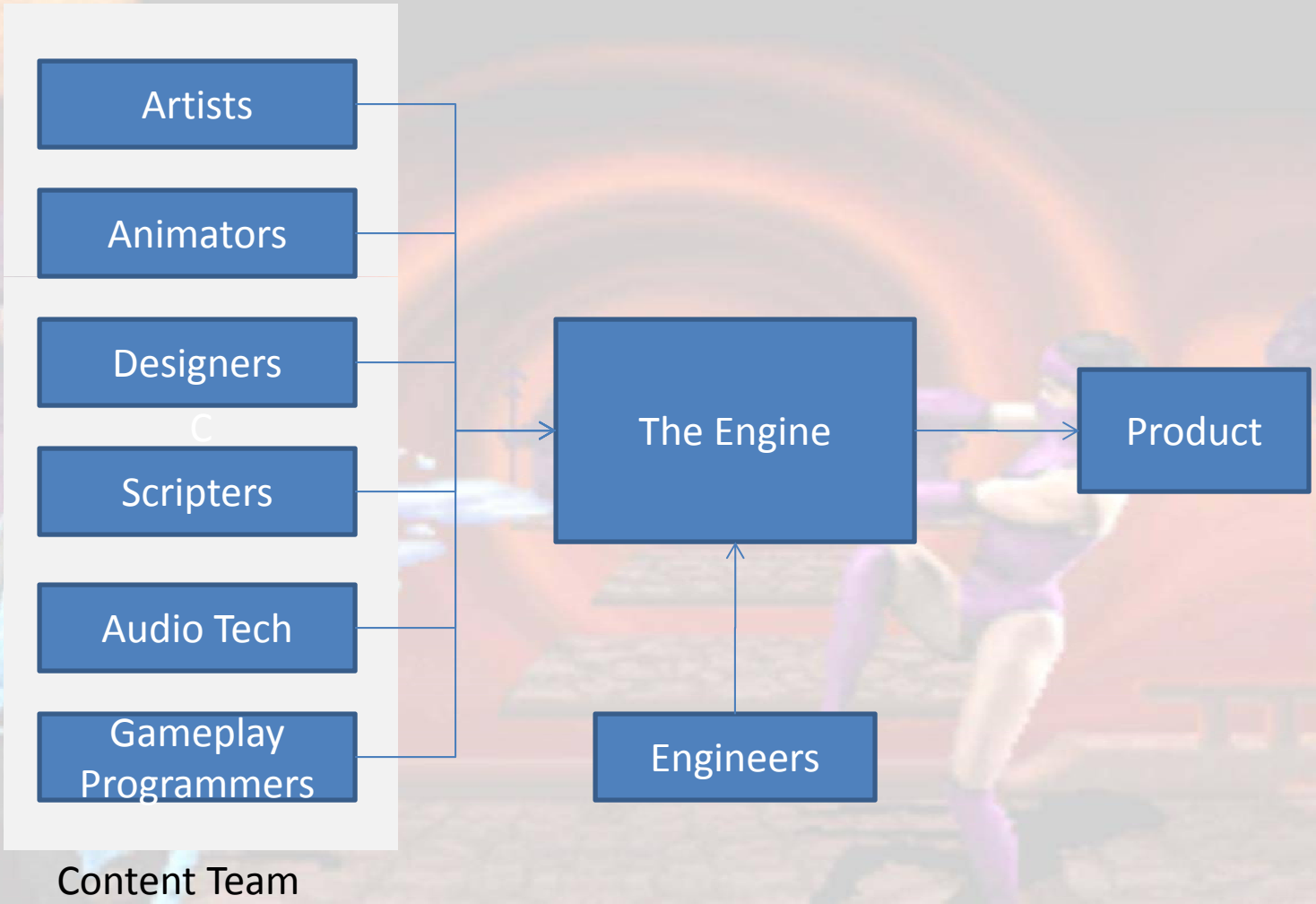
Doom Engine cemented the idea

Doom released in 1993

- Spawned HeXen, Heretic and so on
- Started the idea that an engine is potentially valuable on its own

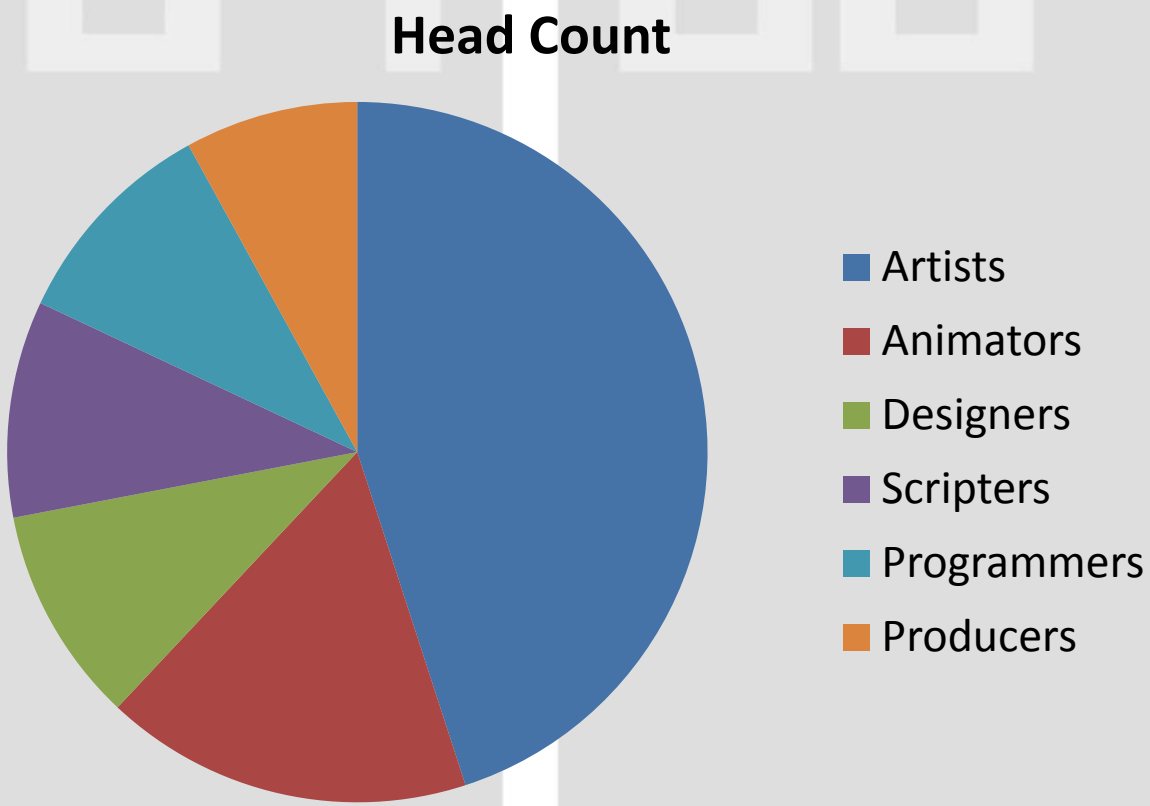


A more detailed view of today…



Engineer = programmer = software developer

Distribution of People (large project)



On large projects, programmers are a small part
On smaller projects, a larger part
Where is test? Forgotten as usual..

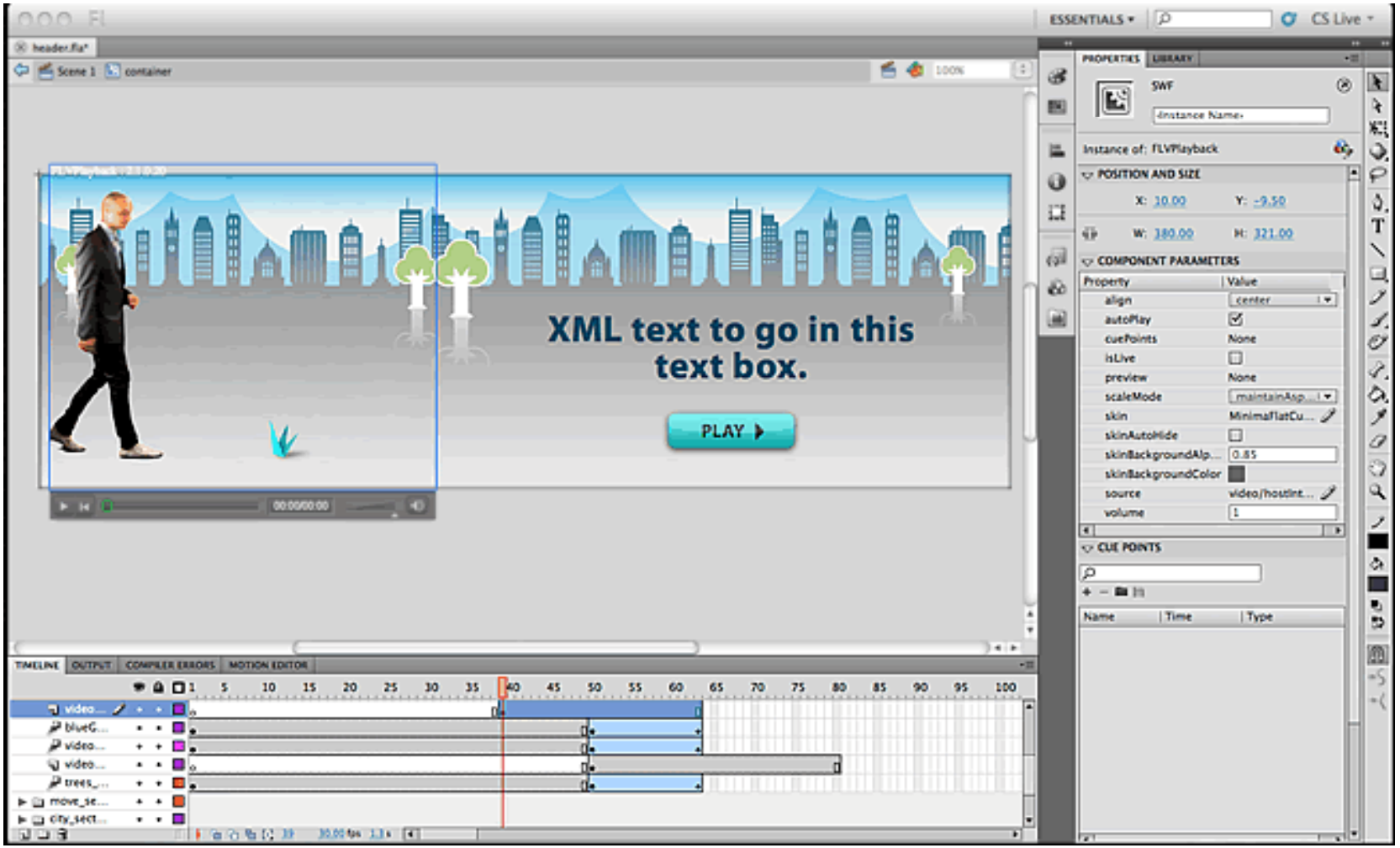
The real task of engineers

- The main task of engineers in a commercial game company is to make tools and runtime to enable artists and designers to make games.
  - Saves money, but just as important increases predictability.
- This is how most industries work anyway…you don't need programmers to use Autocad.
- How to design and create the perfect engine is very much unsolved.*
- Not to worry, we are decades away from losing the chance to be creative.

Actually it has been sort of solved

- Flash has taken over the market for 2D games.
- It's a huge success.
- Flash games can be made with only scripters.
- This is possible because:
  - Performance not an issue for 2D
  - 2D games are vastly simpler
- So successful that MS is making their own: Silverlight.
- Future is unknown: Will HTML 5 replace it, or will Flash succeed with 3d support.

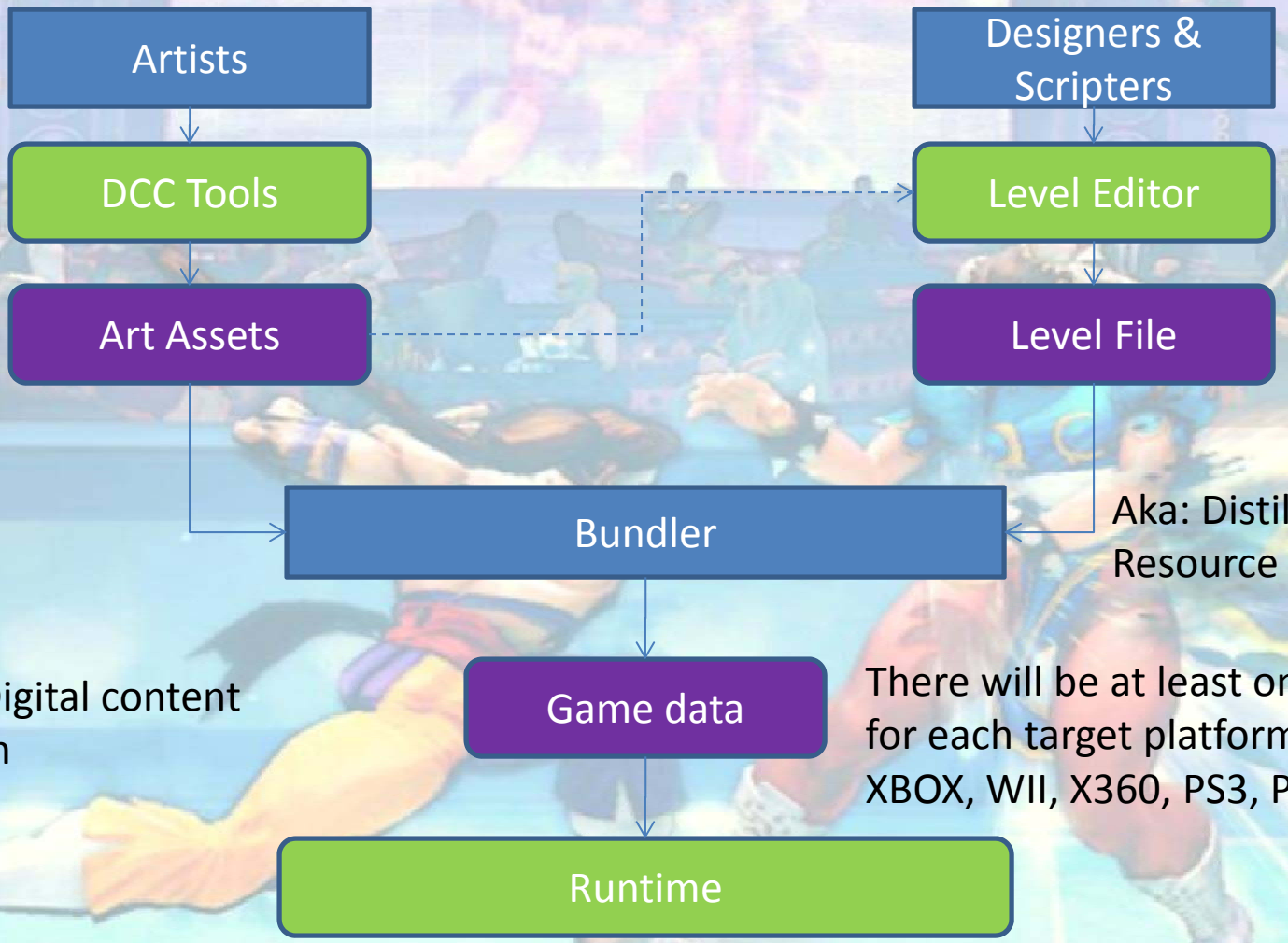
Adobe Flash CS5



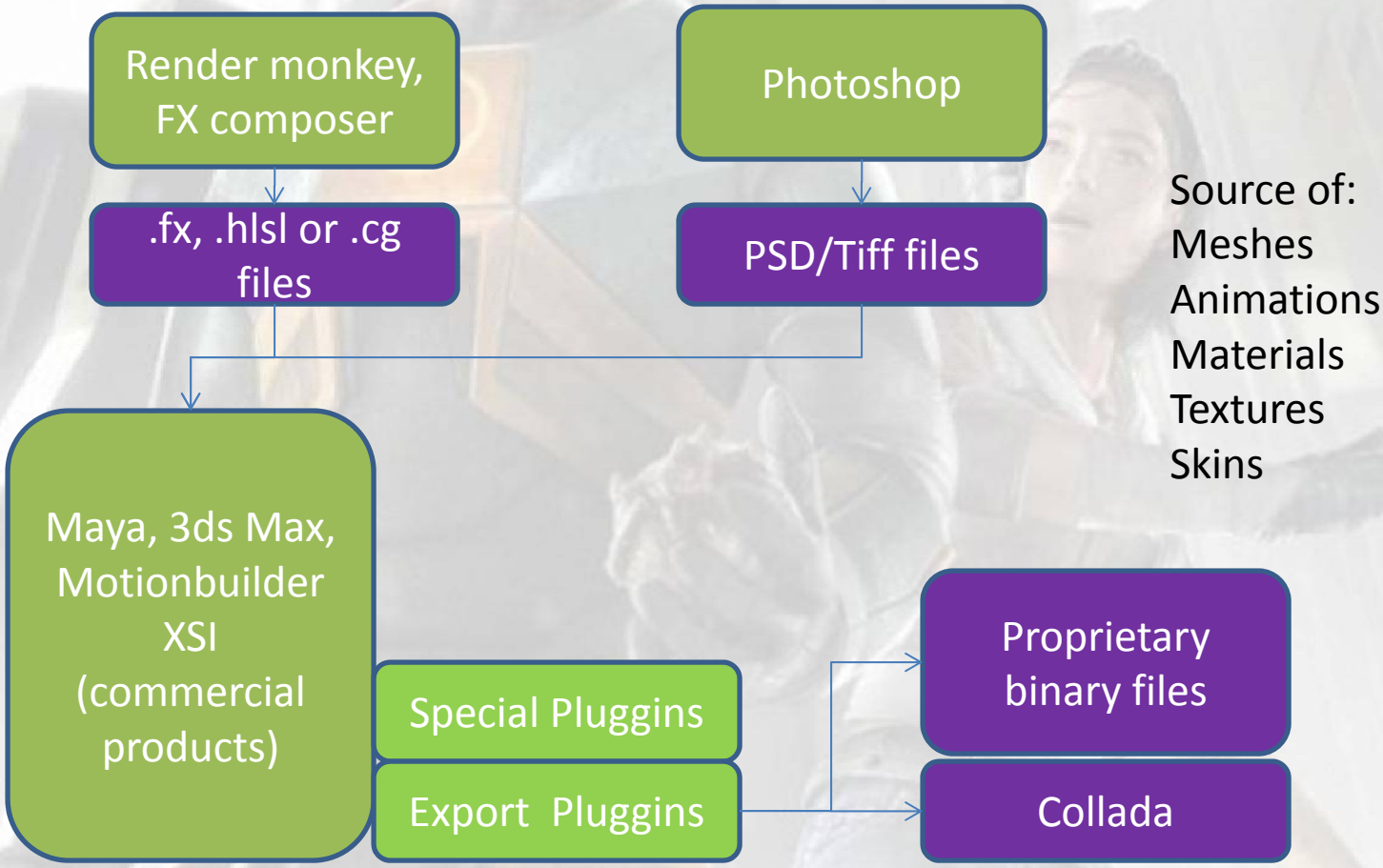
Flash suggests form of the general solution

- Artists make assets.
- Designers use the assets to make levels.
- The levels are packed to make game data.
- The runtime interprets & processes the game data.
- Sound familiar?
  - Source file →Compiled EXE
  - EXE run by an OS

A slightly more detailed view…

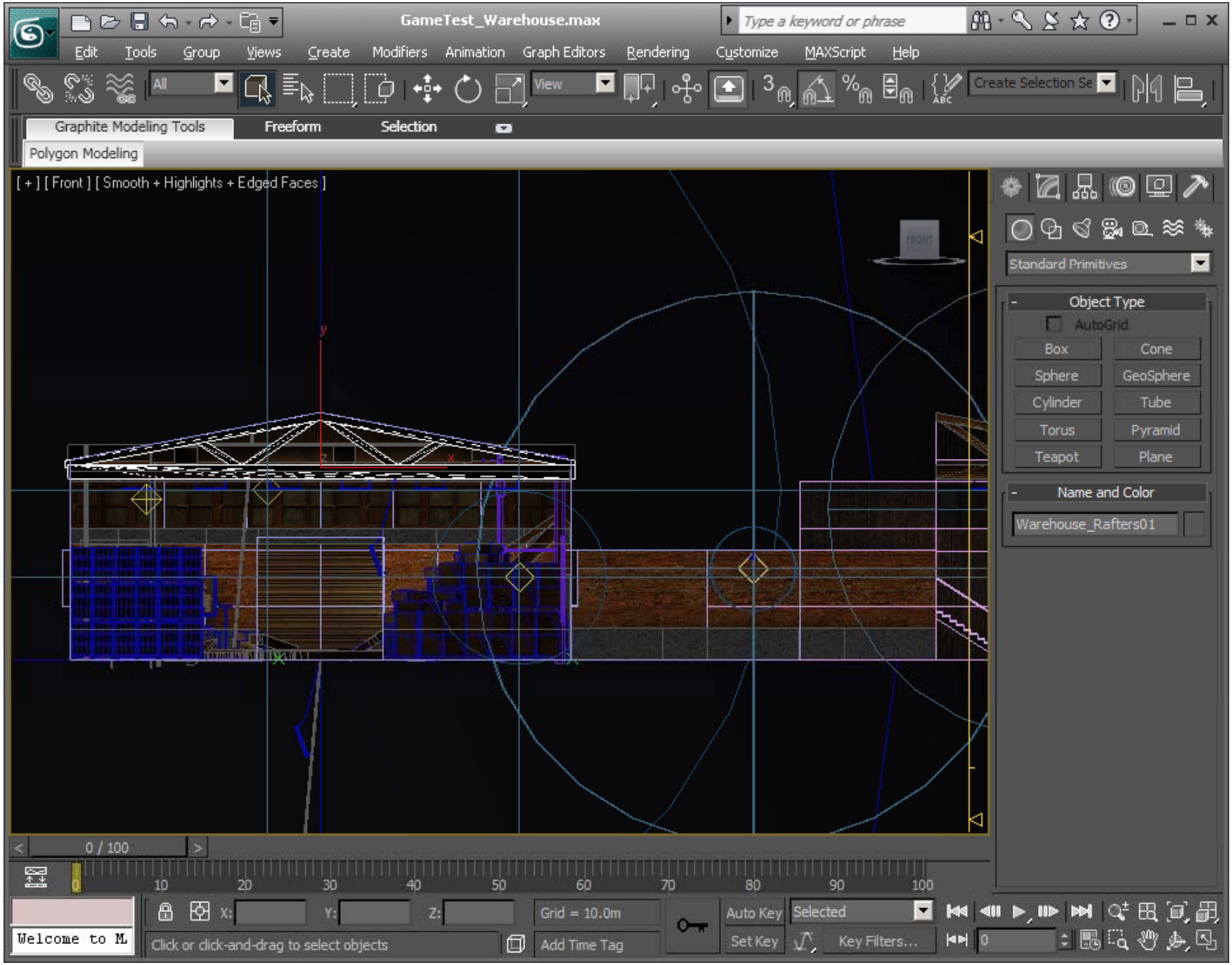


The art pipeline…



Source of:
Meshes
Animations
Materials
Textures
Skins

Originally targeted at film.


GameTest_Warehouse.max
Type a keyword or phrase
Edit Tools Group Views Create Modifiers Animation Graph Editors Rendering Customize MAXScript Help
All
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FRONT
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Tube
Torus
Pyramid
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Key Filters...
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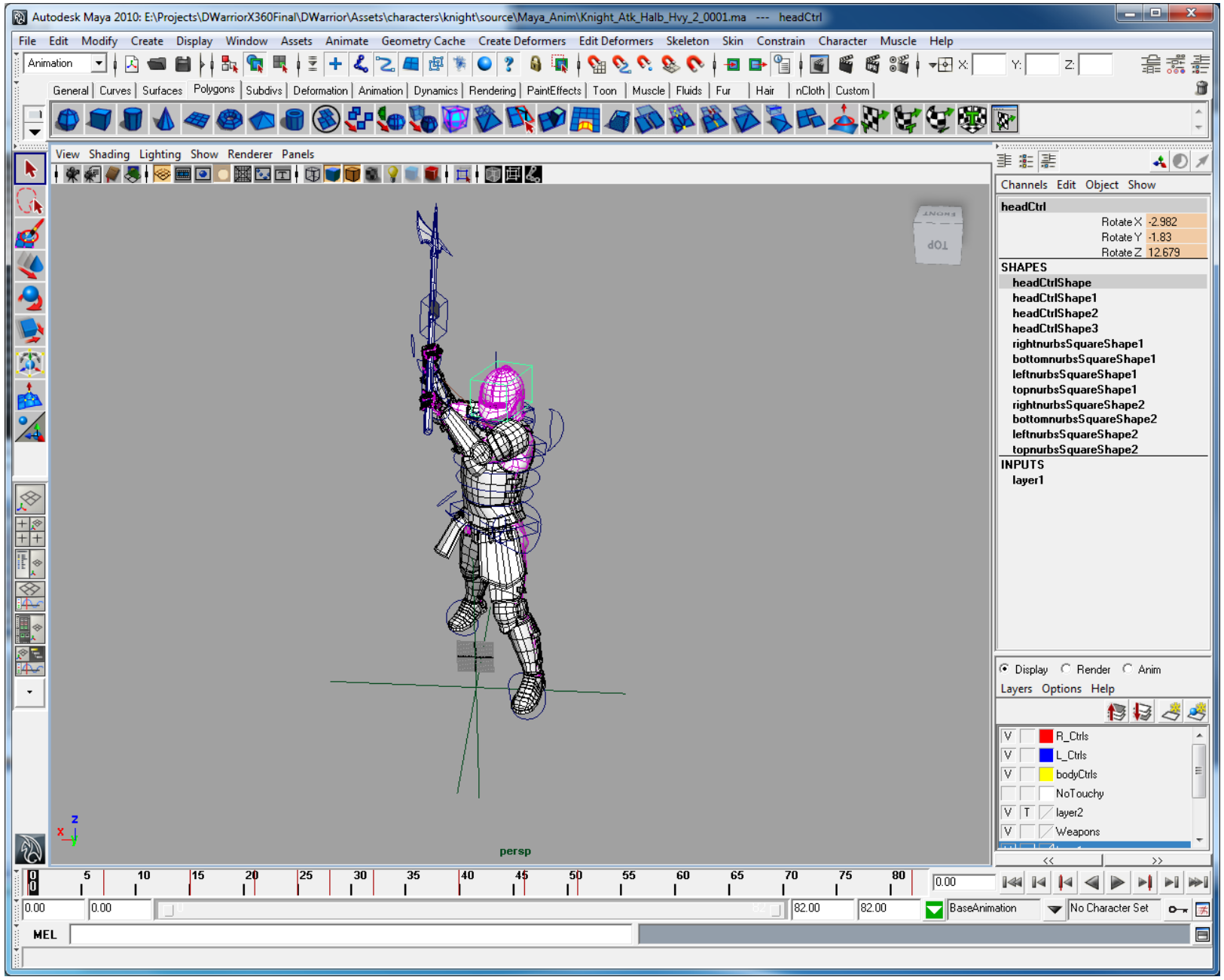
Autodesk Maya 2010: E:\Projects\DWarriorX360Final\DWarrior\Assets\characters\knight\source\Maya_Anim\Knight_Atk_Halb_Hvy_2_0001.ma --- headCtrl
File Edit Modify Create Display Window Assets Animate Geometry Cache Create Deformers Edit Deformers Skeleton Skin Constrain Character Muscle Help
Animation
General Curves Surfaces Polygons Subdivs Deformation Animation Dynamics Rendering PaintEffects Toon Muscle Fluids Fur Hair nCloth Custom
View Shading Lighting Show Renderer Panels
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Rotate Y -1.83
Rotate Z 12.679
SHAPES
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headCtrlShape2
headCtrlShape3
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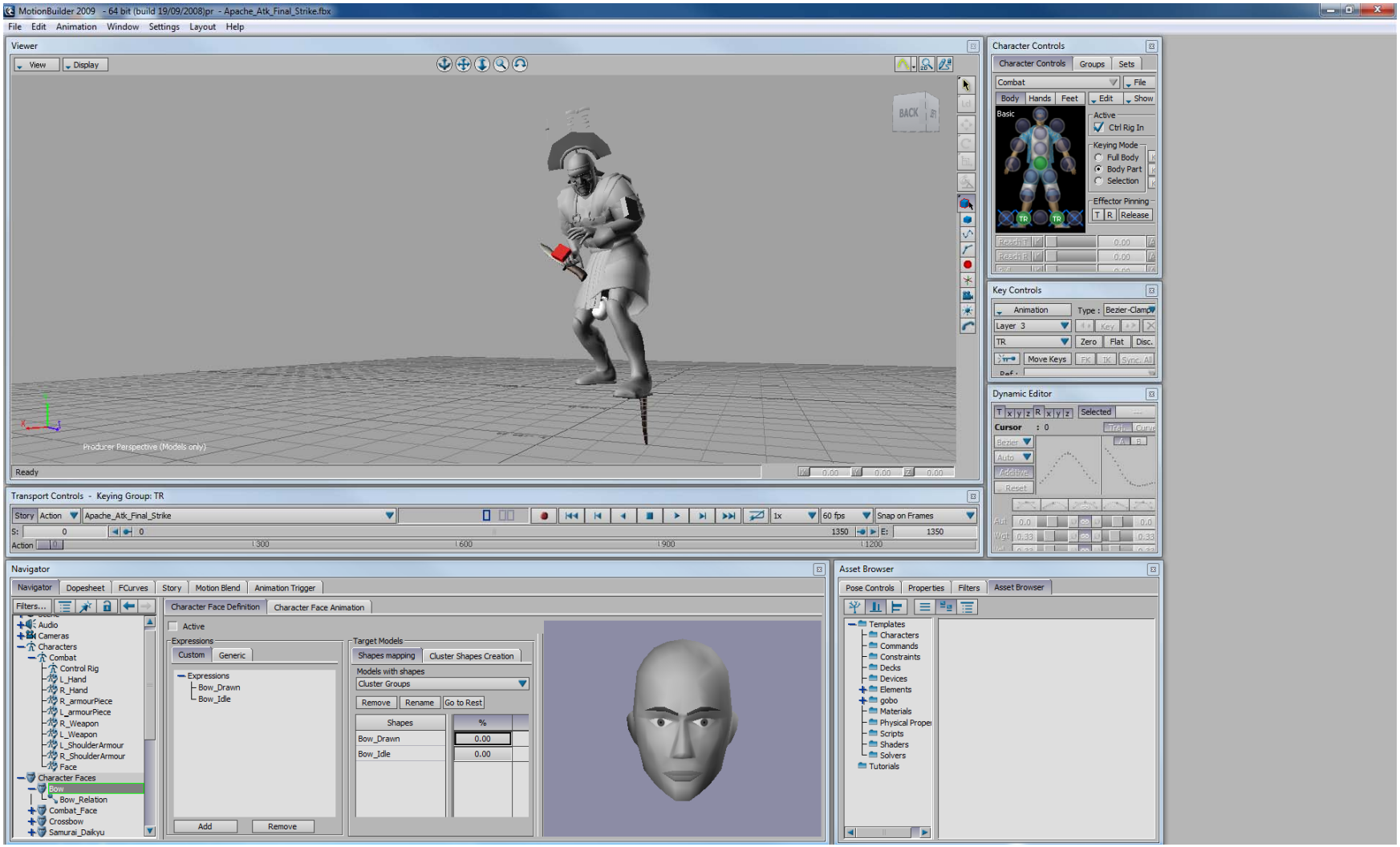
bottomnurbsSquareShape1
leftnurbsSquareShape1
topnurbsSquareShape1
rightnurbsSquareShape2
bottomnurbsSquareShape2
leftnurbsSquareShape2
topnurbsSquareShape2
INPUTS
layer1
Display Render Anim
Layers Options Help
R_Ctrls
L_Ctrls
bodyCtrls
NoTouchy
layer2
Weapons
BaseAnimation
No Character Set
MEL


MotionBuilder 2009 - 64 bit (build 19/09/2008)pr - Apache_Atk_Final_Strike.fbx
File Edit Animation Window Settings Layout Help
Viewer
View Display
BACK
Producer Perspective (Models only)
Ready
Character Controls
Character Controls Groups Sets
Combat File
Body Hands Feet Edit Show
Basic
Active
Ctrl Rig In
Keying Mode
Full Body
Body Part
Selection
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Key Controls
Animation Type : Bezier-Clamp
Layer 3 Key
TR Zero Flat Disc.
Move Keys FK IK Sync. All
Dynamic Editor
Selected
Cursor : 0
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Story Action Apache_Atk_Final_Strike
1x 60 fps Snap on Frames
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Navigator
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Filters...
Audio
Cameras
Characters
Combat
Control Rig
L_Hand
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R_armourPiece
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R_Weapon
L_Weapon
L_ShoulderArmour
R_ShoulderArmour
Face
Character Faces
Bow
Bow_Relation
Combat_Face
Crossbow
Samurai_Daikyu
Character Face Definition
Character Face Animation
Active
Expressions
Custom Generic
Expressions
Bow_Drawn
Bow_Idle
Add Remove
Target Models
Shapes mapping
Cluster Shapes Creation
Models with shapes
Cluster Groups
Remove Rename Go to Rest
Shapes
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Bow_Drawn 0.00
Bow_Idle 0.00
Asset Browser
Pose Controls Properties Filters Asset Browser
Templates
Characters
Commands
Constraints
Decks
Devices
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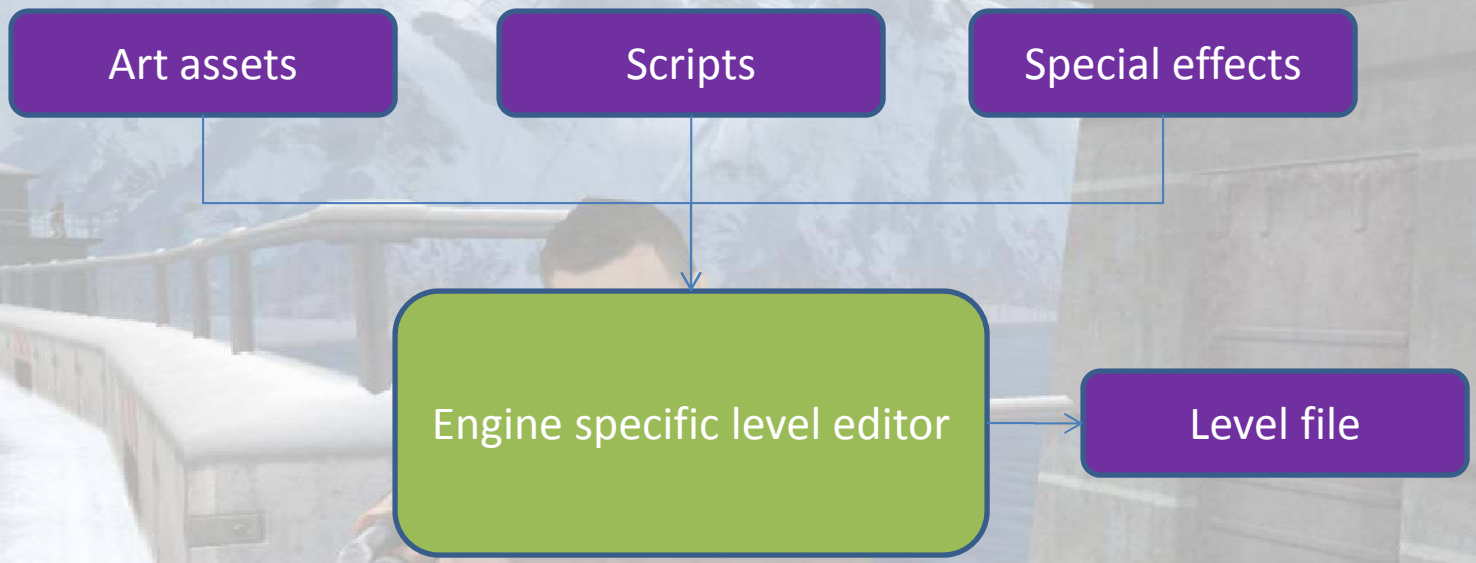
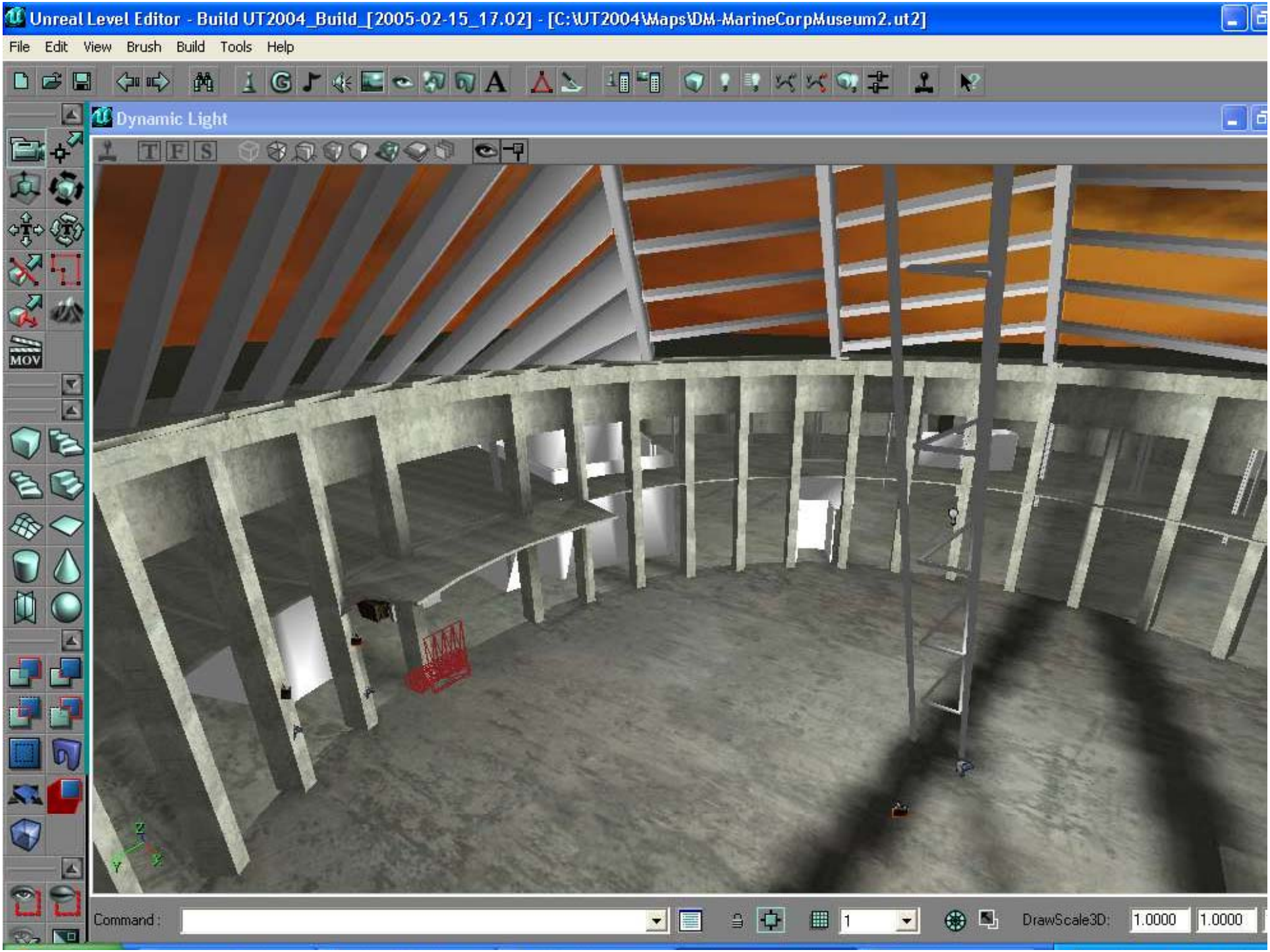
Materials
Physical Prope
Scripts
Shaders
Solvers
Tutorials

The level editing pipeline…



- Object placement & properties
- Setup lights
- Create light/shadow maps
- Script binding (connect triggers and so forth)
- Script testing
- Create camera paths & cinematic sequences.
- In some cases…creating of the static world geometry (now out of fashion)


Unreal Level Editor - Build UT2004_Build_[2005-02-15_17.02] - [C:\UT2004\Maps\DM-MarineCorpMuseum2.ut2]
File Edit View Brush Build Tools Help
Dynamic Light
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Command :
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DrawScale3D:
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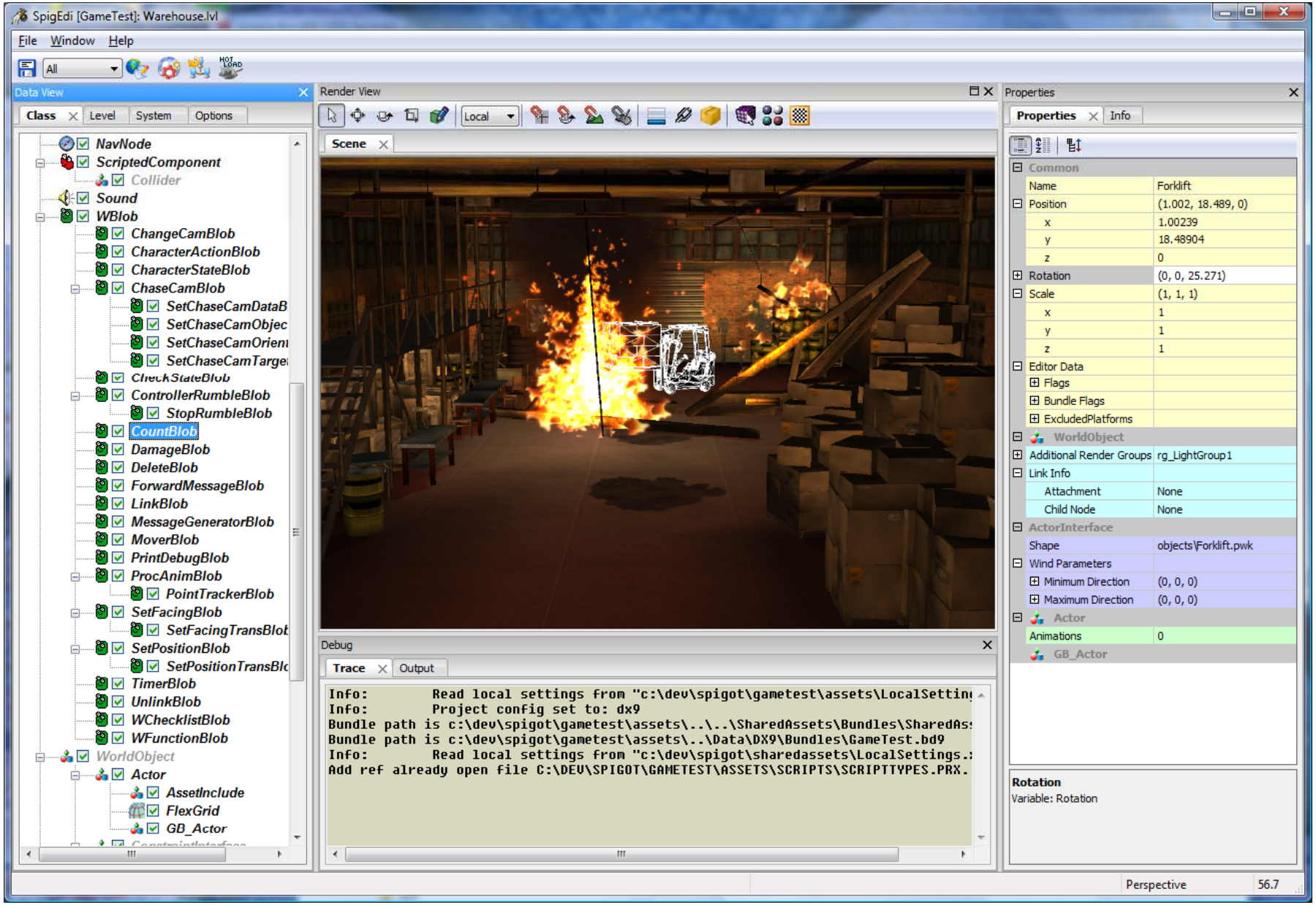
SpigEdi [GameTest]: Warehouse.lvl
File Window Help
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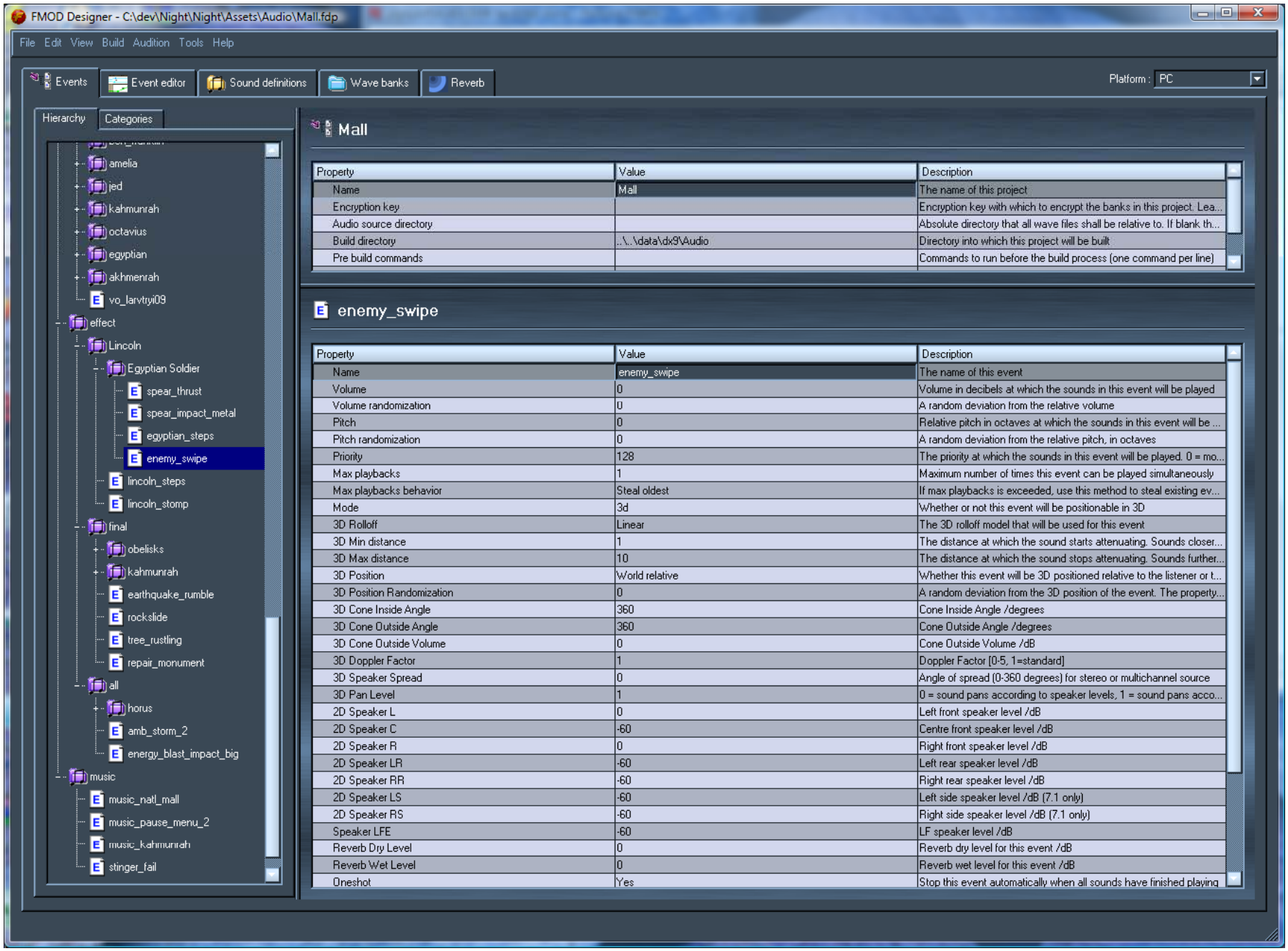
CharacterActionBlob
CharacterStateBlob
ChaseCamBlob
SetChaseCamDataB
SetChaseCamObjec
SetChaseCamOrien
SetChaseCamTarge
ControllerRumbleBlob
StopRumbleBlob
CountBlob
DamageBlob
DeleteBlob
ForwardMessageBlob
LinkBlob
MessageGeneratorBlob
MoverBlob
PrintDebugBlob
ProcAnimBlob
PointTrackerBlob
SetFacingBlob
SetFacingTransBlob
SetPositionBlob
SetPositionTransBlo
TimerBlob
UnlinkBlob
WChecklistBlob
WFunctionBlob
WorldObject
Actor
AssetInclude
FlexGrid
GB_Actor
Render View
Local
Scene
Debug
Trace Output
Info: Read local settings from "c:\dev\spigot\gametest\assets\LocalSettin
Info: Project config set to: dx9
Bundle path is c:\dev\spigot\gametest\assets\..\..\SharedAssets\Bundles\SharedAs
Bundle path is c:\dev\spigot\gametest\assets\..\Data\DX9\Bundles\GameTest.bd9
Info: Read local settings from "c:\dev\spigot\sharedassets\LocalSettings.
Add ref already open file C:\DEV\SPIGOT\GAMETEST\ASSETS\SCRIPTS\SCRIPTTYPES.PRX.
Properties
Properties Info
Common
Name Forklift
Position (1.002, 18.489, 0)
x 1.00239
y 18.48904
z 0
Rotation (0, 0, 25.271)
Scale (1, 1, 1)
x 1
y 1
z 1
Editor Data
Flags
Bundle Flags
ExcludedPlatforms
WorldObject
Additional Render Groups rg_LightGroup1
Link Info
Attachment None
Child Node None
ActorInterface
Shape objects\Forklift.pwk
Wind Parameters
Minimum Direction (0, 0, 0)
Maximum Direction (0, 0, 0)
Actor
Animations 0
GB_Actor
Rotation
Variable: Rotation
Perspective
56.7

How to design a level editor is still unsettled…

- Some engines use the DCC as the level editor
- Some approaches have a special build of the game that is also the level editor.
- In some cases, the level editor also does the bundling.

Other tools

- Special Fx editor
  - Particle systems very important for look and feel.
  - Edit and tweak particle systems
  - Can be really fun to work with & neglected academically
- Sound editor
  - Take sound samples (from Sound Forge or whatever) and create runtime sound-effects by applying patches, filters etc.
- Asset management
  - This is a huge problem with > 10^5 files


FMOD Designer - C:\dev\Night\Night\Assets\Audio\Mall.fdp
File Edit View Build Audition Tools Help
Events
Event editor
Sound definitions
Wave banks
Reverb
Platform : PC
Hierarchy
Categories
amelia
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akhmenrah
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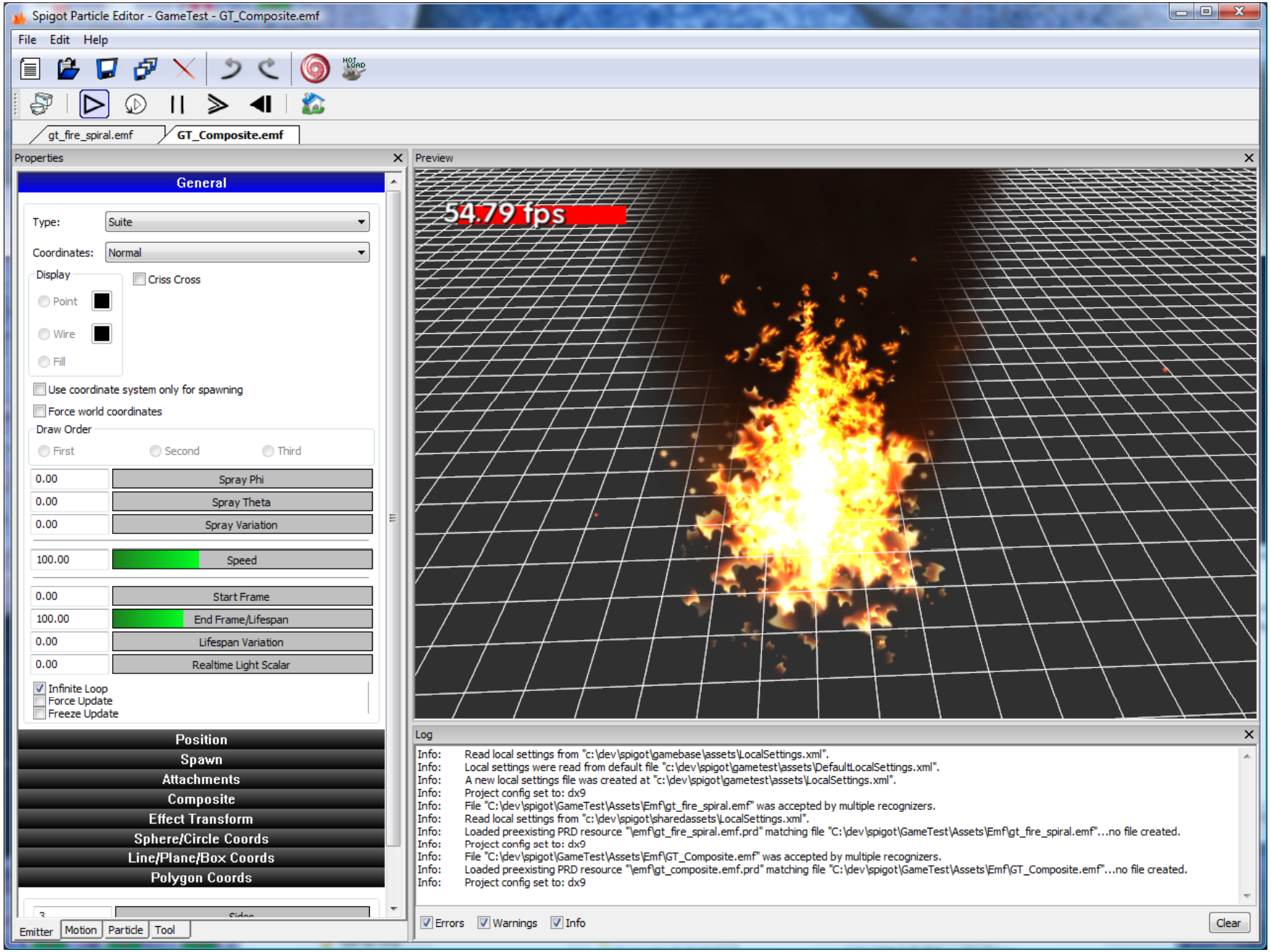
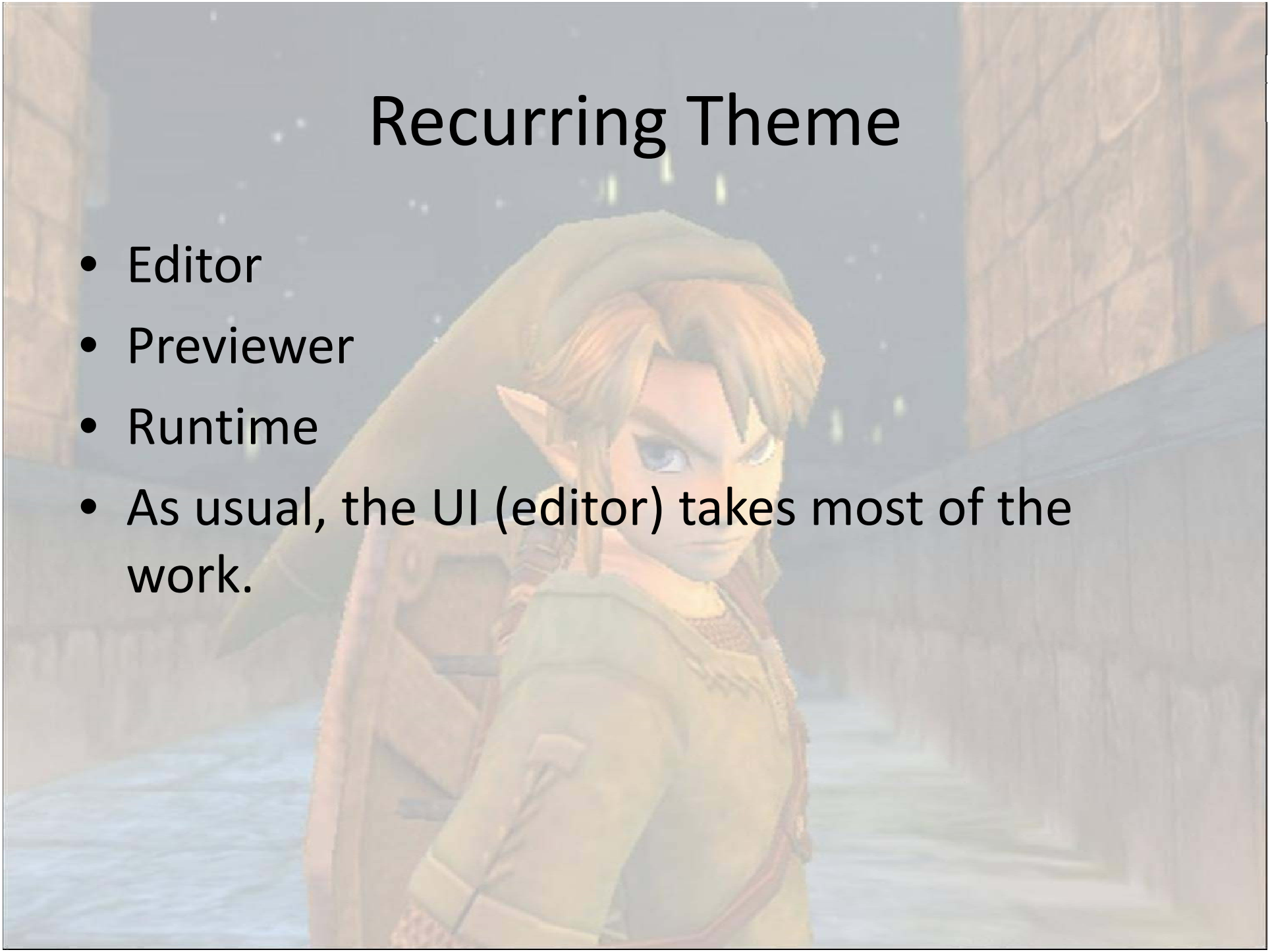
effect
Lincoln
Egyptian Soldier
spear_thrust
spear_impact_metal
egyptian_steps
enemy_swipe
lincoln_steps
lincoln_stomp
final
obelisks
kahmunrah
earthquake_rumble
rockslide
tree_rustling
repair_monument
all
horus
amb_storm_2
energy_blast_impact_big
music
music_natl_mall
music_pause_menu_2
music_kahmunrah
stinger_fail
Mall
Property
Value
Description
Name
Mall
The name of this project
Encryption key
Encryption key with which to encrypt the banks in this project. Lea...
Audio source directory
Absolute directory that all wave files shall be relative to. If blank th...
Build directory
..\..\data\dx9\Audio
Directory into which this project will be built
Pre build commands
Commands to run before the build process (one command per line)
enemy_swipe
Property
Value
Description
Name
enemy_swipe
The name of this event
Volume
0
Volume in decibels at which the sounds in this event will be played
Volume randomization
0
A random deviation from the relative volume
Pitch
0
Relative pitch in octaves at which the sounds in this event will be ...
Pitch randomization
0
A random deviation from the relative pitch, in octaves
Priority
128
The priority at which the sounds in this event will be played. 0 = mo...
Max playbacks
1
Maximum number of times this event can be played simultaneously
Max playbacks behavior
Steal oldest
If max playbacks is exceeded, use this method to steal existing ev...
Mode
3d
Whether or not this event will be positionable in 3D
3D Rolloff
Linear
The 3D rolloff model that will be used for this event
3D Min distance
1
The distance at which the sound starts attenuating. Sounds closer...
3D Max distance
10
The distance at which the sound stops attenuating. Sounds further...
3D Position
World relative
Whether this event will be 3D positioned relative to the listener or t...
3D Position Randomization
0
A random deviation from the 3D position of the event. The property...
3D Cone Inside Angle
360
Cone Inside Angle /degrees
3D Cone Outside Angle
360
Cone Outside Angle /degrees
3D Cone Outside Volume
0
Cone Outside Volume /dB
3D Doppler Factor
1
Doppler Factor [0-5, 1=standard]
3D Speaker Spread
0
Angle of spread (0-360 degrees) for stereo or multichannel source
3D Pan Level
1
0 = sound pans according to speaker levels, 1 = sound pans acco...
2D Speaker L
0
Left front speaker level /dB
2D Speaker C
-60
Centre front speaker level /dB
2D Speaker R
0
Right front speaker level /dB
2D Speaker LR
-60
Left rear speaker level /dB
2D Speaker RR
-60
Right rear speaker level /dB
2D Speaker LS
-60
Left side speaker level /dB (7.1 only)
2D Speaker RS
-60
Right side speaker level /dB (7.1 only)
Speaker LFE
-60
LF speaker level /dB
Reverb Dry Level
0
Reverb dry level for this event /dB
Reverb Wet Level
0
Reverb wet level for this event /dB
Oneshot
Yes
Stop this event automatically when all sounds have finished playing


Spigot Particle Editor - GameTest - GT_Composite.emf
File Edit Help
gt_fire_spiral.emf
GT_Composite.emf
Properties
General
Type: Suite
Coordinates: Normal
Display
Criss Cross
Point
Wire
Fill
Use coordinate system only for spawning
Force world coordinates
Draw Order
First Second Third
0.00 Spray Phi
0.00 Spray Theta
0.00 Spray Variation
100.00 Speed
0.00 Start Frame
100.00 End Frame/Lifespan
0.00 Lifespan Variation
0.00 Realtime Light Scalar
Infinite Loop
Force Update
Freeze Update
Position
Spawn
Attachments
Composite
Effect Transform
Sphere/Circle Coords
Line/Plane/Box Coords
Polygon Coords
Emitter Motion Particle Tool
Preview
54.79 fps
Log
Info: Read local settings from "c:\dev\spigot\gamebase\assets\LocalSettings.xml".
Info: Local settings were read from default file "c:\dev\spigot\gametest\assets\DefaultLocalSettings.xml".
Info: A new local settings file was created at "c:\dev\spigot\gametest\assets\LocalSettings.xml".
Info: Project config set to: dx9
Info: File "C:\dev\spigot\GameTest\Assets\Emf\gt_fire_spiral.emf" was accepted by multiple recognizers.
Info: Read local settings from "c:\dev\spigot\sharedassets\LocalSettings.xml".
Info: Loaded preexisting PRD resource "\emf\gt_fire_spiral.emf.prd" matching file "C:\dev\spigot\GameTest\Assets\Emf\gt_fire_spiral.emf"...no file created.
Info: Project config set to: dx9
Info: File "C:\dev\spigot\GameTest\Assets\Emf\GT_Composite.emf" was accepted by multiple recognizers.
Info: Loaded preexisting PRD resource "\emf\gt_composite.emf.prd" matching file "C:\dev\spigot\GameTest\Assets\Emf\GT_Composite.emf"...no file created.
Info: Project config set to: dx9
Errors Warnings Info
Clear



Recurring Theme

- Editor
- Previewer
- Runtime
- As usual, the UI (editor) takes most of the work.

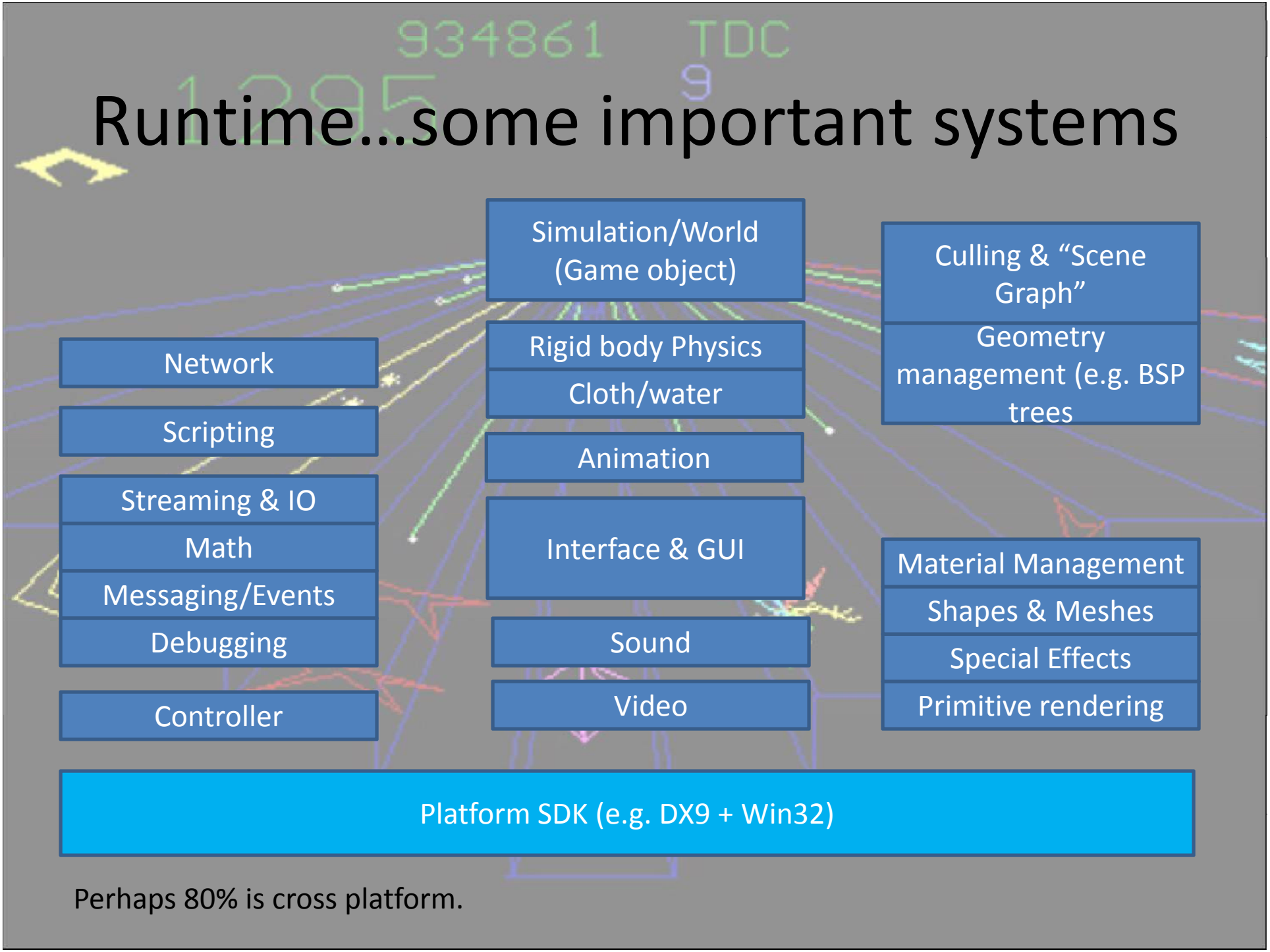
On to the Bundler…

- The bundler does the final conversion of assets to a platform specific format.
  - Like the compiler
- Stripify & build meshes
- Convert texture formats
  - Also build texture atlases.
- Compress everything that can be compressed.
- Layout binary data for streaming.
- Handles endian swapping.
- Build large data structures (e.g. BSP or kD trees)
- **Do every possible preprocess operation!**
  - Among other advantages, finds errors early.

Runtime

- Game runtime is a real-time simulation
  - Predictable performance is important
    - Amortization is not the answer
    - Garbage collection is…garbage
  - Resources are limited, memory is generally scarce (relative to the PC)
  - Hardware has poor memory bandwidth & small caches

Runtime…some important systems



Perhaps 80% is cross platform.

Runtime design issues

- Grouping of libraries varies, but functionality is common.
- Biggest unsolved question in runtime design is how to achieve threading.
  - Or, on PS3 how to use the SPE's
- Note that I have broken the engine down much farther that the tools side. Many of the components exist there as well.

The point…

- The whole tool chain is very important, and the runtime often gets too much attention.
- Our task as engineers is to think about the WHOLE engine, not just the runtime.

When it all goes together, you get:

Perspective

- The tools complexity, by line count, will be multiples of the runtime side (at least for a single platform).
- The engineers use the runtime, but all the content people use the tools.
  - Training time on tools is much higher, cause more people are involved.
  - Productivity payoff is much higher for the same reason.
- Runtime changes with platform and fads, but tools can remain forever.
- A lot of what makes a runtime “good” is performance, but the payoff to the user may be low.
  - 2x increase in poly count is often barely noticeable
- **Iteration makes games good, and the tool chain allows iteration.**

Iteration – DW1 vs DW2

Issues with engine-centric development

- You can make a game without tools, but you can't make a game without runtime.
  - Just like you can make a game without artists, but no without programmers.
- For financial and technical reasons, you have to make the engine in stages.
- It is very easy to screw up. The world is filled with failed engine initiatives.
- Making an engine genre agnostic is very hard…potentially impossible.
  - Genres: FPS, RTS, RPG, fighting, puzzle, driving and the all-important 3rd persona action adventure
- In the end, users don't give a darn…they want a fun game.

Are you excited yet!

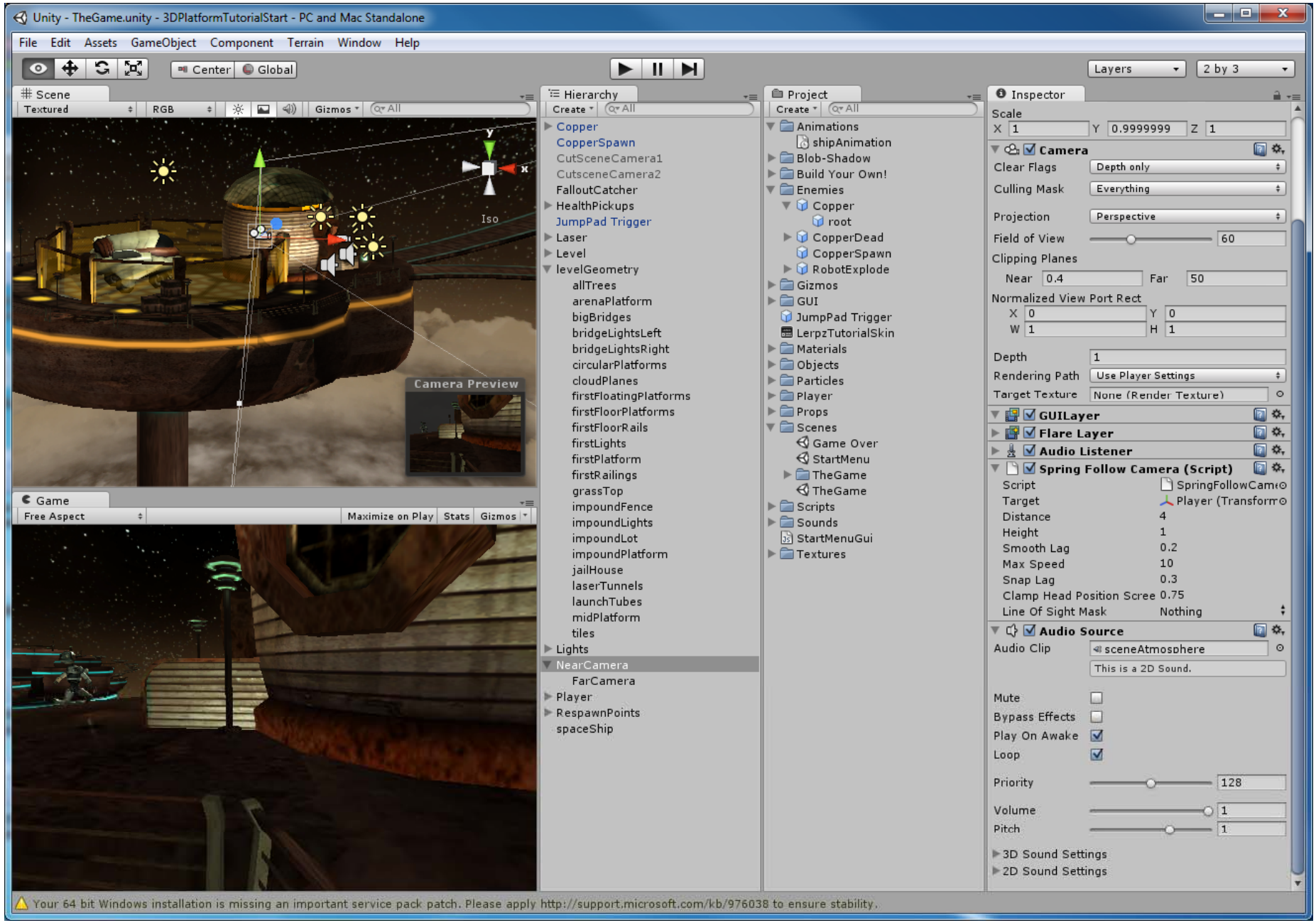
- Engine design and implementation is utterly fascinating (at least for me).
- It touches more disciplines that almost any other software development area.
- Entry is through scripting/game programming, which is fun anyway.

What about small developers?

- Until recently, needing an engine was a barrier to entry.
- A small company can't maintain an engine team.
  - Pipeworks, at 54 people is probably too small.
    - Our secret is that we've been at it for 12 years!
    - Key to this is software engineering…another topic.
  - "Small" gets larger every year.
- Viable 3rd party engines now exist.

Unity

- Combines in one tool:
  - Level editor
  - Particle editor (weak)
  - Previewer
- Missing UI system…but they are working on it
- Targeted at mobile & browser.
  - In fact, owns this market.
  - Moving quickly: support for larger teams and so on.
  - The world is Unity's to lose.
- Unlike Ogre and some others, used to make many commercial games.
- Unity is an excellent thing to study!


Unity - TheGame.unity - 3DPlatformTutorialStart - PC and Mac Standalone
File Edit Assets GameObject Component Terrain Window Help
Center Global
Layers
2 by 3
Scene
Textured RGB Gizmos All
Iso
Camera Preview
Game
Free Aspect Maximize on Play Stats Gizmos
Hierarchy
Create All
Copper
CopperSpawn
CutSceneCamera1
CutsceneCamera2
FalloutCatcher
HealthPickups
JumpPad Trigger
Laser
Level
levelGeometry
allTrees
arenaPlatform
bigBridges
bridgeLightsLeft
bridgeLightsRight
circularPlatforms
cloudPlanes
firstFloatingPlatforms
firstFloorPlatforms
firstFloorRails
firstLights
firstPlatform
firstRailings
grassTop
impoundFence
impoundLights
impoundLot
impoundPlatform
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laserTunnels
launchTubes
midPlatform
tiles
Lights
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FarCamera
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Project
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Animations
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Blob-Shadow
Build Your Own!
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CopperDead
CopperSpawn
RobotExplode
Gizmos
GUI
JumpPad Trigger
LerpzTutorialSkin
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Player
Props
Scenes
Game Over
StartMenu
TheGame
TheGame
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Sounds
StartMenuGui
Textures
Inspector
Scale
X 1 Y 0.9999999 Z 1
Camera
Clear Flags Depth only
Culling Mask Everything
Projection Perspective
Field of View 60
Clipping Planes
Near 0.4 Far 50
Normalized View Port Rect
X 0 Y 0
W 1 H 1
Depth 1
Rendering Path Use Player Settings
Target Texture None (Render Texture)
GUILayer
Flare Layer
Audio Listener
Spring Follow Camera (Script)
Script SpringFollowCame
Target Player (Transform
Distance 4
Height 1
Smooth Lag 0.2
Max Speed 10
Snap Lag 0.3
Clamp Head Position Scree 0.75
Line Of Sight Mask Nothing
Audio Source
Audio Clip sceneAtmosphere
This is a 2D Sound.
Mute
Bypass Effects
Play On Awake
Loop
Priority 128
Volume 1
Pitch 1
3D Sound Settings
2D Sound Settings
Your 64 bit Windows installation is missing an important service pack patch. Please apply http://support.microsoft.com/kb/976038 to ensure stability.

What if you use a 3rd party engine…

- **Even if you use a 3rd party engine, you need people who understand how engines work.**
  - We are doing a Unity project right now, and we have 8 engineers on it!
    - Last year, our big Unity project had 6
  - More than our Spigot projects!
- Line between engine and gameplay programmers blurs.

The price of admission…

- Most of game & engine programming is just solid CS.
- However, there are areas which are typically missing from a CS program.
  - Mathematical modeling, vector math
  - Simulation & physics
  - Graphics, particularly special effects
  - Low level (not TCP based) networking
- This is why I'm so excited about this class!
- Database and server programming are now important as well.

High-level unsolved problems

- Should materials be edited inside DCC tools?
- How should art assets be exported from DCC tools?
- How much game logic should be in script, vs.. the engine?
- Is there a visual programming solution for scripting?
- How to have a data-driven design and still get predictable performance?
- What language should tools be written in? C++, C#, Java, Python?
- How should cut-scenes be created?
- At what level should network replication occur?
- How to analyze and tweak a freemium economy.

Lower-level problems…

- Engine structure for multiple cores/threads
- Class organization for a complex simulation
- Realistic human animation
- Destructible stuff
- Hair, Fire, Water, Smoke (Fur is mostly under control)
- Lighting
- Shadows
- Convincing & predictable AI
- Non-creepy human rendering
- Non-interior environments: Foliage, urban scenes

SOMO

(social mobile)

- The most popular game console ever is…the iPhone.
  - Total consoles – around 300million
  - Total mobile/social players around 1 billion.
- Mobile devices are starting to approach consoles in power.
  - Power consumption is still a bit limit
- Technically, similar to consoles.
  - Input, play patterns are quite different

Back End

- Almost all games now have a back end
  - Cloud based save load
  - Easy multiplayer implementation
  - Social integration
  - Freemium economy & transactions
  - Piracy protection
    - Also used games
  - Hosting services (Amazon, Rackspace) make it simpler
- Typically implemented via a HTTP/HTTPS & REST
  - Most common back ends are PHP, but all kinds used
  - Most common database is MySQL, but nosql is gaining
    - Games are much more write heavy than other Web apps
  - Scalability is a problem

Console Evolution

	NES	PS1	PS2	PS3	Current PC
CPU	MOS Technology 6502 1.79 MHz	MIPS R3000A-32-bit RISC chip running at 33.8688 MHz	294 MHz MIPS "Emotion Engine"	3.2 GHz POWER-based PPE with seven 3.2 GHz SPEs	8 Cores at 3 GHz
GPU	-	66 MIPS vector math unit on CPU	147 MHz "Graphics Synthesizer"	550 MHz based on Nvidia G70	Gerforce 650 1058 Mhz 384 Cores
Storage	Cartridge	CD	DVD	Blu-Ray	Internet

Content is King

- We have already reached the sweet spot for most game features:
  - 4 enemies to 8 → big difference
  - 64 enemies to 128 → small difference
- PS2 was the tipping point between ability to display content and ability to make it.
  - We are now firmly in the era where content creation cost is the driving factor.
    - Ironically, main content limit is DVD->Memory transfer