

GAME ENGINE

ARCHITECTURE, GAME LOOP, UNITY

TOMÁŠ POLÁŠEK IPOLASEK@FIT.VUT.CZ

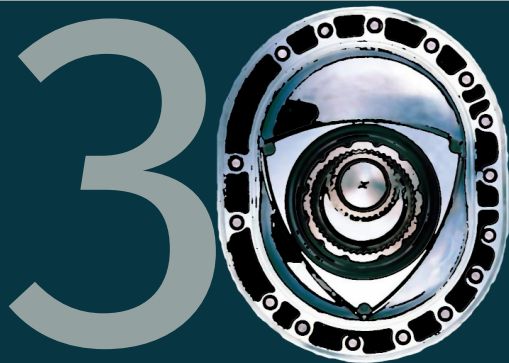
BRNO UNIVERSITY OF TECHNOLOGY

FACULTY OF INFORMATION TECHNOLOGY

DCGM, CPhoto@FIT

FACULTY OF FINE ARTS

GAME MEDIA STUDIO



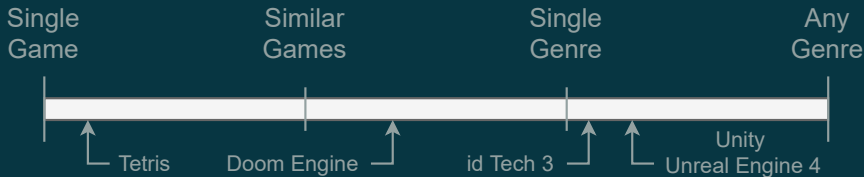
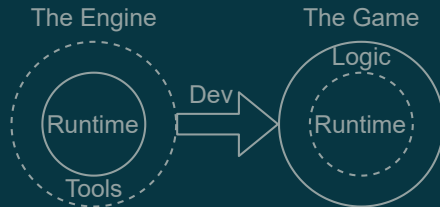
WHAT IS A GAME ENGINE?

- Reusable Software → Platform
- **Goal:** Simplify Game Development
- There is **One** There are **Many**
- Build Your Own?
- “Choosing the Right Tool for the Job”
 - ▶ Licensing & Royalties
 - ▶ Internal tools
 - ▶ Ecosystem Integration
 - ▶ Target Platform
 - ▶ Game Genre, Style, Gameplay
 - ▶ Community



GAME ENGINE SOFTWARE

- “Fun Activity” vs “Soft Real-Time Simulation”
- Game Engine = **Runtime** + **Tools**
- Gamut of **Reusability**
- Generality × Optimality

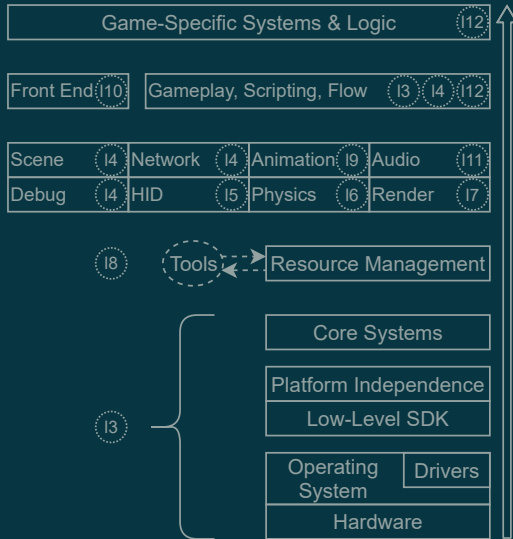


Source: Game Engine Architecture [1]

ENGINE ARCHITECTURE

GAME ENGINE OVERVIEW

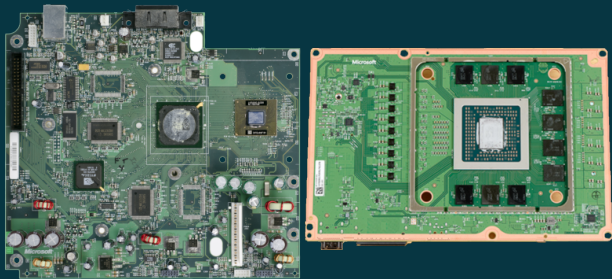
- **Complex** Software Architecture ¹
- Layers & Dependencies
- System Overview



¹Jason Gregory – Game Engine Architecture [1]

HARDWARE & OS

- Architecture, Optimization
- Varied → Uniform
- Operating System = Software Layer
- Drivers = Hardware Interface



Source: Xbox 2001, Xbox Series S 2020

Operating System		Drivers
Security		Resources
Scheduling		Processes

Hardware		
CPU	GPU	Memory
Acceleration		Storage

LOW-LEVEL LIBRARIES

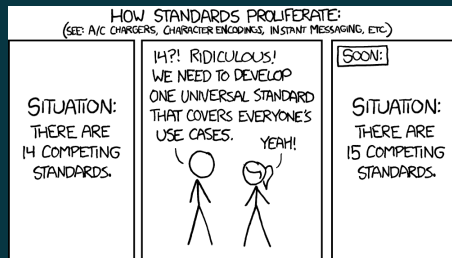
- APIs, SDKs, Standard Library, ...

Low-Level Libraries

Middleware

SDKs

APIs



Source: XKCD – Standards

PLATFORM INDEPENDENCE LAYER

- Platform Independence
- Unified Interface
- Multiplatform Development

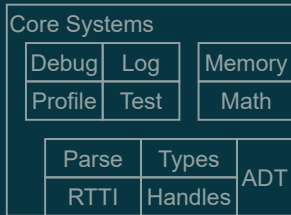
Platform Independence			
		FS	Detection
		Threads	Wrappers
		Network	Unification



Source: Unreal, Unreal Engine 5

CORE SYSTEMS

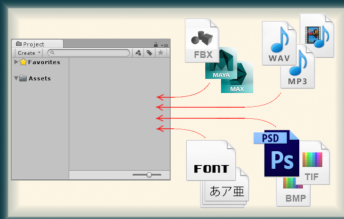
- Library of Utilities
- Base Debugging & Logging
- Memory Management
- Data Types
- Serialization, RTTI, Parsing
- Mathematics – Transform, Geometric, Solvers
- ...



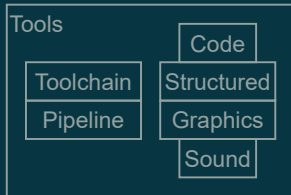
```
Player player = new Player();  
player.level = 1;  
player.health = 100.0f;  
player.name = "Thomas";  
  
{  
    "level": 1,  
    "health": 100.0,  
    "name": "Thomas"  
}
```

RESOURCE MANAGEMENT

- Unified Data Access
- Resources & Assets
- **Toolchain** → **Pipeline** → **Assets**
- “Mark of Style”



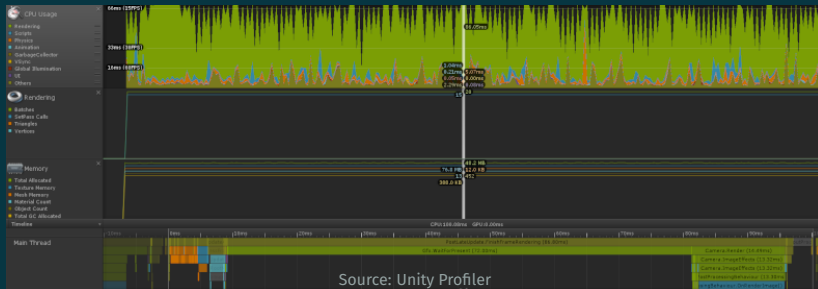
Source: Unity Manual – Asset Workflow



DEBUGGING & PROFILING

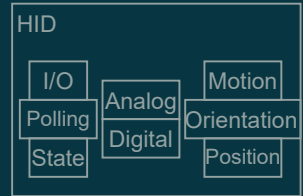
- Complexity → Bugs
- What is Wrong?
- **Instrumentation & Logging**
- Playtime Statistics, Core Dumps
- Remote Debugging & Profiling

Debug		D&P Server	
		Statistics	
		Playback	
Assert		Cheats	
Logging			
Instrumentation		Console	



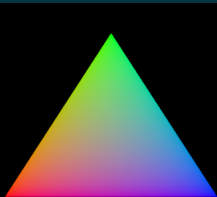
HUMAN INTERFACE DEVICES

- **Input & Output**
- Raw I/O → API
- Wide Range
- Device Sensors
- User Feedback

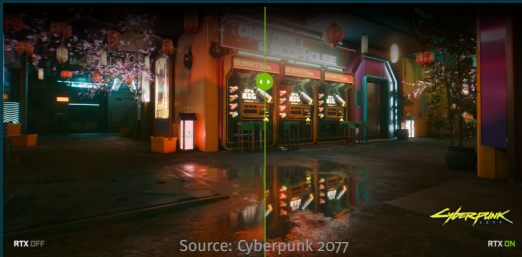


RENDERING ENGINE

- Visualization of the Game
- “From Zero to Mirrors”
- Scene Graph
- Materials, Effects, Lighting
- Interface Rendering



Source: Vulkan Samples



Source: Cyberpunk 2077

Rendering Engine

Renderer	Camera	Viewport
	Graphics API	Shaders

Scene Graph		Occlusion
LOD	Spatial	Hierarchy

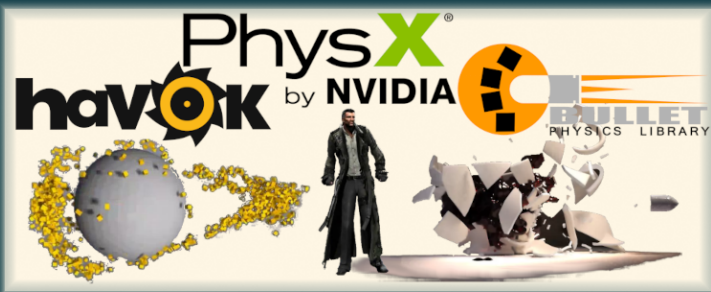
Effects	Particles	Lighting
Materials	Shadows	Shading

Interface		UI	Font
	HUD	Menu	Video

PHYSICS

- Collision Detection → Resolution
- Physical Simulation
- Simplified Models
- Static & Dynamic Objects

Physics	Havok	PhysX	
Collision			
Simulation		Constraint	
Rigid	Soft	Cloth	Ragdoll
Dynamics		Statics	



ANIMATION

- Making Things Move
- Animation vs Physics
- Kinematics & Dynamics
- Rigging, Skinning



Source: Unreal, Unity

Animation

Texture	Rigid	Skeleton
Sprite	Vertex	Morph
Kinematics		Skinning
Dynamics		Rigging

NETWORK

- Network Stack
- Frontend × Backend
- Latency, Replication, Authority

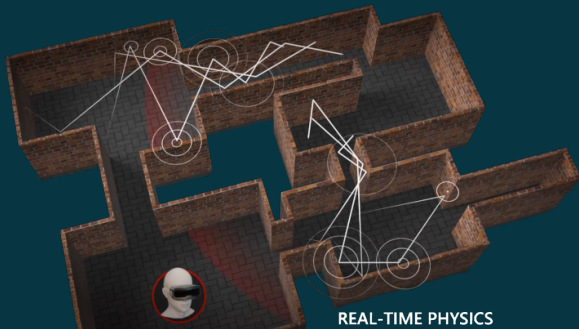


Source: Unity

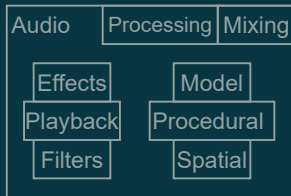
Network		
	Latency	VoIP
Frontend	Authority	Chat
Backend	Replication	
MatchMaking		Infrastructure

AUDIO

- Often Neglected
- Fidelity & Procedural
- Realistic Modeling

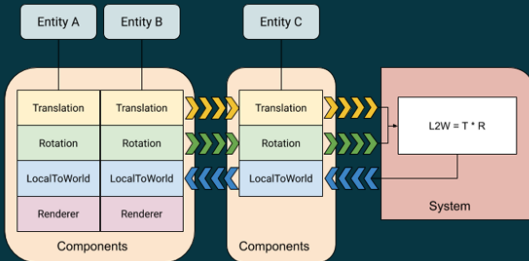
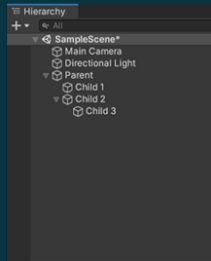


Source: AMD TrueAudio Next

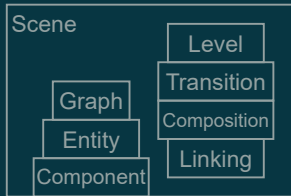


SCENE

- Graph Data Structure
- World Hierarchy
- Entity-Component-System
- Composition & Linking



Source: Unity



FRONT END

- UI & UX
- Aural Feedback
- Widgets, Layouts
- Data Binding

Front End

UI

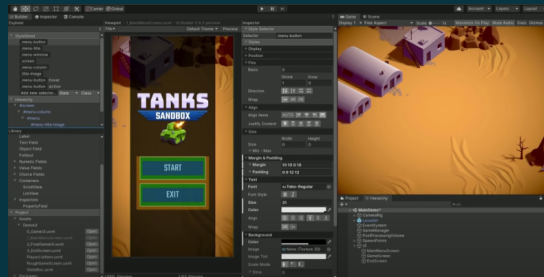
UX

Text

Data
Binding

Widget

Format



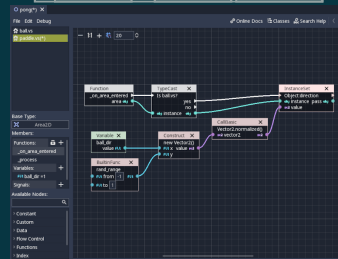
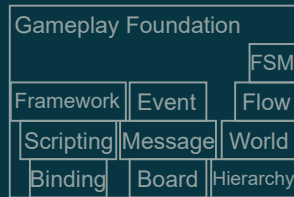
Source: Unity UI Builder

GAMEPLAY FOUNDATION

- Framework for Building the Game
- Scripting Utilities
- Low-Level $\iff$ Gameplay
- Game Object Hierarchy
- Game Loop [2]



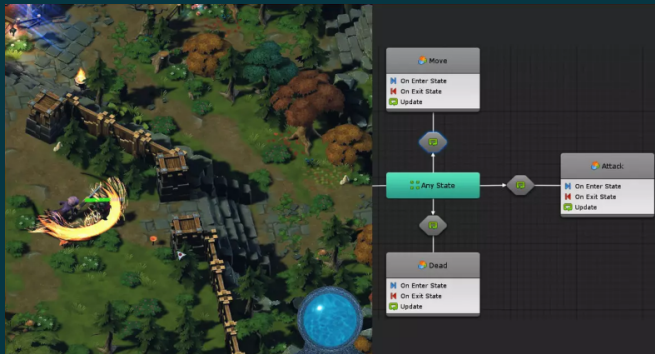
Source: Robert Nystrom – Game Programming Patterns



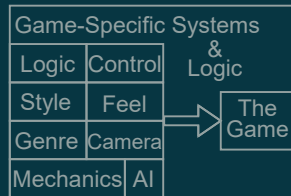
Source: Godot Visual Scripting

GAME-SPECIFIC SYSTEMS

- This is "**The Game**"
- Gameplay Implementation



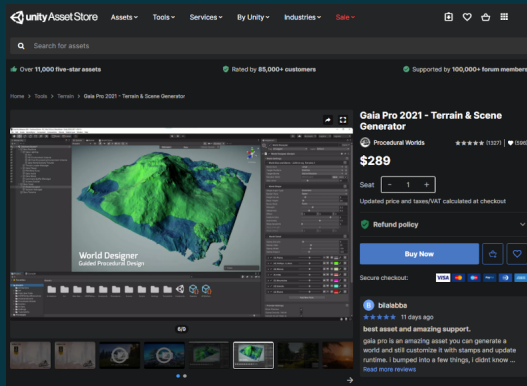
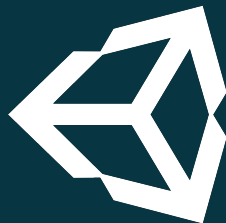
Source: Unity Bolt

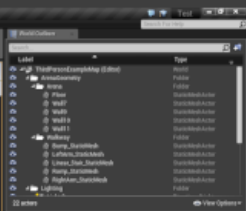
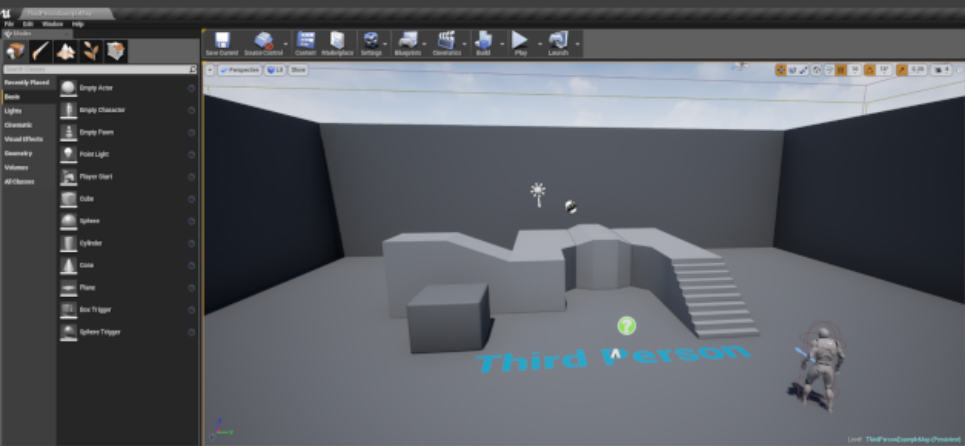


UNITY ENGINE

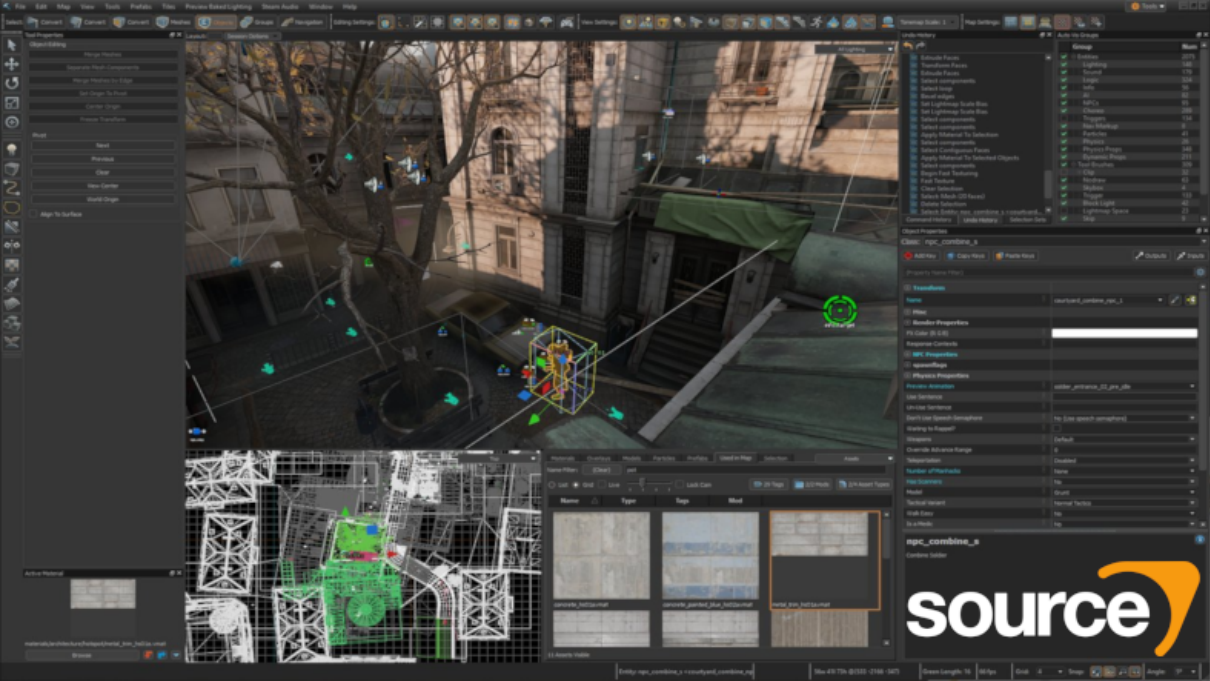
WHAT IS UNITY?

- Game Engine
- Development Platform
- Documentation & Community
- **Why Unity?**





UNREAL
ENGINE



- Entity Outliner
- Rooted_T
 - legionsnaire_posed
 - Default Actor Environment
 - Light

Asset Browser

C:\rooted_cinematic

- Swords
 - Rooted_Cinematic_sword
 - Rooted_Cinematic_sword
 - Rooted_Cinematic_sword
 - Rooted_Cinematic_sword
 - Rooted_Cinematic_sword
 - swords_OcclusionFog
- Teeth
 - Rooted_Cinematic_tooth
 - Rooted_Cinematic_tooth
 - Rooted_Cinematic_tooth
 - Rooted_Cinematic_tooth
 - Rooted_Cinematic_tooth
 - Rooted_Cinematic_tooth
 - teeth_OcclusionFog



Rooted_Cinematic_FBX

Perspective



Entity Inspector

Name: Rooted_T

Status: Start active

Entity ID: 48399241175

Add Components

Search

Transform

Parent entity

Values

Translate: 0.0 m, 0.0 m, 34.0 m

Rotate: 0.0 deg, 0.0 deg, 180.0 deg

Uniform Scale: 1.0

Add non-uniform scale

Parent activation

Static: Original relative transform

Mesh

Mesh Asset: rooted_cinematic

Sort Key: 0

Lod Override: Low Set

Exclude from reflectance

Use Forward Pass

Material

Generate/Manage Source Materials...

Default Material: Default

Model Materials: 17 elements

arms1: material_roots_arms

belt1: material_roots_belt

brooch1: material_roots_brooch

cape1: material_roots_cape

chainmail1: material_roots_chainmail

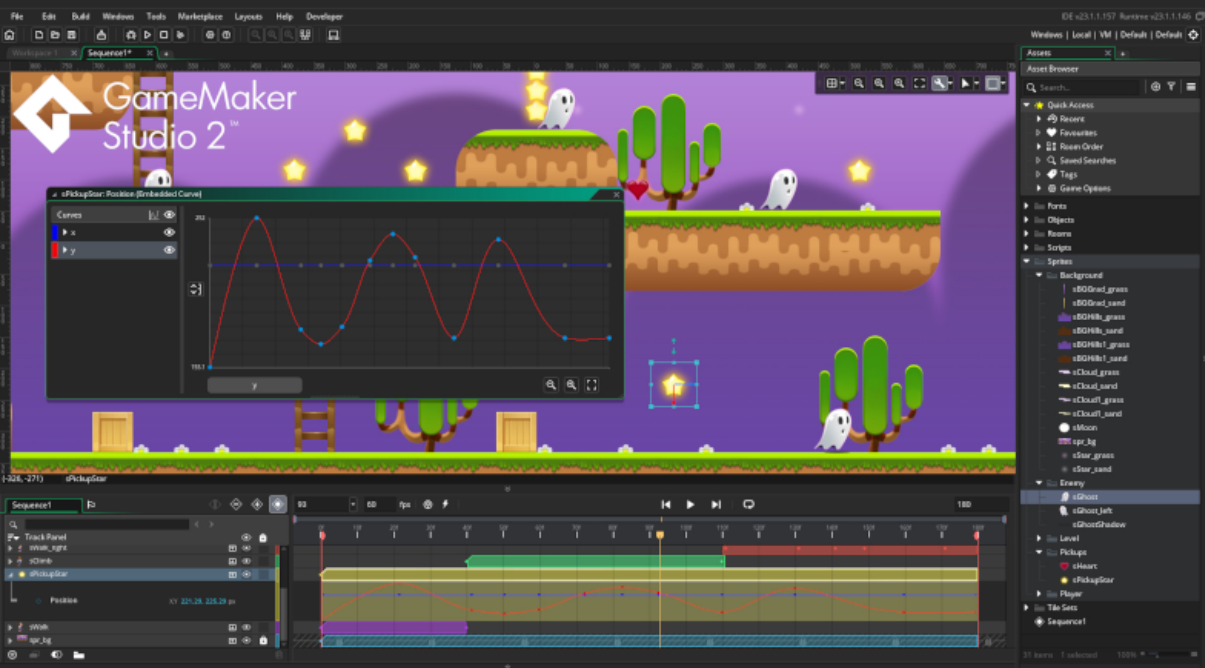
default_material: material_roots_material

eye: material_roots_eyes

eyebrow_01: material_roots_eyebrow

hair: material_roots_hair





Object Window

Filter: Show only active (1) items

Filter	Editor ID	Count	Class	Path To
Archer				
Audio				
Character				
Item				
Map				
Music/Banner				
Special Effect				
WorldData				
WorldObject				
Actor				
Container				
Door				
Place				
Function				
Game				
Light				
WorldReference				
Static				
Static Collection				
Tree				

288

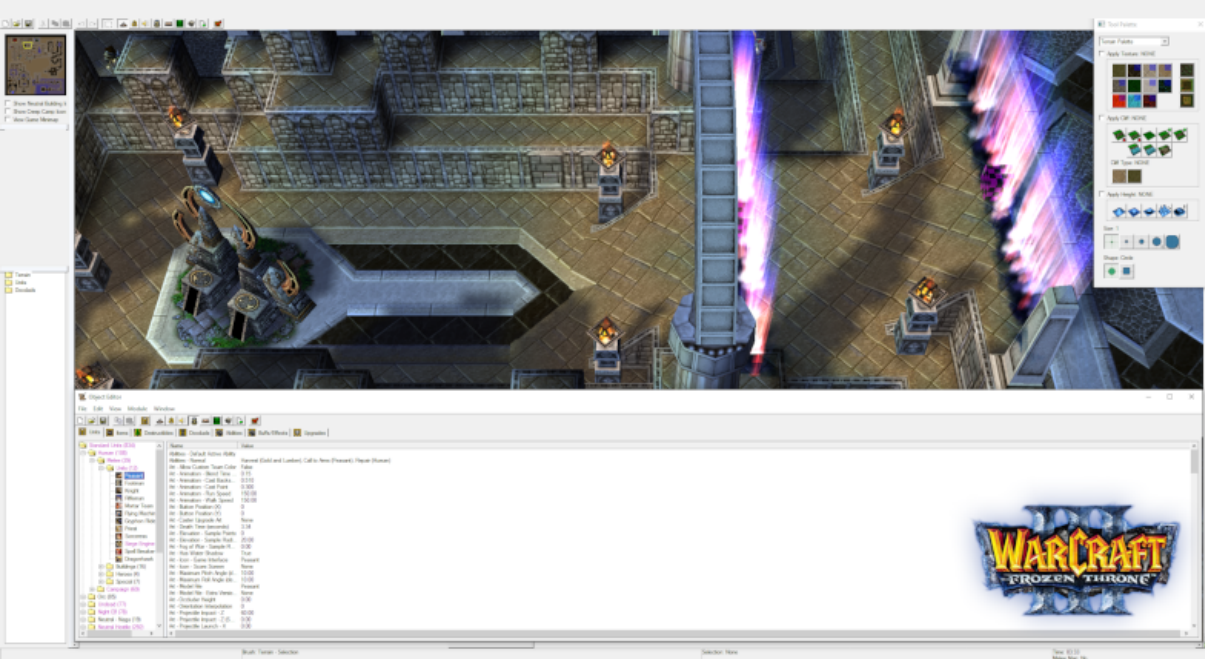


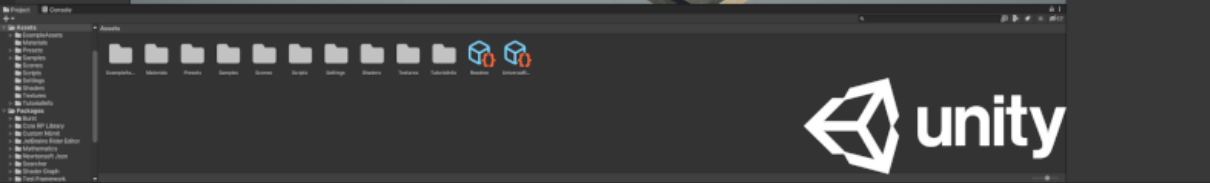
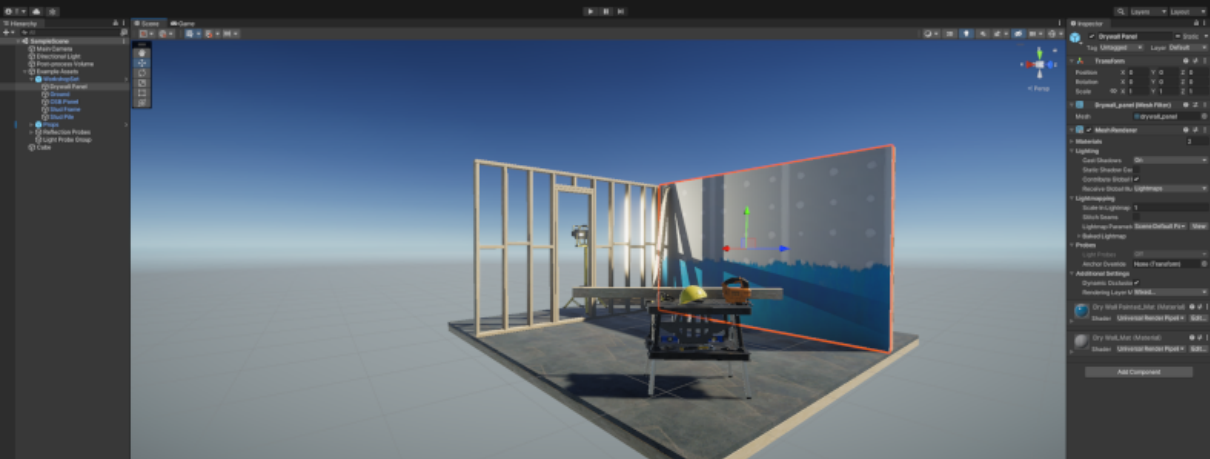
Cell View

World Space

Selected: Loaded: Show only active (1) cells

Editor ID	Name	L	Count	Location	Owner
uWorldBase01	uWorldBase01	0	1	(0, 0, 0)	Game
uWorldBase02	uWorldBase02	0	1	(0, 0, 0)	Game
uWorldBase03	uWorldBase03	0	1	(0, 0, 0)	Game
uWorldBase04	uWorldBase04	0	1	(0, 0, 0)	Game
uWorldBase05	uWorldBase05	0	1	(0, 0, 0)	Game
uWorldBase06	uWorldBase06	0	1	(0, 0, 0)	Game
uWorldBase07	uWorldBase07	0	1	(0, 0, 0)	Game
uWorldBase08	uWorldBase08	0	1	(0, 0, 0)	Game
uWorldBase09	uWorldBase09	0	1	(0, 0, 0)	Game
uWorldBase10	uWorldBase10	0	1	(0, 0, 0)	Game
uWorldBase11	uWorldBase11	0	1	(0, 0, 0)	Game
uWorldBase12	uWorldBase12	0	1	(0, 0, 0)	Game
uWorldBase13	uWorldBase13	0	1	(0, 0, 0)	Game
uWorldBase14	uWorldBase14	0	1	(0, 0, 0)	Game
uWorldBase15	uWorldBase15	0	1	(0, 0, 0)	Game
uWorldBase16	uWorldBase16	0	1	(0, 0, 0)	Game
uWorldBase17	uWorldBase17	0	1	(0, 0, 0)	Game
uWorldBase18	uWorldBase18	0	1	(0, 0, 0)	Game
uWorldBase19	uWorldBase19	0	1	(0, 0, 0)	Game
uWorldBase20	uWorldBase20	0	1	(0, 0, 0)	Game
uWorldBase21	uWorldBase21	0	1	(0, 0, 0)	Game
uWorldBase22	uWorldBase22	0	1	(0, 0, 0)	Game
uWorldBase23	uWorldBase23	0	1	(0, 0, 0)	Game
uWorldBase24	uWorldBase24	0	1	(0, 0, 0)	Game
uWorldBase25	uWorldBase25	0	1	(0, 0, 0)	Game
uWorldBase26	uWorldBase26	0	1	(0, 0, 0)	Game
uWorldBase27	uWorldBase27	0	1	(0, 0, 0)	Game
uWorldBase28	uWorldBase28	0	1	(0, 0, 0)	Game
uWorldBase29	uWorldBase29	0	1	(0, 0, 0)	Game
uWorldBase30	uWorldBase30	0	1	(0, 0, 0)	Game
uWorldBase31	uWorldBase31	0	1	(0, 0, 0)	Game
uWorldBase32	uWorldBase32	0	1	(0, 0, 0)	Game
uWorldBase33	uWorldBase33	0	1	(0, 0, 0)	Game
uWorldBase34	uWorldBase34	0	1	(0, 0, 0)	Game
uWorldBase35	uWorldBase35	0	1	(0, 0, 0)	Game
uWorldBase36	uWorldBase36	0	1	(0, 0, 0)	Game
uWorldBase37	uWorldBase37	0	1	(0, 0, 0)	Game
uWorldBase38	uWorldBase38	0	1	(0, 0, 0)	Game
uWorldBase39	uWorldBase39	0	1	(0, 0, 0)	Game
uWorldBase40	uWorldBase40	0	1	(0, 0, 0)	Game
uWorldBase41	uWorldBase41	0	1	(0, 0, 0)	Game
uWorldBase42	uWorldBase42	0	1	(0, 0, 0)	Game
uWorldBase43	uWorldBase43	0	1	(0, 0, 0)	Game
uWorldBase44	uWorldBase44	0	1	(0, 0, 0)	Game
uWorldBase45	uWorldBase45	0	1	(0, 0, 0)	Game
uWorldBase46	uWorldBase46	0	1	(0, 0, 0)	Game
uWorldBase47	uWorldBase47	0	1	(0, 0, 0)	Game
uWorldBase48	uWorldBase48	0	1	(0, 0, 0)	Game
uWorldBase49	uWorldBase49	0	1	(0, 0, 0)	Game
uWorldBase50	uWorldBase50	0	1	(0, 0, 0)	Game
uWorldBase51	uWorldBase51	0	1	(0, 0, 0)	Game
uWorldBase52	uWorldBase52	0	1	(0, 0, 0)	Game
uWorldBase53	uWorldBase53	0	1	(0, 0, 0)	Game
uWorldBase54	uWorldBase54	0	1	(0, 0, 0)	Game
uWorldBase55	uWorldBase55	0	1	(0, 0, 0)	Game
uWorldBase56	uWorldBase56	0	1	(0, 0, 0)	Game
uWorldBase57	uWorldBase57	0	1	(0, 0, 0)	Game
uWorldBase58	uWorldBase58	0	1	(0, 0, 0)	Game
uWorldBase59	uWorldBase59	0	1	(0, 0, 0)	Game
uWorldBase60	uWorldBase60	0	1	(0, 0, 0)	Game
uWorldBase61	uWorldBase61	0	1	(0, 0, 0)	Game
uWorldBase62	uWorldBase62	0	1	(0, 0, 0)	Game
uWorldBase63	uWorldBase63	0	1	(0, 0, 0)	Game
uWorldBase64	uWorldBase64	0	1	(0, 0, 0)	Game
uWorldBase65	uWorldBase65	0	1	(0, 0, 0)	Game
uWorldBase66	uWorldBase66	0	1	(0, 0, 0)	Game
uWorldBase67	uWorldBase67	0	1	(0, 0, 0)	Game
uWorldBase68	uWorldBase68	0	1	(0, 0, 0)	Game
uWorldBase69	uWorldBase69	0	1	(0, 0, 0)	Game
uWorldBase70	uWorldBase70	0	1	(0, 0, 0)	Game
uWorldBase71	uWorldBase71	0	1	(0, 0, 0)	Game
uWorldBase72	uWorldBase72	0	1	(0, 0, 0)	Game
uWorldBase73	uWorldBase73	0	1	(0, 0, 0)	Game
uWorldBase74	uWorldBase74	0	1	(0, 0, 0)	Game
uWorldBase75	uWorldBase75	0	1	(0, 0, 0)	Game
uWorldBase76	uWorldBase76	0	1	(0, 0, 0)	Game
uWorldBase77	uWorldBase77	0	1	(0, 0, 0)	Game
uWorldBase78	uWorldBase78	0	1	(0, 0, 0)	Game
uWorldBase79	uWorldBase79	0	1	(0, 0, 0)	Game
uWorldBase80	uWorldBase80	0	1	(0, 0, 0)	Game
uWorldBase81	uWorldBase81	0	1	(0, 0, 0)	Game
uWorldBase82	uWorldBase82	0	1	(0, 0, 0)	Game
uWorldBase83	uWorldBase83	0	1	(0, 0, 0)	Game
uWorldBase84	uWorldBase84	0	1	(0, 0, 0)	Game
uWorldBase85	uWorldBase85	0	1	(0, 0, 0)	Game
uWorldBase86	uWorldBase86	0	1	(0, 0, 0)	Game
uWorldBase87	uWorldBase87	0	1	(0, 0, 0)	Game
uWorldBase88	uWorldBase88	0	1	(0, 0, 0)	Game
uWorldBase89	uWorldBase89	0	1	(0, 0, 0)	Game
uWorldBase90	uWorldBase90	0	1	(0, 0, 0)	Game
uWorldBase91	uWorldBase91	0	1	(0, 0, 0)	Game
uWorldBase92	uWorldBase92	0	1	(0, 0, 0)	Game
uWorldBase93	uWorldBase93	0	1	(0, 0, 0)	Game
uWorldBase94	uWorldBase94	0	1	(0, 0, 0)	Game
uWorldBase95	uWorldBase95	0	1	(0, 0, 0)	Game
uWorldBase96	uWorldBase96	0	1	(0, 0, 0)	Game
uWorldBase97	uWorldBase97	0	1	(0, 0, 0)	Game
uWorldBase98	uWorldBase98	0	1	(0, 0, 0)	Game
uWorldBase99	uWorldBase99	0	1	(0, 0, 0)	Game
uWorldBase100	uWorldBase100	0	1	(0, 0, 0)	Game





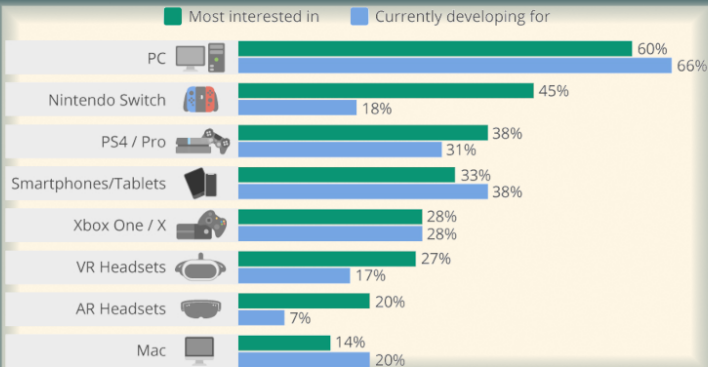
WHICH TO CHOOSE?

- AAA & Realistic → **Unreal Engine**
- Agile & Indie → **Unity Engine**
- Non-Programmer → **Game Maker**
- Open & Free → **Godot Engine**
- Learn Engine-ering → **Roll Your Own**
- Learn GameDev → **Unity Engine**



ADDITIONAL RESOURCES

- [Thesis] James Lear: The Video Game Asset Pipeline
- [Online] Robert Nystrom: Game Loop
- [Online] Unity: Order of Execution for event functions



Source: Statista – The Most Important Gaming Platforms

MENTAT

OPTIONS

Credits

12

Thanks For
Your Attention!



TANK



DMG

ATTACK

MOVE

RETREAT

GUARD



Dune 2 : The Building of a Dynasty

REFERENCES I

- [1] JASON GREGORY. **GAME ENGINE ARCHITECTURE, SECOND EDITION**. 3rd. USA: A. K. Peters, Ltd., CRC Press, 2018. ISBN: 1351974288.
- [2] R. NYSTROM. **GAME PROGRAMMING PATTERNS**. UK: Genever Benning, 2014. ISBN: 0990582906.