

GAME ENGINE

ARCHITECTURE, GAME LOOP, UNITY

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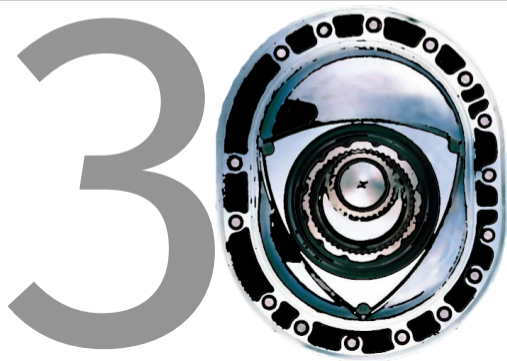
BRNO UNIVERSITY OF TECHNOLOGY

FACULTY OF INFORMATION TECHNOLOGY

DCGM, CPhoto@FIT

FACULTY OF FINE ARTS

GAME MEDIA STUDIO



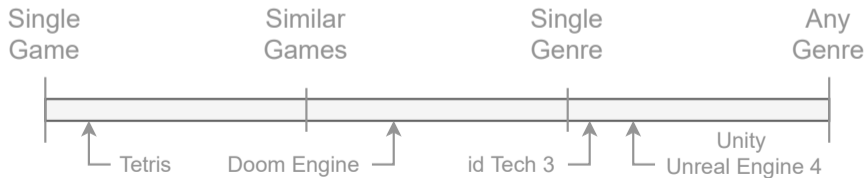
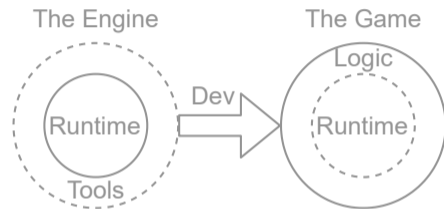
WHAT IS A GAME ENGINE?

- 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

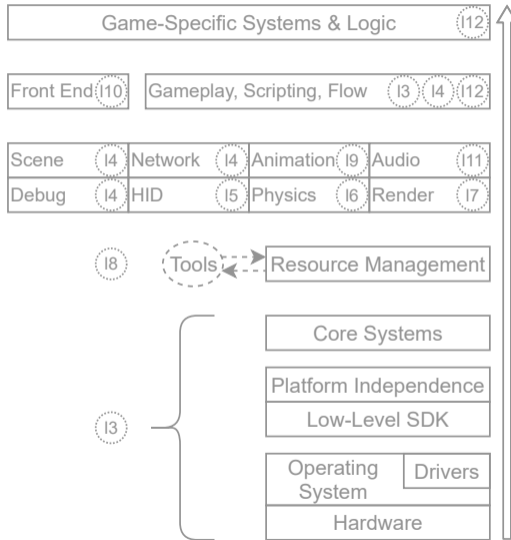


Source: Game Engine Architecture [1]

ENGINE ARCHITECTURE

GAME ENGINE OVERVIEW

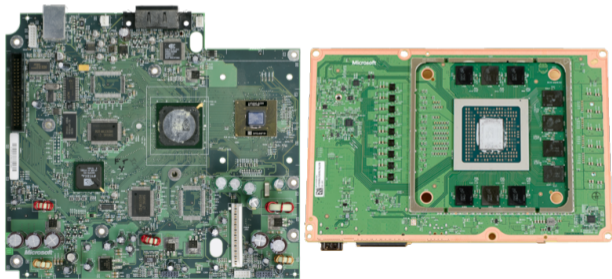
- **Complex** Software Architecture ¹
- Layers & Dependencies
- System Overview



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, ...

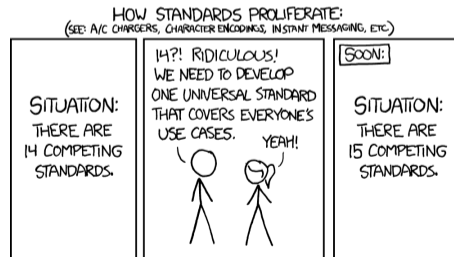


Low-Level Libraries

Middleware

SDKs

APIs



Source: XKCD - Standards

PLATFORM INDEPENDENCE LAYER

- Platform Independence
- Unified Interface
- Multiplatform Development

Platform Independence	
FS	Detection
Threads	Wrappers
Network	Unification



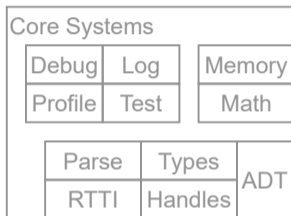
Source: Unreal, Unreal Engine 5



CORE SYSTEMS

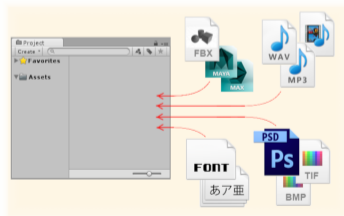
- Library of Utilities
- Base Debugging & Logging
- Memory Management
- Data Types
- Serialization, RTTI, Parsing
- Mathematics – Transform, Geometric, Solvers
- ...

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

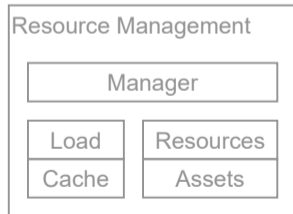
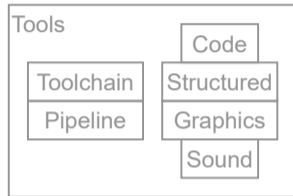


RESOURCE MANAGEMENT

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



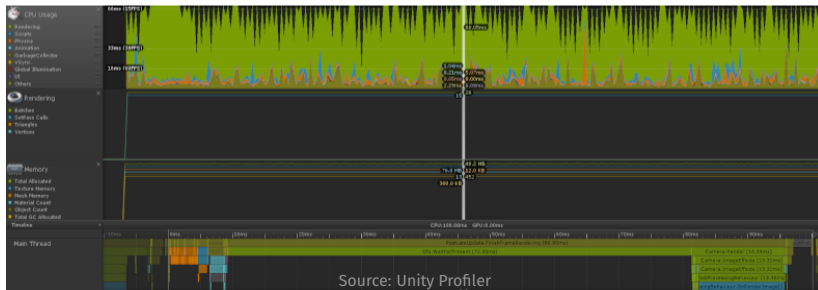
Source: Unity Manual – Asset Workflow



DEBUGGING & PROFILING

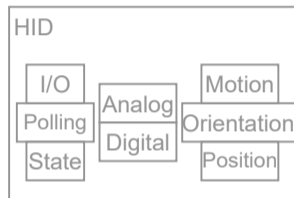
- Complexity → Bugs
- What is Wrong?
- **Instrumentation & Logging**
- Playtime Statistics, Core Dumps
- Remote Debugging & Profiling

Debug	D&P Server
	Statistics
Assert	Playback
Logging	Cheats
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

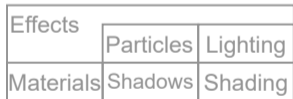
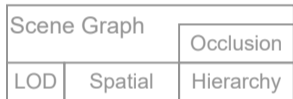
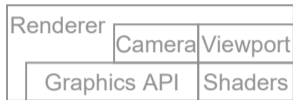


RTX OFF

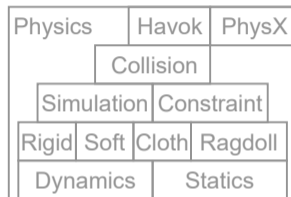
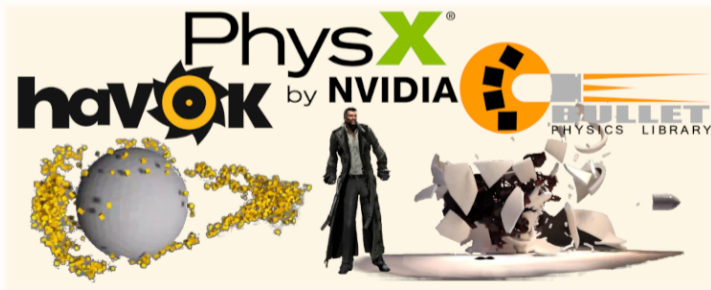
Source: Cyberpunk 2077

RTX ON

Rendering Engine



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



ANIMATION

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

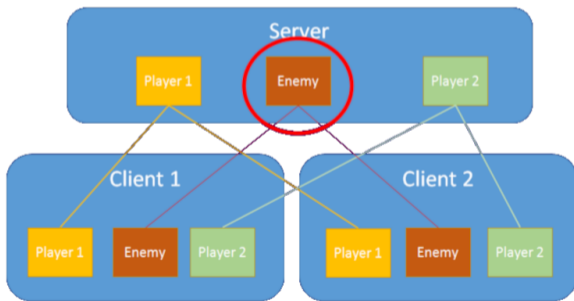


Source: Unreal, Unity

Animation		
Texture	Rigid	Skeleton
Sprite	Vertex	Morph
Kinematics		Skinning
Dynamics		Rigging

NETWORK

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

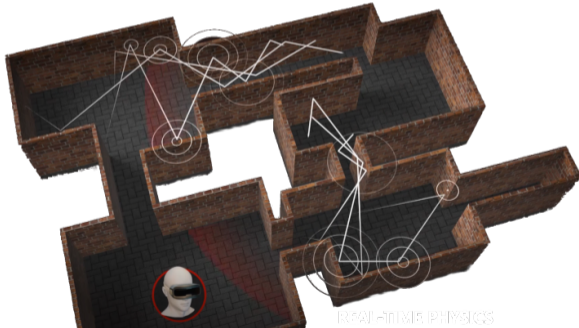


Source: Unity

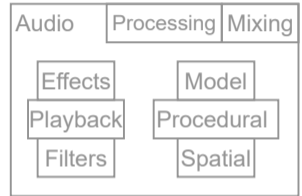
Network		
	Latency	VoIP
Frontend	Authority	Chat
Backend	Replication	
MatchMaking		Infrastructure

AUDIO

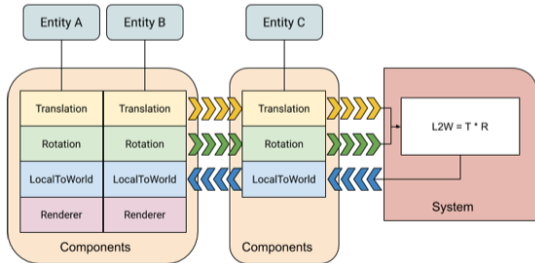
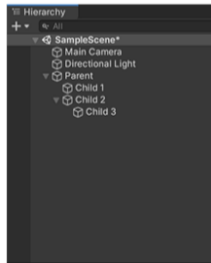
- Often Neglected
- Fidelity & Procedural
- Realistic Modeling



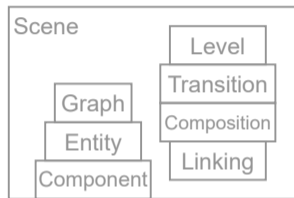
Source: AMD TrueAudio Next



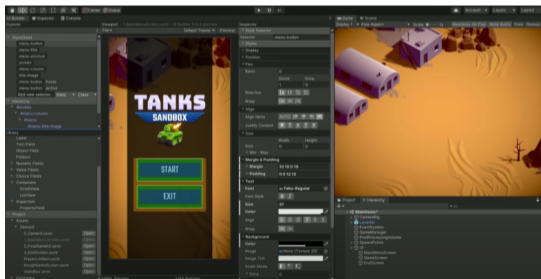
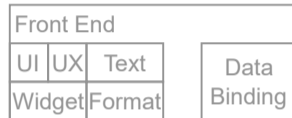
- Graph Data Structure
- World Hierarchy
- Entity-Component-System
- Composition & Linking



Source: Unity



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



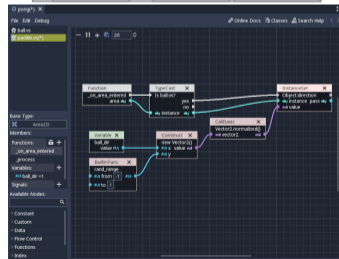
Source: Unity UI Builder

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



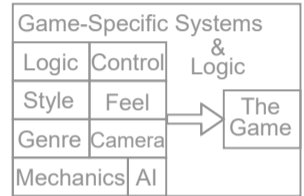
Source: Godot Visual Scripting

GAME-SPECIFIC SYSTEMS

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



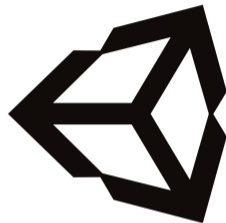
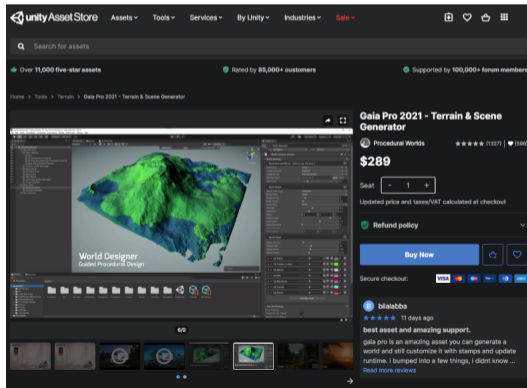
Source: Unity Bolt

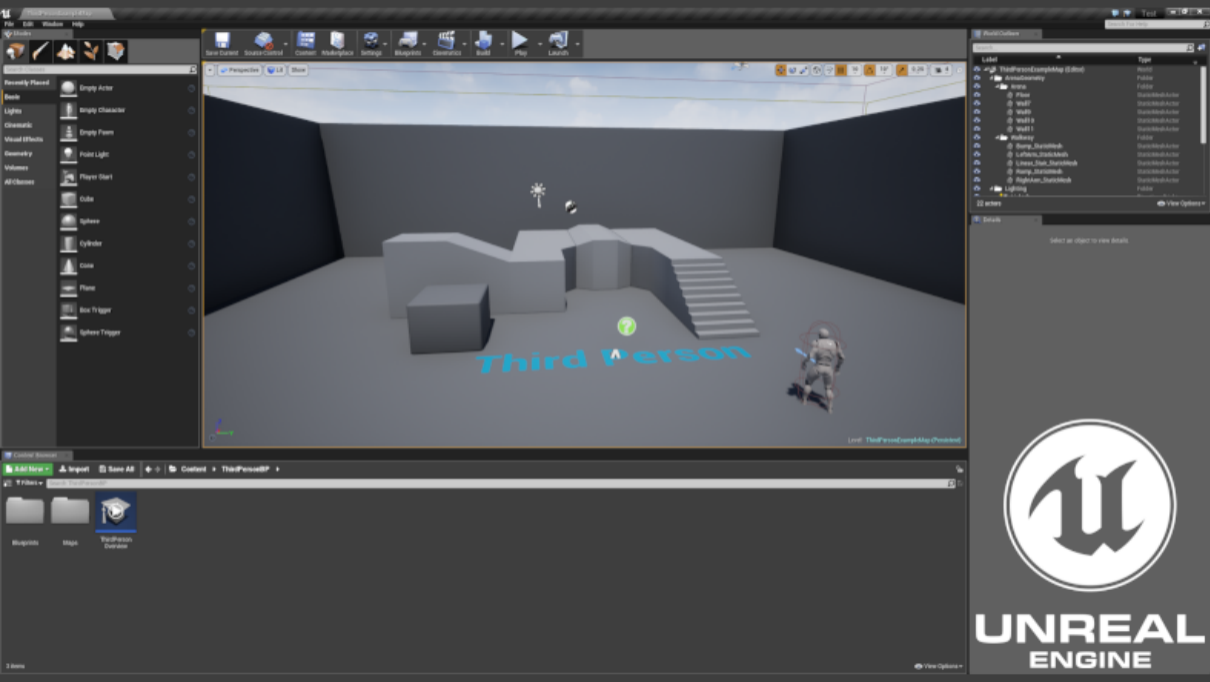
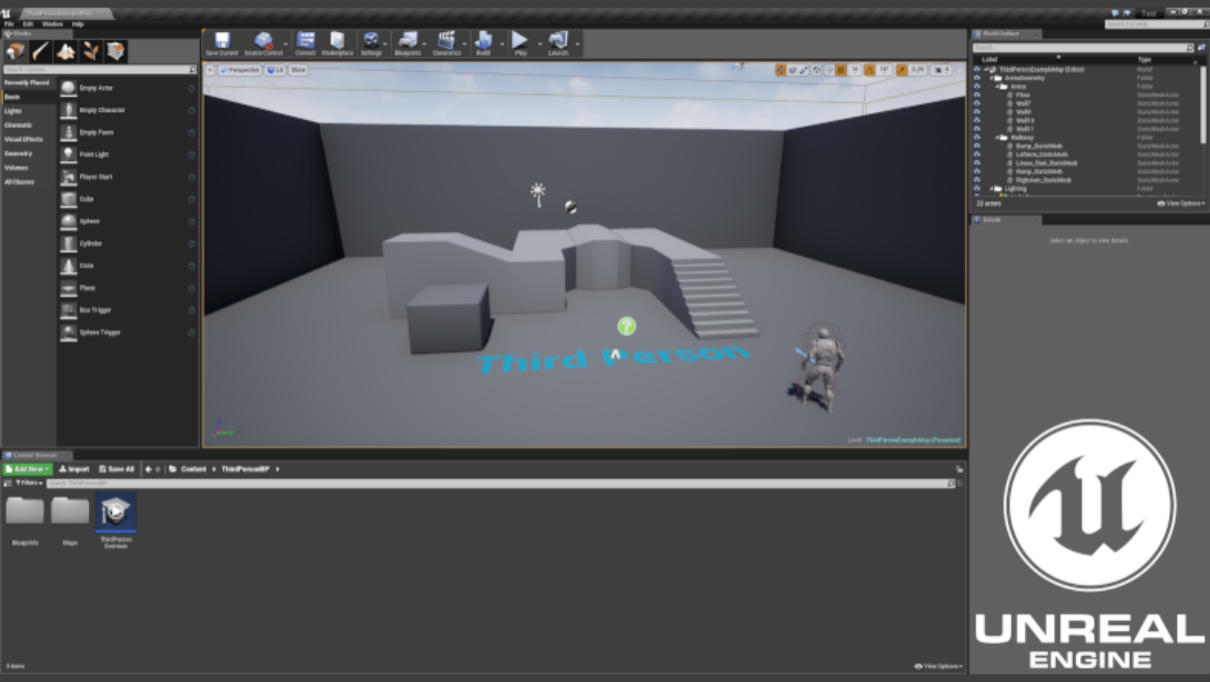


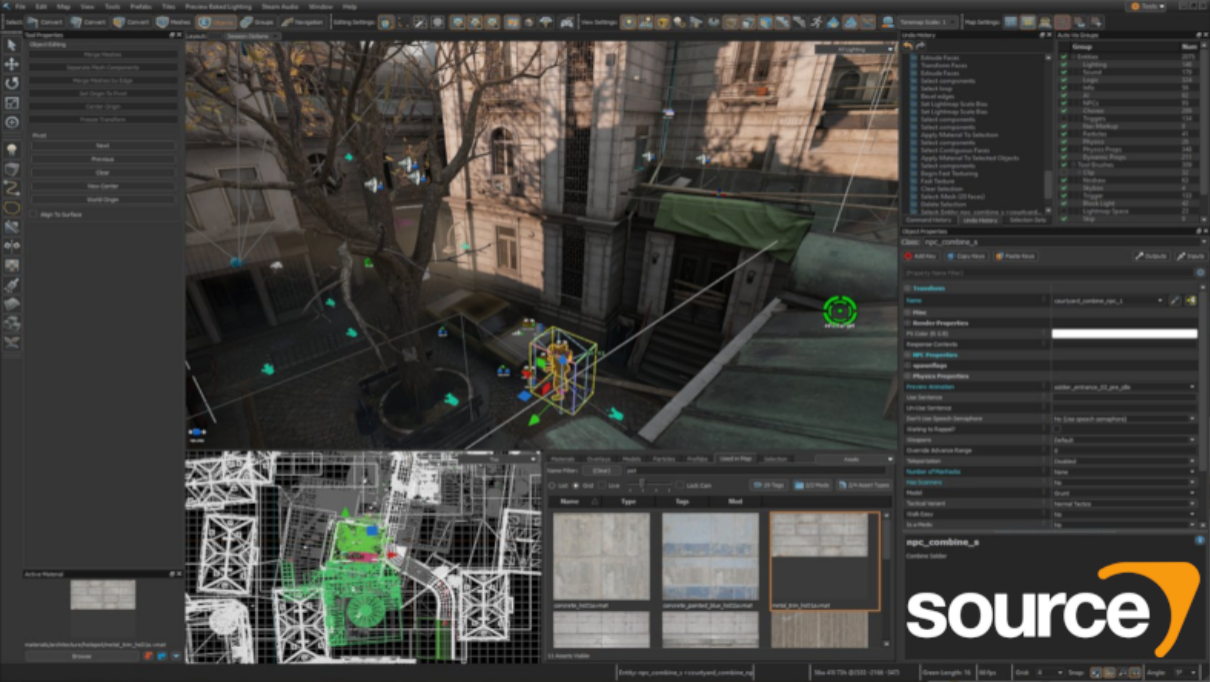
UNITY ENGINE

WHAT IS UNITY?

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





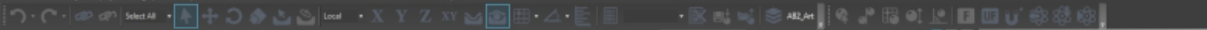


source

Name	Type	Tags	Model
combine_1000_mat			
combine_garbage_bin_1000_mat			
npc_combine_1000_mat			

Property Name	Value
name	combine_1000_mat
color	
renderproperties	
material	
physicsproperties	
physicsanimation	
usecontrols	
usecontrols	
deathusecontrols	
waitingtopass	
weapons	
overrideadvancedrange	
teleportation	
numberofhealths	
hasweapons	
model	
technicalname	
highexp	
isapiece	

Group	Value
Entity	2075
Lighting	150
Sound	120
Logic	100
AI	50
AI2	50
AI3	50
AI4	50
AI5	50
AI6	50
AI7	50
AI8	50
AI9	50
AI10	50
AI11	50
AI12	50
AI13	50
AI14	50
AI15	50
AI16	50
AI17	50
AI18	50
AI19	50
AI20	50
AI21	50
AI22	50
AI23	50
AI24	50
AI25	50
AI26	50
AI27	50
AI28	50
AI29	50
AI30	50
AI31	50
AI32	50
AI33	50
AI34	50
AI35	50
AI36	50
AI37	50
AI38	50
AI39	50
AI40	50
AI41	50
AI42	50
AI43	50
AI44	50
AI45	50
AI46	50
AI47	50
AI48	50
AI49	50
AI50	50



Perspective

By Name, Hide Unused, AMO

FOV: 60°

Ratio: 116:293 1548 x 879

Help for



Use Ctrl+Drag to Arrange Layers

000	+	AB1
000	+	AB2
000	+	AB2_A01
000	+	AB2_Landscape
000	+	AB2_Lens
000	+	AB2_Navigation
000	+	AB2_Particles
000	+	AB3
000	+	AB4
000	+	Boundary Collision
000	+	LightScrubbers
000	+	Man
000	+	Shaman
000	+	Shrub
000	+	Water Substrate
000	+	World



CRYENGINE®

- 0.0.0.0
- Rosad_T
- legionnaire_posed
- Default Asset Environment
- Light

Asset Browser

rosad_cinematic

- Swords
 - Rosad_Cinematic_sword
 - Rosad_Cinematic_sword
 - Rosad_Cinematic_sword
 - Rosad_Cinematic_sword
 - Rosad_Cinematic_sword
 - swords_OcclusionFougl
- Teeth
 - Rosad_Cinematic_tooth
 - Rosad_Cinematic_tooth
 - Rosad_Cinematic_tooth
 - Rosad_Cinematic_tooth
 - Rosad_Cinematic_tooth
 - Rosad_Cinematic_tooth
 - teeth_OcclusionRough



Rosad_Cinematic_PBR



Name: Rosad_T
 Status: Start active
 Empty ID: 48999241175
 Add Component +

Search

Transform

Parent empty:

Values

Translate: X: 0.0 m, Y: 0.0 m, Z: 44.0 m
 Rotate: X: 0.0 deg, Y: 0.0 deg, Z: 190.0 deg
 Uniform Scale: 1.0

Add non-uniform scale

Parent activation: Original relative transform
 Static:

Mesh

Mesh Asset: rosad_cinematic
 Mesh Key: 0
 Lod Override: Low Set
 Exclude from reflect:
 Use Forward Pass L:

Material

- Generate/Manage Source Materials...
- Default Material:
- Model Materials: 17 elements
- arms1: mat:rosad_arms
 - belt1: cinematic:rosad_belt
 - brooch1: mat:rosad_brooch
 - cape1: mat:rosad_cape
 - chainmail1: cinematic:chainmail
 - default_unassigned: mat:rosad_sword
 - eye: mat:rosad_eyes
 - eyebrow_01: mat:rosad_belt
 - hair: cinematic:hair





Scene Import

+ Filter nodes

- tester
- environment
- testers
- white plastic
 - MeshInstance
- mirror
 - MeshInstance
- dark wood
 - MeshInstance
- cheese
 - MeshInstance
- stones
 - MeshInstance
- brick
 - MeshInstance
- wood
 - MeshInstance

FileSystem

< resur

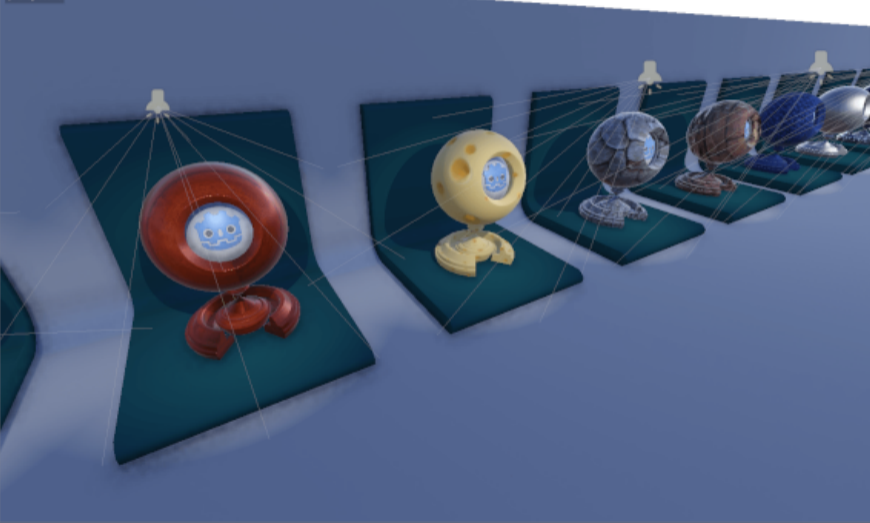
Search files

- ★ Favourites:
- resur
 - aluminium_albedo.png
 - aluminium_flow.png
 - aluminium_normal.png
 - experiment.hdr
 - GodotBall.dae
 - godot_ball.mesh
 - icon.png
 - lobby.hdr
 - marble_albedo.png
 - night.hdr
 - park.hdr
 - pbr_bed.dae
 - rock_albedo.png

tester X +

Transform View

Perspective



Inspector Node

tester

Filter properties



(-326, -271) oPickUpGear

Sequence1

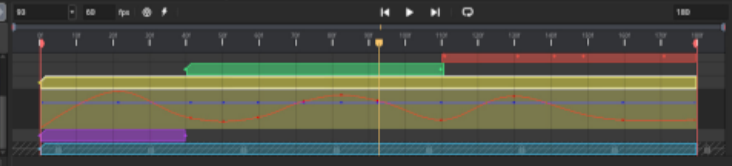
Track Panel

- swan_spr
- swan
- scweb
- oPickUpGear

Position: XY 225.28, 225.29 px

swan

apr_bg



Asset Browser

Search...

- Quick Access
- Recent
- Favourites
- Room Order
- Saved Searches
- Tags
- Game Options

Rooms

- Objects
- Rooms
- Scripts

Sprites

- Background
 - oBGGrad_grass
 - oBGGrad_sand
 - oBGHib_grass
 - oBGHib_sand
 - oBGHib1_grass
 - oBGHib1_sand
 - oCloud_grass
 - oCloud_sand
 - oCloud1_grass
 - oCloud1_sand
 - oMoon
 - apr_bg
 - oStar_grass
 - oStar_sand
- Enemy
 - oGhost
 - oGhost_left
 - oGhostShadow
- Level
- PickUpGear
 - oHeart
 - oPickUpGear
- Player
- Tile Sets
- Sequence1

37 items, 1 selected, 100%


Object Window

Class: []

Editor ID: [] Count: [] View: [] Path To: []

Objects within 10 units

- Archer
- Asak
- Chandelier
- Door
- Map
- WallBanner
- Special Boat
- WallData
- WallDecor
- Archway
- Chest
- Door
- Flare
- Furniture
- Grass
- Light
- WallDecor
- Water
- Static Collection
- Tree




Cell View

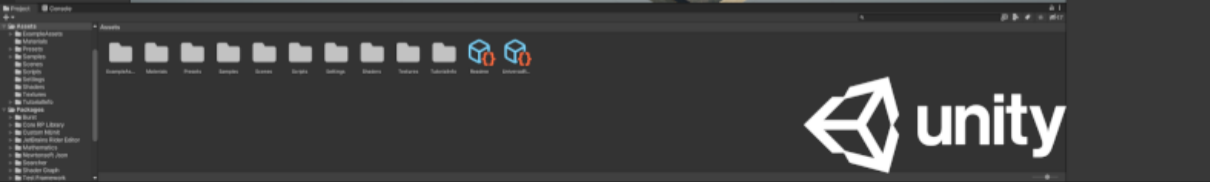
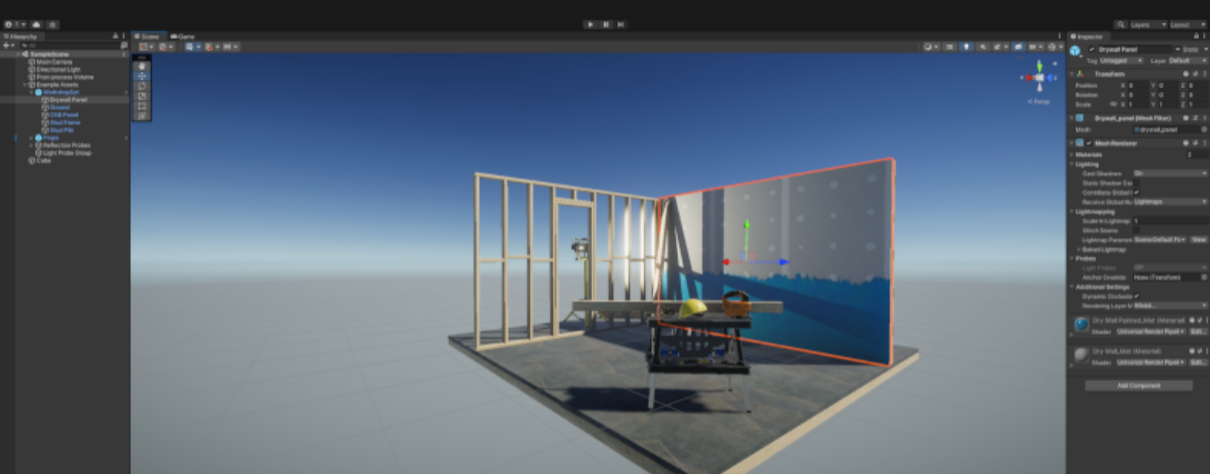
World Space

Selected: []

Loaded: []

Objects within 10 units

Editor ID	Name	L	Count	Location	Owner
u100000001	u100000001	Static	1		
u100000002	u100000002	Static	1		
u100000003	u100000003	Static	1		
u100000004	u100000004	Static	1		
u100000005	u100000005	Static	1		
u100000006	u100000006	Static	1		
u100000007	u100000007	Static	1		
u100000008	u100000008	Static	1		
u100000009	u100000009	Static	1		
u100000010	u100000010	Static	1		
u100000011	u100000011	Static	1		
u100000012	u100000012	Static	1		
u100000013	u100000013	Static	1		
u100000014	u100000014	Static	1		
u100000015	u100000015	Static	1		
u100000016	u100000016	Static	1		
u100000017	u100000017	Static	1		
u100000018	u100000018	Static	1		
u100000019	u100000019	Static	1		
u100000020	u100000020	Static	1		
u100000021	u100000021	Static	1		
u100000022	u100000022	Static	1		
u100000023	u100000023	Static	1		
u100000024	u100000024	Static	1		
u100000025	u100000025	Static	1		
u100000026	u100000026	Static	1		
u100000027	u100000027	Static	1		
u100000028	u100000028	Static	1		
u100000029	u100000029	Static	1		
u100000030	u100000030	Static	1		
u100000031	u100000031	Static	1		
u100000032	u100000032	Static	1		
u100000033	u100000033	Static	1		
u100000034	u100000034	Static	1		
u100000035	u100000035	Static	1		
u100000036	u100000036	Static	1		
u100000037	u100000037	Static	1		
u100000038	u100000038	Static	1		
u100000039	u100000039	Static	1		
u100000040	u100000040	Static	1		
u100000041	u100000041	Static	1		
u100000042	u100000042	Static	1		
u100000043	u100000043	Static	1		
u100000044	u100000044	Static	1		
u100000045	u100000045	Static	1		
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u100000082	u100000082	Static	1		
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u100000090	u100000090	Static	1		
u100000091	u100000091	Static	1		
u100000092	u100000092	Static	1		
u100000093	u100000093	Static	1		
u100000094	u100000094	Static	1		
u100000095	u100000095	Static	1		
u100000096	u100000096	Static	1		
u100000097	u100000097	Static	1		
u100000098	u100000098	Static	1		
u100000099	u100000099	Static	1		
u100000100	u100000100	Static	1		



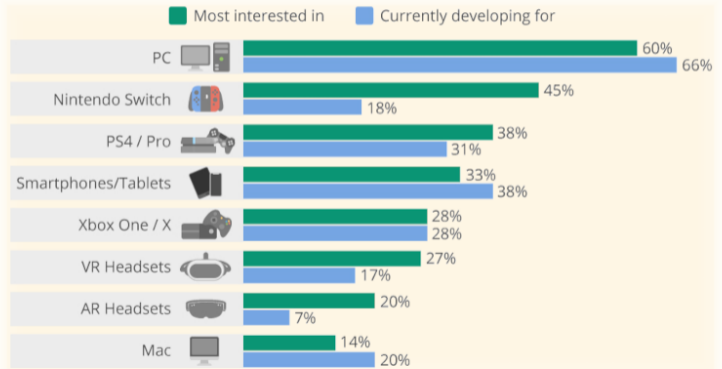
WHICH TO CHOOSE?

- 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

10

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.