Games and Simulation

2021-2022

Fernando Birra
Rui Nóbrega

Game Engine Runtime Architecture

Fernando Birra
Rui Nóbrega

Game Engine

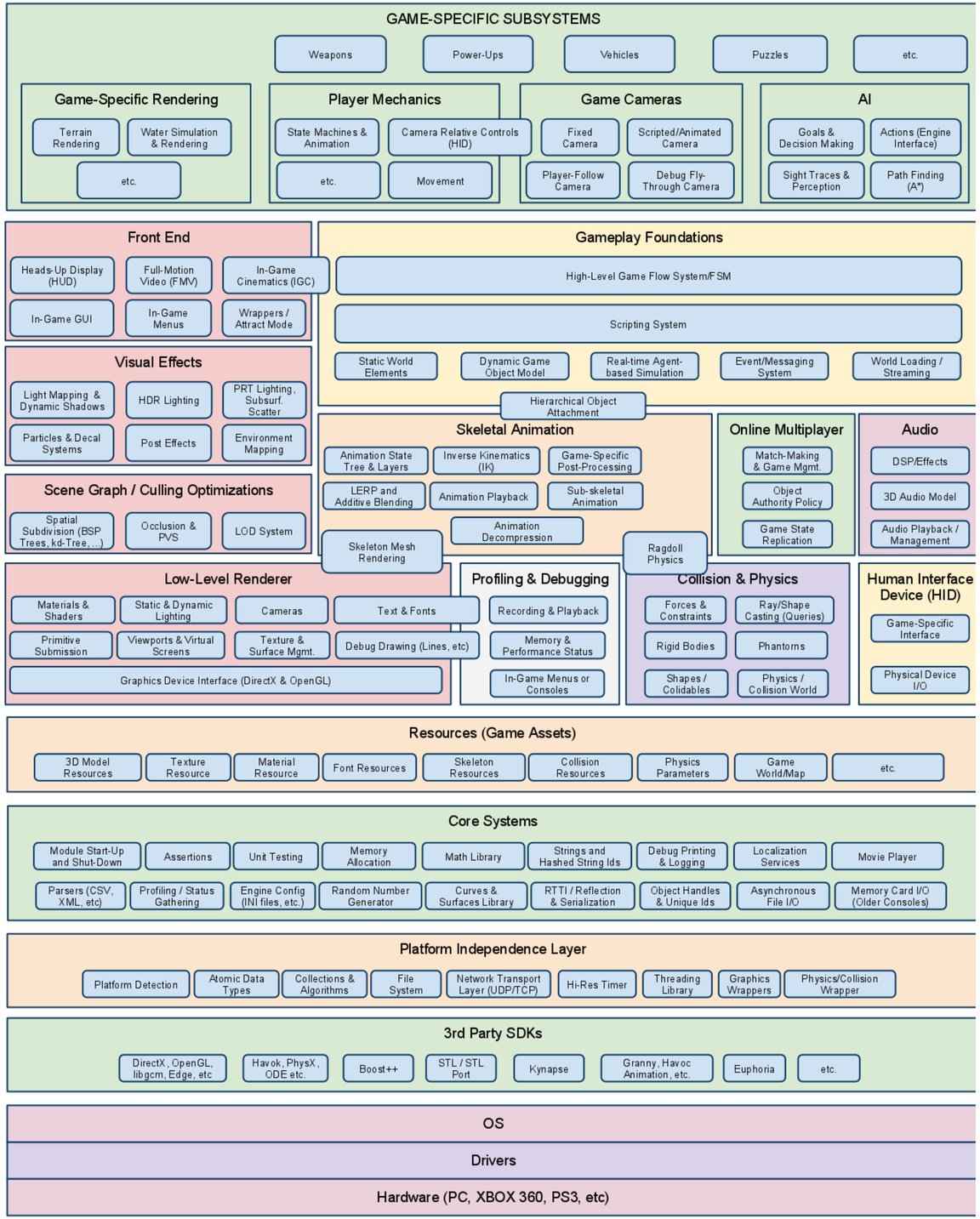
- Usually composed of:
  - A set of tools (tool suite)
  - A runtime component

game specific layer

The runtime component of a game engine is a highly complex piece of software built using a layered approach

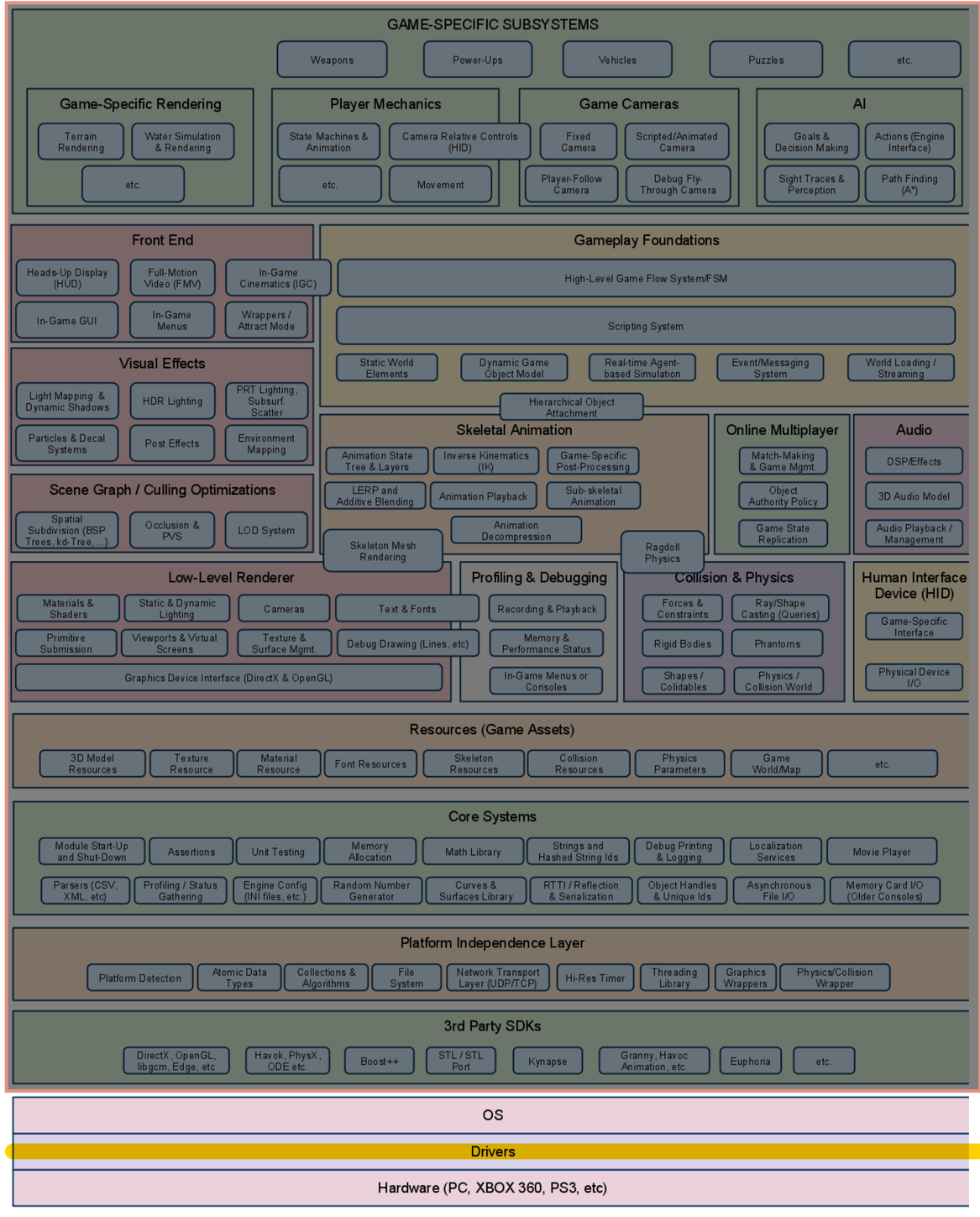
Increasing abstraction

hardware and OS



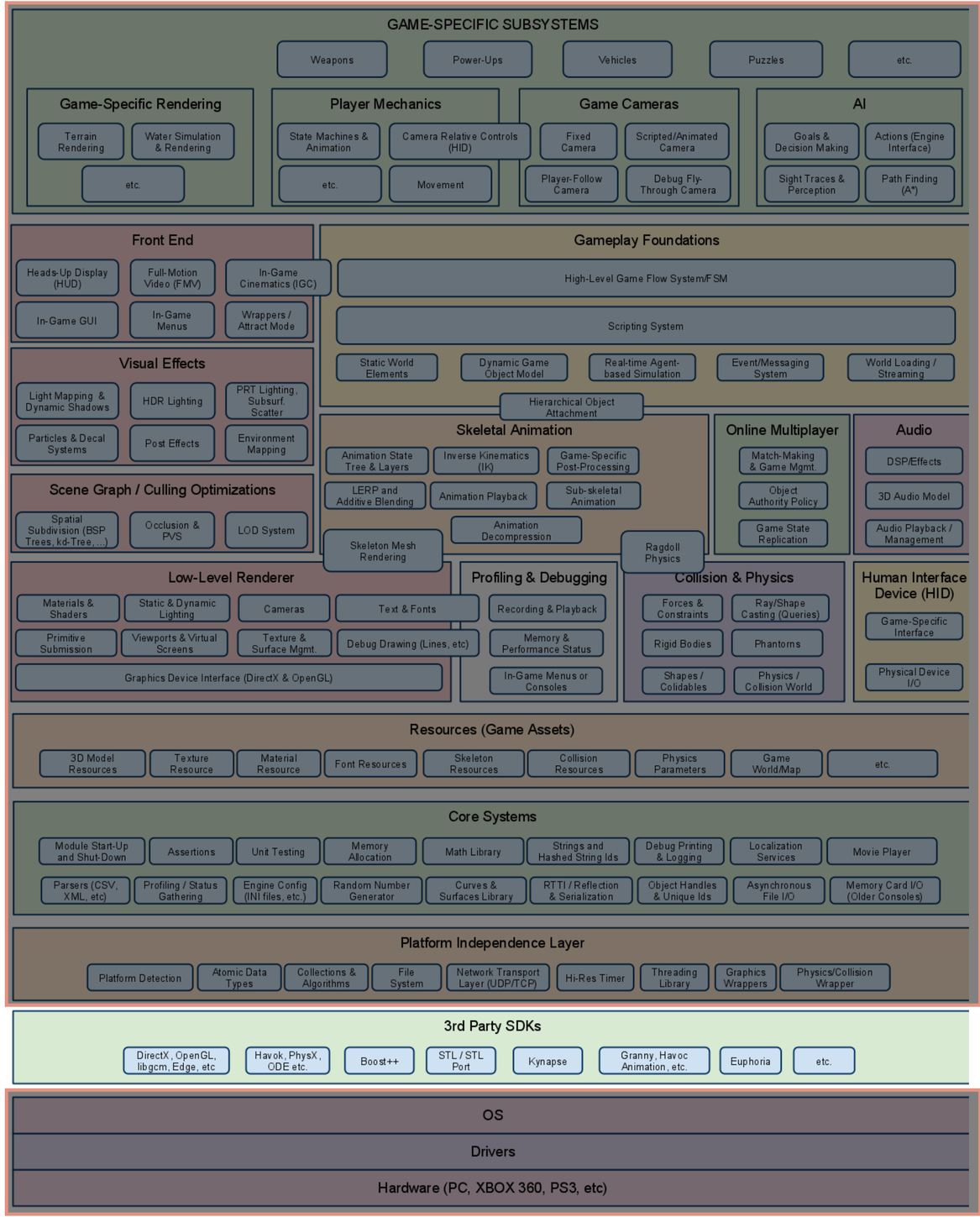
Hardware and OS

- The OS includes the drivers to access the specific hardware devices available.
- In consoles, the OS layer used to be a thin library linked with the game app.
- From Xbox and PS3 onwards, the OS is able to interrupt the game and display notification messages, reducing the gap between computers and console OS.



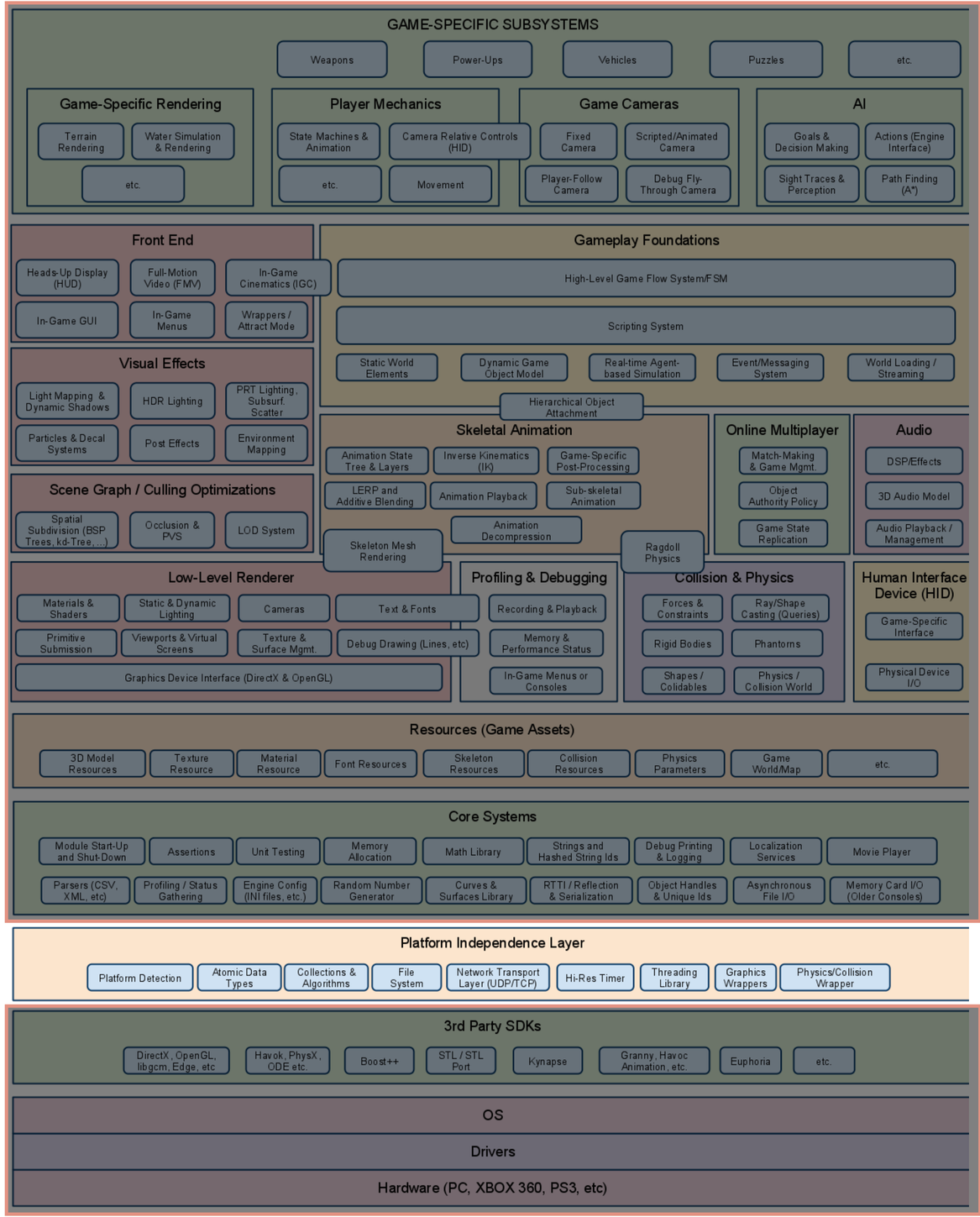
3rd Party SDK and middleware

- Graphics API (DirectX, OpenGL, libgcm, …)
- Collision and Physics (Havok, PhysX, ODE, …)
- Data structures and algorithms libraries (Boost, STL)
- Character Animation support (Granny 3D, Havoc Animation, …)
- AI middleware (Kynapse, …)
- Dynamic motion synthesis based on Biomechanics (Euphoria)
- …



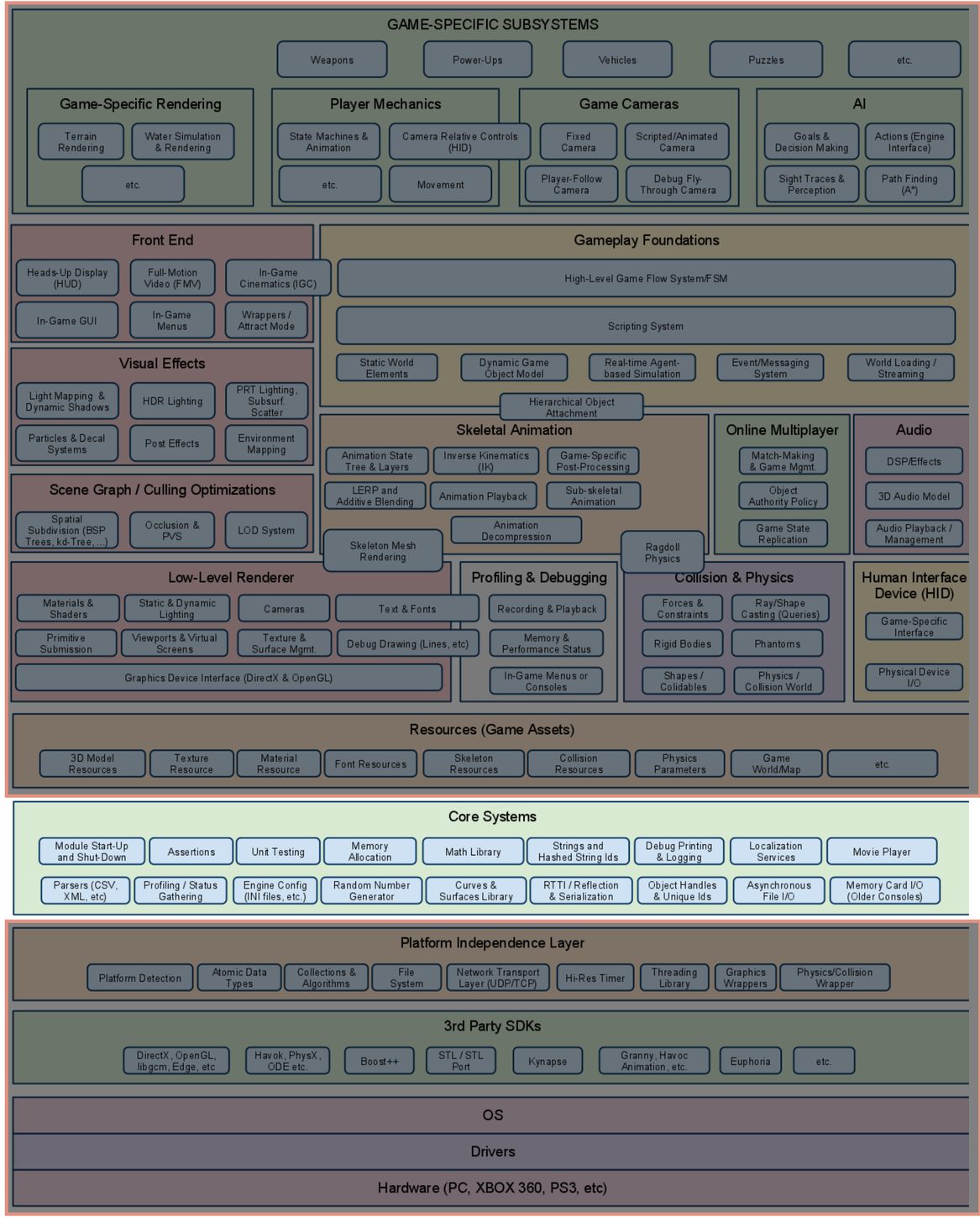
Platform Independence Layer

- Required for all game engines running on different hardware platforms.
- Most studios sell their games for several platforms (except first party studios)
- Shields the rest (top part) of the engine from knowledge of the underlying platform.



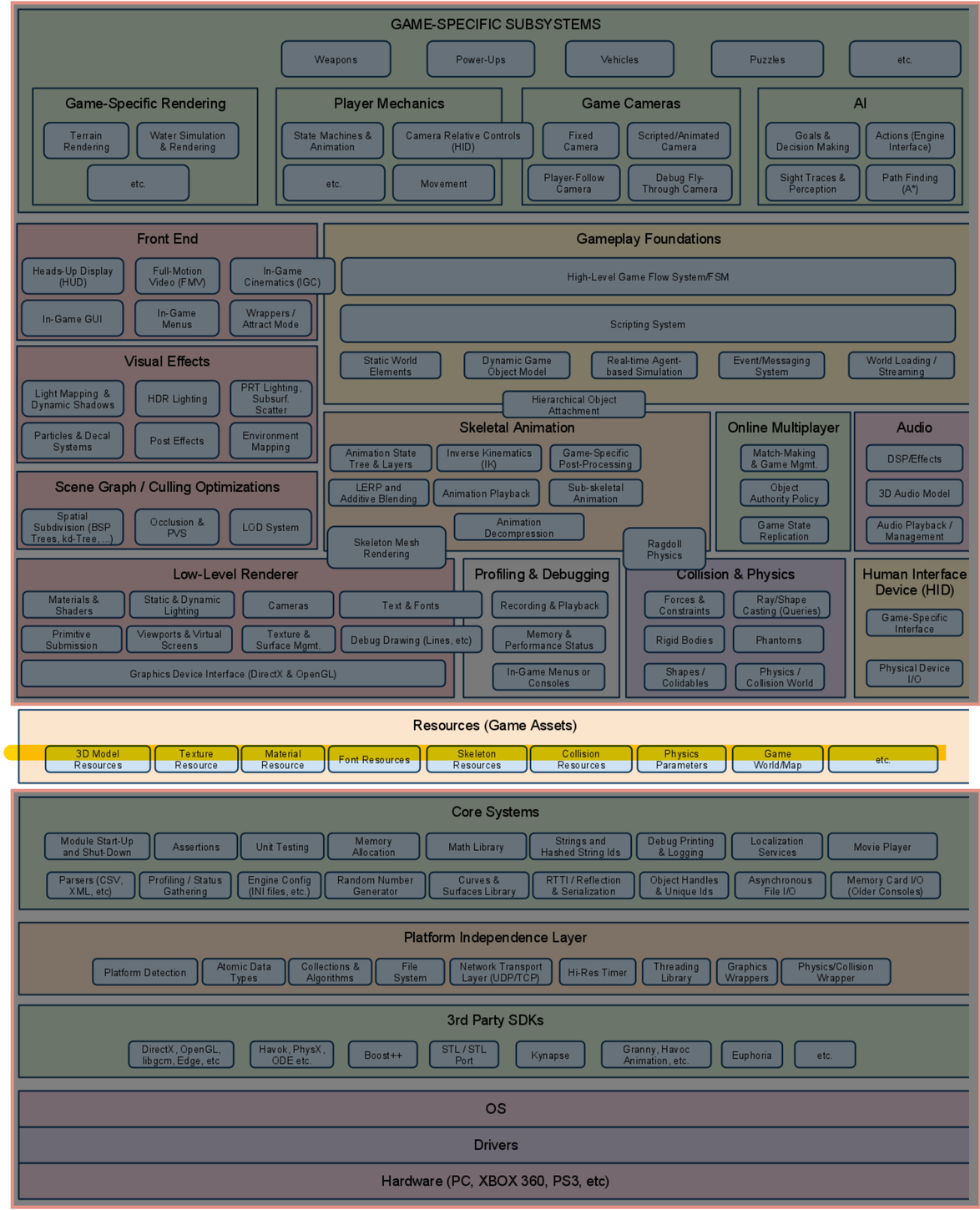
Core Systems

- Examples of “stuff” that go into Core System:
  - Assertions
  - Math library
  - Memory Management
  - Custom Data Structures and Algorithms



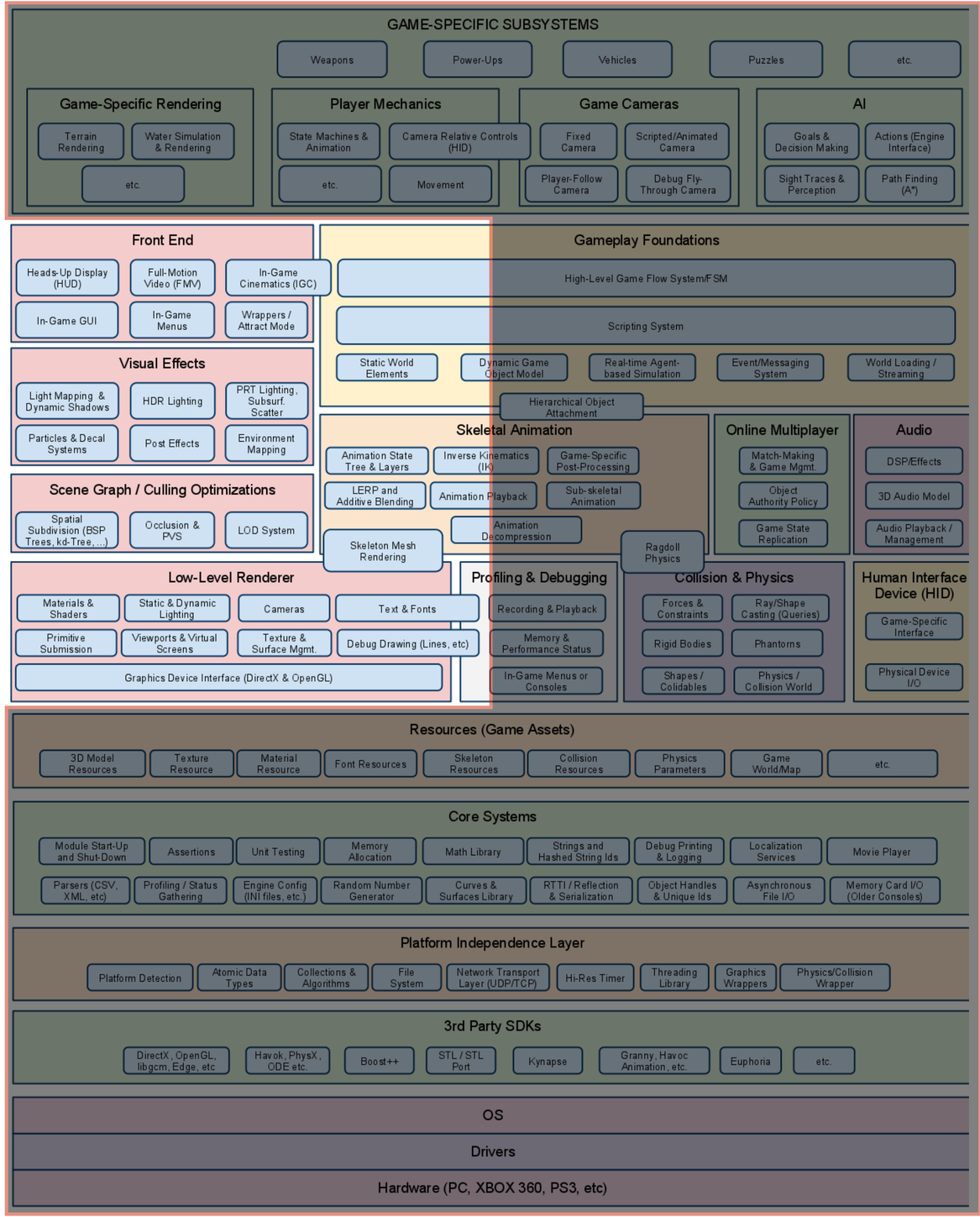
Resource Manager

- Provide interfaces to access game assets and other input data:
  - 3D models, textures, fonts, audio files, skeletons, terrains, …
  - Ad-hoc access to single files vs. resource bundles



Rendering Engine

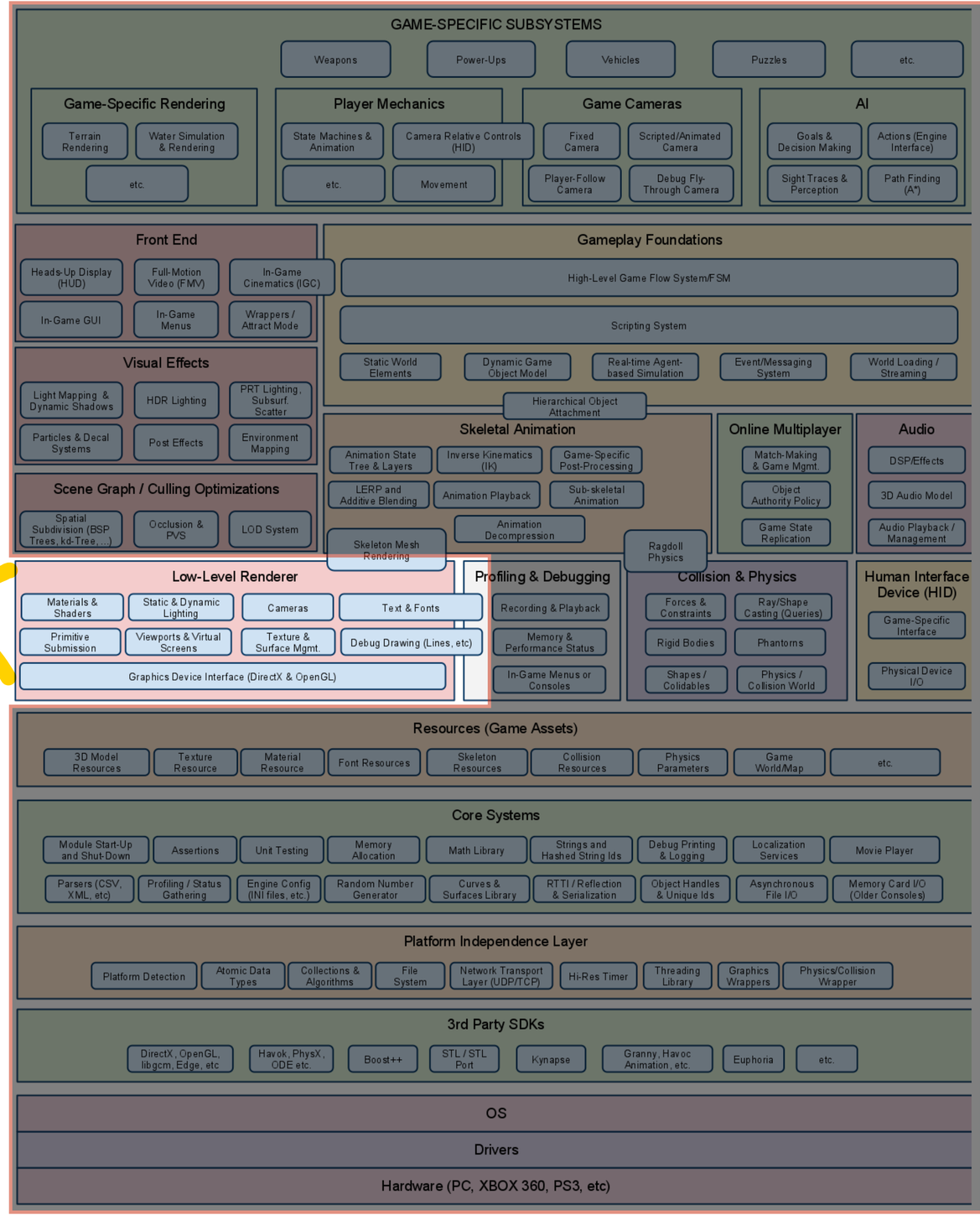
- One of the largest and most complex components
- Usually structured in several layers with upper levels providing higher abstraction features



Low Level Rendering

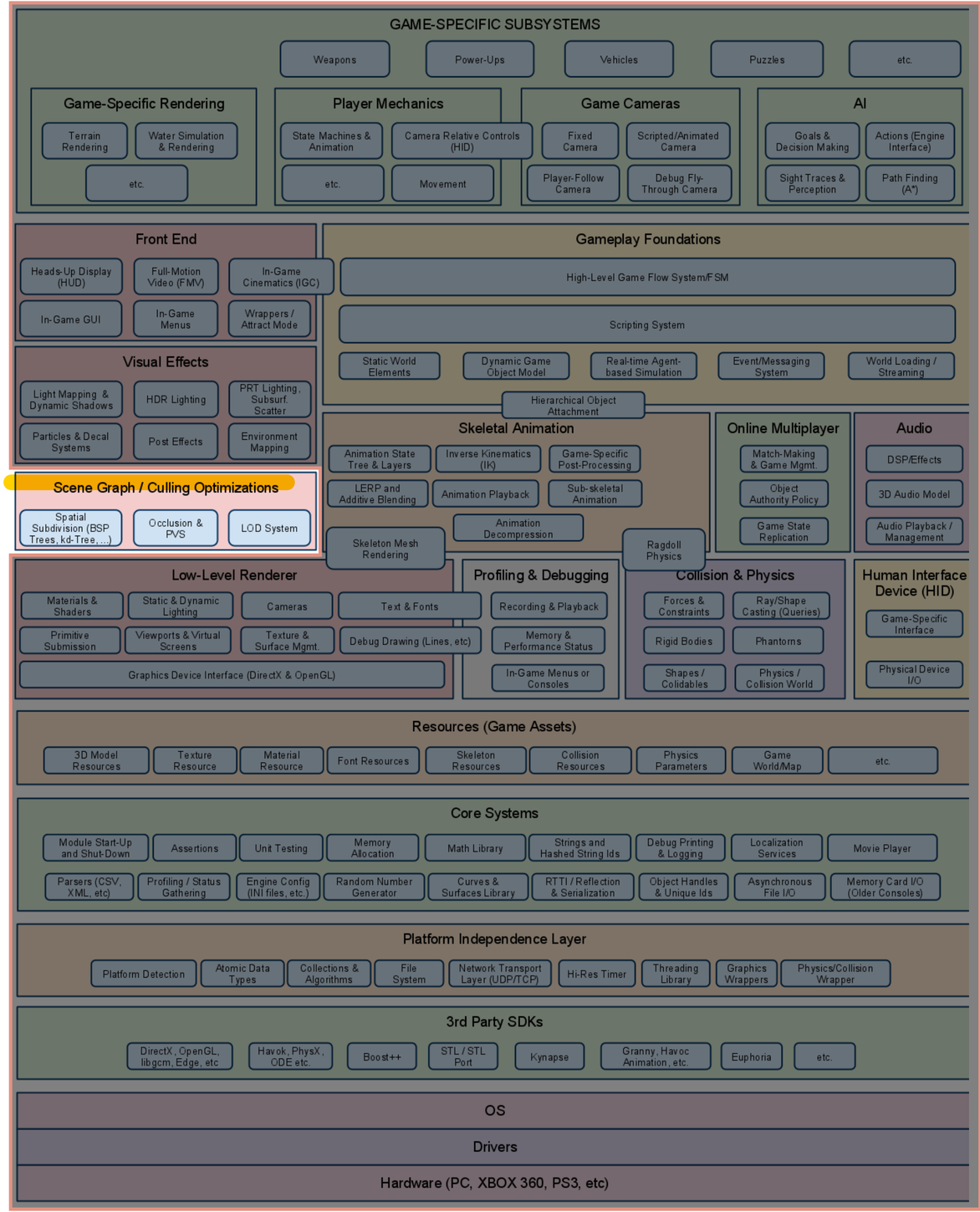
- The lower part deals with graphics API: enumerate the devices, buffer allocations (color, depth, stencil, etc.)

- The upper parts offer support commonly found in 3D graphics pipelines: primitive submission, materials and shader support, textures, lighting, viewports, cameras, …



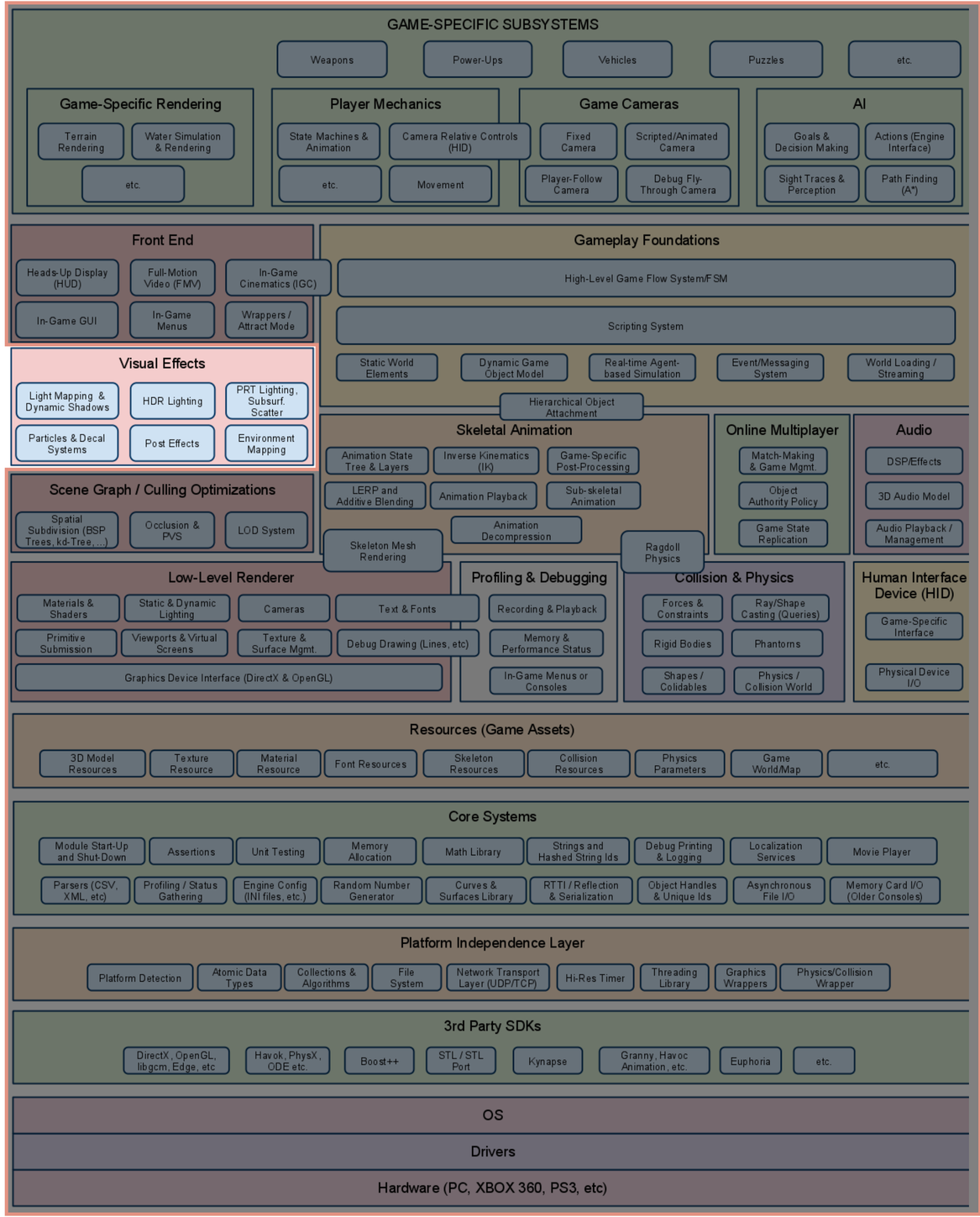
Scene Graph Handling

- Game action can potentially take place in large virtual worlds and/or include a very large number of actors/entities.
- Efficient handling of this large amount of model data is needed so not to stall the pipeline.
- Spatial data structures are employed to discard objects outside of view volume.
- Objects may occlude other objects and lead to further optimizations.
- Objects at different distances from the camera may be rendered with different levels of detail.



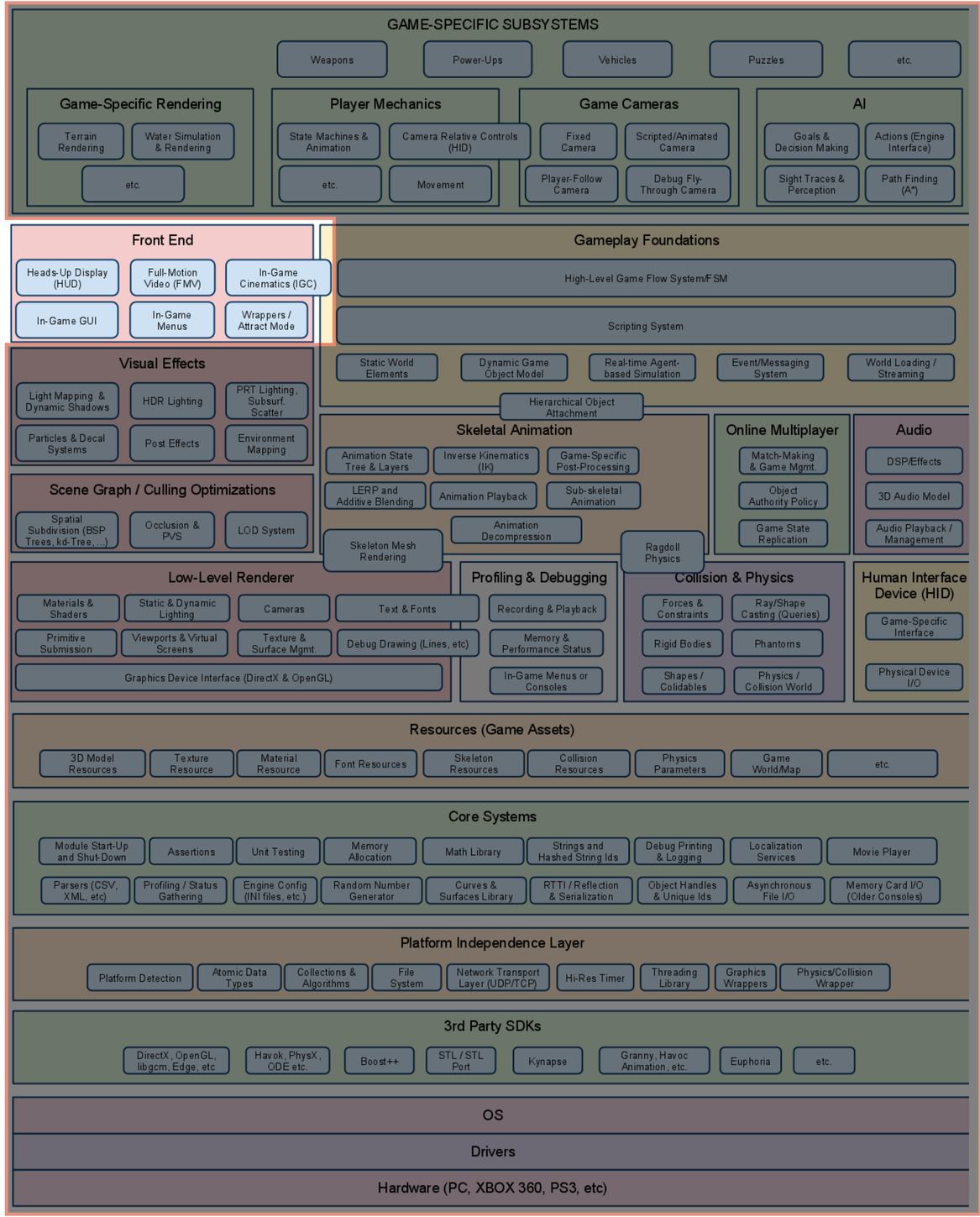
Visual Effects

- Modern video games include highly advanced visual effects:
  - particle systems (water splashes, smoke, fire,…)
  - decals (bullet holes, footprints, …)
  - light mapping and environment mapping
  - dynamic shadows
  - full-screen post effects (HDR, FSAA, color correction/shift)



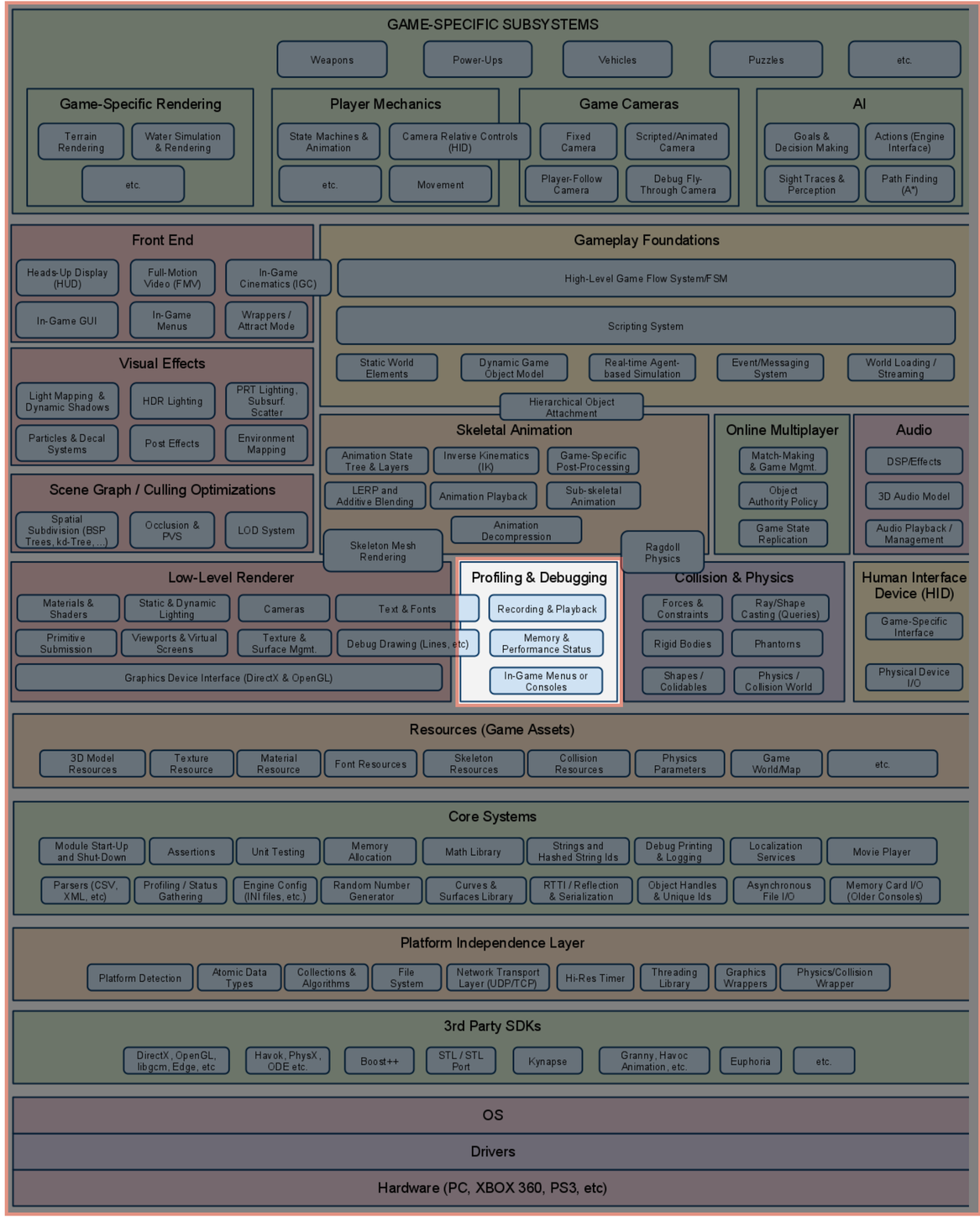
Front End

- Examples:
  - Heads-up display
  - In-game menus, console, development tools (may not ship with the game)
  - In-game GUI to manipulate the character's inventory, deploy units to battle, …
  - Video playback and scripted Cinematics Choreography using the Engine
- A large portion of these features require making 2D textures to the screen (orthographic view) or in 3D billboards (always facing the camera).



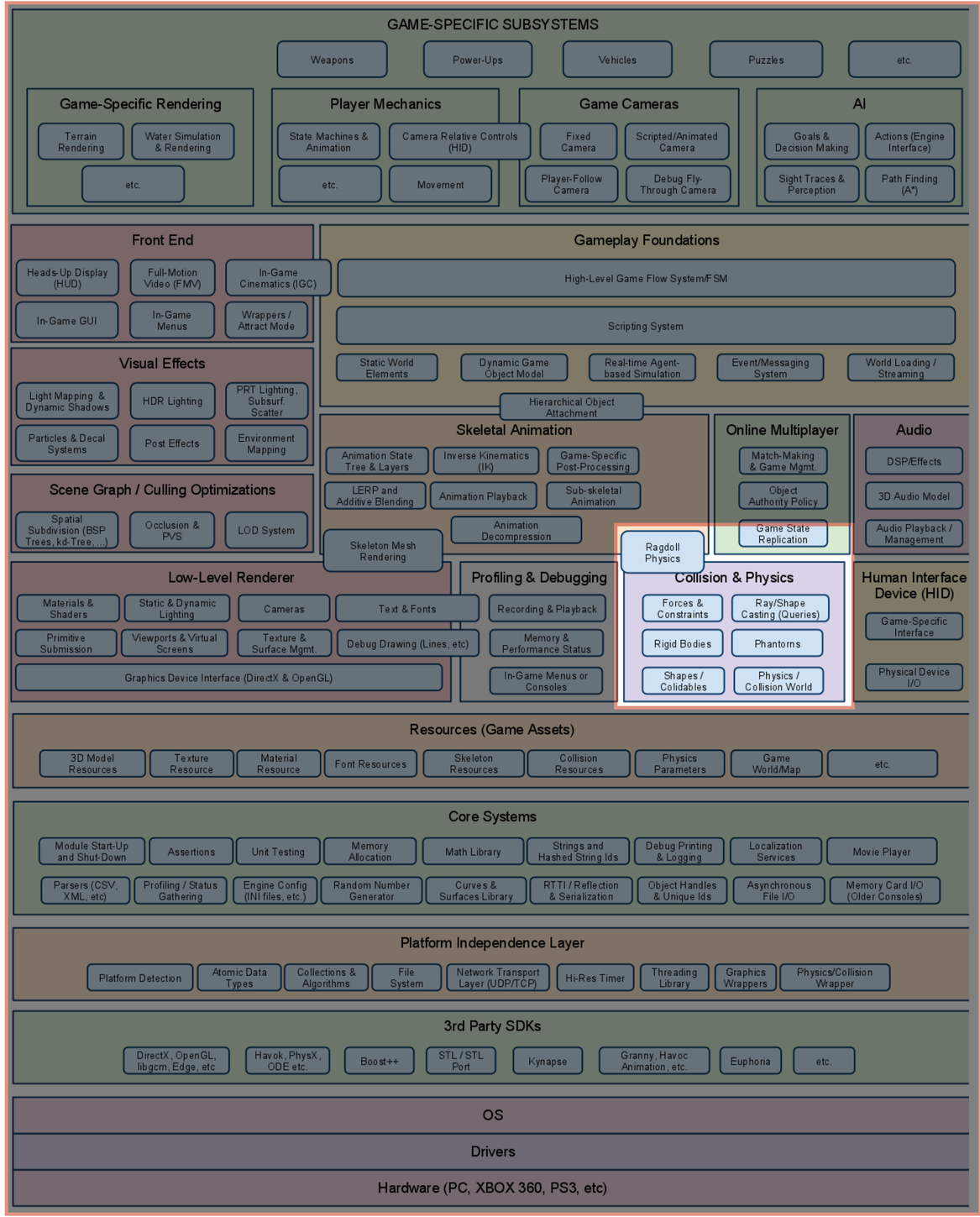
Profiling and Debugging

- Performance is a top priority in game development
- Console hardware quickly becomes outdated and resources are scarce.
- In-game debugging tools often include a development console and drawing facilities.
- Recording, playback, stopping the game clock, dumping stats, etc…



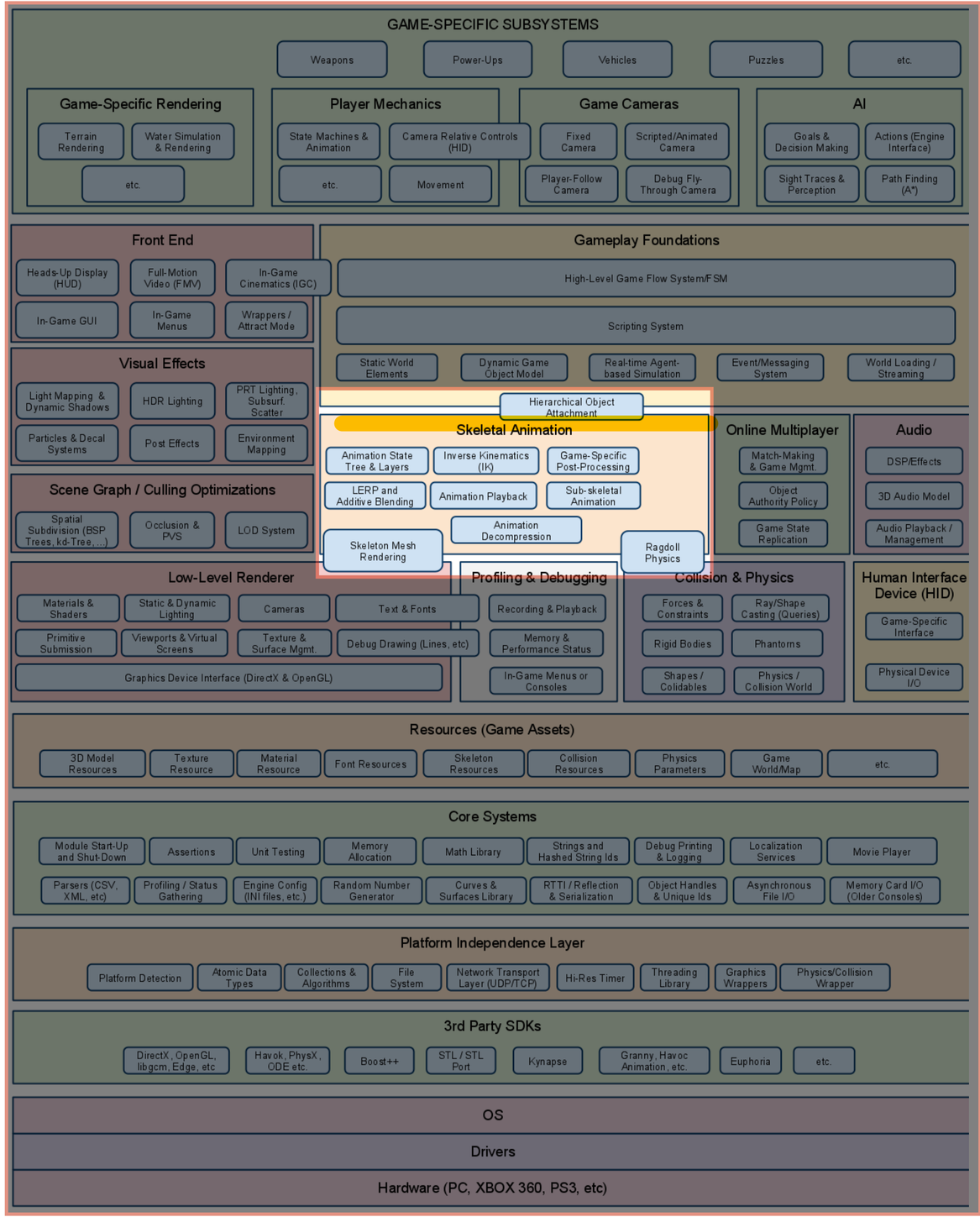
Collisions and Physics

- Collisions is at the heart of every game. Without them, objects would overlap and no interaction with the virtual world would be possible.
- Collision is commonly done with low detail, simpler, shapes
- The Physics system comprises rigid body dynamic simulation based on forces, torques and restrictions.



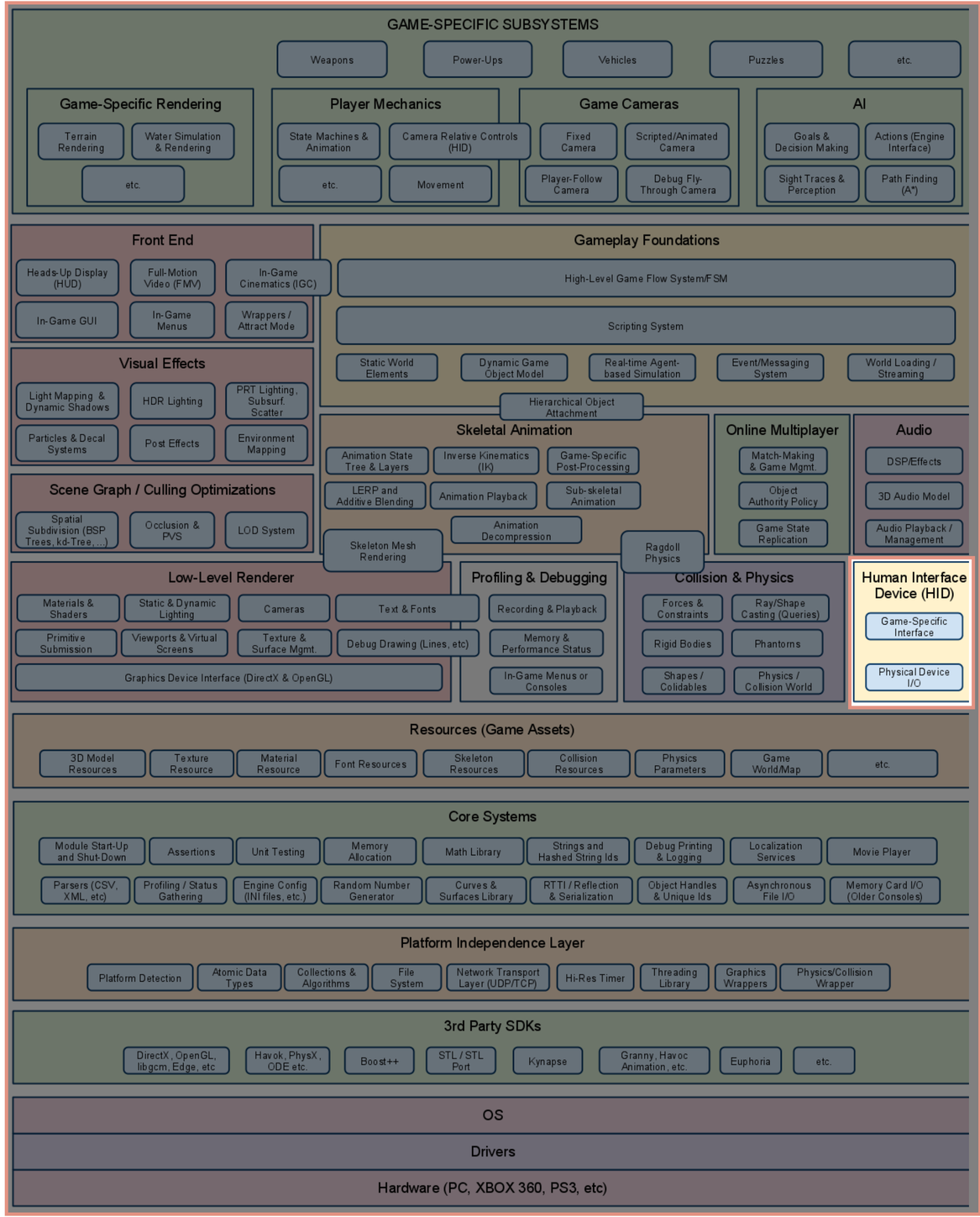
Animation

- Animation systems are needed for modeling humans, animals, cartoon characters, robots,…
- types of animation systems:
  - sprite/texture animation (2D)
  - rigid body hierarchy animation (machines, robots)
  - skeletal animation (humans, animals, cartoon characters,…)
  - vertex animation
  - morph targets



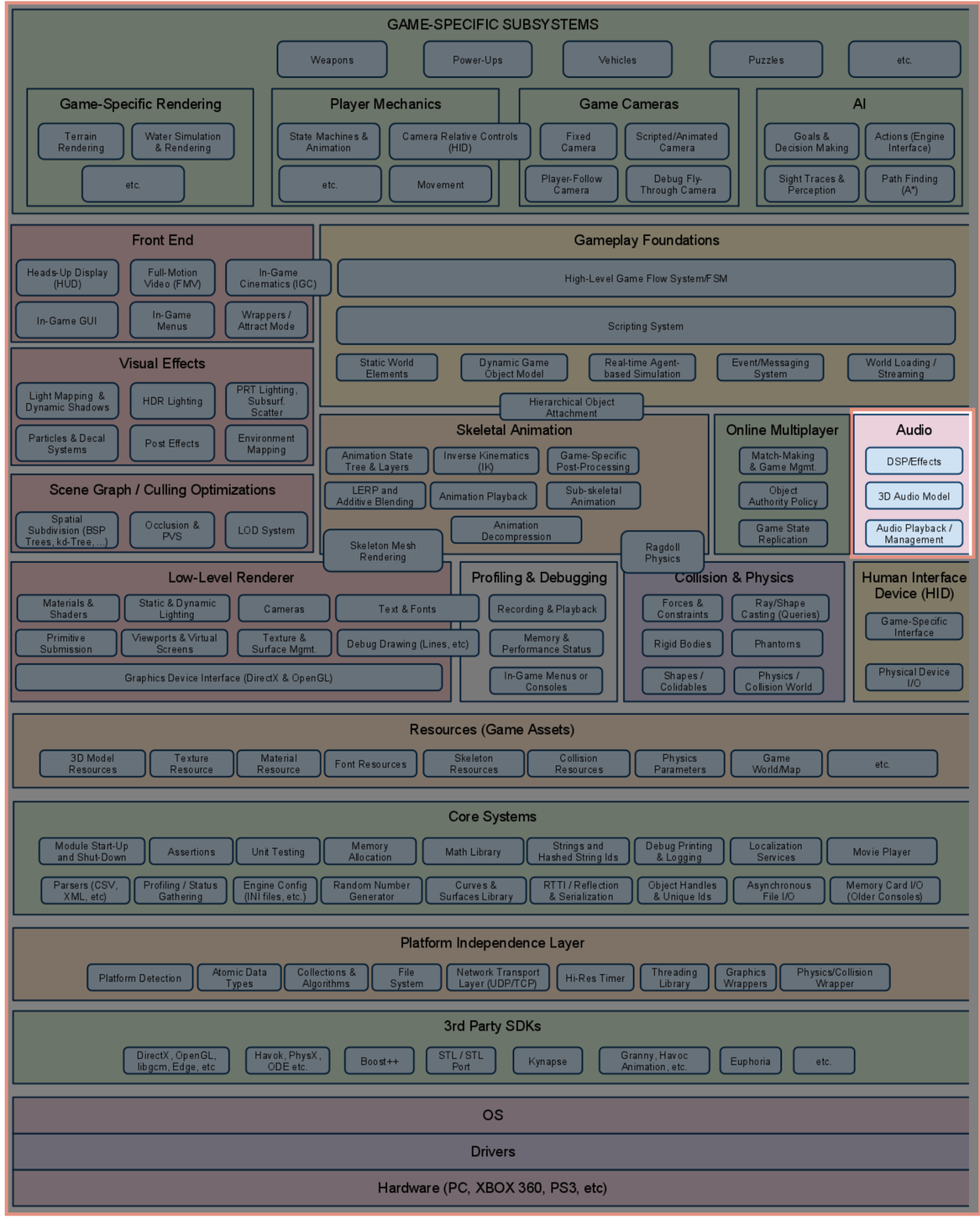
Human Interface Devices

- Process user input from HID:
  - keyboard, mouse, joypad, specialized game controllers
- process raw data:
  - dead zone around center position of joypad stick
  - debounce button presses
  - interpret and smooth signals from accelerometer
  - allow for user customized mappings
  - detect chords, sequences and gestures



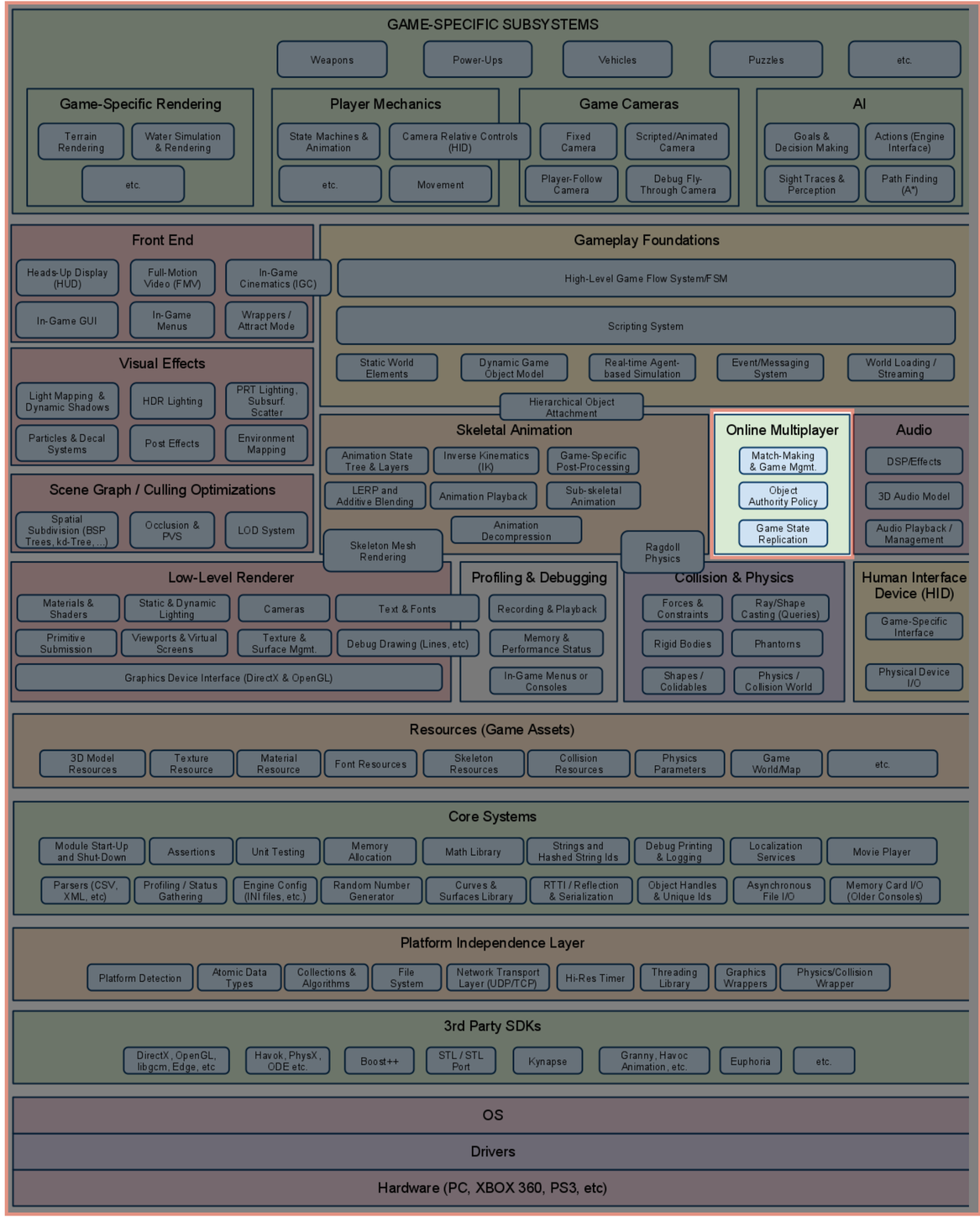
Audio

- Just as important as rendering and physics
- Essential to create immersive experiences
- Can be as simple as basic playback but often includes 3D spatialisation and DSP/Effects
- Examples of Audio engines: X3DAudio, SoundR!ot, Scream



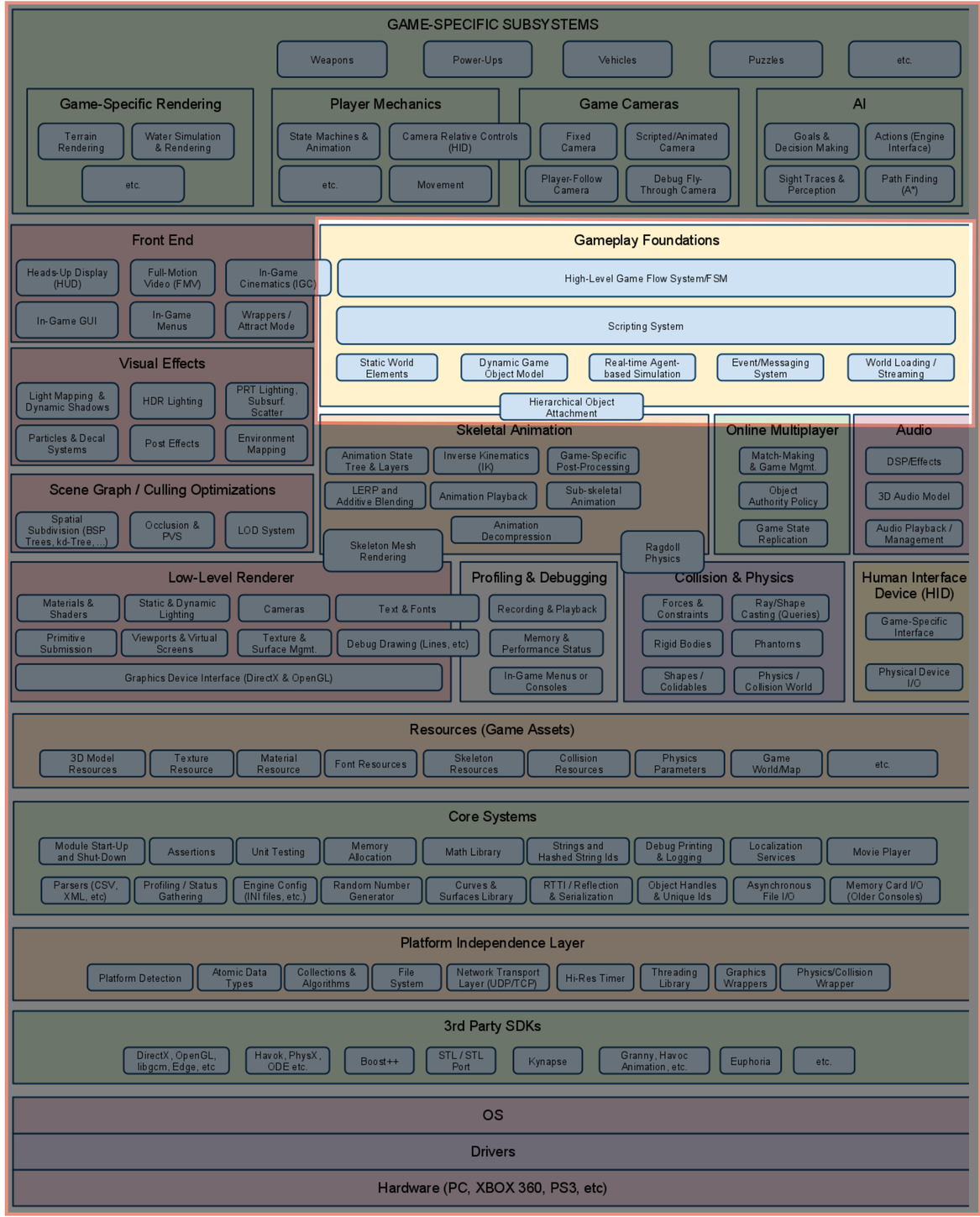
Online Multiplayer/ Networking

- Allow for multiple human players in the same virtual world
- 4 flavour:
  - Single-screen multiplayer
  - Split-screen multiplayer
  - Networked multiplayer - Each machine hosts one player
  - Massively multiplayer online games (MMOG) - A battery of central servers host a common and persistent game world.
- Easy to change a multiplayer game into a single player, harder the other way around.



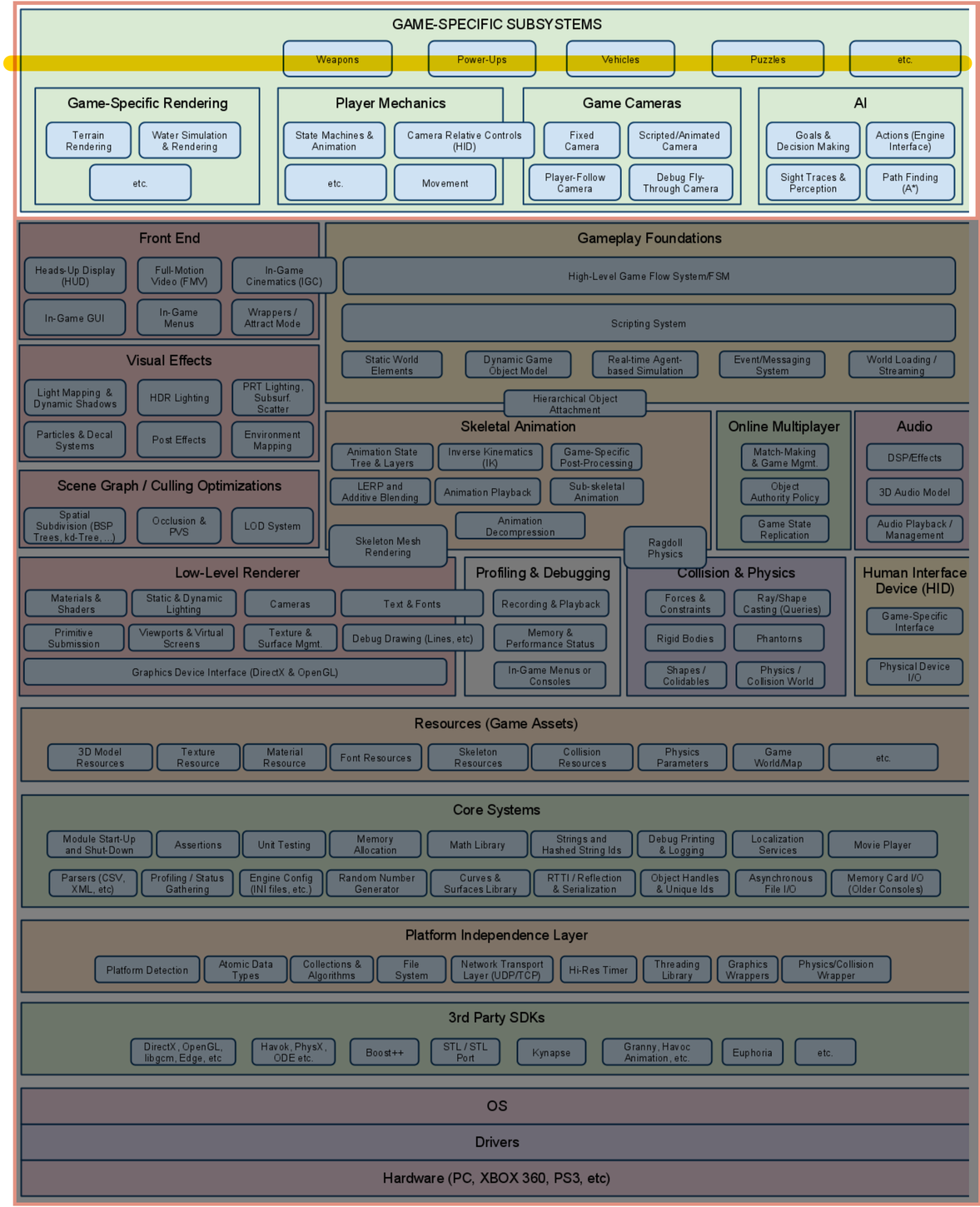
Gameplay Foundation Systems

- Rules of the game world/character abilities,…
- Implemented in native or scripting language
- Includes:
  - Game world and object models for static background, dynamic rigid bodies, PC and NPC, weapons, projectiles, vehicles, lights, cameras,…
  - Event system for inter object communication
  - Scripting system for easier and more rapid development of game rules
  - AI foundations



Game Specific Subsystems

- Everything that is required by the game but not included in the game engine…



Further readings and resources

- Cap. 1 Game Engine Architecture - Jason Gregory (adopted book)
- http://www.gameenginebook.com/index.html