

Special Topics in A4: Video Game Graphics

The following slides have been modified to remove computer architecture topics.

For the full lecture, see the Visual Computing System Lecture on Video Game Architecture:

http://graphics.cs.cmu.edu/courses/15473/f25/assets/lectures/VCS_Lecture_21.pdf

- Counting The Bits
- In With The 3rd Dimension
- State Of The Art

What is the earliest game you can think of?

Magnavox Odyssey (1972)



- 28 games for the console
 - The most notable being pong
- Two wired rectangular controllers
- Displayed three square dots and one line of varying height on the screen
 - **Q: Why the limit on dots?**
- Advertised as an electronic at-home media device
 - Before the term “video game” was coined

ATARI 2600 (1977)

- Revolutionary joystick controls
 - Putting the feel of an arcade in your home
- 30 million units sold across its lifetime
- By the end of its primary lifecycle (1983) games were more than four times the storage size of the launch games



E.T.: The Extra-Terrestrial

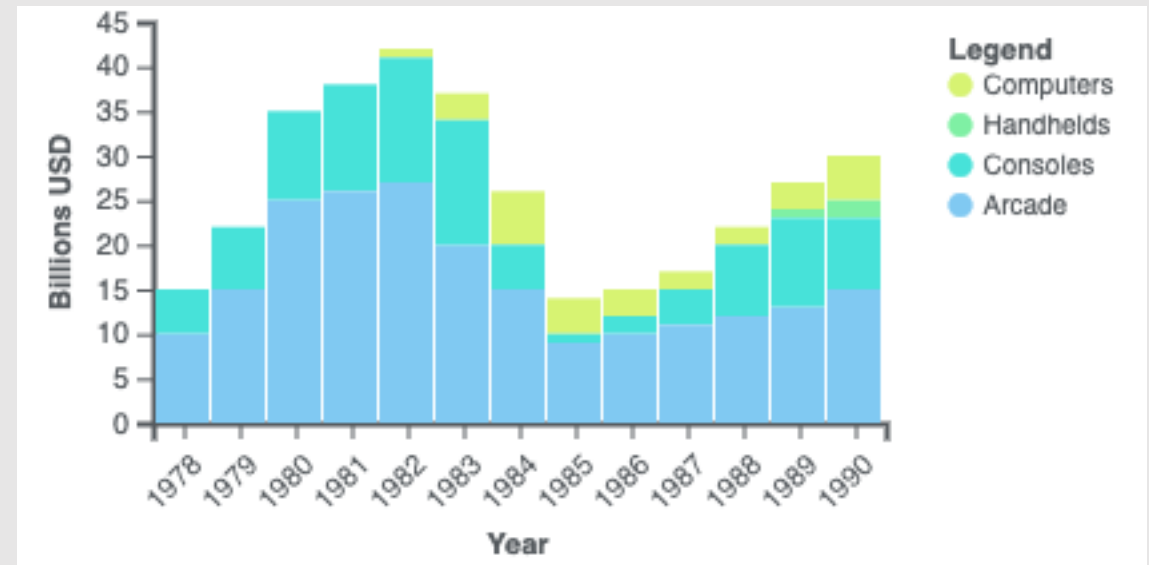


Unsold cartridges secretly buried in a landfill in New Mexico

- Atari buys rights to E.T. for several million dollars
 - Howard Warshaw was given 5 weeks to develop a game based off the hit ET franchise
- 5 million copies made
 - Only 1 million sold
- Numerous bugs arose due to a tight schedule
 - Historically regarded as one of the worst, yet most influential, video games of all time

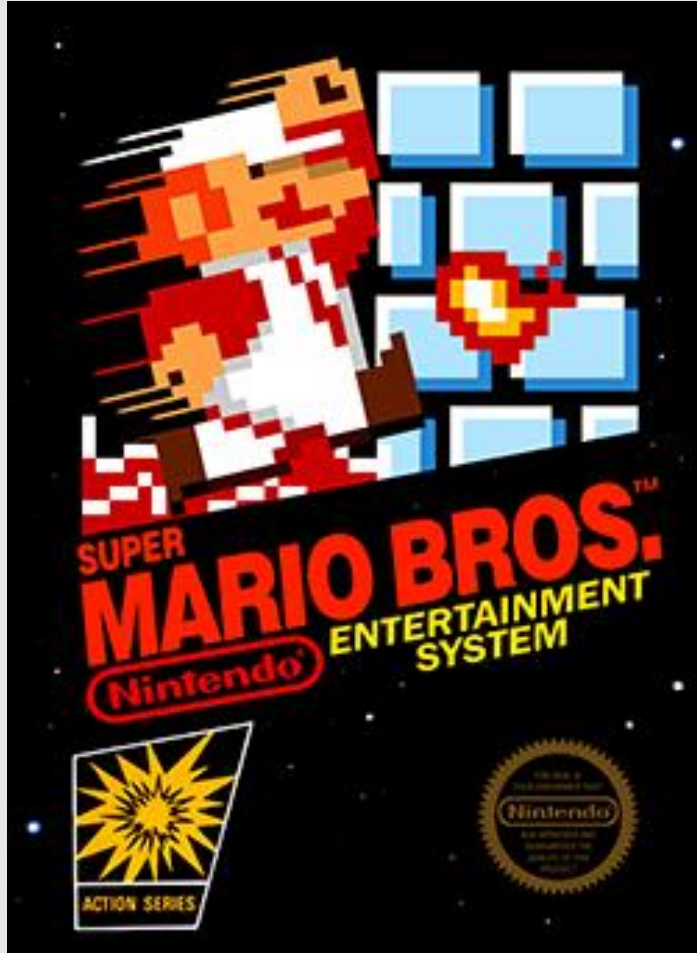
Video Game Crash of 1983

- Video games had a sharp decline following the production of ET: Extra Terrestrial
 - Lost consumer trust in video games
 - Customers returning consoles and games
- Atari cuts their workforce from 10K to 2K in a few months after ET's release
- Nintendo (a card maker) enters the scene around this period
 - Advertises their console as a “game”, steering away from the bad publicity of video games



Wikipedia

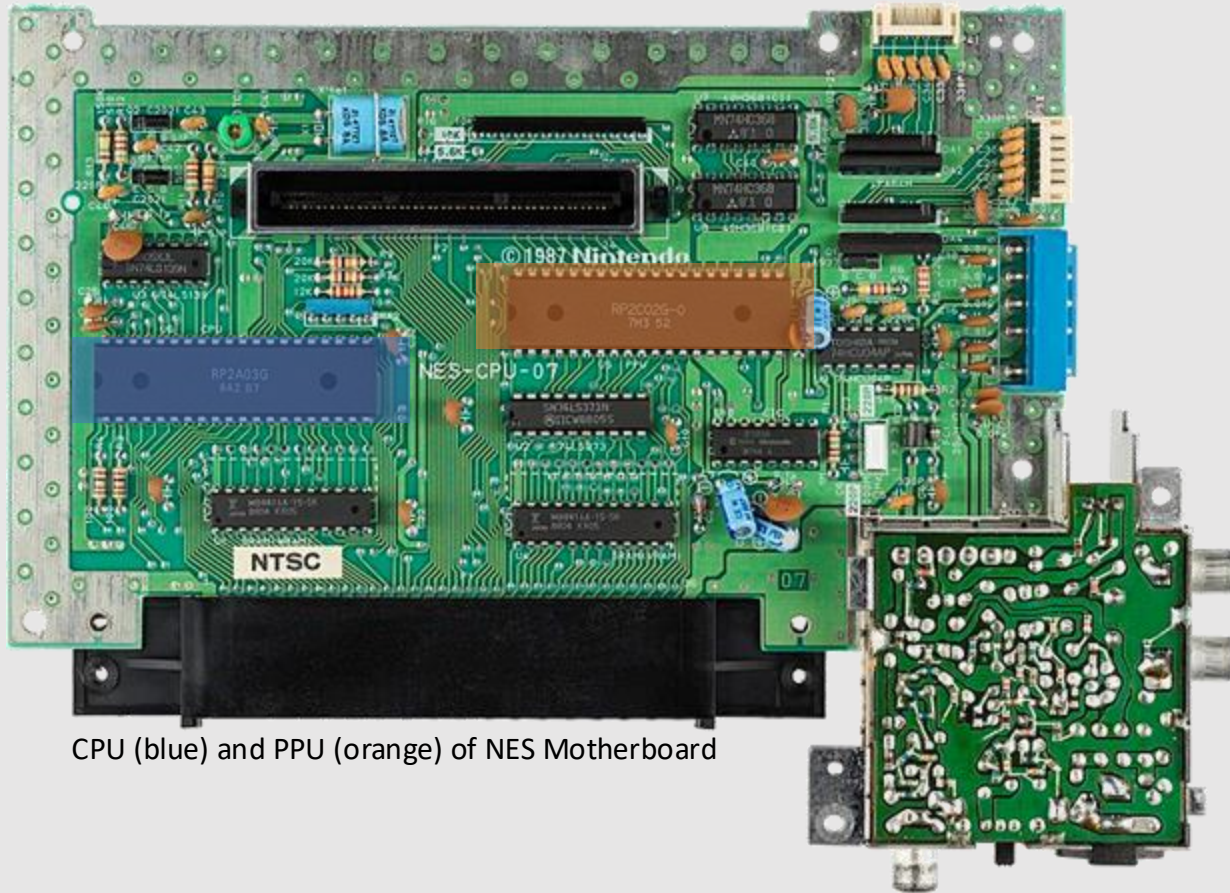
Reviving The Video Game Market



- 40.24 million copies of the original NES release have been sold worldwide
 - 29 million copies sold in North America
- All-time best-selling game for more than 20 years
 - Wii Sports stole this title
 - As of 2022, 6th highest selling video game
 - 1st highest selling video game franchise

Rank ↕	Title ↕	Sales ↕	Platform(s) ↕	Initial release date ↕	Developer(s) ^[a] ↕
1	Minecraft	238,000,000 ^[b]	Multi-platform ^[c]	November 18, 2011 ^[d]	Mojang Studios
2	Grand Theft Auto V	155,000,000	Multi-platform	September 17, 2013	Rockstar North
3	Tetris (EA)	100,000,000	Mobile	September 12, 2006	EA Mobile
4	Wii Sports	82,900,000	Wii	November 19, 2006	Nintendo EAD
5	PUBG: Battlegrounds	75,000,000	Multi-platform	December 20, 2017	PUBG Corporation
6	Super Mario Bros.	58,000,000	Multi-platform ^[e]	September 13, 1985	Nintendo
7	Mario Kart 8 / Deluxe	51,810,000	Wii U / Switch	May 29, 2014	Nintendo EAD
8	Pokémon Red / Green / Blue / Yellow	47,520,000	Game Boy / Color	February 27, 1996	Game Freak
9	Wii Fit / Plus	43,800,000	Wii	December 1, 2007	Nintendo EAD
10	Tetris (Nintendo)	43,000,000	Game Boy / NES	June 14, 1989	Nintendo R&D1

Nintendo Entertainment System (1983)



CPU (blue) and PPU (orange) of NES Motherboard



- 256x240 resolution
 - NTSC rather than RGB values
 - Common color scheme for television broadcasting at the time

Picture Processing Unit (PPU)

- 2 KB of video RAM
 - Stores the positions, colors, and tile indices of up to 64 sprites on the screen
 - Allows selection of background and sprite colors
- Tiles 16 bytes in length
 - Represents an 8x8 region on screen

Source pattern table entries

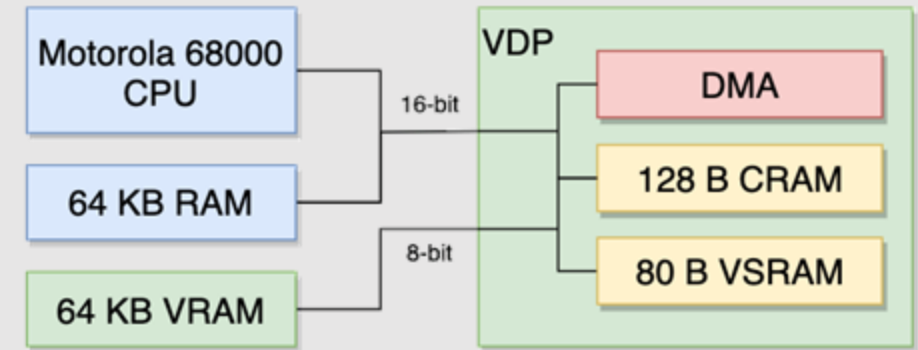
0x00 = 00000000	
0x00 = 00000000	
0x00 = 00000000	
0x00 = 00000000	
0x00 = 00000000	
0x00 = 00000000	
0x7E = 01111110	
0x3C = 00111100	
0x3C = 00111100	
0x7E = 01111110	
0x7E = 01111110	
0xFF = 11111111	
0xFF = 11111111	
0xFF = 11111111	
0x42 = 01000010	
0x00 = 00000000	

Composite result

Row 1 = 00222200	
Row 2 = 02222220	
Row 3 = 02222220	
Row 4 = 22222222	
Row 5 = 22222222	
Row 6 = 22222222	
Row 7 = 03111130	
Row 8 = 00111100	
Row 1 = 00 00 10 10 10 10 00 00	
Row 2 = 00 10 10 10 10 10 10 00	
Row 3 = 00 10 10 10 10 10 10 00	
Row 4 = 10 10 10 10 10 10 10 10	
Row 5 = 10 10 10 10 10 10 10 10	
Row 6 = 10 10 10 10 10 10 10 10	
Row 7 = 00 11 01 01 01 01 11 00	
Row 8 = 00 00 01 01 01 01 00 00	

Sega Genesis (1988)

- 512 possible colors
 - 61 colors at once
- Backwards compatible with the Sega Master System
- Vertical Scroll RAM (VSRAM)
- Color RAM (CRAM)



Rodrigo Copetti



Sonic The Hedgehog (1991)



- Development began in 1990 when Sega ordered its developers to create a game featuring a mascot for the company
- Wanted the playable character to move fast
 - Problems such as flickering, slow frame rates, and shaky animation became apparent for Genesis
- 24 million copies sold worldwide across all platforms
 - America's best-selling video game for several months in 1991, outselling Super Mario
 - Best-selling home video game of 1991

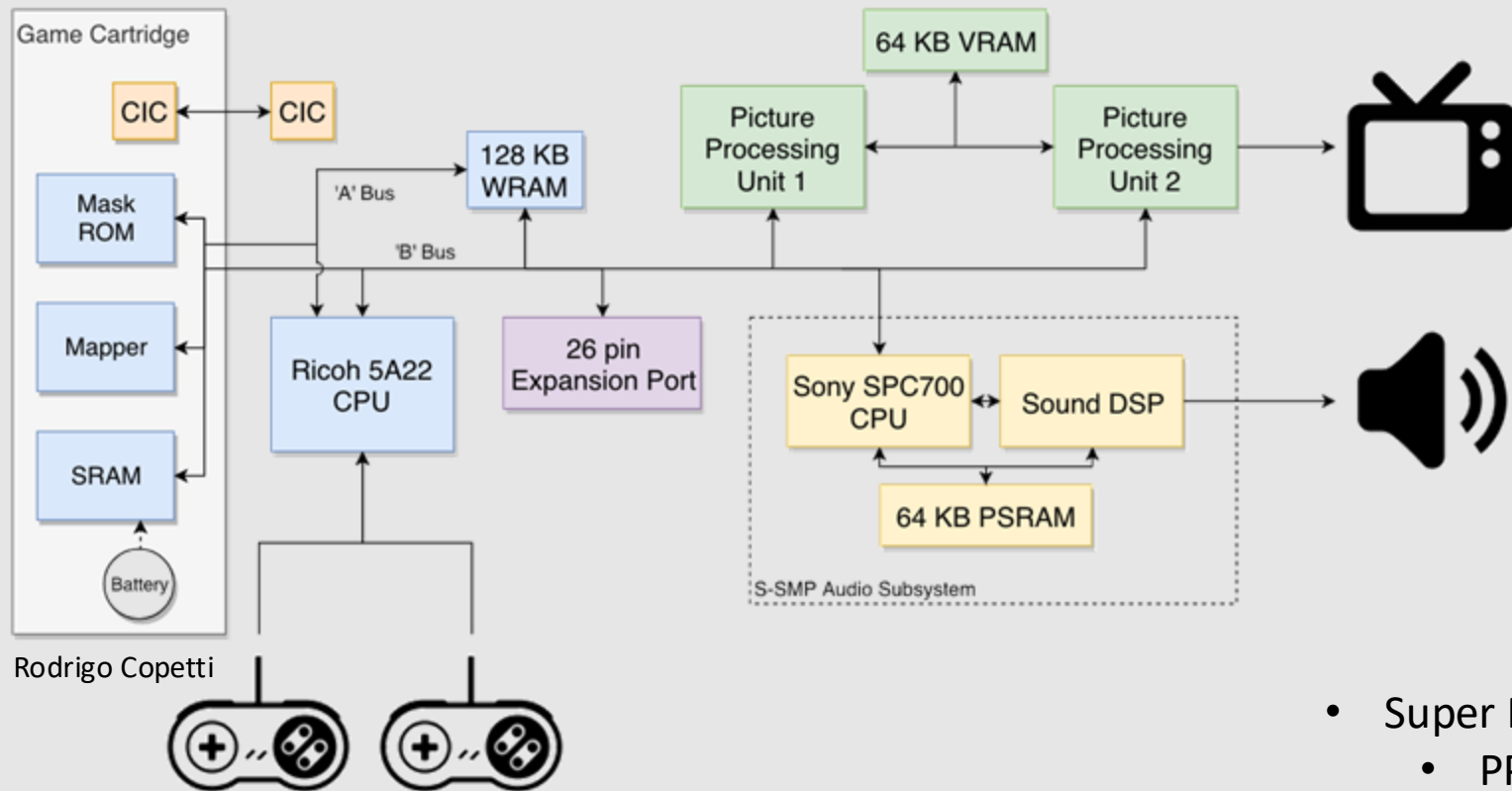
Super Nintendo Entertainment System (1990)

- Nintendo releases their next generation NES
 - Sales and IPs were so good from previous generation that they knew SNES would be a success
- Nintendo re-establishes them as the king of the 16-bit era



Super Mario Kart (1992) Nintendo

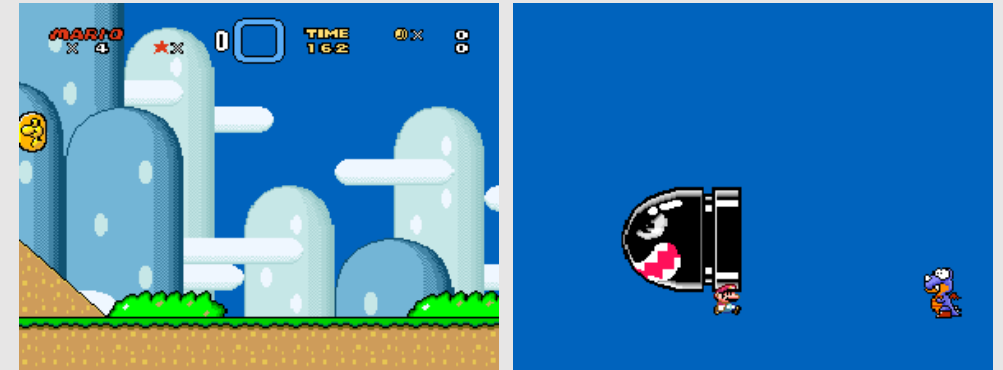
Super Nintendo Entertainment System (1990)



- Super PPU: 2 Picture Processing Units (PPU)
 - PPU 1: Renders graphics
 - PPU 2: Provides post-processing effects

Super Nintendo Entertainment System (1990)

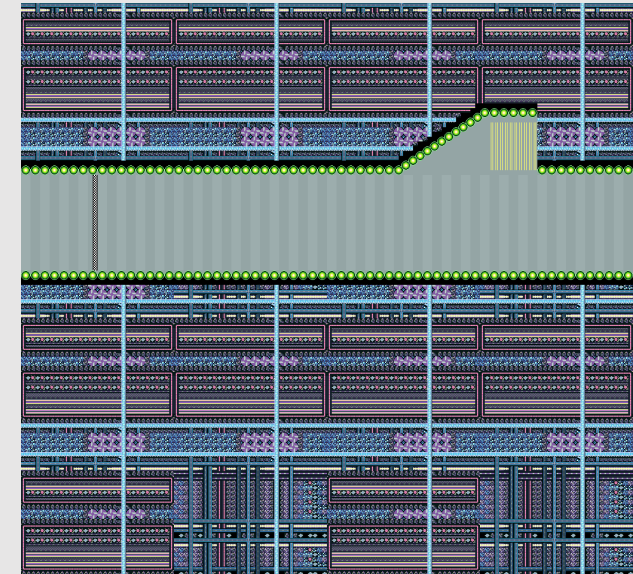
- **Mode 0:** 4 layers with 4 colors each
- **Mode 1:** 2 layers with 16 colors each + 1 layer with 4 colors.
- **Mode 2:** 2 layers with 16 colors each
 - Extra effect: Layers can have each of its columns scrolled
- **Mode 3:** 1 Background layer with 128 colors + 1 Background with 16 colors
 - Colors can be set as RGB values instead of using CGRAM references
- **Mode 4:** Mode 2 and 3 combined
 - Column scroll + RGB color mapping
- **Mode 5:** 1 layer with 16 colors + 1 layer with 4 colors
 - Useful for multiplayer
- **Mode 6:** Combination of Mode 2 and 5
 - Column scroll + High resolution



Super Mario World (1990) Nintendo

Mode 7

- Allows the following affine transformations on the background layer:
 - Translation
 - Scaling
 - Rotation
 - Reflection
 - Shearing
- Rotation matrix requires sin/cos
 - Expensive to CPU, even with fixed-point math
 - Ricoh CPU include multiply/divide registers
 - Helps offload workloads



F-Zero (1990) Nintendo

- ~~Counting The Bits~~

- In With The 3rd Dimension

- State Of The Art

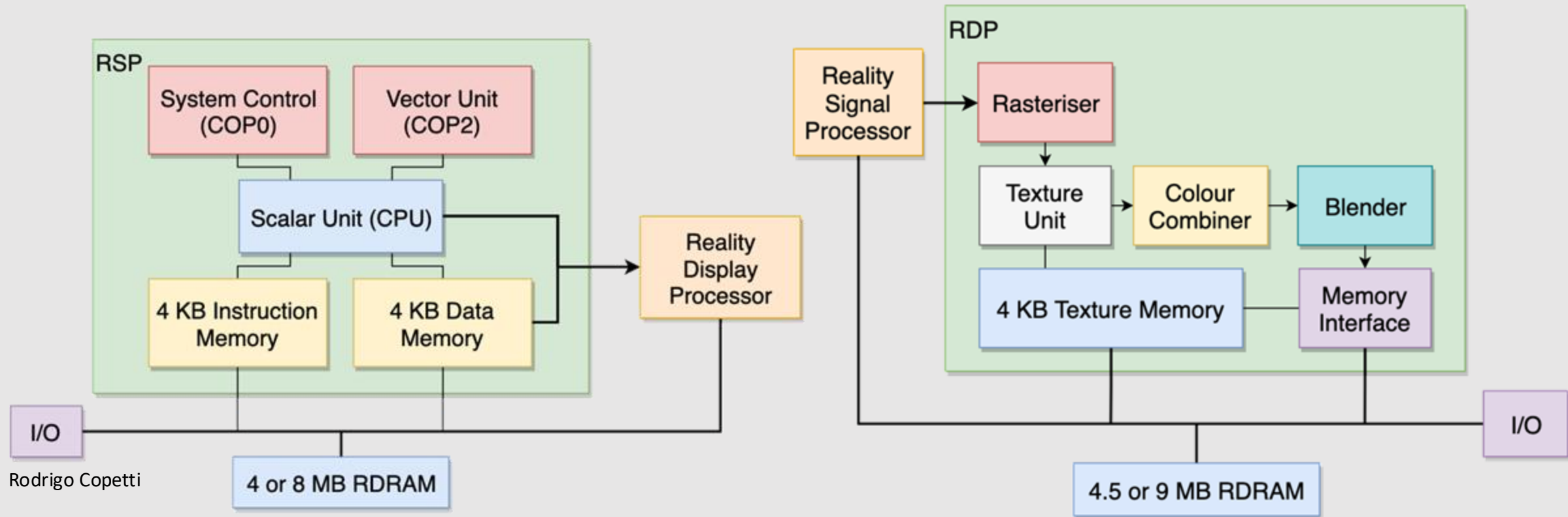
Nintendo 64 (1996)



- 64-bit processor
 - Games generally used faster and more compact 32-bit data-operations
- 4 Mb unified memory subsystem
 - First of its kind
 - Shared by CPU, audio, and video



Nintendo 64 (1996)



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- **Idea:** GPU shouldn't be just for rasterization
- Use GPU for math computations
 - compute shader
- Reality Signal Processor (RSP): math
- Reality Display Processor (RDP): rasterization

Nintendo 64 (1996)



Super Mario 64 (1996) Nintendo

Vertex Shader



Pixel Shader

- RDP allocates hardware-based Z-Buffer in memory
 - Programmers do not need software-based polygon sorting methods which drain a lot of CPU resources

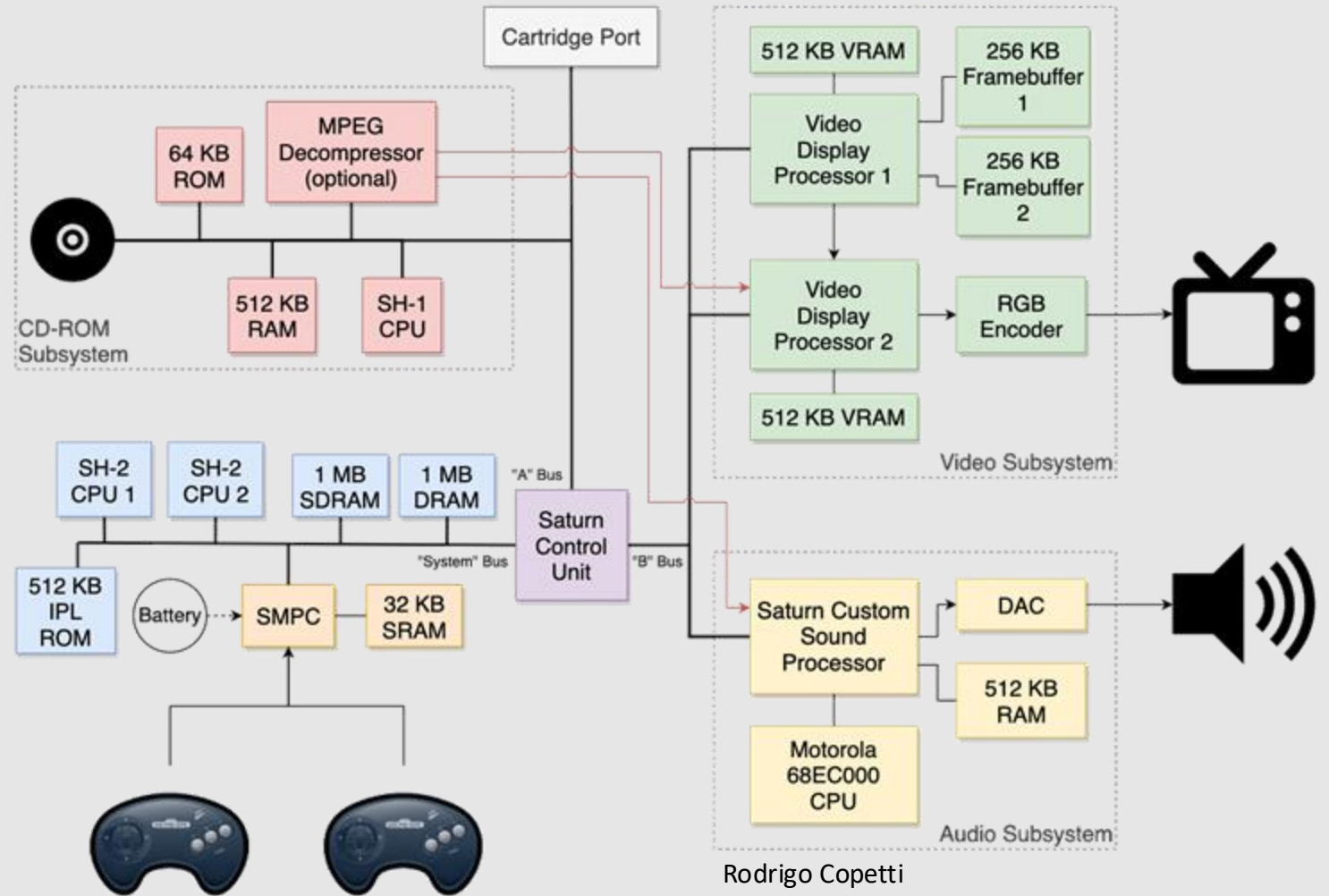
Sega Saturn (1994)



- 8 processors
 - 2 Hitachi SH-2 Microprocessors
 - 2 audio processors
 - 2 video display processors
 - VDP1: handles sprites and polygons
 - VDP2: handles backgrounds
 - CD-ROM drive controlled by a dedicated Hitachi SH-1 processor
- More cores == harder to program
 - Both CPUs shared the same bus and were unable to access system memory at the same time

Sega Saturn (1994)

- CPU incorporates vector operations to keep up with GPU parallelism
- New graphics features
 - Flat and Gouraud shading
 - Anti-aliasing
 - Clipping
 - Transparency



Sega Saturn (1994)



- No Sonic games during this generation
 - Sonic-Xtreme planned first 3D game
 - Canceled due to technical limitations
 - Led to poor Saturn sales
 - Unlike Nintendo with multiple IPs, Sega only had one:
 - Mario
 - Donkey Kong
 - Legend of Zelda
- Sega CEO Hayao Nakayama resigned as president due to Saturn's failure

SNES CD-ROM

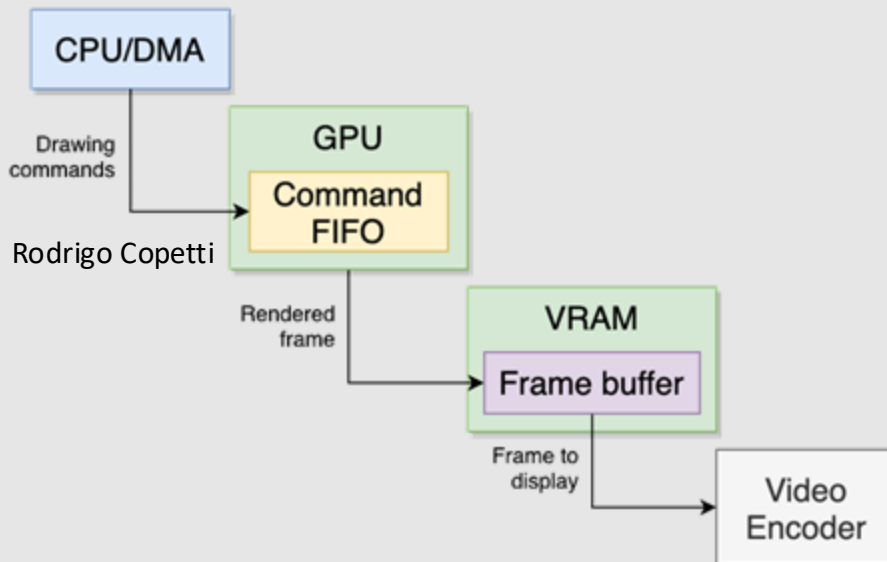


- Sony had been working to produce games for Nintendo consoles
- SNES used cartridge-based games
 - Sony wanted them to switch from ROM cartridges to CD-ROM disks
 - Faster production
 - Cheaper costs per disk
- A CD-ROM extension was planned, but after disputes, was never released
 - Under their agreement, Sony would develop and retain control over the Super Disc format, with Nintendo thus effectively ceding a large amount of control of software licensing to Sony
- Sony parts ways to create their own big thing...

A New Entry In The Playing Field



Sony Playstation (1994)



- Geometry Transformation Engine (GTE)
 - Matrix/vector multiplication and addition
 - Perspective transformation
 - Depth Cueing
 - Z/depth average
- GPU chip draws 2D polygons and apply shading and textures to them
 - GTE focuses on 3D transforms
 - Draw commands submitted in 2D
 - CPU manually sorts the polygons based on depth
 - Early depth test

Jittery Pixels



Final fantasy VIII (1999) Square Enix

- Rasterizer samples triangles with full pixel coverage
 - Ignores triangles with partial pixel coverage
 - Leads to sharp changes in pixels for subtle movements
 - Triangles sharing same vertices will compete for pixels, causing temporal flickering
- **Idea:** anti-aliasing
 - Present in future architectures

A Console For The Competitive



Michael Jackson Presenting Playstation at E3 (1995)

- Unlike other console libraries, Sony's library was strongly aimed at competitive, single-player gamers
 - Marketed towards teenagers
 - Kids looked up to teenagers
 - Parents bought for teenagers
- Very large library
 - Games were coded in C and could use GCC for quick debugging
 - Appealed to many developers
 - Largest third-party developer: Square Enix
 - Final Fantasy
 - Kingdom Hearts
- CD-ROM turned out to be very successful
 - Sony could produce games at 60% the cost of regular cartridge ROM compared to Nintendo

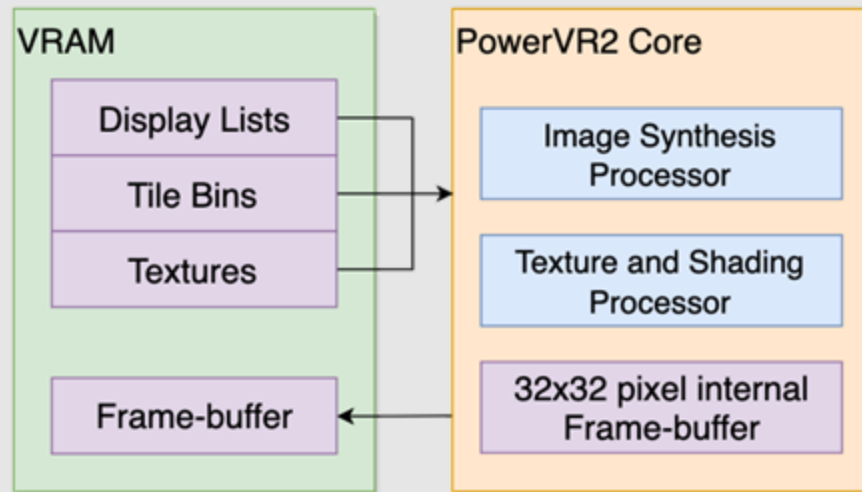
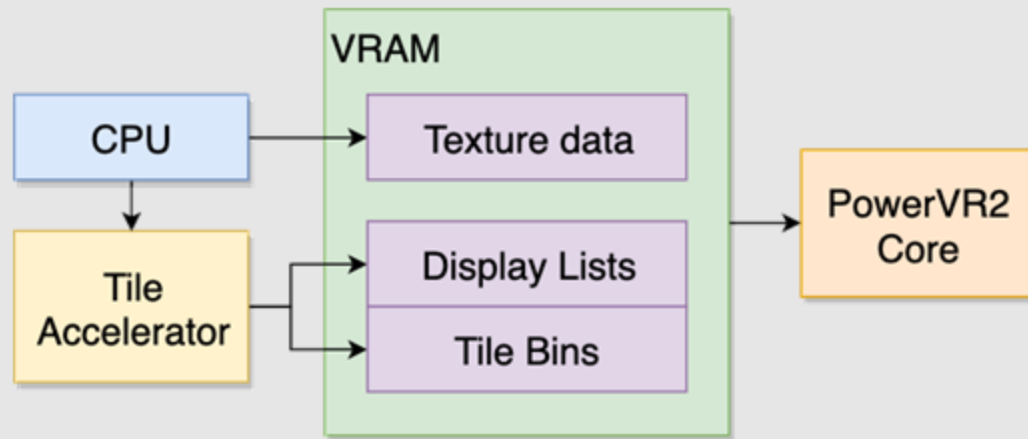
Sega Dreamcast (1998)



Sonic Adventure (1999) Sega

- High-speed geometric processing
 - 7 million raw polygons/second
 - 6 million polygons/second with textures and lighting
 - 3 million polygons/seconds in reality
 - Game logic and physics reduce peak graphic performance
- Sega's last entry in the video game console war
 - A console truly ahead of its time
 - But other consoles would quickly steal the spotlight

Sega Dreamcast (1998)



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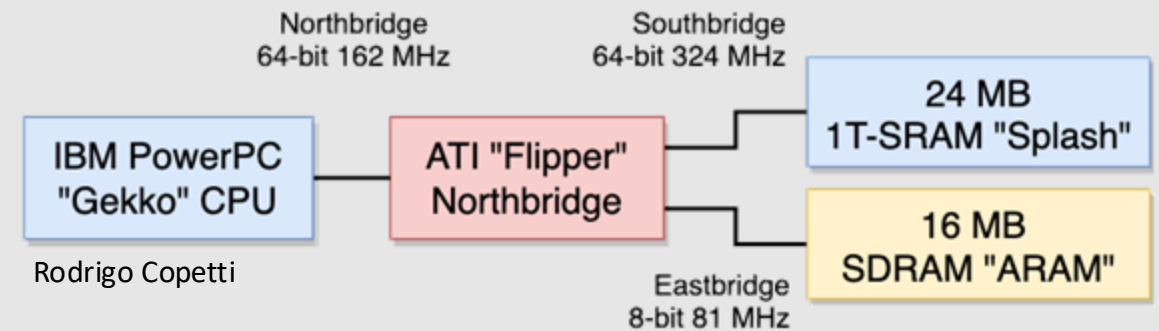
- Tile-Based Deferred Rendering (TBDR)
- Tile Accelerator (TA) partitions geometry into Tile Bins
- Image Synthesis Processor (ISP) discard blackfacing and z-culled geometry
 - Texture/Shading Processor (TSP) performs shading on surviving fragments
- TSP introduced new features:
 - Alpha blending
 - Isotropic/Anisotropic Filtering
 - Environment Mapping
 - Bump Mapping

Nintendo Gamecube (2001)

- Unified memory failed on Nintendo 64
 - Just give GPU its own fast memory
- Nintendo started using (mini) disks



Super Mario Sunshine (2002) Nintendo

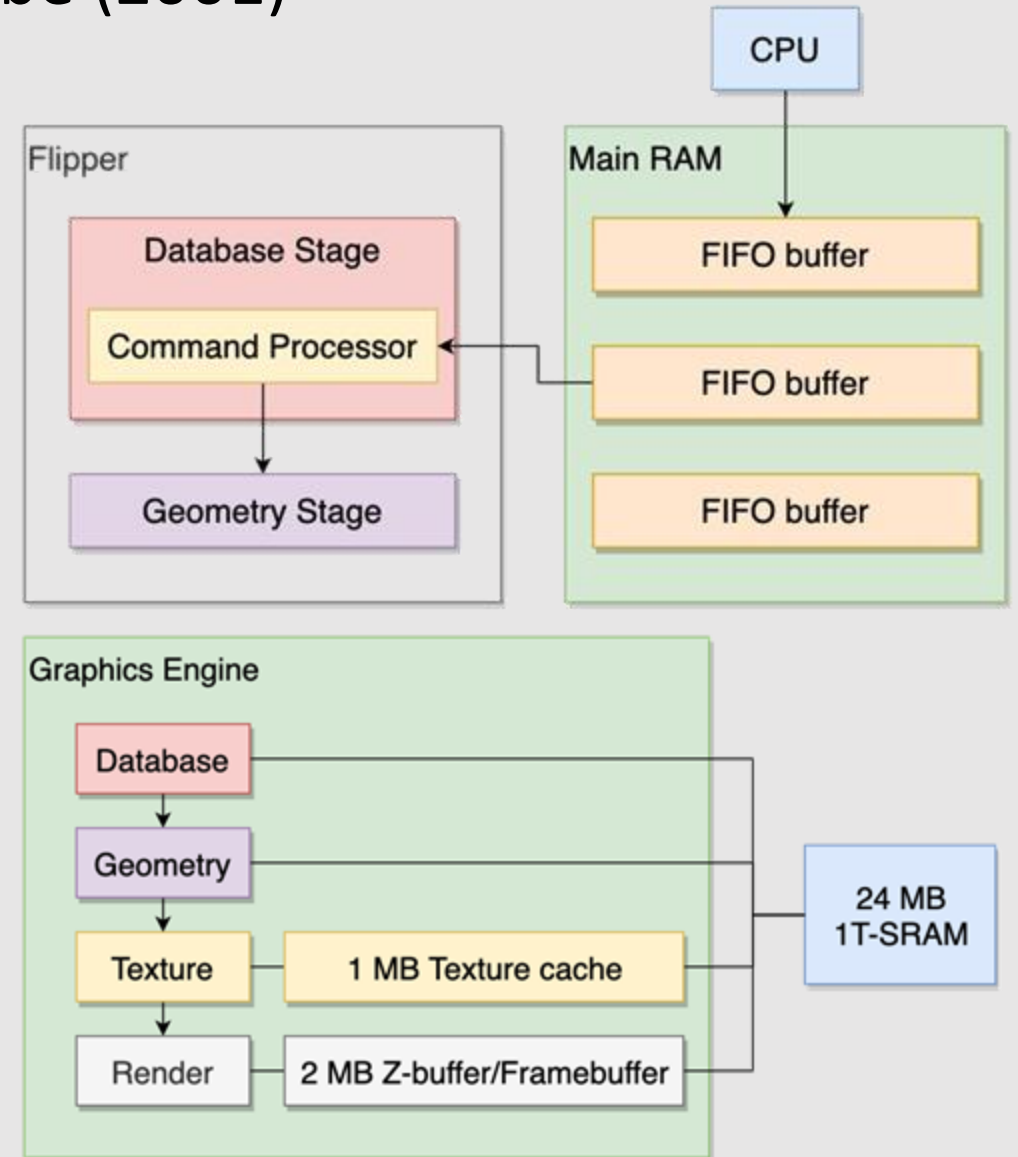


Nintendo Gamecube (2001)

- Texture Environment Unit (TEU)
 - Programmable 16-stage color blender
 - While not fully programmable like a shader, closest we got to shader
 - Fixed in the number of possible instructions/operations
 - Can finally do cel shading



The Legend of Zelda: Wind Waker (2003) Nintendo



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Do you hear that?



Sony Computer Entertainment

oh that was nothing, just the sound of the
best selling video game console of all time

The King Of Play

- More than 155 million units sold
 - Continued manufacturing until 2013
 - Longest lifetime (13 years) for any video game console
- Responsible for poor sales of Sega Dreamcast
 - Pushed Sega to leave video game console market
 - But don't worry. They're still making games, and for Sony consoles now
- Backwards compatible with PS1, the most popular console from the last generation
- Built in DVD player
 - Kids could convince parents to get the PS2 by advertising it as a home media player



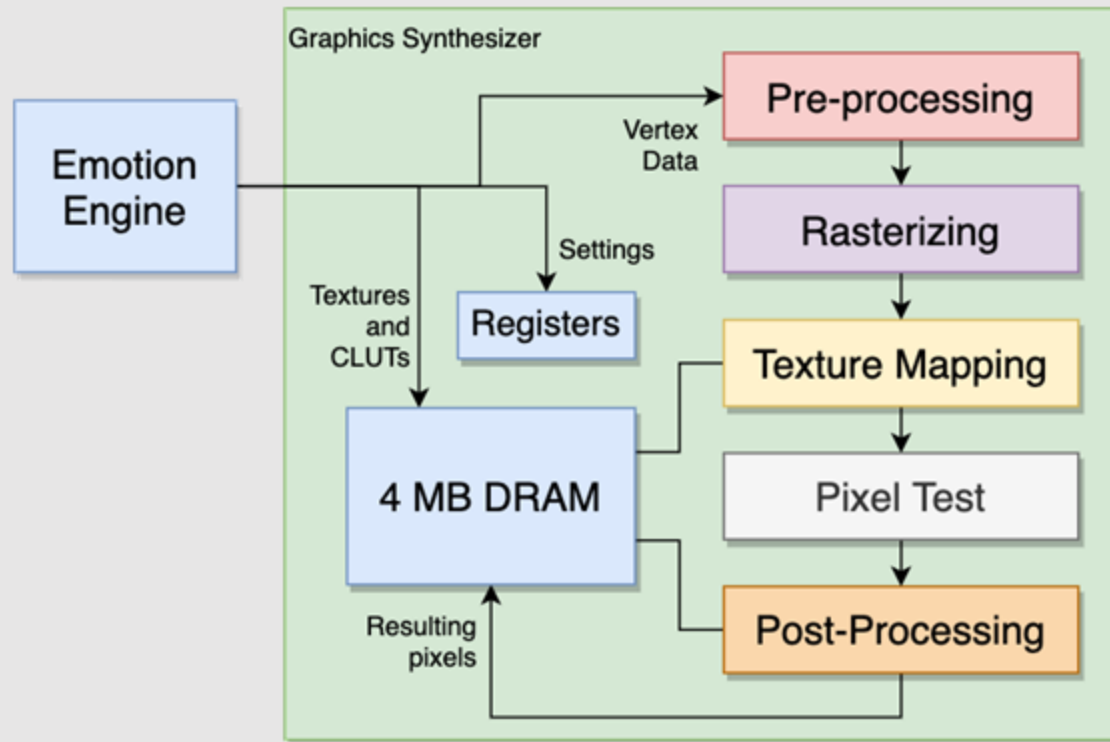
Sony Playstation 2 (2000)

- Image Processing Unit (IPU) designed for image decompression
 - Can decode an MPEG2 movie without jamming the main CPU
- Pre-rendered cutscenes could produce better graphics
 - Memory burden: cost much more to save on disk
 - **Idea:** save compressed version and decode on playback
 - Compression can be slow
 - Decompression must be fast



Kingdom Hearts (2002) Square Enix

Sony Playstation 2 (2000)



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- GPU focuses on rasterization
 - Less flexible implementation
 - VPUs do vertex shading
- Cel shading done on VPUs
 - Store colors in vertices, interpolate when shading



Sly Cooper (2002) Sony Interactive Entertainment

Microsoft DirectX

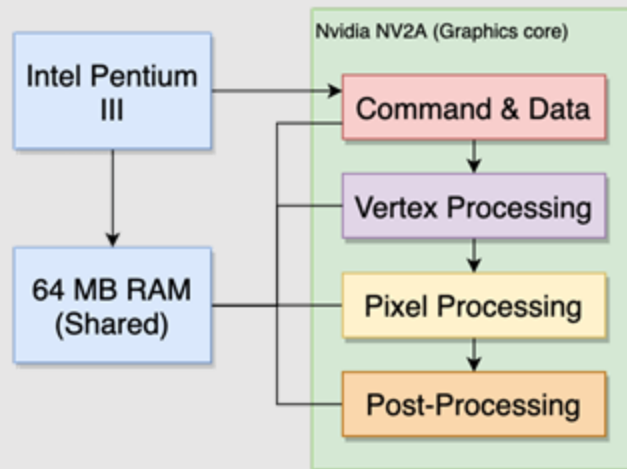


Moana (2016) Disney

- DirectX (1995) created as Microsoft's main graphics API, and a tool for Windows game development
 - But people didn't want to make games for Windows back then
- Microsoft got together a small team to work on dedicated gaming hardware supported by DirectX
 - The "DirectX Box"
 - The "Direct XBox"
 - The "Xbox"
- Somehow they got Dwayne Johnson to help reveal the product
 - What could Dwayne say, except **"You're Welcome" :)**

Microsoft Xbox (2001)

- This thing could play Halo
 - Instant success
- Pushed the boundaries of online gaming



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Halo: Combat Evolved (2001) Microsoft Game Studios

- ~~Counting The Bits~~
- ~~In With The 3rd Dimension~~
- State Of The Art

Nintendo Wii (2006)

- Nintendo president Satoru Iwata directed the company to avoid competing with Microsoft and Sony on computational graphics and power
 - Focus on a broader demographic of players through novel gameplay
- 100+ million units sold
 - Nintendo's best selling home unit
 - Their actual best selling unit was the DS, but this encompasses DS Lite and DSi as well
- Nintendo Wii was a generation behind Sony and Microsoft graphics
 - As such, games were cheaper to produce (less graphics intensive) and more affordable



Nintendo Wii (2006)

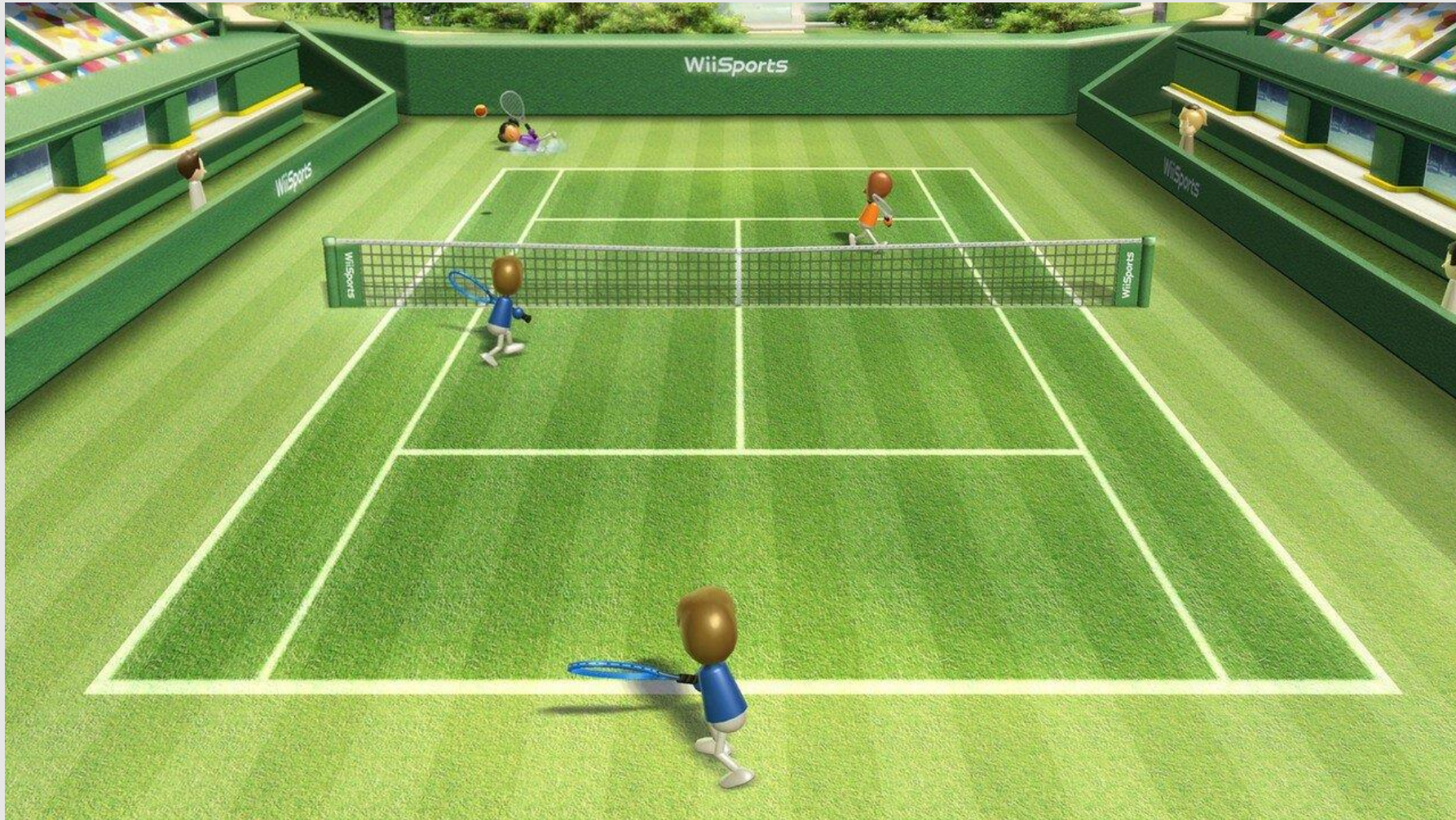


- Central CPU not much difference than GameCube CPU
 - Easier for backwards compatibility
 - Easier for GameCube developers to switch to Wii
 - Developers saw it as a 1.5x-2x faster GameCube



Super Mario Galaxy (2007) Nintendo

Wii Sports (2006)



- Best selling single-platform game of all time
 - 4th best selling video game of all time

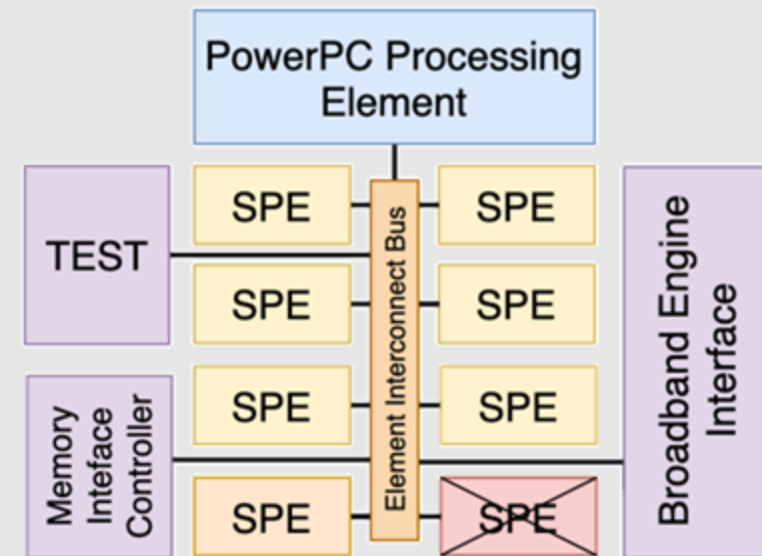
First-Party Wii Games



- Nintendo establishing themselves as a creative video game marketplace
 - Trend would continue into their next generations of consoles

Sony Playstation 3 (2006)

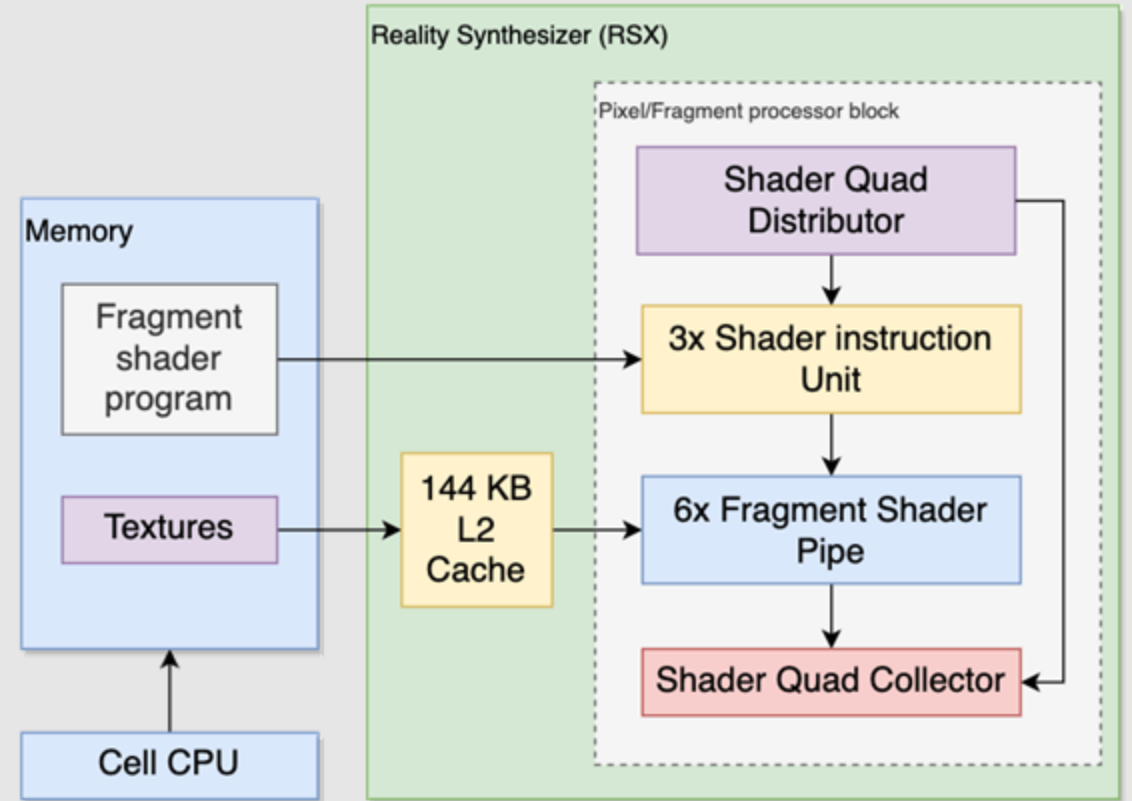
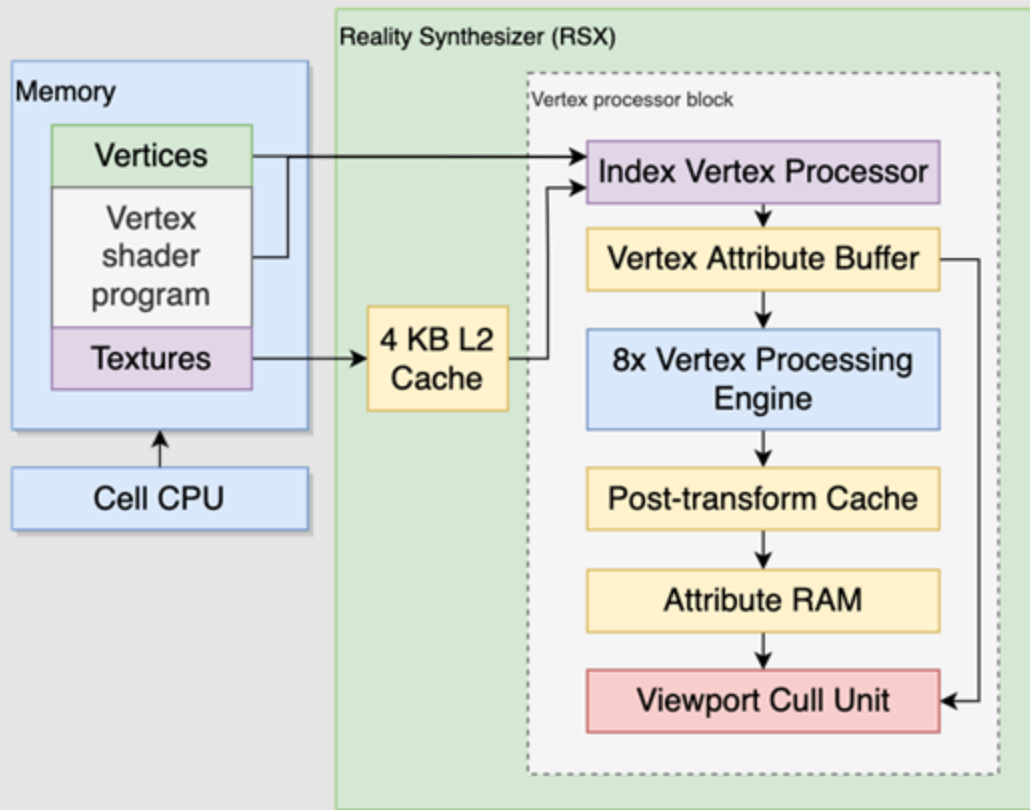
- A supercomputer made to play video games
- Powered by a large homogeneous cell of cores
- Power Processing Element (PPE) delegates tasks
- Synergistic Processing Elements (SPE) compute tasks
 - **Problem:** Running single-core programs on the PPE results in 60% performance reduction
 - Need to start writing parallel code



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Sony Playstation 3 (2006)

- Nvidia Reality Synthesizer X (RSX) card
 - 8x Vertex Shaders
 - 6x Fragment Shaders



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Microsoft Xbox 360 (2005)



- Multi core, multi-threaded CPU
 - Need to write parallel code for this machine too
- Unified shading architecture for vertex and fragment shader
 - No dedicated units for either shader. Units could switch between shader stages at will



Sonic The Hedgehog (2006) SEGA

Microsoft Xbox One (2013)

- AMD Jaguar Accelerated Processing Unit (APU)
 - CPU + GPU on same chip
- Supports 1080p displays
 - Xbox One S (2016) supports 4K HRD displays
- Do you want a Kinect? No? Too bad
 - +\$100 more than PS4



Gran Theft Auto V (2013) Rockstar Games

Sony Playstation 4 (2013)



- AMD Jaguar Accelerated Processing Unit (APU)
 - CPU + GPU on same chip
 - “The most powerful APU we developed to date” – AMD
 - Sorry Microsoft
- Secondary custom chips for downloading, uploading, and social gameplay
 - Dedicated video decoder
 - Not for pre-rendered cutscenes, but for social media sharing
 - Cutscenes became real-time renders
 - Graphics files always smaller than their renders
- Supports HDR
 - Later released PS4 Pro (2016) supports 4K
- 2nd best home-selling console
 - 4th best selling console

A Wii Just For U



- Iwata was impressed with capabilities of touchscreen smartphones
 - Wanted to create a controller with a touchscreen
 - Success of Nintendo DS pushed this idea further
- As always with Nintendo, strive for uniqueness in gameplay, not performance
 - Left Sony and Microsoft to fight for better graphics

Nintendo Wii U (2012)



- 6.2 inch touchscreen
 - Assistive screen to television (think DS)
 - Dedicated screen if no TV (Off TV Play)
- Asymmetric gaming: players have different content on their screen
 - Good for multiplayer games with varying roles and objectives
- 9-degree motion detection:
 - 3-axis accelerometer
 - 3-axis gyroscope
 - 3-axis magnetometer
- Infrared array to replicate Wii Sensor Bar
 - Needed to have the same features as a Wii mote to be backwards compatible

Can't Spell 'Failure' Without U

- Low sales, primarily credited to a weak lineup of launch games
 - Focused too much on playing Wii games, which the Wii was already fine at
 - Bulky controller
- Companies like Electronic Arts and Ubisoft pull out from developing Wii U games after the first year
- 13.56 million sales
 - Nintendo's lowest selling device
- Nintendo president Satoru Iwata at the time took a 50% pay cut in order to take blame for failure of a system



Switching Things Up



- 103.54 million sales
 - Remember the Wii? This thing has been out for fewer years and already surpassed it
- **Nintendo learned from their mistakes and put to work a very good lineup of video games on release**
 - Mario Kart 8 Deluxe
 - Animal Crossing: New Horizons
 - Super Smash Bros. Ultimate
 - The Legend of Zelda: Breath of the Wild
 - Pokémon Sword and Shield
 - Super Mario Odyssey

Platform	Type	Firm	Released ^[2]	Units sold	Ref.
PlayStation 2	Home	Sony	2000	>155 million	[note 1]
Nintendo DS family	Handheld	Nintendo	2004	154.02 million	[32]
Game Boy & Game Boy Color	Handheld	Nintendo	1989, 1998	118.69 million	[32][note 2]
PlayStation 4 #	Home	Sony	2013	116.9 million	[22]
Nintendo Switch #‡	Hybrid	Nintendo	2017	103.54 million	[32]
PlayStation	Home	Sony	1994	102.49 million	[34]
Wii	Home	Nintendo	2006	101.63 million	[32]

Maybe Too Good A Lineup...

NEWS NINTENDO WII U

Zelda: Breath of the Wild on Switch is outselling the console itself

How?! Why?!

By Samit Sarkar | @SamitSarkar | Apr 27, 2017, 10:31am EDT

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Nintendo EPD/Nintendo

The Legend of Zelda: Breath of the Wild continues to be the Nintendo Switch's best-selling game, with worldwide sales of 2.76 million copies through March 31, Nintendo announced today.

14

Most Read

Wait, How Did 'Zelda: Breath of the Wild' For Switch Outsell The Switch Itself?



Paul Tassi Senior Contributor

Games

News and opinion about video games, television, movies and the internet.

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⌚ This article is more than 4 years old.

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The Legend of Zelda: Breath of the Wild NINTENDO/PAUL TASSI

GAMING NINTENDO CULTURE

Nintendo sold more copies of Zelda for Switch than actual Switch consoles

By Sam Byford | @345triangle | Apr 13, 2017, 8:34pm EDT

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It's no surprise that *The Legend of Zelda: Breath of the Wild* is the best-selling game on the Nintendo Switch, a console that just had its strongest US opening ever for the company. But managing to sell more copies than consoles that can actually play it? That's what's happened in the US, amazingly — Nintendo just [announced](#) that it sold 906,000 Switch consoles in March along with 925,000 copies of *Breath of the Wild*.

The Wii U version moved almost 460,000 units on top of that, making for total sales of over

Zelda: Breath of the Wild and Nintendo Switch sell more than 2.7 million units



Nintendo blew fans away with the latest trailer for Zelda, and the score was a big reason for that. Image Credit: Nintendo

GamesBeat Summit 2022 returns with its largest event for leaders in gaming on April 26 - 28th. Reserve your spot [here](#)!

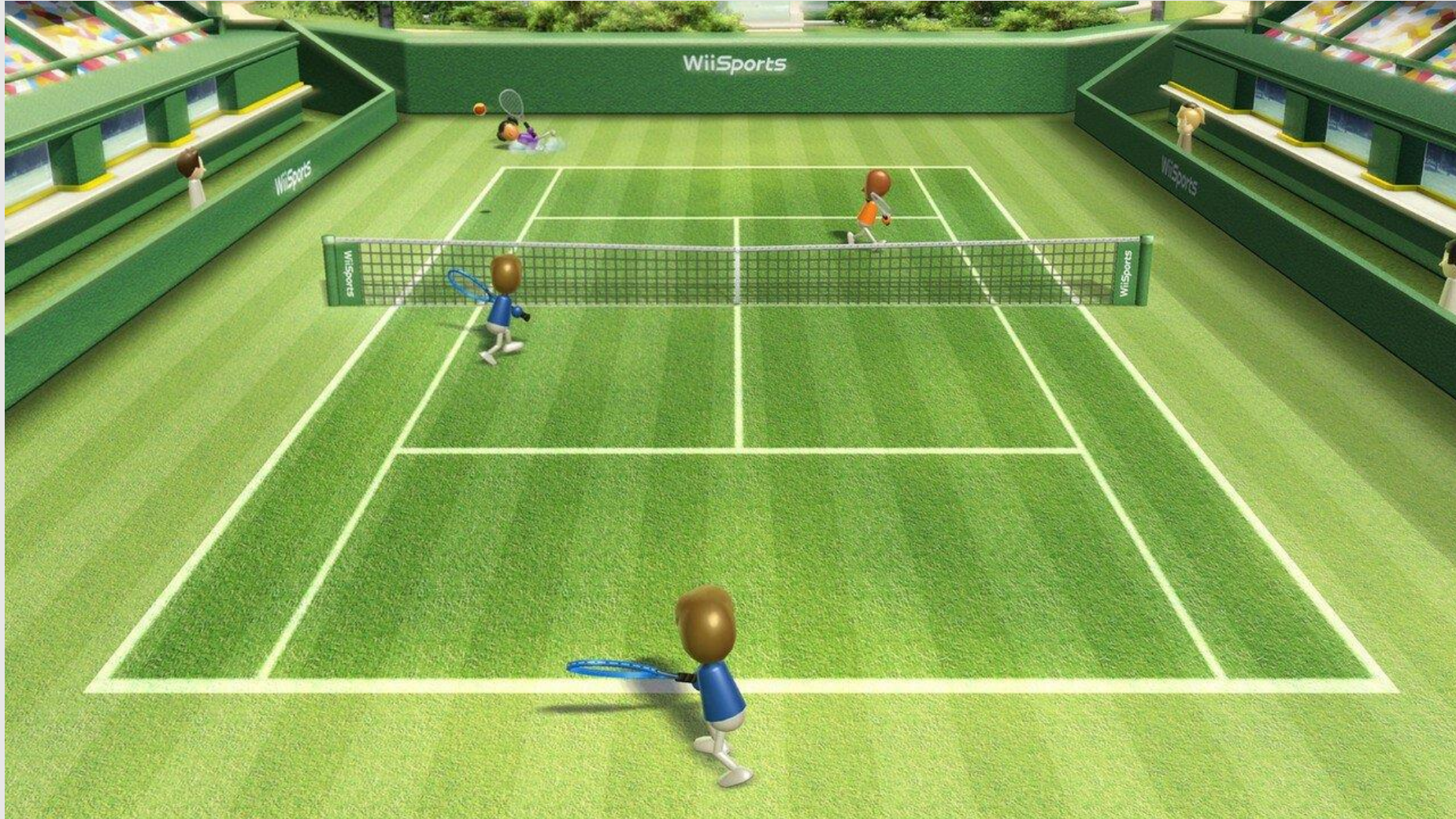
Nintendo reported tonight that it has sold more than 2.74 million units of its Nintendo Switch game console since it went on sale in March, and it has also sold more than 2.76 million copies of its flagship Switch game, *The Legend of Zelda: Breath of the Wild*.

Nintendo Switch (2017)

- "TV Mode": console in dock supports play on TV
- "Tabletop Mode": console on a table with detached joycons
- "Handheld Mode": console with joycons plugged in
- Undocked: 720p 60FPS
- Docked: 1080p 60FPS
- Dock provides nothing special
 - \$90 for a piece of plastic : /
 - **Q: Why do we get higher resolution when docked?**
 - Drawing from power outlet allows Switch to not worry about battery conservation



Wii Sports (2006)



Remember this game?

Nintendo Switch Sports (2022)



Yeah...

Microsoft Xbox Series S/X (2020)



- S for Slim
- X for Xtreme
- Supports real-time ray tracing
 - Audio ray tracing
 - Variable refresh rates
- 4x more powerful CPU than Xbox One X
- 2x more powerful GPU than Xbox One X (Series X only)
 - Series S was mainly unchanged in performance

Sony Playstation 5 (2020)

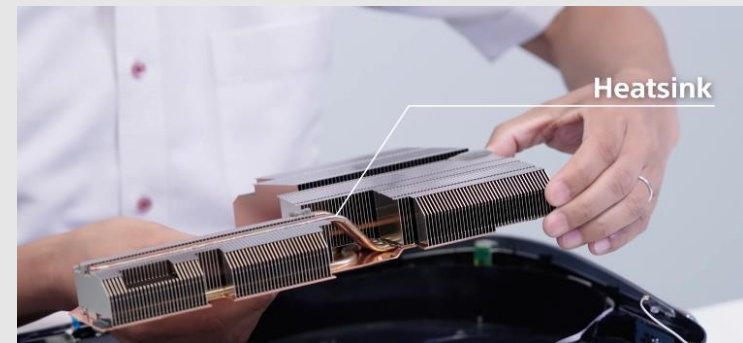
- Same CPU as Xbox S/Xs
- AMD's SmartShift technology
 - If CPU running at lower frequency, increase GPU frequency, and vice versa
- Targets 4K resolution at 60 FPS
- Hardware ray tracing support



Sony Playstation 5 (2020)



- A "Ring of RAM"
 - 8x 16 GB GDDR6 surrounds SoC
 - 448 GB/s read speeds
- SSD Storage
 - 3x 825 GB SSD chips
 - 5.5 GB/s read speeds
- Massive heatsink required to keep thermals low
 - 80% of the architecture is cooling



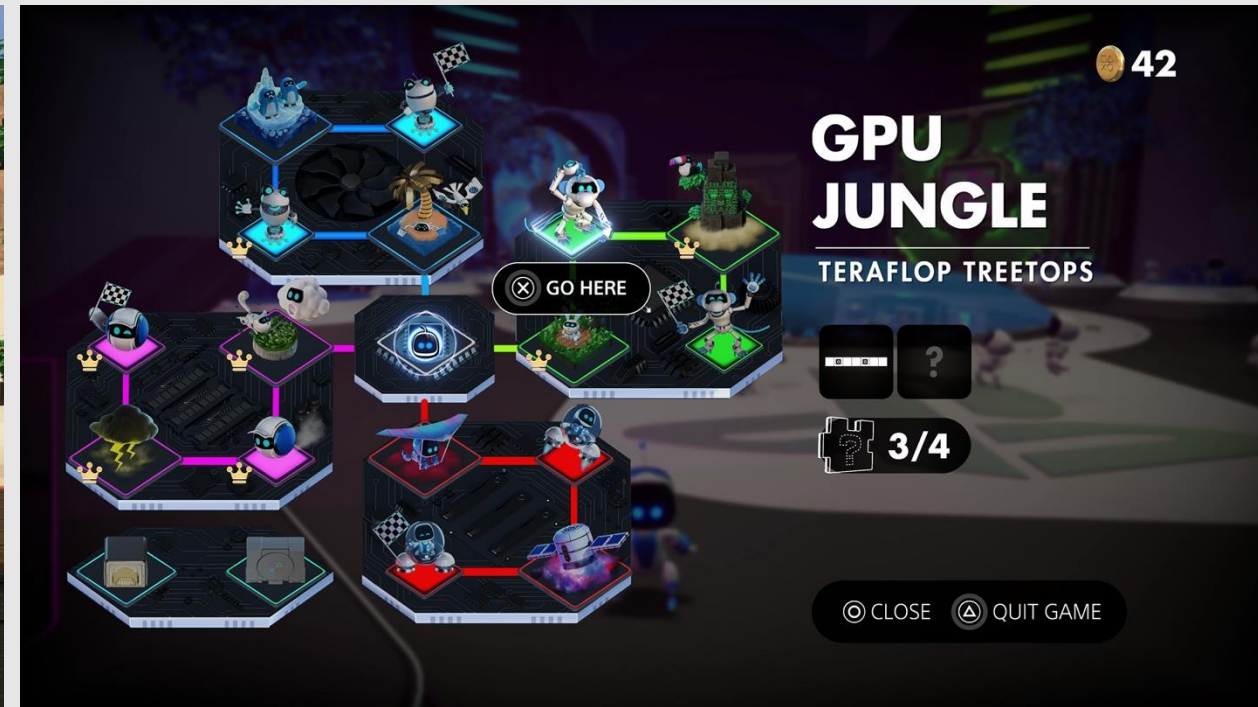
Sony Playstation 5 (2020)



Sony was nice enough to take apart the PS5 so we don't have to

A Side Note

- The PS5 Ships with a video game where you can play through the system's architecture
 - If you're lucky enough to get your hands on a PS5, I highly recommend playing it



Astro's Playroom (Sony) 2020

Astro's Playroom (2020)



- Setting Sony apart from Microsoft: **Recognizable IPs**
 - In an age of similar hardware, exclusives define the playing field

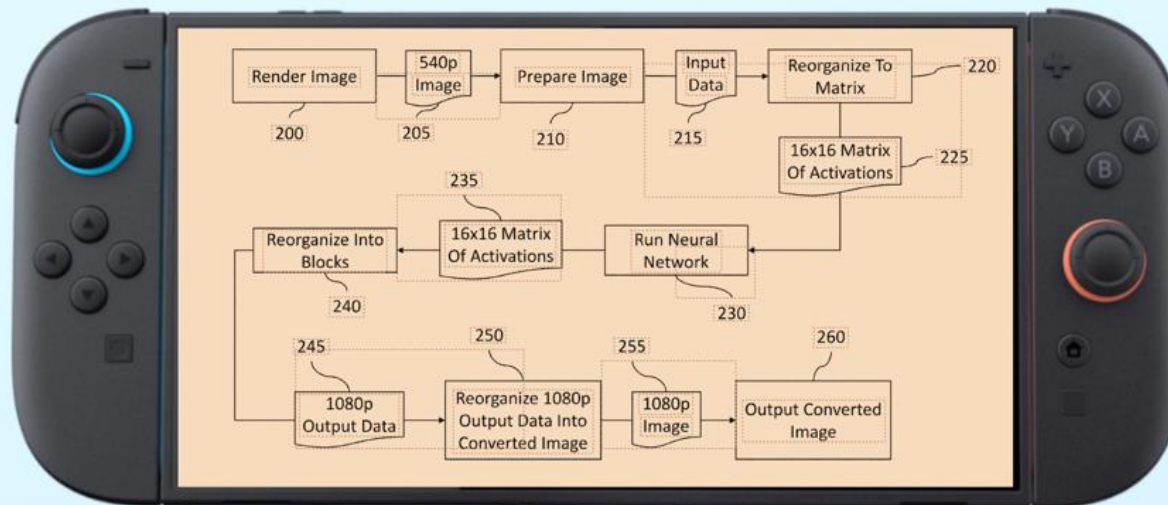
Sony Playstation 5 Pro (2024)

- Same CPU as PS5
- 1.7x more powerful GPU
- Playstation Super Spectral Resolution (PSSR)
 - AMD's solution to DLSS
 - Render less expensive raytracing components, use AI to infer results
 - Denoising
 - Upscaling
 - Interpolation



Nintendo Switch 2 (2025)

- 1920×1080 7.9" wide-gamut LCD display
- Undocked: ~~720p 60FPS~~ 1080p 60FPS
- Docked: ~~1080p 60FPS~~ 4K HDR 60FPS
- Nvidia-backed AI image upscaling (similar to DLSS)
 - Render at 1080p, upsample to 4K HDR



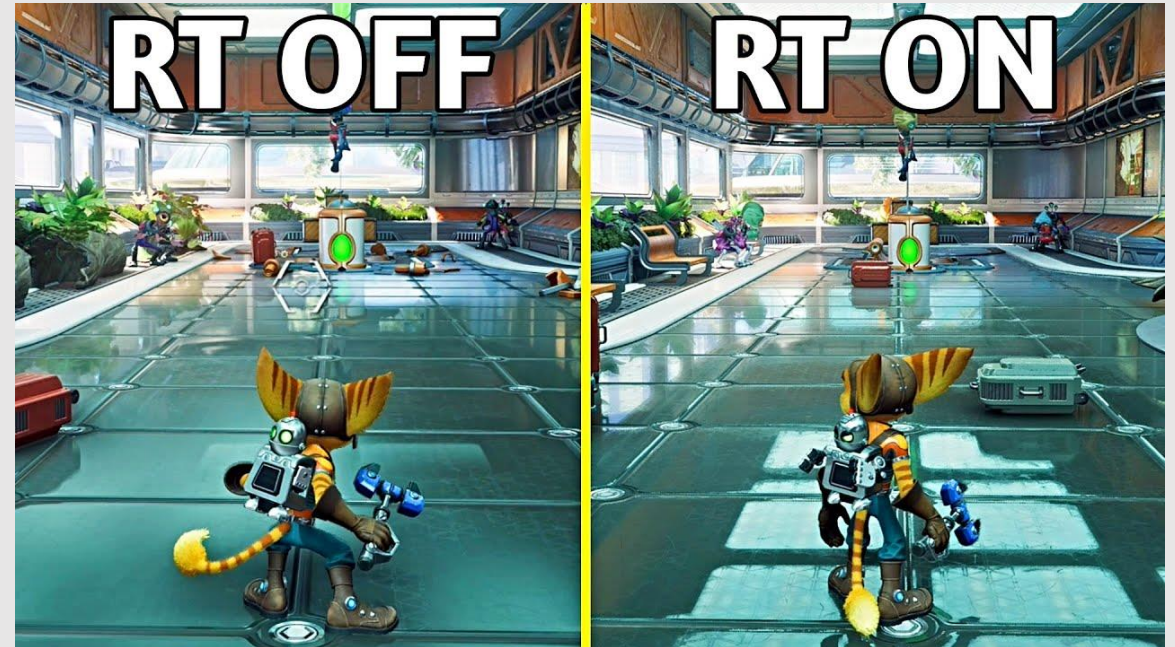
A Better Switch

- Fastest selling console in history
- 9 million units sold (Sept' 25)
 - Beat 6 million trajectory
- Strong Exclusive lineup:
 - Mario Kart World
 - Donkey Kong Bananza
 - Kirby Air Riders
- Switch 2 Upgrades:
 - Legend of Zelda
 - Super Mario Party
 - Kirby & the Forgotten Land
 - Pokemon Legends



Before Ray Tracing

- Lighting and shadows were “baked” into the scene
 - **Key Idea:** Lights do not move
 - Treat all lights as ambient, compute light/shadow maps
 - Render as texture on top of scene
- If light moves, overlay lights over scene
 - Shadows don’t move with light anymore
- Reflections/Refractions precomputed as textures
 - Alternatively, have a camera at the site of reflection and rasterize a second view to a texture (we call this the stencil buffer)
 - Sample from texture for reflection



Ratchet & Clank: Rift Apart (2021) Insomniac Games

So Why Have Video Games Looked So Good?



One Piece: World Seeker (2019) Bandai Namco Entertainment

- Reflections and lighting are smoke and mirrors
 - Game designers have gotten really good at faking them!
 - Sometimes slip-ups happen...

The "Global Illumination" In Video Games

- Rasterization is the baseline, raytracing enhances
 - Use rasterization as a first pass, with light and shadow maps baked into the scene
 - Call upon raytracing only when it makes a substantial difference
 - Reflections/Refractions
 - Shadow rays
 - Cannot spend too many rays to do anti-aliasing
 - Use denoising post-processing
 - DLSS (NVIDIA's upper hand)
- **Key Idea:** Raytracing in video games does not mean raytracing everywhere
 - Just in regions where it makes a significant difference



Fortnite (2021) Epic Games

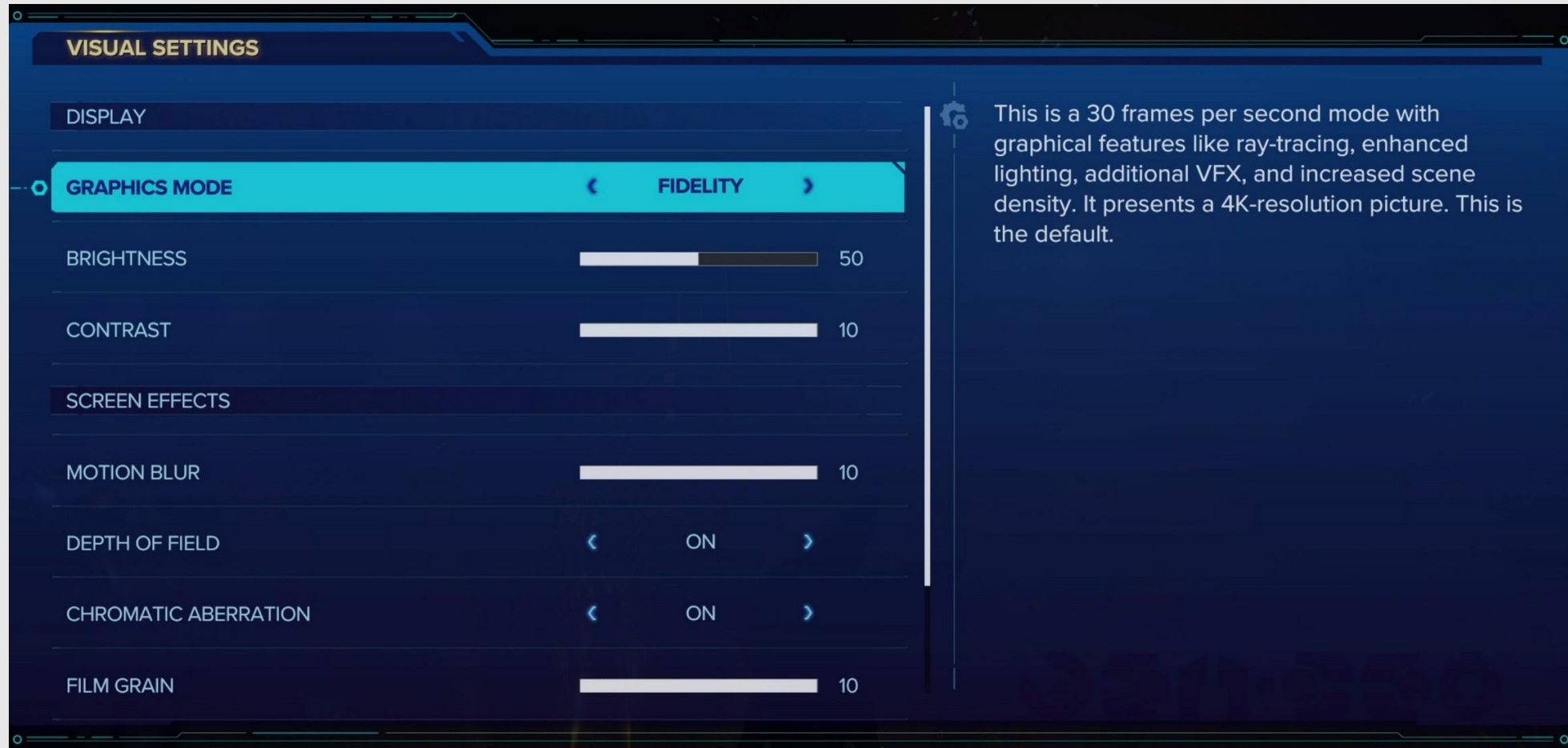
Future of Video Game Raytracing



Minecraft (2021) Mojang

- Raytracing can be used to compute sound
 - Sound waves can be approximated as beams
 - Properly occlude sound around corners the same way shadows are occlusions
 - Directional (3D) sound
- Game developers do not need to focus on baking light and shadow maps
 - Scenes no longer need to be static
 - Worlds can deform and blow up, and the developers do not need to create a new baked texture for each frame. Simply leave it to ray tracing
- Support for non-traditional lighting
 - Fireworks
 - Particle systems
 - Fog

Ray Tracing Costs



Ratchet & Clank: Rift Apart (2021) Insomniac Games

- Ray Tracing is still a quality vs. quantity argument
 - Better graphics at lower frame rate (30fps)
 - Worse graphics at higher frame rate (60fps)

Course Roadmap



[A1: Rasterization]



[A2: MeshEdit]



[A3: PathTracer]



[A4: Animation]