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Inside the Sixteen-Millisecond Frame

Reading level 14 · 2146 words

At 60 hertz, a screen wants a new picture about every 16.7 milliseconds (1,000 divided by 60). MDN's guide to web games, which rounds that to sixteen and a half, treats it as a budget of time. In a simple game loop, reading what the player did, working out the new state of the world and drawing it must all fit inside the gap to keep up with a 60 hertz display. Other displays run at 30, 120 or 144 frames per second, so the gap changes. Dividing 1,000 by the rate gives about 33 milliseconds at 30 frames and about 8 at 120. The same guide adds that a system that cannot keep up loses visual quality. This essay follows that gap through the engine, then asks what a game costs and ends on an argument the business has not settled.

The loop that spends this time is simple to state. Robert Nystrom, in Game Programming Patterns, says each turn processes input without blocking, updates the game state and renders, and that the update step runs the AI and the physics. The hard part is time. Nystrom's variable step scales each move by the real time since the last frame, so the game keeps a consistent speed on different hardware, but he warns that it makes the game unstable. Glenn Fiedler's 2004 article calls a fixed step, such as 1/60th of a second, the simplest way to move a physics simulation forward, though on a slow machine it runs slower than intended. He warns of the spiral of death, when a simulation cannot keep up with the steps it is asked to take. His remedy is to clamp the steps per frame, so the simulation slows down instead, which he calls arguably better than spiraling to death.

Drawing begins with geometry. An object is a mesh, a collection of vertices, edges and faces, and the faces are usually triangles. The tutorial LearnOpenGL divides a graphics pipeline into two large parts. The first transforms three-dimensional coordinates into two-dimensional ones. The second turns those coordinates into actual colored pixels. Microsoft's description of Direct3D 11 names the first programmable stage the vertex shader. It processes each vertex with operations such as transformations, skinning, morphing and lighting. The word shader sounds like art, but it means a small program, and each stage takes the output of the one before it, which is why the whole thing is called a pipeline.

The second half is where the numbers grow. The rasterizer stage converts shapes into a raster image made of pixels, and the pixel shader then runs once for each pixel that a shape covers. A 1080p frame is 1,920 pixels across and 1,080 down, which is 2,073,600 pixels. A frame of 3,840 by 2,160, the usual television meaning of 4K, has 8,294,400, four times as many. At 60 frames per second, that is roughly 500 million pixels every second, by our arithmetic. Graphics cards manage this because, as LearnOpenGL puts it, they have thousands of small processing cores that run these small programs in parallel. When the time

is still too short, MDN's warning applies, and quality gives way first.

Physics has a different difficulty, which is contact. Engines advance bodies in discrete time steps, and the Box2D documentation says that without intervention this can lead to tunneling. A fast object can sit on one side of a thin wall in one step and on the other side in the next. By our arithmetic, something moving 600 meters per second covers 10 meters in a 1/60-second step, far more than a wall is thick. Unity's manual describes continuous collision detection as a safety net for colliders that would otherwise pass through each other. It is more accurate but usually costs more computation, and it does not always give physically accurate results. Engines also split the work: PhysX says the broad phase reports only potential collisions between bounding boxes, and the narrow phase detects the actual ones.

Where does randomness enter a designed game? In Spelunky's 2008 original, which was remade in 2012, Darius Kazemi found by studying the code in 2009 that every level is a 4 by 4 grid of 16 rooms, and each room is 80 tiles, 10 across and 8 high. He estimated that each room's layout is something like 80% hand-crafted and 20% randomly generated, and he put the placement of traps and monsters at 100% procedural. That is one analyst's estimate for one version of one game, but it shows the usual shape of this method, which has people making the pieces and the rules. In Wikipedia's definition it typically combines human-generated content with algorithms and computer-generated randomness. The computer then makes the combinations.

Random in a game is rarely random in the everyday sense. The Minecraft Wiki says the world generator uses an algorithm called Perlin noise to produce a pseudo-random value, and the same seed generates the same terrain every time. In 2014, before the game came out, Hello Games' Sean Murray said that No Man's Sky holds 18,446,744,073,709,551,616 possible planets. He said every planet has a single number, a random seed, that defines everything about it. That figure is 2 to the power of 64, which is what you get by multiplying 64 twos together. Murray added that discovering one planet every second would take 585 billion years, which checks out by our arithmetic. The overview of a 2017 GDC talk by one of the game's programmers says the game uses procedural generation by necessity, and it describes the challenge of building a vast world as a small team.

Because the same seed gives the same world, a player can reuse a seed to get a world back. But the match holds only for one version of the recipe. The Minecraft Wiki, a community wiki and not the studio, records that when the world generator is updated, usually by adding new biomes, the same seed no longer generates the same terrain. A seed is only a starting number for a particular recipe. Change the recipe and the number describes something else. Spelunky sits at the other end, with hand-built rooms whose arrangement the computer chooses, and No Man's Sky leans on generation by necessity. Where the line falls between designed and generated is a choice each team makes.

A game must also be tested, and testing is a pipeline of its own. Wikipedia lists common milestones, and studios define them differently. In alpha, the key gameplay is in and the assets are partly finished, though one studio's guide describes alpha as a usable, engaging experience. In beta, the game is feature complete and only bugs are being fixed. The gold master is the final build used to produce the game. Human testers write bug reports with, where possible, the steps that reproduce the problem, and engine makers also ship automated test tools. Unity's Test Framework, for one, lets developers test their code in Edit Mode and Play Mode. After release, Wikipedia says, most developers and publishers quickly release patches when a game ships with bugs. The early access model goes further by inviting players to pay in before the planned release, partly to gather feedback and bug reports.

Cyberpunk 2077 is a well-documented case of a big game that shipped with problems. It was released on December 10, 2020. Video Games Chronicle reported that the PC version was largely well received despite numerous bugs, but that the game's performance on consoles was heavily criticized, and on December 18 Sony removed it from the PlayStation Store and offered refunds. CD Projekt said it should have paid more attention to making the game play better on PlayStation 4 and Xbox One, and promised large patches in January and February. The episode does not prove that testing failed. It does show how many different machines a game has to run on, and how public the cost is when one of them is missed.

What does all this add up to as an industry? The Entertainment Software Association, a trade group, says that 212.3 million Americans play video games every week, in its June 2026 report, and that Americans spent $60.8 billion on games in 2025, after a March revision. It also says the U.S. industry creates and supports more than 250,000 jobs and generates $95.8 billion in total economic impact. Those are the industry's own estimates. A different picture comes from the people who work in it. GDC's 2026 survey of more than 2,300 professionals found that over one in four respondents, 28%, had been laid off in the past two years. A survey counts only the people who answer it, but the finding points to a business that grows and shrinks at the same time.

What does a big game cost? Few studios say. CD Projekt, a company that sells shares on the stock market, published a filing on October 5, 2023, about Phantom Liberty, an expansion for Cyberpunk 2077. By its initial data, direct production expenses were about 275 million Polish zloty, and the launch marketing it ran itself cost about 95 million. It also reported more than 3 million copies sold in the first week. By our arithmetic, marketing was about a quarter of the two figures together. Team size is only a clue to cost. Rockstar's producer Rob Nelson said roughly 2,000 people worked on Red Dead Redemption 2, and Supergiant's creative director put the team for Hades at just under 20, but neither gave a price. Eric Barone made Stardew Valley mostly alone for more than four years, and formed a small team only after its release.

Size has its own trade-offs. Supergiant's creative director said that small teams are not intrinsically better than big ones, but that being small makes communication less complicated and lets decisions spread faster. He said the studio grew for Hades to get an early version out quickly, knowing it would be an Early Access game. Money also arrives through selling items inside games, and regulators have looked at it. In January 2025, the Federal Trade Commission announced a settlement with the maker of Genshin Impact that would require it to stop selling loot boxes to players under 16 without parental consent. The FTC had alleged the company hid players' odds of winning rare prizes, and the company said it believed many of the allegations were inaccurate. That is the one detail here on that subject, and it is a settlement the FTC announced, not a court ruling.

Now the argument. GDC's 2026 survey found that 36% of the professionals surveyed use generative AI tools in their jobs, most often for research or brainstorming. It also found that 52% think generative AI is having a negative impact on the business, up from 30% a year earlier and 18% the year before. About 7% said positive. The most negative groups were visual and technical art at 64%, game design and narrative at 63% and programming at 59%. The survey asked developers, marketers, investors and others, so the 36% mixes very different jobs. Use and opinion are separate questions, and the summary page does not say how far the 36% and the 52% overlap. It also does not say what a respondent counted as using the tools, so the numbers record opinion, not outcomes.

Now the people arguing about it. In late 2025, Epic Games CEO Tim Sweeney said in a post on X that AI disclosure "makes no sense for game stores, where AI will be involved in nearly all future production." PC Gamer's Tyler Wilde, writing in January 2026, sided with Valve. He wrote that he did not see how it helps consumers to treat generative AI as ordinary software. He said what consumers most want to know is whether art, writing, music and voices were made by people. He pointed to concerns that these tools were trained on other people's creations without consent, and he noted that there is disagreement on that point. He also called disclosure a complicated question for developers.

Platforms have had to decide what to say. In January 2026, PC Gamer reported that Valve's Steam form asks developers to disclose pre-made generative AI only when it is used in marketing or in content that ships with the game and is consumed by players. The same form treats AI that makes content while the game runs separately, and asks what guardrails stop it from making illegal content. In PC Gamer's reading, the rule does not cover AI tools used behind the scenes for efficiency. That leaves hard cases, and Wilde names one. Does it count if someone used a generative fill tool on concept art that was never meant to be seen? That is still open, and so is the line between a tool and a product. Whatever made the picture, it still has to arrive in about 16.7 milliseconds.

Questions

1. What does the essay say the 16.7-millisecond figure is?

A. A budget of time for the work on one frame in a simple game loop at 60 hertz

B. The length of one game level

C. The delay in a gamepad cable

2. Why can a fast object tunnel through a thin wall in a physics engine?

A. Walls are drawn as flat sprites

B. Bodies move in discrete steps, so it can be on one side in one step and the other side in the next

C. The engine turns collisions off for fast things

3. What does "procedural generation" mean in this essay?

A. Content built from human-made pieces and rules plus computer-made randomness

B. Content drawn entirely by hand

C. Content copied from older games

4. Why can the same seed give a different Minecraft world after an update?

A. Seeds expire after a year

B. A seed is only a starting number for one version of the recipe

C. Players change the seed by themselves

5. What did Tim Sweeney say about AI disclosure on game stores?

A. It should be larger

B. It makes no sense for game stores, because AI will be involved in nearly all future production

C. It should only be used for music

6. In GDC's 2026 survey, which share said generative AI has a negative impact on the industry?

A. 7 percent

B. 36 percent

C. 52 percent

Words to know

raster: pixel grid
shader: small program
tunneling: passing through
procedural: rule-built
seed: starting number
patch: fix update

Answer key: Inside the Sixteen-Millisecond Frame

1. A. A budget of time for the work on one frame in a simple game loop at 60 hertz
2. B. Bodies move in discrete steps, so it can be on one side in one step and the other side in the next
3. A. Content built from human-made pieces and rules plus computer-made randomness
4. B. A seed is only a starting number for one version of the recipe
5. B. It makes no sense for game stores, because AI will be involved in nearly all future production
6. C. 52 percent