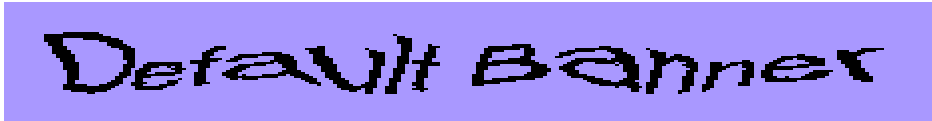


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The Halo Effect

The highly anticipated sequel Halo 2 sets the stage for a new era of graphics in games

By Martin McEachern

On Tuesday, November 9, 2004, the video game *Halo 2* made entertainment history when it logged a first-day sales record of \$125 million. The game's opening-day revenues even trounced the reigning opening-weekend ruler at the box office, 2002's *Spider-Man*, which raked in \$115 million during a three-day period. Without question, this event signaled to the world that the video game industry has become a cultural and economic force that rivals, if not surpasses, the film industry. Grossing \$10 billion last year, the video game sector eclipsed Hollywood's \$9 billion at the box office, and when *Halo 2*'s glow dims, it could even sink *Titanic*'s billion-dollar record.



If previous gaming blockbusters sent ripples through pop culture's mainstream, *Halo 2* sent a tidal wave, splashing on the covers of newspapers and magazines and flooding evening newscasts. Arriving amid this media frenzy, *Halo 2* quickly established itself as the flagship game for Microsoft's Xbox game console, but in the process it may also have become the standard-bearer for the entire game industry.

At the close of the original game, the cybernetically enhanced super-soldier Master Chief defeated the alien race known as the Covenant on its home world of *Halo*. But the victory was only temporary, as the sequel, set in the year 2552, finds the Covenant renewing its mission to conquer humanity by destroying all human colony worlds and beginning its conquest of Earth. Guided by AI advisor Cortana and aided by marine allies, the player assumes the role of Master Chief and leads the resistance against the aliens' campaign of elimination, eventually taking the fight back to *Halo* in hopes of ending the conflict once and for all.

The Covenant comprises several alien races, including the Elites (the founders of the alien alliance) and the Prophets (the spiritual leaders of the Covenant). *Halo 2* also introduces the Brutes, a gorilla-like alien species that is hostile to both humans and the Covenant. Though their true identity is unknown, the Brutes may actually be related to

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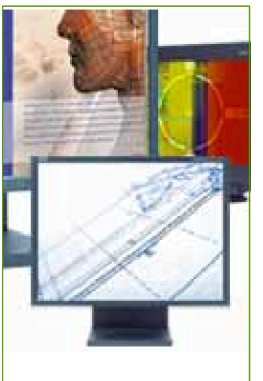
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the Forerunners, the race responsible for building *Halo*.

Like most first-person shooter games, *Halo 2*'s combat-intensive gameplay imposes some limitations on the number of paths available to the player and, therefore, restricts much of its interactivity to a localized level. "There are hundreds of ways to take out an individual enemy," says Jaime Griesemer, design lead for Bungie, the developer of the *Halo* phenomenon. "That makes it a little easier to lead the player through a mission, but makes it much harder to construct each battle."

Bungie 3D artist Robert McLees addresses the challenge of leading the player through an interactive experience in metaphoric terms: "Every game that has a beginning and an end has two things in common: blinders and a leash. The challenge lies in maintaining the illusion of freedom, which is wholly dependent on the beauty of the blinders and the comfort of the leash."

Model Soldiers

Bungie designed *Halo 2* to push the Xbox to its absolute limit—so far, in fact, that players with older Xbox consoles may see artifacts, like level-of-detail (LOD) popping or blurred texturing, because of their slightly slower hard drives. Following this mandate to surpass the quality of the previous title, the artists had two main goals for *Halo 2*: make it better and make it run faster. This required the team to build all the new and returning characters with lighter geometry.

Despite the lower polygon counts, the new models outshine their predecessors in detail, thanks to an increased reliance on normal mapping, a form of texture mapping that greatly enhances the realism and lighting of a surface by encoding details using three vectors of information instead of the usual two vectors designated by bump maps.

In *Halo 2*, the spotlight is on Master Chief, which 3D artist Eric Arroyo built vertex by vertex within Discreet's 3ds max. While modeling the cyber-soldier's smoothly curving metallic surfaces, with their sharp ridges, and beveled edges, Arroyo and the rest of the team paid special attention to the Master Chief's joints, to ensure that the complex structural design of the highly detailed battle suit would deform realistically.

In particular, the group was concerned with the character's extreme poses. So on difficult areas, like the shoulders and other T junctions, the artists made sure they had proper edge looping at the seams. But with no special tools for handling real-time problem joint deformation, they ran into a number of joint-rotation pinching problems that could not be solved. Instead, artists hid the problematic seams by constraining the rotation of the joints or positioning the camera to conceal them from the player's view.

To accommodate users of older Xbox consoles, Bungie maintained conservative polygon counts not only for the main character, but for the others as well, so the many characters, vehicles, weapons, and huge environments could appear on the screen at the same time without the player encountering rendering delays. For instance, Master Chief and the principal aliens were outfitted with five levels of detail, with a meager 3000 polygons comprising the highest LOD and each successive model representing a 50 percent reduction in density. However, most of the aliens, as well as the vehicles and weapons, feature only three LODs, so their geometric complexity drops off sooner as they recede into the distance. This allows the engine to draw more of them on screen at once and animate them much faster.

For generic, homogeneous characters such as the marines, Bungie built a male and female base model for the body and variant heads that individualized all the characters. The modelers divided the characters into regions—head, arms, torso, legs, and attachments—and created multiple permutations for each. These body parts could then be assembled into one conglomerate model.

"Through our tag system, we could define variables for each of these regions to create custom characters, or let the system randomly choose certain parts for various regions," says art director Marcus Lehto. To further personalize the marines, the artists varied such add-ons as backpacks, pouches, and the like. As distinct as the marines are from one another, Bungie learned from the original *Halo* that gamers, assaulted by the constant barrage of on-screen action, remained oblivious to most of the differences between members of any given alien species. Therefore, save for multiple color variations to help the player identify aliens from a distance, little was done to differentiate a particular alien race.

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The character Master Chief returns in Halo 2, this time with fewer polygons but a higher level of detail, thanks to normal mapping, a texturing technique that enhances a model's realism.

For *Halo 2*, Bungie relied heavily on normal mapping to add details to the models. "Instead of creating elaborate, super high-res models, we figured it would be easier to tweak normal maps rather than thousands of vertices," says Shi Kai Wang, lead 3D and effects artist. "This proved true when we had to make changes to characters because of design characteristics or limitations imposed by the game engine." In fact, Bungie extols the power of normal mapping as its only saving grace in meeting the challenge of upgrading characters such as Master Chief under the constraints of the aging Xbox hardware, which precluded any drastic increase in polygon counts.

In addition to the normal mapping, Bungie developed a proprietary shader system that uses templates to define the fundamental output of the desired material. For instance, artists could choose transparent, opaque, illuminated, or other basic shader types, then choose environment mapping for reflections and specify whether or not the reflection mapping respected the bump map or ignored it. For example, the Master Chief uses a three-pass shader: the base diffuse, bump, and detail maps were the first; the reflection mapping was the second; and the surface lighting was the third. In addition, the artists created a shader for Master Chief's armor and visor that gave the applied surface the characteristics of shiny metal, and offered controls for adjusting such attributes as color, shine, and bloom.

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To achieve dual firearm activity, the team created separate movements that blend with and play over a base animation.

The team also defined the eyes, hair, skin, and other organic features using custom-shader templates. Strapped for texture memory, the artists furnished the characters with only a single 128x128 map for facial resolution, though some cinematic characters had

256x256 maps.

Land, Sea, and Air

If the rolling thunder of the previous *Halo*'s massive array of armored assault vehicles weren't enough for gamers, the battlefields of *Halo 2* rumble with twice as many. After modeling and UV-mapping all the different modes of transportation in 3ds max, the artists exported them to the game engine, and then used Adobe's Photoshop to hand-author bump maps, texture maps, and specular maps. Moreover, the near-indestructibility of all the vehicles demanded they be modeled in various stages of damage.

"Object damage was the most strategic and time-consuming aspect of their creation," says Lehto. "Before introducing destructible vehicles, you first have to think about what's underneath the bodywork. In *Halo*, without seeing the technology under the hood, gamers just took for granted that the Warthog ground vehicle could drive and that the Ghost [the Covenant's standard battle vehicle] could hover. Well, now that you can blow off the outer panels, the underlying technology needs to exist." Therefore, the artists had to design parts that could sustain damage and fall off, and then model the various degrees of deterioration in three to five LODs, in addition to the machinery beneath.



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Each character, including the alien Elites, contains a unique skeletal system with as many as 60 bones for a range of movements.

To create scorched and battle-worn metal and rubber, mirrored cockpit glass, and so forth, artists used shader templates to define a surface's light-reflecting properties, and a combination of texture maps to define areas as either shiny or dingy. For example, the metal of the Warthog includes a bump map for chiseling out fine detail and scratches; a texture map for supplying a basic color scheme and adding details like dirt, scuff, subtle light, and shadow; a specular map for defining areas that are bright or dull; a detail map for providing fine detail and noise at close viewing; and a metal shader for giving the surface a reflective shine, with a hint of the mirrored environment that adds depth.

Troop Movements

The mandate of speeding up the gameplay extended to *Halo 2*'s character animations as well as the modeling. For the first time, Master Chief can holster his weapon and break into a powerful sprint, effectively doubling his running speed. In addition, the character can now combine melee attacks; execute "jacking" animations to board vehicles; peer around corners; dodge, leap, and jump; fire two weapons in tandem; and perform myriad close combat and evasive maneuvers. For each character, the team built a unique skeleton in Alias's Maya that contained approximately 40 bones for the simplest characters, such as the humans, and up to 60 bones for some of the more complex aliens, such as the Elites, which feature a Z-shaped leg like that of a horse, four articulate fingers on each hand, and four articulate man-dibles (mouth appendages).



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The group embedded Havok's physics technology within the vehicle models to realistically simulate friction, torque, and more.

The Master Chief, even with his rigid armor and steel exterior, had some malleable soft spots, like the shoulders and the groin area, that were often frustrating to animate, notes Lehto. Whenever possible, the team addressed these deformation issues by adjusting point weighting and bone placement, and limiting the freedom of the bones driving the deformation. Moreover, to ensure that the malleable and rigid regions of the Chief's body received the proper binding and deformed correctly, the artists used the material type of the regions to define the binding. Then, by correlating the weighting of a region with its assigned material type, Bungie efficiently weighted a character without accumulating superfluous data.

For seamlessly transitioning through Master Chief and the other characters' run and walk cycles, Bungie developed a sophisticated blending system that could overlay these cycles to produce intermediary rates of speed, such as a fast or a slow jog. Bungie also "bookended" the cycles with transition animations, which bridged these cycles by providing more natural starting and stopping momentum that is most apparent when a character shifts its weight to start a run or skids to a stop. These bridging animations overcome the "floaty" interpolation and hard pops often seen in games when a string of animations play consecutively.



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Halo 2 sports single- and multi-player functionality, allowing as many as 16 gamers to play against people around the world through Microsoft's Xbox Live, which redefines the social aspect of online gaming.

The characters' lip syncing and facial animation, meanwhile, was created by combining a 24-frame phoneme animation system with a 14-frame emotion system. While creating the facial poses for each system, the artists bypassed morph targets and direct-mesh animation in favor of traditional skinning of a set of bones to an overlying mesh. Then, for running real-time lip sync on the characters, Bungie used Impersonator Studio by OC3 Entertainment, which allowed the team to run pre-recorded audio to *Halo 2*'s characters and have them talk in real time using

the 24 individual phoneme poses for the mouth, brow, eyelid, and head. Once the lip sync was accomplished, the animators could overlay an additional set of 14 facial bone poses for emotional expressions—from amorous to shocked to angry—that could be mixed and matched independently of the lip-sync animation to achieve almost unlimited control over facial expressivity during a given line of speech.

Gaze tracking was also achieved through simple bone manipulation. “We reserved two bones in the face to direct the eyes at a given target,” says engineer Greg Snook. “During the game, either the artificial-intelligence system or direct scripted commands can specify a point in space for the eyes to focus on. The game engine then aims the eye bones at these points in each frame, while simple rotation limits prevent the eyes from rolling too far back into the head when focused on points to the side or behind the actor.”

Hallowed Halo

Halo 2's record-breaking sales have been touted as the gaming industry's triumph in the entertainment world, and Hollywood moguls may henceforth view the hours and money invested in gaming as a threat to their movies and DVDs. Nevertheless, the two mediums still offer very different types of experiences that may never converge, simply because the promise of interactive storytelling has yet to be realized.



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The popular game also supports cooperative play, allowing a person to team up with a friend, and together, save mankind.

Despite these differences, *Halo 2* has proven that the two art forms are now, at the very least, on equal footing. In fact, rumors abound of Hollywood's interest in acquiring *Halo* as a film property. But with the game's towering success, Bungie is likely to keep Master Chief fighting right where he is—at the controls of millions of gamers around the world.

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