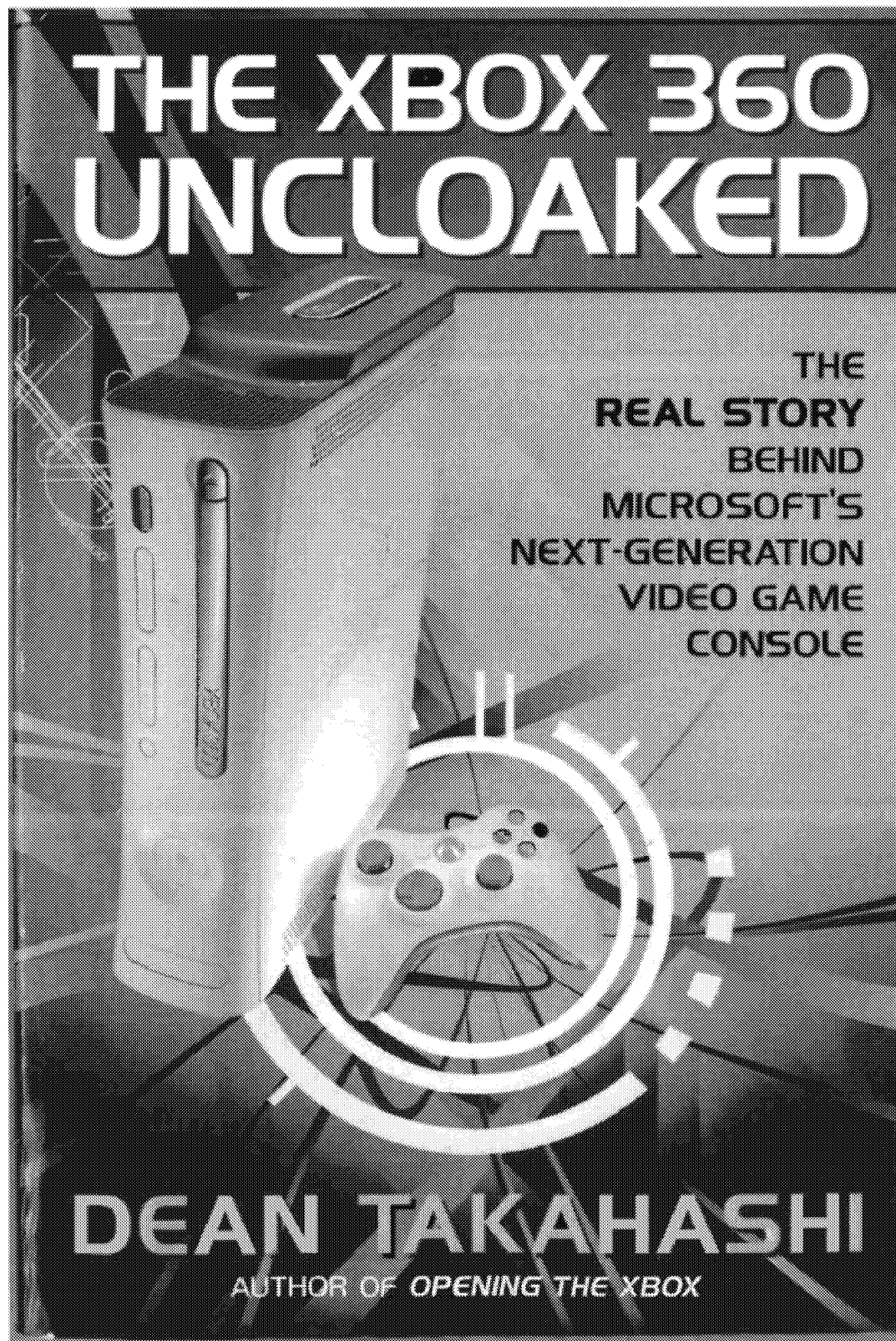




THE XBOX 360 UNCLOAKED

THE REAL STORY BEHIND
MICROSOFT'S NEXT-GENERATION
VIDEO GAME CONSOLE



DEAN TAKAHASHI



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Published by SpiderWorks, LLC.
<http://www.spiderworks.com>

ISBN-10: 0-977-78421-5
ISBN-13: 978-0-977-78421-5

Library of Congress Control Number is available from the publisher.

Edited by Dave Mark
Cover Design by Dave Wooldridge
Cover Background Illustration: mecaleha (istockphoto.com)
Interior Page Design by Robin Williams and Dave Wooldridge

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elements were essential to making money on Xenon.

"That's not our traditional way of doing business," said Don MacDonald, an Intel executive.

Intel typically owned its own designs, redesigned its chips on its own schedule, and made them in its own captive factories. Nvidia did the same, with the exception of making its chips at either IBM's factories or those belonging to Taiwan Semiconductor Manufacturing Co. Neither Intel and Nvidia would ever trust each other enough to share their chip designs with each so they could be merged into a single chip. Negotiations with those vendors hit a brick wall.

To Nick Baker and Jeff Andrews, that was OK. They saw that ATI was starting to take the lead in PC graphics chips. ATI was a \$2 billion company with 3,000 employees. Its Radeon 9700 chip that came out in August, 2002, was retaking the high-end of the graphics chip market for the first time ever for ATI.

Bob Feldstein, vice president of engineering at ATI, gathered a dozen ATI veterans, including Clay Taylor and Steve Narayan, to contemplate graphics for a game box. They knew that Microsoft wanted to highlight high-definition gaming and launch in the fall of 2005 at the price of a traditional video game console, about \$300. They also knew that Microsoft wanted to own the design that ATI would create and fabricate it in a factory of its choosing. While that was a tough hurdle for Nvidia, ATI's Santa Clara team had done such a deal with Nintendo already. It received a fee for the engineering work and a royalty on each console sold. It wasn't as much money as if ATI had made the chip for Nintendo, but it was money that floated to the bottom line.

With that information, they contemplated what they could do, using different teams than the Santa Clara engineers who were again going to work for Nintendo. Feldstein tapped engineers in Marlboro, Mass.; Orlando, Fla., and Toronto, Canada.

"We were doing a chip from the ground up," Feldstein said. "It was kind of liberating. We had long pursued the ideal of photorealism. We could see it up there just on top of the hill. We thought we could deliver fluid reality, and that would truly be a next-generation experience."

They didn't have to worry about making a chip work with all sorts of display resolutions. All they had to worry about was making it run on standard TVs as well as high-definition TVs. (In this case, running at 720P). The engineers tapped pieces of the PC chips that were already in the works to shorten the development schedule, but they also proposed several unique pieces that made the chip different from a PC graphics chip. In essence, they needed to create a machine gun that fired a bunch of dots at a display screen, and they had to make sure that the machine gun never ran out of ammo and never overheated.

Their alternative to the expensive PC graphics chip was to simplify it. They took two different processors that handle separate jobs on the PC graphics chip, and then combined them into a single processor that could handle both jobs. They called this combination processor a "unified shader." A shader is a program that the graphics chip runs to make a 3-D illusion look real. Two types of shaders



were necessary. One type noted where an object was in 3-D space. The other gave it the proper lighting, color, and surface texture.

In the ATI design, the unified shader was smart enough to juggle between the two types of shaders. The graphics chip would have 48 unified shader pipelines running at the same time. It wasn't as many as the 64 that Nick Baker originally wanted, but it was better than the 32 the team had expected. But because it was more efficient at balancing the load of work at any given moment, it might actually be able to keep up with a graphics chip that had many more of the separated shaders. The design for this graphics chip was similar to a cook in a fast food restaurant with 48 arms, making both pizzas and tacos at the same time. The result in the restaurant would be more food served, and the result for gamers would be more detailed visuals. Now, games would have objects with realistic fur, hair, grass or cloth.

Jon Peddie, a graphics expert and analyst at Jon Peddie Research, believed that the unified shaders would be an experiment for the entire industry. Microsoft would be taking a chance by being the first to undertake it. The question was whether the unified shaders could balance the workload or not. The system had to efficiently allocate the shaders to either type of processing at any given moment. The unified shaders were less likely to be wasted. But they were complicated.

"Are they more efficient? The answer is yes, no, maybe," Peddie said. "Some observers think unified shaders are not the obvious right answer right now, that we as an industry just have to learn more about how to exploit them, the Xbox360 is a great laboratory. However, in the long term, we expect that the industry will migrate toward a unified architecture, because we'll solve all of the problems with a unified design, and maybe the efficiency will matter less than the flexibility."

The Microsoft engineers also thought about the bottlenecks in the PC and how to deal with the limited amount of memory in the machine. The Xbox had only 64 megabytes of main memory, and Greg Gibson, the system architect, figured that Microsoft would be able to afford about 256 megabytes in Xenon. This was such a scarce resource in PCs that most graphics cards came with their own dedicated memory. This PC approach wasn't an option in a game console because it drove up the costs dramatically. Without that dedicated memory, the graphics chip had to wait a long time to get data from memory. That slowed the machine down, and it was often the reason why console graphics lagged behind the more expensive personal computers that hardcore gamers bought.

So Feldstein's team came up with a solution. They would include a separate chip that held nothing but memory for the graphics chip. The amount of memory was small, about 10 megabytes, but it would allow the graphics chip to keep itself busy with processing tasks rather than go out over the long pathway to main memory. Dubbed "intelligent memory," this added some costs to the box, but it reduced the bottlenecks without requiring a lot more memory. At first, the memory would be a separate chip that was connected to the graphics chip in a common package, or multichip module. Over time, this memory created by



Japan's NEC could be embedded into the graphics chip. That would cut costs, and Feldstein felt it would give "infinite bandwidth" for graphics processing. This meant that the machine would be able to do anti-aliasing, or smoothing out of jagged edges, even while displaying images in high-definition resolutions. The embedded memory operating at 256 gigabytes per second helped take a huge amount of traffic off the data pathway to memory.

Lastly, ATI would combine the system memory controller, typically a separate chip in a PC, into the graphics chip itself. With the memory so close, the graphics chip itself didn't have to be as powerful as a PC graphics chip. That made it smaller and easier to produce. Again, that would cut costs. Microsoft's own engineers had to build some specialized translation software to make this new kind of shader work.

Nick Baker and Jeff Andrews sent their engineers back to evaluate the proposal. They wanted to make sure that this would work well with the solution being proposed by the microprocessor vendors. Feldstein favored Intel because of its track record, while IBM was a bigger risk. But he complied with Microsoft's request to come up with a joint solution with IBM. By the spring of 2003, ATI still didn't have a contract. But it had enough confidence to move forward, putting an engineering team to work.

IBM started working on the bus, or data pathway, that would have common elements inside the microprocessor and the graphics chip. This meant that IBM was proposing to design part of the graphics chip. IBM proposed a bus that could transfer data at 22 gigabytes per second, much faster than a PC. This was the kind of collaboration that Microsoft needed to make sure that the solution for Xenon was properly customized. They didn't want a solution for a personal computer.

The technical solutions on the graphics chip were moving along swiftly, but the contract negotiations were starting to drag out. It was always very hard for chip designers to figure out what prices they could charge for chips that weren't even designed yet. So much depended on the yield, or how many good chips came out of every batch. Typically, costs were fixed for a silicon wafer. If that wafer had low yields where only a few chips worked, the chips had to be priced high. But if the yield was high, and the wafer produced 90 working chips, then each chip could be priced lower. These were unknowns a few years from shipping. Who was responsible for cost reduction, which often meant lots of engineers working on a redesign? Who was going to take the profits when yields improved in the factory?

"There was both a terror of losing the contract and the terror of winning the contract," Feldstein said.

The contract teams started their negotiations, leaving both companies room to opt out. Nvidia, despite its aversion to working with Microsoft again, was still in the bidding. It was proposing its own solution, and the Microsoft team knew life would be so much easier with the backward compatibility to the original Xbox that Nvidia offered. Nvidia could also offer the option of lowering prices on Xbox 1 graphics chips, where it was making healthy profit margins, much to



president of ATI. "Jen-Hsun said it wasn't a good deal. It was a good deal. We wouldn't have signed it otherwise. He just lost it."

Microsoft's chip experts, Nick Baker and Masoud Foudeh, had defined an impressive project for ATI. They had ordered a custom graphics chip with 232 million transistors, and a companion embedded memory chip with 100 million transistors. The graphics chip would have 48 unified shaders that could execute 24 billion shader instructions per second. Most graphics chips had separate shaders for vertex (locating a position) or pixel (giving it texture) processing.

The graphics chip would run at 500 megahertz, and process 500 million triangles per second. The chip would display images on both standard analog TV screens and on digital TVs with a resolution of 720p. That wasn't the highest possible quality target, but Microsoft figured it would be the sweet spot of the market. ATI would also design a memory controller into the chip, and design the embedded memory chip that connected to the graphics chip at high speeds.

"ATI was thinking of this as a game console chip and not a PC chip," said Greg Gibson, the system designer.

On the technical side, that is what won ATI the design. The idea of putting embedded memory in the box made a great deal of sense to Gibson. If it wasn't there, the traffic on the main memory bus – the data highway between memory and both the CPU and the graphics chip – would have been too heavy. A shortage of memory bandwidth was the Achilles heel for systems such as the PlayStation 2, the original Xbox, and gaming PCs. Since the embedded DRAM was connected directly to the graphics chip, the graphics chip could fetch a great deal of what it needed from the embedded memory without needing to go across the bus to main memory. The game developers could have used more embedded memory, but its presence was a relief. It would allow the system to achieve more of its theoretical performance, in contrast to systems that could never come close to hitting their maximum theoretical performance.

"There's a huge amount of traffic that never touches the bus," Gibson said. "That was a huge thing that ATI brought to bear."

Feldstein had a team working since the spring on the project. Now he could kick into high gear, adding scores of engineers to the team. Larry Yang, the head of Microsoft's chip division in Mountain View, Calif., worked closely with Feldstein's team to set up the schedule. Microsoft would check progress on the work and then set up the fabrication schedule at its chip contract manufacturer, Taiwan Semiconductor Manufacturing Co. Meanwhile, Microsoft coordinated with NEC, which would make the embedded memory that would be coupled with the graphics chip. Foudeh was the program manager who stayed in constant contact at ATI's facilities.

Feldstein created solid walls so that the engineers working for Nintendo wouldn't be in contact with the engineers on Microsoft's project. He had to hold out some contingency plans, depending on whether ATI's graphics chip would be coupled with IBM's or Intel's microprocessors. The odds were strong that IBM would win the deal, but it wasn't signed yet. Microsoft still didn't know



Microsoft's Xenon hardware team had now grown to more than 200 people.

"We hit what we called high tide in the summer," said Leslie Leland, director of hardware evaluation in Mountain View, Calif. "It was the time when we had to finish all of our work to make the launch happen."

Greg Gibson put his people to work on engineering validation. The industrial design from Jonathan Hayes' team was done. Don Coyner's team had moved on to testing the user interface software, getting reaction from Cheskin Research's random consumers. But the look and feel of the hardware was done, and that meant that Gibson's team could finally zero in on a single design and a single set of parts to test.

Gibson wanted to test whatever subsystems he could before the chips were finished. The first task was to take an early development machine, an Apple Macintosh G5, tear it apart and remove the motherboard. The team hacked into the board so that they could run some of the hardware that was ready. They tested the DVD drive, the wireless game pad module, and a version of the operating system software being created by a team headed by Tracy Sharp and Dinarte Morais. By integrating the subsystem together and testing it, Gibson's team was able to drive some of the risk out of schedule. They didn't have to wait for everything to be finished before they could start testing parts of it.

The first test version of the IBM CPU came out of the factory in August, 2004. Not all of the features were working on this test chip. It was called version 0.9, as opposed to the 1.0 traditionally used to name the first chip. Andrews worked with the board engineers, going through a couple of hundred steps just so that they could produce one or two working boards a day. Bill Gates visited the labs in Mountain View where the engineers were looking at a chip. When he heard the description of what it could and couldn't do, he remarked, "So you really mean it's version 0.1?" But it was enough to boot the operating system. All of the systems that were dependent on the microprocessor could now be tested.

In September, 2003, just a month after IBM finished its test chip, ATI taped out the graphics chip. It was an astonishing accomplishment because the team had signed the agreement only a year earlier. The engineers pushed the button and sent the design on its 12-week journey through the Taiwan Semiconductor Manufacturing Co. factory.

While the graphics chip and the CPU were the most time-sensitive, there was a lot of unsung work on the rest of the components. Taiwan's Silicon Integrated Systems was designing the "south bridge," or the input-output communications chip that allowed the major chips to communicate with the outside world or the hard disk drive. Adamec said the chip stayed on schedule and never rose high on the radar. That was thanks to an engineer named Yahbin Sim. He had visited Taiwan so often that the manager of the Ambassador Hotel in Taipei took him out to dinner. One of his counterparts at SiS invited Sim over so frequently that the man's children called him "Uncle Yahbin."

Meanwhile, the logistics staff installed a new version of the software for tracking each of the parts through the supply chain. Microsoft's parts buyers

MICROSOFT'S MULTI-BILLION DOLLAR GAMBLE

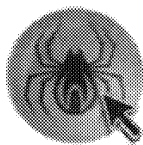
A fascinating insider's look at the evolution of the Xbox 360 and Microsoft's ambitious pursuit to become a leading force in the multi-billion dollar video game industry. Through extensive interviews and unprecedented access, *San Jose Mercury News* Technology and Gaming Writer **Dean Takahashi** takes you behind the scenes as he reveals:

- The birth of the machine as seen through the eyes of the Xbox 360 engineers who designed it.

- Blow-by-blow coverage of the heated internal debates as senior Microsoft executives battle to define the future of the Xbox brand.

- The strategic chess moves as Bill Gates, Steve Ballmer, and company take risk after risk, trying to outmaneuver their archrivals for the brass ring: dominance of the incredibly lucrative video game market.

Sony, Nintendo, Electronic Arts, the entire Microsoft Xbox 360 team, and the industry's most celebrated game developers – all of the major players are included in this captivating story.



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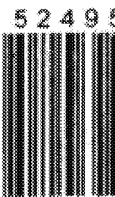


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THE XBOX 360 UNLOCKED: THE
Used, Acceptable



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