How We Designed the Personal Computer of the Year 2000

Luke T. Young
Kurt H. Thearling
Department of Electrical and Computer Engineering
University of Illinois at Urbana-Champaign

The Challenge

On September 3rd, 1987, Apple Computer's "PROJECT 2000" Competition was announced at a faculty meeting at the University of Illinois as part of a challenge that was being extended to eleven other colleges and universities across the nation. The Challenge: *to design the personal computer of the year 2000*. It was essentially an essay contest open to teams of up to five students and at least one faculty advisor. That same day, several professors sent electronic mail out to their students, encouraging them to enter the competition. By dinner time, several members of our team were already at work on what would eventually earn $32,000 in prizes for our team and a $20,000 Macintosh Lab for the University.

Representatives from Apple and the University of Illinois gathered on the night of September 15th to speak about the competition and answer any questions we had. Despite bad weather, many students attended the public seminar. There we learned that we would be competing against Berkeley, Brown, Caltech, Carnegie-Mellon, Cornell, Dartmouth, Drexel, Michigan, Minnesota, Princeton, and Stanford. We had until November 15th to submit a design for judging at the university level. Over the past week and a half, the composition of our team had been gradually taking form. By the end of that night's meeting, our little think tank was complete.

The student members were Bartlett Mel, Arch Robison, Steve Skiena, Kurt Thearling, and Luke Young. For faculty members, we bribed Professors Steve Omohundro and Steve Wolfram with free dinners. We agreed to meet weekly every Wednesday evening until the deadline. We knew we had it made, since Professor Omohundro and Steve Skiena (from now on, just "Steve") were among the featured speakers at the meeting. Their words sounded nice but carried only useless information and (thanks to Steve) a message of discouragement to others planning on entering.

For Luke, Steve, and Arch the arrangement was very convenient — they all lived in the same apartment and would literally see each other every day. As research assistants at the Coordinated Science Lab, Kurt and Luke had offices on the same hallway. Bartlett, like Arch and Steve, was in Computer Science and an old friend to most of the group anyway. All of our student members were graduate students and lived within a few hundred feet of each other, which made getting together simple. The only things that complicated our get-togethers were the problems of deciding on a dinner that could be accepted by all and dealing with the fact that we now had three members of the team named *Steve*.

The Meetings

Over the ensuing weeks, nearly all of our meetings would be held over dinner at the apartment of Arch, Luke, and Steve. The menu would go from pizza to Chinese take-out to submarine sandwiches as we decided on how to please everyone's taste. For some, only a concoction of orange juice and seven-up would suffice as an acceptable drink. At one point, a professor exclaimed, "I can't eat this. I've got to have **real** food!" He excused himself, made a quick trip to the store, and returned with a dozen *Häagen- dazs* bars. Eventually the menu converged on the lowest common denominator of our individual tastes — roast beef sandwiches.

Although we had trouble agreeing on food, the same could not be said about agreeing on design. The first meeting was held on September 23rd. We threw out ideas for general discussion and evaluation. We considered whom we would target as end-users of the personal computer we wanted to design. We looked at where technology was headed and how much improvement we could expect in the twelve years remaining until the year 2000. We also thought about what we would like the machine to be capable of, how people would interact with it, how information would be stored and retrieved through it, and the general design philosophies we should follow. Finally, we compiled a list of technology questions to be researched individually for presentation at the next meeting.

Over the remaining weeks we kept our eyes open for journal articles that discussed the year 2000's promises. As relevant seminars came up, we would notify each other through electronic mail so that at least one of us would be able to take notes. We looked at constraints in antennae length, bandwidth, heat-dissipation, power, noise isolation, and feature resolution. We examined issues such as security, data compression, speech recognition, encephalization, communication, and many socio-economic issues. We talked to experts and drew on as much inside information as we could. We made especially sure that we could justify saying what the machine would **not** be. The medium of electronic mail was vitally instrumental to the solidification of our design. Through it, we distributed the text of our ideas to all the other members of the team. It greatly simplified the final task of editing all of our ideas into one manuscript.

For continuity of style, we needed to have one person act as sole editor. That person would meld the different parts of our proposals into a single, coherent manuscript. Steve was an obvious choice because of his previous experience in writing an essay that won him a Honeywell

Futurist award. We submitted our texts to him through electronic mail, and he crystalized our thoughts with finesse. By November 7th, we had our first rough draft. It took us a few more revisions before everyone was satisfied with the work. Meanwhile, we contracted Luke's thirteen year old sister to create a cartoon for the title page — a ploy to gain the attention of the judges. On November 12th at 3:40 pm we turned it in. With three days to spare, we were the first ones to hand anything in. It would only be eleven days before we learned how we did against the other teams on campus.

Round One

Just for entering the contest, we each received a T-shirt, a shiny medal, and a cheap plastic pen. Out of the dozen or so entries submitted, the University had to select two entries to pass on to national levels. A quick call on November 23rd to the office of the *Special Assistant to the Chancellor* yielded the news we wanted to hear. Steve went to pick up the T-shirts and prizes, along with the copies of the judges' comments. The other winning entry from our school was entitled "Project Sushi." Steve described the entry as "a slick job — slicker than ours, with very artsy pictures and interesting quotes at section headings." Still, we felt we had the edge in terms of technical quality, since we knew that the next set of judges would be made up of Apple engineers.

We had until the 30th to make suggested improvements to our paper, so we had another meeting on the 28th to discuss issues of software and information handling and, getting cocky, what to wear in California. Two days later, we sent the final version off to Cupertino for the second round of judging. Bartlett surprised us all by renaming our project at the last minute and without telling us to "*TABLET: The personal computer of the year 2000*" — a name Steve still hates to this day. On the same day, the Daily Illini announced the names of some of the people who would represent the University at the second round of judging. We were a little upset that one of our team's professors was left off the list and another member's name was misspelled. The faculty advisor for the other team had been misidentified as well. What's to be expected from a paper that couldn't even get the day's date right (Monday, December 1, 1987)? We would know how we did against the other 23 national entries on December 14th. We crossed our fingers until then.

Round Two

The 14th came and went. No word. Luke called up the University office to find out if anyone had heard from Apple. The university personnel said that he would check with Apple and call back. Fifteen minutes later, Luke got a call saying that we were probably among the top five entries that Apple would fly out to Cupertino. **Probably???** Luke called up the University Relations Department at Apple to hear it straight from the horse's mouth. The victory was verified. The other winning entries came from Princeton, Berkeley, Minnesota, and Drexel. Apple had sent Federal Express Packages out to the winning teams the day before. We should have received a package that day. We learned later that the heavy snow that morning had forced the airport to close. **Nobody** in town got a Federal Express package that day. With Steve singing "*California, here I come*" non-stop, we all left town that week to celebrate the news with our families over the semester break.

After we returned from the break, Apple soon began to contact us about travel arrangements. The whole program was supposed to run from the evening of the 27th to the evening of the 28th. Apple was going to pay for our travel and accommodations. Kurt, not wanting to miss the first day of class, was reluctant to leave right away. He scheduled his flight so that he would arrive just in time for the start of the scheduled events in Cupertino. Having learned about a shareholders meeting on the morning of the first day of events, Luke asked if he could arrive a day early. Apple complied. Kurt wanted to stay over the weekend to visit friends in the area. Apple liked the idea that airfare would be cheaper if we stayed longer, so they okayed the extension. In fact, we all liked the idea and asked to stay longer. When all the bargaining was over, we each had our own suites with two color TV's, two telephones, two queen-sized beds, a VCR, a dining room with refrigerator, our own rental cars, and all that for five days!

On January 13th, we held another planning meeting to discuss the format of the presentation that we would make before the judges. Apple's judging panel would consist of Diane Ravitch, Alan Kay, Alvin Toffler, Ray Bradbury, and Steve Wozniak. We would get only fifteen minutes to speak. After the first trial run received poor reviews, we knew we needed to make some major changes in our strategy. We had to become salesmen.

The first step was to overhaul our overhead transparencies by creating a fast-paced, color slide show that we hoped would weave some humor into a technically fascinating presentation. We worked on gag lines and cooked up concepts like "*video wallpaper*" and "*video clothes*". Since we were told that several networks and journalists would be at the presentations, we figured that it would be good to have something to show to the photographers and that would leave a visual impression on the judges. We decided to construct a life-sized prototype of the machine we had envisioned. After a few rehearsals before video cameras and an audience full of stumping questions that ranged from "Will it be IBM compatible?" to "How will it help women and minorities?," we were ready to take the competition on.

The Winners

Apple flew most of our team out to Cupertino on Tuesday evening (January 26th). When we arrived, we decided to do a little visiting in the Silicon Valley area. The 60 degree weather in Cupertino was a welcome change from the 18 degree weather we had left back in Illinois. Wednesday evening was the big social event. There, in the lobby of the Cupertino Inn where we were staying, we had the chance to meet our "competition." At this point, however, nobody really cared about who was going to beat whom. They were a really great bunch of men and women and all "winners." Dave Patterson, advisor for the Berkeley team was there. So were the engineering deans of some of the other schools. While all the fun was going on, teams were taken aside individually to a video studio for some "file-footage" interviews.

The next day was very busy. We went on tours to see where all the U.S. made Macs are built. We saw Apple's purple Cray supercomputer, went on a shopping spree at Apple's *company store*, and finished the tour with lunch at the *Fontana* Seafood Restaurant. After a sumptuous meal, we took a break and readied ourselves for the presentation banquet. After having set up the stage area, we were sent to a conference room to "cool-down," phone home, or discuss final strategies as a team. One by one, our judges arrived at the scene.

When everyone was ready, we went out to the banquet area. John Sculley, whom Luke had seen at the shareholders meeting, had to leave town for an emergency meeting and wasn't there. By a casting of lot, our team was chosen to go fourth in line. Evidence of attempts to placate the judges became obvious when the five designs were unveiled one by one. Many of the teams had given their designs "*apple*" names like "CORE" from the University of Minnesota or "P.I.E." (Personal Information Environment) from Princeton — a combination radio-television-telephone computer touted to be the next step in the evolution of the *boom-box*. Not even in our own presentation could we resist featuring computerized dossiers of our five judges, complete with pictures, in a slide demonstrating the "get-acquainted mode" of our computer. To illustrate the anti-theft capabilities of our design, we created a slide showing Professor Omohundro disguised as a terrorist armed with an uzi and demanding the relinquishment of our prototype from a dismayed-looking Steve. The next slide depicted the consequences of such an act: a very remorseful Omohundro clenching the bars of his prison cell. The judges had very few questions. After the five presentations were over, the judges deliberated for half an hour, and we decided to start enjoying the hors d'oeuvres. A Princeton member suggested a jacuzi party after the banquet. Her idea sounded good. After what seemed more like two hours, the judges resurfaced. We felt that our presentation had gone over well, and hoped to place somewhere in the top three. The winning team count-down began: Third place went to the University of Minnesota. Second place went to Princeton University. The announcer paused. This was it. It would be all or nothing. Luke asked Kurt, "Are you thinking what I'm thinking?" Kurt retorted, "I don't want to think about it." The announcer continued, "And first place goes ... to the team from ... the University of ... Illinois!" High-fives sailed through the air — we had won!

After collecting our trophies, we sat down to tables of fine cuisine. Each table had either a judge or an Apple vice-president seated. Few of us resisted the chance to snap up autographs and discuss company plans — it's not every day that one gets to rub elbows with a corporate vice-president or famous author. Two students from the Drexel team had the foresight to bring their electronic mice and an engraver to the banquet. Now they each have a mouse that bears the simple insignia "Woz." To finish the banquet off, Apple presented a five-minute video of their own. It was entitled "The Knowledge Navigator" and revealed a scenario of life for a professor of the year 2010.

After the banquet, we had to pose for group photos and make several more video appearances. They claimed we were going to become part of an education video and asked for our views on a number of computer issues in education. By the time all that was over, it was getting pretty late. The jacuzi back at the hotel was a fitting welcome for a team of victors. We spent the rest of the week visiting friends, relatives, campuses and companies in the area and just having a good time. We had press conferences waiting for us back in Illinois. We didn’t mind letting them wait.

The Press

When we got back in town late Sunday night, our answering machines were full of calls from reporters and congratulations from friends who had learned of our victory from the local newspapers. The next day (February 1, 1988), a camera crew from WCIA-TV came up to our offices at the Coordinated Science Lab. There, Molly Hall interviewed Luke and Kurt about our project. Later that afternoon, we held a press conference at the Center for Complex Systems Research and made the Six O’clock Evening News. This encounter with the press would later prove to be only the first in a series of interviews. To date, the fallout from our project has yet to cease. Examples of our media exposure include the WILL radio talk show and coverage in newspapers such as USA Today, the Chicago Tribune, the Detroit Free Press, the New Brunswick Home News, the Baton Rouge Sunday Advocate, the Daily Illini, Illini Week, the Champaign-Urbana News Gazette, the ACM Banks of the Boneyard, and the U of I Alumni Newsletter. Magazines such as Macintosh Today, Mac World, and MacWeek, covered us as well. Our latest photo session was on May 11th when Apple representatives presented us with a plaque bearing our names.

All this publicity has served to instill in us a sense of caution when speaking to reporters. Remarks by the media have been scathing as well as flattering. Our design has been called everything from a "*Dynabook Clone*" to a product of "*the Steve Jobs and Steve Wozniaks of the future*". Misunderstandings have resulted in a number of amusingly inaccurate accounts. One article claimed that our machine's "infrared light beams would enable it to be connected to any nearby electrical outlet." Another claimed that the "Global Positioning System, or GPS, is used by the Department of Defense to keep track of ships around the world." And, of course, we had our share of misspelled names.

On the other hand, all the publicity has provided us with many invitations to speak at various seminars. To date, our team members have given a combined total of fourteen separate presentations on both the east and west coasts, and the slides we use for the show have traveled over 20,000 miles. The various fora have come from our Apple banquet, our press conference, Arch's hometown Computer Club meeting, an Illini Mother's Association meeting, a Computer Systems Group seminar, a U of I Computer Fair lecture, an EE312 class lecture, an Engineering Open House exhibit, and seven different job interviews.

Just when we begin to think we've gotten as much mileage out of this project as possible, new benefits seem to spring up. The $2000 discount on Apple products was a prize that was just low enough to prevent each of us from buying a full system with it. Fortunately, both the Computer Science and the Electrical & Computer Engineering departments realized that fact and earned our sincerest gratitude by graciously increasing the prizes by another $1000 for each student. >From a professional standpoint, benefits have come in the form of published technical reports and journal articles. When Sun Microsystems co-founder Bill Joy last spoke at the Coordinated Science Lab, we had a chance to talk to him about our design and invited him to stick around for one of our presentations that would be held in the same room later that day. Unfortunately he had to leave town before then, so we gave him a copy of our paper to read on the plane. Through other contacts, we were able to slip a copy of our paper to Steve Jobs of NeXT, Inc. When Apple followed up on the guaranteed summer internships that were part of our prizes, none of us expected that the call would be from Apple's Advanced Technology Vice President, Larry Tesler.

The Mercenaries

This June, three significantly different versions of our project will be hitting the magazine stands as articles in *OMNI*, *Communications of the ACM*, and *Academic Computing*. Before that could become a reality, and in what would have to be the most memorable of our experiences, we had to launch a three-phased invasion against the magazine world. Phase I of our "*magazine war*" involved wrestling the copyright for our design from Apple Computer, Inc. Phase II involved rewriting articles that were *based* on our design yet different enough from each other to keep from getting sued. We ended up transferring our copyright to Communications of the ACM. Phase III involved securing payment. OMNI has already paid us $1000 for the condensed version of our design, and we had no trouble from *Communications of the ACM*. *Academic Computing*, however, was another matter.

Since early February, the editors of *Academic Computing* had planned to publish the original manuscript of our design. It was only after they had started work on it that they finally told us what they had in mind. By then, we had already made other arrangements. They tried to bribe us by offering a free page of advertising to Professor Wolfram. It was unacceptable. Things looked like they were going to get ugly, when suddenly the solution was found: We would write an article about the impact that computers such as ours might have on education in the year 2000. This article would no longer infringe on the copyright we were going to give to *Communications of the ACM*. Plus, it would be of equal or superior quality to our original manuscript. There was just one loose end remaining — **payment**!

The editors of Academic Computing had never been in the practice of paying for their articles, nor did they plan to change that practice. Nonetheless, the page of advertisement they had thrown at us had a market value of $5000, and it was too late for them to retract the offer. So, we black-mailed the editors into accepting our new manuscript on the condition that they let us use the free page. They reluctantly accepted. Immediately, Steve and Luke began phoning old friends who had their own start-up computer companies, in hopes of selling the page for $2000. The friends were interested. The next morning, however, we received a call from the editor-in-chief of Academic Computing. Somehow, the thought of a bunch of students selling **his** ad space out to potential clients at cut rates was enough to give him nightmares. He wanted to settle in cash. That was fine with us — it kept things simple. He asked if we thought $1000 was a fair price. Steve, who was handling our end of the phone conversation, quickly agreed. A little too quickly, thought Luke and Arch. "Hey!" Luke complained, "we've already got customers ready to pay two grand, let's not be hasty." Arch agreed. "Can you hear what's going on out here?," Steve asked the editor. Convinced that most magazines would probably pay more for our article, the editor asked us to name a reasonable price. Luke suggested $1800. The editor countered with \$1500.... Sold!

The Design

The remainder of this article is a brief description of our design. Detailed descriptions are available as departmental technical reports or from the June issue of *Communications of the ACM*. In considering our design, we made no supposition of expected breakthroughs in technologies such as superconductivity or artificial intelligence. We made no supposition about new national infrastructures. After all, the year 2000 is only twelve years away. There is no major feature of *Tablet* that is not in some sense sitting in a laboratory today. We looked at what was possible and took it from there.

Tablet will have the same dimensions as a standard notebook. This rectangular slab will look like an $8'' \times 11''$ monolith from the movie *2001*, and weigh but a few pounds. Having neither buttons nor knobs, the front surface will be a touch-sensitive display screen. One side will have a credit card sized slit, and the other three sides will support ruby-colored ridges. To the user, however, the freedom and power of this instrument can only be appreciated as a synergy of its individual components, which we will now describe.

The I/O Surface

The most important part of any computer is its user interface. The front surface of *Tablet* is a high-resolution touchscreen, which yields slightly to the touch. With this single input device, we get the tremendous flexibility of a soft interface: from the low-resolution but traditional means of pointing with your finger to the higher-resolution available using a stylus. The touchscreen can emulate a mouse, or a soft keyboard - customized to the user's finger size and taste.

But if we are holding a stylus, why bother with the keyboard? We can write and draw directly on the surface of the screen, integrating text and graphics. And, if we wish, handwriting recognition software will convert our scrawl to typed text. Finally, this color display is more than just an imitation notebook page, it will be fast enough to support video communications.

Without question this is technologically achievable. Liquid crystal displays are inherently pressure sensitive, and the density is increasing fast enough that by 2000 they will be of laser printer quality and in color. The touchscreen resolution will mimic the finest ball point. Cursive character recognition systems with training and spelling correction techniques can achieve nearly 100% accuracy. Of course, no human or silicon system will recognize all handwriting, particularly from the medical community, but what isn't recognized will be highlighted in a different color and reentered by the user.

It might seem surprising that voice is not a major interface. Science fiction seems to specialize in talking to computers and listening to what they have to say. However, in many of the contexts where *Tablet* will be used, such as the classroom, the airplane, or a shared office, talking out loud will not be appropriate. This is not to say that speech is not a viable form of input for our design. A microphone and speech recognition processor will allow a user to communicate via speech if he or she chooses. Although dictating letters and memoranda is a skill which takes time to master, a system allowing the user to alternate between a speech-to-text mode and a text editor could spare the user a great deal of time in preparing reports — especially when the words that are spoken match words already appearing somewhere on the screen. In addition, there are circumstances where speech may be the only way a physically handicapped user could communicate with our computer. Our design has the flexibility of allowing the user to communicate in whatever way is desired.

The *LaserCard* Mass Storage Unit

To replace classical rotating-disk/movable head media, we propose *LaserCard*. These credit card sized optical RAMs will be a convenient, inexpensive, and physically robust data storage medium. Through data compression techniques, a single one-gigabyte card will hold four hours of video or two thousand books from a personal library. People will carry them in their shirt pockets and trade them like baseball cards. The only moving part in the whole machine will be the lid which keeps the optics dry if we use it in the rain.

One gigabyte is a healthy chunk of memory. However, it is only twice the capacity of a compact disk. We will use *LaserCard* for convenience, but it is clear that the real databases of the world will have to be elsewhere but still easily accessible.

The *DataLink*

To get this easy access, we need communication capabilities. Thus, *Tablet* integrates a cellular telephone link. This will not only support voice but data communications as well. The ISDN standard combined with compression techniques is sufficient to transmit video at conference quality rates today.

To use this link for voice communications, we will need a microphone and speaker built into the unit. These are inexpensive and justified by other applications. However for privacy, in most applications we will use a headset attachment clipped onto the infrared bar.

The Infrared Interface

Along three sides of *Tablet* will be an infrared bar interface, through which *Tablet* will talk to its local environment: printers and projectors, stereo headsets and video cameras, toasters and roasters, other *Tablets* and just about anything else. Every smart device in the world will have its own unique 256 bit key - so a simple protocol will enable devices to talk intelligently to each other. There are nowhere near 2^{256} atoms in the universe, so we need not worry about running out of keys. With infrared light, low bandwidth devices need not be physically connected while indoors. The infrared interface may be extended by repeaters stationed in large offices and clip-on optical cables to boost bandwidth to gigabaud rates.

What types of peripherals will people need? One of the most widely owned peripherals will be a tactile keyboard. The handwriting interface and simulated keyboard will suffice for portable applications, but for rapid text entry, nothing beats a good solid keyboard. Another extremely popular peripheral will be a lapel sized video camera. Charge-coupled devices (CCDs) make inexpensive and rugged solid-state cameras. The cameras will record meetings, electronic mail videos for instruction and personal communication, and digitize those printed documents which remain in the year 2000. The notion of digitizing documents is important, because a substantial number of printed documents will remain, such as old books and new contracts. After digitization, an image can be processed to cleanup and recognize the text to allow searching by keyword and context.

Tablet will have a GPS (Global Positioning System) receiver as a built-in component. GPS is an existing satellite-based system which enables objects to locate themselves in the world to within a few *meters*. By plugging in the *Rand McNally Road Atlas LaserCard* before a drive, it can provide us with the ideal route and parking place for that new French restaurant in the city.

Its usefulness extends well beyond driving, however.

These, then, are the elements of our design. We can hardly wait to hold one of these computers in our hands. We believe it is both realizable and desirable, and with a few years of engineering ... **coming soon to a store near you!**