Preface to
"Chronology: The Design and Development of the PCs Limited 286[12] "

The "Chronology" was originally produced in response to the hand written note from Lee Walker, President of PCs Limited (later, Dell Computer Corporation) in July, 1987. The "Robert Burns matter" refers to a threatened lawsuit against PCs Limited by brothers of Robert Burns, who was my friend and consulting partner for the previous ten years. Robert was not directly a part of this "lawsuit", which claimed that Robert Burns was a designer of the hardware known as the PCs Limited 286[12].

In fact, Robert had nothing to do with the actual hardware design, but was essential in creating the robust, reliable software BIOS that powered the 286[12] as described in the "Chronology". In addition to perfecting the "SmartVu" portion of the BIOS, he produced the first IBM-compatible BIOS that included a complete peripheral set-up interface that allowed changes to the input-output devices BEFORE booting into the disk operating system software. Prior to the 286[12] BIOS, IBM PCs and clones from Compaq, Texas Instruments, and myriad others had to boot a special set-up diskette to change or upgrade the hard disk drive, for example. Or even to add a second newer or larger disk drive.

In later years, Robert Burns served as a consultant to Dell Computer Corporation for several projects, including developing one of the first RAID disk systems. (RAID = Redundant Array of Independent Drives). He's best known in England as a consultant to military and aerospace firms and for his work for CitiCorp in London in computerizing first the currency exchange, and later the stock market. This CitiCorp software was also installed in the CitiCorp Tokyo exchanges in mid-1987.

Robert Burns was one of the three most brilliant minds I ever had the honor of working with. The others were Glenn Henry and Terry Parks, who also worked at Dell Computer for many years.

This "Chronology" describes an early stage of Michael Dell's success, though he had already been in business for over a year and had achieved over $20 million in annual sales. It was an exciting (and exhausting) six months. On July 5th, 1986, I thankfully welcomed the second great designer at Dell, David Lunsford. As insurance for Michael, I forced him to first design his 80386 product using the C&T 80286 chip set. He hated it, but it was a backup in case C&T had bugs in their 80386 chip set. They did. And it delayed the release of the PCs Limited 80386 product...

Jay — 7-25-87

Very important re Robert Burns matter:

① Label each of your hand written pages "PRIVILEGED AND CONFIDENTIAL FOR LEGAL COUNSEL OF ~~COMPANY~~ PC's LIMITED".

② once finished send it directly to Kelley Grant. Do not show it to Michael or me first. Do not give us copies. Thanks Lee

Copyright 2014 Joseph W. Bell, Jr.

Chronology: The Design & Development of the PCs Limited 286[12]

By Jay Bell
(As Written in July 1987 with 2014 Notes)

In mid-October, 1985, Michael Dell asked me to meet with him to discuss a "hardware design". Since I suspected that the topics would also include software design to complement the hardware, I asked Michael if I could include Robert Burns and Charles Zeller in the meeting. He agreed.

It became clear to me during the first meeting that Michael wasn't sure just what he wanted, or even if he wanted to get involved in producing his own hardware; he was just beginning to gather information. (During the past two years, I've come to recognize this "gathering" stage as very typical of Michael's modus operandi in deciding to pursue new business opportunities.)

Michael didn't say much during the meeting, so I took the lead in discussing the computer field in general, Robert's Charles' and my past consulting experience, and approaches to succeeding in major projects with short lead times. Since Michael took so much time for the meeting (about three hours), I knew that the topic was very important to him, even though we accomplished practically nothing. After that first meeting, Charles indicated that whatever it was that Michael wanted, it probably wouldn't require Charles' services. He was wrong.

Michael, Robert and I had at least three more meetings prior to November 9, 1985, although there may have been another shorter meeting just between Michael and myself.

By the second meeting it was clear that Michael had spoken with some others about hardware designs, because he had more specific questions to ask. However, he revealed almost nothing about what he really wanted from us (Robert Burns and myself). So, we covered much of the same ground in the second meeting as in the first. Again, the meeting was about three hours long. During that second meeting Robert Burns told Michael that he would not be able to undertake a full-time project since he already was consulting with Micro Design (a hard disk peripheral manufacturer) on an Apple Macintosh project.

The next couple of meetings had Michael talking a bit more about what he might be attempting to do. I include all the conditional adjectives because

Michael never really came out and called a spade a spade. But, he did finally show us some vendor documentation and a schematic that closed the information loop for me. The documentation was from Chips and Technologies, and the schematic was for a design of an 80286 AT-type computer. Much of our previous discussion had concerned the not-yet-released Intel 80386 computer chip, and Michael's feeling that it would be the most significant microprocessor chip for the next decade.

(2014 note: He was exactly right... it evolved into the 80486 through 1995.)

Prior to our final meeting of November 9, 1985, I thought hard about what it was that Michael wanted to do. To my mind he had some bigger ultimate goal in mind, and was looking for the right way (and the right people) to get him there. I searched my mind for the right strategy (and the right words) that would convince him that I was the man who could get him wherever he wanted to go. I knew I would have to do more than talk to really convince him. I knew that he was obviously talking with other hardware designers. I also knew that he would need more than just a hardware designer to get it all going. I prepared for the final meeting by discussing the issues with Robert, and by thinking, thinking, thinking.

Robert told me that he absolutely would NOT write a BIOS for an IBM-compatible machine, no matter how much money Michael might be willing to pay. (Although we both agreed that Michael was so tight-fisted that he would never pay what it was worth.) ...Four years before I had tried unsuccessfully to get Robert interested in such a BIOS project (even before Phoenix Software appeared on the scene), knowing there was big money to be made. For the jillionth time Robert told me how much he hated the IBM-type of computer, how low-class it was compared to the Apple Macintosh. (His bumper sticker says "I'd rather be driving a Macintosh".) He finally agreed that he might do "clean-up" work on some assembly language software for an eventual machine, if he wasn't already booked for something else... days later he and Charles were booked by CitiCorp in London to automate their currency exchange operation.

So, I went into the final meeting with these things in mind:

1. I knew Michael's supply lines were stretched from here to Taiwan. Operating with irrevocable letters of credit drawn on the day of shipment, he had to be forced into expensive air shipments and tough cash flow situations. Bank credit had to be minimal, I surmised, because of the nature of bankers, and because he was not yet 21 years old. And, since any other company could import and assemble computers as he was doing, he would soon be forced into a losing price war at the low end, with

the battles taking place in the magazine advertising pages.

2. The FCC was finally coming to grips with the personal computer market, and would most certainly begin to apply pressure. The most natural targets of the FCC would be the big advertisers who assembled foreign subcomponents into systems. The FCC's most potent weapon would be detaining imported parts at the port of entry, thus amplifying the cash-flow problem. The detention would also cause credibility problems with customers who would be forced to wait for indeterminate time periods for delivery of their systems. I already knew Michael was having quality control problems. Such a parts shortage would cripple his ability to satisfy paying customers by shipping them another new (and presumably working) computer.

3. The manufacture of his own hardware design would give him direct control over his supply line. Cash control could be better managed. Inventory could be more easily controlled. He could begin to counter the import trend by advertising "Made in the USA". In short, he HAD to manufacture his own machine to continue any growth at all, and to nullify some of the unforeseeable variables.

4. Michael didn't understand software. Like bankers, he could understand the tangible nature of hardware - software was a necessary evil to be avoided if at all possible. Since Robert didn't want to participate, and since the hardware would have to be designed first anyway, I would stress hardware, hardware, hardware. That emphasis on hardware would allow me to make whatever deal I couldd, and I would be the only one who would have to make good on it. Paying Robert would therefore not be a factor in my negotiations with Michael.

5. I felt I would have to acquire Michael's confidence in stages. I knew he would not pay what the project was worth, at least at the front end. I knew Michael was impatient - he wanted it yesterday. (And he wanted an 80386 later.)

6. I suspected Michael probably wanted me to just follow the Chips and Technologies schematic design and not throw any variables into the picture. This was my biggest sticking point. Past years of experience would not allow me to blindly commit myself to an unknown design. I would have to convince him to trust me to deliver a design that was close-to, but not necessarily identical to the C&T schematic.

7. I was sure I would have only one more chance to make the sale. It would be all or nothing at the next meeting. I resolved that I would put-upI would produce a working design for Michael before he had to pay a nickle.

If I couldn't get it to work, he wouldn't lose money. Since time was important to him, I would promise completion within three weeks. My price would be in the $4000 range, with Michael reimbursing me for parts and supplies used in the project.

I wanted Michael's full attention for that final meeting, so we scheduled it for 9 am, Saturday, November 9, 1985. Robert and I met alone with Michael until just after noon. We talked and talked for about two and a half hours before Michael said "but what's the DEAL..., what's the deal?".

So, watching for any and every facial reaction (there were none), I explained how Robert wouldn't be involved..., how I would put-up first..., how I couldn't blindly commit to an unknown design schematic..., how I would do the job in three weeks with a hand-wired working board..., and that I'd do it for essentially the equivalent of one month's salary. Now we were talking his language, money. I knew he would have to complain. He did.

He said that if I was actually going to do the work in three weeks, then why would he have to pay a four-weeks' salary? I countered strongly with a "time is money" argument, stating that while the actual calendar time would be three weeks (which was advantageous to him), I would actually have to put in substantially more hours than a normal month's worth to be able to accomplish such a feat. I was trading in sleeping hours for productive hours to his benefit. But I knew as I spoke that I would need something else...

Michael had found his wedge, and continued to hammer at it. I finally said that my price was NOT out of line based on my experience and reputation, and that I was already guaranteeing him success before he had to pay. But, that as a final sign of good faith, that I would agree to his three week's worth of cash payment, but that I would require that I get the first two computers off the production line of my own to offset his cash reduction. Michael hesitated just long enough to calculate the equivalence of his AT costs with the disputed cash difference. "You'll get the first ones off the line." We had a deal!

(2014 note: Michael discounted my original offer by 10%, but I did get the first two computers off the line on May 31, 1986, as we awaited the FCC's final approval to ship on June 2, 1986 ...less than six months after demonstrating the working prototype design on December 6, 1985. I still have a working PCs Limited 286[12].)

During the next couple of weeks in November, 1985, Michael exhibited at

the Fall COMDEX in Las Vegas, Robert finished up work for Micro Designs, and I prepared for depositions with Xerox attorneys in an ongoing copyright-breach of contract lawsuit. I knew I had to get Xerox off my mind before I would be able to concentrate on the hardware. The pressure and stress were going to be tremendous. I wondered if I would be able to pull it off.

Luckily, I finished the Xerox depositions by November 25. I worked day and night to get the project done. Fortunately for me, the PC's Limited purchasers had caused a delay by purchasing the wrong kind of IC socket, so I couldn't complete the design within the three-week period. I did, however, show Michael the progress I had made, and he was ecstatic. He had never seen a prototype board like this one before. He was even more excited because h knew it was going to be his...

At 10 pm, December 5, 1985, I called Michael at PCs Limited to tell him I had the board partially working. He insisted that I bring it down. I was met by Michael and Alan Baden (who I assumed was some sort of Vice President). The board was sort of working, though not very well. But it was obvious to everyone that we were there. After about an hour and a half, I found that the original C&T schematic and documentation was incorrect. I reiterated my stance that I would stay close to the Chips design, but would not commit to it 100%, for just the kind of errors we had just discovered. At about midnight Michael, Alan, and I adjourned to the PCs Limited conference room. Judging by the conversation, I knew within the first five minutes that Michael had accepted my design, or that he was at least confident that the design would be 100% in a very short time.

During the midnight meeting of December 5 - 6, 1985, Michael poured out a lot of information, plans, strategies. We agreed that I would work with PCs Limited as a consultant on a month-to-month basis at a rate of $1800 each payday (or about $3600 per month). Michael informed me that he had another group of engineers retained as consultants, and that he expected us to work together to further the goals of PCs Limited. I had no problem with that...

Michael told me that the Indian national engineers had both hardware and software expertise, and had previously designed a 10 Mhz 80286 computer system. They also had an AT-compatible BIOS that Michael was considering buying. He wanted me to be aware of the BIOS and help him evaluate it in the coming weeks. I told him I would certainly do so, but that it would be wise to seek Robert's expertise in the evaluation, and I asked that I be allowed to keep Robert fully informed of the project status. Michael agreed.

In the remaining days before Christmas we had a meeting with Michael, Robert, myself, and the seven or eight Indian nationals (who were represented mostly by Shankar, because of his proficiency in English). Shankar, et al., were doing a paper-design-review and evaluation of the Chips and Technologies chip set and its capabilities at CPU speeds of 8 Mhz and 10 Mhz. While Michael had always alluded to a 10 Mhz machine, I had committed only to an 8 Mhz design, and I held firmly to that commitment, although I had every intention of increasing the CPU speed if it could be reliably tested at speed by the manufacturer. Intel was planning on releasing only an 8 Mhz 80286 in the coming months. Shankar was fairly certain that the C&T chip set could not support 10 Mhz operation, but they wanted until December 31 before they presented their conclusions. The suspicion forming in the back of my mind told me that Shankar had wanted to do the 80286 design, and he wished I'd never been born.

Though I found the situation a little disconcerting, I figured that a some friendly competitiveness would be good. The beneficiary would be PCs Limited.

My biggest worry was the capability of the C&T chips. Was Shankar right? Could the chips work only at 8 Mhz? I already knew they could do a 10 Mhz design (by pushing a 6 Mhz CPU to 10 Mhz... not guaranteed by Intel). I knew PCs Limited could take advantage of the extra speed. My fear: the chip set was a dog, and it was all I had to work with...

I suspected that Shankar would avoid a direct confrontation with me and the specifics of my design. His best bet to get control of the 80286 design would be to denigrate the capabilities of the C&T chip set. So, while Shankar worked it all out on paper over the Christmas holidays, I spent many, many hours refining the design and taking full advantage of every speed trick I'd learned in the past ten years. On December 29, 1985, I succeeded. But I decided not to tell Michael. I felt it was crucial that Shankar's group commit themselves and tie their own knot. They did.

(2014 note: Shankar's group was a formidable, really intelligent set of engineers. In 1986 most of them moved to Atlanta where they formed American Megatrends, well known even today for their AMI BIOS... and Michael did buy the first rudimentary version source code for that BIOS. It underwent many, many corrections and additions at PCs Limited for two years.)

During January, 1986, I worked hundreds of hours to verify the existing design and get it into layout for the printed circuit board. Luckily we found a small Austin engineering company with a woman who was the best

board router I ever met. She smoked like a chimney, but let Michael look over her shoulder for hours. He was really fascinated with the process and could observe the day-to-day progress; his confidence increased daily.

Meanwhile, I continued to work out a coherent no-lose design strategy for PCs Limited, knowing any changes to the layout had to be minor. By listening to Michael and learning how to read between his unspoken lines, I went over and over the possibilities. Since I was already aware of his inborn impatience and his belie that a "bird in the hand..." is better than any possible change to the existing known design, I resolved to avoid telling Michael about each and every detail I was working on, even though he pressed me for every scintilla of progress I made. Here's the way I figured it:

The entire computer industry was in a downward price spiral, particularly the mail-order houses. Week by week the IBM-compatible price was eroding. Component prices, however, weren't declining at anywhere near the same rate. To keep margins from evaporating, one could only increase sales volumes and hope the volume discount on components would balance out. But any variation in the quality of the final product would adversely affect the rate of returns from customers. The hidden losses of returned and recycling computers and peripherals might not be quantifiable for months and too late to avert disaster.

Increased volumes would almost certainly demand increased cash flow impossible to sustain without a credit line increased of at least an order of magnitude. Michael was almost 21, but... bankers. I knew he would need additional credibility. I immediately thought of Lee Walker, a money genius who was helping my former company with its Xerox lawsuit. I would save that for later, after Michael turned 21.

The only solution from my end, it seemed, would be to create a product that could reverse an industry trend toward lower prices. But even that might not be enough. We had to have a product at the low end that had much better margins. We also had to be able to better control the quality of the final system and reduce the return rate substantially. Reducing the problem to the moderately impossible, all we had to do was to create:

1. An IBM-compatible clone for which people would pay a higher price.
2. A clone with better margins at the extreme low end of the market.
3. Clones reliably manufactured to reduce inventory requirements and returns from customers.
4. Clones that were distinguishable from the hundreds of clones flooding the market.

5. Clones that were so good the buying public would not think of them as clones at all, but as in improvement to the IBM standard.
6. A product instantly recognizable as a PCs Limited offering.

A fortuitous meeting with AMD in mid-January, 1986, helped solidify the direction. AMD had 80286 CPUs operating at 12.5 Mhz in the lab. I asked if AMD could test and would label the parts at 12.5 Mhz. AMD, quick to see an opportunity for higher margins themselves, said it could be done.

My technical competition was no longer Shankar, et. al., but rather getting the C&T chip set to perform reliably at 12 Mhz, even though 10 Mhz operation seemed almost impossible a couple of weeks before. (Though I had accomplished that December 29, 1985.) Working entirely alone, without the help or consultation of Robert Burns (who was in London by this time), I finally succeeded in 12 Mhz operation during the last week of 1986.

Not what I promised, just better. Using the same printed circuit motherboard, we now had three product variations: A very low cost computer operating at 8 Mhz (to be introduced by Intel in March, 1986). A 10 Mhz computer, which would be faster than any other IBM-AT clone on the market. The third variation at 12 Mhz, which would eclipse ALL competitors. Even if competitors had 12 Mhz 80286 CPUs, I had found a bug in the C&T chip set that prevented 12 Mhz operation without non-obvious corrective circuitry. Overnight, PCs Limited would establish a technical benchmark TWO steps ahead of any competition, foreign or domestic.

To this day the tricks used to achieve operation of the 80286 system at speeds up to 16+ Mhz have never been totally disclosed. Appendix A of this original document describes these critical design details, and are unknown to Robert Burns, since he was NOT involved in the hardware design.

I was reasonably confident that the high-speed versions could be sold at much higher prices with only a cost increase of about $100 for the faster on-board memory. But I felt Michael's original price target for the 12 Mhz machine was too low and that he was leaving money on the table. He finally concurred, and raised the target price from $2295 to $2695.

My final task was to make the PCs Limited machine instantly recognizable to the buying public. I resurrected a long-time ambition to have some sort of self-contained display on the computer system. I had tried, unsuccessfully, to sell the idea to clients including Digital Equipment Corp. and Xerox. In late January, 1986, I began this phase of the design.

At Michael's request, I had transferred my base of operations from my house to a locked office at the front of the PCs Limited Headway Circle location during the first two weeks of January. I was still a month-to-month consultant at this time, using my own tools, my own analytical instruments, and my own electronic parts and supplies. It should be noted that the Headway Circle location had no provision for handicapped access, and thus was impossible for the wheelchair-bound Robert Burns to enter without assistance. For that reason Robert had no involvement in the hardware design. He and Charles Zeller had already been hired by CitiCorp in London, and by January were both out of the country until early March, 1986.

(2014 note: Robert's fear of being trapped in a burning building without assistance fueled his decision to never work in the Headway Circle building. The building was divided into two halves, and I was locked into my office half while working at night, though I could exit in emergency. One night I inadvertently walked from my half to the other half of the building setting off a silent alarm - I didn't know there was no one left inside. Minutes later there were sirens, flashing lights, and rattling doors as multiple police officers checked security. Finally I went to the employee lunch room in my half of the building and showed myself at the window, which caused guns to be drawn... fortunately they were able to hear me through the windows as I explained who I was and why I was in the building and showed my driver's license. Police stood down and I was eventually allowed to go back to my secret office to continue working. Even during the day Michael forbade me from talking to any PCs Limited employees... it was 100% secrecy within the company.)

Since I had not revealed my intention to design a captive display to Michael (and because of my prior experience trying to convince other manufacturers to incorporate such a display), I knew I would have to create some excitement in Michael one step at a time if I were to succeed. The display had to provide substantial benefit to the overall system, but it also had to have enough "sex appeal" to be an obvious and natural addition without a heavy cost burden. Getting the "appeal" without the cost would be the most formidable problem, I suspected.

Having just gone through weeks of debugging and diagnosing the hardware of the design, it was natural that the display be able to assist a naive user and phone support tech in isolating failing components or incorrect hardware operation. After all, I already knew what kinds of things had failed and how I had detected and corrected the problems. Displaying these failings would be an obvious system asset. And, the

whole idea of a self-diagnosing system fit perfectly with the market niche PCs Limited occupied: with no dealers or on-site service organization, PCs Limited had to rely on telephone-based technical support of the user. And the biggest problem in telephone support is in how an unsophisticated user communicates the nature of a suspected computer failure to technical support. The user's lack of understanding computer jargon and vocabulary creates an almost insurmountable language barrier. The captive display helps provide a common vocabulary in solving the failures over the phone. The benefits would be demonstrable and quantifiable. PCs Limited would undeniably have a better mousetrap in its given market niche.

The first hardware display plugged into the (often) empty socket for the optional 80287 numeric processor and consisted of two 7-segment displays. This display could represent one 8-bit byte of information displayed in the traditional computerese "hexadecimal" format. This was a natural first step because the IBM-AT BIOS stored an 8-bit byte of information at I/O port location 80h as it progressed through its rudimentary diagnostic tests of the hardware. This information, while stored on an IBM system, was never able to be seen or examined as diagnostics progressed. By using this newly-designed display I would be able to actually read that information byte, and by backtracking through the BIOS listing, be able to ascertain exactly what the failure mode was. Thus, for my first version of the display, I needed write no software, just use the IBM BIOS.

By purposely creating a defect on the system motherboard, I could see if the BIOS halted operation with a correct information byte displayed. It worked perfectly. When I finally showed it to Michael he was ecstatic - here was something entirely new! The as-yet-unnamed and incomplete "SmartVu" was operational and beneficial. Robert Burns had not participated in the concept nor the execution of this diagnostic display. This fiirst version was operational in the last week of January, 1986, and took only two nights of work to complete.

The second version of the diagnostic display was very similar to the first. Rather than the less-than-readable 7-segment displays however, the next version used two special hexadecimal display devices that incorporated most of the necessary interface logic, the Texas Instruments TIL311. And rather than using the numeric processor socket, this second version had its own dedicated connector with the required signals to drive the display. Like version one, the IBM BIOS provided the software interface for version two. Version two became operational in mid-February, 1986. It was not enough to satisfy my own goals for a diagnostic display.

(2014 note:

The Final "SmartVu" Design

It was mid-February, 1986, and PCs Limited was scheduled for Spring COMDEX in Atlanta around April 20th. I feared it was too late to do a final design and be able to get the changes to the board layout in time to produce printed circuit boards at Bird Circuits in the former East Austin chicken slaughterhouse. It was a six-layer board about 3/4ths the size of the IBM-AT motherboard (... whose size would become the industry standard for small AT-style motherboards).

My plan was to complete the "SmartVu" design ASAP, but to work toward incorporating it into a Rev 2.0 of the product for the Fall COMDEX. After all, an external display would require a change to the front panel of an in progress new chassis design to accommodate the smaller motherboard (and reduce costs).

I had located the display I needed by looking to non-USA suppliers, namely Siemens, the gigantic German heavy equipment manufacturer! It had everything: a four-character LED dot-matrix, just the right size and look. It also took direct ASCII characters as inputs to the display (greatly simplifying the design), and contained all the special characters used in European languages. Wow. Country-specific diagnostic messages could make it a world-class machine.

I had already designed a diagnostic connector port that was just included into the beta PC board layout. The complete hardware interface would require only two additional signals be routed to that connector to complete the hardware design. After two days I had hand-wired a tiny circuit board that would attach to the outside of the new chassis, with a ribbon cable to the inside motherboard.

However, the approach of using the built-in IBM diagnostic byte would not work and was too simplistic for the Siemens display. I needed new BIOS messages that were four-characters long... much more descriptive than what I had originally envisioned.

It was the third week of February, 1986. Robert Burns would return from London on March 1st for two weeks. But I could not wait until then, since Michael was to meet with the editors of PC Magazine at their annual survey of vendors in Dallas around March 5th. I had to work the Shankar group BIOS to incorporate new diagnostic messages, and an output driver interface to the Siemens display. A two-day process to complete, but the biggest difficulty I had was constructing the four-character diagnostic

messages so they didn't just look like gobbledegook. Alas, there were too many types of errors, and the messages were confusing. What was needed was the ability to repeatedly send out a full sentence to the display and have that long sentence scroll across the four-character display like a Times Square news headline display. But could the Siemens handle that without the moving text look like smeared, unreadable nonsense?

The last day of February, I had a buggy driver that scrolled, but it was jerky and uneven, though the messages were amazingly readable.

Just in time for Robert's arrival, plus 24 hours to let him recover from the long flight from London. I was going to hold him to his promise to do "BIOS clean-up" work. So, while Robert did no hardware design work, he was a genius with Shankar's BIOS.

A few hours cleaning up my scrolling driver and it was easy to read paragraphs of scrolling information. We worked for a while to optimize the scroll rate for naive users who might need more time to read the message without having to wait for it to repeat time after time.

It is now two days before Michael departs at 4am for Dallas where he'll get his first indication of whether he has a winner or a dog going into production. Robert and I poured through the BIOS constructing new error messages for every significant point in the boot-up process. The SmartVu would display the last pre-failure message, even if the system "blew up" and no longer worked... there would still be four characters displayed.

As we closely examined the BIOS from beginning to end, we were finding several subroutines with common errors we had found in working on BIOS versions from both Xerox and Digital Equipment. Michael had already bought the BIOS, but it really needed the fast clean-up attention Robert could give for the next ten days before he and Charles Zeller returned to CitiCorp. (The BIOS debugging continued for the next six months. Fortunately, Charles tired of the CitiCorp consulting job and returned to the US in late June, taking final control of the job with the able help of newly-imported talent from Texas A&M, Tony Overfield and Al Sato.

But back to SmartVu. We showed Michael what we had done and I think he was very surprised... but with his talent for stonefacing, I wasn't sure. I told him of my thought of a Rev 2.0 introduction later in the year, but he wanted to take it to Dallas. I literally finished honing a kludge mechanical attachment to the chassis for the display about 15 minutes before he arrived to load up for the Dallas trip. I left to sleep for about 15 hours.

After returning from the PC Magazine review, Michael said they told him he simply could not release the machine without the SmartVu display. I was delighted and depressed at the same time. Delighted at the acceptance of a well-executed add-on by a discerning group of editors, and depressed because I did not think it was possible to have the chassis guys design a new mechanical front display mount, and because I did not think I could route a small PC board and get it manufactured in time for Spring COMDEX. It was March 7th or so, and we still had to get the early motherboards assembled and tested... where could I get the resources?

Unfortunately the chassis manufacturing was underway and they could not make a new panel mount. Fortunately, I had worked with a South Austin owner of a metal fabrication shop who could do the mechanical design and manufacturing... as he had proven in designing a transportable chassis during our consulting work for Xerox as a competitive product against Compaq's transportable.

As for the display's printed circuit board, I'd used one of the fastest, best prototype printed circuit houses ever: West Coast Circuits. I had fifty PCBs in about a week. The chassis front panel mount took a little longer. One thing I did not think of was the need for the display mount's plastic label for the chassis lock and necessary contrast enhancement color for the Siemens display. Another rush job at the last minute, with another Austin vendor coming through in time.

Whoops. Forgot about having the label die-cut for the round hole needed for the chassis lock. Cutting that hole by hand turned out to be the toughest, most time-consuming job of the SmartVu phase. It's not easy to cut a round hold using a dime and X-acto blade. Very dangerous and too easy to have the blade slip and ruin either your hand or the label.

We had a very limited number of labels for the machines being shipped to Atlanta. After watching impatiently as label after label was tossed, Michael decided to pitch in. We were down to the last five labels, and Michael had already destroyed two. Wisely, he backed off and we had one spare.

PCs Limited was on its way to the ONLY COMDEX where the entire industry showed Intel-based 80286 systems (running at 8 Mhz) and a single well-advertised upstart racing fully tested and guaranteed systems 50% faster. I'll never forget seeing Rod Canion followed by about seven marketing ducklings marching over to the PCs Limited booth to see why this "garage operation" was running a 12 Mhz system, when Compaq had just introduced only an 8 Mhz transportable a month before using the SAME CHIP SET! He got no answers, and did not stay long...