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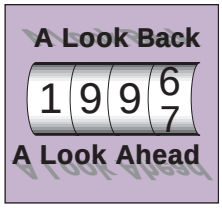
MICROPROCESSOR REPORT

THE INSIDERS' GUIDE TO MICROPROCESSOR HARDWARE

Alpha Sails, PowerPC Flails

x86 Poses Significant Threat to RISC Workstation Sales



by Linley Gwennap

Last issue, we reviewed the x86 market. Our New Year's coverage continues with articles about general-purpose RISC processors, media processors (see **110102.PDF***), and embedded processors (see* **110103.PDF***).*

During the past year, market prospects for PowerPC melted faster than ice cream on an Exponential chip, despite a renewed effort by the processor vendors to deliver competitive price/performance. Apple's problems proved too severe to fix quickly, and the company lost a third of its market share. After finally loosening its hold on Mac OS, Apple failed to find any other significant system maker to boost the Mac platform. The year ended with a whimper when IBM and Motorola admitted that not even their own internal systems groups are interested in Windows NT on PowerPC.

This announcement, combined with strong execution by Digital, puts Alpha in a surprisingly good position. After brief incursions by Intel and HP, Digital regained the microprocessor performance lead last fall, as Figure 1 shows. With the announcement of the 21264, due around the end of this year, Digital set a high hurdle for any vendor wishing to challenge that lead. Perhaps more important, Alpha is now the only RISC architecture supporting Windows NT and thus is the only alternative to x86 in this growing market. The company is pinning its NT hopes on the 21164PC, a new low-cost device due in 2Q97, along with x86 compatibility provided by its FX!32 emulator/translator.

In the meantime, uncharacteristically weak execution let Intel's boot heel slip ever so slightly off the throat of its RISC competition. After dramatically gaining the integer performance lead in late 1995 with its 200-MHz Pentium Pro, the company has yet to announce a faster processor, watching idly as most of the RISC vendors passed Intel's best performance. Worse yet, faster parts such as Klamath, Deschutes, and Merced have reportedly slipped 3–6 months. We still believe that market forces leave Intel well positioned in the workstation and server markets that have been the core of RISC's success, but Intel's slippage gives the RISC vendors a bit more breathing room.

Once again, we offer our RISCie awards to acknowledge the best and worst RISC events of 1996. This year, we decided to let Intel join in the fun as an honorary RISC vendor. For the purposes of these awards, however, we have left out other x86 processor vendors as well as RISC processors aimed at the embedded market.

Digital Bets on NT

Another year, another title. Digital grabs its fourth award for **World's Fastest Microprocessor (shipping)**, this time for the 500-MHz 21164, rated at 12.6 SPECint95 (base). Yields on this chip seem to be good, so we expect Digital to squeeze out a speed boost, perhaps to 550 MHz, in the next few months. The company has demonstrated 600-MHz parts, but this frequency may not be attainable in volume production.

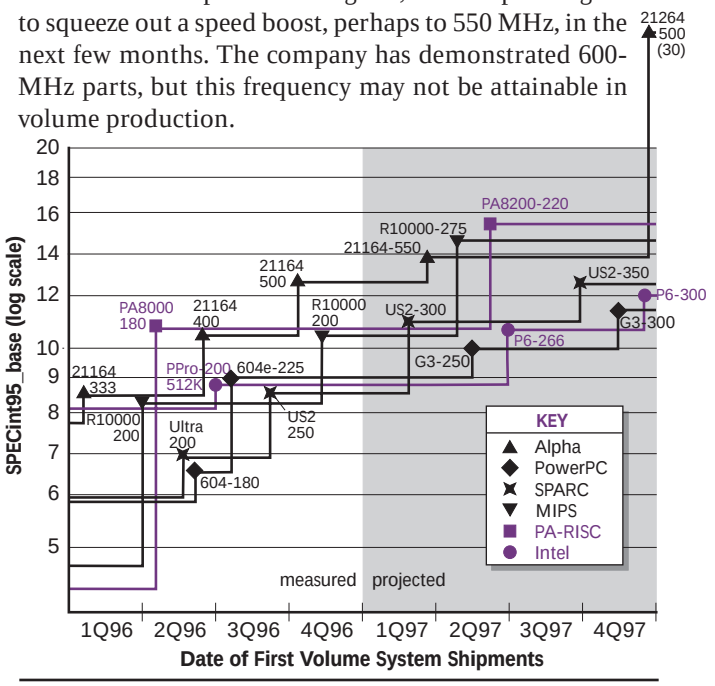


Figure 1. Digital will see increased competition for the integer performance lead in 1997, but the 21264 will be its trump card. (Source: SPEC for 1996 data, MDR for 1997)

Any such speed boost will have to last until the end of the year, when the 21264 is set to debut. Digital claims the forthcoming device will achieve a stunning 30 SPECint95 and 60 SPECfp95 (base), making it the **World's Fastest Microprocessor (announced)**. These figures represent more than twice the performance of the fastest chips today and, if achieved, should keep Digital in the performance lead.

To date, however, this lead has not led to a large market share for Alpha. Digital's hopes for a significant increase in volume lie with Windows NT. The vast majority of NT users continue to work with x86 systems, as most NT customers are buying systems for $4,000 or less. Few Alpha systems are available at this price today, but Digital plans to change that with the 21164PC, a stripped-down version of the 21164 that supposedly retains that chip's superior performance while using PC-style cache and memory chips. Digital may need a **Bit of Magic Dust** to deliver on this claim; if it does, users willing to consider a non-x86 processor will find the 21164PC a solid competitor for Klamath in the high-end NT market.

Contrary to our projections, Mitsubishi stayed aboard the Alpha ship despite another year of essentially no Alpha revenue. The company is a codeveloper and second source of the 21164PC and thus could take advantage of any NT gains. The potential for NT-on-Alpha also attracted newcomer Samsung to the fold. The Korean giant will initially focus on the 21264 core but may try to muscle in on the 21164PC action. By 1998, Mitsubishi could get **Caught in a Squeeze Play** between Samsung's low manufacturing costs and Digital's developed sales channels.

The second prong to Digital's NT strategy is FX!32. This emulation/translation software wins our **Alchemy Award** as the best product yet to convert x86 code into RISC. Although much delayed, FX!32 finally achieved open availability last fall. At least by some measurements, the product achieved its goal of delivering 70% of native Alpha performance when running translated x86 programs. FX!32, combined with native versions of Microsoft Word and Excel as well as many performance-hungry applications, will help wean some NT users from their x86 systems.

For Alpha to succeed, particularly from the viewpoint of Mitsubishi and Samsung, the platform must ultimately attract more system vendors. The Silicon Graphics purchase of Cray, which will ultimately replace the Alpha chips in Cray's MPP system with MIPS processors, leaves Digital as the only Alpha system vendor most people have ever heard of. To make its chips more attractive, Digital has given up its title as maker of the **Most Expensive Microprocessors**. As we recommended last year, the company cut its processor prices in half, bringing them more in line with Intel's.

Any meaningful financial benefits from the NT strategy are unlikely to accrue before 1998. The Alpha vendor must find some other way to stem its recent flow of red ink before the wave drowns corporate interest in Digital products.

PowerPC Resets Goals

During the past year, IBM Microelectronics and Motorola got their act together, taking advantage of new manufacturing processes to aggressively increase the clock speeds of their mainstream PowerPC chips. With both companies shifting most of their production to 0.35-micron CMOS, the 603e climbed to 240 MHz while the 604e reached 225 MHz, earning the rarely seen **Ahead of Schedule** award. The vendors also reined in their marketing groups, not announcing products until they were actually shipping, for a change.

Unfortunately, this success did not extend to the ill-fated PowerPC 620. This chip, originally due in 3Q95, wins the **Flying Dutchman** award: doomed to roam the seas forever, occasionally glimpsed through the mist but never finding its way to port. The latest plan has the 620 showing up in IBM systems sometime in 2H97—maybe. Users needing 64-bit support may instead turn to IBM's Apache, an internally developed 64-bit PowerPC processor. This would leave Groupe Bull as the only customer for the 620.

After reaching the end of the original PowerPC roadmap (except for the aforementioned Dutchman), Motorola and IBM unfurled a new map that extends through 2001, giving them the **Biggest Crystal Balls** award. This year will see the debut of the first G3 processors, which are derived from the 603 and 604 cores but add new cache and bus interfaces to increase performance. The G4 is due in late 1998, and the 2K is planned for 2001.

Despite recent advances, PowerPC has little hope of establishing a significant performance advantage over Intel's processors. And while every other major processor vendor is adding multimedia extensions, the PowerPC partners refuse to even acknowledge a plan to implement them, earning the partners a dubious **Mental Eclipse** award. This blind spot will put PowerPC chips well behind Intel's MMX processors in performance on many multimedia applications.

IBM rolled out its P2SC, a single-chip version of its Power2 processor, last fall. The massive chip wins several awards, including **Most Transistors** (15 million), **Best Memory Bandwidth** (2.2 Gbytes/s), and on the downside, **Highest CPU Manufacturing Cost** ($375 estimated). The six-way superscalar POWER processor offers pedestrian integer performance but superlative speed on high-end scientific code and high-bandwidth commercial applications such as OLTP.

Newcomer Exponential unveiled its x704, due to ship in 2Q97. The PowerPC chip uses bipolar logic to achieve clock speeds of up to 533 MHz and better projected performance than any PowerPC processor from Motorola or IBM. We give this chip the **Light Bulb** award, in honor of its good ideas and its power dissipation (85 W). Apple and others will use this chip in high-end Macintoshes.

Even as the PowerPC hardware plot improved, the software story descended into lurid prose. PowerPC wins the award for **Most Dead Operating Systems**, as IBM dropped OS/2 support, Sun de-emphasized Solaris for PowerPC, and Windows NT on PowerPC is left with no announced system

vendors. The once all-consuming PowerPC universe has essentially collapsed to proprietary IBM operating systems (AIX, OS/400) and Mac OS.

Despite the dire straits of its own company's processor, IBM's PC group continues to thwart every attempt to leverage its sales channels in support of PowerPC, earning the **Barry Bonds Poor Teammate** award. IBM has a license to sell Mac clones and could become the first major PC maker outside of Apple to adopt Mac OS, but don't expect to see this happen any time soon.

With the evaporation of NT support, major vendors such as Canon and Toshiba have abandoned the PowerPC ship. Although Apple finally opened its Mac OS licensing campaign early last year, it was a case of **Right Place, Wrong Time**. The unimpressive results are that Macintosh clones are available from Motorola and a handful of small companies that few non-Mactivists would know.

The inability of IBM and Motorola to deliver significantly better performance or price/performance than Intel has led to this lack of interest. Recent improvements are simply **Too Little, Too Late**. There remains little reason to use PowerPC for any software that already runs on x86. At this point, PowerPC's market share is tied to Mac OS, the one operating system that doesn't run on x86. Apple's ongoing problems, however, have caused the Mac's market share to drop from about 10% to 7% in the past year, as forecast by Nick Tredennick *(see* **0812VP.PDF***)*.

We're not sure what to make of Apple's new OS strategy *(see* **1101MSB.PDF***)*. If the plan fails, Apple's share will continue to plummet, although the Mac faithful may keep the company alive indefinitely. But even in the best case, a revived Mac OS, along with the next-generation Rhapsody OS, seems unlikely to exceed a single-digit market share. Interestingly, Next's OS has already been ported to x86; we would not be surprised to see Rhapsody on x86 or IA-64 as well as on PowerPC.

Many pundits, including ourselves, had forecast that PowerPC could achieve a 20% share of the desktop market by 2000. Now, it looks like PowerPC will be lucky to own 5–10% at that point. This share is still far better than that of any other RISC and is plenty to keep the architecture afloat, but it won't threaten Intel and, compared with the initial bright hopes for PowerPC, is a **Major Disappointment.**

HP Regains Performance Competitiveness

As Figure 1 shows, HP started 1996 trailing the other major processor vendors, including Intel, in integer performance. The debut of the PA-8000 in April changed all that, pushing HP into the lead in both integer and floating-point performance and completing a **Worst-to-First Leap.** Although the 500-MHz 21164 later surpassed HP's integer score and matched its floating-point score, the PA-8000 remains ahead of all other shipping microprocessors.

The PA-8000 is an impressive device. With a buffer of 56 instructions, it has the **Most Reordering Capacity** of

Major RISC Events of 1996

Digital's 21164 rocketed from 333 MHz *(see* **1002MSB.PDF***)* to 400 MHz *(see* **1003MSB.PDF***)* and then 500 MHz *(see* **100901.PDF***)*. The company also revealed its superfast 21264 *(see* **101402.PDF***)*. Samsung signed on as a third source for Alpha processors *(see* **1009MSB.PDF***)*. Digital cut its processor prices in half *(see* **1017MSB.PDF***)*.

Digital gave a peek at its low-cost 21164PC *(see* **1005MSB.PDF** *and* **1014MSB.PDF***)*. The chip will be the first with Alpha's multimedia extensions *(see* **101505.PDF***)*. The company's FX!32 emulator/translator *(see* **100302.PDF***)* began shipping in the fall *(see* **1014MSB.PDF***)*.

Exponential taped out its BiCMOS PowerPC chip in January *(see* **1002MSB.PDF***)* and described its internal architecture at the Microprocessor Forum *(see* **101401.PDF***)*.

The **PowerPC** 604e jumped to 180 MHz *(see* **1006MSB.PDF***)*, then eased up to 200 MHz *(see* **100703.PDF***)* and ultimately 225 MHz *(see* **1010MSB.PDF***)*. The PowerPC 603e used a shrink to 0.35-micron CMOS to reach 200 MHz (5/27/96, p. 13) and later 240 MHz *(see* **1014MSB.PDF***)*.

Motorola and IBM jointly revealed a new PowerPC roadmap *(see* **101103.PDF***)*.

Apple expanded its Mac OS licensing program by allowing Motorola *(see* **1003MSB.PDF***)* and IBM *(see* **100602.PDF***)* to sublicense the OS to third parties. By year end, seven companies had licensed Mac OS *(see* **1013MSB.PDF***)*.

IBM began shipping its P2SC processor in August *(see* **101104.PDF***)* and outlined plans to deploy a 64-bit Apache processor in mid-1997 *(see* **1004MSB.PDF***)*.

HP shipped limited volumes of the PA-8000 in April *(see* **1005MSB.PDF***)*, seizing the performance lead from Digital. PA-8000 workstations followed in June *(see* **1008MSB.PDF***)*. HP revealed plans for the PA-8200 and 8500 at the Microprocessor Forum *(see* **101403.PDF***)*.

MIPS announced MIPS V and MDMX *(see* **101505.PDF***)*. R10000 servers began shipping in March *(see* **1002MSB.PDF***)*, but workstations didn't ship until the fall *(see* **1013MSB.PDF***)*. The R5000 was announced at 200 MHz *(see* **100102.PDF***)* but shipped at 180 MHz *(see* **1002MSB.PDF***)*.

QED announced plans to sell its own chips *(see* **1012MSB.PDF***)* starting with the RM7000 *(see* **101409.PDF***)*.

Fujitsu's TurboSparc *(see* **101504.PDF***)* began shipping as a successor to MicroSparc-2. **Sun** revealed plans for UltraSparc-2i *(see* **101301.PDF***)*, which will fill in the low end starting in late 1997.

Netpower dumped MIPS in favor of **Pentium Pro** *(see* **1003MSB.PDF***)*. Amdahl chose Pentium Pro over RISC *(see* **1007MSB.PDF***)*. Compaq rolled out its first workstations, all based on Pentium Pro *(see* **1012MSB.PDF***)*.

Microsoft dropped support for **Windows NT** on MIPS *(see* **1014MSB.PDF***)*. IBM and Motorola extinguished NT on PowerPC *(see* **1017MSB.PDF***)*.

any microprocessor *(see* **1101CW.PDF***)*. Its dual floating-point multiply-accumulate units are also unique. All this power comes at a price: at 345 mm^2 in an antiquated 0.5-micron process, the PA-8000 also takes the award for **Biggest Die.**

The company plans to stay in the performance race with a pair of processors derived from the PA-8000. The PA-8200, due this spring, will boost performance by about 40% with a few relatively small changes and a clock-speed boost. As Figure 2 shows, this chip should give HP leadership FP performance, at least until the 21264 appears. The PA-8500, planned for mid-1998, will challenge the 21264's performance using a 0.25-micron process. The 8500 will fill the gap until Merced appears in 1H99.

HP started shipping its new midrange processor, the PA-7300LC, in September. The chip delivers performance similar to that of a 200-MHz Pentium Pro (a bit better on FP, a bit worse on integer). HP itself is now selling Pentium Pro workstations, preparing for the ultimate unification of its product lines around Merced and other IA-64 chips. While the company has a solid plan to address the high end, efforts on IA-64 may prevent progress in the midrange; the 7300LC is probably the last PA-RISC chip to address that space. Well before Merced appears, many HP customers will be faced with the choice of paying a premium to stay with PA-RISC or getting maximum price/performance by adopting Pentium Pro. At least HP can make a sale in either case.

Silicon Graphics Revamps Products

SGI spent the year reworking its entire system lineup, moving to the R10000 at the high end and the R5000 at the low end. Both chips provided performance disappointments, earning MIPS a penalty for **Elastic Marketing Claims.** The R5000 was announced at 200 MHz but never got past 180 MHz in SGI's systems. Performance fared worse, as the announced 5.2 SPECint95 (base) turned into 4.0 when systems rolled out, although it later crept up to 4.7. The chip is now shipping at 200 MHz in embedded applications but not in workstations.

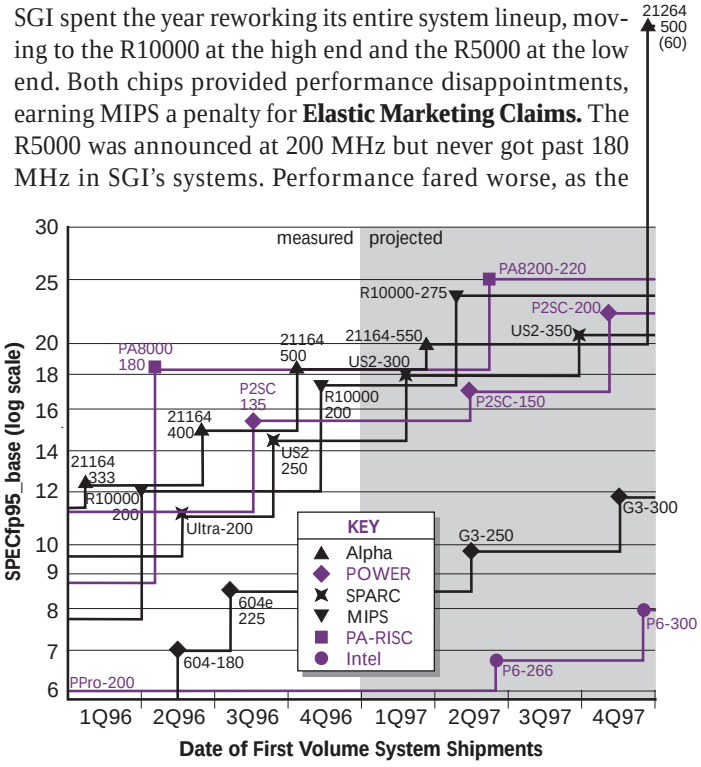


Figure 2. HP is tied for the FP performance lead with Digital and hopes its PA-8200 will reign supreme during 2H97. (Source: SPEC for 1996 data, MDR for 1997)

The R5000 offers significantly lower performance than a Pentium Pro, even on floating-point code, but it costs much less to manufacture. In fact, at just $25, the R5000 has the **Lowest Manufacturing Cost** among all desktop RISC processors. Although this low cost will ultimately aid the R5000 in the embedded market, it does little to help SGI.

The R10000 rolled out in 1Q96, but yield problems prevented the processor from achieving significant volume until the fall. NEC and Toshiba continue to be unable to get more than a few parts to yield at the advertised 200 MHz, although there are enough 195-MHz parts to enable SGI to ship some high-end servers at that speed. These yield problems caused the price of the 200-MHz R10000 to remain at $3,000, making it the **Most Expensive Microprocessor.**

The R10000 had its own performance disappointment: the initial systems were rated at 13 SPECfp95 (base), far short of the 18 originally promised. MIPS explained that system limitations were hampering performance, and by the end of the year, new systems appeared that demonstrated the "true" performance of the R10000 is 17.4 SPECfp95. A final blow was NEC's manufacturing problem that forced it to recall the few thousand R10000s it had shipped, earning the **Most Embarrassing Bug** award.

The past year also saw the demise of Windows NT on MIPS, a promising product cruelly ignored by MIPS parent Silicon Graphics. Earning a **Squandered Advantage** penalty, SGI's complete disdain for NT drove Acer, NEC, and ultimately all other NT-on-MIPS system vendors from the market, leaving Microsoft no choice but to pull the plug, despite having originally developed NT on MIPS systems.

In 1997, SGI will look to the RM7000 to revitalize its midrange. This chip, the first sold under the QED name, is projected to deliver in excess of 10 SPECint95 and 10 SPECfp95, keeping pace with Intel's high end. The R10000 should see a shrink to 0.25-micron in 1H97, boosting the clock speed to 275 MHz and keeping SGI in the performance race with other high-end RISC vendors.

Sun Focuses on Java

It seems an odd match, but we are giving Sun the **Silent Running** award for saying so little about SPARC during 1996, at least in part because the Java spigot was on full (see page 16). One minor misstep: Sun Microelectronics (SME) announced a 182-MHz version of UltraSparc that never shipped; the vendor jumped directly to 200 MHz a quarter later.

In a bigger snafu, SME claimed UltraSparc-2 was shipping in volume at 250 MHz back in June, yet to date the part has appeared in only a few expensive Sun servers for which no benchmarks have been published, earning UltraSparc-2 a **Phantom Product** citation. The culprit appears to be Texas Instruments' manufacturing process, as the UltraSparc-2

design has been complete for months. TI's aggressive plans to advance its IC process technology *(see* **101203.PDF***)* seem to be falling short.

Even if we give Sun credit for the estimated performance of its 250-MHz part, the company languishes in its traditional role of sporting the **Slowest High-End Processor**. If TI can get back on track, UltraSparc-2 may reach 350 MHz this year, but this improvement will be merely enough to compete with Intel's Klamath and the PowerPC G3 for last place in the integer performance race.

Throughout 1996, Sun Microsystems (SMCC) relied on the skanky MicroSparc-2 (1.4 SPECint95) to "power" its low-end and midrange workstations. SMCC recently rolled out systems based on Fujitsu's new TurboSparc chip, which offers twice the performance of MicroSparc-2 but still lags well behind Pentium, much less Pentium Pro, in performance. To gain a competitive low end, Sun needs to move to UltraSparc-2i, a highly integrated derivative of UltraSparc, but this chip isn't due until late 1997 or early 1998.

SMCC's adoption of UltraSparc ended its brief flirtation with Ross Technology's HyperSparc CPU. This loss, coupled with the erosion of the SPARC clone market, left Ross reeling; expenses exceeded revenues by more than 30% in the most recent quarter. Apparently, Ross didn't expect Sun to cut off its purchases of HyperSparc, earning the Texas vendor the **Jeane Dixon Forecasting** award.

Intel Gains Despite Slips

In a change of style, Intel rolled out four speed grades of its new Pentium Pro processor in late 1995 rather than doling them out one per quarter. This strategy vaulted Intel into the integer performance lead, albeit briefly, and garnered plenty of attention. For 1996, however, we are flagging Intel for **Illegal (Lack of) Motion,** as the 200-MHz Pentium Pro remained its high-end processor for the entire year. This inactivity leaves Intel well behind Digital and HP—and, to a lesser extent, MIPS and PowerPC—in integer performance, although Intel still leads the laggard SPARC.

Things are looking better for 1997. The next P6 processor, Klamath, is expected to appear in 2Q, boosting clock speeds to 266 MHz. Faster clock speeds await the deployment of Intel's 0.25-micron process, due in 2H97. We expect to see the P6 hit 300 MHz by the end of this year, but even this improvement will not allow Intel to approach the performance lead in 1997.

Intel's only new desktop processor for most of 1996 was the 200-MHz Pentium. Introduced with "immediate availability" in June, the chip was extremely difficult to find in systems until well into the fall, earning Intel a **Phantom Product** citation. Intel denies any production problems; the good news is that the chip is now widely available.

Despite these problems, even the 1995-vintage Pentium Pro was enough to disrupt RISC vendors' plans. Earning an **Operation Crush** award, the chip delivered enough performance to block MIPS and PowerPC from gaining NT design wins, as vendors from Amdahl to Netpower chose Pentium Pro over RISC chips. Only Alpha, with its superior performance, remains to challenge Intel in the NT space.

These NT vendors represented only incremental business to RISC chip vendors, so losing them does little harm. Pentium Pro's real threat is against the RISC workstation and server businesses that form the heart of the revenue streams of Sun and Silicon Graphics. This threat is exemplified by Compaq's entry into the workstation market, with its lineup based entirely on Pentium Pro and Windows NT. These systems offer performance (integer, floating-point, and 3D graphics) similar to that of low-end and midrange RISC workstations but, taking advantage of PC components and economies of scale, at significantly lower prices.

Leveraging their own PC businesses, Digital and HP are now offering similar Pentium Pro workstations, using the **Eat Your Own Young** strategy popularized by Intel. Sun and SGI, however, have no such alternative; their low-end and midrange business appears doomed. Sun is trying to reinvent itself as a high-end-server and thin-client vendor, while SGI appears to be positioning itself as a high-end 3D and supercomputer company. Both companies see Web servers as a major market opportunity, although Pentium Pro will provide competition there as well. We believe these tricky business conversions will limit growth for at least the next few years, making it more difficult to support in-house RISC architectures such as SPARC and MIPS.

Intel Challenges Cozy RISC Vendors

Within the cozy confines of the RISC enclave, 1997 appears devoid of earthshaking events. Digital and HP will vie for the performance leadership crown. Quarter-micron versions of the R10000 and UltraSparc-2 will improve the competitiveness of these parts. PowerPC and Intel will trail in performance, particularly on floating-point applications, but the gap on integer code will not be as great as in the past. No new processor cores are slated to appear from the major vendors until the debut of the 21264, likely to be at the very end of the year (or later). When it appears, the forthcoming Alpha chip will open an enormous performance gap.

Among customers considering either RISC- or Intel-based systems, however, the plot is more likely to resemble that of *Mars Attacks!*, with the P6 playing the role of the little green men. The combination of the P6 and Windows NT delivers a price/performance advantage over RISC/Unix systems, and the P6, particularly in low-cost dual-processor configurations, can match the performance of all but the fastest RISC systems on most tasks. Because of the high degree of software lock-in among RISC users, this effect will not vaporize any RISC vendors overnight, but it will place a drag on sales and particularly on profits. As in *Independence Day*, RISC vendors must devise an innovative solution to thwart an incredibly powerful and aggressive foe. M