"Mike Malone does the legacy of Hewlett and Packard a great service with this book. I hope it inspires a whole new generation of entrepreneurs to rise to the standards set by these two remarkable leaders."

—Jim Collins, author of *Good to Great*, coauthor of *Built to Last*

MICHAEL S. MALONE

BILL & DAVE

How Hewlett and Packard Built the World's Greatest Company

Contents

A selection of photographs follows p. 214

more realistic final version of the model 3000? Very likely. Did they take credit for having stage-managed the whole thing? Never.

Listening to Outsiders

Hewlett-Packard's entry into a second new market during the 1960s offers another glimpse at the way Bill and Dave were evolving their management techniques to match the changing nature of their company.

The Loveland division's decision to conduct its own R&D, and thus free HP Labs to explore emerging technologies, resulted not only in HP's entry into computers, but also calculators. Even more than computers, arithmetic calculators had a very long history, predating electronics by centuries. Their roots lay in ancient mechanical devices, such as the abacus, and, beginning in the seventeenth century with John Napier's discovery of a logarithmic equation to perform multiplication and division, the slide rule. By the early twentieth century, mechanical adding machines were a common desk tool and the heart of accounting and statistics. By the 1950s, these machines were not only electrified, but capable of very sophisticated mathematical calculations. They seemed a natural target for the improvements in speed, power, and miniaturization made possible by the transistor and the integrated circuit.

But was it a job for Hewlett-Packard to take on? Dave Packard had thought perhaps so, but his visit to Wang Labs had convinced him otherwise.

Yet just a few months later he not only changed his mind, but embraced the idea of an HP calculator with even greater fervor than he had the computer. Why? Because Packard finally saw a version of the technology that fit the company's criteria for innovation, contribution, and integration with current HP products. What makes this story especially compelling is that it came from a most unlikely source. HP had almost always invented its own products—and when it didn't, it acquired those products and their underlying technologies, patents, and so on as part of a corporate acquisition.

But in the case of HP's entry into calculators, one of the most momentous decisions in its history, the idea literally walked in through the door—twice.

In 1965, just as HP Labs was embarking on the 2116A project, Barney Oliver was visited, independently, by two inventors over the course of as many weeks. The two men, who had never met each other, in fact embodied the absolute leading edge of the two great movements in the automated computation world.

Malcolm McMillan was a Los Angeles physicist and mathematician who had come across the innovative work of an aerospace engineer named Jack

Volder. In 1956, Volder had published an internal Convair report (published in two formal reports to the IRE three years later) describing how to use binary numbers in a process of repeated shifts and adds to perform amazingly complex trigonometric and other calculations.

McMillan realized that this "algorithm," called CORDIC, which had originally been created for use in the world's first supersonic bomber, the B-58 Hustler, could be used as the brains of a new kind of calculator for scientific applications. He contacted Volder, convinced him to team up, and together they built the prototype of the world's first scientific calculator. Then McMillan hit the road to find a buyer.

Given his background, it wasn't surprising that McMillan eventually arrived at Hewlett-Packard, where, in June 1965, he made a presentation of his product, code-named "Athena," to Barney Oliver and Paul Stoft (the latter back from his work on the 2116A). As Oliver described his meeting with McMillan, "He and the other guy [Volder] had developed a calculator which could perform transcendental operations, transcendental functions, and he brought this big kluge with him. It was a box about the size of two beehives. They finally got it working and computed a tangent and other trig functions for us. It took over a second to do this."[13]

Oliver may have been disappointed with McMillan and Volder's hardware, but he instantly recognized that the CORDIC algorithm was a major breakthrough. So he decided to show just enough interest to keep the pair talking to HP, but not enough to let them any closer than arm's reach. Meanwhile, he hoped to find a hardware solution somewhere.

Within days, in an amazing bit of serendipity, that solution walked into his office.

Tom Osborne was a singular individual, a classic Silicon Valley personality. A young Berkeley grad, he was working at a typewriter/office equipment company, SCM, that was already a major manufacturer of old-fashioned rotary mechanical calculators under the Smith-Corona brand. SCM knew that if it was going to stay competitive it would need to get into electronic calculators. It licensed just such a technology from consultant (and former Manhattan Project physicist) Stanley P. Frankel—and then hired Tom Osborne to evaluate the idea, then make it real.

It wasn't long before Osborne hit what seemed an insurmountable obstacle: Frankel's design required a lot of diodes, and to cut costs, SCM wanted to use "off-spec" diodes, which cost a nickel, rather than higher quality, full-performance versions that cost a quarter. Osborne knew it wouldn't work: SCM's plan would either produce a machine that didn't work at all, or would be painfully slow.

But he couldn't convince his superiors. "I was a junior employee and

totally unable to convince them that there was a better way to design things," he recalled.[14] Finally, he could stand no more: he refused to continue working on the project: "In the fall of 1963 I told them that I could no longer help them produce a calculator that, in my opinion, was doomed to failure (it was, and it did). I offered to design a machine for them at no cost if they would give me lab space. Later, if they liked what they saw, they could pay me for the time I had spent in the design and construction.[15]

SCM turned him down, saying it didn't conform to company policy. Then the company turned around and threatened to sue him if he didn't turn over all of his research into the alternative calculator design, as well as the calculator prototype itself. When Osborne replied that there was no prototype, the SCM lawyers refused to believe him, determining that no one could be so confident as to make such a "can't lose" offer to a major corporation without having already built one. Exasperated, Osborne hired his own lawyer and ran the company off.

(SCM did in fact go on and build its calculator with the off-spec diodes. Introduced in 1966, it was a disaster. Oliver himself dismissed it as "a miserable machine. It took forever to do anything.")[16]

Tom Osborne began 1964 "unemployed, miffed, but well armed with good design techniques."[17] With his wife supporting him, he set out to finally build the calculator that had existed only in his imagination. From the start, he planned to build a prototype that was "going to be about 100 times faster, take about one tenth of the power, be about a third of the size and weight of the then-existing calculators, and have a floating point arithmetic unit that produced 10 significant digits of accuracy."[18] In other words, he planned to build the first true electronic calculator.

Shrewdly, he also decided to divide the prototype into two connected boxes—one with a keyboard and display that would show the anticipated size of the finished calculator, the other containing the real processor guts of the calculator. This enabled him, unlike McMillan, to show the actual anticipated size of the finished product—and not scare prospective customers into thinking the machine would be huge.

It took him most of the year to build the prototype, all the time wishing he had just such a calculator to help him design it. He finished on December 24, 1964.

> Finally, on Christmas Eve afternoon in 1964 the calculator was totally functional. I remember the overwhelming realization that sitting in front of me on a red card table in the corner of our bedroom/workshop, sat more computing power per unit volume than had ever existed on this

> planet. I felt more like the discoverer of the object before me than its creator. I thought of things to come. If I could do this alone in my tiny apartment, then there were some big changes in store for the world.[19]

Mounting the components it into two handmade balsa-wood boxes, Osborne finished by spray-painting everything with Cadillac green automotive paint. Then, with his "Green Machine" in hand, he set out to find a buyer.

He soon discovered the nightmare of being a lone inventor trying to show a new product to a major corporation. Some flatly refused to talk with him. Others demanded he sign a nondisclosure agreement so onerous that he could only conclude they were preparing to legally defend themselves after they stole his idea.

There were times when Osborne's sales tour devolved into farce:

> The IBM people were not slowed down a bit by their inability to find [my] apartment's slightly hidden entry. They climbed the fire escape and knocked on the fire exit window. I opened it and they entered by climbing over the hi-fi set which partially blocked their entry. Through it all they retained their composure.[20]

The only good thing to come out of that meeting was that henceforth Osborne adopted IBM's nondisclosure agreement as his own.

Before he was done, Tom Osborne pitched to and was turned down by thirty companies—including Hewlett-Packard. A few had even passed on the calculator but offered Osborne himself a job—and he returned the favor by turning them down. The absolute nadir came in a series of meetings with Friden Corp., then the world's leader in calculators, and the reason SCM had been rushing to get into electronic calculators. Friden initially showed enormous interest in his calculator, but as negotiations went on, Osborne grew increasingly suspicious of the company's motives. Finally, he nixed the deal—only to learn later that Friden had planned to buy his technology and kill it to get rid of any competition to its current line.

It was a weary, frustrated, and much wiser Tom Osborne ("I was about at my rope's end") who, in June 1965, finally decided to take a break after six miserable months pitching his invention, and gave himself a vacation.

At precisely that moment, across the Bay in Palo Alto, Tony Lukes, an HP engineer, was talking with Paul Stoft about the meeting with McMillan and Volder. They've got something there, Stoft told him, at least in the software. But the hardware is a mess. We can't even consider taking it on without a better box to put it in.

A light went on in Lukes's head. He told Stoft about a guy he used to work with at SCM, a terrific design guy, who he heard was working on a calculator project of his own.

Bring him in, said Stoft, and let's see what he's got.

But when Lukes called, he only got Osborne's answering machine. Eventually the two men connected, and Tom Osborne at last found himself inside Hewlett-Packard, in Paul Stoft's office, giving yet one more demonstration of the Green Machine. Stoft quietly watched the presentation for a few minutes, then asked if Osborne minded if they could be joined by Barney Oliver, the head of the lab. Sure, said Osborne.

Oliver in turn watched the presentation and, like Stoft before him, realized that he was seeing the future: Tom Osborne's Green Machine, the best calculator hardware design yet devised, running McMillan and Volder's CORDIC algorithm. There would be nothing on the planet to match—and likely nothing even being developed close to it. And the two company scientists knew that HP's customers would love it.

Recounts historian Steve Leibson, "How did Oliver and Stoft know? They used the same marketing technique that served HP well from its founding in 1939 to about 1990: next-bench market research. Briefly, next-bench market research means taking an idea to the engineer at the next bench. If he (all HP engineers were 'he' back then) liked it, then it was sure to succeed."[21]

Oliver had only one question: could Osborne redesign his device to run CORDIC? "Yes," replied Osborne, not knowing what Oliver was talking about, but convinced he could do anything with his design.

Oliver then took Osborne down the hall and showed him a prototype printed circuit board for a new kind of onboard computer memory for microcode called read-only memory (ROM). The Green Machine only used simple diode-based logic. Could the calculator be redesigned using this? Osborne hesitated, not because he didn't think he could do it, but because he wasn't sure that HP Labs could really scale the ROM up the fifty times needed to drive his calculator. "Yes," he finally said, praying that he was right.

Great, said Oliver. He inquired if Osborne could return the next day and meet with Bill and Dave. "Bill and Dave who?" Osborne asked.

> The meeting the next day was memorable. Nothing like it had occurred with the previous companies. It appeared to me that while other companies were looking for a weakness that might preclude them from success, HP was looking for the opportunity that might lead to a success.*
>
> We discussed the project's good points, its weak points, and the risks involved to both parties. We agreed to give it a try for six weeks during which I would explain my design processes to HP's engineers and per-

form a total evaluation of the project. The meeting was about over when Mr. Packard said, "Oh Tom, we won't take the project without you coming along with it." I said, "You can't have it without me."

In those few words it was clear to me that one of my main tasks was to transfer the information that existed only in my mind into the minds of the people with whom I would be working for a couple of years. It was also clear that I was among people who were open minded and trained to advance the state of the art.[22]

At the end of the meeting, Hewlett asked if he could take the Green Machine home for a few days and play with it. Osborne agreed, but when he returned to HP to pick up the machine and get to work, he was met by a sheepish and apologetic Bill Hewlett. It seemed that Bill had been so excited playing with the calculator that he had somehow managed to poke his thumb right through the balsa-wood box. Worse, he was afraid that he'd burned out all of the circuitry by accidentally plugging in the power supply backwards—which appeared to have shorted out the Green Machine.

Luckily, Tom Osborne had prepared for just such an eventuality by installing a protective power diode. It saved the calculator. Relieved, Hewlett welcomed Osborne to HP, and they agreed upon a brief four- to six-week evaluation period to work with McMillan (now a company consultant) and HPer Dave Cochran to see if the Green Machine could be turned into a real, CORDIC-equipped product. Osborne recalled:

At the end of the six-week evaluation process, Al Smith of HP's legal department dropped by and gave me a check which meant that the project was a go. I was excited. The check was nice, but the opportunity to do the project was everything I had hoped for. At that time, I decided that if the project was to get into serious trouble, I would be the first one to know, and I would immediately tell Barney that we should cancel the project. The HP people had placed a great deal of faith and trust in me and I was not going to misuse it.[23]

Tom Osborne, it seems, was already part of the HP Way. He would never be a Hewlett-Packard employee ("He had a kind of free spirit about him," recalled Oliver) but would remain connected with the company for more than a decade as a consultant or contractor. His very presence at HP—an increasingly legendary figure who would come and go at the company according to when he was needed or when inspiration struck—was something new for Hewlett-Packard.*

The First Desktop Revolution

The product that emerged from the marriage of the Green Machine and CORDIC was the Hewlett-Packard model 9100A desktop calculator. The prototype, built at the same time and alongside the 2116A computer at HP Labs, took just over a year to complete.

It was a masterpiece of design discipline. Oliver would later describe the creation of the HP 9100A as "exothermic," thereby comparing it to a chemical reaction in which various components mixed together spontaneously produce heat and light. What he meant was that the 9100A project brought together the lab's in-house experts in logic circuits, minicomputer core memory, software, firmware, displays, and industrial design. And presiding over it all was the nonemployee Tom Osborne.

Some of the most important players in the project had no real experience in what they were assigned to do. Thus, Dave Cochran, who had just finished work on an HP digital voltmeter, found himself in a meeting about the calculator, listening to Barney Oliver talk about developing the right algorithms for the calculator to compute efficiently. "What's an algorithm?" Cochran asked—and Oliver immediately gave him the job of devising them. Cochran quickly embarked on a months-long research project—including learning how to program a computer—before he could even get started on his new assignment. He recalled, "Up until at least the 1980s, HP believed that any engineer it hired could undertake just about any engineering project: analog design, digital design, IC design, software programming, production engineering, component design, etc. After all, Bill Hewlett was an engineer's engineer and the same was expected of all HP's engineers."[24]

Cochran's experience wasn't unique. In fact, the engineer eventually assigned to manage the 9100A project, Dick Monnier, had most recently been a project director in oscilloscopes, and he had almost no experience with computers.

But it all worked, not least because Tom Osborne's long months working in his apartment had given him not only an unequaled expertise in calculator function, but the kind of supreme adaptability that comes from building sophisticated electronics with Elmer's glue, balsa wood, and automotive paint. Over and over through that year, whenever the project hit a wall in circuit design or architecture, he somehow—and to the astonishment of others on the project—came up with a solution.

The most famous of these was Osborne's decision to use a most unlikely form of memory in the calculator. In those days, any integrated circuits you could trust were too expensive for use in anything but rockets and aircraft, and those you could afford for everyday use were too unreliable. For that rea-

son, HP decided to build the guts of the 9100 from standard diodes and other discrete semiconductor devices and stacked, custom-made printed circuit boards. But, as Osborne laid out this circuitry, he realized that the 9100A just didn't have enough read-only memory.

His solution was to create a memory 'rope': a braid of wires linking together an array of tiny doughnut-shaped magnets (the "core" in old-fashioned mainframe computer core memory) threaded through the limited space that remained in the box. It was this kind of practical engineering genius that made Osborne a legend inside HP even before the 9100A was completed.

All the while, watching over the 9100A project like a nervous father, was Bill Hewlett. Perhaps in part because he had almost destroyed the Green Machine, and because he was, in Leibson's words, something of "an engineering aesthete," but most of all because he wanted HP to create the biggest possible splash in the calculator market, Hewlett ordered for the 9100A an absolutely top-notch package: sleek and space-age, it was so distinctive for the time that the 9100A would eventually find a home as a prop in a number of movies. (It would also be echoed in the design of the iconic Apple II.)

Practical as always, Hewlett also made another demand of the 9100A: calling a meeting in his office, he had the team gather around his walnut desk. Pulling out the standard typing stand built into the desk, he told the team that he wanted the new calculator to not only fit on the stand, but also be small enough to be folded away with it just like a typewriter. If the 9100A really was to be an office tool, as well as a lab tool, Hewlett told them, it would have to fit into the office world. Writes Leibson, "It was a little ironic that the form factor of this extremely complex and advanced piece of electronic computing equipment was to be determined by an old piece of office furniture . . . a 19th century piece of equipment."[25]*

But Hewlett was right. One revolution at a time. If the assembled team suppressed a collective gulp, they also now knew exactly what was expected of them. And if they set to work with serious doubts whether they could accomplish everything expected of the 9100A, they also had the enthusiasm of engineers working at the very limits of the known tech world. Recalled Osborne, "For the next two years I spent some long hours keeping the various aspects of the HP 9100 project on course. I was barely able to stay ahead of the alligators on my tail."[26]

The prototype of the 9100A was at last finished in early 1967. In the end, it was everything HP wanted in its first calculator: a beautiful design, breakthrough technology, and performance that far outdistanced anything else on the market. The 9100A didn't just make a contribution, as required by the HP Way, but fundamentally changed an entire industry—arguably creating a brand-new one. Calculators would never be seen the same way again; almost

overnight, they went from being simple arithmetic tools to powerful computational engines. And in a world still ruled by slide rules, the HP 9100A literally changed, in both labs and offices, the very notion of what constituted precision in measurement.

But there was still one small matter: would it fit in Bill Hewlett's desk?

Luckily, Hewlett was out of town. So the team carefully lugged the prototype calculator over to his office—tellingly, how many other CEOs would allow employees to wander around his office while he was gone?—and set it on the desk's typewriter stand.

It fit. The team silently cheered.

Now the acid test: they slowly folded the stand into the opening in the desk. There was a dull clunk as the top of the 9100A smacked into the top of the opening. The team gasped: it didn't fit. Now what?

What happened next offers an interesting glimpse into not only the ingenuity but also the generally unappreciated humor and iconoclasm that also characterized Hewlett-Packard during this era.

The team quickly agreed upon a solution, and one of them ran off to retrieve one of the carpenters from downstairs in the company shop. He soon arrived with his tools, and under the instruction of the team widened the opening in the desk by about an eighth of an inch, then carefully cleaned up the evidence.

According to Dave Cochran, Hewlett never noticed the subterfuge. But other team members weren't convinced; they believed that Hewlett immediately spotted the work done to his desk and, amused, never said a word.*

The first public unveiling of the 9100A was to be at the March 1968 IEEE Electro show in New York. By then, the team had built five prototypes and planned to set them up in a hotel suite (standard procedure for new products not yet ready for market) to show off to select visitors, such as large customers, distributors, and even competitors.

One of those competitors invited, out of professional courtesy, was An Wang, the already legendary CEO of Wang Laboratories, the company Dave Packard had long ago visited and concluded that calculators weren't in HP's future. Now HP had a calculator that it believed put in the shade anything in the Wang catalog.

But not long before Wang was schedule to arrive, Barney Oliver did one last quick check-over of the five machines. As he opened the lid of one to check on the components inside, his tie, full of static electricity from having walked across the suite's carpet, accidentally brushed across the 9100A's logic board, shorted out the circuitry—and instantly killed the prototype.

Hewlett quickly ordered the dead calculator taken away and hidden, the four surviving machines were rearranged, and the team pretended that noth-

ing had happened. When Wang at last arrived, Hewlett immediately led him to a 9100A and had Oliver and Osborne demonstrate to him how the machine worked.

Wang watched the demonstration in stunned silence. Then he shook the men's hands and took his leave. At the door, he turned to Hewlett and said, "You have a good machine. We had better get busy."

It was a moment of triumph. In just two years Hewlett-Packard had come out of nowhere, entering one of the most innovative and hotly contested new businesses in high tech, and had produced an initial product so superior to anything on the market or under development that it had left one of the current industry leaders in a state of barely concealed panic. The HP 9100A was about to make Hewlett-Packard Co. a fortune.

(Thirty years later, *Wired* magazine noted that an October 4, 1968, ad for the $4,900 "Hewlett-Packard 9100A personal computer" was the very first recorded use of that term. It seems that the 9100A not only kicked off the scientific calculator revolution, but, in language at least, the personal computer age as well.)

The others may have been ready to go out and celebrate. But not Bill Hewlett. In one of the defining moments of his career, he was already looking ahead. Wang, to save his company, would now move heaven and earth to catch HP. So would Friden. HP had won today, but it would be a brief victory if the company didn't keep moving.*

Hewlett turned to Osborne and pointed at the row of shiny new calculators. "I think the next machine should be a tenth the cost, a tenth the size, and be ten times faster than the HP 9100."

Tom Osborne was at least as shocked as An Wang had been. At that moment he was the world's leading expert on electronic calculators. He had just built the greatest calculator in the world. And now, at the moment when he should have been savoring his achievement, he'd been given instead a new assignment—one that he knew in his heart was technically impossible.

Four years later, with the help of some fortuitous technology breakthroughs, Osborne built that calculator. It would be the most famous product in Hewlett-Packard history.

In the Chips

The third in this troika of new businesses for Hewlett-Packard in the 1960s was semiconductors. With all of the attention given to HP computers and calculators, the fact that HP was both a pioneer and a major player in