WHERE ARE THE WORLD'S TOP 100 I.T. FIRMS--AND WHY?

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Like the Internet after 1994, the personal computer or PC started a new era in the evolution of information technology (IT). In 1981, prompted by the success of the Apple II, IBM introduced its PC and marketed it to the business world as a machine with a "killer application," the Lotus 1-2-3 spreadsheet. The PC's birth pangs rattled the geography of the U.S. computer industry. To speed product development, IBM had out-sourced the microprocessor and operating system. That new policy both recognized and accelerated the realignment of the industry away from the Northeast.

Today, in the resurgent American IT sector of the late 1990s, the new dominant firms are headquartered in the West. The result might be described as "The Westward Rebirth of American Computing." (R.D. Norton, 1996.) In an earlier paper by that name, I made the case that the regional realignment was a key step toward restoring the U.S. lead in the information-technology race with Japan, because IBM and Digital Equipment Corporation (DEC) had bogged down in the bureaucratic inertia characteristic of large, mature firms. New entrepreneurs had to enter the arena, and their innovations could blossom best in the more open and fluid economic cultures of the West.

This paper updates the story by examining where the world's leading IT firms were headquartered in 1997, and why. Our method is to structure the weltering crosscurrents of theory and evidence via five questions and to propose five tentative answers.

The key issue is, "*…and Why?"* This, it turns out, is actually three distinct questions. The lead states in the new IT geography--California, Texas, and Washington--hold strikingly different roles in the spatial division of labor. In a nutshell, the Texans embody the efficiency and marketing skills that IBM and Route 128 once claimed. For its part, Silicon Valley is widely recognized as the world's most creative regional network for new activities--including Internet-related activities. Yet it is Seattle, not the Valley, that has become the current command center for the world's IT activities. Bill Gates, a classic robber-baron visionary, may have had as much to do with the westward realignment and the American resurgence as Silicon Valley's clustered fountain of youth.

1. WHERE WERE THE 100 "MOST INFLUENTIAL" I.T. FIRMS IN 1997?

TABLE 1 shows the July 1997 *PC Magazine* list of the world's 100 "most influential" I.T. firms. The criteria for the list are subjective. As the compiler puts it, "Our effort to create this…list started (rather than ended) with a mere enumeration of the sales leaders. …we expanded our search to target not just the richest or best-known companies but the most influential. …And judging from

TABLE 1

PC MAGAZINE'S 100 MOST INFLUENTIAL PC COMPANIES IN THE WORLD IN 1997

1	Microsoft Corp.	
2	Intel Corp.	
3	IBM Corp.	
4	Netscape Communications	
5	Sun Microsystems Inc.	
6	Compaq Computer Corp.	
7	Hewlett-Packard Co.	
8	Cisco Sytems Inc.	
9	Oracle Corp.	
10	Toshiba Corp.	Japan
11	Dell Computer Corp.	
12	Apple Computer Inc.	
12	Adobe Systems Inc.	
14	Gateway 2000 Inc.	
15	Novell Inc.	
16	3Com Corp.	
17	Corel Corp.	Canada
18	America Online Inc.	
19	PointCast Inc.	
20	Packard Bell NEC Inc.	
21	Softbank Corp.	Japan
22	Intuit Inc.	
23	Digital Equipment Corp.	
24	Silicon Graphics Inc.	
25	Symantec Corp.	
26	U.S. Robotics Corp.	
27	Canon Inc.	Japan
28	Progressive Networks Inc.	
29	Macromedia Inc.	
30	id Software Inc.	
31	Seagate Technology Inc.	
32	Advanced Micro Devices Inc.	
33	S3 Inc.	
34	Acer Group	Taiwan
35	Marimba Inc.	
36	McAfee Associates Inc.	
37	Micron Technology Inc.	
38	Autodesk Inc.	
39	Bay Networks Inc.	

40	Creative Technology Ltd.	Singapore
41	GT Interactive Software Corp.	
42	Ascend Communications Inc.	
43	Sony Corp.	Japan
44	Cyrix Corp.	
45	Diamond Multimedia Systems	
46	CUC International Inc.	
47	Computer Associates Intl.	
48	AT&T Corp.	
49	Texas Instruments Inc.	
50	International Data Group	
51	Seiko Epson Corp.	Japan
52	Xerox Corp.	
53	Iomega Corp.	
54	Dialogic Corp.	
55	Samsung/AST Research	Korea
56	Logitech International SA	Switzerland
57	Matsushita Electric Industrial	Japan
58	National Semiconductor Corp.	
59	PC Connection Inc.	
60	Sharp Corp.	Japan
61	Fujitsu Ltd.	Japan
62	Hitachi Ltd.	Japan
63	NEC Corp.	Japan
64	Borland International Inc.	
65	MetaToold Inc.	
66	Matrox Graphics Inc.	Canada
67	Sybase Inc.	
68	MCI Communications Corp.	
69	Motorola Inc.	
70	Hayes Microcomputer Products	
71	Adaptec Inc.	
72	Philips Electronics NV	Netherlands
73	Western Digital Corp.	
74	Activision Inc.	
75	Cirrus Logic Inc.	
76	Cabletron Systems	
77	ATI Technologies Inc.	Canada
78	Aimtech Corp.	
79	Computer Discount Warehouse	
80	Quarterdeck Corp.	

81	CompuServe Inc.	
82	Idealab!	
83	DeLorme Mapping Co.	
84	Informix Software Inc.	
85	Lexmark International Inc.	
86	Madge Networks Inc.,	
87	Broderbund Software Inc.	
88	Phoenix Technologies Ltd.	
89	Power Computing Corp.	
90	Be Inc.	
91	Number Nine Visual Technologies	
92	Eastman Kodak Co.	
93	The Santa Cruz Operation Inc.	
94	ViewSonic Corp.	
95	Rockwell Semiconductor Systems	
96	SAP AG	Germany
97	The Learning Company Inc.	
98	Tektronix Inc.	
99	Yahoo! Inc.	
100	Firefly Network Inc.	

our own debate, the relative rankings of the group as a whole will be more than a little controversial."   (Jake Kirchner, 1997, p. 214.)

Several obvious caveats are in order here. First, the list attempts to answer the question, "Which companies are the true leaders in personal computing?" (P. 213.) Hence the perspective is from the PC industry, not from that of mainframes or (whatever is left of) minicomputers. Still, and as will be suggested shortly, PC's now set the agenda for all of I.T. Second, this is an American list; to that extent it is subject to the usual notorious cultural myopia of the U.S.A. Third, the lack of a single, objective criterion (like the ones used in the traditional *Fortune 500* list, for example) renders the exercise open to dispute, as the editors suggest.

These objections appear slight. Our concern is not whether the listing of Microsoft first, Intel as second, and IBM as third is precisely the right ordering. Further, perhaps a key firm or two at some functional distance from the PC industry, or in another country, has been mistakenly left off the list. Such nuances will not matter much here. The method to be employed below is simply to count regional (and national) locations, among the putative top 100. Any other list of the top 100 I.T. firms would probably show quite a similar histogram across regions and nations.

This method does have its own specific bias or distortion, however. That is to give as much weight in a state's profile to a virtual unknown like Massachusetts' little Firefly Network Inc. (number 100 in the list, and since taken over by Microsoft) as to, say, IBM. One cannot necessarily judge a particular state's importance in the I.T. picture by the number of top-100 firms that call it home. Texas and Washington are cases in point--I.T. giants with few (or only one!) top-100 firms.

THE LOCATIONS OF THE TOP 100

That said, a few basic observations can be made about TABLES 1 and 2. Our aim at this stage is only to lay out the landscape, not to explain the patterns.

<u>(1) Most (80) of the 100 top firms are American</u>. Japan accounts for 10 listings: Toshiba (number 10), Softbank (21), Canon (27), Sony (43), Seiko (51), Matsushita (57), Sharp (60), Fujitsu (61), Hitachi (62), and NEC (63). Canada has three: Corel (17), Matrox Graphics (66), and ATI Technologies (77). Collectively, Europe has three (Switzerland's Logitech International, the Netherlands' Philips Electronics, and Germany's SAP), but none in the top 50. Taiwan's Acer is ranked at 34, and Korea's Samsung/AST Research at 55. Putting the counts and ranks another way,

TABLE 2

THE TOP 100 BY STATE, REGION, AND NATIONALITY

State	City	Company	Primary activity
North (22)			
NY (6)	New York	GT Interactive Software Corp.	Software
NY	Armonk	IBM Corp.	hardware/software
NY	Alameda	Ascend Communications Inc.	Internet
NY	Islandia	Computer Associates International Inc.	Software
NY	New York	AT&T Corp.	Telecommunications
NY	Rochester	Eastman Kodak Co.	Software
MA (4)	Framingham	International Data Group	Media
MA	Maynard	Digital Equipment Corp.	hardware/software
MA	Lexington	Number Nine Visual Technologies Inc.	Telecommunications
MA	Cambridge	Firefly Network Inc.	Internet
NH (3)	Milford	PC Connection Inc.	Distribution
NH	Rochester	Cabletron Systems	Internet
NH	Nashua	Aimtech Corp.	Software
IL (3)	Skokie	U.S. Robotics Corp.	Telecommunications
IL	Schaumburg	Motorola Inc.	Semiconductors
IL	Vernon Hills	Computer Discount Warehouse	Distribution
CT (2)	Stamford	CUC International Inc.	Software
CT	Stamford	Xerox Corp.	Hardware
OH (2)	Mayfield Village	Progressive Networks Inc.	media/internet
OH	Columbus	CompuServe Inc.	Internet
ME	Yarmouth	DeLorme Mapping Co.	software/internet
NJ	Parsippany	Dialogic Corp.	Semiconductors
South (5)			
GA (2)	Norcross	Hayes Microcomputer Products Inc.	Telecommunications
GA	Norcross	Intuit Inc.	Software

KY	Lexington	Lexmark International Inc.	Hardware
VA	Dulles	America Online Inc.	Software
DC	Washington	MCI Communications Corp.	Internet
West (53)			
CA (43)	Santa Clara	Intel Corp.	Hardware/semiconduct.
CA	Mountain View	Netscape Communications Corp.	software/internet
CA	Mountain View	Sun Microsystems, Inc.	Software
CA	Palo Alto	Hewlett-Packard Co.	Hardware
CA	San Jose	Cisco Systems Inc.	Internet
CA	Redwood Shores	Oracle Corp.	Software
CA	Cupertino	Apple Computer Inc.	Hardware
CA	San Jose	Adobe Systems Inc.	Software
CA	San Jose	Novell Inc.	Software
CA	Santa Clara	3Com Corp.	Internet/hardware
CA	Sunnyvale	PointCast Inc.	Telecomm./internet
CA	Sacramento	Packard Bell NEC Inc.	Hardware
CA	Mountain View	Silicon Graphics Inc.	Hardware
CA	Cupertino	Symantec Corp.	Software
CA	San Francisco	Macromedia Inc.	Internet
CA	Scotts Valley	Seagate Technology Inc.	Hardware
CA	Sunnyvale	Advanced Micro Devices Inc.	Semiconductors
CA	Santa Clara	S3 Inc.	Semiconductors
CA	Mountain View	Marimba Inc.	Software
CA	Santa Clara	McAfee Associates Inc.	Software
CA	San Raphael	Autodesk Inc.	Software
CA	Santa Clara	Bay Networks Inc.	(network)
CA	San Jose	Diamond Multimedia Systems Inc.	media (entertainment)
CA	Santa Clara	National Semiconductor Corp.	Semiconductor
CA	Scotts Valley	Borland International Inc.	Software
CA	Carpinterid	MetaTools Inc.	Software
CA	Emeryville	Sybase Inc.	Software
CA	Milpitas	Adaptec Inc.	Semiconductor
CA	Irvine	Western Digital Corp.	Semiconductor (software)
CA	Santa Monica	Activision Inc.	Software
CA	Fremont	Cirrus Logic Corp.	Semiconductor
CA	MarinaDelRay	Quarterdeck Corp.	internet/software

CA	Pasadena	Idealab!	(internet)
CA	Menlo Park	Informix Software Inc.	(database?)
CA	Novato	Broderbund Software Inc.	Software
CA	San Jose	Pheonix Technologies Ltd.	Software
CA	Cupertino	Power Computing Corp.	Hardware
CA	Menlo Park	Be Inc.	Software
CA	Santa Cruz	The Santa Cruz Operation Inc.	Internet
CA	Walnut	ViewSonic Corp.	Hardware
CA	Santa Clara	Yahoo! Inc.	Internet
CA	Costa Mesa	Rockwell Semiconductor Systems	Semiconductor
CA	Fremont	The Learning Company Inc.	Software
TX (5)	Houston	Compaq Computer Corp.	Hardware
TX	Round Rock	Dell Computer Corp.	Hardware
TX	Mesquite	id Software Inc.	Software
TX	Richardson	Cyrix Corp.	Semiconductor
TX	Dallas	Texas Instruments Inc.	Semiconductor
UT	Roy	Iomega Corp.	Software
WA	Redmond	Microsoft Corp.	Software
ID	Boise	Micron Technology Inc.	Semiconductor
OR	Wilsonville	Tektronix Inc.	Hardware
SD	Sioux City	Gateway 2000 Inc.	Hardware
Non-U.S. (20)			
Japan (10)	Tokyo	Toshiba Corp., Japan	Hardware
Japan	Tokyo	Softbank Corp., Japan	software/internet
Japan	Tokyo	Canon Inc., Japan	Hardware
Japan	Tokyo	Sony Corp., Japan	Semiconductors
Japan	Tokyo	Matsushita Electric Industrial, Japan	Hardware
Japan	Yao	Sharp Corp., Japan	Hardware
Japan	Tokyo	Fujitsu Ltd., Japan	semiconductors/hard.
Japan	Tokyo	Hitachi Ltd., Japan	Semiconductors
Japan	W. Hills, CA	NEC	Hardware
Japan	Torrance, CA	Seiko Epson	Hardware
Canada (3)	Montreal	Matrox Graphics Inc., Canada	Semiconductors
Canada	Toronto	ATI Technologies Inc., Canada	Semiconductors
Canada	Ottawa	Corel Corp., Canada	Software
Netherl. (2)		Philips Electronics NV, Netherlands	software/hardware

Netherlands	Hoofddorp	Madge Networks Inc.	Telecommunications
Germany		SAP AG, Germany	Internet
Taiwan	San Jose, CA	Acer Group	Hardware
Singapore		Creative Technology Ltd., Singapore	Media
Korea		Samsung/AST Research, Korea	Semiconductor
Switzerland	Freemont, CA	Logitech International SA	Hardware

44 of the top 50 I.T. firms are American. The role of U.S. firms is thus even more dominant than the 82% figure suggests since most of the other 18 firms placed only in the second half of the list.

(2) Within the U.S., 53 of the 80 are in the West. (TABLE 2.) The computer business originated within the U.S. in the Northeast, presaged by military research in Cambridge and Philadelphia during World War II, then initiated at IBM in the 1950s, and rejuvenated by the minicomputer makers along Boston's Route 128 in the 1960s. By 1997, however, and as the table shows, 53 of the world's top 100 firms are located in states in the western U.S. Are these numbers representative of influence within I.T.? Of the top 10 American firms in the list, the only one headquartered outside the West is IBM. *Nine of the top 11 I.T. firms in the world, by this count, are in the U.S. West.*

(3) Numerically, 43 of the 53 are in California. At sight, Silicon Valley does it all. The Valley's firms make chips (Intel), microcomputers (Apple), network software(Sun and Oracle), and all manner of Internet-related products and services.

(4) Functionally, Texas and Washington also stand tall. In practice, Texas has emerged as the leader in PC sales with number one Compaq/Digital, and distribution powerhouse Dell. Similarly, the pace-setter for the world's software is Seattle, where Bill Gates and Paul Allen chose to return home, where they would court and eventually trade places with IBM.

2. HOW DID THE PC RE-DRAW THE TECHNOLOGY MAP?

Most of today's top 100 I.T. firms are headquartered in the American West because the entrepreneurial energy driving the PC revolution originated there. That is the premise we are exploring. To illustrate this idea, FIGURE 1 links regional roles to the evolution of computing.

The industry stages were suggested by researchers at Morgan Stanley, an investment bank. (Meeker and DePuy, 1996.) As it happens, Commerce Department data on I.T.'s share of corporate investment in business equipment tend to support the stages approach. The data show the I.T. expenditure share jumping first with the advent of personal computers and then after 1994 with the fruition of the Internet. (FIGURE 2.)

In FIGURE 1, then, I assign characteristic home-regions to the mainframe, mini, and PC eras. These are New York State for mainframes, Route 128 for minicomputers, and the West

FIGURE 1. CHANGES IN REGIONAL ADVANTAGE OVER THE LIFE CYCLES OF MAINFRAME, MINI, PC, AND INTERNET-ENABLED SYSTEMS

(Dominant region)	**New York State**	**Route 128**	**The West**	**?**

(Computer system)

|Internet enabled systems | (c. 1997–2010)

|Personal computer| (c. 1980–2002) |-----------------→

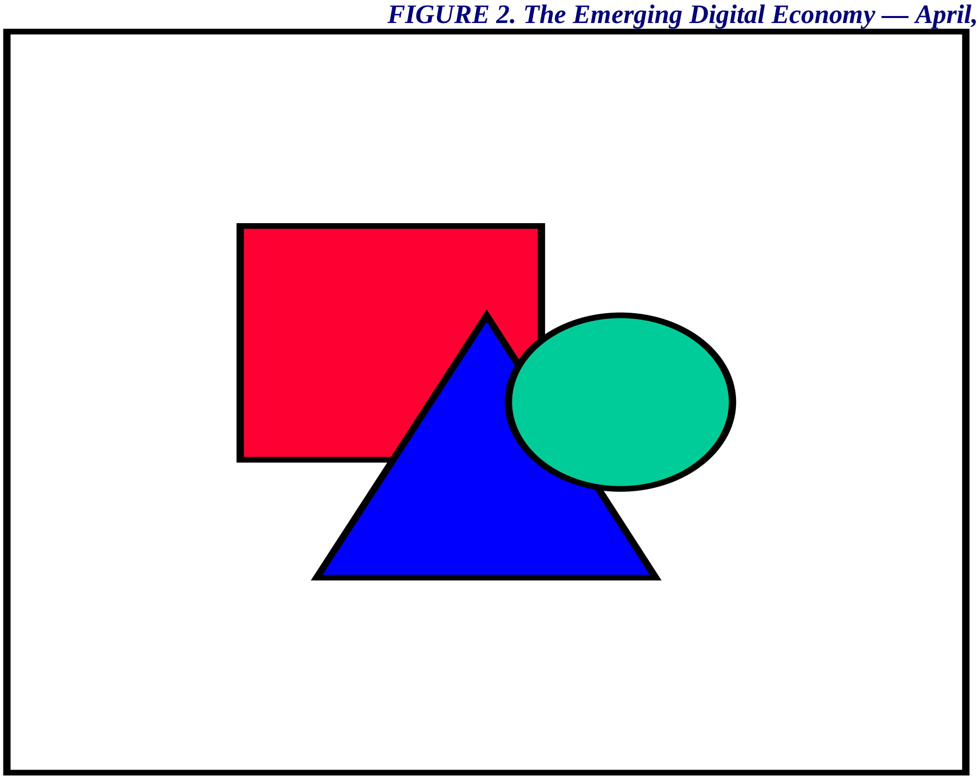
|Minicomputer| (c. 1970–1990) |----------------→

|Mainframe| (c. 1955–1973) |-------------------------------→

1950	1960	1970	1980	1990	2000	2010

Source: Adapted by the author from Morgan Stanley Research Estimates as reported in Mary Meeker and Chris DePuy, *The Internet Report* (New York: Morgan Stanley, 1996), p. I-9.

FIGURE 2. The Emerging Digital Economy — April, 1998



generally for the PC era beginning around 1980. (The fourth and current stage, Internet-Enabled Systems, begins about 1994.)

Did employment shifts reflect the westward shift in corporate power? Yes. Between 1986 and 1994, U.S. employment in computers, chips, and software grew by 13 percent. But in this job-gaining national context, the Northeast *lost* six percent of its I.T. employment, as measured by the aggregates for the three categories. (R.D. Norton, 1998.)

Since 1994, of course, the Internet has sparked a new outburst of entrepreneurial energy. To help place the transition from the PC era to the Internet era in perspective, we can consider the ways in which the PC ushered in the Information Age.

HOW THE PC UNIFIED HIGH TECH

Before 1981 there were three major technology industries: mainframe computers, electronic components, and medical instruments. The market for computers per se had only two components. Fortune 500 companies used big computers to compile data-bases for customer billing and employee records. The federal government (where the Defense Department and NASA relied on mainframes and supercomputers for military and space programs and the Census Bureau kept counting) was the other.

The IBM PC broadened the market from corporations and the federal government to include all manner of activities. The definition of I.T. changed accordingly:

> Today, due in large part to that one significant product introduction in 1981, virtually every person, company, and government is a customer for technology products. The definition of technology industries has expanded from large computers to include personal computers, software, semiconductors, semiconductor equipment, communications (both telecommunications and data communications), and medical technology (biotechnology and medical devices). (Michael Murphy, p. 47.)

In this view, the information technology sector today has seven components. These are (1) large computers, (2) personal computers, (3) software, (4) semiconductors, (5) semiconductor equipment, (6) communications, and (7) medical technology (biotech and instruments).

THE DIGITAL ARENA

The unifying element for all these activities (save only biotech) is digitization. Based on the microprocessor, a "computer on a chip," the PC could fully reap the advantages of digitization in ways mainframes and minis could not. But in addition to digitization four other concepts or "laws" come into play here. One is Moore's Law (the doubling of chip power every 18 months). The other three apply to networks. The following capsule summaries may begin to suggest how the Internet dovetails with the PC to bring telecommunications into the I.T. mainstream.

(1) Digitization. Digitization refers to our capacity to express the four main types of information (letters, numbers, sounds, and visual images) in terms of 0's and 1's. It permits a new synthesis in which seemingly all information can be converted to the on-off states that transistors can process at high speed. It thus ushers in an era in which diverse technologies become not more mysterious ("kludgey") and distinct, but more elegant and understandable, as analog information becomes increasingly converted to and stored and processed in binary (digital) forms. (Steve Byrnes, 1998.)

(2) Moore's Law. Gordon Moore's durable empirical rule on the doubling of chip storage capacity every 18 months implies a new hardware generation every three years or so. As this logic unfolds decade after decade, the cost savings that follow spread to an ever-wider circle of activities, goods, and services. In competitive terms, it also means that *the I.T. race goes to agile firms*, much to the chagrin of IBM and Japan after 1990.

(3)Packet Switching. As opposed to circuit routing (using a single circuit for a complete message, but taking up the whole circuit to do it), packet switching allows multiple usage of a given line. Each packet has 48 characters of content, and 5 as a header. Packet-switching is how the Internet works, and what makes it so powerful.

(4) Metcalf's Law. The cost of adding another node to the network increases linearly, while the value to network participants of adding a new member to the network increases with the square of the number of users. Graphically, a linear increase in costs can thus be overtaken by a quadratic rise in user benefits. That is, beyond a certain threshold benefits swamp costs, enhancing the value of large networks. By contrast, before the Internet proprietary closed networks kept numbers small enough to prevent the payoffs from accruing. The Internet, a network of networks, broke such constraints.

(5) Gilder's Law. Another empirical "law," this describes the unsteady movement toward fiber optic cable as an ultimate stage for transmitting digital information. It predicts (thus far reliably) a tripling of bandwidth or carrying capacity every 12 months.

3. HOW DID TEXAS BECOME THE PC STATE?

"The war is over, and the Texans have won."

The quotation refers to Compaq's 1998 takeover of Digital Equipment Corporation (DEC), the tarnished jewel in the faded crown of the minicomputer complex along Boston's Route 128. The result is a consolidation of operations that will trim15,000 DEC employees while giving Compaq a diversified service dimension enabling it to challenge IBM across the spectrum.

Texas has the two leading PC producers in the world, Compaq and Dell. On the list, Compaq is rated the fifth most influential I.T. company, Dell the 11th.

How did the Lone Star State become the PC State? The two different companies present two different puzzles to be solved, in that their origins are completely independent of each other. For Compaq, the answer is a classic case study in industrial evolution. For Dell, the story turns more on the sheer entrepreneurial prowess of the company founder, who began the business from a college dorm room at the University of Texas in Austin.

Compaq's lineage traces a precise logic of industrial evolution. In the 1930s engineers with a new technology for seismic oil exploration came to Dallas and founded Texas Instruments (TI). The technologies they employed led naturally to semiconductor research and in 1959 to the co-discovery of the integrated circuit by Jack Kilby, a TI engineer. Military and space contracts from the federal government spurred the company's ascent to one of the top semiconductor manufacturers in the U.S. by the 1970s.

In 1983 (?) four TI engineers from the company's Houston facility broke away to form a spin-off. Their leader was Rod Canion, and the company was Compaq. The new company patiently reverse-engineered the then new IBM PC, so that it could legally invent its own BIOS chip to emulate the PC for 100 percent software compatibility. That was Compaq's breakthrough, and it allowed the company to serve the role of legitimate king of the PC clonemakers. That is how

Compaq achieved the fastest rise from corporate inception to Fortune 500 status in history--a record Dell would itself later break.

What is the moral of the story? *The link between resource endowments and innovative capacity*. Historically, the development of technological strength in an American region can typically be traced to the region's resource base. (Harvey Perloff and Lowdon Wingo, 1968.) A given resource endowment either generates or fails to spark a related set of resource-processing activities that in turn encourage the development of new skills and technologies. (Norton and Rees, 1979.) That was the Manufacturing Belt of the Northeast and Upper Midwest attained its status as the nation's seedbed for innovation in the century from 1850 to 1950. The 60-year path from oil exploration to Compaq's world leadership in PC production displays a similar logic.

In contrast, Dell's meteoric rise in the 1990s has no such precisely traceable lineage. Instead, Michael Dell's strategy of devising a new distribution system to "mass-customize" the PC to order and to get the product delivered in a matter of days through the mail blazes no new technology trails. That, come to think of it, is the same accusation that is often made about Bill Gates: "His skills are not in technology, but in business acumen." Whether this comment is negative depends of course on the context. In any case, it points up the possibility that an entrepreneurial genius on the order of Gates or Dell may have a unique story to offer, one that fits awkwardly at best into any traditional location-theory framework.

And that brings us to the software side, and to the center of the world software industry, Seattle.

4. WHY DID SEATTLE GET TO MAKE THE NEW RULES?

Why is Seattle the center of power in the world software industry today? On one level, the answer is self-evident. Bill Gates and Paul Allen returned home from New Mexico to Seattle when he and Paul Allen were ready to move their tiny start-up software company to the next stage. That may actually be the long and the short of Microsoft's location. Bill Gates (by all accounts a business genius on a par with Andrew Carnegie, John D. Rockefeller, or Henry Ford), happens to have come from Seattle, and chose to locate the business in the Seattle suburb of Redmond. Then he unleashed his boundless ambition upon the software world and conquered it.

There are two further and related points that help put the conquest in perspective, but neither of them has much to do with location theory.

One is the familiar story of *IBM's outsourcing decision* in its crash campaign to get the PC from the drawing board to retail shelves within one year. That deadline led Big Blue to go outside its corporate walls for the microprocessor (to Intel) and the system software. Initially the system software was to come from Gary Kildahl in California. He dropped the ball, however, and so IBM turned to Bill Gates, who was initially their choice only for his version of the BASIC programming language. IBM wanted a 16-bit operating system. Gates quickly bought one from another Seattle programmer for a song ($50,000), and the result was to become MS-DOS.

This was the operating system that would be shipped with every IBM PC. Like the Intel chip, it became the standard all clones and all PC software developers would have to use in their designs. As it happened, the fees Microsoft earned from IBM, whether up-front or per machine, were negligible. The payoff came from firms like Compaq and the clone-makers, all of whom had to pay per-machine licensing fees.

How IBM and Microsoft traded places can be sketched briefly here. Just as Compaq managed to reverse-engineer the PC's BIOS chip and outsource for the hardware components and software, so too would the army of other clone-makers around the world. Despite the tremendous initial revenues the PC brought IBM, as the 1980s wore on competition from the cheaper clones steadily eroded IBM's profits from the PC. Meantime Microsoft's sales and power mounted apace. By the early 1990s (thus well before Windows 95 became the resident operating system on 9 out of 10 of the world's personal computers), Microsoft's stock-market capitalization, like Intel's, surpassed IBM's. The reason Wall Street viewed Microsoft and Intel so favorably was that the two together had replaced IBM as standard-setters for much of the I.T. sector.

The second consideration in Seattle's ascent, then, is that the key to profitability in the new computer world from about 1986 onward is *standard-setting*. For Intel, Microsoft, Hewlett-Packard (regarding printer protocols), Novell (temporarily), and other standard-setting firms, the key to success is the paradoxical combination of proprietary control of a dominant open-systems standard. In the open-systems (i.e., published codes and specifications) competition that has flourished since the mid-1980s, the company that manages to set a standard for software developers and peripheral devices has an advantage over its competitors--even though its competitors have access to most of its code and designs. (Charles H. Ferguson and Charles R. Morris, 1994.) Other I.T. players, notably to PC manufacturers themselves, are left scrambling for the crumbs in an intensely competitive world of razor-thin profit margins.

In sum, to the question of why Seattle gets to set the standard for the PC's evolution, the answer has little to do with location theory, and everything to do with the role of a titanic entrepreneur who saw before others the strategic advantage conferred by standard-setting.
Here we might recall Thomas Carlyle's nineteenth-century "great-man" theory of history that, in effect, France conquered Europe because Napoleon was a Frenchman. By the same token, it appears that Seattle makes the rules because Bill Gates happened to grow up there.

5. HOW DID SILICON VALLEY HAPPEN?

Silicon Valley started with electronic components and transistors, moved on to memory and logic chips, and diversified across the whole I.T. spectrum. Perhaps a word or two about the name of the world's most famous industrial cluster is in order. William Shockley had been a co-inventor of the transistor in 1947 for Bell Labs, which would later garner him a Nobel Prize. (He then parleyed the prestige of the prize to publicize his peculiar "theories" of racial differences.)

In 1955 Shockley returned from New Jersey to his home state to start a transistor company in Mountain View, near Stanford. He called it Shockley *Semiconductor* because the transistor could be switched on or off to register a 0 or 1 in binary code, depending on whether it was in a conductive or non-conductive mode. This "semiconductor" property is present in the minerals germanium and *silicon.* Years later, in 1971, a newsletter writer named Don C. Hoefler accordingly coined the term, "Silicon Valley." (Everett M. Rogers and Judith K. Larsen, 1984, pp. 25-26.)

STANFORD AS A CATALYST

Shockley moved west to Mountain View in part because it was his native ground and his mother still lived there. But business logic also favored the move. Two key components were already in place to create a seedbed for new enterprises. One was the Stanford Industrial Park launched in 1951 and followed in 1954 by the Stanford Research Park. The impetus was not economic development but the desire to make money from real estate the university owned yet (by the terms of Leland Stanford's gift) could not sell. The second keystone was Hewlett-Packard, started on the eve of World War II to manufacture electronic oscillators by two Stanford students, who were encouraged by an electrical engineering professor interested in negative feedback, Fred Terman. The two components converged in 1954 when H-P took a lease in the Stanford Research Park and served as the anchor for subsequent tenants. (Rogers and Larsen, chapter 2.)

In any case, Shockley had barely started his semiconductor company when it foundered on a legendary spin-off, which would eventually beget Intel. As Robert X. Cringely has said, Silicon Valley is "a place that was invented one afternoon in 1957 when Bob Noyce and seven other engineers quit en masse from Shockley Semiconductor" to found Fairchild Semiconductor, as a division of the established Syosset, New York, firm Fairchild Camera and Instrument. (Cringely, 1993, p. 36.)

Fairchild's "Traitorous Eight," (as Shockley saw them) share credit with Texas Instruments for inventing *integrated circuits* (ICs). Germanium ICs were designed by Jack Kilby at TI in Dallas, but he lacked a method of layering transistors on a flat surface. Jean Hoerni, one of the Fairchild Eight, came up with a "planar" technique to embed rather than stack component layers. Noyce carried the idea through to create complete circuit maps on a single silicon slice, clearing the way for photolithography (or "burning" the circuits into the slice) and thus for batch production. TI and Fairchild both announced the breakthrough in 1959. ICs came into production within two years, for use by the U.S. government at $100 apiece to miniaturize the future Apollo moon rocket's onboard computer (Palfreman and Swade, 1991, pp. 87-91).

INTEL SPARKS THE PC REVOLUTION

A decade later Noyce, Moore, and others jumped ship again to found Intel, a more egalitarian company than Fairchild's eastern owners would permit. Like Hewlett and Packard before him, and as a minister's son from Iowa, Noyce did without dress codes, reserved parking places, closed offices, executive dining rooms, and the other status trappings of more mature U.S. corporations. The remote control foundered on the divergent philosophies of Syosset and Silicon Valley. "Noyce couldn't get Fairchild's eastern owners to accept that idea that stock options should be a part of compensation for all employees, not just for management. He wanted to tie everyone, from janitors to bosses, into the overall success of the company" (Cringely, 1993, p. 39).

Noyce and his colleagues thus formed Intel in 1968, as a spin-off (like its competitor National Semiconductor and some 50 other companies) from Fairchild. Intel made its mark on the world in November 1971 when it announced a triple breakthrough: the microprocessor, dynamic random access memory (DRAM), and erasable programmable memory (EPROM) for software.

Here was the package to make personal computers a reality. As George Gilder puts it,

> Intel is the most important company in the history of the microcosm. All the key components of the personal computer--the working memory, the software memory, and microprocessor CPU--emerged during the magical first three years of the company's existence, between 1969 and 1971. Until Intel's breakthroughs, computers were large and cost a minimum of tens of thousands of dollars. After Intel's three-year surge, computers could be build for a few hundred dollars. This was…the revolution. (Gilder, 1989, p. 92.)

But for three years nothing happened. The revolution would only finally begin in earnest when a new generation of entrepreneurs stepped onto the stage. In other words, microprocessors were at first ignored by the mainframe and minicomputer establishments. Then the January 1975 edition of *Popular Electronics* spurred Gates and Allen to develop system software for the MITS Altair computer kit adorning the magazine's cover. At that same historical moment, Steve Wosniak and Steve Jobs put together an early Apple, and they did it the same way Hewlett and Packard had made their first oscillators--in a garage in the Valley. Thus it took four teen-ish mavericks from the West to capitalize on the potential of the "computer-on-a-chip." When the dust cleared, the upshot was a westward tilt of American computing, toward Silicon Valley.

By 1982 the Valley was already *the* high-tech seedbed, accounting for 60 percent of the electronics firms in the U.S. That year Route 128's Massachusetts ran a distant second, with 112 firms registered as members of the American Electronics Association--barely 10 percent of California's 1,111 member firms. (Rogers and Larsen, p. 28.)

Nor has the Internet revolution since 1994 diluted the Valley's concentration. In our list of the world's top 100 I.T. firms, *Silicon Valley alone accounts for some 40 firms, or nearly half the entire U.S. contingent.*

REGIONAL NETWORKS

Silicon Valley is therefore if anything more prominent on the world I.T. landscape with every passing year. How do the Valley's origins shed light on its stellar performance as an I.T. seedbed today?

A widely accepted interpretation comes from Annalee Saxenian. She draws on the industrial-district (or cluster) model formulated by Alfred Marshall a century or more ago and re-introduced in 1984 in *The Second Industrial Divide* by Michael Piore and Charles Sabel, a treatise on "flexible specialization" as the developmental stage succeeding "Fordism" or mass production. They emphasized the virtues of the "Third Italy" and its industrial clusters specializing in high-fashion, design-intensive goods. They saw virtuous networks emerging among rival firms, which managed to cooperate around activities of mutual benefit such as training, marketing, and market research. As John Cassidy puts it in a recent reference to their work, "The key to the area's success…was that it was geographically dense but economically decentralized." (Cassidy, 1998, p. 125.)

Saxenian built on this model to compare Silicon Valley's adaptability with Route 128's decline as a minicomputer center. Her 1994 work, *Regional Advantage: Culture and Competition in Silicon Valley and Route 128*, highlights differences in communications patterns between the two clusters. A useful image for her thesis is the "Wagon Wheel," a Santa Clara "watering hole" where engineers and other techies from sometimes competing companies gather to drink and talk shop. (The "watering hole" reference appears to be part of Valley lore, as the same phrase appears in the same context in Rogers and Larsen's earlier account.) No such oasis is detected in Route 128's more buttoned-down, up-tight corporate landscape.

The phrase Saxenian used to describe Silicon Valley is "network-based industrial systems." The phrase refers to a project-oriented adaptive mode of production that may be seen not only in Silicon Valley but also to the south, in Hollywood. As she told Cassidy in a 1998 interview,

> You have these very fluid labor markets and these communities of highly skilled people who recombine repeatedly. They come together for one project--in this case a new film, in Silicon Valley it would be a new firm--and then they move on. The system allows a lot of flexibility and adaptiveness. …Information about new

markets and new technologies flows very quickly. This sustains the importance of geographic proximity, despite the fact that, theoretically, the technology allows you to be anywhere." (Cassidy, p. 125.)

THE SEEDBED AT WORK TODAY

All this helps us to understand Silicon Valley's continuing prominence in the generation of the I.T. firms of the future. One way of appraising its role as a seedbed is to survey a list of the most promising *privately held* I.T. firms. The logic of the inquiry is that firms in the start-up and prototype stages of their life-cycles often rely on venture capital for financing. Venture capital firms, in turn, hope to invest in promising young firms, but to recoup their investment at a profit by taking the firm to an Initial Public Offering (IPO) of stock at the earliest opportunity. Hence to scan a list of promising privately held (i.e., not held publicly by shareholders from the larger world) companies is a way of glimpsing the future of I.T.

In that light, TABLE 3 suggests an even larger role for the Valley as the Internet Age unfolds. Fully two-thirds of the "hot 100" on the list are from California, and all but a handful are from the general vicinity of Silicon Valley. In contrast, Microsoft's home state has only four firms on the list, Texas only three. As befits M.I.T.'s backyard, the state with the second largest count is Massachusetts, which has a dozen. Other countries account for only four firms on the list. Whether this represents American myopia, a failure of participants in international capital markets to recognize foreign opportunities, or both is not clear.

What is clear from the list is that Silicon Valley gives little sign of succumbing to the perils of industrial maturity, or of surrendering its status as the most fertile spawning ground of new I.T. enterprises in the world.

6. ENTREPRENEURS AND CONTINENTS

To sum up, U.S. leadership in information technology has been enhanced by the younger economic cultures of the West, fertile settings for new-enterprise formation. The account offered here may shed light on the varied reasons for the emergence of a new spatial division of labor in American computing. The regional realignment within the continental system allowed the shift

TABLE 3

THE "H0T 100" PRIVATELY HELD IT FIRMS BY REGION

State	City	Company	Primary Activity
North			
MA	Cambridge	Allaire Corp.	Net Infrastructure
MA	Lexington	Centra Software Inc.	Net Infrastructure
MA	Cambridge	Instinctive Technology Inc.	Net Infrastructure
MA	Burlington	SilverStream Software	Net Infrastructure
MA	Concord	StarBurst Communications Corp.	Net Infrastructure
MA	Framingham	Connected Corp.	Enterprise Software
MA	Chelmsford	MatrixOne Inc.	Enterprise Software
MA	Marlborough	Artel Video Systems Inc.	Unlike Anything Else
MA	Framingham	Maker Communications Inc.	Semiconductor
MA	Cambridge	One Source Informations Services Inc.	Online Content
MA	Canton	SR Research Inc.	E-Commerce
MA	Waltham	Trellix Corp.	Business Automation Software
IL	Elmhurst	FastParts Inc.	E-Commerce
MN	Minneapolis	Net Perceptions Inc.	Net Infrastructure
NJ	Iselin	Datek Online Holdings Corp.	E-Commerce
NY	New York	InterWorld Corp.	E-Commerce
OH	Columbus	Pathlore Software	Enterprise Software
PA	Exton	Bentley Systems Inc.	Business Automation Software
South			
MD	Timonium	RDA Consultants Ltd.	Business Automation Software
MD	Germantown	Telogy Networks	Communications Equipment
VA	Dulles	Vastera Inc.	E-Commerce

West

CA	San Mateo	Actuate Software Corp.	Enterprise Software
CA	Mt. View	AlphaBlox Corp.	Enterprise Software
CA	Mt. View	AnswerSoft Inc.	Enterprise Software
CA	Menlo Park	Broadbase Information Systems Inc.	Enterprise Software
CA	Oakland	Cloudscape Inc.	Enterprise Software
CA	Burlingame	CrossWorlds Software Inc.	Enterprise Software
CA	San Francisco	Eventus Software Inc.	Enterprise Software
CA	Emeryville	Extensity Inc.	Enterprise Software
CA	Los Angeles	Glovia International, LLC	Enterprise Software
CA	Sunnyvale	Junglee Corp.	Enterprise Software
CA	Palo Alto	Sagent Technology Inc.	Enterprise Software
CA	Mt. View	SmartPatents Inc.	Enterprise Software
CA	Menlo Park	Sqribe Technologies Corp.	Enterprise Software
CA	San Mateo	Virage Inc.	Enterprise Software
CA	San Jose	BackWeb Technologies Inc.	Net Infrastructure
CA	San Mateo	Inktomi Corp.	Net Infrastructure
CA	Redwood	Liquid Audio	Net Infrastructure
CA	Cupertino	Magnifi Inc.	Net Infrastructure
CA	Mt. View	Marimba Inc.	Net Infrastructure
CA	Menlo Park	NetDynamics Inc.	Net Infrastructure
CA	San Mateo	NetGravity Inc.	Net Infrastructure
CA	San Jose	One Touch Systems Inc.	Net Infrastructure
CA	Cupertino	Preview Software Inc.	Net Infrastructure
CA	Santa Clara	Ramp Networks Inc.	Net Infrastructure
CA	Palo Alto	Tibco Inc.	Net Infrastructure
CA	Foster City	Wallop Software Inc.	Net Infrastructure
CA	Alameda	Wink Communications	Net Infrastructure
CA	Santa Clara	Active Software Inc.	Business Automation Software
CA	San Jose	Agile Software Inc.	Business Automation Software
CA	San Francisco	Amplitude Software	Business Automation Software
CA	Sunnyvale	Ariba Technologies Inc.	Business Automation Software
CA	Palo Alto	Blue Pumpkin Software Inc.	Business Automation Software
CA	Mt. View	Diffusion Inc.	Business Automation Software
CA	Pacific Palisades	GoldMine Software	Business Automation Software
CA	Menlo Park	Informatica Corp.	Business Automation Software
CA	Oakland	Vision Software Tools Inc.	Business Automation

CA	Santa Clara	VitalSigns Software	Software Business Automation Software
CA	Santa Clara	Finjan Inc.	Networking
CA	Mt. View	Juniper Networks Inc.	Networking
CA	Palo Alto	Kana Communications Inc.	Networking
CA	Sunnyvale	RadioLan	Networking
CA	El Dorado Hills	ShareWave Inc.	Networking
CA	San Jose	TeraStor Corp.	Networking
CA	Mt. View	Visto Corp.	Networking
CA	San Jose	VPNet Technologies Inc.	Networking
CA	Santa Monica	GeoCities	Online Content
CA	San Francisco	PlanetOut Corp.	Online Content
CA	Sunnyvale	PointCast Inc.	Online Content
CA	San Francisco	Quokka Sports	Online Content
CA	Palo Alto	Vicinity	Online Content
CA	Mt. View	WhoWhere Inc.	Online Content
CA	Sunnyvale	Chromatic Research Inc.	Semiconductor
CA	San Jose	Logic Vision Inc.	Semiconductor
CA	San Jose	Neoparadigm Labs Inc.	Semiconductor
CA	Santa Clara	Ambit Design Systems Inc.	Semiconductor
CA	Campbell	I-Cube Inc.	Semiconductor
CA	Sunnyvale	Rendition Inc.	Semiconductor
CA	Walnut Creek	Commerce One Inc.	E-Commerce
CA	San Jose	CyberSource Corp.	E-Commerce
CA	Palo Alto	E-Loan Inc.	E-Commerce
CA	San Francisco	Intershop Communications Inc.	E-Commerce
CA	Menlo Park	Release Software Corp.	E-Commerce
CA	Milpitas	Berkeley Networks Inc.	Communications Equipment
CA	Milpitas	Sentient Networks	Communications Equipment
CA	Foster City	Whistle Communications Corp.	Communications Equipment
CA	Menlo Park	Nuance Communications.	Unlike Anything Else
CA	San Jose	Iready Corp.	Unlike Anything Else
TX	Austin	Deja News Inc.	Online Content
TX	Austin	Smart Technologies Inc.	Enterprise Software
TX	Austin	Vignette Corp.	Net Infrastructure
UT	Salt Lake City	TenFold Corp.	Unlike Anything Else
WA	Seattle	Icat Corp.	E-Commerce
WA	Seattle	Ichat Inc.	Net Infrastructure
WA	Bellevue	Onyx Software Corp.	Enterprise Software

WA	Redmond	Portable Software Corp.	Business Automation Software
Intern.			
Canada	North Vancouver	Pivotal Software Inc.	Business Automation Software
Canada	Toronto	Platform Computing Corp.	Enterprise Software
England	Cambridge	Advanced RISC Machines Ltd.	Semiconductor
Israel	Tel Aviv	Mirabilis Ltd.	Online Content

from mature, managerial firms of the Northeast to the more entrepreneurial firms of the West, from Texas to Seattle.

In contrast, one reason for the eclipse of Europe's I.T. sector seems to be the smaller role played by entrepreneurs, relative to large firms. The longstanding failure on the continent to spark the formation and growth of new enterprises over time appears to have left Europe's economies vulnerable to the eventual stagnation that tends to afflict all large, mature corporations.

The result, as Lester Thurow observes, is that Europe has fallen by the wayside in the world's growth industries (Thurow 1998):

> When breakthrough technologies occur, it is very difficult for old large firms to lead. They have to cannibalize themselves to save themselves, and that is simply very difficult to do. If one looks at the 25 biggest firms (based upon stock market capitalization) in the United States in 1960 and again in 1997, six of America's twenty-five biggest firms either did not exist in 1960 or were very small. In contrast, in Europe all of the twenty-five biggest firms in 1997 were big in 1960. In the past four decades Europe has been able to grow no new big firms that could lead the world technologically.

The U.S. has the advantage of regional diversity on a larger scale, within a common institutional framework. The diverse economic cultures of U.S. regions, I have suggested, encourage the generation and development of entrepreneurial enterprises. To that extent, the changes now occurring in Europe may help open up new possibilities for entrepreneurial creativity.

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