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ARTICLE

Spillovers from Oil Firms to U.S. Computing and Semiconductor Manufacturing: Smudging State–Industry Distinctions and Retelling Conventional Narratives

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Histories of semiconductor and computing technology in the United States have emphasized the supporting role of the U.S. state, especially the military, in answer to libertarian denials of state aid that are influential in Silicon Valley today. Somewhat implicit in that historiography, though, is the leading role of actors and organizations that blur any distinction between public and private. Some industries of this sort—telecommunications, aerospace, auto manufacturing—do figure in the historiography, but the class should be expanded further. One such industry—oil—has been exceptionally but almost invisibly influential in the development of computing and semiconductor manufacturing in the United States. Oil firms invested heavily in semiconductors and computing. There was also an "oil spillover" of personnel and technology from oil firms to computing and semiconductor manufacturing. Oil shows up in the biographies of many prominent individuals and organizations in the history of those technologies, from Fairchild Semiconductor to Edsger Dijkstra. These ties potentially hold important implications for the much-needed transition to a more sustainable energy regime.

Keywords: information technology, oil, R&D, US 20th

One of the prominent and long-standing matters of public concern regarding the history of computing in the United States—alongside that of Silicon Valley and the "tech industry" more broadly—is the role of the state versus that of private enterprise. Popular histories such as Walter Isaacson's *Steve Jobs* often present Silicon Valley as the creation of mavericks who needed little help from government.[1] Today's Silicon Valley leaders, such as Marc Andreesen,

1. Isaacson, *Steve Jobs.*

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Elon Musk, and Peter Thiel, similarly promote folk histories of high-tech as an arena of libertarian self-actualization that can only be hindered by the state.[2]

In contrast, academic histories generally depict the state, especially the military, as the prime mover for early U.S. computing and semiconductor manufacturing.[3] Such studies (sometimes explicitly) counter libertarian narratives that denigrate the state.[4] Naturally, commercial enterprises still figure in academic histories of computing, even as they claim a role for the state that prominent actors deny. The most thoughtful studies acknowledge that the state–industry distinction is too binary, because many individuals who shaped semiconductor and computer technologies moved freely between roles in government and industry, and decisions with technological, commercial, and national security ramifications often emerged from networks that spanned state and industry.[5]

Thus, the history of semiconductors and computing shows that even in the United States, there are industries in which it is difficult to distinguish commercial from state actors and commercial strategy coevolves with state policy. Such entangling of public and private is no surprise; I claim no originality in pointing it out.[6] In particular, many studies have documented the contributions that large, state-embedded conglomerates in the New York–Pennsylvania corridor (especially IBM, AT&T, RCA, General Electric, and Westinghouse) made to computing and semiconductors.[7] These companies ran government projects such as ballistic missile testing facilities; rotated senior staff into government commissions; operated under consent decrees from the Department of Justice; and cultivated close ties with both major political parties.[8] For such firms, any line between state and industry obscures rather than clarifies.

Other state-embedded industries also figure in histories of U.S. computing and semiconductors. The West Coast aerospace industry, for instance, formed the backbone of the "military–industrial complex" and appears prominently in histories of, for instance, user innovation in early computing and the invention of the integrated circuit.[9] So, too, the auto industry, which was a lucrative market that assisted semiconductor manufacturers in moving away from dependence on the military.[10] Car companies and their vendors—such as Motorola and Philco—also sponsored solid-state physics research that aided semiconductor manufacturers.[11] The coevolution of Silicon Valley, Detroit, and state policy (e.g., regulations regarding air pollution and energy conservation) made the car a "computer on wheels."[12]

2. Cohen, *The Know-It-Alls.*

3. Riordan and Hoddeson, *Crystal Fire*; Edwards, *The Closed World*; Lécuyer, *Making Silicon Valley*; Abbate, *Inventing the Internet.*

4. Mazzucato, *The Entrepreneurial State*; Heinrich, "Cold War Armory."

5. O'Mara, *Cities of Knowledge*; O'Mara, *The Code.*

6. Block and Keller, *State of Innovation.*

7. Bassett, *To the Digital Age*; Gertner, *The Idea Factory*; Cortada, *IBM*; Choi, "Manufacturing Knowledge in Transit."

8. Usselman, "Fostering a Capacity for Compromise;" Hirshberg, "Targeting Kwajalein"; Hart, "IBM in American Politics;" Russell, *Open Standards.*

9. Akera, *Calculating a Natural World*; Lécuyer, *Making Silicon Valley.*

10. Lécuyer, "Silicon for Industry."

11. Hoddeson and Garrett, *The Man Who Saw Tomorrow*; Johnson, "How Ford Invented the SQUID."

12. Johnson, *Environmental Regulation and Technological Development.*

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Study Aims, Sources, Method, and Parameters

My aim is *not* to analyze the contributions to computing and semiconductors of state-embedded industries as a class. Instead, I focus on a single industry: oil. There should be little dispute that oil is a state-embedded industry: The U.S. government has fought wars partially motivated by desire for oil, has fomented revolutions to retain access to oil, has used oil as a diplomatic tool, and has sought to curb other nations' use of that tool; and its "spymasters" have been "oilmen" and vice versa.[13] More fundamentally, the oil industry's products suffuse Americans' understanding of the state and its proper relationship to themselves, the environment, and the marketplace.[14]

I will show that oil firms rode the state's coattails and shaped public policy to gain access to advanced computing and semiconductor technologies. In that, the oil industry differs little from the aerospace, automobile, or telecommunications industries; I am *not* claiming that the oil industry's contributions were more significant than those industries' contributions. Still, laying out oil's role in semiconductors and computing is warranted for at least two reasons. First, oil firms' contributions are not nearly as well-known as those of the large, regulated monopolies in the northeastern United States, or even those of the auto and aerospace industries. Putting oil at the center of narratives about semiconductors and computing helps us better understand all three industries' relationships to the state *and* the ubiquity of oil in U.S. society and especially U.S. technoscience. The semiconductor and computing industries were hardly unusual in enjoying oil patronage; fields including biotechnology, solar and nuclear power, and medicine have as well.[15] This study is part of a larger project documenting "oil spillovers" to various sciences and technologies. Obviously, "oil spillover" is a pun; however, I am serious in translating the concept of spillovers into business history from the social sciences.[16]

Second, in tracing oil spillovers, this article exposes an underappreciated obstacle to technological solutions to climate change. I thereby add to the recent material and environmental turns in histories of semiconductors and computing.[17] That literature argues—contrary to popular understandings promoted by industry—that computing and semiconductor manufacturing are carbon-intensive and environmentally ruinous. This article further asserts that computing and semiconductor manufacturing just *are*, in part, arms of the fossil fuel industry, and Silicon Valley is an "energy capital" not unlike Dallas and Houston.[18] A better picture of the *historical* oil-computing nexus draws attention to tech firms' *present-day*

13. As documented both in oil-friendly histories such as Yergin, *The Prize*, and in critical studies such as Mitchell, *Carbon Democracy.*

14. Huber, *Lifeblood*; LeMenager, *Living Oil.*

15. For a medical example, see Parker, "Controlling Man-Made Malaria." On solar, Jones and Bouamane, "'Power from Sunshine'"; on biotech, Mody, "Complementary Scarcities"; on nuclear, Cohen, "Firm Heterogeneity, Investment, and Industry Expansion."

16. Griliches, "Issues in Assessing;" Meyer and Whittier, "Social Movement Spillover;" Feldman, "The New Economics of Innovation."

17. Ensmenger, "The Environmental History of Computing;" Lécuyer and Brock, "The Materiality of Microelectronics."

18. Pratt, Melosi, and Brosnan, *Energy Capitals.*

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alliances with oil (and opposition to state action against climate change) and undermines optimism that information technologies will facilitate a *future* low-carbon transition.[19]

Before moving to my empirical material, some notes on scope, periodization, and sources. By the "oil industry," I mean oil producers, both large and small, as well as oil field services firms; I only include petrochemical manufacturers if they also owned substantial oil production or refining units. I focus on firms headquartered in the United States or Western Europe, during the Cold War period when those firms' influence was at its peak. Links between oil and computing are hard to find before the Cold War, and somewhat submerged again after 1989 (though in my "Conclusion" I note some present-day connections between oil and Big Tech).

My argument is that oil firms participated in every major turn in the development of U.S. semiconductor manufacturing and computing during the Cold War. This is counterintuitive, because the oil "industry has a reputation for being slow to develop and adapt innovations"—a reputation confirmed by oil firms' relatively small ("less than 1% of their net revenue") investments in R&D.[20] Yet the oil industry is so large that small investments relative to its revenues can have enormous consequences for nascent firms and technologies. Moreover, the oil industry's influence should not only be counted in dollars, but also in personnel, techniques, ideas, and institutions. To trace those strands of influence, I adopted the "follow the actors" research strategy associated with Bruno Latour and actor-network theory: I first identified networks that were clearly associated with either oil actors or the semiconductor and computing industries and then collected instances of overlap between the two networks.[21]

I begin building my argument somewhat obliquely: first by offering a skeleton history of the U.S. semiconductor and computing industries, told in the conventional way without oil; after which I reinsert oil actors into that narrative. The conventional narrative that I offer does not encompass all work on the history of the U.S. computing and semiconductor industries, but it adequately summarizes surveys of that history such as Martin Campbell-Kelly and colleagues' *Computer*, Paul Ceruzzi's *A History of Modern Computing*, Alfred Chandler's *Inventing the Electronic Century*, Thomas Haigh's "The History of Information Technology," and James Cortada's "Progenitors of the Information Age."[22] The same storyline also structures popular documentaries and fictionalizations.[23]

The device of starting with the conventional narrative and then filling in its gaps is taken from Davis Baird and Ashley Shew's study of participant histories of nanotechnology.[24] The point is to show where particular actors *could* fit in predominant narratives but have not done so thus far. Putting those actors into the storyline makes evident the work and assumptions

19. Pasek, "Seeing Carbon Through Silicon."

20. Perrons, "How Innovation and R&D Happen in the Upstream Oil and Gas Industry," 301, 302.

21. Latour, *Reassembling the Social.*

22. Campbell-Kelly et al., *Computer*; Ceruzzi, *A History of Modern Computing*; Chandler, *Inventing the Electronic Century*; Haigh, "The History of Information Technology"; Cortada, "Progenitors of the Information Age."

23. E.g., Kikim Media's 2018 documentary, *Silicon Valley The Untold Story*, or AMC Studios' fictional series (running 2014–2017), *Halt and Catch Fire.* The oil industry figures prominently in the latter's second season.

24. Baird and Shew, "Probing the History."

required to maintain their invisibility. This approach is not dissimilar to studies that illuminate minoritized and subaltern groups' contributions to computing.[25] Of course, the oil industry is hardly subaltern; bringing its contributions to light serves critique, not empowerment. Indeed, oil firms have themselves occluded their roles in semiconductors and computing. To counter critique and legal challenges, oil firms have been highly selective in making their strategies publicly transparent. Thus, I rely largely on published sources that present the oil industry's own perspective—sources that I nevertheless read in ways oil actors did not intend.

The Established Narrative

I begin in 1947. There is, of course, an earlier history of computing, but I have not found exceptional oil industry involvement with calculating machines or human computing before the end of World War II. Such activity might turn up but would not alter my argument. There was, moreover, no semiconductor industry before 1947, as that year saw the invention of the transistor, the first solid-state semiconductor device to (eventually) be sold commercially. Virtually every popular and academic survey notes the invention of the transistor as a turning point, not just for what became the semiconductor industry, but also for computing and other U.S. high-tech industries, particularly in the San Francisco Bay Area.

The invention of the transistor, a solid-state amplifier and switch, was credited by their employer, Bell Laboratories, to William Shockley, John Bardeen, and Walter Brattain. A chemist, Gordon Teal, also contributed crucial crystal-growing knowledge.[26] Shockley then left Bell Labs in 1956 to form Shockley Semiconductor, a subsidiary of Beckman Instruments, in Palo Alto.[27] That venture gave rise to a more influential breakaway, Fairchild Semiconductor.[28] In 1958–1959, the integrated circuit was simultaneously invented at Fairchild and at Texas Instruments (TI), instigated by the military's need for more reliable transistors.[29] Crucially, the transistors and other components in integrated circuits could be miniaturized, making electronic devices faster and less power-intensive; the steady shrinking of integrated circuitry since the early 1960s is now known as Moore's law, after a Fairchild cofounder.[30] Miniaturization radically decreased the unit price of transistors; however, extreme miniaturization also required more expensive semiconductor manufacturing facilities ("fabs"). Over time, that expense became prohibitive; since the 1990s, firms have abandoned their fabs and outsourced manufacturing to "foundries," particularly the Taiwan Semiconductor Manufacturing Company (TSMC).[31]

25. E.g., Rankin, *A People's History of Computing*; Petrick, *Making Computers Accessible*; Abbate, *Recoding Gender*; Gaboury, "A Queer History of Computing;"

26. Lécuyer and Brock, "The Materiality of Microelectronics."

27. Shurkin, *Broken Genius*, chap. 9; Riordan and Hoddeson, *Crystal Fire*, chap. 11; Brock, "From Automation to Silicon Valley."

28. Riordan and Hoddeson, *Crystal Fire*, chap. 11; Lécuyer, *Making Silicon Valley*, chap. 4.

29. Ibid.; Seitz and Einspruch, *Electronic Genie*; Choi, "Manufacturing Knowledge in Transit."

30. Brock, *Understanding Moore's Law*.

31. Sarma and Sun, "The Genesis of Fabless Business Model."

Semiconductor manufacturing quickly diffused from Bell Labs after 1947. East Coast conglomerates such as RCA and IBM were early leaders, soon joined by firms like TI and Motorola in the Southwest and spin-offs from Fairchild in the Bay Area such as Signetics and Rheem.[32] These "Fairchildren" sprouted thanks to the venture capital (VC) industry in what became known as Silicon Valley. VC money also meant that region's semiconductor firms were later joined by industrial clusters in biotech, personal computing, networking, dot-commerce, and social media.[33]

By the early 1970s, miniaturization and integration of semiconductor components made a "computer on a chip," or microprocessor, feasible—a device first marketed by one of the leading Fairchildren, Intel.[34] Combining many components on one chip in turn made smaller, "personal" computers commercially viable. Such machines had long been forecast, particularly in circles in which the counterculture and military–industrial complex intersected. One such circle connected the Stanford Research Institute (SRI), Portola Institute, and Xerox's Palo Alto Research Center, yielding (among other things) the Xerox Alto, a graphical user interface–based computer that influenced the Apple Macintosh, Microsoft Windows, and billions of similar devices used today.[35]

Members of the same circles were also involved with the ARPANET and early networking technologies. In the 1980s, civilian networks proliferated alongside the ARPANET, such as the NSFNET connecting academic supercomputing centers.[36] The growth of such networks was aided by the dissolution of AT&T's monopoly in 1984. This resulted in competition among telecommunications companies such as Sprint and Ericsson to lay fiber-optic cable and establish cellular networks.[37] These developments stimulated the privatization of the internet in 1995 and the dot-commerce boom.

Meanwhile, miniaturization of semiconductor components continued thanks to advances such as atomic layer deposition and FinFET transistors.[38] Putting those advances to use in laptops and cellphones, however, required parallel advances in power storage, particularly the lithium ion battery. By the twenty-first century, miniaturization made distributed storage fantastically cheap and processing fantastically fast. In the 2010s, these developments combined with progress in artificial intelligence (AI) research to place technologies such as self-driving cars and ubiquitous surveillance within reach.[39]

Replaying in the Key of Oil

The sources cited in my summary of the established narrative contain barely a handful of passing references to oil. Almost the only survey that meaningfully acknowledges oil firms'

32. Choi, "Manufacturing Knowledge in Transit"; Cortada, *IBM*; Klepper, "The Origin and Growth of Industry Clusters."

33. Kenney, *Understanding Silicon Valley.*

34. Bassett, *To the Digital Age*; Zygmont, *Microchip*; Reid, *The Chip.*

35. Bardini, *Bootstrapping*; Markoff, *What the Dormouse Said*; Fong, "ARPA Does Windows."

36. Abbate, *Inventing the Internet*; Gallo, "Speaking of Science."

37. Morgan, "Digital Highways."

38. Van Duijn, "Fortunes of High-Tech," chapter titled "Innovation IV"; O'Reagan and Fleming, "The FinFET Breakthrough."

39. Jones, "How We Became Instrumentalists (Again)"; Stilgoe, "Machine Learning, Social Learning."

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place in the history of computing is in the first volume of Cortada's *The Digital Hand*, in a single chapter on the petrochemical industry.[40] Yet there are oil links to *every single turn* in the narrative presented above. That is not to say that oil conspiratorially lurked behind computing, nor that oil interests *determined* the events I have just sketched. Rather, I offer the more limited claim that oil actors participated in the U.S. semiconductor and computing industries far more than the conventional narrative acknowledges.

To some degree, that claim should not be surprising; oil was ubiquitous in American postwar society generally and in business in particular. A trivial example of that ubiquity comes from one of the earliest Fairchildren, Signetics, which had a former president of Standard Oil of California, Theodore Peterson, on its first board of directors.[41] Peterson only offered generic management expertise and did not steer Signetics in any oil-specific direction. Singly, such ties tell us little about oil *or* computing. Collectively, however, the links I describe were not trivial. The oil and semiconductor–computing industries formed a symbiotic relationship that gave them their present forms. To convey that symbiosis, I revisit the established narrative, this time highlighting oil actors' presence. Then I will explain why oil firms took an interest in semiconductors and computing and what that means for the historiographies of all three industries.

Let us start, again, with the transistor. *All* the people I mentioned in connection with that invention were tied to oil. John Bardeen worked at Gulf Oil's Pittsburgh research lab for several years before starting his PhD at Princeton.[42] While at Princeton, Bardeen became friends with another PhD student, Robert Brattain, who introduced Bardeen to his brother Walter (Bardeen's future collaborator and Nobel co-laureate). Robert Brattain became one of Shell's top scientists and developed a prototype of the IR-1 infrared spectrophotometer that Shell commissioned Arnold Beckman to produce commercially.[43] This stimulated the postwar "instrumental revolution," reorienting chemistry to physical, and specifically electronic, instrumentation.[44] The money Beckman made from that revolution allowed him to hire William Shockley and form Shockley Semiconductor.[45]

Another firm often said to have established the Silicon Valley business model, Varian Associates, also depended heavily on selling spectrometers to oil and petrochemical companies.[46] Yet another California firm founded to sell spectrometers for oil exploration, Consolidated Engineering Corporation, developed an early commercial computer, the CEC 30-103, before selling its computing unit to Burroughs. Renamed the Datatron 203, this became the basis for Burroughs' successful entry into computing; ex-Shell employees were also responsible for Burroughs' widely used version of Algol.[47] As David Brock has shown, the early

40. Cortada, *The Digital Hand*, vol. 1, chap. 6.

41. Lionel E. Kattner, "Signetics History," undated but before 2008, lot no. X7847.2017, Information Technology Corporate Histories Collection, Computer History Museum.

42. Hoddeson and Daitch, *True Genius*, chap. 3.

43. Morris, *A Cultural History of Chemistry in the Modern Age.*

44. Ibid.

45. Thackray and Myers, *Arnold O. Beckman.*

46. Morris, *A Cultural History of Chemistry in the Modern Age.*

47. Kimpel, "The Origins of Burroughs Extended Algol."

history of semiconductor manufacturing, too, owed much to cooperation between oil firms and instrumentation companies, particularly in California.[48]

Finally, the fourth transistor team member, Gordon Teal, left Bell Labs in 1953 to join TI. By that time, TI was largely focused on defense markets, but the company's original incarnation, Geophysical Service Incorporated (GSI), was an oil field services firm. After the company was renamed in 1951, GSI continued until 1988 as its oil field services subsidiary. TI was the number one global semiconductor manufacturer of the 1970s and in the top four well into the 1990s; yet despite TI's importance, semiconductor historians have written almost nothing about the decades-long coexistence of TI's microelectronics and oil field services units.[49]

Clearly, though, oil field services offered an important early market for TI's microelectronics branch. For instance, in 1962 GSI rolled out the 15000-transistor Texas Instruments Automatic Computer (TIAC), intended primarily for seismic analysis and made possible by funding from Mobil and Texaco.[50] The TIAC later gave rise to "the TIAC 870, one of the first integrated-circuit computers," and then in the early 1970s the Advanced Scientific Computer, developed with support from Chevron, Amoco, Texaco, Mobil, Phillips, and Unocal.[51]

Knowledge, technology, and personnel also flowed from TI's oil operations into microelectronics. One example is digital signal processing (DSP) and TI's most famous consumer product, the Speak & Spell. Academic and participant histories of Speak & Spell do not draw a link to GSI, but plainly the oil industry was tremendously important in the development of the DSP chips that went into it.[52] Signal processing of seismic data was an early application of digital computers going back at least to MIT's Whirlwind computer (one of the first real-time digital electronic computers). Historians of computing have depicted Whirlwind as a creature of the military.[53] However, students in MIT's Geophysical Analysis Group were coopting Whirlwind for seismic analysis, with funding from oil firms Magnolia, Stanolind, and Atlantic Richfield, by 1952 (a few months after Whirlwind became operational).[54] Other oil companies, such as Shell, keenly followed the Whirlwind work.[55]

The deconvolution methods developed on Whirlwind soon became standard in oil prospecting.[56] By the early 1970s, those techniques were good enough that some researchers leapt from processing seismic signals to processing (roughly similar) acoustic signals, that is, voice and music. One was John Burg, the son of Kenneth Burg, an early and influential employee of GSI. John Burg developed "the maximum entropy spectrum [as] an outgrowth of the

48. Brock, "Oil Exploration, Automation, and Bits."

49. Riordan and Hoddeson, *Crystal Fire*, Reid, *The Chip*, and Zygmont, *Microchip*, barely mention oil in a lengthy discussion of TI. Even the company's 75th anniversary coffee table book only briefly puts oil and electronics in the same frame and ignores oil after page 20! Pirtle, *Engineering the World.*

50. Pirtle, *Engineering the World*, 16.

51. Pirtle, *Engineering the World*, 17–18.

52. Frantz, *The Speak N Spell*; Marshall, "The Oleaginous Voice."

53. Akera, *Calculating a Natural World*, chap. 5; Redmond and Smith, *From Whirlwind to MITRE*; Edwards, *The Closed World*, chap. 3.

54. Robinson oral history; Shrock, *Geology at MIT*, chap. 23; Bates, Gaskell, and Rice, *Geophysics in the Affairs of Man*, 112.

55. For a 1957 report to Shell headquarters on the Whirlwind research, see Edward Crisp Bullard. "The Work of the Geophysical Analysis Group at the Massachusetts Institute of Technology" (July 1957), folder E218, Papers and Correspondence of Sir Edward Crisp Bullard, 1907–1980, Churchill Archives Center.

56. Priest, "Seismic Innovations."

deconvolution filtering technique long used in oil-exploration data processing" while he—following his father—was employed by TI in the early 1960s.[57] Burg later founded TSP (Time and Space Processing), where he applied the maximum entropy spectrum method to voice transmission over digital networks, primarily for military customers. Through Burg himself and colleagues in ARPANET circles, digital voice processing techniques then flowed back to the TI group that developed Speak & Spell.[58]

TI's microelectronics business was also aided by Texas elites' desire to diversify the region's economy to buffer periodic oil downturns. Indeed, Texas elites even backstopped risky gambles such as the Graduate Center of the Southwest, which TI established in 1961 to train future employees. When the Graduate Center began hemorrhaging money, the Texas state government (at the behest of oil and other business elites) took it off TI's hands and transformed it into the University of Texas–Dallas.[59]

A more frustrated case involved Jack Kilby, famous as coinventor of the integrated circuit. Less well-known is Kilby's work in the 1970s on the TI Solar Energy System (TISES).[60] This was a residential system for generating heat and electricity, which Kilby and another former TI employee, Jay Lathrop, invented in response to the 1973 OAPEC oil embargo. In the late 1970s, TI and the Department of Energy jointly invested more than US$(2022)100 million in TISES.

In 1980, though, the price of oil started to drop, making the economics of TISES less favorable. At that point, TI and Kilby sought investors to help them start up and sustain manufacturing until economies of scale kicked in. They concluded that the only viable sources of that level of investment were oil companies and Saudi princes.[61] This was less counterintuitive than it seems now, because most major oil companies had solar energy programs at the time and the Saudi royal family splashily sponsored various solar power experiments.[62] Oil money was not forthcoming for TISES, however, and TI's attempt to move from semiconductors into solar—inspired by the scarcity of, and with the hoped-for aid of, oil—was canceled in 1983.

Fairchildren and Angels

So far, I have shown that the oil industry multiply intersected with the invention of the transistor, diffusion of transistor manufacturing to Texas and Silicon Valley, and the invention of the integrated circuit. I have also shown that oil firms were crucial early consumers of discrete transistors (in instrumentation for petrochemical manufacturing and oil exploration)

57. Barnard, "The Maximum Entropy Spectrum and the Burg Technique," I-1.

58. Gray, *Linear Predictive Coding.*

59. Leslie and Kargon, "Selling Silicon Valley;" Busch, "An Abstract Thing.'"

60. Mody, "After the IC."

61. "Texas Instruments Takes a Partner," undated (probably 1977), box 2, record group 4, Texas Instruments Records, A2005.0025; Pete Johnson, "OPC review, Project Illinois" (May 17, 1982), folder 4, Solar Energy Reviews 1978–1982, box 68, Jack Kilby papers A2006.0023 Series 1: Manuscripts; both in DeGolyer Library Special Collections.

62. Royal Embassy of Saudi Arabia. "SunDay A Special Day… A Special Relationship" [paid advertisement]. *New York Times*, May 3, 1978, A26.

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and of digital computers and integrated circuits (in digital analysis of seismic signals). The next turn in the conventional narrative, then, is the VC industry and Silicon Valley's start-up culture. There, too, oil was everywhere.

An early example is Dean Knapic, a Shockley Semiconductor employee who carpooled with two of Fairchild Semiconductor's future cofounders.[63] In 1957, Knapic also left Shockley to form a company to sell silicon to spec. Knapic's seed money came from Norsworthy Industries, the investment vehicle of a Dallas oilman, Lamar Norsworthy Jr.[64] Despite the company's rapid growth, Norsworthy withdrew after three years and Knapic folded, ceding the silicon market in part to companies with oil ties, particularly Monsanto. One of Knapic's employees, Robert Lorenzini, later founded silicon suppliers Elmat and Siltec.[65] Another, Arthur del Prado, formed ASM International, today one of the world's leading semiconductor process equipment suppliers.[66] Norsworthy's investment thus stimulated the emergence *and* globalization of Silicon Valley start-up culture.

More broadly, oil firms and actors have been crucial players throughout the history of VC. Most histories credit Georges Doriot with founding the East Coast VC industry, and Eugene Kleiner and Arthur Rock the West Coast variant.[67] However, Martin Kenney and David Hsu have shown that Rockefeller Brothers was equally important in establishing the industry's practices.[68] Rockefeller Brothers (Venrock after 1969), was a vehicle for the Rockefeller siblings to invest money inherited from their grandfather, John D. Rockefeller, founder of Standard Oil. Among Venrock's investments were Intel, Apple, and Mosaic. (Another major early investor in Intel was Gordon Moore's financial adviser, Fayez Sarofim, who made his pre-Intel fortune investing for Houston's oil barons.[69])

Doriot himself put money into oil companies, including George H. W. Bush's Zapata Oil.[70] He also relied on advice from "his former student and family friend Arnaud de Vitry," head of Mobil's operations research unit.[71] In 1957, de Vitry counseled Doriot to make his most famous and successful investment in Digital Equipment Corporation. In the end, though, Doriot was outrun by VC firms that adopted the limited partnership legal template—which was invented by oil wildcatters to collectively share the risk (and profit) from drilling oil

63. Thackray, Brock, and Jones, *Moore's Law*, 147, 153. Knapic appears in a pejorative light in Lojek, *History of Semiconductor Engineering*, 91–92, and in a footnote in Berlin, "Robert Noyce and Fairchild Semiconductor."

64. Van Duijn, *Fortunes of High-Tech*, chap. 2. Worden & Risberg, Evaluation Silicon Monocrystal Market, report on Knapic Electro-Physics to Norsworthy Industries, 1959, from Arthur del Prado papers, courtesy Jorijn van Duijn. Lorenzini, oral history.

65. Marsh, "Crystal History."

66. Van Duijn, "Fortunes of High-Tech," argues del Prado would not have started ASM International (and named his first son Charles *Dean* del Prado after Knapic) without his experience at Knapic. One of ASM International's spin-offs, ASML, is also a leading semiconductor equipment manufacturer today: Raaijmakers, *De Architecten van ASML.*

67. Ante, *Creative Capital*

68. Kenney, "How Venture Capital." See also Hsu and Kenney, "Organizing Venture Capital."

69. Thackray, Brock, and Jones, *Moore's Law.*

70. Ante, *Creative Capital*, 163–165.

71. Ante, *Creative Capital*, 150.

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wells.[72] Only in 1959 was the limited partnership imported by "the first venture capital firm in Silicon Valley: Draper, Gaither & Anderson."[73]

As the VC industry matured, oil companies themselves joined in. The leader, founded in 1964, was Exxon Enterprises, which took stakes in (among others) nuclear power, solar energy, and even sporting equipment.[74] Its best-known investment was probably Zilog, one of the most promising semiconductor start-ups of the 1970s. Zilog was founded by Fairchild and Intel veterans, including Federico Faggin, coinventor of the microprocessor.[75] Alongside Zilog, Exxon bought into semiconductors (Supertex), superconductors (Intermagnetics General), word processing (Vydec, Xonex), optical scanning (Scantron), displays (Ramtek, Kylex, EPID), fax machines (Qwip), printers (Qume, Danbury Systems), typewriters (Qyx), digital voice storage and transmission (Delphi Communications), photodiodes (Emdex), semiconductor lasers (Optical Information Services), memory (Micro-Bit, Exxon STAR Systems), voice recognition and synthesis (Dialog [renamed Verbex Voice Systems], Periphonics), office telephony (Intecom), and disk drive heads (Magnex).[76]

In the early 1980s, Exxon packaged these companies' products into an office information suite built around a computer powered by a Zilog chip.[77] In 1984, it abandoned the effort, leaving the associated firms and personnel to seek their fortunes elsewhere. Some, such as James and Janet Baker of Verbex Voice, had more success post-Exxon: elements of their Dragon Naturally Speaking software are today embedded in Apple's and Microsoft's voice recognition packages.[78] In addition, Exxon Enterprises itself trained a few influential venture capitalists.[79]

Where Exxon leads, other oil companies follow. BP, for instance, had both BP Ventures and a venture research unit that offered grants to, among others, the prominent computer scientist Edsger Dijkstra.[80] (It is probably a coincidence, though worth noting, that Dijkstra held the Schlumberger Centennial Chair in Computer Science at the University of Texas from 1980 to 1999; Schlumberger is an oil field services firm.) In 1979, Texaco founded Harrison Capital,

72. Mark Williams Pontin, "Founding Father," *MIT Technology Review*, July/August 2008. Hsu and Kenney, "Organizing Venture Capital."

73. Berlin, "The First Venture Capital Firm in Silicon Valley," 155, cites the Rockefellers rather than unnamed wildcatters as inspiration for applying the limited partnership to venture capital. Either way, oil exploration was the original model.

74. Exxon Enterprises, "Exhibit Highlights: 1977 International Electric Vehicle Exposition"; Solar Thermal Systems, "Solar Myths, Solar Truths," undated pamphlet, probably ~1980; Charles E. Petty, "Automating the Office," pamphlet reprinted from Fall, 1981 issue of *The Lamp*; all from folder 2.207/H19B, Exxon Enterprises, 1977–1981, ExxonMobil Historical Collection, Briscoe Center for American History.

75. Elaine Williams, "Challenge to Minicomputers," *Financial Times*, September 15, 1982.

76. John Greitzer, "Executive Changes at Zilog Head off Management Rift," *Computer Business News*, 2, no. 4 (January 22, 1979): 2; "Amdahl Enters Micro-Bit Effort," *Computerworld*, 11, no. 4 (January 24, 1977): 42; "STC to Buy Exxon Division," *Computerworld*, 15, no. 24 (June 15, 1981): 96; Brad Schultz, "Exxon in DP Market: Why?," *Computerworld*, 14, no. 20 (May 19, 1980): 109ff; Stacy Moran, "Public Spotlight: Supertex, Inc.," *Electronic Business*, 10, no. 6 (March 1984): 208.

77. Byrne, "When Exxon Wanted to Be the Next Apple"; Anthony J. Parisi, "Exxon Offers Laser Devices," *New York Times*, January 24, 1979, D1.

78. Simson Garfinkel, "Enter the Dragon," *MIT Technology Review*, September 1, 1998.

79. Ron Leuty, "VC Takes Innovation Message to Beltway," *San Francisco Business Times*, July 27, 2010.

80. Donald Braben, "BP Backs Revolutionary Research," *New Scientist*, April 21, 1983, 142–145. Dijkstra—sans oil—features in, among others, Ensmenger, *The Computer Boys Take Over*, chap. 5; Payette, "Hopper and Dijkstra."

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while in 1980 Standard Oil of Ohio formed Vista Ventures (explicitly modeled on Exxon Enterprises).[81] Vista "invested about $20 million, primarily in computer companies, including Fortune Systems… [While] about 50% of Harrison's investments [were] in computer companies, including Iomega … and Micro-Five."[82] Atlantic Richfield's ARCO Ventures was mostly focused on solar and biotech but also funded signal processing research at Stanford's Ginzton Lab in the early 1980s.[83]

Amoco Technology similarly mainly invested in solar but made bets in computing, including acquiring Stanford AI researcher Ed Feigenbaum's company, Intelligenetics, in 1986.[84] Amoco Technology also bought 15 percent of chip manufacturer Analog Devices in 1977 and then formed a joint investment venture, Analog Devices Enterprises (ADE), in 1980.[85] ADE put money into computing-related companies such as Signal Processing Circuits, International Imaging Systems, Charles River Data Systems, Numerix, Photodyne, GigaBit Logic, Quantitative Technology Corp, TestSystems, Bipolar Integrated Technology, Imagerie Industrie Systeme, and Altera.[86]

Spillovers Beyond Money

Oil firms' contributions to computing and semiconductor manufacturing were not, however, limited to investment. Their in-house capabilities, too, spilled over to other industries. For instance, in the mid-1970s, Sun Oil established Sun Information Services (SIS) to handle its data processing.[87] SIS then attracted interest from external clients interested in data backup for disaster recovery. In 1983, Sun spun off SIS and four other computing subsidiaries (SunGard Services, Applied Financial Systems, Catallactics Corporation, and NMF Inc.) to form SunGard, one of the top data backup and disaster recovery firms until the 2010s.[88]

Sometimes, capabilities developed for one purpose unexpectedly spilled into computing. For instance, Exxon's formation of an Advanced Battery Division in the late 1970s was originally intended to help it get into "batteries to power electric vehicles."[89] Yet, as Matthew

81. Kathleen K. Wiegner, "Signs of Life," *Forbes*, June 7, 1982, 154.

82. Ibid.

83. Siegman, "Annual Progress Report."

84. Feigenbaum, like Dijstra, is well-known to historians of computing; Grier, "Interviews: Edward Feigenbaum." Amoco's investment in Feigenbaum's company is not, however. Amoco's 60 percent ownership of Intelligenetics is from Tom Kehler, "Facsimile from Tom Kehler to Qunio Takashima [cc'ed to Feigenbaum]," October 6, 1989, box 2, folder 22, SC0340, Accession 2005-101, Edward A. Feigenbaum Papers, Special Collections, Stanford University Libraries.

85. Theresa Engstrom, "Analog Devices Converts Ambition into Dollars," *Electronic Business*, 11, no. 10 (May 15, 1985): 73ff.

86. Ibid. "Analog Devices Buys $1 Million of Photodyne Stock," *Lasers & Applications*, 1, no. 1 (September 1982): 28; Peter Dunn, "TestSystems: Failure in the Final Test," *Electronic News*, 34, no. 1690 (January 25, 1988): 36; "Analog Devices," *PR Newswire*, July 25, 1984; "Altera-Corp; Closes Third-Round Financing," *Business Wire*, March 26, 1985.

87. Russ Banham, "Welcome to Hell," *Treasury & Risk Management*, 9, no. 6 (August 1999): 61–63.

88. Peter Key, "SunGard Buy Gets Analysts' Praise," *Philadelphia Business Journal*, December 10, 2001.

89. "Exxon's Effort to Find Investment Outlets," *Business Week*, April 24, 1978, 78–79. Also, Exxon Enterprises, "Exhibit Highlights: 1977 International Electric Vehicle Exposition," folder 2.207/H19B, Exxon Enterprises, 1977–1981, ExxonMobil Historical Collection, Briscoe Center for American History.

Eisler documents, Exxon's contributions to lithium ion batteries, along with parallel contributions by Atlantic Richfield and Schlumberger, instead made possible today's mobile phones and portable computers.[90]

In semiconductor manufacturing, oil firms' materials expertise plugged directly in rather than spilling over. The chemicals used in semiconductor processing include various petrochemicals, especially photoresists used in lithography, sold by chemical suppliers such as Rohm & Haas and KMG Chemicals. Historically, chip-grade silicon was a specialty chemicals market too: as Monsanto's president put it in 1983, "Monsanto is the world's largest producer and marketer of polished silicon wafers. We have been an active member of the semiconductor industry for the past 24 years."[91] Note that, from 1955 to 1975, Monsanto also operated an oil refinery and gas station chain.

Oil firms also offered challenging organizational environments where advances in computing could be refined. ARCO headquarters, for instance, was one of four locations where the Xerox Alto was field-tested in 1978 (alongside Xerox, the White House, and the U.S. House of Representatives).[92] Thus, firms involved in complex oil exploration and production projects have led development of advanced database systems, such as Stone & Webster's Construction Management Display System and the Amoco Distributed Database System.[93]

The *physical* environments across which oil firms operate also stimulated innovation. Oil companies were, for instance, among the first customers for GPS technology.[94] Likewise, the rancher and oilman Thomas Carter invented the Carterfone, an attachment for connecting a two-way radio to a telephone, for users working far from telephone lines. AT&T's opposition to Carter, and the FCC's landmark 1968 decision backing him, accelerated AT&T's breakup and fostered "the motley world of funny receivers, slick switch boxes, and rickety answering machines. More importantly, [because of the Carterfone decision] consumers quickly embraced the modulate/demodulate device, otherwise known as the telephone modem."[95]

At times, the combination of oil's geography and materiality plus oil firms' complexity inspired developments in computing and especially networking. ARPANET's topology, for instance, was partly derived from earlier studies of offshore oil and gas pipeline networks.[96] Much later, Amoco "led a group of 20 network companies and government agencies" as well as Chevron, Shell, and Schlumberger (and the American Petroleum Institute) in the ARIES project in the early 1990s. This was an influential pilot of asynchronous transfer mode network

90. Eisler, "Exploding the Black Box."

91. Quote is from "Monsanto Company," *PR Newswire*, May 11, 1983. For Monsanto's oil and electronics units, see "The Reworking of Monsanto," *Chemical Week*, January 12, 1983, 42.

92. High Tech History, "A Brief, Early History of Xerox PARC"; Computer History Museum, "Computer History Museum Add Historic Xerox Alto."

93. Coles and Reinschmidt, "Computer-integrated Construction"; Thomas et al., "Heterogeneous Distributed Database Systems."

94. Trimble, oral history.

95. Sterling, Bernt, and Weiss, *Shaping American Telecommunications*,125. Russell, *Open Standards*, 141–142, 159, puts Carterfone in the context of the breakdown of AT&T's monopoly and the creation of alternative standards for networked communications. Quote is from Matthew Lasar, "Any Lawful Device: Revisiting Carterfone on the Eve of the Net Neutrality Vote," *Ars Technica*, December 13, 2017.

96. Frank interview. Thanks to Martin Schmitt for alerting me to this source.

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protocols for moving data from remote locations (such as oil platforms) to central facilities where the data could be interpreted.[97]

A particularly convoluted example is the U.S. arm of Swedish telecommunications giant Ericsson. Despite benefiting greatly from AT&T's breakup in 1984, Ericsson had virtually no presence in the United States before 1980, when it formed a joint venture, Anaconda-Ericsson, with Atlantic Richfield (a collaboration arising from the two companies' Mexican subsidiaries).[98] Atlantic Richfield's contribution was a subsidiary called Anaconda Telecommunications, a spin-off from Anaconda Wire and Cable. Wire and cable are critical material infrastructure for telecommunications, but also lucrative markets for copper companies such as the giant mining conglomerate, Anaconda Copper, which ARCO had taken over in 1977.[99]

As the maze of subsidiaries in the Anaconda–Ericsson episode indicates, oil firms dabbled in many non-oil industries, particularly in the 1970s. Thus, the standard explanation for oil firms' computing ventures is that they were "part of a diversification effort" (as Bo Lojek dismissively described Schlumberger's 1979 purchase of Fairchild).[100] Yet just because a business appears (especially retrospectively) unrelated to oil production does not mean that an oil company invested in it solely to diversify its portfolio. And even where diversification strategies were at work, we have to ask why oil companies diversified in some directions and not others.

Schlumberger, for instance, bought Fairchild for specific reasons: "Schlumberger used computerized tools for measurement and oil research and, therefore, required increasing amounts of semiconductor components."[101] Purchasing Fairchild also gave Schlumberger an umbrella under which to place related acquisitions such as Accutest, a semiconductor test equipment manufacturer.[102] Perhaps most importantly, Schlumberger stocked the Fairchild Advanced Research Laboratory with leading AI researchers from Stanford and SRI, including Peter Hart, Jay Martin Tenenbaum, Harry Barrow, and Richard Duda.[103] Several prominent Silicon Valley figures spent time at Schlumberger, including Reed Hastings (cofounder of Netflix) and Michael Kass (an Oscar-winning computer graphics developer at Pixar).[104]

Moreover, other oil companies "diversified" into AI at exactly the same time. In the early 1980s, BP and Shell worked with Intelligent Terminals Limited, a start-up associated with prominent academic AI researchers Donald Michie and Jean Hayes-Michie, while Amoco bought an AI company founded by Stanford's Ed Feigenbaum.[105] Others venturing into

97. Lori Valigra, "Amoco Leads ATM Trial to Aid Global Oil Exploration," *Infoworld*, June 12, 1995, 50.

98. "LM Ericsson Acquires Full Interest in Ericsson, Inc. in Pact with Atlantic Richfield," *Fiber Optics & Communications Newsletter*, December 1985, 5.

99. Leech, *The City That Ate Itself*, 311–315, 335–340.

100. Lojek, *History of Semiconductor Engineering*, 171.

101. Malerba, *The Semiconductor Business*, 169.

102. Schlumberger Limited, *Schlumberger Annual Report 1982.*

103. Nils J. Nilsson, "Introduction to the COMTEX Microfiche Edition of the SRI Artificial Intelligence Center Technical Notes," *AI Magazine*, 5, no. 1 (1984): 41–52. Hart was formerly director of the SRI AI center, one of the primary nodes of AI research in the world. Nilsson describes the group that left for Schlumberger as a majority of "the people who had seen us [the center] through the tumultuous '70s."

104. Grinapol, *Reed Hastings and Netflix*; Farmer, "A Talk with 2017 ACM Fellow, Michael Kass."

105. Intelligent Terminals, corporate overview and FAQ, Turing: The Papers of Alan Mathison Turing, GBR/0272/AMT/A/43, Archive Center, King's College.

1980s-vintage AI included Exxon, Elf Aquitaine, Saga Petroleum, Gulf, Chevron, and Phillips.[106] With respect to AI, then, "diversification" is an explanation that begs further explanation of why oil companies concentrated their investments in certain areas.

Even in cases in which diversification was less targeted, we should still note its consequences. Oil companies' magnitude, combined with their diverse and often short-term pursuits, has allowed them to serve as stepping-stones for many figures in the history of semiconductors and computing, from John Bardeen to Reed Hastings. Not all were successful: the final president of RCA before its collapse was Thornton Bradshaw, formerly president of Atlantic Richfield.[107] Some we might wish had been less successful: Auto-Tuned pop music descends from geophysical algorithms developed by Andy Hildebrand at Exxon.[108] Some carried little trace of oil: Adam Osborne marketed "the first successful portable computer" and wrote "the documentation for the first microprocessor" after being fired from Shell.[109] Yet to understand the recruitment networks that brought people into semiconductors and computing, we need to acknowledge the oil industry's role in training large numbers of technical personnel and instilling the dissatisfaction or entrepreneurialism needed to move to other pursuits.

The Wider Context

I invite readers now to reread my "Established Narrative" with an eye to the connections to oil that I have made visible in subsequent sections. So far, I have offered reasons why those connections existed, but I have not shown how oil and computing coevolved in some broader historical context. That is a topic for future research. Here I simply paint in broad strokes the major trends that brought oil and computing together.

The main reason for oil-computing spillovers is that the semiconductor industry and the digital electronic programmable computer came into being *exactly* as oil extraction was becoming much more technologically intensive. From the 1950s onward, new sources of oil could only be found in increasingly difficult political and physical environments: the North Sea, Gulf of Mexico, North Slope of Alaska, Arabian Peninsula, and so on.[110] Thus, oil companies grabbed technological advantages to overcome competitors, rentier states, and a recalcitrant Earth. Computing aided everything from designing offshore oil rigs to analyzing seismic data to predicting future prices to automating refineries. Before long, the oil industry existentially depended upon digital technologies to maintain profits and continue expanding

106. J. Scot Finnie, "Sudden Shower Enriches MIS Turf," *Computerworld*, October 17, 1988, 77; Kenneth Brooks, "AI Tackles Real-Time Process Control," *Chemical Week*, September 10, 1986, 38; Braunschweig, "Artificial Intelligence in the Petroleum World."

107. Marilyn Berger, "Thornton F. Bradshaw Dies at 71: Led RCA until Purchase by GE," *New York Times*, December 7, 1988, D24.

108. Marshall, "Tuning *in Situ*," 55ff.

109. Jack Schofield, "Adam Osborne," *The Guardian*, March 27, 2003.

110. Priest, "The Dilemmas of Oil Empire"; Priest, *The Offshore Imperative*; Veldman and Lagers, *50 Years Offshore*; Coates, *The Trans-Alaska Pipeline.*

operations. Drilling in the North Sea, for instance, could not have extended into deep offshore waters if not for advances in software for controlling pipeline flows.[111]

Oil companies also used computing to obtain *political* advantage. In particular, from the late 1960s onward, the largest producers headquartered in Western Europe and the United States faced growing demands from "petrostates" in the Global South for a greater share of revenues.[112] Thus, where the majors earlier dismissed talk of scarcity or "peak oil," by the late 1960s, a few oil actors were sponsoring and publicizing forecasts that oil would become precipitously more expensive and harder to access.[113] Computer modeling helped legitimate forecasting as a modern and objective practice. Oil firms had already adopted computer models for *internal* use: "The Sun Oil Corporate Financial Model developed … between 1965 and 1968 was the first large-scale model ever built; it was also an abject failure which was completely abandoned in 1969."[114] Sun's model was superseded by the Industrial Dynamics model developed by Whirlwind inventor Jay Forrester, which led the Club of Rome to commission Forrester to model global resource scarcity; several Club members (Frits Böttcher, Maurice Strong, Joseph Slater) were current or former oil or gas executives, as were close allies of the Club such as George Mitchell and Robert Anderson. The resulting World3 model underlay the Club's bestselling 1972 *Limits to Growth* report, which spurred a global debate about scarcity to which oil firms were very much interested parties.[115] Oil companies also developed alternatives to Industrial Dynamics, such as scenario planning and long-range planning, that were not necessarily computing intensive.[116] Shell's scenario planning approach, in particular, proved immensely popular among Silicon Valley techno-optimists who were skeptical of *Limits to Growth*.[117]

In the short-term, though, *Limits*' claims were bolstered by the 1973 OAPEC oil embargo.[118] The oil shock led to windfall profits for oil companies. It also inspired innovation in energy conservation, such as computerized "smart grids" and the battery and electric vehicle research mentioned earlier.[119] Many of the direct oil investments in computing that I have outlined occurred in this period from the late 1960s to the mid-1980s. Oil firms needed to park their windfall profits somewhere, and computer and semiconductor technologies offered good returns on investment. The same technologies also looked like promising aids in the search for oil and other fossil fuels.

Then the price of oil started to decline in 1980, reaching pre-1973 levels by 1986. That left oil firms starved of the cash they earlier put into computing.[120] Legislative and financial changes also shifted power to activist investors who demanded short-term returns and an end to long-term investment in technologies not immediately related to oil production.[121]

111. Nygaard, "Controlling the Flow of Oil and Gas Subsea."
112. Garavini, *The Rise and Fall of OPEC.*
113. Priest, "Hubbert's Peak."
114. Clarke and Tobias, "Complexity in Corporate Modeling," 20.
115. Baker, "World Processors."
116. Fosbrook, "How Scenarios Became Corporate Strategies."
117. Turner, *From Counterculture to Cyberculture.*
118. Bini, Garavini, and Romero, *Oil Shock.*
119. Slayton, "Efficient, Secure, Green."
120. Basosi, Garavini, and Trentin, *Counter-Shock.*
121. Holmstrom and Kaplan, "Corporate Governance and Merger Activity."

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Oil companies were still active in computing after 1986, but in more focused, less visible ways than before. Thus, U.S. oil firms were not visible contributors to the dot-com and social media booms, even if those booms built on technologies and institutions in which oil firms formerly invested. In recent years, however, Big Tech companies—particularly Google and Microsoft—have quietly provided crucial aid in extending the life of the fossil-fuel industry.[122] In return, oil money—particularly from Saudi Arabia—has underwritten the emergence of new computing-based industries such as rideshare platforms.[123] The story of oil and computing is by no means over.

Conclusion

Does recognizing the oil–computing nexus have significance beyond the proverbial gap in the historiography? I offer three affirmative answers. First, oil spillovers help explain why U.S. firms took an early lead in the computing and semiconductor manufacturing industries. The usual reason given for that lead is that the U.S. state, especially the military, provided a much larger market than other nation-states could sustain. That explanation is valid, but the American semiconductor and computing industries were *also* aided by the peculiar nature of the American oil industry. Thanks to the breakup of Standard Oil and the peculiarities of American capitalism, the U.S. oil industry was much more fragmented than that of any other country—which in turn meant many more sources of transfers from oil to semiconductors and computing.[124]

Other countries have oil companies, of course, and those firms were as involved in computing as their American counterparts. To give just a few examples: Norsk Hydro and Statoil were major funders of Norway's leading academic computing facility of the 1980s, and Hydro collaborated with Matra and SGS on a supercomputer project.[125] The Finnish national oil company, Neste Oy, was the leading sponsor of atomic layer deposition (ALD) development; ALD is today a key technique in semiconductor manufacturing.[126] Sino-American Petroleum was one of the founding investors in TSMC.[127] In the early 1980s, BP partly owned Mercury Communications and wholly owned Telcom General, the latter headquartered in Silicon Valley.[128] No country, though, has as diverse an oil and gas industry as the United States. Oil companies all across the spectrum—from tiny Norsworthy Industries to giant Exxon—have allied with semiconductor and computing firms. That would not have been possible if the United States had a national oil company similar to other countries. How much that has

122. Cool, "Oil Is the New Data."

123. Mike Isaac and Michael J. de la Merced, "Uber Turns to Saudi Arabia for $3.5 Billion Cash Infusion," *New York Times*, June 1, 2016.

124. Maugeri, *The Age of Oil.*

125. "Europe's Eureka Plan Remains to Be Shaped," *New York Times*, July 22, 1985; Costello, "Norway."

126. Van Duijn, "*Fortunes of High-Tech*," chap. 28.

127. Meaney, "State Policy and the Development of Taiwan's Semiconductor Industry."

128. Walter L. Morgan, "Unisat," *Satellite Communications*, April 1983, 44; "BP Buys 80% of Telcom General," *Satellite News*, 8, no. 26 (July 1, 1985): 7, https://archive.org/details/sim_satellite-news_1985-07-01_8_26/mode/2up.

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mattered to the development of the American and global semiconductor and computer industry is beyond my scope but worth further research.

Second, we need to grapple with the complexities of oil firms' sponsorship of technological development beyond oil. In recent years, scholars such as Naomi Oreskes and Erik Conway have exposed the oil industry's agnotological role: that is, its promotion of ignorance rather than knowledge, particularly regarding climate change.[129] In contrast, this article surveys oil firms' patronage of knowledge-intensive technological activities. Obviously, oil firms' climate denialism is in no way mitigated by their contributions to computing and semiconductor manufacturing. The world must reduce fossil fuel emissions, and thus oil companies must become smaller and less influential. Yet this article indicates that that transition could leave holes in the U.S.—and global—innovation system. Important R&D institutions, seemingly unrelated to oil, in fact depend on flows of money, technology, and personnel to and from the oil industry. For instance, one of the most prominent universities in histories of computing, Carnegie Mellon, is named after the family (Mellon) behind Gulf Oil. Many other U.S. universities with long histories in computing and semiconductors—Caltech, Stanford, Rice, University of Texas, MIT—have buildings and professorships endowed with oil money.

Any energy transition that relies on innovations from such institutions will require that the oil industry's current influence be counterbalanced and then replaced. The distorting effect of oil money on academic research is already clear.[130] But we also need to acknowledge that *some* of the academic research that oil money funds—notably in semiconductors and computing—is robust and beneficial to many and that universities long starved of funding have therefore long sought oil patronage. Plans for an energy transition need to include ways to make up for the loss of oil money that flows into universities and other research organizations.

Finally, tracing the longevity of oil firms' involvement with computing and in Silicon Valley helps make sense of the present. Historians of computing and Silicon Valley have done this before, in confronting the sexism and racism of "brogrammer" culture at companies like Google, advocating for a unionized tech workforce, and highlighting tech firms' cooperation with the national security state.[131] Silicon Valley firms' ongoing collaborations with oil companies have sparked debate recently, but that debate so far lacks historical grounding.[132] This article presents the long historical context for Google's and other tech companies' assistance in extending the carbon economy. And where there is history there are alternatives: things were different in the past, the present was arrived at contingently, things can be otherwise in the future. For the future to be different, however, we must understand that the wheels of e-commerce have long been lubricated with a thick, if strangely invisible, layer of oil.

129. Oreskes and Conway, *Merchants of Doubt*; Proctor and Schiebinger, *Agnotology.*

130. Ben Franta and Geoffrey Supran, "The Fossil Fuel Industry's Invisible Colonization of Academia," *The Guardian*, March 13, 2017; Jelmer Mommers, "Als de fossiele industrie de onderzoeksagenda op je universiteit bepaalt," *De Correspondent*, May 16, 2017.

131. M. Hicks, "Why Tech's Gender Problem Is Nothing New," *The Guardian*, October 12, 2018; Margaret O'Mara, Jessia Ma, and Ash Ngu, "Lyft's IPO Is Making the Same Circle of Men Rich, Again," *New York Times*, March 29, 2019; Margaret O'Mara, "Silicon Valley Can't Escape the Business of War," *New York Times*, October 29, 2018, A19.

132. Merchant, "How Google, Microsoft, and Big Tech Are Automating the Climate Crisis."

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