

World War II, the Cold War, and the Knowledge Economies of the Pacific Coast*

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World War II had enduring effects on the economies of the Pacific Coast, but not necessarily in the ways most commonly adduced. In his classic *World War II and the West*, historian Gerald D. Nash suggests that the war transformed the region from a colonial “Third World” economy based on agriculture and mining into a modern, technology-driven manufacturing dynamo. The war did indeed generate a flood of new workers into the West, propelled by an unprecedented infusion of federal spending for military production. But wartime spending did not particularly favor the West over other regions. And most of these jobs were transitory; employment in such industries as aircraft and shipbuilding fell rapidly between 1945 and 1948. Thus, as some analysts have observed, it was if anything *postwar* federal spending policy that sustained high income levels in the Pacific states, “preventing decline that might otherwise have mirrored the Midwest.”¹

Moreover, the prewar geographic remoteness of the West Coast did not imply impoverishment or backwardness. Because southern California was already the nation’s leading aircraft center by the 1930s, that region’s prominence in wartime production was more a consequence of prior development than a cause. In Seattle, Boeing’s production of seaplanes for military purposes dates from World War I not II, and the company was already on its way to national competitiveness in the 1920s. Referring to the peninsula that later became known as Silicon Valley – famous for rags-to-riches success stories featuring impecunious inventors toiling in garages – historian Stephen B. Adams writes that in reality the valley was “born on third base” in light of its tight connections to San Francisco’s legal and financial networks, and to an “abundance of supporting institutions” in the state of California.²

Despite the persuasiveness of these critiques, this paper nonetheless maintains that World War II was indeed the triggering shock that set in motion chains of events whose outcome was

the Pacific coast economy as we now know it. Of course there were many historical links between World War II and the Cold War, from global geopolitics to domestic political ideologies. The focus here is on the handful of “knowledge economy” clusters that dot the country’s western coastline, and the main association is with the far-reaching change in national technology policy that came out of wartime experience. A famous landmark in that transition was the 1945 report to President Roosevelt by Vannevar Bush: *Science the Endless Frontier*. The report reflected a national consensus that science-based technology had been crucial to winning the war, and that investments in science and its applications would better prepare the country for future conflicts. But whereas Bush envisioned a single agency to support basic science for defense and nondefense purposes, as events unfolded early federal support for Research and Development was overwhelmingly military in sponsorship. This new stream of technology-oriented funding was unprecedented in scale and qualitatively different from wartime patterns. In particular, it strongly favored establishments and research universities on the West Coast, building an enduring regional infrastructure in the process.

This paper traces the institutional and economic evolution of four Pacific Coast knowledge economy clusters from wartime to Cold War to commercialization: Los Angeles, San Francisco Bay area, Seattle, and San Diego. Devoting primary attention to just these areas may seem limiting, but these were four of the top seven metropolitan-area recipients of prime military contracts in fiscal year 1960; and the largest counties in each comprised four of the top five counties nationally in that year. Three of these counties were among the top seven in 1980, 1990, and 2000.³ Indeed, extreme geographic clustering is one of the hallmarks of the emergent high-tech economy of the twenty-first century, a consideration of far broader significance than can be adequately covered here.⁴ Although the four areas have a common heritage in military support for research-intensive enterprise, they differed markedly in their responses to the dramatic cuts in military spending at the end of the Cold War. The Bay area high-tech economy continued to thrive during and after the transition, so much so that its Cold War origins are frequently forgotten or denied. Los Angeles, in contrast, never fully recovered from the 1990s dismantling of the aerospace economy. Seattle and San Diego represent intermediate variations, cautioning against simple formulaic historical interpretations.

The Economic Impact of World War II

Unquestionably, wartime demands dramatically increased the population and scale of economic activity in the Pacific states. Despite departures for military service, the region's civilian population increased by 2.4 million (25 percent) between 1940 and 1945, primarily from interstate migration. Because the war pulled the region as well as the nation out of the Great Depression, civilian employment grew even more rapidly, led by a doubling of manufacturing jobs. Although California turned migrants away during the 1930s, by 1942 Henry J. Kaiser and other shipyard managers were scouring the country for workers, targeting southern and midwestern cities. By 1943, war authorities declared Los Angeles, Portland-Vancouver, San Diego, San Francisco-Oakland, and Seattle-Tacoma "congested production areas" and placed restrictions on new procurement in these metropolitan areas.⁵

Employment gains were greatest in shipbuilding and aircraft. The Pacific Coast accounted for 52 percent of all vessels produced during the war, and 46 percent of all aircraft. The scale of the project was massive, but two features deserve emphasis: these were industries in which the region had already established strong comparative advantage before the war; and most of the mobilization was transitory, the postwar employment cuts being even more rapid than the wartime buildup. A 1948 report by the San Francisco Federal Reserve concluded: "The distribution of workers among major industry groups is now not markedly different than before the war. Little trace remains of the wartime pattern of employment." Referring to California, historian Roger Lotchin concludes: "Much of what happened from 1941 to 1961 was merely a continuation of trends well underway in the interwar period."⁶

Seeing the wartime experience in longer-term perspective is essential, but there is a danger in overstating the case and seeing the entire episode as fleeting and therefore inconsequential. For one thing, scale matters. Most migrants from other parts of the country chose to stay after the war, despite cutbacks in military employment. Drawing on insights from the New Economic Geography, Paul Rhode finds that "home market effects" were significant for the postwar regional growth of "nonwar" industries, such as automobiles, rubber tires, petroleum and chemicals. The larger population required housing, which in turn supported expanded job opportunities in residential construction, infrastructure, transportation and trade. These trends were no doubt underway before the war, but the pace at which home-market thresholds were

crossed clearly increased with the surge in population. In Los Angeles, many war production plants were converted into peacetime factories, and new branch plants were opened by such companies as Sylvania Electric, General Motors, and Quaker Oats.⁷

For our purposes, the deeper and more lasting legacies of the war were institutional and political, reflections of what might be called a “ratchet” effect well-documented in both psychology and economics: the powerful impulse to *retain* a status or achievement that has already been attained, as contrasted with open-ended but less intense efforts to improve on the status quo. Roger Lotchin documents ongoing efforts by California cities to secure federal military dollars for plants, bases, and infrastructure, dating back to the preparedness debates before World War I. But he also shows that in the wake of unprecedented upheaval during World War II, the same cities were determined to hang onto what a state commission called “war winnings.” San Diego established a postwar planning committee as early as July, 1942, dedicated to retaining payrolls after the war and ensuring the city’s future as a “navy-industrial city.” The Los Angeles Chamber of Commerce opened an office in Washington DC during the war to help local small businesses secure government contracts. The Chamber’s Military Affairs Committee was revived and reorganized in 1947, charged to act “in a liaison capacity between the nation’s military establishment and local businessmen and industry and to assist the army in the solution of appropriate problems.” San Francisco’s postwar planning was less focused on naval or aircraft industries, but Bay cities like Vallejo actively lobbied to retain naval bases, and the area foresaw a large federal, defense-based role in hoped-for infrastructure investments. A Bay Area Council publication argued: “Close contacts between Federal and private business groups built up during the war should be continued and strengthened...Government business – Federal State, and local – is a big business in the Bay Area and is a vital factor in its economy.”⁸

What was true for cities held even more strongly for defense firms and universities: nearly all parties hoped to extend wartime economic relationships into the postwar era. It is perhaps not surprising that producers of aircraft, ships and weapons for the war effort would actively seek defense contracts. Doing so typically required restructuring towards greater technological sophistication, but many firms were able to manage that transition. The leading aerospace firms of the 1950s all descended from major aircraft producers of World War II. They were joined by electronics companies entering aerospace and firms specialized in propulsion

units for rockets and engines for aircraft.⁹ Wartime experience undoubtedly helped in securing these contracts, but there is little indication that the contracting process itself was geographically biased. Nonetheless the geography of military contracts did shift markedly over time.

The most dramatic discontinuity associated with the war was in the relationship between the federal government and the country's leading research universities. As historians Roger M. Geiger and Creso M. Sa write: "The mobilization of university scientists during World War II permanently altered the perception and the reality of academic research." It was not that federal military funding invaded and corrupted what had previously been an isolated ivory tower world. Responsiveness to market forces and engagement with private-sector interests have long been distinctive traits of American universities. Cal Tech in particular was a foremost aeronautical research center before the war, with close ties to aircraft companies, which in turn implied indirect funding from the War Department. Even before Pearl Harbor, however, the Institute's Kellogg Radiation Lab began work on rocket projectiles, primarily for the Navy. Eventually the rocket project became so big that it took over the Kellogg Lab, the optical shop, the steam plant, the astrophysics shop, Bridge Laboratory of Physics, the Astrophysical Laboratory, and several off-campus buildings as well, prompting the Institute's historian to call it "an educational institution in name only during the war." Afterwards the Institute returned to its educational mission, but with a substantially increased role for federally-funded research (especially including the National Aeronautics and Space Administration, founded in 1958).¹⁰

The most famous research mission was the Manhattan Project to develop an atomic bomb, often said to have ushered in the age of "Big Science." But many other projects were contracted to research universities, and the wartime experience established many basic institutional arrangements that persisted afterwards. Vannevar Bush, Director of the Office of Scientific Research and Development (OSDR) during the war, understood that an important background objective was to strengthen the infrastructure of scientific departments and industrial labs, so institutional overhead rates were relatively generous. This policy was continued after the war, when for idiosyncratic reasons, the Office of Naval Research emerged as the primary provider of federal research funding. Although Bush himself pictured broad support for science in the interests of both national security and economic progress, the advent of the Cold War

meant that defense funding led the way. As Paul Koistinen writes: “Money flowing from the armed services was unlike anything academia had ever seen or imagined.”¹¹

To be clear, nothing in this emerging policy was intended to support any one region more than another. Berkeley’s Radiation Laboratory (later the Lawrence Laboratory) was an important player in the Manhattan Project, but no more so than the MIT Radiation Laboratory or the Applied Physics Laboratory at Johns Hopkins. But the new orientation of U.S. technology in a science-driven direction may reasonably be considered an effect of World War II, which ultimately did have important regional consequences. The regime change was sufficiently visible that even Stanford University, which played no important role in wartime research, understood that tapping into defense support was the key to future institutional success. Frederick Terman, then a rising Stanford engineer, spent the war years directing the Radio Research Laboratory (a spinoff of MIT’s Rad Lab) at Harvard, an experience that impressed upon him the importance of close interaction between scientists and engineers for institutions that aspired to elite status. Pondering his personal plans late in the war, Terman wrote to his colleague Paul Davis: “The years after the war are going to be very important and also *very critical* ones for Stanford. I believe that we will either consolidate our potential strength, and create a foundation for a position in the west somewhat analogous to that of Harvard in the East, or we will drop to a level somewhat similar to that of Dartmouth, a well thought of institution having about 2 per cent as much influence on national life as Harvard.” In pursuit of this goal, Terman returned to Stanford as Dean of Engineering, bringing at least eleven former RRL members with him. Contacts with the ONR developed by Terman and his RRL colleagues also proved valuable, as this agency soon became Stanford’s largest funder.¹²

The Cold War and the Pacific Coast Economy

The postwar rise of the Pacific Coast economy may thus be seen as the intersection of two war-related but largely separate developments: regional population growth accelerated by the war, and the shift into science-based technologies coming out of the wartime experience. But there was a third contingency, by no means independent of the first two but at the same time not historically inevitable: the intensification of the Cold War and consequent expansion of federal defense spending. Some observers argue that this process was itself a ratchet effect, as military agencies and their clients resisted budget cuts and actively lobbied for more resources. This perspective may well have validity, but it is undeniable that fears of the Soviet Union in the postwar era were real, punctuated by the 1948 Communist coup in Czechoslovakia, the Berlin Blockade of 1948-1949, and the Soviet atomic bomb detonation in August 1949. According to Paul Rhode, West Coast business leaders in the immediate postwar years did not foresee military spending as a plausible long-term foundation for the region's economy. But such skepticism was swept away with the surge in spending after the outbreak of the Korean War in 1950. By that year, employment in defense-related industries such as aircraft and electronics (though not shipbuilding) exceeded wartime peaks; the same was true of defense R&D budgets.¹³

Even during the pre-Korean War years when defense spending was relatively stable, the development of Cold War institutional arrangements continued virtually without interruption. The Federal Airport Act of 1946, providing generous federal support for urban airport projects, was billed in part as a defense measure, foreshadowing the creation of the National System of Interstate and Defense Highways in the 1950s.¹⁴ The ONR continued its cultivation of relationships with academic scientists and departments, supporting projects at 200 institutions almost immediately after the war's end and interpreting the defense-related research mission broadly. Private industry had relatively little interest in direct support for academic science at the time, but firms responded eagerly to the prospect of drawing upon federal R&D funding, often with close ties to universities.¹⁵ Meanwhile, new organizational forms were taking shape to pursue mutual interests of defense agencies, universities, and private businesses. Project RAND was initiated in 1946 as a research arm of the Douglas Aircraft Corporation, with an infusion of funds from the Army Air Force, to consolidate scientific and technological research on air warfare. Because of conflicting interests among companies, the organization became an

independent nonprofit corporation in 1948 – one year after the Air Force itself became an independent military service. Primarily funded by the military, RAND made numerous technological contributions in such areas as orbital satellites, material science, airborne reconnaissance and over-horizon radar, but subsequently broadened its scope to encompass complex systems, the cost-effectiveness of weapons systems, linear programming and game theory.¹⁶ The Stanford Research Institute was founded in 1946 with a large loan from the University, soon became a leading client of the ONR and consultant to such firms as the Chevron Corporation and the Disney Company. The Stanford Industrial Park opened in 1951.¹⁷

Although the preservation and expansion of military spending was in many ways a continuation of developments launched during World War II, the transition to Cold War witnessed a remarkable change in the geographic distribution of these funds. The shift is succinctly summarized in Table 1, extracted from a report issued by the Secretary of Defense in 1962. Whereas the Pacific states received just 12.3% of military prime contract awards during the war, that share jumped to 23.9 percent in 1961, California the largest gainer by far. While every other region experienced a decline in military contract awards across the three periods, only the Mountain and Pacific regions actually received increased funding over time. Somewhat defensive about this regional imbalance, the report – issued in response to “many inquiries for information on the geographic distribution of defense contracts” – insisted: “Defense policy stresses awards on merit.” Its summary explanation was as follows:

“We have moved swiftly away from mass production into research, development and small quantity production as the normal character of major weapon system procurement. This phenomenon has created significant change in the military industrial base in many communities, states and regions. The report recommends no course of action. It should be recognized, however, that Defense must seek its needs where capability exists, in order to be responsive to the technological requirements of modern warfare.”¹⁸

The report goes on to document the increase in contracts supporting “experimental, developmental, test and research work,” especially the “vast expansion of missiles and electronics procurement” (p. 4).

Thirty years later, these themes were picked up and elaborated by economic geographer Ann Markusen and her collaborators in *The Rise of the Gunbelt*, which argued that the Western

military-industrial frontier featured a “new locational logic” in which the continual pressure to innovate to satisfy demanding technological standards reinforced tendencies toward agglomeration, clustering and extreme geographic concentration.¹⁹ Confirming the Secretary of Defense’s 1962 observation that “a Region that gains a long head start in a new and expanding field of procurement is bound to enjoy an enduring advantage, especially when R&D is a primary element,” these authors found that regional distribution maps of procurement and defense-related manufacturing were essentially stable from the 1950s through the 1980s. They warned, however, that regions dependent on specialized production for military demand were highly vulnerable when funding was reduced, as it was in the 1990s with the end of the Cold War.²⁰ Subsequent sections reconsider this prognosis with respect to the two main bases for technological clustering in the Cold War era, aerospace and electronics.

Aircraft and Aerospace

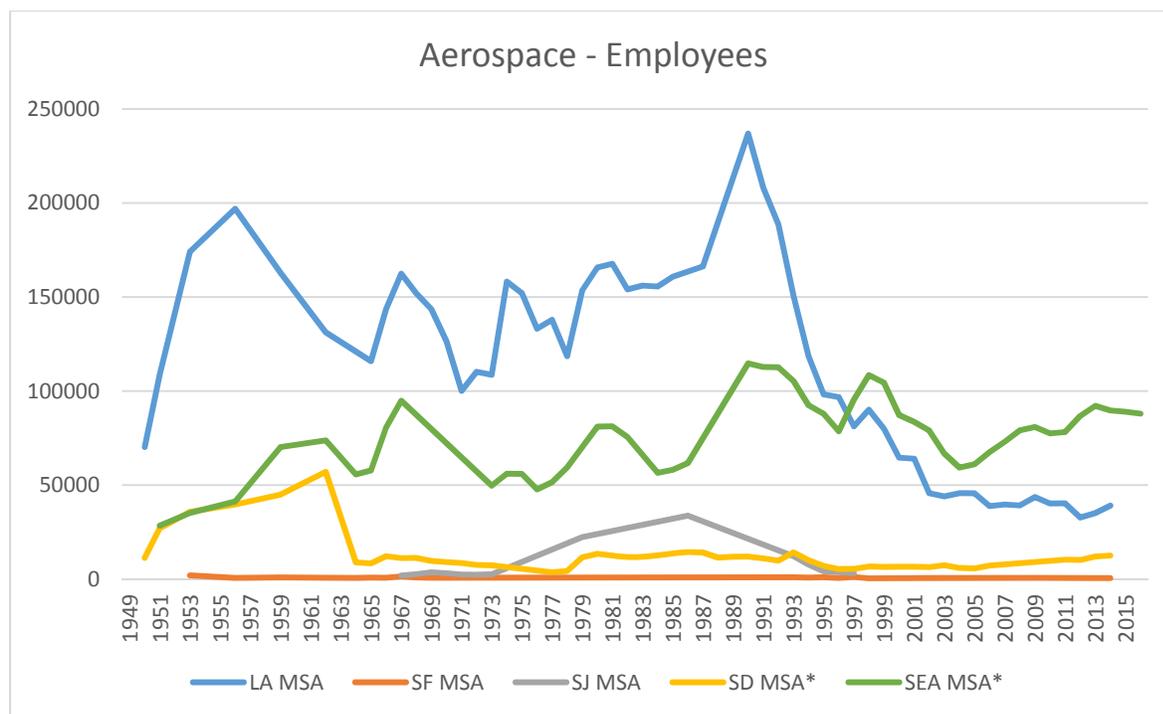
As noted, the Pacific region was already a major center of aircraft production prior to World War II. Between 1929 and 1939, California surpassed New York to become the leading aircraft state, as measured by employment, establishments, or value-added. In seeking to understand this pattern, one has to contend with the powerful retrospective impulse to see it as the inevitable consequence of geographic conditions, chiefly the mild climate and favorable terrain for flying. Rigorous analyses, however, almost always reject such natural advantages as decisive for aircraft production. Firms were located throughout the country in the prewar era, including such inclement areas as Buffalo (Curtiss-Wright) and Seattle (Boeing). Aerospace historian Peter Westwick notes that “almost all aerospace work was, in the end, conducted indoors.” In his classic 1951 study of the aircraft industry, economic geographer William Cunningham acknowledged a role for climate but identified the key characteristics of the main product: “The airplane is a nonstandardized product created largely for the military market. With such a product in such a market, performance, even above cost, often determines the allocation of contracts and the survival of firms.” As early as 1927-1933, military sales accounted for two-thirds to three-fourths of sales for leading aircraft manufacturers.²¹

What drove Pacific Coast aircraft leadership in the interwar years was new technology originating in the West, specifically the “airframe revolution” that replaced wooden frames with metal and set new standards for speed and efficiency. Notable models included Lockheed’s L-10

electra (1933), Boeing's 247 (1934), and Douglas Aircraft's DC series, which dominated commercial sales by the late 1930s. An important individual figure was John Northrop, a committed Californian who worked for both Lockheed and Douglas before founding his own firm in 1932. Northrop's designs emphasized aerodynamic streamlining and stressed-skin metal construction, providing much of the technological basis for U.S. leadership in the industry. This period also saw important regional developments in infrastructure, such as the founding of the Guggenheim Aeronautical Laboratory (forerunner of the Jet Propulsion Laboratory) at Caltech in 1929, under the directorship of Theodore von Karman. Douglas provided instructors to the school to teach aircraft design, and in turn the firm made much use of the Caltech wind tunnel during the 1930s. Even Boeing arranged to use the Caltech wind tunnel from far-off Seattle, though that firm developed closer ties to aeronautical engineers at the University of Washington. One may also observe the prewar emergence of networks of sub-contract shops and parts suppliers: In addition to its six major aircraft assembly plants, Los Angeles in 1939 featured thirty aircraft accessories and parts suppliers and three aeronautical instruments manufacturers.²²

Prewar aircraft in the Los Angeles area thus displayed many features that later became prominent in Pacific Coast knowledge clusters: military demand for high-performance products, links between private firms and research universities, inter-firm mobility of leading inventors, and local networks of specialized suppliers and skilled labor. The area's response to wartime demands certainly built on these strengths, though the war years actually saw a decline in the coastal shares of production. These features were accentuated in the postwar era by increases in scale and in the scientific sophistication of the industry.

Figure 1. Aircraft and Aerospace Employment by MSA, 1949-2014



Source: *County Business Patterns*, various years. Seattle MSA 1990-2016 from Washington State Employment Security Department, *Historical Employment Estimates*.

Figure 1 shows the rapid growth of aerospace employment in the Los Angeles metropolitan area at the time of the Korean War. The industry employed more than 40 percent of manufacturing workers in Los Angeles County throughout the 1950s and 1960s, in an era of manufacturing workers in Los Angeles County throughout the 1950s and 1960s, in an era when manufacturing drove economic growth for the region and state. Spreading into Orange County and further south and west after 1960, the MSA accounted for 75 to 80 percent of aerospace employment in California. As pioneering aviation companies exited the Midwestern cities in which they originated, the Los Angeles area seemed to exert a powerful gravitational force for profit-seeking firms in this fast-changing industry.²³

From one perspective, the concentration of aerospace in the greater Los Angeles area can be seen as a direct consequence of federal policy choices, “a strong case of California-itis” on the part of key decision-makers, particularly by the Air Force. The Army Air Corps looked west for advanced technologies throughout the war, continuing its support for rocket research at Caltech’s Jet Propulsion Laboratory and in 1946 awarding a \$1.9 million contract for a missile study to

Consolidated-Vultee (Convair), then of Los Angeles. Hughes Aircraft of Culver City recruited Caltech Ph.D.s Simon Ramo and Dean Wooldridge in 1945 to build capability in advanced aviation electronics, winning an \$8 million contract to produce radar weapons control units in 1948. A watershed for regional aerospace was the report of the Strategic Missile Evaluation Committee (known as the “teapot committee”), appointed in 1953 and chaired by John von Neumann, which endorsed development of an Inter-Continental Ballistic Missile (ICBM) with a nuclear warhead. The report led directly to establishment of an Air Research and Development field office on the West Coast, and to the Western Development Division (WDD) and the Special Aircraft Project Office, both based in Inglewood, California. So committed was the Air Force to southern California for missile projects that it petitioned the Eisenhower Administration for an exemption to the policy requiring that missile development as well as production be dispersed away from coastal areas. Although initially rejected, the exemption was granted by the Secretary of the Air Force in 1955.²⁴

The geographic preferences of Air Force officials, however, can hardly be attributed to idiosyncratic regional loyalties or favoritism. Taking a longer view, it seems clear that decision-makers responded to already-established capacity in key technologies, on the part of individual firms and even individual scientists and engineers. Air Force decisions in the early 1950s were undoubtedly central, but by the end of that decade there may have been little real choice, given the objective of developing complex systems with many interdependent components and the sense of urgency provided by the Cold War context. The Air Force philosophy of relying on private-sector expertise put a premium on identifying the most technically advanced firms and called for new organizational forms to supervise and coordinate the work – further enhancing the value of proximity. Thus the petition for exemption to the dispersal policy invoked the importance of avoiding delays in development schedules, and the waiver was approved so that the ICBM program would be “restricted only by technological considerations.”²⁵

These agglomeration economies tended to cumulate and become institutionalized over time. Both UCLA and USC established aeronautical engineering programs in the 1940s, and research laboratories, both corporate-sponsored and independent, dotted the landscape in the 1950s. More market-based forms of institutionalization were local networks of suppliers and service firms, and a stock of skilled workers and engineers residing in the area. Empirical

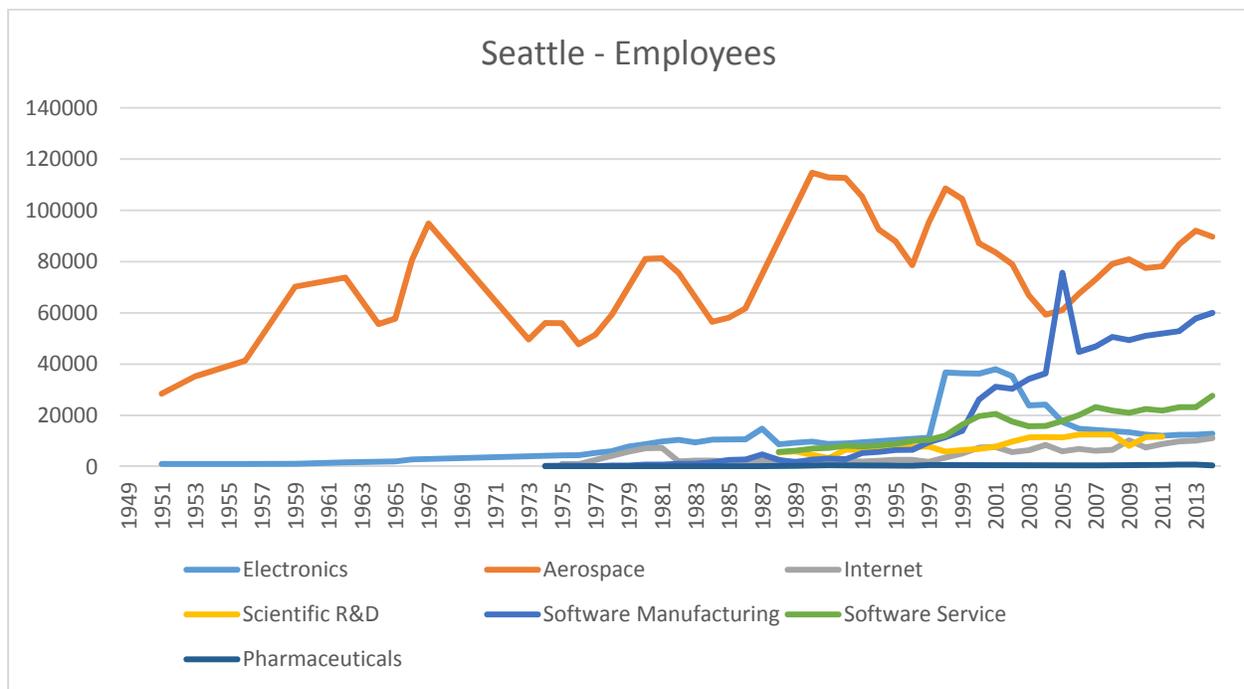
verification may be found in sociologist Allen J. Scott's 1993 book *Technopolis*, presenting survey evidence from the late 1980s. Scott documented a "dense local web" of transactions and subcontracting activity, especially among smaller establishments, featuring frequent face-to-face contact and site visits. Employee residences tended to cluster in island-type groups tightly defined by establishment size and journey-to-work distances. The survey question on previous employment revealed a "fair degree of shifting around," especially among younger workers, but the moves (including those of scientists and engineers) were primarily within the metropolitan area. Writing just after end of the Cold War, Scott was careful to note that this fine-tuned adaptation in one specialized sector left the area vulnerable to cutbacks in military spending.²⁶

San Diego is sometimes included as part of a broader Southern California supply chain, and that city enjoyed a dramatic but brief aerospace surge in the 1950s (Figure 1), when Convair (now relocated to San Diego) recaptured a lead role in the first WDD prime missile contract, to build what became the Atlas missile. With the takeover of Convair by General Dynamics, the venture gained renewed vigor in its new location at the Kearney Mesa Industrial Park, created by the city in 1958 to house precisely such a project. After 1962, unfortunately, San Diego aerospace lost out to competition in both military and commercial markets, an early taste of the dangers of specializing in defense industries. But the city had a more stable economic base through its long-term association with the Navy, and more importantly, its broader scientific and technological infrastructure continued to develop across the decades. The Scripps Institution of Oceanography, whose origins pre-dated World War I, established a vital research link with the Navy during World War II, culminating in the Naval Electronics Laboratory (a consolidation of two existing labs) in 1945. The NEL engaged in important research on precision radar navigation and electronic recognition systems, moving on to marine life issues such as the sudden disappearance of the California sardine fishery. SIO's reputation and close linkage to the Navy research establishment gave it leverage to push for a San Diego campus of the University of California, which welcomed its first undergraduates in 1964. UCSD in turn became the base for a world-class biological and health sciences complex by the end of the century.²⁷

Seattle offers an instructive variant case: an aerospace center second only to Los Angeles in scale, yet distinct in its domination by the Boeing Company. As early as the 1920s, when the company won big contracts from both the U.S. Army and Navy, Boeing was distinctive among

aircraft firms in building its own airliners and operating them over its own routes. Like other Pacific Coast cities, the Seattle MSA experienced rapid growth in both aircraft and shipbuilding during World War II, but failed to develop the complex local supplier and labor market networks seen in Los Angeles. Figure 2 shows the roller-coaster character of Seattle aerospace employment, with repercussions felt throughout the MSA. Writing in 1991, Markusen et al called Seattle “a classic example of an ossified, single-sector economy, where one or a few firms dominate local resource markets.”²⁸

Figure 2. Seattle MSA Employment by Industry, 1951-2015



Source: County Business Patterns, various issues. Aerospace for 1990-2015 is from Washington State Employment Security Department, *Historical Employment Estimates*.

Domination by a single firm had its compensations, however, in that Boeing internalized many aspects of the MSA, taking on a role that one analyst calls a “surrogate university.” Thus in 1970 Boeing formed a wholly owned subsidiary called Boeing Computer Services, which became the region’s largest software supplier in the 1980s. Boeing also maintained a high-wage internal labor market, sponsoring programs at local high schools and colleges. The company

itself became more stable after the devastating losses of the early 1970s, emphasizing risk-sharing with contractors elsewhere in the U.S., Japan and Europe. Unlike other dominant firms, Boeing did not fight departures by entrepreneurial employees launching their own companies; as many as thirty-seven start-ups in high technology trace their origins to Boeing or BCS. The area's fortunes may have been enhanced by the fortuitous loyalties of individuals: Seattle native Dr. William B. Hutchinson founded both the Pacific Northwest Research Foundation and the Fred Hutchinson Cancer Research Center in the late 1950s; Bill Gates and Paul Allen (two Washington natives) brought Microsoft to Seattle in 1979. But these institutions would have been less likely and less successful if the area had not already been congenial to high-tech enterprise. On all of these fronts, Seattle was better-positioned than Los Angeles to respond to cuts in military spending in the 1990s.²⁹

Computers and Electronics

The technologies now most closely associated with Silicon Valley represent a confluence of two earlier technological streams: computers, traceable back to the Jacquard Loom and Herman Hollerith's punch cards, leading to the ENIAC computer at the University of Pennsylvania in 1946; and semiconductor electronics, coming out of wartime research on radar for submarine detection and the invention of the point contact transistor at Bell Labs in 1947. Neither of these originated on the Pacific Coast, and in both cases, fundamental postwar developments took place in older parts of the country. Prior to the marriage of the two streams, it was widely believed that demand for giant vacuum-tube computers would be limited to less than one hundred nationwide. As with aerospace, the vast majority of semiconductor R&D (85 percent according to one 1959 estimate) was funded from the defense budget. Even at Bell Labs, nominally in the private sector, improvements on the transistor were driven by high performance standards demanded by the military: tolerance of extreme temperatures, resistance to radiation, and the ability to amplify high-frequency signals. Half of IBM's data-processing revenue during the 1950s came from two military projects.³⁰

Not only were core technologies in flux during the 1950s, but the division of labor between northern and southern California had not yet taken clear shape. Some of the earliest customers for computers were aerospace companies, because of the enormous computational requirements of aircraft design. Computer pioneers J. Presper Eckert and John Mauchly, lacking

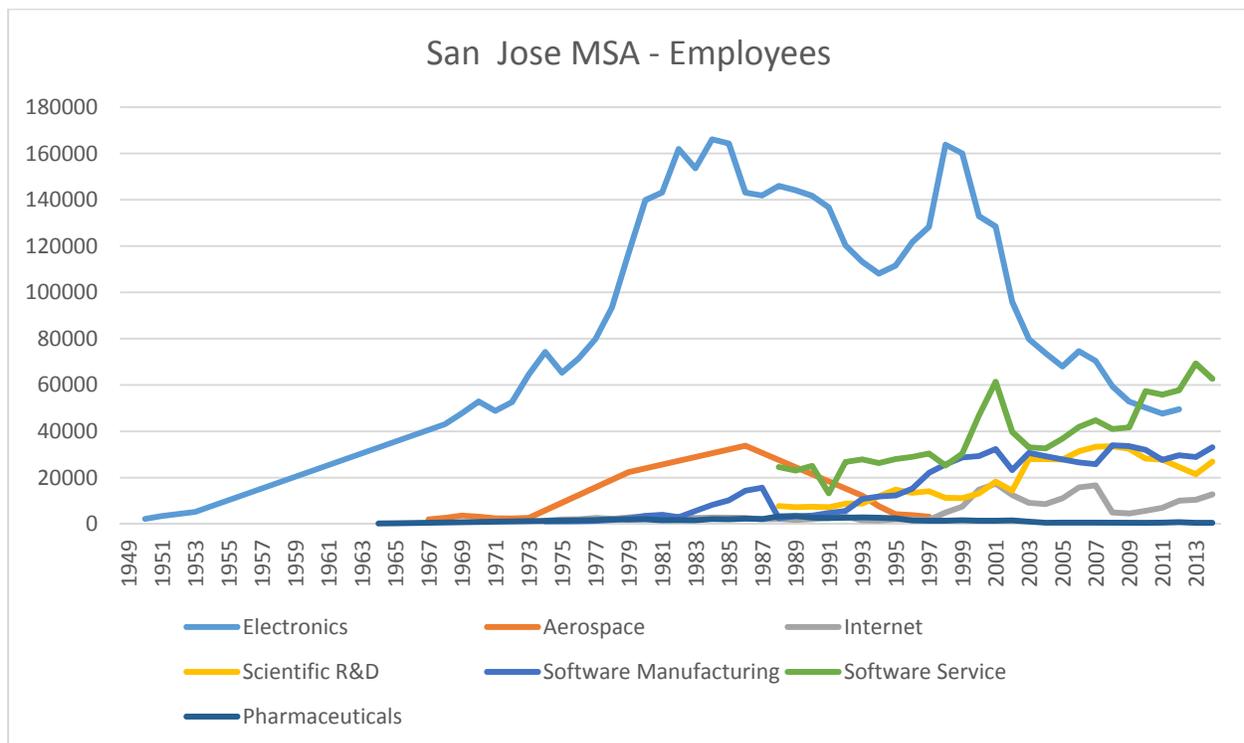
academic positions or financial support, signed a contract in 1946 with the Northrop Aircraft Company to design a digital computer to be used for guidance of the Snark missile, then under development for the Air Force. The Northrop computer group also contracted with a little-known Palo Alto firm named Hewlett-Packard to produce a series of digital difference analyzers for missile guidance. Hughes Aircraft made military computers until the mid-1950s, and the Rand Corporation built the JOHNNIAC computer (named for Von Neumann) in 1953.³¹

At the same time, the Bay Area had a longstanding tradition in aeronautics, also with strong military connections. Stanford's had an aeronautical engineering program in the interwar years, supplying many of the top people at Lockheed and other southern California firms. After years of lobbying, the National Advisory Committee on Aeronautics opened its new aerodynamics laboratory (the Ames Research Center, later called Moffett Field) in Sunnyvale in 1939; with the Alameda Naval Air Station and the Army's Hamilton Field, the area had a niche in the research and repair sections of the industry. Northern California largely missed out on the postwar aviation boom, but the Hiller Aircraft Company employed mechanics from East Bay shipyards and aerodynamicists from Stanford and Cal Poly to win many R&D contracts for helicopters in the 1950s. A major event for the peninsula was the move of Lockheed Missiles and Space to Sunnyvale and into the Stanford Industrial Park in 1956. Building on the peninsula's expertise in electronics, Lockheed won big missile contracts from the navy, the air force, and the CIA, becoming the valley's largest employer by the 1960s. By that time, however, Santa Clara Valley was well on its way to becoming Silicon Valley.³²

The main stream to Silicon Valley was through semiconductor electronics, propelled by Cold War military support and demand. As in aerospace, there were prewar beginnings. Historian Christophe Lécuyer recounts the early activities of William Eitel, Jack McCullough, and Charles Litton, Peninsula ham radio enthusiasts who became expert at making "power" vacuum tubes for long-distance transmission. Their expertise was sufficiently advanced that the Naval Research Laboratory and the Signal Corp Engineering Laboratories in New Jersey asked Eitel and McCullough in 1937 to adapt their tubes to the specific requirements of their radar systems. The firm mechanized production methods in response to wartime demands and expanded to 3600 employees by the summer of 1943. Litton was also interested in power tubes, but found his niche making glass lathes and other equipment for tube producers. Both firms

recovered well from the postwar crisis, becoming major manufacturers of microwave tubes. Litton in particular had strong ties to Stanford University, serving as lecturer and advisor to the new vacuum electronics program. Litton was also business mentor to David Packard and William Hewlett as they launched their electronic instrumentation company.³³

Figure 3. San Jose MSA Employment by Industry, 1949-2014



Source: County Business Patterns, various issues. Industries shift from SIC to NAIC codes in 1998.

Figure 3 shows the steady growth of electronics employment in the San Jose MSA after 1950, accelerating in the mid-1970s. The leading sub-categories within this growth spurt were Computers and peripherals, Components, and Communications equipment, all closely linked to the semiconductor economy. On one reading, the rise of Silicon Valley represented an organic coevolution of technology and institutions, a “social process of bricolage...an unplanned iterative learning process” leading to a “regional recipe for creating and nurturing startups,” in the words of analysts Martin Kenney and Donald Patton. A notable landmark in this narrative was the move of William Shockley (co-inventor of the transistor) to Mountain View in 1956 –

fortuitous because Shockley's mother lived in Palo Alto, where he himself grew up – but not strictly exogenous because Provost Frederick Terman had encouraged the inventor to locate his new firm near Stanford. When Shockley's despotic managerial methods led to the resignations of the firm's leading employees, this “traitorous eight” formed an alliance with Fairchild Camera and Instruments of Long Island, one of the first venture capital agreements on the West Coast. Fairchild Semiconductor soon became famous not just for pioneering the planar process and its commercial success, but for establishing the pattern of spinoffs and high mobility among technical people in the Valley. These economic arrangements and supportive entrepreneurial culture were celebrated by AnnaLee Saxenian in her 1994 book *Regional Advantage*, comparing the Valley's external-economy structure favorably to the internal economies of large, vertically-integrated corporations on the East Coast. Historians differ on the relative importance of large corporations, startups, dense personal networks, Venture Capital, and Stanford, but these are largely matters of emphasis on what is best seen as an interdependent coevolutionary process.³⁴

If instead we search for ranges of plausible historical variation, however, it is difficult to escape the conclusion that the entire process would not have been launched, much less boosted to escape velocity, if it had not been for research funding from federal military sources, traceable to the Cold War and in turn back to World War II. As late as 1959, more than 85 percent of U.S. electronics R&D was funded by the federal government, overwhelmingly from defense. In the early days on the peninsula, even local firms deploying practical skills and workmanship, like Eitel-McCullough and Litton, actively pursued military contracts at every opportunity, enjoying their most rapid growth during the Korean War. Military demand dominated early markets for transistors and then for integrated circuits, leaving a lasting impact on specifications and direction for these technologies. At Stanford, the Korean War doubled the size of the electronics program. When the DOD through its Advanced Research Projects Agency (ARPA) sought to establish materials science as an academic discipline, alert responses by metallurgist Robert Huggins won contracts from the Air Force and the Navy, boosting the new department near the top of national rankings. The promise of rising support from military agencies loomed at a time when support from private industry for university research was essentially stationary.³⁵

What was so special about military funding? Defense agencies served as both investors and purchasers, with limited concern for price; sole-source contracts could be extremely

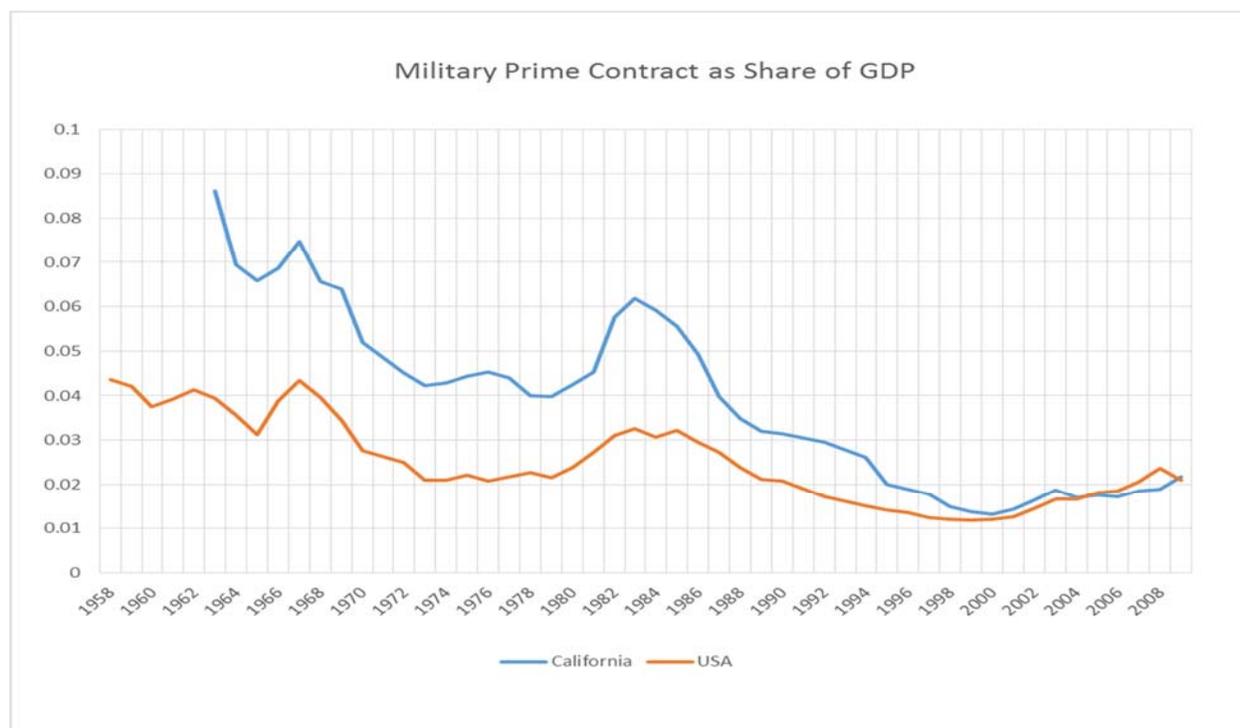
lucrative, providing a market for new, complex components that were still too expensive for industrial or commercial markets. But it would be a mistake to suggest that the defense budget was simply a gravy train for easy money. Military purchasers could be extremely demanding in terms of technical requirements and delivery times. Fairchild's high-frequency transistors did not initially meet the reliability criteria of the Minuteman ICBM. Adapting its technologies to meet these standards pushed the firm to innovate, first through the planar process and then the integrated circuit. The demands of military avionics impelled Fairchild to set up a Reliability Evaluation Division to appraise the dependability of transistors, logging millions of transistor-hours of testing, "orders of magnitude higher than those results from previous evaluations in the industry." In the 1950s large private firms like IBM and NCR were reluctant to invest large sums in risky projects with uncertain markets. Yet Fairchild's progress down the learning curve rapidly reduced costs and opened doors of new opportunity in commercial markets.³⁶

Because the military wanted to cultivate technological capabilities in American firms, sponsors often promoted dissemination of information as broadly as possible. In the early phase of transistor development, Bell Labs was explicitly tasked with holding a symposium featuring lectures and demonstrations to representatives from military services, universities and electronics firms. A second conference for Bell licensees in 1952 distributed more detailed information, generating two substantial volumes that became known as "the Bible" of transistor technology. At Stanford's Applied Electronics Laboratory, part of the understanding with its military sponsors was that it would work closely with industrial firms, streamlining the transition from prototypes to deliverables. In 1951 and 1952, Stanford physicists gave a series of lectures on klystron design and theory to Eitel-McCullough engineers, eager to avoid any appearance of privileged access for Varian (and encouraged to do so by the Renegotiation Board, overseers of excess profits). When UC-Berkeley opened its integrated circuits laboratory in 1962, they were assisted by Gordon Moore of Fairchild and by military contractors such as Westinghouse and Texas Instruments, who were instructed by the Air Force to share their semiconductor manufacturing expertise. Fairchild's founders actively encouraged technicians to establish their own equipment-supply firms, extending the Valley's startup tradition.³⁷

The End of the Cold War and the Civilianization of High-Tech

Military R&D spending fluctuated markedly across time. Figure 4 tracks the value of prime contracts as a share of GDP, for California and for the nation as a whole. After a brief hiatus at the end of the Korean War, the launch of Sputnik in October 1957 led in quick succession to the creation of the Advanced Research Projects Agency (later DARPA) to execute R&D projects and the National Aeronautics and Space Act creating NASA. Although NASA was a civilian agency, the space race was undeniably part of the Cold War. Vietnam caused another spending spurt in the 1960s, followed by a decade of steady decline. The Reagan buildup of the 1980s interrupted the trend, but cutbacks had resumed even before the fall of the Soviet Union in 1989. As Figure 4 shows, both expansions and long-term decline were magnified in California relative to the nation as a whole.

Figure 4.



Source: 1958-1964, 1975-1981, 1986-1988: Department of Defense, Prime Contract Awards by Region and State; other years Statistical Abstract of the United States, various issues.

Despite the formative role of military R&D spending for the nation's scientific and technological infrastructure, by the 1980s distinctly different voices could be heard about the continued value of these programs. Observing competitive inroads in markets for advanced

manufactured goods, critics complained that defense-oriented technologies put American producers at a disadvantage relative to countries like Japan and Germany, whose engineers could concentrate on “leading-edge technologies devoted to socially useful ends.” Studies appeared with titles such as *The Militarization of High Technology*, *Military Expansion Economic Decline*, or *The Baroque Arsenal*. Writers sometimes grudgingly acknowledged a few transfers into civilian uses, such as computers, jet planes, and lasers, but these were considered rare and overly expensive when they did occur. As analyst Robert DeGrasse Jr. put it: “Using scientific and engineering talent to solve military problems is an inefficient means of stimulating scientific or commercial advancement.” Such formulations seemed to take underlying national technological capabilities as a given, viewing deployment of these resources for military pursuits as “skewed” and “inefficient.” With the end of the Cold War, defense analysts contended even more forcefully that because of the high degree of segregation between military and commercial activities, the “spinoff model” was outdated and inefficient.³⁸

From this perspective, one of the worst aspects of a sophisticated, high-tech military is that whole communities became dependent on highly-specialized economic pursuits and hence exposed to fluctuations in defense policy. In their portentous 1992 critique, Ann Markusen and Joel Yudkin wrote that the rise of the Gunbelt “has led to increasing geographical segregation of military-industrial activities from other sectors in the economy, creating communities with pro-military cultures and greater vulnerability to downturns in the military spending cycle.” The authors identified several major metropolitan areas as highly dependent on defense spending, listing Los Angeles and San Diego (“California is perhaps the most vulnerable, at least in absolute terms”) and “Seattle as a one-company industrial city.” At the root of the regional adjustment problem, according to defense industry surveys, is that firms committed to the military found it “difficult if not impossible...to make the transition to nondefense businesses.” A spokesman for the Aerospace Industry Association said “conversion is baloney...these [defense] companies use highly specialized technologies.” Norman Augustine, CEO of Lockheed-Martin, said “conversion efforts have been unblemished by success.”³⁹

With the aid of hindsight, we can now say that some defense-dependent metropolitan areas were more successful than others in the transition to civilian markets. The Bay Area was not included on the endangered-regions lists of the 1990s because well before that decade, many

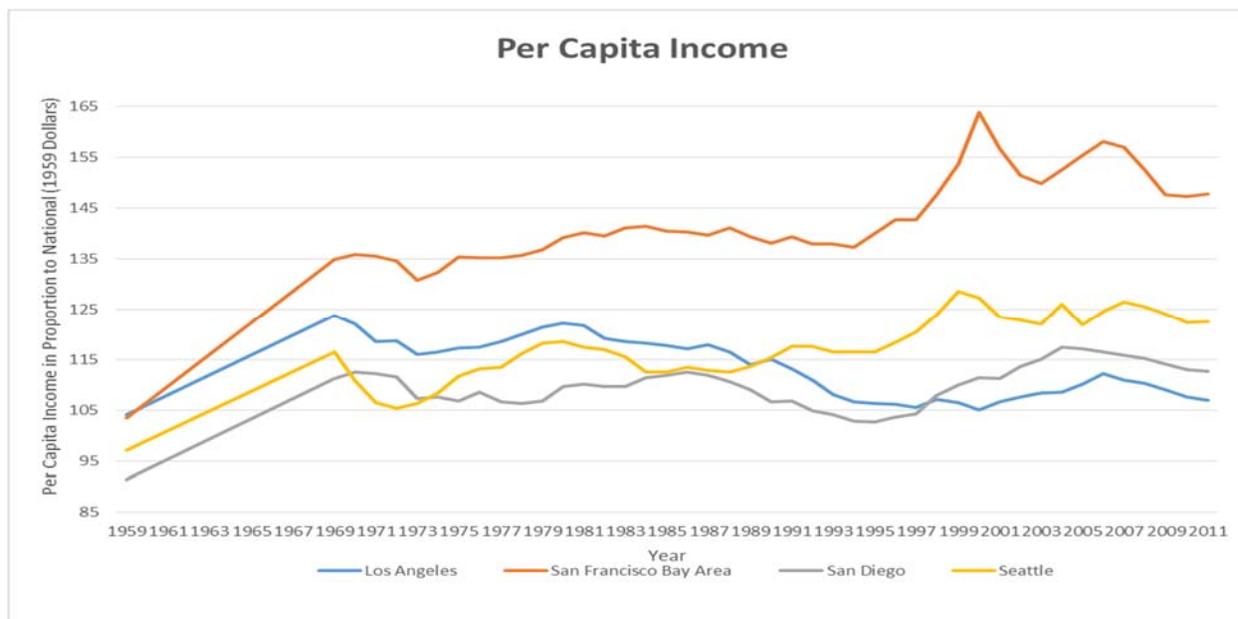
of its leading firms had achieved independence from military funding. Shaken by shifts in defense procurement policy in the early 1960s, producers began to diversify into commercial markets for computer and electronic systems. Ongoing progress in semiconductor technology opened up major new markets in consumer electronics, such as microwave ovens, transistor radios, burglar alarms, and soon, personal computers. So rapid was the transition that leading entrepreneurs came to minimize the role of military funding in their own histories. Robert Noyce claimed that Fairchild had “stayed clear of military involvement...because I thought it was an affront to any research people to say that you are not worth supporting out of real money,” while his colleague Gordon Moore wrote that “from our perspective, the impact exerted by defense R&D was quite small.” In fact, Santa Clara County continued to be a leading recipient of prime military contracts throughout the 1990s, but these transactions did not deter prominent executives from adopting a hands-off, anti-government rhetoric that did violence to the historical record. One venture capitalist told the *New York Times* in October 2000: “I’ve worked in the valley since 1963...and I don’t think government ever had a role in it.” Despite the vagaries of historical memory, however, there is little reason to question Moore’s recollection that he and others at Fairchild saw semiconductors as a general-use technology and actively pursued commercial applications from the beginning. Moving the department of application engineering from R&D to marketing in 1961 was perhaps symbolic.⁴⁰

The semiconductor industry stumbled in the 1980s, more from Japanese competition than defense cutbacks; but it recovered strongly in the 1990s, partly through accelerated technological change but primarily by shifting toward design-intensive product innovation. Market fundamentalists had their world-views reinforced when NSF’s 1994 announcement of plans to privatize the internet launched the dot.com boom of the late 1990s, centered in Silicon Valley. Despite the excesses of that half-decade, the area emerged in the 21st century as the world’s largest and strongest high-tech economy. The transition from military to commercial markets was as smooth as the transition from hardware to software (see Figure 3).⁴¹

The transition for LA aerospace was never that easy. In 1987, California had one in four aerospace jobs nationally, Los Angeles County alone accounting for one in ten. Within ten years of the end of the Cold War, aerospace employment had fallen by more than 50 percent, and by 2011 to less than one-third of its peak. Economists and policy analysts have debated the

incidence of these cuts since the 1990s, with somewhat inconclusive results. Close industry observers such as Maryellen Kelly and Todd Watkins rejected the caricature of overspecialized military contractors, insulated from competition and out of touch with civilian technologies; they point to many examples of defense firms shifting into commercial production, such as ultralightweight insulation (Aerojet), satellite TV systems (Hughes), navigation gear for commercial aircraft (Litton), and laser machine tools for assembly lines (TRW). Many plants shut down, however, and according to economists Valery Ramey and Matthew Shapiro, their capital was highly “sector specific” and sold at steep discounts. Employees had more mobility than physical capital, but studies found that displaced aerospace engineers experienced long unemployment spells and a decline in earnings after finding new positions. The ultimate outcome for displaced workers is difficult to determine, however, because an estimated 60 percent of those who lost their jobs migrated out of the region. A study by UCLA geographers concludes: “After the end of the Cold War, Los Angeles never re-established its previous levels of focus in technology-related industry.” The authors argue that the root of the area’s problem was not the direct costs of defense cutbacks, but the failure to replace aerospace with a new technological focus. In other words, Los Angeles was not Silicon Valley.⁴²

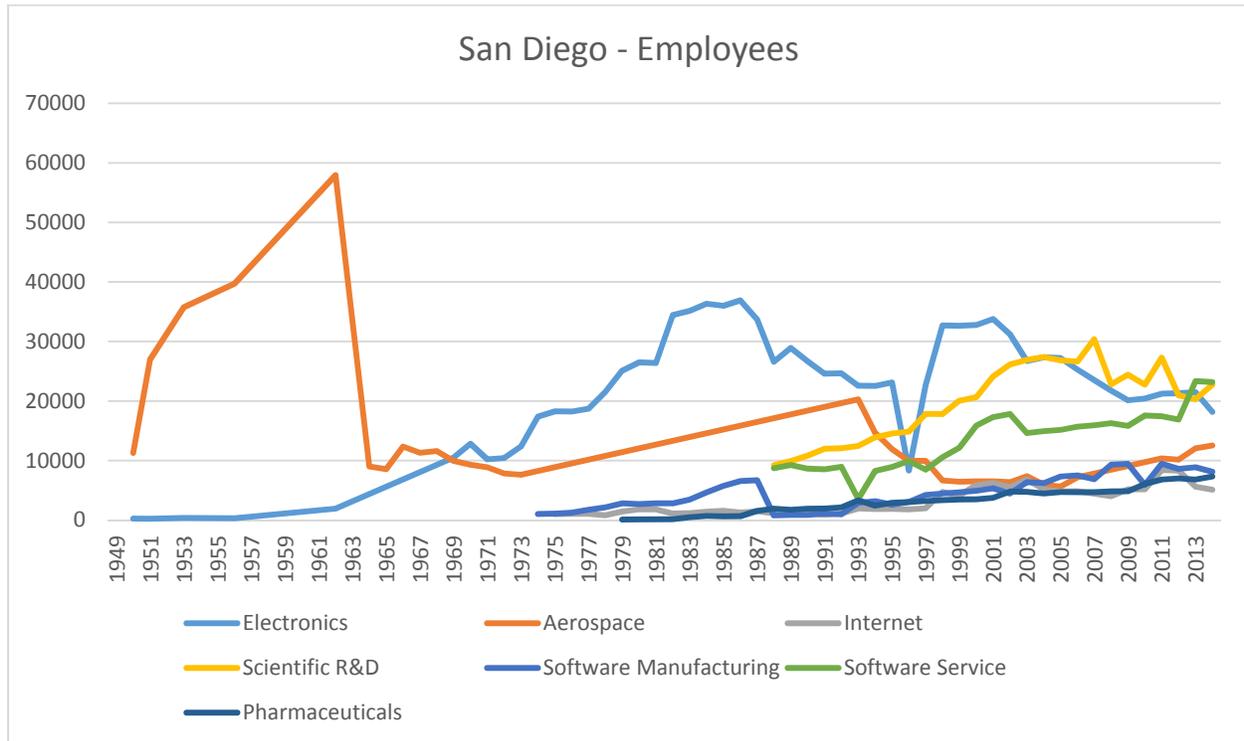
Figure 5. Per Capita Income relative to US Average, Four MSAs, 1959-2011



Source: Mary Meghan Ryan (ed.), *Patterns of Economic Change by State and Area* (Lanham MD: Bernan Press, 2014).

The contrast between the two metropolitan areas is multi-faceted. One important factor is simply that defense aerospace is more specialized and less readily transferable between sectors than the diverse cluster of electronic and information technologies that characterize the Bay Area. Defense consultant James Hasik notes that “the development processes for military and commercial aircraft are quite different, particularly because combat aircraft producers have not often profitably speculated on projects.” A simple theory of intrinsic sectoral properties is contradicted, however, by the counter-example of Seattle, even more aerospace-centered than Los Angeles, but which managed a relatively smooth transition into a diversified knowledge economy. Boeing was one of the most diversified major defense contractors all along, adapting well to both domestic and export markets after 1995, so that overall aerospace employment in Seattle held up remarkably well (Figure 2). Despite shifting its corporate headquarters to Chicago in 2001, Boeing over the years invested substantially in the area’s infrastructure of schools, social services and arts. The growth of Microsoft as a second “hub” also spawned generations of internet and software companies on the Silicon Valley model. The startup culture now extends to commercial aerospace, merging the city’s two lineages.⁴³

Figure 5 compares per capita income in the four metropolitan areas. The post-Cold War surges of the Bay area and Seattle are evident, as is the decline of Los Angeles over the same period. San Diego represents an interesting variant (Figure 6). Without historic strengths in aerospace or electronics, and lacking a major university, the city was long seen as a lethargic “martial metropolis.” But building on its connections to the Navy and high-tech oceanography, San Diego successfully pushed for its own UC branch, which opened its doors in 1964. Chancellor Richard C. Atkinson, a former Stanford faculty member, consciously emulated the “Terman model” of university partnership with firms in telecommunications and biotechnology. In 1985 the area became home to telecommunications powerhouse Qualcomm, whose success led Forbes to declare San Diego the “World’s Wireless City” in 2012. Infused by funding for health research, UCSD and the surrounding area attracted a new generation of “bioscientific entrepreneurs.” Historians Mary Lindenstein Walshok and Abraham Shragge write that “in little more than a decade, many of these companies gave rise to new commercial enterprises, which eventually found their way into the market economy even though their roots were in products of value to the U.S. Department of Defense or other federal agencies.” The payoff may be seen in San Diego’s post-Cold War income spurt, surpassing Los Angeles by 1998.⁴⁴

Figure 6. San Diego MSA Employment by Industry, 1949-2014

Conclusion

This paper argues that defense support for advanced technologies generated the infrastructure for knowledge-economy clusters in all four Pacific Coast metropolitan areas, comprising networks of firms, research universities, supplying firms, and educated professionals. With the end of the Cold War, each of the four cases offers a different variation on the adjustment to civilian technologies and commercial markets. Silicon Valley was eager for commercialization early on, and its networks spread to encompass virtually the entire Bay Area. For Los Angeles, in contrast, the loss of government funding devastated the aerospace network, and the area high-tech economy has yet to recover. Seattle was equally specialized in aerospace, yet its metropolitan area has managed a relatively smooth transition into a diversified modern knowledge economy. The divergence between Seattle and Los Angeles reflects many factors: Boeing's unique balanced between defense and commercial markets; Boeing's sponsorship of local infrastructure and tolerance of spinoffs; the arrival of Microsoft in 1979, itself partially attributable to the area's attractiveness for high-tech enterprise. San Diego represents yet another path, gradually nurturing a high-tech community around a new university, while avoiding debilitating budget cuts in the 1990s.

Per capita income is by no means a comprehensive indicator of a metropolitan area's economic performance. Despite the success of its high-tech economy, San Diego's per capita income level remained only slightly higher than that of Los Angeles. This pattern raises the larger question of what knowledge-economy development implies for lower-income, less-educated populations. In the heyday of the Cold War, new technologies generated well-paying jobs for blue-collar workers in the same metropolitan areas. That linkage began to break down in the 1980s, through the combined effects of outsourcing, import competition, and labor-saving technologies. In successful knowledge-economy centers, these three forces were augmented by the effects of rising property values on the cost of living, effectively squeezing low-income people out of the area. The relatively low per capita income levels of Los Angeles and San Diego primarily reflect the fact that these areas, despite the presence of prospering high-tech sectors, still have space in which lower-income populations can survive if not necessarily to flourish. Storper et al show persuasively that the quality of knowledge-economy networks in post-Cold War Los Angeles has not measured up to that of the Bay area. If LA had done so, however, it is far from clear that the majority of its residents would have gained.⁴⁵

References

Adams, Stephen B. "Follow the Money: Engineering at Stanford and UC Berkeley During the Rise of Silicon Valley," *Minerva* 47 (2009): 367-390.

Adams, Stephen B. "Born on Third Base: Silicon Valley's Rich Inheritance. Presented at the Business History Conference, Miami FL, 2015.

Alic, John A.; Lewis M. Branscomb; Harvey Brooks; Ashton B. Carter; Gerald L. Epstein. *Beyond Spinoffs: Military and Commercial Technologies in a Changing World*. Boston: Harvard Business School Press, 1992.

Bilstein, Roger E. *The Enterprise of Flight: The American Aviation and Aerospace Industry*. Washington DC: Smithsonian Institution Press, 2001.

Boyne, Walter J. *Beyond the Horizons: The Lockheed Story*. New York: St. Martin's Press, 1998.

Braun, Ernest, and Stuart MacDonald. *Revolution in Miniature*, Second Edition. London: Cambridge University Press, 1982.

Bugos, Glenn E. "The Aerospace Impetus to Silicon Valley," *Journal of the West* 36 (1997): 97-104.

Bush, Vannebar. *Science: The Endless Frontier*. Report to the President on a Program for Postwar Scientific Research. Washington: USGPO, 1945.

City of Los Angeles. Office of the Mayor. *The Economic Development of Southern California, 1920—1976*. Two Volumes. June 1976.

Collins, Martin J. *Cold War Laboratory: RAND, the Air Force, and the American State 1945-1950*. Washington DC: Smithsonian Press, 2002.

Cunningham, William Glenn. *The Aircraft Industry: A Study in Industrial Location*. Los Angeles: Lorrin L. Morrison, 1951.

DeGrasse, Robert W. Jr. *Military Expansion Economic Decline*. New York: Council on Economic Priorities, 1983.

- Flamm, Kenneth. *Creating the Computer*. Washington DC: Brookings, 1988.
- Flanigan, James. *Smile Southern California, You're the Center of the Universe*. Stanford CA: Stanford University Press, 2009.
- Geiger, Roger L. *Research and Relevant Knowledge: American Research Universities Since World War II*. New York: Oxford University Press, 1993.
- Geiger, Roger L., and Creso M. Sa. *Tapping the Riches of Science: Universities and the Promise of Economic Growth*. Cambridge MA: Harvard University Press, 2008.
- Goodstein, Judith R. *Millikan's School: A History of the California Institute of Technology*. New York: Norton, 1991.
- Gray, Mia; Elyse Golob; Ann R. Markusen; and Sam Ock Park. "Seattle: A Classic Hub-and-Spoke Region," in Ann R. Markusen, Yong-Sook Lee, and Sean DiGiovanna (eds.), *Second Tier Cities: Rapid Growth Beyond the Metropolis*. Minneapolis: University of Minnesota Press, 1999.
- Greenstein, Shane. *Innovation, Privatization, and the Birth of a New Network*. Princeton: Princeton University Press, 2015.
- Guillen, Reynal. "The Air Force, Missiles, and the Rise of the Los Angeles Aerospace Technopole," *Journal of the West* 36 (1997): 60-66.
- Hasik, James *Arms and Innovation: Entrepreneurship and Alliances in the Twenty-First Century Defense Industry*. Chicago: University of Chicago Press, 2008.
- Heinrich, Thomas. "Cold War Armory: Military Contracting in Silicon Valley," *Enterprise and Society* 3 (2002): 247-284.
- Hensel, Nayantara D. *The Defense Industrial Base: Strategies for a Changing World*. Surrey, England: Ashgate Publishing Limited, 2015.
- Isard, Walter, and James Ganschow. *Awards of Prime Military Contracts by County, State and Metropolitan Area of the United States, Fiscal Year 1960*. Philadelphia: Regional Science Research Institute, 1961.

Johnson, Marilyn S. *The Second Gold Rush: Oakland and the East Bay in World War II*. Berkeley: University of California Press, 1993.

Kaldor, Mary. *The Baroque Arsenal*. New York: Hill and Wang, 1981.

Kelley, Maryellen, and Todd A. Watkins. "In from the Cold: Prospects for Conversion of the Defense Industrial Base," *Science* 268 (1995): 525-532.

Kenney, Martin, and Donald Patton. "The Coevolution of Technology and Institutions: Silicon Valley as the Iconic High-Technology Cluster," in Pontus Braunerhjelm and Maryann Feldman (eds.), *Cluster Genesis: Technology-Based Industrial Development*. Oxford: Oxford University Press, 2006.

Kenney, Martin, and David C. Mowery (eds.). *Public Universities and Regional Growth*. Stanford: Stanford University Press, 2014.

Kleinhenz, Robert A.; Kimberly Ritter-Martinez; Rafael De Anda. *The Aerospace Industry in Southern California*. Los Angeles: The Kyser Center for Economic Research, 2012.

Koistinen, Paul A.C. *State of War: The Political Economy of American Warfare, 1945-2011*. Lawrence KS: University Press of Kansas, 2012.

Lécuyer, Christophe. *Making Silicon Valley: Innovation and the Growth of High Tech, 1930-1970*. Cambridge MA: The MIT Press, 2006.

Leslie, Stuart W. *The Cold War and American Science*. New York: Columbia University Press, 1993.

Leslie, Stuart W. "How the West Was Won: The Military and the Making of Silicon Valley," in W. Aspray (ed.), *Technological Competitiveness*. IEEE, 1993.

Lowen, Rebecca S. *Creating the Cold War University: The Transformation of Stanford*. Berkeley: University of California Press, 1997.

Macher, Jeffrey T.; David C. Mowery; and David A. Hodges. "Reversal of Fortune? The Recovery of the U.S. Semiconductor Industry," *California Management Review* 41 (1998): 107-136.

Markusen, Ann; Hall, Peter; Campbell, Scott; Deitrick, Sabina. *The Rise of the Gunbelt: The Military Remapping of Industrial America*. New York: Oxford University Press, 1991.

Markusen, Ann, and Joel Yudken. *Dismantling the Cold War Economy*. New York: Basic Books, 1992.

Marolda, Anthony J. "Commercialization of Defense Technology: The Success Factors," in R.D. Norton (ed.), *Regional Resilience and Defense Conversion*. Research in Urban Economics 11 (1997): 31-53.

Mayer, Helke. "Entrepreneurship in a Hub-and-Spoke Industrial District: Survey Evidence from Seattle's Technology Industry," *Regional Studies* 47 (2013): 1715-1733.

Misa, Thomas. "Military Needs, Commercial Realities, and the Development of the Transistor, 1948-1958," in Merritt Roe Smith (ed.), *Military Enterprise and Technological Change*. Cambridge MA: MIT Press, 1985.

Misa, Thomas. *Leonardo to the Internet*. Cambridge MA: Harvard University Press, 2014.

Moretti, Enrico. *The New Geography of Jobs*. Boston: Houghton Mifflin Harcourt, 2012.

Moore, Gordon, and Kevin Davis. "Learning the Silicon Valley Way," in Timothy Bresnahan and Alfonso Gambardella (eds.), *Building High-Tech Clusters: Silicon Valley and Beyond*. Cambridge: Cambridge University Press, 2004: 7-39.

Morrill, Richard, and Paul Sommers. "Seattle as a Digital City: Unexpected or Inevitable?" *Canadian Journal of Regional Science* 28 (2005): 349-368.

Nash, Gerald D. *World War II and the West: Reshaping the Economy*. Lincoln: University of Nebraska Press, 1990.

Niosi, Jorge, and Majlinda Zhegu. "Aerospace Clusters: Local or Global Knowledge Spillovers?" *Industry and Innovation* 12 (2005): 5-29.

O'Mara, Margaret Pugh. *Cities of Knowledge: Cold War Science and the Search for the Next Silicon Valley*. Princeton: Princeton University Press, 2005.

Ramey, Valery A., and Matthew D. Shapiro. "Displaced Capital: A Study of Aerospace Closings," *Journal of Political Economy* 109 (2001): 958-992.

Rhode, Paul W. "The Nash Thesis Revisited: An Economic Historian's View," *Pacific Historical Review* 63 (1994): 363-392.

Rhode, Paul W. "After the War Boom: Reconversion on the Pacific Coast, 1943-1949," in Timothy W. Guinnane, William A. Sundstrom, and Warren Whatley (eds.), *History Matters: Essays on Economic Growth, Technology, and Demographic Change*. Stanford: Stanford University Press, 2004.

Rosenberg, Nathan, and Richard Nelson. "American Universities and Technical Advance in Industry," *Research Policy* 23 (1994): 323-348.

Saxenian, AnnaLee. *Regional Advantage: Culture and Competition in Silicon Valley and Route 128*. Cambridge MA: Harvard University Press, 1994.

Schoeni, Robert F.; Michael Dardia; Kevin F. McCarthy; Georges Vernez. *Life After Cutbacks: Tracking California's Aerospace Workers*. Santa Monica CA: RAND, 1996.

Scott, Allen J. *Technopolis: High-Technology Industry and Regional Development in Southern California*. Berkeley: University of California Press, 1993.

Sell, T.M. *Wings of Power: Boeing and the Politics of Growth in the Northwest*. Seattle: University of Washington Press, 2001.

Steelman, John R. *Science and Public Policy, A Report to the President*. Washington DC: USGPO, 1947.

Storper, Michael; Thomas Kemeny; Naji P. Makarem; Taner Osman. *The Rise and Fall of Urban Economies: Lessons from San Francisco and Los Angeles*. Stanford CA: Stanford University Press, 2015.

Suarez-Villa, Luis. "California's Recovery and the Restructuring of the Defense Industries," in R.D. Norton (ed.), *Regional Resilience and Defense Conversion*. Research in Urban Economics 11 (1997): 85-114.

Tirman, John (ed.). *The Militarization of High Technology*. Cambridge MA: Ballinger Publishing Company, 1984.

United States Department of Defense. Office of the Secretary of Defense. *The Changing Patterns of Defense Procurement*. Washington DC: June 1962.

Vander Meulen, Jacob A. *The Politics of Aircraft: Building an American Military Industry*. Lawrence KS: University Press of Kansas, 1991.

Verge, Arthur C. "The Impact of the Second World War on Los Angeles," *Pacific Historical Review* 63 (1994): 289-314.

Walshok, Mary Lindenstein, and Abraham J. Shragge. *Invention and Reinvention: The Evolution of San Diego's Innovation Economy*. Stanford: Stanford Business Books, 2014.

Westwick, Peter J. (ed.). *Blue Sky Metropolis: The Aerospace Century in Southern California*. Berkeley and San Marino: University of California Press, 2012.

Notes

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¹ Nash, *World War II and the West*, pp. xii, 2; Markusen et al, *Rise of the Gunbelt*, p. 21.

² Adams, "Born on Third Base."

³ Isard and Ganschow, *Awards of Prime Military Contracts*, Tables 2 and 3. County figures for later years are from the Defense Contract National Data System, National Archives.

⁴ This phenomenon is analyzed in Moretti, *The New Geography of Jobs*.

⁵ This paragraph draws on Rhode, "After the War Boom," pp. 189-194; Johnson, *The Second Gold Rush*, pp. 34-45.

⁶ Nash, *World War II and the West*, pp. 42, 69; Lotchin, *Fortress California*, p. 171. The Federal Reserve report is quoted in Rhode, "After the War Boom," p. 199.

⁷ Rhode, "After the War Boom," pp. 205-213; Verge, "Impact of the Second World War on Los Angeles," p. 312.

⁸ Lotchin, *Fortress California*, pp. 156-205. Quotes appear on pages 159, 203. The Bay Area Council publication is quoted in O'Mara, *Cities of Knowledge*, pp. 104-105.

⁹ Compare the list of major aircraft manufacturers on p. 93 with the list of leading missile producers 1956-1961 on p. 97 in Markusen et al, *Rise of the Gunbelt*. (Convair was formed in 1943 through the merger of Consolidated Aircraft and Vultee Aircraft. McDonnell and Northrup were both important wartime producers, though not in the top ten.) See also Koistinen, *State of War*, p. 91.

¹⁰ Geiger and Sa, *Tapping the Riches of Science*, p. 10; Goodstein, *Millikan's School*, pp. 255, 262. On the longstanding industrial orientation of U.S. universities, see Rosenberg and Nelson, "American Universities and Technical Advance in Industry."

¹¹ Koistinen, *State of War*, pp. 119, 124.

¹² Leslie, *The Cold War and American Science*, pp. 51-57; Lowen, *Creating the Cold War University*, pp. 110-111. Terman's letter is quoted by Leslie, p. 44. Stanford in fact offered its presidency in 1941 to Vannevar Bush, who was Terman's thesis advisor at MIT (Lowen, p. 52).

¹³ Rhode, "After the War Boom," p. 201. R&D estimates for years prior to 1951 are not necessarily comparable to later figures compiled by the NSF. But a series for 1930-1947 was compiled in Steelman, *Science and Public Policy*, p. 10. It shows total federal R&D expenditures of \$625 million in 1947, compared to a wartime average of \$500 million. Of the 1947 total, \$500 million were sponsored by the War and Navy Departments.

- ¹⁴ Lotchin, *Fortress California*, p. 252.
- ¹⁵ Geiger, *Research and Relevant Knowledge*, pp. 24-25, 44, 49;
- ¹⁶ Collins, *Cold War Laboratory*, pp. 74-85, 98-111; 119-161; Lowen, *Cold War University*, pp. 97-100;
- ¹⁷ Leslie, *Cold War and American Science*, p. 68.
- ¹⁸ Office of the Secretary of Defense, *The Changing Patterns of Defense Procurement*, pp. I, 11.
- ¹⁹ Markusen et al, *Rise of the Gunbelt*, esp. pp. 35-37, 234-237.
- ²⁰ *Ibid.*, pp. 255-256. The warning became more explicit one year later in Markusen and Yudken, *Dismantling the Cold War Economy*.
- ²¹ Westwick, *Blue-Sky Metropolis*, p. 3; Cunningham, *The Aircraft Industry*, pp. 196-197; Vander Meulen, *The Politics of Aircraft*, p. 57.
- ²² Goodstein, *Millikan's School*, pp. 168-174; Scott, *Technopolis*, pp. 59-61. This paragraph also draws on Paul W. Rhode, "Technology, Markets, and the Dynamics of Business Location." Rhode argues that the isolation of the "flying-minded" regional market gave Western producers an early advantage in the pre-war years.
- ²³ City of Los Angeles, *Economic Development of Southern California*, Volume I, pp. 29-33; Markusen, *Rise of the Gunbelt*, Chapter 4.
- ²⁴ This paragraph draws on Markusen, *Rise of the Gunbelt*, pp. 93-96; Scott, *Technopolis*, pp. 63-67, 79-82; Guillen, "The Air Force, Missiles, and the Rise of the Los Angeles Aerospace Technopole," pp. 60-66.
- ²⁵ Guillen, "The Air Force," p. 65.
- ²⁶ Scott, *Technopolis*, pp. 96-112, 157-178.
- ²⁷ Markusen, *Rise of the Gunbelt*, p. 96; Lotchin, *Fortress California*, pp. 309-312; Walshok and Shragge, *Invention and Reinvention*, pp. 71-94, 101-2.
- ²⁸ Bilstein, *Enterprise of Flight*, p. 25; Markusen, *Rise of the Gunbelt*, pp. 155, 161.
- ²⁹ Mayer, "Entrepreneurship in a Hub-and-Spoke Industrial District," pp. 1718, 1723-1724; Gray, Golub and Markusen, "Seattle," pp. 273-279; Morrill and Sommers, "Seattle as a Digital City;" Nisoi and Zhegu, "Aerospace Clusters."
- ³⁰ Braun and McDonald, *Revolution in Miniature*, pp. 27-30, 69; Flamm, *Creating the Computer*, pp. 16-20, 29; Misa, "Military Needs," pp. 277-284; Misa, *Leonardo to the Internet*, p. 221.
- ³¹ Flamm, *Creating the Computer*, pp. 65-68.
- ³² Bugos, "The Aerospace Impetus to Silicon Valley," pp. 97-99; Leslie, "How the West Was Won," pp. 83-84; Lotchin, *Fortress California*, pp. 61, 125; Boyne, *Beyond the Horizons*, p. 97.
- ³³ This paragraph draws on Lécuyer, *Making Silicon Valley*, pp. 14-51.
- ³⁴ The description of Silicon Valley as "social bricolage" is from Kenney and Patton, "The Coevolution of Technologies and Institutions," p. 38. The story of Shockley and the birth of Fairchild is recounted in many places, but good summaries are Lécuyer, *Making Silicon Valley*, pp. 129-139; Leslie, *Cold War*, pp. 71-72; on the planar process, see Braun and McDonald, *Revolution in Miniature*, pp. 73-87; Saxenian, *Regional Advantage*.
- ³⁵ Flamm, *Creating the Computer*, p. 16; Lécuyer, *Making Silicon Valley*, pp. 72-83, 100-116; Leslie, *Cold War*, pp. 60-62, 212-227; Geiger, *Research and Relevant Knowledge*, p. 44.
- ³⁶ Braun and McDonald, *Revolution in Miniature*, pp. 72-87; Flamm, *Creating the Computer*, pp. 75-79; Lécuyer, *Making Silicon Valley*, pp. 130, 159-167.
- ³⁷ Misa, "Military Needs," pp. 267-268; Leslie, *Cold War*, p. 62; Lécuyer, *Making Silicon Valley*, pp. 112-113, 165-167; Kenney and Mowery, *Public Universities and Regional Growth*, pp. 26-27.
- ³⁸ The quotation about Germany and Japan is from Markusen and Yudkin, *Dismantling the Cold War Economy*, pp. 5-6. The DeGrasse quotation is from *Military Expansion Economic Decline*, p. 105. See also Tirman, *Militarization of High Technology*; Kaldor, *The Baroque Arsenal*. A prominent post-Cold War statement was Alic et al, *Beyond Spinoffs*.
- ³⁹ Markusen and Yudkin, *Dismantling the Cold War Economy*, pp. 171, 173-181, 205; Marolda, "The Commercialization of Defense Technology," p. 41.
- ⁴⁰ Lécuyer, *Making Silicon Valley*, pp. 180-209. The Noyce quotation is from Braun and Macdonald, *Revolution in Miniature*, p. 142. The Moore quotations are from Moore and Davis, "Learning the Silicon Valley Way," pp. 21-22. The continued importance of military contracting for Silicon Valley is documented in Heinrich, "Cold War Armory." The Venture Capitalist is quoted by Heinrich on p. 248.
- ⁴¹ Macher et al, "Reversal of Fortune?" Greenstein, *How the Internet Became Commercial*, pp. 117-118, 185, 286.
- ⁴² Kleinhenz et al, *Aerospace Industry in Southern California*, pp. 10-12; Kelley and Watkins, "In from the Cold;" Ramey and Shapiro, "Displaced Capital;" Suarez Villa, "California's Recovery and the Restructuring of the Defense Industries," p. 99; Schoeni et al, *Life After Cutbacks*; Thomas and Ong, "Barriers to Rehiring of Displaced Workers;" Storper et al, *Rise and Fall of Urban Economics*, pp. 48-49.

⁴³ Hasik, *Arms and Innovation*, p. 183 (note 31); Hensel, *The Defense Industrial Base*, p. 66; Mayer, “Entrepreneurship,” p. 1723; Sell, *Wings of Power*, pp. 52-53; Nick Wingfield, “Seattle Sets a Course for Deep Space,” *New York Times* August 2, 2016.

⁴⁴ Flanigan, *Smile Southern California*, pp. 31-41; Kenney and Mowery, *Public Universities and Regional Growth*, pp. 127-152; Adams, “Follow the Money,” p. 387; Walshok and Shrage, *Invention and Reinvention*, pp. 90-94, 112-126.

⁴⁵ Storper et al, *Rise and Fall of Urban Economies*, pp. 57-58, 80-93, 145-162, 169-192.