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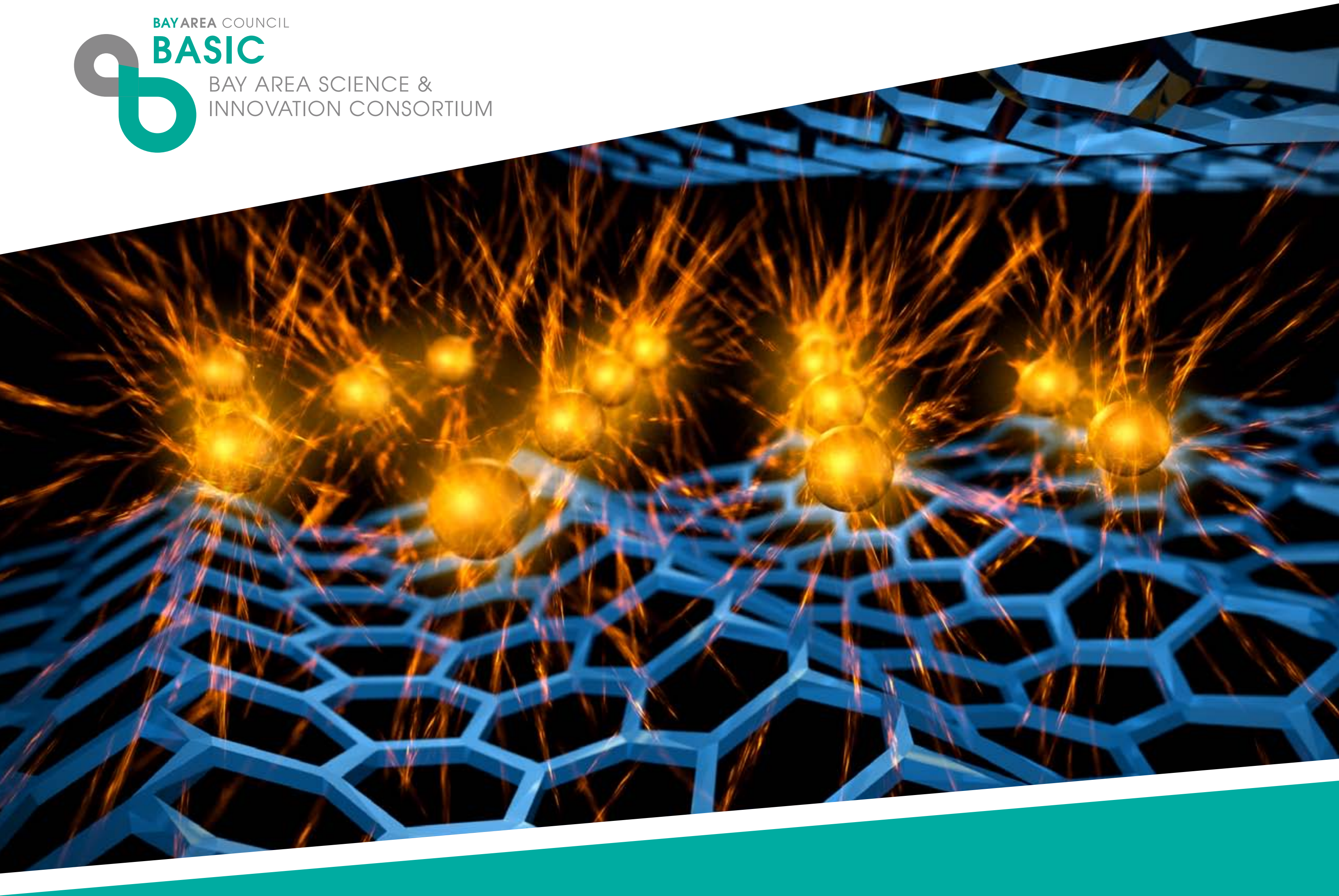

The Bay Area Innovation System

Science and the Impact of Public Investment

March 2019

BAY AREA COUNCIL
ECONOMIC
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About BASIC

BASIC is the science and technology affiliate of the Bay Area Council and the Bay Area Council Economic Institute. A collaboration of major organizations in the Bay Area's scientific research community, it brings together leaders from the region's university, national laboratory and business communities to facilitate collaboration and address key issues and opportunities impacting the region's research base and its ability to support technology-led growth.

BASIC is led by a Board composed of research leaders at the region's universities and national laboratories, plus CTOs and lab directors at many of its leading technology companies. BASIC Advisers, a committee of non-research-based companies with an interest in science and technology, interacts with the Board, providing further perspective and insight. The Bay Area Council Economic Institute provides BASIC's management and support, and the Bay Area Council's policy team connects its initiatives to the regional business community and policy leaders in Sacramento and Washington. Together, they work with BASIC to support economic growth and competitiveness by advancing the Bay Area's leadership in science, technology and innovation.

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“The best way to predict the future is to invent it.”
Alan Kay
Palo Alto Research Center (1971)

Introduction

The San Francisco Bay Area, which includes Silicon Valley, has for decades served as the world’s flagship hub for technology, innovation, and entrepreneurship. This status has been earned through a collaborative relationship among the region’s research universities, venture capital firms, and technology and life sciences companies, which combined have produced an unparalleled track record of revolutionary change and technology commercialization. Parallel with technology, companies are developing and executing innovative business models. Positive and interconnected networks and feedback loops have sustained this flourishing environment.

This report examines the scientific roots of this process and the contribution of public investment to the research on which much of the region’s technological success has been built. Because the region’s innovation process grows out of an organic relationship among its components, it is important to understand the contribution that each makes to the system as a whole, as a strengthening or weakening of any one component can impact the others. This report addresses this dynamic in two phases.

The first phase in Chapter 1 maps and assesses the Bay Area’s innovation system and how it operates. It builds on the Bay Area Science and Innovation Consortium’s 2012 report *The Bay Area Innovation System: How the San Francisco Bay Area Became the World’s Leading Innovation Hub and What Will Be Necessary to Secure Its Future*, providing updated data and analysis on how the ecosystem has evolved. This includes the identification of key institutional, corporate, and non-profit players, and a discussion of the collaborative relationships among them.

The second phase begins in Chapter 2 with a focus on the importance of government investment in scientific research. It includes discussion of the respective roles of industry, federal, and state funding, and of major government funding flows by source and destination. Key findings include the following:

- California leads the nation in R&D activity, accounting for 25 percent of total national R&D expenditures in 2015.
- While industry is responsible for the largest share of R&D expenditures, most of that funding is spent on product-related R&D. Basic research (scientific research without an immediate commercial objective) provides a critical and necessary foundation for technology breakthroughs that underlie the region’s and the nation’s economic leadership and may ultimately be commercialized. The largest share of basic research expenditures comes from government sources, and almost half of basic research is performed by the higher education sector (49.1 percent in 2015).
- California received $15.3 billion in federal support for science in 2015, 93 percent of which came from the Department of Defense, the Department of Health and Human Services, NASA, and the Department of Energy.
- California also leads the nation with the highest level of state government R&D expenditures ($573.9 million in 2016).

Chapter 3 continues with a more detailed examination of how research generated with public support has broad impacts on the economy. This includes a series of case studies that illustrate the impacts of support for innovative startup companies, including how grants from federal agencies have impacted R&D and the flow of technology to the marketplace. The contributions of state support through the University of California and agencies such as the California Energy Commission and the California Institute for Regenerative Medicine (CIRM) are also examined. Chapter 3 concludes with an assessment of the role played by public policies at both the federal and state levels and the importance of sustained public investment in scientific research as a critical foundation to regional, state, and national economic leadership. Its key findings and recommendations are the following:

- Federal investment in science is essential to US economic competitiveness and leadership. Investment should be increased in both physical and life sciences and sustained in a consistent manner in order to more effectively pursue long-term goals.
- The federal government should prioritize and fund AI research, encouraging multidisciplinary approaches, and should prioritize implementation of the National Quantum Initiative Act, which was passed in December 2018.
- The federal government should also reform H1-B visa and green card processes to ensure that the state, the region, and the nation have access to the world's best technical talent. S.2355, the "I-Squared" bill offered by Senator Orrin Hatch, comprehensively addresses these issues. The federal government should also create an entrepreneur visa program to make it easier for entrepreneurs from other countries to start companies here.
- At the state level, California should sustain and increase support for the University of California; continue and extend the Energy Commission's EPIC program (which advances the commercialization of clean energy and low carbon technologies); continue to support the Strategic Growth Council's Climate Change Research Program (which funds other climate-related and resiliency research); and establish an Innovation and Science Adviser in the Governor's Office.
- California must also accelerate 21st century technological skills development in high schools and community colleges and address the region's and the state's housing deficit, which increases the cost of living and makes it more difficult to attract and retain talent.

The Evolving Innovation System and Its Linkages

The Bay Area's already considerable impact on the national and global economies is continuing to grow. Over the last six years, since BASIC's first mapping of the region's innovation ecosystem,[1] we have seen the rapid acceleration of emerging technologies and their applications, including machine learning, personalized medicine, autonomous vehicles, cleantech, and virtual reality, to name only a few. These technologies are profoundly impacting the future of business and how we live. As Silicon Valley's reach expands to the farthest corners of the globe, hundreds of millions more people will use and benefit from the technology and services that Bay Area businesses generate.

While the key components identified in BASIC's last report—universities, federal labs, independent labs, joint research facilities, corporate labs, incubators, accelerators, and venture investment—continue to provide the system's base, new players such as federal innovation offices, corporate innovation centers, and industrial innovation centers have been added. This "innovation cloud" has proven its resilience, repurposing itself again and again with dynamic, non-linear developments across the technology sector.

Research Universities

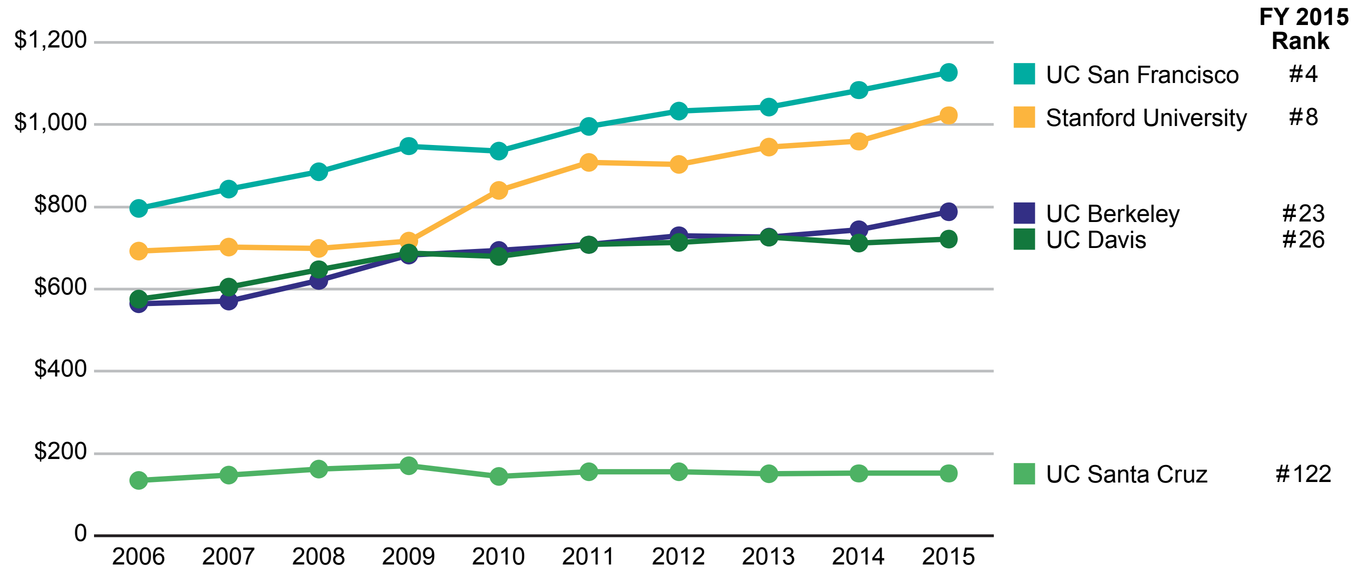
Research universities—Stanford and the four regional campuses of the University of California—play a central role in the innovation process. Their importance has grown as private companies, which before the 1990s operated major laboratories conducting basic research (theoretical research without an immediate commercial objective), have largely shifted their focus to applied research (research with shorter-term, product goals). This places the primary burden for basic research on universities and independent non-profit laboratories. While that research may begin with the drive to advance scientific inquiry and knowledge and may never lead to companies or products, theoretical research that began at universities has been responsible for many of the most transformative commercial breakthroughs. Examples include the Hepatitis B vaccine, which was made possible by gene cloning at UC San Francisco,[2] and the promise of low-cost solar cells made possible by materials science research on perovskites (a class of crystals with light-capturing properties) at Stanford University.[3]

UC San Francisco, Stanford, UC Davis, and UC Berkeley all rank among the top 30 universities in the United States for R&D expenditures, with UCSF and Stanford both in the top 10. With the exception of UC Santa Cruz, R&D expenditures at these campuses have grown since 2009.[4]

Exhibit 1

The Bay Area's research universities are critical to the innovation process; four are among the top 30 unversities in the US for R&D expenditures.

Research University R&D Expenditures, FYs 2006–2015, $ millions



Source: National Science Foundation, Higher Education Research and Development Survey, Fiscal Year 2015, Institutional Rankings, Table 16: Higher education R&D expenditures, ranked by FY 2015 R&D Expenditures, FY 2006–15, https://ncsesdata.nsf.gov/herd/2016/html/HERD2015_DST_16.html

Analysis: BASIC

The economic output of these institutions can be measured in several ways, including patents and technology licenses as well as graduates who found companies.

The University of California Office of the President reports that in its 2017 fiscal year (July 1–June 30) UC research led to

- the disclosure of 1,716 new inventions, contributing to UC's total portfolio of 12,528 active inventions;
- the filing of 1,899 US patent applications, contributing to UC's total portfolio of 4,763 active US patents covering UC inventions—more than any other university in the country;
- 192 new licenses for UC's utility inventions and 65 licenses for plant cultivars; and
- the launch of 96 new companies (bringing the total number of startups founded on UC patents since 1980 to 1,125).[5]

Stanford's Office of Technology Licensing (OTL) has set a high standard for technology management and commercialization since 1970, supporting more than 8,000 inventions and 3,000 licenses.[6]

While licenses are important, the graduates are even more important. Many of the region's best-known companies have been started by faculty or graduates of Berkeley, UCSF, or Stanford. Examples include Genentech, Chiron (since acquired by Novartis), Agilent Technologies, Cisco Systems, Dolby Laboratories, Apple, eBay, Alphabet (Google), Hewlett-Packard, Electronic Arts, PayPal, NVIDIA, LinkedIn, Netflix, Sun Microsystems (since acquired by Oracle), Tesla, Instagram (acquired by Facebook), Yahoo!, Varian, VMWare, NetApp, and Intuit.

Stanford has led the nation in developing programs tailored for entrepreneurs. These include the Lean LaunchPad experiential learning course offered to graduate student teams by the School of Engineering's

Stanford Technology Ventures Program (STVP), the ten-week Launchpad course for graduate students offered by the Stanford d.school, and The Spirit of Entrepreneurship course offered by STVP.

According to the 2011 Stanford Innovation Survey, technical innovators—who have created new products, processes, or business models—are more likely than other Stanford alumni to have participated in these entrepreneurship courses and programs. Sixty percent of founders who received venture investment within three years of graduating had participated in an entrepreneurship course at Stanford. The same survey found that 35 percent of technical innovators and 40 percent of founders had participated in entrepreneurial competitions.

Informal networks also support Stanford entrepreneurs, who actively draw on alumni and faculty members who mentor and support local companies by serving on their boards. This wide-ranging support system serves to attract entrepreneurially-oriented students; among the innovation survey respondents who became entrepreneurs in the past decade, 55 percent reported choosing Stanford for its entrepreneurial environment. Analysis of the data from the same survey estimated that 39,900 active companies can trace their roots to Stanford.[7]

Exhibit 2

The Bay Area produces some of the most entrepreneurial undergraduates in the world.

2017 Ranking of Top Undergraduate Universities and MBA Programs by Number of VC-Backed Founders Produced

Undergraduate Ranking 2017	Entrepreneur Count, #	Company Count, #	Capital Raised $ Billions	Venture Capital Backed Companies
1 Stanford	1,127	957	22.6	Snap; Solyndra; Guardant Health; Opendoor; Sunru
2 UC Berkeley	1,089	961	17.1	Cloudera; Zynga; Auris Surgical Robotics; Machine Zone; Sapphire Energy
3 MIT	907	780	16.1	Oscar; Dropbox ; Human Longevity; Gilt; Humacyte
4 Harvard	844	750	21.9	Coupang; Cloudera; BabyTree; Zenefits; Peloton
5 University of Pennsylvania	788	712	13.9	Snapdeal; Zynga; Fuze; Flatiron Health; EVA Automation
6 Cornell	721	666	14.8	Lyft; Moderna; Adaptive Biotechnologies; Just; Wayfair
7 University of Michigan	689	614	9.4	Groupon; Medalla; Twilio; 23andMe; Altiostar
8 University of Texas	600	551	5.9	Casper Sleep; Zalora; Apollo Endosurgery; Jounce Therapeutics; HotelTonight
9 Tel Aviv University	582	486	6.7	Houzz; Trax Image Recognition; Zerto; IronSource; Kaltura
10 University of Illinois	506	460	6.3	Avant; Affirm; ZocDoc; Desktop Metal; CRISPR Therapeutics

MBA Ranking 2017	Entrepreneur Count, #	Company Count, #	Capital Raised $ Billions	Venture Capital Backed Companies
1 Harvard	1,203	1,086	28.2	Grab; Zynga; Oscar; BabyTree; Jet
2 Stanford	802	716	18.3	SoFi; Sea; Funding Circle; Fab; Sunrun
3 University of Pennsylvania	666	585	16.0	Flipkart; Dianping.com; Jet; Deliveroo; Adaptive Biotechnologies
4 INSEAD	455	406	7.8	Houzz; BlaBlaCar; MongoDB; Gilt; Apttus
5 Northwestern University	445	417	5.7	Lazada Group; Westwing Home & Living; Kaminario; Fastly; Nubank
6 Columbia University	441	410	5.5	Vroom; Betterment; ZocDoc; Compass; Castlight Health
7 MIT	437	384	7.8	Rocket Internet; Lazada Group; HelloFresh; Foodpanda; Storm8
8 University of Chicago	405	368	5.5	Sapphire Energy; Juno Therapeutics; EVA Automation; Zalora; Cell Medica
9 UC Berkeley	344	314	5.2	51credit; Netskope; RetailNext; Renew Financial; QuantumScape
10 UCLA	247	232	4.0	Radiology Partners; One Kings Lane; Future Finance; The Honest Company; Fulcrum BioEnergy

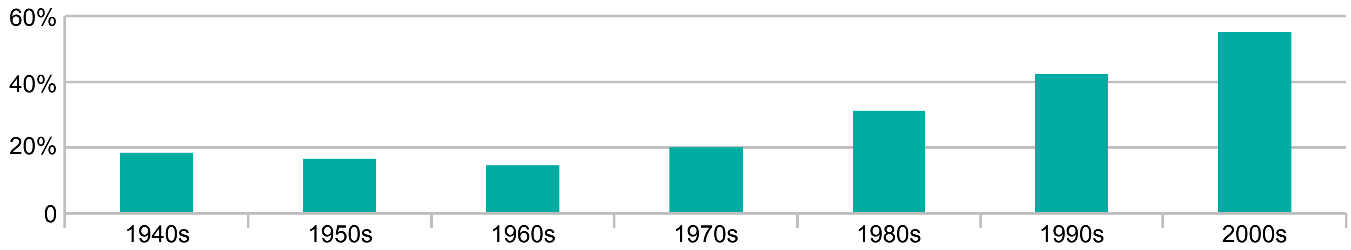
Note: Ranking is based on analysis of 2009–"current date" data on the education level of founder(s) of VC-backed companies

Source: PitchBook 2017 *Universities Report* Visualization: Bay Area Council Economic Institute and McKinsey & Company

Exhibit 3

Stanford University's reputation as a suppportive environment for entrepreneurs has grown in recent decades.

Proportion of Entrepreneurs Choosing Stanford for Its Entrepreneurial Environment, by Graduation Decade



Source and Analysis: Charles E. Eesley and William F. Miller, *Impact: Stanford University's Economic Impact via Innovation and Entrepreneurship*, Stanford University, October 2017, https://papers.ssrn.com/sol3/papers.cfm?abstract_id=2227460 Visualization: BASIC

Leveraging strong programs in engineering and life sciences, UC campuses and the University of California Office of the President (UCOP) are also deeply engaged in technology commercialization activity through incubators, accelerators, business plan competitions, grants and in some cases direct investments designed to support faculty and student entrepreneurs. Often these programs draw on private funding. Examples in the Bay Area include

- UC Berkeley's SkyDeck;
- the Sutardja Center for Entrepreneurship and Technology associated with Berkeley's College of Engineering;
- Lawrence Berkeley National Laboratory's Molecular Foundry and Cyclotron Road;
- QB3 (a California Institute for Science and Innovation managed by UCSF, UC Berkeley, and UC Santa Cruz);
- the Mike and Renee Child Institute for Innovation and Entrepreneurship at UC Davis;
- the Center for Innovation and Entrepreneurial Development at UC Santa Cruz;
- and the UC Ventures fund managed by UCOP.

Using datasets compiled by UCOP and Dr. Martin Kenny at UC Davis, the Bay Area Council Economic Institute's 2016 study *Entrepreneurs, Startups, and Innovation at the University of California* found that between 1968 and 2015, active startups coming out of the system's ten campuses generated $16.2 billion in aggregated revenue and 38,832 jobs, received $16.4 billion in venture capital investment, and were responsible for $20.1 billion in value added to the state's economy.[8]

SPOTLIGHT

California State Universities and Community Colleges

The Bay Area's five California State University campuses and 25 (out of a total of 115) California Community Colleges play critical supporting roles in the region's innovation system. While research universities are the major source of scientists and company founders, state universities provide the bulk of the region's bachelor's and master's level engineering workforce, and community colleges provide many of its technicians. Silicon Valley companies hire more alumni from San Jose State University than from any other US university, and SJSU alumni currently working at Apple outnumber both the Stanford and UC Berkeley alumni working there.[9]

Interdisciplinary and Collaborative Research

Within university campuses, centers that encourage cross-disciplinary interaction and collaboration actively leverage research capabilities to promote innovation. A leading example is Stanford's Bio-X, which networks the schools of Humanities & Sciences, Engineering, Medicine, Earth Sciences, and Law, and facilitates interdisciplinary research and teaching in bioengineering, biomedicine, and biosciences. The related BioDesign initiative, which started as a course in Bio-X, focuses on the invention and early testing of health technologies in bioscience and engineering, targeting opportunities growing out of domains such as nanotechnology and molecular biology.

Stanford's d.school (formally known as the Hasso Plattner Institute of Design) offers another example. Founded in 2005, the d.school is a non-degree program that teaches students from across the campus how to use design methodology to address problems in their own fields. The d.school currently works with about 350 students from law, business, education, medicine, and engineering, drawing on more than 70 faculty members from across the campus and from industry. Classes focus on real-world projects, with partners such as Facebook, Procter & Gamble, Kaiser Permanente, Google, Walmart, Mozilla Foundation, and Electronic Arts.[10]

In another type of cross-disciplinary collaboration, UC Berkeley's College of Engineering and the Haas School of Business bring engineering and business skills together through the Management, Entrepreneurship & Technology (M.E.T.) program, a four-year curriculum offered only to those applying to UCB as freshmen, which allows students to earn two bachelor's degrees at once. M.E.T. students combine a business degree with a second degree in one of five engineering tracks: bioengineering (BioE), civil engineering (CE), electrical engineering and computer sciences (EECS), industrial engineering and operations research (IEOR), or mechanical engineering (ME). The integrated instruction program, which includes industry internships and career coaching, is designed to create leaders who have a seamless understanding of technology innovation from idea to impact and are ready to start their own companies, lead innovation from within an established firm, or contribute to a social impact venture.

Collaboration between campuses also drives innovation. Based on a three-year $3.75 million grant from the National Science Foundation, The Bay Area NSF Innovation Corps (a regional I-Corps node) is a collaboration between UC Berkeley, UC San Francisco, and Stanford, which focuses on innovation and commercializing university research. The initiative is one of three I-Corps nodes established across the country in 2013 with the goal of increasing the impact of NSF-funded research. Its programs catalyze innovation ecosystems within universities to support entrepreneurs, encourage partnerships with industry, and commercialize science. The resources offered through the program are available to NSF principal investigators and their graduate students as well as to local and national startups.

SPOTLIGHT

California Institutes for Science and Innovation in Northern California

QB3

A collaboration by UC San Francisco, UC Berkeley, and UC Santa Cruz, QB3 focuses on the convergence of information technology with life sciences, building on the biology departments of all three campuses, UCSF's medical program, UC Berkeley's engineering and physical science programs, and UC Santa Cruz's strength in computational biology. Launched in 2004, QB3 now has 1,200 researchers and staff, with funding for research coming primarily from the National Institutes of Health (NIH). Major areas of focus include diagnostics, synthetic biology, therapeutics, and translational medicine.

CITRIS

CITRIS addresses the application of computer science and societal-scale information systems to California's future social and economic needs. Within the partnership, UC Berkeley focuses on health, energy, and the relationship of data to democracy; UC Davis focuses on clean energy, healthcare, and sustainable cities; UC Santa Cruz focuses on sustainable energy and computer networking applications; and UC Merced focuses on solar energy, robotic systems, intelligent infrastructure, computer networking systems, and data and democracy.

A particularly noteworthy model of cross-campus research collaboration can be seen in the California Institutes for Science and Innovation (CISI), which were created by the State of California in 2000 to maximize the of impact of research being conducted at the UC system's ten campuses. The core requirement was that at least two participating campuses were needed to qualify for the formation of a research center with a focus on a field of priority to the state; $400 million in seed funding was initially made available, primarily for facilities, with the funding for research partnerships coming from federal or industry sources. Ultimately, four CISIs were created: Calit2 (the California Institute for Telecom and Information Technology, a partnership of UC San Diego and UC Irvine) and the California Nanosystems Institute (a partnership of UCLA and UC Santa Barbara) in Southern California; and QB3 (the California Institute for Quantitative Biosciences, a collaboration of UCSF, UC Berkeley and UC Santa Cruz) and CITRIS (the Center for Information Technology Research in the Interest of Society, a collaboration of UC Berkeley, UC Santa Cruz, UC Davis, and UC Merced) in Northern California. UC Merced, located in the Northern San Joaquin Valley—part of the growing Northern California Megaregion—is increasingly being tied into the Bay Area innovation network.

National Laboratories and Federal Research Facilities

National laboratories and federal research facilities are another core component of the region's innovation ecosystem. The Bay Area is home to four US Department of Energy labs—Lawrence Berkeley National Laboratory, Lawrence Livermore National Laboratory, the California campus of Sandia National Laboratories, and the SLAC National Accelerator Laboratory—as well as NASA's Ames Research Center. Other federal facilities include the San Francisco Veterans Affairs Medical Center, the Veterans Affairs Palo Alto Health Care System, and the Joint Genome Institute (managed by Lawrence Berkeley National Laboratory).

SLAC National Accelerator Laboratory

SPOTLIGHT

National Laboratories and Federal Research Facilities

Lawrence Berkeley National Laboratory: With a 2016 annual budget of $897.5 million,[11] LBNL supports 3,395 full-time employees, 493 students, 9,330 facility users, and 1,524 visiting scientists. Areas of focus include computational science, nuclear physics, biosciences, nanoscience, and engineering technologies.[12]

Lawrence Livermore National Laboratory: With an annual operating budget of approximately $1.5 billion,[13] LLNL had 6,586 employees as of FY 2017 and a workforce of scientists and engineers (40 percent of whom are PhDs) numbering 2,700. Areas of focus include nuclear nonproliferation and security, counterterrorism, biosecurity, energy, and environmental security.[14] Its campus is home to the National Ignition Facility, the largest laser in the world, and the world's fastest computers.

Sandia National Laboratories (California and New Mexico): With an annual budget of $3.2 billion,[15] Sandia supports 12,000 employees in New Mexico and 900 staff plus 250 contractors, postdoctoral fellows, and students in California.[16] Areas of focus include nuclear deterrence, cybersecurity, energy (vehicle and stationary), bioscience, advanced manufacturing, homeland security, and global security.

SLAC National Accelerator Laboratory: With an annual budget of $476 million in 2016,[17] SLAC supports 1,500 employees, 430 postdocs and graduate students, and 66 faculty. Operated by Stanford University and located on 426 acres leased from the university, SLAC's facilities are used by 2,700 scientists each year.[18] Areas of focus include accelerator science and technology, particle physics, and plasma and fusion energy science.

Ames Research Center (NASA): With an annual budget of $929 million in 2016, Ames supports 4,700 employees.[19] Areas of focus include space and earth science, astrobiology, and re-entry systems.[20]

San Francisco Veterans Affairs Medical Center: The San Francisco VA Medical Center has the largest funded research program in the Veterans Affairs network, with more than $70 million in annual research expenditures and more than 220 active research projects. The Center is closely associated with UCSF, with all physicians jointly recruited by SFVAMC and UCSF. Areas of focus include cardiovascular disease, post-traumatic stress disorder, and advanced medical imaging.[21]

Veterans Affairs Palo Alto Health Care System: The VA Palo Alto Health Care System has the third largest research program in the Veterans Affairs network. Areas of focus include research on spinal cord injury, genomics, diabetes, and pain management, often conducted in affiliation with Stanford University.[22]

Joint Genome Institute: With an annual budget of $69.5 million in FY 2017,[23] the US Department of Energy (DOE) Joint Genome Institute (JGI) at Lawrence Berkeley National Laboratory supports about 250 scientists and technicians sequencing and analyzing more than 60 terabases of DNA per year. JGI genome sequencing, data acquisition, and analysis supports DOE mission needs in bioenergy, carbon cycling and biosequestration, and biogeochemical processes.[24]

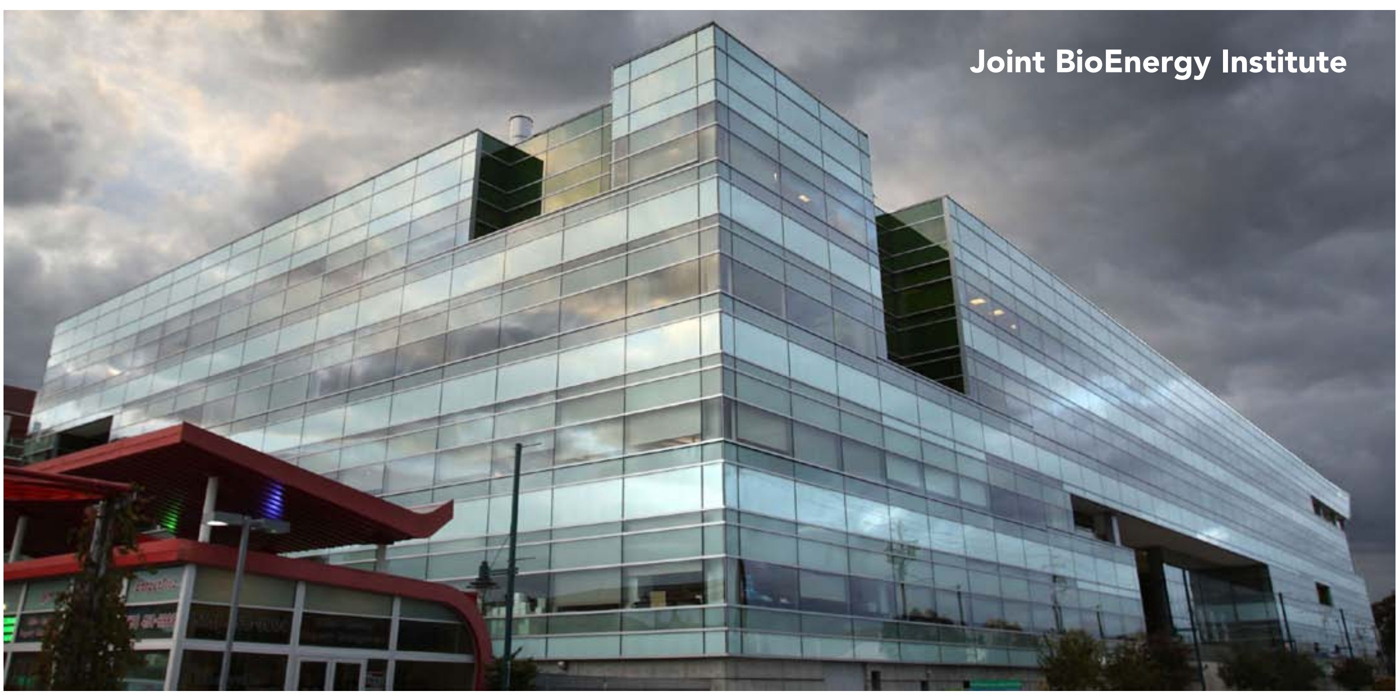
The National Laboratories, which initially had only one client—the federal government—have diversified their relationships to include partnerships with the private sector and a growing focus on moving technology into the marketplace. This has led to the formation of new companies that impact the economies of the communities where they are located. Sandia's entrepreneurial leave program, for example, allows employees to leave the lab to start a new company, giving them the option to return to the lab within two years. While core research remains focused on national priorities, and not all research conducted at the labs is available for commercialization, the National Laboratories increasingly support initiatives designed to maximize the economic carryover of laboratory work into the economy.

NASA's Ames Partnership Directorate identifies new technologies with commercial potential that are developed at Ames Research Center and supports their commercialization.[25] It provides support for startup companies to utilize these technologies, many of which are announced in its online Technology Catalog.[26]

Another lab-to-market example is the Livermore Valley Open Campus, a joint initiative of Lawrence Livermore and Sandia National Laboratories, created to facilitate collaboration with private industry. Located on publicly-accessible property between the two labs, the Open Campus includes Sandia's Combustion Research Facility (where joint research on combustion engines is conducted with the automotive sector), the Center for Infrastructure Research and Innovation (focusing on advancing zero emission goals through hydrogen infrastructure), a Cybersecurity Technologies Research Laboratory, a High-Performance Computing Innovation Center, and a new Advanced Manufacturing Laboratory. The Sandia-Lawrence Livermore partnership also supports i-GATE, an accelerator program located in the nearby city of Livermore.

SLAC National Accelerator Laboratory's Technology Innovation Directorate supports industry and university partnerships that foster the deployment of technology developed at its facility. For example, its PHASER (Pluridirectional High-energy Agile Scanning Electron Radiotherapy) system, developed with Stanford Medical School, will enable radiation treatments to be delivered at 300 times the current rate—in less than one second as opposed to multiple sessions over weeks—and with greater precision in targeting tumors. Other collaborations are underway with AT&T on 5G connectivity with implications for rural medicine/education, emergency services, smart grid, and IoT. SLAC also supports a growing neuroscience program, focusing on non-invasive brain stimulation and feedback devices that could potentially be used to treat multiple mental and visual disorders. Current collaborations with startup companies focus on 3D sensing for autonomous vehicles and Improvised Explosive Device (IED) detection.[27]

The collaborative model also extends to multi-partner institutions such as the Joint BioEnergy Institute (JBEI), a US Department of Energy facility that focuses on advanced biofuels—liquid fuels derived from the solar energy stored in plant biomass that can replace gasoline, diesel, and jet fuels. The Institute's broad objectives include reducing the nation's dependence



Joint BioEnergy Institute

on foreign oil, curbing the effects of climate change, and reducing organic waste by converting non-edible biomass such as crop residue into biofuels.

> “Ultimately, JBEI’s research will make biofuels affordable and create new renewable bioproducts for consumers and jobs in the agriculture and biotechnology sectors.”
>
> Jay Keasling, JBEI Chief Executive Officer[28]

Managed by Lawrence Berkeley National Laboratory, JBEI’s research partners include the Sandia, Lawrence Livermore, Pacific Northwest and Brookhaven national laboratories; UC Berkeley; UC Davis; UC Santa Barbara; and Iowa State University. One hundred fifty research scientists, engineers, and support staff, headquartered in the city of Emeryville, combine expertise in genetic, biological, and computational science, as well as robotics. JBEI collaborates closely with industry and actively licenses its intellectual property. In the ten years since its founding in 2008, JBEI has generated 15 startups and has produced 685 peer reviewed publications, 619 invention disclosures, 397 patent applications, 199 licenses/options, and 101 patents.[29]

CIRM: A State Research Institute

The California Institute for Regenerative Medicine (CIRM) was created in 2004 when the voters of California passed Proposition 71, which allocated $3 billion to the new agency for investment in stem cell research in California. The state’s research universities and colleges have been major recipients. Funds have been invested to support research, particularly basic research in the early years, as well as to build new research facilities and attract world-class scientists to work in them. CIRM funding has been instrumental in helping these institutions become leaders in the field and has created a pipeline of promising projects that are now moving from the lab and into clinical trials.

Independent Laboratories and Research Institutes

The Bay Area is also home to a large network of independent non-profit laboratories that conduct research on contract or with support from federal grants or from state agencies. Some, such as the Gladstone Institutes, are associated with universities. Others, such as the Buck Institute for Research on Aging, include science and teacher education programs in addition to their research missions.

Buck Institute for Research on Aging

SPOTLIGHT

Representative Independent Laboratories and Research Institutes

SRI International: Founded as the Stanford Research Institute, spun off from Stanford University in 1970, and renamed in 1977, SRI International is an independent, non-profit research center serving government and industry. Revenue from SRI's sponsored R&D is reinvested in SRI's capabilities, facilities, and staff of about 2,100 people worldwide. Over 70 years, SRI has led the discovery and design of ground-breaking products, technologies, and industries—from Siri and online banking, to medical ultrasound, the computer mouse, and cancer treatments. Areas of focus include biomedical sciences, computing and information technology, and technology in learning.[30]

PARC, A Xerox Company: Founded in 1970 as Xerox Palo Alto Research Center, PARC was incorporated and turned into a wholly owned independent subsidiary of Xerox Corporation in 2002. PARC has a staff of more than 150 scientists, engineers, and designers working on innovation in fields they believe to be the future of technology. Areas of focus include AI and human-machine collaboration, IoT and machine intelligence, digital design and manufacturing, and microsystems and smart devices.[31]

Electric Power Research Institute (EPRI): Advised by its member electric utilities, businesses, government agencies, regulators, and public or private entities engaged in electricity generation, delivery, or use, EPRI is an independent non-profit organization that performs public interest energy and environmental research. Areas of focus include efficient electrification, energy storage, and integrated grid modernization.[32]

Bay Area Environmental Research (BAER) Institute: Housed at NASA's Ames Research Center and supported by grants and contracts from NASA and other federal and state agencies, BAER supports over 100 scientists, engineers, and project staff working across 35 different projects primarily in the fields of earth science, astronomy, and astrophysics.[33]

Children's Hospital Oakland Research Institute CHORI): With an annual overall budget of $50 million, CHORI supports over 400 clinical trials and 200 scientists researching problems that threaten the health of children. Areas of focus include immunobiology, infectious disease prevention, and oncology.[34]

Buck Institute for Research on Aging: Located in Novato, the Buck Institute is the nation's first independent research facility focused solely on understanding the connection between aging and chronic disease, with the goal to increase the healthy years of life. Its annual budget of $38 million supports 210 employees from 30 countries, on a 150,000 square foot campus designed by I.M. Pei. Scientists work to understand how normal aging contributes to the development of conditions such as Alzheimer's disease, Parkinson's disease, cancer, stroke, osteoporosis, heart disease, diabetes, macular degeneration, and glaucoma.[35]

Gladstone Institutes: With an annual budget of $80 million,[36] Gladstone is an independent biomedical research institution located adjacent to UCSF, with which it has a close academic affiliation. Gladstone's more than 350 scientists and trainees focus on cardiovascular biology, immunology, neuroscience, and stem cell biology.[37]

Ernest Gallo Clinic and Research Center: Closely affiliated with the Department of Neurology within the UCSF School of Medicine, the Gallo center is a non-profit multidisciplinary research institution and one of the world's preeminent academic centers devoted to the study of the biological basis of alcohol and substance use disorders. Gallo center faculty and students are integrated into the academic and research community of UCSF.[38]

California Academy of Sciences: With an annual research budget of $21 million, the non-profit Academy is home to a major biodiversity science and sustainability program that supports more than 100 scientists, 100 associates, and 400 fellows working to understand the nature and sustainability of life on Earth.[39] The Academy also supports an active science education program.

Exploratorium: Known for its museum at San Francisco's Pier 15, the Exploratorium is a globally connected science education and research organization with an annual budget of $49 million. It employs 10 research scientists with a focus on educational research and learning experience design.

SETI Institute: A key research contractor to NASA and the National Science Foundation, SETI is a non-profit scientific research institute that collaborates with industry partners on projects investigating Mars, planetary science, exobiology, and related topics, as well as searching for extraterrestrial intelligence. The Institute employs more than 130 scientists, educators, and administrative staff whose work is anchored at three centers: the Carl Sagan Center for the Study of Life in the Universe (research) the Center for Education, and the Center for Outreach.[40]

Corporate Laboratories and Innovation Centers

Corporate laboratories play a central role in the region's innovation system. While all conduct applied research, many conduct basic research as well. Fields of focus are widely distributed across IT, semiconductors, energy, and biotechnology.

In the last decade, laboratories run by Bay-Area-headquartered technology and biotechnology companies have been joined by a growing number of facilities established by companies that are headquartered outside the region—in the United States or overseas—and have established a research presence as a way to participate in the Bay Area's innovation ecosystem. The size of their research presences varies from dozens to thousands of engineers and scientists. In some cases, the larger centers serve as the national or global base for their companies' research and innovation activity, most often centered on digitization: e.g., GE Digital for software development, Walmart Labs for electronic commerce, and SAP Labs for digital cloud and IoT applications. In the life sciences, Bayer's facility in Berkeley serves as the company's global center for biotechnology.

Similarly, many of the world's major automotive companies have established a research and testing presence in the region to address the impacts of digital technology on the automotive sector through autonomous and electric vehicles. They join leading Bay Area companies such as Alphabet (Waymo), Lyft (Lyft Level 5 Engineering Center), and Tesla.

> "The car is the ultimate mobile device of the future, and the future is being written in Silicon Valley. This means it is particularly important to be right next door to leading IT companies in the USA, as this allows us to identify trends early and invest in new technologies at the right time. In addition to our own potential for innovation, above all we want to form strong partnerships."
>
> Thilo Koslowski, Managing Director, Porsche Digital[41]

Overseas-based companies are also present through "innovation outposts" that don't conduct scientific research but perform any or all of several functions: following technology developments and reporting to headquarters on trends that could influence corporate strategy; partnering with universities or with platform companies such as Google, Twitter, or Facebook; or finding startups they can invest in or support as a way to advance their global strategies.[42]

INSIGHT

US and Overseas Automotive Companies with a Research or Innovation Presence in the Bay Area

Alphabet (Waymo)
Audi Innovation Research San Francisco
BMW Technology Office
Borgward (US headquarters and R&D center)
BYTON (US headquarters)
Daimler Business Innovation / Lab1886
Delphi Labs @ Silicon Valley
Ford Research and Innovation Center Palo Alto
GM Advanced Technology Silicon Valley Office
Honda Innovations
Hyundai CRADLE
Lyft Level 5 Engineering Center
Mercedes-Benz Research & Development North America, Inc.
NIO (US headquarters)
Nissan Research Center Silicon Valley (part of Renault-Nissan Alliance)
PlusAI (US headquarters)
Porsche Digital, Inc.
SF Motors (US headquarters)
Tesla
Toyota Research Institute, Inc.
Volkswagen Automotive Innovation Lab
Volvo Cars R&D Silicon Valley Technology Center

SPOTLIGHTS

Nestlé

Based at Switzerland's Pier 17 facility, Nestlé's Silicon Valley Innovation Outpost (SVIO) anchors the company's global innovation activity. Of its 16 employees, 6 rotate from other global Nestlé sites to look for new technologies and spread what they learn to the company's business units worldwide. SVIO particularly partners with startups—10 to 30 in any given year—with a focus on how consumers engage digitally through technologies such as artificial intelligence and IoT. As described by Senior Global Innovation Manager Stephanie Naegeli, "The platform, externally, is just a platform. But internally, it will completely change Nestlé's innovation process."[43]

BNP Paribas

With offices in Paris, San Francisco, and Shanghai, L'Atelier BNP Paribas helps the Paris-based BNP Paribas Group and its international banking clients adapt to digital change by guiding decision making to accelerate innovation. As a detection post for emerging trends, the San Francisco office serves as the Group's eyes and ears on the digital transformation being driven by Silicon Valley. Activity at its facility in San Francisco's Dogpatch neighborhood focuses on research, business transformation consulting services, and business acceleration programs.

Siemens

An evolution of the Siemens Technology-to-Business (TTB) center, which was launched in Berkeley in 1999, Next47 is a new innovation unit of the Munich-based engineering company, designed to foster disruptive ideas and accelerate the development of new technologies. With offices in seven cities around the world including Palo Alto,[44] where the global head of Next47 is based, it connects and supports the company's startup activities and leverages Siemens' internal ecosystem in an environment where ideas can be pursued outside the company's day-to-day operations. Next47 also functions as Siemens' venture capital arm. Areas of focus include artificial intelligence, autonomous machines, distributed electrification, blockchain, and e-mobility.

Bayer

Bayer's West Coast Innovation Center (WCIC), located adjacent to UCSF in San Francisco's Mission Bay district, focuses on research and partnerships for the discovery and development of new treatments in fields with high unmet patient needs. Mission Bay is also home to Bayer's San Francisco CoLaborator, one of the company's five worldwide incubators for life sciences startups.[45] The West Coast Innovation Center is closely associated with the company's development and manufacturing teams on the Bayer campus in Berkeley and with the company's global research groups in Germany. WCIC focuses on Bayer's core therapeutic areas, including cardiovascular, oncology, and gynecological therapies, as well as ophthalmic and hematology indications, and offers partnering and networking opportunities to startups and entrepreneurs focused on novel drug discovery platform technologies and new drug targets.[46]

Representative Bay Area, US, and Overseas Corporations with a Bay Area Research or Innovation Presence

Bay Area Headquartered

23andMe
Adobe Research
Agilent Research Laboratories
Alphabet (Waymo)
Apple R&D
Applied Materials Inc.
AMD
Autodesk Technology Center
BioMarin
Bio-Rad Laboratories
Cadence
Calico
Chevron
Cisco Systems
Cypress Semiconductor
Dolby Laboratories Inc.
Exelixis
Facebook
Genentech (Roche)
Gilead Science
Google X
HP Labs, Palo Alto
Impax Laboratories, LLC
Intel Research
Juniper Networks Inc.
Kaiser
Lam Research Corp.
LinkedIn
Lyft Level 5 Engineering Center
Nektar Therapeutics
Neustar
NVIDIA
Onyx Pharmaceuticals
Oracle Labs
PARC, A Xerox Company
PlusAI
Sandisk Corp.
Seagate
Symantec Research Labs
Tesla
Theravance Biopharma
Twitter
Varian Medical Systems
Visa Innovation Center
Wells Fargo Digital Labs
Yahoo! Research

US Headquartered

Abbott
Accenture Labs
Amazon Lab 126
Amgen
AT&T Foundry Innovation Center
Barnes & Noble
Boston Scientific
Bristol-Myers Squibb
Capital One Labs
Comcast Labs
Corning
Delphi Labs @ Silicon Valley
FIS Innovation Lab
Ford Research and Innovation Center Palo Alto
GE Digital
GM Advanced Technology Silicon Valley Office
IBM Research–Almaden
Lockheed Martin Corporation Advanced Technology Center
Macy's Technology
Mars Advanced Research Institute
McDonald's
Merck
Microsoft Research Silicon Valley
Morgan Stanley
Pfizer Worldwide Research & Development at Rinat
Qualcomm MEMS Technologies
SEPATON West Coast Advanced Development Office
Sprint Applied Research & Advanced Technology Labs
Staples Innovation Lab
Target Technology Innovation Center
Texas Instruments
US Bank
Verizon Innovation Center
Walmart Labs

Overseas Headquartered

Airbus (Europe)
Alibaba Group (China)
Audi Innovation Research San Francisco (Germany)
AXA Labs (France)
Baidu (China)
Bayer US Innovation Center (Germany)
BMW Technology Office (Germany)
BNP Paribus (France)
Borgward (China)
Bosch Research and Technology Center North America (Germany)
BT (UK)
BYTON (China)
Carl Zeiss Meditec (Germany)
Daimler Business Innovation / Lab1886 (Germany)
Deutsche Telekom Silicon Valley Innovation Center (Germany)
Dragon Group (China)
Elan (UK)
Ericsson (Sweden)
Genencor, a Danisco Division (Denmark)
GlaxoSmithKlein (UK)
Hanwha Solar North America R&D Center (South Korea)
Hitachi Global Center for Innovation–North America (Japan)
Honda Innovations (Japan)
Huawei R&D (China)
Hyundai CRADLE (Republic of Korea)
Infosys Digital Studio (India)
JOINN laboratories (China)
Mercedes-Benz Research & Development North America (Germany)
Mindray (China)
NEC Laboratories America, Inc.
Nestlé SVIO (Switzerland)
NIO (China)
Nokia (Finland)
Novartis Institutes for Biomedical Research (Switzerland)
Novo Nordisk (Denmark)
Orange Labs (France)
Porsche Digital (Germany)
Renault-Nissan Research Center (France-Japan)
Ricoh Innovations (Japan)
Roche Molecular Systems (Switzerland)
Royal Bank of Canada (Canada)
Samsung (Korea)
SAP Labs (Germany)
Sennheiser Technology and Innovation Center (Germany)
SF Motors (China)
Siemens Next47 (Germany)
Suning Commerce R&D Center USA (China)
Swisscom (Switzerland)
Tech Mahindra (India)
Tencent (China)
Total Energy Ventures (France)
TOTVS Labs (Brazil)
Toyota Research Institute, Inc. (Japan)
Volkswagen Automotive Innovation Lab (Germany)
Volvo Cars R&D Silicon Valley Technology Center (Sweden)
Wipro Silicon Valley Innovation Center (India)
Xuzhou Silicon Valley Science & Technology Exchange Center (China)
ZGC Innovation Center (China)
Zhejiang Innovation Center (China)

Incubators and Accelerators

Technology commercialization is also advanced through a highly developed infrastructure of incubators and accelerators. Many are independent for-profit entities, while others are supported by governments, universities, corporations, or national laboratories. As a rule, they provide cost-effective office or laboratory space, equipment, advisory services, networking opportunities, exposure to investors, and sometimes direct investment for thousands of small to mid-size startup companies.

Incubators and accelerators play a critical role as landing pads where entrepreneurs, startups generated by the region's universities, or startups coming from elsewhere in the US or overseas find the support and resources that can help them grow to the next stage. The largest accelerators in the Bay Area—such as Plug and Play Tech Center, 500 Startups, Runway, RocketSpace, and Y Combinator—may house dozens of smaller, more specialized incubator and accelerator programs.

Universities are active in this space, as they look not only to generate research but also to maximize its impact. Stanford's StartX, the iconic non-profit business incubator founded in 2011, got its start as an arm of Stanford Student Enterprises, an on-campus business and entrepreneurial organization, and is currently funded with $1.2 million annually from Stanford, along with corporate sponsorships and other donations.[47] The first technology incubator in the UC system, the Garage@UCSF, was launched in 2006. More recently, UC campuses have dramatically increased their commitment to incubator programs, bringing public universities more deeply into the region's incubator and accelerator infrastructure. These programs are typically linked to other campus initiatives designed to support student and faculty entrepreneurs, including entrepreneurial training programs, hackathons, innovation awards, business plan competitions and, on occasion, direct funding.

Federal laboratories are also developing incubator programs. Examples include Berkeley Lab's Cyclotron Road and i-GATE (a partnership of Lawrence Livermore and Sandia National Laboratories with the East Bay cities of Livermore, Pleasanton, Dublin and Danville).

INSIGHT

Representative Bay Area Incubators, Accelerators, and Co-Working Communities

- 500 Startups
- Accelprise
- Alchemist Accelerator
- Angelpad
- Berkeley Startup Cluster
- Blackbox
- Boost VC
- BRIIA (Bishop Ranch Intelligence Innovation Accelerators)
- Cleantech Open
- Fast Forward
- Founder Friendly Labs
- Founder Institute
- Founders Space
- Global Social Benefit Institute
- Greenstart
- GSVlabs
- i/o Ventures
- Imagine K12
- Impact Hub Oakland
- Impact Hub SF
- IndieBio
- Innovation Center
- Johnson & Johnson Innovation JLABS
- JOINN Innovation Park
- Morgan Stanley Multicultural Innovation Lab
- Nasdaq Entrepreneurial Center
- NewME
- Playground
- Plug and Play Tech Center
- Powerhouse
- RocketSpace
- Runway
- Salesforce Incubator
- San Jose BioCube
- Silicon Valley Innovation Center
- Singularity University
- SoCo Nexus
- Techhub Innovation Center
- Techstars
- The Gate 510
- The Port Workspaces
- The Vault
- TopLine
- Uptima Business Bootcamp
- Upwest Labs
- US Market Access Center
- Women's Startup Lab
- Y Combinator

The Bay Area's incubator and accelerator community is global. Internationally-sponsored incubators and accelerators, often supported by governments or government-industry partnerships, serve as platforms to enable young companies from other countries to learn how Silicon Valley works, access venture capital, and scale into the US and global markets from a Bay Area base. A growing number of corporate incubators and accelerators from overseas also help sponsoring companies identify and nurture new talent and ideas that can support their global mission.

In many cases, multiple internationally-sponsored accelerator programs may be organized or hosted by larger umbrella facilities. For example, in the past five years the US Market Access Center has worked with more than 1,500 startups from 41 countries, including 23 of 28 EU members, and conducted programs in 35 of them.[48] Many of its programs, which typically involve screening and training for startups in their home countries followed by intensive bootcamps in Silicon Valley, are sponsored by national governments. Plug and Play Tech Center, in addition to hosting a wide range of internationally sponsored accelerator and innovation programs at its headquarters in Sunnyvale, operates facilities in 19 cities overseas, including Guadalajara, Paris, Amsterdam, Berlin, Stuttgart, Abu Dhabi, Tokyo, Beijing, Shanghai, Xi'an and Jakarta.[49]

SPOTLIGHT

QB3 Incubators

At QB3, one of Northern California's two California Institutes for Science and Innovation, a key focus has been how to maximize its economic impact by enabling and supporting scientists with the motivation and ideas that might one day lead to companies. The Garage@UCSF was launched in 2006 as the first technology incubator in the UC system, with initial residency by six companies. Within two years, four had received venture funding and a fifth was acquired, validating the model. Today QB3 supports a network of five incubators in the region: Garage@UCSF, Garage@Berkeley, the East Bay Innovation Center, QB3@953, and StartX-QB3 Labs in Palo Alto, plus an investment arm, Mission Bay Capital. As of 2016, 155 firms had been supported by these facilities, attracting more than $600 million in funding. Of the companies in QB3's incubators, one-third are using technologies derived from UC licenses.

INSIGHT

Representative Incubators and Accelerators with University and National Laboratory Affiliations

- Bakar BioEnginuity Hub (QB3/UC Berkeley, projected opening 2021)
- Cyclotron Road (Lawrence Berkeley National Laboratory)
- DRIVE™ (Distributed Research Incubation & Venture Engine) Program (UC Davis)
- East Bay Innovation Center (QB3)
- Engineering Translation Technology Center (ETTC) (UC Davis)
- Garage@Berkeley (QB3)
- Garage@UCSF (QB3)
- Haas School of Business LAUNCH Accelerator (UC Berkeley)
- i-GATE (Lawrence Livermore and Sandia National Laboratories)
- QB3@953 (QB3)
- SkyDeck (UC Berkeley)
- Startup Sandbox (UC Santa Cruz)
- StartX (Stanford University)
- StartX-QB3 Labs (QB3)
- SVLink (UC Santa Cruz)
- The House (UC Berkeley)
- UC Davis-HM.CLAUSE Life Science Innovation Center (UC Davis)
- Venture Lab (UC Berkeley)

INSIGHT

Representative International Incubators, Accelerators, and Co-Working Communities

ABC Silicon Valley (Slovenia)
Australian Landing Pad (Australia)
Bayer CoLaborator (Germany)
Belcham Atelier San Francisco (Belgium)
Block 71 (Singapore)
Canada House (Canada)
Canada Technology Accelerator (Canada)
Danish Innovation Center (Denmark)
DayDayUp (China)
EIT Digital Silicon Valley Hub (EU)
Free Electrons (multinational)
French Tech Hub (France)
German Accelerator Tech (Germany)
Hanhai Silicon Valley Innovation Center (China)
HAX (China)
Innospring (China)
KIC (Korea Innovation Center) Silicon Valley (Republic of Korea)
New Silicon Valley Offshore Incubator (Launching Pad) (China)
Nordic Innovation House (Nordic Region)
PARISOMA (France)
SAP.iO Foundry (Germany)
Shanghai Lingang Overseas Innovation Center (China)
Shenzhen Valley Ventures (China)
Spain Tech Center (Spain)
TechCode (China)
The Refiners (France)

Federal Innovation Offices

The region's innovation system also includes the innovation offices of several federal government agencies that aim to advance national priorities by harnessing the innovation coming from new and emerging technology companies.

The CIA's investment arm In-Q-Tel, has been active in the region since 1999. It was joined in 2015 by the Department of Homeland Security's Homeland Security Innovation Program, which cultivates relationships with innovators, startups, large companies, investors, incubators, and accelerators, in order to solve difficult homeland security problems.

Also in 2015, the Department of Defense (DOD) established the Defense Innovation Unit Experimental (DIUx) in Silicon Valley to provide capital, through pilot contracts, for innovative smaller companies that have technology with the potential to address DOD-specific challenges. The contracts also connect smaller companies with larger defense contractors and attract venture investors who can accelerate commercialization and deployment. In August 2018, the US Deputy Secretary of Defense announced that in recognition of DIUx's value in fostering innovation across the DOD, its name would be shortened to Defense Innovation Unit (DIU), with the removal of "experimental" signifying the permanence of the unit within the Department.[50]

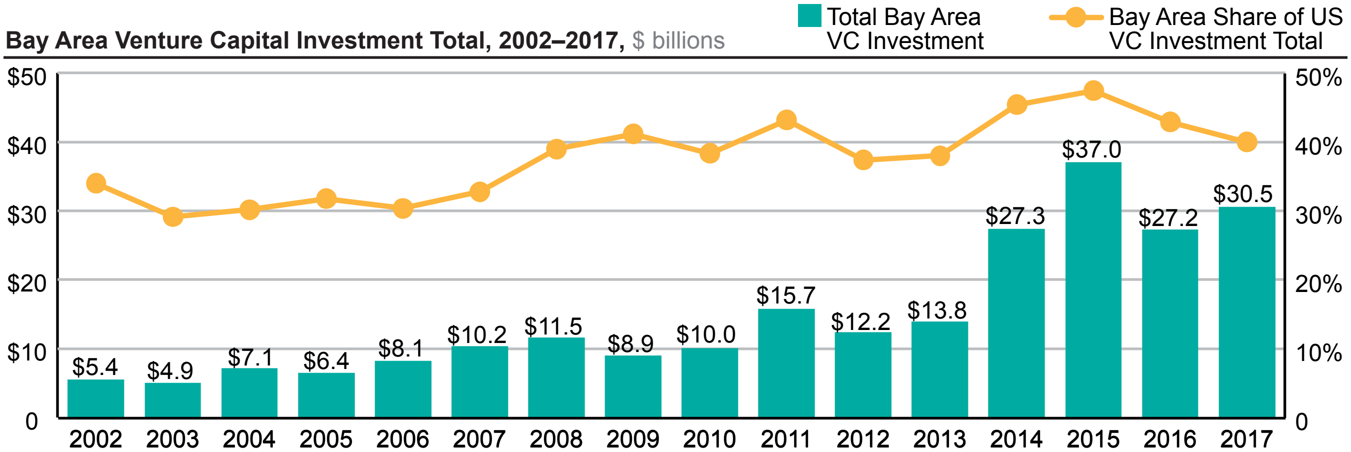
Risk Capital

The financial side of the commercialization process, which transforms innovative technologies and ideas into companies, is fueled by a deep reservoir of venture capital, angel investment, and private equity that finances startup, early-stage, and later-stage companies. In addition to providing funding, venture capital investors also enhance the potential for new companies to succeed, by contributing specialized knowledge, access to networks of contacts, and managerial expertise. Mentorship by serial entrepreneurs and investors who have enjoyed success can be a critical asset for young companies that are looking to avoid mistakes and extend their investment dollars.

The venture capital investment model we know today established its Bay Area roots a stone's throw from Stanford on Sand Hill Road with the founding in 1972 of both Kleiner Perkins Caufield & Byers and Sequoia Capital. Since then, a large proportion of the nation's venture capital investment has been concentrated in the Bay Area, which has received shares ranging from 29 to 47 percent of total US venture capital investment over the last 15 years: in 2017, the Bay Area received $30.5 billion, or 40 percent of that total.[51]

Exhibit 4

The Bay Area attracts much of the nation's venture capital investment.



Note: Bay Area numbers represent a combination of the North Bay Area and the South Bay Area as defined by PwC MoneyTree[52]
Source: PwC MoneyTree Report
Analysis: Bay Area Council Economic Institute

Exhibit 5

Bay Area venture capital firms are active in all stages of investment.

Nine Bay Area Venture Capital Firms Most Active in 2018 by Fund Round Type

Venture Capital Firm	Most Active Funding Round Types	Notable Portfolio Companies or Successful Exits
Plug and Play Ventures	Seed Stage	Paypal, Dropbox, Lending Club, Zoosk
New Enterprise Associates	Lead Investor Early Stage Late Stage	Groupon, Jet.com, Tableau, Workday
Intel Capital	Early Stage	AVG, Broadcom, CNET, VMware
Khosla Ventures	Late Stage	Plastiq, Cylance, Stripe, Boku
Andreessen Horowitz	Late Stage	GitHub, Okta, Box, Zulily
Accel	Lead Investor Early Stage	Facebook, Slack, Supercell, Spotify
Y Combinator	Early Stage	Cruise Automation, Twitch, WePay, Disqus
500 Startups	Seed Stage	MakerBot, Talkdesk, Mayvenn, Realty Shares
Sequoia Capital	Lead Investor Early Stage Late Stage	WhatsApp, Google, LinkedIn, Square

Note About Notable Companies or Successful Exits: Although companies usually receive investments from more than one VC firm, in order to highlight a larger variety of companies, this list shows each company only once.
Source: Alejandro Cremades, *Forbes*[53]
Analysis: BASIC

Industrial Innovation Centers

Beyond corporate R&D performed in company laboratories or collaboratively with universities or federal labs, private companies are advancing manufacturing through open platforms that enable startup companies to test new technologies. An example at scale is provided by Autodesk's Technology Center located at Pier 9 on San Francisco's Embarcadero. One of four Autodesk-sponsored Technology Centers in the world (the other three being in Boston, Toronto, and Birmingham, UK), the San Francisco facility focuses on configurable microfactories and the future of manufacturing. Emerging companies can access at no cost a wide range of advanced manufacturing equipment (e.g., 3D printers, robotics), shop facilities, and workspaces to design and test new ideas, with support from academic researchers, industry thought leaders, and Autodesk personnel. Residencies are established on a rolling basis for periods of two weeks to one year.

Specialized Service Providers: Design

Though often overlooked, business service providers are an important part of the region's innovation system, especially law and accounting firms that have deep industry expertise and experience with intellectual property and IPOs. One particularly significant player is the region's design industry, which may be the world's largest. Anchor companies include industry leaders IDEO, frog, LUNAR, and Eight Inc., which work with companies and organizations to accelerate innovation by focusing on how people and technologies interface. Smaller companies in the region, such as Whipsaw (Nike+ Fuelband SE), NewDealDesign (Fitbit), Astro Studios (Xbox 360), and Ammunition Group (Beats by Dr. Dre), also contribute. Technology companies, such as Autodesk (at its Technology Center at San Francisco's Pier 9) and Samsung (at its Design Innovation Center in San Francisco's Jackson Square), support design facilities that focus on topics such as wearables and smart TV or enable employees and partners to experiment with 3D printing and precision machining. Educational anchors in the design community include Stanford's d.school, the California College of the Arts, and San Jose State University's Department of Design.

The region's design industry grew in parallel with its technology sector, marrying the skills of artists and engineers and contributing to the worldwide success of products such as Apple's iPhone. In the process, Silicon Valley has served as an incubator of design firms, drawing global talent and creating a rapidly growing market. Design industry chronicler Barry Katz observes that "the expanded field of professional [design] practice is not specific to Silicon Valley. What is unique, however, is the intimacy and immediacy of the relation between the new technologies and the designers who were enlisted to make them accessible, meaningful, and pleasurable. The migration of the personal computer from research lab to retail outlet—to take only the most obvious example—can be traced within the circumference of an easy bicycle ride."[54] Once anchored in industrial product design, the industry has grown by drawing on a range of disciplines to include organizational and systems design and the application of "design thinking" to business challenges and to social issues such as education, poverty, and health.

> “Today there are arguably more design professionals working in Silicon Valley and its Bay Area environs than anywhere else in the world: large consultancies such as IDEO and frog, and one-person studios with names like Monkey Wrench and Shibuleru (Swiss German for "calipers"); world famous corporate design offices (Apple, Amazon, Adobe); and academic programs to train the next generation of their employees. Whole new fields of design have their origins in Silicon Valley as the profession has responded to the challenges of electronic games, personal computers, interactive multimedia, and hybrid products that may be portable, wearable, or implantable. Making them work has been the historic task of engineering; making them useful is the job of design.”
>
> Barry M. Katz, *Make it New*[55]

IDEO, with offices at San Francisco's Pier 28 Annex, works with large companies and organizations, but also with startups. Its activity has particularly grown since large corporations from across the US have established R&D anchors in the region. More than half of its Bay Area work is now for companies from outside the region. For example, Ford's research center in Palo Alto—Greenfield Labs—is operated in conjunction with IDEO and specializes in fields such as autonomous vehicles and mobility services as Ford expands its customer focus to include cities and integrated mobility systems. This arrangement reflects a global trend toward joint working facilities in which design is an integral part.

On the startup side, IDEO supports a startup-in-residence program that hosts early-stage companies for six months in return for a small share of equity. Medical companies are a particular focus. Another feature of its activity is CoLab, a collaborative platform that works at the intersection of emerging technologies in partnership with a member network of many large companies. Graduate students and small companies participate through design sprints, becoming integral parts of the network. Design is being applied to social entrepreneurship challenges, as IDEO works with emerging companies in fields such as women's health and financial inclusion.

"As the requirement to meet user needs has become more crucial for startups, design has moved more centrally into the Bay Area's ecosystem. This is happening in hardware but also in high-growth companies such as Airbnb and Facebook, which critically depend on their user interface. For these entrepreneurs, design has to be at the center from the start. The level of technology might not be high in all cases, but systems and service innovation is where the breakthroughs are being made."

Tim Brown, CEO, IDEO

Autodesk Technololgy Center – San Francisco

Innovation Districts

At the sub-regional level, the Bay Area's innovation system is continuing to evolve with the emergence of innovation districts—distinct geographies, often anchored by a major research institution, that aggregate and catalyze research and commercial activity in particular fields. Typically, innovation districts include research facilities, related industry clusters, and incubators or accelerators, connecting them in ways that facilitate interaction and accelerate innovation. In a sense, Stanford created the first innovation district in Palo Alto decades ago with Stanford Research Park, catalyzing business and research activity that eventually became Silicon Valley. More recently, three Bay Area innovation districts are noteworthy: Mission Bay (San Francisco), Livermore Valley Open Campus (an innovation hub between the Lawrence Livermore and Sandia national laboratories), and NASA Research Park at NASA's Ames Research Center (Mountain View).

Mission Bay

The Mission Bay district of San Francisco, anchored by the campus of UC San Francisco, concentrates resources in life sciences. In the *U.S. News & World Report* professional schools rankings released in 2018, UCSF ranks number two for primary care and number five for medical research and is the only medical school in the United States to rank in the top five for both categories. In 2017, it was also the second largest recipient nationwide of funding from the National Institutes of Health.

UCSF has played a key role in the creation of the biotechnology industry. Over several decades, however, the companies it generated grew in other cities such as South San Francisco. The development of the Mission Bay Campus, a greenfield expansion from the original campus at Parnassus Heights in western San Francisco, provided an opportunity to create a new environment that would permit life sciences companies to cluster in new facilities adjacent to the campus. Drawing on the university's research and teaching facilities and its hospitals—including the UCSF Benioff Children's Hospital, the UCSF Betty Irene Moore Women's Hospital, and the UCSF Bakar Cancer Hospital—UCSF itself now accounts for more than half of all life-sciences-related building space in San Francisco, with approximately 1.7 million square feet dedicated to research. Off campus, the Mission Bay district is home today to more than 75 biotech startups.[56]


Mission Bay skyline

University entrepreneur-oriented programs are coordinated through UCSF's Entrepreneurship Center, which offers access to a rich array of Silicon Valley resources and is an inclusive, open program that welcomes participants from UC Berkeley, Stanford, and the business community. UCSF's support chain for entrepreneurs also includes the Catalyst Awards, the centerpiece of the University's accelerator Catalyst Program, that provide funding for early-stage startups through prizes of up to $100,000 for diagnostics and medical device inventions and $50,000 for digital health innovations.

Most important is the California Institute for Quantitative Bioscience (QB3), the California Institute for Science and Innovation in which UCSF participates together with UC Berkeley and UC Santa Cruz. Created in 2005 to help the University increase its impact by enabling and supporting scientists who had the motivation and ideas that might one day lead to companies, today QB3 supports a network of five regional incubators including, in the Mission Bay district, Garage@UCSF and QB3@953. Of the companies in QB3's incubators, approximately one-third are using technologies based on UC licenses. The balance of residents in the incubators aren't UC-affiliated but are there in order to be close to the university's staff and facilities. With other venture firms, Mission Bay Capital, an investment fund created in 2009 and subsequently spun out from the University, provides investment capital.

The Mission Bay district has attracted major life sciences and pharmaceutical companies that, like the startups, have either spun off from UCSF or have located there to be close to the University's research and faculty. This complex includes the research operations of Bayer (the West Coast Innovation Center) and industry-sponsored incubators and accelerators that are not managed by UCSF but that interact with it—in particular the incubator space at FibroGen, Bayer's CoLaborator, and the Illumina Accelerator.

Livermore Valley Open Campus

Another innovation district is developing in the eastern Bay Area's Tri-Valley region, catalyzed by the Sandia and Lawrence Livermore (LLNL) national laboratories. National security facilities like these require security clearances to enter. To foster easier collaboration with industry, including startups, the labs have jointly created the Livermore Valley Open Campus (LVOC), an unclassified research and development environment on land adjoining the two national laboratory campuses.

The first phase of LVOC, which opened in 2011, includes the initial facility housing LLNL's High Performance Computing Innovation Center (HPCIC); an expanded public-private 110,000 square foot facility is pending, which would allow the co-location of lab scientists with industry collaborators as tenants. Construction has recently been completed on a new Advanced Manufacturing Laboratory (AML) that will house state-of-the-art equipment for advanced and additive manufacturing. Other resources at AML will include materials evaluation and characterization equipment, high performance computing modeling and simulation systems, and manufacturing capabilities drawn from active LLNL programs. Advances at the AML will be accelerated through a combination of dual-use—commercial and government—products. Proposed new facilities include an office building to house lab researchers and their industrial and academic partners, and a center to host collaborative meetings and conferences.

On the Sandia side, the Open Campus includes the Combustion Research Facility, the Center for Infrastructure Research and Innovation, the Cybersecurity Technologies Research Laboratory, and the Biotech Collaboration Center.

Research partnerships with industry and technology commercialization are at the heart of the Open Campus concept and anchor the two labs' engagement in the Tri-Valley economy. LLNL's formal partnering with industry is managed by its Innovation and Partnerships Office (IPO), which focuses on strategic partnerships that create competitive advantages for US industries by providing access to national laboratory technologies, research capabilities, and expertise. IPO reports that as of 2017, LLNL has commercial licenses with more than 300 companies,[57] accounting for more that $300 million in annual sales of products based on LLNL technologies.[58]

LLNL and Sandia jointly support the annual National Labs Entrepreneurship Academy, a three-day entrepreneurship business training course for their scientists and engineers, designed to assist them in starting companies or pitching their technologies to

businesses. The labs also partner on i-GATE, a non-profit incubator and innovation program supported by four adjacent cities (Livermore, Pleasanton, Dublin, and Danville) that works to move startups from the idea stage through first-round funding. Its facility provides collaborative workspace, mentors, training and networking for startups either launched in or moving to the Tri-Valley region, including companies founded by Sandia and LLNL researchers. Startup activity in the adjacent area is growing. Downtown Livermore is now home to two i-GATE-operated facilities: The Switch (a 16,000 square foot startup incubator and co-working space) and Switch Labs (an incubator that provides 9,000 square feet of industrial lab space, a prototyping shop, and meeting and office space for hard tech startups and founders with science and engineering backgrounds).

NASA Research Park

Located in the heart of Silicon Valley, NASA's Ames Research Center has emerged as a catalyst for technology research and commercialization, starting in fields connected to space but now reaching beyond. Advancing NASA's goal to move technologies with potential commercial value to the private sector, the Partnerships Directorate at Ames Research Center develops partnerships between NASA and US industrial firms for technology development.[59]

One vehicle is NASA Research Park, a shared-use R&D and educational campus for innovation and entrepreneurship that fosters both formal and informal collaboration. The Park currently hosts more than 70 industry and university partners, including established companies that collaborate with NASA and smaller technology companies with NASA-related missions.[60] An example of a pioneering company that emerged from the Park is Bloom Energy, which still maintains an operational facility there after moving its corporate headquarters to nearby Sunnyvale. Bloom Energy is a provider of solid oxide fuel cell technology; Bloom Energy Servers currently provide highly efficient onsite power for many Fortune 500 companies.

The Park is also home to Carnegie Mellon University's Silicon Valley Campus, an extension of the leading engineering and computer science university based in Pittsburgh. Established in 2002, the Silicon Valley campus serves about 400 students through graduate programs in three departments—Electrical and Computer Engineering, the Information Networking Institute, and the Integrated Innovation Institute—each providing technical but also business and organizational skills required for entrepreneurial success. The Information Networking Institute's programs are bicoastal, with initial semesters conducted in Pittsburgh and final semesters conducted in Silicon Valley. The University also operates several research centers in the Park: the Carnegie Mellon Innovations Laboratory, one of the world's leading aerospace technology research centers; the CyLab Mobility Research Center, which focuses on context-aware applications and services; the Disaster Management Initiative, which connects first responders, citizens, government, and industry to better support disaster recovery; and the Center for Open Source Investigation, which focuses on developing, adopting, managing, and integrating systems that incorporate open source technology.

NASA Research Park also hosts Santa Clara University's Center for Nanostructures and is home to Singularity University, a global interdisciplinary institution founded in 2008. A unique catalyst for innovation, Singularity focuses on empowering leaders to solve global grand challenges through breakthrough solutions using accelerating technologies such as AI, robotics, and digital biology. Offerings include educational courses, programs and summits; enterprise strategy, leadership, and innovation programs; and programs to support and scale startups with social impact. Singularity's guiding philosophy is built around the idea of exponential change and the acceleration of solutions to meet the world's largest economic and societal challenges.[61]

System Connections

What is unique about the Bay Area's innovation system isn't simply the volume or quality of the research being conducted, the amount of risk capital that's available, its large number of entrepreneurs, or the infrastructure available to support them—although each is critical. Many of these elements could be replicated in other innovation ecosystems and to varying degrees they have been. Undergirding these institutions and organizations, however, is a set of values that permeates decision making. At its core is an openness to new ideas, to sharing information, and to collaboration across institutional boundaries. While barriers exist, they are comparatively low, a factor that reduces friction in the system and serves to accelerate innovation. People and ideas move freely and quickly, combining ideas across disciplines. For example, universities have well-developed research collaborations with industry and actively support entrepreneurs and technology commercialization, eschewing the ivory tower model of the past. Federal labs collaborate with universities and corporations, and all work with entrepreneurs and investors. Networks are critical to these processes and exist on multiple levels.

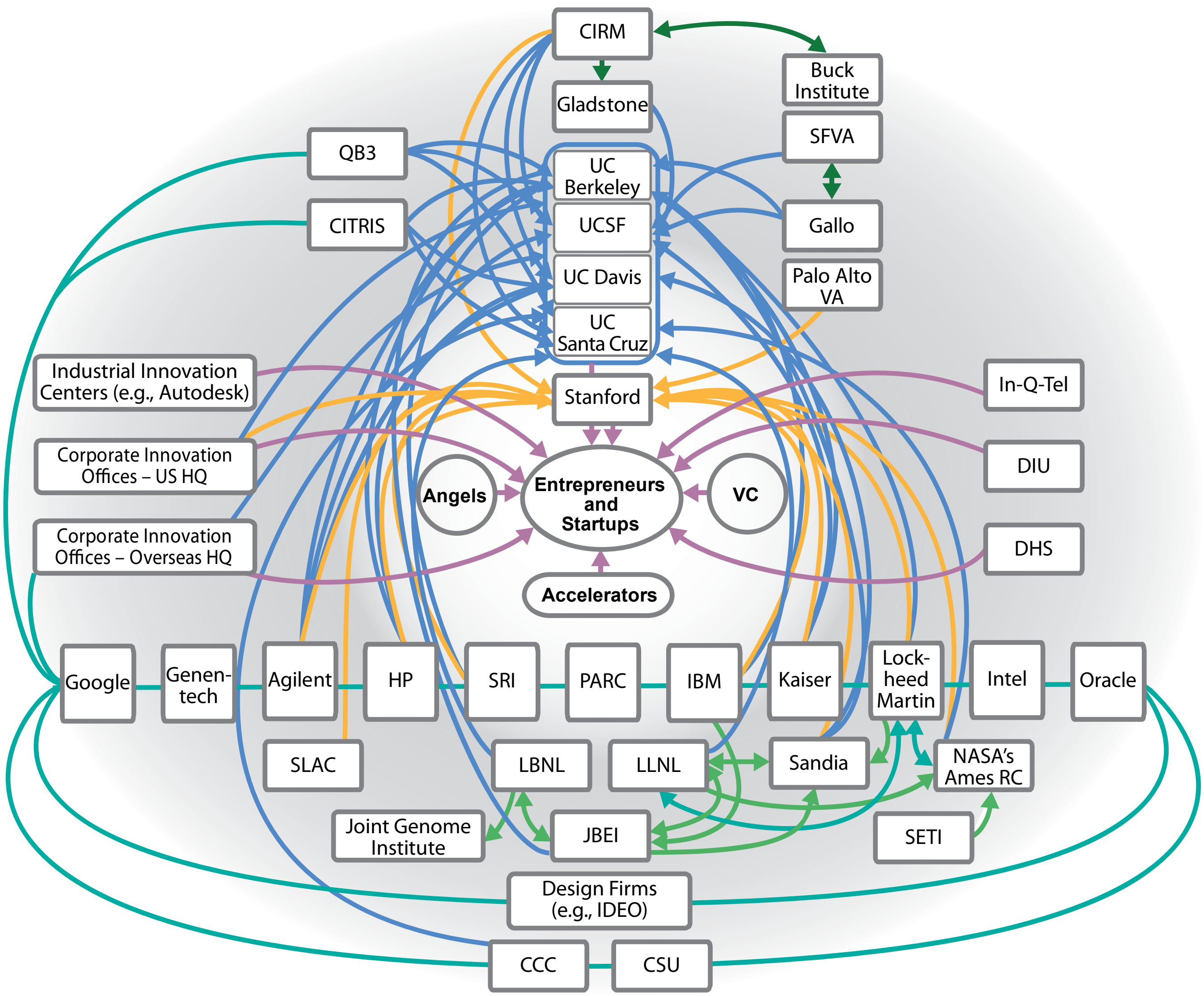
Uniquely, this is also an international conversation, where global collaborators are welcome and actively participate as integral partners in the system. One consequence of this openness is a global workforce, where talented and highly educated individuals from throughout the world actively contribute to the innovation process—as engineers, executives, and entrepreneurs. This is central to the Bay Area's status as a global innovation platform, where ideas from both inside and outside the region are developed and tested in an accelerated and highly competitive environment. It also connects the Bay Area to other technology and innovation economies around the world with which it actively exchanges human capital and investment.

Nearly all the actors in this system share a high tolerance for risk, and with it a willingness to accept failure. Scientific research doesn't always produce assured results, and most startups fail. But investors are prepared to overlook past failures if they believe that experience has enabled the entrepreneurs they invest in to grow their skills. Put differently, failure need not be permanent, particularly when in pursuit of large goals. Many entrepreneurs are successful only on their second or third try, and often go on to become investors themselves. This produces a virtuous circle where creative ideas and promising technologies are rewarded, and where success leads to reinvestment in the system.

Exhibit 6

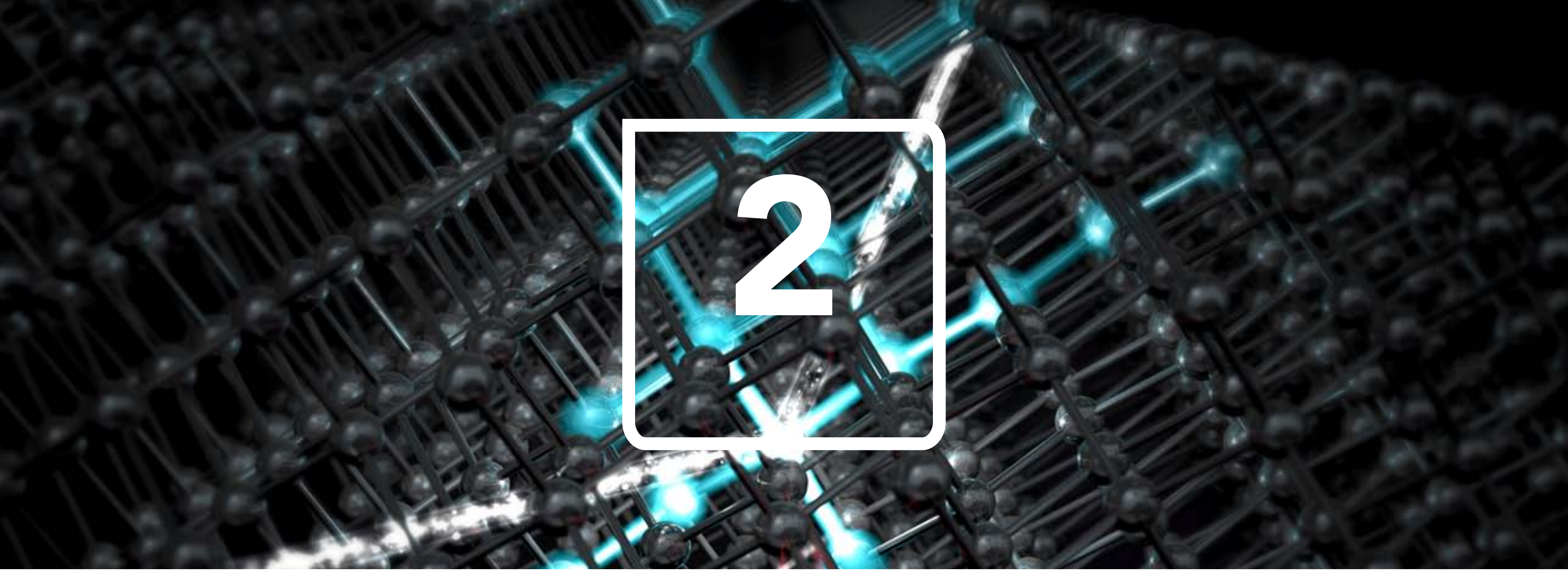
Interconnected networks and positive feedback loops sustain the Bay Area's innovation system.

Representative Collaborative Patterns in the Bay Area Innovation System



Source and Visualization: BASIC

The Exhibit 6 diagram describes, in highly simplified form, how the system works and how its players interact. The boxes indicate representative organizations and institutions, while the arrows indicate patterns of shared research and collaboration: corporations with universities and federal laboratories, independent research laboratories with universities, multi-institutional entities with multiple partners, major companies and institutions with startups and investors, and platform service providers with both public and private clients.

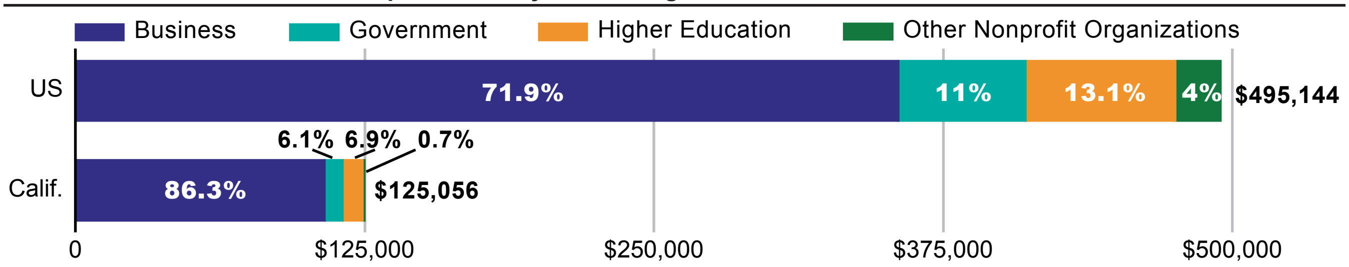


Funding Research and Development in the Bay Area

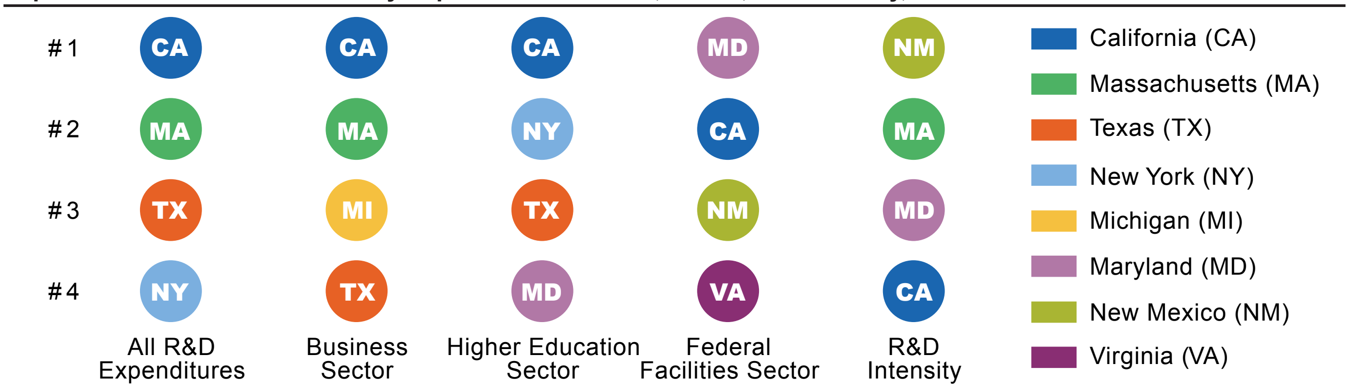
Exhibit 7

California leads the nation in research and development activity, accounting for 25 percent of the US R&D expenditures total in 2015.

US and California Overall R&D Expenditures by Performing Sector, 2015, $ millions



Top States in R&D Performance by Expenditures Amount, Sector, and Intensity, 2015



Source: NSF NSB | *Science & Engineering Indicators 2018* and *NCSES National Patterns of R&D Resources: 2015–2016 Data Update*, Table 10
Visualization: BASIC

Exhibit 8

California ranks second in both the Overall Scores and the Innovation Capacity subcategory in *The 2017 State New Economy Index.*

2017 State New Economy Index Top Five States Overall and Innovation Capacity Rankings

	# 1	# 2	# 3	# 4	# 5
Overall Score	MA	CA	WA	VA	DE
Innovation Capacity	MA	CA	DE	WA	MI

Massachusetts (MA)
California (CA)
Washington (WA)
Virginia (VA)
Delaware (DE)
Michigan (MI)

Source: ITIF *2017 State New Economy Index* Visualization: BASIC

The Bay Area is one of the great research centers in the world. As suggested in Chapter 1, the scale and diversity of its scientific resources are unique. When combined with the assets of the private sector—risk capital, sector expertise, an entrepreneurial business culture, and deeply interconnected networks—its research accomplishments underpin the region's innovation economy. Public investment in science is a key priority for both the business and scientific communities.

California leads the nation in research and development activity. *Science & Engineering Indicators 2018*, the latest biennial National Science Board analysis from the National Science Foundation (NSF), reports that California's overall R&D expenditures total was more than $125 billion in 2015. Nationwide, private industry performed 71.9 percent of overall R&D and provided 67.3 percent of the funding for it;[62] in California, private industry performed 86.4 percent of overall R&D and provided 76.4 percent of the funding for it.[63] In the NSF's ranking of state R&D activity in each of the three main R&D-performing sectors, California ranks first in the business and higher education sectors and second (after Maryland) in the sector defined as federal intramural R&D facilities and federally funded R&D centers (FFRDCs).[64]

In 2015, 10 states (California, Massachusetts, Texas, New York, Maryland, Michigan, Washington, Illinois, New Jersey, and Pennsylvania) accounted for 65 percent of all US research and development expenditures. California alone accounted for 25 percent of the US $495 billion total, about four times as much as Massachusetts, the next highest state. In addition to ranking first nationally for overall R&D expenditures, California ranks fourth in terms of R&D intensity (commonly expressed as the ratio of R&D expenditures to gross domestic product), behind New Mexico (#1), Massachusetts (#2), and Maryland (#3).[65] It should be noted that New Mexico ranks high due to its small population and the presence of two national laboratories (Sandia and Los Alamos), while Maryland ranks high due to its proximity to Washington, D.C. and the presence of a range of federal research facilities.

Industry Funding for University Research

In 2015, California companies funded $95.574 billion in R&D, with the majority of that support ($95.020 billion) going to in-house research.[66] The remaining $554 million of that industry funding went to research conducted at California's universities. This is a comparatively small amount (6.3 percent of all higher education R&D expenditures in California in 2015[67]) but is an important indicator of both the availability of top-tier university research and California's overall innovation capacity.

In 2017, the Information Technology & Innovation Foundation (ITIF) published the eighth edition of its *State New Economy Index*,[68] which assesses states' capacities for technological innovation. It found that strong industry funding of a state's university research correlates with strengths in key innovation variables such as venture capital, high-tech startups, and academic patents.[69] Industry investment in research and development in general is one of the seven variables in a suite of indicators that compose the Innovation Capacity subcategory of the *Index*. The other six indicators are the number of jobs in high-tech industries, the number of scientists and engineers in the workforce, the number of patents granted, non-industry investment in research and development, movement toward a clean energy economy, and venture capital investment. California ranks second (after Massachusetts) in both the Innovation Capacity subcategory and the Overall Scores in the *Index*.[70]

Federal Funding

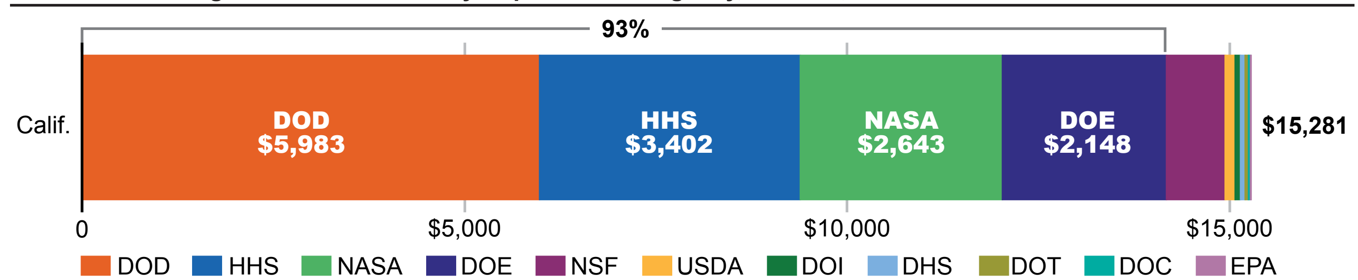
While fifteen federal departments and a dozen other federal agencies provide funding for research and development, eight federal departments or agencies provide the preponderance, with each obligating more than $1 billion annually: Department of Defense (DOD), Department of Health and Human Services (HHS), Department of Energy (DOE), National Aeronautics and Space Administration (NASA), National Science Foundation (NSF), Department of Agriculture (USDA), Department of Homeland Security (DHS), and Department of Commerce (DOC). Taken together, they accounted for about 97 percent of the federal R&D and R&D plant funding in 2015.[71]

California and the Bay Area are major beneficiaries of this investment. Nationally, California was the second highest recipient (after Maryland) of federal research and development funding in FY 2015, receiving $15.3 billion in federal obligations from 11 departments or agencies, with the majority (93 percent) coming from DOD, HHS, NASA, and DOE. The Department of Transportation (DOT), the Department of the Interior (DOI), and the Environmental Protection Agency (EPA) also provided R&D funding to California in FY 2015.[72]

Exhibit 9

California received $15.3 billion in federal R&D obligations in FY 2015; 93 percent came from DOD, HHS, NASA, and DOE.

Federal R&D Obligations to California by Department or Agency, FY 2015, $ millions

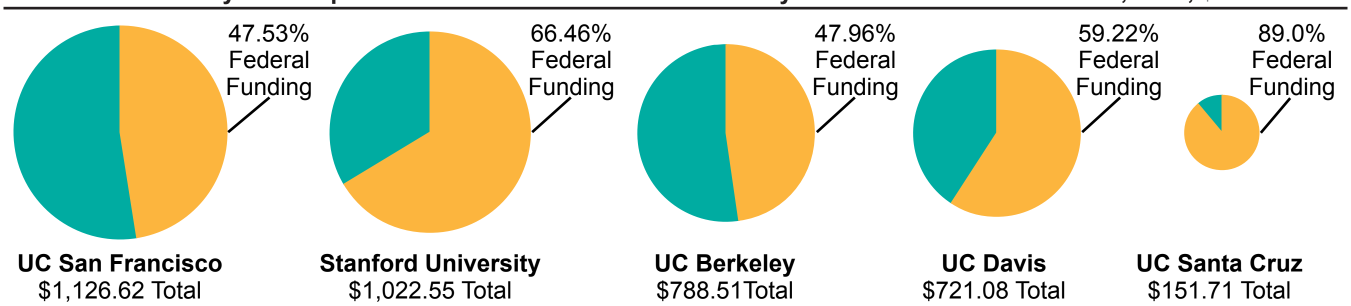


Source: NSF, *InfoBrief NCSES*, March 2017 NSF 17-316 — Visualization: BASIC

Exhibit 10

The Bay Area is home to five major research universities that each receive 47.5 percent or more of their research expenditure dollars from federal sources.

Research University R&D Expenditures Totals and Shares Funded by Federal Government Dollars, 2015, $ millions

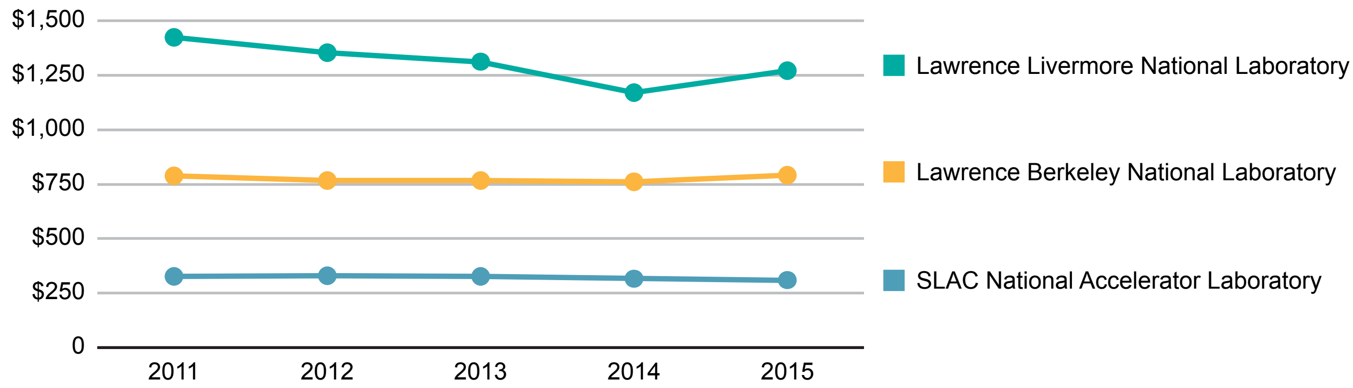


Source: NSF, NCSES HERD Survey FY 2015, Table 16, HERD2015_DST_16.xlsx — Analysis: BASIC

Exhibit 11

The Bay Area's Lawrence Livermore National Laboratory is among the five FFRDCS nationwide that each have R&D expenditures totals exceeding $1 billion.

R&D Expenditures by National Laboratories in the Bay Area, FYs 2011–2015, $ millions



Source: NSF, *InfoBrief NCSES*, March 2017 NSF 17-314

Visualization: BASIC

To provide insight into the differences in R&D project motivations and investments, the NSF classifies R&D expenditures into three categories: basic research (theoretical research without an immediate commercial objective), applied research, and experimental development. In contrast to the latter two categories, where the business sector performs and funds most activity, the largest share of basic research expenditures comes from the federal government (44.3 percent in 2015); almost half of basic research is performed by the higher education sector (49.1 percent in 2015).[73]

Research Universities

Federal government funding was the source for half of all R&D expenditures made by California's higher education institutions in 2015.[74] The Bay Area's extended higher education network includes five major research universities that each received 47.5 percent or more of their 2015 research expenditure dollars from federal sources:

- Stanford University is one of 10 US universities with annual R&D expenditure totals that exceed $1 billion.[75] About two thirds of Stanford's R&D expenditure funds came from federal sources in 2015, with HHS and DOD providing the largest shares.[76]

- UC San Francisco also has an annual R&D expenditures total that exceeds $1 billion, with 98 percent of those expenditures dedicated to medical research, and 61 percent funded by HHS.[77]

- UC Berkeley had an R&D expenditures total of roughly three quarters of a billion dollars in 2015, with about 48 percent of those funds provided by the federal government. The largest federal funders were NASA, the National Institutes of Health, and the National Science Foundation.[78]

- UC Davis had an R&D expenditures total of just under three quarters of a billion dollars in 2015. The largest source of that funding was HHS, which includes the National Institutes of Health; the second and third highest funders were the Department of State and the National Science Foundation.[79]

- The UC Santa Cruz R&D expenditures figure has been under $200 million annually in the past ten years. The University's Office of Planning and Budget reported that 89 percent of its sponsored project awards were funded by the federal government in 2014–2015. The largest funding source was NASA.[80]

Combined, these five universities accounted for just over $2 billion in R&D expenditures sourced from federal funds in 2015, or about 45 percent of the $4.7 billion in 2015 federal R&D funding received by higher education institutions in California.

National Laboratories and Federal Research Facilities

The Bay Area is also home to numerous federal research facilities, federally funded research and development centers (FFRDCs), and national laboratories.

- A federal research laboratory is a facility funded and managed by a specific federal agency. Among the federal research laboratories in the Bay Area are the USDA's Western Regional Research Center in Albany, the EPA's Central Regional Laboratory in Richmond, and the FDA's San Francisco Laboratory in Alameda.
- FFRDCs are federal research institutions funded by an agency or department and managed by a third-party entity.
- The term national laboratories refers specifically to DOE's 17 facilities nationwide that conduct research and development in areas related to energy and technology. Sixteen of the national laboratories are FFRDCs and one is both government owned and operated.

There are three national laboratories in the Bay Area—Lawrence Berkeley National Laboratory, Lawrence Livermore National Laboratory, and SLAC National Accelerator Laboratory—and a fourth national lab, the Albuquerque-based Sandia National Laboratories, has a second main facility in Livermore. These four facilities along with NASA's Ames Research Center constitute the largest federal research investments in the Bay Area. Three of the national laboratories are managed by universities (two directly and one through a partnership), producing intimate research relationships between the campuses and the labs.

- Lawrence Berkeley National Laboratory operates under the oversight of the Department of Energy's Office of Science. The University of California has managed the Lab since its founding in 1931.
- Lawrence Livermore National Laboratory (LLNL) is managed by Lawrence Livermore National Security, LLC—a partnership of Bechtel Corporation, the University of California, Babcock and Wilcox, URS Corporation, Battelle, and the Texas A&M University System.
- Operated and managed by National Technology and Engineering Solutions of Sandia, LLC, a wholly-owned subsidiary of Honeywell International, Sandia is a National Nuclear Security Administration (NNSA) research and development laboratory. Covering all its facilities in New Mexico, California, Nevada, Hawaii, and other locations, Sandia's R&D expenditures totaled $2.6 billion in FY 2015.
- Stanford University operates the SLAC National Accelerator Laboratory for the DOE's Office of Science.

Of the nation's 42 FFRDCs, five each had R&D expenditures totals exceeding $1 billion in FY 2015, and the Bay Area's Lawrence Livermore National Laboratory is one of those five. The combined FY 2015 R&D expenditures of the Lawrence Livermore, Lawrence Berkeley, and SLAC National Accelerator laboratories exceeded $2 billion, accounting for 46 percent of the more than $5 billion in total FFRDC R&D expenditures in California and almost 13 percent of the more than $18 billion in FFRDC expenditures nationwide. The R&D expenditures level trends for all three of these national labs show the same pattern experienced by all FFRDCs in recent years, with a decline or flattening early in the decade followed by a rebound beginning in 2015.[81]

State Funding

Across the US, state government research and development expenditures totaled $2.2 billion in FY 2015 and rose to $2.3 billion in FY 2016. Five states—California, New York, Texas, Florida, and Ohio—accounted for 61 percent of all state government R&D in FY 2015 and 64 percent in FY 2016. California leads the nation with the highest amount of state government R&D expenditures overall and with the highest amounts distributed to each of the two R&D performer categories—i.e., (1) intramural performers, defined as employees within the same state department or agency and services performed by others in support of internal projects, and (2) extramural performers, defined as academic institutions, companies, and individuals, and other non-intramural performers. In FY 2015, California's state government R&D expenditures totaled $500.1 million, with 11 percent of those funds going to intramural performers and 89.0 percent to extramural performers. In FY 2016, the total rose to $573.9 million, with 16.5 percent supporting intramural performers and 83.5 percent supporting extramural performers. The portion of the extramural support going to academic institutions was 46.5 percent (about $207 million) in FY 2015 and 40.7 percent (about $195 million) in FY 2016.[82]

Reflecting the state's policy priorities, $251.1 million of California's total state government R&D expenditures in FY 2016 was directed to energy research, while $199.5 million was health-related, $38.3 million was directed to transportation, and $7.5 million went to agricultural R&D.[83]

California supports extramural research at universities and research-oriented non-profits through a variety of programs:

California Energy Commission (CEC), Energy Research and Development Division

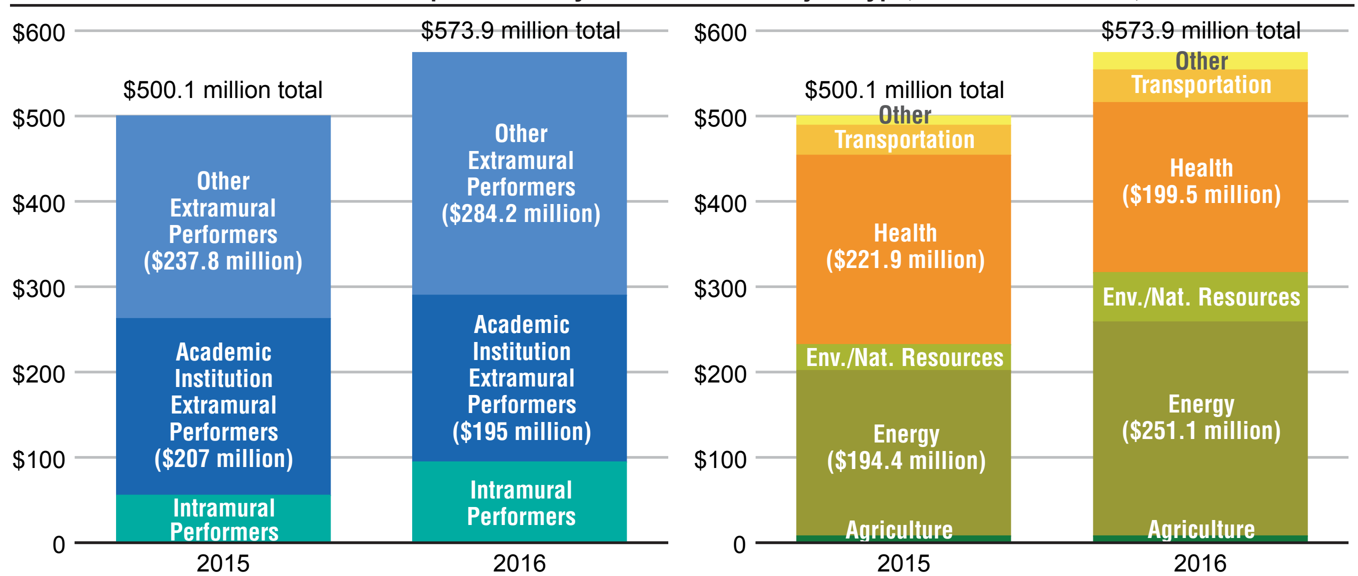
Since 1975, the California Energy Commission has made public-sector investments in research, development, and demonstration (RD&D) programs with the potential to improve California's energy systems and resources.[84] The Energy Commission funds research at businesses, utilities, energy companies, non-profits, California universities, and national laboratories, to help advance science and technology in energy efficiency, renewable energy, advanced technologies, energy-related environmental protection, transmission and distribution, and transportation technologies.[85]

- CalSEED provides small grant funding for entrepreneurs and researchers to demonstrate concept feasibility of their new clean energy technology ideas.
- Federal Cost Share provides cost share funding for applicants submitting a proposal to a funding opportunity from the US Department of Energy.

Exhibit 12

California leads the nation with the highest level of state government R&D expenditures.

California State Government R&D Expenditures by Performer and Project Type, FYs 2015 and 2016, $ millions



Source: NSF, *InfoBrief NCSES*, Dec. 2016 NSF 17-307 and Dec. 2017 NSF 180-305

Visualization: BASIC

- Natural Gas R&D provides funding to advance scientific approaches and technology solutions for California's natural gas sector.
- Electric Program Investment Charge (EPIC) provides funding to advance scientific approaches and technology solutions for California's electricity sector.[86]

Strategic Growth Council, Climate Change Research Program

With the passage of California Assembly Bill 109 in 2017, the Climate Change Research Program was created to support research on carbon emissions reduction, including clean energy, adaptation, and resiliency. In the 2017–18 and 2018–19 fiscal years, the Program received a total of $29 million in appropriations from the Greenhouse Gas Reduction Fund, which is the depository for Cap-and-Trade auction proceeds.[87] Administered by the Strategic Growth Council, the Climate Change Research Program aims to build an innovation partnership between the State and the research community that will directly support achieving California's climate change goals.[88]

California Breast Cancer Research Program (CBCRP)

In 1993, California passed statewide legislation to publicly fund breast cancer research. The California Breast Cancer Act increased the tobacco tax by 2 cents per pack, with 45 percent of the revenue going to CBCRP. Nationally, CBCRP is the largest state-funded breast cancer research effort in the nation and funds research into basic breast cancer biology, causes and prevention of breast cancer, innovative treatments, and ways to live well following a breast cancer diagnosis. Since 1994, CBCRP has awarded over $280 million in research funds to institutions across California.[89]

California HIV/AIDS Research Program (CHRP)

The California HIV/AIDS Research Program was founded in 1983 in response to the AIDS epidemic and the lack of federal funding to understand HIV/AIDS. CHRP funds research into treatment option efficacy, affected population disparities, and policy impacts. Since its founding, CHRP has funded over 2,000 research projects and allocated more than $275 million in grants.[90]

California Institute for Regenerative Medicine (CIRM)

California's stem cell agency was created in 2004 with the passage of Proposition 71, the California Stem Cell Research and Cures Initiative.[91] Like the formation of the California HIV/AIDS Research Program, CIRM was formed to fill a void in federal research funding.

As of November 2018, CIRM has awarded more than 1,000 grants at more than 70 institutions and companies in the state, advancing California's role as a global leader in stem cell research. This includes funding for 49 clinical trials; another 11 projects that received early funding are in FDA-sanctioned clinical trials. Only the NIH invests more in stem cell research.

The Bay Area is a major recipient of CIRM support. Over the years, CIRM has invested more than $947 million in 351 awards to 40 different Bay Area institutions. This includes around $800 million to 17 different non-profit institutions and approximately $147 million to 23 for-profit businesses.[92]

Tobacco-Related Disease Research Program (TRDRP)

In 1988, California voters approved Proposition 99, the Tobacco Tax and Health Protection Act, which instituted a 25-cents-per-pack cigarette surtax. Five cents of each dollar collected supports critical tobacco-related research. In 2016, California voters reaffirmed their commitment to publicly funded research and approved Proposition 56, the Tobacco Tax Increase Initiative, which increased the cigarette surtax by 2 dollars, with equivalent increases on other tobacco products and electronic cigarettes. Revenue from the cigarette tax funds physician training; prevention and treatment of dental diseases; Medi-Cal; tobacco-use prevention; research into cancer, heart, and lung diseases, and other tobacco-related diseases; and school programs focusing on tobacco-use prevention and reduction.[93]

California also supports research & development through tax credits and incentives:

- **California R&D Tax Credit**

  In 1987, California established a research and development tax program that allows companies to reduce their tax liability if they engage in qualified research activities within the state. This credit was adopted in order to remain competitive with other states with R&D tax credits, and to stimulate R&D activity in California. The California Tax Research Credit allows entities engaged in qualified basic research activities to take up to a 24 percent tax credit.[94] To accommodate longer-term research activities, the credit can be used to offset current-year tax liabilities, and can be carried forward to offset liabilities in future years.[95] California's R&D tax credit is one of the highest in the nation[96] and is California's largest business tax expenditure (in terms taxes not collected) at a projected $1.7 billion in 2016–17.[97]

- **Manufacturing and Research & Development Equipment Exemption**

  The Manufacturing and Research & Development Equipment Exemption allows manufacturers and certain researchers and developers to obtain a partial exemption from sales and use tax on certain manufacturing and research and development equipment purchases and leases.[98] The exemption is targeted towards manufacturing, biotech, and food processing businesses located in California.

Philanthropic Funding

Philanthropic private funding plays a small but significant role in the R&D process, particularly in support of basic research. While private funding cannot provide levels of research support comparable to those supplied by the federal or state governments, it nonetheless plays an important role in advancing research in niche areas. Private funders often have more freedom in making research funding decisions, allowing them to fund scientifically uncertain projects, with government supporting the research once more scientific certainty emerges.[99]

Although it's difficult to track the flow of private funding into research activities, the Science Philanthropy Alliance made a start in assembling the data with their first-ever survey of higher education institutions and private funding of basic research in 2015. The survey sample was small, with reporting coming from only 26 of the 62 members of the American Association of Universities plus one additional graduate-only university, but the results provide an initial estimate of the significance of philanthropic support for basic research. The 27 reporting universities received a total of $2.2 billion in basic science research private funding, with $1 billion (47 percent) of that going to the life sciences, $158.9 million (7 percent) going to the physical sciences, and $35.6 million (2 percent) going to mathematics.[100] Although private funding for basic research is small compared to the $33.5 billion in overall R&D support provided to the higher education sector by the federal government in 2015,[101] it provides an alternative to the more risk-averse federal funding model. This alternative could prove particularly valuable for life scientists seeking support for innovative research that faces high risk but could lead to breakthroughs.

The Human Cell Atlas is a recent example of how philanthropic funders are supporting basic research in the life sciences. Launched in late 2016, the international project aims to create comprehensive reference maps of all human cells as a basis for understanding human health and diagnosing, monitoring, and treating disease. The National Institutes of Health is among the various government and philanthropic organizations that are supporting the project, which includes a Data Coordination Platform that will host the data for researchers worldwide. The private Chan Zuckerberg Initiative (the foundation created by Facebook co-founder Mark Zuckerberg and his wife Priscilla Chan) is supplying critical support for the Atlas, by providing grants for component projects and key support for the Data Coordination Platform.[102] Support from the Chan Zuckerberg Initiative (CZI) is particularly important to non-US scientist participants who are not receiving NIH funding.[103]

Funding for Startups

As a rule, research and development funding does not support the activities required to take innovative research out of the lab and into new products and companies. That comes primarily from private industry, in the form of angel and venture investment, and from federal Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR) grants that pick up where traditional research funding stops.

A 2016 Bay Area Council Economic Institute study entitled *Entrepreneurs, Startups, and Innovation at the University of California* found that 1,267 companies were generated by the university between 1968 and June 2015. The count included only startups in STEM-related fields (science, technology, engineering and mathematics) that were formed using UC-generated intellectual property or were founded by faculty, staff, or postdoctoral, graduate, or undergraduate students within one year of completing their UC affiliation. Of these companies, 622 were still in business ("active") in June 2015, and 603 of those companies were headquartered in California. Both federal funds, via the SBIR or STTR grants, and private venture funds were important factors in their success. Among the active companies, 189 had received $326,139,269 in SBIR and/or STTR grants, and 268 had received $9,812,978,018 in venture capital investment.[104]

Other direct and indirect support for the commercialization of university-originated technologies comes, on a smaller scale, through university-sponsored incubators, accelerators, business plan competitions, grants, entrepreneurial education programs, and in some cases direct investments. Often these programs draw on private funding. UC-sponsored examples in the Bay Area include UC Berkeley's SkyDeck startup accelerator, the CITRIS Foundry applied tech incubator, the network of five incubators supported by QB3, the Mike and Renee Child Institute for Innovation and Entrepreneurship at UC Davis, and the UC Ventures investment fund managed by the University of California Office of the President (UCOP).[105]

Recognizing this activity, in 2016 California's legislature approved and the governor signed Assembly Bill 2664, the innovation and entrepreneurship expansion bill under which one-time funding of $2.2 million each for the UC system's ten campuses was provided in January 2017 for investment in infrastructure, incubators, and entrepreneurship education programs. According to UCOP's November 2017 report to the legislature, that investment has subsequently supported more than 500 new startups and existing companies, helped launch at least 47 new products, and enabled companies to attract $3.7 million in additional investments.[106]

In addition to its extensive network of entrepreneurial support initiatives identified in Chapter 1, Stanford University provides direct support through programs including SPARK, under which selected medical and diagnostics projects receive up to $50,000 and mentoring from industry volunteers for two years; the Coulter Translational Research Grants; the Spectrum Innovation Accelerator Seed Grant Program, which provides seed grants of $15–50 thousand per year (with the possibility of a single renewal) for promising translational technologies in medtech, therapeutics, diagnostics, and population health sciences; TomKat Energy Innovation Transfer Seed Grants, which focus on energy, transportation, and the energy-water nexus with commercialization potential; and Stanford Woods Institute Environmental Venture Projects, providing seed grants to interdisciplinary teams addressing environmental challenges.[107]

Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR)

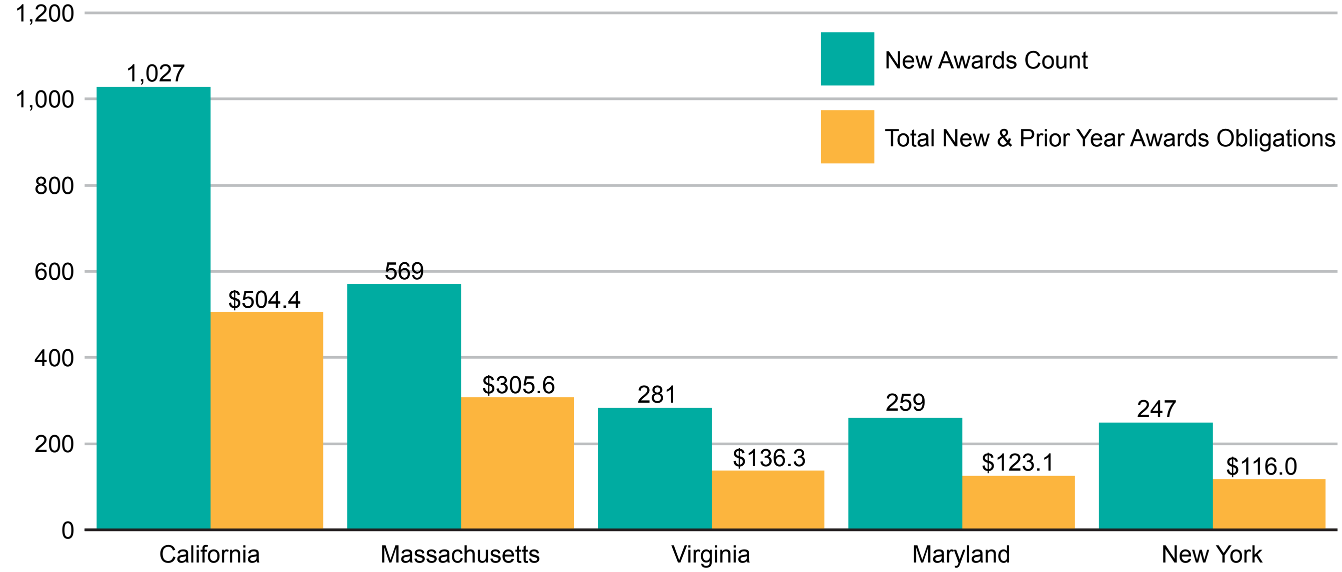
The SBIR grants program supports R&D by US small businesses, helping entrepreneurs and their emerging companies to bridge the gap between basic research and commercial applications. The STTR program expands federally-funded research opportunities to collaborative venture opportunities between small businesses and research institutions.

In FY 2015, 1,027 new SBIR/STTR grant awards were made to California small businesses,[108] with a little less than a third of those awards going to companies in the nine-county Bay Area.[109] The total dollar amount obligated to California in both new and prior year awards in 2015 was $504.4 million. California had both the highest number of new awards and the highest level of dollars obligated, followed by Massachusetts (with 569 new awards and $305.6 million obligated) and Virginia (with 281 new awards and $136.3 million obligated).[110]

Exhibit 13

In 2015, California had both the highest number of SBIR/STTR new awards and the highest level of dollars obligated.

SBIR/STTR New Awards Counts and New and Prior Year Awards Obligations, Top Five States, FY 2015, $ millions



Source: SBIR | STTR Annual Report FY 2015, data snapshot 04/03/18

Analysis: BASIC

Science and the Economy: Public Investment in Economic Leadership

Chapter 1 of this report analyzed the Bay Area/Silicon Valley innovation system, including a review of its key components and how they interact. Chapter 2 then looked at how that system is supported by public investment in scientific research that can lead to new discoveries and economic advances. One of the Bay Area's most significant competitive and collaborative assets is its deep scientific base, which enables basic scientific inquiry but also technology breakthroughs that generate new world-class companies—and often create or transform entire industries. Because the working parts of the region's innovation system are so closely interconnected, any weakening of one can impact other elements and the system as a whole. A key theme of this report is that consistent, sustained public investment in science provides a critical foundation for the region's and the nation's scientific and economic leadership.

Translating Research Into Economic Benefits

Research generated with public support has broad impacts on the economy, with basic research often finding commercial applications. A few of many possible examples follow.

From Research to Market

Space Technologies Applied on Earth

NASA offers a spectrum of examples of technologies originally developed for use in space that also have important applications on earth:

- NASA's silver ion technology, originally developed to purify water for the Apollo astronauts, purifies and softens water while inhibiting bacteria growth in filtering units; it is being used today in home water filtration systems.[111]
- NASA-designed wind turbines, engineered to support future Mars missions and tested in Antarctica, are generating power around the world.[112]
- NASA-originated improvements to the fire-resistant properties of polymer fabric used in spacesuits are now widely incorporated into the protective gear used by firefighters.[113]
- A NASA-designed filter that blocks blue light waves (which make it difficult to discern colors at the edge of the visible spectrum) is being used to improve visibility in snow goggles by canceling up to 95 percent of blue light.[114]
- Image sensors first developed by NASA for space missions in the 1990s are the basis of the sensors used in cell phones and digital cameras today.[115]

- Crop irrigation is the most significant draw on water supplies today. Researchers using thermal images from NASA's Landsat 8 earth-observing satellites are teamed with Google Earth to use satellite images to map water evaporating from the ground or transpiring from plants. Applications will help farmers better determine their optimum water use.[116] Imagery from Landsat 8 and NASA's Moderate Resolution Imaging Spectroradiometer instruments, also in earth orbit, is being leveraged to accurately predict crop yields.[117]
- High speed camera and software technology developed to measure impacts in the wake of the space shuttle Columbia disaster is being used to test materials for safety, including Boeing's 787 Dreamliner and Ford truck bodies.[118]

To encourage use of its patented technologies to benefit the economy, NASA's patent portfolio is available to US citizens who want to commercialize it, with up front licensing fees waived; a royalty fee is charged only when a company starts selling a product. Applicants can access its patent portfolio through www.technology.nasa.gov/patents, and can submit online licensing requests through www.technology.nasa.gov/startup.[119]

Energy Efficiency

Technologies developed at the DOE national labs that are now used in a variety of everyday products offer other examples.

- An LBNL device designed to inexpensively monitor building energy use now provides real-time power diagnostics for homeowners and utilities through Whisker Labs' Connected Savings platform.[120]
- A technology invented at LBNL to reduce energy losses through HVAC ductwork is the foundation for Aeroseal, a ductwork-sealing company with 600 dealers in North America, Europe, Asia, and Australia.[121]

Potential Future Impacts

While the technologies cited above are already in the market, other pre-commercial technologies have the potential for important future impacts. Two examples suggest the possibilities.

Mars and Cancer

In the field of UV radiation and cancer, Dr. Nathalie Cabrol at the SETI Institute is conducting NASA-funded research into environments on earth that could be instructive for future space missions. Her recent research conducted in the Andes is connected to a possible mission to Mars, but has earthbound applications. Looking for what kind of life might be expected on Mars, she explored harsh environments in the high Andes through a five-year project that included the monitoring of UV radiation. UV levels are extremely high at altitudes of 14–20 thousand feet, but her research found habitats where microbial life has survived and successfully adapted by developing protective pigments. Oncologist David Agus joined the project in 2015, and using samples and measurements that were collected, members of his team are now assessing whether there is something special about these microbes that could advance cancer research. The findings could have important benefits if new ways can be found to protect humans against harmful UV ray damage such as skin cancers and cataracts.[122]

Understanding the Brain

Federal investment in brain research offers a different example of how pre-commercial research portends important societal impacts.

The federal BRAIN (Brain Research through Advancing Innovative Neurotechnologies®) initiative, administered by the National Institutes of Health (NIH) since 2013, supports public-private research collaborations to develop innovative technologies and applications that further our understanding of how the brain works. The potential applications are compelling.

The ability of scientists to understand the brain is limited by the tools they have, which in turn limits the questions they can ask and answer. Dr. Loren Frank at UC San Francisco began his research with a set of philosophical questions: How do we work and how can we help people work better and make better decisions? How do we make and use memories? How does the brain imagine things? The challenge of mental illness was particularly vexing: brain functions depend on distributed networks, and you can't fix the brain unless you know how it works. The challenges to doing that are formidable, however: the brain is the most complicated thing we know of in the universe, and there is a vast difference between the complexity of its system and what we can currently observe. As Dr. Frank observes, "It's not just input-output, it's what's constantly reverberating inside."

Partners include materials and instrumentation engineers at Lawrence Livermore National Laboratory (LLNL) to design and develop novel neural probes; chip designers and software scientists at Lawrence Berkeley National Laboratory (LBNL) to help understand the large data sets being generated; and scientists at UC Berkeley. The first support came six years ago from the Lab Fees program administered by the University of California Office of the President, which supports collaborations between UC campuses and national laboratories. The primary support came in the form of two subsequent BRAIN grants. Dr. Frank notes that each award has been a stepping stone toward understanding how the results of this research might one day be used in people: "Memory, imagination, decision making all engage many brain areas. The tools we're developing try to map those processes, over long periods of time and over many sites in the brain, so you can see how many parts of the brain communicate. That makes it possible to think about these questions and address them in a more fundamental way than was possible before."

The project's current focus is on flexible polymer probes (electrodes) that measure brain activity. The data produced needs to be filtered and digitized for processing in a computer. As the density of available data goes up with the number of neurons being measured, so does the computational challenge. Local tech company SpikeGadgets is building the electronics for data collection. The pieces need to work as a system where the data comes from the brain through electrodes and is digitized, stored, and analyzed. As noted again by Dr. Frank, "Unless you have all these elements working together, you have nothing."

The project's goal under the second BRAIN grant is to achieve another 10X density of recording ability (500 MB of data per second coming from the brain). The potential applications extend only as far as the imagination. If we know how memories are stored, it may be possible to help people store memories better. Or it may be possible to help Alzheimer's patients by intervening earlier to help the brain work better. In cases of epilepsy, if we can measure far better than we can today, can seizures be stopped before they start? Other potential applications are related to depression and PTSD. When activity in the brain can be measured, where aberrations are found, it may be possible to push it back to normal levels.[123]

Science-Enabled Startups

Other technologies are in the commercial pipeline through innovative startups whose explicit purpose is to apply technology originating in the lab.

Many leading technology and life sciences companies trace their roots to research first developed at universities. Much of this starts with basic research—research that is inquiry-based and is conducted with the goal of advancing knowledge, not a commercial product. As often happens in science, breakthroughs or advances then lead to unplanned applications. Google, for example, traces its roots to Stanford's Department of Computer Science, where founders Larry Page and Sergey Brin both worked under an NSF grant, identifying ways to search digital libraries.[124]

The impact of public investment can be seen in startup activity across a range of sectors. The following case studies—a few of the many hundreds that could be cited—illustrate how technologies originated at universities and national laboratories have been moved into the marketplace by startup companies and how public investment at a critical stage has often helped these new technologies and fledgling companies advance. In many cases, this has happened through SBIR and STTR grants, and in others through research grants from the National Science Foundation (NSF), the National Institutes of Health (NIH), the Department of Energy (DOE), or other federal agencies. Some technologies, particularly in energy and climate science, have advanced with state support through the University of California or state government agencies. For nearly all science-based startups, public investment at the federal or state level has enabled technologies with commercial potential to advance, helping to close the gap between scientific theory and business applications.

Environment

Bloom Energy

Bloom Energy (initially called Ion America) was founded in 2001 using technology originally developed at NASA's Ames Research Center. Today, it is a leading provider of solid oxide fuel cell technology generating clean, efficient, on-site power for commercial facilities. Bloom Energy Servers currently produce power for companies such as Apple, Google, Walmart, AT&T, eBay, Staples, Coca-Cola, and Kaiser Permanente. Through its Mission Critical Systems practice, Bloom also provides grid-independent power for critical loads in data centers and manufacturing.[125]

CinderBio

Researchers at Lawrence Berkeley National Laboratory (LBNL) have produced enzymes from microbes called extremophiles (that live in extreme temperatures or toxic conditions) to replace chemicals used in biofuel production, paper pulping, and operations in the textile and food processing industries. Seeing the potential across a range of industrial applications, the researchers, Jill Fuss and Steve Yannone, founded a startup—CinderBio—based on the LBNL technology. It has successfully used this technology to clean dairy processing equipment in place of industry-standard chemicals, reducing water use by almost 30 percent.[126] CinderBio continues to develop the technology with an eye to reducing chemical waste in the food processing industry. It is part of Cyclotron Road's fourth cohort of entrepreneurs, and founder Jill Fuss won a 2015 Visionary Award from the Berkeley Chamber of Commerce. The company has earned SBIR Phase I and II awards topping $1 million from the National Science Foundation.[127]

Emerging Objects

Emerging Objects, which describes itself as a "3D Printing MAKE-tank," was co-founded by UC Associate Professor of Architecture Ron Rael, who received startup support from the Bakar Fellows Program operated by the University of California Office of the Vice Chancellor of Research.[128] The Bakar Fellows Program provides support for up to five years for selected Fellows whose research shows commercial promise. Emerging Objects designs 3D printed materials—some at unprecedented sizes including full-scale architectural applications—with a focus on sustainability and recycled materials. Its "cool brick" masonry system composed of 3D-printed ceramic blocks can be used to build walls that passively cool interiors in desert climates through a process in which water held in the micropores of the ceramic evaporates, bringing cool air into an interior environment. Rael and his co-founder Virginia San Fratello have recently unveiled Potterware, a design app for 3D printing of pottery.

SkyCool Systems

The day may be coming when the temperature inside a building in the middle of the day can be lowered using the cooling capacity of the sky—instead of electricity. Supported by a combination of public and private funding sources, including DOE's ARPA-E program and the Stanford University Global Climate and Energy Program, engineers in Stanford Professor Shanhui Fan's laboratory developed a multilayer optical film that reflects sunlight and emits thermal energy in a way that spontaneously cools a surface to below the ambient temperature. The system is entirely passive (meaning no energy is used in the process) and has a number of promising applications, including cooling buildings and providing off-the-grid air conditioning. SkyCool Systems was formed by a team of the system's inventors after participating in the I-Corps program. Further support for the project came from Stanford's TomKat Center and the StartX Accelerator Program. SkyCool now has pilot demonstration systems operating in California.[129]

Lygos

Lygos is a biotechnology startup focused on sustainable chemistry, building on technologies developed at the Joint BioEnergy Institute (JBEI) with support from the Office of Technology Transfer at UC Berkeley. Its technology is a platform for making environmentally-benign, bio-based chemicals, particularly products made through fermentation. Similar to brewing beer, its process uses yeast, sugar, and water to produce specialty chemicals, contributing to cleaner, more sustainable manufacturing.

The startup's first product and biology-based production process delivered a novel way to manufacture malonic acid using yeast. Malonic acid is a high-value specialty chemical used in the electronics industry, flavors and fragrances industry, specialty solvents, polymer crosslinking, and the pharmaceutical industry. In less than four years, Lygos, working with LBNL's Advanced Biofuels and Bioproducts Process Demonstration Unit (ABPDU), has proven the scalability of the new malonic acid biomanufacturing process at production costs competitive with conventional technologies. This is significant because until recently the only way to make malonic acid and its derivative compounds was through a petroleum-based process that relies on toxic chemicals such as cyanide and chloroacetate. The toxicity of this process has pushed most malonic acid production overseas. In contrast, the Lygos bioprocess is based on a genetically engineered microbe producing an enzyme that can convert a cellular precursor into the desired renewable chemical.

As of July 2018, Lygos had raised over $40 million in financing and had announced multiple partnerships.[130] Through an award from the US Department of Energy, Lygos is currently working in a multi-million dollar partnership with the Agile BioFoundry to accelerate the adoption of biological engineering practices to develop a set of new high-value chemicals.[131] In addition to producing cleaner chemicals, the bioproduct approach will enable manufacturing of these products to return to the United States.

Picarro

Picarro's story began in the laboratory of Professor Richard Zare in Stanford University's Chemistry Department. With an innovation called cavity ring-down spectroscopy (CRDS)—an optical technique that has exquisite sensitivity in measuring trace chemicals in the air—it became possible to detect molecules at the parts-per-billion level, which is orders of magnitude more sensitive than traditional instruments. With this degree of precision, CRDS has applications in a wide variety of fields, ranging from analytical chemistry to medical diagnostics to environmental monitoring. The research was supported by the US Department of Energy, the US Air Force, the US Navy, and the National Institutes of Health. After graduating PhD student Barbara Paldus attended a Stanford class on technology venture formation, she and Dr. Zare co-founded Informed Diagnostics, which later evolved into Picarro. The company's CRDS products were launched in 2004 and are being used today by atmospheric scientists and geophysicists to monitor the effects of climate change.[132]

Health

Cortera Neurotechnologies

Founded in 2013[133] by a faculty and graduate student team at UC Berkeley, Cortera Neurotechnologies designs medical devices aimed at revolutionizing the treatment of incurable neurological conditions. It is currently a participant in a multi-institution collaboration with Lawrence Livermore National Laboratory, UC Berkeley, UCSF, Cornell University, New York University, and Posit Science, that has received DARPA funding to develop an implantable neural interface with the ability to record and stimulate neurons in the brain. Applications include the treatment of neuropsychiatric disorders such as anxiety and depression.[134]

Nurix

Nurix is commercializing a protein regulation platform that can enable therapies for cancer, inflammatory diseases, and immune disorders. The company was founded in 2009 by three internationally-recognized UC professors in the fields of ligase biology and immunology: one from UCSF, Dr. Arthur Weiss; and two from UC Berkeley, Dr. John Kuriyan and Dr. Michael Rapé, a Bakar Fellow. In February 2013, the company was awarded a $300,000 SBIR grant from the Department of Health and Human Services. By May 2014, the company had raised more than $25 million in venture capital. Two high profile partnerships with other biotechnology companies led to a $150 million deal with Celgene in September 2015, under which the two companies collaborated to create a new class of drugs that work by selectively modulating cellular protein levels.[135]

Zephyrus Biosciences

Zephyrus Biosciences, which spun out from the lab of bioengineering professor and UC Berkeley Bakar Fellow Amy Herr in 2013, provides research tools to enable protein analysis at the single cell level, permitting new insights into the biology of cancer, stem cells, and neurology. Supported by Berkeley incubators QB3 and SkyDeck, it was awarded a $350,000 SBIR grant by the US Department of Health and Human Services in 2014. Zephyrus has also received $1.86 million in seed funding from Life Sciences Angels, The Angel Forum, the Stanford University StartX Fund, and Mission Bay Capital to support development of its scWestern system for protein analysis. The company was acquired by BioTechne Corporation in March 2016.[136]

Circle Pharma

Circle Pharma was founded based on a technology developed by UC Santa Cruz's Scott Lokey and UCSF's Matt Jacobson. Circle is developing macrocyclic peptides—essentially small circular proteins—as therapeutics that can reach targets that conventional drugs can't. QB3's Collaborative Startups program brokered a partnership between Circle and pharma giant Pfizer, in which QB3's venture capital fund also invested. Circle's collaboration with Pfizer has led to the identification of a series of bioavailable macrocyclic peptides capable of acting as potent and cell-permeable modulators of CXCR7, a receptor that is a promising therapeutic target for the treatment of tumors.[137]

Caribou Biosciences

Launched at UC Berkeley by Jennifer Doudna and Rachel Haurwitz, Caribou Biosciences is at the forefront of gene splicing, a field with wide ranging impacts from the treatment of blood disorders and cancer to anti-bacterial therapies and treatments for household pets. Caribou was incorporated with the help of QB3's Startup in a Box, and QB3's venture fund is an investor. With a business model that includes both partnerships with larger firms and spinning off new ones, Caribou is commercializing the CRISPR gene-editing technology in a Berkeley space leased from QB3 partner Wareham Development. Its list of industrial partners includes Dupont and drug giant Novartis, with the Novartis partnership having led to the spinoff of Intellia Therapeutics, a company focused on using the CRISPR/Cas9 system to develop curative treatments for genetic diseases.

In May 2016, Caribou announced a new partnership allowing the use of the CRISPR-Cas9 gene editing technology platform by animal genetics company Genus. Caribou has received $11.5 million in Series A funding from firms including Novartis, Mission Bay Capital, Fidelity Biosciences, 5 Prime Ventures, and a syndicate of angel investors, and completed a $30 million Series B round in May 2016. In June 2018, CRISPR Therapeutics, Intellia Therapeutics, and Caribou Biosciences announced that The Regents of the University of California, the University of Vienna, and Dr. Emmanuelle Charpentier had collectively been awarded a US patent covering methods of CRISPR/Cas9 genome editing.[138]

Forty Seven, Inc.

Supported by $25.3 million in California Institute for Regenerative Medicine (CIRM) grant funding, Dr. Irving Weissman of Stanford University has advanced the development of an anti-CD47 antibody therapy that targets cancer stem cells. In 2015, Forty Seven Inc. was founded to commercialize anti-CD47 immunotherapy. In 2016, the company raised $75 million in Series A funding led by Lightspeed Venture Partners and Sutter Hill Ventures. Another $10 million in CIRM funding in late 2016 supported a phase 1 trial of the anti-CD47 and cetuximab combination therapy for advanced cancers. The company subsequently raised an additional $75 million in Series B funding, led by Wellington Management, and was awarded another $5 million by CIRM for a phase 1 trial of the anti-CD47 antibody in combination with azacitidine for treatment of acute myeloid leukemia. In 2018, Forty Seven Inc. raised $113 million in its initial public offering, and has recently established strategic partnerships with Roche, Genentech, Merck, and Lilly to advance its pipeline of anti-CD47 immunotherapy candidates for solid and hematologic cancers.[139]

Unity Biotechnology

Aging is a universal human condition, and how and why we age is receiving increased scientific attention. Unity Biotechnology was founded by Dr. Ned David, who had previously founded several medical technology startups. He subsequently engaged Dr. Judy Campisi, a research scientist at the Buck Institute for Research on Aging who had been recruited to Lawrence Berkeley National Laboratory (LBNL) in 1991. Campisi was conducting research on cancer, not on ageing, but saw the connection and converted to an appointment at the Buck Institute in 2003 where she now spends 90 percent of her time, shifting to a part-time role at LBNL.

Unity is developing small molecule drugs that can selectively kill, inhibit, or possibly reverse the development of senescent cells (cells that have stopped dividing) that accumulate in the ageing process and are the cause of an extraordinarily large number of age-related diseases, including cancer metastasis, osteoarthritis, Parkinson's disease, Alzheimer's disease, metabolic syndrome and others. This strategy has the potential to both prevent disease from happening and ameliorate its progression. In principle, diseases could be reversed in cases where senescent cells interfere with stem cell generation. Since a large number of distinct diseases are linked to senescent cells, the research team shares its models with other US laboratories that have a particular disease focus, in order to test its application. Through one such published collaboration, scientists at Johns Hopkins University have been able to repair arthritis in injured joints. Similar applications were recently demonstrated for models of Parkinson's disease.

Dr. Campisi's foundational research was almost entirely publicly funded, initially by the NSF but mostly by the NIH. Other grants have come from the Department of Energy, which is looking at radiation-induced cell damage, and the Department of Defense, but also from private foundations such as the American Federation for Aging Research.

Unity's first drugs for two specific age-related diseases—glaucoma and osteoarthritis—are in phase 1 clinical trials, with more trials to come for other diseases. The company went public on the Nasdaq in 2018, and has grown from a few post-docs to approximately 100 employees at its headquarters in Brisbane. Successful development of its drugs would have economic as well as personal impacts for millions in affected populations: 80 percent of the US healthcare budget goes to treating people over age 65, a growing population that will produce a growing economic burden. Dr. Campisi notes "I've been in the field 25 years, and it's now possible for us to think about therapeutics."[140]

Materials

Bolt Threads

Bolt Threads, a company developing genetically engineered silk for the textile market, was founded in 2009 by three graduate students—two from UCSF and one from UC Berkeley. Their research spun out of then-UCSF professor Chris Voigt's synthetic biology laboratory. Bolt Threads has developed proteins inspired by the natural silks made by spiders, creating new technology and a large-scale production process to spin the engineered silk proteins into fibers with remarkable properties, including high tensile strength, elasticity, durability, and softness. For several years, Bolt was resident in QB3's Garage@UCSF, and QB3's affiliated venture fund invested in Bolt's Series A funding. Bolt Threads partnered with LBNL's Advanced Biofuels and Bioproducts Process Development Unit (ABPDU) to investigate the biophysical characteristics of their engineered silk proteins and to refine methods for separating and purifying them, taking advantage of the ABPDU's specialized equipment and flexible process development options.[141] With the closing of a $123 million Series D funding round in January 2018, the total amount of venture funding raised by Bolt reached $213 million, and the company has advanced in the apparel sector, partnering with Patagonia and Stella McCartney, and acquiring Best Made Company, an outdoor apparel and accessories business.[142]

Electronics

Nanosys

Widespread use of electronic devices—from tablets and smartphones to laptops and high definition (HD) televisions—leads to an increased demand for energy to power them. More energy-efficient displays, with uncompromised color accuracy and brightness, are needed. Lawrence Berkeley National Laboratory (LBNL) discovered that spherical nanocrystals only 50 atoms wide, made from a cadmium selenide core inside a cadmium sulfide shell, could be made to emit multiple colors of light, depending on the nanocrystals' size. With further research, LBNL scientists learned to manipulate these nanocrystals, called quantum dots, to emit extremely pure color at nearly 100 percent photo conversion efficiency.

LBNL's quantum dot technology portfolio, a breakthrough in nanoscience, was licensed by startup Nanosys, Inc. for use in electronic displays. Nanosys then partnered with LG Innotek and 3M to develop Quantum Dot Enhancement Film™ (QDEF), introduced in 2011. QDEF, an engineered sheet containing quantum dots, provides a 50 percent wider color spectrum for brighter, more vivid colors in electronic displays at a comparable price and with 20 percent lower power consumption levels than a standard liquid crystal display (LCD).[143]

The Nanosys plant in Milpitas is capable of producing enough quantum dots to build six million big-screen TVs annually. In recent years, the company has developed cadmium-free quantum dots, which have become the platform technology for multiple display architectures, including LCD, OLED, microLED, and emissive QDEL. Quantum dot technology is now in use in consumer products such as Samsung's Q-series QLED TVs and Vizio's P-series Quantum TVs.[144]

Data Storage

Ceph

UC Santa Cruz alumnus Sage Weil turned his PhD thesis into the highly successful data storage system called Ceph. Already a founder of the web hosting company DreamHost when he came to Santa Cruz to study data storage, Weil developed Ceph—an open source software-defined storage system that runs on commodity hardware—with other students at the Baskin School of Engineering. After completing his degree in 2007, he founded the spinoff Inktank Storage as a commercial company to offer paid support for Ceph. In 2014, Inktank was acquired by open source software provider Red Hat for $175 million.[145] Ceph is currently the leading storage system for the OpenStack community.[146]

Radiation Detection

ORTEC

A public-private partnership between LLNL and Tennessee-based ORTEC helped speed critical homeland-security technology to the marketplace. Radscout is a portable radiation detector developed by LLNL's weapons program for emergency first responders and inspection personnel who need to rapidly detect and identify material to determine the nature and scope of a threat. The resulting product, now part of ORTEC's Detective line of radioisotope identification devices that includes the lighter-weight Detective X model released in 2017,[147] is being used to screen for dangerous radioisotopes in luggage or shipping containers. The detector rapidly reports results and is being used at border crossings, cargo ship docks, and transportation terminals.[148]

Moving Forward: Policy Initiatives at the Federal Level

> “Public funding is our lifeblood. It's very open-ended, and gives you the freedom to change course. You can say "we believe X in skin aging is affected by senescent cells" and do the research—which is where the breakthroughs and surprises come from. Though very important, private funding is much more focused, with less latitude for discovery.”
>
> Dr. Judy Campisi
> Faculty, Buck Institute for Research on Aging
> Scientific Co-Founder, Unity Biotechnology

Federal Support for Science

Federal investment in scientific research is critical to US competitiveness. This is particularly the case as other nations such as China are increasing their investment in scientific research. In the FY 2019–2020 and future budgets, it is essential that federal support for science be sustained and, where possible, increased. Consistency of funding flows over time is also important to ensure that scientists can commit their energies and careers to long-term goals, without fear that changes in near-term priorities will strand their research or frustrate its completion.

In particular, investment should be increased in both biomedical research and physical sciences (which are comparatively underfunded), with the goal of sustained increases at key agencies including NSF, DOE (Office of Science), and DARPA. With climate change a growing concern, the Advanced Research Projects Agency–Energy (ARPA-E) budget should also be expanded.

The United States should also embrace funding and policy strategies to assure a continued US lead in key technologies that will be critical to competitiveness and security in the 21st century, particularly advanced materials, synthetic biology, AI, and quantum computing.

The "AI Race"

Other countries have prioritized AI and developed ambitious national plans. In addition to major funding commitments, China has identified 17 key areas as priorities for AI development and has called on Chinese research institutions and technology companies to participate as a national team to achieve technology breakthroughs and make China an AI world leader. Its goal is to build a domestic AI industry worth $150 billion by 2030; since announcing a national AI strategy in 2017, it has recruited leading companies to build open innovation platforms in their respective fields.

In the United States, DARPA has announced plans for a $2 billion investment in a multi-year AI Next initiative to advance AI research. The NSF currently funds $122 million in AI research, but this number is less than needed, falling short of the aggregate value of the most highly ranked proposals it receives. The National AI R&D Strategic Plan (2016) addresses the need for R&D funding but is not linked to budgets. The United States should prioritize AI research, with commensurate funding, emphasizing multidisciplinary approaches that reflect the growing convergence of AI with a wide range of functions and disciplines.

A Unified Strategy for Leadership in Quantum Computing

Quantum computing holds the promise of solving science problems that are far beyond the reach of today's computers, potentially providing breakthroughs in disciplines such as materials, cybersecurity, medicine, synthetic biology, financial services, and artificial intelligence. It is particularly important to national security, as QIS (Quantum Information Science) will enable completely secure communications networks as well as powerful encryption capabilities. The nation that leads this field will have enormous strategic advantage across these and other disciplines. China and the European Union are investing heavily.

Research on quantum computing is still in its early stages and activity is fragmented. With potentially revolutionary applications that will impact both national security and the economy, quantum computing—like AI—merits a focused national strategy. H.R. 6227, the National Quantum Initiative Act, was passed and signed into law in December 2018. It creates a 10-year federal program to centralize investment and put in place a unified strategy to secure US leadership in the field. The Act establishes a National Quantum Coordination Office within the White House Office of Science and Technology Policy to oversee interagency coordination, provide strategic planning support, and conduct outreach to promote commercialization of federal research by the private sector. It also supports QIS standards development, basic research at the Department of Energy, and the establishment of national research centers and academic multidisciplinary research and education centers, and seeks to engage US high-tech companies and quantum startups in the national effort.[149] Implementation of the National Quantum Initiative Act should be prioritized. Recent Department of Energy funding totaling $218 million for 85 research awards in QIS offers an example of how the US can move quickly.

Visa and Immigration Policy

The Bay Area's innovation economy depends heavily on talent and the ability to attract and retain many of the world's best and most creative minds. This includes both domestic talent and talent from overseas.

As one metric, approximately 45 percent of technology startups in the Bay Area have immigrant founders. Many Bay Area technology companies use H-1B visas to augment their workforces where it is difficult to find specific skills domestically. Regulatory tightening of H1-B visa reviews and restrictions on the ability of the spouses of H-1B visa holders to work, however, threaten the region's long-term ability to draw the international talent it needs.

The federal government should reform H-1B policy to ensure that the program is focused on its original purpose—to fill critical skills gaps—and to ensure that American workers are not displaced by lower-cost workers from abroad who lack these critical skills. Any reform should also ensure that H-1B visas are available in the numbers required to meet industry needs and that the complexity of the application process does not deter qualified workers from applying.

Green cards, which offer permanent residence, are often more important than H-1B visas for technology companies looking to secure long-term technical and scientific talent. It is particularly important that the number of available green cards be expanded and wait times reduced. The Immigration Innovation ("I-Squared") bill proposed by Senator Orrin Hatch in 2018 (S.2344) comprehensively addresses both H-1B and green card reform.

US immigration policy should also be modernized to include a special-purpose entrepreneur visa that enables company founders from other countries who wish to start a technology company in the US to remain and grow their businesses here. Other countries that are competing for the same talent have this program and are reaping the benefits, particularly when US barriers discourage entrepreneurs from staying.

Moving Forward: Policy Initiatives in California

As a state, California leads the nation in its scientific capacity and its track record of translating technological advances into companies and products. It is also a place that has led the nation through its forward-looking thinking, setting trends and pioneering models that others ultimately adopt. Looking forward, California's approach to science should be characterized by big thinking: a visionary perspective on the key challenges of our time and a willingness to put resources behind their solution. Goals that are aggressive but may be achievable can capture the imagination and mobilize talent, capital, and public support to achieve great leaps. This calls for new initiatives, but also for continued investment in the state's scientific base and a sharper focus on the role that science plays in advancing its economy.

State Support for Science

Funding for the University of California

In inflation adjusted dollars, the University of California, the crown jewel in the state's innovation system, is receiving approximately half of the state investment that it received in 2000. Although the state has worked to restore cuts from the Great Recession, additional investments are needed in areas such as research, infrastructure, and enrollment growth. Funding for UC should be sustained and where possible increased, to ensure that the university continues to support promising students from across its communities and attract the research faculty that will ensure its long-term leadership. Research funding helps make California a first mover in key technologies and supports its economic competitiveness.

Stem Cell Research

The California Institute for Regenerative Medicine (CIRM) has to date invested $2.6 billion of the $3 billion entrusted to it by the voters of California to fund stem cell research projects. The impact of this investment in more than 1,000 projects, including 49 clinical trials, has been amplified by an additional $3.1 billion in leveraged funding (co-funding, partnerships, and follow-on funding). As reported in Chapter 2, CIRM's investment in the Bay Area alone (as of November 2018) totals $947 million: $800 million to non-profit academic institutions and $147 million to 23 for-profit Bay Area businesses.

Under its research funding plan, CIRM will run out of money to fund new projects by the end of 2019. As most of its current and expected new awards are multi-year projects, that means it will still be funding and managing research through 2022–2023. However, without an injection of new funds, it will not be able to support new projects. A group led by Bob Klein (who was the driving force behind Proposition 71, the original funding initiative) is currently considering a second statewide ballot initiative in 2020 that would, if approved, generate an additional $5 billion for CIRM and stem cell/regenerative medicine research.

Energy/Climate

California has set ambitious goals aimed to address climate change and accelerate the state's transition to a low-carbon economy. Initiatives and policies developed by successive administrations in Sacramento have made California the largest clean energy market in the country; the nation's leading center for clean energy technology research, investment, and deployment; and a global leader on climate policy, as witnessed by the Global Climate Action Summit held in San Francisco in September 2018.

Sustained and expanded state investment in climate and renewable energy research is important if the state's increasingly ambitious goals are to be met—particularly the target of achieving a 30 percent reduction in greenhouse gasses below 1990 levels by 2030, an 80 percent reduction by 2050, and pursuant to Governor Brown's Executive Order B-55-18, overall carbon neutrality by 2045. California should continue its investments by extending and strengthening the California Energy Commission's EPIC (Electric Program Investment Charge) program, which provides over $100 million annually from 2012–2020 for advancing and commercializing clean energy sources and low-carbon solutions. It should also continue to support the Strategic Growth Council's Climate Change Research Program, which funds research for climate adaptation and resiliency along with other areas not funded by existing research programs.

Appoint a California Science and Innovation Adviser

Given the critical role that science and technology play in California's economy and its potential to achieve ambitious goals, the Governor should appoint a Science and Innovation Adviser to support policies and strategies that advance California's technological and economic leadership. The individual appointed should be respected within the science community in both the public and private sectors; be familiar with both research and public policy issues; be able to work with the legislature and coordinate state agencies; and be knowledgeable on federal policy and grantmaking. Candidates for the position should be identified by the Governor in consultation with both university and private sector leaders.

Skills Development and Housing

Investment is also needed in civic infrastructure, to support the region's ability to attract and retain a highly skilled science and technology workforce.

Accelerate 21st Century Skills Development

The state should increase the number of schools and after-school programs that offer training in 21st century skills (e.g., computer science, computational thinking, maker-centered learning, human-centered design). More technology companies should encourage their employees—where possible with paid time off—to mentor teachers and students in these skills and partner with community colleges on technical skills development.

Technology companies are already finding creative ways to invest in K–14 and lifelong learning programs that grow the technical workforce and bring more Californians into the 21st century economy. Oracle's support for the Design Tech High School (d.tech) offers one example. A pioneering California public charter school, d.tech focuses on student learning through a combination of academics, technological skills development, and real-world problem solving using a design thinking approach similar to that taught at Stanford University's Hasso Plattner Institute of Design.[150] In 2018, d.tech moved into a new $43 million building specially created for the school by Oracle on its Redwood Shores campus. The new facility includes a two-story maker space designated as the Design Realization Garage. Special resources available to students include 2-week "intersessions" held four times a year during which the Oracle Education Foundation and other non-profits offer special skill-building courses in areas such as coding, user-centered design, and financial literacy. Outside the regular curriculum, d.tech students will lead summer workshops on design thinking that are open to elementary and middle school students.[151] Oracle's novel support model offers an excellent example of the kind of innovative contributions that motivated technology companies can make to skills development and to the educational foundation on which innovation in the Bay Area and California relies.

Another example is P-TECH (Pathways in Technology Early College High), a national and global extended high school (grades 9–14) public education redesign model linking education with workforce development. The P-TECH partnership combines the expertise of public and private systems and institutions—school districts, community colleges, and industry—with high-level government support. When students graduate, they have earned both their high school diploma and an associate's degree that is directly aligned with industry needs. Since P-TECH's establishment in 2011, the initiative has grown from one school to 110 across eight states, as well as Australia, Morocco, Singapore, and Taiwan, with 550 industry partners. The first cohort to complete the program at P-TECH Brooklyn achieved a graduation rate more than four times higher than the on-time average for community college students. Some graduates are now pursuing bachelor's degrees, while 23 have been hired into full-time positions directly after graduating with their AA degrees,[152] some in "new collar" jobs ranging from associate analyst to digital design developer.[153] Governor Jerry Brown's final budget in 2018 set aside $10 million to launch a P-TECH pilot project in California that will consist of seven schools to start, with applications accepted through the California Community Colleges Chancellor's Office.

Address the Region's Housing Issues

The Bay Area's cost of living is among the highest in the United States. While many factors contribute, the major problem is housing. Over several decades, the region has consistently failed to permit enough new housing to be built to meet the rate of natural population growth and new job creation. Between 2007 and 2017, San Francisco saw the creation of 147,000 new jobs but approved only 29,000 new housing units; in the same period, Silicon Valley saw 200,000 new jobs created but approved only 73,000 units.

Among other impacts, this has the perverse effect of deterring talented individuals—who could be assets to the region—from coming and pushes out others who would like to stay but can't afford to even on a professional income. This includes highly educated individuals who could make critical contributions to science and the economy, including young university faculty and startup founders looking to extend their investment dollars. In order to remain competitive in attracting and retaining students, some Bay Area higher education institutions have resorted to creative new housing development and land reuse projects. For example, UCSF is collaborating with UC Hastings College of the Law on plans to replace the law school's old Snodgrass Hall with a 14-story, 592-unit residential tower that will house students from both schools.[154]

To ensure that the region remains the world's most important pool of creative technology and innovation talent, state and local leaders must urgently address the region's housing challenges.

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Page 39: "Archaea S Layer," created by Gregory Stewart, SLAC National Accelerator Laboratory. The image depicts a tiny pore in the crystaline shell of an ammonia-eating archaea microbe; surrounding proteins are shown in blue. The pore's negative charge attracts ammonium ions from the environment, which interact with an enzyme complex (yellow) to produce all the energy the microbe requires.

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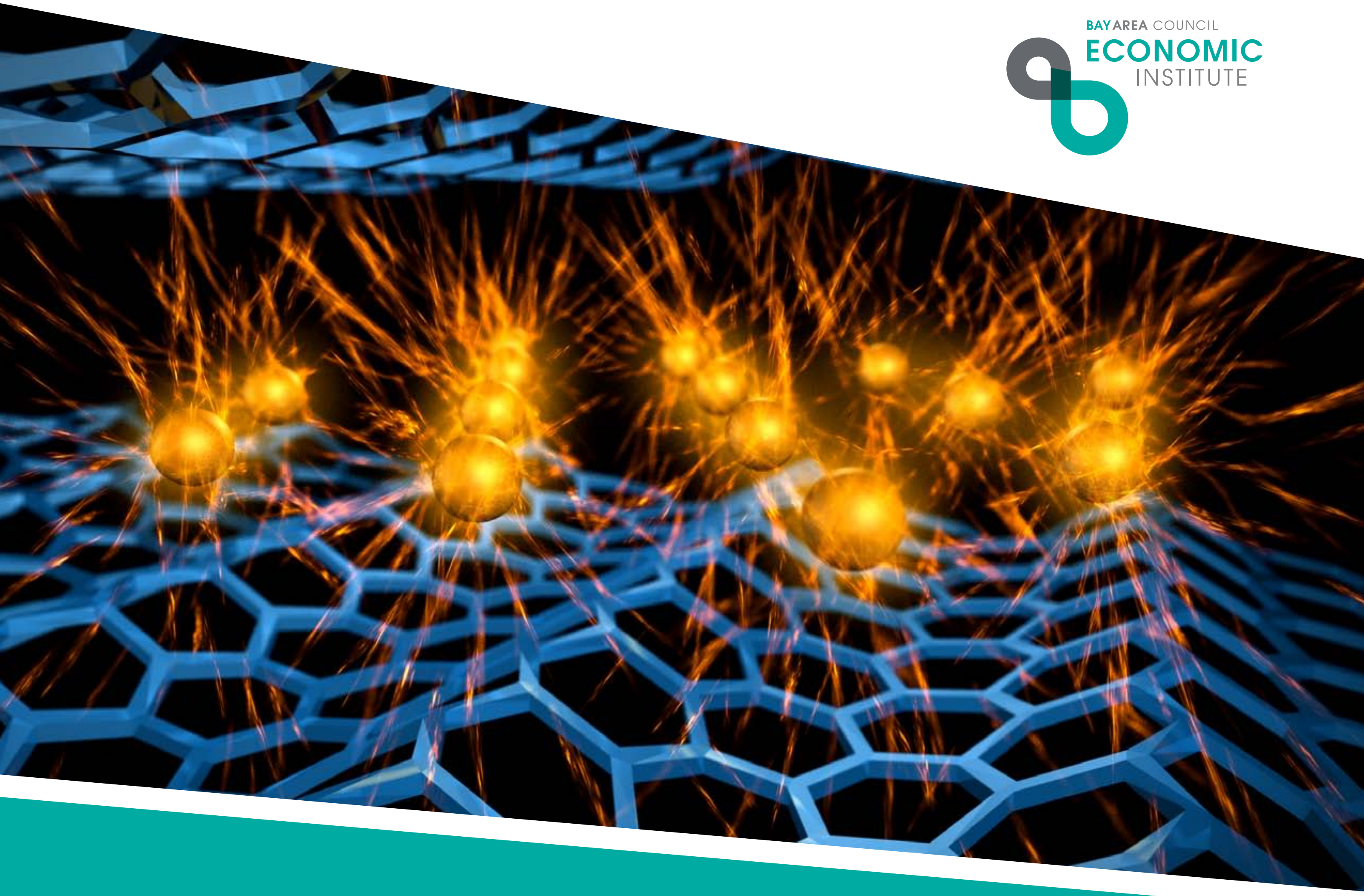

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