

The Origins of Silicon Valley: Why and How It Happened Here


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Past Communications Director,
IEEE SF Bay Area Council

Presented at the Flash Memory Summit
August 11, 2016

or ... *You Are There!*



A step back through
Santa Clara Valley and
SF Bay Area history



Classic Silicon Valley: 1976

1975, MP; Gordon
French garage; O

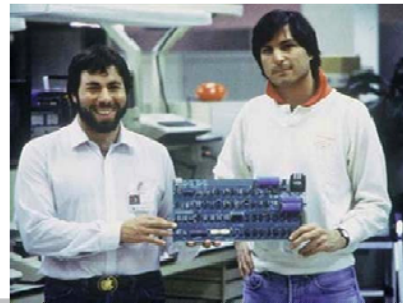
■ Homebrew Computer Club

- Hobbyists meeting in Menlo Park and at SLAC

- Steve Wozniak and Steve Jobs



- The Apple I (to sell to friends)



Classic Silicon Valley: 1976

■ Wozniak-Jobs partnership

- called it “Apple Computer Company”
- Started in a **garage** in Los Altos
- Now has largest stock market capitalization
- Most **valuable brand** in the world

How could this happen?
Why in the SF Bay Area?

Before 1900 ...



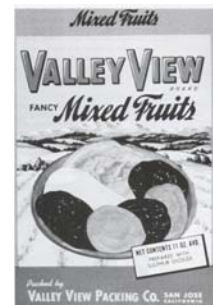
The Santa Clara Mission



"Valley of the Heart's Delight"


Before 1900

This was more typical ...

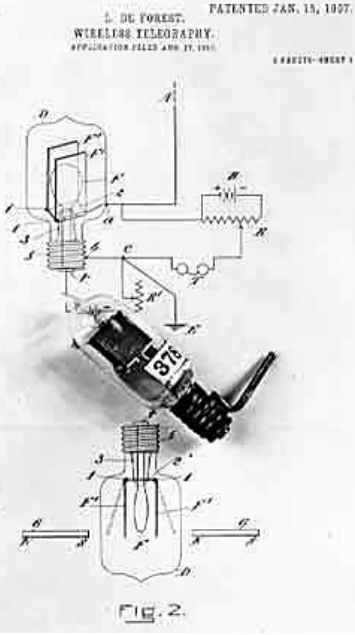
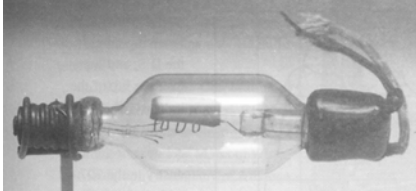


Let's Go Back ...

- **Federal Telegraph**
 - Formed in 1909 in Palo Alto (by Cyril Elwell, a Stanford grad)
 - **Lee de Forest** invented the audion oscillator and amplifier in 1907
 - Pioneered continuous-wave radio





De Forest tube



No. 841,398 L. DE FOREST. WIRELESS TELEGRAPHY. PATENTED JAN. 15, 1907. APPLICATION FILED APR. 17, 1905. 3 PAGES—4827 1

Federal Telegraph

- Paulsen Arc Transmitter, 1909
 - Demonstrated sending CW and voice
- Raised funds from “angel investors”, including David Starr Jordan, Stanford’s president
- Demonstrated communication from S.F. to Honolulu in 1912 →
- **First venture capital**
- **Stanford’s Involvement**



Federal Telegraph

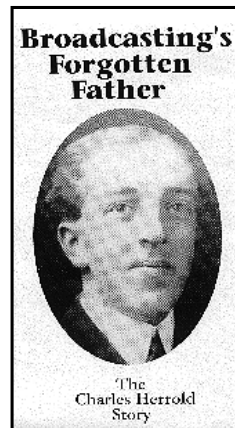
- By 1926, had three high-power stations that covered much of the Pacific Ocean
- In support of maritime shipping companies
- California Historical Plaque in Palo Alto



Let's Go Back ...

■ 1st regular commercial radio broadcast

- Charles “Doc” Herrold
 - Early Stanford EE grad
 - Started a San Jose school near SJSU to teach radio arts (1909)
- First Commercial broadcast, San Jose, 1909
 - voice and music: “San Jose Calling”
- FN, then SJN, then KQW, **becomes KCBS**
 - 740 AM, 106.9 FM (also founded KLIV)



Example: Early Roots of Entrepreneurial Technology

■ Otis Moorhead

- Early Stanford EE grad
- Radio amateur & vacuum tube entrepreneur
- Established **Moorhead Laboratories**
 - In San Francisco in 1917
- Moorhead manufactured “bootleg” receiving tubes for radio sets
- A **patent-infringement lawsuit** put him out of business in the early 1920s.



Testing tubes, 1919

Defining Events

- Independent private **wealth**, from gold rush
- Titanic Sinking in 1912
- World War I
 - Importance of **technology**
- US Navy “push” for ship-to-shore and other communications modes
- **Economics**: desire to replace expensive telegraph lines, undersea cables with the new “wireless” technology
- Brought frenzy of activity, funds to S.F. Bay Area



We Now Follow Three Pioneers

- **William Eitel**
- **Jack McCullough**
- **Charles Litton**

- Bay Area families with a strong history of entrepreneurship
- Born/raised here

William Eitel

- Took shop classes at Los Gatos High School
- Worked in his father's quarry
 - ass't blacksmith, machine operator
- Visited shops of Hall-Scott Motor Car Co.
 - Operation of Complex machinery

William Eitel, W6UF
1908 - 1989

sports cars
aircraft "Liberty engine"



Bill Eitel in 1941 (Photo courtesy of Dave Atkins, W6VX)

Jack McCullough, Charles Litton

- Attended **California School of Mechanical Arts**
Now Lick-Wilmerding High School, San Francisco (private)
- Opened in 1895; free education for boys, girls
- One of the best West Coast **technical high schools**
 - Rigorous training in the mechanical trades
 - Gained "a realistic 'feel' of materials and processes" [Litton]

Jack McCullough, W6CHE
1908 - 1989



Jack McCullough, Charles Litton

- **McCullough** continued at a local junior college
- **Litton** enrolled in Stanford's Mechanical Engineering dept:
 - Small department (3 instructors)
 - Classes with strong practical flavor
 - Got BS-Mechanical Engineering in 1924
 - Grad work in communication engineering
 - Took Stanford's first course on communication engineering fundamentals

Eitel, Litton, and McCullough

- Introduced to **amateur “ham” radio** through their families and friends in 1910’s, ’20’s
 - Became acquainted with the technology of power tubes through activities in ham radio
- **Ham Radio in SF Bay Area**
 - Isolated; maritime orientation; major seaport
 - Several military bases; US Navy presence
 - Shipping companies needed radio operators
 - Over 1,200 licensed amateurs
 - **10 percent** of US total (a **bubble**)

Ham Radio in SF Bay Area

- Active center of radio mfg in the 1910s, ’20s
- Electronics firms:
 - **Remler** - made radio sets
 - **Magnavox** - leading manufacturer of loudspeakers
 - **Heintz and Kaufman**
 - Designed custom radio equipment
 - **Federal Telegraph**
 - Produced radio transmitters in the 1910s; up to 1,000,000 watts in 1919.
- Radio parts available to **local hobbyists**
- Jobs for radio amateurs

Ham Radio Subculture

- **Camaraderie** and intense sociability
 - A way to make friends
 - Communicating "over the air" and face to face
- **Egalitarianism** and a democratic ideology
 - little heed to **distinctions of class**, education
 - Santa Clara County radio club, which Eitel chaired in the mid 1920s, had "**farm boys, Stanford students, Federal Telegraph technicians, and retired executives**"

Ham Radio Subculture

- Representatives of the citizenry
 - In contrast to large companies, monopolies
- Interest in extending radio technology
 - Built personal reputations:
innovating new circuitry; devising clever transmitters; contacts with faraway lands
- Mix of competitiveness and collaboration

**A lot like Home Brew Computer Club,
and today's Silicon Valley ...**

Following our Entrepreneurs ...

- Eitel, Litton, McCullough, ham friends
 - Learned about **vacuum tubes**
 - Built their own parts, equipment
- Made notable contributions
 - 1924: Litton and Stanford radio club made **first radio contact** with Australia, New Zealand
 - 1928: Eitel pioneered **10-meter waves** (30 MHz)
 - transcontinental communication

The Tube Business

- General Electric, Westinghouse, AT&T
 - All East Coast companies
 - Developed hi-power transmitting tubes in early 1920s
 - Difficulties in producing consistent, reliable ones
 - Required precise machining, glass blowing (Pyrex)
 - Exotic materials, sophisticated sealing techniques

Following our Entrepreneurs ...

- **Litton** got local job through a ham friend:

- Research at **Federal Telegraph**
- Built up to 60 engineers
- Became sole supplier of radios to IT&T



- **Eitel** got local job through ham friend:

- Mechanic at **Heintz and Kaufman Inc**
 - Heintz was a ham
 - focus on HF radio equipment
- Recruited **McCullough** a year later

Federal Telegraph,
at Perham home,
916 Emerson St,
Palo Alto, 1912

The Tube Business in the '20s

- Could not buy transmitting tubes on open market
 - Navy and GE set up **RCA** to ensure US dominance
 - Took over non-US companies: Telefunken, Marconi ...
 - RCA, GE, Western Electric, and Westinghouse
 - **Exclusive cross-licensing** of 2000 radio patents
 - Sole producers/distributors of power-grid tubes
 - Refused sale to Bay Area firms
 - Threats to RCA's domination
- So both companies developed triodes
 - Litton, Eitel headed their tube shops

Tube Shops' Challenge

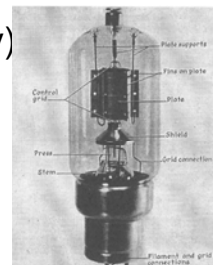
- Design around ~250 RCA patents
 - Enormously difficult task

- Hired locally (many were hams)
 - Eitel, Litton **collaborated** with each other *(novel!)*
 - Based on friendships over the years

- Worked closely with **patent attorneys**

Tube Shops' Challenges

- Heintz, Eitel, and McCullough engineered a rugged **new** power tube:
 - New materials, manufacturing methods
 - Tube's plates of tantalum (avoid patents)
 - New shock-resistant seals
 - Create high vacuums (better reliability)
- More reliable, longer life than RCA's tubes
- **Didn't infringe RCA's patents**



Heintz and Kauffman
354 Power Triode Tube

The US Depression

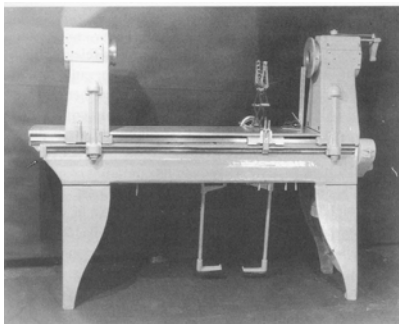
- Formed Eitel-McCullough Inc (Eimac)
 - To build high-power, high-frequency tubes
- Financing:
 - Harrison: real-estate agent in San Bruno
 - Preddey: ran movie theaters in San Francisco
 - Eitel and McCullough brought their know-how
 - Ownership, profits to be shared



Precursor to today's Menlo Park Venture-Capital Firms

Tube Shops' Challenge

- Litton **invented** the glass lathe
 - For assembly, glass blowing, and sealing
 - Make complex tubes in large quantities
 - Allowed high repeatability, precision
- Built tube shop on **parents' property**



The US Depression

- Litton, Eitel, McCullough **cooperated** closely
 - Litton helped set up Eimac vacuum tube shop
 - Gave castings, engineering blueprints for lathe
 - **Freely exchanged** technical, commercial information
 - Reduced risks, for the two small tube-related businesses

Like Jobs & Wozniak, Homebrew Computer Club

The US Depression

- 1936: **Frederick Terman*** asked Litton to join Stanford EE department as lecturer
 - Shared knowledge with staff, students
 - Sperry \$1000 Litton klystron grant: let Terman bring **Packard** to campus for grad studies
 - with Litton, Hewlett, others
- Formed Hewlett-Packard



Demonstrates University/Industry cooperation

* Built his first radio receiver at 13; 6XH with HH Jr; turned this hobby into a career.

Threats to Peace

- Growing threats from Japan and Germany
 - President Roosevelt rebuilt the Army, Navy
 - New electronic system: **radio detection and ranging (radar)**

- Needed high-voltage high-frequency transmitting tubes
 - Only Eimac’s best tubes worked at the high voltages and frequencies needed

The Klystron

- Russell and Sigurd Varian
- They worried about Germany
 - Hoped to use microwaves to detect planes
 - 1937: Moved to Stanford’s labs to work with Hansen
 - developed the **klystron** in 1937
 - Used Litton’s free **advice**
 - Used Hansen’s theoretical assistance





The Klystron

- Sperry (NY) invested, got exclusive rights
 - Bought lathes, welders, pumps from Litton
- Litton made klystrons for IT&T, for France
 - Needed for war effort, French radar
 - Transformed klystron from lab to production
 - Litton became IT&T's de facto VHF and microwave design arm
 - Continuous-wave klystrons, VHF/radar triodes

SF Bay Area/Stanford was microwave hotbed

Wartime Expansion

- Progressive Approach to business
 - Egalitarian relations among engineers, between companies

- Managerial techniques to thwart unions, keep employees happy, productive
 - **Profit-sharing**, cafeteria, medical clinics

Similar to Hewlett-Packard, Fairchild, Intel, Tandem ...

Post-War Realignment

- RCA, others focused on TV, broadcast (NBC)

- Eimac developed new line of better tubes
 - Power tetrodes for high frequencies

- FCC’s surprise shift of **FM radio** to VHF (88-108 MHz)
 - RCA, others’ tubes **wouldn’t work** at VHF
 - RCA **copied** Eimac’s tubes, which **did** work

Reversal of Fortunes

- In 1947, Eimac sued RCA and GE
 - alleging patent **infringement**
 - GE, RCA lost lawsuit, halted production
 - Eimac transformed them into its own sales force and distribution network
 - Let them buy Eimac products and resell them under their own names

The “Big Dog” was now Silicon Valley!

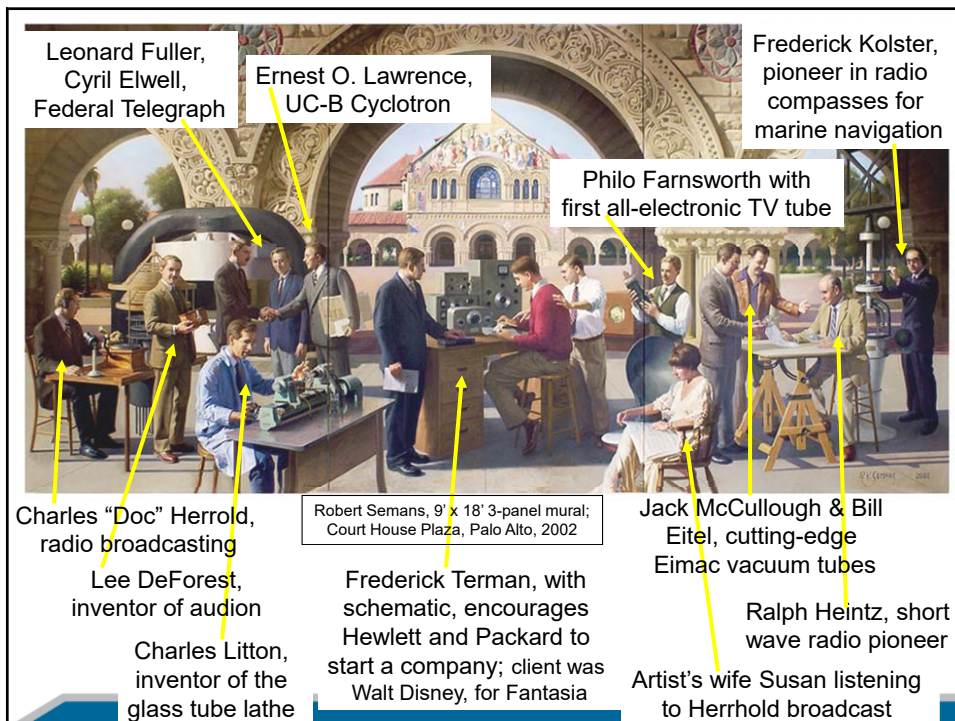
Charles Litton After the War

- Focus on higher-power klystrons
 - For physics research, linear accelerators
 - Scaled from 30 **kilowatts** to 30 **megawatts**
 - Transformed Stanford into a major player
 - 2-mile-long linear accelerator: physics research
 - Developed “**Recipe**” to build a firm:
little initial capital; R&D contracts or a new idea;
engineering teams and a product line;
move to production

Varian Associates

- 1948: Sold microwave measurement instrument plans to H-P for \$20,000
- Enabled Hewlett-Packard to enlarge its product line, increase revenues in 1950s
- Santa Clara division became Agilent (largest IPO in history), now Keysight

David Packard and Bill Hewlett





Fast Forward to 1950's

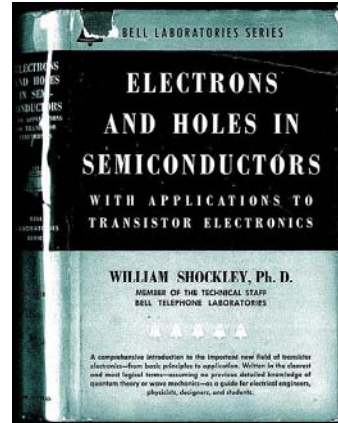
- William Shockley invented transistor while at Bell Labs
Raised in Palo Alto; CalTech, MIT
- Point-contact Germanium device
- Developed to replace vacuum tubes

William Shockley (seated), John Bardeen, and Walter Brattain, 1948.

The photograph shows three men in white shirts and ties working on a piece of electronic equipment. One man is seated and looking at the equipment, while the other two stand behind him, one pointing at the equipment. The equipment is a complex of wires and components.

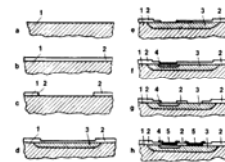
Fast Forward to 1950's

- William Shockley left the East Coast, returned to CalTech
 - His mother, graduate of Stanford, lived here
 - Funded by Beckman
 - 1955: Shockley Semiconductor in Mt View
 - “Traitorous 8” left him in 1957 to **form** Fairchild, with first real venture capital funding (Sherman Fairchild)



The Planar Process

- Developed by Dr. Jean Hoerni at Fairchild Semiconductor in 1959
- Required a special infrastructure:
 - **High-vacuum** technology;
 - **precise** furnaces
 - **Glass/quartz capability** and machinists
 - Ultra-pure gasses/water
- **Process control**;
continuous improvement



Built on top of all of the capabilities developed here during the '20's, 30's, '40's

At the end ... (1960's)

- Situation had changed dramatically
- Peninsula was a major electronics center
- The main center for development and production of tubes, semiconductors, ICs
 - Half of the microwave tubes
 - In every advanced weapons, space system
 - In a wide range of industrial goods (broadcast, TV, microwave ovens)
- SV was central to the US defense effort and to the US manufacturing economy

Why?

Silicon Valley Business Climate

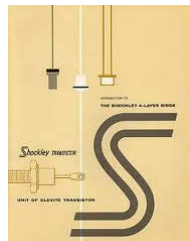
- **East's** large, vertically integrated firms
 - Focus on protecting current products
 - Slow to adjust to technology, market changes
- **SV:** highly fragmented, **decentralized** structure
 - **Specialized** firms, nimble/flexible, **engineering-driven**
 - Dense regional **network** of small & medium-size firms that support each other; draw from common work force
 - **California** (since 1870s) doesn't enforce employment contracts
 - Adapt **more rapidly** to change
 - Thrived in the new environment

Silicon Valley Uniqueness

▣ Practices, skills, and competencies:

- Developed over 100+ years
- Communities of hobbyists; collaboration
- Analog → digital → SW → biotech → mobile
→ Big Data → Deep Learning → VR
- Large number of cutting-edge entrepreneurs
- Engineers and venture capitalists
- Local universities, research, development
- Supporting industries
- Role models, expectations
- **Special Culture of Innovation**

The '40's and '50's



AMPEX



FAIRCHILD
SEMICONDUCTOR

SPACE SYSTEMS
LORAL







Major companies moving here ...

Logos displayed include: OPERA software, SAMSUNG, IBM Research Accelerated Discovery Lab, Microsoft Research, Volkswagen, ALJAZEERA AMERICA, at&t, TOYOTA, BMW, Walmart, NIKE JUST DO IT, and the United States Patent and Trademark Office seal.

Streaming Media and Biotech ...

Logos displayed include: MatchStick, Roku, GeneWEAVE, Calico, Transcryptic, chrome Chromecast, METABIOTA, BAYBIO, abbvie, Genome Compiler, syapse, CAMBRIAN GENOMICS, Maverix BIOMICS, Zephyrus Biosciences, BUCK INSTITUTE FOR RESEARCH ON AGING, One Codex, DNAnexus, Counsyl, and Perlestein Lab.

Stanford alumni and faculty created 39,900+ companies between the 1930s and 2011

“Stanford University's Economic Impact via Innovation
and Entrepreneurship”, published in 2011:

- a large-scale, systematic survey of Stanford alumni and faculty
- by Charles Eesley, Stanford School of Engineering, and
William F. Miller, Stanford Graduate School of Business
- created **5.4 million jobs** since the 1930's
- **\$3 trillion in economic impact** each year
- 39,900+ companies (18,000 in CA), plus 30,000 non-profits
- not just in Silicon Valley and California but **across the globe**
- Tesla Motors, Charles Schwab, Gap, Nike, Netflix, Trader Joe's...
- **39% of all alumni founding firms located within 60 miles of Stanford**
- if an independent nation, would constitute the world's 10th largest economy



Where is “Silicon Valley”?



"A map of **Silicon Valley** in 2013, which originally just included the Santa Clara Valley from Gilroy to Palo Alto. Today it is a **metaphysical space** stretching from San Jose to San Francisco and Berkeley."


A History of Silicon Valley, p. 264




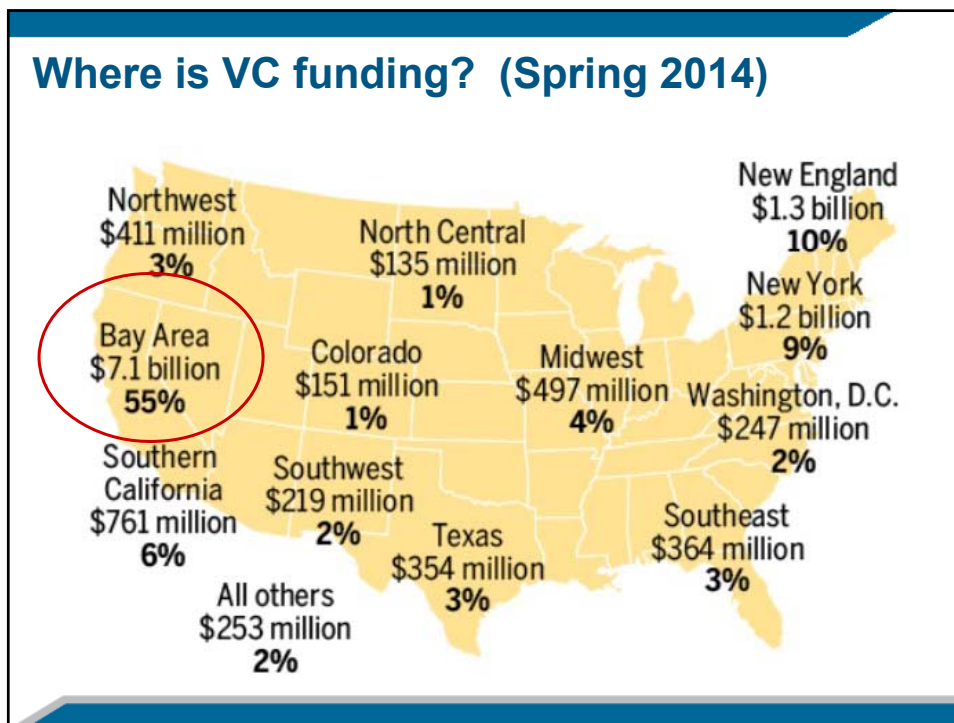
Other Technology Centers

- ▣ Silicon Roundabout (London)
- ▣ Silicon Forest (Oregon)
- ▣ Silicon Allee (Berlin)
- ▣ Silicon Cape (S. Africa)
- ▣ Silicon Alley (New York City)
- ▣ Silicon Prairie (Omaha; DFW)
- ▣ Silicon Valley-India (Bangalore)
- ▣ Silicon Valley-Taiwan (Hsinchu)
- ▣ Silicon Oasis (Dubai)
- ▣ Silicon Wadi (Israel)
- ▣ Silicon Hills (Austin)







Where is Innovation Today?

- Hackathons
- TechShop
- Maker Faire
- Incubators →
- Open Source software projects
 - Egalitarian use of jointly-developed software
- Android, iOS Apps

... and dozens of other collaborative spaces

Like Ham Radio, Homebrew Computer Club



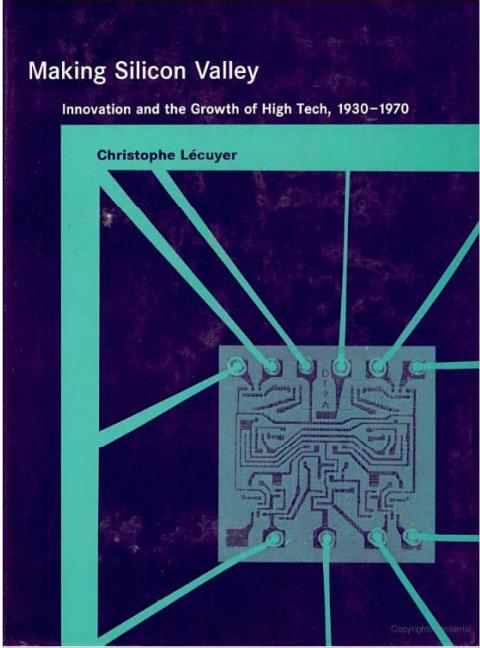
The slide features several logos: '500 Startups' in a box, 'TECH CRUNCH DISRUPT SF' in green, 'Y Combinator' with two orange 'Y' icons and 'Research' in a box, 'Regus' with a crown icon, and 'Google VENTURES' in blue.

How Different are We?

- “In Silicon Valley, great ‘collaborators’ are prized; in Washington, DC, they are hanged. When they say ‘collaborator’, they mean ‘traitor’; here [SV], they mean ‘colleague’.”
Thomas Friedman, NY Times, Jan 13, 2013
- It’s our **attitude** in Silicon Valley:
“**Failure** is a **feature**, not a bug.” 100:1 (in SV: 100:5)

Get the book!

Learn MUCH
more about
those early
days ...

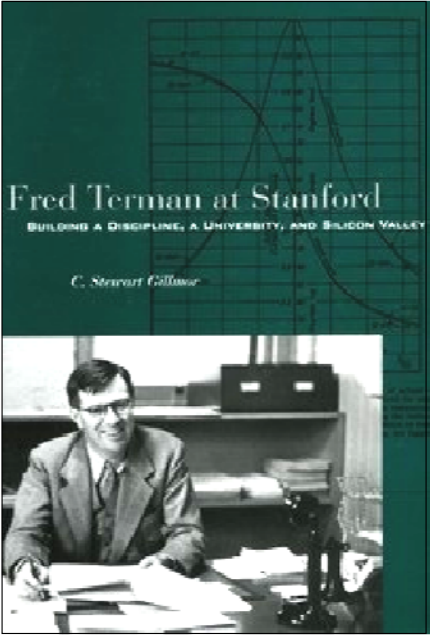


Making Silicon Valley
Innovation and the Growth of High Tech, 1930-1970
Christophe Lécuyer

***More about that
period ...***

**Fred Terman at
Stanford:** Building
a Discipline,
a University,
and Silicon Valley
by Stewart Gillmor

2004,
ISBN 978-0804749145

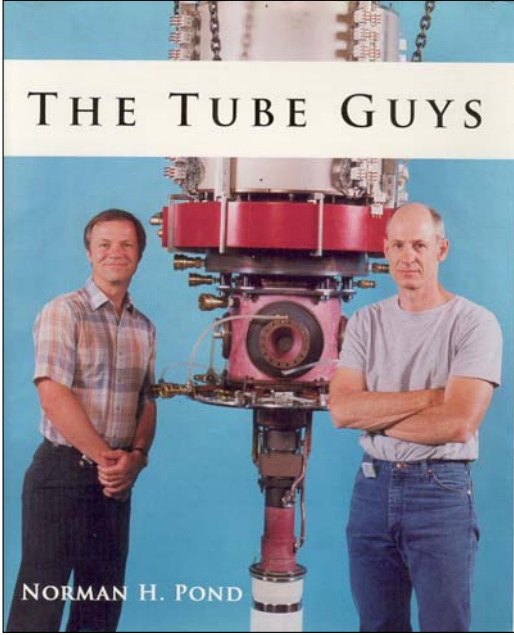


Fred Terman at Stanford
BUILDING A DISCIPLINE, A UNIVERSITY, AND SILICON VALLEY
C. Stewart Gillmor

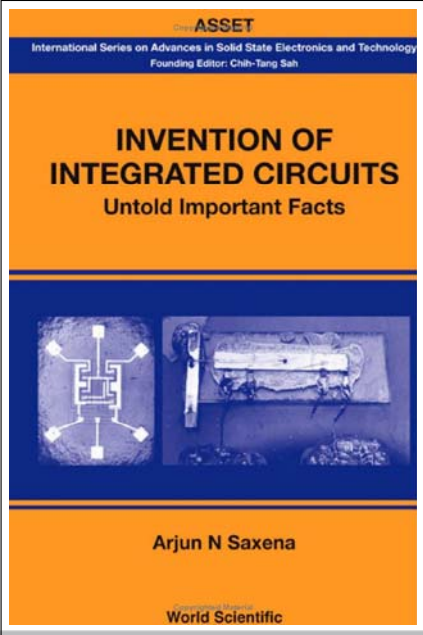
Another fun book

Norm Pond was president of Varian Associates (*Sigurd and Russell's company*), then formed Intevac and is CEO

2008,
ISBN 978-0-9816923-0-2
www.russcochran.com



To explore the invention of the integrated circuit:

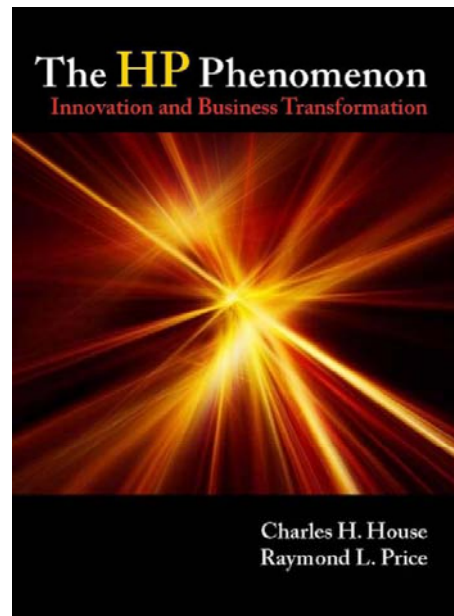


INVENTION OF INTEGRATED CIRCUITS
Untold Important Facts

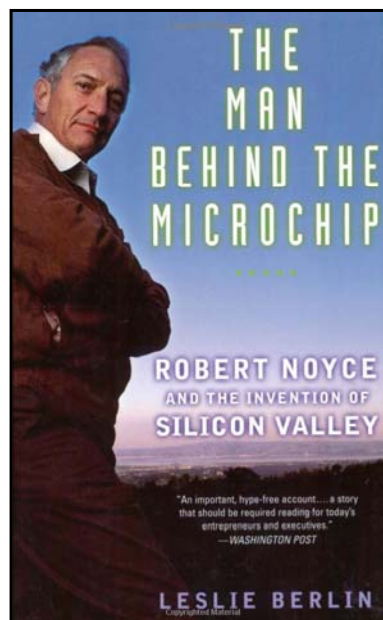
Arjun N Saxena

World Scientific

To understand how H-P
was a product of
Silicon Valley, and
shaped its culture
through a number of
re-inventions
(1930s, up
through 2009)



I also recommend
Leslie Berlin's
recent book on
Bob Noyce



For another view of Silicon Valley



Steve Jobs by Walter Isaacson



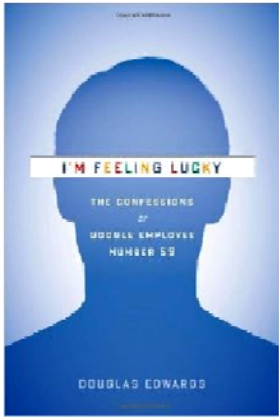
STEVE JOBS: THE BIOGRAPHY
AN EXCLUSIVE EXCERPT FROM WALTER ISAACSON'S NEW BOOK PAGE 96
FORTUNE

43 UNDER 40
THE HOTTEST
YOUNG STARS
IN BUSINESS
FROM 2015

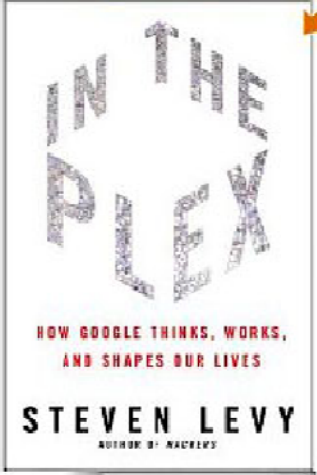


© Albert Watson

For a view of another Innovation Environment



I'M FEELING LUCKY
THE CONFESSIONS
OF
GOOGLE EMPLOYEE
NUMBER 53
DOUGLAS EDWARDS



IN THE PLEX
HOW GOOGLE THINKS, WORKS,
AND SHAPES OUR LIVES
STEVEN LEVY
AUTHOR OF HACKERS

On Netflix Streaming:
2011 video, 85 minutes
(SXSW Best Documentary)
Covers funding and startup of Apple, Intel, Genentech, Tandem, Cisco, with views from the key funders (Rock, Perkins ...) and entrepreneurs (Moore, Treybig ...)



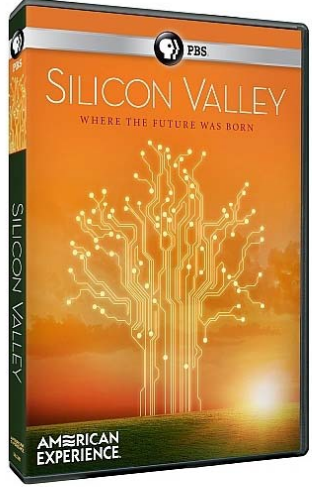
WRITING THE CHECK IS THE EASY PART

OFFICIAL SELECTION SAN FRANCISCO INTERNATIONAL FILM FESTIVAL
OFFICIAL SELECTION SEATTLE INTERNATIONAL FILM FESTIVAL
BEST DOCUMENTARY SANTA CRUZ FILM FESTIVAL
BEST DOCUMENTARY 2011

SOMETHING VENTURED
RISK, REWARD, AND THE ORIGINAL VENTURE CAPITALISTS

MIRALAN PRODUCTIONS PRESENTS CELLESCHUBINE PRODUCTIONS
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EDITED BY LARISA KOSTYUKOVA
COSTUME DESIGNER: PAUL HILLIARD
PRODUCTION DESIGNER: PAUL HILLIARD
EXECUTIVE PRODUCERS: DAN KELLER, CELESTE SCHAEFER-SCHYTER
PRODUCED BY DAN KELLER, DAN KELLER, CELESTE SCHAEFER-SCHYTER
DIRECTED BY DAN KELLER, DAN KELLER, CELESTE SCHAEFER-SCHYTER
WWW.SOMETHINGVENTURED.COM

On PBS's American Adventure:
“Silicon Valley: Where the Future was Born”
video, 85 minutes, \$20
(Broadcast on Feb. 5, 2013)
Can be streamed online



SILICON VALLEY
WHERE THE FUTURE WAS BORN

AMERICAN EXPERIENCE

“The creativity of the founders of Fairchild Semiconductor, including physicist Robert Noyce, helps transform Santa Clara County into Silicon Valley the story of the pioneering scientists.”

Reviewing the Good Ol' Days
... to understand how
Silicon Valley became the
hub of technology development
... *and STILL is* ...

Download the slides (3 MB)
and suggestions for further reading at:
learn.e-grid.net/docs/1608-wesling.pdf

p.wesling@ieee.org