

# Characteristics of Successful Tech Hubs and Start-ups: Lessons from the Origin and Growth of Silicon Valley

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IEEE SF Bay Area Council**

**UC-Davis School of Engineering,  
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**Paul Wesling** received degrees in electrical engineering and materials science from Stanford University. He then worked locally at companies including Lenkurt Electric, Sperry-Univac, Datapoint Peripheral Products, and Amdahl, joining Tandem Computers in Cupertino in 1985. Paul retired from HP in 2001, then served as “Mr. IEEE” for the San Francisco Bay Area for 10 years. He is a Life Fellow of the IEEE.



As vice president of publications for the IEEE Electronics Packaging Society for 22 years, he supervised four archival journals and a newsletter. He received the IEEE’s Centennial Medal, the Board’s Distinguished Service award, the Society Contribution Award, and the IEEE’s Third Millennium Medal. An Eagle Scout, he served as scoutmaster of his local Boy Scout Troop for 15 years (with the call sign **K6BSA**), was Advisor of a High-Adventure Crew, and enjoys backpacking, fly fishing, guitar and amateur radio (call sign: **KM6LH**).

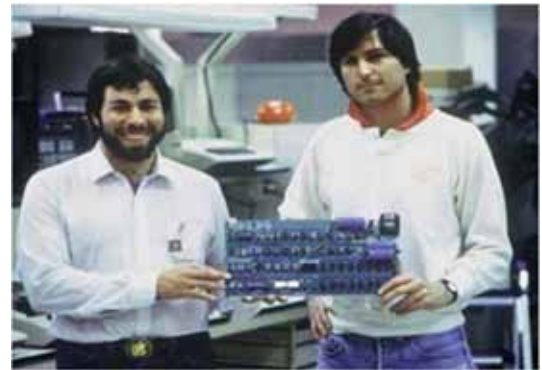
## Classic Silicon Valley: 1976

### Homebrew Computer Club

- Hobbyists meeting in Menlo Park and at SLAC



- Steve Wozniak 6502 (US\$20) and Steve Jobs
- The Apple I (to sell to friends) sold HP-65, VW Van



Neighbors; introduced by a friend

## 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?

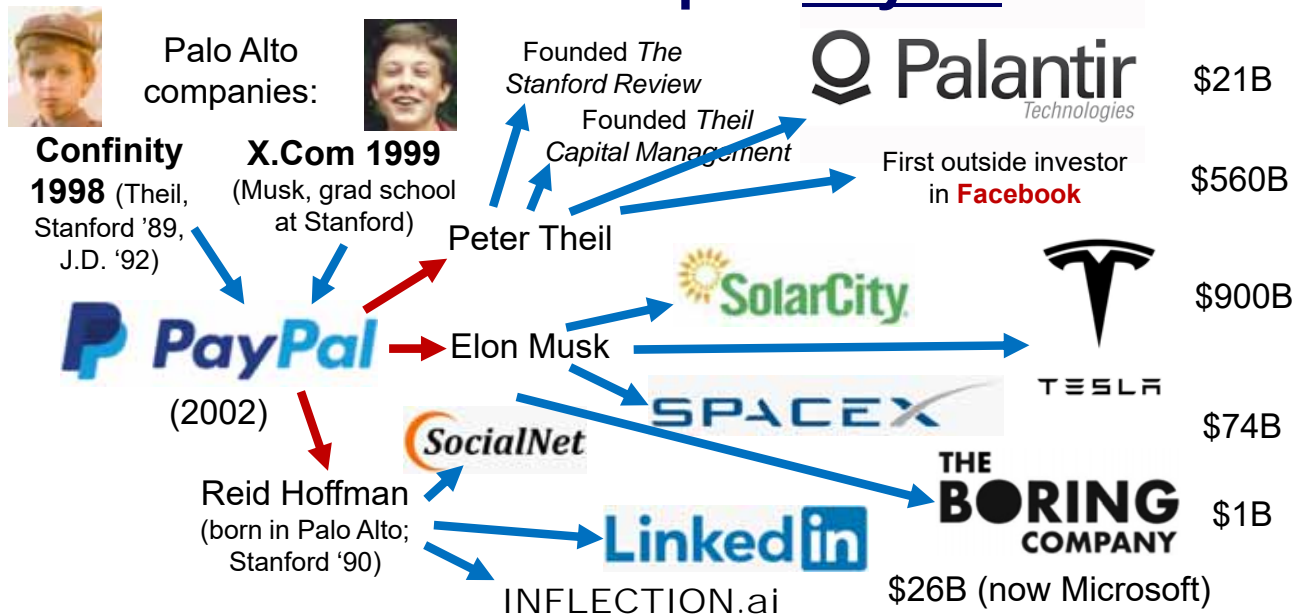


## A more recent example: PayPal

- Immigrants (Ukraine, Canada/So. Africa, Germany)
  - Started on the second floor of a Palo Alto bakery
  - Some were students/grads of Stanford
  - Names like Thiel, Musk, Levchin, Hoffman ...
  - Known now as the "PayPal Mafia"



## A more recent example: PayPal



## Characteristics we will discuss:

- Competition *and* cooperation
- Often hobby-focused
- Small, dynamic companies
- Favorable California legal framework
- Great universities willing to engage
- Large pools of entrepreneurs, technologists
- . . . . .

*Let's dig in!*

## Before 1900 ...



The Santa  
Clara Mission

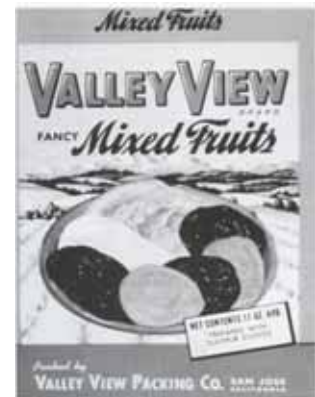
"Valley of the  
Heart's Delight"





## Before 1900

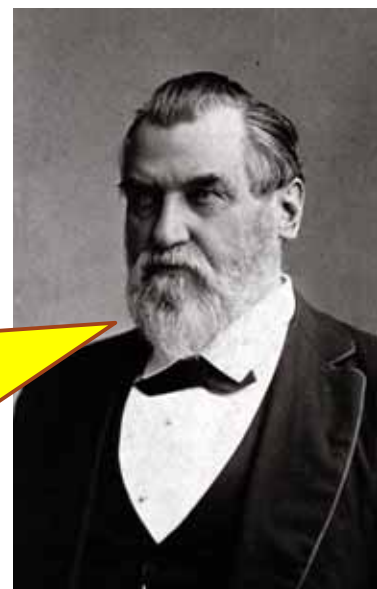
This was more  
typical ...



## Late 1880's Prediction

"Some day you will see Palo Alto blooming with nearly all the flowers of the earth and the fruit and shade trees of every zone.... In the future we shall can this fruit and send it all over the globe in exchange for wealth ..."

... but soon *technology* was to overtake agriculture.



Senator Leland Stanford

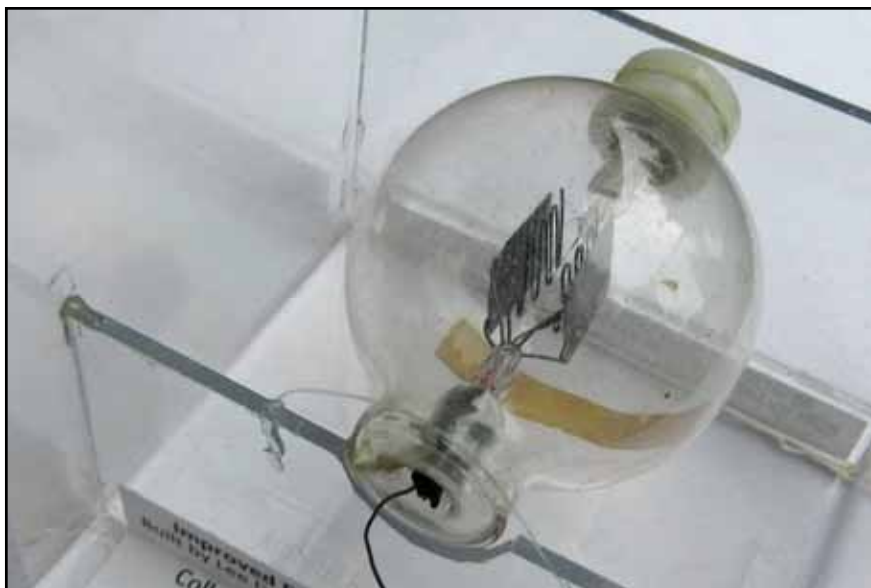
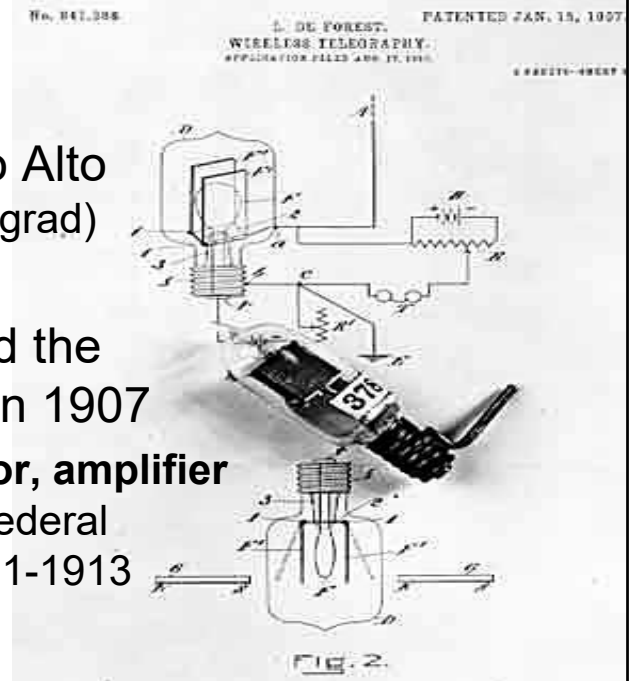
## Let's Go Back ...

### ■ Federal Telegraph

- Formed in 1909 in Palo Alto (by Cyril Elwell, a Stanford grad)
- **Lee de Forest** invented the audion (vacuum tube) in 1907
- Invented/patented **oscillator, amplifier circuits** while working at Federal Telegraph in Palo Alto, 1911-1913

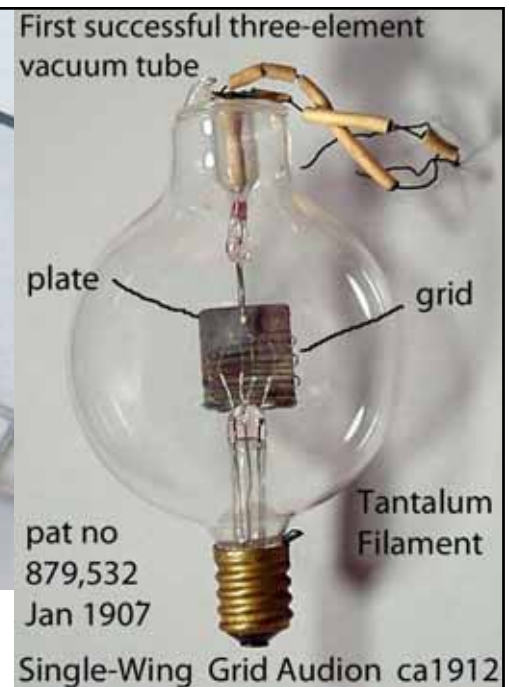


Improved triode



### Improved Dual-Wing Grid Audion ca1912

Built by Lee De Forest at Federal Telegraph, Palo Alto  
Collection of Leonard Fuller, Chief Engineer,  
Federal Telegraph (1912-1919)  
Property of Clark Canham, San Jose

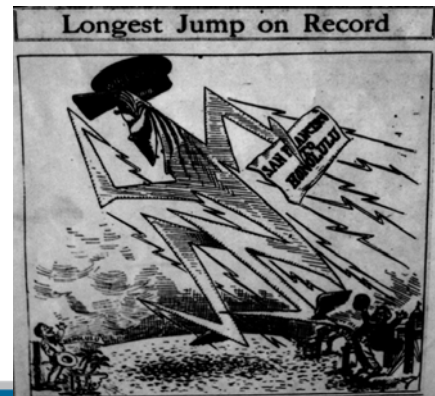


## Federal Telegraph

- Poulsen Arc Transmitter, 1909
- Raised funds from "angel investors", including David Starr Jordan, Stanford's president (plus Marx, Branner)
- Demonstrated communication from S.F. to Honolulu in 1912



- **First "venture capital"**
- **Stanford's Involvement**



## Federal Telegraph

- By 1920s: three high-power stations that covered much of Pacific Ocean
- In support of maritime shipping companies
- California Historical Plaque in Palo Alto



## Example: Early Roots of Entrepreneurial Technology

### ■ Otis Moorhead

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



Testing tubes, 1919

## Defining Events

- Independent private **wealth**, from California gold rush
- Titanic Sinking in 1912
- World War I
  - Importance of **technology**
- US Navy “push” for ship-to-shore, 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
- Born/raised here



Charles Litton, 11,  
Outside his  
"Wireless House"

## William Eitel

- Took shop classes at Los Gatos High School
- Worked in his father's quarry
  - assisted as a blacksmith, machine operator
- Summer at Hall-Scott Motor Car Co.
  - Operation of Complex machinery

**William Eitel, W6UF**  
**1908 - 1989**



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

## Jack McCullough, Charles Litton

- Attended **California School of Mechanical Arts**  
James Lick funding -- Now Lick-Wilmerding High School, San Francisco (private)
- Opened in 1895; free education for boys, girls
  - 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:
  - Classes with strong practical flavor
  - Got BS-Mechanical Engineering in 1924
  - 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
- **Ham Radio in the SF Bay Area**
  - Isolated; maritime orientation; major seaport
  - 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 production in the 1910s, ’20s
- Electronics firms:
  - **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-watt transmitters in 1920.
  - Radio parts available to **local hobbyists**
  - Jobs for radio amateurs

## Ham Radio Subculture

- **Camaraderie** and 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

- Interest in extending radio technology
  - Built personal reputations on improvements
  - Mix of **competitiveness** *and* **collaboration**

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



## Another Pioneer: Young Fred Terman

- Los Angeles, then Stanford
- Herbert Hoover rented across the street;  
HH Jr; also Roland Marx, George Branner, Jack Franklin

HH Jr: "All three of us [*Fred, Jack*] were neighbors, and upon pushing the key of one of our imposing contraptions, would holler out the window to see if it had been received on the other side of the street."



Herbert Hoover, Jr, ca 1923

## Young Fred Terman

- "If you saw a 90 foot pole sticking up somewhere, you'd go and knock on the door and get acquainted with him."
- Hung out at Federal Telegraph (a few blocks away), then worked there one summer



Fred Terman at 17, with his Ham radio

## Following our Hobbyists/Entrepreneurs

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

## Following our Hobbyists/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

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

## The Tube Business in the '20s

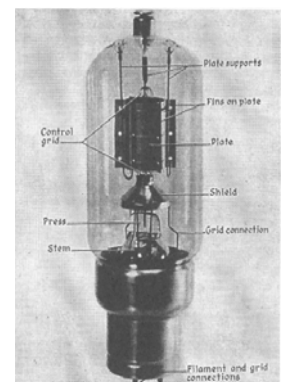
- Could not buy transmitting tubes on open market
  - Navy and GE set up **RCA** to ensure US dominance
  - RCA, GE, Western Electric, and Westinghouse
    - **Exclusive cross-licensing** of 2000 radio patents
  - Sole producers/distributors of power-grid tubes
    - Refused sale to Bay Area firms
    - Seen as threats to RCA, USA control
- So both companies needed to develop triode tubes
  - 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
  - New shock-resistant seals
  - Create higher vacuums (better reliability)
- More reliable, longer life than RCA's tubes
- **Didn't infringe RCA's patents**

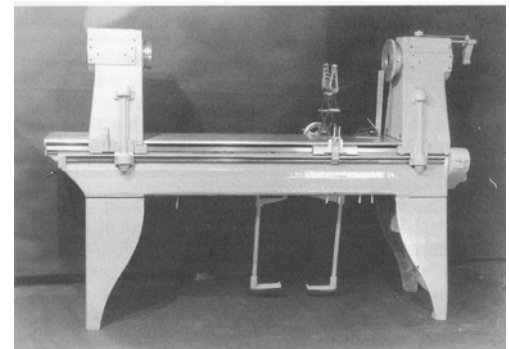


Heintz and Kauffman  
354 Power Triode Tube



## Tube Shops' Challenge

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



## 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 SF
  - Eitel and McCullough brought their know-how
  - Ownership, profits to be shared



**Precursor to today's Menlo Park Venture-Capital Firms**

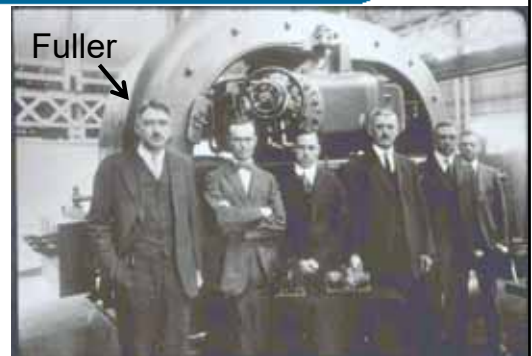
## The US Depression

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

**Like Jobs & Wozniak,  
Homebrew Computer Club**

## The US Depression

- Federal Telegraph in late 1920's
  - Leonard Fuller (Chief Engr) donated several arc transmitters to Stanford, for radio lab
- Federal Telegraph was sold, moved to East Coast
  - Left-over magnets for a 1MW transmitter donated by Fuller to UC-Berkeley, for Lawrence's 42" cyclotron
  - Enabled high-energy physics research, Nobel Prizes (Lawrence, McMillan, Seaborg, Chamberlain, Segrè, Glaser)



## The US Depression

- 1936: **Frederick Terman** asked Litton to join Stanford EE dept as lecturer
  - Shared knowledge with staff, students
  - Sperry \$1,000 Litton klystron grant: let Terman bring **Packard** back to campus for grad studies
  - with Litton, Hewlett, others
- Formed Hewlett-Packard



**Demonstrates University/Industry cooperation**

## Threats to Peace

- Growing threats from Japan and Germany
  - President Roosevelt rebuilt the Army, Navy
  - New electronic system: **RA**dio **D**etection **A**nd **R**anging (radar)
- Needed high-voltage high-frequency transmitting tubes
  - Only Eimac's tubes worked best at the high voltages and frequencies needed



Eimac 50T

## 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

Rus and Sig,  
boys in Palo Alto



## The Klystron – PA Times, Jan. 30, 1939



## Wartime Expansion

- SF Bay Area/Stanford was microwave hotbed
- Developed a Progressive Approach to business
  - Egalitarian relations within, between companies
- Managerial techniques thwarted unions, kept employees happy, productive
  - **Profit-sharing**, tuition, cafeteria, medical clinics
  - “HP Way” philosophy

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

## Post-War Realignment

- RCA, others focused on TV, broadcast (NBC)
- Eimac developed new line of better tubes
  - Designed for higher frequencies (for hobbyists, hams)
- 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!**

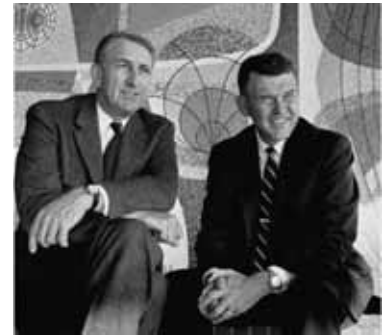
## Charles Litton After the War

- 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; cancer treatment today uses the Litton klystron
  - In 2022: added the 2-mile superconducting particle accelerator (LCLS-II)
    - Liquid helium at 2° K; explore chemical events, quantum phenomena
    - X-rays 10,000X brighter than before



## Varian Associates (another example)

- 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 Rosa, Santa Clara divisions became Agilent (largest IPO in history), now Keysight



HP 200A Audio Oscillator

David Packard  
and Bill Hewlett

Leonard Fuller,  
Cyril Elwell,  
Federal Telegraph

Charles "Doc"  
Herrold, radio  
broadcasting

Ernest O. Lawrence,  
UC-B Cyclotron

Philo Farnsworth with  
first all-electronic TV tube

Lee de Forest,  
inventor of audion  
Charles Litton,  
inventor of the  
glass tube lathe

Frederick Terman, with  
schematic, encourages  
Hewlett and Packard to  
start a company; client was  
Walt Disney, for Fantasia

Jack McCullough & Bill  
Eitel, cutting-edge  
Eimac vacuum tubes  
Ralph Heintz, short  
wave radio pioneer

Robert Semans, 9' x 18' 3-panel mural;  
Court House Plaza, Palo Alto, 2002

## The Mural in Palo Alto



## Fast Forward to 1950's

- William Shockley  
Raised in Palo Alto;  
went to Caltech, MIT
- Invented transistor  
while at Bell Labs
- Developed to replace  
vacuum tubes
- Nobel Prize in 1956



Bill Shockley, 8, in front  
of home in Palo Alto

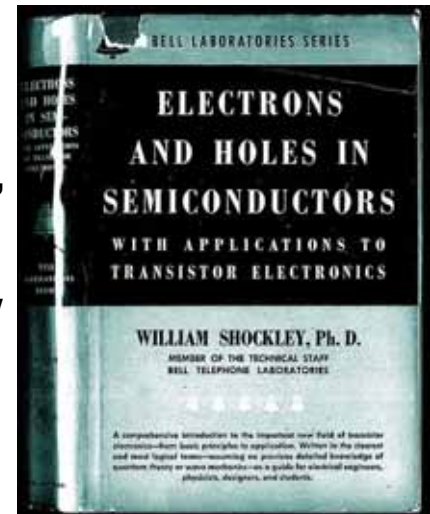


1948: William Shockley (seated),  
John Bardeen, and Walter Brattain



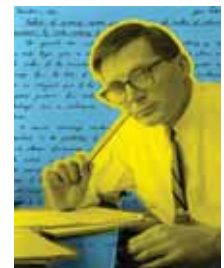
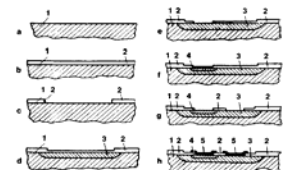
## Fast Forward to 1950's

- William Shockley left the East Coast, returned to Caltech
  - Funding from Arnold Beckman
  - His mother, graduate of Stanford, lived in Palo Alto
  - 1955: Shockley Transistor, Mt View
  - "Traitorous 8" **left** him in 1957 to form **Fairchild**, with first real venture capital funding



## The Planar Process

- Needed, for diffused transistors
- 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**



## The Planar Process

Isaac Asimov said this was

"the most important moment since man  
emerged as a life form"

... perhaps with a bit of exaggeration.



## At the end ... (1960's)

- Situation had changed dramatically
- Peninsula, Valley were major electronics centers
- Dev't, production of tubes, Semiconductors, ICs
  - Half of the microwave tubes
  - In every advanced weapons, space system
  - In a wide range of industrial goods
- SV was central to the US defense effort and to the US manufacturing economy

**Why?**

## Silicon Valley Business Climate

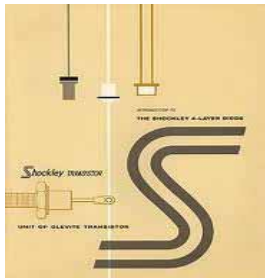
- **East's** large, vertically integrated firms
  - Focus: protecting current products, markets
  - Slow to adjust to technology, market changes
- **SV:** highly fragmented, **decentralized** structure
  - **Specialized** firms, nimble/flexible, **engineering-driven**
  - Dense regional **network** of small & medium-size firms that support each other; draw from common work force
  - **California** (since 1870s) doesn't enforce **non-compete clauses**
    - Only 5 US States have this
  - 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/sharing
  - Analog → digital → SW → biotech → mobile  
→ Big Data → Deep Learning → VR → self-driving ...
  - Large number of cutting-edge entrepreneurs
  - Supported by 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®

**hp** HEWLETT®  
PACKARD



**SPACE SYSTEMS**  
**LORAL**

## The '60's

**AMD**

**National**  
Semiconductor

**intel**®

**memorex™**

**intersil**™

**APPLIED**  
MATERIALS®

**frog** design





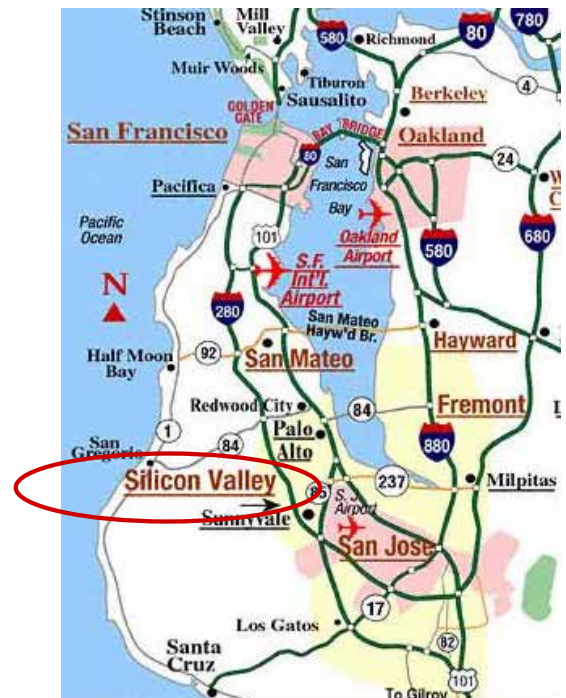




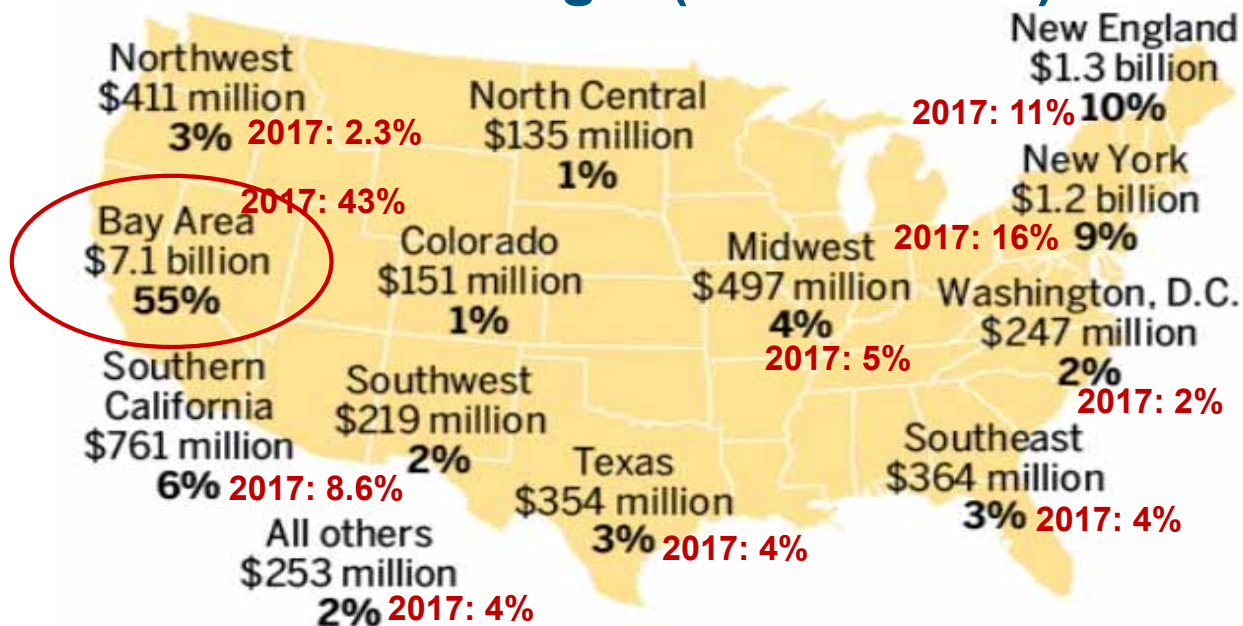
## Where is "Silicon Valley"?

"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



## Where is VC funding? (2014 & 2017)



## How Different is Silicon Valley?

- Grass-roots innovation and initiative; bottom-up approach
- It's our **attitude** in Silicon Valley:  
"Failure is a feature, not a bug."  
"Move Fast, Break Things"
- Yoda: "Do or do not — there is no *try*." full commitment

## Characteristics of SV: Ideas for your Tech Hub

- Competition **and** cooperation (not adversarial)
- Often hobby-focused (for start-ups with friends)
- Small, dynamic companies (work hard, play hard)
  - Avoid vertical integration like the plague
- Fluidity and flexibility (ability to "pivot", fail, recycle)
- Egalitarian: parking, offices, "open door" policy, 20% time, Friday beer busts, employee-focus
- Ready venture capital and stock market

## Characteristics of SV: Ideas for your Tech Hub

- Favorable California legal framework  
*(no enforcement of non-compete clauses)*
- A number of great universities: engage with startups
- Location attractive to educated professionals
- Large pools of entrepreneurs, technologists and opportunities (which attract additional techies)
  - **Network effect** (Metcalfe’s law: Influence  $\propto$  # of users squared)
- Energetic entrepreneurs from previous companies (successful, failed) available for next enterprise
- ... and other cultural, management factors

## ... and a few issues

- Cost of housing in SF Bay Area
  - “High-tech clusters tend to be located in cities with high labor and real estate costs — cities like San Francisco, Boston, or Seattle”
- Not enough educated technologists
- Disruption of existing business models
  - GovTech: accelerating pace, downsizing
- Retraining of displaced workers
- Shared-economy workers (ICs)

## Key Fields for the Rest of the Decade

- **Hardware Platforms**
  - 5G Cellular system, smartphones
  - Vehicular Technology
- **Virtual & Augmented Reality**
- **Deep Learning**
- **Sharing Economy**
- **Artificial/Machine Intelligence**
- **Industrial Analytics**
- **Medical and environmental electronics**

## Is Silicon Valley “over the hill”?

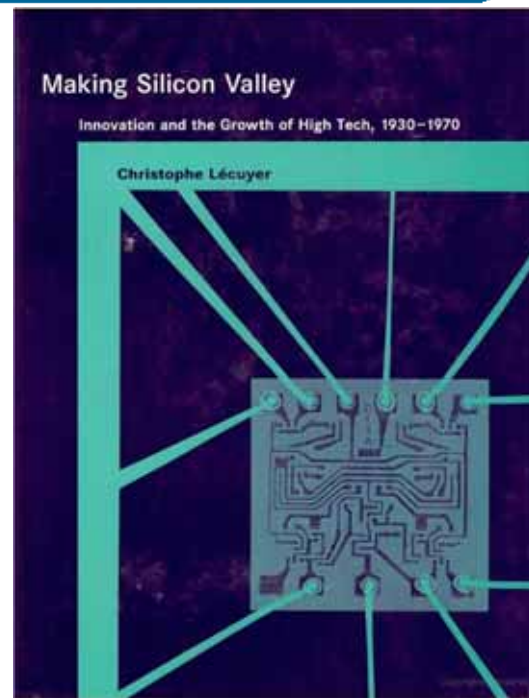
### During the pandemic, did techies leave SV?

- Top Tech Hubs **increased** employment 0.3%
- “Rising star” hubs increased 0.1%
- Increased movement *within* metro areas, rather than *between* metros
- “The California metropolises really do retain their irreplaceable depth and strength.”

Los Angeles TIMES, 3/23/2022

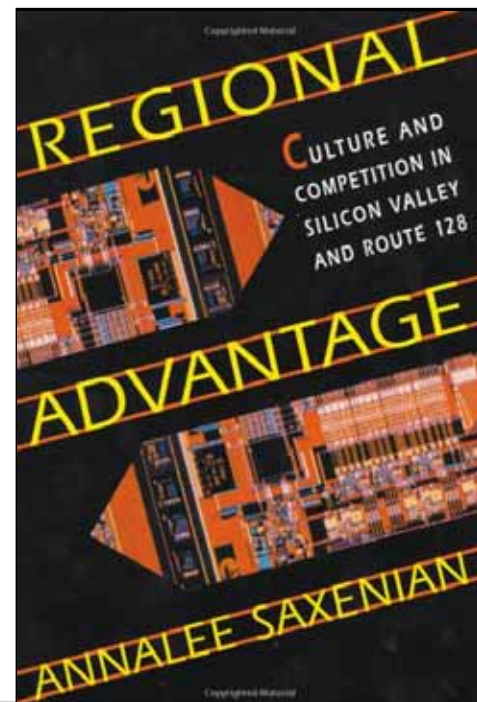
## Get the book!

Learn MUCH more  
about those early  
days ...



## AnnaLee Saxenian's book compares Silicon Valley to Boston's Route 128...

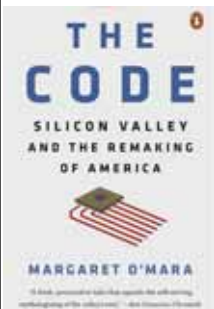
professor at UC-Berkeley



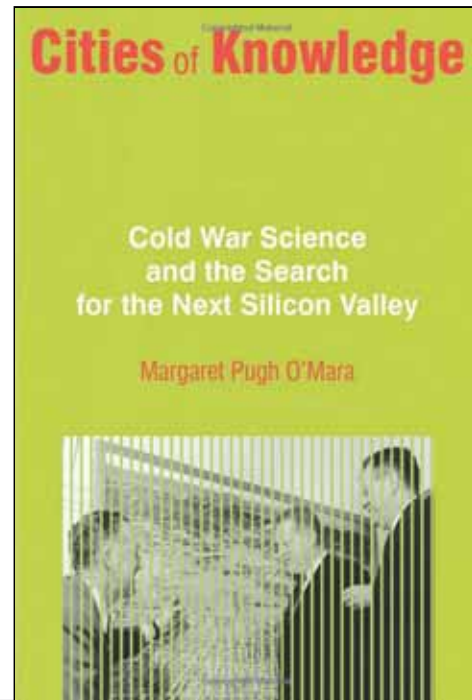


## Margaret O'Mara's book comparing tech areas around Stanford, U-Penn and GaTech...

professor of political, economic, and  
metropolitan history

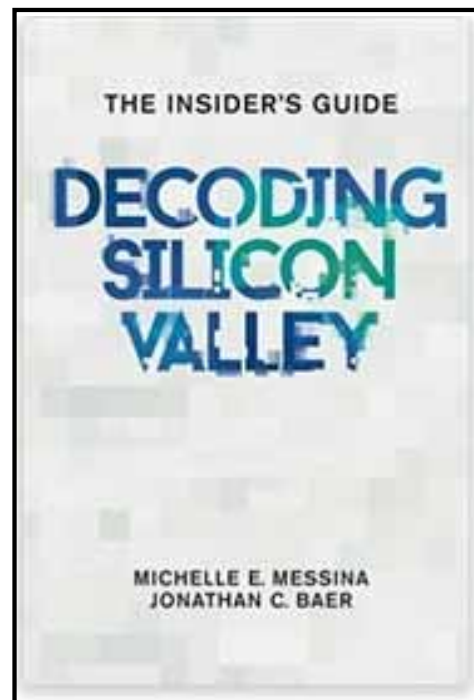


## ... and her new book "The Code"



## A good book for understanding how things work here, and ideas for duplicating the Valley in other places.

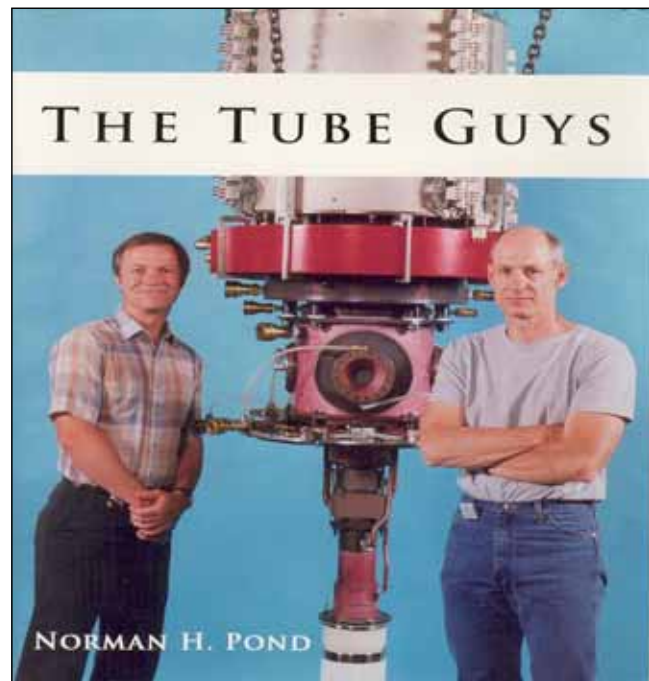
2016, soft- or hard-cover,  
ISBN 978-0-9973624-0-4



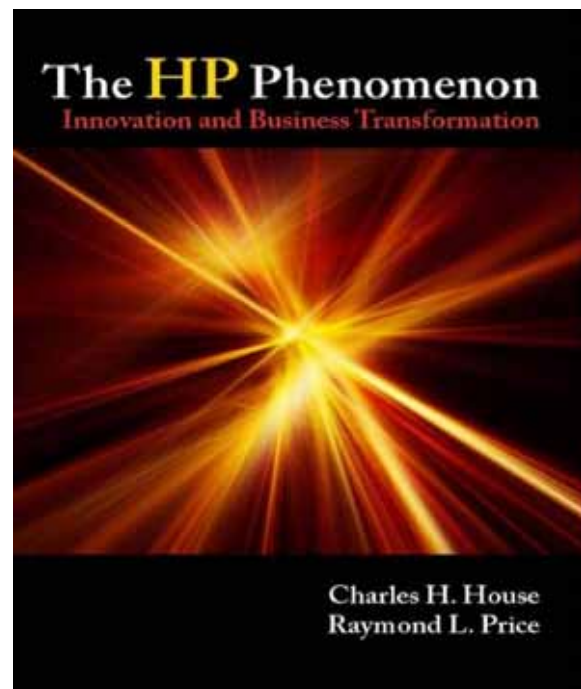
## Another fun book

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

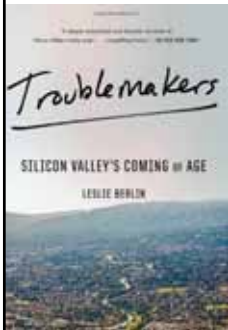
2008,  
ISBN 978-0-9816923-0-2  
[www.russcochran.com](http://www.russcochran.com)



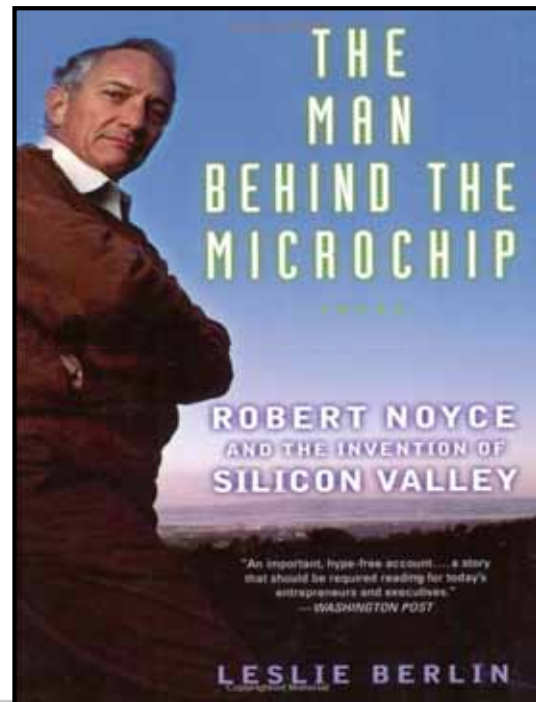
**To understand how H-P  
was a product of  
Silicon Valley, and  
shaped its culture  
through a number of  
re-inventions  
(1930s, up  
through 2009)**



**I also recommend Leslie  
Berlin's book on Bob  
Noyce...**



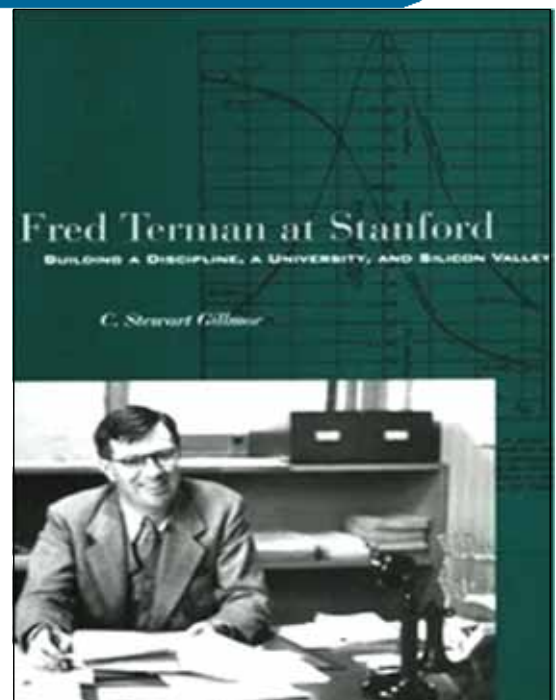
**and her new book  
"Troublemakers"**



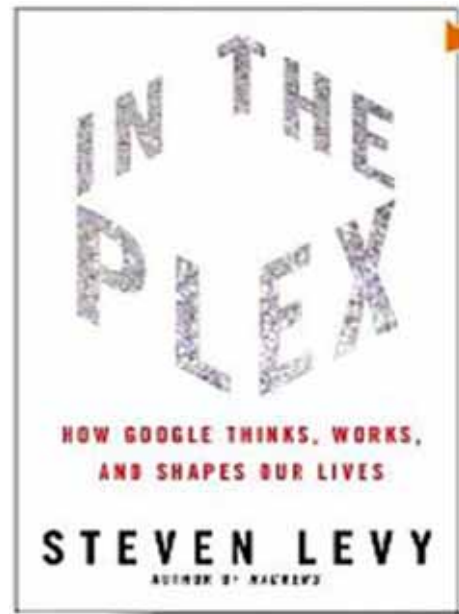
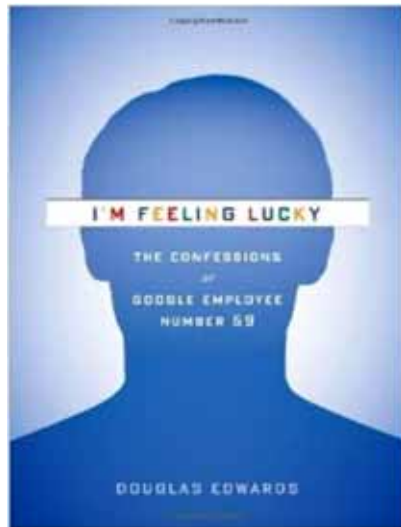
***More about that period ...***

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

**2004, ISBN 978-0804749145**



## For a view of another Innovation Environment



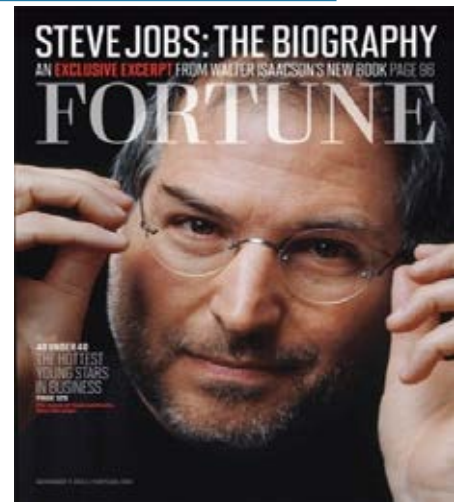
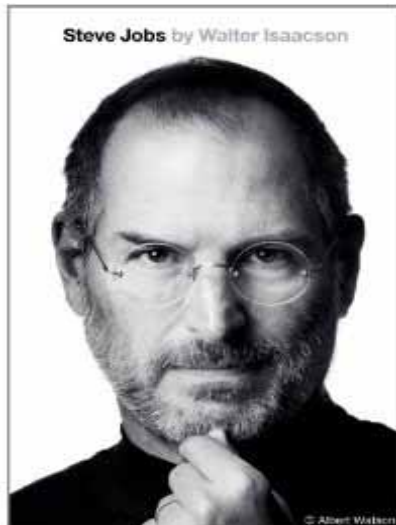
## On Streaming (various services):

**2011** video, 85 minutes  
(SXSW Best Documentary)

**Covers funding and startup of  
Apple, Intel, Cisco, Tandem,  
Genentech, with views from the  
key funders (Rock, Perkins ...) and  
entrepreneurs (Moore,  
Learner, Treybig ...)**



## For another view of Silicon Valley



## Understanding Tech's Primary Hub ... how Silicon Valley became the center of technology development ... *and STAYS that way* ...

Download the slides and reading list (2 MB) at:

[pwesling.com/docs/2204-ucd.pdf](http://pwesling.com/docs/2204-ucd.pdf)

Video: *"The Origins of Silicon Valley"*

– Stanford's YouTube Channel: [goo.gl/cSdSUH](https://goo.gl/cSdSUH) (26,000 views)

[p.wesling@ieee.org](mailto:p.wesling@ieee.org)