



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

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IEEE SF Bay Area Council  
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Presented at Holmdel, NJ,  
IEEE Coastal NJ Section Sept 23, 2019



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## Classic Silicon Valley: 1976

### Homebrew Computer Club

- Hobbyists meeting in Menlo Park and at SLAC
- Steve Wozniak and Steve Jobs
- The Apple I (to sell to friends)



6502 (\$20)



Neighbors; introduced by a friend

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## 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?**

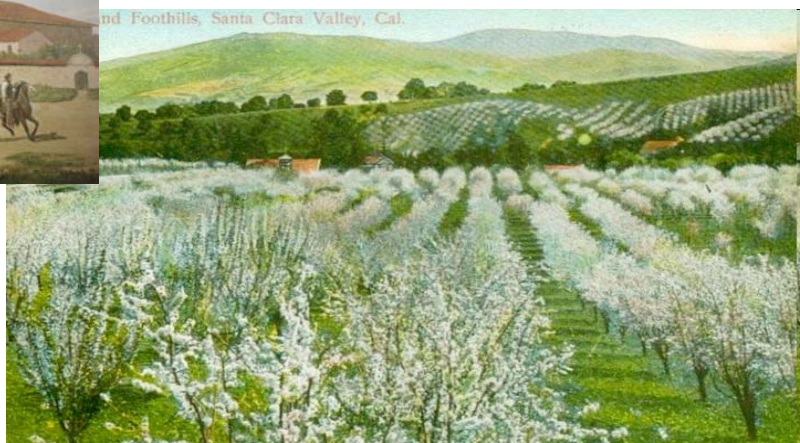
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## Before 1900 ...



The Santa  
Clara Mission

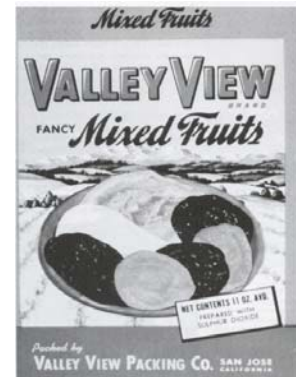
"Valley of the  
Heart's Delight"



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## Before 1900

This was more  
typical ...

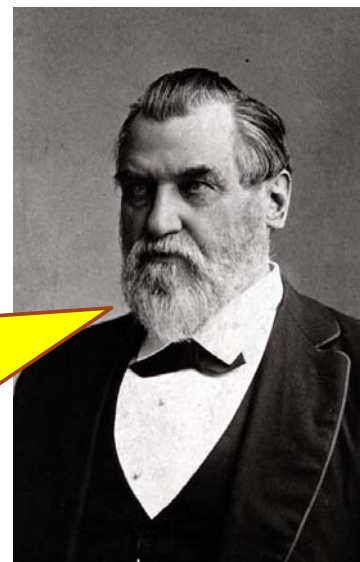


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## Late 1880's Prediction

"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

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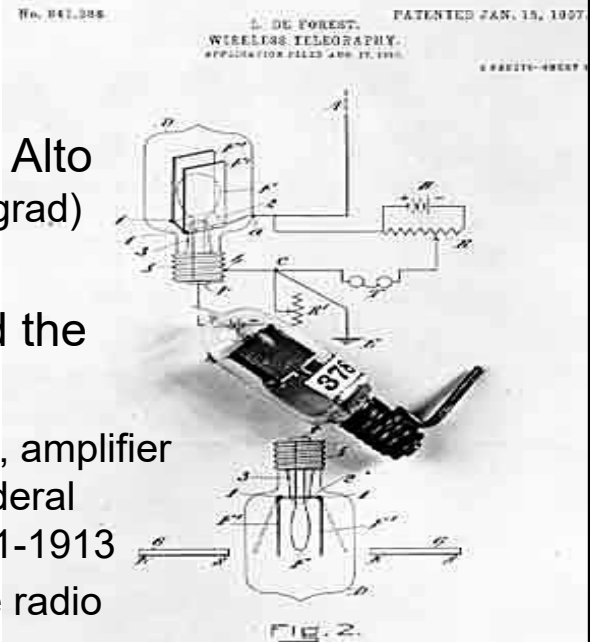
## Let's Go Back ...

### ■ Federal Telegraph

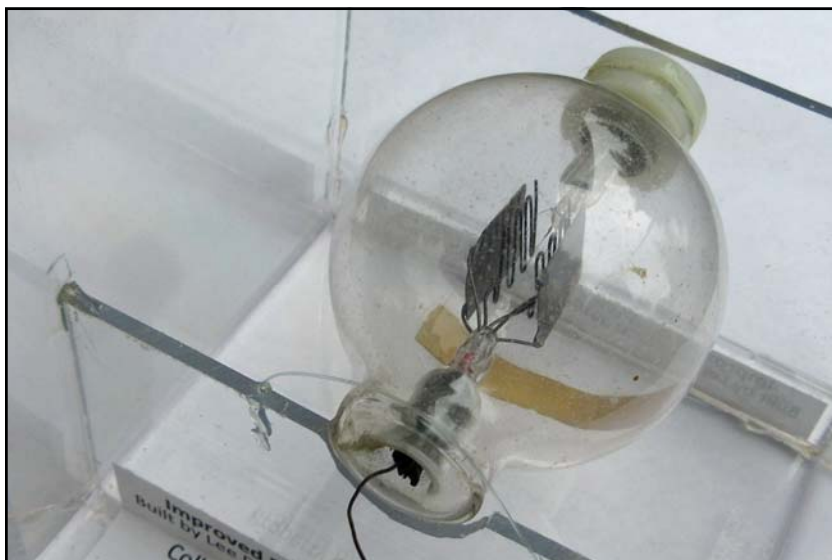
- Formed in 1909 in Palo Alto (by Cyril Elwell, a Stanford grad)
- **Lee de Forest** invented the audion in 1907
- Invented/patented oscillator, amplifier circuits while working at Federal Telegraph in Palo Alto, 1911-1913
- Pioneered continuous-wave radio



Improved triode



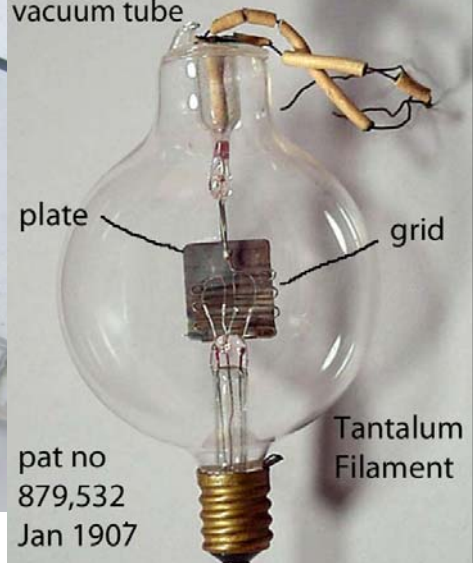
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### Improved Dual-Wing Grid Audion ca1912

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

First successful three-element vacuum tube



Single-Wing Grid Audion ca1912

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## Federal Telegraph

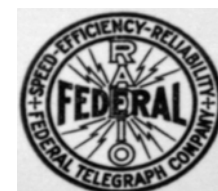
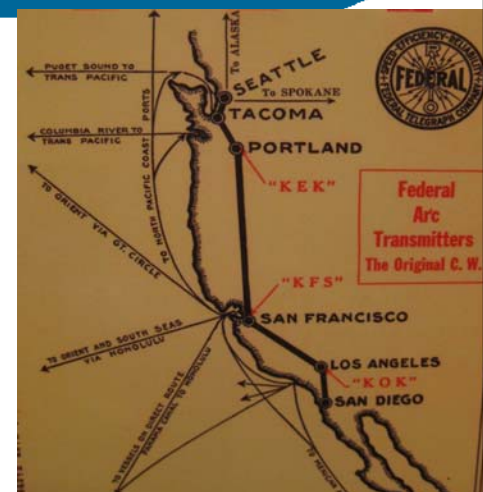
- Poulsen Arc Transmitter, 1909
  - Demonstrated sending CW, voice
- Raised funds from "angel investors", including David Starr Jordan, Stanford's president (plus Marx, Branner)
- Demonstrated communication from S.F. to Honolulu in 1912 →
- **First venture capital**
- **Stanford's Involvement**



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## 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

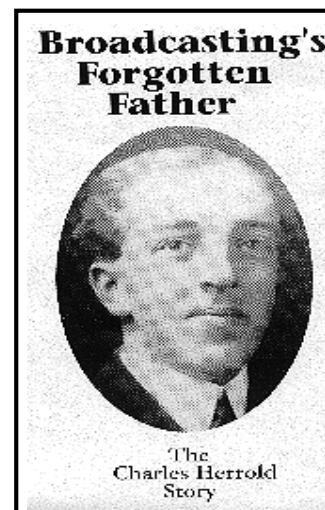


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## Let's Go Back ...

### ■ 1<sup>st</sup> regularly scheduled radio broadcast

- Charles "Doc" Herrold
  - Early Stanford engineering student
  - Started a San Jose school near SJSU to teach radio arts (1909)
- First scheduled 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)

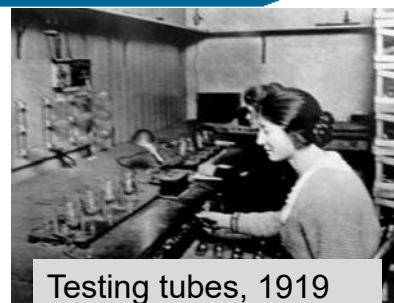


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## Example: Early Roots of Entrepreneurial Technology

### ■ 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

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## 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



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## We Now Follow Three Pioneers

- **William Eitel**
- **Jack McCullough**
- **Charles Litton**
- Bay Area families with a strong history of entrepreneurship
- Born/raised here



Charles Litton, 11,  
Outside his  
"Wireless House"

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## 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



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

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## 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
- 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



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## 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
  - Grad work in communication engineering
  - Took Stanford's first course on communication engineering fundamentals

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## 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**)

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## Ham Radio in SF Bay Area

- Active center of radio production 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-watt transmitters in 1920.
  - Radio parts available to **local hobbyists**
  - Jobs for radio amateurs

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## 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**"

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## Ham Radio Subculture

- Interest in extending radio technology
  - Built personal reputations: innovating new circuitry; clever transmitters; contacts with faraway lands
- Mix of competitiveness and collaboration

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

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## 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

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## 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

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## Following our 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

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## 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

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## 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)

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## 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 triodes
  - Litton, Eitel headed their tube shops

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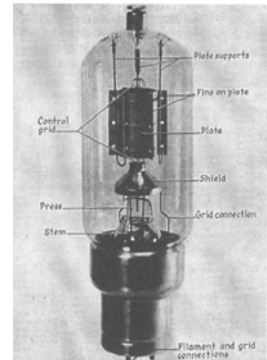
## Tube Shops' Challenge

- Design around ~250 RCA patents
  - Enormously difficult task
- Hired locally (many were hams)
  - Eitel, Litton **collaborated** with each other (*novell!*)
  - Based on friendships over the years
- Worked closely with **patent attorneys**

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## 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 higher vacuums (better reliability)
- More reliable, longer life than RCA's tubes
- **Didn't infringe RCA's patents**

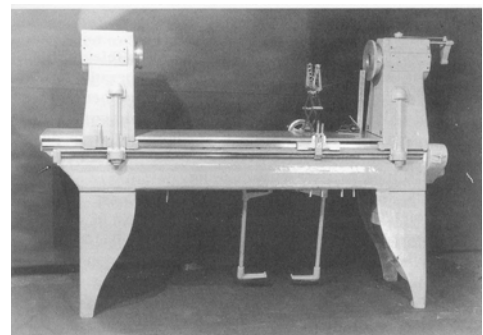


Heintz and Kauffman  
354 Power Triode Tube

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## 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**



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## 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**

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## 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

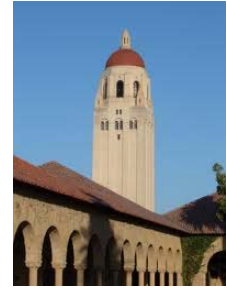
**Like Jobs & Wozniak,  
Homebrew Computer Club**

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## 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**

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## 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

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## 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



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

**Hitler Warns: Let Us Alone!**  
NEW STANFORD RADIO INVENTION HERALDS REVOLUTIONARY CHANGES

**Denies Plan To Attack Other Lands**  
Anniversary Address Is Denunciation Of Bolshevism

**Klystron Harnesses Ultra Short Wave Transmission**  
By JULIUS L. JACOBS  
An invention so breath-taking in its possibilities, that it may alter the future radio development of aeronautics, as well as telephone, telegraph, and television communication, was announced today by Dr. Ray Lyman Whittier, president of Stanford University.

**Six Killed In Blizzard**  
CHICAGO, Jan. 30 (AP) — A paralyzing blizzard whipped across the southern Great Lakes states and the Ohio valley today, burying Chicago under one of the heaviest snowfalls on record.

**Prison Farm Recommended By Grand Jury**  
Meeting in closed session with the Santa Clara County Board of Supervisors, the grand jury recommended that the county purchase a 100-acre tract near the Santa Clara County Jail for the purpose of establishing a prison farm.

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## 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 ...**

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## Post-War Realignment

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

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## 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!**

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## 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
  - Developed **“Recipe” to build a firm:**  
little initial capital; R&D contracts or a new idea;  
engineering teams, a product line; go into production



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



HP 200A Audio Oscillator

David Packard  
and Bill Hewlett



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Leonard Fuller,  
Cyril Elwell,  
Federal Telegraph

Ernest O. Lawrence,  
UC-B Cyclotron

Charles "Doc"  
Herrold, radio  
broadcasting

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

Philo Farnsworth with  
first all-electronic TV tube

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

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## The Mural in Palo Alto



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## 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



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

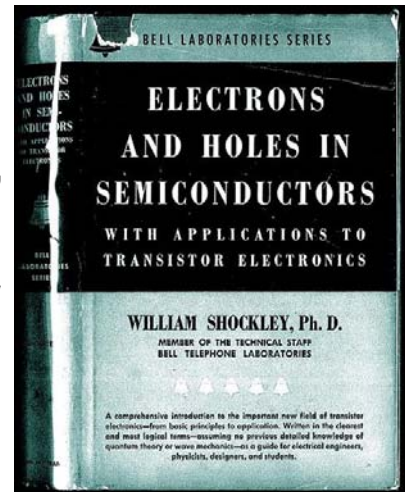


1948: William Shockley (seated),  
John Bardeen, and Walter Brattain

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## Fast Forward to 1950's

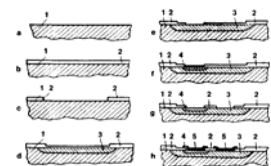
- William Shockley left the East Coast, returned to Caltech
  - Funding from Arnold Beckman
  - His mother, graduate of Stanford, lived in Palo Alto
  - 1955: Shockley Transistor, Mt View
  - "Traitorous 8" **left** him in 1957 to form **Fairchild**, with first real venture capital funding



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## 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**

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## The Planar Process

It all happened here ...

At original Fairchild Semiconductor plant on Charleston Road, Palo Alto



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## 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.



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## The Fairchildren: Formation of Intel

- Gordon Moore and Bob Noyce
  - Left Fairchild in 1968 to form Intel
  - To focus on memory ICs
  - Venture capital (Arthur Rock)
  - First microprocessor in 1971



- See my Nov 2014 interview with Ted Hoff (empl #12) [www.SiliconValleyHistory.org](http://www.SiliconValleyHistory.org)

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## 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 (broadcast, TV, microwave ovens)
- SV was central to the US defense effort and to the US manufacturing economy

**Why?**

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## 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**
  - Adapt **more rapidly** to change -- thrived in the new environment

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## 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

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## The '40's and '50's



**AMPEX**

**FAIRCHILD**  
SEMICONDUCTOR®

**hp** HEWLETT®  
PACKARD



**SPACE SYSTEMS**  
**LORAL**

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## The '60's

**AMD**

**National**  
Semiconductor

**intel**

**memorex™**

**intersil**

**APPLIED**  
MATERIALS®

**frog** design

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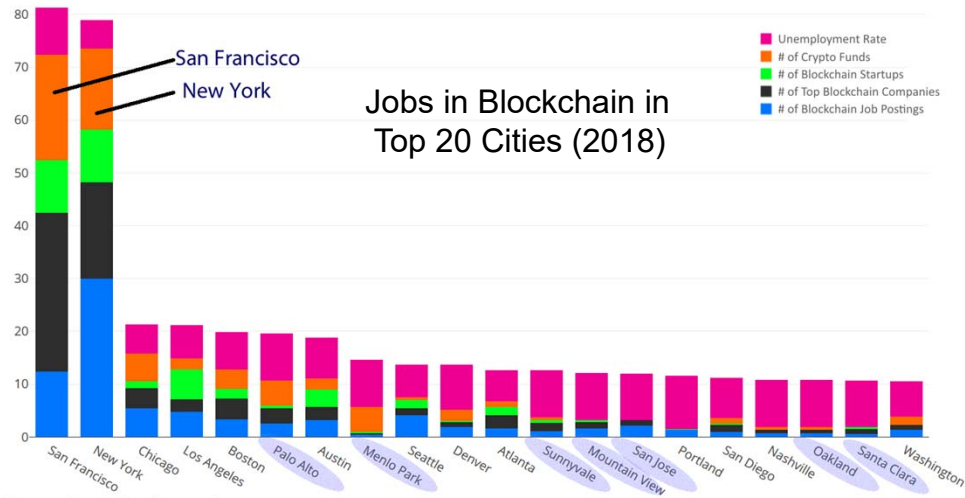
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## New Technologies: Blockchain

Top US Cities for Blockchain Jobs

Cumulative Five-Factor Score (Max=100)

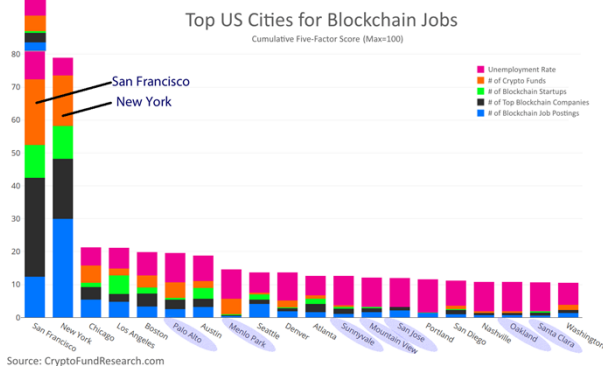


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## Blockchain

... with Bay Area cities added  
(2.4X those in NY)

So looking at where the  
most jobs are in blockchain ...



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## Where is "Silicon Valley"?

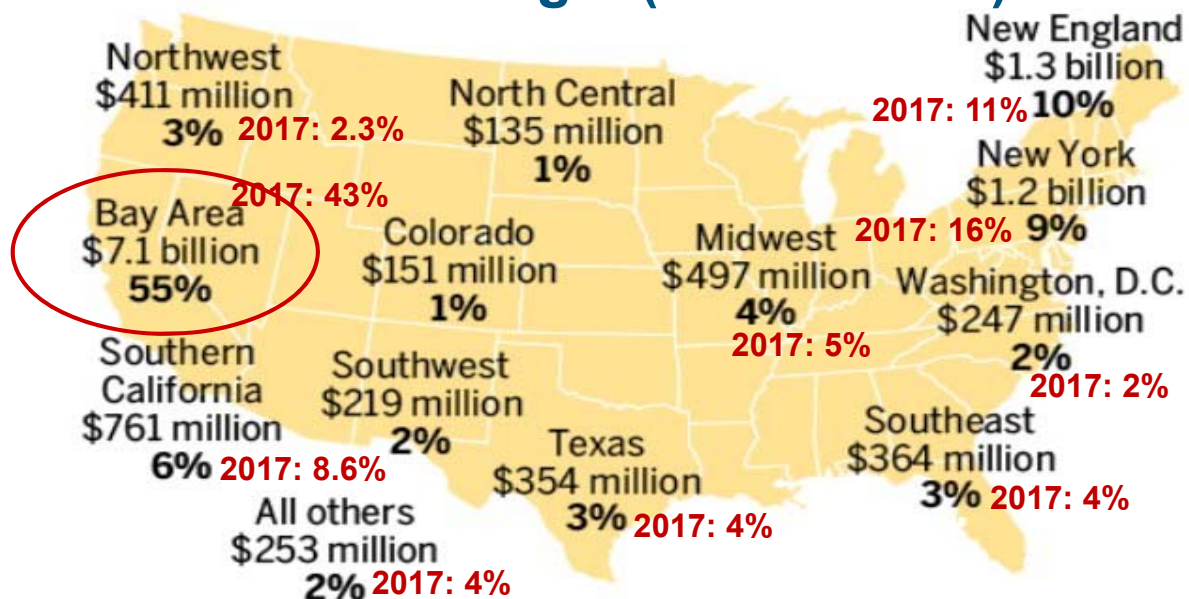
"A map of **Silicon Valley** in 2013, which originally just included the Santa Clara Valley from Gilroy to Palo Alto. Today it is a **metaphysical space** stretching from San Jose to San Francisco and Berkeley."

*A History of Silicon Valley*, p. 264



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



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## Where is Innovation Today?

- MeetUps, Maker Faire, 
- AngelList (bought Product Hunt)
- Shared Spaces    
- Open Source; Open Compute Project
  - OCP: Facebook, Intel, Google, Apple, Microsoft, Dell, Rackspace ...
  - Egalitarian use of jointly-developed software
  - ... and dozens of other collaborative spaces

Incubators:

500

500 Startups



Y Combinator



**Like Ham Radio, Homebrew Computer Club**

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## 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.” “Move Fast, Break Things”
- “America **innovates**, China **duplicates** and Europe **regulates**.” Jeremy Warner
- Yoda: “Do or do not — there is no *try*.” full commitment

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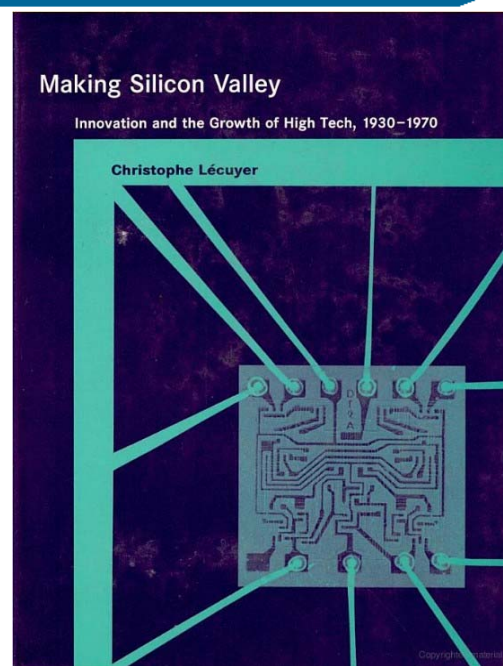
## Defining Characteristics for SV

- Competition **and** cooperation
- Often hobby-focused (for start-ups)
- Small, dynamic start-ups, companies
- Fluidity and flexibility (ability to "pivot")
- Egalitarian: parking, offices, "open door" policy, 20% time, Friday beer busts, employee-focus
- Large pool of entrepreneurs, technologists  
*... and other cultural, management factors*

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## Get the book!

Learn MUCH more  
about those early  
days ...

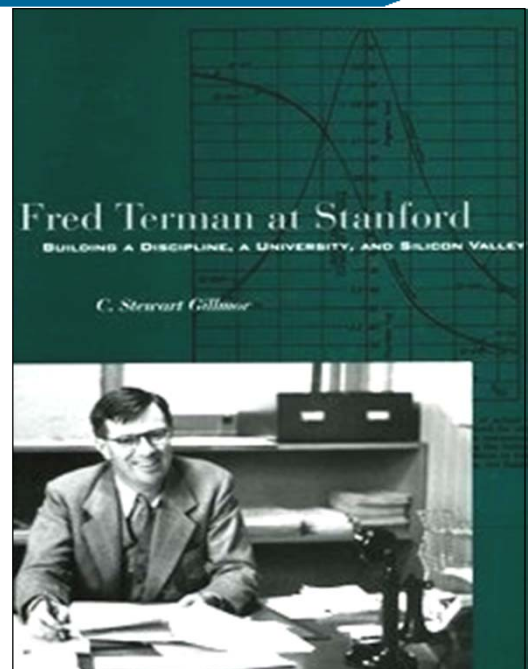


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## ***More about that period ...***

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

2004, ISBN 978-0804749145

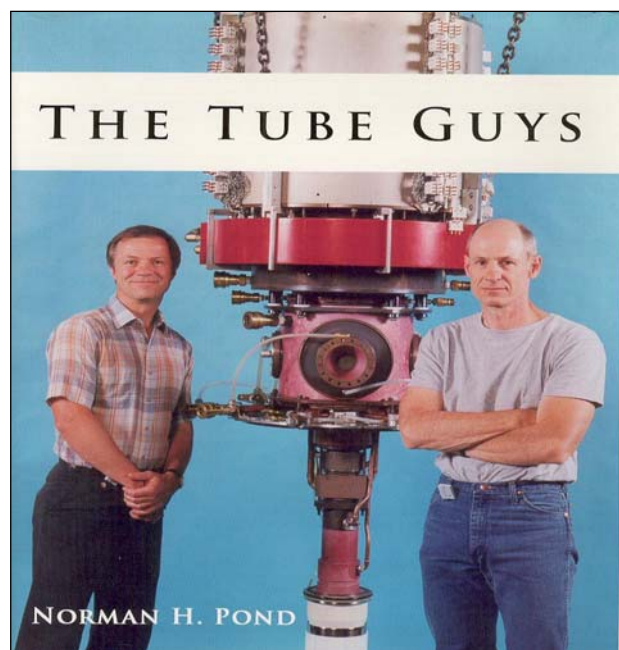


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## **Another fun book**

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

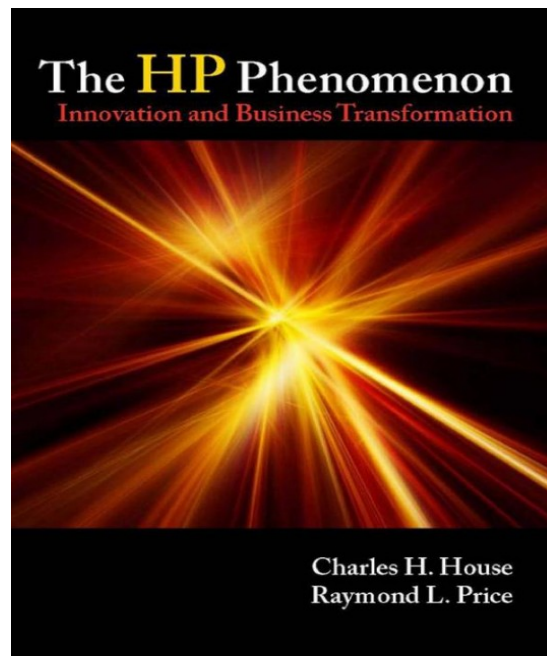
2008,  
ISBN 978-0-9816923-0-2  
[www.russcochran.com](http://www.russcochran.com)



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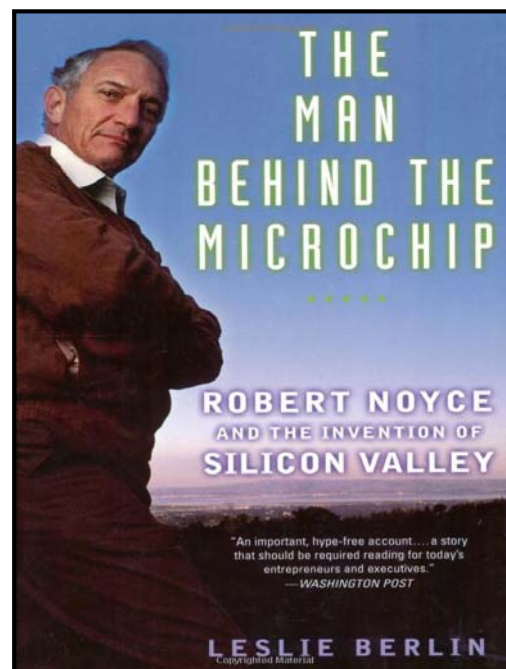


**To understand how H-P  
was a product of  
Silicon Valley, and  
shaped its culture  
through a number of  
re-inventions  
(1930s, up  
through 2009)**



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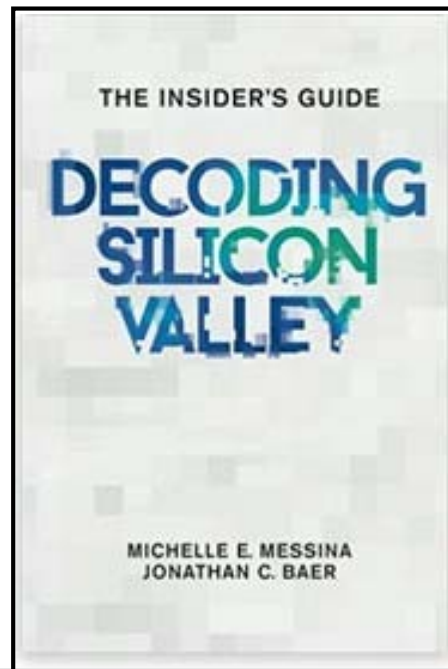
**I also recommend  
Leslie Berlin's book  
on Bob Noyce...  
and her new  
book "The  
Troublemakers"**



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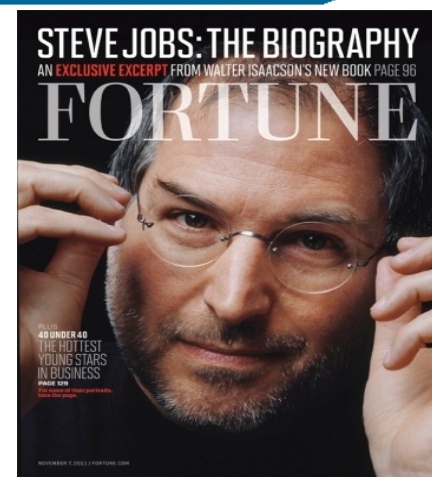
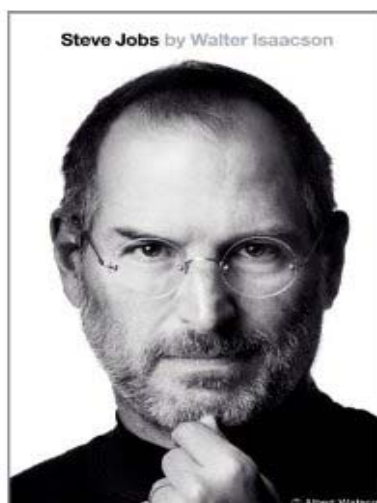
**A good book for  
understanding how  
things work here, and  
ideas for duplicating  
the Valley in other  
places.**

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ISBN 978-0-9973624-0-4**



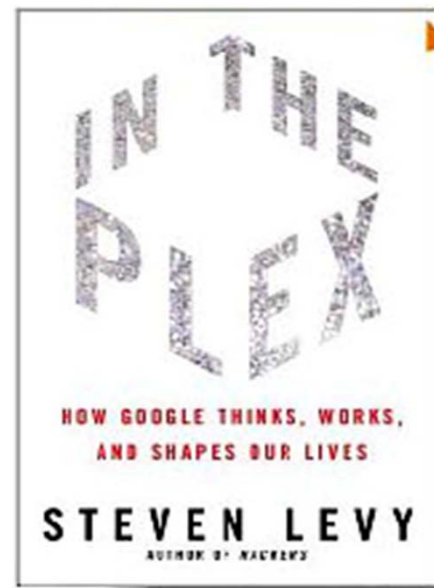
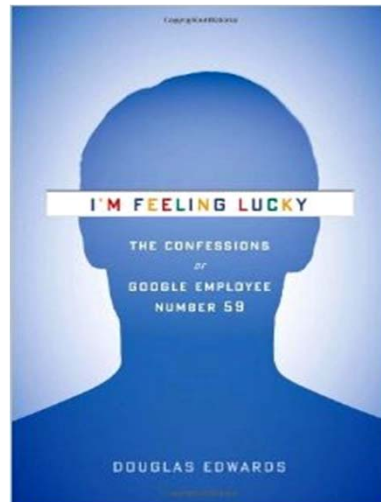
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**For another view of  
Silicon Valley**



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## For a view of another Innovation Environment



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## On Netflix Streaming:

**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,  
Lerner, Treybig ...)**



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## **Reviewing the Good Ol' Days**

... how **Silicon Valley** became the hub of technology development ... *and STAYS that way* ...

Download the slides and reading list (6 MB) at:  
**[pwesling.com/docs/1909b-wesling.pdf](http://pwesling.com/docs/1909b-wesling.pdf)**

This lecture is mounted on **Stanford's YouTube channel**:  
On SmartTV, search YouTube for "**stanford silicon valley**"

For other Silicon Valley Technology History Talks/Interviews:

**[www.SiliconValleyHistory.com](http://www.SiliconValleyHistory.com)**  
**[p.wesling@ieee.org](mailto:p.wesling@ieee.org)**

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## **QUESTIONS and STORIES?**

- **Where you worked; who you knew**
- **What you recall from the mid-20<sup>th</sup> century**
- **Digging into more of the details**

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