The Origins of Silicon Valley: Roots in Ham Radio

Paul Wesling KM6LH, H-P (retired), IEEE Life Fellow
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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)

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?
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 in 1907

- Invented/patented oscillator, amplifier circuits while working at Federal Telegraph in Palo Alto, 1911-1913

- Pioneered continuous-wave radio

Improved triode
Improved Dual-Wing Grid Audion ca1913

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
  ▪ 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
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
Let’s Go Back …

1st regular commercial radio broadcast

- Charles “Doc” Herrold
  - Early Stanford engineering student
  - 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 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.
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 with a strong history of entrepreneurship
- Born/raised here

Charles Litton, 11, Outside his “Wireless House”; two 100’ towers
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
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 Engineering School:
  - Classes with strong practical flavor
  - Got BS in 1924
  - Grad work in communication engineering
  - Small department (3 instructors)
  - 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:
  - Remler - made radio sets (“Radio Elmer” spelled backwards)
  - 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 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 grassroots hobbyists
  - In contrast to large companies, monopolies

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 …
Another Pioneer: Young Fred Terman

- San Bernardino, Glendale, 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 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
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**
    - Leonard Fuller (Stanford’s first Engineering PhD, 1919) had served as Chief Engineer
    - 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
      - Seen as threats to RCA, USA control
- So both companies needed to develop 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 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

- 1936: Frederick Terman asked Litton to join Stanford EE dept 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
Threats to Peace

- Growing threats from Japan and Germany
  - President Roosevelt rebuilt the Army, Navy
  - New electronic system: RAdio Detection And Ranging (radar)

- US NRL needed high-voltage high-frequency transmitting tubes for radar
  - Only Eimac’s tube (the 50T) worked well at the high voltages and frequencies (200 MHz) needed
  - First order of 10,000 tubes in 1940 (3,000,000 during war)!
Tubes for Hams

Transmitting Tube:
- Eimac 3-500Z
- Designed in 1968
- 3000 volts; up to 110 MHz
- Forced-air cooled
- Full legal power (using 2)

This one: built in Oct. 1980. Handle carefully!

Courtesy of Mike Yamamoto
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 – PA Times, Jan. 30, 1939

Hitler Warns. Let Us Alone!

Denies Plan To Attack Other Lands

Anniversary Address Is Denunciation Of Bolshevism

State Official Tells of Plan To Widen 101

NEW STANFORD RADIO INVENTION HERALDS REVOLUTIONARY CHANGES

Six Killed In Blizzard

Prison Farm Recommended By Grand Jury

For Franklin Delano Roosevelt, it was a birthday—his 57th—and the occasion for a nation-wide rally in behalf of a great humanitarian movement, the campaign against infantile paralysis. Thousands poured into the Civic Center here yesterday to hear every part of the nation while more than 8,000 stars gathered in Washington and other cities for birthday balls.

Meanwhile, across the Atlantic, Adolf Hitler celebrated the sixth anniversary of his accession to power, giving the world a warning to other nations to keep hands off Germany’s development. The threat that he must have instilled a dearness of ‘bolshieism’ and a desire to prevent a possible conflict among democratic nations of the world.

Hitler referred to his policy as the solution to Germany’s problems. He said that the solution was “our strength and defense.”

Klystron: Ultra Short Wave Transmission

Prison Farm Recommended By Grand Jury

Meeting in closed session with the Santa Clara County Board of Supervisors, the recommendation was made for a plan to widen 101. Delays in getting assurance that the plan would be implemented were discussed.

Prison Farm Recommended By Grand Jury

Six Killed In Blizzard

Chicago, Jan. 30 (AP) — A paralyzing blizzard whipped across the northern Great Lakes states and the Ohio Valley. The storm, which began in the middle of the night, moved through Chicago under one of the heaviest snowfalls on record.

Forecasters C. A. Daniel and R. J. Berman said the storm continued all day, with a wind gusting up to 82 mph in the city. The blizzard was expected to last into the early morning hours.

Six people were killed in Chicago, including a man who died after being hit by a tree. The city was covered in 24 inches of snow, with gusts up to 82 mph.

Hitler warned the world that the future of the Reich is in the hands of the people. He urged them to unite in the struggle against Bolshevism.

A new invention in radio transmission, the Klystron, was announced today by Dr. Julius Jacob, professor of radio physics at Stanford University. The Klystron, he said, would make possible the transmission of ultra-short waves, which have been used in the sport of Ortho-Ortho.

The Klystron, which is currently being tested at Stanford University, has the potential to revolutionize radio transmission. It is expected to be available for widespread use within the next few years.

The Palo Alto Times, Jan. 30, 1939

Palo Alto Times
AN INDEPENDENT NEWSPAPER
47th Year—No. 25
PALO ALTO, CALIFORNIA, MONDAY EVENING, JANUARY 30, 1939

I. V. SUP
HIGH
14 P
Los

14 P
Los
The Klystron

- Sperry (NY) invested, got exclusive rights
  - Bought lathes, welders, pumps from Litton
- Litton made klystrons for IT&T, for France
  - Transformed klystron from lab to production
  - Continuous-wave klystrons, VHF/radar triodes

SF Bay Area/Stanford was microwave hotbed
Wartime Expansion

- Progressive Approach to business
  - Egalitarian relations within, between companies
- Managerial techniques to thwart unions, keep 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
  - Power tetrodes for high frequencies (4-150A, 4-250A)

- FCC’s surprise shift of **FM radio** to VHF (88-108 MHz)
  - RCA, others’ transmit 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
- Developed “Recipe to build a firm:
  little initial capital; R&D contracts or a new idea; engineering teams, a product line; go into 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 Rosa, Santa Clara divisions became Agilent (largest IPO in history), now Keysight

David Packard and Bill Hewlett

HP 200A Audio Oscillator
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.

Ernest O. Lawrence, UC-B Cyclotron

Ralph Heintz, short wave radio pioneer

Lee de Forest, inventor of audion

Charles Litton, inventor of the glass tube lathe

Leonard Fuller, Cyril Elwell, Federal Telegraph

Charles “Doc” Herrold, radio broadcasting

Jack McCullough & Bill Eitel, cutting-edge Eimac vacuum tubes

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

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

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

- Developed by Dr. Jean Hoerni at Fairchild, 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
The Planar Process
It all happened here …

At original Fairchild Semiconductor plant on Charleston Road, Palo Alto
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 (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: 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
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
The ’60’s
The ’70’s

TANDEM

FOUR-PHASE SYSTEMS, INC.

KPCB

parc

ComputerLand

Apple

SOLECTRON

ORACLE

3COM

AMD

CYPRESS

ATARI

WD

Western Digital

Convergent Technologies

Genentech
The ’80’s

Adobe

Intuit®

LSI

Atmel®

RSA

CISCO

Almaden Research Center

Symantec

EA

Electronic Arts™

Sun Microsystems

Silicon Graphics

MIPS Technologies

Fry’s Electronics
The '90’s and beyond
Major companies have moved here ...
Biotech … Stanford Recombinant DNA

$200 million
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? (Spring 2014)

- **Bay Area**: $7.1 billion (55%)
- **New England**: $1.3 billion (10%)
- **New York**: $1.2 billion (9%)
- **Washington, D.C.**: $247 million (2%)
- **Southeast**: $364 million (3%)
- **Northwest**: $411 million (3%)
- **North Central**: $135 million (1%)
- **Colorado**: $151 million (1%)
- **Midwest**: $497 million (4%)
- **Southern California**: $761 million (6%)
- **Southwest**: $219 million (2%)
- **Texas**: $354 million (3%
- **All others**: $253 million (2%)

Total VC funding: $12.5 billion
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”

Tech start-up Failure Rate – typically 9 in 10 (in SV: 8 in 10)

“The future is already here — it’s just not very evenly distributed.” William Gibson
Get the book!

Learn MUCH more about those early days ...
More about that period …

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

Another fun book

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

2008,
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 recent book on Bob Noyce.
For another view of Silicon Valley
For a view of another Innovation Environment
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, Learner, Treybig …)
Reviewing the Good Ol’ Days
... how hams created this hub of technology development ...

Download the slides and reading list (6 MB) at:
www.pwesling.com/docs/1902-wesling.pdf

For other Silicon Valley Technology History Talks/Interviews:
www.SiliconValleyHistory.com
p.wesling@ieee.org
QUESTIONS and STORIES?

• Where you worked; who you knew
• What you recall from the mid-20th century
• Digging into more of the details