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

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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

- **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, amplifier in 1907.
- Pioneered continuous-wave radio.

Federal Telegraph

- Paulsen Arc Transmitter, 1909
  - Demonstrated sending CW, 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: 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 EE 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 EE 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 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"
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

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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
- 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; 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

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’s domination
  - So both companies needed to develop triodes
    - Litton, Eitel headed their tube shops
Tube Shops’ Challenges

- 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
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

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
- 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 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)

- 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 – PA Times, Jan. 30, 1939

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 was IT&T’s VHF and uwave 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, 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

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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 DeForest, inventor of audion

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

Charles Litton, inventor of the glass tube lathe

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; CalTech, MIT
- Invented transistor
  while at Bell Labs
- Point-contact Germanium
device
- Developed to replace
vacuum tubes

1948: William Shockley (seated), John Bardeen, and Walter Brattain
Fast Forward to 1950’s

- William Shockley left the East Coast, returned to CalTech
  - His mother, graduate of Stanford, lived in Palo Alto
  - Funded by Arnold Beckman
  - 1955: Shockley Semi in 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 …

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
  - Development and production capability

At the end … (1960’s)

- In a wide range of industrial goods (FM and TV broadcast, microwave ovens)
- SV was central to the US defense effort and to the US manufacturing economy

Why?

Raytheon “Radarange” prototype (1946)
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 ➔ self-driving …
  - 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

The ‘60’s
The ’90’s and beyond

Major companies moving here ..
Stanford alumni and faculty created 39,900+ companies from 1930s to 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 (Engineering) and William F. Miller (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
- **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

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Other Technology Centers

- Silicon Roundabout (London)
- Silicon Forest (Oregon)
- Silicon Allee (Berlin)
- Silicon Alley (New York City)
- Silicon Valley-India (Bangalore)
- Silicon Valley-Taiwan (Hsinchu)
- Silicon Oasis (Dubai)
- Silicon Wadi (Israel)
- Silicon Hills (Austin)
Where is VC funding? (Spring 2014)

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

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
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 …
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

www.russcochran.com
To explore the invention of the integrated circuit:

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 ...
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

“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.”

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**The Origins of Silicon Valley**  
Download the slides *(5 MB)* and suggestions for further reading at: 
[www.e-grid.net/docs/1608-wesling.pdf](http://www.e-grid.net/docs/1608-wesling.pdf)  
[p.wesling@ieee.org](mailto:p.wesling@ieee.org)

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