The Origins of Silicon Valley: Roots in Ham Radio

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Classic Silicon Valley: 1976

• Homebrew Computer Club (hobbyists)
  – 6502 Processor
    • 4,000 transistors
    • Design-around Motorola patent
    • Cheap (1/6th the price)
    • Hobbyist-level device
  – Steve Jobs and Steve Wozniak
  – 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
  - Sold 200 or so; attracted attention of investors
  - IPO in 1980: 2\textsuperscript{nd}-largest IPO since Ford Motor Company 25 years earlier
  - Now ~ largest stock market capitalization

- How could this happen?
  Why here?

Before 1920

This was more typical …
Let’s Go Back …

- **Federal Telegraph**
  - Formed in 1909 in S.F.
  - **Lee de Forest** invented the audion oscillator and amplifier in 1907
  - Pioneered continuous-wave radio
  - Sold equipment to US Navy in World War I

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**Defining Events**

- Titanic Sinking in 1912
- World War I
- Importance of Technology
- US Navy “push” for ship-to-shore and other communications modes
- Brought frenzy, funds to S.F. Bay Area
Early Roots …

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

Let’s Go Back …

- **1st commercial radio broadcast**
  - Charles “Doc” Herrold
    - Early Stanford EE grad
    - Started an SF firm
    - Destroyed in the 1906 earthquake/fire
    - Started a San Jose school to teach radio arts
  - First Commercial broadcast, San Jose, 1909
  - FN, then SJN, then KQW, becomes KCBS

Clear-Channel; Music ‘til Dawn
We Now Follow Three Pioneers

- William Eitel
- Jack McCullough
- Charles Litton

- Deep roots in the Bay Area
- Families with a strong history of entrepreneurship
- Born/raised in San Francisco, San Mateo and Santa Clara counties

William Eitel

- Mechanical skills: shop at Los Gatos HS
- Worked in his father’s quarry
  - ass’t blacksmith, machine operator
- Visited shops of Hall-Scott Motor Car Co.
  - Learned about machine-shop practice
  - Operation of complex machinery

William Eitel, W6UF
1908 - 1989

- First displayed his new tube at the Fresno Hamfest
- Met his wife at a hamfest
Jack McCullough, Charles Litton

- Attended **California School of Mechanical Arts**
- Founded in S.F. in by **James Lick**, $540,000
- Opened in 1895; free education for boys, girls
- One of the best West Coast **technical hi schools**
  - Rigorous training in the mechanical trades
  - Became excellent machinists
  - 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 ME dept:
  - Curriculum with strong practical flavor
  - Knowledge of mechanics and metalworking
  - Organized around courses in shop work & administration, machine drawing & design, power plant engineering, chemistry courses
  - BS-ME in 1924
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
  – Ventured into tube production at local radio firms in the late 1920s and the early 1930s
  – Bay Area had 1,200 licensed amateurs
    • 10 percent US total

Ham Radio in SF Bay Area

• Isolated and peripheral region
  – A continent away from urban and industrial centers
  – But a large and vibrant ham radio community

• Geographical and cultural factors:
  – Strong maritime orientation
  – SF was one of the largest sea ports on the West Coast
  – Several military bases; US Navy presence
  – Commercial shipping firms relied on radio comm’n
  – Considerable visibility for technology in 1900s ’10’s
  – Navy, shipping companies employed radio operators, some of whom were involved in amateur radio
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
    • One of the earliest radio companies in the US
    • Produced radio transmitters in the 1910s.

• These firms made radio parts available to local hobbyists, hired radio amateurs

Ham Radio Subculture

• Camaraderie and intense sociability
  – A way to make friends
  – Communicating "over the air," face to face in clubs
  – Organized "hamfests" with hundreds of amateurs plus suppliers of radio equipment

• 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
  - against large companies, patent monopolies, undemocratic organizations

- Interest in extending radio technology
  - Built reputations: innovating new circuitry, devising clever transmitters, contacts with faraway lands

- Mix of competitiveness and information sharing

- A lot like today’s Silicon Valley …

Following our Heroes …

- Eitel, Litton, McCullough, ham friends
  - Experimented with short waves
  - Learned about vacuum tubes
  - Built their own equipment, parts
  - Made notable contributions
  - 1924: Litton and Stanford radio club made first contact with Australia and New Zealand
  - 1928: Eitel pioneered 10-meter waves (30 MHz) for transcontinental communication
  - Opened VHF bands to radio communication
Following our Heroes …

• Litton learned to **fabricate** vacuum tubes
  – Especially power-grid tubes (reading; disassembling)
  – Remarkable achievement for an independent experimenter (had help from ham Moorhead)

• General Electric, Westinghouse, AT&T (WECO)
  – Developed hi-power transmitting tubes in early 1920s
  – Difficulties in producing consistent, reproducible
  – Required precise machining, glass blowing (Pyrex)
  – High vacuum; baked at high temperatures for hours
    To release occluded gases in their metallic elements
  – Exotic materials, sophisticated sealing techniques
  – Tight joints between envelope and metallic elements
  – Use of "getters"

Following our Heroes …

• Litton got local job through ham friend
  – Research at **Federal Telegraph**
  – Got contract with IT&T (Europe, So. America)
  – Built to 60 engineers and scientists
  – Became sole supplier of radio 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 McCollough a year later
The Tube Business in the ’20s

- Could not buy transmitting tubes on open market
  - RCA, GE, Western Electric, and Westinghouse
    - **Exclusive cross-licensing** of 2000 patents, to control market
  - **RCA** set up by GE, US Navy to ensure US dominance
    - To control ship-to-shore, transoceanic communication
  - Sole producers/distributors of power-grid tubes
    - Refused sale to Federal Telegraph, Heintz & Kaufman
  - Threats to RCA’s domination
  - RCA to sue if they bought transmitting tubes from Europe

- Both companies developed triodes
  - Litton and Eitel headed their tube shops

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Tube Shops’ Challenges

- Design around ~250 RCA triode patents
  - Enormously difficult task
  - RCA had shut down Sylvania’s tube business
  - Ordering materials difficult (Corning in NY)
- Hired locally (many hams); got resources from IT&T (French engineers)
  - Collaborated with each other (novel!)
  - Based on friendships over the years
  - Didn’t compete with other’s market
- Worked closely with patent attorneys
Tube Shops’ Challenges

• Heintz, Eitel, and McCullough engineered the **gammatron**
  – Rugged power tube
  – New materials, manufacturing methods
  – Tube plates of tantalum (avoid getter patents)
  – New shock-resistant seals
  – Create high vacuum envelopes (> reliability)
• More reliable, longer life than RCA’s tubes

Tube Shops’ Challenges

• Litton invented the glass lathe
  – For assembly, glass blowing, and sealing
  – Make complex tubes in large quantities
  – Allowed high repeatability, precision
• Built tube shop on parents' property
The Ham Radio Market

Heintz and Kauffman 354
Power Triode Tube

The US Depression

• Formed Eitel-McCullough Inc
  – To build high-power, high-frequency tubes
• Financing: Walter Preddey, Bradshaw Harrison
  – Harrison: real-estate agent in San Bruno
  – Preddey: ran movie theaters in San Francisco
  – Eitel and McCullough brought their know-how
  – Profits to be shared
  – Preddey was the president, Eitel a vice-president

Like today’s Menlo Park Venture-Capital Firms
The US Depression

• Litton, Eitel, McCullough cooperated closely
  – Litton helped set up vacuum tube shop
  – Gave castings, engineering blueprints for lathe
  – Eitel and McCullough then made high-quality glass lathes at low cost
  – Freely exchanged technical, commercial information
  – Reduced risks, for the two small tube-related businesses
  – Like Jobs, Wozniak, Homebrew Computer Club

The Depression

• Litton expanded into vacuum pumps
  – Replaced mercury (cooled with liquid air) with oil
  – Compact, higher speed, better vacuum
  – Distiller, to produce his oil from commercial motor oil

• 1936: Frederick Terman asked Litton to join Stanford as EE department lecturer
  – Shared knowledge with staff, students
  – Litton $1000 grant: let Terman bring Packard to campus for grad studies, work with Litton

Start of University/Industry cooperation
The Depression

- Eimac focused on transmitting tubes
  - Amateurs: most demanding users of tubes
  - Higher power, higher frequencies
  - Close, precise element spacing
    - Related to tube performance
    - Fabrication of VHF transmitting tubes
    - Operate: high voltages, overloads, longer lifetimes
  - High vacuums, better out-gassing
  - New lathe, vacuum, cleaning techniques were closely guarded

Eimac’s Expansion

- Eitel-McCullough’s new tubes
  - Marketed to radio amateurs, Small manufacturers
  - 1937: sales of $100,000 (half from each market)

- Gradually enlarged their workforce
  - Almost exclusively hobbyists from radio clubs
  - Most were in their early twenties

- Radio amateurs had the skills needed:
  - Familiarity with transmitting tubes
  - Expertise in design of radio systems
Threats to Peace

- Growing threats from Japan and Germany
  - President Roosevelt rebuilt the Army, Navy
  - New electronic system: radio detection and ranging (radar)
  - Secret research programs in short-wave radio at Naval Research Labs (NRL) Fort Monmouth, NJ

- Needed high-voltage transmitting tubes
  - Only Eimac tubes worked at the high voltages

Pre-War Expansion

- Eimac: two different versions of ham tube
  - Shorter leads; side entry (rectangular shape)
  - Another version of same tube for the Navy

- RCA, Western Electric selected for prod’n
  - NRL helped Eimac get sub-contracts
  - Bank of America financing, volume production

- Managerial techniques to thwart unions
  - Profit-sharing, cafeteria, medical clinic
Wartime Expansion

• Litton: Expanded
  – New plant in Redwood City
  – Lathes allocated by the War Production Board
• Became very profitable

Post-War Realignment

• Glut of tubes dumped on market
  – Layoffs, plant closings
• RCA, others focused on TV, broadcast
• Eimac developed new line of better tubes
  – Made war-surplus ones obsolete
  – Power tetrodes for high frequencies
  – FCC surprise shift of FM radio to VHF
  – RCA, others’ tubes wouldn’t work at VHF
  – They copied Eimac’s tubes, which did work
Reversal of Fortunes

• In 1947, Eimac sued RCA and GE
  – alleging patent infringement on tetrode
  – GE and RCA had copied Eimac’s new line of tubes for FM radio, TV broadcasting
  – GE, RCA lost the 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!

The Klystron

• Russell and Sigurd Varian developed the klystron at Stanford University in 1937
  – Russell went to Stanford, then worked at Television Laboratory in SF
  – Philo Farnsworth pioneered TV in 1920’s
• They worried about Germany
  – Hoped to use <1m waves to detect planes
  – 1937: Moved to Stanford to work with Hansen
  – Used Litton’s free advice
  – Used Hansen’s theoretical assistance
The Klystron – PA Times, Jan. 30, 1939

The Klystron
The Klystron

- Not just a component – an integrated RF circuit
- Like an antenna, with resonant traps

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
  - Korean War: Armed-Forces contracts
  - Developed “Recipe to build a firm: little initial capital; R&D contracts; engineering teams and a product line; move to production
Fast Forward to Silicon Valley

• **William Shockley** invented transistor while at Bell Labs

Fast Forward to Silicon Valley

• William Shockley left the East Coast, returned to CalTech, then to Palo Alto
  – His mother, graduate of Stanford, lived there
  – 1955: Shockley Semiconductor in Mt View
  – “Traitorous 8” left in 1957 to form Fairchild

The Planar Process

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

All of the capabilities developed during the ’20’s, 30’s and ’40’s
The Planar Process

It all happened here …

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.
Fast Forward to Silicon Valley

• Silicon Valley continues to be the leading high-tech hub:
  – Large number of cutting-edge entrepreneurs
  – Engineers and venture capitalists
  – Local universities and research
  – Supporting industries

• This phenomenon can be traced back to ham radio operators
  – Early developments in radio in S.F.
  – Breaking of RCA patents to make better tubes
  – Collegial spirit from hams, hobbyists

Silicon Valley Business Climate

• East’s large, autarkic, vertically integrated firms
  – adjust slowly to swift technological and market changes
  – Protective, inward, monopolistic (ATT, RCA)

• SV: highly fragmented, decentralized structure
  – Specialized firms, flexible, engineering-driven
  – Dense regional network of small & medium-size firms
  – Autonomous and often competing teams
  – Adapt more rapidly to change
  – Thrived in the new environment

(Ref: Saxenian 1994)
Get the book!

Learn MUCH more …

Another fun book
For another view of Silicon Valley

Remembering the Good Ol’ Days … and understanding how Silicon Valley became the hub of technology development

Thank you for attending!

Download the slides at: www.e-grid.net/docs/1206-wesling.pdf