Amateur Radio at Stanford
Its Role in Competitive Advantage

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W6YX via Zoom
History – A Guide to the Future

- Decision Tree – Life, Career, Education, Business
  - Chain of contingent events, in competition
  - Each step depends on prior decisions & environment

- Strategy – Optimize Choices
  - Strategy – Plan before objective is in view
  - Tactics – Carry out strategy after objective is at hand

- Study Paths of Others – A Guide to Choices
  - Identify their strategies – See how it worked out
  - I focus on history, but can apply to present
Strategy Ideas & Examples

- **Significant Strategic Concepts**
  - Limit competition – Segments & differentiation

- **Radio Technology is Unique**
  - A differentiating skill – Then & now

- **Amateur Radio Experience**
  - An engaging exercise in radio technology
    - Making and operating
  - Basis of culture & key events – Stanford & Silicon Valley

- **History Examples Bear This Out**
  - Career & institutional successes have flowed from amateur radio
Elements of Competitive Strategy

- **Segmentation – Part of Customers/Market with Defining Limits**
  - Limit competition – By location, experiences, technology, organization
  - Fortress concept – Safe inside, no advantage outside
    - Compete where you can win

- **Differentiation – Strength Against Others in Segment**
  - Identify needed advantages – Singular skills, relationships, culture, location
  - Build from experience – Learn from self, colleagues, mentors
    - Experiences in one sphere apply to others
Combine Multiple Strategic Elements

- **Additional Factor Creates More Focused Segment**
  - Restricts field to intersection of capabilities
  - Greatly reduces population of competitors

- **Radio Technology – A Singular Differentiation**
  - Subtle characteristics unique to wireless, not widely appreciated
  - Combines physics and electronics – Energy efficient
  - Key to mobility & instant communications
    - Cellphones, WiFi – Connections > population of earth
Radio – Unique Strategic Attributes

- **Propagation Physics**
  - Geometric path loss
  - Atmospheric absorption
  - Reflection, refraction, diffraction
  - Wave interference – Multipath fade
  - Ionosphere – Solar interaction

- **Sources**
  - Circuits – Include distributed transmission lines
    - Frequency limits of active devices
  - Antennas – Directivity, polarization & sources of noise

- **Shared Spectrum**
  - Contention & interference from competing users
  - Competition for bandwidth
    - Frequency allocation, regulation & licensing
Amateur Radio – Learning Techniques Hands-on

- Amateur Radio – Mastered Through Direct Experience
  - Making equipment & antennas – Ionospheric HF and LOS VHF/Microwave
  - Operating – Direct personal experience of radio attributes
    - Avocation – Less performance pressure

- Clubs & “Elmers” – The Culture of Cooperation
  - Regional & university clubs since early radio
    - Stanford club – Licensed by 1923, affiliated ARRL 1924
  - Share techniques & advances, even with competitors

- Mentors & Sponsors – Behind Every Success
  - Relationships critical to chain of contingent career events
  - Hard to find – When you find one, you must qualify
    - W6YX – Direct access to Stanford & Silicon Valley affiliate members
Radio Competitive Environment 1920s-1930s

- **SF Bay Area – Unique Wireless Situation**
  - Rich region, but no manufacturing – Shipping & port critical
  - Shipping companies fostered radio – Created interest & opportunity

- **The RCA Monopoly – Unintended Consequence of Patent Pool**
  - Post WWI – Radio (RCA), telephone (AT&T) & aircraft patent pools
    - Intended widespread licensing – Worked only for aircraft
  - RCA created radio monopoly
    - Network effect – Utility grows by $N^2$ with number of users
    - Familiar issue today – Internet services
  - Only exclusive licensees could make or buy vacuum tubes
    - RCA sued small companies, put them out of business

- **Regional radio strategy – Segment to Circumvent RCA**
  - Non-patent vacuum tubes, microwave, instruments
  - Government (infringement protection) & captive customers
    - Prewar amateur radio segment led to huge WWII radar market
Regional Advantage – A Unique Cooperative Culture

- **Regional Culture – Favors New Enterprise Formation**
  - Not risk-averse in career, investment – Flexible local support
  - Shared information & equity – Employees as partners, owners
    - Reliance on younger managers, entrepreneurs
  - Free to move – Non-compete void in California (§16600 1872)
    - “Traitorous Eight” leave Shockley & then Fairchild

- **Cooperation, Even With Competitors**
  - Origin in regional amateur radio
    - 10-15% of US amateurs in California

- **100-year History of Success**
  - Over many product life cycles
  - Wireless a significant factor
    - Cell, WiFi, Bluetooth, GPS, satellite
    - Most important Apple product
Cultural Contrast – Ham Radio at MIT & Stanford

- **W1MX vs. W6YX – Representative Cultures, 1960**
  - W1MX: Caged amplifier vs. W6YX: Open
    - “FINE! Go do it!” vs. “Grandfather didn’t …” *
    - “Hewlett would climb in the window …” *

* O. G. Villard, Jr., W6QYT, W6YX Faculty Advisor 1950s-80s, Oral History Interview

- **Different Cultures – Insular vs. Cooperative**
  - East – Authoritative, rigid, insular, established
    - MIT: Venture investment “too risky … not consistent with prudence”
  - West – Open, cooperative, flexible, not risk-averse, rising
History – Amateur Radio at Stanford

- Callsigns & Stations

6CBK
1930s

W6YX
1960s

Today

Litton 6AO ('24), Scofield 6JK ('24) & Wentworth 6OI ('26)

First station to contact all continents

THE WATCHES AT LICK OBSERVATORY, MARCH 23 TO 21, 1926

BROWN, 6CBK; FOSTER, 6JK; WENTWORTH, 6OI; SCOFIELD, 6JK; INGEBRITSON, 6AI

 yielding | Stanford University
## Amateur Radio Strategy Examples I

- **Historic Careers Sparked by Amateur Radio**

<table>
<thead>
<tr>
<th>Name</th>
<th>License</th>
<th>Stanford?</th>
<th>Career</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cyril Elwell</td>
<td>Pre-1912</td>
<td>'07, AM '08</td>
<td>Founder, Federal Electric 1909 — Regional center of radio</td>
</tr>
<tr>
<td>Haraden Pratt</td>
<td>SKH / 6TM</td>
<td>UC ‘14</td>
<td>Federal Electric, Mackay Radio, ITT VP/GM — IRE President 1938</td>
</tr>
<tr>
<td>Ralph Heintz</td>
<td>6AUQ / 6RH</td>
<td>'20</td>
<td>Heintz &amp; Kaufman — Ship &amp; aircraft radio, Gammatron power tube</td>
</tr>
<tr>
<td>Herbert Hoover, Jr.</td>
<td>6SR / 6XH</td>
<td>'25</td>
<td>Aircraft radio (ARINC), United Geo — Air safety &amp; exploration</td>
</tr>
<tr>
<td>Phil Scofield</td>
<td>6JK</td>
<td>'24, Eng. '25</td>
<td>Heintz &amp; Kaufman chief engineer, Litton colleague</td>
</tr>
<tr>
<td>Bart Molinari</td>
<td>6AWT</td>
<td></td>
<td>Farnsworth TV Lab — Chief engineer,</td>
</tr>
<tr>
<td>Bill Eitel</td>
<td>6UF / W6UF</td>
<td></td>
<td>Eimac — Power tubes, 3M for WWII radar; Postwar FM &amp; TV</td>
</tr>
<tr>
<td>Jack McCullough</td>
<td>6CHE / W6CHE</td>
<td></td>
<td>Eimac — Co-founder 1934</td>
</tr>
<tr>
<td>John Woodyard</td>
<td>Maritime op.</td>
<td>Ph.D. '40</td>
<td>Stanford — Klystron; UC Lawrence Lab — Accelerators</td>
</tr>
<tr>
<td>David Packard</td>
<td>9DRV</td>
<td>'34, Eng. ‘39</td>
<td>Hewlett-Packard — Founder</td>
</tr>
<tr>
<td>Stan Kaisel</td>
<td>W9QBE / K6UD</td>
<td>MA '47, Ph.D. '50</td>
<td>RCA, Litton, Microwave Electronics Corp — Founder, CEO,</td>
</tr>
<tr>
<td>Tay Howard</td>
<td>W6HD</td>
<td>'55</td>
<td>Chaparral Communications — Founder, 1st private sat. dishes</td>
</tr>
<tr>
<td>Paul Flaherty</td>
<td>N9FZX</td>
<td>MS '89, Ph.D. '94</td>
<td>AltaVista search engine — Inventor</td>
</tr>
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### Amateur Radio Strategy Examples II

#### Nobel Laureates & Technology Successes

<table>
<thead>
<tr>
<th>License</th>
<th>Distinction</th>
<th>Career</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ernest O. Lawrence</td>
<td>9APC</td>
<td>Nobel Prize</td>
</tr>
<tr>
<td>Joe Taylor</td>
<td>K1JT</td>
<td>Nobel Prize</td>
</tr>
<tr>
<td>W. E. Moerner</td>
<td>WN6I</td>
<td>Nobel Prize</td>
</tr>
<tr>
<td>Albert H. Taylor</td>
<td>9YN</td>
<td>IRE Liebmann Prize</td>
</tr>
<tr>
<td>Merle Tuve</td>
<td>9NB</td>
<td>Presidential Medal</td>
</tr>
<tr>
<td>Masaru Ibuka</td>
<td>J3BB</td>
<td>Sony</td>
</tr>
<tr>
<td>Akio Morita</td>
<td>JP1DPF</td>
<td>Sony</td>
</tr>
<tr>
<td>Nolan Bushnell</td>
<td>W7DUK</td>
<td>Silicon Valley</td>
</tr>
<tr>
<td>Steve Wozniak</td>
<td>WA6BND</td>
<td>Silicon Valley</td>
</tr>
<tr>
<td>David Boggs</td>
<td>AB4XW</td>
<td>Silicon Valley</td>
</tr>
<tr>
<td>Phil Karn</td>
<td>KA9Q</td>
<td>Internet</td>
</tr>
<tr>
<td>Scott Redd</td>
<td>KØDQ/P4ØQ</td>
<td>National Medal</td>
</tr>
</tbody>
</table>
Some Representative Quotes

Joe Taylor: "While in middle school, I learned Morse code and became an amateur radio operator. This experience encouraged me onward" to the field of radio astronomy.

Akio Morita: “I built my own ham radio transmitter, when a youngster in school. It has always been my hobby as well as my business”

Scott Redd: "Ham radio was my window on the world that generated an interest in far-away places and a vision to do something beyond my home town. Electricity, electronics and especially, the electromagnetic spectrum, were key aspects. Being comfortable with technology -- having built kits, antennas and the like ... gave me a leg up."
Radio at Stanford – Terman Before WWII

- **Prof. Frederick Terman 6AE (‘20, Eng. ‘22, MIT Ph.D. ’24)**
  - 1919 Amateur radio 6AE, job at Federal
  - 1924 MIT Ph.D. under Vannevar Bush
  - 1925 Brings radio interest back to Stanford
  - 1927 Communications Laboratory established in EE
  - 1928 W6YX licensee
  - 1932 *Radio Engineering* text published
  - 1934 Concern for lack of area jobs for grads
    - Student visits to local firms
  - 1937 Chair, EE; text 2nd edition, collaboration & friendship with Hansen
    - Small department – Grad students to physics
    - W6YX in his communications lab – Faculty advisor
  - 1938 Industrial funding – Packard & Hewlett assistantships
    - Sperry $ for Litton patent idea, Packard RA under R. Varian & Litton
  - 1939 Facilitates Hewlett-Packard founding
  - 1941 IRE President
  - 1942 Recognized national radio expert – Called to form WWII government lab
Radio at Stanford – Hansen Before WWII

- **Prof. William W. Hansen 6CSY (‘29, Ph.D. ’32, MIT Postdoc ‘34)**
  - 1924 Amateur radio 6CSY, high-school grad, too young for college
  - 1927 Stanford physics undergrad, X-rays by electron bombardment
    - Coaches Russell Varian in electronics
  - 1929 Varian roommate, graduates, appointed lecturer
    - Impresses summer faculty, Depression begins
  - 1931 High-voltage X-rays – Learns of UC resonant cyclotron
  - 1932 Quarter at Caltech, Stanford Ph.D.
  - 1933 MIT postdoc under Philip Morse, his mentor in EM theory
  - 1934 Returns to Stanford as Professor – Proposes resonant electron acceleration
  - 1935 Invents cavity resonator for electron acceleration
  - 1937 Invents microwave cavity klystron, with Varian brothers, collaborates with Terman
  - 1938 Sperry funding for new patents – More $ than all Stanford physics history
  - 1939 Blind landing system, array antennas, IRE symposium reveals klystron
  - 1940 First microwave Doppler radar – Consults on MIT radar
  - **1941 Recognized national microwave expert – Called to WWII government lab**
Radio Segments – Stanford’s “Steeples”

- WWII Experience – Terman & Hansen in Cambridge 1941-1945
  - Terman – Founder, director of WWII Radio Research Lab at Harvard
    - Countermeasures against UHF radar – Classified ECM work & customers
    - Manages staff of 800 (100+ hams) & learns Harvard university finance
  - Hansen at WWII Radiation Laboratory at MIT (Microwave radar)
    - Lectures weekly – Writes 1200-page microwave radar “bible”
    - Also at Sperry – Invents pulse Doppler radar among 70 patents
  - They learn: Government will continue radio research funding postwar

- Postwar – Stanford Radio & Microwave Segments 1945-1960s
  - Terman – Clients fund key RRL staff at Stanford EE lab
    - Stanford flourishes in government-funded radio research in new lab
  - Hansen – Founder, Director of Microwave Laboratory, Terman guidance
    - Gov’t. funded NMR, megawatt klystrons, traveling-wave linear accelerators
    - Legacy: $100M for SLAC in 1960s – Quarks & other basic particles
  - “Steeples of Excellence” – Key new faculty attract funded radio projects
  - Microwave & ECM spinoff companies populate Stanford Industrial Park
Radio at Stanford – Villard, My Mentor

- **Prof. O. G. (“Mike”) Villard, Jr., W6QYT (Eng. ’42, Ph.D. ‘49)**
  - 1930 Amateur radio W1DMV
  - 1931 Hotchkiss School W1FCG – Year in Europe
  - 1934 Yale – From publishing family, majors in English
  - 1937 Essay prize – Buys Terman book, wants engineering
  - 1938 Graduates, comes to Stanford to study under Terman
    - Meets Hewlett, Packard & Hansen
  - 1941 Radio receiving project & freq. scan ionospheric sounder
  - 1942 Radio Research Laboratory (RRL), with Terman
  - 1946 Stanford Prof. – Meteor scatter & single sideband, QST articles
    - 1948 First amateur SSB contact, from W6YX
  - 1949 Ph.D. & faculty advisor, W6YX
  - 1952 Ionospheric backscatter – QST article
  - 1957 IEEE Liebmann Award; Transequatorial backscatter
  - 1958 Director of Stanford RadioScience Laboratory
  - 1959 Over-the-horizon ionospheric radar – QST article 1980
  - 1961 Elected to National Academy of Sciences
My Own Journey to Stanford & Silicon Valley

- My Life in Radio
  - 1941 Radio! 1952 Amateur radio W6QHS – “I've never worked a day in my life”
    - 1950 Because photons have zero-rest-mass, Communications >> Transportation
    - 1954 Pacifico Radio Club K6BAG – Win FD, learn projects & managing
  - 1951-54 Radio repair, the antenna job I missed ➔ the bank ➔ Hughes hams
    - Stanford & W6YX – attracted by Villard’s 1952 QST Backscatter article
    - MIT & Stanford theses on nonlinear frequency multipliers (later solve instabilities)
    - Circuits for Villard projects, maintain W6YX & outfit Villard back-yard lab
  - 1955-64 Hughes Aircraft – Pulse Doppler radar & spacecraft signal sources
    - Advancement limited, Villard introduces me to Stanford spinoff
  - 1964-68 Applied Technology, Inc. (ATI) – Radar countermeasures, $2M - $30M
    - Director of Microwave Laboratory – Low-phase-noise stable radar signal sources
    - ATI sold to Route 128 firm – Villard writes me a blank check for new startup
  - 1968-1993 California Microwave, Inc. – Villard & Terman investors, Saunders 1st customer
    - Phase noise & frequency multipliers – Radar, microwave relay, satellite, WiFi (802.11 member)
    - Fund startups in same segments, grow from components ➔ systems
  - 1993- Stanford – Teaching, writing, angel investments, W6YX, HC8N
California Microwave, Inc.

- Wireless Infrastructure
- Founded 1968
- Low-noise source 1968
- Radar 1969
- Microwave radio 1972
- Satellite 1976
- Avionics 1979
- Drones 1980
- WiFi 1991
- I retired 1993
- Divisions sold 2001
Strategic Paths – Based on Radio

- **Individual Examples – Radio Made the Difference**
  - Succeeded in segments where they were differentiated by radio
  - Amateur-radio interest & experience was the spark

- **Early Bay Area Companies – Avoided RCA**
  - Avoided RCA strengths – Focused on segmented radio products
  - New postwar technologies not RCA – UHF, microwave, semiconductors
    - Heintz & Eimac win key litigations

- **Terman, Hansen & Stanford’s Emergence**
  - “Steeples of Excellence” – Segment by radio technology & clients
  - Differentiation through targeted faculty recruitment

- **Villard as My Sponsor**
  - His youthful interest with ionospheric radio led to all his advances
  - My own radio background made for fruitful relationship
    - Radio basis of California Microwave strategies

- **History Examples Confirm Strategic Thesis**
  - Individual & institutional successes have flowed from amateur radio
But What About Now? “Do People Still Do That?”

- Yes, but Things Have Evolved
  - Digital, optical technology dominate
  - More than ever – Wireless is the key to mobility

- Amateur Radio Unique Experiences – Career Advantage
  - Hands-on experimenting – The original maker culture
  - Experience cooperation, competition, project management
  - Understand noise, dynamic range, antennas, propagation, systems

- Amateur Radio – Still a Special Path to Mentors & Sponsors
  - W6YX – Unique community, equipment, freedom

- It’s Up to You – Actively Seek Out Opportunities
  - There’s more in wireless – IoT, Nano energy harvest, biomedical
Links for Reference

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  > https://w6yx.stanford.edu/images/Talks/Lessons_from_Silicon_Valley_History_Rev2_sm.pdf

- The Uses of Amateur Radio

- A Personal View of Silicon Valley: The Central Role of Radio (pp. 7-14)

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  › http://faculty.salisbury.edu/~sbadams/research.htm

- Adams "Arc of Empire: The Federal Telegraph Company, the U.S. Navy, and the Beginnings of Silicon Valley”
Books and Courses

- Course: Perspectives on Silicon Valley
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Author Note: There are many other presentations, papers, books and online references about the history of Silicon Valley. The author acknowledges access to many more than are listed here, as well as in-person access to archives at Stanford, MIT, National Archives, Hagley Library, and other online archives too numerous to detail here. Also, discussions with authors and archivists are gratefully acknowledged, as is the opportunity to experience personally over sixty years of the emergence of Silicon Valley.
Oral History Interviews and Biographical Memoirs

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