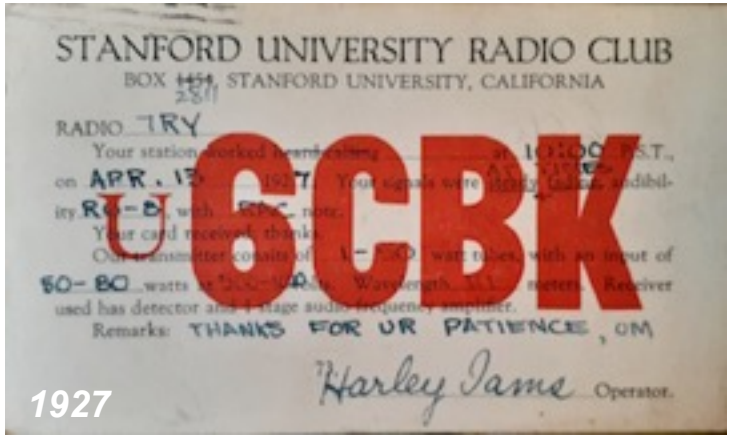
Amateur Radio at Stanford

Its Role in Competitive Advantage

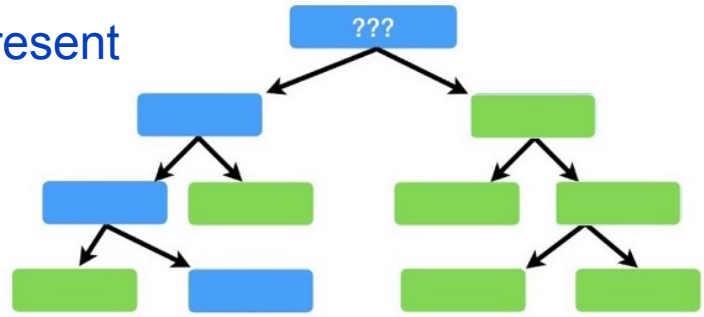


D. B. Leeson, W6NL

W6YX via Zoom

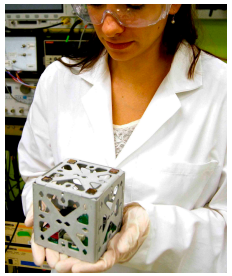
History – A Guide to the Future

- **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

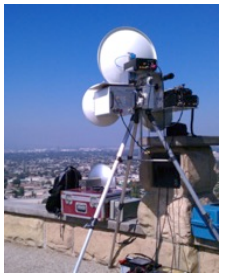


Strategy Ideas & Examples

- **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

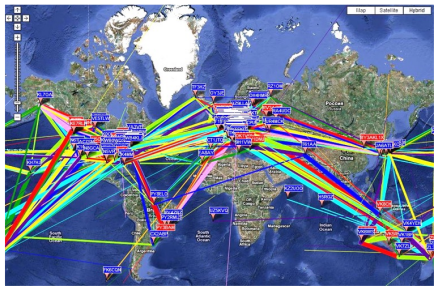


CubeSat



Microwave

Moonbounce "EME"



Amateur Digital Worldwide

CubeSats in space

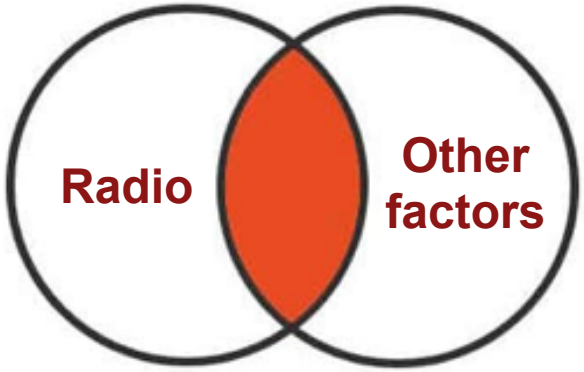
Elements of Competitive Strategy

- **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

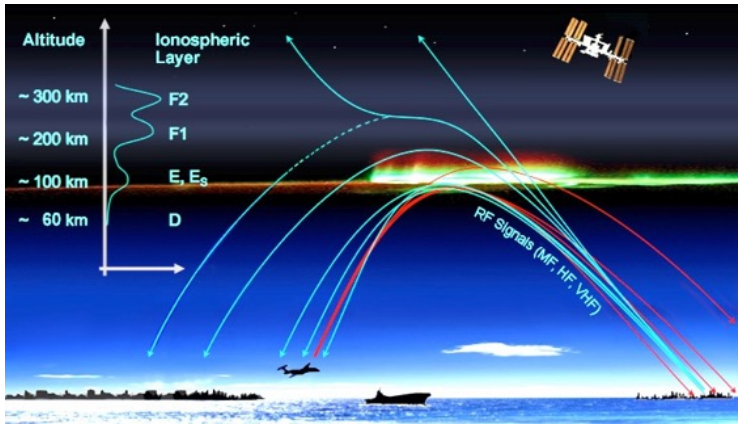
- **Additional Factor Creates More Focused Segment**
  - Restricts field to intersection of capabilities
  - Greatly reduces population of competitors



- **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

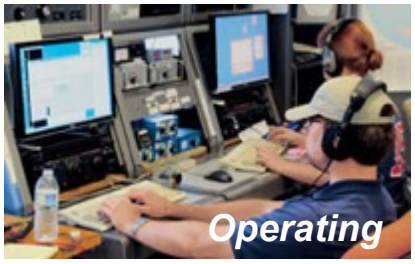
- **Propagation Physics**
  - › Geometric path loss
  - › Atmospheric absorption
  - › Reflection, refraction, diffraction
  - › Wave interference – Multipath fade
  - › Ionosphere – Solar interaction



- **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

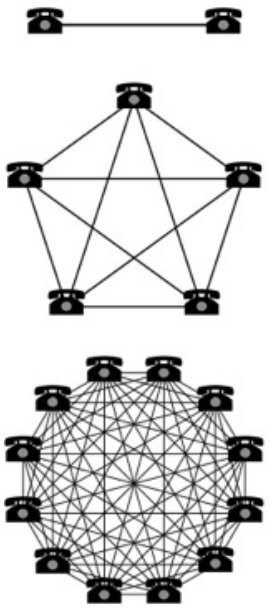
Amateur Radio – Learning Techniques Hands-on

- **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



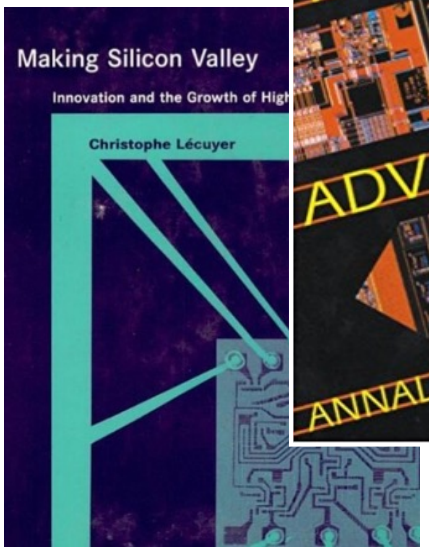
Radio Competitive Environment 1920s-1930s

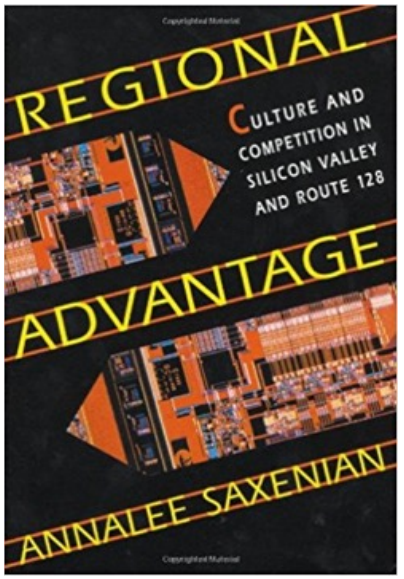
- **SF Bay Area – Unique Wireless Situation**
  - › Rich region, but no manufacturing – Shipping & port critical
  - › Shipping companies fostered radio – Created interest & opportunity
- **The RCA Monopoly – Unintended Consequence of Patent Pool**
  - › Post WWI – Radio (RCA), telephone (AT&T) & aircraft 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

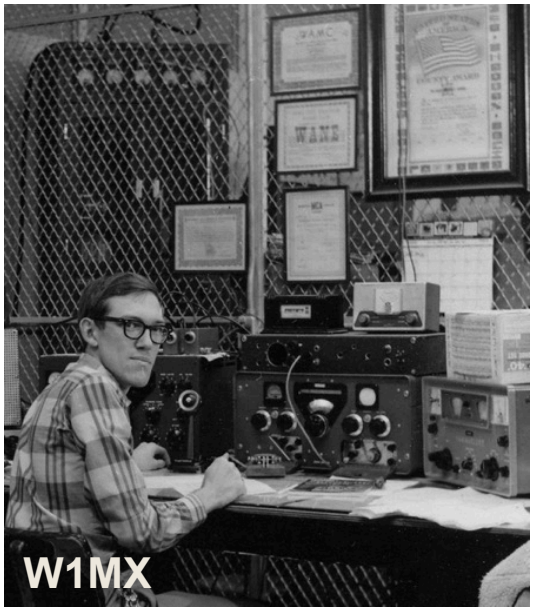
- **Regional Culture – Favors New Enterprise Formation**
  - › Not risk-averse in career, investment – Flexible local support
  - › Shared information & equity – Employees as partners, owners
    - Reliance on younger managers, entrepreneurs
  - › Free to move – Non-compete void in California (§16600 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 …" *

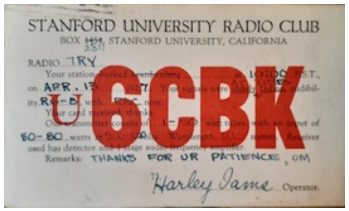
* O. G. Villard, Jr., W6QYT, W6YX Faculty Advisor 1950s-80s, Oral History Interview

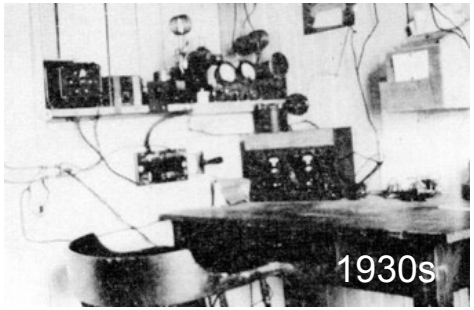
- **Different Cultures – Insular vs. Cooperative**
  - East – Authoritative, rigid, insular, established
    - MIT: Venture investment "too risky … not consistent with prudence"
  - West – Open, cooperative, flexible, not risk-averse, rising

History – Amateur Radio at Stanford

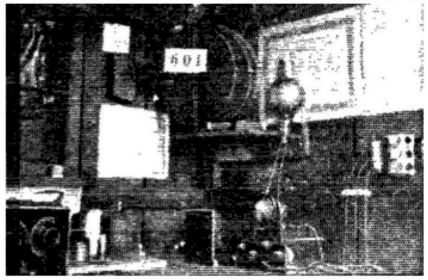
- **Callsigns & Stations**

6CBK | Stanford University Radio Club. | Box 656, Stanford University, Calif...

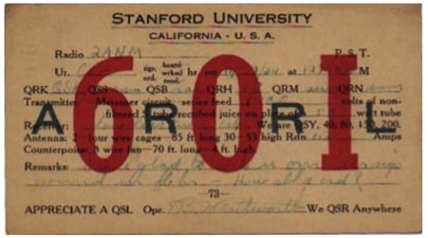


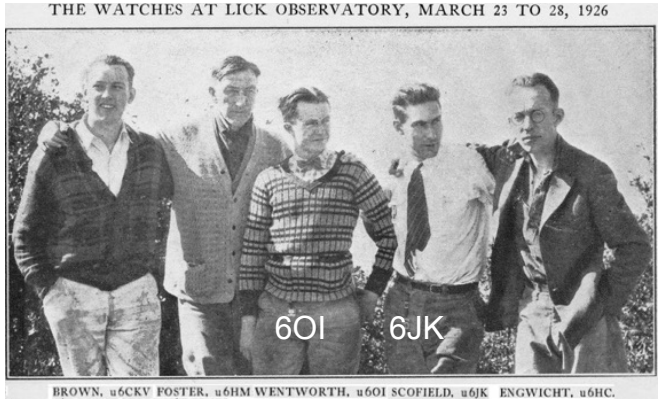


Litton 6AO ('24), Scofield 6JK ('24) & Wentworth 6OI ('26)



First station to contact all continents





Amateur Radio Strategy Examples I

- **Historic Careers Sparked by Amateur Radio**

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

Amateur Radio Strategy Examples II

- **Nobel Laureates & Technology Successes**

	License	Distinction	Career
Ernest O. Lawrence	9APC	Nobel Prize	Cyclotron — Inventor, UC Berkeley 1929
Joe Taylor	K1JT	Nobel Prize	Pulsars, LIGO, WSJT & FT8 — Radio astronomy; Princeton
W. E. Moerner	WN6I	Nobel Prize	Molecular imaging — IBM, UCSD, Stanford (W6YX)
Albert H. Taylor	9YN	IRE Liebmann Prize	Director, Naval Research Lab — Skip distance, ionosphere, radar
Merle Tuve	9NB	Presidential Medal	Pulsed ionospheric sounder — Inventor 1925
Masaru Ibuka	J3BB	Sony	Founder, mentor
Akio Morita	JP1DPF	Sony	Founder, CEO — Pocket radios, Walkman, TV, recorders
Nolan Bushnell	W7DUK	Silicon Valley	Atari
Steve Wozniak	WA6BND	Silicon Valley	Apple Computer
David Boggs	AB4XW	Silicon Valley	Xerox PARC — Ethernet Co-inventor
Phil Karn	KA9Q	Internet	Bell Labs, Qualcomm — Internet protocol, from AX25
Scott Redd	KØDQ / P4ØQ	National Medal	Admiral, US Navy — Cmdr. 5th Fleet; National intelligence

Amateur Radio Strategy Examples III

- **Some Representative Quotes**

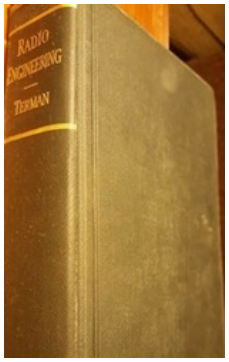
Joe Taylor: "While in middle school, I learned Morse code and became an amateur radio operator. This experience encouraged me onward" to the field of radio astronomy.

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

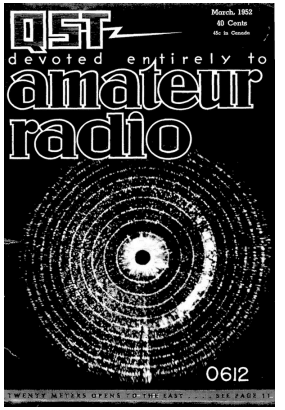
- **Prof. William W. Hansen 6CSY ('29, Ph.D. '32, MIT Postdoc '34)**
  - 1924 Amateur radio 6CSY, high-school grad, too young for college
  - 1927 Stanford physics undergrad, X-rays by electron bombardment
    - Coaches Russell Varian in electronics
  - 1929 Varian roommate, graduates, appointed lecturer
    - 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

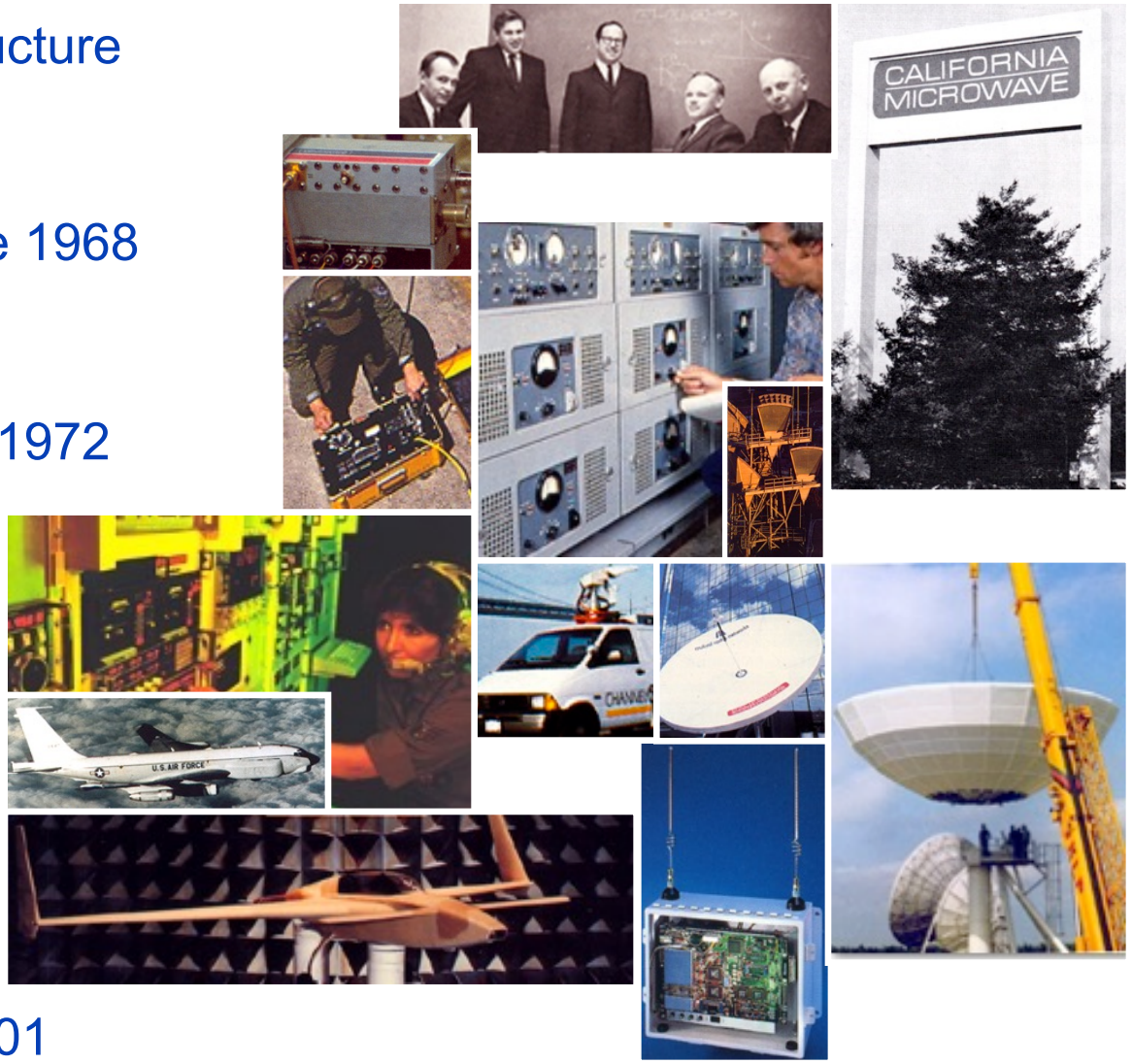


My Own Journey to Stanford & Silicon Valley

- **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
  - 1954-58 Caltech, 1958-59 MIT, 1959-62 Stanford
    - 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
    - W. J. Saunders sponsors for NASA/IEEE phase-noise group – Journal papers 1964-71
    - 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

- **Lessons from Silicon Valley History**
  - https://w6yx.stanford.edu/images/Talks/Lessons_from_Silicon_Valley_History_Rev2_sm.pdf
- **The Uses of Amateur Radio**
  - https://w6yx.stanford.edu/images/Talks/The_Uses_of_Amateur_Radio_Rev2_sm.pdf
- **A Personal View of Silicon Valley: The Central Role of Radio (pp. 7-14)**
  - https://www.radioclubofamerica.org/wp-content/uploads/2015/07/RCA_2016_Proceedings_Spring_public_lowres.pdf
- **W. W. Hansen (1909-1949): Microwaves from Stanford to Silicon Valley**
  - https://ethw.org/w/images/9/9c/Presentation20160210-Leeson.pdf at https://ethw.org/William_W._Hansen
- **Microwaves and Silicon Valley**
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- **Gillmor "The 'Prehistory' of Silicon Valley"**
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- **Leslie “How the West Was Won: The Military and the Making of Silicon Valley”**
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