



Outline for this evening

- **The early years:** Vacuum Tubes, Radio
 - The People; the Companies, the Culture
- **The War Years:** Klystron, Magnatron
 - Radar, electronic countermeasures
- **The Post-War Years:** Improvements, medical use, communications
- **The '50's and '60's:** Transistor & IC
 - Local design: Intel, various Intel products, the working environment
- Questions for the Panelists (*use form*)

Before 1900 ...



The Santa Clara Mission

"Valley of the Heart's Delight"



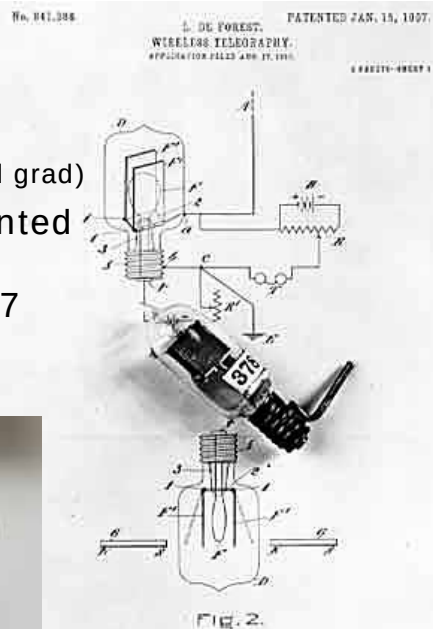
Let's Go Back ...

■ Federal Telegraph

- Formed in 1909 in Palo Alto (by a Stanford grad)
- **Lee de Forest** invented the audion oscillator and amplifier in 1907
- Pioneered continuous-wave radio



De Forest tube



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

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
- Desire to replace expensive telegraph lines, undersea cables with the new "wireless" technology
- Brought frenzy of activity, funds to S.F. Bay Area



William Eitel

- Took shop class 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"



Bill Eitel in 1941 (Photo courtesy of Dave Atkins, W6VX)

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 hi 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's Mechanical Engineering dept:
 - Small department (3 instructors)
 - Classes with strong practical flavor
 - BS-Mechanical Engineering in 1924
 - Grad work in communication engineering
 - 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
 - Several military bases; US Navy presence
 - Shipping companies; radio operators
 - Over 1,200 licensed amateurs
 - **10 percent** of US total (a **bubble**)

Ham Radio Subculture

- **Camaraderie** and intense sociability
 - A way to make friends
 - Communicating "over the air," 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**"

Following our Entrepreneurs ...

- Eitel, Litton, McCullough, ham friends
 - Learned about **vacuum tubes**
 - Built their own equipment, parts
- Made notable contributions
 - 1924: Litton and Stanford radio club made **first contact** with Australia, New Zealand
 - 1928: Eitel pioneered **10-meter waves** (30 MHz) - transcontinental communication

The Tube Business

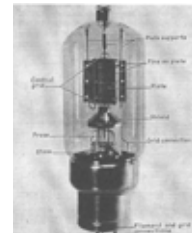
- General Electric, Westinghouse, AT&T
 - All East Coast companies
 - Developed hi-power transmitting tubes in early 1920s
 - Difficulties in producing consistent, reliable
 - Required precise machining, glass blowing (Pyrex)
 - Exotic materials, sophisticated sealing techniques

Following our Entrepreneurs ...

- **Litton** got local job through ham friend:
 - Research at **Federal Telegraph**
 - Built to 60 engineers and scientists
 - 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
 - **RCA** set up by GE, US Navy to ensure US dominance
 - RCA, GE, Western Electric, and Westinghouse
 - **Exclusive cross-licensing** of 2,000 patents
 - Sole producers/distributors of power-grid tubes
 - Refused sale to Bay Area firms
 - Threats to RCA's domination
- So both companies developed triodes
 - Litton, Eitel headed their tube shops



Heintz and Kauffman
354 Power Triode Tube

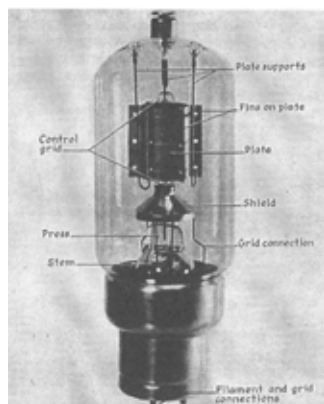
Tube Shops' Challenge

- Design around ~250 RCA patents
 - Enormously difficult task (*Samsung vs Apple case*)
- Hired locally (many 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 (> reliability)
- More reliable, longer life than RCA's tubes
- **Key:** Didn't infringe RCA's patents

The Ham Radio Market

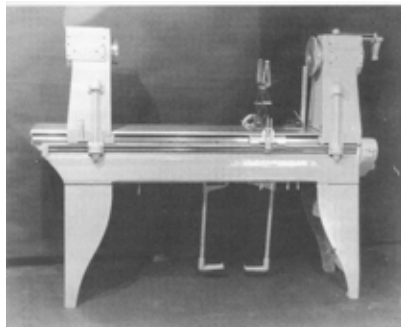


Heintz and Kauffman 354
Power Triode Tube



New Processes, Equipment

- Litton **invented** the glass lathe
 - For assembly, glass blowing, and sealing
 - Make complex tubes in large quantities
 - Allowed high repeatability, precision



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 San Francisco
 - Eitel and McCullough brought their know-how
 - 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 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;

Like today's Hackathons, Open Source software

The US Depression

- 1936: **Frederick Terman*** asked Litton to join Stanford EE department 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



Start of University/Industry cooperation

* Built his first radio receiver at 13; 6XH with HH Jr; turned this hobby into a career.

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 transmitting tubes
 - Only Eimac's best tubes worked at the high voltages and frequencies

Post-War Realignment

- RCA, others focused on TV, broadcast
- Eimac developed new line of better tubes
 - Power tetrodes for high frequencies
- FCC's surprise shift of **FM radio** to VHF
 - 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
 - They bought Eimac products and resold them under their own names

The “Big Dog” was now Silicon Valley!

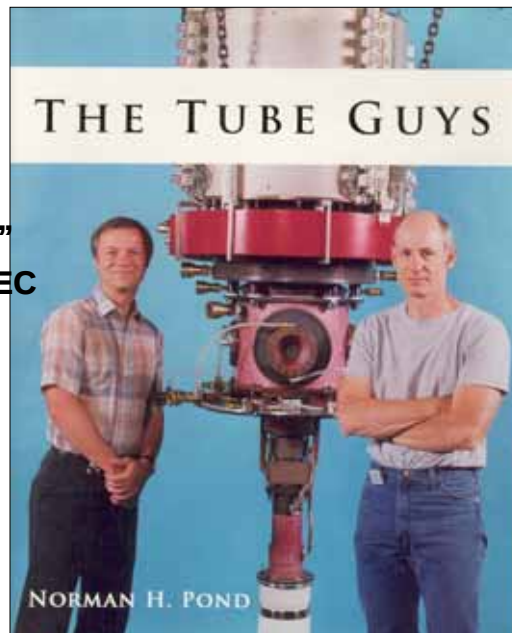
Questions for our Panel

- Please print your question or story on the sheets provided and pass them to the moderator
- Some of these will be addressed to our panelists after the presentations

Norm Pond

- U-Mo at Rolla
- Became a "Tube Guy"
- Hughes; Teledyne-MEC
- Varian Associates (president)

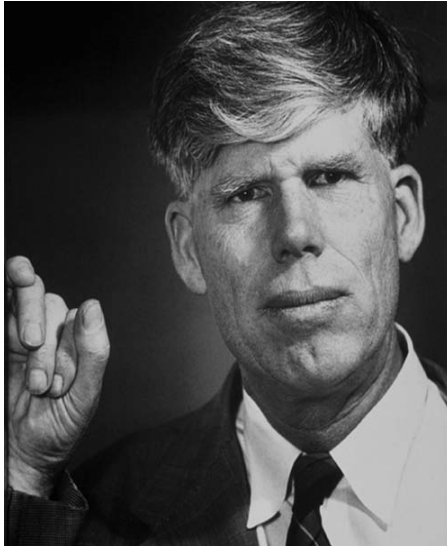
2008,
ISBN 978-0-9816923-0-2
www.russcochran.com



Scary Times



Russ & Sig Varian



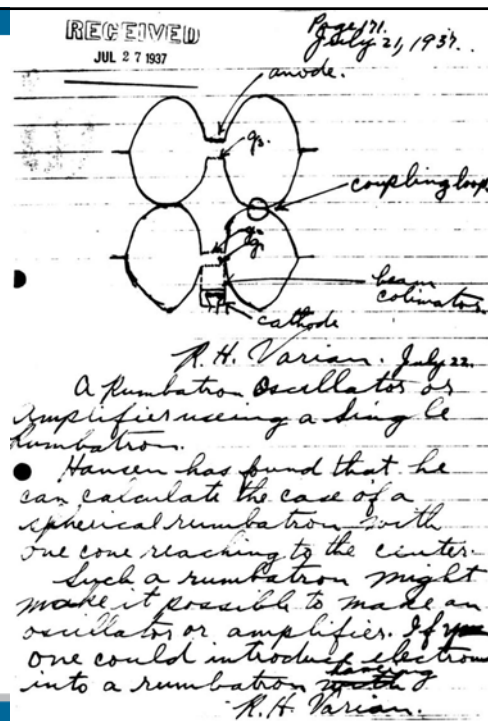
Varian Brothers Thought Process

- Aircraft pose major military threat (how to detect?)
- Aircraft need improved navigation
- We need to find solutions to these needs
- We should start a laboratory
- Whoops We need help
- Back to Stanford

Russ Varian and Bill Hansen



The concept that became known as the "Klystron" described in Russ Varian's Lab Book

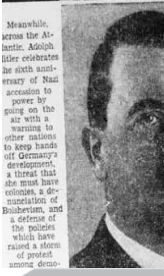


Palo Alto Times Jan. 30, 1939

TWO ANNIVERSARIES



For Franklin Delano Roosevelt it was a birthday—his fifth—and the occasion for a nation-wide rally in behalf of a great humanitarian movement, the campaign against infantile paralysis. Dimes poured into the White House from individuals in every part of the nation while movie and stage stars gathered in Washington and other cities for birthday balls.



Meanwhile, across the Atlantic, Adolf Hitler celebrates the sixth anniversary of Nazi accession to power by going on the air with a warning to other nations to keep hands off Germany's development, a threat that she must have colonies, a disputation of Bolshevism, and a defense of the policies which have raised a storm of protest among democ-

Palo Alto Times
AN INDEPENDENT NEWSPAPER

47th Year—No. 25 PALO ALTO, CALIFORNIA, MONDAY EVENING, JANUARY 30, 1939

Hitler Warns: Let Us Alone!

Denies Plan To Attack Other Lands

Anniversary Address Is Denunciation Of Bolshevism

By LOUIS F. LOCHNER
BERLIN, Jan. 30 (AP)—Adolf Hitler, in his address to the Reichstag on the occasion of the sixth anniversary of the Nazi rise to power, "It often does not believe this it does not matter and does not impair our rights," he continued.

He disclaimed any idea that Germany needed colonies "to set up armies there."

"I need not assure you that in the future also we shall tolerate no attempts at interference in matters concerning us alone with the purpose of preventing

NEW STANFORD RADIO INVENTION HERALDS REVOLUTIONARY CHANGES



By JULIUS L. JACOBS
An invention so breath-taking in its possibilities, that it may alter the future radio development of aeronautics, as well as telephone, telegraph, and television communication, was announced today by Dr. Sigurd Varian, president of Stanford University.

Born in the brain of a Pan-American Airways pilot as he flew the Latin-America route, the invention was developed and perfected in the physics department of Stanford University.

The university holds the patent on the amazing new apparatus, which has harnessed the forces of ultra-short-wave radio transmission. These same patent rights have been turned over to the Sperry Gyroscopic Corporation, which will make possible the commercial development and production of the new discovery in radio technique.

By a \$25,000 gift to the Stan-

Six Killed In Blizzard

CHICAGO, Jan. 30 (AP)—A paralyzing blizzard whipped across the southern Great Lakes states and the Ohio valley today, burying Chicago under one of the heaviest snowfalls on record.

Forecaster C. A. Donnel said if the storm continued all day the city might have snow totaling more than the existing record of 19.2 inches in March, 1899. The fall was one foot by noon.

Six deaths were recorded in the storm area. Among them was Samuel P. Manning, 66, general secretary of the Chicago board of health, who apparently died of over-exertion.

There were three elevated train collisions in Chicago in which 50 persons were injured. In each instance a heavily loaded train crashed into the rear of another.

'Klystron' Harnesses Ultra Short Wave Transmission

By JULIUS L. JACOBS
An invention so breath-taking in its possibilities, that it may alter the future radio development of aeronautics, as well as telephone, telegraph, and television communication, was announced today by Dr. Sigurd Varian, president of Stanford University.

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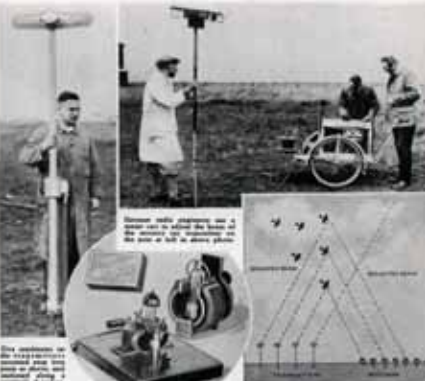
Prison Farm Recommended By Grand Jury

CHICAGO, Jan. 30 (AP)—A grand jury today recommended that the city of Chicago build a prison farm on a 1,000-acre tract near the city.

The jury, which heard testimony from several witnesses, including a former inmate of the city prison, found that the city had been negligent in its handling of the land.

The jury also recommended that the city build a new prison on the tract, and that it should be used for the re-education of prisoners.

MYSTERY RAYS "SEE" Enemy Aircraft



AMERICAN and German War Departments announced simultaneously new experiments of "seeing" enemy aircraft through fog, clouds, or dark, at distances of up to fifty miles. First tests in this country are being held at the Lighthouse Station near Highlands, N. J., by the War Department, the details of the invention being closely guarded by military police.

No larger than a penny match box is the German mystery ray machine, a highly-perfected ultra-short wave radio transmitter.

Groups of these transmitters, stationed along the border of a country and adjusted to send their "beams" beams into the sky at a fixed angle, could be used for air defense. The

Others Were Trying to Develop RADAR

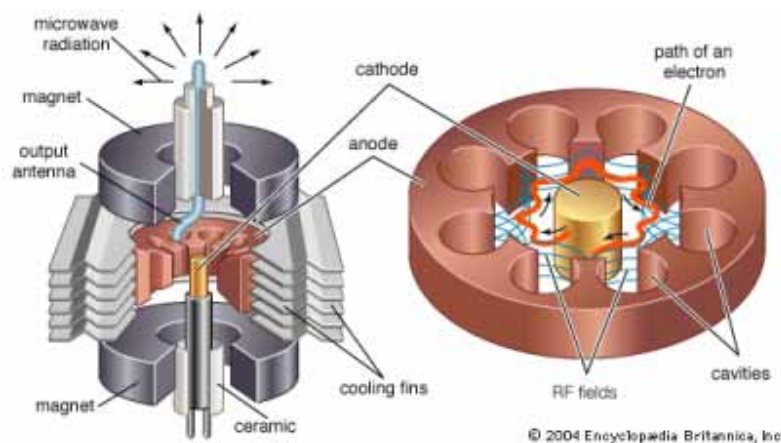
**Modern
Mechanics
October
1935**



**John
Randall &
Harry Boot**

**Inventors of
the Cavity
Magnetron**

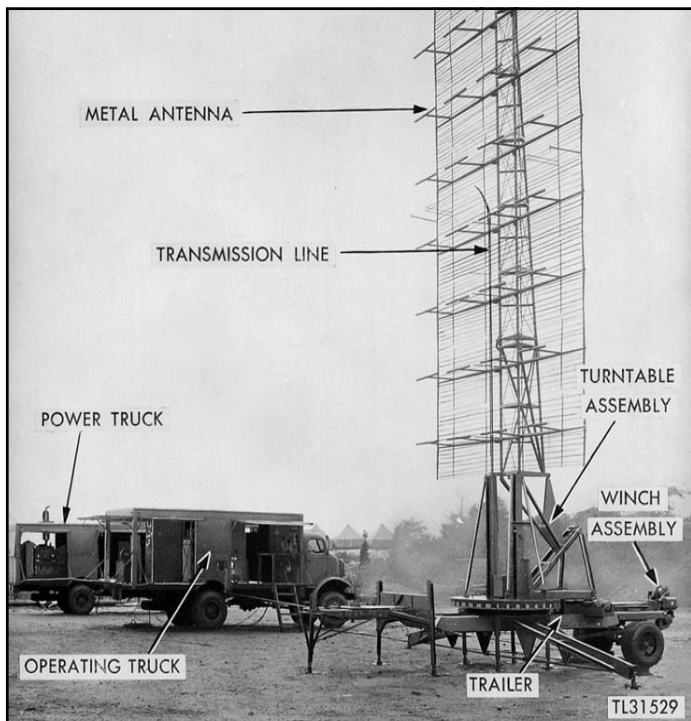
Circa 1939



Microwave Magnetron Operation

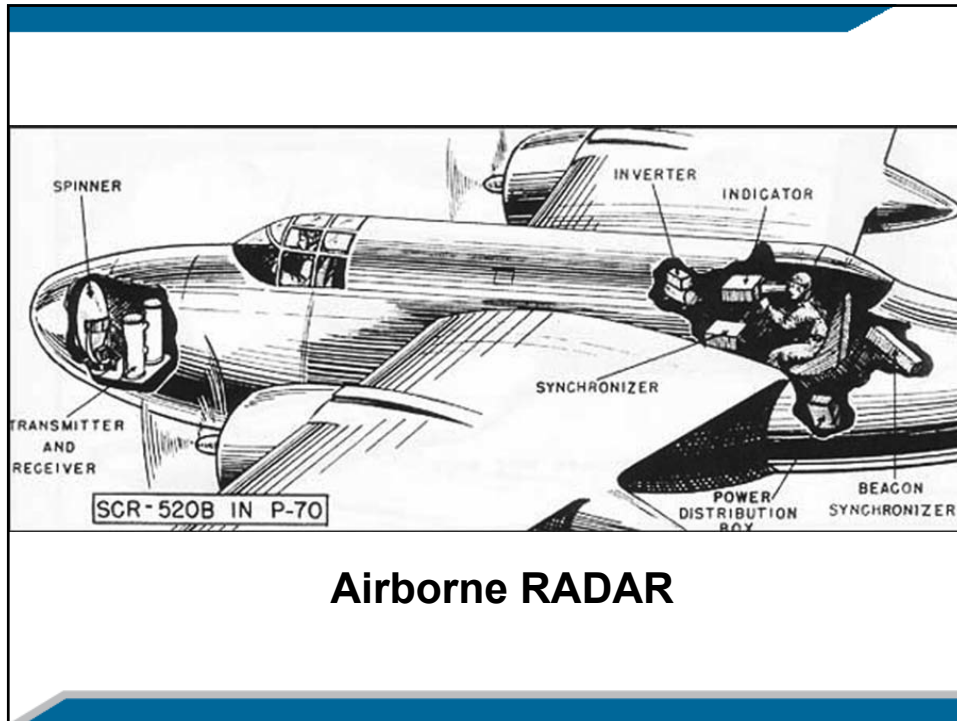


Desperate Times in London



SCR- 270

Ground Based RADAR



The Original Varian Staff

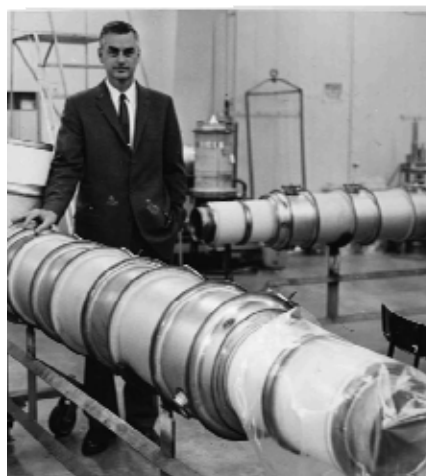


The Original Varian Staff, from left to right: Russ Varian, Sig Varian, Marvin Chodorow, Dorothy Varian, Richard Leonard, Esther Salisbury, Ed Ginzton, Fred Salisbury, Donald Snow, Myrl Stearns

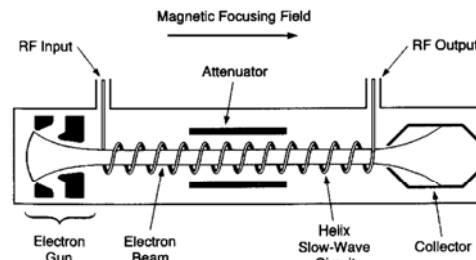


First Varian Building, San Carlos, CA

Klystrons of Many Shapes and Sizes



Rudolph Kompfner Invents
Traveling Wave Tube in 1944



RADAR & ECM were Major Factors in Cold War



*F-16 Equipped with ALQ-119 Pod
Mounted on Fuselage*



*U.S. Navy Ship Equipped with
Aegis Radar Launching Missile*



B-52, with Lots of ECM Gear

Linear Accelerators



Students Kaisel, Carlson, Kennedy, with Bill Hansen and Early Linear Accelerator



First Patient to be Treated with the Medical Linear Accelerator, 1956



Varian Medical Systems Executives with CLINAC, Klystron and Accelerator

Microwave Ovens



"RADAR Range" Circa 1946

Bad Marketing, Negative Reaction to RADAR / Fear of Radiation..



Why did Silicon Valley Win?

- **Eastern companies were large with lots of resources, and lots of bureaucracy, with "Systems" mentality**
- **Eastern companies treated microwave tubes as extension of receiving tubes**
- **Silicon Valley companies had limited resources, small staff, made own equipment ... treated microwaves as a new era / no need to use past practices**
- **East had pervasive labor unions**

Silicon Valley Advantages

- **People with various skills**
- **Process Know-How / Discipline**
- **Infrastructure**
- **Precision**
- **Cleaning**
- **High Vacuum**
- **High Temperature**
- **High Voltage**
- **RF Expertise**
- **Materials**
- **.....**

- **Start of the Semiconductor Era**

Silicon Valley in the 1950's

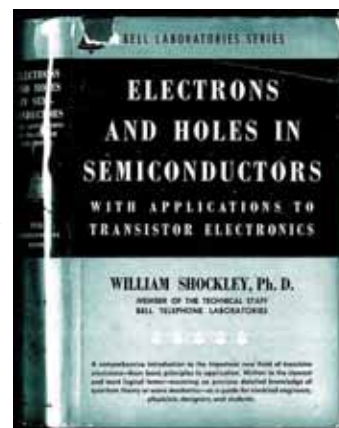
- William Shockley invented transistor while at Bell Labs
Raised in Palo Alto; MIT
- Point-contact Germanium device
- Developed to replace vacuum tubes

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



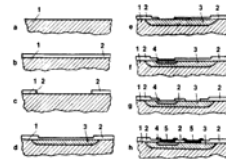
Silicon Valley in the 1950's

- William Shockley left the East Coast, returned to CalTech
 - His mother, graduate of Stanford, lived here
 - Funded by Beckman
 - 1955: Shockley Semiconductor in Mt View
 - “Traitorous 8” **left** him in 1957 to **form** Fairchild, with first real venture capital funding (Sherman 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** 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

SILICON VALLEY IN THE 1960s

Marcian E. "Ted" Hoff

- Attended RPI; BS in Electrical Engineering
- NSF Fellowship: MS and PhD at Stanford
- Intel employee #12

Pre 1960 Events

- Core Memory—1940s & 1950s
- Ampex/Video Recording 1955
- IBM, San Jose and RAMAC 1956
- Stanford Industrial Park 1950s
- Shockley Semiconductor 1956
- Fairchild Semiconductor 1957
- Integrated Circuit 1959

How I Got Here

- Rochester, NY—GRS & transistors—1954
- BEE Rensselaer Polytechnic Institute 1958
- NSF



Related Political Issues

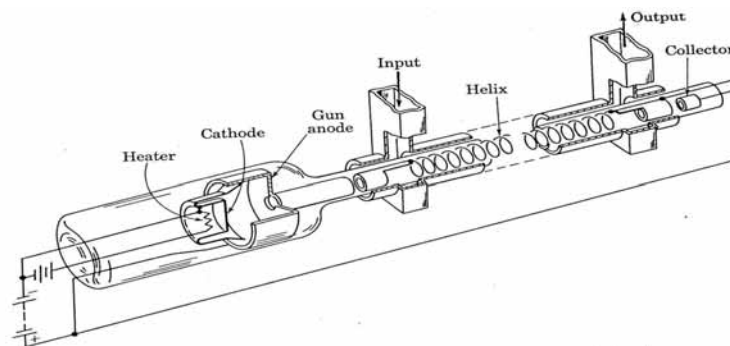
- Dwight Eisenhower as president
- Recession—1958—Unemployment rises from 4.1 (1956) to 6.8 percent
- Tough job market
- Impact on RPI Graduating Class
- Viet Nam—Impact to come

How I Got Here—Part 2

- Stanford University 1958-1962
- Stanford to San Jose, orchards all the way
- Solid state electronics
- 1959—Last summer in Rochester, NY
- Adaptive systems
- The memistor
- Research Associate 1962-1968

Electronics Research Laboratory

- On the Stanford campus
- Electroplating shop—microwaves and lasers
- Analog memory device
- Glassblowers and TWTs
- Connections to local companies



1960s

- IBM 1620 computer, then IBM 1130
- Punched cards as input method
- Data storage costly—core memory, paper and magnetic tape
- 1130 had removable cartridge disk
- Data transmission capability very limited

Microwave Technology

- Lenkurt, founded 1944, GTE 1959, >4000 employees in mid 1960s
- Farinon, founded 1958—all solid state 2 GHz radio, 1965
- AvanteK, founded 1965, microwave ICs
- Used for land, satellite communication

Stanford University

- Big Dish Antenna
- Government sponsored research
- Impact of Viet Nam War
- Campus politics
- Fate of government research

New Semiconductor Companies

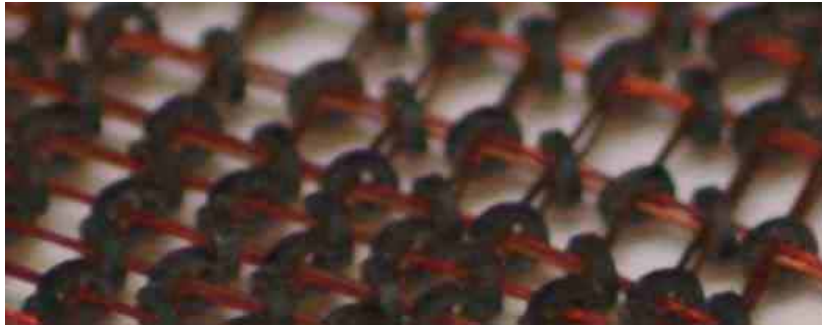
- National Semiconductor 1959
- Rheem 1959
- Clevite 1960
- Electroglas 1960
- Raytheon 1961
- DW Industries
- Signetics 1961
- Teledyne 1961
- Molectro 1962
- General Microelectronics 1963
- Avantek 1965

More New Semi Companies

- Union Carbide 1965
- AMI 1966
- Applied Materials 1967
- Electronic Arrays 1967
- Intersil 1967
- AMD 1968
- Cermetek 1968
- Intel 1968
- Monolithic Memories 1968
- PMI 1968
- Four Phase Systems 1969

Intel Corporation

- Founded by Bob Noyce, Gordon Moore, July, 1968
- Goal—Semiconductor memory to replace cores



Intel Starts Up

- September, 1968, Mountain View
- Schottky bipolar process
- Silicon gate MOS process
- 3101 16x4 bipolar memory
- 1101 256x1 MOS SRAM
- 3-transistor cell DRAM
- Moore's law

Busicom Project

- To generate revenue
- Agreement, April 1969
- 60,000 calculator sets
- Price not to exceed \$50/set
- Engineering team brings specifications, June 1969

The Microprocessor

- Busicom sets too complex, too expensive to produce at \$50
- Authorization: try to simplify
- Suggestions rejected by Busicom engineers
- Ultimately leads to 4004 architecture
- September 16, 1969 letter
- Meeting at Intel—Intel approach chosen

Microprocessor Story

- Many authors have told the tale
- Some have done well, some just OK
- One in particular not to be believed
- Dozens of errors, outright fabrications
- Many significant omissions
- See ITHistory.org/blog/?p=2229
- See ITHistory.org/blog/?p=2261

Comparing 8008 to 4004

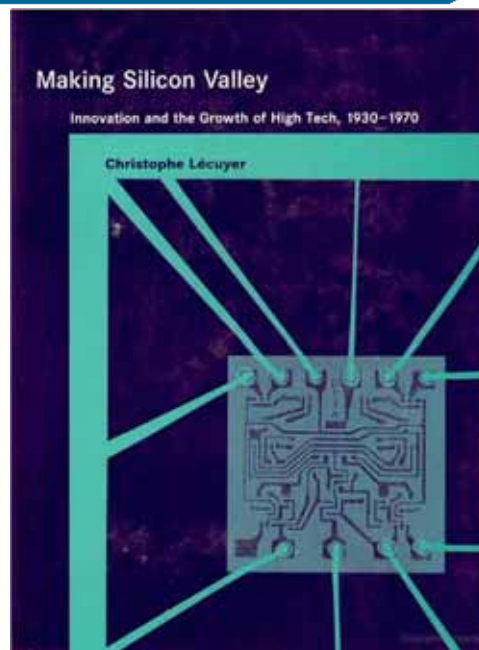
- | | |
|--|----------------------------------|
| ■ Intel Trinity | ■ Reality |
| ■ 8008: a turbocharged 4004 (8x speed) | ■ 8008 actually about 1/3 slower |
| ■ 4004: 108 kHz clock | ■ 4004: 740 kHz |
| ■ 8008: 800 kHz clock | ■ 8008: 500 kHz(/2) |
| | ■ multi 8-bit add: |
| | ■ 4004: <160 uS |
| | ■ 8008: >210 uS |

In Conclusion

- Lots of interesting electronics progress in the 1960s
- The very beginning of the semiconductor revolution—semiconductor memory and the microprocessor are both launched.

Get the book!

Learn MUCH
more about
those early
days ...



***More about
that period***

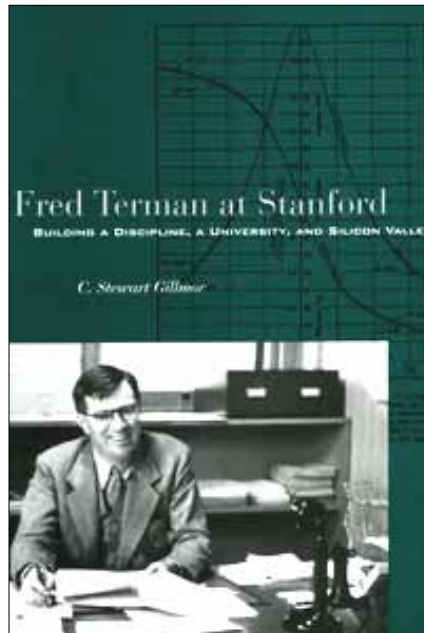
...

**Fred Terman
at Stanford:**

**Building a Discipline,
a University,
and Silicon Valley
by Stewart Gillmor**

2004,

ISBN 978-0804749145



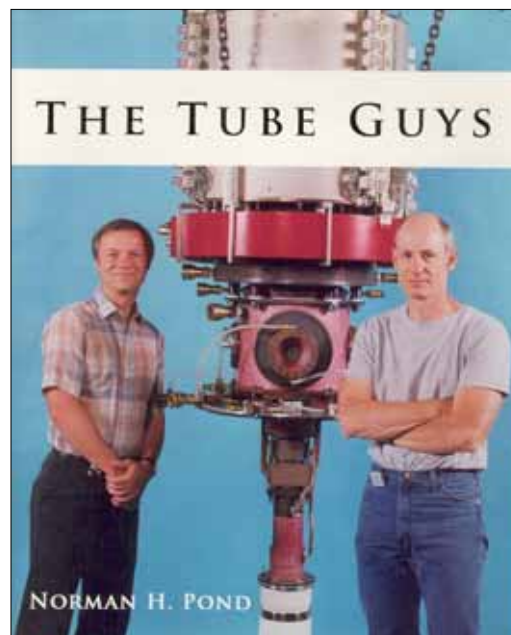
**Another
fun book**

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

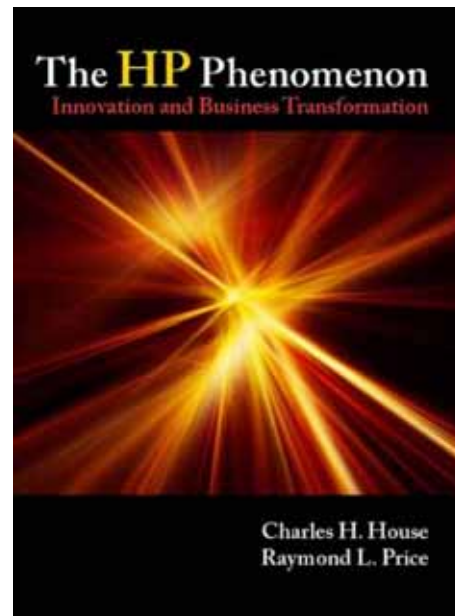
2008,

ISBN 978-0-9816923-0-2

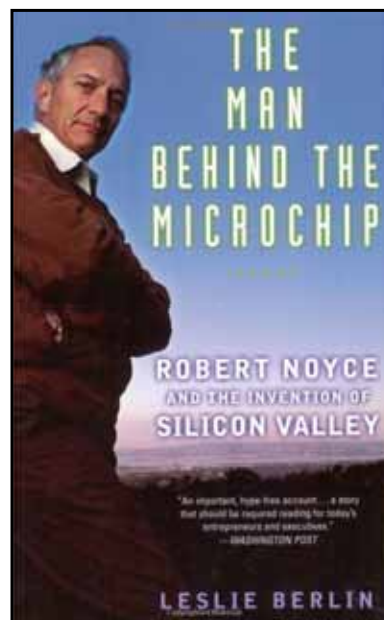
www.russcochran.com



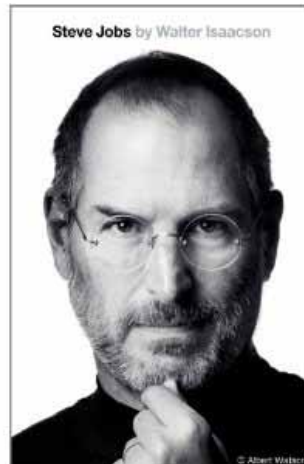
**To understand how
H-P was a
product of Silicon
Valley, and
shaped its
culture through a
number of
re-inventions
(1930s, up
through 2009)**



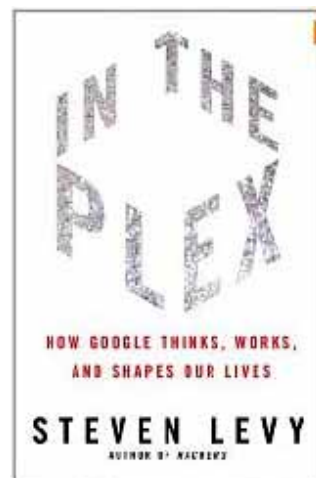
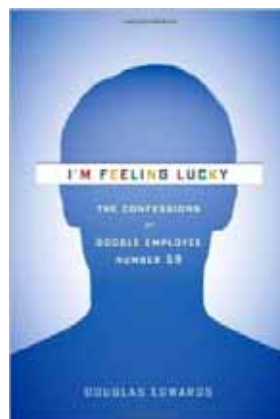
**I also
recommend
Leslie Berlin's
recent book on
Bob Noyce**



For another view of Silicon Valley



For a view of another Innovation Environment



On Netflix Streaming:

2011 video, 85 minutes
(SXSW Best Documentary)

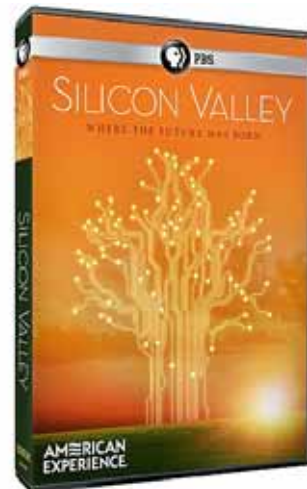
**Covers funding and
startup of Apple,
Intel, Genentech,
Tandem, Cisco, with
views from the key
funders (Rock,
Perkins ...) and
entrepreneurs
(Moore, Treybig ...)**



**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."

Reviewing the Good Ol' Days

**Thank you for attending this
meeting of the
IEEE Santa Clara Valley Section's
Committee on Silicon Valley
Technology History**

Link: sites.ieee.org/sv-techhist

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