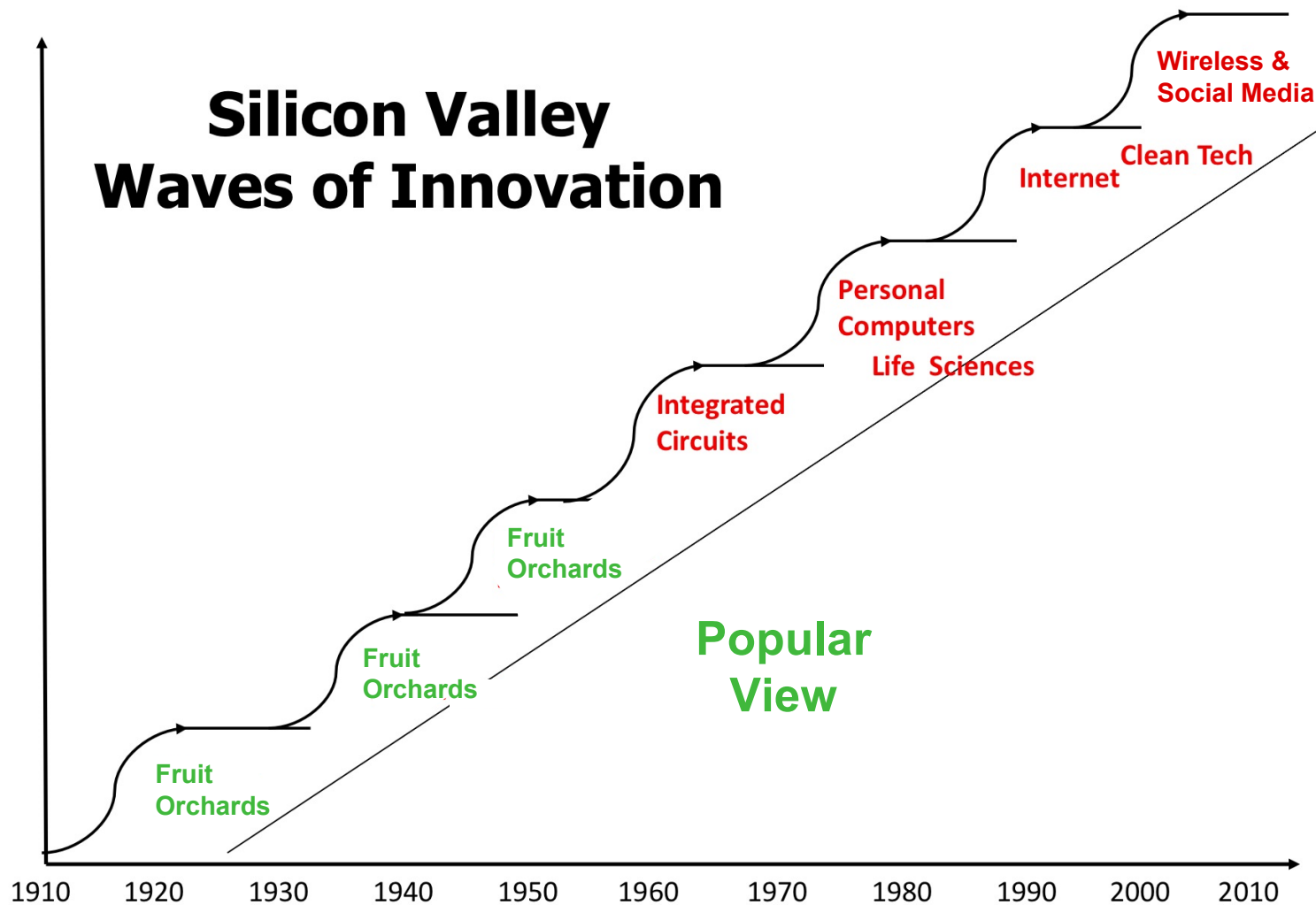


W. W. Hansen (1909-1949): *Microwaves from Stanford to Silicon Valley*



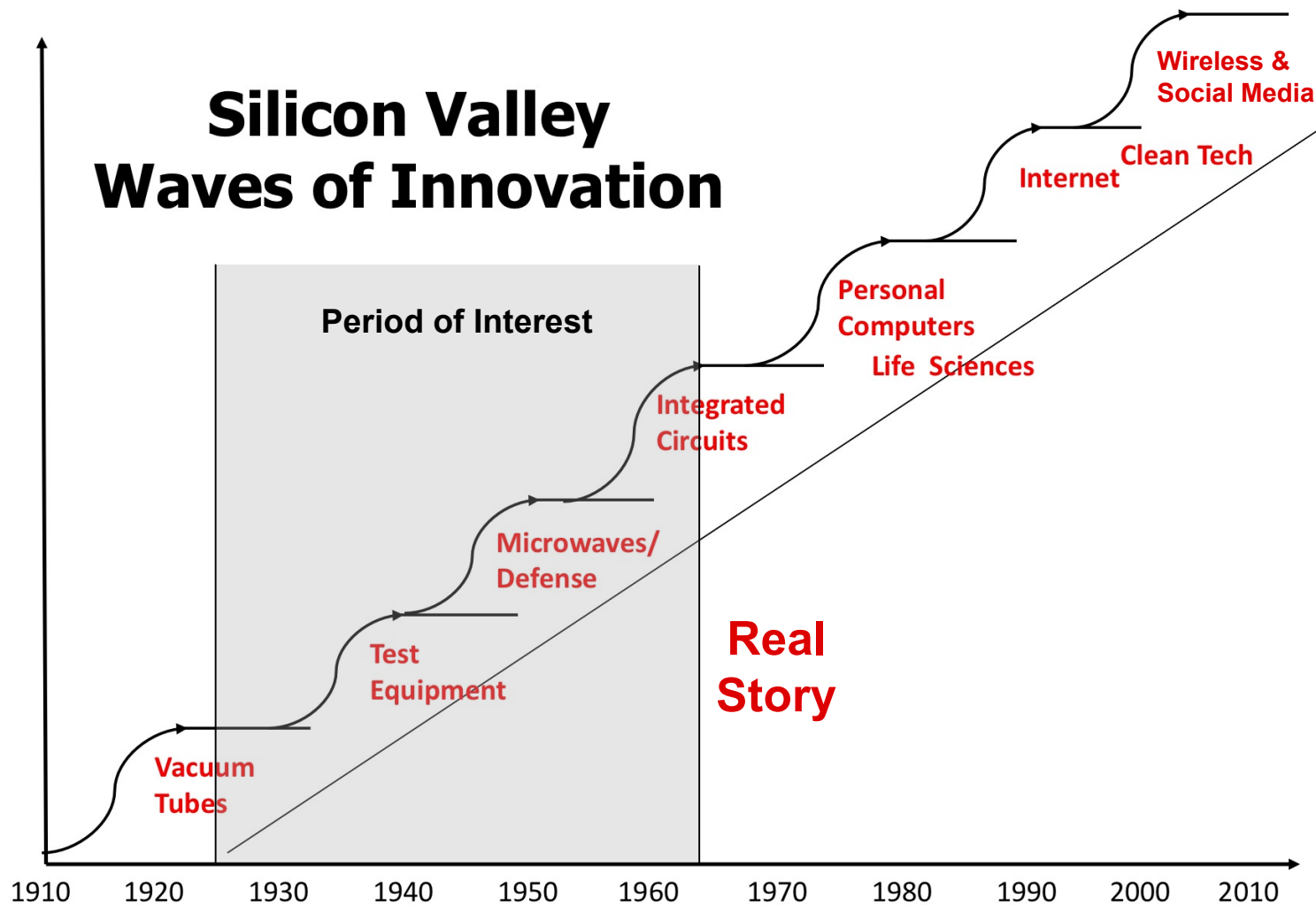
D. B. Leeson
March 10, 2016 ©

Silicon Valley Waves of Innovation



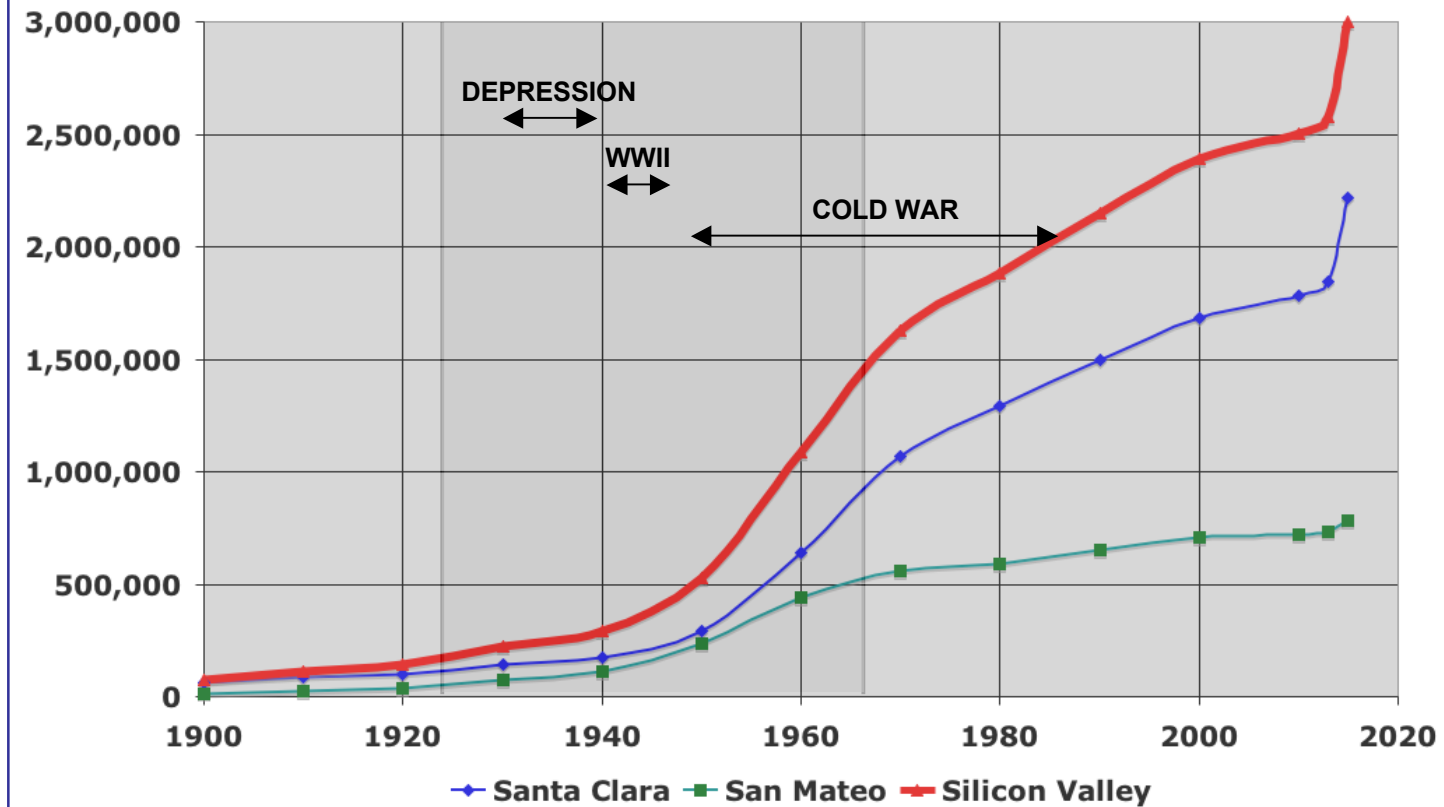
<http://steveblank.com/2012/05/21/why-facebook-is-killing-silicon-valley/>

Silicon Valley Waves of Innovation



<http://steveblank.com/2012/05/21/why-facebook-is-killing-silicon-valley/>

Silicon Valley Population



Stanford University

Rise of Stanford & Silicon Valley

- **Prewar: Big East Coast institutions dominate**
 - › RCA & AT&T patents, Harvard & MIT research
 - › Stanford regional & struggling, West Coast industry small
- **Varian-Hansen klystron: Turning point for fame, \$**
- **WWII: Terman & Hansen go east, emerge as leaders**
 - › Big labs at MIT & Harvard (but not Stanford)
- **Postwar: New experts, technology, gov't funding**
 - › Terman strategy: New labs, **keep classified sponsorship**



Stanford University

Rise of Stanford & Silicon Valley

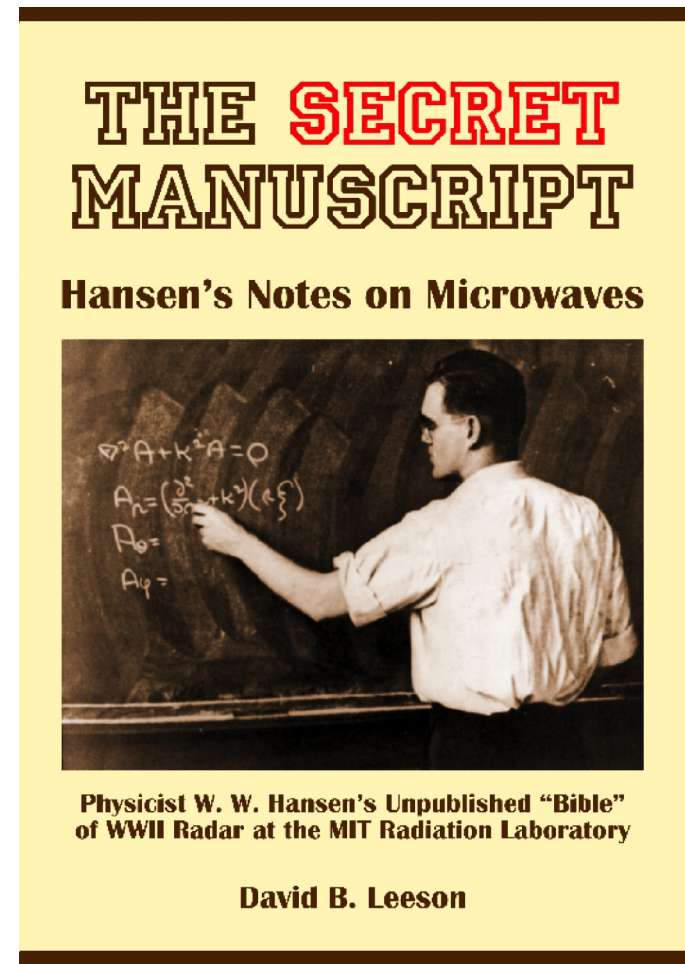
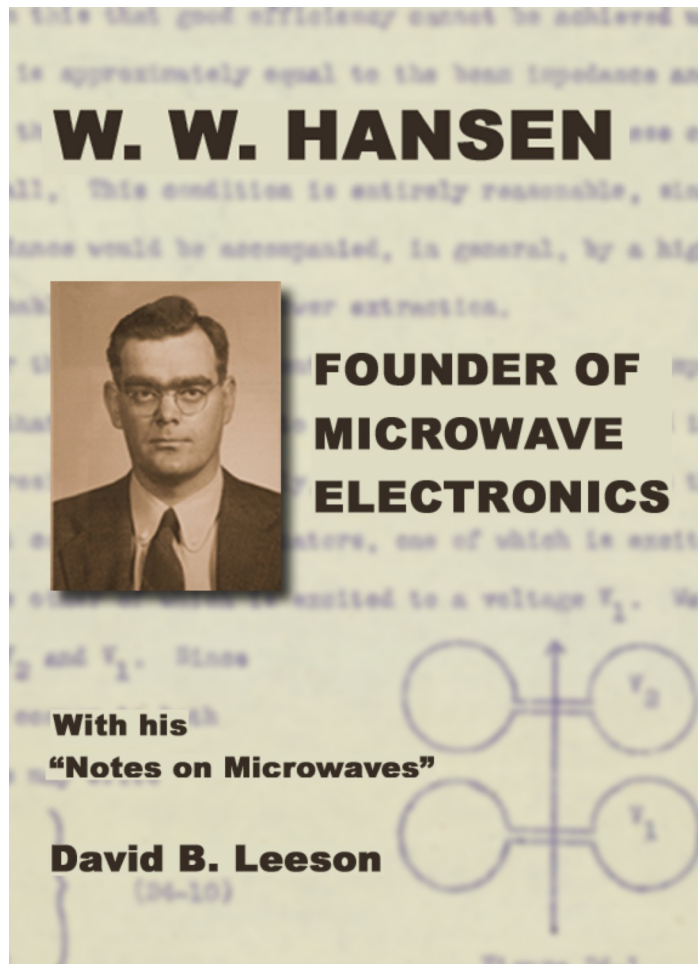
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 - › Big labs at MIT & Harvard (but not Stanford)
- **Postwar: New experts, technology, gov't funding**
 - › Terman strategy: New labs, **keep classified sponsorship**
- **Stanford emerges: Funded research, spin-offs**
 - › Linear accelerators, microwave tubes, radar countermeasures
- **SLAC: Center of particle research**
- **Microwave companies set stage for venture funding**



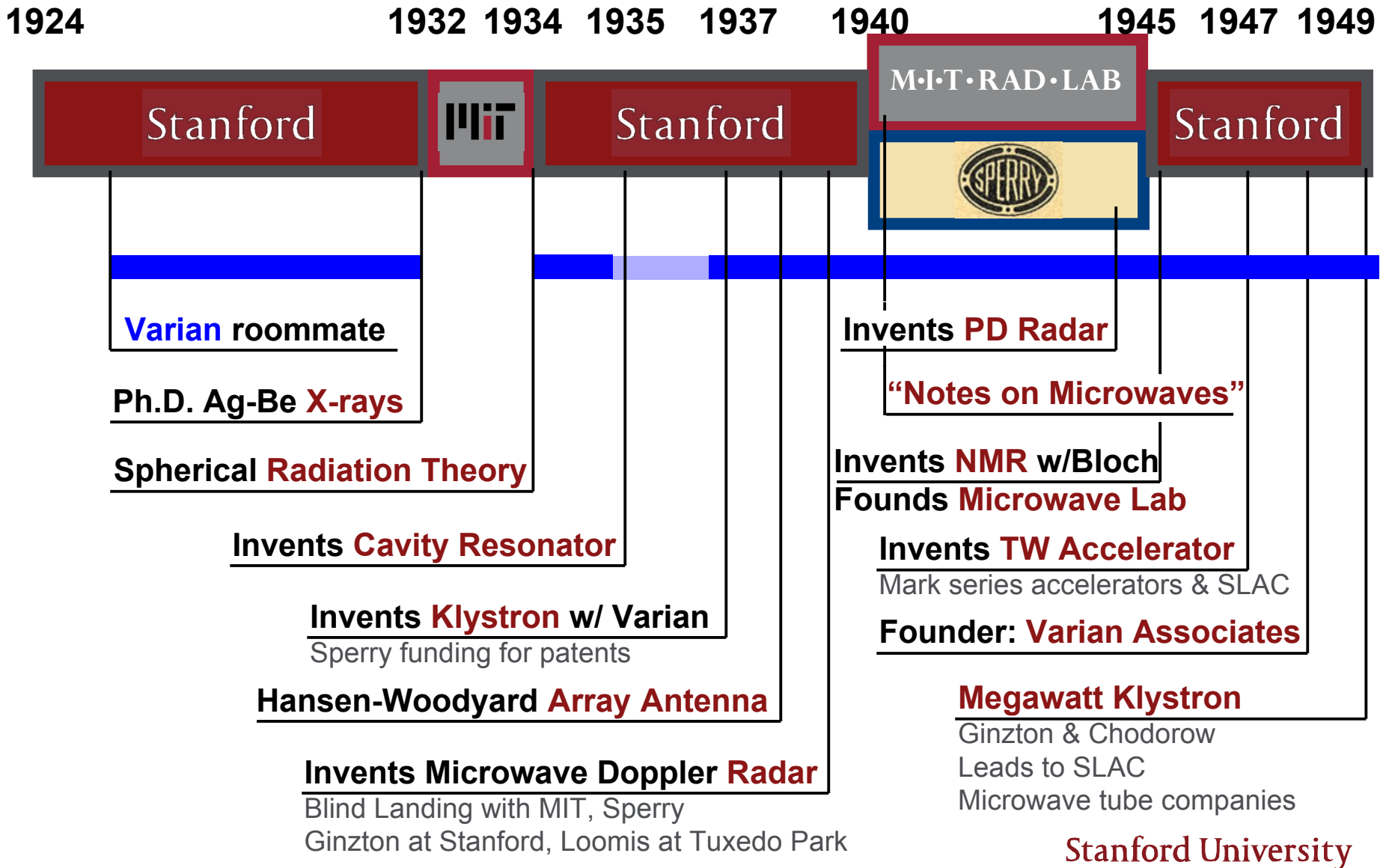
Stanford University

My Interest: Recognizing Hansen

- Hansen archives lost for 25 years after his death



W.W. Hansen's Legacies



X-rays at Stanford, Radiation at MIT

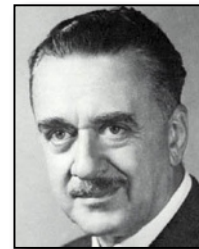
- Ph.D.: 200 kV X-rays, $e^- \rightarrow$ Ag on Be
- MIT postdoc: Spherical radiation
 - › P. M. Morse: Boundary value problems
- Stanford: 3 MeV “Supervoltage”
 - › Too expensive, not funded
 - › Hansen & Varian: Resonant acceleration



PHYSICAL REVIEW

A New Type of Expansion in Radiation Problems

W. W. HANSEN,* *Stanford University*
(Received August 9, 1934)



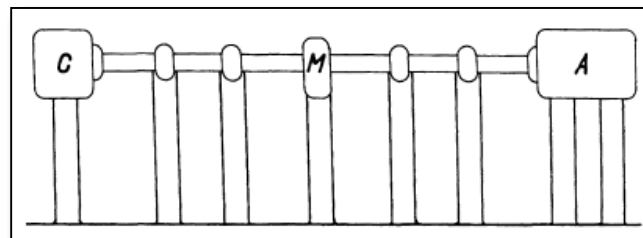
Morse



Varian



Webster



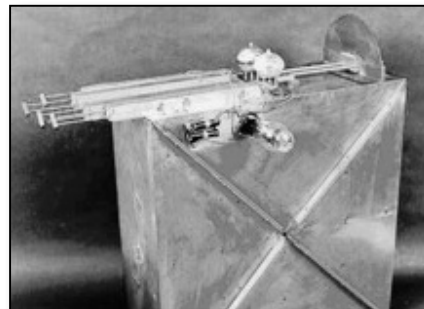
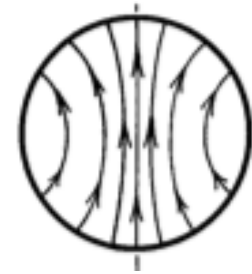
Supervoltage 100' Accelerator Tube



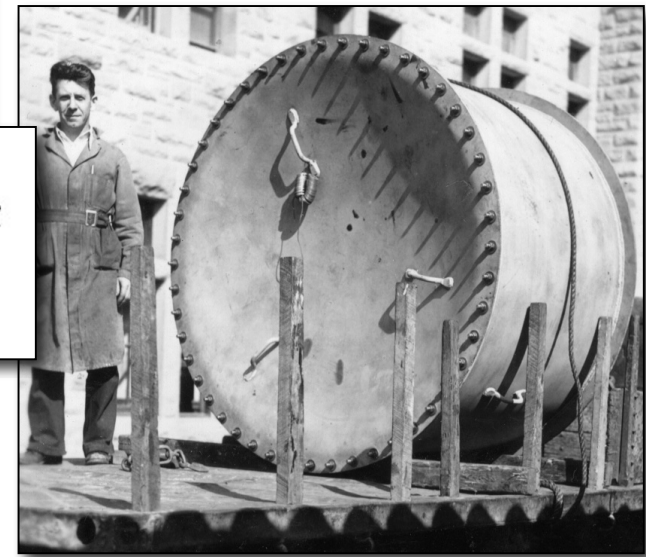
Stanford University

Cavity Resonator Invention 1935

- Spherical radiation with conductive boundary
 - › “Varian and Hansen’s big oscillating sphere”
 - › “Rumbatron”: Resonant particle acceleration
 - › Surprise: No external field, very high Q



JOURNAL OF APPLIED PHYSICS
A Type of Electrical Resonator
W. W. HANSEN
Stanford University, California
(Received July 17, 1937)*



Feb. 20, 1940. W. W. HANSEN 2,190,712
HIGH EFFICIENCY RESONANT CIRCUIT
Filed July 27, 1936

Stanford University

\$100 Idea: Klystron Invention 1937

- **Varian bros: Microwaves from Hansen cavity**
 - › **May: Lab & shop, \$100, no pay, share royalties**

IEEE TRANSACTIONS ON ELECTRON DEVICES, VOL. ED-23, NO. 7, JULY 1976

The \$100 idea

How Russell and Sigurd Varian, with the help of William Hansen and a \$100 appropriation, invented the klystron

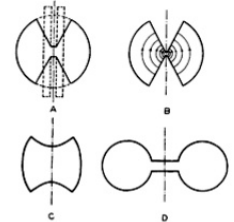
Edward L. Ginzton Varian Associates

I first met Russell Varian in 1939 on a stairway landing in the Stanford University Physics Building. I had just been hired as a part-time research associate on

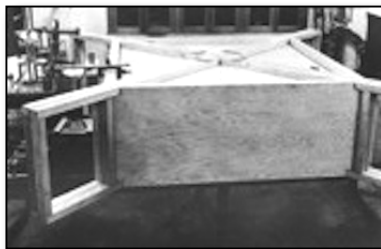
“The very efficient high frequency resonators described in this Journal by [William] Hansen have been made the basis for construction of amplifiers

\$100 Idea: Klystron Invention 1937

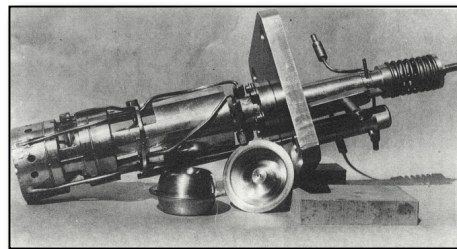
- **Varian bros: Microwaves from Hansen cavity**
 - › May: Lab & shop, \$100, no pay, share royalties
 - › July: Patent notebook entry
 - › August: Working 10 cm. model



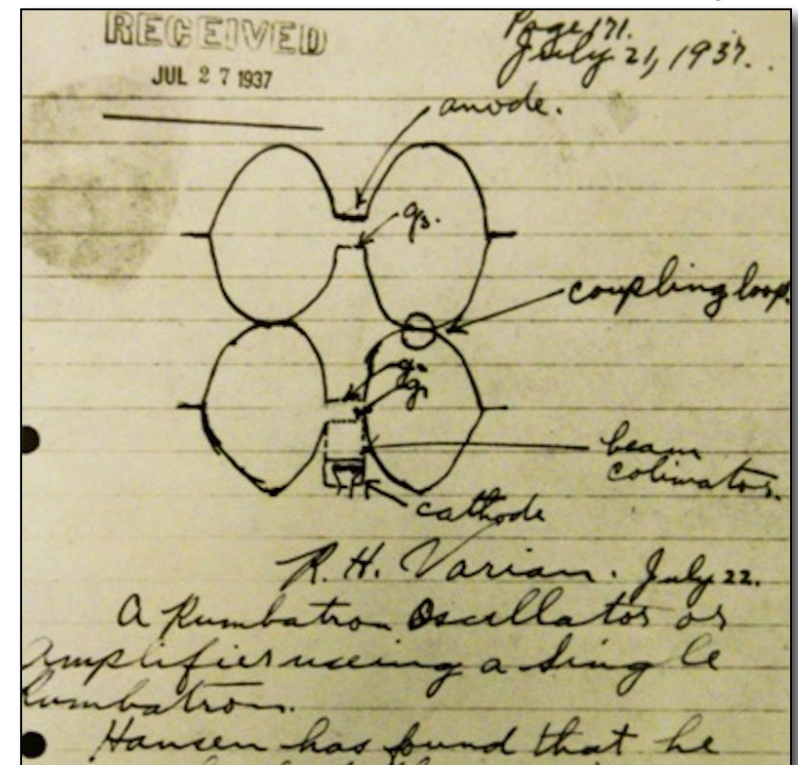
Woodyard



Wood Cavity, July '37

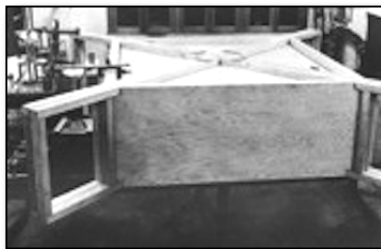
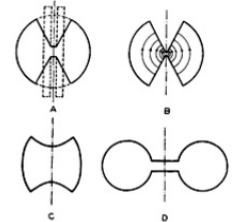


Klystron Model A, Aug. '37

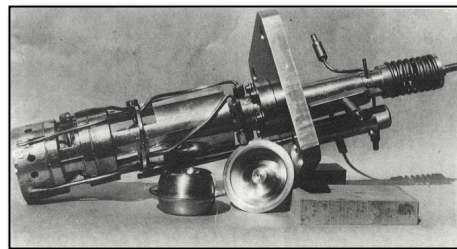


\$100 Idea: Klystron Invention 1937

- **Varian bros: Microwaves from Hansen cavity**
 - › **May: Lab & shop, \$100, no pay, share royalties**
 - › **July: Patent notebook entry**
 - › **August: Working 10 cm. model**
 - › **October: Patent filed**
 - › **April '38: Sperry \$25,000/year**

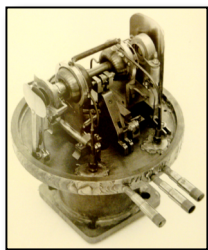


Wood Cavity, July '37

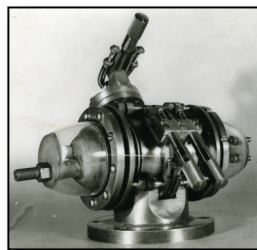


Klystron Model A, Aug. '37

May 20, 1941. R. H. VARIAN 2,242,275
ELECTRICAL TRANSLATING SYSTEM AND METHOD
Filed Oct. 11, 1937



Model B '38



Model C '38



Sig with Model C

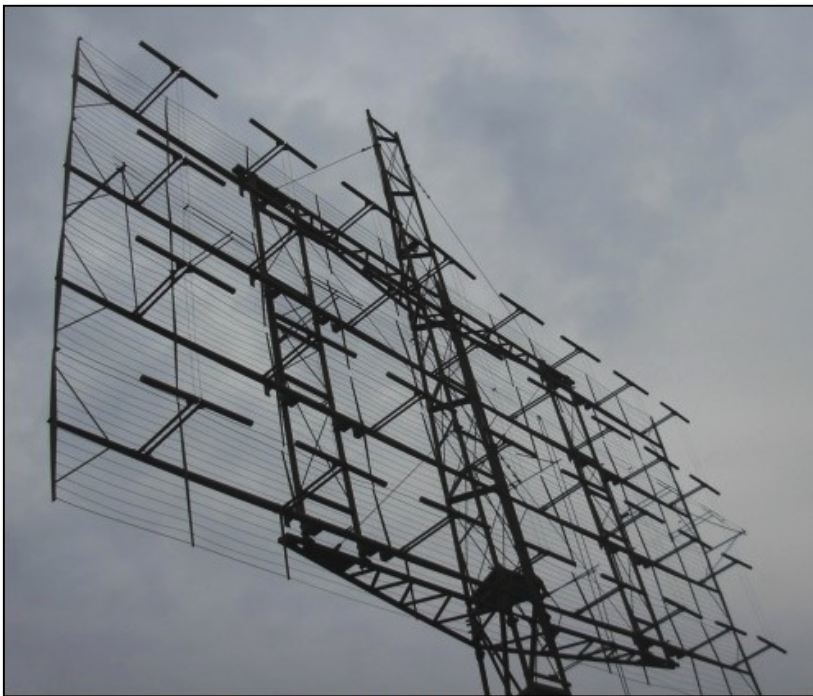


"Klystron Boys": R. Varian & Hansen

Stanford University

Hansen-Woodyard Array Antenna 1938

- **Standard WWII VHF radar antenna (“Bedspring”)**
 - › Beamwidth $\propto L^{-1}$; Yagi $\propto (\log L)^{-1}$
- **Also with F.E. Terman**



Inventors
William W. Hansen
Frederick E. Terman



Terman

Oct. 15, 1940. F. E. TERMAN ET AL 2,218,487
DIRECTIONAL RADIATING SYSTEM
Filed Feb. 19, 1938

Proceedings of the Institute of Radio Engineers
Volume 26, Number 3 March, 1938

A NEW PRINCIPLE IN DIRECTIONAL ANTENNA DESIGN*

BY
W. W. HANSEN AND J. R. WOODYARD
(Stanford University, California)

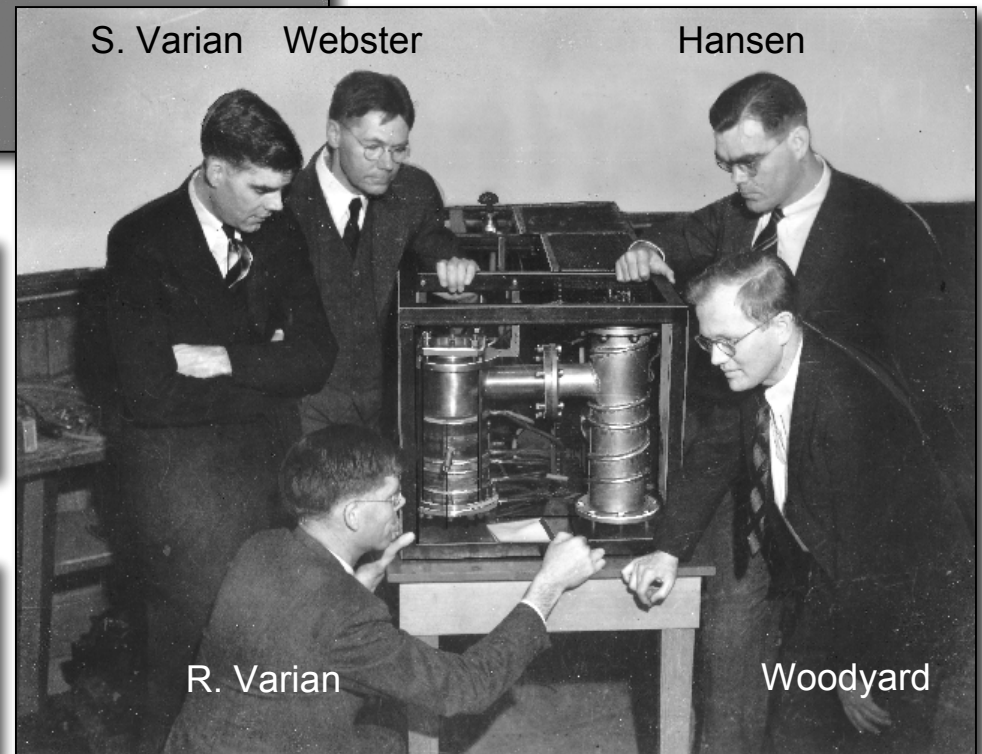
Blind Landing: 40 cm Klystron 1939



- **CAA-MIT-Sperry**
 - › Boston, Feb. 1939
- **750 MHz Klystron**

The New York Times
LAND BLIND WITH RADIO; Pilots Use Only Klystron Tube in New Device to Conquer Fog
By JOHN H. CRIDER ();
March 19, 1939.

Aug. 18, 1942. W. W. HANSEN 2,293,058
BLIND LANDING ANTENNA ARRAY
Filed Sept. 28, 1939

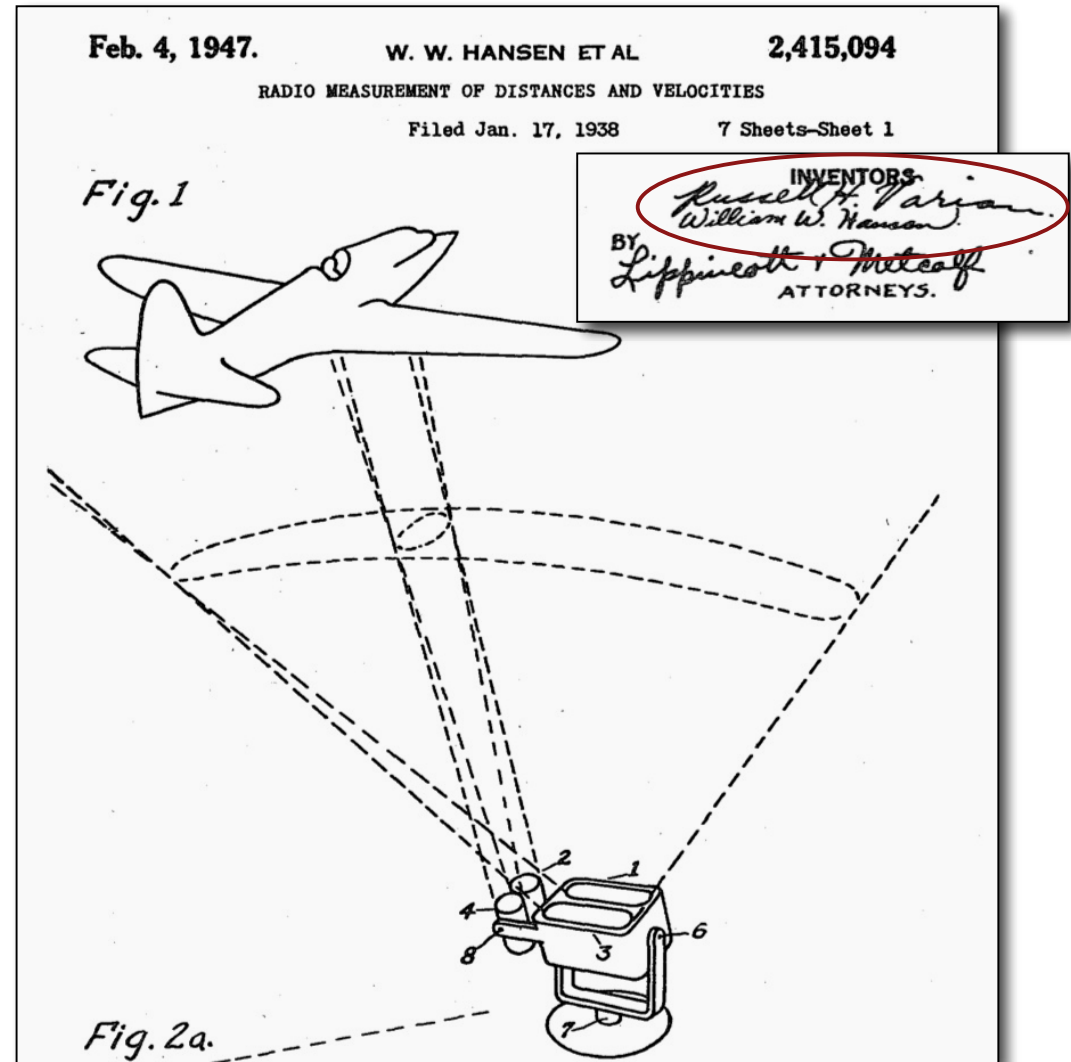


Stanford University

CW Doppler Radar 1939-40



Ginzton



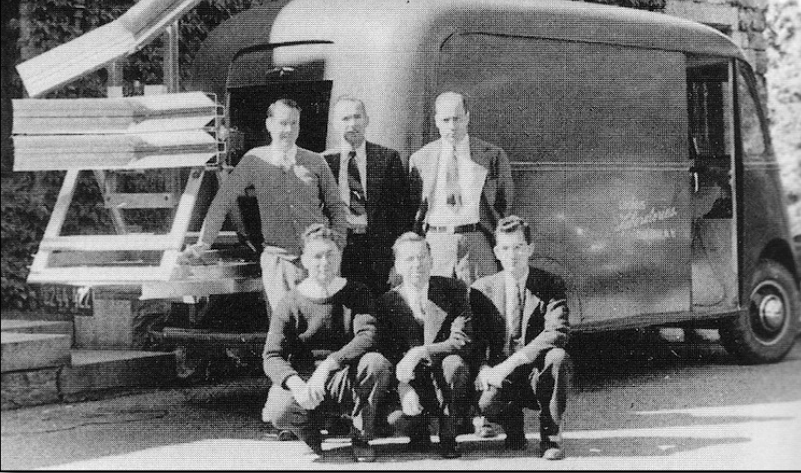
Stanford University

CW Doppler Radar 1939-40

“Boomatron” at Stanford



The “Didey Wagon” at Loomis Lab



September 3, 1940.

Prof. William W. Hansen,
Department of Physics,
Stanford University,
Stanford University, Cal.

Dear Bill:

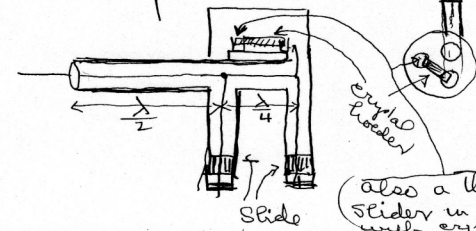
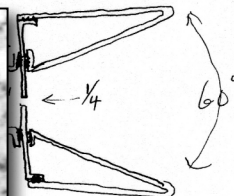
Thank you for your letter of August 26th. We will build the horn for the 20 cm. Klystron right away. We have installed in the laboratory some big brakes and shears, and have developed an aluminum bending and welding technique that makes the production of this horn

Do let me know how you obtain a one-sided beam and any other new things that you have found out this summer.

We have built crystal pick-ups designed as indicated in the sketch that are very easy to tune and which provide for easy interchange of crystals.

Cordially yours,

Alfred N. Sponner

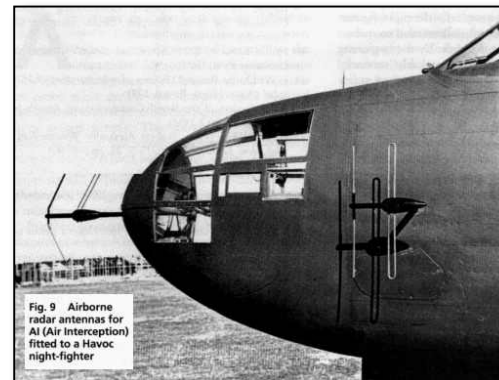
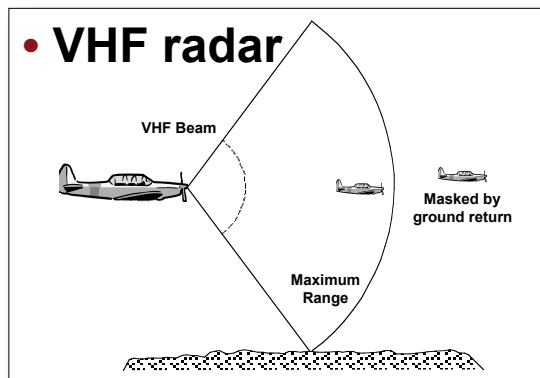
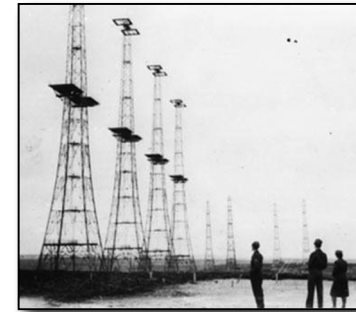


Loomis

Stanford University

WWII Radar

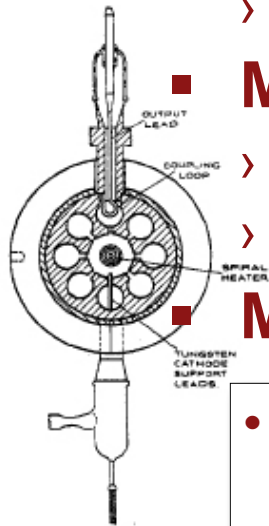
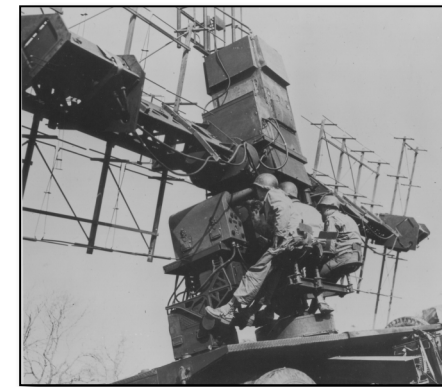
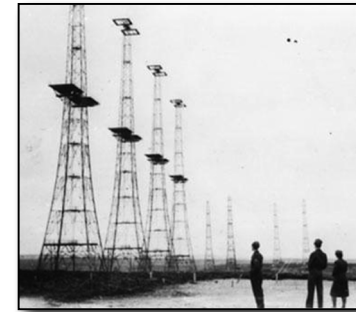
- **See through darkness, cloud & fog**
 - › Invented many times & countries
- **HF pulse radar 13m: Battle of Britain**
- **VHF radar 1m: Fixed & airborne**
 - › Airborne antenna: Beam too wide



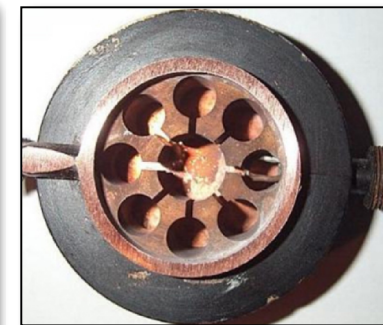
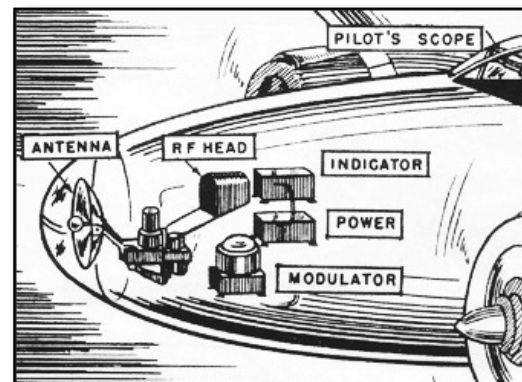
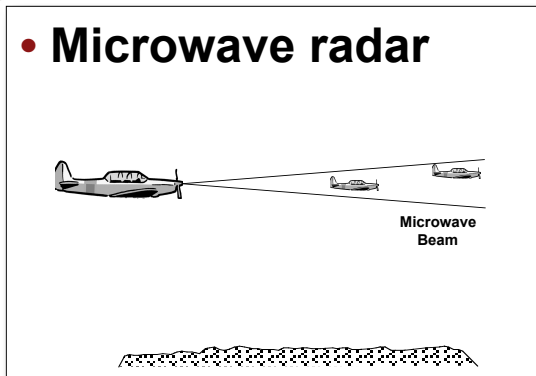
Stanford University

WWII Radar

- See through darkness, cloud & fog
 - › Invented many times & countries
- HF pulse radar 13m: Battle of Britain
- VHF radar 1m: Fixed & airborne
 - › Airborne antenna: Beam too wide
- **Magnetron** inspired by klystron
 - › Randall & Boot, UK Feb. '40
 - › Tizard mission: Basis of MIT Rad Lab
- **Microwave** radar 0.1m: Airborne



• Microwave radar



Stanford University

The MIT Radiation Lab 1940-45

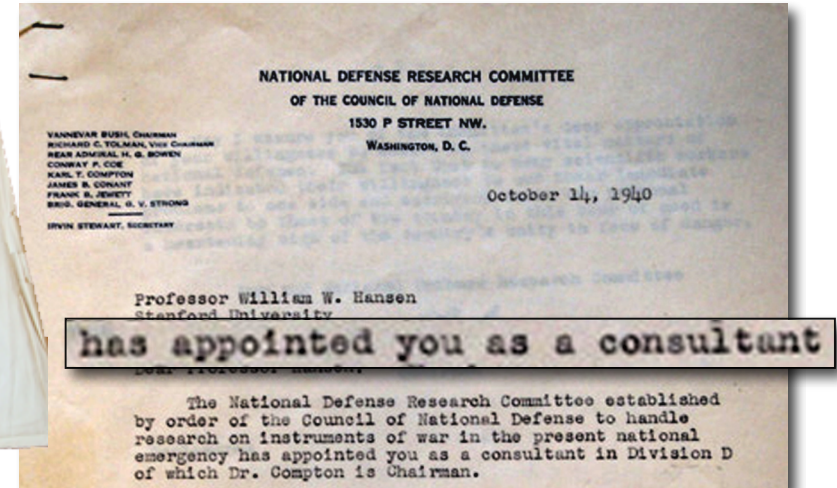
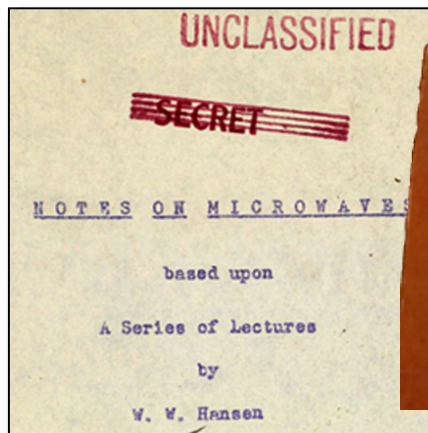
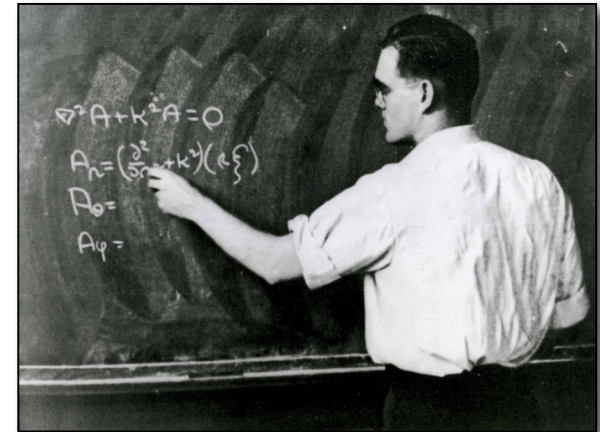
- **Rad Lab: Microwave radar 1940**
 - › Loomis committee founds & funds
 - › Lawrence recruits “cyclotroneers”



Lawrence

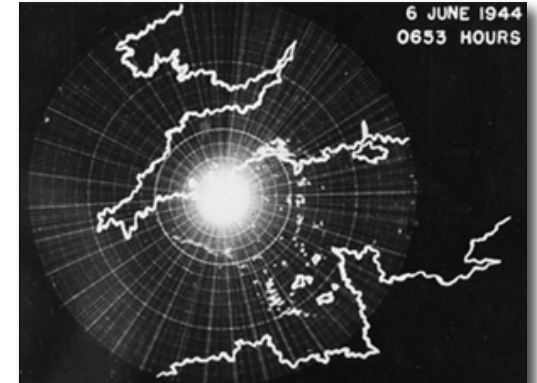
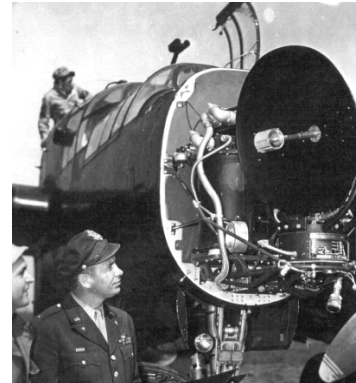
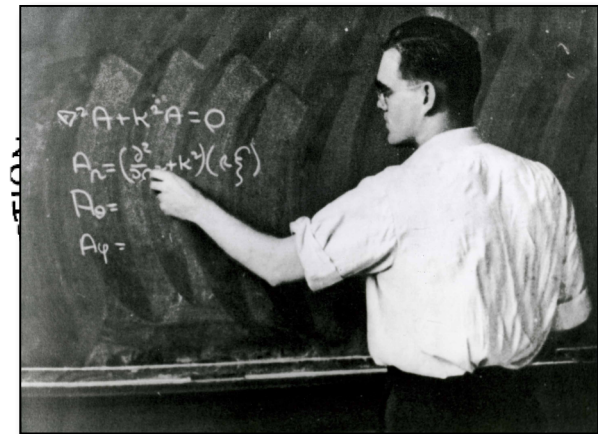
The MIT Radiation Lab 1940-45

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- **Hansen: Weekly staff lectures**
 - › “Notes”: 1200 pg. classified “bible”



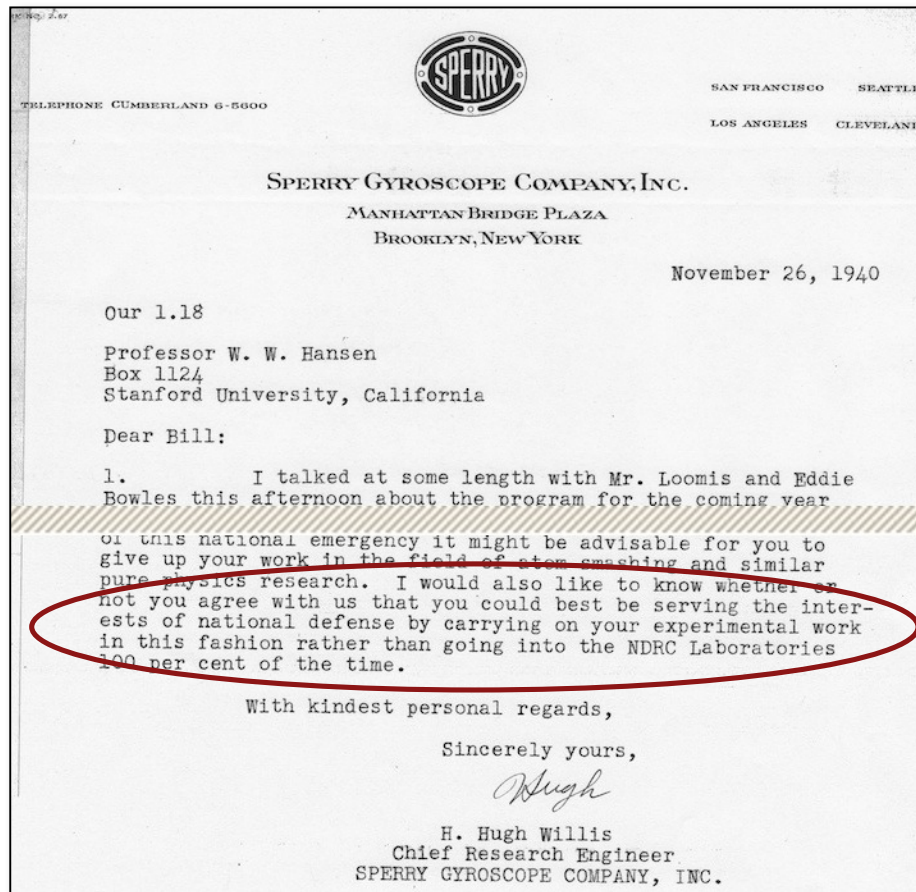
The MIT Radiation Lab 1940-45

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 - › Loomis committee founds & funds
 - › Lawrence recruits “cyclotroneers”
- **Hansen: Weekly staff lectures**
 - › “Notes”: 1200 pg. classified “bible”
- **Staff 4000, \$1.5B radars**
 - › Defeats airplanes, ships, U-boats, V-1



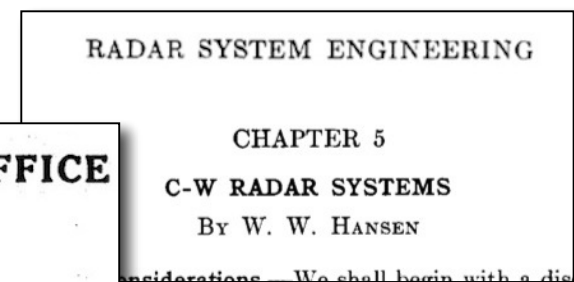
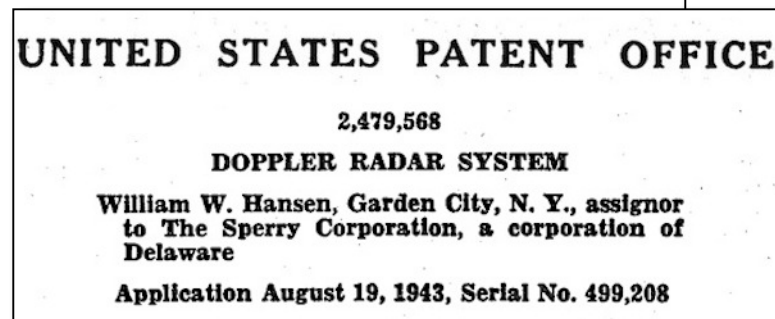
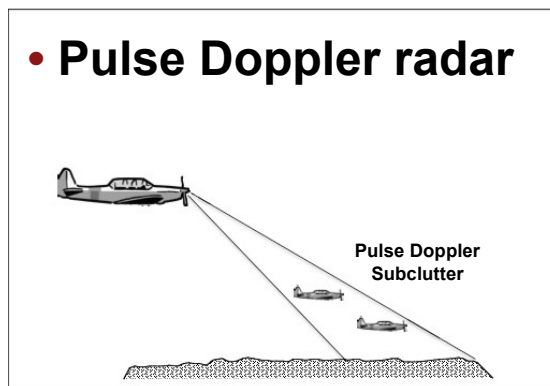
Sperry in WWII 1940-45

- Hansen's group moved to Long Island



Sperry in WWII 1940-45

- Hansen's group moved to Long Island
 - › Varians, Ginzton, Woodyard and others
 - Ginzton proves to be excellent manager
 - Future Dir. of SLAC, Chairman of Varian Assoc.
 - Hansen 70 patents: Klystrons, radar
 - Dreams: Microwave Lab & Varian Associates
- Hansen to MIT Rad Lab every week
- Hansen invents coherent pulse Doppler radar 1943

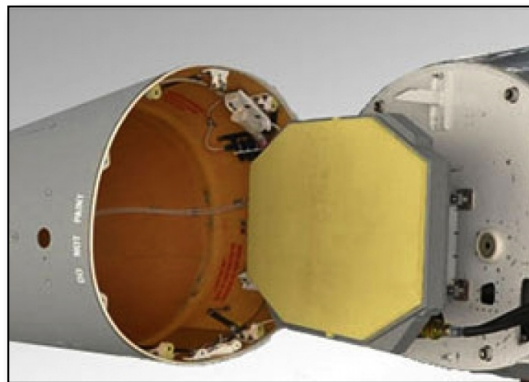
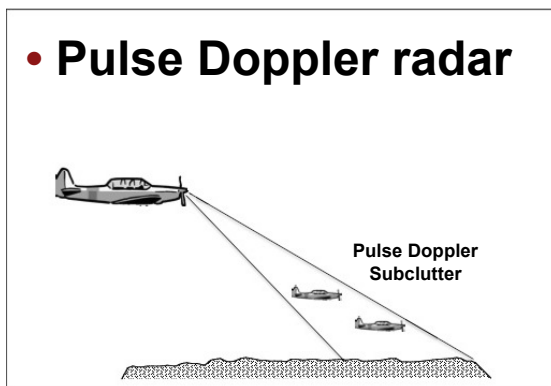
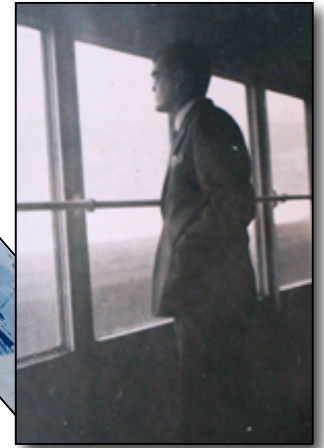


Rad Lab Series
Vol. 1, 1947

Stanford University

Sperry in WWII 1940-45

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 - Ginzton proves to be excellent manager
 - Future Dir. of SLAC, Chairman of Varian Assoc.
 - Hansen 70 patents: Klystrons, radar
 - Dreams: Microwave Lab & Varian Associates
- Hansen to MIT Rad Lab every week
- Hansen invents coherent pulse Doppler radar 1943
 - › Modern form of radar

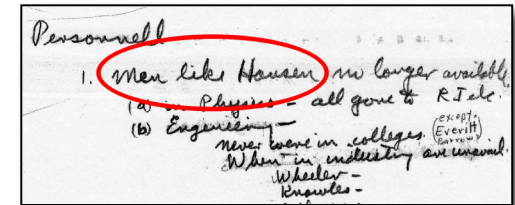


Stanford University

Radio Research Lab Harvard 1942-45

- **RRL: Top-secret radar intelligence & jamming**

- › **Director: F. E. Terman of Stanford**
- › **Highly classified: Personal connection**



F. E. Terman

Stanford University

Radio Research Lab Harvard 1942-45

- **RRL: Top-secret radar intelligence & jamming**
 - › Director: **F. E. Terman** of Stanford
 - › Highly classified: Personal connection
- **Hansen: Microwave Lab proposal**
 - › Sperry staff, Rad Lab technology to Stanford
- **Terman: Postwar Eng. Dean, Provost**
 - › RRL staff & gov't sponsorship to Stanford
 - › “Father of Silicon Valley”

Personnel
1. Men like Hansen no longer available.
(a) Physics - all gone to R.Talc.
(b) Engineering - never were in colleges (except Harvard)
When in industry an unusual
Wheeler -
Knowles -



F. E. Terman

RADIO RESEARCH LABORATORY
HARVARD UNIVERSITY, 19 DIVINITY AVENUE
CAMBRIDGE 38, MASSACHUSETTS

OPERATING UNDER THE SUPERVISION
OF THE
OFFICE OF SCIENTIFIC RESEARCH
AND DEVELOPMENT

KIRKLAND 7660
September 27, 1944

Dr. D. B. Tressidder, President
Stanford University
California

Dear Dr. Tressidder:

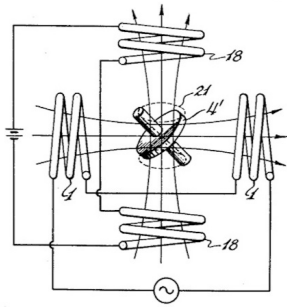
In the following, which is essentially a resume of our conversation
in August, I will attempt to make clear my ideas as to what would constitute
a first class micro-wave laboratory and roughly what the cost will be. Some

a first class micro-wave laboratory

William W. Hansen

Stanford University

Bloch & Hansen: Nuclear Mag. Res. 1945



PHYSICAL REVIEW

Nuclear Induction

F. BLOCH, W. W. HANSEN, AND MARTIN PACKARD
Stanford University, Stanford University, California
January 29, 1946

UNITED STATES PATENT OFFICE

2,561,489

**METHOD AND MEANS FOR CHEMICAL
ANALYSIS BY NUCLEAR INDUCTIONS**

Felix Bloch, Palo Alto, and William W. Hansen,
Stanford University, Calif.

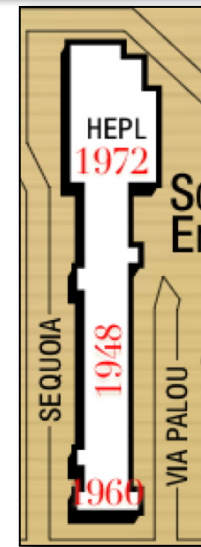
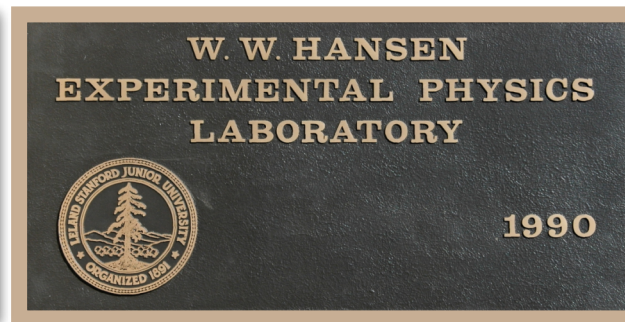
Application December 23, 1946, Serial No. 718,092



Stanford University

Hansen's Microwave Laboratory 1946

- **Key to Terman postwar strategy**
 - › Largest Stanford research contracts
- **Hansen: Founder, director 1946**
 - › Ginzton: Assoc. director; Woodyard to UC
- **First linear electron accelerators 1947**
- **Megawatt klystrons 1949**
- **New accelerator building 1948**
 - › Later named in Hansen's memory
 - › 3 Nobels, 13 NAS, 750 PhD's by teardown after 60 years



Stanford University

Varian Associates 1948

- **Hansen: Founder, his house**
 - › His last-minute \$17,000 saves day
- **Klystrons, NMR, accelerators**



Stanford University

Varian Associates 1948

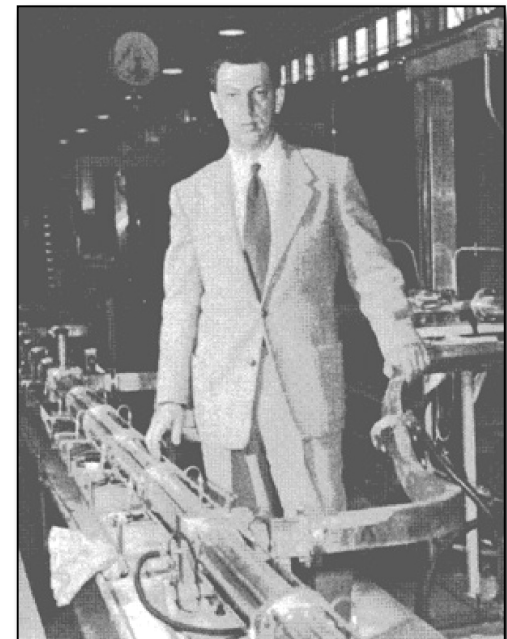
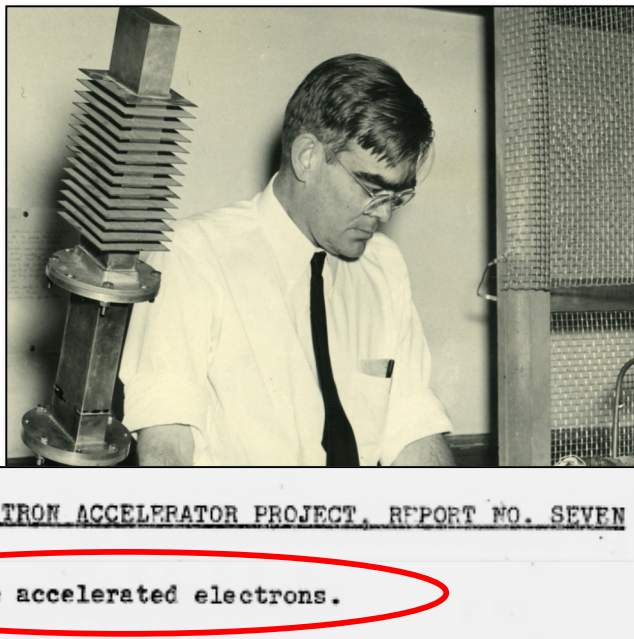
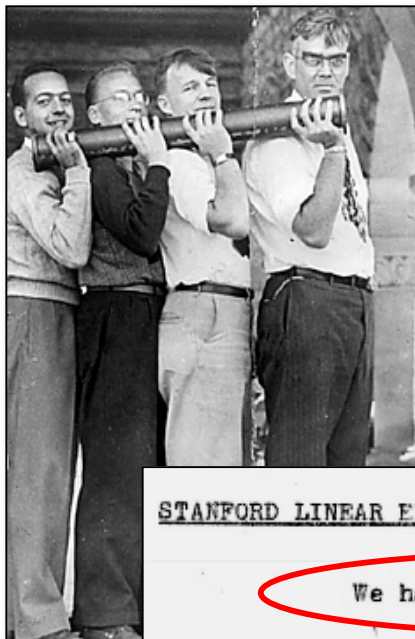
- **Hansen: Founder, his house**
 - › His last-minute \$17,000 saves day
- **Klystrons, NMR, accelerators**
- **1st in Stanford Industrial Park**
 - › Varian's idea: Close to Stanford
 - › Terman recognizes the value



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Mark Series Accelerators 1947-54

Mark I 1947	6 MeV 12 ft.	0.9 MW magnetron	Loaded waveguide electron LINAC
Mark II 1951	49 MeV 10 ft.	20 MW klystron	Prototype Mark III
Mark III 1952	730 MeV 214 ft.	(20) 20 MW klystrons	Nuclear research
Mark IV 1954	80 MeV 20 ft.	(2) 20 MW klystrons	Prototype for Proj. M two-mile LINAC

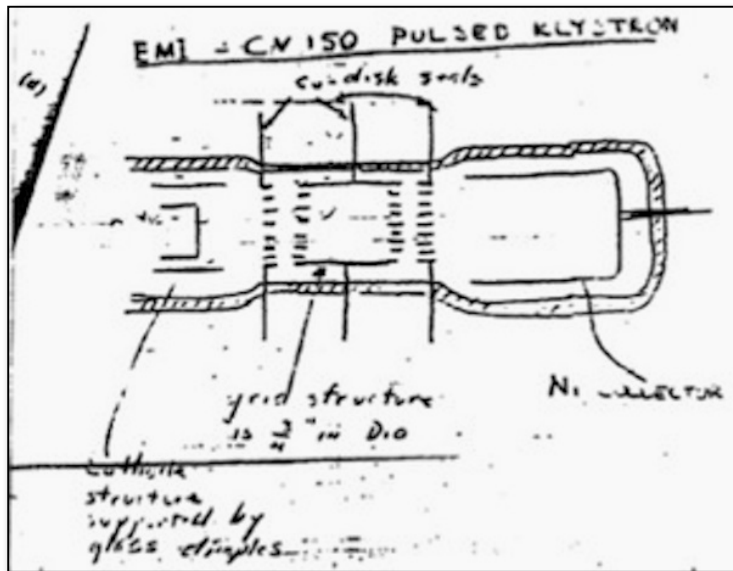


<http://www.slac.stanford.edu/history/mark.shtml>
<http://www.slac.stanford.edu/history/pubs/MARKtable.pdf>

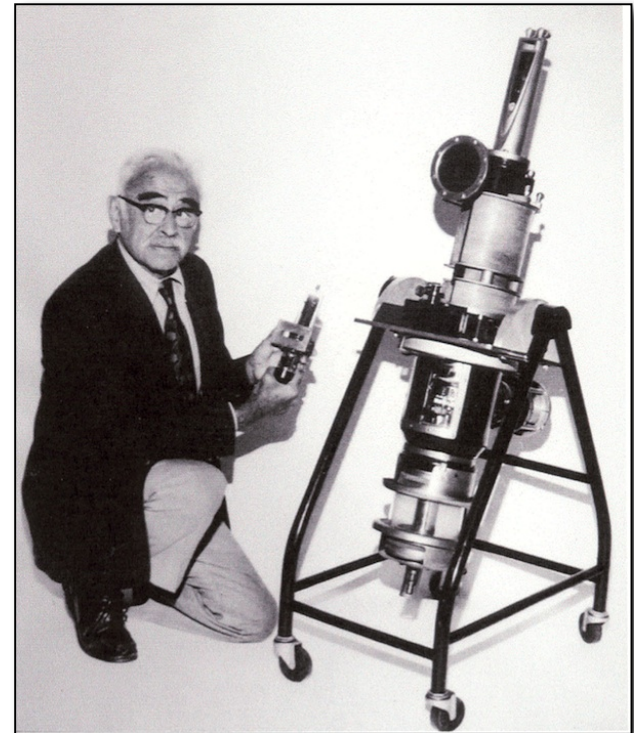
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Megawatt Klystrons 1949

- **Ginzton and Chodorow**
 - › **Ginzton UK trip 1944: Visualizes megawatt klystron**
 - › **First demonstration before Hansen's death**
 - 20 kW to 20 MW in one step
 - › **Coherent radar & accelerators**



Ginzton's Notes re CV-150

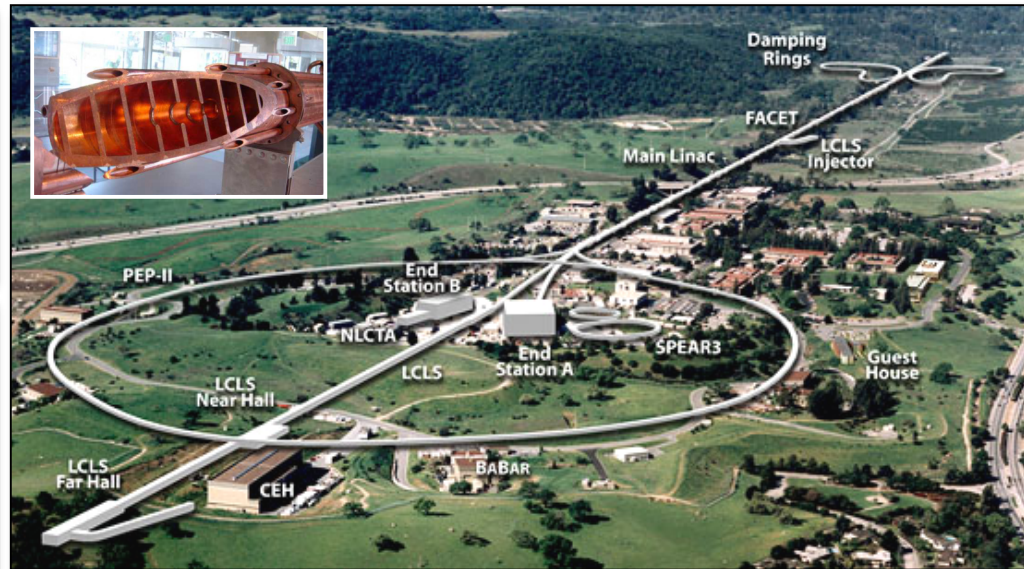


Chodorow holds CV-150 by Mark III Klystron

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SLAC Timeline

SLAC 1966	20 GeV 2 mi.	(240) 24 MW klystrons	Electron LINAC
SPEAR 1972	3 GeV 250 ft.	J/Psi 1974; Tau 1976	e ⁻ e ⁺ collider ring
SSRL 1974	SPEAR	Synchrotron ring	Radiation source
PEP 1980	29 GeV 1.4 mi.	+ PEP-II '98 & BaBar	e ⁻ e ⁺ collider ring
SLC 1987	91 GeV 2 mi.	e ⁻ e ⁺ LINAC	e ⁻ e ⁺ linear collider
LCLS 2009	LINAC	Free electron laser	X-ray source



<http://www.slac.stanford.edu/pubs/slacreports/reports04/slac-r-062.pdf>

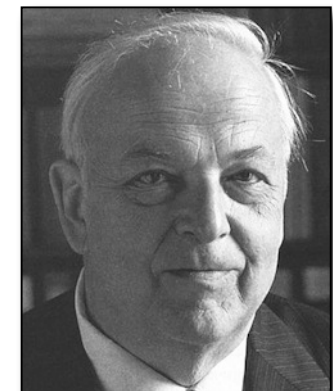
<http://www.slac.stanford.edu/gen/grad/GradHandbook/slac.html>

<http://slac50.slac.stanford.edu/interactive-timeline.asp>

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Stanford Physics Nobels by 1995

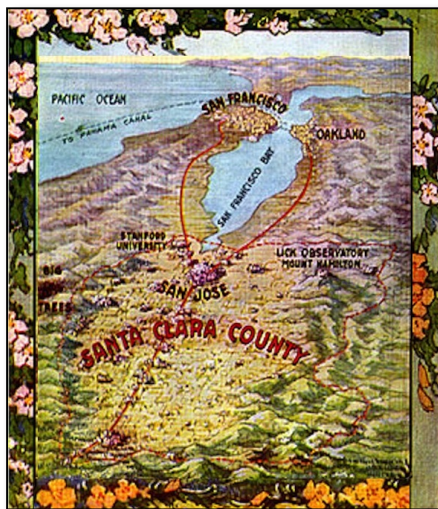
- Felix Bloch 1952
- Robert Hofstadter 1961
- Burton Richter 1976
- Richard Taylor 1990
- Martin Perl 1995



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Stanford Microwave Companies

Tubes	EW	Solid State
Eimac	Lockheed MSD	Microwave Eng. Labs
Litton	Sylvania EDL	Farinon
Varian	Admiral	Fairchild Microwave
GE Microwave	Zenith	Western Microwave
Watkins-Johnson	ESL	AEL
MEC	Dalmo Victor	Avantek
Stewart	Granger	HP Associates
Huggins	Applied Technology	California Microwave



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