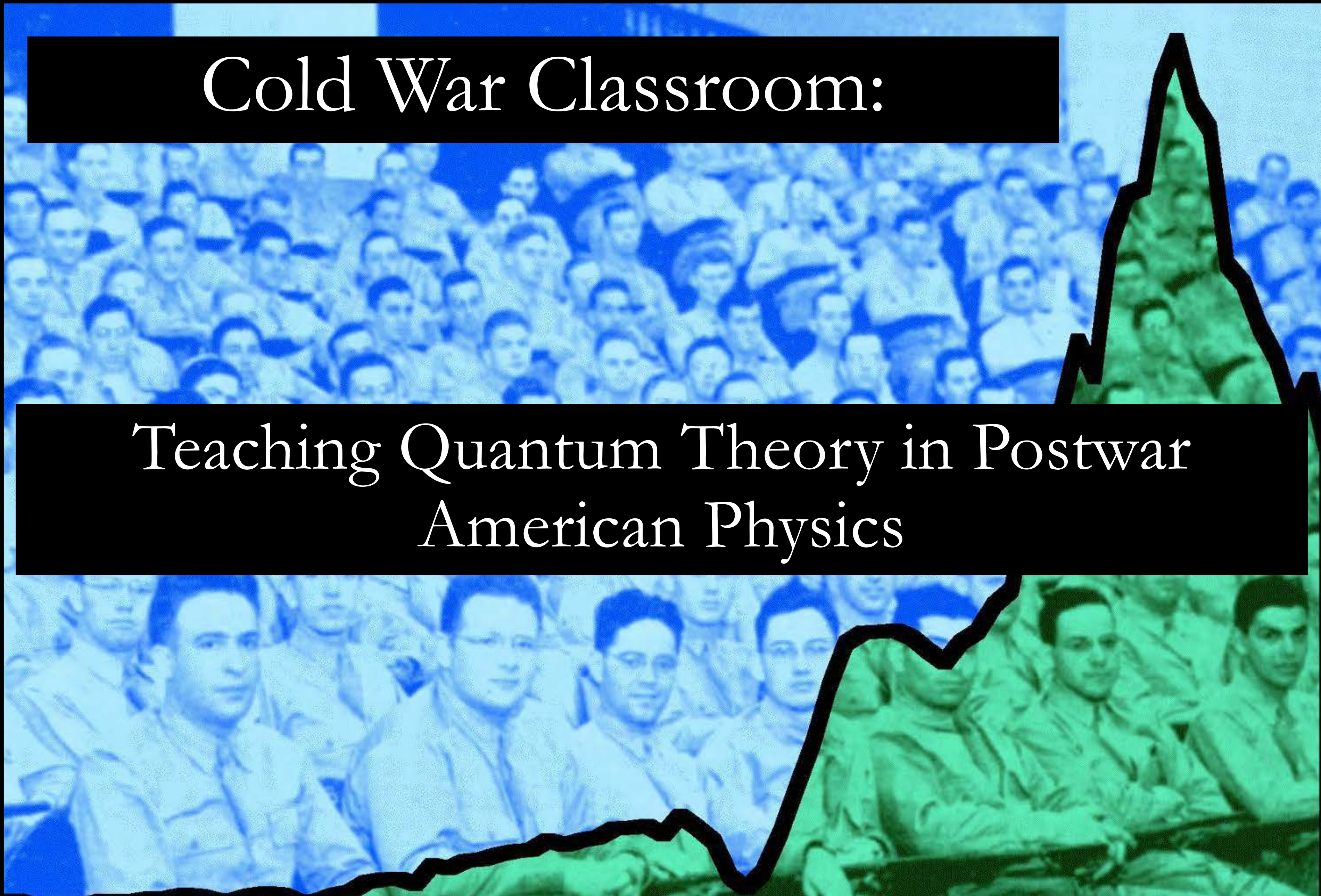
Cold War Classroom:

Teaching Quantum Theory in Postwar American Physics



8.225 / STS.042, Physics in the 20th Century

Professor David Kaiser, 4 November 2020

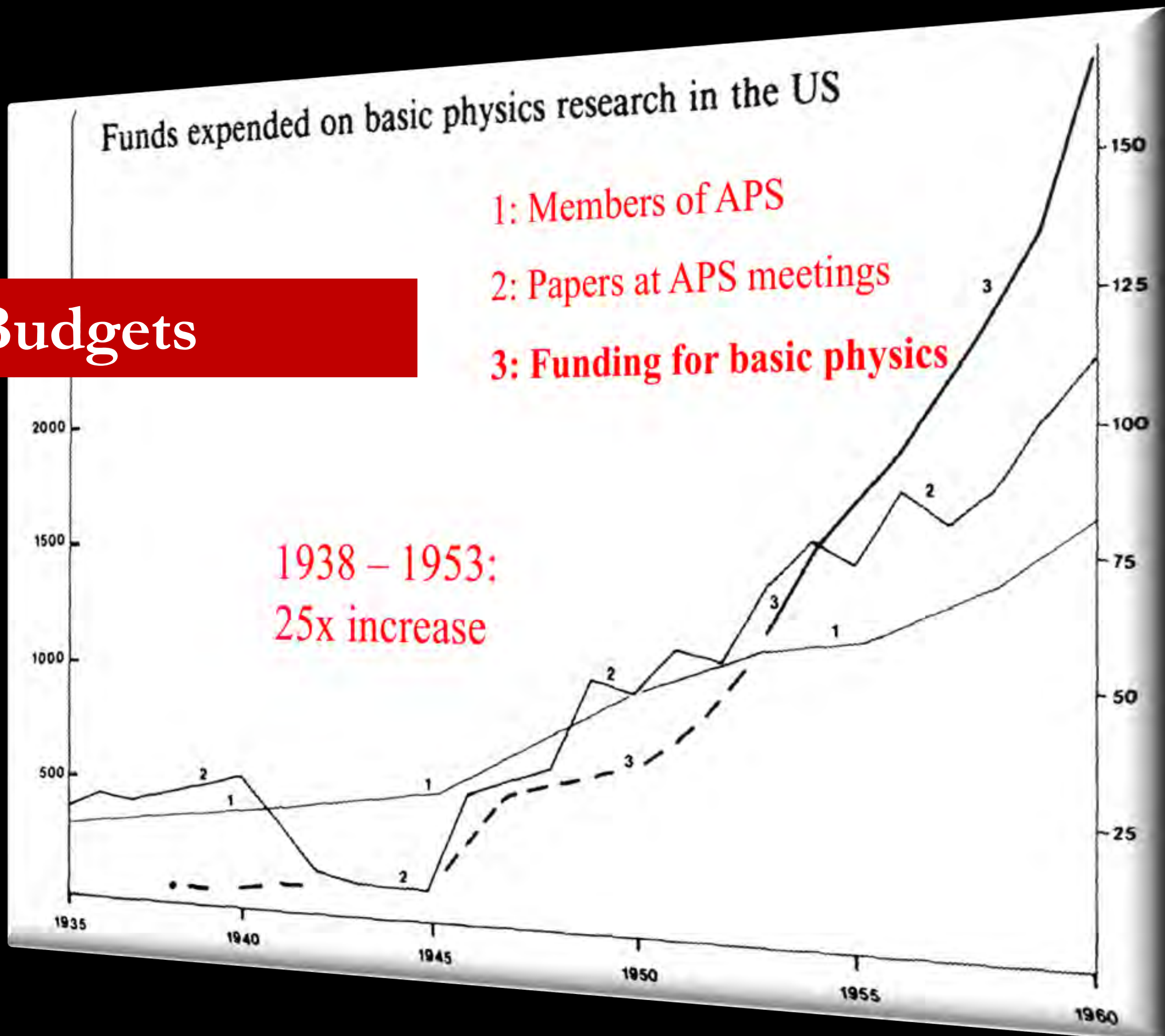
1. “Big Science”

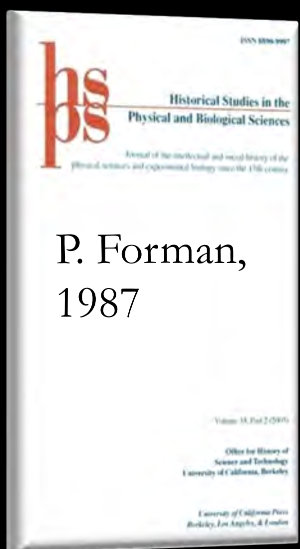
2. The “Scientific Manpower” Bubble

3. Training Quantum Mechanics

“Big Science”

Big Budgets



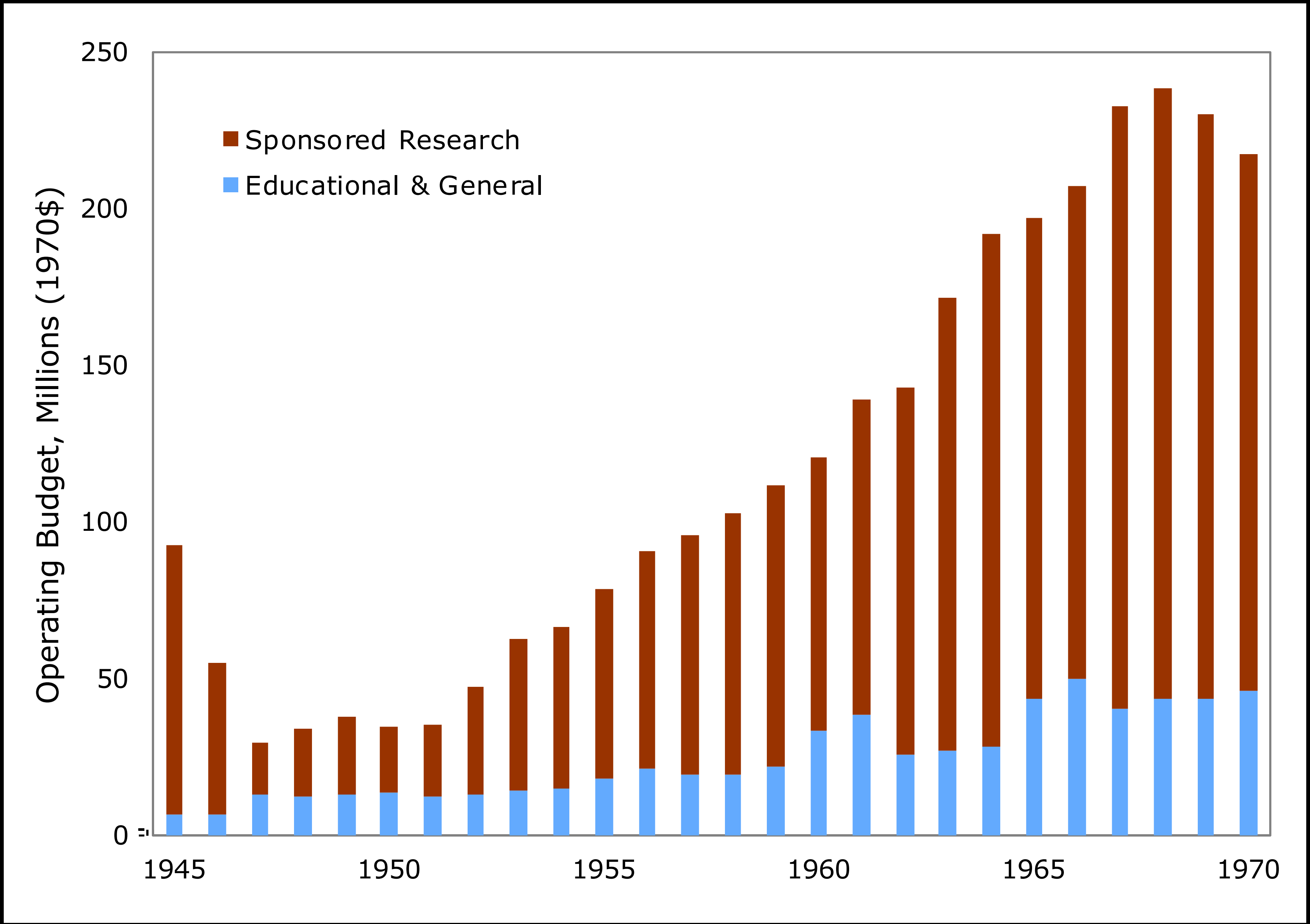


P. Forman, 1987

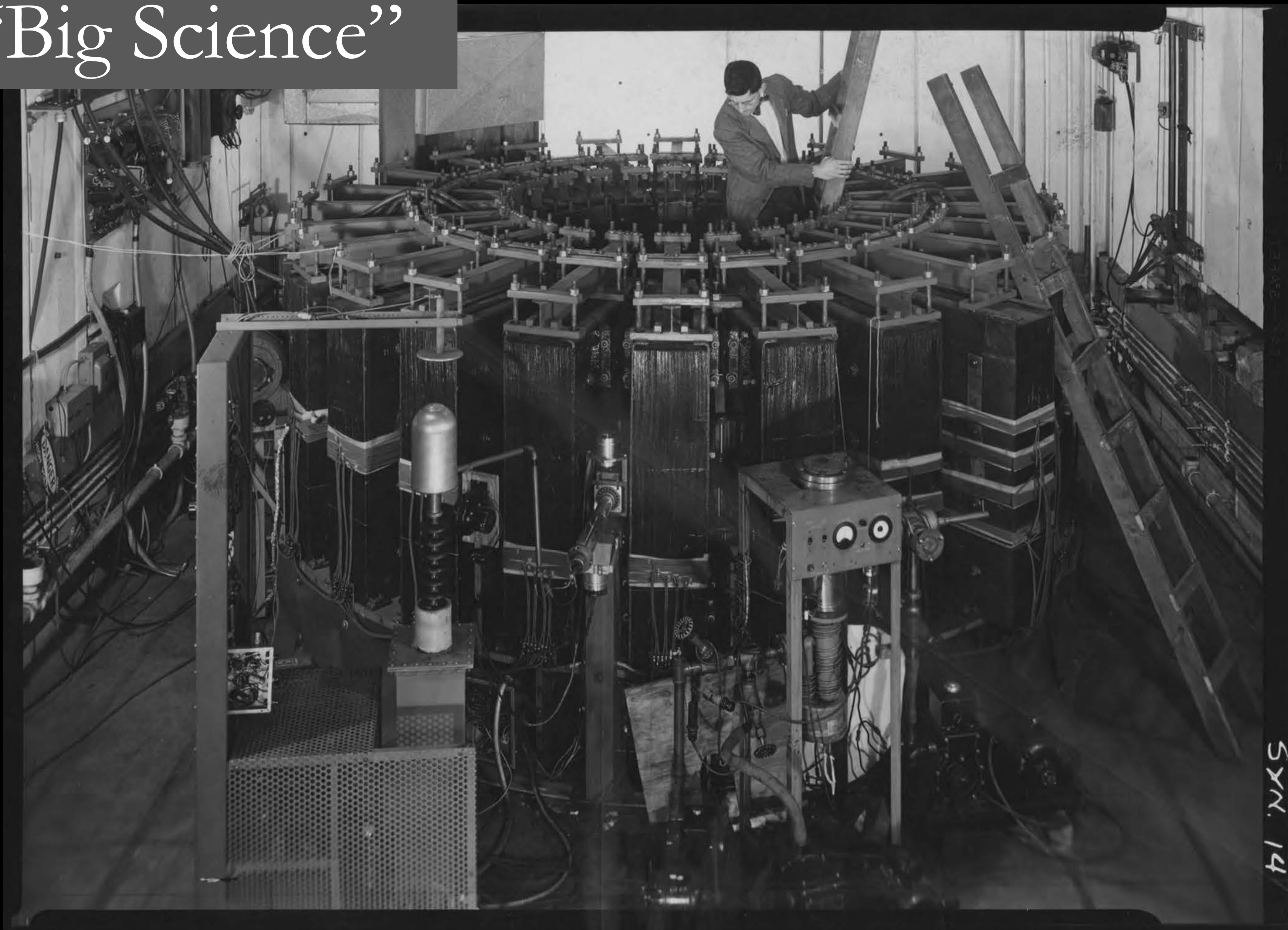
1949: 96% of funds for academic physics research from military

1954: 98% of funds for academic physics research from military

MIT Operating Budget (constant dollars)

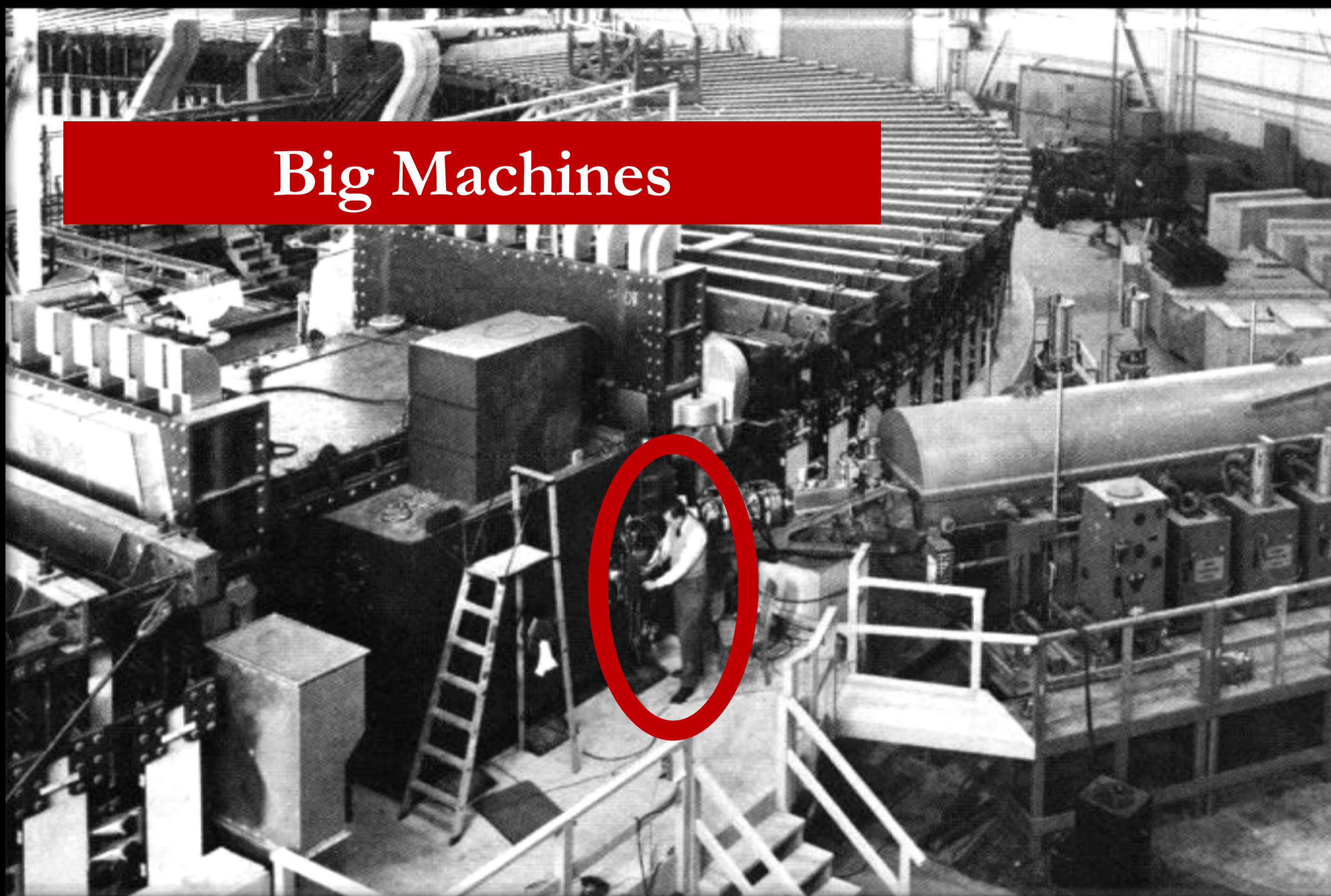


“Big Science”

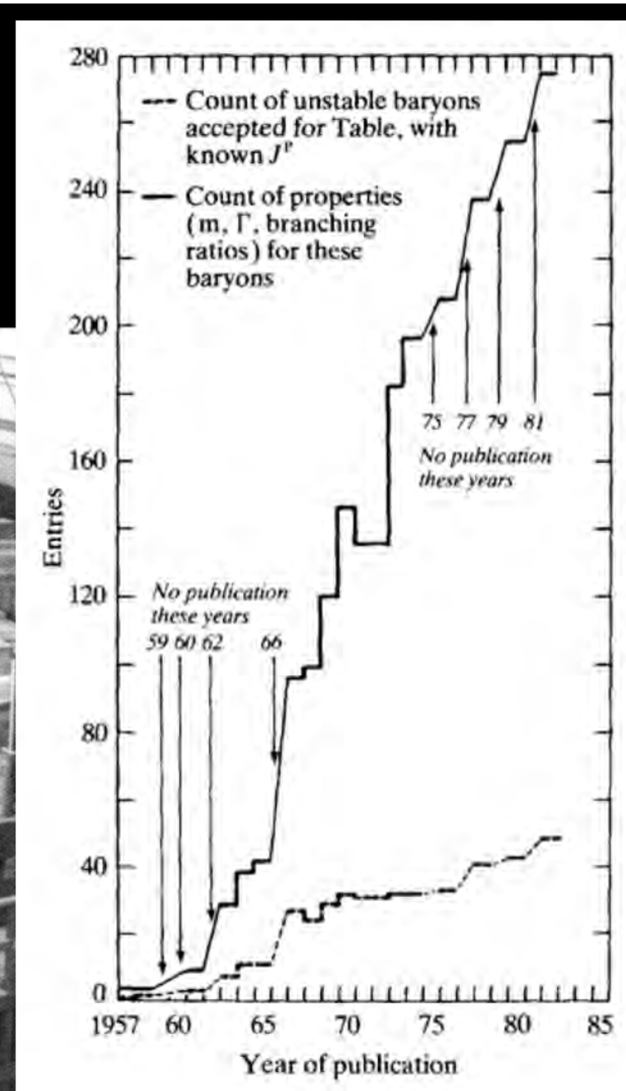


MIT’s 350 MeV synchrotron, mid-1950s

“Big Science”



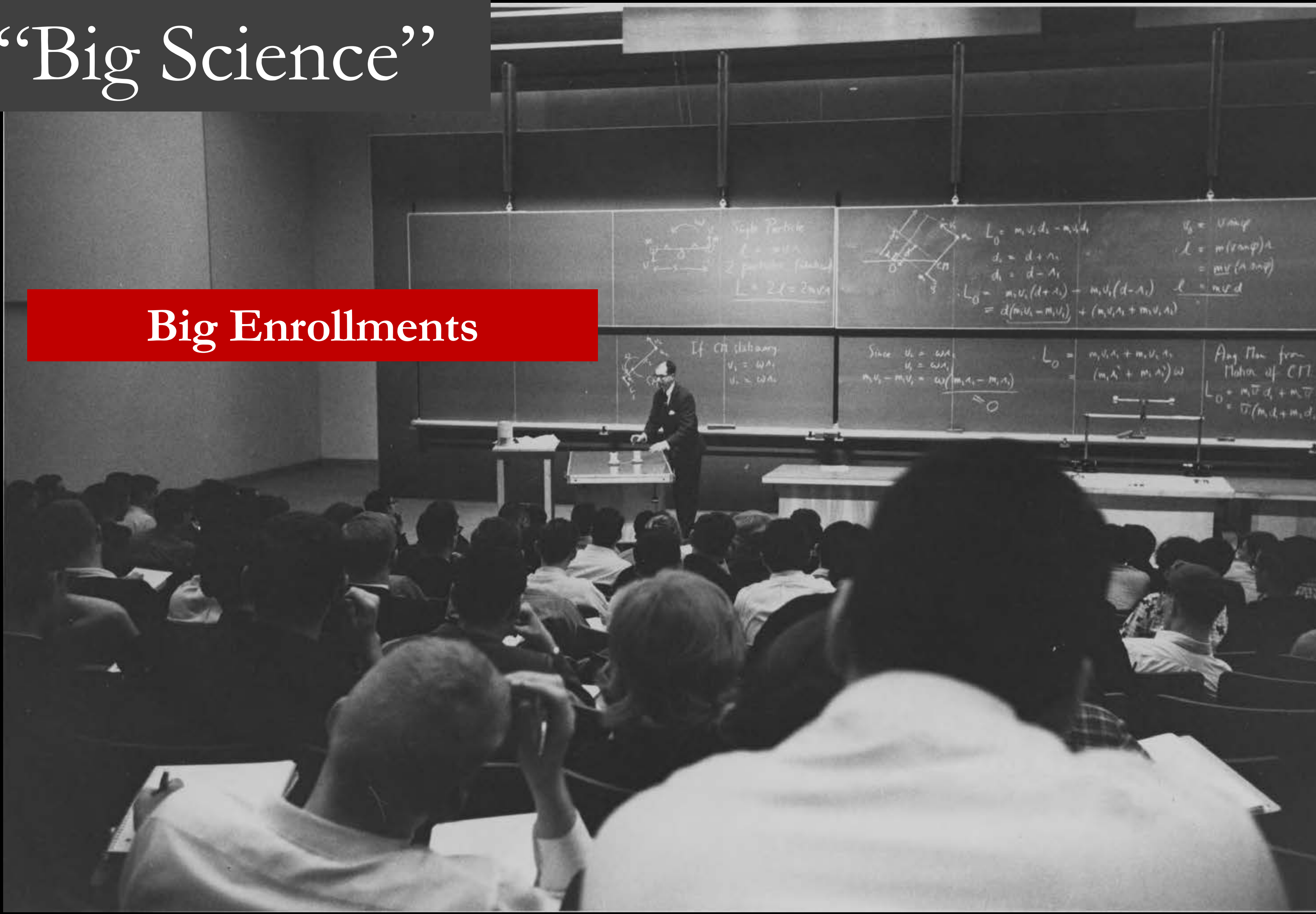
Berkeley Bevatron, 1955



By 1952, physicists began to joke that a new particle seemed to be discovered *every month.*

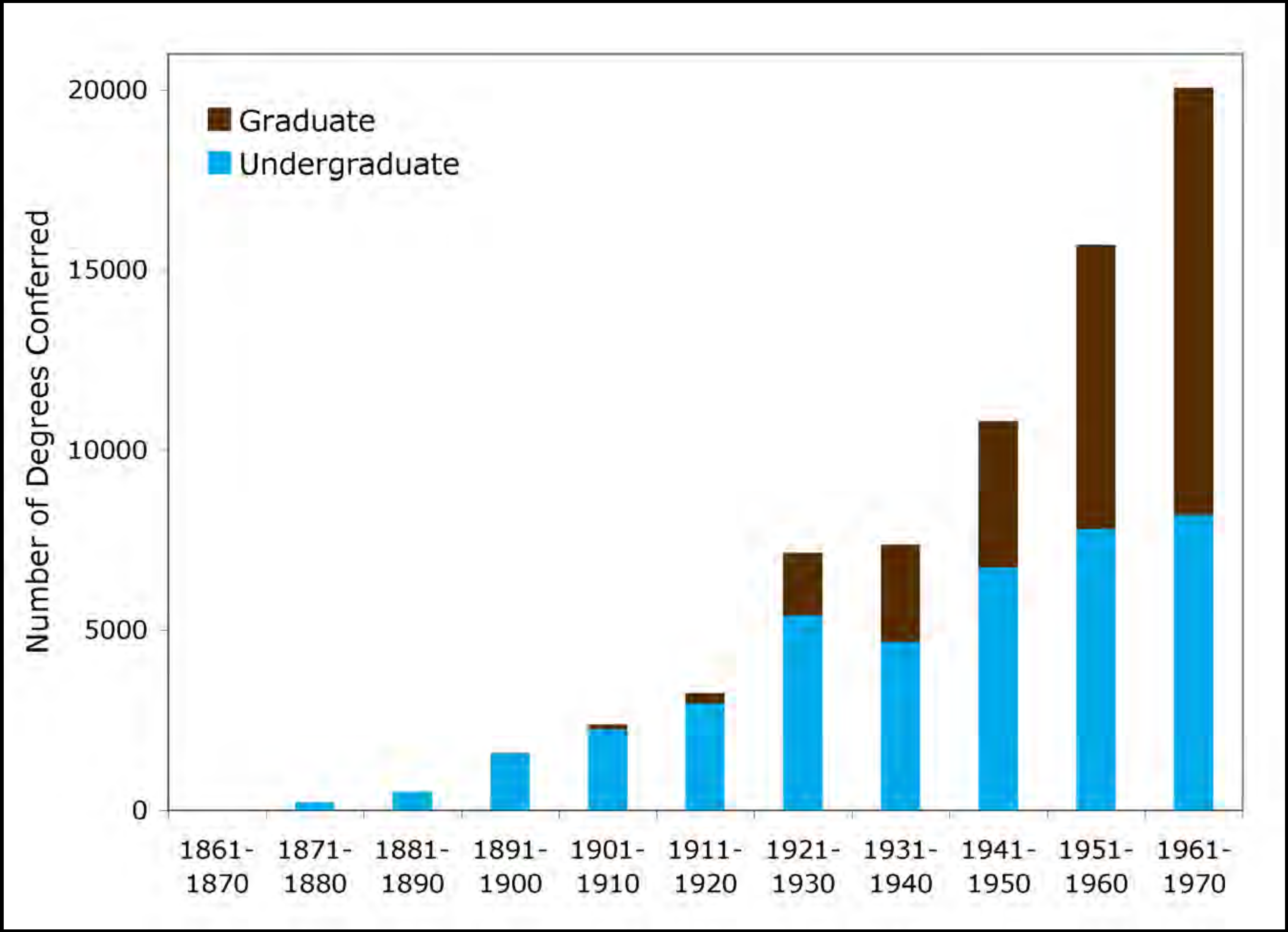
“Big Science”

Big Enrollments

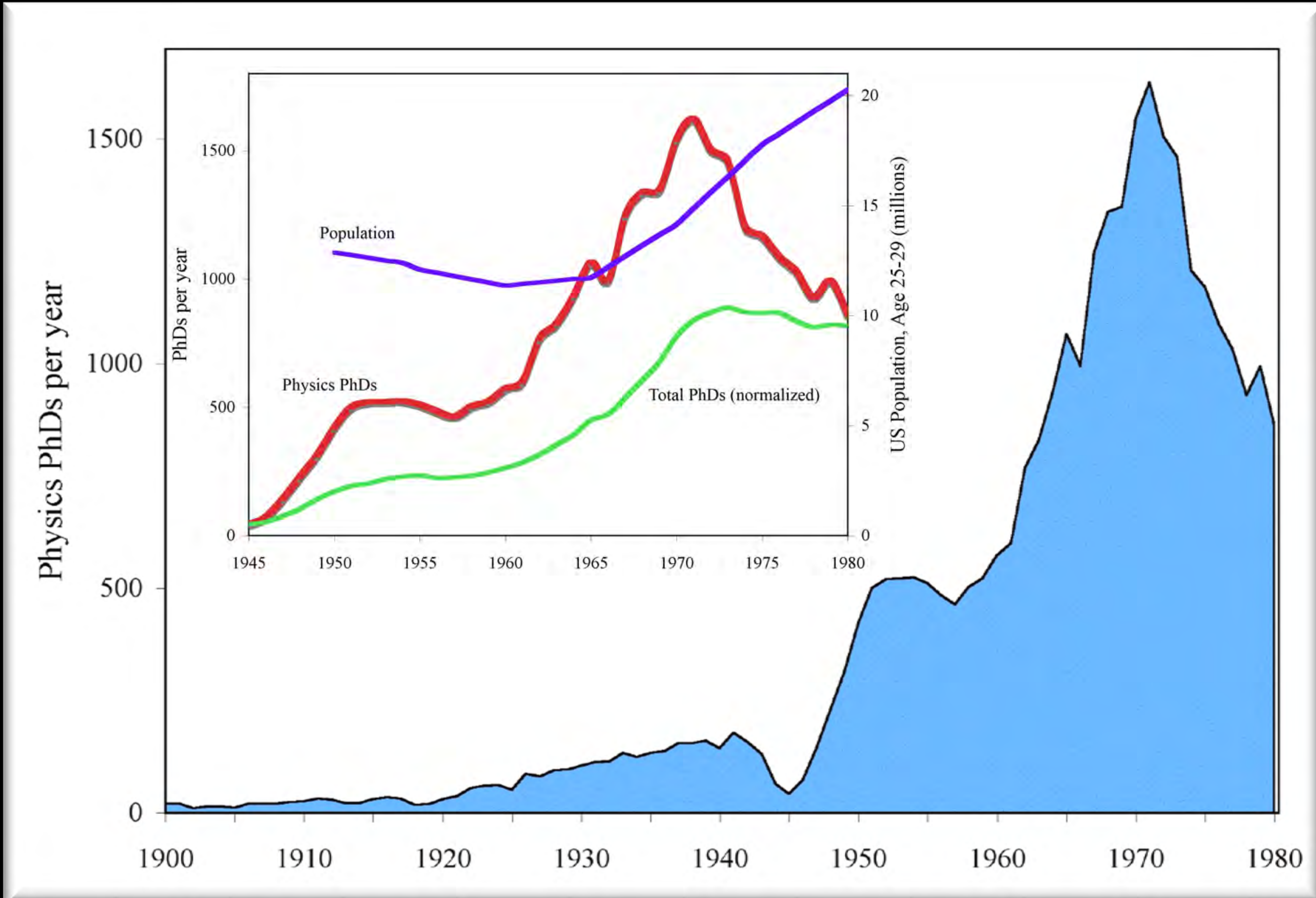


Prof. Anthony French teaching physics at MIT in 26-100, 1964

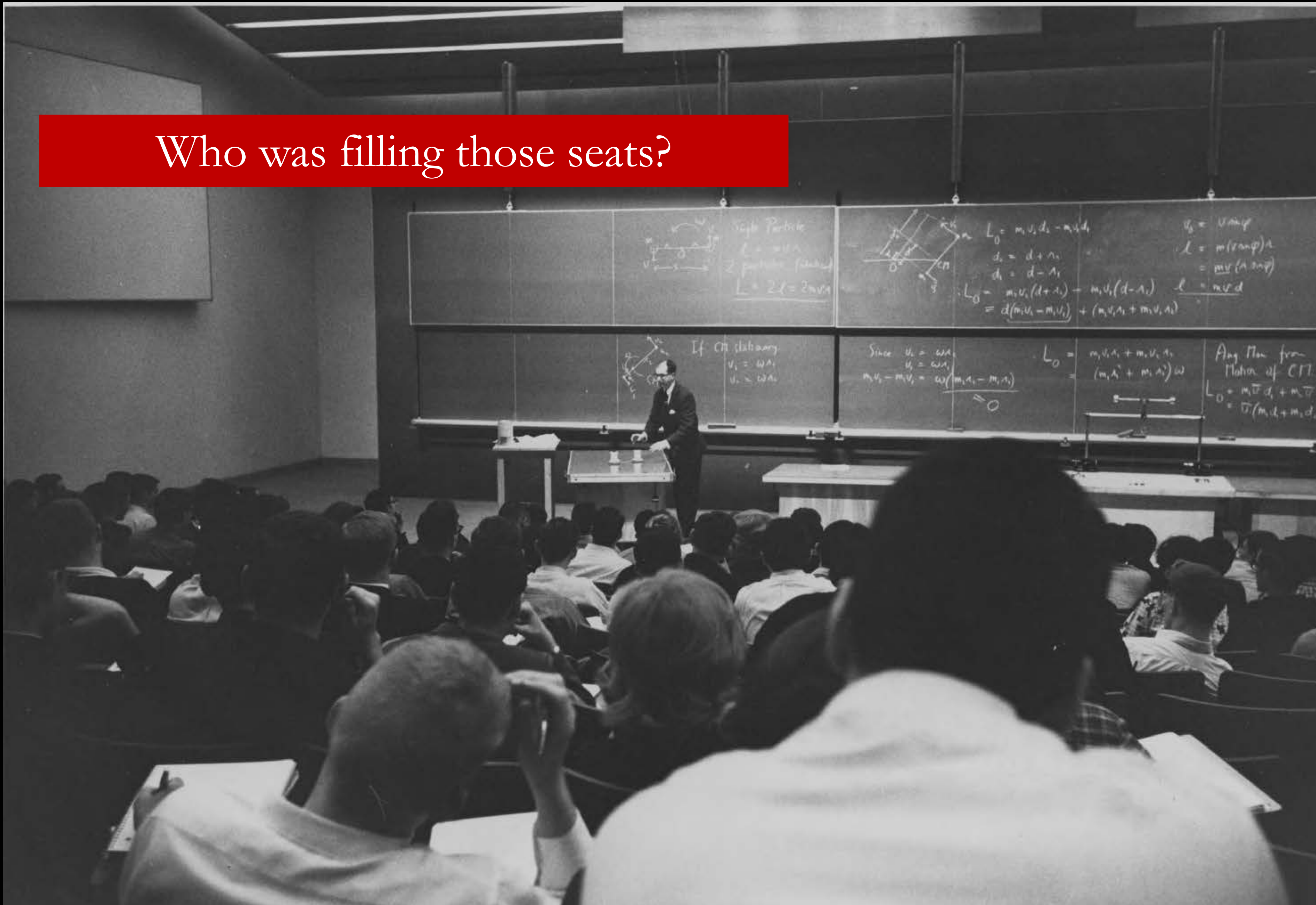
Number of Degrees Conferred by MIT, 1861-1970



Physics Ph.D.s in the US



Who was filling those seats?



Prof. Anthony French teaching physics at MIT in 26-100, 1964

Harvard letter of recommendation for a physics PhD student applying for a position at the AEC's Argonne National Laboratory, 1954: the student had a traditional-sounding Japanese last name, so the letter-writer emphasized that the student was actually a US citizen from Honolulu and a US veteran of World War II.

Naval Academy (Annapolis) job ad for a new physics faculty member, 1953: only those who were "white, male, and an American citizen" were eligible to apply.

February 1950 notes on prospective faculty candidates, Berkeley physics department: "Medium height, dark, rather handsome Jewish type," whereas a different candidate with "Jewish features" was "perhaps slightly forward in manner."

Berkeley's physics department chair, 1955: the department had "practically no minory group problems. So far as race is concerned, we have never yet had a negro graduate student in the department, hence that particular problem [*sic*] has never arisen."

Throughout the 1930s, women had accounted for about 16% of the physics B.A. degrees earned each year in the US. During the 1950s, the proportion fell to *4%*. Meanwhile, the proportion of women earning PhDs in physics dropped from 4% to 2% each year.

“The married [physics graduate] student’s wife expects him home every evening at five or five-thirty. Now the laboratories are dark at night.” Interview with psychologist Ann Roe, 1950

Job ads in *Physics Today*, 1950s

Physics Wives “Get Acquainted Tea,” Berkeley, 1961

John Slater (MIT): “Present students find it harder to settle down to work. Wives and babies take up a lot of time that my generation put into physics. The wives, it is true, help to type their husbands’ theses, but in the older days the necessity of doing this ourselves made us learn typing.” *Physics Today* 1969

Prof. Evelyn Fox Keller

At Harvard during the 1950s, the Physics Department included between 3 and 7 women PhD students each year (out of 100 PhD students). The women were registered through the "Radcliffe Graduate School," even though Radcliffe did not have its own physics department. Once enrolled, their files were put in a "Radcliffe" pile—so they sometimes missed notifications like the time and place for final exams.

1962 AIP data: women who *did* pursue careers in physics averaged ***30% lower earnings*** than men who had achieved the same level of education in the field.

Physics Dept Jr. Faculty Skit, Univ. Illinois, 1963: Men should submit their credit ratings on admissions forms, while "girls could submit photos in bathing suits, and give critical measurements."

Cold War "big science" meant a *certain kind* of booming enrollments—and a colossal, collective failure of the imagination.

Product ad in *Physics Today*, 1950s

Questions?

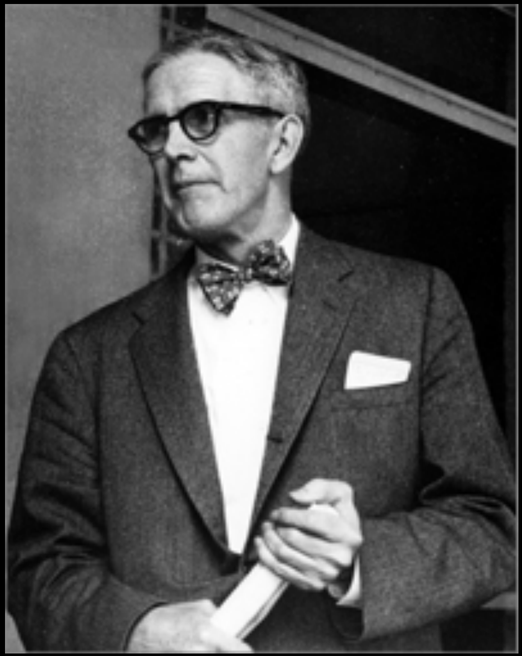
“Manpower”

“In a time of national emergency, this country would think nothing of spending a million dollars to survey, develop, and conserve a short commodity like natural rubber or tin. Highly trained and able human resources, viewed as a commodity, are far more important.”

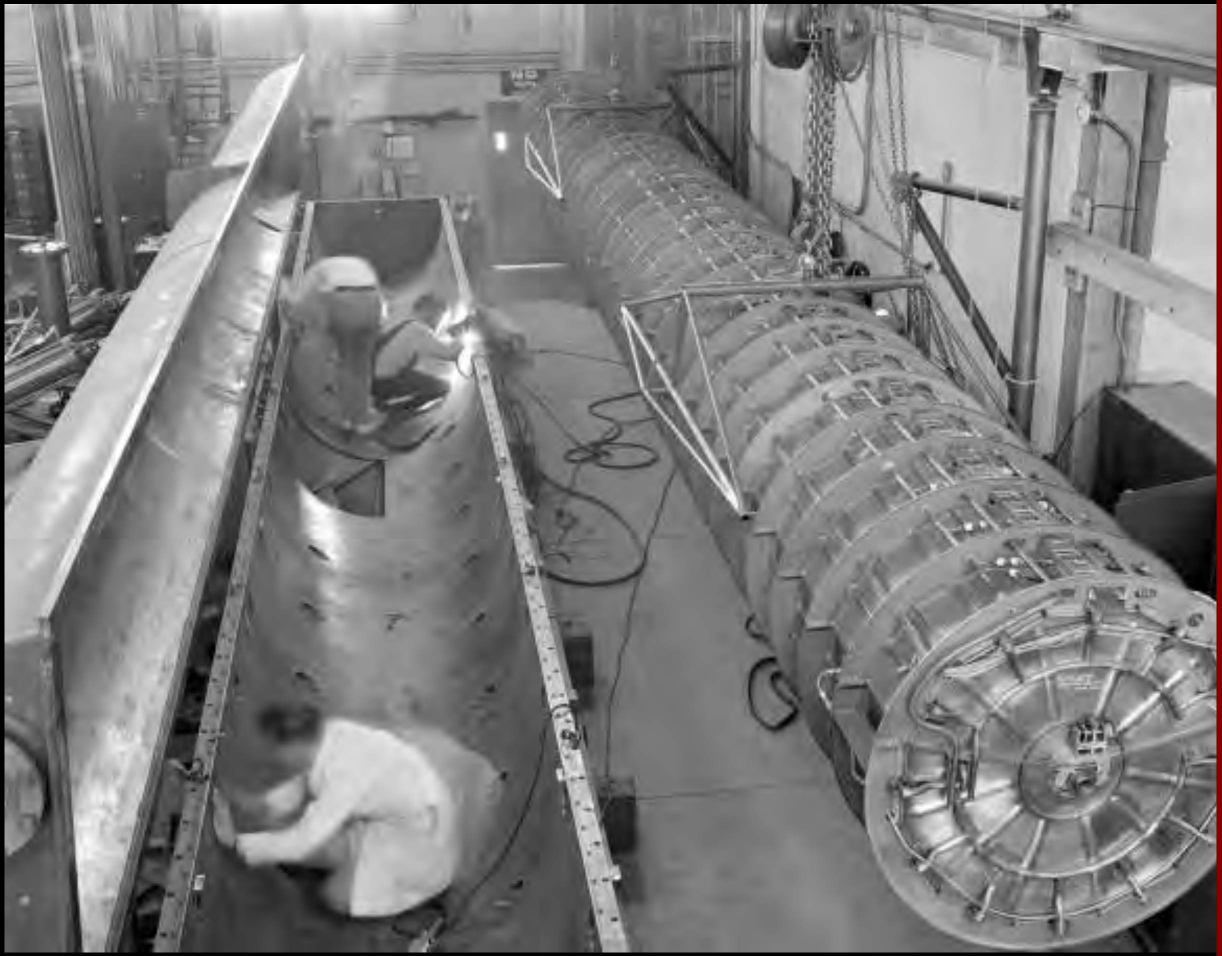
H. A. Barton, AIP, 1948

“Scientific manpower” was a “war commodity,” a “tool of war,” and a “major war asset,” and hence needed to be “stockpiled” and “rationed.”

H. D. Smyth, 1950



"Big Science"



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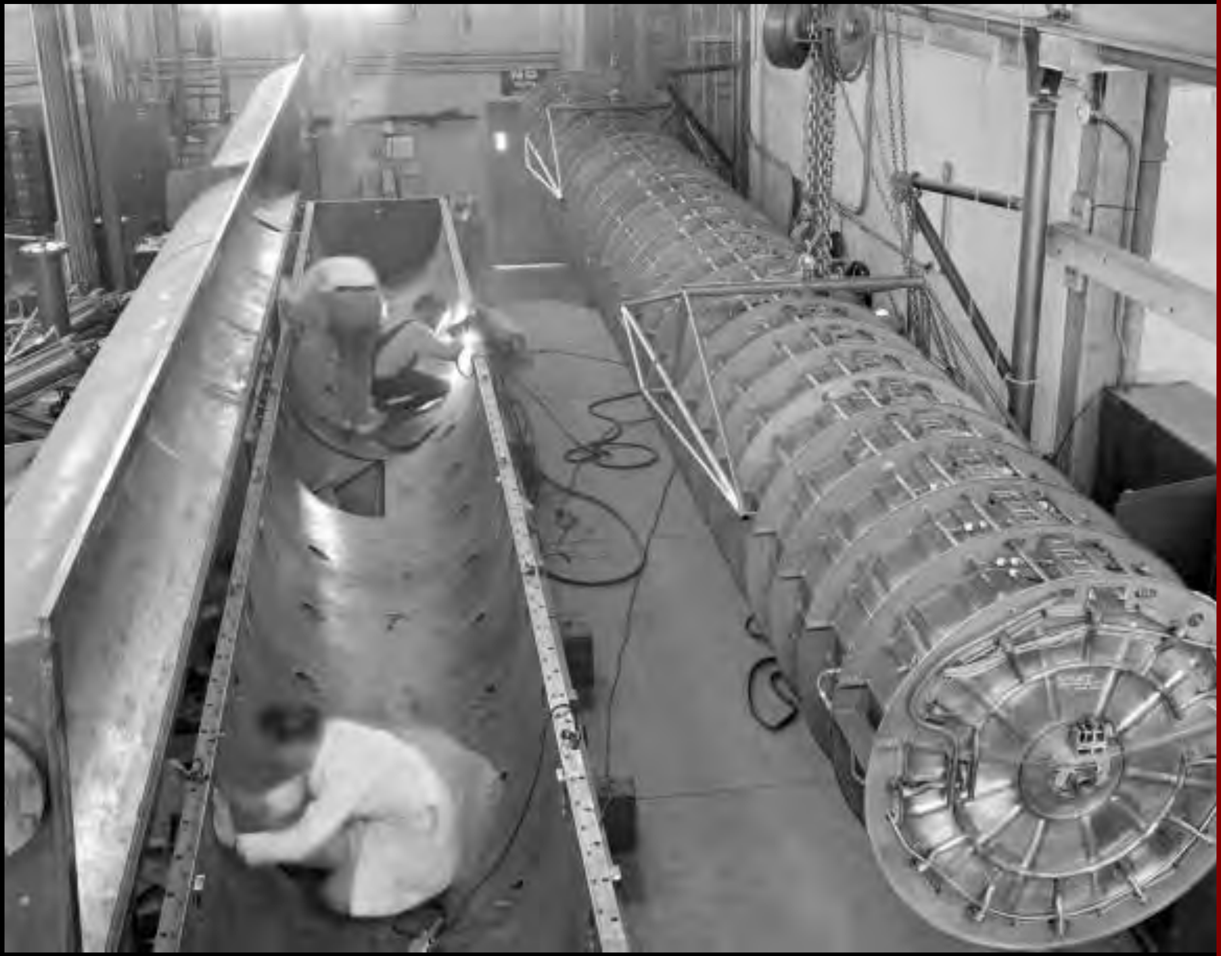
If N nuclear physicists were "willing, able, and eager to use particle accelerators, and on average five such men per accelerator is an effective team," then the AEC should build $N/5$ accelerators, or two per year for as long as "the international situation remains roughly as at present."

AEC memo, July 1951

In 1948 the AEC *overruled* its GAC, which had argued that only *one* GeV particle accelerator was necessary, scientifically. The AEC built *two* to avoid hurting physicists' "morale."

"Big Science"



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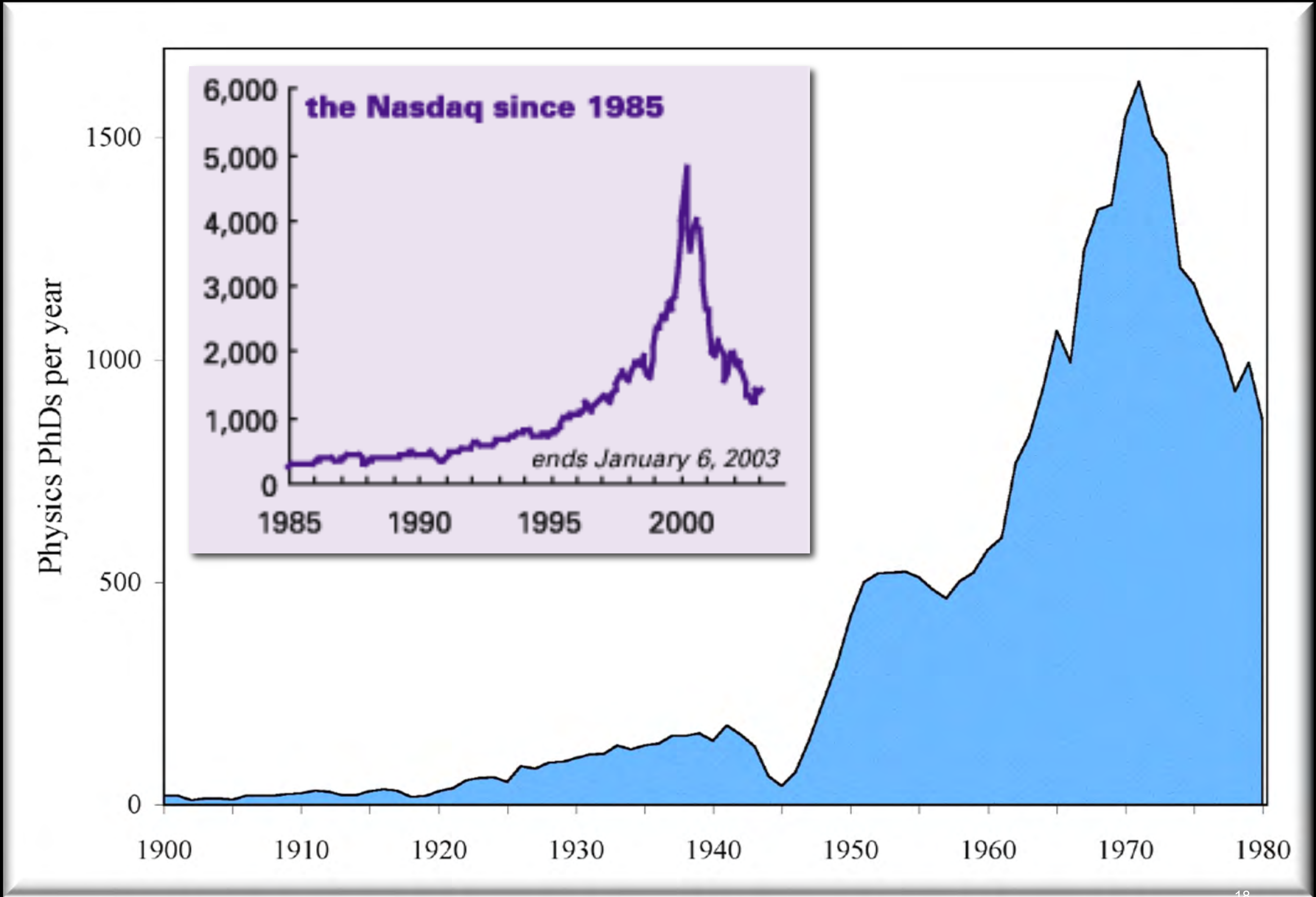
AEC memo, July 1951

1953: 75% of physics PhDs who completed their degrees with AEC support took jobs with the AEC.

The Cold War Bubble



Speculative Bubbles

- Tulip craze, 1630s
- South Sea Bubble, 1720
- Tech stocks, 1990s
- Housing prices, 2000s

"a situation in which temporarily high prices are sustained largely by investors' enthusiasm rather than by consistent estimation of real value." *Robert Shiller*

Roles of *hype*, *amplification*, and *feedback loops*.

Assessing the Soviet Threat

Nicholas DeWitt, *Soviet Professional Manpower: Its Education, Training, and Supply* (1955)

Alexander Korol, *Soviet Education for Science and Technology* (1957)

Nicholas DeWitt, *Education and Professional Employment in the USSR* (1961)

DeWitt: "an indefatigable digger"; Korol: "fastidious"

\$\$\$\$\$\$\$\$ ← → \$\$\$\$\$\$\$\$

“Perplexities and Pitfalls”

Both DeWitt and Korol warned against getting lost in the “numbers game”:

- large fraction of Soviet engineers worked in administration, not R&D
- extreme specialization
- standards jimmied to fit “production quotas” of 5-year plans
- extension and correspondence students inflating the ranks: 1/3 in 1955, >1/2 in 1960.

nonferrous metals metallurgy

1. copper and alloys;
2. precious metals refining;
3. …

11.

Enrollment Patterns

Korol refused to tabulate enrollment data side by side, to avoid "unwarranted implications." DeWitt did so only after emphasizing all the caveats. He found:

Annual Degrees in Higher Education

	US		USSR
full-time students:	3	:	1
full + extension:	4	:	3
science and technology:	25%	,	75%

The Soviets were graduating 2-3 times more students per year in engineering and applied sciences than the US.

Hype: “Two to Three Times…”

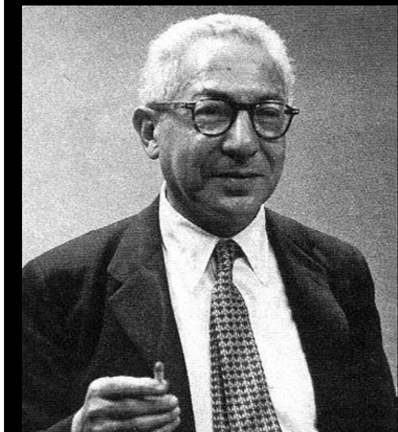
Red Technical Graduates Are Double Those in U. S.

Russia Is Overtaking U.S. In Training of Technicians

Eisenhower and Sputnik images are in the public domain.

…and then came Sputnik

Amplification



I. I. Rabi, chair of PSAC: Urged Eisenhower to use Sputnik as a pretext for closing the "manpower gap."

AMERICAN INSTITUTE OF PHYSICS

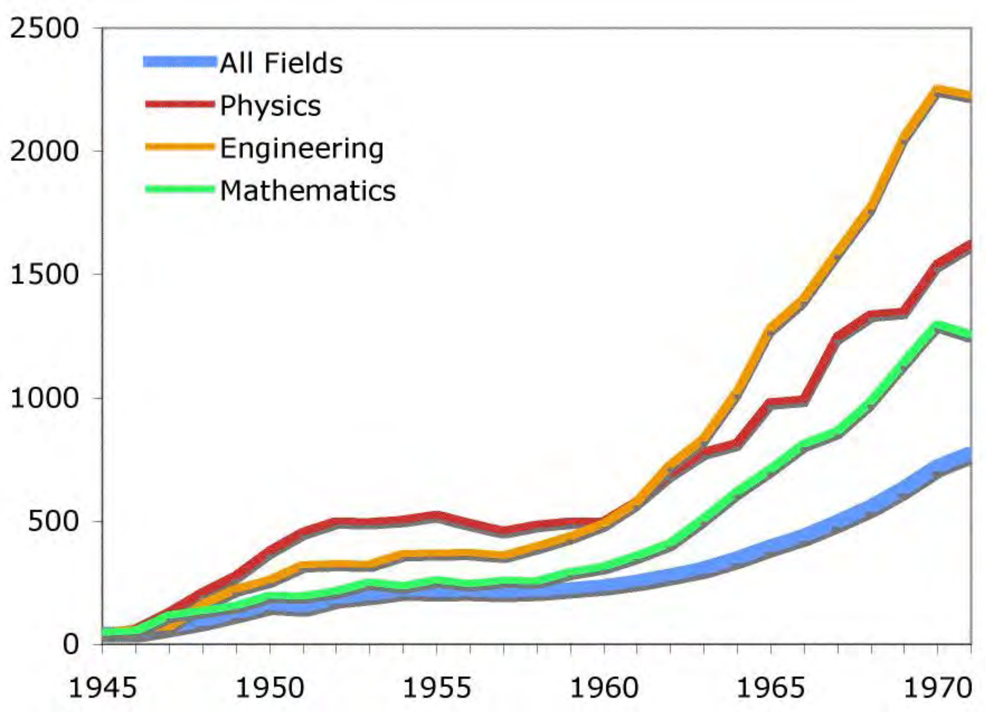
Elmer Hutchisson, director of AIP: "an almost unprecedented opportunity" to "influence public opinion greatly."

Hans Bethe, past president of APS: repeated DeWitt's ratio without knowing from whence it came or how it had been computed.

Eager press: count up number of hours spent on physics in US and USSR high schools.

Feedback Loop

NDEA enacted, Sept 1958: \$1b (~\$9b in 2020\$). First federal aid to education in a century.



First 4 years: 7k graduate fellowships; 500k undergrads.

Plus block grants and added incentives to states to increase enrollments. Sputnik scare had been used as a "Trojan Horse."

NDEA's proponents "were willing to strain the evidence to establish a new policy."

All aid was restricted to "defense" fields: science, math, engineering, and area studies.

Lies, Damn Lies, and Statistics

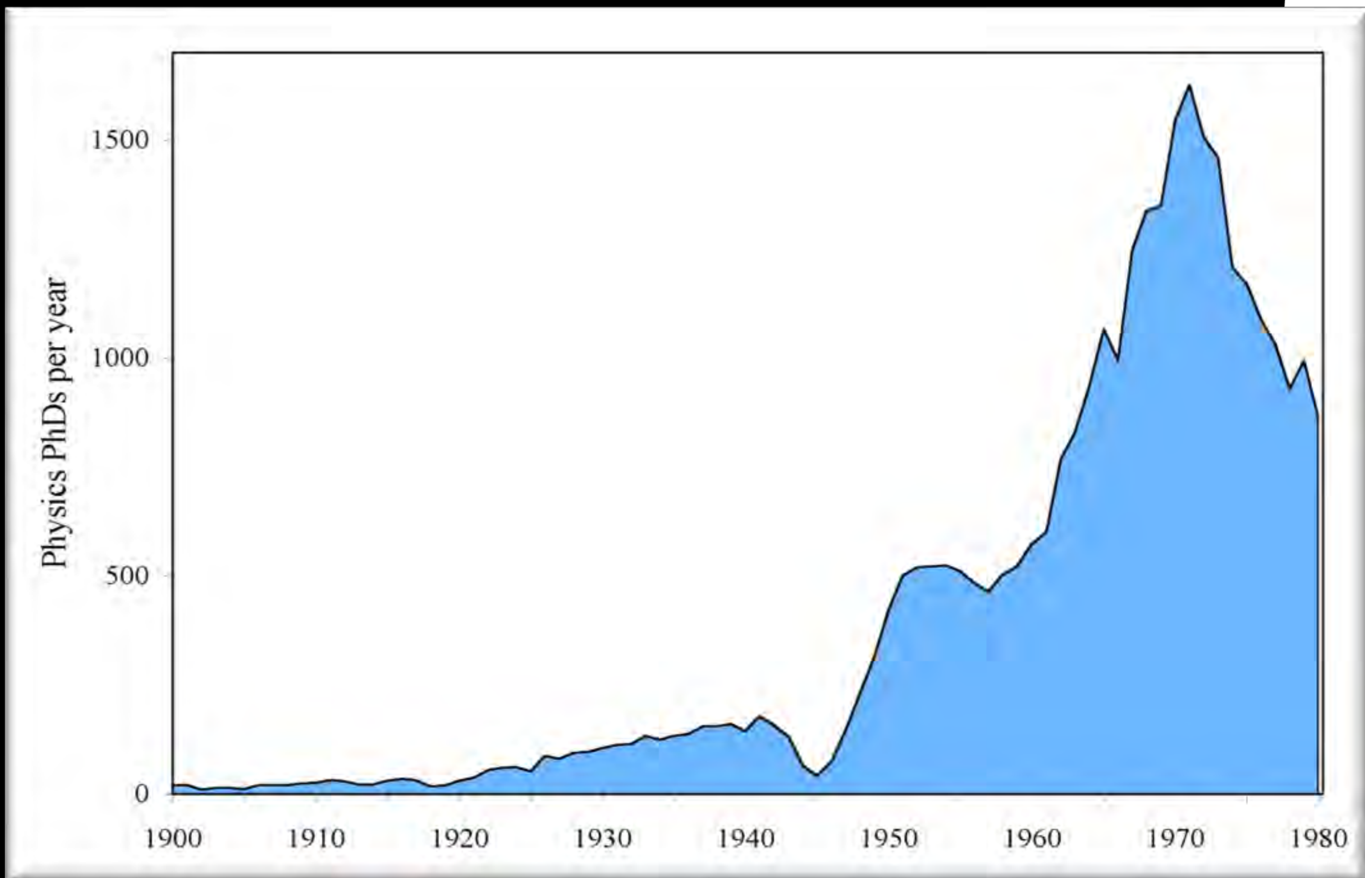
Even aside from DeWitt's and Korol's caveats — uneven quality, severe specialization, and inflation from extension and correspondence students — the numbers themselves deserved a closer look.

DeWitt: "engineering and applied sciences" = *engineering*, *agriculture*, and *health* → "2 to 3 times"

Trofim Lysenko

If drop agriculture and health and include science and math, the Soviet lead *fell by a factor of 10.*

The Bubble Bursts

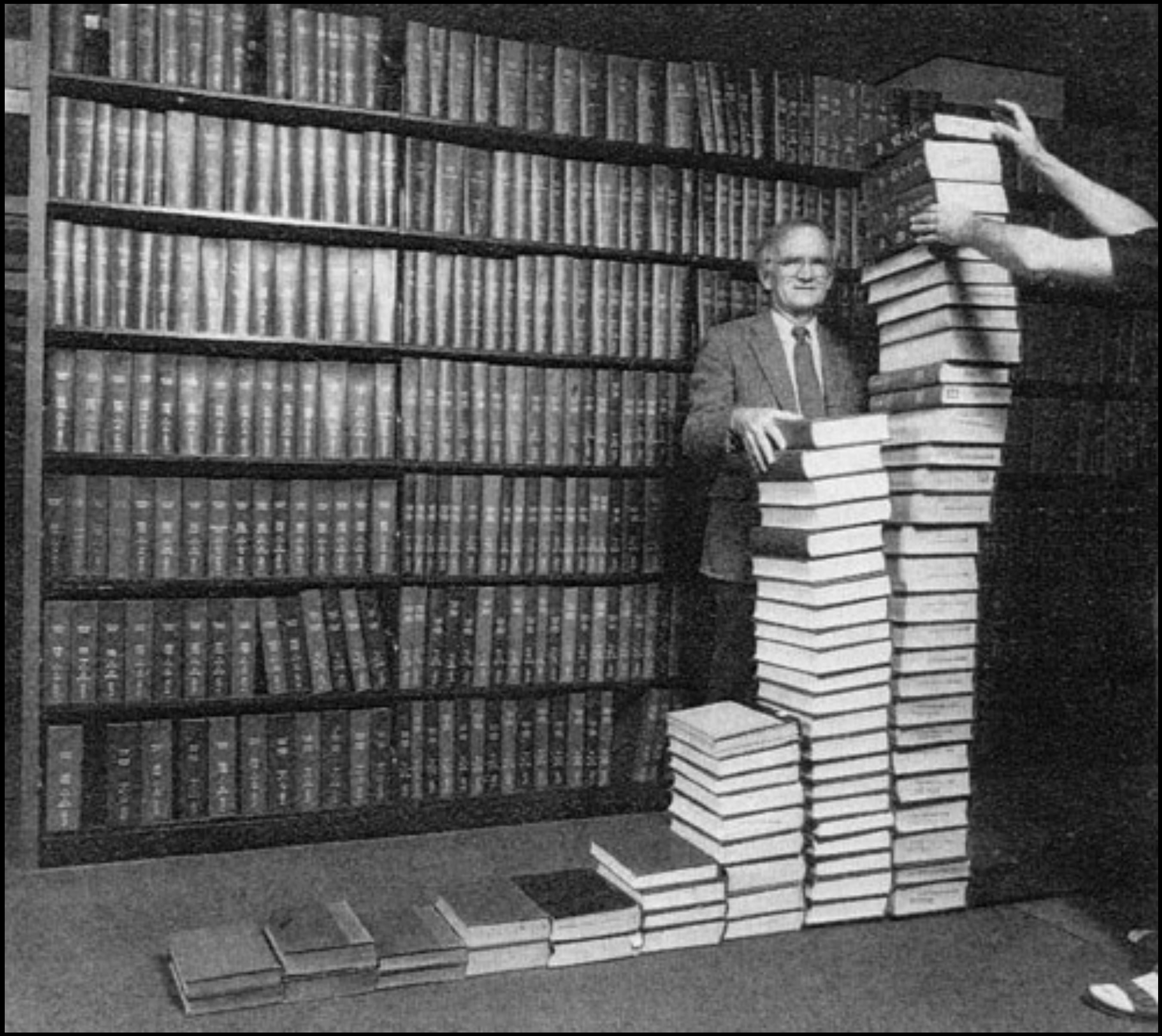


AIP Job Placement Registries

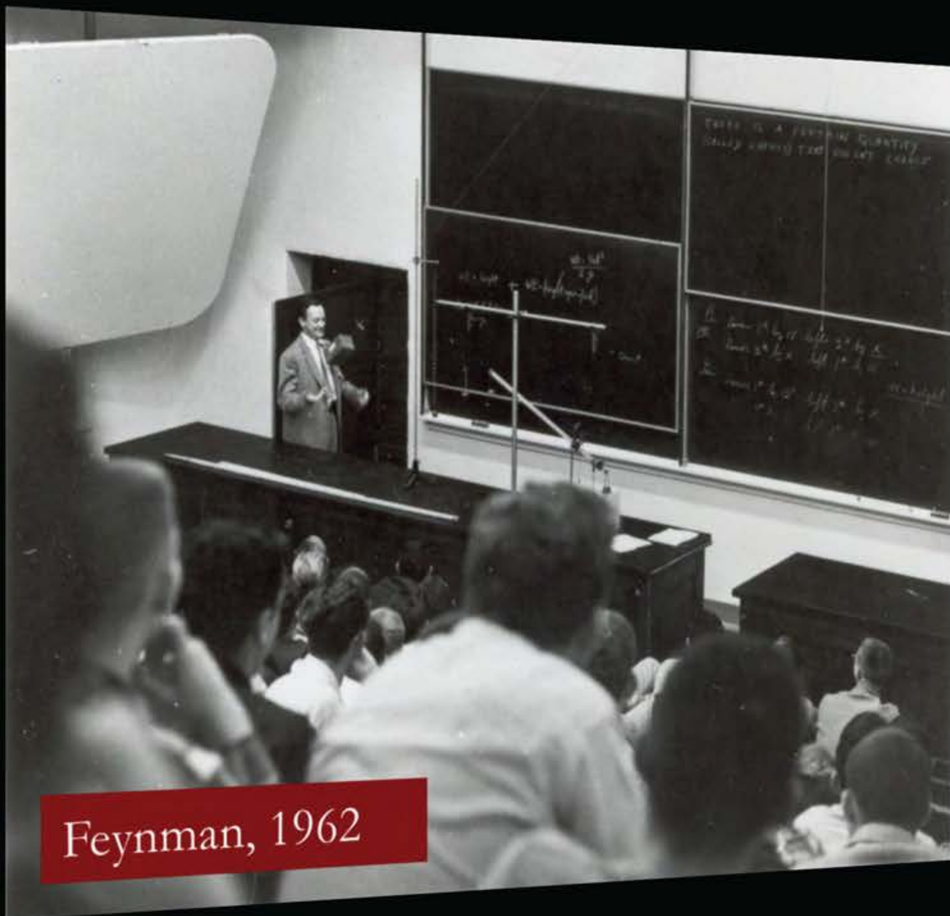
	Students registered	*Jobs on offer*
1963	449	514
1968	989	253
1970	1010	63
1971	1053	53

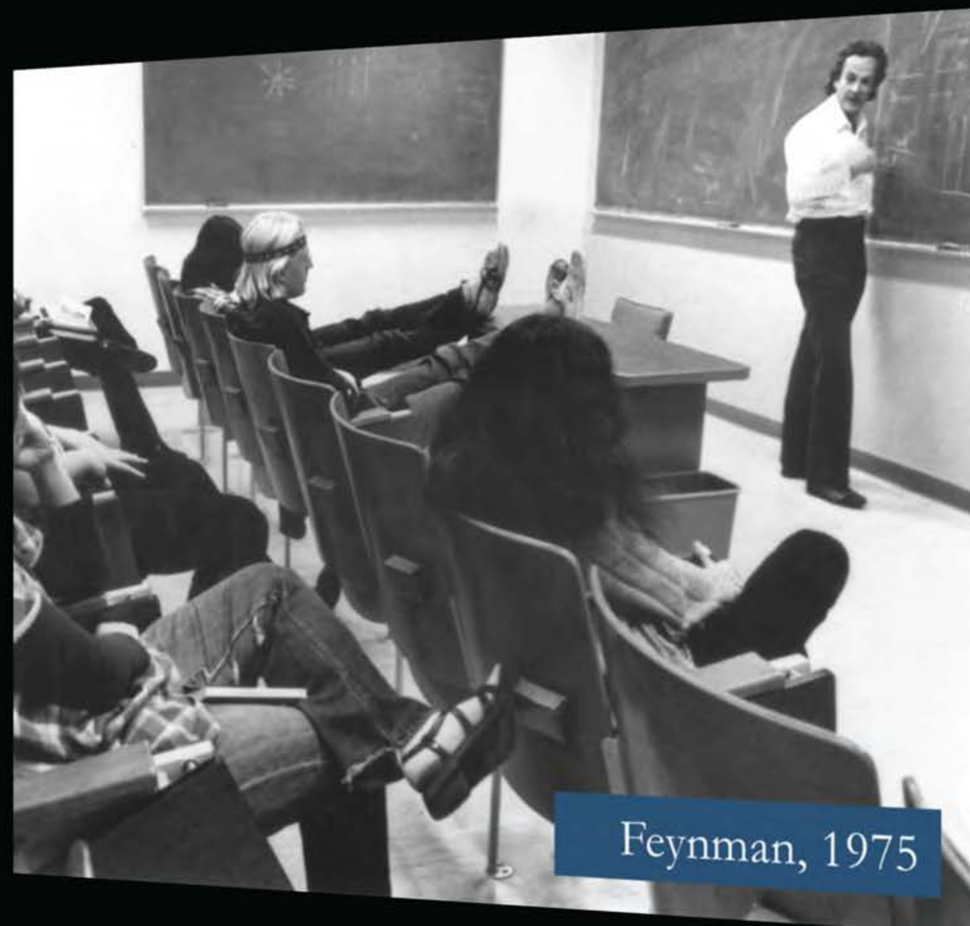
Questions?

Bubbles and the World of Ideas



Stacks of the *Physical Review* by decade, 1890s-1970s


Feynman, 1962


Feynman, 1975

“The General Epistemological Lesson…”

Kant

Mach

Jung

and friends

Quantum Americans

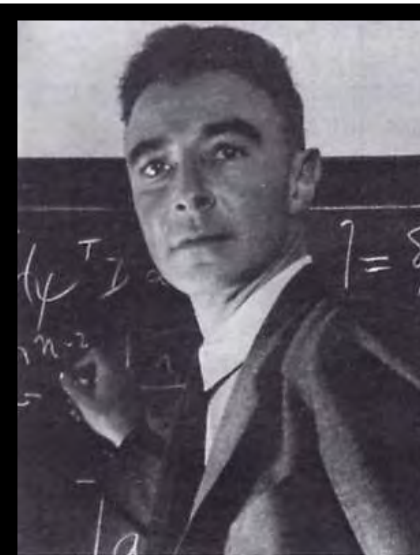
Bridgman

Condon

Morse

Kemble

Urey



Oppenheimer

Caltech oral exams, 1930s:

- measurement problem and the role of the observer
- uncertainty principle and the nature of physical explanation

Lecture notes, exams, textbooks, book reviews…

Philosophy Disappears

Feshbach

"Enough with this musty atavistic to-do about position and momentum…"
Feshbach, 1962

Book reviews: "avoids philosophical discussion"; "omits distracting, philosophically tainted questions"…

"Shut up and calculate!"

Caltech oral exams, 1950s:

- "the effort invested in analysis of paradoxes and queer logical points was of no use in the exam."
- best advice: "memorize" and "rehearse" stock problems ("the usual spiel").

General exams elsewhere: interpretive essay questions (1930s-40s) replaced by coterie of standard calculations (1950s).

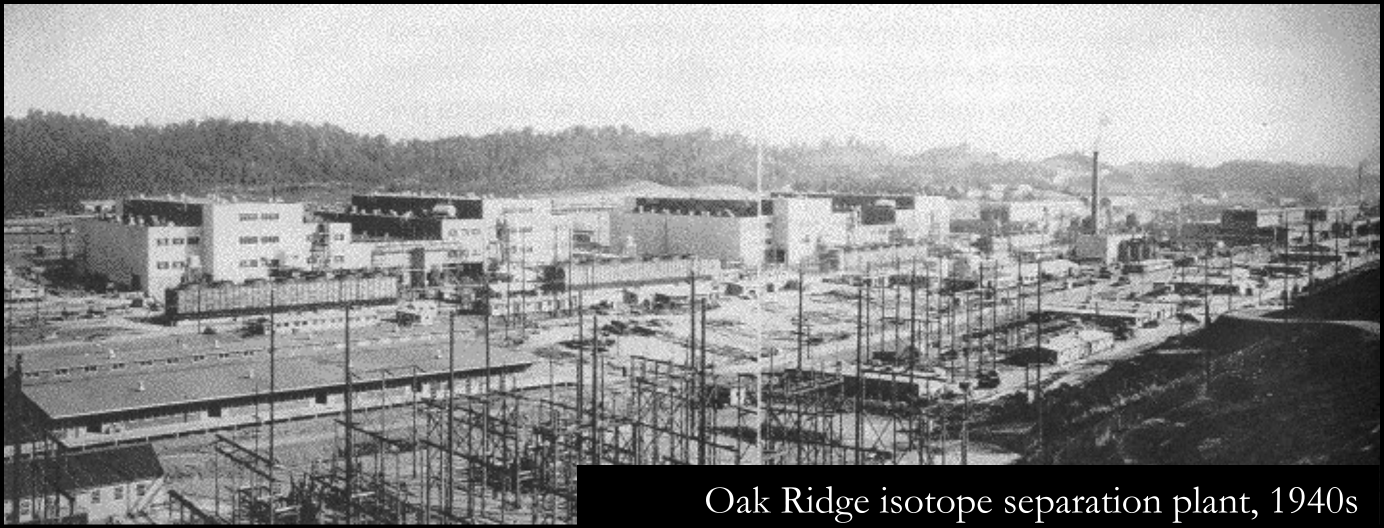
Accounting for the Shift

- *Were the puzzles and paradoxes resolved?*

No: still subject of active research outside the US.

- *Did war work turn US physicists into pragmatists?*

Not entirely: Nordheim, Epstein, Hill, …



Oak Ridge isotope separation plant, 1940s

- *Changing patronage or employment demands?*

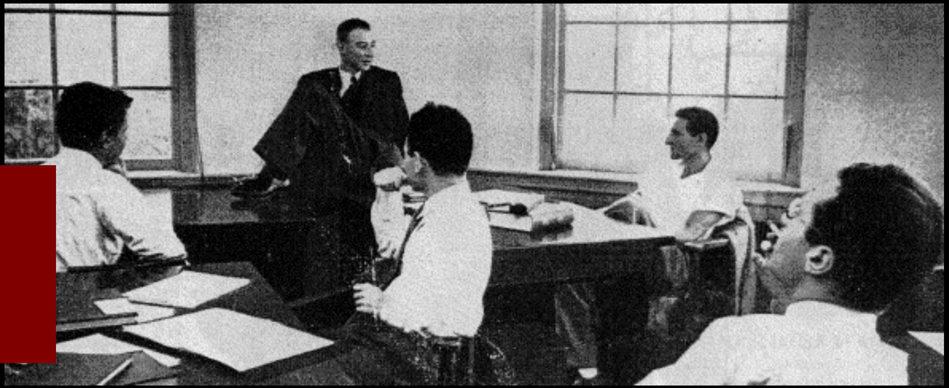
No correlation between the style of a department's QM courses and where that department's students got jobs.

- *Pedagogical pressures?*

Compare across US classrooms at the same time; and compare US and international textbooks over long time.

Class Size and Teaching Style

Graduate-level QM courses in US, mid-1950s



"philosophical" classrooms

enrollment: 12.7 ± 5.7

interpretive material: 12.8 ± 1.4%

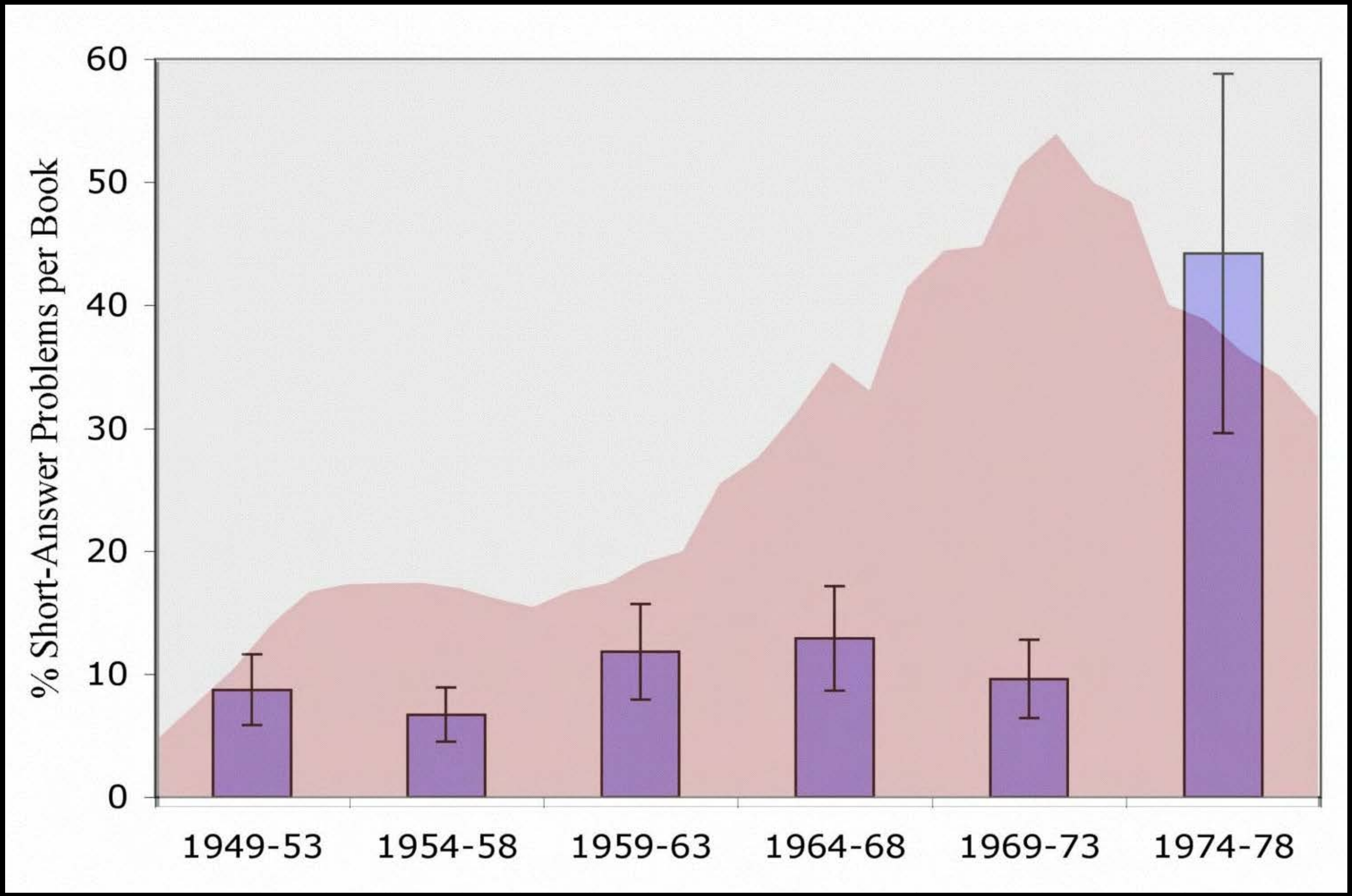
"pragmatic" classrooms

enrollment: 39.3 ± 13.4

interpretive material: 2.6 ± 1.5%

Essays and Algebra

US physicists published 33 graduate-level QM textbooks during 1949-78, containing 6,261 problems.

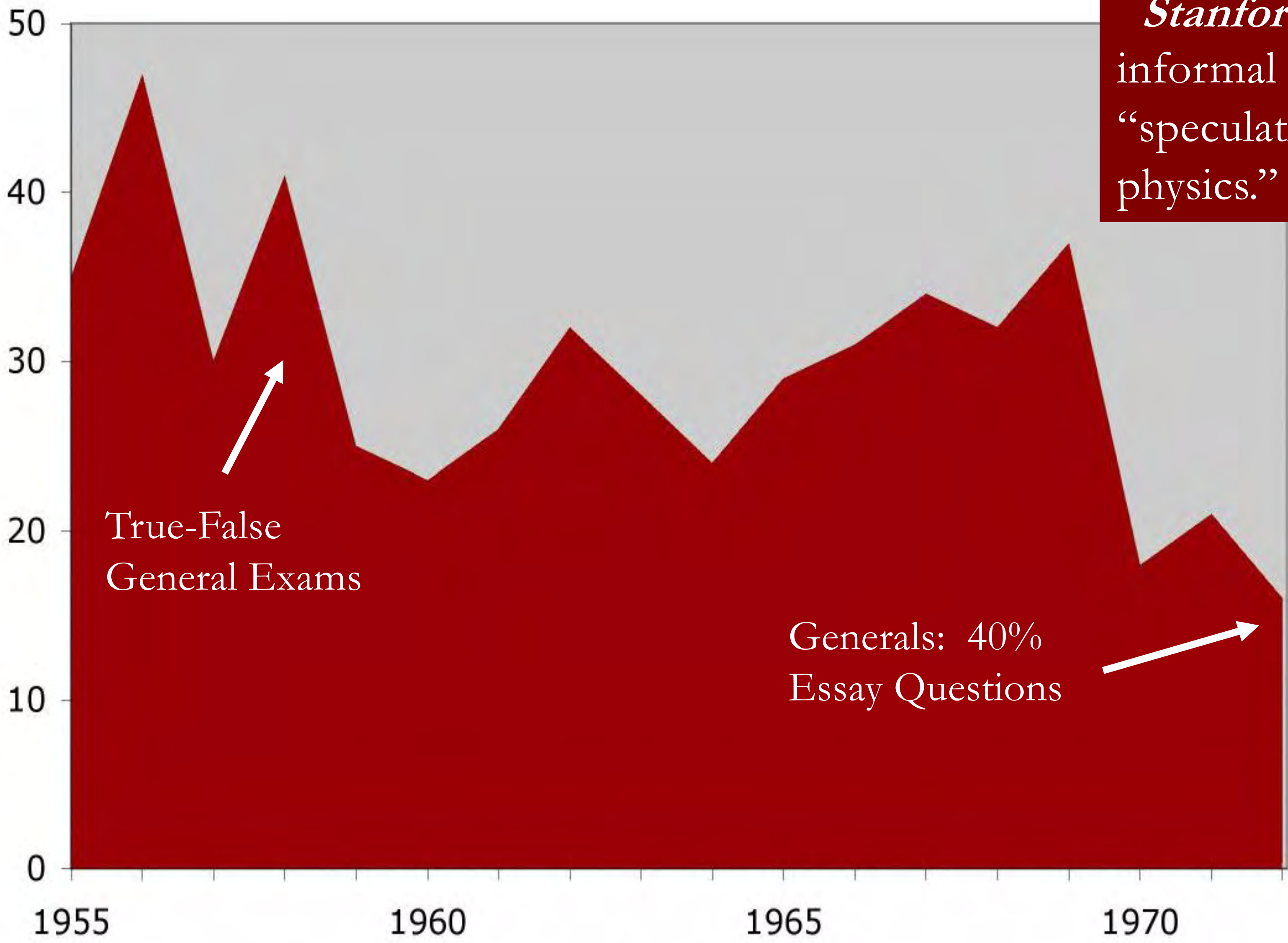


Bubble Physics

Berkeley case, mid-1950s. Research on foundations of quantum field theory was deemed pedagogically inappropriate:

"It is not the sort of work that can readily be used for Ph.D. theses. ... Hence it seemed to our committee that [he] was not carrying his fair share of the load of graduate student research. ... It was therefore felt that he would not be particularly valuable to us since we have a very large number of graduate students who must be guided to the Ph.D. degree."

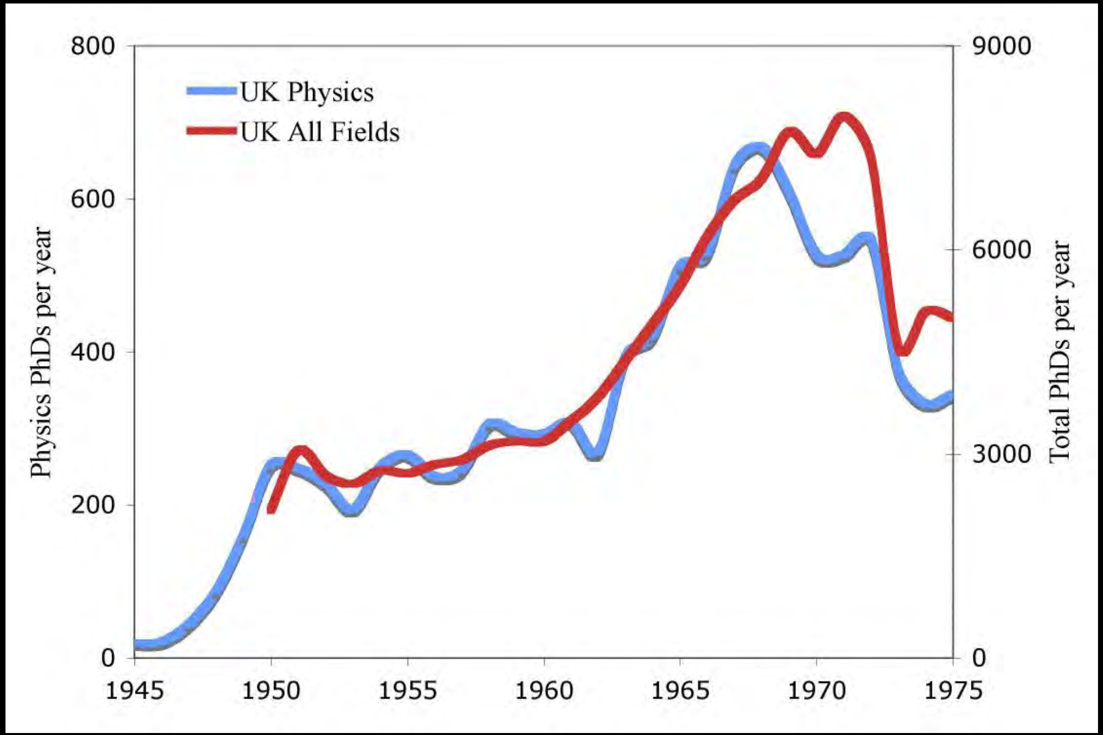
Entering Graduate-Student Cohort, Stanford Physics Department



Stanford, 1972: new informal seminar on "speculations in physics."

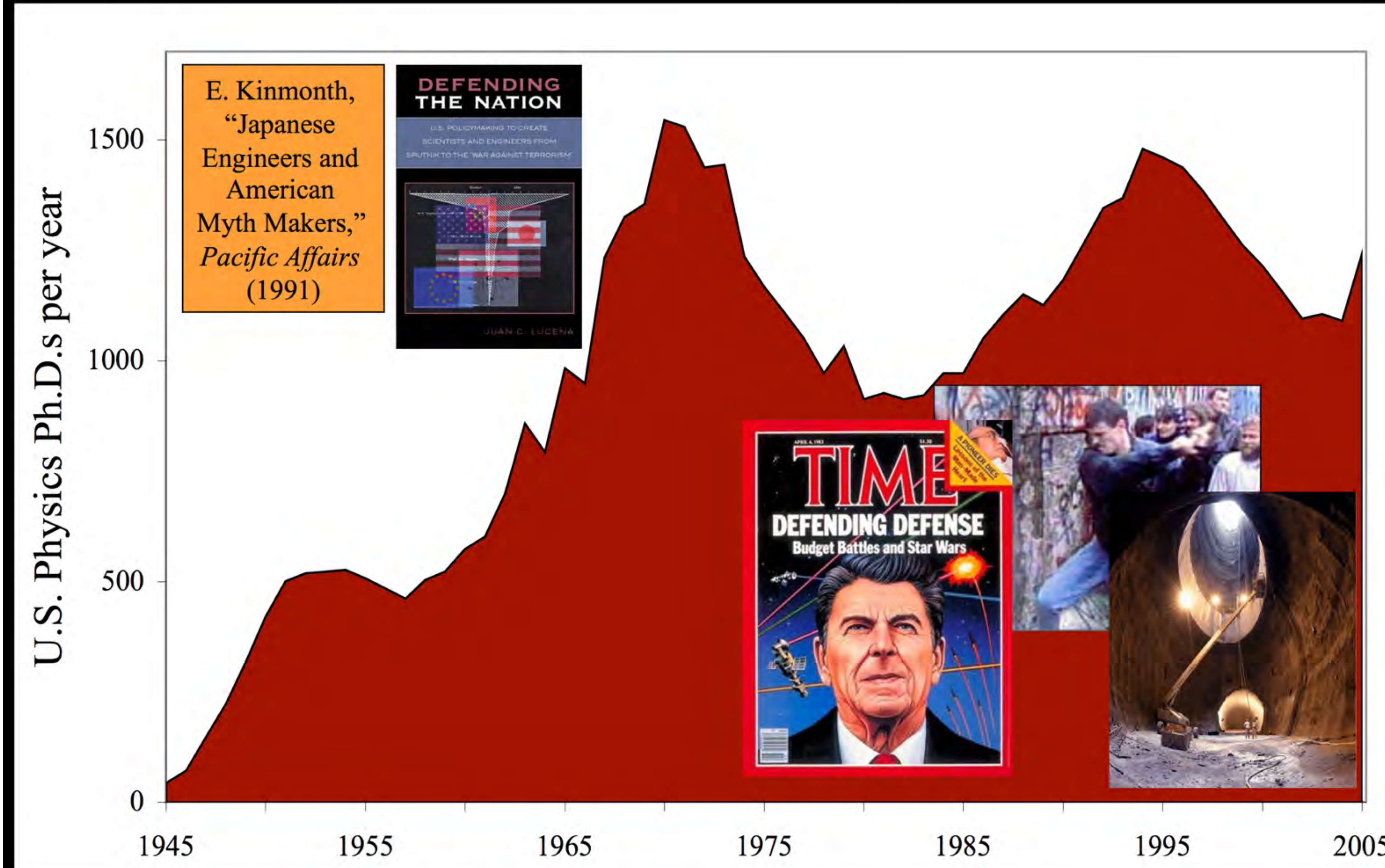
International Trends

Canada, UK: Similar enrollment pattern; similar QM textbooks.



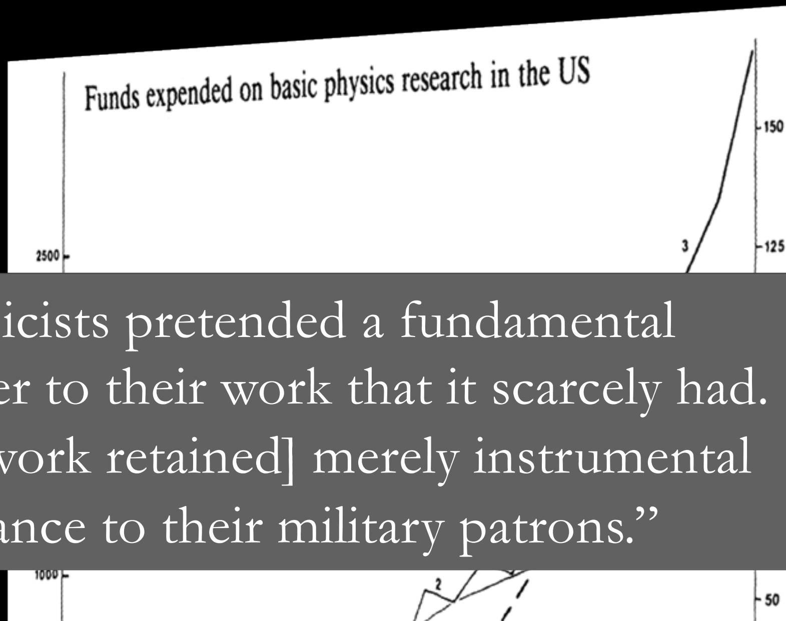
W. Europe: Little enrollment pressure after the war. Postwar QM textbooks still included long sections on philosophy. (US reviewers: "excessive," "overdone.") Few books included any problems at all; those that did averaged ***three times*** the proportion of short-answer problems as US books.

A Second Bubble



Physics and the Cold War

Paul Forman, "Behind quantum electronics" (1987)



"Physicists pretended a fundamental character to their work that it scarcely had. [Their work retained] merely instrumental significance to their military patrons."

Left unexplained is how patronage might shape the world of ideas. The gears mesh in institutions and infrastructure.