

CLASS FIVE: INNOVATION AT THE INSTITUTIONAL LEVEL – THE ORGANIZATION OF FEDERAL SCIENCE SUPPORT

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“Innovation Systems for
Science, Technology,
Mfg., Energy and Health”

Quick Summary of Classes 1 to 4:

• CLASS ONE: GROWTH THEORY

- Intro. to Growth economics –
- **Solow**: “Technology and Related Innovation” is the key factor in economic growth – not capital supply, not labor supply
- **Romer**: The driver behind technological innovation is “Human Capital Engaged in Research”

• CLASS TWO: INNOVATION SYSTEM ELEMENTS

- **Nelson** – there are “national systems of innovation” – reviews the effectiveness of a “nation’s innovation actors” (we looked at Korea and Japan’s MITI)
- **Rycroft and Kash** – must “network” the actors right
- – how do you organize the “human capital engaged in research”, and connect it to the other actors (like venture capital, accounting, fiscal policy, IP, etc.)?
- **Schultze** – where do you want to draw the line on public and private sector innovation responsibilities?

Summary, Con' t, Classes 1-4:

- POINT OF CLASSES 3 AND 4 – US HAS AN INNOVATION CHALLENGE AHEAD
 - IE, THIS CLASS IS NOT JUST AN ACADEMIC, ABSTRACT, IVORY TOWER CLASS
- CLASS THREE – Past history of MFG. PROBLEM
 - Kent Hughes – how US got out of its 70-80' s mfg. crisis
 - How Korea and Japan' s MITI are organizing mfg. efforts; distributed mfg.; China' s effort
- CLASS FOUR – CURRENT U.S. MFG. PROBLEM
 - The “Seven Stories” –bring on mfg. innovation advantage?
 - The “comparative advantage” debate – can one nation capture another' s innovation lead?- Samuelson
 - Social Disruption story
 - Can Advanced Manufacturing bring in new paradigms for production?

PART ONE: Org. History of US R&D Innovation Actors:

- US SCIENCE ORG. IN
WORLD WAR TWO
AND THE EARLY
POST WAR PERIOD:

David M. Hart, Forged Consensus- Science, Technology and Economic Policy in the U.S., 1921-1953 (Princeton Univ. Press 1998)

- 5 Visions of the Liberal state and Governance of Technological Innovation, 1921-53
- 1) CONSERVATISM:
 - Saw need for state to provide for defense, including military technological innovation
 - Goal: keep this sphere isolated from domestic economy
 - Movement was reaction to the “excesses” of Wilson’s WW1 mobilization – industrial controls

David Hart, Forged Consensus, Con't:

- 1) CONSERVATISM, con't:
 - Frank Jewett – an exponent of this direction– Pres. of Bell Labs, head of Nat'l Academy, '38
 - Felt federal meddling with R&D and patents laws would slow growth of science advance
 - But: supported WW2 gov't role in science
 - Postwar – supported retrenchment of gov't role
 - Sen. Robert Taft – post-WW2 – military strategy was to control cost through limits on force size, therefore dependant on tech. innovation and nuclear arsenal
 - Summary – gov't's defense science role and needs should be isolated from domestic economy

David Hart, Forged Concensus, Con' t:

- 2) ASSOCIATIONALISM:

- Exponent: Herbert Hoover – engineer, war relief organizer, Commerce Sec., President
- Saw the power of state action
- Felt unlimited economic competition inhibited tech. innovation – price competition prevented risk of innovation – competition blocked large scale R&D because it fragmented industry
- Associationalism originated in WW1 war mobilization
- FDR adopts Hoover' s associational idea – but his NRA is an organizational disaster – then Vannevar Bush adopts this model for WW2 science and war mobilization

David Hart, Forged Concensus, Con't:

- **3) ASSOCIATIONALISM, con't:**
 - The government's role:
 - Disseminate best practices to rationalize industry continuously
 - Foster industry-wide R&D facilities run by trade association supported by gov't
 - Or: gov't service agencies run these R&D facilities
 - Must be close ties between industry R&D managers and bench scientists
 - Basic idea: gov't industry cooperation, pool resources together, avoid duplication
 - Example: Hoover's Dept. of Commerce – the Bureau of Standards:
 - to reorganize 'sick' industries with new technology
 - Build industry collaborative R&D
 - Tear down barriers that limit high growth industry

David Hart. Forged Concensus, Con' t

• 3) REFORM LIBERALISM:

- Espoused after NRA failure in 1935 (exponent -Henry Wallace – Commerce Sec.)
- Basic theory: reestablish markets by gov' t regulation (ex., antitrust)
- Saw gov' t as an economic actor
- Sought end of suppression of tech. innovation by cartels, monopolies
- State could develop and commercialize new technology itself, or
- Break bottlenecks that hold back innovation
- WW2 mobilization by joint associative gov' t-industry effort ended this movement
- Post-WW2 – displaced by Keynesianism

David Hart, Forged Consensus, Con't:

- 4) KEYNESIANISM:

- Emerged in 40's – (J.M. Keynes econ. theory)
- basic view: gov't spending to contribute liquidity to private markets, to spur demand
- Debate over gov't S&T role – 2 views conflict:
 - Tech innovation is logical result of private investment, only gov't macro tools needed; vs.
 - Widespread market failures in provision of S&T – state should correct by S&T investment
- Korean War – resolved conflict – Keynesians argue aggregate S&T spending, including defense R&D spending, benefits economy
 - Example: NSF R&D spending indicators – come from this macro orientation

David Hart, Forged Consensus, Con' t

- **5) NATIONAL SECURITY STATE:**
 - Emerged in WW2 and Cold War
 - Use any means/any model necessary to reach S&T leadership for defense needs
 - WW2 – associative state and national security state merge
 - Led by Vannevar Bush in WW2
 - During the Cold War –
 - Congressional Repub. - Conservatives – wanted high tech force (Air Force) – cheaper than mass force
 - Dem. Keynesians – military R&D was still R&D – contributed to aggregate R&D spending
 - Were they right???
 - Examples: aerospace, computing, electronics were results

David Hart, Forged Consensus, Con't:

- REALITY: HYBRID GOV'T S&T MODELS DOMINATE THE LAST 50 YEARS, THROUGH THE END OF THE COLD WAR:
- We have a blend of different visions of the state role
- The underlying conflict between positions goes unresolved; pragmatism reigns as usual; mix of:
- Conservative – gov't domestic R&D role – defense only; separate sectors; private sector should play domestic economy S&T role
- Nat'l Security – use any model for S&T to gain military leadership
- Associative – Hoover, FDR, Vannevar Bush – latest: Clinton's public-private partnerships
- Keynesian – aggregate R&D spending is key, defense and private sector adequate

Jennet Conant, Tuxedo Park

(bio of Alfred L. Loomis) (Simon & Shuster 2002)

- Alfred L. Loomis – 1887-1975
 - Father deserted family, Loomis is forced to law and Wall St., despite love of science, to support family
 - Made fortune in emerging electrical utility industry – sold out before '29 crash
 - Experimented in physics of ultrasound in 20's-30's
 - Authored 29 science papers before 1939
 - Set up his own R&D lab in his Tuxedo Park mansion north of NYC in 30's
 - Brought in greatest science physics talent in the world for “summer studies” – informal management
 - MIT's RAD Lab was a scale-up of this model
 - Loomis' cousin Henry Stimson, FDR's Sec. of War, is a surrogate father

The whole crew: L-R – Earnest Lawrence. Arthur Compton, Vannevar Bush, James Conant, Karl Compton, and Alfred Loomis



Jennet Conant, Tuxedo Park, Con' t

• MICROWAVE RADAR

- Loomis's Lab had developed 10cm doppler radar system
- British invent "resonant cavity magnetron" microwave source (inventors: John Randall, Henry Boot) – far higher power output
- Britain lacks the industrial capacity to scale engineering dev. and mass production – US is world's leading mfg. power
 - [Note: relationship between mfg. and technology leadership – unified whole]
- British had to reach out to mass production capacity of US economy even though US not yet in war – so Tizard Mission
- US military reluctant to trade secrets with British
 - Stimson/Marshall – Army - more open
 - Ernest King – Anglophobe – distrustful, delay
- Loomis himself is inventor – family ties to Stimson, and to US science leadership that he has been funding, esp. Ernest Lawrence of Berkeley, the leading US physicist
- Vannevar Bush heads FDR's Nat'l Def. Res. Comm. – NDRC
- Loomis is a radar experimenter, heads NDRC's microwave committee – is a Bush ally
- 9/11/40 – in his Wardman Park Hotel suite Loomis develops British Tizard Mission trust – British brief him on cavity magnetron- he sees value of microwave radar magnetron immediately
- 9/28/40 at his Tuxedo Park Lab, British give Loomis cav mag #` 12

Jennet Conant, Tuxedo Park, Con't

• LOOMIS INVENTS THE “FFRDC”

- The day after seeing the magnetron, Loomis works on the idea of a civilian scientist run lab with contract to DOD
 - later called “Federally Funded R&D Center”-FFRDC
 - British using similar system under Tizard
- Loomis sees incredible promise of microwave radar – England is being night-bombed, has no defense, U-boats on verge of starving Eng. – microwave radar can be mounted on a plane and defend against both
- Immediately proposes a large central microwave lab
- Civilian scientist controlled, not military controlled
- To take scientists from both Univ' s and industry
 - Draws on British lab model
- Loomis knows the value of tech leadership – “the boat ahead gets the new breeze first, just because it is ahead and thereby increases its lead.”
- Loomis immediately moves to set up this lab – gets approvals from the NDRC Microwave Comm, Sec. Stimson and Gen. Marshall the next day

Jennet Conant, Tuxedo Park, Con't

- LOOMIS INVENTS THE FFRDC, Con' t:
 - Loomis immediately invents the 3 major R&D tasks for the new lab –
 - Airborne interception (AI)
 - Gun-laying for anti-aircraft weapons (GL)
 - Long range aircraft navigation (becomes Loran)
 - Loomis the next day recruits Ernest Lawrence (Loomis has been funding his Berkeley accelerator experiments) to start up the lab and start phoning and hire the finest physics talent in the US
 - Loomis, not even a gov' t 'ee, authorizes contracts for magnetron by the end of the weekend
 - By Oct. – finest US physics talent joins the new lab
 - INCREDIBLE SPEED OF DEVELOPMENT

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- Loomis Invents the FFRDC, Con' t
 - Bell Labs' Frank Jewett tries to locate at his co. – Loomis, with MIT' s Compton, V.Bush, Harvard's James Conant, outmaneuvers him and locates at MIT
 - Becomes “Rad Lab” – Radiation Lab – over name since atomic research viewed as long term and not war-relevant
 - Loomis sets up unprecedented partnership: between gov' t.-univ.-industry
 - Loomis and friend Ernest Lawrence of Berkeley use their respect with physicist friends to recruit great talent
 - 11/11/40 – first meeting of Rad Lab researchers at MIT
 - Farmed out separate component mfg. to industry and all deadlines met as of 11/11/40, so could focus on integrating a system

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- CHARACTERISTICS OF RAD LAB - Model for the Postwar FFRDC:
- GREAT TALENT
 - 10 Nobel prizes go to Rad Lab scientists
- FLEXIBLE FUNDING:
 - Loomis himself advances the funds for start-up
 - Contracting with industry is non-bid; Loomis just awards – there's a war
- LOOSE, INFORMAL ORGANIZATIONAL MODEL
 - Non-bureaucratic org., loose, interacting groups teams Leadership based solely on talent
 - “easy comradeship”; casual tone; interactive
 - “long hours”
 - Almost all scientists – few in support staff – at first, 36 scientists, 1 secretary
- ABILITY OF LAB HEAD TO GO TOP
 - Loomis heads Microwave Comm above Rad Lab – reports officially to V. Bush of NDRC - Lee Dubridge (later Caltech Pres) heads Rad Lab on site
 - BUT- Loomis frequently goes directly to War Sec. Stimson
 - Loomis forces slow military bureaucracy to adopt new technology
 - SO: another key to Rad Lab – access to top decisionmakers

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- MANHATTAN PROJECT

- “Uranium Comm.” had been set up after Einstein to FDR– not progressing – viewed as long term project, post-war realization
- Ernest Lawrence sees possibility of atomic weapon; all fear German science
- Lawrence goes to Loomis, he persuades Stimson and V.Bush to expedite and reorganize effort – FDR immediately approves
- Manhattan project set up on same org. model as Rad Lab
 - Military tried to put it into military bureaucracy – put scientists into uniform
 - Based on success of Rad Lab precedent, approach rejected – kept out of uniform
- Key Rad Lab staff, including Luis Alvarez and I.I. Rabi, come to staff Los Alamos

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- THE RAD LAB DOES DEVELOPMENT
 - Loomis moves Rad Lab from fundamental science base to applied science at the outset
 - Radar advances at Rad Lab: 3 cm radar, Loran navigation system, “blind” landing system, gun laying radar, MEW large area interception radar, etc
 - .- 85% of V1 missiles shot down
 - By 8/42 Loomis with Sec. Stimson works to force collaboration with Army so that technology becomes tied to Army’ s “operational framework” – forces movement of invention into doctrine
 - Classic problem that haunts all defense R&D
 - Loomis adds engineering design, design form mfg., and mfg. prototyping to role of Rad Lab
 - INVENTS: integrated science lab R&D model

Jennet Conant, Tuxedo Park, Con' t

- POSTWAR: RAD LAB' S INTEGRATED MODEL ENDS
 - Loomis, even though he achieves the “Associationalist” (see Hart) model of gov' t-industry-academic partnership for brilliant and fast R&D development, dismantles it
 - In postwar he is a Conservative (see Hart) – suspicious of the Associationalist model
 - Shuts down Rad Lab shortly after the end of the war
 - Decides it won' t work without war pressure
 - Retains deep faith in private enterprise
 - V. Bush shares his view
 - Bush fights to retain gov' t role in basic research

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- LOOMIS' ACCOMPLISHMENTS:

- As a technologist:

- LORAN long range radar beam based navigation (originally named after him – he rejects title)
- Key role on blind landing system for aircraft (ground controlled radar based approach)
- Re: both Rad Lab and Manhattan Project – he forces both projects into rapid development –critical to the two leading tech developments of the war

- MORE IMPT: As a science organizer:

- Development of the FFRDC model is a critical organizational step for US science
- Also implements the model for integrated science and technology at the Rad Lab – fundamental research through prototyping, eng. design, and initial stage mfg. – this model still not repeated

Vannevar Bush, 1890-1974



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Vannevar Bush, “Science, The Endless Frontier” (at nsf.gov, 1945)

- 11/17/44 – FDR writes Bush (did Bush draft it for him?)
 - 1) How to diffuse science knowledge gained from the war?
 - 2) How to organize “war against disease”?
 - 3) gov’ t role in supporting public and private sector research?
 - 4) gov’ t role in developing science talent?
- FDR’ s “new frontiers of the mind”
 - Grasps V.L. Parrington’ s concept of the role of the frontier in American life
 - Proposes new science frontier as next American frontier

Vannevar Bush, Science the Endless Frontier, Con't:

- BACKGROUND:

- V. Bush's paper comes out in July 1945 after FDR's death – it is the most influential policy paper ever written on US science organization
- V. Bush is thinking through the postwar model for US science, thinking about the gov't's future role
- The “Associationalist” model dominates WW2
- V. Bush dis-agregates science away form this model
 - Probably convinced politics will dismantle the WW2 model of integrated research and development
 - Wants to salvage basic research for a gov't role
 - Concerned that applied science dominated WW2 – sees need to restore basic science

Vannevar Bush, “Science, The Endless Frontier”, Con’t:

- V. Bush’s Report Defines the Future Direction of US Science Progress:
 - Bush announces new popular causes for US Science
 - Science is to be “part of a team” for “health, security, prosperity” –
 - separates science as a separate player from other innovation actors – against integrated model for science
 - Announces 3 goal areas for science:
- 1) “War Against Disease” Direction:
 - Bush and FDR saw huge medical gains in WW2
 - Antibiotics key – reduced disease, cut death from disease in WW2 to .6/1000, from WW1 of 14,1/1000
 - Health provides new public purpose for science

Vannevar Bush, “Science, The Endless Frontier”, Con’t:

- 2) National Security Direction:
 - Pre-Cold War, but argues military research in peacetime vital for US security, can’t rely on allies (lesson of WW2 preparedness)
 - But insists on Loomis’ Rad Lab approach – must be civilian control of defense science, with “close liaison” to military
 - Because NSF is not formed until after Cold War starts, NSF never assigned defense R&D
- 3) “Public Welfare” Direction:
 - Goal is “full employment” – big postwar anxiety
 - Proposes idea that “basic research is public capital”
 - science role is to add capital, value to innovation system, not to dominate it or be integrated into it
- 4) Nurture “Talent” Direction:
 - Bush envisions gov’ t role in educating science talent

Vannevar Bush, “Science, the Endless Frontier”, Con’t:

- Bush has a “pipeline” theory of innovation:
 - Science with gov’ t backing will contribute basic research, not applied
 - Industry will apply it to practical problems
 - Gov’ t role is to increase “scientific capital” by supporting academic research
 - This form of research is removed from “pressure for immediate tangible results”
 - Bush’ s idea: remove science from the fray – protect it, put it back into the ivory tower
 - Is that a good idea?

Vannevar Bush, “Science, The Endless Frontier”, Con’t:

- Bush’ s Vision of Postwar Gov’ t Role in Science”
 - Sharply limited from WW2 role he oversaw
 - Support for science talent development
 - Offer industry an R&D tax deduction
 - Reform the patent system
 - Gov’ t should also develop mechanisms to disseminate science advances to industries outside the reach of scient
 - Notes that a big backlog of APPLIED science advance from WW2 efforts are available to solve practical problems
 - Gov’ t should “lift the lid” and enable industry to access
 - Opening “new frontiers” is historical US gov’ t role – extends concept for opening frontiers to justify gov’ t science role – but limited and controlled role

Summary of PART ONE Readings:

- DAVID HART: STORY ONE:
 - Explains the political currents behind defining the gov' t role in support for science/R&D
 - Associationalist theory still battling with Conservative/National Security movements
- LOOMIS AND V.BUSH: STORY TWO – WW₂ LEADS TO NEW MODEL
 - Bush and Loomis unify US Science R&D under Bush' s NRDC and its successor OSRD
 - Even though they are funded by the military, they react against the military' s WW₁ role and create a new civilian controlled model

Summary of PART ONE, Con' t

- STORY 2, Con' t - Loomis sets of the Rad Lab R&D center outside not just Defense but outside the gov' t, at MIT
- “FFRDC” – Loomis invents this model and it is a key to how US science will evolve post- WW2 – civilian scientist control, flexible org.
- organized in loose teams, fast and flexible R&D contracting, great talent, non-bureaucratic
- Bush unifies US science under a central directorate (ie, Bush); Loomis unifies basic and applied research in the non-gov' t FFRDC R&D center

Summary of PART ONE, Con' t

- STORY THREE: POSTWAR SHATTERS THE UNITY
 - The immediate postwar shatters the unified science organization that Bush and Loomis created
 - Bush himself dismantles it – that' s one message in his famous manifesto “Science, The Endless Frontier” - Bush decides that Gov' t should only support basic research – walks away from the applied/basic mix he and Loomis set up at Rad Lab and Manhattan Proj.
 - He tries to unify science research at NSF but his fight with Truman stalls it
 - SO: by the early cold war – unity of science research is broken and the unity of basic and applied science research is broken

PART TWO: Org. History of US R&D Innovation Actors:

- THE COLD WAR AND
THE EVOLUTION OF
US SCIENCE
ORGANIZATION:

William A. Blanpied, “Inventing US Science Policy” (nsf.gov 1998)

- Article portrays the battle between the Truman Administration and Vannevar Bush on the Direction and Organization of US Science
- V. Bush’s “Science the Endless Frontier”:
 - “astonishing recommendation to set up a new agency that would publicly fund all basic research, including medical and military research performed inside and outside of gov’t labs”
 - “bold and novel proposition that the US gov’t has both the right and responsibility to support self-directed basic research by academic scientists”
 - Gov’t support of science activity, not gov’t seeking science support for its policy – reversal of policy
 - Bush proposed having scientists control agency with very curtailed Admin. role

Harry Truman vetoes Bush's NSF Act in 1946 – “The Buck Stops Here”



This image is in the public domain.

Blatant, Inventing US Science Policy, Con't:

- Steelman Report - 1947

- John Steelman, small college prof., the first Presidential “Special Ass’t”, helped resolve coal miner and railroad labor disputes
- Steelman report came out three months after Truman vetoed Bush’s NSF plan in 1946
- Much more detailed than V.Bush’s Manifesto
- Rather than the “let science alone” *laissez faire* approach of V.Bush, Steelman proposed an integrated system of R&D, with central coordination of fed. R&D agencies, and connections with industry
- Academic research was one part of a coordinated larger R&D enterprise – but the major federal focus would be on basic research
- Foresaw competitiveness battles where US R&D would be important
- Steelman’s Committee proposed:
 - doubling US R&D expenditures in a decade
 - US R&D expenditures should be 1% of GDP
 - Percentage allocations of federal R&D \$ to policy areas
 - Systematic talent needs assessment
 - Central coordination of R&D through Exec. Off. of the President

Blatant, Inventing US Science Policy, Con't:

- Bush opposed the “Associationalist” features of Steelman Report, and his stronger Presidential role which he feared would politicize science
- Steelman report, however, was a more accurate predictor of what organizational structure would evolve
- Most interesting feature of Bush Report is that it proposed a single, centralized science agency to support all basic research
- But the 5-year delay in adopting a modified NSF with a Presidential role acceptable to Truman meant that US science would be decentralized – other agencies moved to fill the void: ONR, AEC (which inherited the old Manhattan Project), NIH
- We rationalize the pluralistic R&D approach now but it largely occurred by bureaucratic timing and default

Blatantly, Inventing US Science Policy, Con't:

- Congress didn't take NSF seriously during the early Cold War – left it drastically under-funded compared to proposals
- Sputnik in 1957 led public, media & Congress to conclusion that academic basic research might contribute to US Cold War success
- This led to 3X increase in NSF funding
- Sputnik led Eisenhower to implement many of the Steelman type of recommendations – particularly the Presidential Sci. Advisor, the President's Sci. Advisory Council
- But the lack of centralized science coordination in the V.Bush plan because it wasn't passed in '45 to '46 may well have created a permanent problem for US science coherence

Peter Singer, “...22 Examples of Major Technology Advances that Stem from Federal Research Support” (ITIF 2014)

- Federal research support critical to the development of array of advanced technologies
- Without it, hard to see how these technologies would evolve
- So – basic research support remains critical
- Key enabler in U.S. comparative advantage in radical/breakthrough technologies

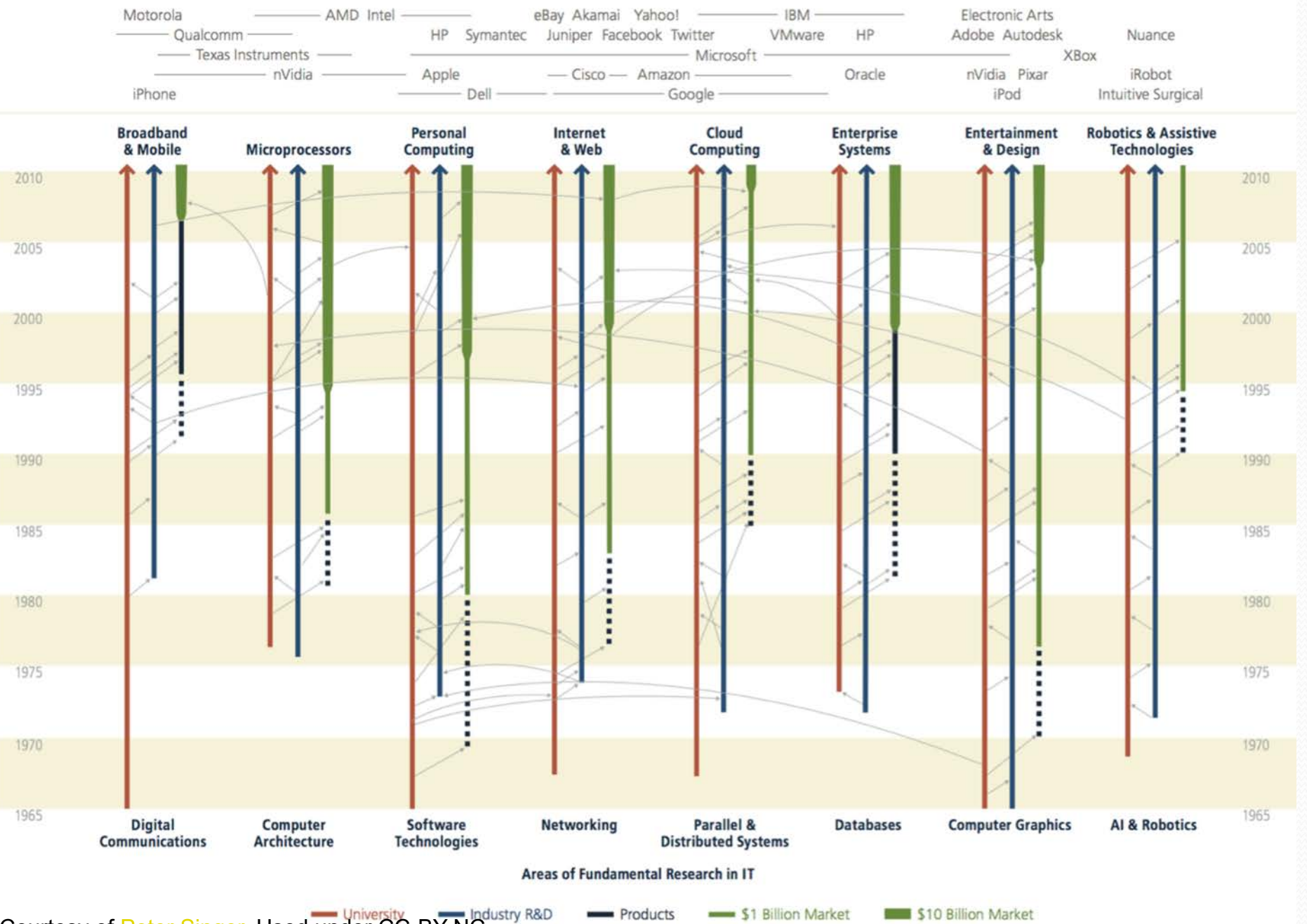
Peter Singer, 22 Examples...Con't

- Examples:
 - **Information Technology**
 - Google Search Engine – NSF
 - GPS – Navy (Atomic Clocks), DOD (Navstar), DARPA
 - Supercomputers – DOE Nat'l Labs
 - Speech Recognition – DARPA
 - ARPANet - DARPA
 - Closed Captioning - NIST
 - Smartphone tech's – DOD, NSF, SBIR, etc.
 - **Energy**
 - Shale Gas/ Seismic Imaging – DOE Nat'l Labs
 - LEDs - USAF

Peter Singer, *22 Examples...*, Con't

- Examples, con't
 - **Health**
 - MRIs – NIH (diffusion tensor imaging), NSF
 - Advanced Prosthetics – VA, DARPA
 - Human Genome – NIH
 - AIDS – NIH, expedited FDA approvals
 - **Math**
 - Reverse Auctions – NSF
 - Kidney Matching Program – NSF
 - **Transportation**
 - Civil Aviation – Army and Navy
 - **Agriculture**
 - Hybrid corn (USDA – Conn. Ag. Exp. Station)

IT Sectors With Large Economic Impact



Prof. Donald Stokes, 1928-1997

Dean of the Woodrow Wilson School at Princeton; died of Leukemia shortly after finishing “Pasteur’s Quadrant”

Donald E. Stokes, “Pasteur’s Quadrant, Basic Science and Technological Innovation” (Brookings 1997)

- The relationship between science and gov’ t was transformed by WW2
 - US prewar had some federal science entities – USGS, agriculture experiment station – pursued agency missions
 - Had nascent research Univ’ s on the German model
 - During interwar years, Univ. science concerned it might lose its “autonomy”
- V. Bush’s OSRD (Office of Scientific Research and Dev. – successor to NDRC) “was the nearest thing to a true central science org. in all of American history”
 - Unparalleled flow of funding into basic as well as applied science - esp. nuclear physics, electronics

Donald Stokes, Pasteur's Quadrant, Con't

- V. Bush's OSRD:
 - V. Bush's OSRD appealed to FDR's love of creating initiatives outside of regular gov't
 - Bush and allies Compton, Loomis, Conant grasped that the war would be technology and science based conflict in significant part
 - Bush worked with FDR through his legendary aide Harry Hopkins - had access to the Pres.
 - OSRD part of the exec Office of the President
 - OSRD contracted for science work, didn't set up own labs
 - Leadership from the scientific elite and elite science institutions

Donald Stokes, Pasteur's Quadrant, Con't

- POSTWAR SCIENCE:
- Sen. Harley Kilgore (W.Va.) sponsored first bill for postwar science organization in '42 – science didn't have the leading voice in his agency
- Bush's goals – federal support of basic science, but curtail gov't control of the performance of that research
- Bush aimed to create an entity with cross-science authority as broad as OSRD's in WW2
- Director would be chosen by a board of scientists, not named by Pres. and Senate- confirmed

Donald Stokes, Pasteur's Quadrant, Con't

- Stokes Argues Bush's Basic Research Cannon Has Two Parts:
- “It is Performed Without Thought Of Practical Ends”
 - Designed To Persuade Country That Attempts To Constrain Free Creativity Of The Basic Scientist Would Be Inherently Self-defeating
- “Basic Research Is The Pacemaker Of Technological Improvement”
 - Designed To Persuade The Policy Community That Investment In Basic Science Would Yield The Technology To Solve A Broad Spectrum Of National Needs

Donald Stokes, Pasteur's Quadrant, Con't

- **BUSH'S ORGANIZATIONAL PLAN IS DEFEATED**
 - Truman rejects scientist control of NSF – insists on Pres. Appointment, general control
 - Congress, completely geography protective, suspicious of elitist funding distribution
 - The 5-year delay fragments the overall science portfolio Bush envisions for NSF
 - ONR, AEC stood up; NIH gets OSRD's medical research contracts
- ***BUT: BUSH'S BASIC SCIENCE IDEALOGY TRIUMPHS***

Donald Stokes, Pasteur's Quadrant, Con't

- WHY BUSH'S BASIC SCIENCE IDEALOGY TRIUMPHS
 - Bush's Postwar Bargain – if gov't funds basic science, I promise you technological progress
 - NSF's Univ. constituents love the idea that pure research is “the font of technological progress” – enables them to provide social rationale for basic research to justify federal funding
 - Sputnik proves how deeply Bush's ideology spread – the American answer to Sputnik is not only an applied science space race, but huge new investments in basic science
 - DOD: “Project Hindsight”: 1 in 100 defense basic research projects result in weapons system advance
 - NSF – its whole rationale is challenged – showed the antecedents of 5 selected technological innovations were basic science-based

Donald Stokes, Pasteur's Quadrant, Con't

- But – NSF was just Showing What Could Be True – Tech. Advance Could Come From Basic Research
- Both DOD And NSF Continue To Think In Linear Model
 - DOD: All That Mattered Is Linear Segment Of: Applied To Dev To Production
 - NSF: All That Matters Is Linear - Basic To Applied To Dev. To Production
- The Ideal Of Pure Inquiry Under Bush's Cannons Dates From Classical Greek Science
- *Bush Paradigm Of The Linear Relation Between Science and Tech Stokes Argues Bears No Relationship To Their True Connection*

Donald Stokes, Pasteur's Quadrant, Con't

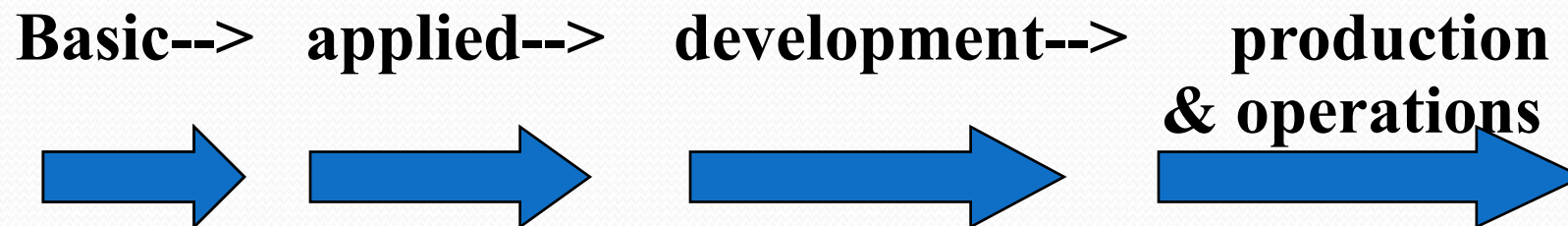
- *But: The Ties Between Science And Technology Aren't Linear, They Are Interactive*
- Use-inspired Science Yields Both Basic And Applied Results
- Bush's Effort On Behalf Of The Science Community To Preserve The Autonomy Of Publically-funded Science Led Him To Decry Efforts To Constrain The Creativity Of Basic Research
 - But It Is Eventually Self-defeating Because It's Not The Right Model
- Challenges To Bush's Ideology Grew Insistent As Us Needs Shifted From The Military To Economic Sphere

Donald E. Stokes, Pasteur's Quadrant, Con't

- **Vannevar Bush's model for gov' t funded undirected basic research, post WW2, was a STATIC model, although he argued it would be "the pacemaker for technological progress"**
- **basic research investment would capture the gain of tech progress**
- **Bush paradigm found deep resonance in Western classical philosophy of science as reason, and its other tradition, Francis Bacon's marriage of science with the practical arts**
- **Bush short-circuited basic research from consideration of use**
- **His linear model was one-dimensional**

Donald Stokes, Con' t

- Bush belief: understanding and use are conflicting goals, so basic and applied research must be separated
- “applied research drives out pure” -V.Bush
- No wonder US has had historic trouble converting its leadership in technology inventions into products – Bush made this a suspect activity
- *Bush 's segmented linear/pipeline model:*



Donald Stokes, Con' t:

- *Stokes' Test Case: Pasteur – the rise of microbiology*
- Pasteur sought a fundamental understanding, via microbiology, of the process of disease
- But he sought this through applied goals of preventing spoilage in various substances including milk, then pursuing anthrax in sheep, cholera in chickens, rabies in animals and humans
- As Pasteur's scientific studies became more fundamental, his inquiry became more applied

Stokes' PASTEUR'S QUADRANT:

- **Consideration of Use?**

No

Yes

Yes

Pure basic research –

Use inspired basic research –

Ex- Nils Bohr

Ex- Louis Pasteur

Review of the particulars not the general

Pure applied research –

No

-- early Darwin

Ex-Thomas Edison

Search for fundamental understanding

Donald Stokes, Con' t

- The deepest flaw in the V. Bush paradigm is that technology development flows one way, from science to technology
- BUT: there is a reverse flow – from technology to science
- Science is interactive – it is a whole, not segregated
- There is a growing amount of technology that flows from science, but the other way is strong:
- For example - Semiconductors – fundamental research that is technology based - built from atomic layer to atomic layer
- Who reaps the technological harvest from science?
U.S. reached technological leadership LONG BEFORE it reached science leadership

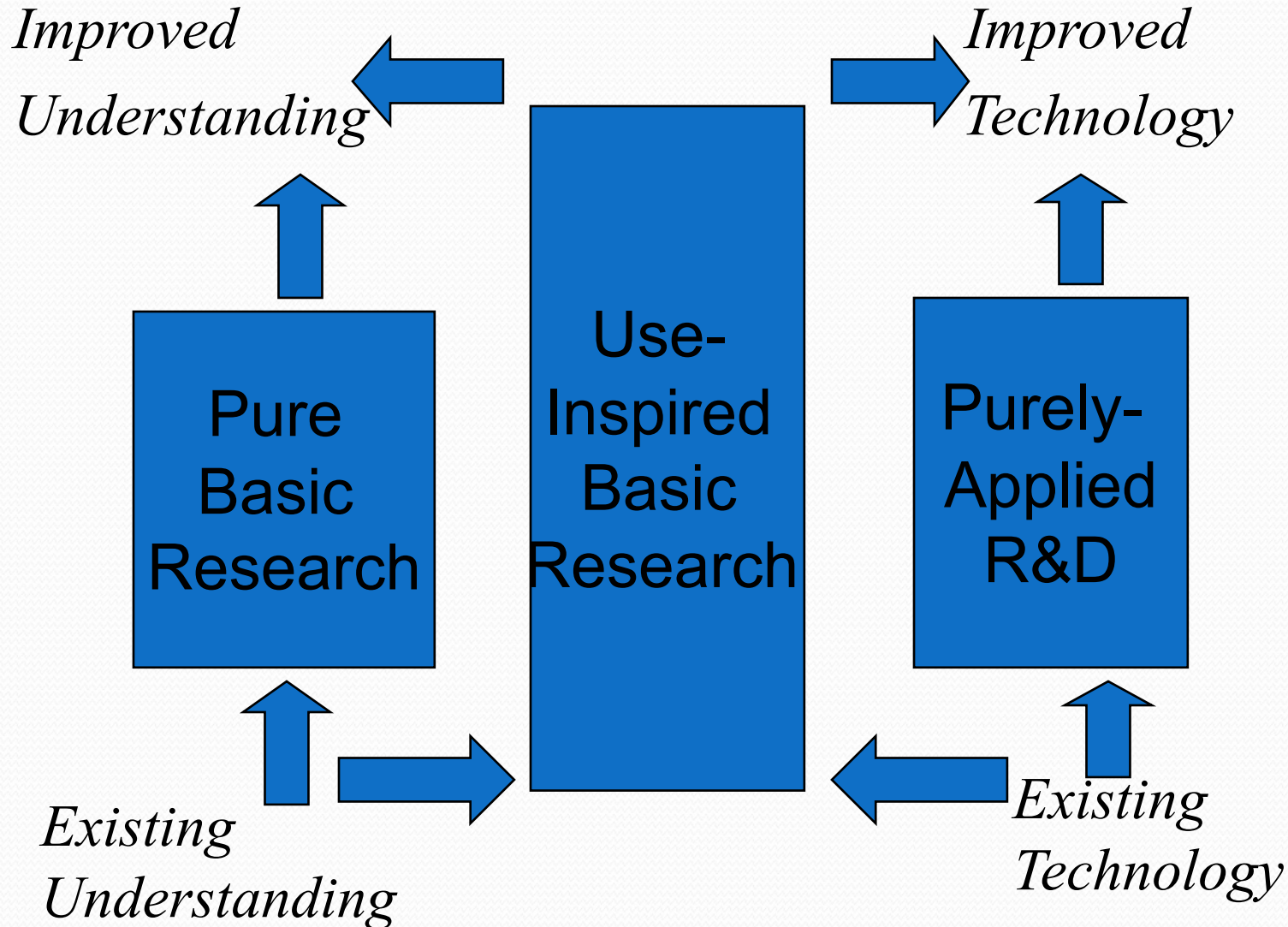
Donald Stokes, Con' t

- The greatest strides in productive technology can be made by nations that lack science leadership – the US in the 20' s, Japan in the 70' s-80' s
- V.Bush' s manifesto presents “a paradox in the history of ideas” – history of science presents so many cases of interactive applied and basic science, how did it become believed that these were in tension?
- James B. Conant, Pres., Harvard – Bush Ally in WW2, first head of Truman' s Nat' l Sci. Bd.: “No one can draw a sharp line between basic and applied research...we might do well to discard altogether the phrases...in their place I should put the words ‘programatic research’ and ‘uncommitted research’ . It would be safe to say all so-called applied research is programatic, but so, too, is much that is often labeled fundamental.” - 1950

Donald Stokes, Con' t

- The U.S., which owes so much for Bush' s stunning science organizational work in WW2, to his vision of how science could be mobilized and energized, to the creation of the federally-funded research university – but lost so much from the postwar narrowness of his view of science -- perhaps due to his fear of the power FDR' s industrial state
- Deborah Shapley & Rustom Roy: “What was lost, in a word, was the importance of applied science and engineering, and something else we shall call pur-positive basic research...”

Stokes' "Dynamic Model"



Donald Stokes, Con' t

- Eventually, Erich Bloch comes to NSF and is able to bring computing and sci/tech and engineering centers – but the “Upstairs-Downstairs” damage to science had been done
- How much was revulsion against what the Manhattan Project did to physics?
- Block (and David Cheney): “Technology that remains in the lab provides almost no economic benefits. Technology that is applied only to gov' t markets such as defense, provides much smaller economic benefits than technologies that contribute to success in the much larger commercial markets, and especially to the ever more important global markets.”

Donald Stokes, Closing Manifesto, Con' t

- “A clearer understanding by the scientific and policy communities of the role of use-inspired basic research can help renew the compact between science and government, a compact that must also provide support for pure basic research.
- “Agendas of use-inspired basic research can be built only by bringing together informed judgments of research promise and societal need.”

SUMMARY OF PART TWO, CLASS 5 ---

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 - NSF will not be a unifying agency for US science coordination – other agencies grow up
 - Although it undertakes some applied work in the 60' s, it remains a basic research agency
 - [Same approach at NIH]
- DONALD STOKES
 - Attacks whole concept of separating basic research
 - Wants “use based” research in addition
 - Argues that basic-only is not the way science evolves
 - Science is not linear, not a pipeline
 - Science is interactive between basic and applied
 - Suggests US made a great mistake in focusing three of its great science agencies (NSF, NIH DOE OS) on basic-only model

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