The Three Methodologies &

Three States of Knowledge

Underlying Technological Innovation

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3 Key Points -

- Technological Knowledge exists in Three States:
  - Conceptual Discovery
  - Prototype Invention
  - Commercial Innovation
- Methodologies each generate Knowledge in One State:
  - Scientific Research
  - Engineering Development
  - Industrial Production

Opinion: Successful STI Policies require clarification between -- and parity among -- these basic concepts.

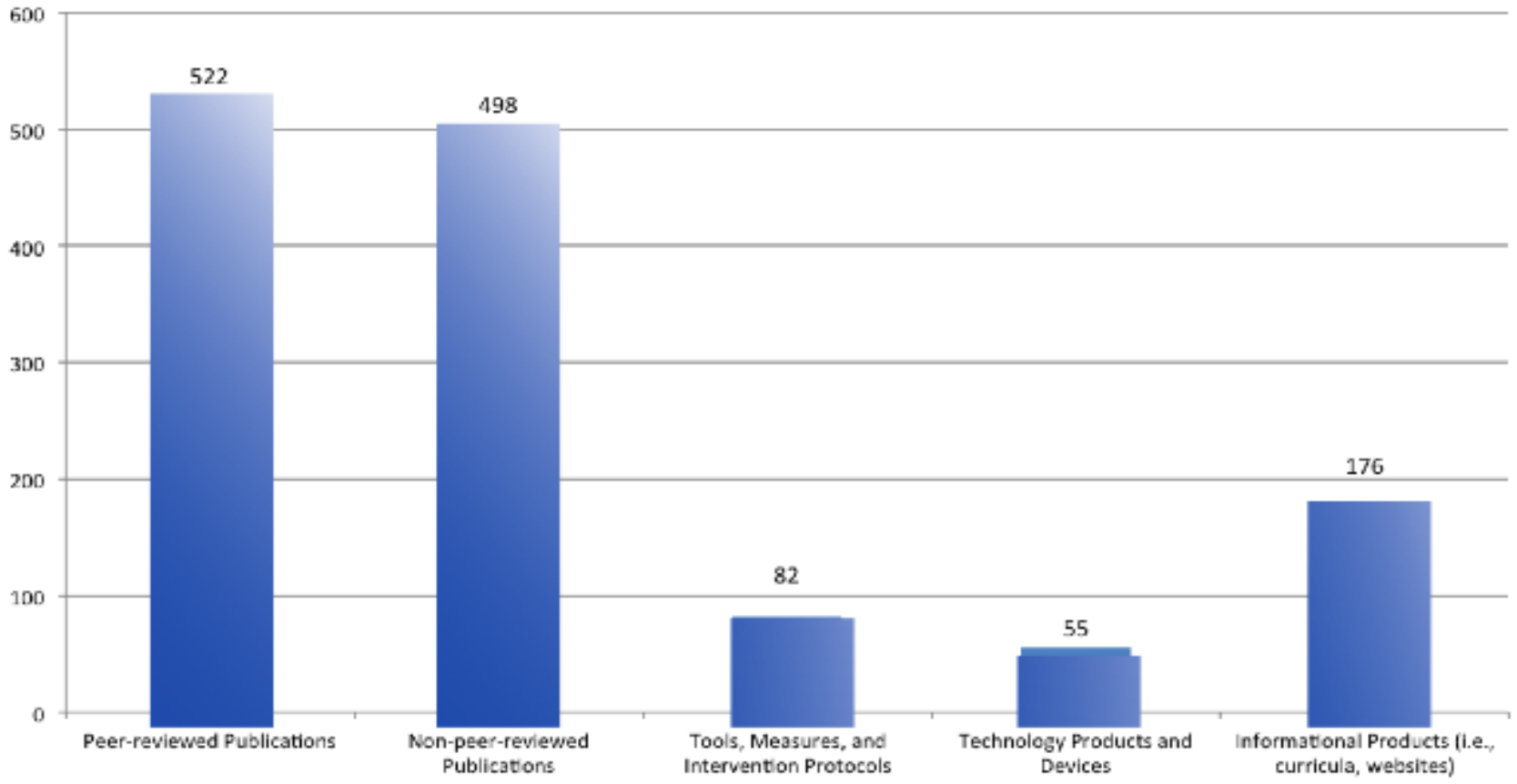
Why does this matter to you?

- Under SECIS, the CTI Renato Archer is tasked with creating CNRTA.
- This national network of cooperative Research, Development Innovation in AT, is supposed to have beneficial impacts!
- But . . . similar networks in North America and Europe are benefitting government and academia -- not industry or society!

CNRTA can do better!

NIDRR/USDE 2013 Outputs

Chart 7: The Number of Different Products Generated by NIDRR Grants in FY 2013



Seminar Organization

1. A Typology of Knowledge States in Ancient Greece.
2. The Evolution of Structured Methodologies to Generate Knowledge States.
3. The Gradual Co-Mingling of Sectors, Methods, Outputs and Terminology.
4. Resolving the Clash of Values through Enlightened Self-Interest.
5. The Muddled Mess of Technological Innovation in Theory and Practice.
6. Restoring Parity in Methods to Achieve Intended Results.

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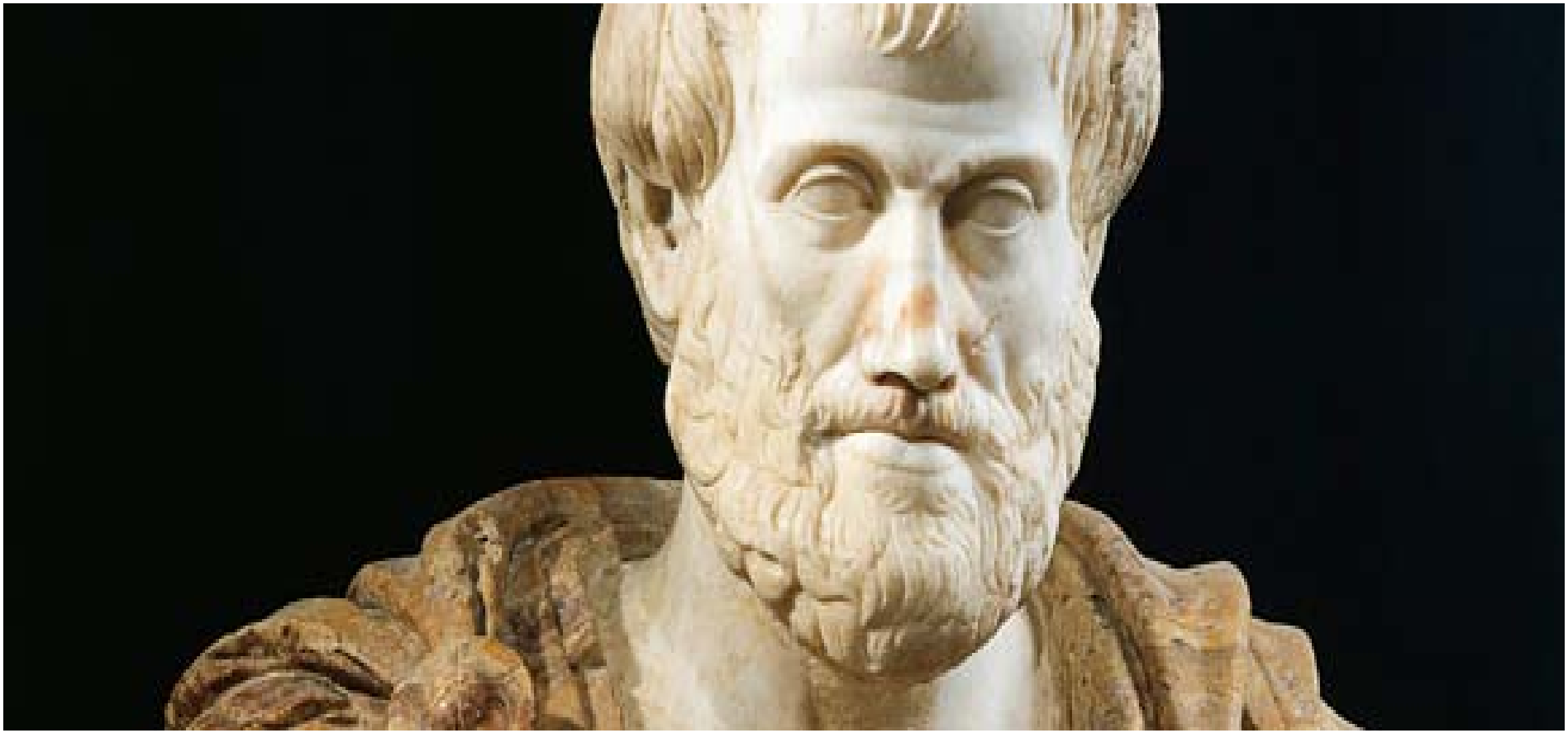
A Typology of Knowledge States in Ancient Greece



"It is the mark of an educated mind to be able to entertain a thought without accepting it."

Aristotle's Knowledge Typology

- *Five types "virtues" of thought (350 B.C.):*
  - Technê
  - Epistêmê
  - Phronêsis
  - Sophia
  - Nous

Three are the core elements of Technological Innovation

- *Epistêmê* – represents the body of knowledge or a system of understanding that provides a basis for generating concepts and theories – a fact.
- *Technê* – represents the body of knowledge or system of understanding that provides the skill to do or create something tangible – an artifact.
- Phronêsis - combines the facts of epistêmê and the skill of technê in a manner that improves quality of life – a product and its experience.

The Evolution of Structured Methodologies to Generate Knowledge in Specific States.

Epistêmê

Epistêmê ➔ Scientific Research Method.

The Method's intended output is knowledge in the state of a novel *conceptual discovery*.

Scientific Research Methodology

Designed to generates objectively observed outputs in the knowledge state of Conceptual Discoveries.

The first 'new to the world' articulation of a Conceptual Discovery – a *know what* -- has primary value as novel intellectual property described in scholarly publications.

Ownership and control of this IP is protected only by international *copyright* law.

Discovery State of Knowledge

Purpose: **Scientific Research** methods create new to the world knowledge.

Process: Empirical analysis reveals novel insights regarding key variables, precipitated by push of curiosity or pull of gap in field.

Output: **Conceptual Discovery** expressed as manuscript or presentation – the '*know what*.'

Legal IP Status: Copyright protection only.

Value: **Novelty** as first articulation of a new relationship/effect contributed to knowledge base.

Technê

Technê ➔ Engineering Development Methodology.

The Method's intended output is knowledge in the state of a *tangible invention*.

Engineering Development Methodology

Designed to generate pre-determined functional outputs in the knowledge state of tangible Prototype Inventions.

The primary value of a ‘new to the world’ Prototype Invention is the demonstration of feasibility – a *know how*.

Ownership and control of IP is protected by international *patent* law.

Invention State of Knowledge

Purpose: **Engineering Development** methods combine/apply knowledge as functional artifacts.

Process: Trial and error experimentation/testing demonstrates proof-of-concept, initiated through opportunity supply or operational demand forces.

Output: **Prototype Invention** claimed and embodied as functional prototype - the '*know how*.'

Legal IP Status: Patent protection.

Value: **Feasibility** of tangible invention as a demonstration of the **Novelty** of concept.

Phronêsis

Phronêsis ➔ Industrial Production Methodology.

The Method's intended output is knowledge in the state of a *commercial product/service innovation*.

Industrial Production Methodology

Designed to create and deliver outputs in the knowledge state of Commercial Innovations.

The primary value of a newly deployed Commercial Innovation is utility; monetary utility to the manufacturer and functional utility to the consumer – a *know why* – as motivation for the commercial transaction.

Ownership and control of IP is protected by international *trademark* law.

Innovation State of Knowledge

Purpose: **Industrial Production** methods codify knowledge in products/components positioned as new/improved products/services in the marketplace.

Process: Systematic specification of components and attributes yields final form.

Output: **Market Innovation** embodied as viable device/service in a defined context, initiated through a commercial market opportunity – '*know why*.'

Legal IP Status: Trademark protection.

Value: **Utility** defined as revenue to company and function to customers + **Novelty + Feasibility**

Government (public) funding for Knowledge Creation followed Two Tracks

- **Track 1: Grant-based Scientific Research Programs** – Exploration to discover new knowledge about physical world (Science/Medicine).
- *Grant Scholarship → Peer Review System → Publish for Tenure*.
- **Track 2: Contract R&D for Production Programs** – Application of S&E to generate products with national value (Defense/Energy):
- *Contract Production → Performance Specifications → Sell for Profit.*

- *BOTH Tracks work very well - because their respective expectations, systems and incentives are closely and properly aligned.*

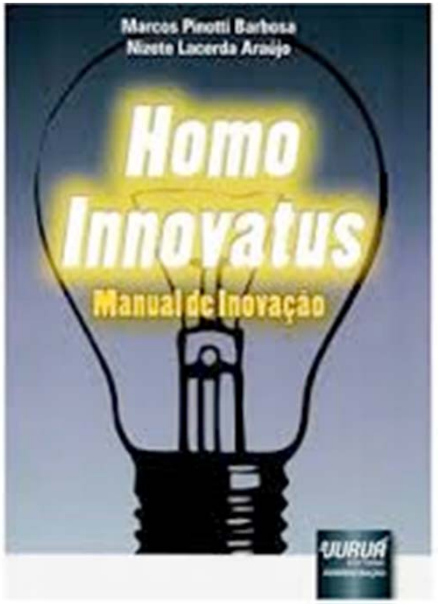
Government Grants vs. Contracts

- Grants permit open exploration as deemed appropriate by investigator, while Contracts specific deliverables, milestones and requirements.
- Typically, Grants go to universities while Contracts go to corporations.
- Grants pay direct and overhead costs to conduct the work, while Contracts pay costs, a profit margin and a commitment to buy the output.

R-D-P Methods embody Values

- Each method has a unique purpose, underlying principles and assumptions, education and training requirements, certification of mastery and legal status.
- Each method's outputs are valued differently by sectors within society, as are society's expectations for their contributions.
- Aristotle's typology reflected pure states of knowledge, while in the modern world interest groups coalesced around – and sought to influence – each state of knowledge.

Marcos Pinotti Barbosa - Universidade Federal de Minas Gerais - UFMG



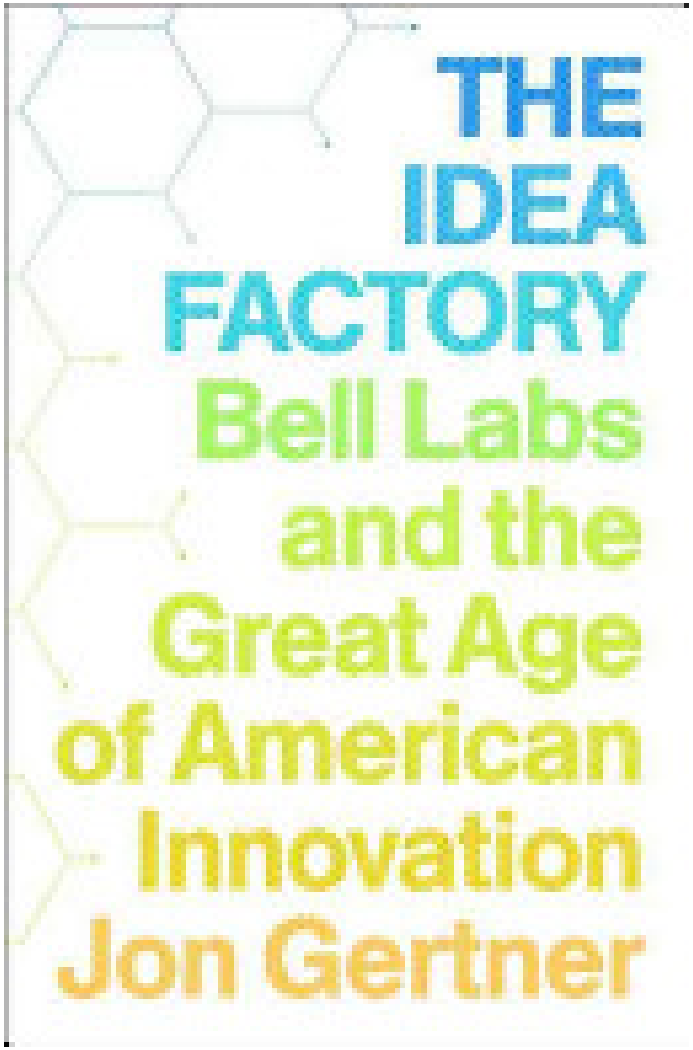
lab-bio
laboratório de bioengenharia

A Gradual Co-Mingling of Sectors, Methods, Outputs and Terminology.

1880's – 1930's

- Inventor/Entrepreneurs established "R&D" laboratories to move beyond cut-and-try techniques:
  - Eastern Dynamite Co. (Al DuPont, 1895);
  - Menlo Park Lab (T. Edison, 1876).
- Scientists, engineers and managers moved between the industrial, academic and government sectors commensurate with the pace of technology-oriented discoveries and technology-based inventions.
- The private sector sponsored "Managed R&D" conducted by S&E personnel with practical and theoretical expertise.

AT&T's monopoly position allowed it to freely sponsor basic and applied science (Bell Labs) linked directly to New Product Innovations (Western Electric).



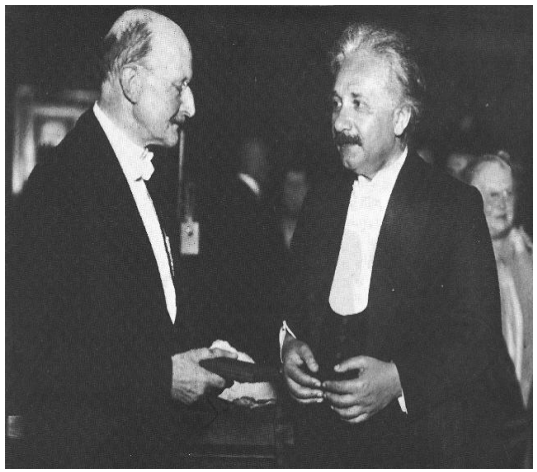
Pre-1940's Trends in USA

- Leading experts readily moved between economic sectors by serving as New Product Development Managers, University Faculty, Deans & Presidents, or Government department heads, Cabinet officers & Presidential advisors. Many became independent inventors and some became serial entrepreneurs.
- Private sector activity drove most technological innovation as government was relatively small and universities were primarily privately funded.
- This revolving door of experts became more common as technology-oriented discoveries and technology-based inventions multiplied.

Trends in Europe

European experienced the same co-mingling as individual nations sought to compete within the continent's markets and to compete globally.

Germany's Physikalisch-Technische Reichsanstalt (1895) linked scientists (Albert Einstein & Max Planck) with major corporations (Siemens AG, Krupp & Zeiss).



The United Kingdom created the Committee of the Privy Council for Scientific and Industrial Research (1915) to compete with S&E advances in Germany and in France.

WWII Period 1935 - 1945

- Germany's rapid conquests demonstrated their superior military technologies (ballistics, aeronautics, communications, guidance, detection, telemetry etc.) .

"Depend upon it, sir, when a man knows he is to be hanged in a fortnight, it concentrates his mind wonderfully." -- Samuel Johnson 1709-1784

- The threat of global domination focused the minds of Allied leaders – with little concern about the relative contributions of scientists, engineers and corporations.

U.S. National Defense *Research* Committee

Seated, L-R: Brigadier General George Strong, James Conant, Vannevar Bush, Richard Tolman, Frank Jewett; standing: Karl Compton, Irvin Stewart, and Rear Admiral Harold Bowen. Missing is Conway Coe, the Commissioner of Patents.

Success!! The mobilization of all sectors in the managed pursuit of clearly articulated goals.

Vision for Innovation

Science: The Endless Frontier - Dr. Vannevar Bush (1945): *Focus cross-sector resources on targeted socio-economic issues.*

What happened instead?

Despite ancient and clear distinctions between Episteme & Techne, the two underlying Methodologies were merged as “Research & Development” (R&D) in the late 1940’s.

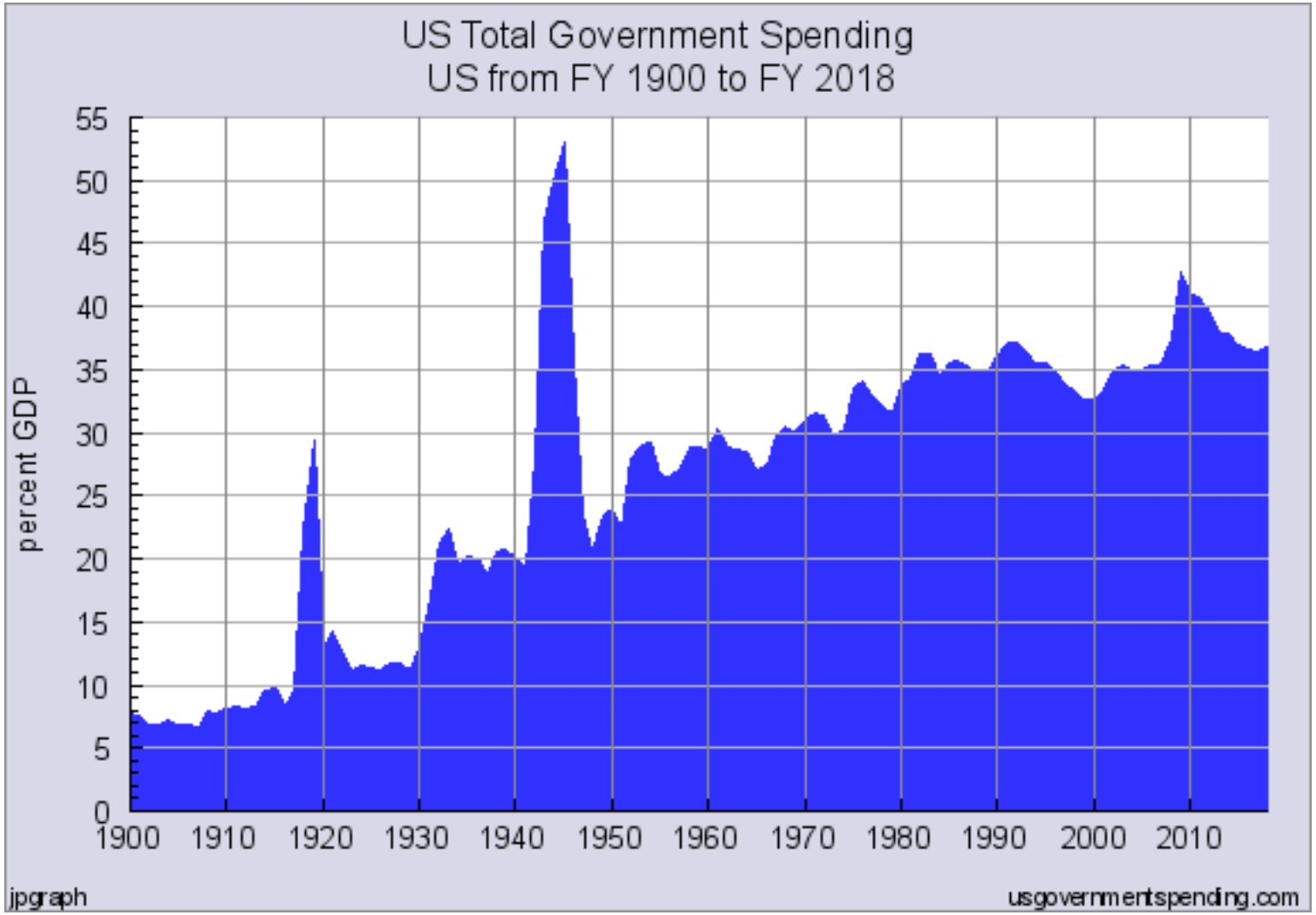
Special Interests Intervened

The U.S. Congress set about establishing and expanding a plethora of agencies and programs lacking a central focus or guiding agenda. Pork Barrel politics grew.

Each new Government agency and program obtained more funding and more staff. Government grew.

The U.S. university system positioned itself – through the Linear Model of Innovation – to be the conduit for public revenues. Academia grew.

President Eisenhower's caution about the "Military-Industrial Complex went unheeded. Defense Industry grew.


US Total Government Spending
US from FY 1900 to FY 2018
percent GDP
55
50
45
40
35
30
25
20
15
10
5
0
1900
1910
1920
1930
1940
1950
1960
1970
1980
1990
2000
2010
jpgraph
usgovernmentspending.com

Post WW II: 1945 – 1965

- Economic boom in U.S.
- Reconstruction in Europe and Asia.
- Cold War between U.S. and Russia.
- Space Race.

All accelerated pace of technological innovation for both national and consumer markets. Plenty of public and private money for expansion – so no concern for distinctions between “R” and “D”.

Bureaucratic/Academic Complex

Caption: Dr. Vannevar Bush (l), President Harry S. Truman (c), James B. Conant, President, Harvard University, USA.

1960's – A Clash of Values

- Military & Industry - Contention over resource allocations caused the U.S. Defense Industry to challenge the Linear Model of Innovation:
  (DOD's Project Hindsight)
- Academia & Government – The findings were successfully countered by a set of ad hoc studies disguised as scholarship:

  (NSF's TRACES)

Solution: Throw *more* money at problem!

- Government responds for calls to increase innovation by channeling even larger allocations to the academic sector -- doubling agency budgets over short timeframes.
- Established metrics for innovation were simply surrogate measures of other logic model elements:
  - Government expenditures & University Awards = inputs.
  - Level of sponsored research activity = process.
  - Bibliometrics & Patents = Outputs

Perhaps no one anticipated the long-term erosion to a nation's pace of technological innovation, especially because the effect was subtle and gradual.

The Muddled Mess of Technological Innovation in Theory and Practice.

Public Support for Knowledge Creation

- **Grant-based Scientific Research Programs** – Exploration to discover new knowledge about physical world (science/medicine).
  Grant-based Scholarship → Peer System → Publish for Tenure.

- **Contract R&D for Production Programs** – Application of S&E to deliver specified products with national value (defense/energy):
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- *BOTH of these programs work well - because their respective expectations, systems and incentives are closely and properly aligned.*

- ***Sponsored "R&D" for "S&T" Innovation*** – Generate S&E outputs for commercial exploitation to generate beneficial socio-economic impacts.
  Scholarly outputs for tenure ≠ Corporate requirements for profit

  - HYBRID programs have many problems because their expectations, systems and incentives are misaligned or even incongruent!

What are these Hybrid programs saying?

- *That academia is better equipped than industry to deliver value for money?*
- *That tenured/career employees should dictate the rules of innovation for the private sector?*
- *That corporations are devoid of ideas for new products and services?*
- *That students and small businesses have the primary insight into societal needs?*
  - *Yet these absurd premises remain unchallenged.*

Hybrid Programs intending Impact

- **United States –**
  - All SBIR & STTR Programs**;** **NSF** – Engineering Research Centers (ERC); Industry/University Cooperative Research Centers (I/U CRC); Innovation Corps (I-Corp); **NIH** – Program on Public/Private Partnerships; **NIST** – Technology Innovation Program (TIP); **DoEd** – Rehabilitation Engineering Research Centers (RERC); Field Initiated Development (FID).
- **Canada** –
  - Natural Science and Engineering Research Council (NSERC); Canadian Institutes for Health Research (CIHR).
- **European Union –**
  - Research Framework Programme; Competiveness; Innovation Framework Programme.
- **Latin America & Southeast Asia** - CNRTA??

False Dichotomies/Erroneous Contractions

- *Supply/Science/Technology Push vs.*

  Demand/Market/Society Pull

- *Research & Development (R&D)*
- *Science & Technology (S&T)*
- *Discovery/Insight/Invention/Innovation*
- *Scholarly vs. Societal: Outputs/Outcomes/Impacts*
- *Expenditures & Bibliometrics vs. New Net Wealth*
  - Counting what is countable vs. Counting what matters.

Silly Metrics based on Vague Models

- ∑ (R + D) / GDP = Innovation
- ∑ (95%R + 5%D) ≠ ∑ (5%R + 95%D)
- ∑ (X%R + Y%D) ≠ Products/Services

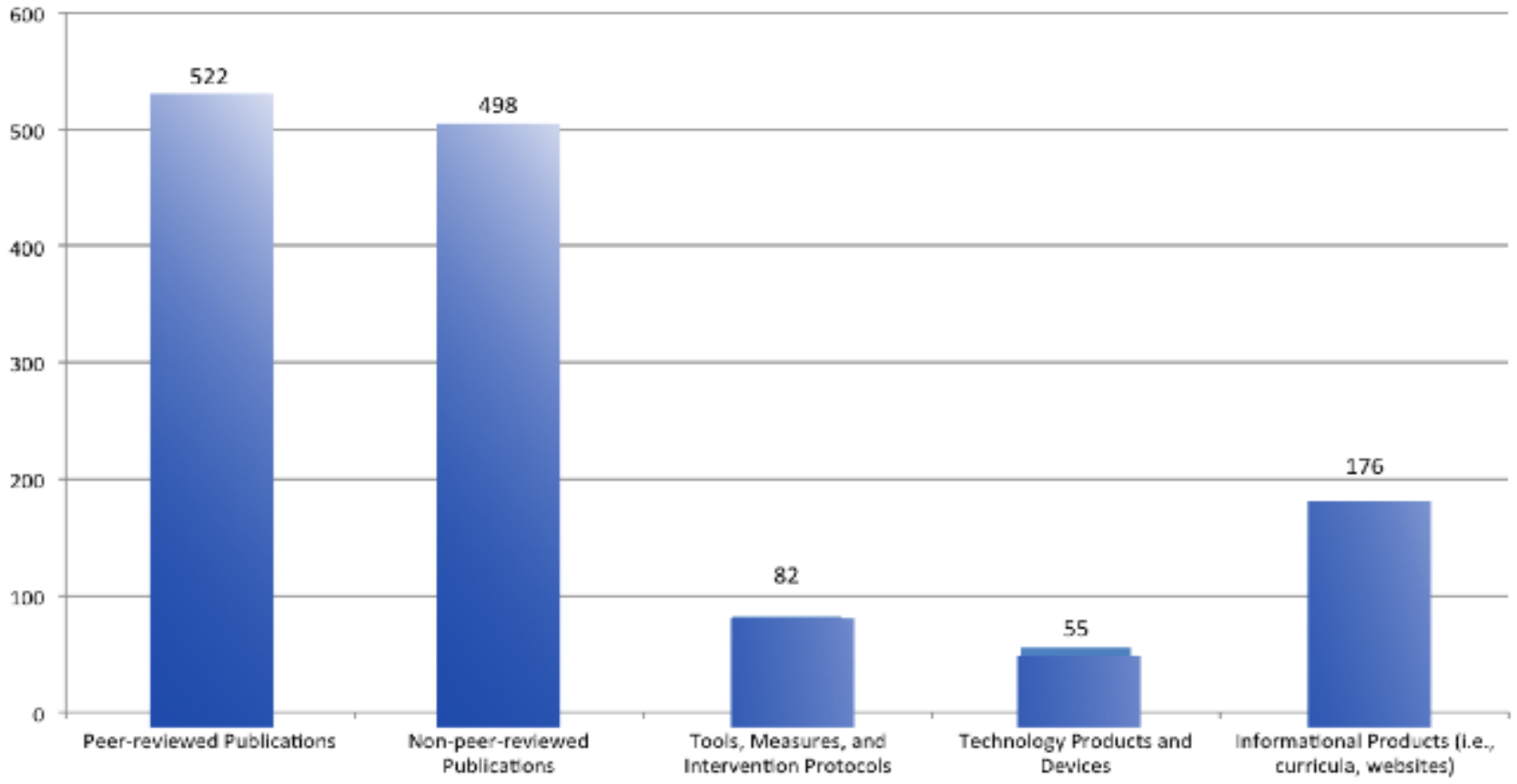
Such measures co-mingle inputs, ignore key factors, and ignore causal links.

Newest government models lack utility (description, explanation, prediction, control).

(http://www.ott.nih.gov/PDFs/NIH-TT-Plan-2013.pdf)

NIDRR/USDE 2013 Outputs

Chart 7: The Number of Different Products Generated by NIDRR Grants in FY 2013



So why do they persist?

- Largesse of public funding since the 1940's shifted power and influence over budgets from corporate to non-corporate sectors.
- Distortion of V. Bush's national R&D proposal by entrenched agency interests:
  - Military/Industrial AND Academic/Bureaucratic Complex
- Perpetuation of false paradigms by beneficiaries in government and academia (Linear Model).
- Passive acceptance of "aspirational" language and unintended consequences by general public.

Knowledge Translation
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Technology Transfer

Restoring Parity in Methods to Achieve Intended Results.

Clarifying the Muddled Mess in STI Policy

- *Establish Terms, Definitions & Proofs:* These are essential yet currently absent from STI Policy.
- *Acknowledge Knowledge States & Transitions:* Methods of knowledge creation and output state attributes dictate opportunity and constraints for knowledge kernel.
- *Apply proper transitions between Knowledge States:* Ensure models, methods and metrics are congruent and designed to communicate information based on rigor and relevance, *not on rhetoric*.
- Apply the scholarly values of demonstration, replication, skepticism and peer review to all elements and actors.

Innovation & Impact

- Traditionally, each sector defined terms in own narrow context, unconcerned with downstream market activities or broader societal benefits, comfortable in status quo budgets and paradigms. But . . .
- U.S. National Science Board (2012) – "*Innovation is defined as the introduction of new or significantly improved products (goods or services), processes organizational methods, and marketing methods, in internal business practices or in the open marketplace.*" (OECD/Eurostat, 2005).

“Innovation” Impact implies Utility

Public support for investment in technology-based *innovations* grounded in 3 expectations:

✓ New/improved devices/services with economies of scale that contribute to societal quality of life.

✓ Sufficient return on investment through sales to sustain company, pay taxes and compete globally to generate new net wealth.

✓ Benefits realized in short-term (5–10 yrs).

Innovation’s context is Societal Impact via Commercial Marketplace.

Commercial Market is path to Utility

- Industry survives in competitive system by translating knowledge into market utility through Production methods (beyond R&D).
- Utility = Money to Seller / Function to Buyer.
- No $ale – Research discoveries are freely published and globally disseminated, while Development prototypes lack commercial hardening or economies of scale.

R and D outputs ≠ Market Innovation.

Importance of Untangling Innovation Terms

- Each Methodology has its own rigor and jargon.
- Actors are trained and operate in one Method and tend to over-value that one Method.
- Academic & Government sectors dominate “STI” Policy at the expense of Industry – the only sector with time and money constraints. . .
- Methods are actually *inter-depen*dent, while traditional dichotomies are all *complementary* factors supporting innovation outcomes/impacts.

Relational Attributes from Literature

Episteme	*Techne*	*Phronesis*
Know what	Know how	Know why
Science	Engineering	Industry
Research	Development	Production
Intellectual	Technological	Commercial
Long term	Mid term	Short term
Concept	Prototype	Product
Novelty	Feasibility	Utility
Translation	Transfer	Transaction
DISCOVERY	INVENTION	INNOVATION

The Way Forward: Integrate *Conceptual* but Differentiate *Operational*

- *Consider three distinct states:* Know role of Research, Development and Production methods in context of each project – plan and budget accordingly.
- *Engage Industry early:* Government/Academic projects intended to benefit society fail to cross gaps (death valley vs. Darwinian sea) to business & open markets.
- *Apply evidence-based framework:* Link three methods; Communicate knowledge in three states; Integrate key stakeholder who will determine eventual success.

Need to Knowledge (NtK) Model

Related Publications

- *Lane,JP, Godin, B.* (2013) ***Methodology Trumps Mythology****, Bridges, The Translatlantic STI Policy Quarterly from the Office of Science & Technology, Embassy of Austria, Washington, DC, 36, December 2012/OpEds & Commentaries.*

- *Lane, JP, Godin, B, (2012)* ***Is America's Science, Technology, and Innovation Policy Open for Business?*** *Science Progress, June 12, 2012, http://scienceprogress.org/2012/06/is-america%E2%80%99s-science-technology-and-innovation-policy-open-for-business/*

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