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Corporate-University R&D

B. Chehroudi, PhD

Managing Director
Research, Development, and Education
Advanced Technology Consultants
4 Hidden Crest Way
Laguna Niguel, California, USA
www.advtechconsultants.com

Professor, Head, University-Industry R&D Liaison
School of Engineering
Mechanical Engineering Department
Arkansas Tech University
Russellville, Arkansas, USA
www.atu.edu

Kasetsart University
50th Street Mall Road, Chatuchak
Bangkok, Thailand

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R&D, Innovation, and Bottom Line

- P&G has 21 brands with annual sales of $ 1BN to $10BN, and 11 brands with sales of $500M to $1BN
- The company has operations in close to 70 countries, including more than 130 manufacturing sites, in about 40 countries

Hemispheresmagazine.com

D: How does the company approach innovation?

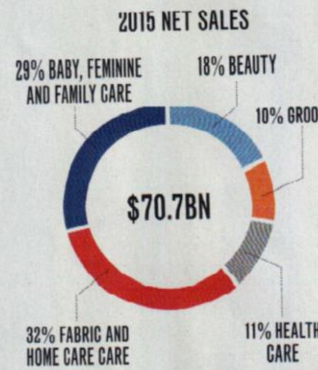
T: We spend about $2 billion in R&D every year. and that R&D is really geared to understanding the categories that we compete in. It's important to make sure we're understanding the latest trends.

We have three innovation campuses in Greater Cincinnati, but we also partner with a lot of other businesses, universities and even private inventors, so we really cast a broad net looking for

these new technologies and these innovative approaches.

SPOTLIGHT: PROCTER & GAMBLE

We speak to Carolyn Tastad, North America president at the consumer products giant, which has been headquartered in Cincinnati from its very beginning



Dossier: What differentiates P&G from its peers?

Tastad: At the heart of P&G is a very deep commitment to serving consumers around the world. We talk about the consumer being at the center of all of our decisions, and that really is a founding principle of how we work. We take our responsibility seriously to improve life in those very small but meaningful ways every day, day in and day out.

D: So how do you make sure you stay on top of what consumers want?

T: We spend hundreds of thousands of hours every year engaging with consumers. In order to serve them, we really have to understand them. We spend time with them, often in their homes, not only watching how they use our products but understanding the role our products play in their lives. That understanding of consumers is embedded in every Pampers diaper, Gillette razor, or Tide or Ariel product that helps consumers keep their clothes clean.

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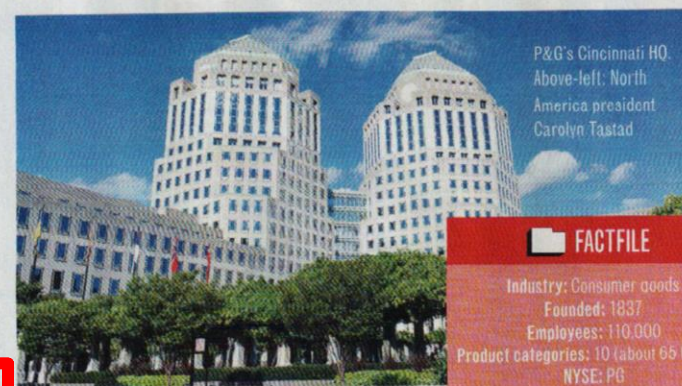

P&G's Cincinnati HQ. Above-left: North America president Carolyn Tastad

FACTFILE

Industry: Consumer goods
Founded: 1837
Employees: 110,000
Product categories: 10 (about 65 brands)
NYSE: PG

D: What's your vision for P&G for the future?

T: Our aspiration, at least, is to serve the world's consumers better than our best competitor in every category and every country in which we choose to compete, and in doing so create shareholder value.

We're focused on building those leading brands and we want to continue to delight consumers through innovation and superior performing products. We want to strengthen our reach through great marketing and strong go-to-market capability. And we'll also ensure we create a world where we can attract and develop the very best talent and outstanding leaders that are going to continue to serve consumers for the next 180 years.

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R&D, Innovation, and Bottom Line

- In 4 seconds, GE90 engine can suck the air out of Madison Square Garden !

Hemispheresmagazine.com

GE AVIATION
DAVID JOYCE, PRESIDENT AND CEO

During this decade, the world's largest jet engine maker will put the $1 billion-plus it invests annually in R&D to full use, as it and its partners complete nine new engine development programs. In doing so, it will introduce a range of new technologies that will change the way we fly—from the industrialization of lightweight ceramic matrix composites that allow engines to run more efficiently, to the introduction of 3D additive manufactured parts that are made in a fraction of time of other methods.

"We have one example where the designers took a portion of a jet engine that was made up of 300 individual parts and made it out of one additive, 3D-printed part," says president and CEO David Joyce. "That one part looks dramatically different and is dramatically improved because the engineers can now focus more on performance and less on the limitations."

Why do R&D ?

- The study of economic returns to R&D investment has developed over the past 30 years. Although estimates of the rates of return differ, the leading researchers in the field agree that R&D has a significant and important positive effect on economic growth and the overall standard of living.

- It should be noted, however, that the precise magnitude of these returns cannot be measured without the use of simplifying assumptions in the analysis. A survey article by Nadiri (1993) examined 63 studies in this area published by prominent economists, mostly in reference to the United States, but also in reference to Japan, Canada, France, and Germany. Looking at the results of these studies, he concluded that R&D activity renders, on average, a **20 to 30 percent** annual return on private (industrial) investments. This is not to say that every research project has a high, or even a positive, rate of return. Rather, ***portfolios of scientific research projects*** selected for analysis have the rates of return cited above. Since they reflect average returns to a selected group of projects, these returns cannot be applied to aggregate R&D expenditures. It should also be pointed out that ***the more basic the research, the harder it is to evaluate the returns to R&D***.

Estimated annual rates of return to R&D expenditures

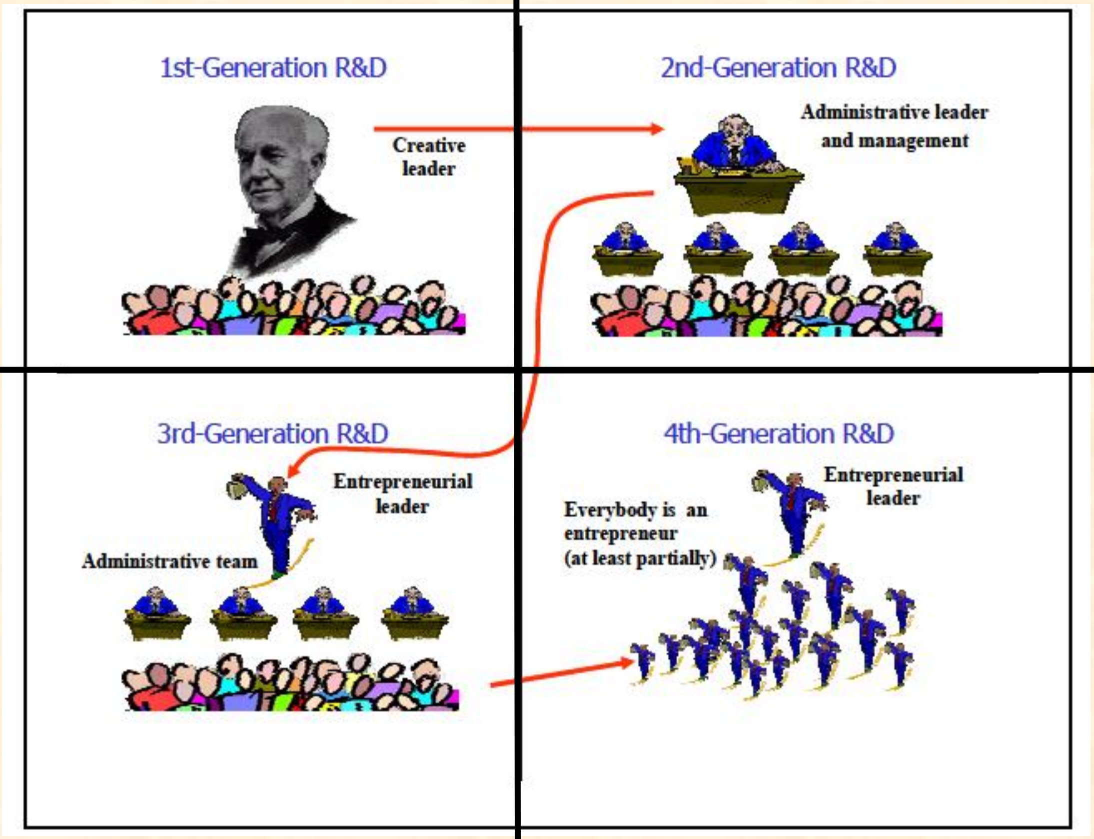
Author(s) and year of study	Rate of return[a]
Firm-level studies	
Link (1983)	3
Bernstein-Nadiri (1989b)	7
Schankerman-Nadiri (1986)	13
Lichtenberg-Siegel (1991)	13
Bernstein-Nadiri (1989[a])	15
Clark-Griliches (1984)	19
Griliches-Mairesse (1983)	19
Jaffe (1986)	25
Griliches (1980)	27
Mansfield (1980)	28
Griliches-Mairesse (1984)	30
Griliches-Mairesse (1986)	33
Griliches (1986)	36
Schankerman (1981)	49
Minasian (1969)	54
Industry-level studies	
Terleckyj (1980)	0
[b] Griliches-Lichtenberg (1984a)	4
Patel-Soete (1988)[c]	6
Mohnen-Nadiri-Prucha (1986)	11
Terleckyj (1974)	15
Wolff-Nadiri (1987)	15
Sveikauskas (1981)	16
Bernstein-Nadiri (1988)	19
Link (1978)	19
Griliches (1980)	21
Bernstein-Nadiri (1991)	22
Scherer (1982, 1984)	36

[a]For studies for which Nadiri (1993) reports a range of possible returns, the midpoint of that range is provided in this table.
[b]Not significantly different from zero in a statistical sense. This result, however, may be a reflection of limitations in the quantity of data used in the study.
[c]Economy-level study (all industries grouped together). SOURCE: M.J. Nadiri, "Innovations and Technological Spillovers," Working Paper No. 4423 (Cambridge, MA: National Bureau of Economic Research,

R&D Management is Important for Success

The 1st generation had a simple structure: a creative leader with entrepreneurial skills (an Edison-type individual) and personnel (often lacking formal scientific or engineering education) working on his/her assignments

The 2nd generation emerged when most major companies established large R&D departments. An R&D department typically had a more structured administrative scheme managed by an administrator (sometimes with a scientific background) rather than a scientific leader. Recruited scientific personnel had to meet specific requirements wit regard to their education and scientific skills



The 3ed generation was initiated by the marketing revolution, forcing R&D leaders to balance their portfolio of high- and low-risk projects. While the general structure of R&D centers remained mostly unchanged, the leaders had to acquire entrepreneurial skills to deal with risks, ROI, etc.

The 4th generation involves an increased initiative of all participants and the application of new tools. Thus it is very important that the new R&D organization be market driven, have a long-term vision, and be able to use incentives to motivate personnel. In other word, *every participant must be market driven and have some entrepreneurial skills*

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Key Processes in a Corporate New Product R&D

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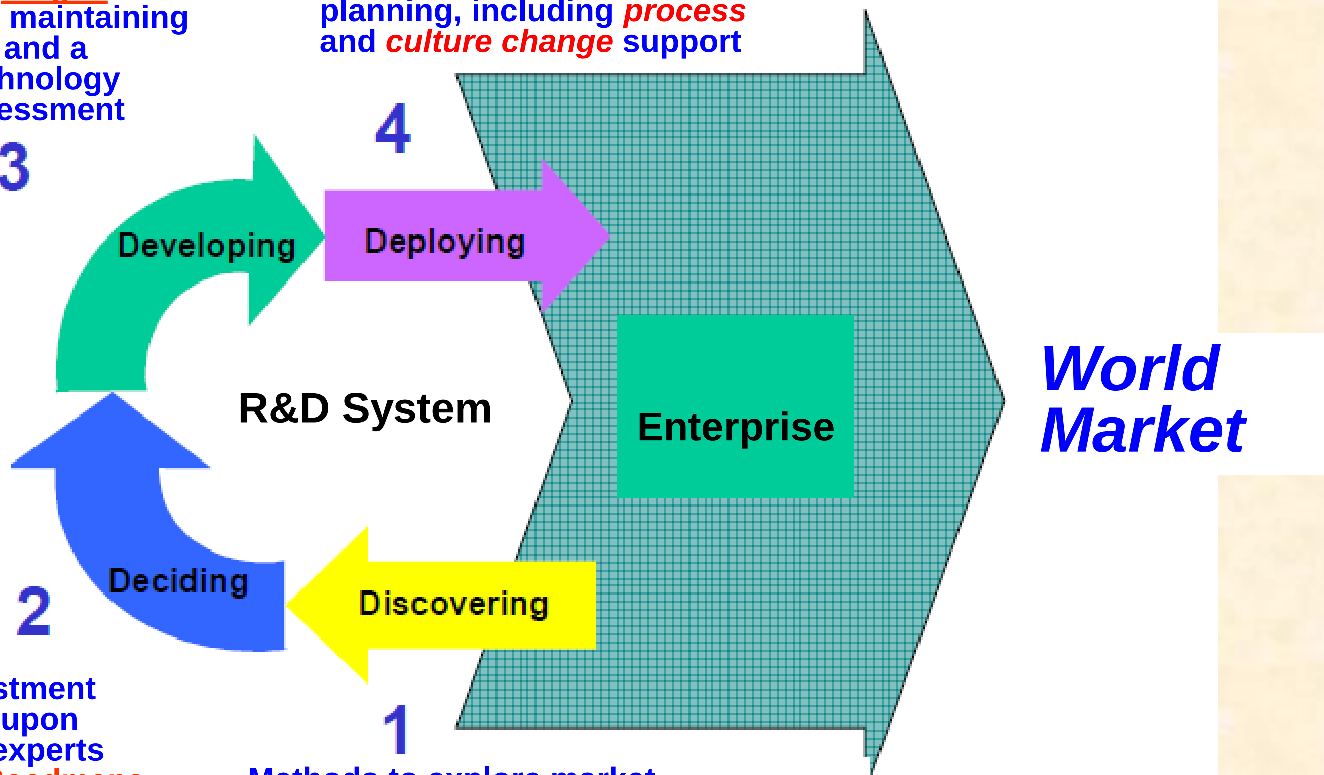
Develop and manage projects with a Staged Gated Process, maintaining strategic focus and a continuous technology maturation assessment

Proactive deployment planning, including *process* and *culture change* support

Think of these as four continuous parallel processes…



Technology investment decisions drawn upon collaboration of experts using Strategic Roadmaps, and analytical assessment of value to select proposed technology solutions

Methods to explore market opportunities, such as Strategic Roadmapping, Scenario Workshops, and Industry/Academic Cross-talks.

Pratt & Whitney

(Aviation Industry)

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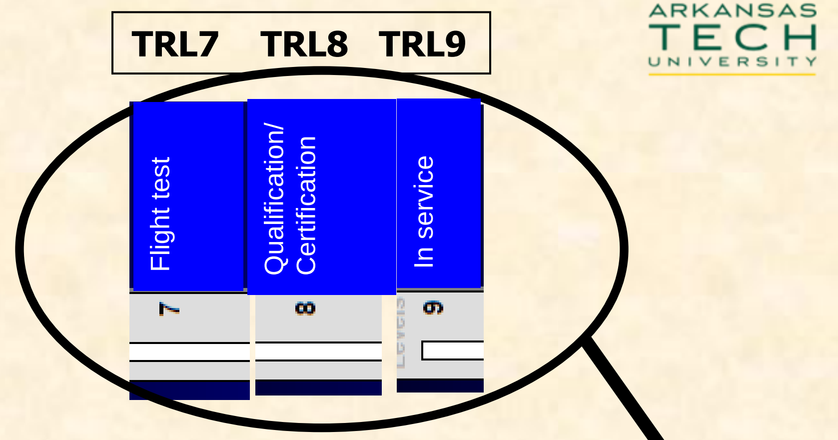
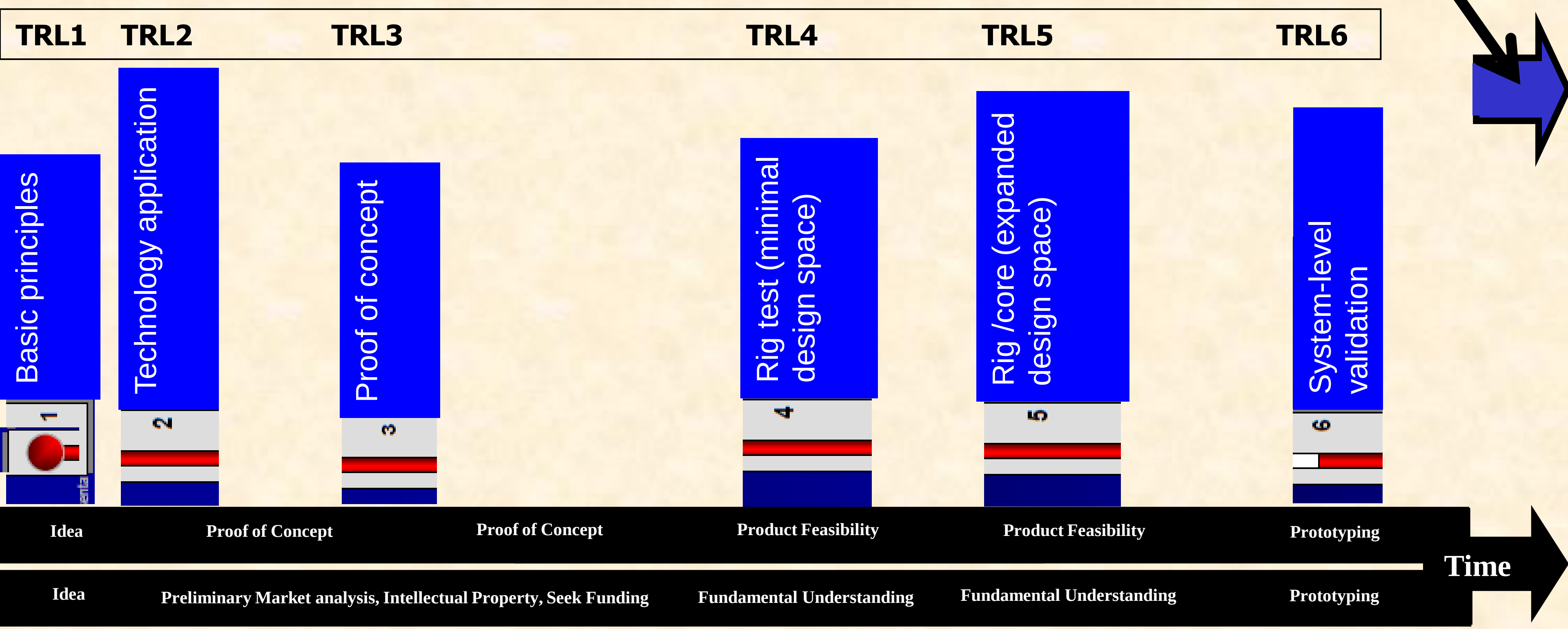
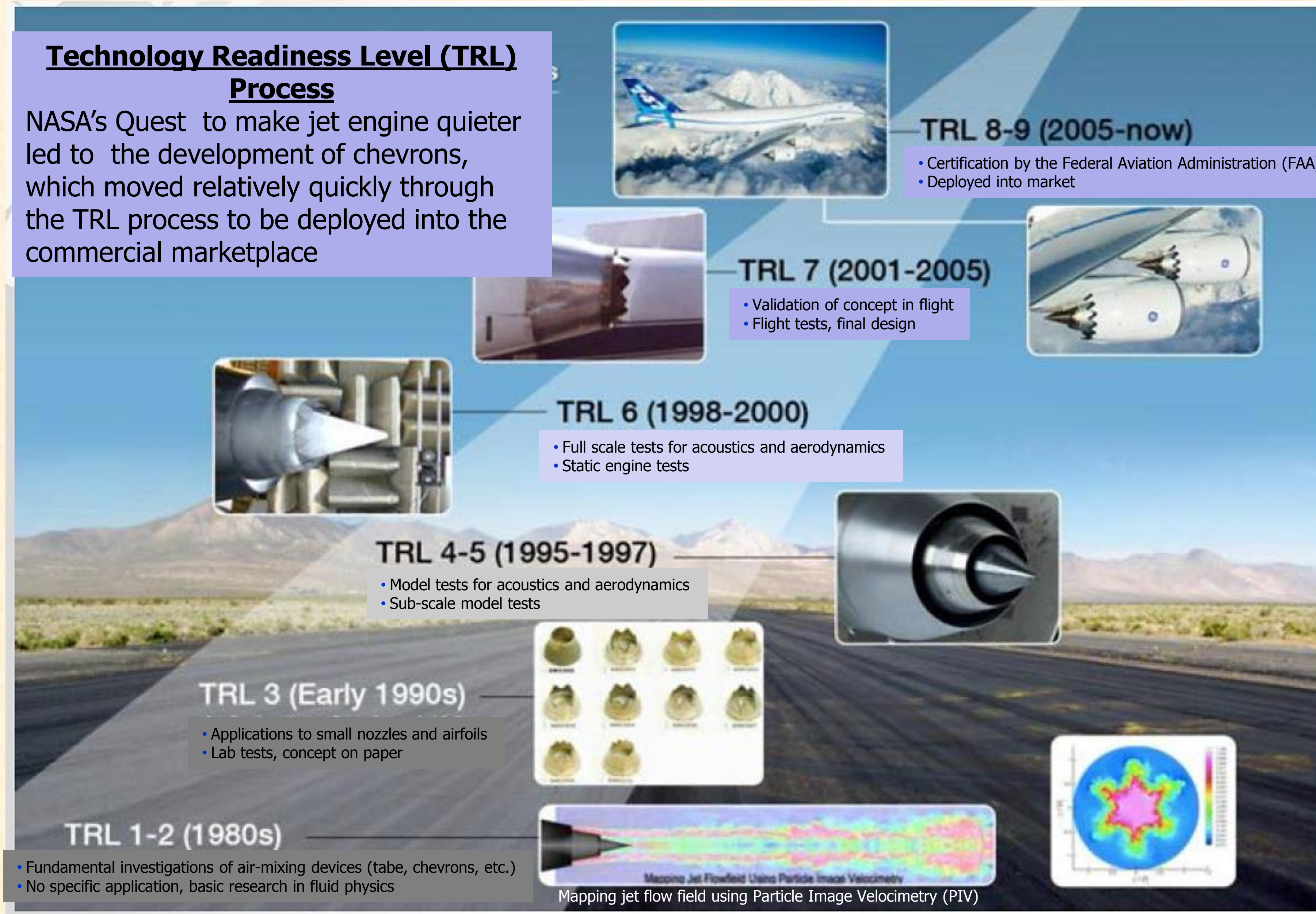
Technology and Product Roadmaps

- Technology Readiness Level (TRL)
- Shown is the P&W (Technology Readiness Level) TRL System and its equivalent



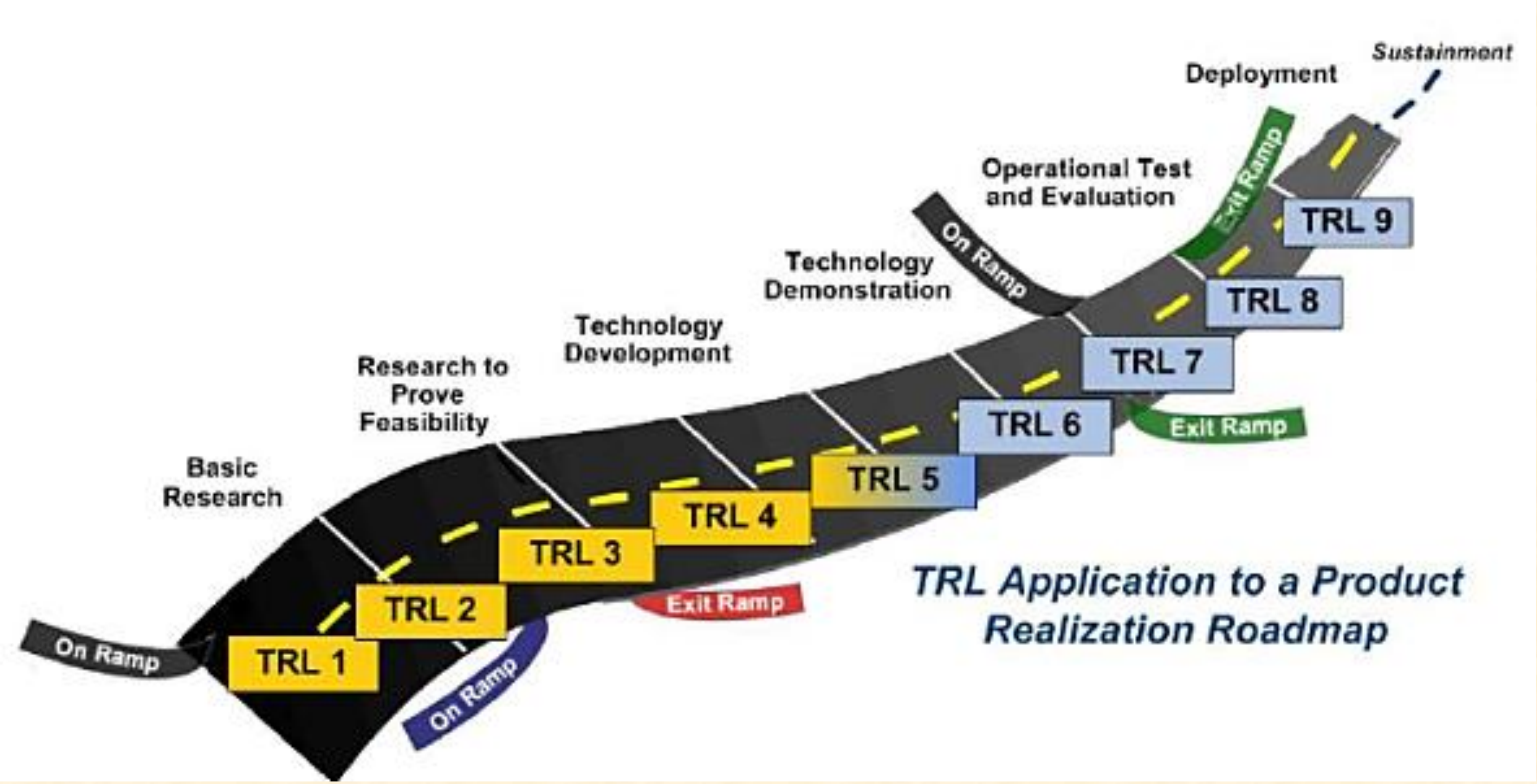


Technology and Product Roadmaps



Tribology challenges in aerospace Industry TRL P&W UTRC TRL EXCELLENT

Application of TRL: Product Realization Roadmap



Application of TRL:
Funding Energy Innovation at Different TRL Levels

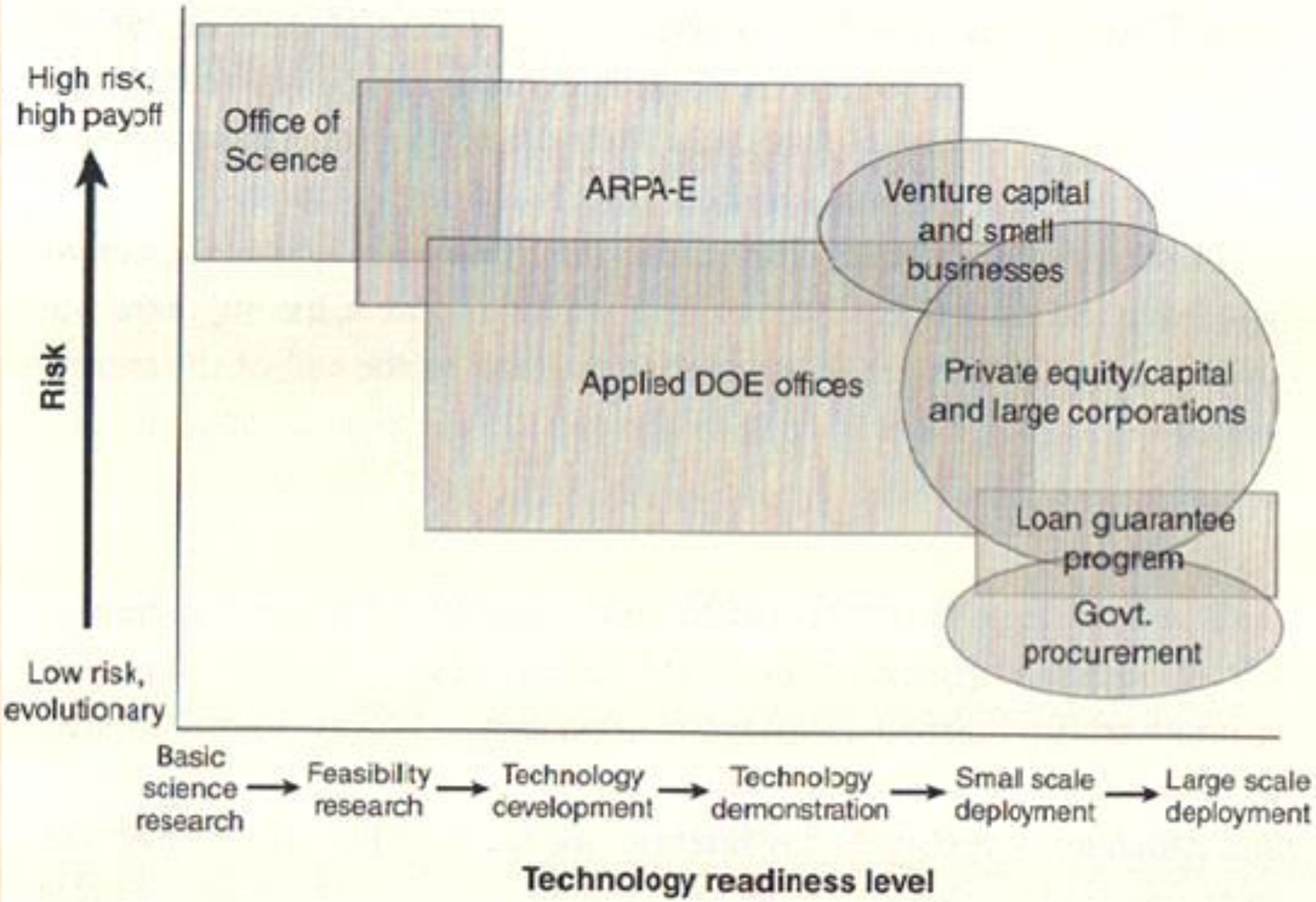


Figure 7.1

Energy innovation ecosystem. *Source:* Arun Majumdar, Director, ARPA–E, Woodrow Wilson International Center, Washington, DC, July 27, 2010.

Application of TRL:
Canadian Government allocation of funds in Aerospace Technologies TRL7-9

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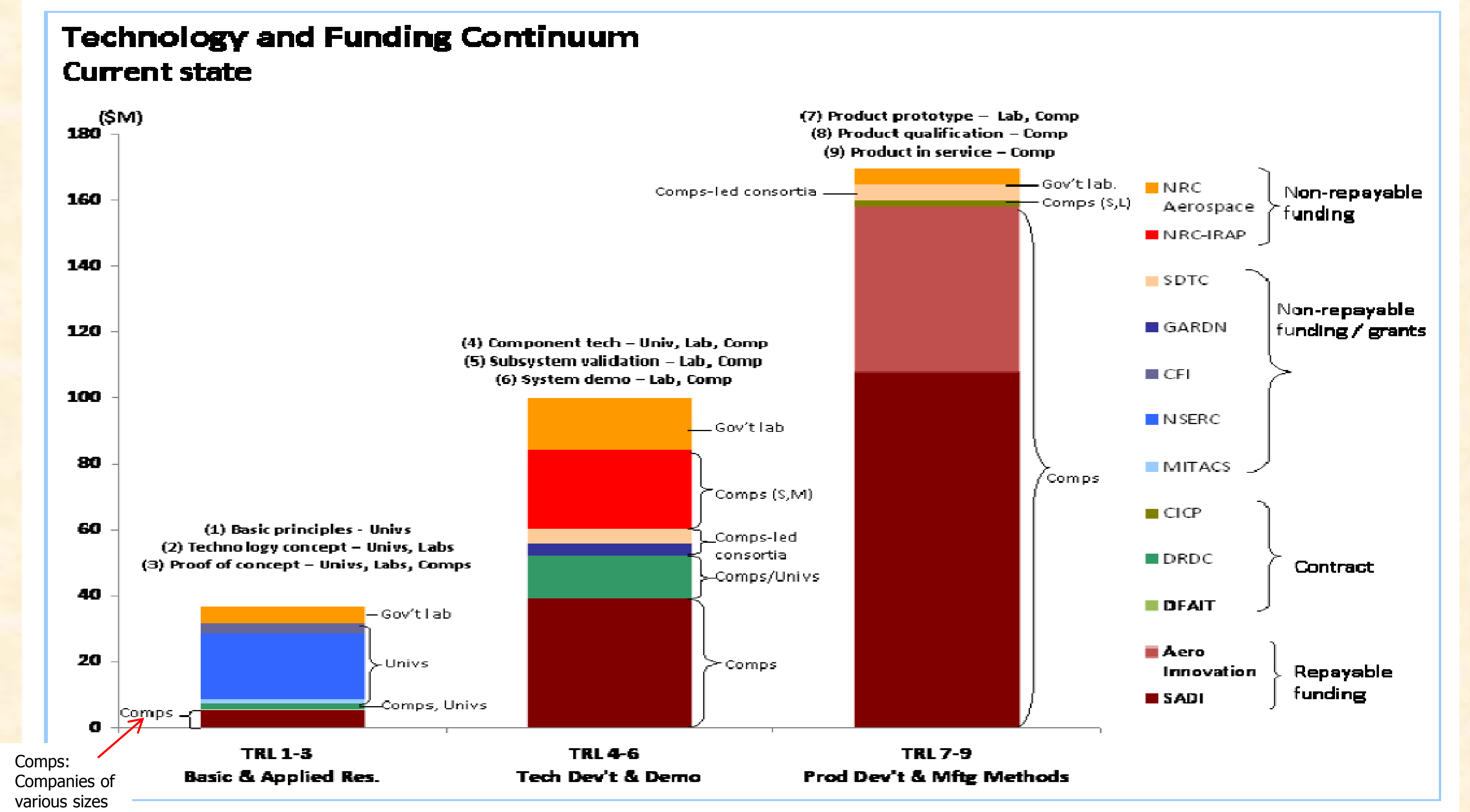

Current landscape of direct government funding for the aerospace industry and stakeholders by Technology Readiness Level (TRL)

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GDP per Capita in the World

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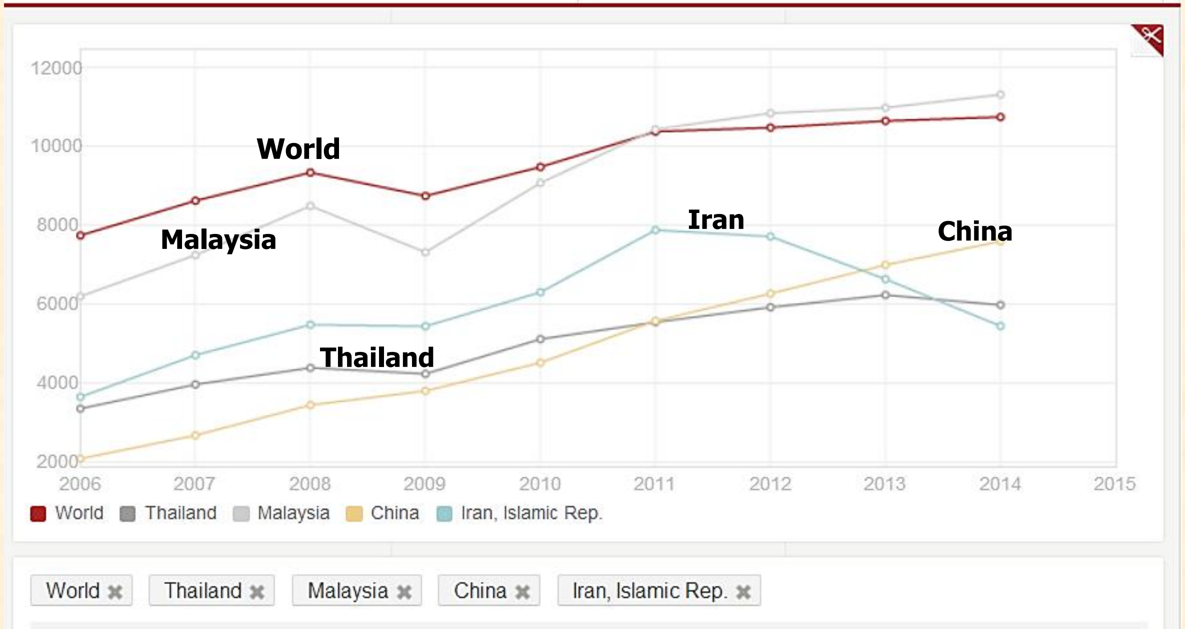
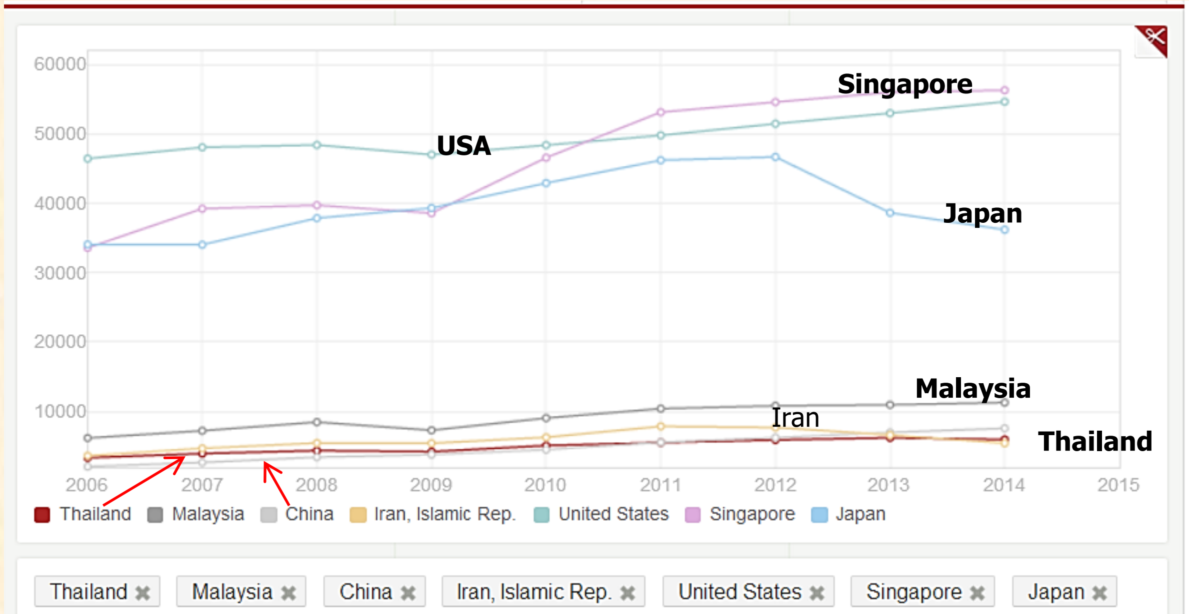
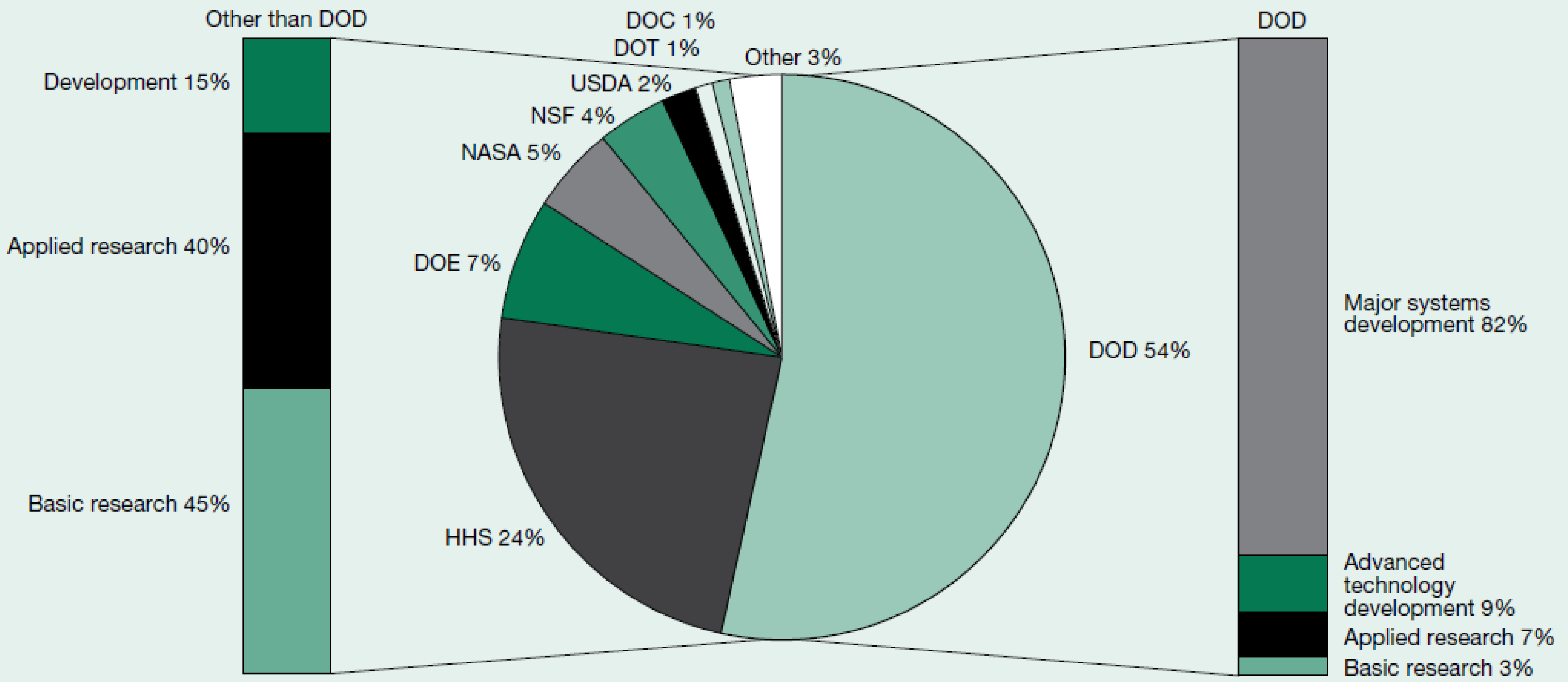




http://data.worldbank.org/indicator/NY.GDP.PCAP.CD/countries/TH-MY-CN-IR-US-SG-JP?display=graph

Federal R&D by Agency and Character

US Federal Obligations for R&D, by Agency & Character of Work (FY 2011)



DOC = Department of Commerce; DOD = Department of Defense; DOE = Department of Energy; DOT= Department of Transportation; HHS = Department of Health and Human Services; NASA = National Aeronautics and Space Administration; NSF = National Science Foundation; USDA = U.S. Department of Agriculture.

NOTE: Detail may not add to total due to rounding.

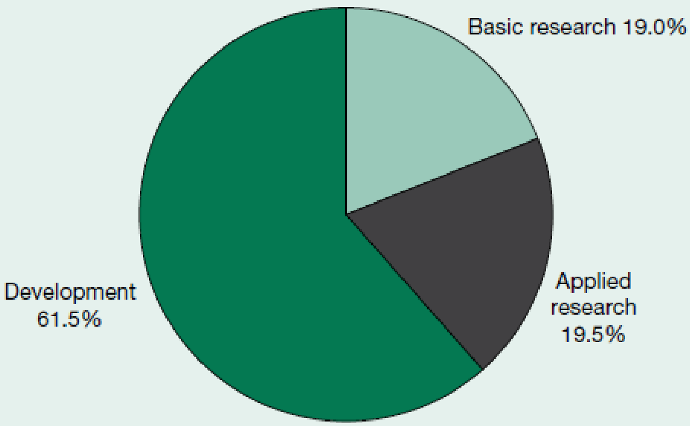
SOURCE: National Science Foundation, National Center for Science and Engineering Statistics, Federal Funds for Research and Development (FYs 2010–12). See appendix table 4-35.

Science and Engineering Indicators 2014

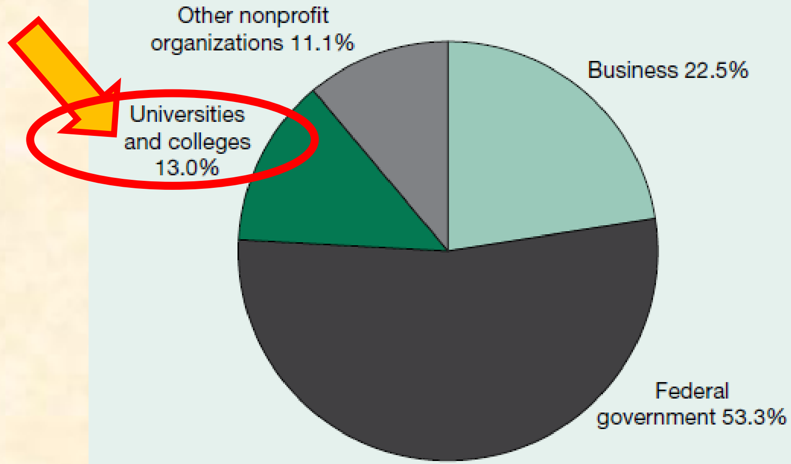
US R&D by Character of Work, Basic Research by Performing Sector, and Basic Research by Source of Funds

U.S. R&D by character of work, basic research by performing sector, and basic research by source of funds: 2011

US Total R&D, by Character of Work

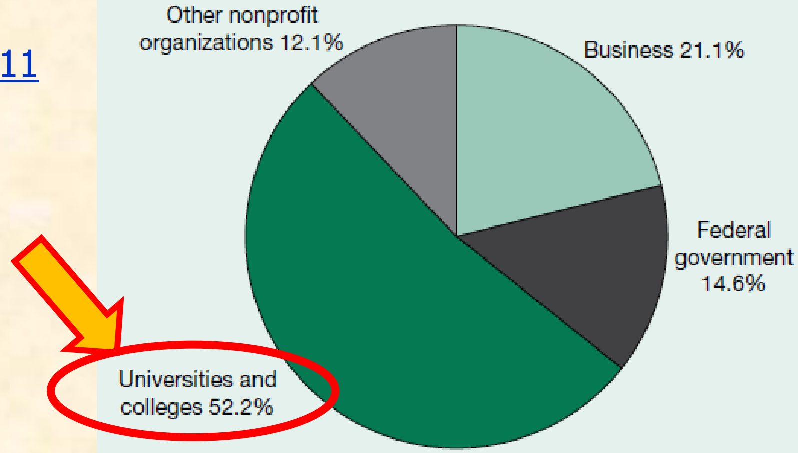


Basic Research, by Source of Funds



FY 2011

Basic Research, by Performing Sector



NOTES: National R&D expenditures were estimated at $424.4 billion in 2011. National basic research expenditures were estimated at $75.0 billion in 2011. Federal performers include federal agencies and federally funded R&D centers. State and local government support to industry is included in industry support for industry performance. State and local government support to universities and colleges is included in universities and colleges support of performance by universities and colleges.

SOURCE: National Science Foundation, National Center for Science and Engineering Statistics, National Patterns of R&D Resources (annual series). See appendix tables 4-3–4-5 and 4-7.

Science and Engineering Indicators 2014

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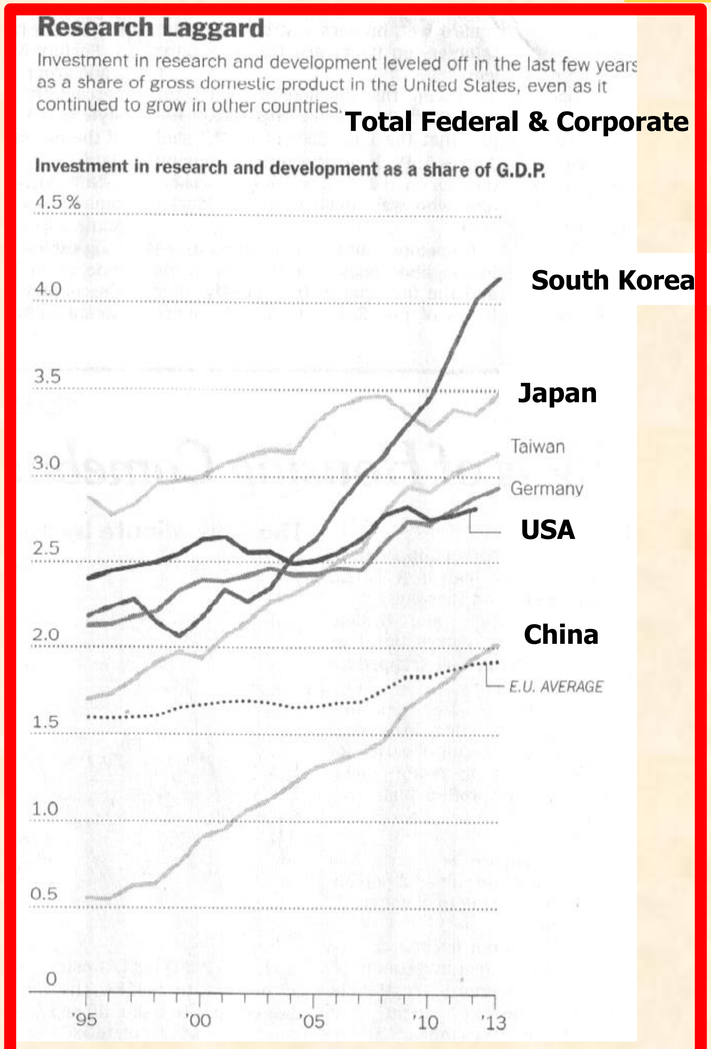
R&D Expenditure in the World as % of GDP

Innovation Rests on Weak Foundation as Research Spending Slows

- A shifting landscape: Rapid rise of R&D spending in South Korea, and China
- South Korea *surpassing* Japan's spending in terms of % of GDP
- US R&D spending as % GDP has been slowly rising (but not monotonically) from 2.5 to 2.75% since 1995, while South Korea, China, and even Japan show a steady rise in % of GDP spending

Innovation Lies on Weak Foundation



Federal R&D Expenditure as a Percentage of the GDP

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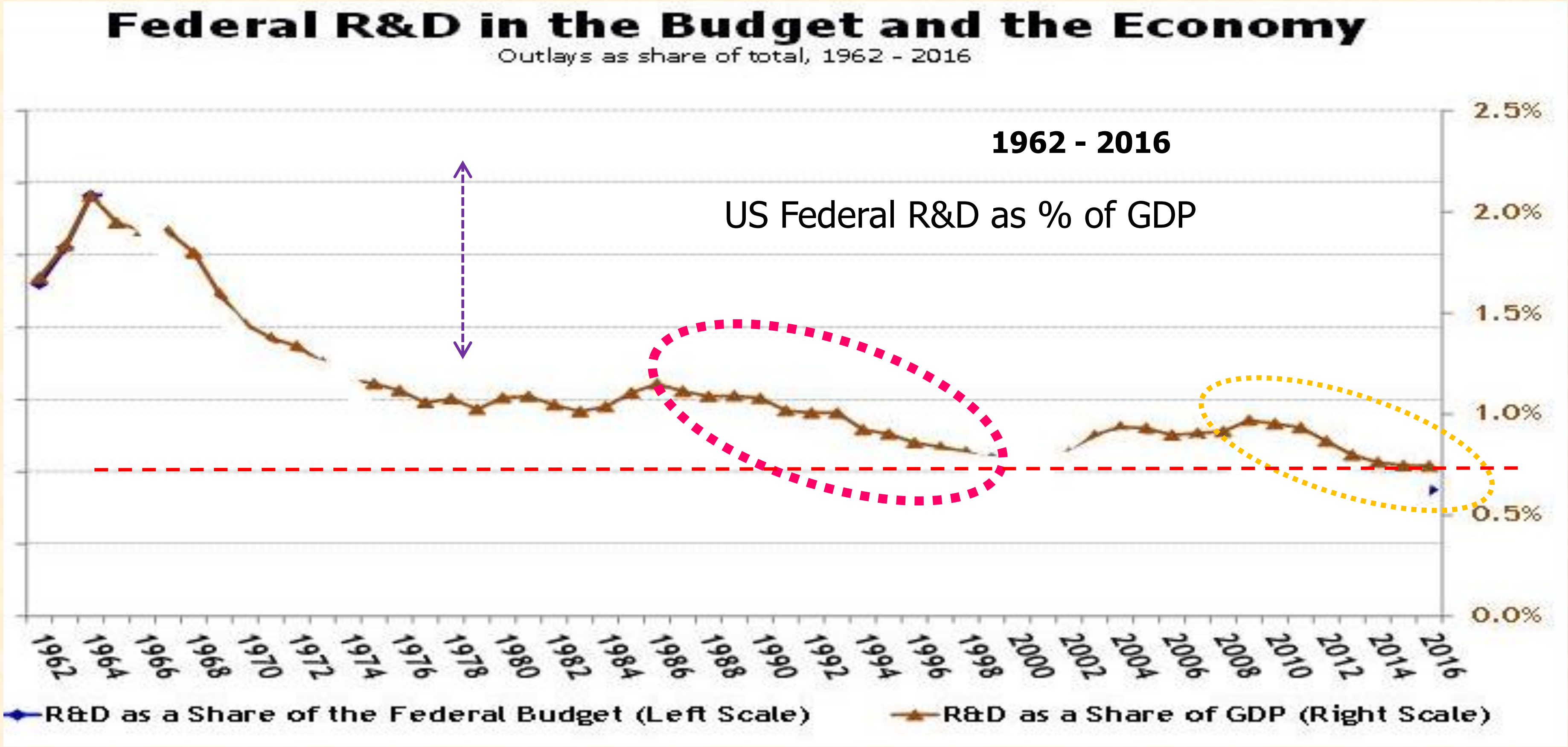

- US technological competitiveness may have been compromised in later years as a result of decrease in Fed R&D spending (as % of GDP) during 1987 to 2001

R&D Budget & Policy Programs: http://www.aaas.org/spp/rd/

R&D Expenditure Statistics in the World

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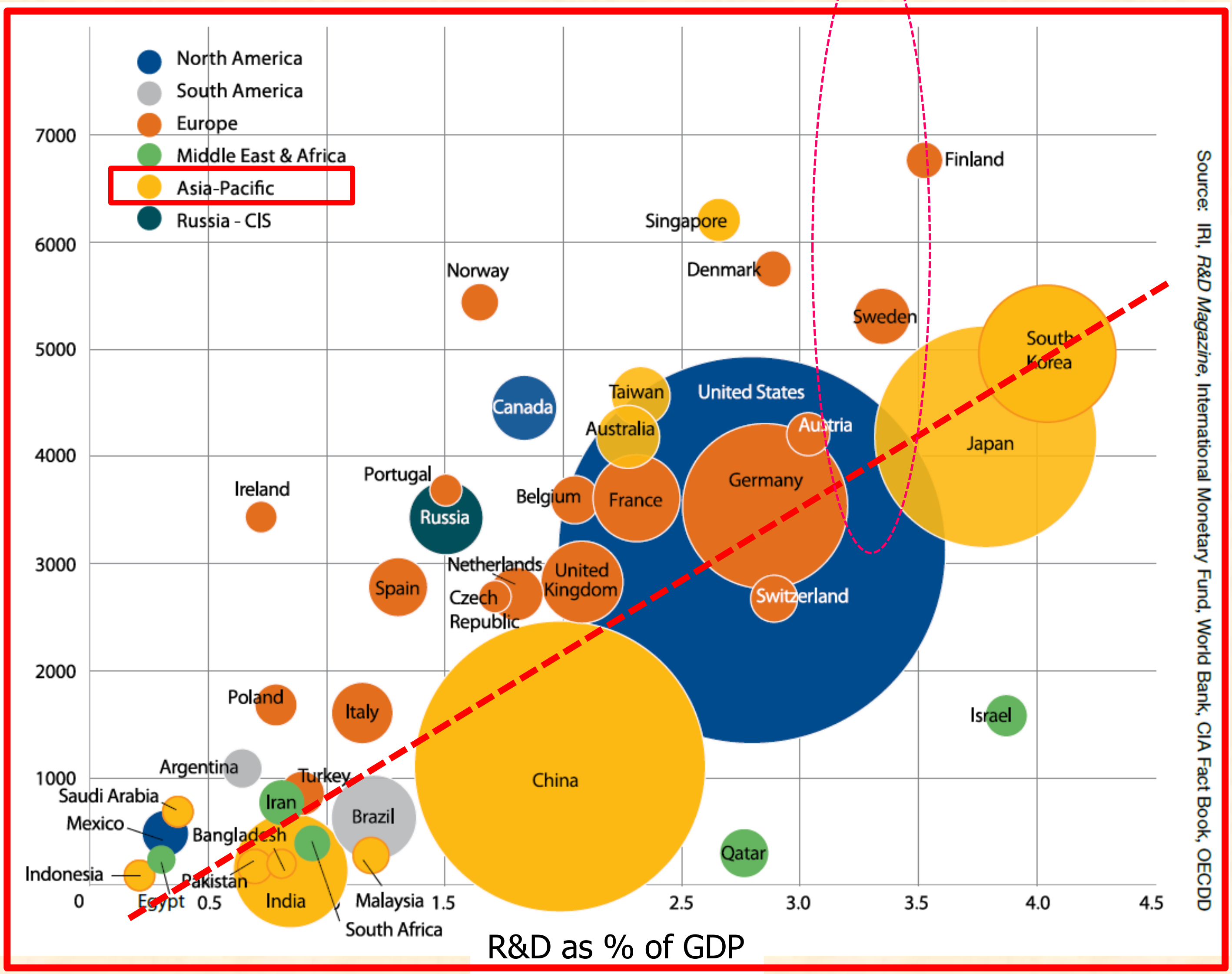
Size of the circles reflects the relative amount of annual R&D spending by the indicated country.
Note the regional grouping of countries by the color of the balls.



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How Well-Educated the Population is in Different Countries

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NSF Science & Engineering Indicators (2014)

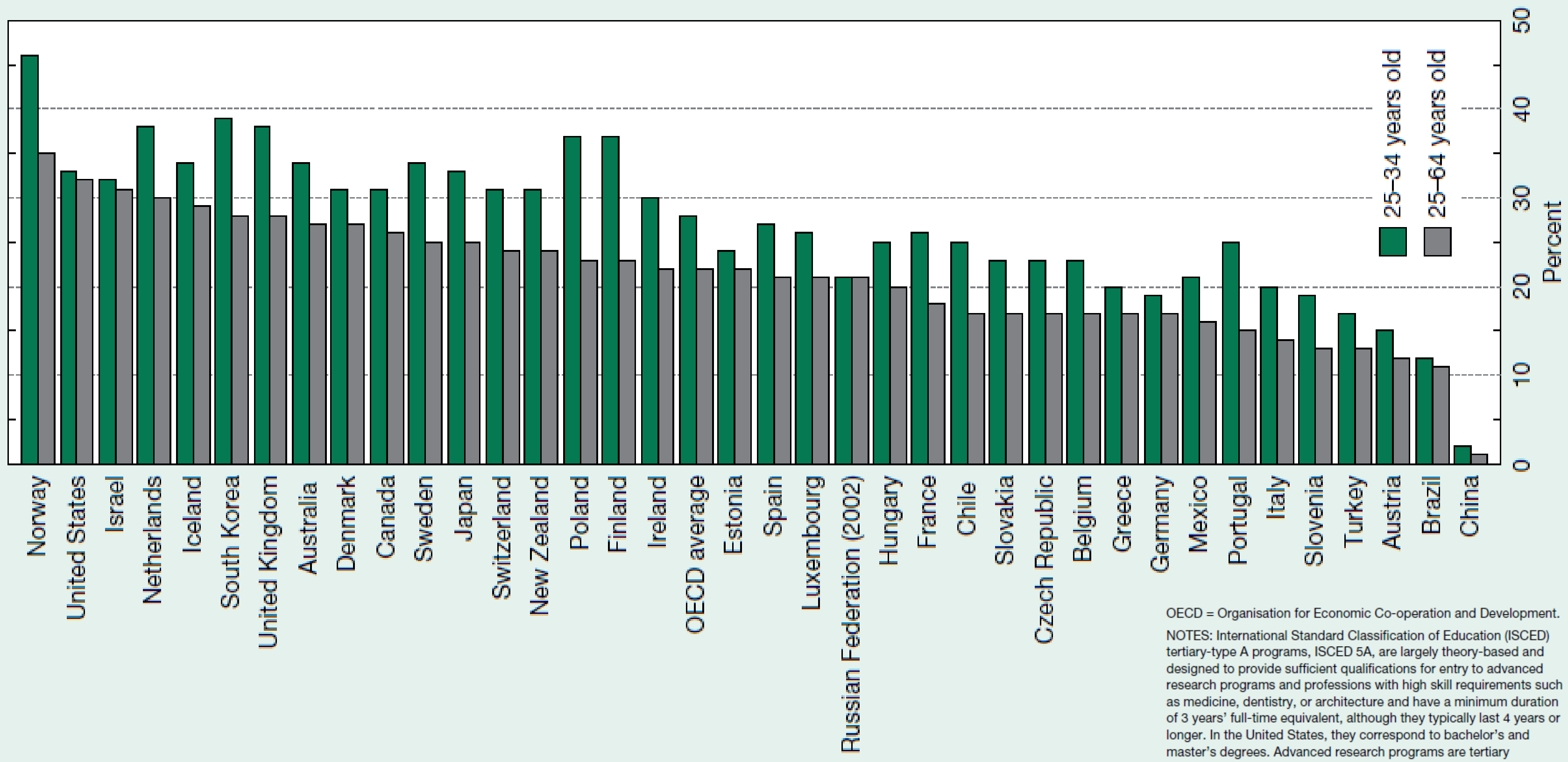

Figure 2-31
Attainment of tertiary-type A and advanced research programs, by country and age group: 2010

OECD = Organisation for Economic Co-operation and Development.

NOTES: International Standard Classification of Education (ISCED) tertiary-type A programs, ISCED 5A, are largely theory-based and designed to provide sufficient qualifications for entry to advanced research programs and professions with high skill requirements such as medicine, dentistry, or architecture and have a minimum duration of 3 years' full-time equivalent, although they typically last 4 years or longer. In the United States, they correspond to bachelor's and master's degrees. Advanced research programs are tertiary programs leading directly to award of an advanced research qualification (e.g., doctorate).

SOURCE: OECD, *Education at a Glance 2012: OECD Indicators* (2012).

Science and Engineering Indicators 2014

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Gross Domestic Expenditure on R&D as a Percent of GDP

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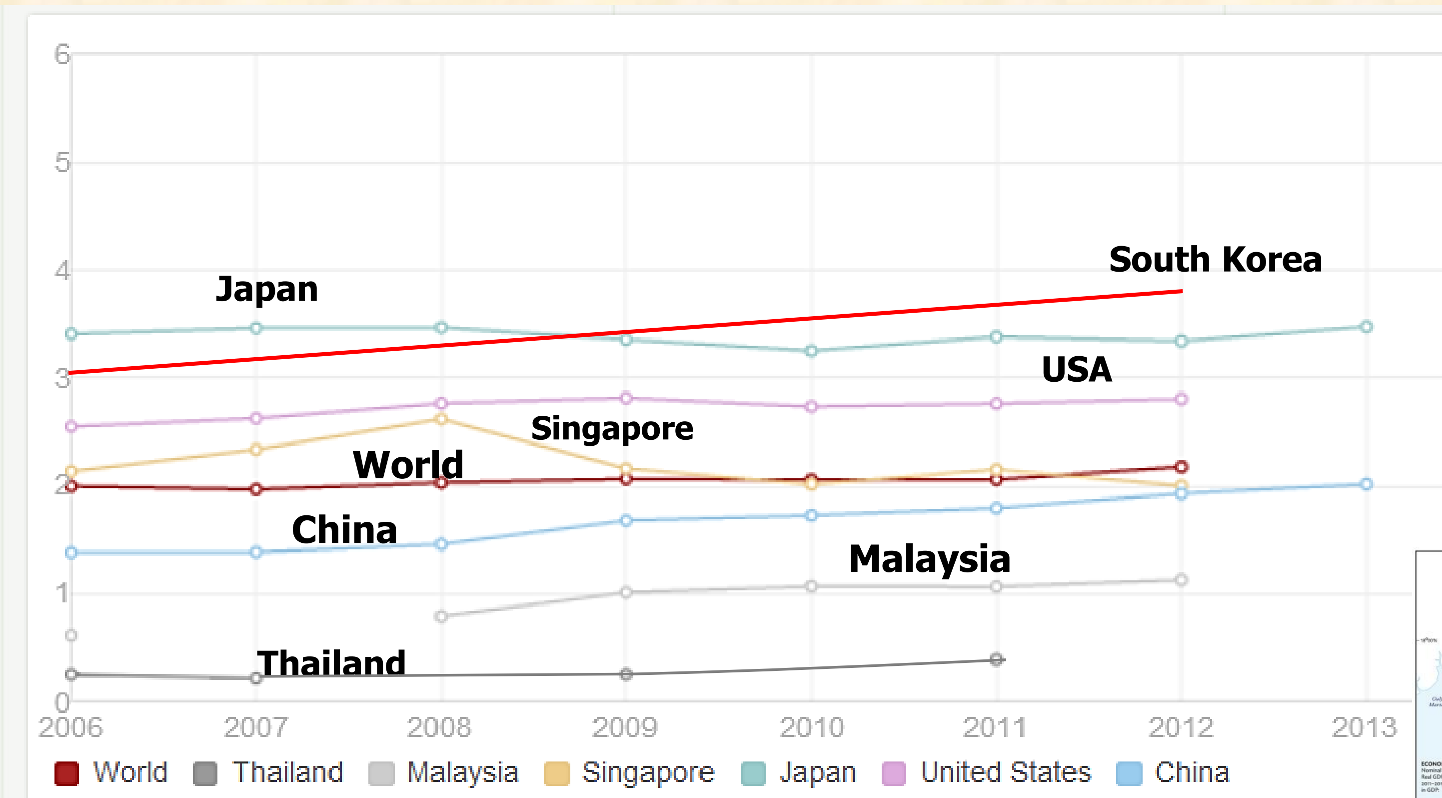
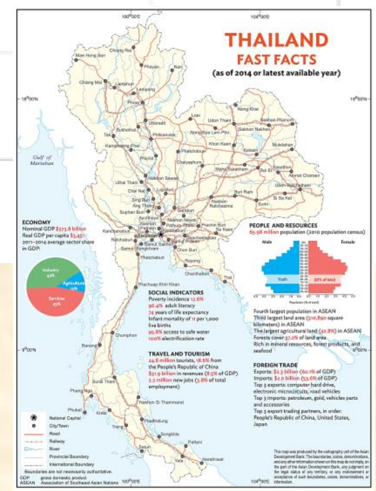
R&D Index

Widely used Indicators for measuring the level of R&D resource allocation in countries include the followings.

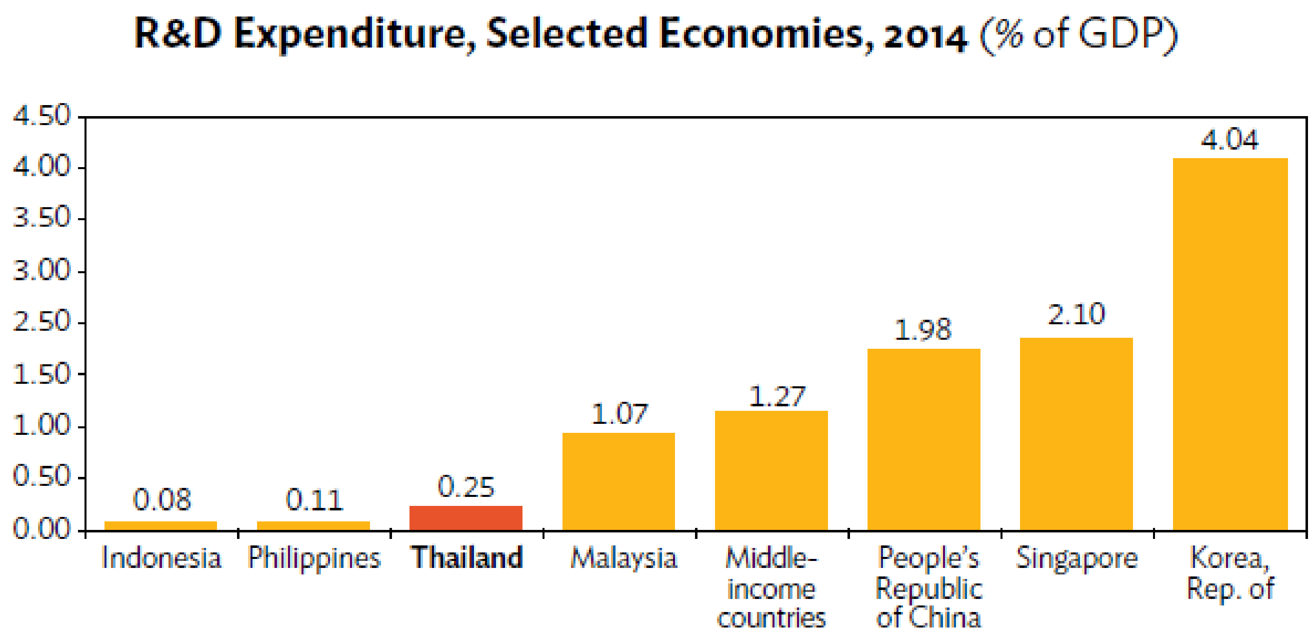
1. Gross domestic expenditure on R&D (GERD)
2. The Ratio of GERD to GDP





R&D Expenditure as % of GDP (2014)

Moving beyond the catch up industrialization requires substantial increases in R&D…



GDP = gross domestic product.
Note: Data for the Republic of Korea and middle-income countries are for 2011; data for the People's Republic of China and Singapore are for 2012.
Source: World Bank. World Development Indicators. http://data.worldbank.org/data-catalog/world-development-indicators (accessed September 2015).

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Types of R&D in Thailand

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- Although Thai firms conduct some basic R&D, the proportion that do is small
- The Outlay for Basic Research as a % of total R&D spending (18.63%) compares favorably with other countries (however, the overall amount of R&D is well below others in East Asia)
- The bulk of their R&D is geared towards Experimental Development and Applied Research (45.33 % and 35.04%, respectively)
- Universities are responsible for much of the Basic Research (85.43%), supplemented by the government sector (16.08%)
- Most R&D by Thai Universities consists of Applied Research

Table 3.2: Share of R&D spending by Sector and Types of R&D

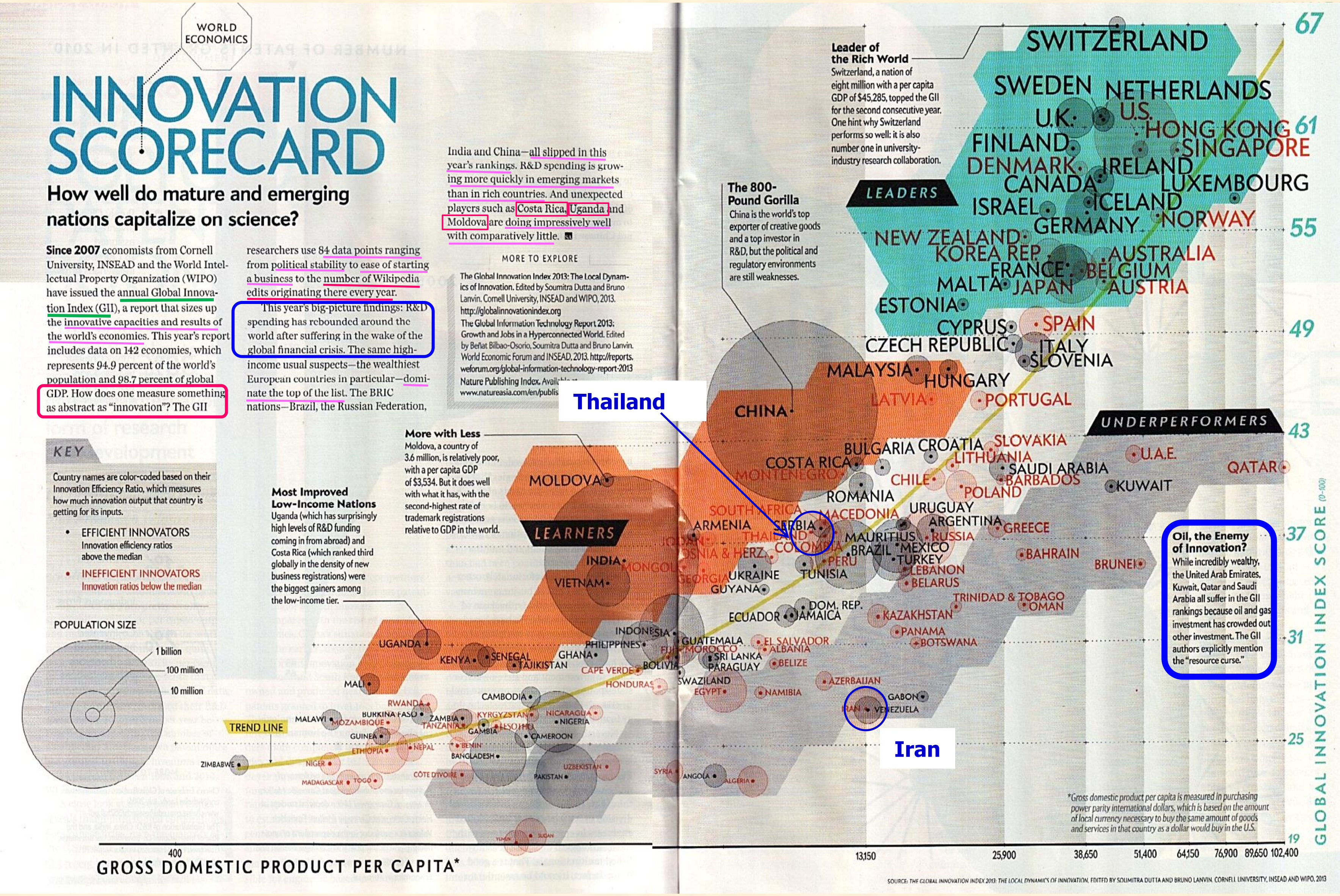
Sector of performance	Share (%)	Type of R&D: Basic research (%)	Applied research (%)	Experimental development (%)
Government	22.54	16.08	54.5	29.42
Higher ed. (Public)	30.06	35.35	51.22	13.42
Higher ed. (Private.)	0.94	50.08	40	9.92
Public enterprise	5.66	4.33	26.31	69.31
Private enterprise	38.24	9.28	37.7	53.02
Private non- profit	2.56	4.42	92.51	3.06
Total	100	18.63	45.33	35.04

Source: National Research Council of Thailand.

- Large firms in Thailand (i.e., subsidiaries of MNCs or domestic corporations), along with a small number of SMEs have the capability to do any significant R&D
- Since 1997, some Thai firms started nurturing in-house technological capabilities that have enhanced their innovativeness

Source: Yusuf, Wang, and Nabeshima (2005); "Ministry of Economic Affairs, Taiwan" 2006; "Ministry of Science and Technology, Korea" 2006; The International Institute for Sustainable Development 2004.

R&D Trends in the World



WORLD ECONOMICS

INNOVATION SCORECARD

How well do mature and emerging nations capitalize on science?

Since 2007 economists from Cornell University, INSEAD and the World Intellectual Property Organization (WIPO) have issued the annual Global Innovation Index (GII), a report that sizes up the innovative capacities and results of the world's economies. This year's report includes data on 142 economies, which represents 94.9 percent of the world's population and 98.7 percent of global GDP. How does one measure something as abstract as "innovation"? The GII researchers use 84 data points ranging from political stability to ease of starting a business to the number of Wikipedia edits originating there every year.

This year's big-picture findings: R&D spending has rebounded around the world after suffering in the wake of the global financial crisis. The same high-income usual suspects—the wealthiest European countries in particular—dominate the top of the list. The BRIC nations—Brazil, the Russian Federation, India and China—all slipped in this year's rankings. R&D spending is growing more quickly in emerging markets than in rich countries. And unexpected players such as Costa Rica, Uganda and Moldova are doing impressively well with comparatively little.

MORE TO EXPLORE

The Global Innovation Index 2013: The Local Dynamics of Innovation. Edited by Soumitra Dutta and Bruno Lanvin. Cornell University, INSEAD and WIPO, 2013. http://globalinnovationindex.org

The Global Information Technology Report 2013: Growth and Jobs in a Hyperconnected World. Edited by Beñat Bilbao-Osorio, Soumitra Dutta and Bruno Lanvin. World Economic Forum and INSEAD, 2013. http://reports.weforum.org/global-information-technology-report-2013

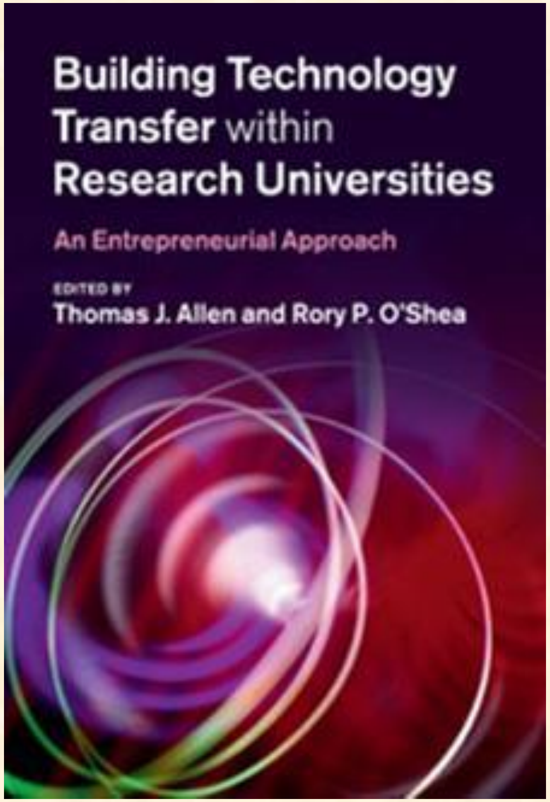
Nature Publishing Index. Available at www.natureasia.com/en/publis

Transferring University Technology

- Research at universities are critical to generating new knowledge, building new infrastructure, and educating innovators and entrepreneurs
- In US: The Land-Grant Acts of the 19th century and the G.I. Bill and government-university research partnerships of the 20th century showed how federal action can catalyze fundamental change

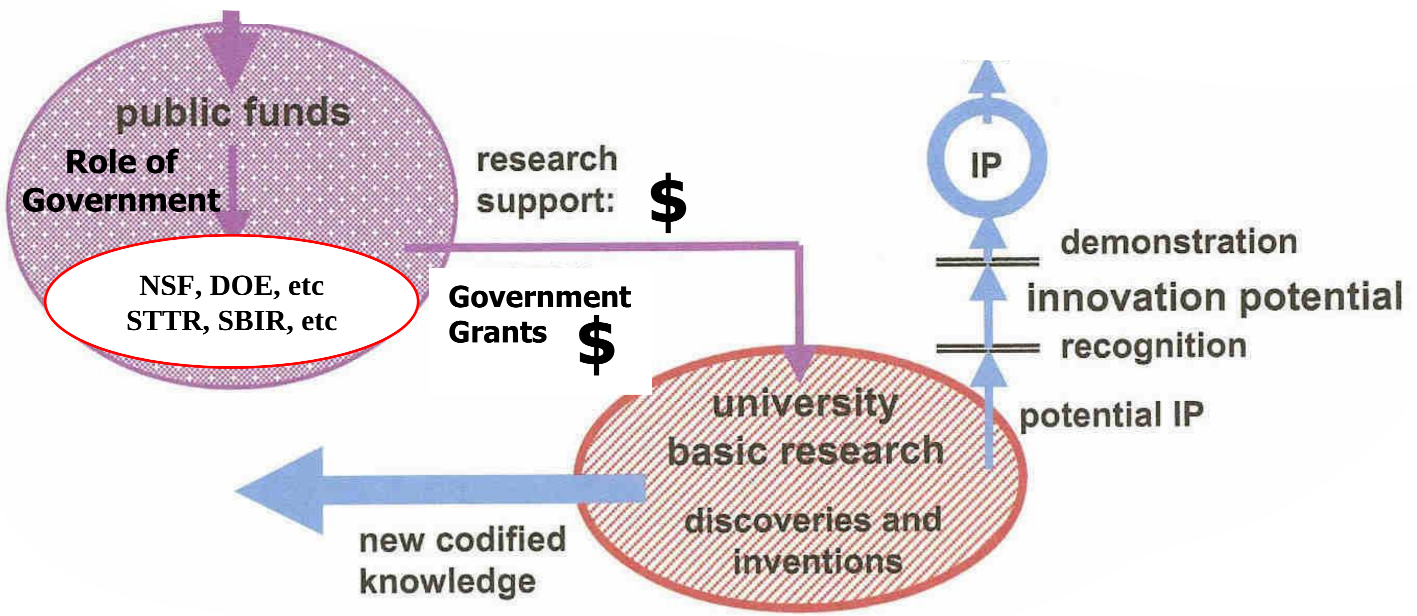
- In the past,
  - Universities dealt primarily with issues and problems that could be solved either by a disciplinary approach or by a multidisciplinary approach among science and engineering disciplines

- To meet future challenges, however,
  - Universities will need a new approach that includes schools of business, social sciences, law, and humanities, as well as schools of science, engineering, and medicine.
  - Solving the complex systems challenges ahead will require the efforts of all of these disciplines



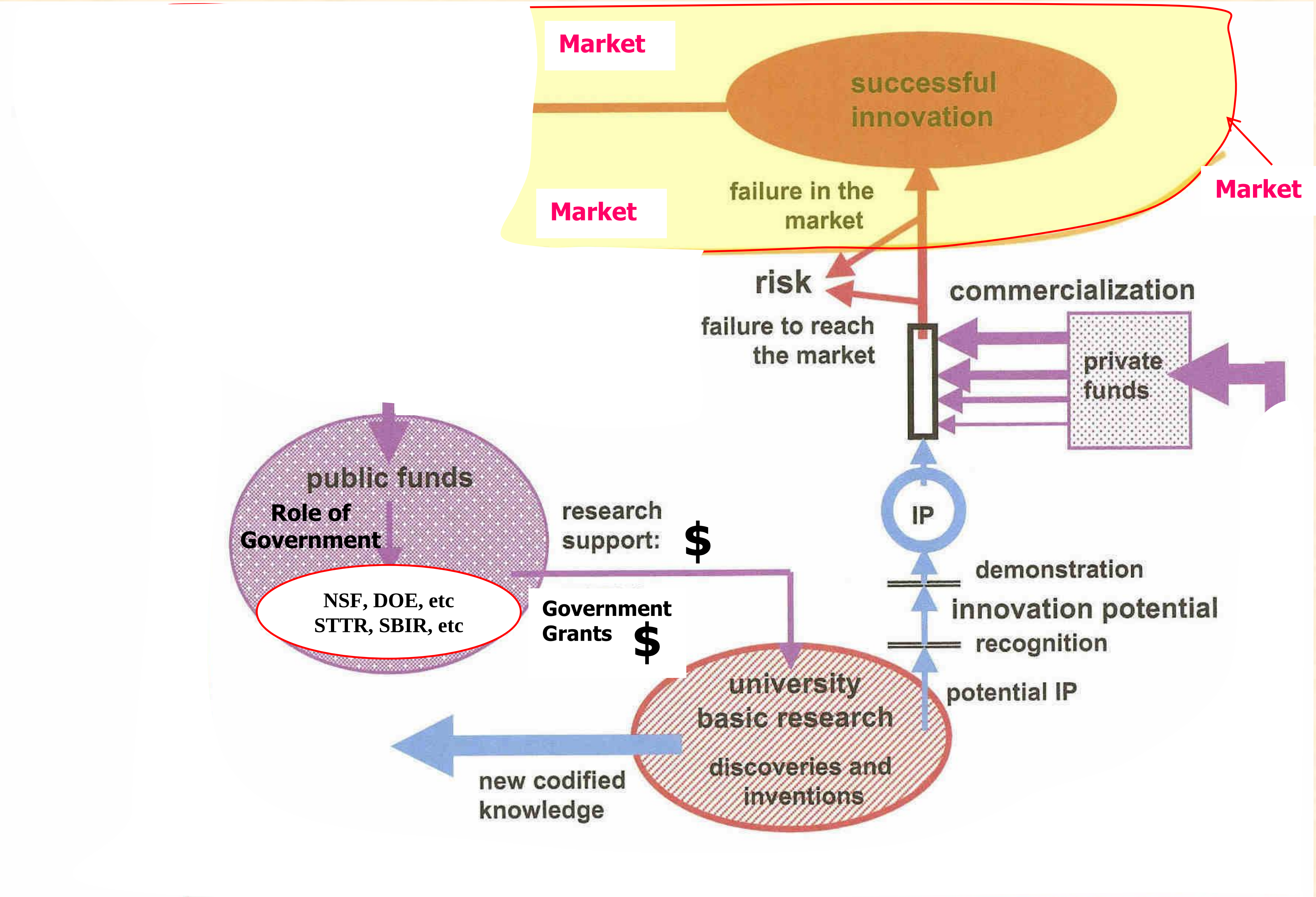
ENGINEERING RESEARCH AND AMERICA'S FUTURE 2005

Commercializing the Results of University Research



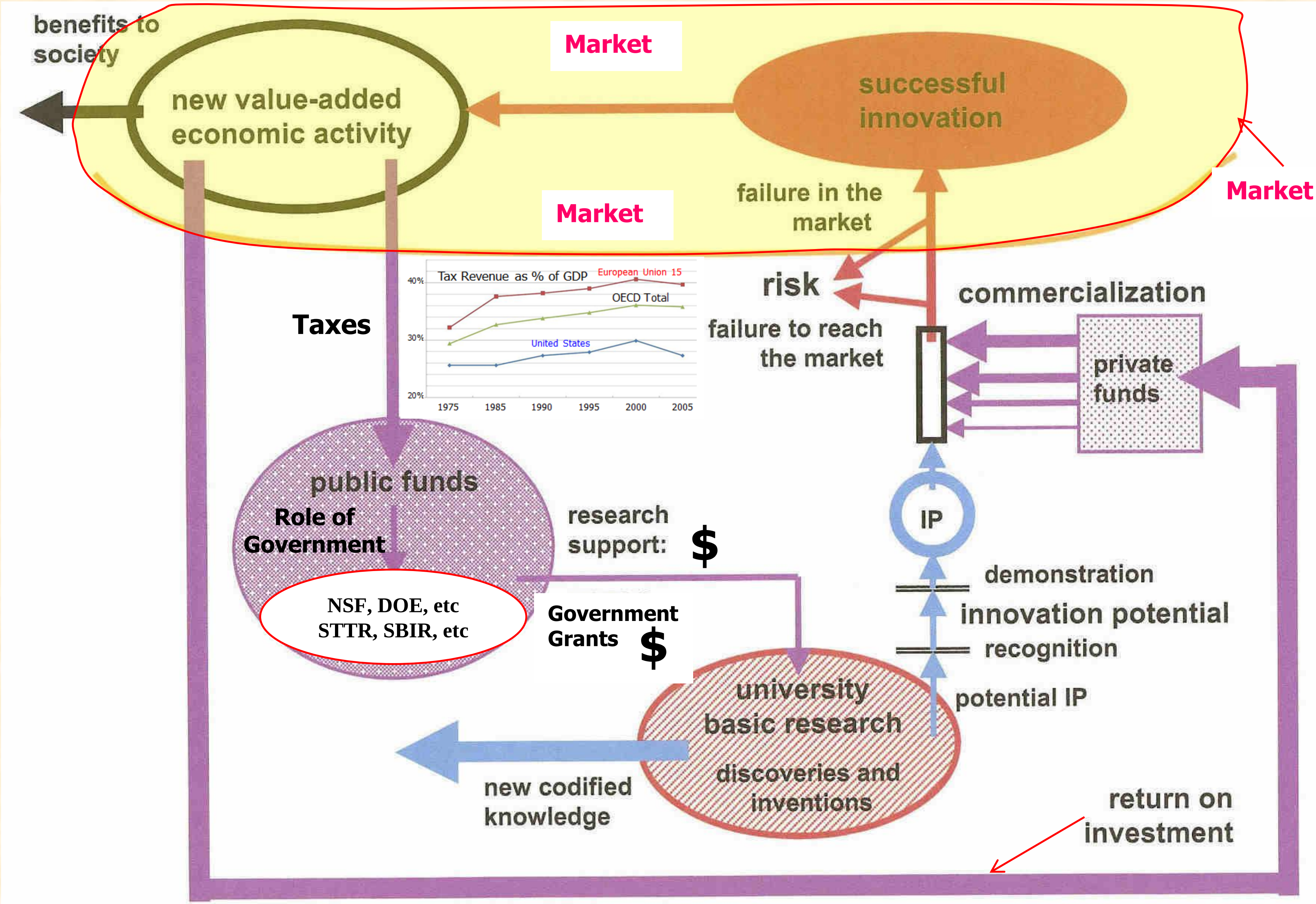
NSERC: National Science & Engineering Research Council

Commercializing the Results of University Research



NSERC: National Science & Engineering Research Council

Commercializing the Results of University Research



NSERC: National Science & Engineering Research Council

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Traditional and New Model of Technology Transfer and Product Development

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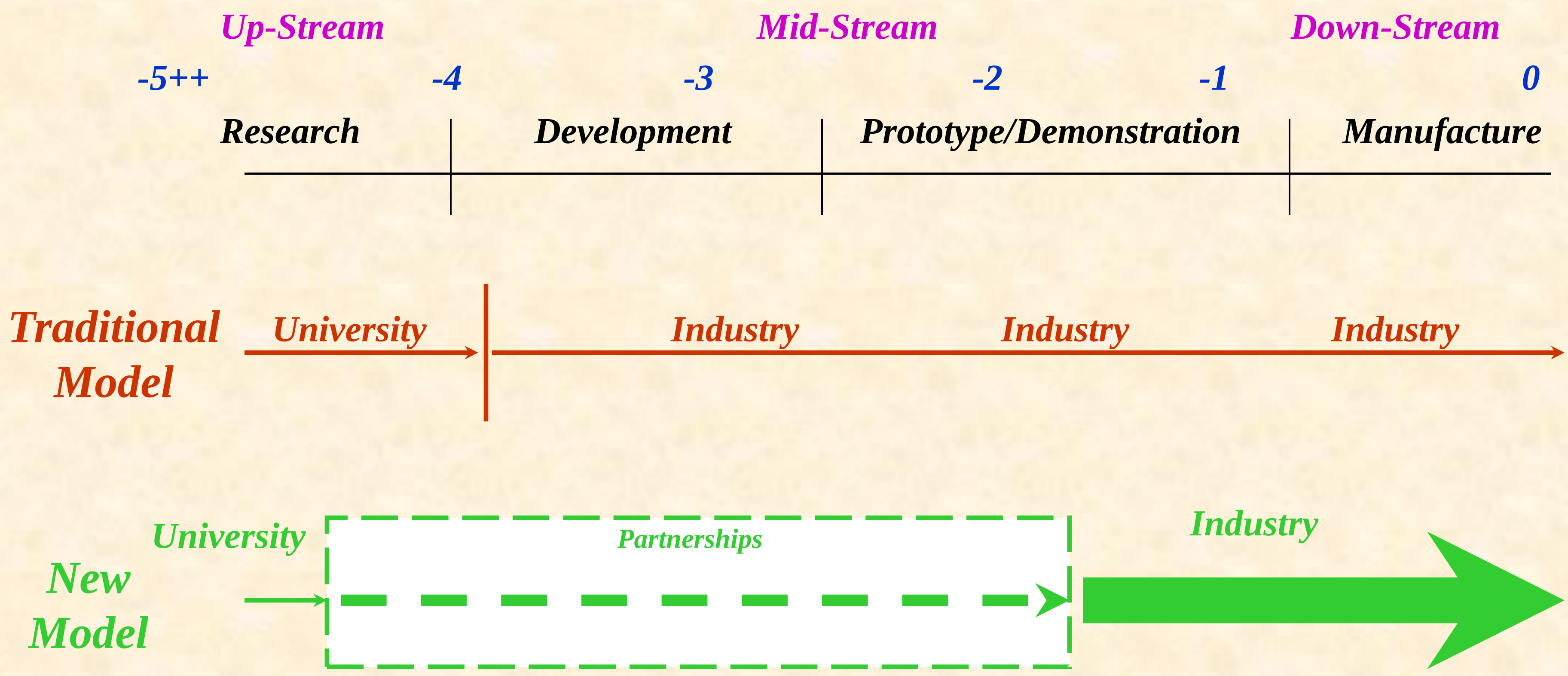

B. Chehroudi, PhD

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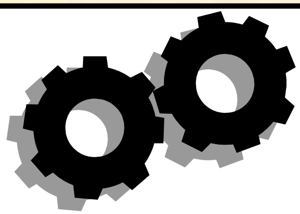
Vision of Partnerships with External Stakeholders

University Center

External Stakeholders (Industry/Practitioners/Others)



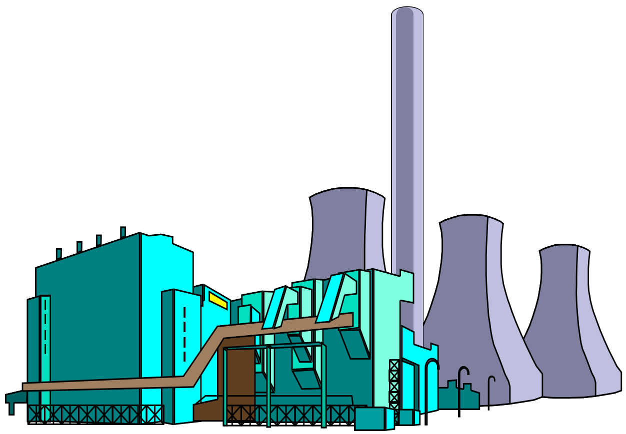
Technologies/Ideas

Human Resources

Collaboration

"Partnerships"

Transfer



Partnerships with external stakeholders:
A Key Component of the strategic objectives

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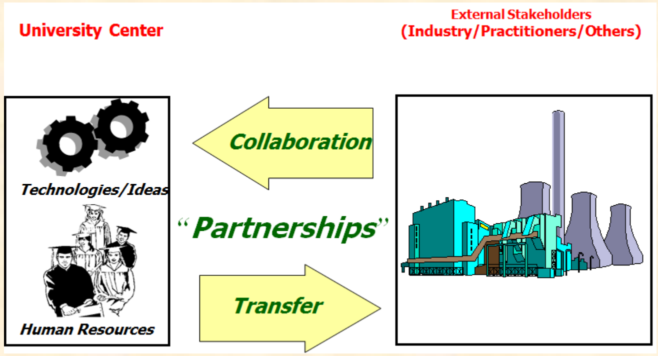
The Evolving University-Industry Relationship

- Traditional University Culture of inquiry is slower paced
  - University mission to educate and conduct basic research
- Industry Culture is faster paced with a problem-solving orientation

- Now Universities and Industry are establishing creative and entrepreneurial environments for
  - Problem-oriented research and the
  - Commercialization of University Intellectual Property
  - Universities & Industry are learning to work together
  - Flexibility is key; SBIR, STTR promote this Collaboration



Factors to Consider for University-Industry Collaboration

- **Negotiating agreements**
  - When a university-industry research relationship is of sufficient magnitude,
    - collaboration partners should consider negotiating master contracts.
    - Universities also should consider developing model agreements for single research projects and ensure that the terms do not unduly disadvantage small and medium-sized companies
  - Confidentiality agreements, when necessary, should be signed by the company, the university, and the researchers involved.
    - The company and the university must take responsibility for safeguarding confidential information. Publication delays to protect IP rights should generally be no longer than 60 to 90 days. Any publication delays should be carefully monitored both to preserve academic freedom and to protect against any early disclosure that might invalidate patent claims
  - Indirect costs are a legitimate expense of performing university research.
    - In most cases, companies should expect to pay at least the negotiated federal Facilities and Administrative charge for the research they sponsor in universities

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Factors to Consider for University-Industry Collaboration

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- **Negotiating agreements**
  - Although ownership and control of IP resulting from a collaboration must be decided by the collaboration partners it usually will be appropriate for the university to retain ownership.
    - Both parties should remain flexible during negotiations, and the key measure should be whether the corporate partner has the ability to commercialize the fruits of the research to the benefit of the public. Universities should update their copyright policies to allow industry sponsors to be granted licensing terms on a basis similar to that provided with parents
  - Collaboration partners should avoid engaging in contentious licensing negotiations during a collaboration negotiation, while preserving the ability of the university and its faculty to share in the benefits of successes.
    - Should the partners agree to preset a royalty rate or range, the university should be mindful of federal tax regulations governing commercialization terms of sponsored research that takes place in buildings or uses equipment funded by tax-exempt bonds.
  - Companies have the legitimate reasons for requesting background rights to sponsored projects and, as part of their due diligence, should assist universities in locating potential conflicts.
    - Universities have the legitimate rights, but they should make a strong effort to do so when appropriate and feasible. Universities should closely consult with faculty and confirm that all contractual obligations can be et before signing binding agreements.

Factors to Consider for University-Industry Collaboration

- **Best Practices for Universities**
  - Research collaborations must be based on the willingness and enthusiastic participation of individual faculty members.
    - A university can assist faculty in finding new collaboration partners, but should do so based on faculty interest, the research strengths of the university, and industry research opportunities. Hiring , tenure, and promotion processes should give appropriate credit to university researchers who collaborate with industry
  - Universities should coordinate the efforts of the various offices that support university researchers in their work with companies and, where appropriate, should consider co-locating them.
    - The university campus president should establish a cooperative tone toward university-industry research collaborations and should align incentives to encourage teamwork and promote research collaborations

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Factors to Consider for University-Industry Collaboration

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- **Best Practiced for Industry**
  - Companies should encourage internal champions of research collaborations to identify potential university partners based on shared research priorities.
    - To expedite this process, companies should make it as easy as possible for potential university partners to communicate with the company research organization, and should consider establishing a central coordinating unit for this purpose
  - Companies should strive to integrate university research collaboration into their product and service development process where appropriate.
    - They should involve their business units in this process, manage the collaborations appropriately, and plan for the turnover of key company personnel. Wherever possible, the company should involve students n the collaboration. The company should modify its personnel evaluation system as necessary to reward the establishment of internal and external interdisciplinary teams. To achieve results, company leaders must make a long-term commitments.

Conclusion

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- Future competitive advantage will be heavily based on R&D
- Impressive ROI for R&D if managed effectively
- Technology Readiness Level (TRL) a valuable tool for decision making
- Changes are taking place in the R&D landscape in the world
- Transferring technology at the university level and university-corporation partnership are the way to go
- Always consider "Best Practices" recommended
- **Advanced Technology Consultants offers consulting services relevant to University-Industry collaborations for R&D**

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Dr. B. Chehroudi

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Dr. Chehroudi, has accumulated years of technical and leadership experiences in different capacities and organizations. This includes such positions as a Principal Scientist and Group Leader appointment at the Air Force Research Laboratory (AFRL) ERCInc, a Chief Scientist at Raytheon STX, a Visiting Technologist at Ford's Advanced Manufacturing Technology Development (AMTD) center, a tenured Professor of Mechanical Engineering at Kettering University and University of Illinois, and served as a Senior Research Staff/Research Fellowship at Princeton University. Dr. Chehroudi directed numerous multimillion dollar interdisciplinary projects in areas involving chemically reacting flows, combustion and emission of pollutants, sustainable and alternative energy sources, distributed ignition, material/fuel injection, advanced pollution reduction technologies, propulsion concepts, gas turbine and liquid rocket engines, combustion instability, laser optical diagnostics, spectroscopy, supercritical fluids and applications in environmental and propulsion systems, advanced composites, MEMS, nanotechnology, and micro fluidics. He has won many merit and leadership awards by such prestigious organizations as the Society of Automotive Engineers (1. *Arch. T. Colwell Merit Award* for technical excellence only to top 1% yearly, 2. *Ralph R. Teetor Award* for outstanding teaching/research/leadership, 3. *Forest R. McFarland Award* for sustained leadership in professional and educational service and a key contributor to the Continuing Professional Development Group, 4. Appreciation Award for 10 years of dedicated and inspiring service and commitment to providing quality technical education, and 5. *Outstanding Faculty Advisor*), American Institute of Aeronautics and Astronautics (*Best Publication Award of the Year*), Air Force Research Laboratories (1. *Outstanding Technical Publication Award*, and 2. *STAR Team Award* for demonstrating world-class combined scientific and leadership achievements), Institute of Liquid Atomization and Sprays Systems (*Marshall Award* for best publication with lasting contributions), Liquid Propulsion Sub-committee of Joint Army-Navy-NASA-Air Force (JANNAF) (*Best Liquid Propulsion Paper Award* involving undergraduate/graduate students), and the 2nd International Symposium on Turbulence and Shear Flow Phenomena (*Top 10 Technical Publication Award*). He has been a consultant with many organizations such as, Ford, GM, Honda R&D, AFRL, Honeywell, NASA, AFOSR, VW, Bosch, Siemens, NGK, Cummins, and TRW. Through professional societies, Dr. Chehroudi delivers invited professional seminars on Management of R&D Teams and Organizations, Management of Innovation, Combustion and Emission of Pollutants in Automotive and Gas Turbine Engines, Ignition Issues, Gasoline Direct Injection engines, R&D on Homogeneously-Charged Compression Ignition (HCCI) engines, and Liquid Injection Technologies. He has a PhD in Mechanical & Aerospace Engineering and Post-Doctoral Fellow (Princeton University), MS in Mechanical Engineering (Southern Methodist University, *Summa Cum Laude*), MS in Economics (Swiss Finance Institute, *Magna Cum Laude*, and BS in Mechanical Engineering (Sharif University). He is a senior member of American Institute of Aeronautics and Astronautics *Propellant & Combustion Committee* (2008-present) and an *Associate Fellow* of American Institute of Aeronautics and Astronautics. Dr. Chehroudi acts as a reviewer for many scientific and engineering journals and publishers, has delivered over 200 presentations in technical meetings and to nontechnical audiences, over 20 technical reports (Princeton University, General Motors, Ford Motor Co, Department of Energy, NASA, Air Force Research Laboratory), five 600-plus-page monographs on combustion and emission of pollutants from mobile power plants, ignition technologies, liquid material injection, and nanotechnology, two book chapters on propulsion system combustion instability and applications of graphene (a nanotech product) in ignition and combustion of fuels, ground-breaking patents on applications and synergy between nanotechnology, light, and chemical reaction for a light-activated distributed ignition of fuel-air mixtures, and has more than 150 publications with extensive experience in both scientific and management areas and intensive trainings in finance and financial engineering.

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