OPTIMIZING INTERNATIONAL SCIENCE & TECHNOLOGY COLLABORATION THROUGH SCIENTOMETRIC STUDIES

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Acknowledgments

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Abstract

This dissertation seeks to understand the human component in the conduct of International Science and Technology (S&T) collaboration within a mission-oriented S&T enterprise. Innovation broken down to its core constituents is really about the creation, diffusion, absorption, and utilization of knowledge. An innovation system cohesively binds innovation's core constituents wherever these activities may occur. Improving the system requires a thorough understanding of these activities, where they occur within the system and how it functions as a whole. The actors within a mission-oriented S&T Enterprise conducting International Basic Science Collaboration include Program Managers (PM) who seek out science to fund, Primary Investigators (PI) found in academia or industry whose job is to conduct the research, and the bench scientists who reside in the enterprise who rely upon knowledge generated outside of the enterprise to further their efforts. How well the enterprise creates, diffuses, absorbs and utilizes knowledge is dependent upon complex human interactions, structured processes, personalities, and capabilities – all human endeavors and attributes. Literature already recognizes the need for the systematic study of the causes and determinants of activities within an innovation system which allows for the development of theories about the relations between the variables within the system. This dissertation adds to this body of knowledge by analyzing the activities of Program Managers funding basic science overseas who are part of a Military Service's Science & Technology Enterprise within the United States Department of Defense. Through macro-level analysis, it is understood that the strategic goals of the DoD for funding basic science overseas is to improve U.S. capabilities, accelerate the pace of U.S.

research and development, and leverage emerging global opportunities. An operational analysis of a Military Service's S&T Enterprise reveals that the enterprise operates as a competitive marketplace for new knowledge creation which is intended to meet the warfighter's requirements. This constant pressure for results has created a scientific and engineering ecosystem with foundational underpinnings dependent upon the creation, diffusion, absorption, and utilization of new knowledge. The operational analysis provided the context to the environment in which the PMs function and allowed for the creation of evaluation mechanisms to determine whether various engagement models were more effective in meeting the strategic goals. A micro-level analysis of a PM's actions and interactions in selecting knowledge to create, a bibliometric study of the generated knowledge, and an analysis of the diffusion mechanisms and impact on the enterprise were resultant from the nesting of strategic, operational and tactical level analyses. The studies showed that the engagement model does seem to have an impact on the selection of high-quality science as well as how efficiently knowledge diffuses within the enterprise. There was a statistical difference between the time devoted towards selecting projects to fund between the two engagement models. It is unclear, however, whether it is the only determinant in the selection of high-quality research. Finally, this study revealed that overseas program managers do not have any great insight into the selection of emerging research areas. By thoroughly analyzing the DoD's innovation system from the strategic down to program manager level activities, this dissertation revealed that it is possible to identify quantifiable mechanisms which allow those providing governance and management of international S&T investments the insight required so that they may achieve an optimal outcome.

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Chapter 1 - Introduction

1.1 International Science and Technology Engagement

The International Science and Technology (S&T) environment has changed dramatically in recent decades. "Today, the globalization of science and technology has profoundly impacted the global research landscape and the ways in which the international research community accesses, participates in the production of, and exchanges scientific knowledge" (National Research Council [NRC], 2014, p. 1). The motivation for participating in international S&T cooperation varies by individual, organization, and country. Scientists like to participate in international cooperative efforts to seek scarce funding, gain access to foreign labs, link directly with foreign partners, share information in real-time or enhance the creativity of research (RAND Science and Technology Policy Institute, 2002). Companies cooperate internationally to boost competitiveness by enhancing local customization, accessing markets, building networks, and participating in standardization efforts, as well as to leverage knowledge, capacity and the talent of their foreign collaborators (Nakamura & Nakamura, 2004; NRC, 2014). Nations use S&T cooperation in multi-faceted ways. For developing nations wanting to increase their technological capability, foreign direct investment, offset policies, and international S&T cooperation all are methods to enhance knowledge diffusion and technology spillover to increase economic capacity and productivity (Acharya & Keller, 2009; United Nations, 2010). Developed nations use it as a diplomatic tool to leverage the growing technological capabilities, research facilities and human capital outside their borders. Joseph Nye (1990) famously wrote about the changing face of power and coined the phrase soft or co-optive power, describing how one nation can achieve outcomes by getting other countries to want what it wants without the use of hard or military power. Science & Technology Cooperation is an ideal tool that diplomats, economists, and military strategists can shape and utilize to help achieve a country's desired end state when dealing in international matters.

> A nation's scientists and engineers can promote meritocracy, transparency, open data, sharing of scientific information and ideas, reproducibility of scientific results, critical thinking, diversity of thought, and respect for intellectual property… ST&I (Science, Technology & Innovation) will help strengthen the global innovation community, expand access to the Internet and communications technologies, create economic opportunities, reduce the risk of conflict and promote human rights. (National Science and Technology Council [NSTC], 2016, p. 7)

The United States is formulating a whole-of-society approach to strategic engagements in S&T collaboration. There are a vast number of international engagements conducted by U.S. government agencies and departments, private companies, academia, nongovernmental organizations, and other institutions which play a significant role in international activities that need coordinating to advance the overall interests and broad national goals of the United States. Diplomats look toward building relations and opening societies through the commonality of science. S&T builds trust and goodwill among nations (Sunami, Hamachi, & Kitaba, 2013). Economists target strategic areas for development by promoting either knowledge creation, diffusion or technology catch-up. Humanitarians promote research into environmental, health and quality of life issues while security strategists investigate defense S&T collaborations which can lead to increased capabilities of one's own or a target nation’s military forces. International S&T engagements alone will not unilaterally bring forth an outcome but when integrated and synchronized with other instruments of national power, they can with more forethought contribute tremendously to the end state goals. Implementing such a strategy requires a thorough analysis and studies in understanding the S&T landscape of the various nations targeted for engagement. Strategists need foresight assessments to focus on where S&T engagements will have the most significant benefit to a nation’s interests (Department of State [DOS], 2015). Applying the appropriate vehicles or tools to facilitate cooperation is another consideration. The Institute for Defense Analysis (2011) categorizes the United States Government’s science and technology efforts as falling into one of the following four themes:

Collaborative R&D and Research Training occurs when U.S. and international scientists, students, and technicians jointly participate directly in the research or training. Examples include training foreign scientists in the United States, funding local research or activities which build capacity and funding U.S. researchers to conduct research in other countries with foreign investigators.

S&T Capital Spending is the allocation of funds destined for S&T facilities outside the United States. Examples include support for scientific collections/databases accessible by international entities, funding of U.S. government S&T and R&D related facilities in foreign nations, funding sensor networks which warn of impending tsunamis or earthquakes, and the operations of the Naval Medical Research Units.

S&T Development Funds directly assist foreign countries in the construction, operation, and maintenance of technology-based infrastructure out of the U.S. to include power plants, hospitals, water treatment facilities, and other science-based services.

S&T in Overseas Program Operations does not explicitly involve scientists, technicians or students but is necessary for the promotion, facilitation or negotiation of S&T activities.

In addition to having an understanding of the S&T landscape of potential foreign partners, nations need to fully understand their own internal capabilities and inherent strengths and weaknesses in science and technology. Therefore it is imperative that the selection of the correct tools or instruments of engagement align the science and technology realities of a nation with the desired end state goals of the strategy (Carnegie Commission, 1992; European Commission [EC], 2009). Strategies typically attempt to shape the current environment to create strategic effects which will bring favorable outcomes toward realizing the desired end state. A strategy first captures and documents an understanding of the environment. Furthermore, it articulates the desired end state (ends), the approach needed to achieve the desired end state (ways), and the resources needed to execute the approach (means) (Army War College, 2015). Those managing and creating a country's international S&T strategy create the linkages (Figure 1-1) between the desired outcomes and the S&T community's efforts to fully and effectively leverage the power brought forth by science and technology engagements. The strategy takes national objectives and overlays S&T landscape considerations in conjunction with a selection of tools and methodologies to develop a plan to meet and assess the desired end state. In other words, planners must analyze and answer the following Engagement Questions:

1. What does the nation hope to achieve with S&T Engagements (ends)?
2. How will S&T Engagements support attaining the desired end state (ways)?
3. Which Agencies or Departments should engage and what tools or mechanisms are most appropriate (means)?

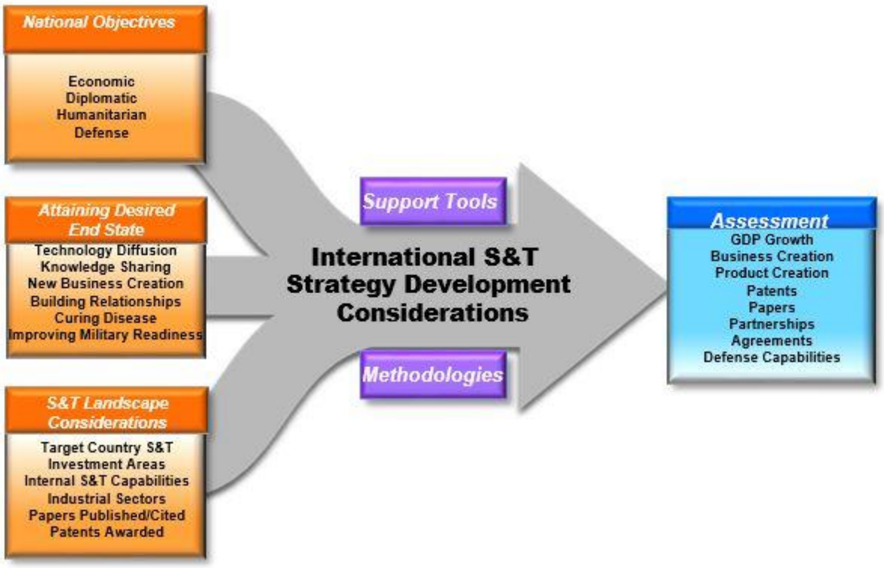


Figure 1-1. Strategy Development – Creating Linkages

1.2 The Department of Defense's (DoD) International S&T Engagement Strategy

The Department of Defense's International S&T Engagement Strategy addresses the ends, ways, and means through its vision, mission statement, technology objectives, and guiding principles. The proponents envision:

> Coordinated DoD global S&T engagement to enhance interoperability, relationship building and collaboration with partner nations, accelerate the pace of U.S. research and development, leverage emerging global opportunities, improve U.S. capabilities and those of our partner nations,

> mitigate the risk of global threats, and gain economic efficiencies. (Shaffer & Webster, 2014, p. 1)

The DoD strategy calls for the creation of a baseline of global S&T concepts that consists of existing and emerging technologies and capabilities. It will compare this baseline to existing engagements conducted by the DoD Component Activities (the Military Services: Department of the Army, Department of the Navy, and Department of the Air Force) to identify gaps and develop plans to address those which are a priority. The strategy further delineates the roles and responsibilities between the DoD and the Military Services. The DoD concentrates on providing strategic guidance, S&T landscape development, coordination between the Services for cross-cutting research and providing the information technology (IT) infrastructure for capturing these activities across the Department. The majority of these activities fall under the auspices of the Under Secretary of Defense for

Acquisition, Technology & Logistics/International Cooperation and the Assistant Secretary of Defense for Research & Engineering. The Services identify their priority areas, create engagement strategies, conduct outreach activities, identify the collaboration mechanisms (data exchange agreements, project agreements, exchange engineers, basic science investments), execute the collaborations and populate the DoD database (Figure 1-2). These activities are done through the Military Service's international program offices, and the international S&T offices found worldwide (Shaffer & Webster, 2014).

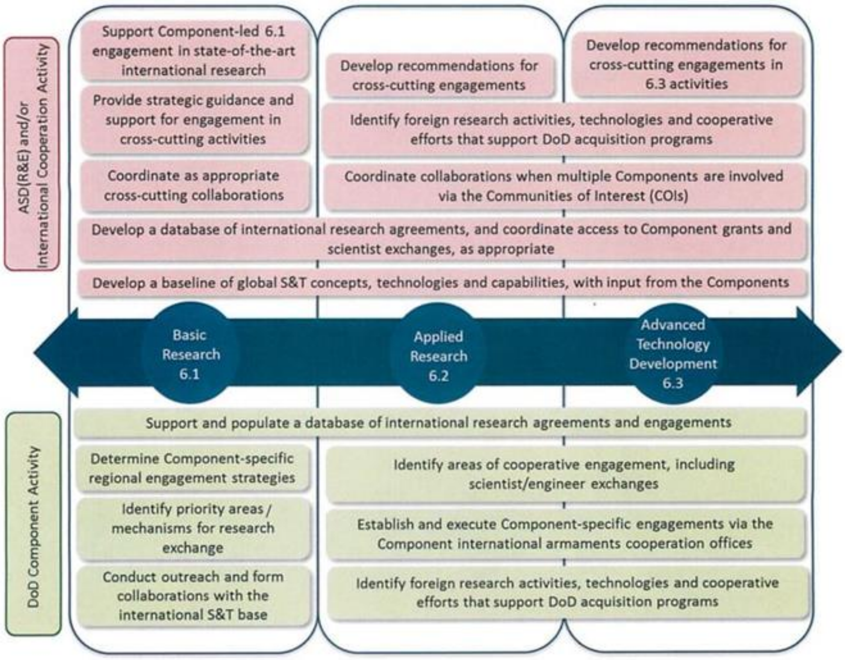


Figure 1-2. DoD's International S&T Engagement Strategy (Shaffer & Webster, 2014, p. 2)

1.3 The Military Service's International S&T Offices

Each Military Service at the Headquarters level has a lead for international engagements which oversees all Security Assistance and Armaments Cooperation programs. The individual mission statements of these organizations reflect a commonality to build relationships, engage U.S. allies and partners to advance partner capabilities and achieve U.S. national security objectives (Department of the United States Army [DA], 2017; Department of the United States Air Force [DAF], 2017; Department of the United States Navy [DON], 2017). The Department of the Navy's International Programs Office (NIPO) manages and implements the Navy's international efforts while the actual international S&T field offices fall under the Office of Naval Research – Global, a subordinate to the Chief of Naval Research. The Navy maintains an overseas presence in London, United Kingdom; Tokyo, Japan; Singapore; Santiago, Chile; and Prague, Czechoslovakia. The U.S. Air Force's International S&T engagements are directed by the Office of the Secretary of the Air Force for International Affairs (SAF/AI), with the field offices falling under the Air Force Office of Scientific Research/International (AFOSR/I). AFOSR is subordinate to the Air Force Research Laboratory and has three detachments worldwide. They are in Tokyo, Japan (Asian Office of Aerospace Research and Development, or AOARD); Santiago, Chile (Southern Office of Aerospace Research and Development, or SOARD); and London, United Kingdom (European Office of Aerospace Research and Development, or EOARD). The U.S. Army's proponent for international cooperation is the Office of the Deputy Assistant Secretary of the Army for Defense Exports and Cooperation (DASA(DE&C)). The international S&T field offices are called the International Technology Centers. The Army has offices in London, United Kingdom; Frankfurt, Germany; Paris, France; Santiago, Chile; Ottawa, Canada; Tokyo, Japan; Singapore; Canberra, Australia; and New Delhi, India. They are subordinate to the U.S. Army Research, Development & Engineering Command (NRC, 2014). Within these offices are scientists and engineers that execute the DoD vision and their Service's International

S&T Engagement Strategies. The Services nest the International S&T Cooperation mission within each of their overall S&T strategies that support the approximately 150,000 (National Academy of Engineering, 2012) scientists and engineers dispersed throughout the Army, Navy, Air Force and other DoD S&T Agencies. Each Service has its own S&T Enterprise or infrastructure which conducts basic and applied research as well as engineering and prototyping. These are mission-oriented enterprises, and their internal efforts feed into the development of new weapons systems and capabilities for the specific Service. Evaluating how the international S&T office supports the mission of its Service's S&T enterprise is the basis for this dissertation. More specifically, referring back to the DoD's vision statement, how do international S&T engagements accelerate the pace of research and development and how do they enable the DoD to leverage emerging global opportunities?

1.4 Objective and Scope of the Study

The Military Service's international S&T field offices are different in many ways. The Air Force Offices purely look to fund basic science. The Navy Offices fund basic science as well as provide science advisor support to the fleet to allow for a mechanism in which current needs flow back to the Naval Research Enterprise. The Army has the most encompassing mission, in which the International Technology Centers seek out technology from the basic sciences through fully productized items, facilitate government to government interactions between U.S. Army and friendly nations' Defense Laboratories, and provide science advisor support to the Army forces in their region (NRC, 2014). The commonality that they do have is that they all fund basic science overseas. This study will investigate the mechanisms utilized to select basic science for funding in order to determine whether there is an optimal methodology which has the most significant impact on a mission-oriented S&T enterprise. Funding research outside of the enterprise accelerates the pace of U.S. research and development if the knowledge that the researchers generate diffuses back to the enterprise for utilization. Although the DoD S&T Enterprise is very large by most standards, it cannot research all approaches in all fields. The selection mechanisms utilized, as well as the diffusion mechanisms, thus play an essential role in knowledge flowing back to the Enterprise. Numerous studies have looked at the functions and activities within an innovation system. Endquist (2005) contends that a systematic study of the causes and determinants of the activities within an innovation system will allow for the development of theories about the relations between the variables within the approach. He identified ten activities he deemed necessary in studying the system:

1. Provision of Research and Development (R&D), creating new knowledge, primarily in engineering, medicine, and the natural sciences.
2. Competence building (provision of education and training, the creation of human capital, production and reproduction of skills, individual learning) in the labor force to be used in innovation and R&D activities.
3. Formation of new product markets.
4. Articulation of quality requirements emanating from the demand side with regard to new products.
5. Creating and changing organizations needed for the development of new fields of innovation, e.g., enhancing entrepreneurship to create new firms and intrapreneurship to diversify existing firms, creating new research organizations, policy agencies, etc.

> 6. Networking through markets and other mechanisms, including interactive learning between different organizations (potentially) involved in the innovation processes. This implies integrating new knowledge elements developed in different spheres of the SI and coming from outside with elements already available in the innovating firms.
>
> 7. Creating and changing institutions—e.g., IPR laws, tax laws, environment and safety regulations, R&D investment routines, etc.—that influence innovating organizations and innovation processes by providing incentives or obstacles to innovation.
>
> 8. Incubating activities, e.g., providing access to facilities, administrative support, etc., for new innovative efforts.
>
> 9. Financing of innovation processes and other activities that can facilitate commercialization of knowledge and its adoption.
>
> 10. Provision of consultancy services of relevance for innovation processes, e.g., technology transfer, commercial information, and legal advice. (pp. 190-191)

This study examines a subset of these activities which specifically focuses on: (1) the creation of new knowledge; (6) the incorporation of knowledge from outside elements; and (9) financing of innovation processes. Differing slightly from a detailed analysis of the machanizations of organizations and institutions, innovation inherently broken down to its core constituents is a process which encompasses the creation, diffusion, absorption, and utilization of knowledge (Eckl, 2012). An innovation system cohesively binds innovation's core constituents wherever these activities may occur. Improving the system requires a thorough understanding of these activities, where they occur within the system and how it functions as a whole. The actors within a mission-oriented S&T Enterprise conducting International Basic Science Collaboration include Program Managers (PM) who seek out science to fund, Primary Investigators (PI) found in academia or industry whose job is to conduct the research, and the bench scientists who reside in the enterprise who rely upon knowledge generated outside of the enterprise to further their efforts. How well the enterprise creates, diffuses, absorbs and utilizes knowledge is dependent upon complex human interactions, structured processes, personalities, and capabilities – all human endeavors and attributes. This dissertation is an investigation of whether there is an optimal international engagement model for selecting basic science overseas within a mission-oriented S&T Enterprise and whether there exist suitable mechanisms to evaluate what the Enterprise funds, focusing on the published International S&T Strategy's end state goals of accelerating the pace of research and development by leveraging emerging global opportunities.

1.5 Overview and Structure

This paper takes three distinct concepts—international S&T engagements in the context of a mission-oriented S&T enterprise; knowledge creation, diffusion, and absorption; scientific and mission impact—and conflates them through analysis and study to determine whether there is an optimal methodology in conducting international S&T collaboration within the basic sciences. In order to put into context the intent of conducting mission-oriented international S&T collaborations, one must have an understanding of the mission-oriented S&T enterprise and the fundamental processes it utilizes in the pursuit of advancing its science and technology efforts. Chapter 2 provides the basis for understanding how a Military Service within the United States Department of Defense's S&T Enterprise interacts with academia and industry in its pursuit of furthering the technological capability of that particular Military Service. By breaking down the enterprise into discrete components and studying the mechanisms of interaction between the enterprise and outside entities, it might be possible to understand the underpinnings in whole and characterize the nature or the intent behind these interactions. This characterization provides the organizational setting for the research portion of this dissertation, which primarily studies the funding of overseas basic science by the enterprise's international offices. Chapter 3 reviews literature on the quantification of international S&T engagements and provides the foundational basis from which the research portion will draw to examine the effectiveness of funding basic science overseas in the context of a mission-oriented S&T Enterprise. Chapter 4 examines the effectiveness of the program managers found in the international S&T offices and attempts to determine whether they are fulfilling the DoD International S&T Strategy objective of accelerating the pace of research and development through leveraging of emerging global opportunities which produce high impact science. Program Managers are those individuals charged with seeking out, selecting and funding science in foreign universities. This chapter will examine two differing international S&T engagement models (subject matter expert model & shared equity model) through a bibliometric study to determine whether there are differences in results between the two models. Additionally, it will produce quantifiable metrics that organizational chiefs can utilize as an indicator for use as a determinant of performance and effectiveness for programs and program managers within their organizations. Chapter 5 attempts to study, through a qualitative survey, the activities of the program managers stateside and internationally in order to identify whether there are significant differences between stateside program managers and international program managers. It will analyze whether there are any differences in professional qualifications or activities which may explain different levels of success in their selection of science. Chapter 6 studies, through a quantitative survey, the utility of the investments made by the international program managers on the efforts of the scientists within the mission-oriented S&T Enterprise. This chapter will also examine the effectiveness of the two international S&T engagement models (subject matter expert model & shared equity model) to determine whether one model is more effective in knowledge diffusion, absorption, and utilization than the other. It will also study whether the level of co-funding of science at its origins has any impact on the incorporation of the knowledge generated by the international research into some ongoing effort within the enterprise. Chapter 7 is an overview and conclusion of the whole study, identifying the policy implications and the theoretical contribution made to research and science.

Chapter 2 - A Mission-Oriented S&T Enterprise

2.1 Background

Toward the conclusion of World War II Vannevar Bush in his seminal report to the President, “Science - the Endless Frontier,” called for the establishment of a permanent independent, civilian-controlled organization that was to have a close liaison with the Army and Navy. Congress would fund it directly, and it would have the clear power to initiate military research that supplemented and strengthened research carried on directly under the control of the Army and Navy (Office of Scientific Research and Development, 1945). What evolved wasn’t independent but an expansion of the Service’s Science and Technology Enterprises. Where Bush called for a national level agency to coordinate national research efforts, what evolved was strong public sector actors (nuclear power, defense, space, and health) that created stovepipes in research and development activities (Lundvall & Borras, 2005; Mowery, 2009). Mission-oriented research would become a prominent policy tool in modern America’s science and technology evolution, which continues to be the case to this day. The current U.S. Administration lists as its first R&D Budget Priority the “Security of the American People” and “calls for leadership in research, technology, and invention to ensure we will be able to fight and win the wars of the future” (Executive Office of the President, 2018, p. 2). In 2018 the Department of Defense would receive ~$16 billion U.S. dollars for basic research, applied research, advanced technology development, and medical research, with an overall research and development budget of ~$93 billion U.S dollars, by far the largest allocation to a Government Department. The Department of Health and Human Services is second receiving $37 billion U.S. dollars (American Association for the Advancement of Science, 2018; Consolidated Appropriations Act 2018, 2018).

Although the DoD S&T Enterprise is mission-oriented, when carefully analyzed and examined the structures and processes which make up the Enterprise are very much knowledge diffusion-oriented. Whether this was by grand design, natural evolution or due to the focusing efforts by the doctrine community, the structural breakdown of research and technology within the Enterprise along with the numerous programs and opportunities to interact with academia and industry highlights the multidimensionality (Figure 2-1) of how knowledge is created, diffused and absorbed within the S&T Enterprise. In each Military Service the names of the organizations, of course, are different, but the structure and functions across each of their S&T Enterprises are similar. Each Service has an organization which oversees the generation and development of warfighting concepts. It is these doctrine organizations which drive the efforts of the S&T Enterprise across all levels of research, ranging from basic research through system development, by creating the warfighting doctrine and force architecture needed to execute the nation's national security strategy for the current, mid and future fight. For the Department of the Navy (2018), it is the Naval Warfare Development Command. For the Department of the Army (2018), it is the Training and Doctrine Command, and for the Department of the Air Force (2018), it is the Curtis E. LeMay Center for Doctrine Development and Education. These organizations provide the forcing function toward action and are the proponents on behalf of the warfighters to hold the S&T Enterprises accountable for their activities.

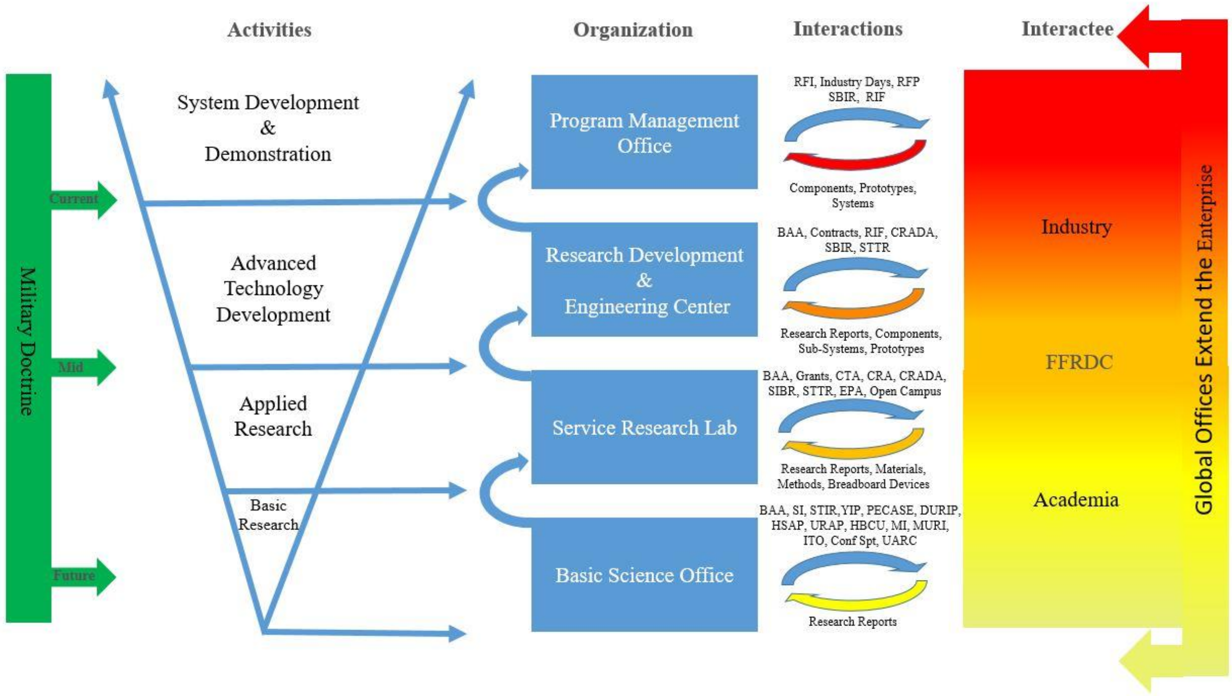


Figure 2-1. Military Service S&T Enterprise Interactions with Outside Activities

2.2 Basic Research

The needs of future military operations impact the early stages of research in the S&T Enterprise. The future force is considered 20-25 years out and the realization of a force with the envisioned capabilities requires early investments in the basic sciences to help provide the foundational knowledge currently lacking or not understood but required to achieve the vision (U.S. Army War College, 2016). The DoD's long-term basic research program funds a wide variety of scientific and engineering fields with "a goal of exploiting new knowledge to enhance – and, where possible, transform – future capabilities" (Defense Science Board [DSB], 2012, p. vii). The DoD considers basic research to be:

> a systematic study directed toward greater knowledge or understanding of the fundamental aspects of phenomena and observable facts without specific

> applications toward processes or products in mind. It includes all scientific study and experimentation directed toward increasing fundamental knowledge and understanding in those fields of the physical, engineering, environmental, and life sciences related to long-term national security needs. It is farsighted high payoff research that provides the basis for technological progress. (Department of Defense [DoD], 2010, pp. 5-4)

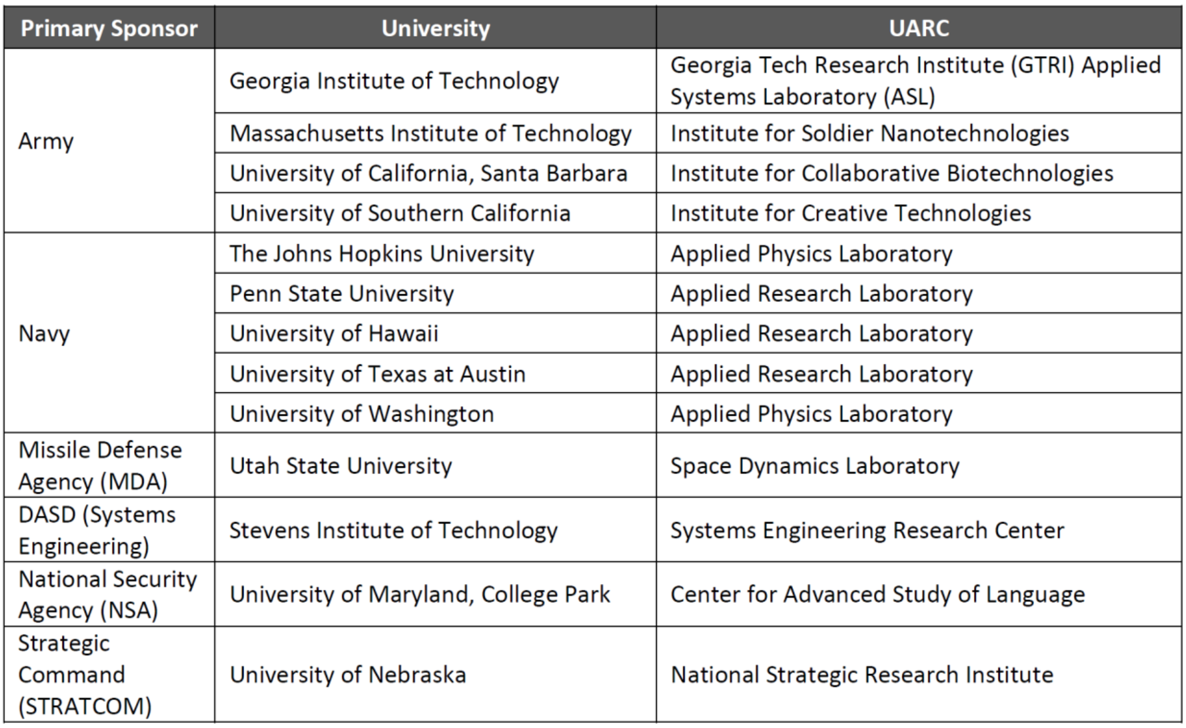
The DoD funds basic science to leverage the very best of intellectual capability found in the world's universities and to conceive of and exploit scientific opportunities which will deliver unimagined capability to the Military Services. The basic science offices steer science toward areas which will solve existing technological needs. Military needs help accelerate the transition of basic research through the creation and strengthening of university, industry, and government partnerships which present opportunities for exploitation. Basic science programs within defense managed by basic science experts familiar with the military mission help prevent technological surprise from adversaries while educating and training the next generation of scientists and engineers to join the DoD's workforce (Army Research Office [ARO], 2017). History has shown that the technological capabilities of one's adversaries are a constant key pressure that does not remain stagnant. As Parker (1998) details in "The Military Revolution" the introduction of technological innovation that supported the development of the capital ship, increased infantry firepower, and artillery fortresses propelled Europe into a position of global dominance, starting its ascent during the sixteenth century, although it was resource inferior to many other parts of the world. Lacking cognizance of potential military capabilities brought forth by breakthroughs in research and development leaves a nation vulnerable. Japan found itself unable to react to gunboat diplomacy during the 19th Century, which was a source of national humiliation. Breakthroughs in steam-powered engines and advances in metallurgy and armaments earlier in the Century went unnoticed while Japan was relatively isolated. Sakuma Shozan, famous for his slogan “Eastern Morality, Western Science,” recognized the insufficiency of Japanese learning and understood the need not just for technology but to understand the arts and sciences which form the basis of technology (The Cambridge History of China, 1980).

There are a variety of mechanisms that the basic research offices utilize to engage with academia. All basic science offices publish a Broad Agency Announcement (BAA) to solicit research proposals for the funding opportunities available for basic science research. Single Investigator (SI) grants are for research in physical, engineering and information sciences targeting single laboratories and topics with an average funding level of $135K U.S. dollars per year for up to three years. Short Term Innovative Research (STIR) grants support very high-risk proposals to assess the merit of innovative concepts. The average award is for $60K U.S. dollars for nine months or under and often, if successful, shapes the direction of research or helps create new research thrusts in that field. Young Investigator Program (YIP) grants target outstanding young researchers with less than five years since obtaining their Ph.D. The objective is to guide them toward pursuing fundamental research which is of interest to the DoD. Grants are generally for three years and funded at $120K U.S. dollars per year. For particularly outstanding young researchers who show leadership in their field, basic science program managers may nominate them to compete for the Presidential Early Career Award for Scientists and Engineers (PECASE). Young researchers bestowed with this prestigious award receive a grant of up to $200K U.S. dollars per year for up to five years. A Defense University

Research Instrumentation Program (DURIP) grant provides funds to acquire laboratory equipment or instrumentation which will improve the capabilities of U.S. Research Institutions of higher education. They are used to either provide for new research capabilities, contribute to research currently proposed or enhance the quality of research currently funded. Grants are one-time awards for up to $200K U.S. dollars. Conference grants support the bringing together of experts in fields critical to national defense where they discuss their research findings and expose others to new research methodologies and educational techniques. The High School Apprenticeship Program (HSAP) and the Undergraduate Research Apprenticeship Program (URAP) are both intended to expose high school and undergraduate students to authentic research opportunities which support national defense. Participants earn an hourly wage. This is add-on funding for a grant already selected and funded through one of the other mechanisms. Historically Black Colleges and Minority Serving Institution (HBCU/MI) grants advocate for and support predominantly minority attended institutions of higher learning to ensure funding opportunities and to encourage participation by minorities in the sciences (ARO, 2017). Multidisciplinary University Research Initiative (MURI) grants require a proposal encompassing two or more scientific disciplines targeting a single collaborative research topic. Collaborators can be in the same or different universities. MURIs are large grants for approximately $1.3M U.S. dollars per year for three years, extendable to five (Institute for Defense Analysis [IDA], 2014). Invitational Travel Orders (ITO) for individuals doing preeminent research in their field provides travel funding so that they can give seminars and participate in conferences or workshops that facilitate the interaction with the Military Service's scientists and engineers to allow for the exploration of cooperation opportunities. It is through these face-to-face encounters that potential research projects are discussed, refined and finalized. This permits the S&T Enterprise to capitalize on that particular researcher's interest while focusing it toward resolving some technology objective. Finally, University Affiliated Research Center (UARC) contracts are awarded to college and university research institutions to maintain and carry out long-term essential research, development and engineering activities beneficial to the DoD. The DoD considers UARCs as strategic partners, and they must be set up to operate in the Public's best interest rather than that of corporate shareholders. UARC contracts are sole-source contracts awarded without competition, with an average value that exceeds $6M U.S. dollars annually. A comprehensive review is done every five years to ensure the maintainance of core competencies, relevance to the DoD mission, cost reasonableness, and adherence to acting within the public interest. The DoD currently has 13 UARCs (Table 2- 1).

Table 2-1

Sponsors, Universities and DoD UARCS (Office of the Secretary of Defense [OSD], 2013, 4)



Primary Sponsor	University	UARC
Army	Georgia Institute of Technology	Georgia Tech Research Institute (GTRI) Applied Systems Laboratory (ASL)
	Massachusetts Institute of Technology	Institute for Soldier Nanotechnologies
	University of California, Santa Barbara	Institute for Collaborative Biotechnologies
	University of Southern California	Institute for Creative Technologies
Navy	The Johns Hopkins University	Applied Physics Laboratory
	Penn State University	Applied Research Laboratory
	University of Hawaii	Applied Research Laboratory
	University of Texas at Austin	Applied Research Laboratory
	University of Washington	Applied Physics Laboratory
Missile Defense Agency (MDA)	Utah State University	Space Dynamics Laboratory
DASD (Systems Engineering)	Stevens Institute of Technology	Systems Engineering Research Center
National Security Agency (NSA)	University of Maryland, College Park	Center for Advanced Study of Language
Strategic Command (STRATCOM)	University of Nebraska	National Strategic Research Institute

2.3 Applied Research

Military investments in basic research provide the foundational knowledge which supports the ongoing applied research efforts in the Military Service laboratories. Each Service lab has an in-house basic research effort to complement and support their applied research efforts. The DoD Financial Management Regulation (2010) defines applied research as the:

> systematic study to gain knowledge or understanding necessary to determine the means by which a recognized and specific need may be met. It is a systematic application of knowledge toward the production of useful materials, devices, and systems or methods, including design, development, and improvement of prototypes and new processes to meet specific requirements. Explanation: This

> activity translates promising basic research into solutions for broadly defined military needs, short of development projects. (p. 5-4)

Applied research spans the needs of the future force through that of the mid-term force, which is generally 10-15 years away (DA, 2017). Research produced extramurally through the funding programs of the basic science offices spirals up to knowledgeable scientists (Figure 2-1) who understand the military needs in their fields. Program Managers from the basic science offices who sponsor extramural research actively seek out these applied research scientists so that there is scientific cognizance (SC) of the funded extramural basic science research. Scientists wanting a more active role in the research, such as visiting a researcher's laboratory, are considered scientific liaisons (SL). Scientific cognizance and scientific liaisons are metrics tracked by the basic science Program Managers (ARO, 2017). This ability to absorb generated basic research results and findings facilitates the transfer of knowledge to applied research and advanced technology development efforts (DSB, 2012). The research laboratories, like the basic science offices, fund academia as well as industry to support the lab's in-house research efforts. The laboratories, similar to the basic science offices, will advertise what research they are seeking in a published broad agency announcement. Other tools they use include Collaborative Technology Alliances (CTA) and Collaborative Research Alliances (CRA), which are industry led and university-led partnerships, respectively, between the research lab, industry, and academia. The focus of the alliance is the rapid transition of innovative technologies to the Service.

> Academia is known for its cutting-edge innovation; the industrial partners are able to leverage existing research results for transition and to deal with technology bottlenecks; and the… Research Laboratory's researchers keep the

> program oriented toward solving complex …technology problems. (Army Research Laboratory [ARL], 2018a, Collaborative Alliances section, para. 2.)

Cooperative Research and Development Agreements (CRADA) allow the laboratories, in order to conduct collaborative research in an area that is consistent with the laboratory's mission, to enter into cooperative agreements with

> other Federal agencies; units of State or local government; industrial organizations (including corporations, partnerships, and limited partnerships, and industrial development organizations); public and private foundations; nonprofit organizations (including universities); or other persons (including licensees of inventions owned by the Federal agency). (United States Government [USG], 2000, Cooperative Research and Development Agreements section, para. 3710a).

Both partners must see a benefit to conducting cooperative research, and a CRADA is most often used to formalize the interactions and partnership between the lab and private industry. A CRADA does not allow for the laboratory to provide funds to any collaborative partner, but the lab can provide personnel, services, facilities, and equipment. However, it is the only mechanism in which a Service lab can receive funding from non-Federal sources for collaborative work (Naval Research Laboratory [NRL], 2018). The laboratories have additional opportunities to interact with industry and academia through the Small Business Innovative Research Program (SBIR) and the Small Business Technology Transfer Program (STTR). Mandated by law, the SBIR Program sets aside funding for small businesses by any government agency expending more than $100 million U.S. dollars annually on research. From an agency’s budget, 3.7% is channeled toward small businesses (considered less than or equal to 500 employees) for use to meet the agency's needs. Additional program goals include increasing private sector commercialization of innovation derived from federal research, stimulating innovation, and fostering participation and entrepreneurship by disadvantaged persons (NRC, 2017; Small Business Administration [SBA], 2014; SBA, 2016). The DoD in 2017 awarded 2,122 SBIR contracts valued at ~$907 million U.S. dollars (SBA, 2017). The STTR program is a set-aside program which facilitates R&D cooperation between small businesses and U.S. Research Institutions. Agencies, in this case, with a research budget greater than $250 million U.S. dollars must channel .45% of their research budget towards STTR grants and contracts (SBA, 2014; SBA, 2016). The DoD in 2017 awarded 360 STTR grants and contracts valued at $126.4 million U.S. dollars (SBA, 2017). One program unique to the Army S&T Enterprise is the Open Campus initiative which allows researchers from academia, industry and other government laboratories to work side by side with Army Research Laboratory (ARL) employees in areas of mutual interest. Educational Partnership Agreements (EPA) and CRADAs are the mechanisms utilized which sanction this collaboration. Both tools provide the ability for outside researchers to access the world-class facilities of ARL, and it provides them with an opportunity to collaborate with subject matter experts in their scientific field. The net benefit to ARL is increased awareness and visibility of ARL-developed technologies intended to spawn opportunities and pathways toward commercialization (ARL, 2018b). The EPA has the additional benefit of exposing young researchers to the unique challenges and problems of the military research community as well as providing outreach support through "equipment loans, help with STEM course development, guest lectures and demonstrations, and workshops for teacher and student science and technology education" (Naval Sea Systems Command, 2018, Educational Partnership Agreements section, para. 1). Federally funded research and development centers (FFRDC) are intended to meet some particular long-term need, generally in engineering, acquisition support, research and development or independent analysis, that in-house capabilities or contracted sources cannot meet. FFRDCs are unique in the sense that, unlike a customarily contracted firm, they have access to government data such as supplier data, to include sensitive and proprietary data, and to employees and installations, equipment and real property. Generally, they are nonprofit organizations, consortiums of universities, or separate operating units of an industrial organization which must operate in the public interest (General Services Administration [GSA], 2005). They support the organization which sponsors them by providing unbiased analysis and advice on technology development choice and technology transfer activities to encourage the commercialization of government-funded research from experts in the field that are typically not available. The DoD currently sponsors nine FFRDCs. Some of the more commonly known centers include the Software Engineering Institute at Carnegie Mellon University, Lincoln Laboratories at Massachusetts Institute of Technology, and the Studies and Analysis Center at the Institute for Defense Analysis (Mitre Corporation, 2015).

2.4 Advanced Technology Development (ATD)

Supporting the needs of the mid-term and the current force are the Research, Development and Engineering Centers that concentrate on the development of advanced technologies and advanced components, which they integrate into subsystems and prototypes for testing in relevant field experiments or simulated environments.

> ATD includes concept and technology demonstrations of components and subsystems or system models. The models may be form, fit and function

> prototypes or scaled models that serve the same demonstration purpose. The results of this type of effort are proof of technological feasibility and assessment of subsystem and component operability and producibility rather than the development of hardware for service use. Projects in this category have a direct relevance to identified military needs. (DoD, 2010, p. 5-4 – 5-5)

The engineering centers receive applied research from the research laboratory as well as generate it from within. Like the basic science office and the service's research laboratory, the engineering center advertises externally, utilizing a broad agency announcement which seeks out advanced technologies in specific areas in which the engineering centers specialize. As an example, the U.S Army Communications, Electronics Research, and Development Engineering Center (CERDEC) may seek out technologies that integrate command, control, communications, computers, intelligence, surveillance, and reconnaissance (C4ISR) capabilities that allow for information dominance on the battlefield. The broad agency announcement may solicit proposals ranging from basic research through applied research up to advanced technology development (Communications-Electronics Research Development and Engineering Command [CECOM], 2014). As a result, each engineering center maintains an ability to conduct basic and applied research within their concentrated efforts on advanced technology development. Rapid Innovation Funding (RIF) allows the Engineering Centers to have opportunities to bring required critical national security technologies into military systems, programs or components, an additional source of revenue outside of their core mission funding. The intent is to mature prototypes created internally or under various small business programs such as SBIR so that they may undergo final development, testing, evaluation and integration for use by the warfighter. Those selected for an award receive up to $3 million U.S. dollars and have 24 months to complete the work (DoD Office of Small Business Programs, 2017; The Washington Headquarters Services, Acquisition Directorate, 2016). The Rapid Prototyping Program "enables the Services and Defense Agencies to rapidly prototype, evaluate, and transition new capabilities to programs of record in order to reduce technical and integration risk and accelerate transition of new capabilities to programs of record" (Under Secretary of Defense, 2018, Rapid Prototyping Program Section, slide 16-17). Other Transaction (OT) Authority allows the

> DoD the flexibility necessary to adapt and incorporate business practices that reflect commercial industry standards and best practices into its award instruments. When leveraged appropriately, OTs provide the Government with access to state-of-the-art technology solutions from traditional and non-traditional defense contractors (NDCs), through a multitude of potential teaming.
>
> OTs can help:
>
> a. Foster new relationships and practices involving traditional and NDCs, especially those that may not be interested in entering into FAR-based contracts with the Government;
>
> b. Broaden the industrial base available to Government;
>
> c. Support dual-use projects;
>
> d. Encourage flexible, quicker, and cheaper project design and execution;
>
> e. Leverage commercial industry investment in technology development and partner with industry to ensure DoD requirements are incorporated into future technologies and products; and

> f. Collaborate in innovative arrangements tailored to the particular project and the needs of the participants. (Under Secretary of Defense for Acquisition and Sustainment, 2018, pp. 4-5)

Like the research laboratories, the engineering centers can cooperate as well with academia and industry through the use of CRADAs, SBIR and STTR contracts.

2.5 Program Mangement Offices (PMO)

The Program Management Offices (PMO) receive the preponderance of the DoD’s Research and Development funding, with the majority of their activities concentrated on development (Consolidated Appropriations Act, 2018). The systems they field are to the current force and reflect a culmination of science and technology investments made upwards of two decades prior. During the Technology Maturation and Risk Reduction Phase of the program, the PMO also makes science and technology investments as they shape the knowledge that they need to overcome potentially challenging requirements. As the System PMO, they have insight into the performance capabilities and limitations, as well as where the technical risk lies in the systems that they are developing (DoD Instruction [DoDI] 5000.02, 2017). One mechanism the PMO utilizes to interact with industry is through a Request for Information (RFI) inquiry. These are announcements made to industry to generate responses which provide ideas, information, and other data that informs the PMO leadership in developing the next steps in the material development process (Defense Acquisition University [DAU], 2018). Often the information provided gives the government insight into what industry is thinking about technological solutions and the state of the possible. A more interactive process is when the PMO conducts an Industry Day, which is an event for the PMO to present the plans for a current or future procurement to representatives from industry. This event typically is held before the release of a Request for Proposal (RFP). Like the RFI it gives the government an opportunity to state its goals and schedule and solicit feedback about the proposed development. It is not uncommon for industry to have private one-on-one meetings with PMO personnel in order to clarify any questions that they may have. Typical Industry Day goals are:

1. ensure synergy between the DoD program office and Industry representatives;
2. incorporate Industry comments into the RFP development process;
3. communicate interoperability and open standards;
4. communicate program requirements and schedule;
5. gain a better understanding of recent Industry developments. (Acquisition Notes, 2018, Proposal Development section, para. 3)

An RFP is an actual solicitation used to communicate government requirements to industry in order to call for proposals. Minimally the RFP will include the system's requirements, the anticipated terms, conditions of the contract vehicle, required information submitted with the proposal, and the criteria the PMO will use to evaluate each proposal and the relative importance of each criterion (DAU, 2018). The PMOs like the engineering centers can leverage small business opportunities through the use of rapid innovation funding, rapid prototyping funding, other transaction, and SBIR contracts as well.

2.6 Overseas S&T Field Offices

The global offices help facilitate the S&T Enterprise's interactions with foreign governments, academia, and industry. Service regulations provide insight into the benefit of conducting these engagements by leveraging resources through cost sharing, knowledge sharing, economies of scale, and duplication avoidance. They also help maintain a strong defense base for the U.S., its allies and other friendly nations as well as modernize, strengthen, and expand alliances by increasing mutual understanding (Army Regulation [AR] 70-41, 2009); Air Force Policy Directive [AFPD] 16-1, 2015). Government-to-government interactions between friendly foreign military research facilities and the Military Service's Research Laboratory or Engineering Centers are intended to find common areas of scientific interest to be codified in a negotiated Data Exchange Annex (DEA), allowed under the DoD's Information Exchange Program. These annexes facilitate the exchange of scientific knowledge and ideas between each nation's military research community to provide awareness, establish or nurture relationships, reduce costs and promote standardization, interoperability and future cooperation (DoD, 2002). Project Agreements (PA) allow the two sides to jointly conduct research and development in areas of decidedly mutual benefit (AR 70-41, 2009; AFPD 16-1, 2015; Secretary of the Navy Instruction [SECNAVINST] 5710.25B, 2005). The Engineer and Scientist Exchange Program (ESEP) allows for the professional exchange of scientific personnel to work in each other's laboratories or engineering facilities. The Foreign Comparative Testing (FCT) Program examines items and technologies of foreign allies that have a high Technology Readiness Level (TRL) in order to satisfy valid defense requirements quickly and economically (Deputy Assistant Secretary of Defense (Emerging Capability& Prototyping) [DASDEC&P], 2018). The Coalition Warfare Program (CWP) allows the Services to compete for funding in order to collaborate with friendly foreign nations in order to address technology gaps, create interoperable solutions for coalition operations, develop new relationships and strengthen current defense partnerships (Office of the Under Secretary of Defense for Acquisition and Sustainment [USDA&S], 2018). Cooperative Test and Evaluation (CTE) projects allow for the reciprocal use of test facilities under the Test and Evaluation Program. International Cooperative Research and Development Agreements (ICRADA), like their domestic counterparts, allow S&T Organizations to enter into cooperative agreements with foreign industrial organizations, public and private foundations, nonprofit organizations (including universities), "or other persons (including licensees of inventions owned by the Federal agency)" (USG, 2000, Cooperative Research & Development Agreement section, para. 3710a) in order to conduct collaborative research in an area that is consistent with the laboratory's mission. The primary means of interfacing with academia overseas is through the funding of basic science. The Air Force through their "Windows on Science" funding, the Navy through their "Long Range Navy and Marine Corps Science and Technology" funding and the Army through their "Seed Projects" allow for the Services to have global reach in selecting scientists and research projects which have the same goal as the basic science program investments stateside (AFOSR, 2018; ONR, 2018; RDECOM, 2018).

2.7 Analysis and Discussion

The overarching operating framework that brings together the activities of the DoD's Science and Technology Enterprise is titled "Reliance 21." It is a set of principles and a means of governance established to ensure that the S&T community provides solutions to the Department's decision makers and the warfighters. The S&T Executive Committee membership consists of the upper echelon leaders within the DoD and Service's S&T Organizations. The Assistant Secretary of Defense for Research & Engineering chairs the Executive Committee, and it has a "strong connection to the warfighter" which underpins the activities of this group (Department of Defense (USDAT&L, 2014). At the heart of these activities are the Communities of Interest (COI) established by the Executive Committee to address emerging technological challenges through assessment and strategy formulation. The COI are made up of senior technical leaders with common technology interests drawn from the Services, Joint Staff, Defense Agencies and the Office of the Secretary of Defense. They generate plans with a ten year time horizon that map out how they will address these technological challenges. The Services use these roadmaps to guide long-term budget decisions. The COI coordinate with the Defense Basic Research Advisory Group to address longer-term challenges they deem farther out than ten years. The S&T Enterprise within each Military Service prioritizes investments based upon COI produced roadmaps. The Services still have the flexibility to make S&T investments in areas which are Service-specific. The instantiation of these investments is the variety of mechanisms utilized in engaging academia and industry [Figure 2-1] that address the gaps identified by the COI in pursuit of bringing new capabilities to the Services. These Science & Technology investments run the spectrum from the most basic of discoveries through applied research and advanced technology development to the engineering of new fieldable systems for use by the Military Services. The basic science offices feed discoveries in basic research to the Military Service Research Laboratories. The wide variety of programs used by the basic science offices to engage with academia ensures that new knowledge generated outside of the S&T Enterprise steadily expands the collective knowledge of the Enterprise as a whole. In many cases, breakthroughs in science come not from within a system but from outside a system. Experts within a prescribed area of science are the most thoroughly familiar with knowledge developed within that given field. New knowledge coming from outside the system can act as a catalyst for further progress or discovery.

> Pasteur was not an MD. The Wright brothers were not aeronautical engineers but bicycle mechanics. Einstein properly speaking was not a physicist but a mathematician, yet his findings in mathematics completely turned upside down all of the pet theories in physics. Madam Curie was not an MD but a physicist yet she made important contributions to medical science. (Maltz, 1953, viii)

The basic science program managers, therefore, place enormous importance on finding and documenting which researchers within the enterprise want to maintain scientific cognizance about or scientific liaison with the funded researcher. The more frequent the number of touchpoints there are with the S&T Enterprise's researchers, the greater the likelihood for absorption and utilization of this externally generated knowledge. Ultimately knowledge diffusion and absorption is the end state goal, and thus the program managers track this as one of their more critical metrics (ARO, 2014). It is not enough to create new knowledge externally; an enterprise must have the ability to absorb and then utilize it in order for it to serve its purpose. The Service Research Laboratory does have this ability. It has its own in-house basic research program and thus can absorb new knowledge and start applying it toward military applications. Early stages of applied research take foundational knowledge and assemble it so that it translates it or materializes it toward some broadly defined military need with its applied research program. The knowledge garnered from applied research spirals up to the Engineering or Systems Centers where it is combined, supplemented and integrated into components and prototypes which will operate under field-like conditions. Like the research laboratory, the engineering centers can absorb this applied research due to their own in-house applied research programs. Additionally, they have a limited basic research capacity, allowing them to examine unexpected phenomena which arise as they pursue their advanced technology goals. Accordingly, they too have their mechanisms to engage with academia and industry. The knowledge created during Advanced Technology Development spirals up to the Program Offices to inform those managers as to what the state-of-the-art is, as well as the-state-of-the-possible. The Program Managers use this knowledge in the writing of their Request for Proposal, which solicits technical responses in meeting required capabilities. In reality, within the S&T Enterprise, science is a continuum of activities from the early to late stages of basic research, applied research, technology development and systems development. The magnitude of the interactions between the enterprise, academia, and industry is tremendous. The multidimensionality, variance and sometimes redundancy in the engagement mechanisms with academia and industry create a continuous dialog as well as a tension in that there are competing ideas that vie for limited resources. The pressure that the warfighting doctrine organization exerts on the mission-oriented S&T Enterprise keeps decisions focused on meeting the needs of the warfighter and supports winnowing down projects that stall or have no path to success. Science generated outside of the enterprise may complement, supplement or even compete directly with in-house efforts. The new knowledge brought in for consumption might be instantiated in ongoing research, may sit idle waiting on some other breakthrough or discovery, or may be cast out if no longer relevant or useful in achieving the research or envisioned warfighter goals. In-house efforts face the same ignominious ending if they too provide no benefit or utility. This constant pressure from the warfighting community to show relevance has resulted in a competitive marketplace for new knowledge creation that is always open and always busy. The resulting scientific and engineering ecosystem is one with foundational underpinnings dependent upon the creation, diffusion, absorption, and utilization of knowledge. As such, research should study each of these primitives in the context of a mission-oriented S&T Enterprise to determine whether the Enterprise operates as desired and whether there are any determinants or indicators which allow managers to make adjustments to optimize knowledge flows within the mission-oriented S&T Enterprise.

Chapter 3 – Measuring the Effectiveness of International S&T Engagements

3.1 Literature Review

There does not appear to be a standardized methodology for evaluating the outcomes of international S&T collaboration. “At present, the mechanisms to understand and measure the benefits and values that flow from international collaborations are limited” (Australian Academy of the Humanities [AAH], 2015). Various countries have different measures of success. The Australian Department of Innovation, Industry, Science, and Research evaluates programs at the individual project level. A key metric for success is knowledge transfer. According to their metric, the amount of international co-funding leveraged during the project is a reflection of the knowledge transferred. Other metrics utilized capture access to infrastructure and capacity building as a result of the collaboration. They demonstrate this through the number of publications authored or co-authored with international researchers. Brazil’s Ministry of Science and Technology looks at improving the knowledge and technology base through the number of joint projects conducted and the number of scientists exchanged. Canada has numerous departments and agencies which have different metrics for success. Their Agriculture and Agrifood Canada (AAFC) has one of the most articulated international collaboration efforts. Similar to Brazil, AAFC quantifies capacity building through the number of collaboration projects with foreign organizations, the number of foreign researchers hosted and the number of publications and joint publications completed. India’s Ministry of Science and Technology defines success as leveraging international expertise, with metrics that track the number of participants in foreign programs and the number of newly established international institutes (European Commision [EC], 2009). The Australian Academy of Humanities in 2015 argued that the value of increasing research excellence is broader than simple citation numbers. They argued that the value of international collaboration includes impacting global reputation, global research rankings, attracting and retaining foreign talent, and using reputation to leverage global funding. Prominent in their findings is recognition of the need to maximize international research collaboration spillovers and knowledge transfers (AAH, 2015). A Rand study (2002) on improving the efficiency and effectiveness of international S&T collaboration looked at four case studies to determine whether there were lessons to be learned to help policymakers think more strategically, creatively and efficiently when utilizing international engagements to advance science. They too concluded that new ways were needed to evaluate the benefits of conducting international collaboration. Within the study, some researchers and policymakers articulated the need to create measures of output and outcomes during the program design phase. In an attempt to evaluate international research in general, the Committee on Science, Engineering and Public Policy evaluated U.S. research in comparison to international research through a process they described as international benchmarking. By assembling expert panels in the field (domestic and international), international benchmarking determines whether a country is at the forefront of a scientific field. This panel considered the mission objectives of the funding organization in the context of assessing leadership. Dependent upon the field that they were evaluating, each panel utilized different methodologies to determine a country's leadership. Some of the tools they used included the virtual congress, citation analysis, journal publication analysis, quantitative data analysis, prize analysis, and international congress speakers. A virtual congress is the naming by each expert on the panel of eight to ten leading experts in the field broken down by subfields. By aggregating and ranking the consensus top individuals, their standings and those of their fellow countrymen dictate a nation's rank relative to the ranking of other countries. The analysis determines whether a country is at the forefront, among the world leaders, or behind the world leaders as indicated by the standings of their researchers. Citation analysis compares the country's citation rate for the field in comparison to the worldwide citation rate for that field. "A relative citation impact greater than 1 showed that the country's rate for the field was higher than that of the world" (AAH, 2015, p. 16). They also considered high impact papers, those that have the most citations in the field for the previous five years. The concern with citation analysis was over the quality of the data and that certain high-quality journals were missing from the database. They considered, however, its relative objectivity to be its major strength. Journal publication analysis examines high-quality journals in the field and tabulates in a quantifiable manner the nationality of the publishing primary investigators. Quantifiable data analysis is the comparison of major features within each country's science enterprise to see how one country stands in comparison to the rest of the world. Comparing simple things like the number of Ph.Ds in each country was found to be difficult due to the different naming conventions and standards for other countries. Prize analysis looks at key awards given in a scientific field. Categorizing researchers by country was problematic due to the mobility of researchers moving to different institutions and countries. Finally, they analyzed invited plenary speakers at international conferences. They compared the country's representation to its proportion of papers published in the field. A concern with this methodology is the conference organizer's tendency to try and get a balanced geographical representation. Overall the panel leaders thought the process of international benchmarking was a reasonable, quick and accurate evaluation tool; however, many participants thought that the whole process needed more rigorous quantitative measurements. The panel in response felt that quantitative measures were helpful, but evaluation requires expert judgment to analyze the relative importance of the metrics (National Academy of Sciences [NAS], 2000).

In 2014, the U.S. National Research Council Committee on Globalization of Science and Technology released a report on the opportunities and challenges for the Department of Defense. Their mission was to assess the DoD’s efforts, through the three Military Services, in leveraging international S&T and for creating and coordinating engagement strategies across the Department. In the report, having visited the DoD’s international S&T field offices, “the committee did not observe effective, consistent, or systematic reachback mechanisms for capturing and sharing S&T information and knowledge” (p. 39). Independent of the engagement mechanisms, the Services needed articulated success metrics to gauge the effectiveness and improve future cooperation activities. They needed “to establish clear objectives and measurable performance metrics for the field offices” (p. 39) The committee went on to further call for a DoD-wide platform to support bibliometrics and other related analytics. An EU Commissioned Report on the drivers of international collaboration in research also identified the lack of analysis to understand the effects of international activities within research organizations and at the institutional level (EC, 2009).

3.2 Research Gap

There is an overwhelming consensus about the lack of standardized evaluation measures for international S&T engagement activities. Researchers have proposed various frameworks which discuss how a nation might go about evaluating international engagements. There is an abundant amount of discussion on qualitative as well as quantitative measures such as financial indicators, bibliometric indicators, and intellectual property indicators (AAH, 2015). The EU Commission Report “Drivers of International Collaboration in Research” (2009) and the U.S. National Research Council Report titled “Strategic Engagements in Global S&T – Opportunities for Defense Research” (2104) specifically call out the lack of quantifiable metrics to understand the impact international S&T engagements have on individual research organizations. By and large, most conclusions lean toward having multiple evaluation methodologies made up of a mix of quantitative and qualitative measures. Touched upon by almost all discussions is the concept of knowledge spillover or diffusion (AAH, 2015; EC, 2009). All agree that one of the chief benefits of being part of an international collaboration activity is exposure to the creation of new knowledge which would not have occurred if the individual had not been a part of the collaboration. Where most of this research looked at the theoretical side, benefits, conceptual processes and frameworks, there is a lack of analysis of an actual mission-oriented research enterprise which conducts international S&T engagements. Recall that a key aspect of the DoD’s end-state goals for its published International S&T Strategy was to “accelerate the pace of U.S. research and development, leverage emerging global opportunities, and improve U.S. capabilities” (Shaffer & Webster, 2014, p. 1). The Military Service’s S&T Enterprises which execute the DoD’s Strategy are scientific and engineering ecosystem dependent upon the creation, diffusion, absorption, and utilization of knowledge. Accelerating the pace of research and development through overseas investments requires the funding of high impact science that may not be occurring within the S&T enterprise nor the United States. By leveraging these emerging global opportunities, the enterprise saves time and resources and expands the collective knowledge of the system by absorbing and utilizing research conducted overseas. As already pointed out, international S&T engagements need quantifiable metrics to understand the impact that these engagements have on the individual organization. A systematic study of the mechanisms involved in the selection of science for funding overseas by a mission-oriented S&T Enterprise provides a challenging set of research questions.

3.3 Research Questions

1. Does the type of engagement model play any role in the selection of high impact science for a mission-oriented S&T Enterprise?
2. Of the science selected for funding, do overseas engagements identify emerging opportunities early?
3. Are there discernable characteristics or demographic and professional approach differences between program managers working under various engagement models?
4. Are there key characteristics of a successful engagement model which identifies impactful science and scientists early?
5. Does the type of engagement model affect knowledge diffusion and knowledge absorption within a mission-oriented S&T Enterprise?

Chapter 4 – Evaluating Research Selections

4.1 Literature Review

In 1963, Derek John de Solla Price published the classic study of the science of science – “Little Science, Big Science, and Beyond.” It is considered the founding treatise for modern scientometric studies. In the book, much of his work focused on scientific articles and publications, and as such he examined publication growth rates, citation rates, networks of scientific papers, the impact of journals, and the scientific impact of countries. He describes the publication of scientific papers as “a carrier of information, an announcement of new knowledge promulgated for the good of the world” (p. 62). Pritchard (1969) described this examination of science as “the application of statistical and mathematical methods to books and other media of communication” (p. 349). From this, he coined the phrase bibliometrics. This discipline has become a mainstay tool for use within the scientific community, with organizations such as the Organisation for Economic Cooperation and Development (OECD) using bibliometric indicators to “depict recent trends and structure in scientific production across OECD countries” (OECD, 2016, p. 3). It also has become an interesting area of research for others. Bibliometrics generally can be broken down into two areas of research. The first attempts to study the body of literature by counting and sorting scientific papers and journals by country, author, year, and discipline. The second attempts to study the use of the body of scientific literature to evaluate the relationships and impact of the literature within the scientific community (Nicholas & Ritchie, 1978; Potter, 1988; Stevens, 1953). This second research thrust depends upon citation analysis to build the networks of relations and to study the impact or so-called “quality” of the research.

A general assumption is that a citation represents the citing author's use of the cited work and indicates an influence of the cited work on the author's new work and as such a flow of knowledge from the cited to the citing works' authors. Citations also indicate relatedness (e.g., similar subject matter or methodological approach) between these two works (Zhao & Strotmann, 2015). Bibliometrics' use in determining quality, however, is a somewhat contentious issue, substantiated through the numerous research articles extensively exploring the development of new bibliometric measures while others capture and critique the issue of trying to quantify quality through a numeric indicator. Early bibliometrcians believed that citation counts could measure the utilization of a single publication or act as a general measure of contribution an individual makes to his scientific field (Garfield, 1979; Narin, 1976). Research shows a positive correlation between highly cited papers and papers highly rated through peer review. A higher citation rate generally reflected a higher peer review rating (Narin, 1976; Rinia, van Leeuwen, van Vuren, van Raan, 1998). Bornmann and Leydesdorff (2012), as part of their extensive research into this subject area, reflected that "there should be a close relationship between both measures, but one should consider in this comparison that citation-based indicators measure only one aspect of research quality (its impact). Peers can additionally assess the other two aspects (accuracy and importance)" (p. 11). The numbers behind a citation count do not necessarily reflect the motivation of the citing authors. The nature of the relationship between the citing document and the cited document is not explicitly borne out through the cumulative citation count (Blackwell & Kochtanek, as cited in Cronin, 1984; Glanzel & Moed, 2013). Early work by Garfield (1964) identified this same point as he captured the reasons authors use citations:

1. Paying homage to pioneers
2. Giving credit for related work (homage to peers)
3. Identifying methodology, equipment, etc.
4. Providing background reading
5. Correcting one's own work
6. Correcting the work of others
7. Criticizing previous work
8. Substantiating claims
9. Alerting researchers to forthcoming work
10. Providing leads to poorly disseminated, poorly indexed, or uncited work
11. Authenticating data and classes of fact – physical constants, etc.
12. Identifying original publications in which an idea or concept was discussed.
13. Identifying original publication or other work describing an eponymic concept or term as, e.g., Hodgkin's Disease, Pareto's Law, Fiedel-Crafts Reaction, etc.
14. Disclaiming work or ideas of others (negative claims)
15. Disputing priority claims of others (negative homage). (p. 85)

Citation counts do not differentiate between these reasons. A reader would need to be wholly familiar with the subject to understand the motivation of the citing author and whether the cited paper was the most appropriate choice of literature in that field. Additionally, there is no way for the reader, unless they have personal knowledge, to know whether there was personal bias in the author's selection process (Cronin, 1984). "This does not mean that citation analysis may not have its purposes, but it does mean that if it is to be taken seriously, investigators must first descend to the documents from which these data are derived in order to reconstruct influences before proceeding" (MacRoberts & MacRoberts, 1986, p. 167). Lipitz (1965) suggested adding shortcodes to identify how citation entries, in an informative way, relate to the citing publication. Other issues in using citation counts as a quality indicator arise when papers sit dormant until discovered or rediscovered. Most highly cited papers are recognized early. Some science has a delayed response. There is a great deal of research into identifying those dormant papers (Cressey, 2015; Jian, 2016; Ke, Ferrara, Radicchi, & Flammini, 2015). Are those papers which gain recognition well after publication considered inferior until discovered? In cases such as this, citation analysis is not a good indicator of quality (Garfield, 1980; MacRoberts & MacRoberts, 2010).

Others are critical of the data used in the analysis. They point out that there are errors with the author's names and institutional names due to homonyms and synonyms. There are problems with the delimitation of subfields and the accuracy of the citation counts. Formal and informal influences are not always cited. There are limitations to the citation indices and bibliographies; not all publications are captured. Accounting for self-citing and multiple authorship presents challenges. There are variations in citation behavior between scientists of different nations as well as whether citation behavior is biased toward developed nations. Importantly, do the citations selected reflect the best work or not (Greyling, 2014; MacRoberts, & MacRoberts, 1989; Moed, 2009; Smith, 1981)? The differences in publication and citation behavior among the various scientific disciplines is also a significant concern. Citation rates and growth rates are different in the various fields, and this has led to research into the idea of normalizing citation data to account for these differences (Garfield, 1979; Moed et al., 2004).

4.2 Normalizing the Data

The research into normalizing citation data falls into two different research methodologies. The first is to create new indicators which account for the various densities and growth rates between fields. The second is the creation of recursive indicators which factor in the prestige of the citing publication, journal or author (Waltman, Yan, & van Eck, 2011). Services provided by companies such as Thomson-Reuters Web of Science and Elsevier's SCOPUS attempt to address normalization through the creation of subject categories. The Web of Science scheme consists of 252 subject categories which fall within the fields of science, social sciences, arts, and humanities. SCOPUS classifies its subjects into four broad subject clusters (life sciences, physical sciences, health sciences, and social sciences & humanities) which have 27 major subject areas and 300+ minor subject areas. Both schemas allow each journal to have multiple subject areas assigned. Published items will reflect each of these subject areas (Elsevier, 2017; Thomson Reuters, 2018). The subject categories of the Web of Science (WoS) over the years have evolved from a scheme for classification of scientific papers into a normalization standard in bibliometric evaluations. Issues arise when journals are more multidisciplinary and not sufficiently discipline-oriented for citation normalization. Articles attributed to one area of science should fall within another (Leydesdorff & Bornmann, 2016).

A different approach, rather than normalizing an article to a field of science, studies the impact of the journal as a whole. The use of Journal Impact Factors (Jif) originated within the U.S. University library system to determine which journals, through an objective methodology, belonged in their holdings (Archambault & Lariviere, 2009). Formalized by the Institute of Scientific Information in 1975, a journal impact factor for “a particular year is the number of citations received in the current year to articles published in the two preceding years divided by the number of articles published in the same two years” (Meho, 2007, p. 7). Critics of this calculation state that a few highly cited articles, or journals which publish numerous review papers (they tend to be highly cited), skew the results toward a higher impact. Others argue that the two-year calculation window is insufficient to cover the long-term value or real impact of many journals. Citing practices between scientific fields, a determination of which articles to include in the calculation, as well as the usual data inaccuracies, are all concerns as well (Meho, 2007; Moed, 2009). This criticism spurred research to address each of these inequities (Archambault, & Lariviere, 2009; Leydesdorff, Zhou & Bornmann, 2013; Moed, 2009; Rousseau & Leydesdorff, 2011). A different approach is to normalize on the individual researcher. The h index is “defined as the number of papers with citation number ≥h, as a useful index to characterize the scientific output of a researcher” (Hirsch, 2005, p. 1).

> However, this bibliometric indicator is hardly useful for comparisons (in particular across different time periods and research fields). Since the h index is dependent on the age of a scientist and on his/her research field, scientists with different ages and fields cannot be compared. (Bormann & Marx, 2014, p. 207)

Even so, both JIF and h index have both gone on to become commonly used bibliometrics as well as an impetus to spawn other research in pursuit of even better or more straightforward ways to present metrics. Co-citation research looks at the relationship between documents regarding commonality of citing references. It is the frequency with which two documents share the same citing papers (Small, 1974). Research has shown that co-cited neighbors have greater commonality through text analysis than exists between other articles published in that same journal. The Relative Citation Ratio indicator normalizes citations received across both the field of science based on its co-cited neighbors and the time of publication in order to measure influence at the article level (Hutchins, Yuan, Anderson, & Santangelo, 2016). One critique of this process is that co-citation networks may evolve as separate enclaves, dependent upon an author’s selection of papers to cite. As such, a comparison to the whole field is not guaranteed (Bornmann & Haunschild, 2016).

Another approach is to use percentiles, which normalize citations of individual scientific papers based upon their subject area, publication year and type of publication (Bornmann & Marx, 2014; Bornmann, Mutz, Marx, Schier, & Daniel, 2011). The study selects papers published within the same field, same year and of the same type (research articles, letters, conference proceedings, etc.) and arranges them in numerical order according to citation counts. Where the paper falls in comparison to its peers determines its percentile standing.

> Bornmann and Leydesdorff (2013) used judgments by peers (F1000 scores as an external criterion) to analyze the validity of percentiles compared to other (advanced) bibliometric indicators. Both indicators and peers refer to the quality of individual papers in the study. Their results show that percentiles correlate most with judgments by peers compared to the other bibliometric indicators. That means they reflect the quality of a paper better than the other indicators – as measured by the opinions of experts. (Bornmann & Marx, 2014, p. 207)

As already pointed out, the subject fields defined by WOS, SCOPUS, and other research services do not necessarily reflect the true subject nature of an article if the article is in a multi-disciplinary journal or as well as co-cited neighbors (Hutchins et al., 2016; Leydesdorff & Bornmann, 2016).

4.3 Research Gap

During the sixty-five years after de Solla Price (1963) articulated that scientific papers are carriers of new knowledge, significant effort has gone into studying the characterization of that knowledge in a quantifiable manner. "In any scientific field the existing 'body of knowledge' is an accumulation of distilled insight, theoretical constructs, experimentally derived data, and empirical observations… citation analysis can be employed to establish the pedigree of ideas, and to unravel networks of scholarly interaction" (Cronin, 1984, p. 25). The debate over the true meaning of citation counts continues. Is it an indicator of quality or is it an indicator of impact? At a minimum, it shows the intellectual influence the cited author has on the citing author, whether there is agreement about the cited material. Citations show the basis for replication and the development of knowledge by others (Cole, 1970; Cole, 2000). In a mission-oriented organization which funds basic science the primary goal would be to fund science which has the potential to have the most significant impact on that particular mission-oriented organization. A secondary goal is that the research has an impact on science in general (Figure 4-1). For if the research acts as a catalyst and spurs on unforeseen advances in science, secondary and tertiary research may still indeed contribute to the efforts of the S&T enterprise. The selection process, therefore, should with equal consideration select those projects which are foreseen to contribute most toward the goals of the enterprise and science as well.

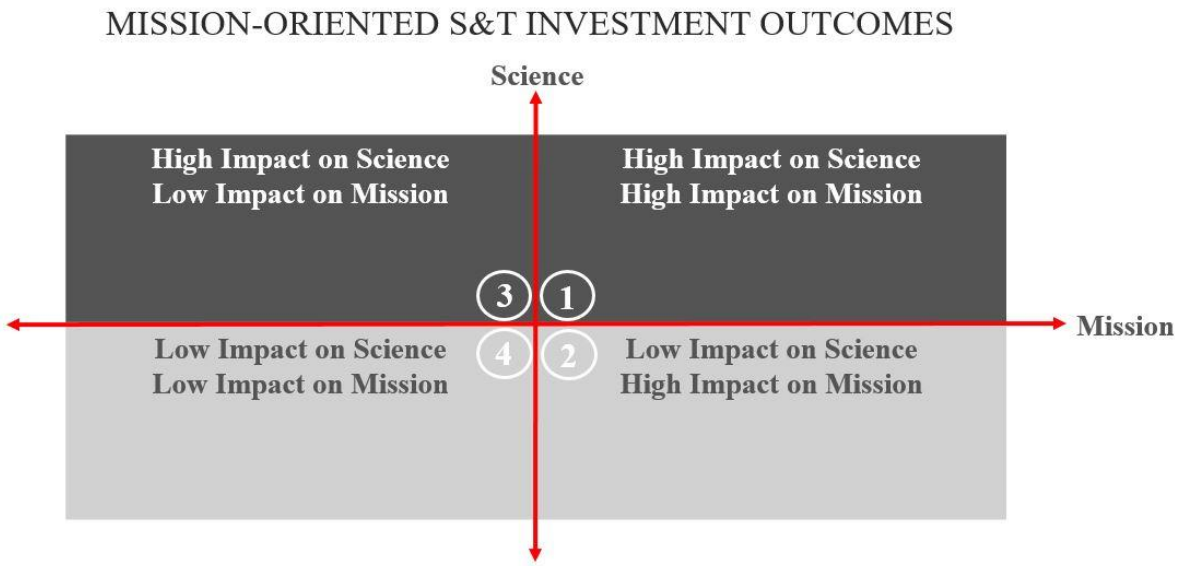


Figure 4-1 Mission-Oriented S&T Enterprise Investment Outcomes

Predominantly the literature, as described above, concentrates on the theory behind utilizing bibliometrics or on the development of new indicators to better evaluate the quantitative outcome of research. Countries, institutions, and academic departments down to the individual researcher have also utilized these indicators in an attempt to quantify their performance (Bornmann & Haunschild, 2018; Colman, Dhillon, & Coulthard, 1994; Moed, Burger, Frankfurt, & Van Raan, 1985). What is lacking is research which studies the selection mechanisms of science that utilize bibliometric indicators to evaluate and correlate program manager activities when selecting science within a mission-oriented S&T enterprise. In simpler terms, instead of focusing on the researchers and their output, there is a research gap in studying whether the individual program manager who selects the researchers and their projects for funding is impacting the mission of a mission-oriented S&T enterprise through the selection of high impact science.

4.4 Research Question 1

Does the type of engagement model play any role in the selection of high impact science for a mission-oriented S&T Enterprise?

4.5 Study Method

This particular study utilizes the science citation and proceedings citation index from Thompson Reuter's Web of Science raw data, consisting of 35,493,196 records. The data were indexed using a tool developed primarily for S&T studies, built around the Apache Lucene text search engine, used to conduct data-mining on semi-structured datasets. Before conducting the study, it was necessary to ensure that the data were normalized. Cleansing the data consisted of running specialized data processing modules within the tool that disambiguated institutional and author names, merged document sources to ensure compliance with canonical journal identifiers published by Thomson Reuters, and removed duplicates. The index built from these records is just a snapshot in time and reflects the abstracts from journal articles and proceedings found within Web of Science's science citation and proceedings index from January 1996 through November 2017.

The individuals who select basic science for funding within the Service's mission-oriented S&T Enterprise are Program Managers (PM). The individual who performs the research in academia or industry and receives the grant is the Primary Investigator (PI). Overseas, there are two methodologies used to select science. The first is the subject matter expert (SME) model, in which the PM is considered an expert in their field and they have considerable leeway in deciding which PIs and which projects get funded. There is an internal review within the global office process, but the rigor of the process is questionable (NRC, 2014). The Shared Equity (SE) model requires the PM to find a customer back in the S&T Enterprise before funding any PI overseas. The SE Model requires either cofunding of the research overseas by the stateside customer organization or requires their senior leadership concurrence that the research will advance the goals of the customer organization. The SE Model is dependent upon the processes established by the customer's S&T Organization for funding science. The Control Group (CG) consists of Program Managers found in a stateside basic science funding organization. The processes used by the stateside funding organization are very mature and structured (DSB, 2012). An individual CG PM begins by looking at the Service's Operational Needs, which are generated and enumerated by various strategies, priorities and requirements documents. The CG PM looks for scientific opportunities which will support those needs, often by assembling a coordinating group (COG) which consists of experts in the field from other funding organizations (NSF, NIH, DOE, etc..), other government and non-governmental laboratories, academia and potentially industry to discuss where future investments are needed. The topic formation may also come from conference or workshop attendance, MURI coordination meetings, or laboratory campaign plans. Once a topic is selected, there is a solicitation for proposals through a broad agency announcement. Evaluation of proposals requires a service laboratory peer review as well as an independent academic review. Evaluations look at the scientific merit of the proposal, relevance and how well the research fits into the program goals. Those projects positively reviewed are submitted to leadership for final approval. CG PMs may also submit for final approval those projects which are not necessarily positively reviewed. The CG PMs have the opportunity to defend the merits of a proposal even though the research may seem unfathomable or success extremely unlikely. If the CG PM's defense is of sufficient rigor to satisfy the management, it may still get funded (ARO, 2015).

This study will compare a sample of projects drawn from PM portfolios selected through use of the SME Model, SE model and those in the Control Group. The Control Group provides the contrast between the international office's results and the results of the stateside basic science offices. This contrast may provide insight into two of the DoD International S&T Strategy's stated goals: accelerating the pace of research and development and leveraging emerging global opportunities and whether the international offices are effective in achieving these goals. An analysis of the portfolios of the three selection models showed an overlap in the following five disciplines: physics, material science, chemistry, computer science, and life sciences. The selection of PMs in the SE model was limited to approximately one per field. The other two models had multiple PMs in each of those fields so one was selected randomly for each of those disciplines so that there could be a one to one to one comparison.

From each PM's portfolio of projects they manage, the study randomly selected a sample of journal articles published as a result of the PM's funding. Using a population proportion calculator the sample size selected from each PM's portfolio conformed to a 90% confidence level with a 5% margin of error. The total number of articles within the PM's portfolio served as the population for the calculation of the sample size required. The n articles were placed in a spreadsheet and a random number generator selected values from 1 to n used to pick the titles examined in this study. The title was entered into the study's bibliometric tool to determine if the article resided in Web of Science. If WOS contained the article, the year of publication, the WOS Subject field and the number of citations were recorded. WOS was then queried pulling all records for that same year and that same WOS subject field, which were sorted in citation rank descending order. The position of the first and last occurrence of the same number of citations for papers in that same subject, published in the same year as the selected paper in question, was also recorded. Bibliometric best practices cite the need for comparing articles of the same type, same year and same subject category (Bornmann, Mutz, Neuhaus & Daniel, 2008). The position number of the last occurrence divided by the total number of WOS subject papers for that year gives the percentage of papers with equal or a greater number of citations (Table 4-1).

Table 4-1 Data Collection and Recording Example

Year	WOS Subject	# of Citations for Selected Paper	WOS Subject # Papers	Rank Order Position	Percentile Rank
2003	CHEMISTRY, PHYSICAL	31	25137	6788-7016	27.91%

The paper's percentile rank is then reflected in the appropriate frequency distribution position:

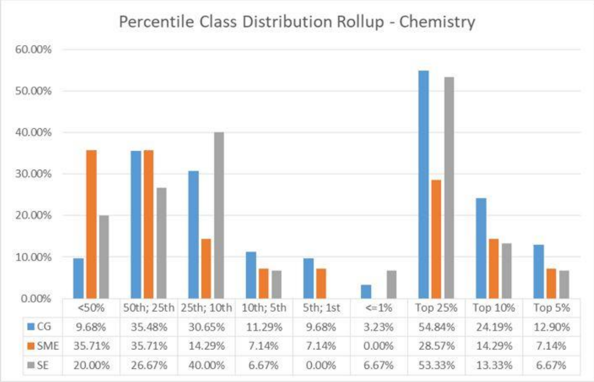
> (1) <50% (papers with a percentile greater than the 50th percentile),
> (2) 50% (papers within the 50th-25th percentile interval),
> (3) 25% (papers within the 25th-10th percentile interval),
> (4) 10% (papers within the 10th-5th percentile interval),
> (5) 5% (papers within the 5th-1st percentile interval),
> (6) 1% (papers with a percentile equal to or smaller than the 1st percentile).
> (Bornmann, 2013, p. 6)

One additional metric provided is a citation ratio between a PM's citation rate for their selection of papers by WOS subject and year and the average overall citation rate per paper for each WOS subject area by year. The Joint Committee of Quantitative Assessment of Research (2008) noted that citation ratios are not an appropriate mechanism for a central tendency in the face of right-skewed data. However, for a mission-oriented S&T enterprise which has a model geared toward knowledge diffusion, it is a worthwhile metric to understand the diffusion rate of papers funded by the enterprise in comparison to the overall average. The analysis includes an expected value (EV) metric calculated from the percentile rank class data. Visual analytics of the PM's performance showing a roll-up of all funded papers falling within the top 25%, 10%, and 5% allow for insightful comparisons between the three study groups. The EV indicator provides a single nominal value utilizing a probability mass function E(X) = $\sum_{k=1}^{K} \mathrm{x} * \mathrm{p}(\mathrm{x})$, where x represents the six categories of the rank classes, ranging from 1 for those papers in the lower 50 percentile to 6 for those in the upper 1 percentile. The theorectical lower limit of a PM's performance is 1 (all papers are in the bottom 50%) with the upper limit (all papers are in the top 1%) being 6. A medium performance by this indicator is "obtained by the sum of the products of percentile class proportions with the numbering classes: 0.50*1 + 0.25*2 + 0.15*3 + 0.05*4 + 0.04*5 + 0.01*6 = 1.9 (<50%, 50th, 75th, 90th, 95th, 99th)." (Bornmann & Mutz, 2011, 229).

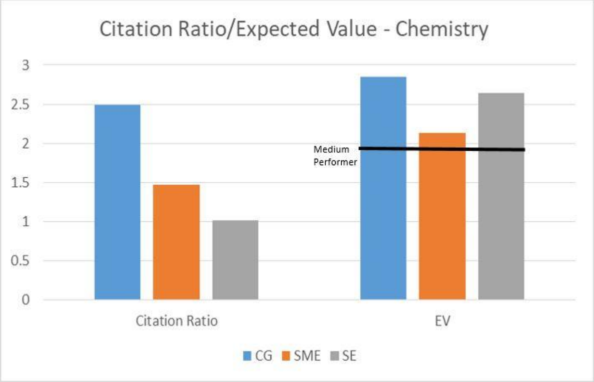
4.6 Results for Research Question 1

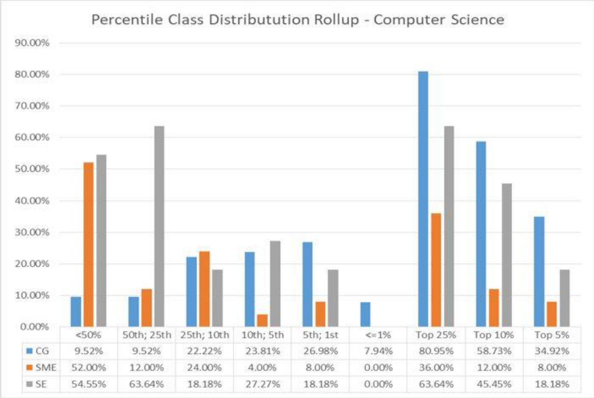
This research conducted bibliometric analysis to evaluate the effectiveness of two international engagement models in basic science utilized within a mission-oriented S&T Enterprise: the subject matter expert model and the shared equity model. Citation analysis of papers selected by program managers utilizing each of these models was studied and analyzed in the context of citation ratios and percentile rankings of the papers based upon their assigned WOS subject area and the year of publication. The analysis also included a control group of research selected by program managers within a stateside basic science office. The control group gives perspective as to the effectiveness of the international offices in the context of the DoD's International S&T Engagement Strategy goals of accelerating the pace of research and development and leveraging emerging global opportunities. Funding high impact science in areas of importance to the DoD accelerates the pace of research and development through greater knowledge diffusion, as reflected by higher citation rates of the projects funded. Greater knowledge diffusion presents more opportunities for advancements in select research areas. There were five categories of science under study: chemistry, computer science, life science, materials science, and physics. The data seem to support that the program managers from the control group and the two international models select research that has an impact on the field equivalent to or higher than that of similar papers published in the same WOS subject area during the same year (Figure 4-2). The control group, across all five areas of science, had an average of 61% of the research funded, making the top 25% of cited papers published for the same subject and year. Approximately 37% of the control group's papers funded were in the top 10%. Additionally, 21% were in the top 5%. For the international engagement investments, the subject matter expert model had 28% in the top 25%; 16% in the top 10%; and 6% in the top 5%. The shared equity model had 47% in the top 25%; 25% in the top 10% and 13% in the top 5%. The control group and the shared equity model were outside the study's sample size selection 5% margin of error for the numbers of papers found in each of the three (top 25%, top 10%, top 5%) percentiles. In one-on-one comparisons, the control group outperformed both international engagement models in the given percentiles across the five fields of science in 12 out of 15 areas. The shared equity model outperformed the subject matter expert model in 12 out of 15 areas. The shared equity model was the only international engagement model which outperformed the control group in any of these categories, having a higher percentage of its papers in three out of 15 categories: the top 25% for life sciences, top 10% for physics and the top

5% for physics. Two notable items in this study highlighted the performance of the control group's material scientist, in which 11% of research selected ending up in the top 1% of papers published and the control group's computer scientist, in which over 80% of research selected ending up in the top 25%. The expected value results, calculated with a probability mass function, showed that both international engagement models exceeded a medium performer, those with a spread of papers equally distributed according to the percentile classes, in four out of the five fields under study. The control group's expected value exceeded an average performance in all fields. The citation ratios of the control group ranged from a minimum of 2.5:1, with a high of over 5:1 for similar papers published in the same year and the same field. Both international models were more likely to generate overall citations at the same rate of similar papers published in the same year and the same field. Across both engagement models and five fields of science, their citation ratios were equal to or greater than 1:1 in eight out of ten fields. The subject matter expert model, however, had higher citation ratios than the shared equity model in three out of five science areas.

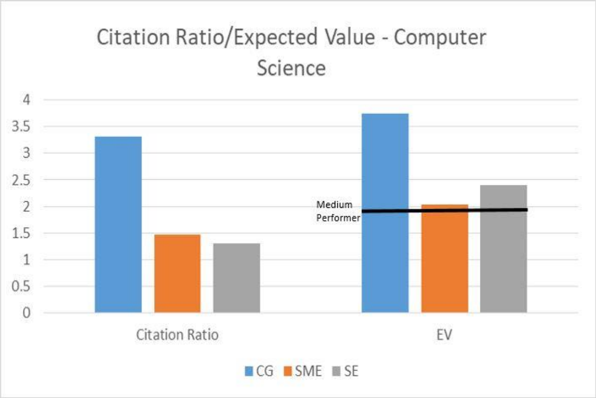


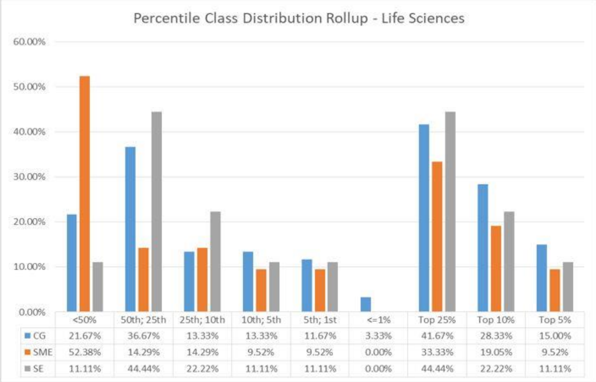
	<50%	50th; 25th	25th; 10th	10th; 5th	5th; 1st	<=1%	Top 25%	Top 10%	Top 5%
■ CG	9.68%	35.48%	30.65%	11.29%	9.68%	3.23%	54.84%	24.19%	12.90%
■ SME	35.71%	35.71%	14.29%	7.14%	7.14%	0.00%	28.57%	14.29%	7.14%
■ SE	20.00%	26.67%	40.00%	6.67%	0.00%	6.67%	53.33%	13.33%	6.67%



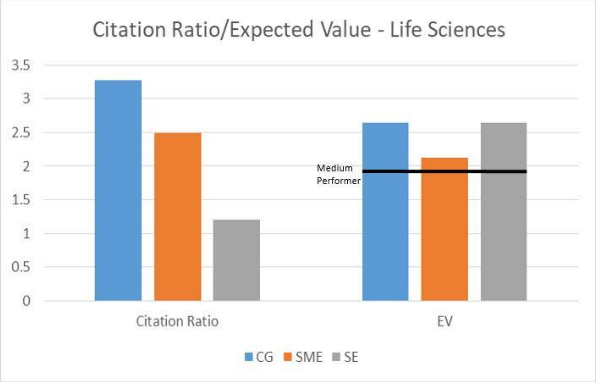


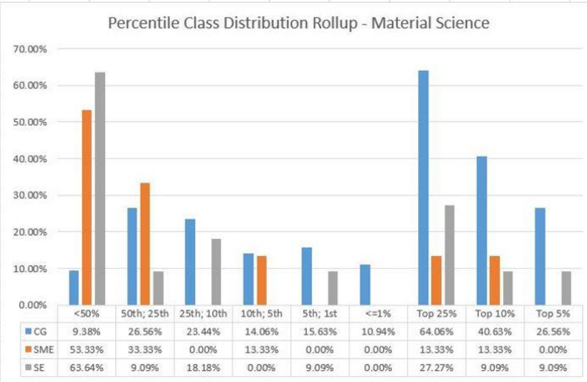
	<50%	50th; 25th	25th; 10th	10th; 5th	5th; 1st	<=1%	Top 25%	Top 10%	Top 5%
■ CG	9.52%	9.52%	22.22%	23.81%	26.98%	7.94%	80.95%	58.73%	34.92%
■ SME	52.00%	12.00%	24.00%	4.00%	8.00%	0.00%	36.00%	12.00%	8.00%
■ SE	54.55%	63.64%	18.18%	27.27%	18.18%	0.00%	63.64%	45.45%	18.18%



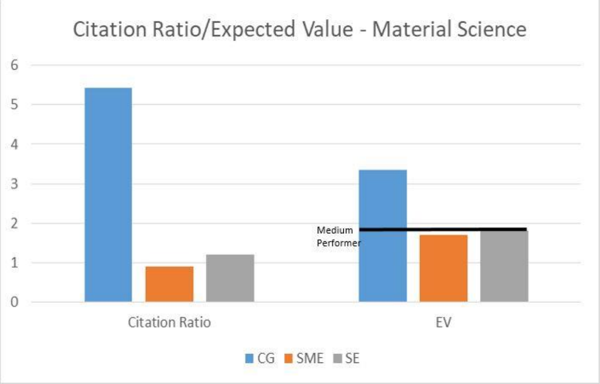


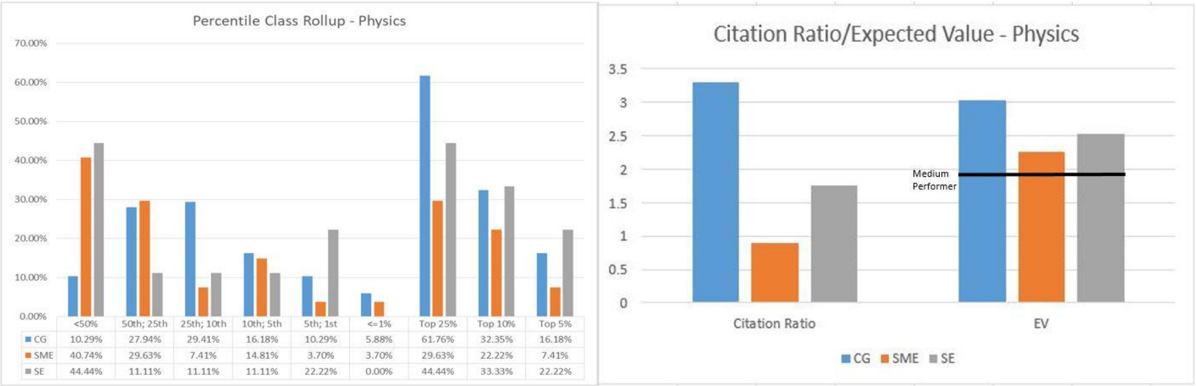
	<50%	50th; 25th	25th; 10th	10th; 5th	5th; 1st	<=1%	Top 25%	Top 10%	Top 5%
■ CG	21.67%	36.67%	13.33%	13.33%	11.67%	3.33%	41.67%	28.33%	15.00%
■ SME	52.38%	14.29%	14.29%	9.52%	9.52%	0.00%	33.33%	19.05%	9.52%
■ SE	11.11%	44.44%	22.22%	11.11%	11.11%	0.00%	44.44%	22.22%	11.11%





	<50%	50th; 25th	25th; 10th	10th; 5th	5th; 1st	<=1%	Top 25%	Top 10%	Top 5%
■ CG	9.38%	26.56%	23.44%	14.06%	15.63%	10.94%	64.06%	40.63%	26.56%
■ SME	53.33%	33.33%	0.00%	13.33%	0.00%	0.00%	13.33%	13.33%	0.00%
■ SE	63.64%	9.09%	18.18%	0.00%	9.09%	0.00%	27.27%	9.09%	9.09%





	<50%	50th; 25th	25th; 10th	10th; 5th	5th; 1st	<=1%	Top 25%	Top 10%	Top 5%
■ CG	10.29%	27.94%	29.41%	16.18%	10.29%	5.88%	61.76%	32.35%	16.18%
■ SME	40.74%	29.63%	7.41%	14.81%	3.70%	3.70%	29.63%	22.22%	7.41%
■ SE	44.44%	11.11%	11.11%	11.11%	22.22%	0.00%	44.44%	33.33%	22.22%

Figure 4-2 Percentile Class Results and Citation Ratio and Expected Value

4.7 Research Question 2

Of the science selected for funding, do overseas engagements identify emerging opportunities early?

4.8 Study Method

As pointed out by Cozzens et al. (2010) the concept of emerging technology has several dimensions of meaning. Of the five dimensions (time, strategic, type, sectorial, and discipline), this study will consider the strategic definition as being most appropriate considering that its use is part of the DoD's International S&T Engagement Strategy. By this definition, an emerging opportunity is considered research that is promising, diffusible, adaptable, potentially disruptive and characterized by faster than average growth. Small et al. (2014) sums it up nicely by associating emergence with newness and growth. It is reasonable to assume that high impact research may have a greater likelihood of being characterized as emerging over other research due to the interest it has generated through citation. Examining the same 159 projects drawn from the program manager portfolios of the international S&T offices used in the previous study, a down-select to those papers only falling within the top 10% published for the same year and in the same Web of Science subject category provides the basis for this study. The study consists of twenty-two papers from six different countries. As in the previous study, the same bibliometrics tool using an Apache Lucene text search engine will analyze 35,493,196 records from the science and proceedings index found within Thompson Reuter's Web of Science from January 1996 through November 2017. The title of each paper is parsed to identify major aspects of the research. Through co-word analysis, the tool identifies documents which are similar due to the co-occurrence of words or phrases. This search spans the entirety of the index and provides a chart showing the occurrence of these terms by year to give visual understanding as to when that aspect of the research emerged and proliferated. A comparison as to when the particular project received funding to this visual queue will indicate whether that aspect of the research was emerging or not when funded by the DoD. The various parsed aspects are combined and analyzed once again to determine if the combination of these aspects provides a basis for determining scientific emergence. Further analysis during each of these stages will compare when the U.S. first started funding research in this area against the nation of the recipient of the funding (Appendix 1). Although from the perspective of science as a whole, the research may not be emerging, it is of interest to note whether the selected country had some leadership in the field over the United States. Leveraging emerging global opportunities implies a level or caliber of science which might not be occurring within the United States. In this case, the U.S. is leveraging a capability that it has not necessarily fully developed. This study is not intended to identify current emerging topics, as others (Chen, 2005; Cozzens et al., 2010; Kleinberg, 2002) already have devoted much research effort toward this. Rather, it provides a retrospective as to whether program managers funding science for the DoD, in light of the DoD Strategy, are meeting the goals of the strategy.

4.9 Results Research Question 2

Of the twenty-two papers analyzed (Table 4-2) only two, or 9%, demonstrated a classic emergence pattern for some aspect of the research. The analysis showed a rapid growth rate in similar types of research following the year the DoD invested. There were six projects where it is unclear whether the funded research is emerging or not. The relative distance between the year of funding and the cutoff date (November 2017) of the data used for this study is the reason for this. Of these same projects, only six countries, or 27%, demonstrated that they emerged before the U.S. in some aspect of the research, with an additional four, 18%, emerging at the same time.

Table 4-2 Emerging Trends Rollup

Country	Parsed Aspects of Research - Search	Emerging			In Relation to the U.S.		
		Yes	No	Unclear	Before	After	Same
Australia	"catalytic alloy" / "graphene And silicon wafers" / "catalytic And graphene And silicon wafers"		✓			✓	
Australia	"quantum metrology" / "quantum metrology And biology"		✓				✓
Australia	"Quantum emission" / "Quantum And emission" / "Quantum And emission And boron nitride"			✓			✓
Australia	"next generation sequencing" / "next generation sequencing / Single nucleotide polymorphisms"		✓			✓	
Australia	"Tunable microwave photonic notch filter" / "Brillouinscattering" / "Tunable microwave photonic notch filter AND Brillouinscattering"			✓	✓		
Australia	"Hybrid photonic circuit" / "multiplexed heralded single photons" / ""Hybrid photonic circuit AND multiplexed heralded single photons"		✓			✓	
Australia	"Efficient Raman frequency conversion" / "high-power fiber lasers" / "high-power fiber lasers AND diamond"		✓			✓	
Italy	"bistable buckled beam" / "vibrational energy harvesting" / "bistable buckled beam AND vibrational energy harvesting"			✓			✓
Japan	"Spark plasma sintering" / "Spark plasma sintering And doped ceramics"		✓		✓		
Japan	"quantum network coding" / "quantum network coding And repeater"			✓	✓		

Country	Parsed Aspects of Research - Search	Emerging			In Relation to the U.S.		
		Yes	No	Unclear	Before	After	Same
Japan	"Germanium Vacancy" / "Germanium Vacancy AND Diamond" / " Single Color Centers AND Diamond"		✓			✓	
Korea	"b doped And Graphene" / "b doped And Graphene And Cathode" / "b doped And Graphene And cathode And solar cell"	✓				✓	
Singapore	"chirality selective synthesis" / "chirality selective synthesis AND single-walled carbon nanotubes" / "chirality selective synthesis AND single-walled carbon		✓			✓	
Singapore	"soliton fiber laser" / "soliton fiber laser And Wavelength-tunable" / "soliton fiber laser And Wavelength-tunable And Topological Insulator"			✓	✓		
Singapore	"Visual SLAM" / "Visual SLAM And Dynamic Environment" / "Collaborative Visual SLAM"		✓				✓
Singapore	"Direct Power Conversion OR Grid Integration" / "Direct Power Conversion OR Grid Integration AND AC/DC"			✓		✓	
Singapore	"Hybrid Perovskite" / "Lead-Free Hybrid Perovskite"	✓				✓	
Singapore	"Stable perovskite" / "Stable perovskite AND lead bromide"		✓			✓	
Singapore	"Phenomenological crystal plasticity modeling" / "detailed micromechanical investigations" / "detailed micromechanical investigations AND Magnesium" / "Phenomenological		✓			✓	
Taiwan	"germanium AND photodetector" / "backside And illuminated And photodetector" / "backside And illuminated And photodetector And		✓		✓		
Taiwan	"Centrality Analysis" / "Centrality Analysis And Social Networks" / "Analysis And Social Networks And Clustering" And "Analysis And Social Networks And Egocentric" / "Analysis And Social Networks And Clustering And		✓		✓		
Taiwan	"photonic microwave generation" / "photonic microwave generation And Stabilization" / ""photonic microwave generation And Stabilization And		✓			✓	

4.10 Discussion and Conclusion

These studies were intended to determine whether the DOD's funding of basic science overseas contributes toward its International S&T Engagement Strategy's goal of accelerating the pace of research and development by leveraging emerging global opportunities through the selection of high impact science. It does not appear that the overseas science office program managers have any great insight into selecting emerging research areas. Less than 10% of the high impact science selected by the overseas offices showed the distinctive rapid growth rate of an emerging area. Additionally, only 27% of the projects funded were from countries which might have had a technical headstart in the funded research area. These facts do not negate the benefits of funding research overseas but reflect the difficulty of selecting research which will spark the curiosity and imagination of others.

On the other hand, research funded by the DoD’s international offices has an above average expected frequency of publications falling within the top 25%, top 10%, and top 5% of similar papers published in the same field and same year. The type of engagement model does seem to play a role in the success of the international program managers. Those operating under the shared equity model outperformed the program managers working within the subject matter expert model by having a larger percentage of papers falling within those same frequency percentages. The stateside basic science office’s selections have an even higher frequency of being in these categories. This disparity, however, may be attributed to the fact that the preponderance of selected research from the basic science offices occurs within the United States. According to R&D Magazine’s 2018 R&D Funding Forecast, the United States still contributes 25.25% toward total global R&D spending. The breadth and sheer volume of research generated within the United States may present more opportunities for selection by the control group program managers to consider.

Further research should investigate at the individual program manager level whether there are discrete differences in the professional experience, activities, and efforts in selecting science and managing programs between the program managers stateside and those found overseas. A study as described may lead to insight that accounts for the differing impact on science between the two international models and the control group. Additionally, to quantify the benefit of funding overseas research, whether knowledge diffuses and is absorbed and utilized by the mission-oriented S&T enterprise is an area that merits further exploration.

Chapter 5 - Selection of Science

5.1 Literature Review

There are over 42,000 articles which contain the term “peer review” in Web of Science. For the scientific community, this is, of course, a topic worthy of discussion in that most researchers aim to publish in a peer-reviewed journal. Publication means validation of their work. There are a significant number of articles and editorials (Gannon, 2001; Govender, 2015; Jennings, 2006) which extol the virtues of the peer review process. Others provide caution to ensure the integrity or the essential role of the process remains intact (Kreiman, 2016; Twaij, Oussedik, & Hoffmeyer, 2014). Some (Alberts, Hanson & Keiner, 2008; Kohane & Altman, 2000) call for a revaluation of the whole system. With the advent of bibliometric methods, others (Abramo & D’Angelo, 2011; Smith & Marinova, 2005) have looked at the policy implications of whether technical analysis reflects research impact and whether it is a suitable replacement for peer reviews. Neufeld and von Ins (2011) would argue that single bibliometric indicators are not necessarily a useful replacement for peer reviews. A combination of indicators, both bibliometric and non-bibliometric, provide better predictions of funding decisions. Others have looked at the ethics of peer reviews and whether they are inherently discriminatory (Helmer, Schottdorf, Neef, & Battalglia, 2017; Wendler & Miller, 2014). Fields of science and research organizations (Gasparyan & Kitas, 2012; Lauer & Nakamura, 2015) are looking inward to ensure their peer review processes provide the best outcomes. Publications and research organizations like the NSF and NIH provide guides and overviews on how the peer review process functions internally to each. Nature Methods (2006) provided insight into their screening and acceptance of articles for publication. As noted previously in this paper, within the Department of Defense the program managers who fund basic science use a peer review process which includes outside entities from academia as well as other government research laboratories besides their in-house expertise. The National Research Council (2014) in their review of the DoD's international S&T program noted that there was an internal review process for the selection of science within the global offices, but the rigor of the process was questionable. Program managers within the international science office operating under the share equity model rely upon the peer review process system of their stateside customers. Program managers following the subject matter expert model follow local review and approval processes.

5.2 Research Gap

Research already presented in this paper demonstrated that there is a difference between the stateside basic science office and the international S&T offices in the outcome of selecting high impact science for funding. The individuals who act as the program managers perform three main functions which occupy their time: determining research thrust areas; finding projects to fund, and managing projects. Unfortunately, as in life, there are distractions which take time away from performing the main job tasks. At a high level, there is an enormous amount of research examining the peer review process, strategic investments and proposed methodologies for improving the whole scientific selection and funding system. Ultimately, however, this work is done by individuals. There is a significant gap in capturing and accounting for the daily activities of the program managers who select science for funding. Even more specific, within a mission-oriented S&T enterprise there is no research which accounts for the differences in outcomes in selecting high-quality science between program managers.

The differences in outcomes may be accounted for by professional experience or professional approach.

5.3 Research Question 3

Are there discernable characteristics, demographics and professional approach differences between program managers working under various engagement models?

5.4 Research Question 4

Are there any key characteristics of a successful engagement model which identify impactful science and scientists early?

5.5 Study Method

This study will examine through survey whether there are significant differences in the professional background or the approach in identifying science taken between program managers of the control group in a stateside basic science office and the program managers operating internationally, working either under the subject matter expert model or that of the shared equity model. As noted in a previous chapter, the control group's execution in selecting science outperformed both international engagement models in the percentage of papers falling in the given percentiles (top 25%, top 10%, top 5%) across five fields of science in 12 out of 15 areas. Professional experience or approach may explain the difference in results. Considerations such as school-age children, spousal career ambitions or desires, homeownership, financial implications and sundry other factors may impact a scientist's decision at specific points within a career to take an overseas assignment. This study will also examine whether the likelihood of having previous experience in academia, industry or government laboratories is more prevalent within one group over the others. Further, it will examine whether any of the groups have a higher propensity to publish in scientific journals, apply for patents or present at professional conferences. If the demographic differences (Table 5-1) cannot explain the different levels of success, the study will provide further examination of whether there are process approach differences in the conduct of selecting science. At a high level there are four primary functions (Table 5-2) which occupy the time of program managers: determining research thrust areas, finding projects to fund, managing projects, and tasks which distract from the business of science, such as mandatory training, administrative functions, and coordinating or participating in VIP visits. These tasks are broken down even further (Table 5-3) to determine if it is possible to identify the critical characteristics of a successful program manager. At the sub-task level, the study will first compare the control group program managers against the stateside basic science office average level of effort for each sub-task. The results will either show unique characteristics of the individual control group members or reflect that the control group does not misrepresent the stateside basic science office at the sub-task level. The study will then compare the control group members against the average level of effort for each sub-task in an international office operating under the subject matter expert model and the shared equity model. Since the control group members outperformed the international S&T offices, the study will determine if there are any levels of effort for a sub-task which demonstrate significant differences statistically. These results might provide unique insight as to why the stateside science offices were more effective than the international offices in selecting science. Statistical analysis through t-testing of two independent samples with unequal variance and chi-square testing for each of the survey data points, with significance level set at .05, will reveal whether there are statistically significant differences.

Table 5-1 Professional Background Data

Professional Background Data	
Scientific Field of Current Position	Subject Matter Expertise Outside Current Field of Work – Listed Fields
Organization	Number of Patents Awarded
Service – Army, Navy or Air Force	Number of Peer-Reviewed Publications Authored
Ph.D. Field of Study	Number of Professional Conference Presentations Given
Years Since Ph.D. – No. of Years	Number of Years Working in a Government Research Lab or Engineering Center
Postdoc Experience – Yes/No	Number of Years in Current Position
Academia Experience Beyond Postdoc – No. of Years	Number of Ongoing Projects in Portfolio
Industrial Experience – No. of Years	Dollar Value of Portfolio

Table 5-2 Major Performance Tasks Percentage of Time Spent

Major Performance Tasks Division of Labor – Percentage of Time Spent	
Selecting Research Thrust Areas	Managing Funded Projects
Selecting Projects to Fund	Distractors

Table 5-3 Major Performance Task Sub-Tasks

Major Performance Tasks Broken Down into Sub-Tasks Percentage of Effort Spent on Sub-Task		
Selecting Research Thrust Areas	Selecting Projects to fund	Managing Funded Projects
Reading Published Research	Reviewing Proposals	Visiting Primary Investigators
Visiting Other Government Labs	Visiting Primary Investigator Facilities	Corresponding/Speaking on the Phone with Primary Investigators
Visiting Academia	Corresponding/Speaking on the Phone with Primary Investigators	Reviewing Progress, Interim and Final Reports
Visiting Industry	Corresponding/Speaking on the Phone with Other Experts about a Proposal	Administratively Maintaining Project Records
Conducting Workshops with Expertise from	Organizing and Obtaining Peer Reviews	Preparation for Program Reviews

Government, Industry, and Academia		
Corresponding/Speaking with other Experts in the Field	Completing and Submitting Project Approval Packets	Other
Reviewing Operational needs/future Requirements Documents	Other	
Other		

5.6 Results

The first comparisons of this study examined the professional demographic differences between the control group program managers in the stateside basic science offices and those found in the overseas offices (Appendix 3). With a significance value set at .05, the comparison revealed that in 12 out of 15 areas there were no significant differences in the professional backgrounds of the basic science office program managers and the overseas science office program managers. There was not a higher likelihood of having in either office program managers who were new Ph.D.s or program managers who were newly assigned. Inexperience as a Ph.D. or as a program manager were not attributable characteristics which could explain the differences in results in the selection of high quality science between the stateside and overseas offices from the previous study. Program managers with PostDoc experience as well as academic, industrial and laboratory experience were equally prevalent. Those with self-proclaimed expertise outside of their currently assigned field, those awarded patents, and those who frequently presented at professional conferences were likely to be found in both offices. The study indicated that there were differences in three areas. Two of the areas were not demographic differences, but more the nature of the office worked in: the number of projects within a program manager’s portfolio and the dollar value of the portfolio. Both of these characteristics were statistically different. An explanation for this difference mainly reflects the budgetary differences between the stateside and international offices. The stateside science office has a more extensive budget than that of the international S&T office, and thus the number of projects and dollar value of ongoing projects are a reflection of this difference. It is feasible that with practice comes better results. However, since the study randomly selected the projects from the stateside program manager's portfolio, projects selected earlier in a career versus later were just as likely to be selected and would have been reflected in the results. It is doubtful that the number of projects and dollar value of ongoing projects impacted the success rate of the control group program managers. An equivalent analogy would assume that a stock fund with the highest portfolio dollar value will have better success than would a smaller fund. If one follows the stock market, we know this not to be true. The third area of significant difference was in the number of peer-reviewed publications written. The stateside office's program managers published at a much higher rate than that of the overseas science office program managers. Having more experience in writing peer-reviewed publications may affect an individual's performance in selecting science through the experience of knowing well the types of publishable research. Two program managers in the stateside basic science office were very prolific, and their numbers skewed the mean to the right. By eliminating these two from the sample, there is no significant difference at alpha = .05 between the program managers of the stateside science offices and the program managers of the overseas science offices. In comparing the breakdown of demographic data between the program managers of the two international office models (Appendix 4), there are no statistically significant differences between the individuals found in these two types of offices except when a program manager has industrial experience. In this case, the likelihood of having industrial experience is not different, but when they do have experience, there is a difference as to whether the experience occurred before or after earning a Ph.D. The lack of clearcut professional background differences is a prompt to continue with the study and examine the differences in approach in selecting science for funding.

In comparing the portion of time devoted as a whole to selecting research thrusts, selecting projects, managing projects, and distractions, chi-square testing revealed that there were no significant differences between the program managers of the stateside basic science offices and the overseas science offices as a whole (Appendix 5). On an individual comparison between each primary job performance task, t-testing also revealed that there were no significant differences. In comparing the program managers from the two international models, the same was found true except in time devoted to selecting science to fund. There was a statistically significant difference. The program managers of the shared equity model devoted 44% of their time to selecting projects. Program managers who operated under the subject matter expert model devoted only 23% of their time. An analysis at the sub-task level (Appendix 6) showed that the selected control group from the basic science office performed the sub-tasks consistently with the average of the basic science office sample. Knowing that the control group was a consistent representation of the basic science office the study compared the control group against the sub-task averages of the program managers of the international science office working under the subject matter expert model. There were no statistically significant differences except in the area of selecting projects for funding. Two out of the five control group program managers showed a statistically significant difference in how they went about selecting projects to fund. Program managers of the subject matter expert model devoted significantly more time to traveling and meeting with the primary investigators as well as doing the paperwork to submit a project approval packet. The control group program managers spent noticeably more of their time devoted to reviewing proposals and speaking with primary investigators on the phone versus visiting in person. When comparing the control group against the sub-task averages of the program managers of the international S&T office working under the shared equity model, there were no statistically significant differences found.

5.7 Discussion and Conclusion

This study set about to determine whether there are discernable characteristics, demographics and professional approach differences between program managers from the stateside basic science office control group and the overseas office program managers who operate under the subject matter expert model or the shared equity model. If there were distinctions, could they be used to explain the differences in results in the ability to identify impactful science and scientists early? Additionally, could the results be used to identify any critical characteristics of a successful program manager who identifies impactful science and scientists early? The demographic study revealed little difference in the range of experiences of the program managers found in each of the offices. The professional approach study did reveal some statistical differences in the time devoted to selecting projects to fund. As a percentage of overall time consumed, the shared equity model program managers devoted more of their time to selecting research. Since the shared equity model program managers seek out research for a customer, trying to find the right research to satisfy their customer requirements might explain the additional time devoted to selecting the right science.

Additionally, at the subtask level, two out of three control group program managers had statistical differences in the time devoted to selecting science when compared to the subject matter expert averages for those same subtasks. In comparing the control group program managers against the sub-task average of the shared equity program managers, there were no statistical differences. Intuitively it makes sense that more time devoted to the selection of science should lead to better results. The control group program managers are forced to spend more time selecting science for funding as a result of the more formal and established processes required by their organizations. The shared equity model program managers spend even more time since they are trying to satisfy their customer requirements. Program managers operating within the subject matter expert model have the most leeway in selecting science but ironically devote the least amount of time toward the selection of science. The study also revealed that distractions under the subject matter expert model were approximately 13% greater than those found in the control group and the shared equity model. This excess time used on distractions might account for the difference in time devoted to selecting science between both the control group and the shared equity model program managers.

Program managers in all offices must find the right balance between accomplishing all other tasks and that of selecting science. The study did not reveal any critical characteristics offering a definitive reason why one program manager was more successful than another. One control group program manager spent 60% of his time selecting science. This amount of time was the highest level of effort seen out of all three groups under study. As noted in the previous chapter, 11% of this program manager’s selected research ended up in the top 1% of papers published. However, the control group’s computer scientist witnessed over 80% of research selected ending up in the top 25%, and he only devoted 20% of his time to selecting science. There are statistical differences between the amount of time devoted to selecting science between the two international models of engagement. The previous chapter showed that the shared equity model is slightly more effective than the subject matter expert model in the selection of high impact science. This chapter revealed that the differences might be due to the amount of time devoted to the selection of science. It also revealed that program managers operating under the subject matter expert model seem to have more distractions than the other offices. A question which naturally arises is can the subject matter expert model reduce the amount of time devoted to distractions and allow more time for the selection of science to improve the outcome? On the other hand, since subject matter expertise already resides in the States (the shared equity model) whose sole job is to stay current and abreast of cutting-edge research in selected narrow fields, is it better to adopt this model as a good standard of practice for the international S&T offices?

Chapter 6 - Impact on Mission

6.1 Literature Review

In a system of innovation, diffusion is one of the main conceptual functions in the innovation process, which is to develop, diffuse and use innovations (Endquist, 2005). Research studying the diffusion of knowledge and specific technologies is abundant. Bruland and Mowery (2005) wrote extensively about the diffusion of technology during the first, second and what they describe as the third Industrial Revolution. They addressed diffusion characteristics such as diffusion speed, sectoral patterns of change, organizational impacts and relationships, and the evolution toward science-based innovation. They did so by citing specific examples ranging from the steam engine during the first, chemical industrial advances during the second, on to information and communications technology during the third Industrial Revolution. Hall (2005) compared the rates of diffusion of household technologies such as cordless phones, televisions, microwave ovens, and the personal computer. He determined that the pace of diffusion is tied to four influencing factors: the benefit received, the cost of adaptation, the industry in which it developed or the social environment surrounding its use, and the factors related to uncertainty and information availability about the technology. Others looked at specific industries. The Meiji Era Japanese Cotton Spinning Industry was a result of Japan having a competitive environment which allowed for knowledge diffusion to talented individuals. The system also weeded out incompetence (Braguinsky, 2015). Research on knowledge diffusion in the tire industry captured how manufacturers and dealers interacted directly with their customer to affect their buying decisions (Ahmad, Belal, & Shirahada, 2014). An examination of the Chinese Sock Industry indicated that the initial pattern of knowledge distribution throughout a cluster impacts the diffusion efficiency (Zhang, Xu, & Liu, 2011). Looking specifically at the spatial impacts, “the literature on knowledge diffusion shows that knowledge decays strongly with distance” (Bahar, Hausmann, & Hidalgo, 2014, p. 1). Others contend it is not just distance but factors such as cognitive and linguistic proximity that play an important role (Maftei, 2010). Instead of focusing on one industry, some researchers have examined how knowledge diffuses through organizational entities such as small to medium enterprises, communities of practice, innovation networks, social networks, global production networks, and strategic communities (Chen, Yang & Han, 2007; Ernst & Kim, 2002; Fink & Ploder, 2007; Neto, de Souza, & de Oliveira, 2010; Storck & Hill, 2000; Xing, 2013). There is abundant literature on mathematical modeling of knowledge diffusion. The Centre for European Economic Research studied the microeconomic linkages between knowledge transfer, knowledge diffusion, and network effects. Within their modeling framework knowledge transfer occurs between innovator and imitator. Knowledge diffusion occurs between innovators as well as imitators. The shape of the adoption pattern indicated whether or not knowledge diffusion occurred. They found that if knowledge transfer did occur, this indicated a stronger network effect, resulting in a unimodal adoption pattern. Slower knowledge transfer was an indication of the difficulty in establishing networks but showed that bimodal diffusion phenomena could occur (Klarl, 2014). The Federal Reserve Bank of Minneapolis modeled knowledge diffusion through personal discovery combined with social learning. They showed that fully specified economies could use these models and show that productivity growth contributes to consumption growth (Luttmer, 2015). Another group of researchers devised a multi-sector, multi-country endogenous growth model to study how innovation and knowledge diffusion affected changes in the cost of trade, comparative advantage, and welfare (Cai, Li, & Santacreu, 2017). Others have looked at the actual mechanisms of knowledge diffusion. Various papers suggest that international spillover from multinational activity diffuses knowledge through worker turnover and mobility (Dasgupta, 2008; Franco & Filson, 2006). Pulkki-Brannstrom and Stoneman (2013) found that international spillover might have a negative impact on countries which are late in adopting the technology. The potential for return is reduced and thus delays the date of adoption. Another study looked at returning Fulbright scholars who studied overseas. This study found that Fulbright Fellows from countries with a weak science base are cited more frequently in their home countries than articles by scientists from the same country who studied overseas but did not return. Additionally, Fulbright scholars cited home country-generated articles at a higher rate than their fellow researchers who stayed overseas (Kahn & MacGarvie, 2016). Trying to measure or trace knowledge diffusion has also spurred a great deal of research. Published or presented scientific papers are often the main venue for the diffusion of new knowledge. Many researchers have conducted a citation analysis to show the lineage of new thoughts or ideas. Visualization techniques combined with network theory can show strong or weak linkages between individual researchers and institutions (Wang, Yu, & Zhao, 2012). High connectivity within a network, either through citations or co-authorship, as well as those who occupy boundary spanning positions between communities, seems to perform better in knowledge creation and diffusion (Liu, Jiang, Chen, Larson, & Roco, 2014). Chen and Hicks (2014) utilized this same type of analysis on patent citations. Patent citation analysis within the field of nanoscience and nanotechnology (N&N) uncovered that the greatest contributions toward driving N&N forward came not from within the field itself but from outside fields like material science, physics, chemical engineering, and electronic and metallurgical engineering (Yu, Wang, & Yu, 2010). The use of bibliometrics for publication and citation analysis of research papers and patents attempts to trace the impacts and origin of knowledge flows. Research seems to indicate that the use of multiple metrics such as licensing, patents, citations and publications is preferable and strengthens the study of knowledge diffusion (Nelson, 2009; Rinia, Van Leeuwen, Bruins, Van Vuren, & Van Raan, 2002).

6.2 Research Gap

There is extensive literature on knowledge diffusion. Much of the research, however, doesn't address "knowledge diffusion" but examines technology diffusion. Technology, of course, is the instantiation of knowledge for practical purposes. Researchers have meticulously traced the historical circumstances and events which contributed to the invention of these technologies. They have studied the speed, mode, and pattern of diffusion as well as the cultural aspects behind why it occurred the way it did. Other research is very theoretically intense. This research centers on creating mathematical models based on various theories (complex network, social network, game, etc.) which estimate how knowledge may diffuse and what variables it may impact given a particular set of parameters. Other research looks at the mechanisms of diffusion such as spillover from the multinational industry, training, and education, as well as the Internet or via websites. Bibliometrics is a useful tool to help trace knowledge diffusion to determine who cited whom. If citations link to patented items, the inferred assumption is that the cumulative knowledge from the cited papers contributed to the instantiation of that technology, process or matter. There has been some attempt to differentiate and study the difference between knowledge diffusion and international knowledge diffusion, but generally, empirical studies on diffusion from an international perspective are limited (Stoneman & Battisti, 2010). Much of that research, however, studies the impact of distance on diffusion or addresses the outcome of the knowledge diffusion through some economic metric such as productivity growth or new business venture formation. Many nations have been collecting innovation statistics in the form of National Innovation Surveys. In 1992 a joint effort between the Office of Economic Cooperation and Development (OECD) and Eurostat resulted in the creation of a formalized and standardized innovation survey process referred to as the Oslo Manual. This manual

> defines what is meant by an innovation, the different ways in which an enterprise can innovate, ways of quantitatively measuring innovation on the input and on the output side, various degrees of novelty of innovation, and various questions regarding the sources, the effects, the obstacles and the modalities of innovation. (Mairesse & Mohnen, 2010, p. 1131)

These surveys, however, do not specifically address knowledge diffusion but do question the respondents about extramural research. The Japanese National Innovation Survey 2015 asks specifically whether the acquisition of knowledge and technology came from other sources and if so what were the sources: internal within the enterprise, external to the enterprise, from universities or government laboratories (National Institute of Science and Technology Policy [NISTP], 2015). The United Kingdom Innovation Survey 2014-2017 collected information on external R&D investments (Department for Business, Energy & Industrial Strategy, 2018). A 2016 OECD technical paper on testing innovation survey concepts looked at externally procured knowledge or technology, examining its impact on the activities of the organization as either high, medium or low (Fernando & Van Cruysen, 2016). A report published by the U.S. National Research Council (1997), "Industrial Research and Innovation Indicators," suggests that when creating innovation surveys, "in light of the prevalence of multiproduct firms, most data elements should be gathered at the business unit rather than at the enterprise level; a business unit reflects the firm's activities within a particular industry" (p. 31). There is a lack of research in studying the specific impact on knowledge diffusion for projects funded overseas and whether knowledge created diffuses back to the mission-oriented S&T enterprise and contributes to any individual researcher in any meaningful way. "Given that knowledge remains a major if diminishing source of competitive strength for U.S. industry, Government will have to develop a broader set of diffusion-oriented policies to complement its traditional emphasis on the generation of new knowledge through R&D" (Alic, 1992, p. 369).

6.3 Research Question 5

Do international engagement models affect knowledge diffusion and knowledge absorption within a mission-oriented S&T Enterprise?

6.4 Study Methods

This particular study continues with the analysis between the two international S&T engagement models: the subject matter expert model and the shared equity model. The research generated by the subject matter expert model either diffuses back through presentations at program reviews or the program manager sends it back to those who requested to maintain scientific cognizance of the research. Under the shared equity model, the program manager sends the research report back to those identified as "customers." Customers either share in the funding of the research, or for those without available funding, submit a request from their leadership asking that the international

S&T office fully fund the project. The international office may or may not fully fund the project, subject to the availability of their on-hand funds. This study used a simple qualitative survey to gauge how well the knowledge diffused back to the customer's organization and whether the research contributed to an ongoing internal research effort. Fifty-six individuals requesting to maintain scientific cognizance of research funded by program managers operating under the subject matter expert model and fifty-six customers of the shared equity program managers received the surveys. Customer investment under the shared equity model ranged as a percentage from zero to 100%. The analysis will include a study to determine whether the amount of contribution affected the knowledge utilization results under the shared equity model. The contribution bands under study include 0%, 1-33%, 34-66% and 67-100%. The survey (Figure 6-1) asked one simple question: What did you do with the research? On a sliding scale, left to right from worst to best, choices were given to gauge the impact of the investment on a mission-oriented S&T Enterprise. Choices and an explanation of each are as follows:

- Didn't Review the Report – a negative implication for S&T investments. A lost opportunity for impact. No chance for knowledge diffusion.

- Don't Recall the Research – slightly better than not reviewing the report at all. A little indication that the knowledge generated contributed to the collective knowledge of the enterprise.

- Reviewed Report, Disappointing Results, No Further Investigation Desired – an unsuccessful outcome that generated knowledge which informed the enterprise as a non-exemplar.

- Reviewed Report, Confirmed Presupposition, Didn't Impact Ongoing Efforts – knowledge generated did confirm some conceptual understanding. However, results were not significant enough to change ongoing research thrusts of the enterprise.

- Reviewed Report, Became Aware of New Research Direction – research outcome which generated new knowledge and research opportunities for the enterprise although no efforts were undertaken to exploit results.

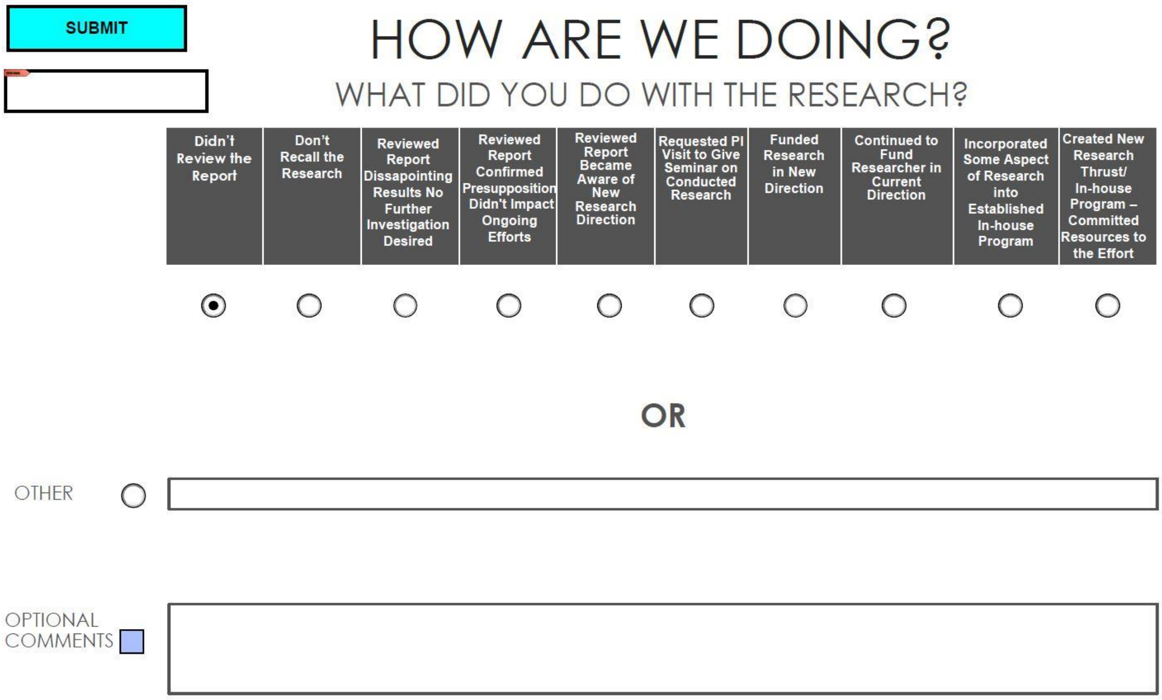
- Requested PI Visit to give Seminar on Conducted Research – a research outcome generating enough interest from the enterprise to garner further discussions with the investigator.

- Funded Research in New Direction – a research outcome was favorable to the mission goals of the enterprise, warranting further exploration although in a different direction.

- Continue to Fund Research in Current Direction – a research outcome was favorable to the mission goals of the enterprise, warranting continued funding.

- Incorporate Some Aspect of the Research into Established In-House Program – a research outcome in which generated knowledge is diffused, absorbed and utilized by the enterprise. An ideal end state for S&T investments.

- Created New Research Thrust, In-House Program, Committed Resources to the Effort – a research outcome so favorable as to impact the direction of the enterprise enough to require allocation of new resources or the reallocation of resources from other efforts. A most favorable outcome in fully absorbing and utilizing knowledge generated from S&T investments.



HOW ARE WE DOING?

WHAT DID YOU DO WITH THE RESEARCH?

Didn't Review the Report	Don't Recall the Research	Reviewed Report Dissapointing Results No Further Investigation Desired	Reviewed Report Confirmed Presupposition Didn't Impact Ongoing Efforts	Reviewed Report Became Aware of New Research Direction	Requested PI Visit to Give Seminar on Conducted Research	Funded Research in New Direction	Continued to Fund Researcher in Current Direction	Incorporated Some Aspect of Research into Established In-house Program	Created New Research Thrust/ In-house Program – Committed Resources to the Effort
●	○	○	○	○	○	○	○	○	○

OR

OTHER ○

OPTIONAL COMMENTS

Figure 6-1. Knowledge Diffusion Survey

There is a natural divide between negative implications and positive implications for the enterprise found within the survey. The response "reviewed report, became aware of new research" is deemed neutral. Although becoming aware of new research is an indication of knowledge transference and absorption, ultimately the end state goal for a mission-oriented S&T enterprise is the incorporation of that knowledge into ongoing activities. To the right of this selection are activities which reflect a more proactive involvement with the research. These include requesting seminars be given by the PI, continuing to fund the research or changing the direction of the research. These particular responses are a reflection that science is a continuum of ongoing research at various stages which may eventually reach a threshold where the knowledge can affect in-house efforts, as reflected by the survey's far-right responses which include incorporating the research into a current program or starting a new research thrust.

Trending to the left from the neutral position are outcomes which do not necessarily reflect a lack of knowledge diffusion and absorption but outcomes which generally characterize a more disappointing or passive result – one which does not change any ongoing activity within the enterprise. The far left of the survey has two of the more undesirable outcomes, reflecting that the research was not even studied or remembered. Rather than assigning Likert scale values to each of the responses, grouping the responses as either positive, negative or neutral should sufficiently show whether there are general trends when conducting a comparison of the two international S&T engagement models.

6.5 Results

Customers of the program managers operating under the shared equity model responded at an 83% rate. Individuals wanting to maintain scientific cognizance of research funded by program managers under the subject matter expert model responded at a 57% rate, significantly less. The data show that the shared equity model over the subject matter expert model generated more research, which garnered active involvement by the S&T enterprise and showed a more positive trend for the enterprise's international S&T investments in basic science (Figure 6-2). The shared equity model projects were predominantly positive, with 66% of the responses falling to the right of neutral, 19% at neutral and 15% to the left trending negative. The projects found under the subject matter expert model trended 22% positive, 16% neutral and 62% negative. The results show almost an inverse relationship between the two models, in which positive outcomes for the shared equity model are two-thirds of the responses whereas nearly two-thirds of the responses for the subject matter expert model trended toward the negative (Figure 6-3). Within the shared equity model, the level of investment by the customer did not seem to have an impact on the knowledge diffusion and utilization within the S&T enterprise. In other words, greater investment did not necessarily equate to a greater likelihood of absorbing and utilizing the knowledge. Projects funded as a percentage by the customer in no particular order with contributions from 0%, 1-33%, 34-66% to 67-100% bottomed out at 43% and achieved as high as 62% for survey responses having positive implications for S&T investments. Highlighting this fact, the shared equity model in which the customer committed zero funding to the research efforts ended up with the most projects, which created a new research thrust or in-house program (found on the far right side of the survey) after the conduct of the international research.

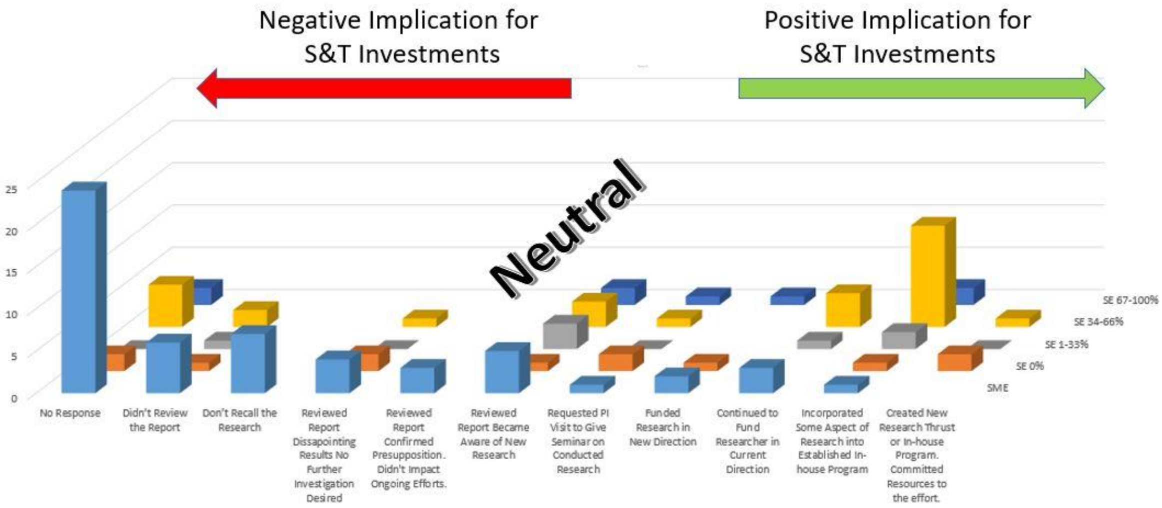


Figure 6-2. Diffusion Trends between the Two Modes of Collaboration

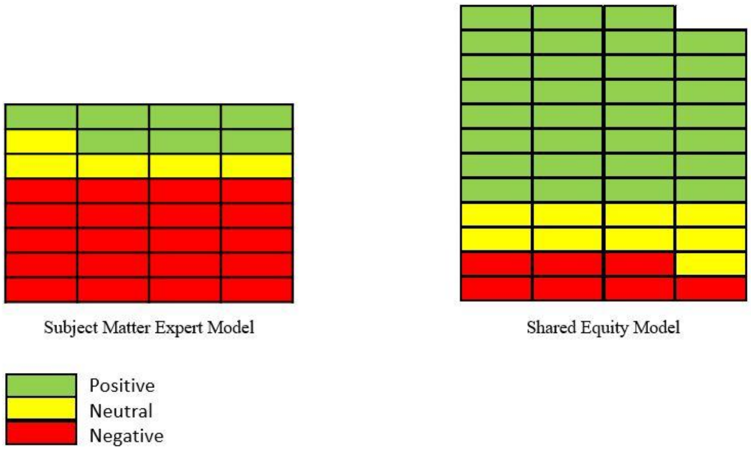


Figure 6-3. Sentiment Analysis between the Two Modes of Collaboration

6.6 Discussion and Conclusion

As described in Chapter 2, basic science feeds the applied research efforts which occur in the mission-oriented S&T enterprises' research laboratories. Externally funded research competes for funding with other externally funded research as well as with the laboratories’ in-house basic science efforts to move the science forward toward capabilities on behalf of the warfighter. The pressure applied by the warfighting and doctrine community to produce research results which deliver these capabilities is a constant tension. Those who manage and lead research efforts are recognized, promoted, or receive bonuses by developing science that delivers these results. “People tend to do more for their own benefit than for the benefit of others” (Sowell, 2015, p. 84). Government managers and employees are no different. The shared equity model provides more opportunities for managers and bench scientists to accelerate their efforts by leveraging external researchers and funding. The model requires a strong connection between what the goals of the research laboratory are and what is proposed to occur from overseas-funded science. The customers are actively involved in shaping the research so that they may potentially benefit from it. This model thus requires a target for the generated knowledge when it diffuses; otherwise, the research will not receive funding from the enterprise. The subject matter expert model, on the other hand, is a more passive model in which those who are tracking for scientific cognizance do so with little to no input in shaping the science. It is up to the subject matter expert to determine what the project is and where the investment should be. The program managers operating under this model do not have the first-hand knowledge nor insight that guides them in their allocation of resources that the shared equity model gets from their customer base. The shared equity model thus creates a market environment driven by the customer's benefit from the proposed research. There are negotiations back and forth between the customer organization and the overseas science office as to what the cost share should be. The overseas office may determine for the research proposed that the suggested cost share will not be a good allocation of their resources, as there may be other projects which may have stronger commitments or interest from other customer organizations. A market-like force, under the shared equity model, creates a more efficient allocation of resources through cost sharing of S&T investments overseas, as prices do for commercial goods in a commercial market. The shaping of the research and the upfront commitment of resources under the shared equity model may explain the more positive implications for knowledge diffusion and absorption within the enterprise than the subject matter expert model. It also might explain the overall response rate difference between the two surveys. In practicality, for a mission-oriented S&T enterprise a non-response to a survey for S&T investment knowledge utilization is a liability for both international engagement models. Without a feedback mechanism, a mission-oriented S&T enterprise cannot evaluate whether the overseas investments are meeting their objectives. Lack of feedback mostly represents lost opportunities. For researchers who generate knowledge which diffuses back to the enterprise and is absorbed and utilized, the overseas office is unaware. Further projects which leverage this research capability, or variations thereof, are potentially never discussed or are lost. Additionally, lack of a negative feedback loop does not allow the overseas offices to make adjustments to pursue other research thrusts which may provide more positive outcomes for the enterprise. Reexamining the sentiment analysis (Figure 6-3) and including a non-response as negative implications for S&T investments, the percentage spread between the two models changes very little. The percentage difference between the two models for positive indicator responses for actual survey results received was 44% in favor of the shared equity model. Including non-responses, as a negative implication, the difference between the two becomes 43%. For negative implication actual responses received, the difference between the two models is 48%, with the subject matter expert model having the greater number of negative responses. Incorporating non-responses as negative implications changes the difference to 50%. Under this analysis framework almost 80%, four out of five projects, funded under the subject matter expert model result in negative implications for the S&T dollars invested. On the other hand, 55%, over half of the projects funded under the shared equity model, contributed toward positive indications for the S&T enterprise.

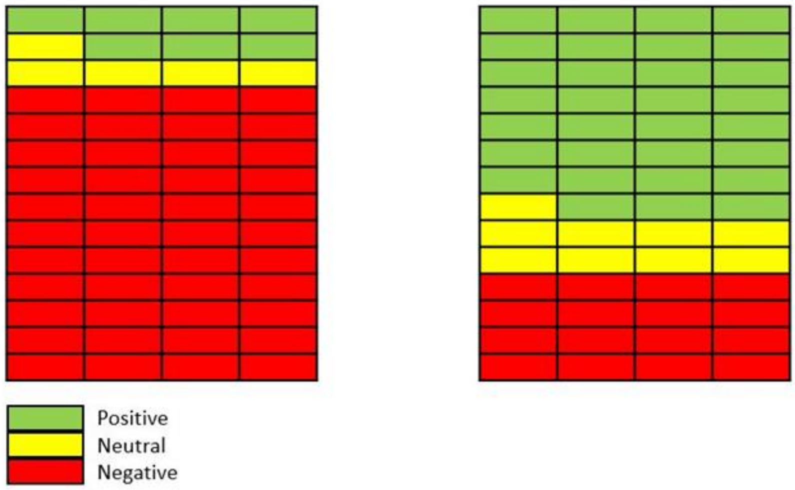


Figure 6-4. Sentiment Analysis Relooked with Non-Response Included

Chapter 7 - Conclusion

7.1 Summary

There is an axiom often misattributed to distinguished management consultant W. Edwards Deming which states that "if you can't measure it, you can't manage it." Deming stressed the importance of evaluating management strategies and processes through the use of data, and thus it seemed likely he would espouse this belief (Hunter, 2015). This dissertation at a micro-analysis level analyzed the activities of program managers, through data collection, working for the United States Department of Defense whose job is to find and fund basic science in academia and laboratories external to the DoD's inherent capabilities. More specifically, it examined whether there were discernible characteristic, demographic and professional approach differences between program managers working in the international science and technology offices and stateside basic science offices. Their fundamental mission is to seek out high impact science in a variety of scientific and engineering fields which will enhance and exploit new knowledge, with the goal of transforming future capabilities. Through the survey of program managers performing these functions in stateside and international offices, the study found minimal professional demographic differences between the individuals who occupied these positions. The study also examined the amount of labor each program manager devoted to the major aspects of their duties, which are to determine where to make strategic investments, finding projects which align with those investments and managing funded projects. The survey requested that the program managers account for their percentage of time devoted to each of these tasks and distractors. Furthermore, it had them break down each of these tasks into a percentage of time devoted to subtasks with the goal of identifying discernible professional approach differences which may account for different levels of success in selecting high impact science. Within this study, there were discernible differences. Program managers working within the international S&T offices performed their duties under one of two models: the subject matter expert model or the shared equity model. Program managers under the subject matter expert model are considered experts in their field and have considerable leeway in deciding which primary investigators and which projects get funded. The shared equity program managers must find a scientist or engineer back in the S&T Enterprise who is interested in the research before funding any primary investigator overseas. Chi-square testing revealed that there were no significant differences between the program managers of the stateside basic science office's control group and the overseas science offices as a whole in time devoted to major tasks and distractors. However, when comparing the two international modes of engagement models, there was a statistically significant difference. Program managers operating within the shared equity model devoted more of their time to selecting projects over those (44% to 23%) working under the subject matter expert model. At the subtask level, once again there were no significant differences between the program managers of the control group within the stateside basic science office and the program managers in the international S&T office working under the shared equity model. When the study analyzed the subtasks of the control group program managers in comparison to the subject matter expert breakdown, two out of the five control group program managers showed a statistically significant difference in how they went about selecting projects to fund. Program managers of the subject matter expert model devoted significantly more time to traveling and meeting with the primary investigators as well as doing the paperwork to submit a project approval packet. Control group program managers spent more of their time devoted to reviewing proposals and speaking on the phone versus visiting a primary investigator in person.

This dissertation also examined at the micro-analysis level, through citation analysis, the scientific impact of the projects selected by the program managers from five different disciplines of science—physics, material science, chemistry, computer science, and life sciences—working within the basic science office and the international offices. The study took papers published as a result of the program manager's selection of projects for funding and conducted a bibliometric study which placed them in a frequency distribution to see whether they fell within the top 25%, 10% or 5% of papers published for that field in the same year. It also examined whether a calculated expected value and citation ratio would exceed that of a perceived average program manager making the same selections in the same fields during the same year. Based upon the previous study, since there were differences between the amount of time devoted toward the selection of science, would there be a discernible difference in the percentages of papers falling within the top 25%, 10%, and 5% percentiles and would the expected value and citation ratios differ? The results of this study indicate that the program managers from the control group and the two international models selected research that had an impact on the field equivalent to or higher than that of similar papers published in the same subject field during the same year. The expected value results, calculated with a probability mass function, showed that both international engagement models exceeded medium performers, those with a spread of papers equally distributed according to the percentile classes, in four out of the five fields under study, while the control group's expected value exceeded an average performance in all fields. The international model's citation ratios were greater than an average performer in eight out of ten instances. Notably, the citation ratios of the control group ranged from a minimum of 2.5:1 to a high of over 5:1 for similar papers published in the same year and the same field. When making direct comparisons between the two international models the shared equity model program managers selected a higher percentage of their papers falling in the top 25%, 10%, and 5% percentiles 12 out of 15 areas over program managers of the subject matter expert model. The control group program managers outperformed both international engagement models in the given percentiles across the five fields of science in 12 out of 15 areas. The shared equity model was the only international engagement model which outperformed the control group in any of these categories, having a higher percentage of its papers in three out of 15 categories.

Additionally, this dissertation examined whether the projects selected by the international program managers supported the DoD International S&T Strategy goal of leveraging emerging opportunities in other nations. This study analyzed only those papers which fell within the top 10% published for the same year and the same subject area funded by the international offices. Only two of twenty-two papers, or 9% of the research, demonstrated a classic emergence pattern for some aspect of the research. Of these same projects, only 27% were from countries which had a technical headstart in the funded research area over the United States.

The final study within this dissertation examined whether the modes of international engagement affect knowledge diffusion, absorption, and utilization within a mission-oriented S&T Enterprise. It utilized a survey of customers of the shared equity model program managers and those wishing to maintain scientific cognizance under the subject matter expert model. The survey requested that the recipient of the research select on a sliding scale of choices how they utilized the knowledge generated by the research. Of the nine choices, three were considered to have negative implications for the S&T enterprise, one was considered neutral, and five choices were positive signs that the investments made generated knowledge of interest to the enterprise. Shared equity model projects were predominantly positive, with 66% of the responses falling in those categories and only 15% trending negative and 19% neutral. Subject matter expert model projects were predominantly negative, with 62% falling within those categories and only 22% trending positive and 16% neutral.

7.2 Policy Implications

Endquist (2005) who studied systems of innovation argued for the systematic study of the causes and determinants of the activities within an innovation system that will allow for the development of theories about the relations between the variables within the approach. He further stated that “Organizations or individuals perform the activities and institutions provide incentives and obstacles influencing these activities. In order to understand and explain innovation processes, we need to address the relations between activities and components, as well as among different kinds of components” (p. 196). This dissertation, through multi-level analyses examined the funding of basic science overseas on behalf of the United States Department of Defense. At a macro-analysis level, it analyzed the Department of Defense’s strategic intent in conducting international S&T engagements. Clearly stated the DoD’s strategic goals included improving U.S. capabilities, accelerating the pace of U.S. research and development, and leveraging emerging global opportunities. At a meso-analysis level, it analyzed the programs and structures of a military service S&T enterprise to understand how the system which was to support the DoD’s strategic goals functioned. This analysis revealed the magnitude of the interactions between the S&T enterprise, academia, and industry. Often redundant, widely varied and multidimensional, these interactions with academia and industry create a continuous dialog as well as a tension in which competing ideas vie for limited resources. The warfighting doctrine community exerts pressure so that the mission-oriented S&T enterprise keeps decisions focused on meeting the needs of the warfighter. This constant pressure from the warfighting community to show relevance has resulted in a competitive marketplace for new knowledge creation. The resulting scientific and engineering ecosystem is one with foundational underpinnings dependent upon the creation, diffusion, absorption, and utilization of new knowledge. The meso-level or operational analysis helped reveal the study methodologies needed to evaluate the programs and activities of the international offices in their role of supporting their Military Service. Finally, a micro-analysis of the actions and outcomes of program managers operating under different international S&T engagement models in selecting and funding basic science underlies systems of innovation theory that institutions provide incentives and obstacles which influence the system's activities. The subject matter model program managers spent more time on distractions and less time on selecting science than their peers operating under the shared equity model. It appears there is a correlation between the selection of high quality science and time devoted towards selection of science in that the shared equity model program managers outperformed the subject matter program managers in 12 out of 15 evaluated areas. The shared equity model's requirement to have a customer, prior to funding, is clearly more successful in diffusing overseas generated knowledge than the activities for diffusion under the subject matter expert model.

The DoD's international S&T offices have existed in some form or another since the 1950s, and yet a 2014 National Research Council Study on the

Defense Department's strategic engagements in global S&T collaboration revealed that the DoD had no criteria for evaluating outcomes. These offices may have served a different purpose after World War II than they do now. At that time and into the Cold War the U.S.'s need to leverage emerging global opportunities to accelerate the pace of U.S. research and development was minimal as the U.S. was at the forefront of much of the world's research. Periodically, policies need revisiting to ensure that the problems of the time remain as defined. More importantly, this dissertation underscored the need to establish evaluation criteria for proposed policies prior to implementation. This is critical so that monitoring and evaluations are purposeful and allow for adjustments if expected outcomes fail to occur. As this research revealed, niether model of international engagement was particuarly succesful in the selection of emerging research areas. Proper policy analysis might have precluded this goal from inclusion into the DoD strategy. Multi-level analyses provides those writing the policies better insight into into creating objectives which are not only beneficial but achievable. Furthering systems of innovation theory through real world examples and data, this research confirms the need for continued systematic studies to understand the causes and determinants of activities within the innovation process in order to shape those same activities. Demonstrated through the analysis of the DoD's innovation system from the strategic down to the program manager level, this dissertation revealed that it is possible to identify quantifiable mechanisms which allow those providing governance and management of international S&T investments the insight required so that they may achieve an optimal outcome.

7.3 Future Research Direction

The research conducted for this dissertation was only a small sample of the historical data available, especially in the stateside basic science offices. This research needs to continue with the evaluation of all data from all program managers to provide a normalized probability mass function expected value and citation ratio for the various fields of science. These indicators will give management of the basic science offices a quantitative metric to help evaluate the effectiveness of their program managers. From these indicators there will be certain program managers who stand out. Further micro-level analysis of their activities may bring more clarity as to what good practices are for program managers who perform these functions. Additionally, there needs to be research into automating this process. Currently, it is very time-consuming and labor-intensive. Finally, the knowledge flow survey also needs refining and automation. Within the S&T enterprise, the ability to trace knowledge created at various levels of science and engineering (basic research, applied research, advanced technology development, system development) does not exist. Having the ability to capture the diffusion, absorption, and utilization of knowledge from basic research through system development provides ample research challenges in quantifying each of these aspects and would support science and technology decision-makers in the budgetary process, strategic planning and resourcing.

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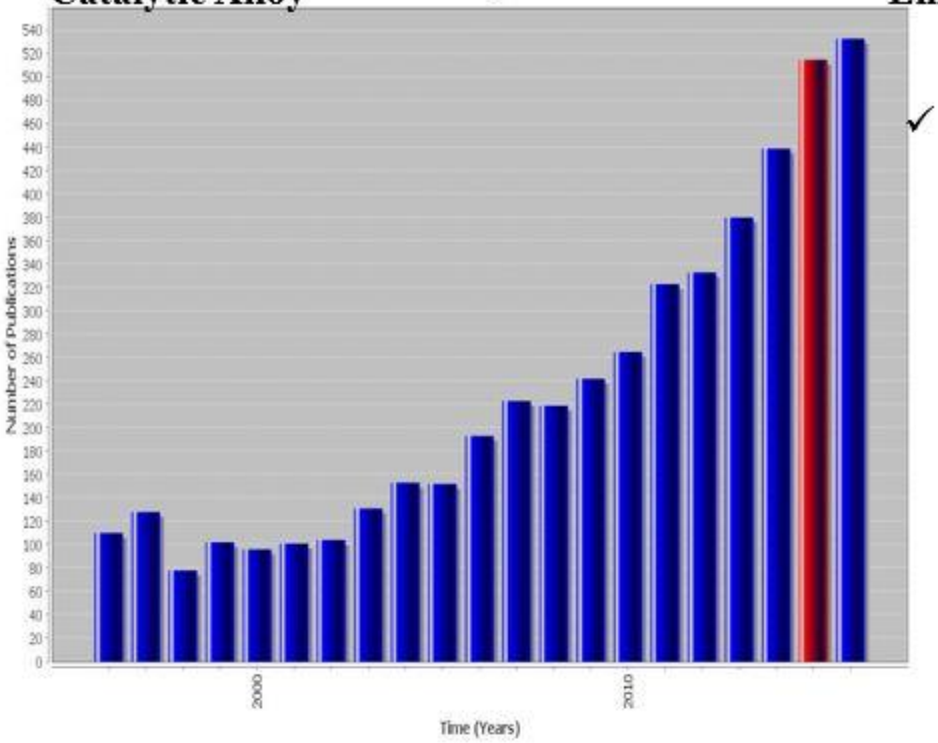
Appendices

Appendix 1 – Emerging Trends Analysis

Catalytic Alloy

Emerging

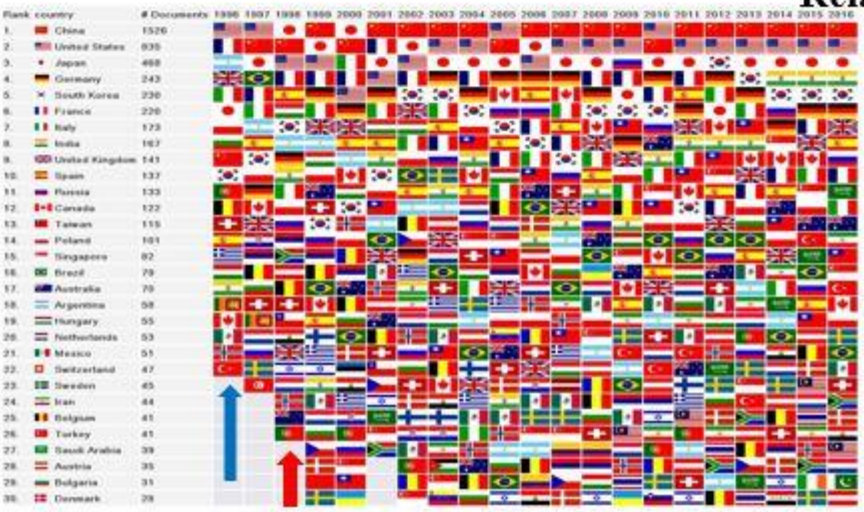


Yes

✓ No

Unclear

Relation to U.S.



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2.	United States	835
3.	Japan	468
4.	Germany	243
5.	South Korea	230
6.	France	220
7.	Italy	173
8.	India	167
9.	United Kingdom	141
10.	Spain	137
11.	Russia	133
12.	Canada	122
13.	Taiwan	115
14.	Poland	101
15.	Singapore	82
16.	Brazil	79
17.	Australia	70
18.	Argentina	58
19.	Hungary	55
20.	Netherlands	53
21.	Mexico	51
22.	Switzerland	47
23.	Sweden	45
24.	Iran	44
25.	Belgium	41
26.	Turkey	41
27.	Saudi Arabia	39
28.	Austria	35
29.	Bulgaria	31
30.	Denmark	29

Before

✓ After

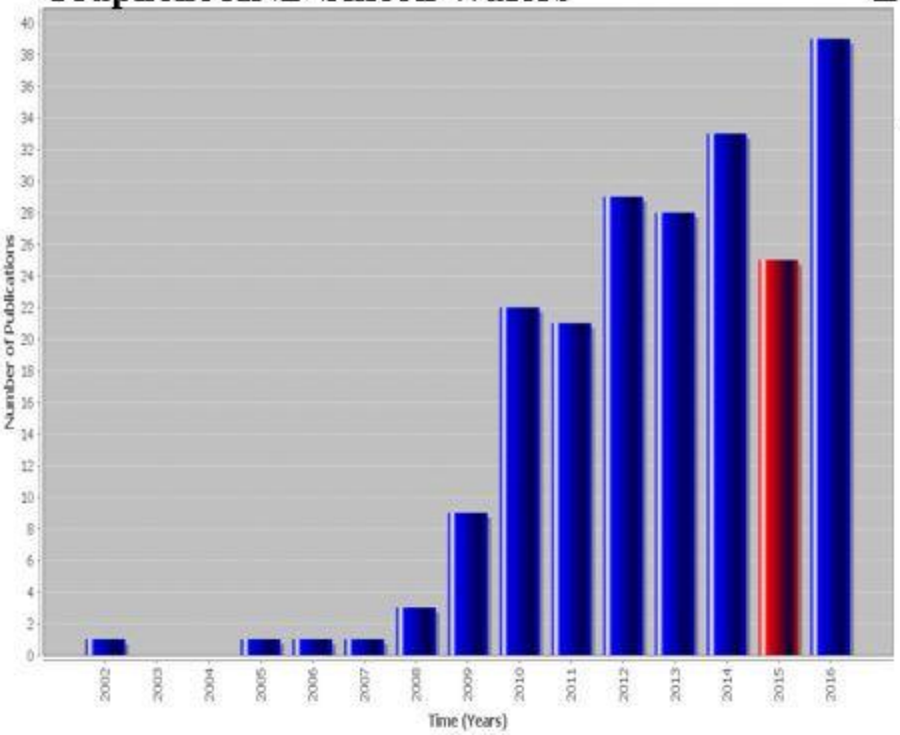
Same

Australia 🟥

U.S. 🟦

Graphene AND Silicon Wafers

Emerging



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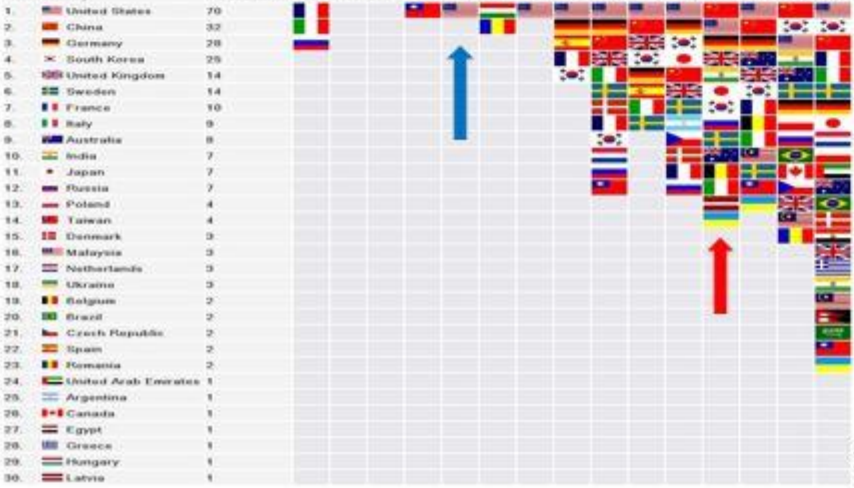
[✓ No]
Unclear

Relation to U.S.



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4.	South Korea	25
5.	United Kingdom	14
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7.	France	10
8.	Italy	9
9.	Australia	8
10.	India	7
11.	Japan	7
12.	Russia	7
13.	Poland	4
14.	Taiwan	4
15.	Denmark	3
16.	Malaysia	3
17.	Netherlands	3
18.	Ukraine	3
19.	Belgium	2
20.	Brazil	2
21.	Czech Republic	2
22.	Spain	2
23.	Romania	2
24.	United Arab Emirates	1
25.	Argentina	1
26.	Canada	1
27.	Egypt	1
28.	Greece	1
29.	Hungary	1
30.	Latvia	1

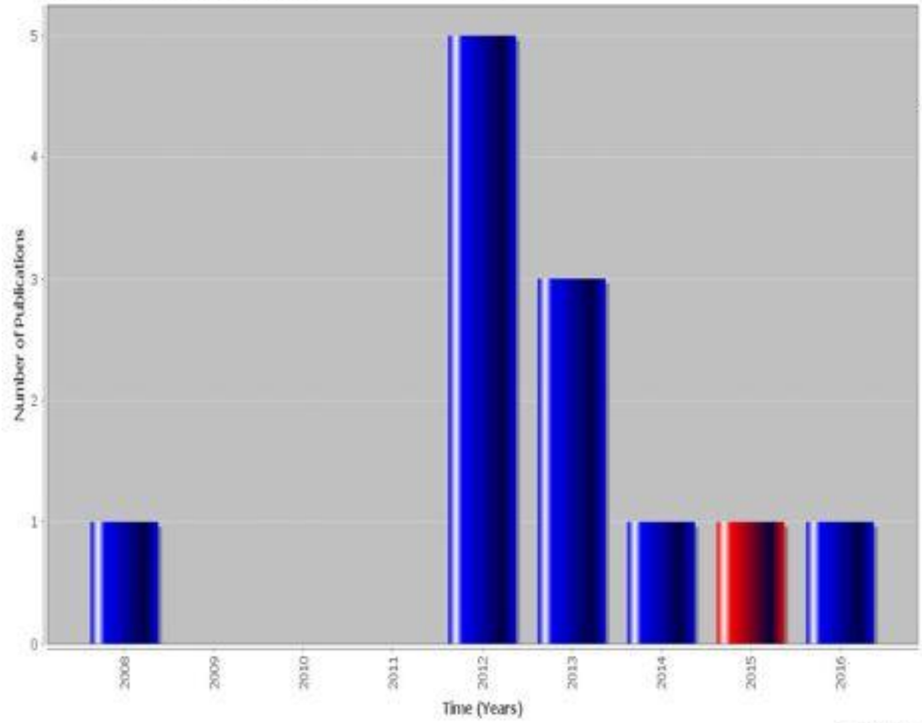
Before
[✓ After]
Same

Australia ➡
U.S. ➡

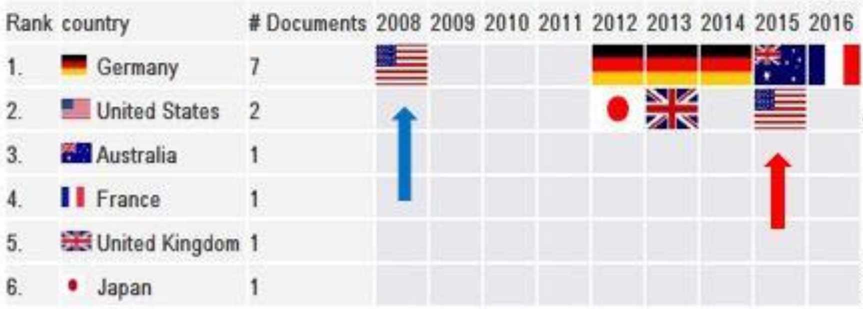
Graphene AND Silicon Wafers AND Catalytic

Emerging

Yes
✓ No
Unclear



Relation to U.S.



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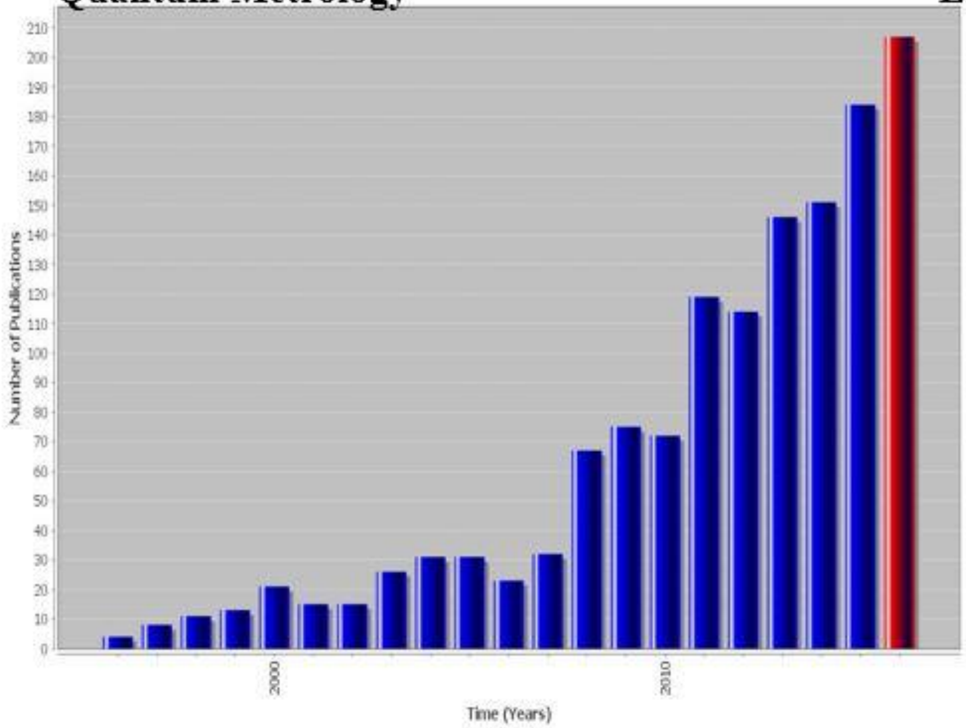
2.	United States	2	↑				🇯🇵	🇬🇧		🇺🇸	
3.	Australia	1								↑	
4.	France	1									
5.	United Kingdom	1									
6.	Japan	1									

Before
✓ After
Same

Australia →
U.S. →

Quantum Metrology

Emerging

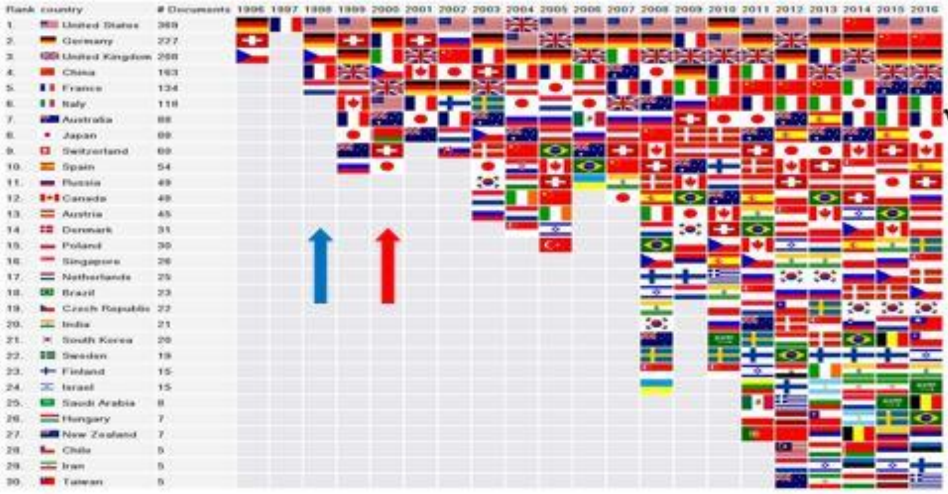


Yes

✓ No

Unclear

Relation to U.S.



Rank	country	# Documents
1.	United States	369
2.	Germany	227
3.	United Kingdom	208
4.	China	163
5.	France	134
6.	Italy	118
7.	Australia	88
8.	Japan	69
9.	Switzerland	69
10.	Spain	54
11.	Russia	49
12.	Canada	49
13.	Austria	45
14.	Denmark	31
15.	Poland	30
16.	Singapore	26
17.	Netherlands	25
18.	Brazil	23
19.	Czech Republic	22
20.	India	21
21.	South Korea	20
22.	Sweden	19
23.	Finland	15
24.	Israel	15
25.	Saudi Arabia	8
26.	Hungary	7
27.	New Zealand	7
28.	Chile	5
29.	Iran	5
30.	Taiwan	5

Before

✓ After

Same

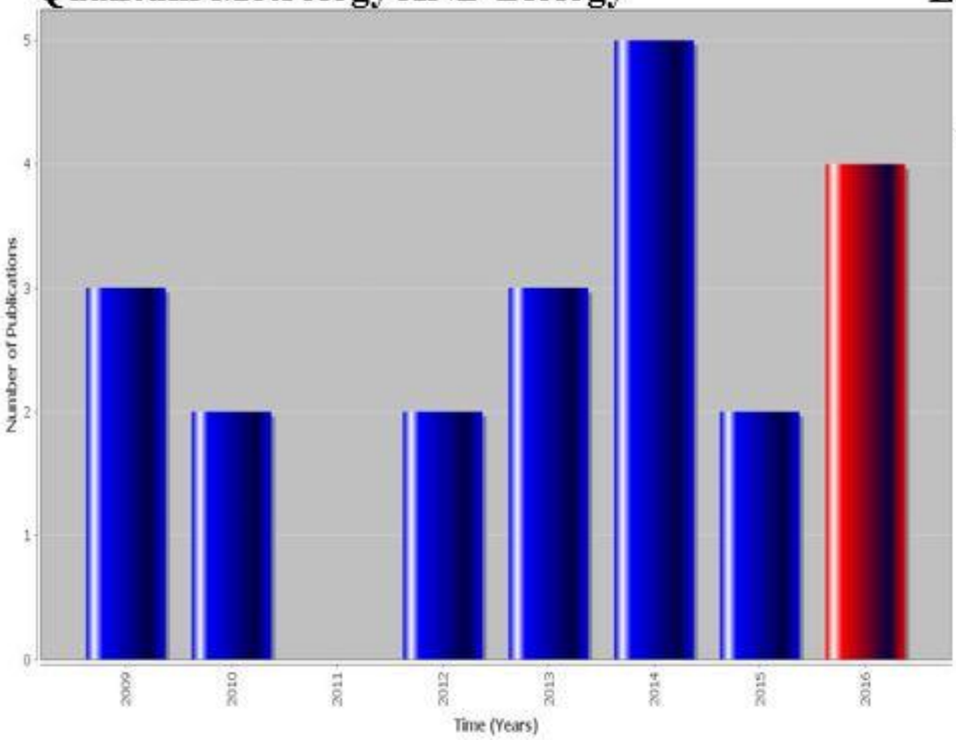
Australia →

U.S. →

Quantum Metrology AND Biology

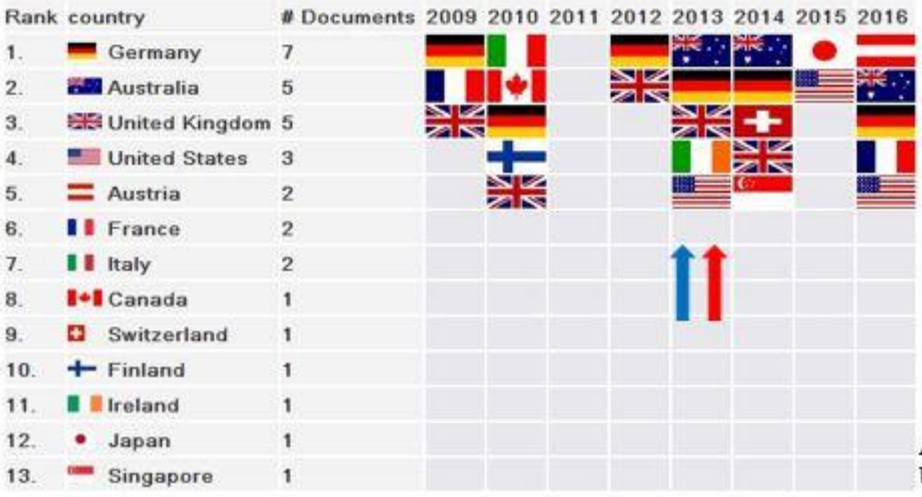
Emerging

Yes
[✓ No]
Unclear



Relation to U.S.

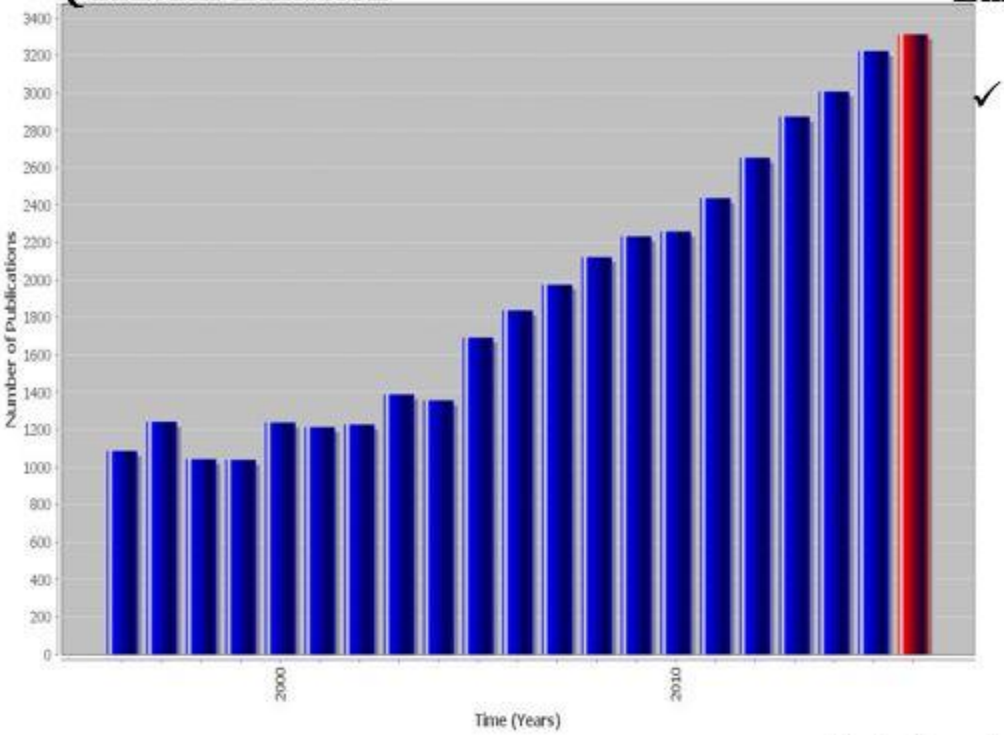
Before
After
[✓ Same]



Rank	country	# Documents	2009	2010	2011	2012	2013	2014	2015	2016
1.	Germany	7								
2.	Australia	5								
3.	United Kingdom	5								
4.	United States	3								
5.	Austria	2								
6.	France	2								
7.	Italy	2								
8.	Canada	1								
9.	Switzerland	1								
10.	Finland	1								
11.	Ireland	1								
12.	Japan	1								
13.	Singapore	1								

Australia ➡
U.S. ➡

Quantum Emission



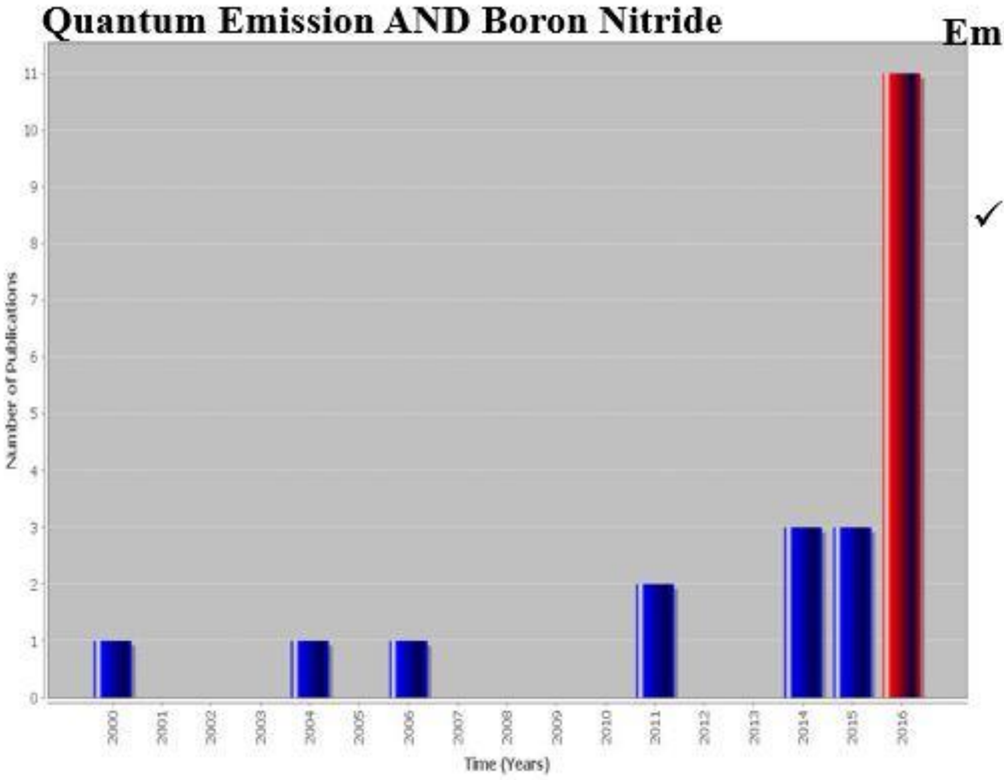
Emerging

Yes
[✓ No]
Unclear

Relation to U.S.

Rank	country	# Documents
1.	United States	[illegible]
2.	China	7941
3.	Germany	4316
4.	Japan	3735
5.	United Kingdom	2612
6.	France	2480
7.	Russia	1899
8.	South Korea	1864
9.	India	1651
10.	Italy	1553
11.	Taiwan	1437
12.	Canada	1147
13.	Spain	1060
14.	Poland	977
15.	Switzerland	817
16.	Brazil	655
17.	Sweden	623
18.	Netherlands	615
19.	Singapore	542
20.	Australia	534
21.	Austria	453
22.	Ukraine	377
23.	Israel	365
24.	Portugal	334
25.	Belgium	314
26.	Iran	298
27.	Mexico	264
28.	Denmark	260
29.	Turkey	256
30.	Ireland	244

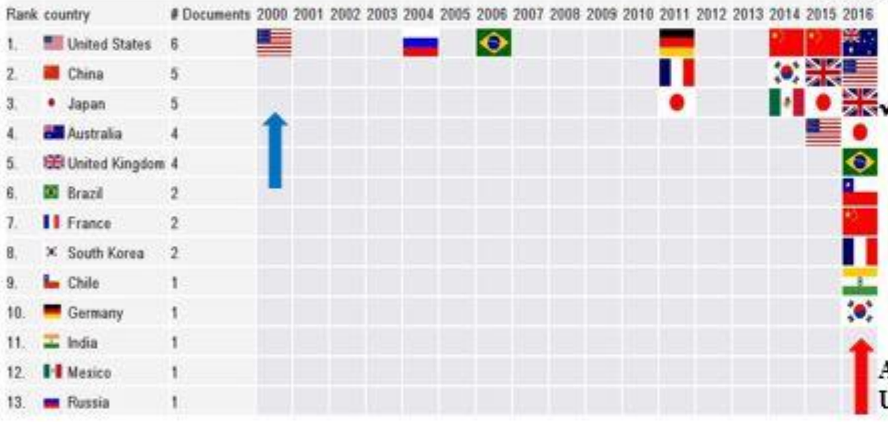
Before
After
[✓ Same]


Quantum Emission AND Boron Nitride

Emerging

Yes
No
[✓ Unclear]

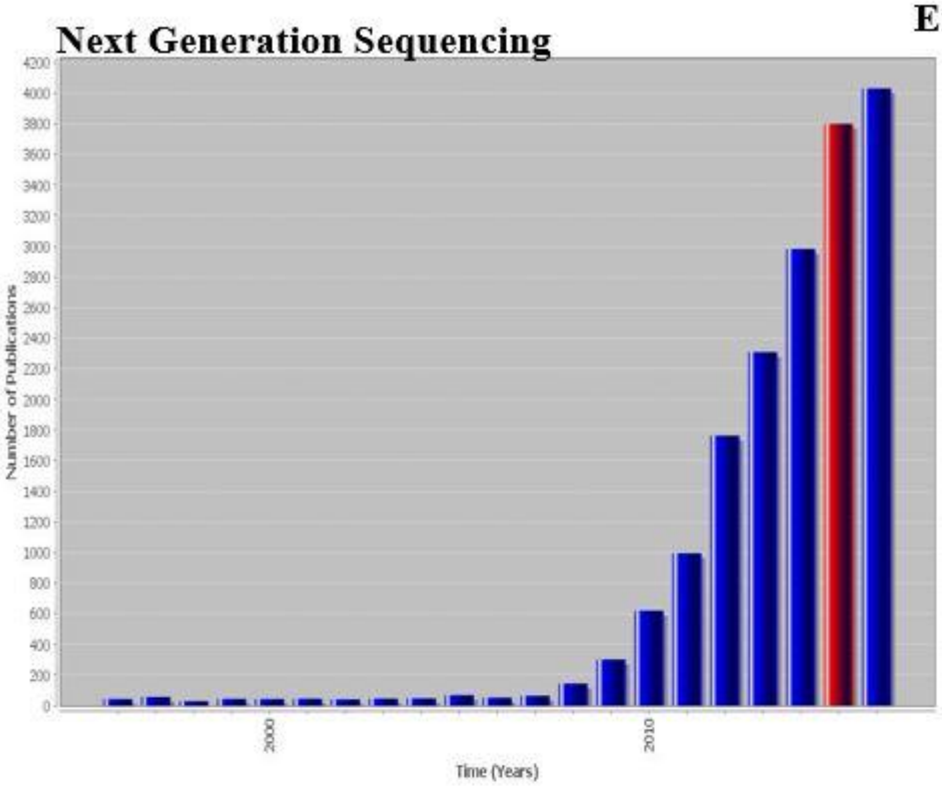
Relation to U.S.



Rank	country	# Documents
1.	United States	6
2.	China	5
3.	Japan	5
4.	Australia	4
5.	United Kingdom	4
6.	Brazil	2
7.	France	2
8.	South Korea	2
9.	Chile	1
10.	Germany	1
11.	India	1
12.	Mexico	1
13.	Russia	1

Before
[✓ After]
Same

Australia →
U.S. →


Next Generation Sequencing

Emerging

Yes
[✓ No]
Unclear

Relation to U.S.

Before
[✓ After]
Same

Rank	country	# Documents
1.	United States	7640
2.	China	1763
3.	United Kingdom	1747
4.	Germany	1657
5.	France	945
6.	Canada	919
7.	Italy	903
8.	Japan	874
9.	Australia	784
10.	Netherlands	691
11.	Spain	682
12.	South Korea	399
13.	India	365
14.	Switzerland	359
15.	Sweden	356
16.	Belgium	327
17.	Denmark	294
18.	Taiwan	284
19.	Brazil	278
20.	Austria	247
21.	Czech Republic	175
22.	Poland	168
23.	Singapore	162
24.	Israel	152
25.	Finland	145
26.	Turkey	143
27.	South Africa	138
28.	New Zealand	135
29.	Norway	131
30.	Saudi Arabia	119

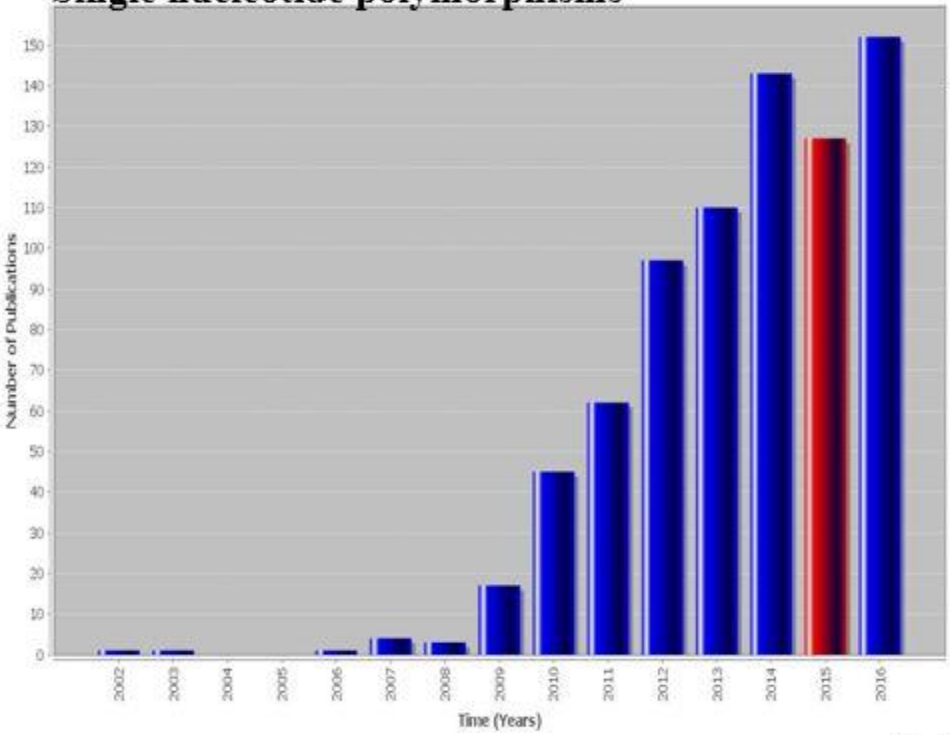
Next Generation Sequencing AND Single nucleotide polymorphisms

Emerging

Yes

✓ No

Unclear

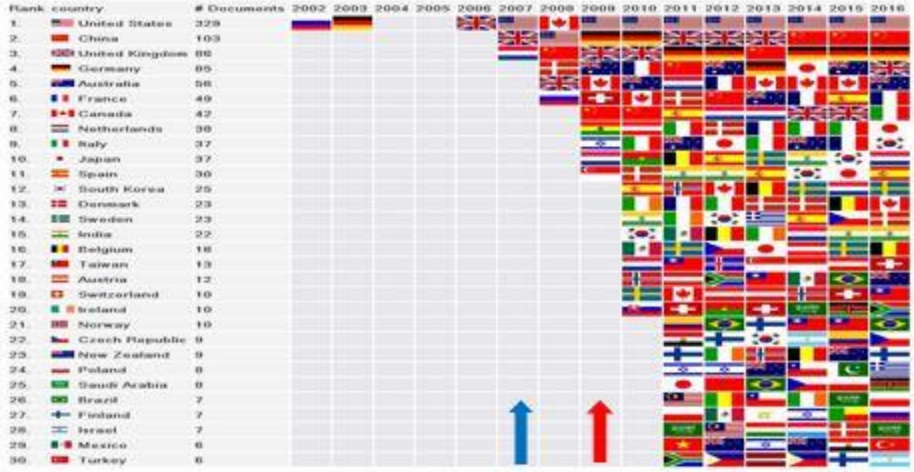


Relation to U.S.

Before

✓ After

Same

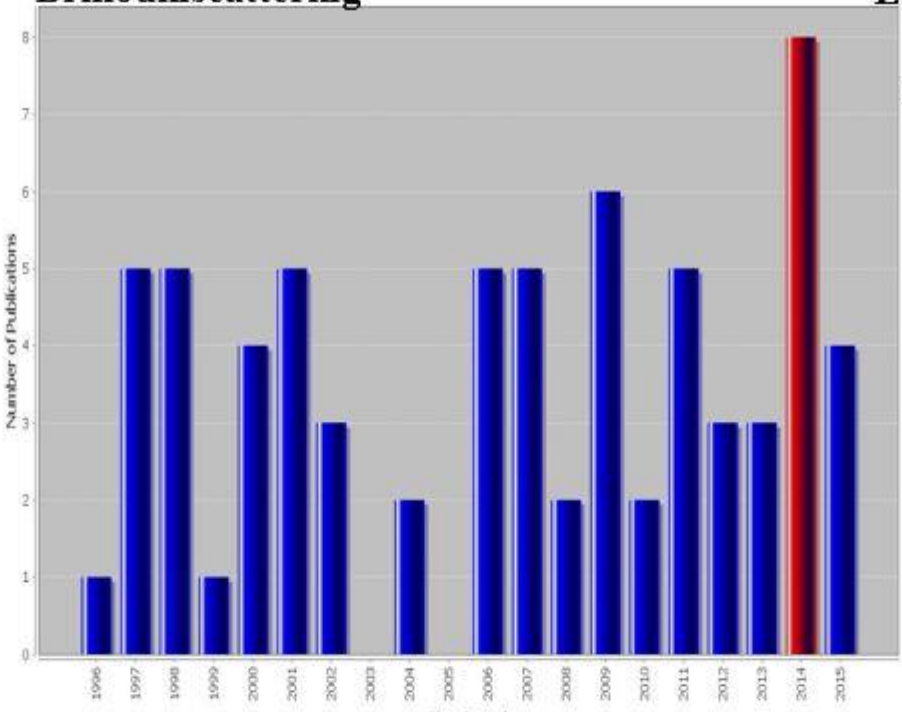


Rank	country	# Documents
1.	United States	329
2.	China	103
3.	United Kingdom	88
4.	Germany	85
5.	Australia	58
6.	France	49
7.	Canada	42
8.	Netherlands	38
9.	Italy	37
10.	Japan	37
11.	Spain	30
12.	South Korea	25
13.	Denmark	23
14.	Sweden	23
15.	India	22
16.	Belgium	18
17.	Taiwan	13
18.	Austria	12
19.	Switzerland	10
20.	Ireland	10
21.	Norway	10
22.	Czech Republic	9
23.	New Zealand	9
24.	Poland	8
25.	Saudi Arabia	8
26.	Brazil	7
27.	Finland	7
28.	Israel	7
29.	Mexico	6
30.	Turkey	6

Australia 🟥

U.S. 🟦

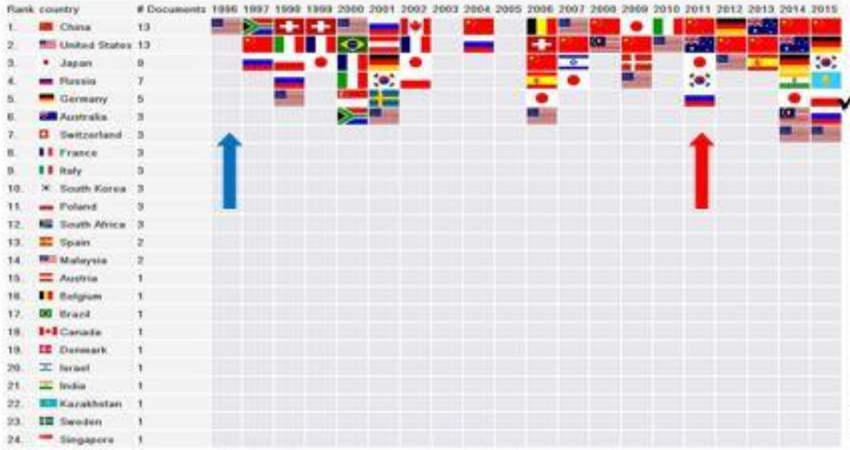
Brillouinscattering



Emerging

Yes
[✓ No]
Unclear

Relation to U.S.

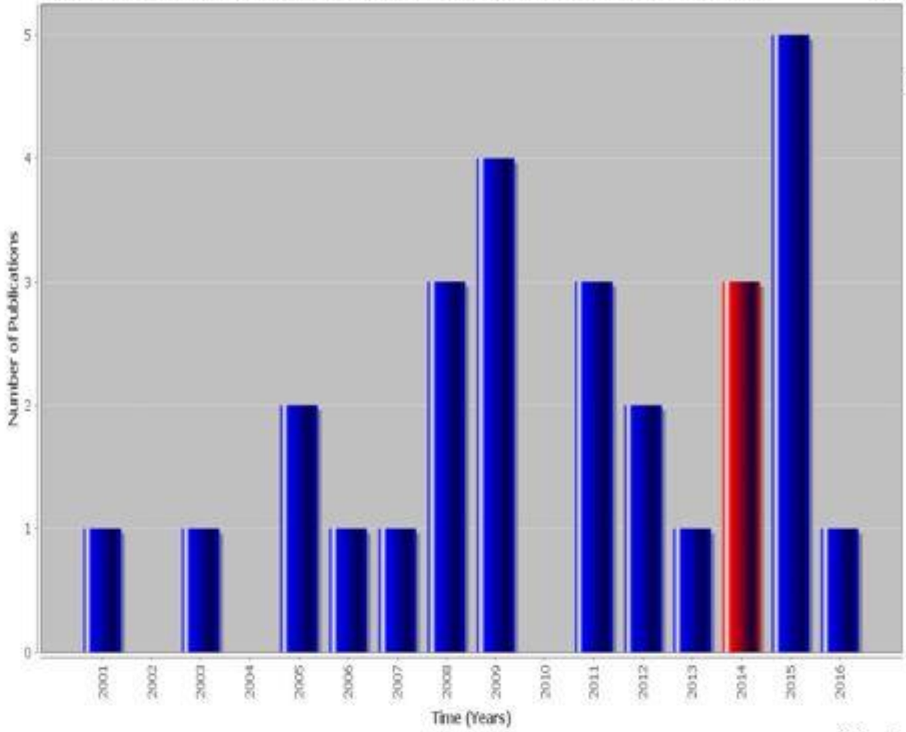


Rank	country	# Documents
1.	China	13
2.	United States	13
3.	Japan	9
4.	Russia	7
5.	Germany	5
6.	Australia	3
7.	Switzerland	3
8.	France	3
9.	Italy	3
10.	South Korea	3
11.	Poland	3
12.	South Africa	3
13.	Spain	2
14.	Malaysia	2
15.	Austria	1
16.	Belgium	1
17.	Brazil	1
18.	Canada	1
19.	Denmark	1
20.	Israel	1
21.	India	1
22.	Kazakhstan	1
23.	Sweden	1
24.	Singapore	1

Before
[✓ After]
Same

Australia →
U.S. →

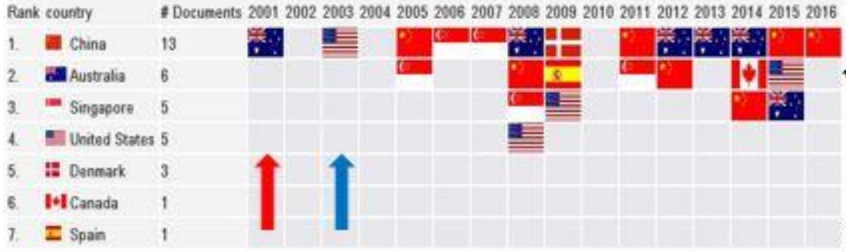
Tunable Microwave Photonic Notch Filter



Emerging

Yes
[✓ No]
Unclear

Relation to U.S.



Rank	country	# Documents	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
1.	🇨🇳 China	13	🇦🇺		🇺🇸		🇨🇳	🇸🇬	🇸🇬	🇦🇺	🇩🇰		🇨🇳	🇦🇺	🇦🇺	🇦🇺	🇨🇳	🇨🇳
2.	🇦🇺 Australia	6					🇸🇬			🇨🇳	🇪🇸		🇸🇬	🇨🇳		🇨🇦	🇺🇸	
3.	🇸🇬 Singapore	5								🇸🇬	🇺🇸					🇨🇳	🇦🇺	
4.	🇺🇸 United States	5								🇺🇸								
5.	🇩🇰 Denmark	3																
6.	🇨🇦 Canada	1																
7.	🇪🇸 Spain	1																

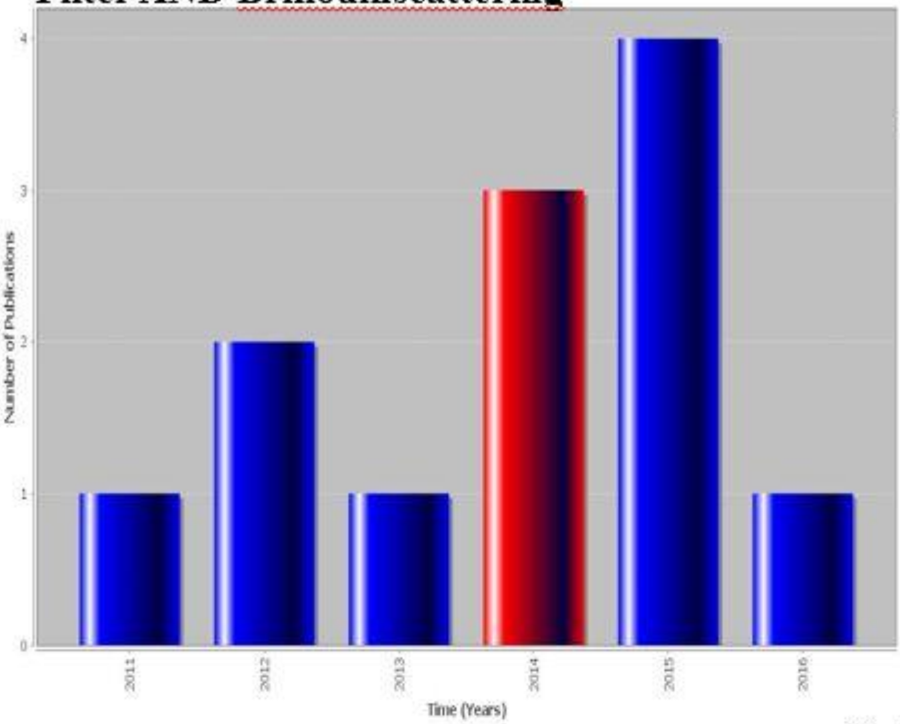
[✓ Before]
After
Same

Australia →
U.S. →

Tunable Microwave Photonic Notch Filter AND Brillouinscattering

Emerging

Yes
No
✓ Unclear



Relation to U.S.

✓ Before
After
Same

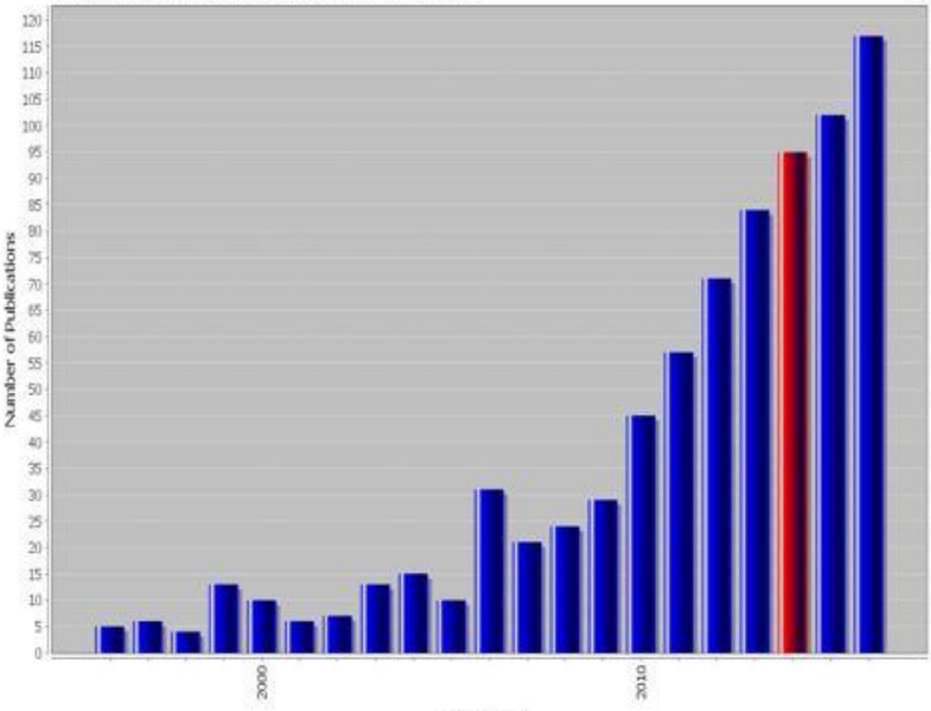
Australia →
U.S. →

Rank	country	# Documents	2011	2012	2013	2014	2015	2016
1.	🇦🇺 Australia	8	🇨🇭	🇦🇺	🇦🇺	🇦🇺	🇦🇺	🇦🇺
2.	🇨🇳 China	3		↑		🇨🇦	🇨🇳	
3.	🇨🇦 Canada	1				🇨🇳		
4.	🇨🇭 Switzerland	1						

Hybrid Photonic Circuit

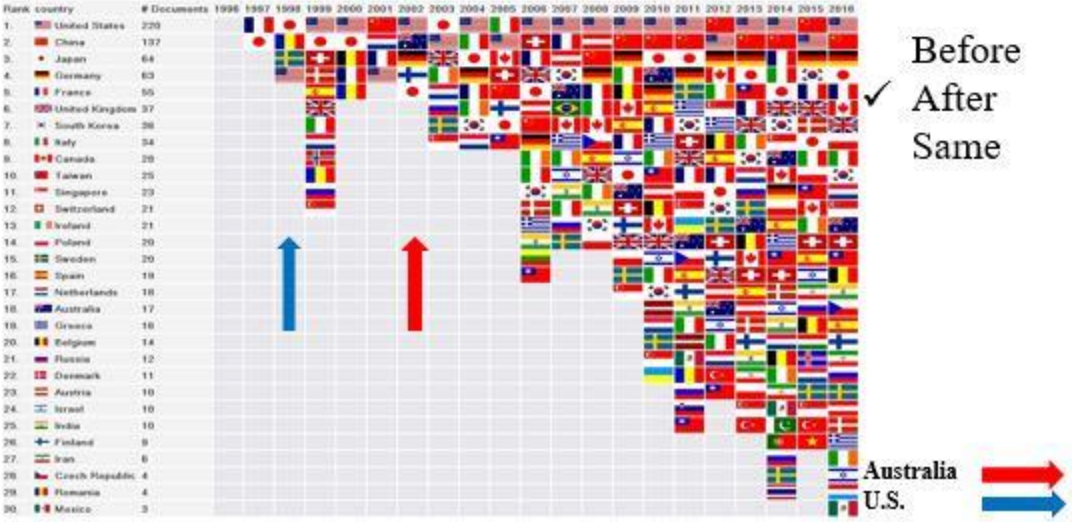
Emerging

Yes
✓ No
Unclear



Relation to U.S.

Before
✓ After
Same

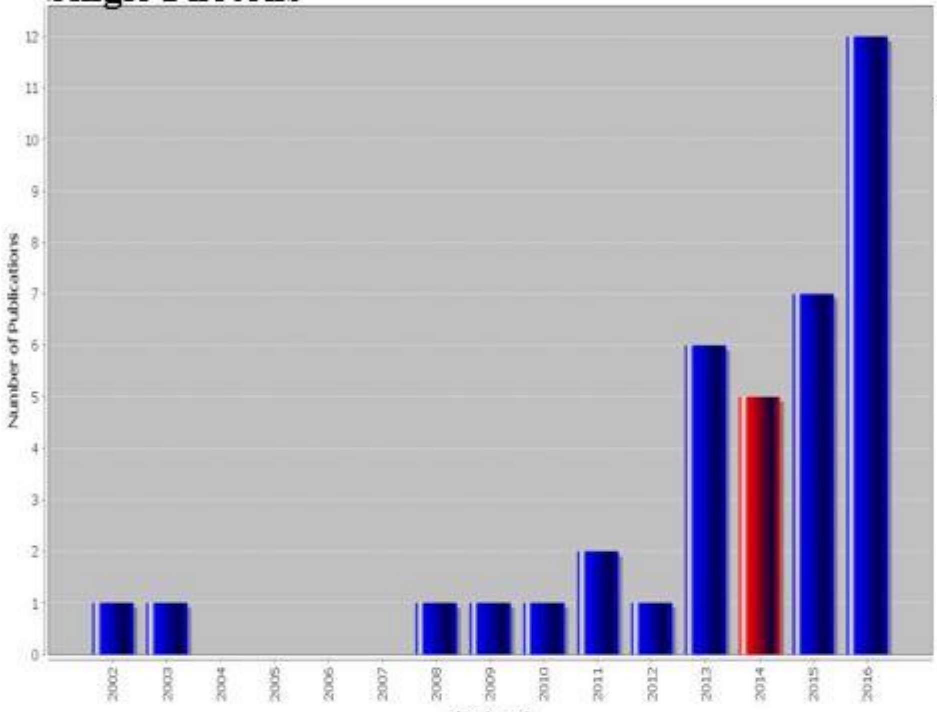


Rank	country	# Documents
1.	United States	220
2.	China	137
3.	Japan	64
4.	Germany	63
5.	France	55
6.	United Kingdom	37
7.	South Korea	36
8.	Italy	34
9.	Canada	28
10.	Taiwan	25
11.	Singapore	23
12.	Switzerland	21
13.	Ireland	21
14.	Poland	20
15.	Sweden	20
16.	Spain	19
17.	Netherlands	18
18.	Australia	17
19.	Greece	16
20.	Belgium	14
21.	Russia	12
22.	Denmark	11
23.	Austria	10
24.	Israel	10
25.	India	10
26.	Finland	9
27.	Iran	6
28.	Czech Republic	4
29.	Romania	4
30.	Mexico	3

Multiplexed Heralded Single Photons

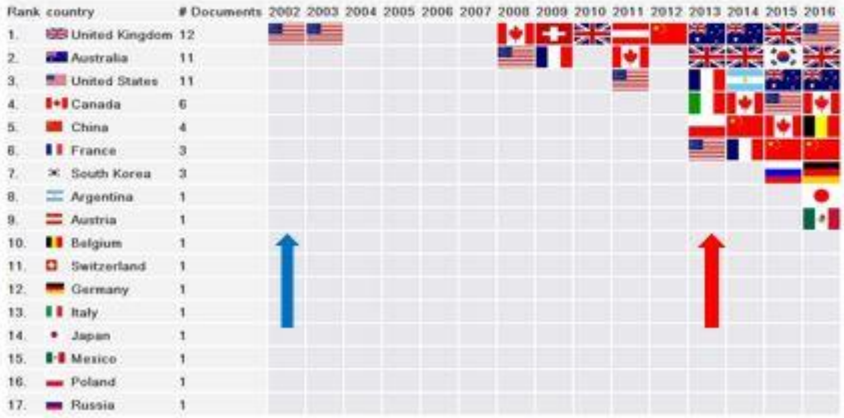
Emerging

Yes
[✓ No]
Unclear



Relation to U.S.

Before
[✓ After]
Same

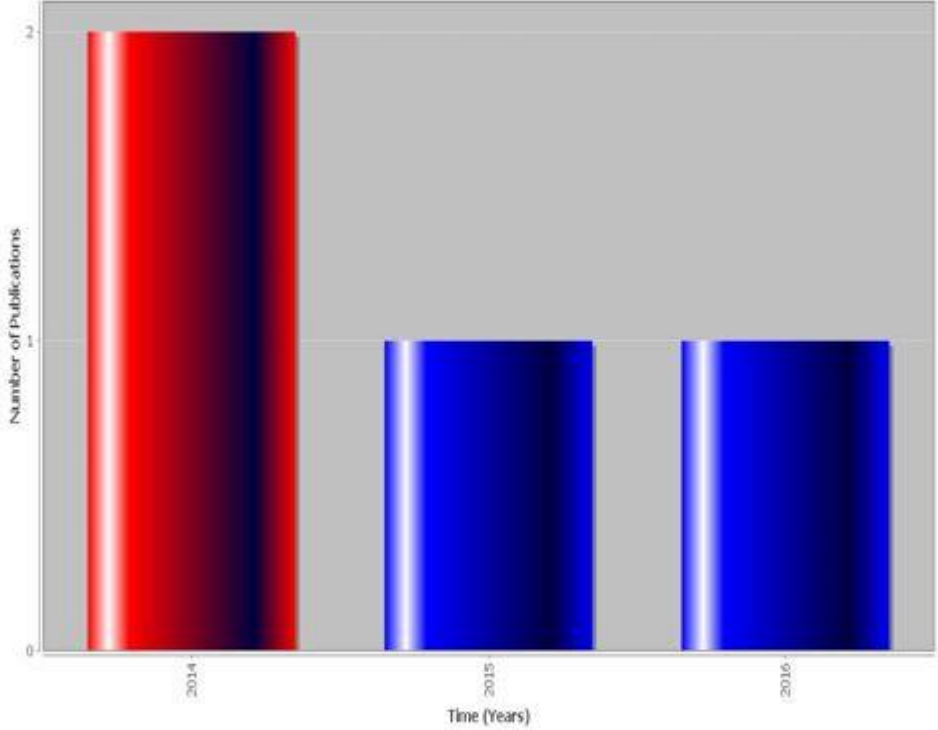


Rank	country	# Documents
1.	United Kingdom	12
2.	Australia	11
3.	United States	11
4.	Canada	6
5.	China	4
6.	France	3
7.	South Korea	3
8.	Argentina	1
9.	Austria	1
10.	Belgium	1
11.	Switzerland	1
12.	Germany	1
13.	Italy	1
14.	Japan	1
15.	Mexico	1
16.	Poland	1
17.	Russia	1

Australia ➡

U.S. ➡

Multiplexed Heralded Single Photons AND Photonic Circuit



Emerging

Yes
✓ No
Unclear

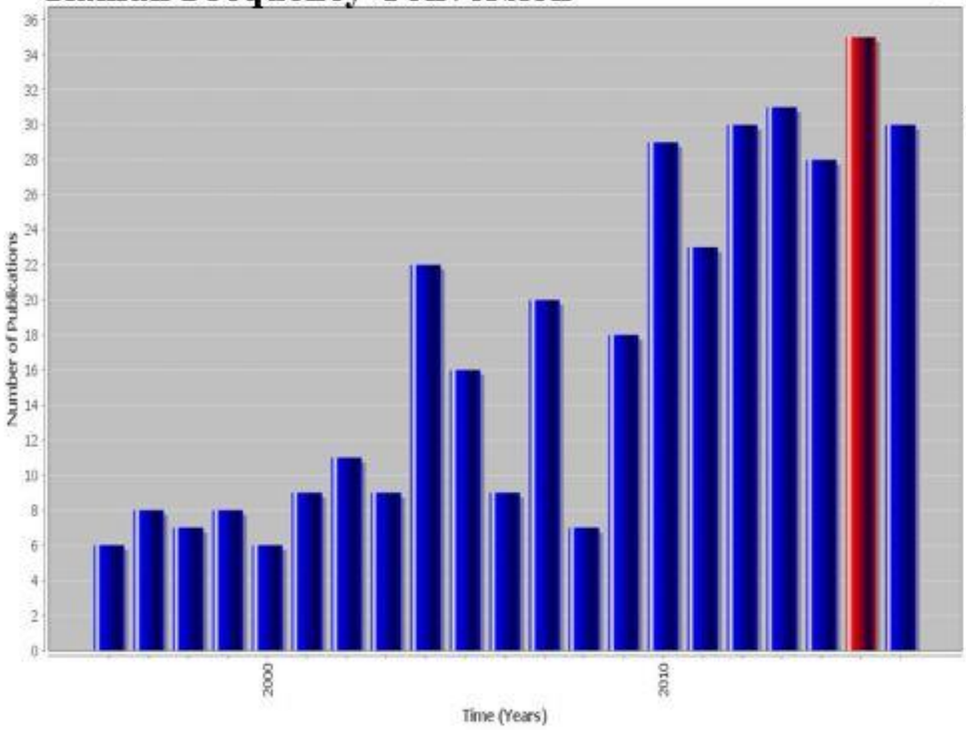
Relation to U.S.

Rank	country	# Documents	2014	2015	2016
1.	🇦🇺 Australia	3	🇦🇺	🇦🇺	🇬🇧
2.	🇬🇧 United Kingdom	2	🇫🇷	🇨🇦	
3.	🇨🇦 Canada	1	↑	🇨🇳	
4.	🇨🇳 China	1		🇬🇧	
5.	🇫🇷 France	1			

Before
✓ After
Same

Australia →
U.S. →

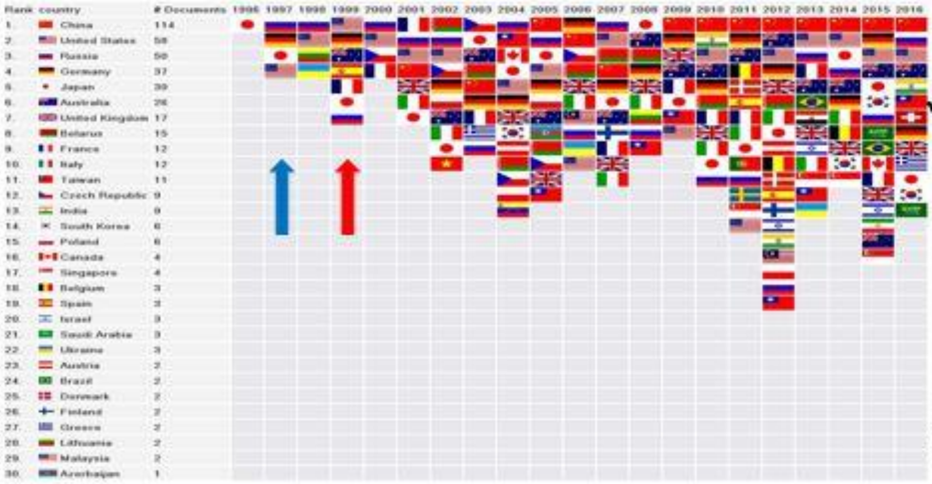
Raman Frequency Conversion



Emerging

Yes
✓ No
Unclear

Relation to U.S.

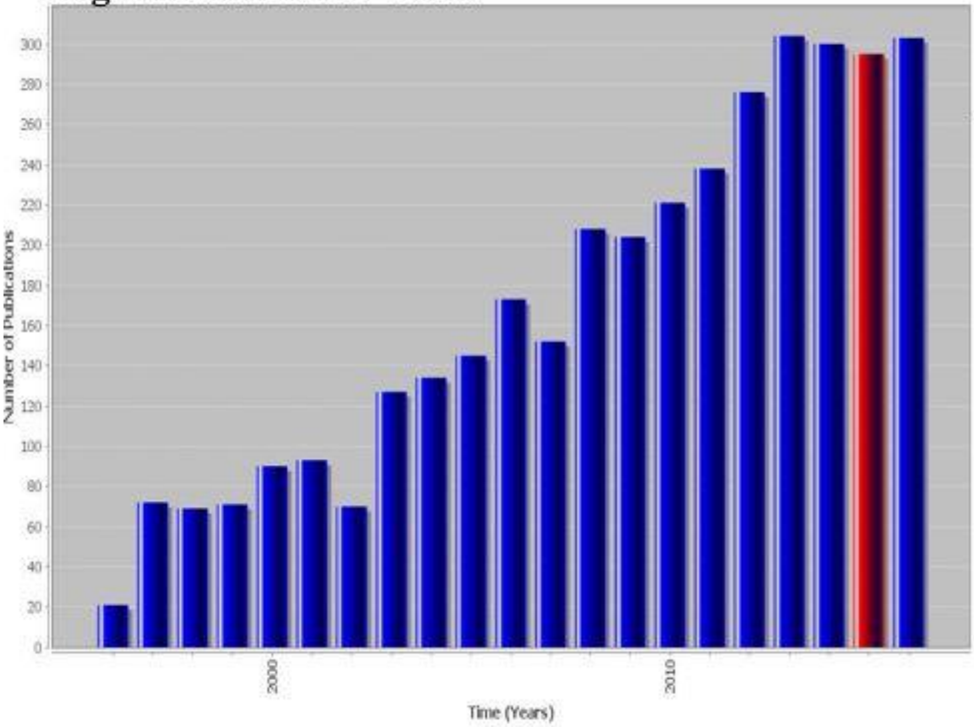


Rank	country	# Documents
1.	China	114
2.	United States	58
3.	Russia	50
4.	Germany	37
5.	Japan	30
6.	Australia	26
7.	United Kingdom	17
8.	Belarus	15
9.	France	12
10.	Italy	12
11.	Taiwan	11
12.	Czech Republic	9
13.	India	9
14.	South Korea	6
15.	Poland	6
16.	Canada	4
17.	Singapore	4
18.	Belgium	3
19.	Spain	3
20.	Israel	3
21.	Saudi Arabia	3
22.	Ukraine	3
23.	Austria	2
24.	Brazil	2
25.	Denmark	2
26.	Finland	2
27.	Greece	2
28.	Lithuania	2
29.	Malaysia	2
30.	Azerbaijan	1

Before
✓ After
Same

Australia 🟥
U.S. 🟦

High Power Fiber Lasers



Emerging

Yes
[✓ No]
Unclear

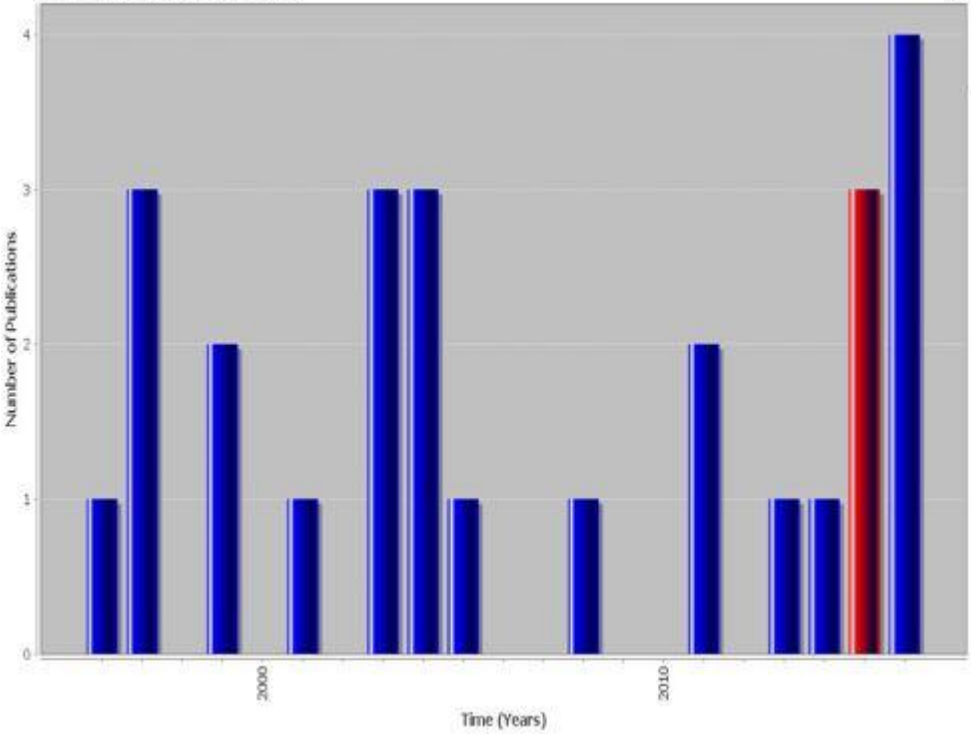
Relation to U.S.

Rank	country	# Documents
1.	United States	874
2.	China	656
3.	Germany	415
4.	Japan	273
5.	United Kingdom	206
6.	France	192
7.	Russia	137
8.	Canada	82
9.	Switzerland	63
10.	Italy	63
11.	Spain	59
12.	India	57
13.	South Korea	55
14.	Taiwan	52
15.	Australia	40
16.	Denmark	38
17.	Singapore	37
18.	Sweden	36
19.	Finland	33
20.	Israel	31
21.	Mexico	31
22.	Czech Republic	25
23.	Poland	23
24.	Malaysia	21
25.	Iran	18
26.	Portugal	15
27.	Austria	13
28.	Turkey	13
29.	Belgium	12
30.	Greece	12

Before
[✓ After]
Same

Australia 🟥
U.S. 🟦

High Power Fiber Lasers AND Diamond

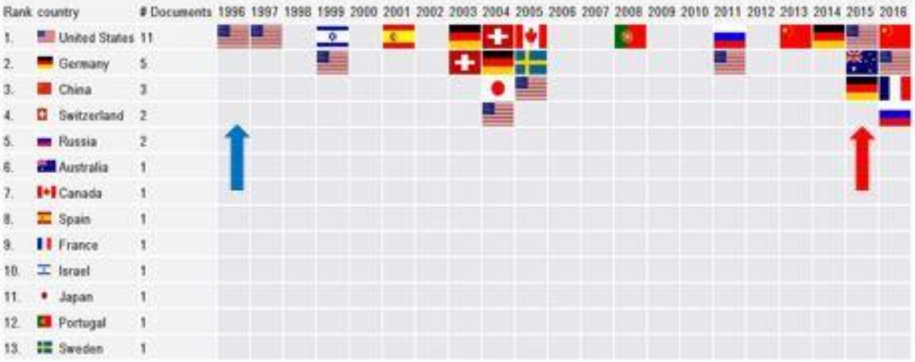


Emerging

Yes
✓ No
Unclear

Relation to U.S.

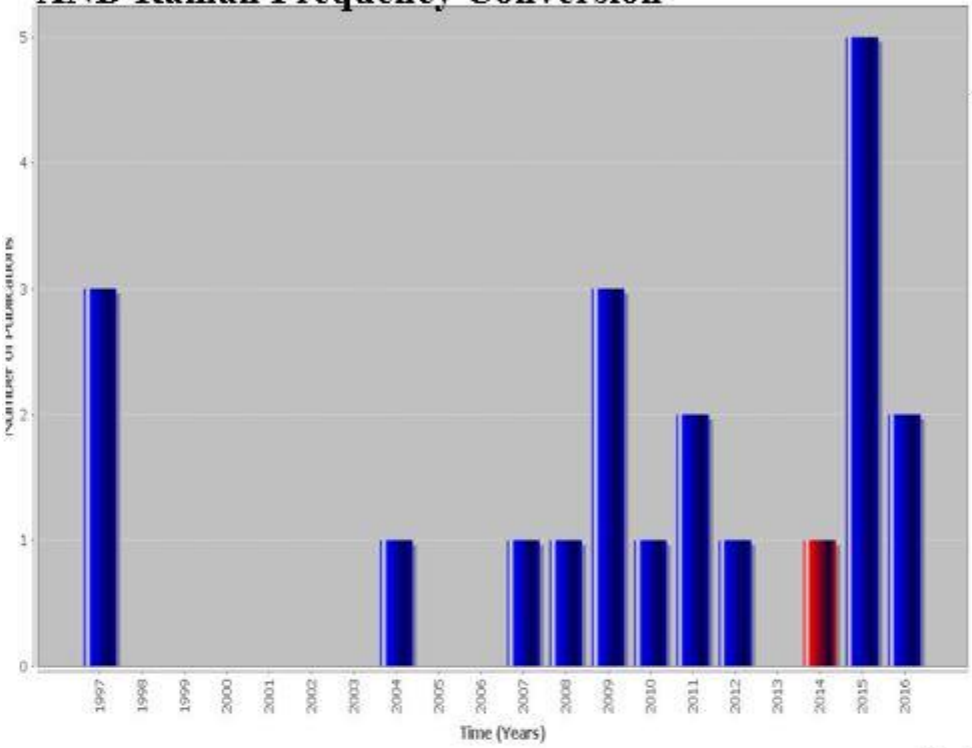
Before
✓ After
Same



Rank	country	# Documents
1.	United States	11
2.	Germany	5
3.	China	3
4.	Switzerland	2
5.	Russia	2
6.	Australia	1
7.	Canada	1
8.	Spain	1
9.	France	1
10.	Israel	1
11.	Japan	1
12.	Portugal	1
13.	Sweden	1

Australia →
U.S. →

High Power Fiber Lasers AND Raman Frequency Conversion

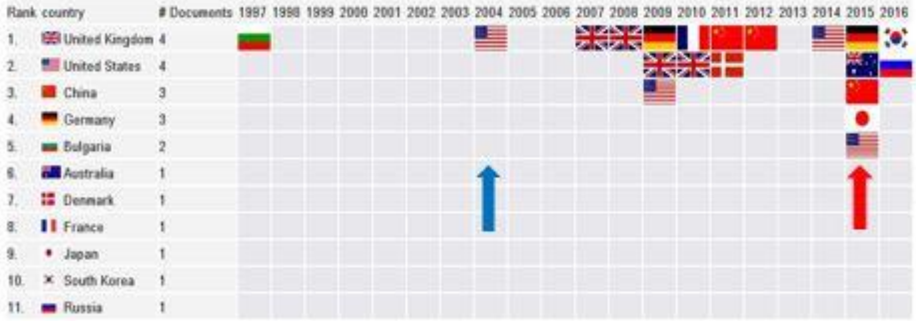


Emerging

Yes
[✓ No]
Unclear

Relation to U.S.

Before
[✓ After]
Same



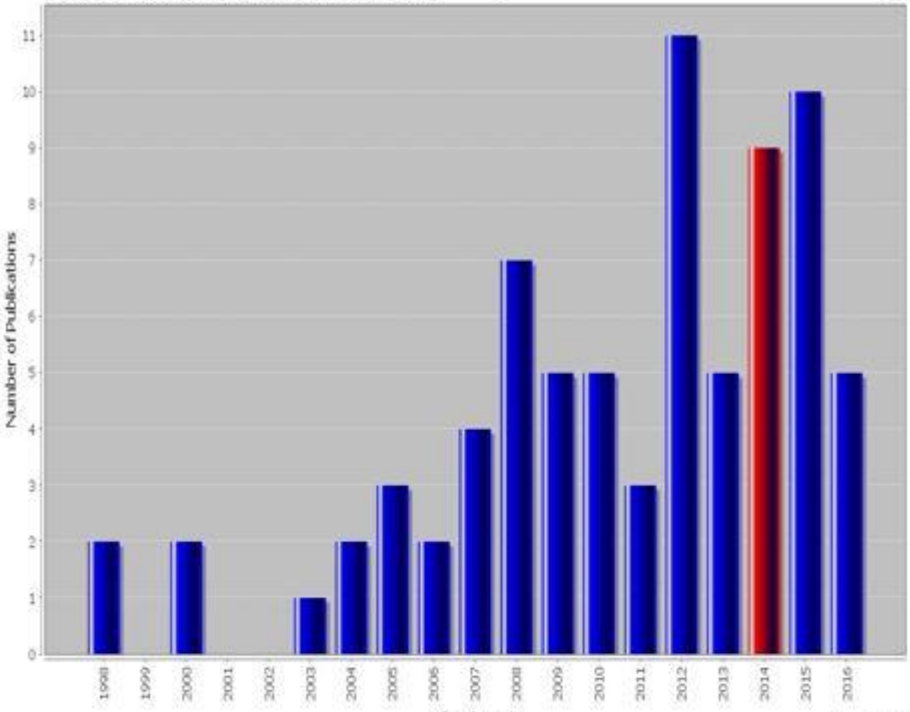
Rank	country	# Documents
1.	United Kingdom	4
2.	United States	4
3.	China	3
4.	Germany	3
5.	Bulgaria	2
6.	Australia	1
7.	Denmark	1
8.	France	1
9.	Japan	1
10.	South Korea	1
11.	Russia	1

Australia 🡒
U.S. 🡒

Bistable Buckled Beam

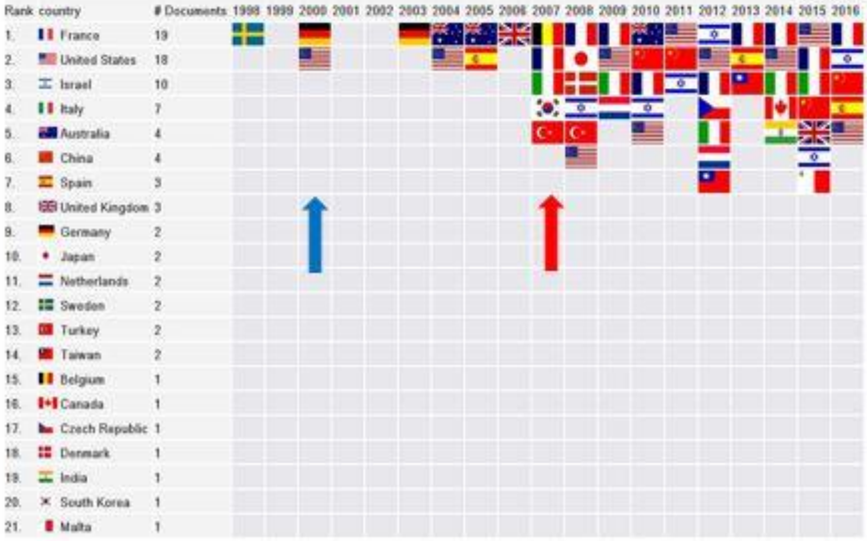
Emerging

Yes
[✓ No]
Unclear



Relation to U.S.

Before
[✓ After]
Same



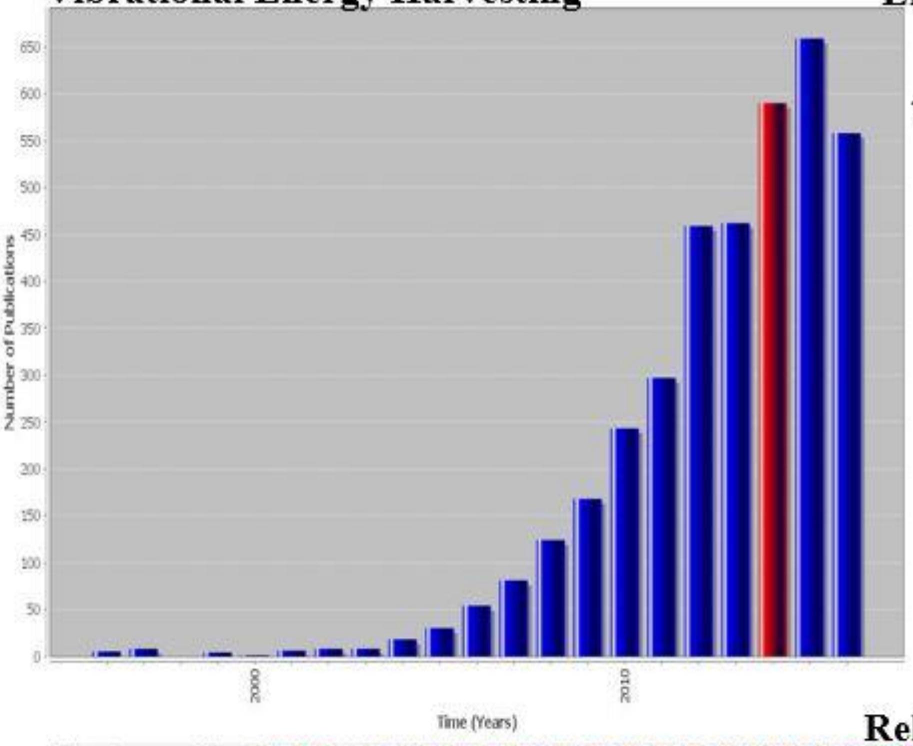
Rank	country	# Documents
1.	France	19
2.	United States	18
3.	Israel	10
4.	Italy	7
5.	Australia	4
6.	China	4
7.	Spain	3
8.	United Kingdom	3
9.	Germany	2
10.	Japan	2
11.	Netherlands	2
12.	Sweden	2
13.	Turkey	2
14.	Taiwan	2
15.	Belgium	1
16.	Canada	1
17.	Czech Republic	1
18.	Denmark	1
19.	India	1
20.	South Korea	1
21.	Malta	1

Italy →
U.S. →

Vibrational Energy Harvesting

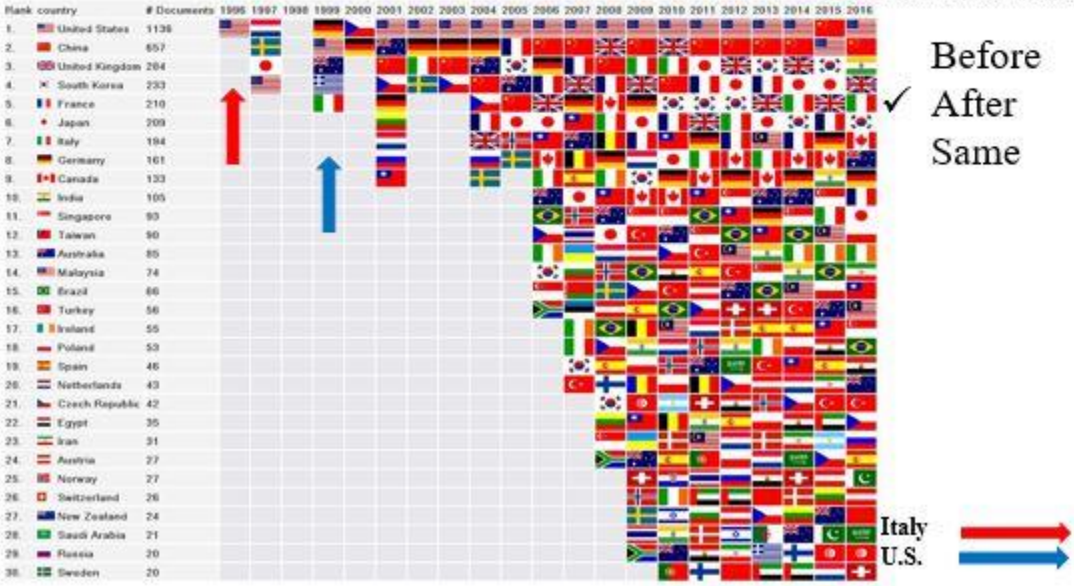
Emerging

Yes
✓ No
Unclear



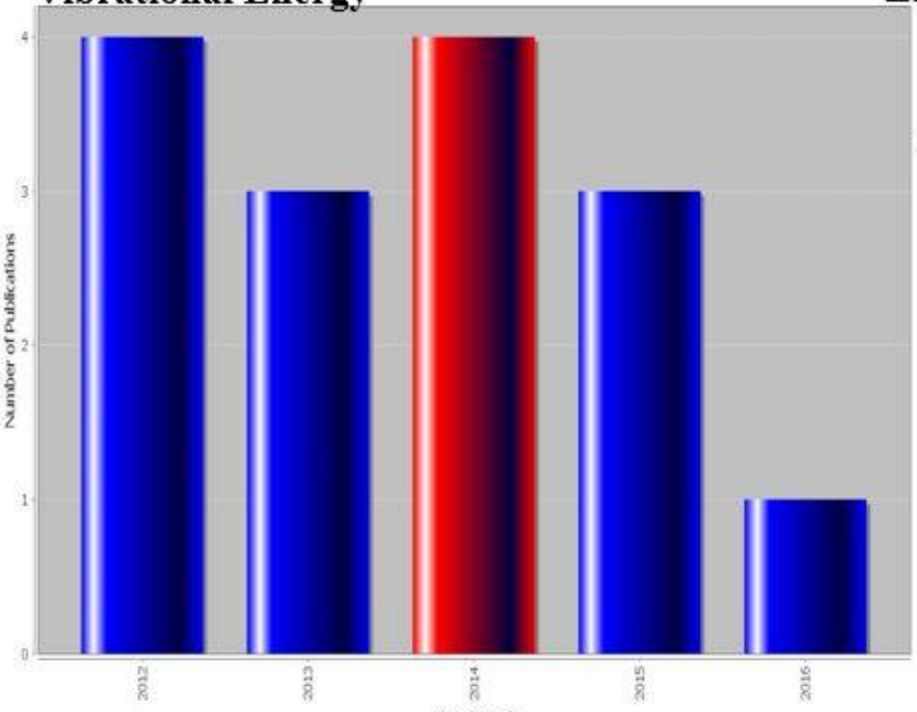
Relation to U.S.

Before
✓ After
Same



Rank	country	# Documents
1.	United States	1136
2.	China	657
3.	United Kingdom	264
4.	South Korea	233
5.	France	210
6.	Japan	209
7.	Italy	194
8.	Germany	161
9.	Canada	133
10.	India	105
11.	Singapore	93
12.	Taiwan	90
13.	Australia	85
14.	Malaysia	74
15.	Brazil	66
16.	Turkey	56
17.	Ireland	55
18.	Poland	53
19.	Spain	46
20.	Netherlands	43
21.	Czech Republic	42
22.	Egypt	35
23.	Iran	31
24.	Austria	27
25.	Norway	27
26.	Switzerland	26
27.	New Zealand	24
28.	Saudi Arabia	21
29.	Russia	20
30.	Sweden	20

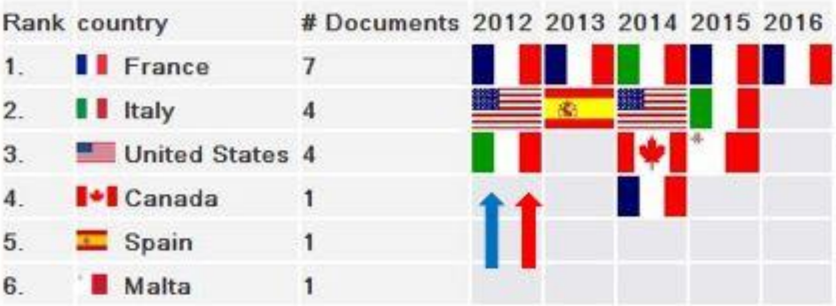
Bistable Buckled Beam AND Vibrational Energy



Emerging

Yes
No
✓ Unclear

Relation to U.S.

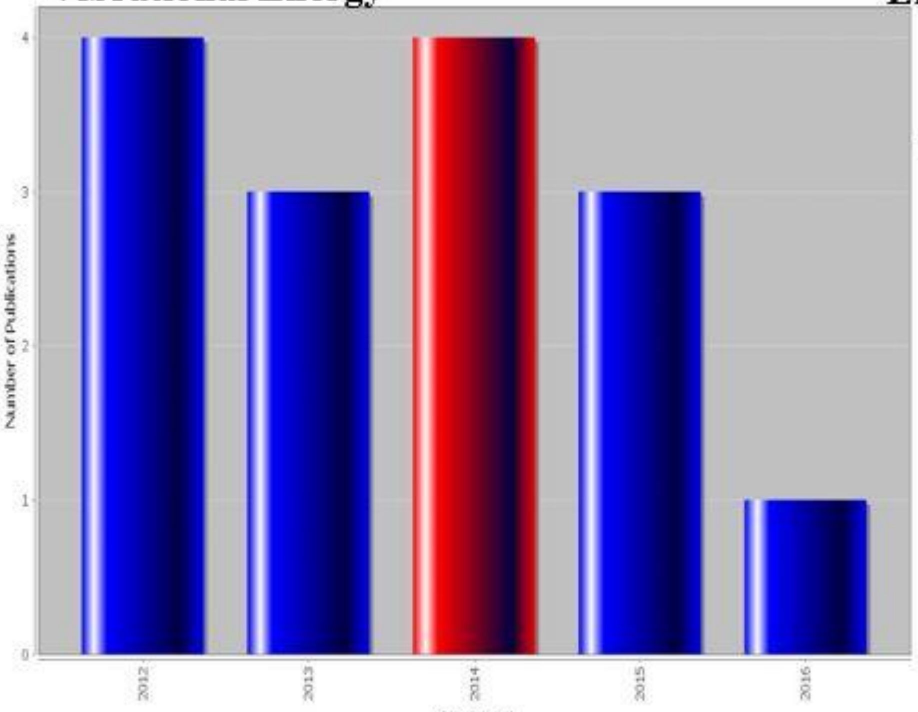


Rank	country	# Documents	2012	2013	2014	2015	2016
1.	🇫🇷 France	7	🇫🇷	🇫🇷	🇮🇹	🇫🇷	🇫🇷
2.	🇮🇹 Italy	4	🇺🇸	🇪🇸	🇺🇸	🇮🇹	
3.	🇺🇸 United States	4	🇮🇹		🇨🇦	🇲🇹	
4.	🇨🇦 Canada	1	↑ ↑		🇫🇷		
5.	🇪🇸 Spain	1					
6.	🇲🇹 Malta	1					

Before
After
✓ Same

Italy →
U.S. →

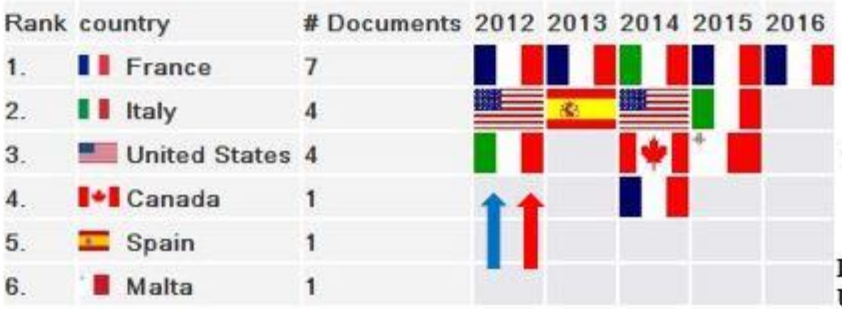
Bistable Buckled Beam AND Vibrational Energy



Emerging

Yes
No
✓ Unclear

Relation to U.S.



Rank	country	# Documents	2012	2013	2014	2015	2016
1.	🇫🇷 France	7	🇫🇷	🇫🇷	🇮🇹	🇫🇷	🇫🇷
2.	🇮🇹 Italy	4	🇺🇸	🇪🇸	🇺🇸	🇮🇹	
3.	🇺🇸 United States	4	🇮🇹		🇨🇦	🇲🇹	
4.	🇨🇦 Canada	1	↑ ↑		🇫🇷		
5.	🇪🇸 Spain	1					
6.	🇲🇹 Malta	1					

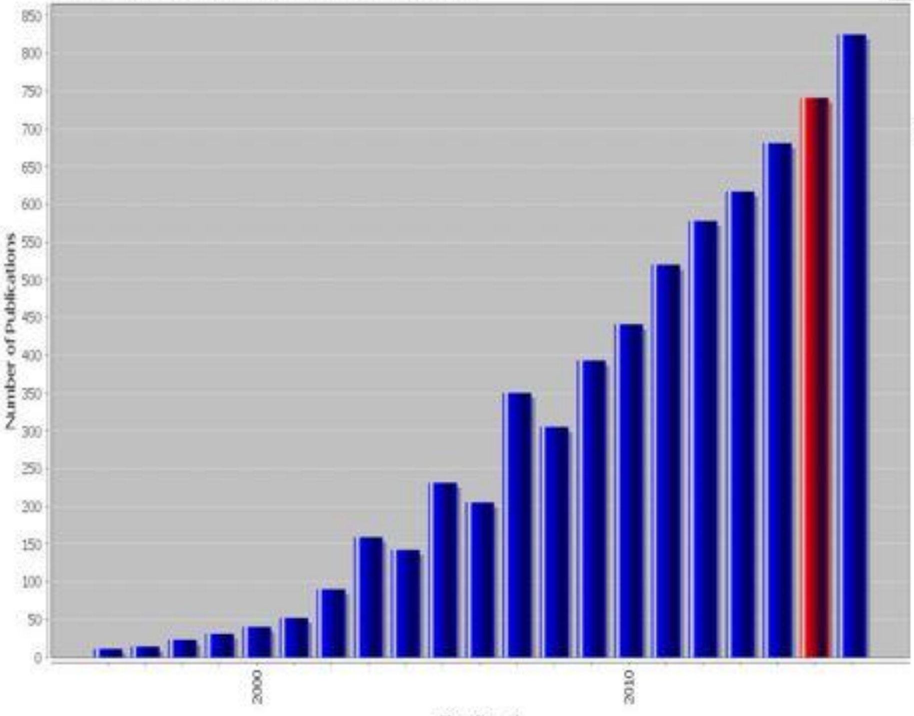
Before
After
✓ Same

Italy ➡
U.S. ➡

Spark Plasma Sintering

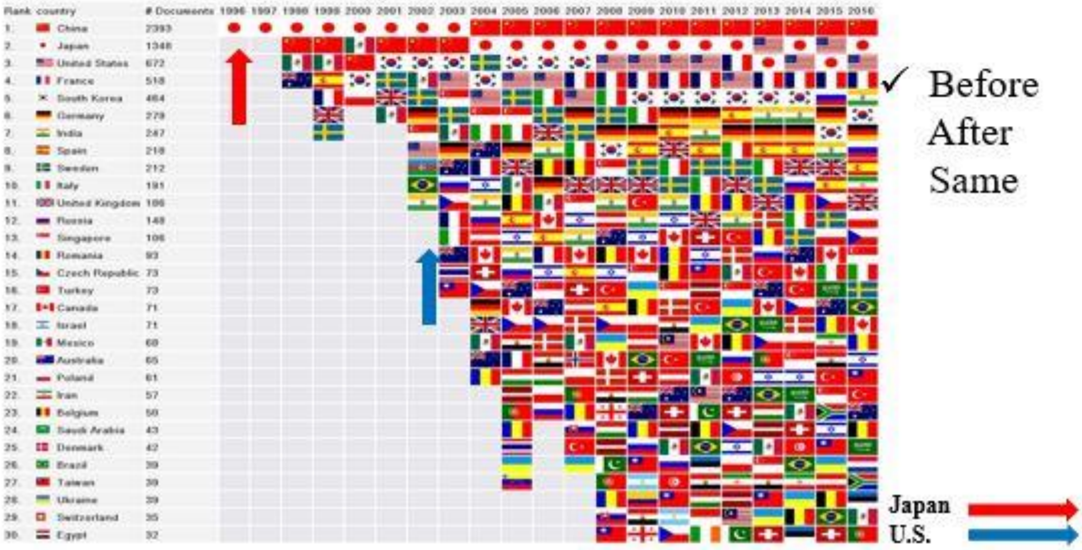
Emerging

Yes
[✓ No]
Unclear



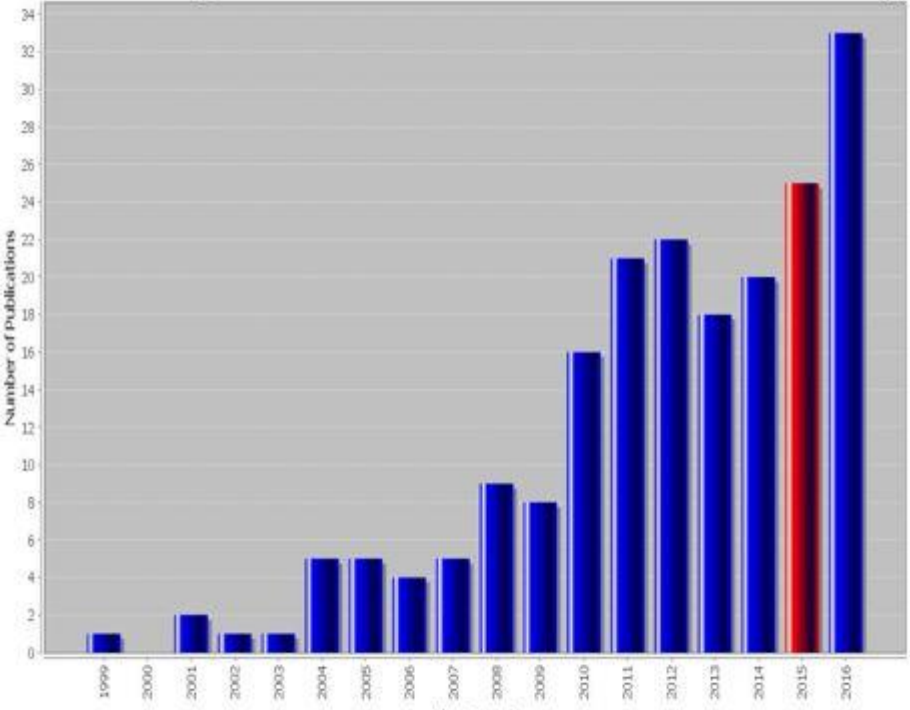
Relation to U.S.

[✓ Before]
After
Same



Rank	country	# Documents
1.	China	2393
2.	Japan	1348
3.	United States	672
4.	France	518
5.	South Korea	484
6.	Germany	279
7.	India	247
8.	Spain	218
9.	Sweden	212
10.	Italy	191
11.	United Kingdom	186
12.	Russia	148
13.	Singapore	106
14.	Romania	93
15.	Czech Republic	73
16.	Turkey	73
17.	Canada	71
18.	Israel	71
19.	Mexico	68
20.	Australia	65
21.	Poland	61
22.	Iran	57
23.	Belgium	50
24.	Saudi Arabia	43
25.	Denmark	42
26.	Brazil	39
27.	Taiwan	39
28.	Ukraine	39
29.	Switzerland	35
30.	Egypt	32

Spark Plasma Sintering AND Doped Ceramics

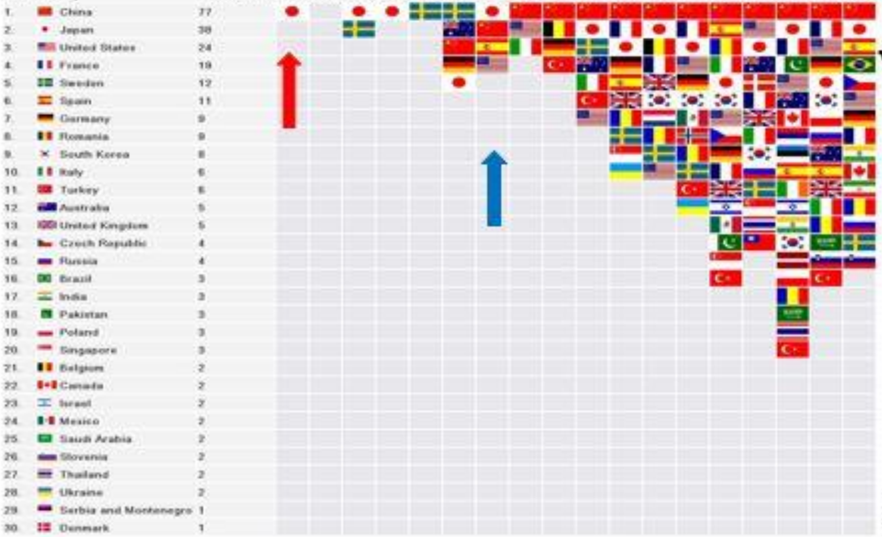


Emerging

Yes
✓ No
Unclear

Relation to U.S.

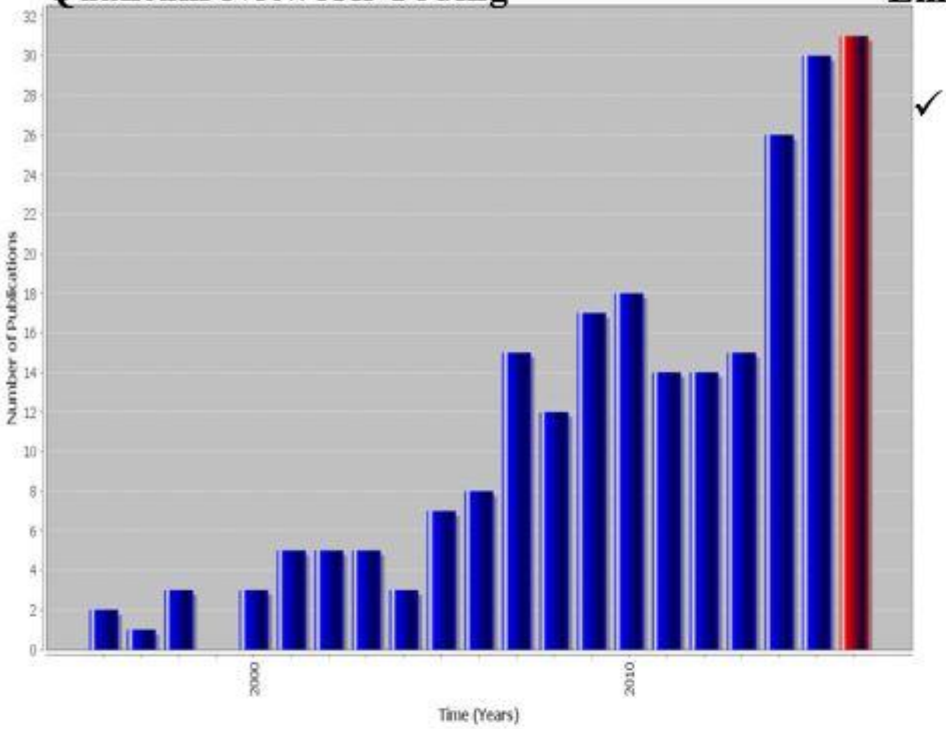
✓ Before
After
Same



Rank	country	# Documents
1.	China	77
2.	Japan	38
3.	United States	24
4.	France	19
5.	Sweden	12
6.	Spain	11
7.	Germany	9
8.	Romania	9
9.	South Korea	8
10.	Italy	6
11.	Turkey	6
12.	Australia	5
13.	United Kingdom	5
14.	Czech Republic	4
15.	Russia	4
16.	Brazil	3
17.	India	3
18.	Pakistan	3
19.	Poland	3
20.	Singapore	3
21.	Belgium	2
22.	Canada	2
23.	Israel	2
24.	Mexico	2
25.	Saudi Arabia	2
26.	Slovenia	2
27.	Thailand	2
28.	Ukraine	2
29.	Serbia and Montenegro	1
30.	Denmark	1

Japan 🟥
U.S. 🟦

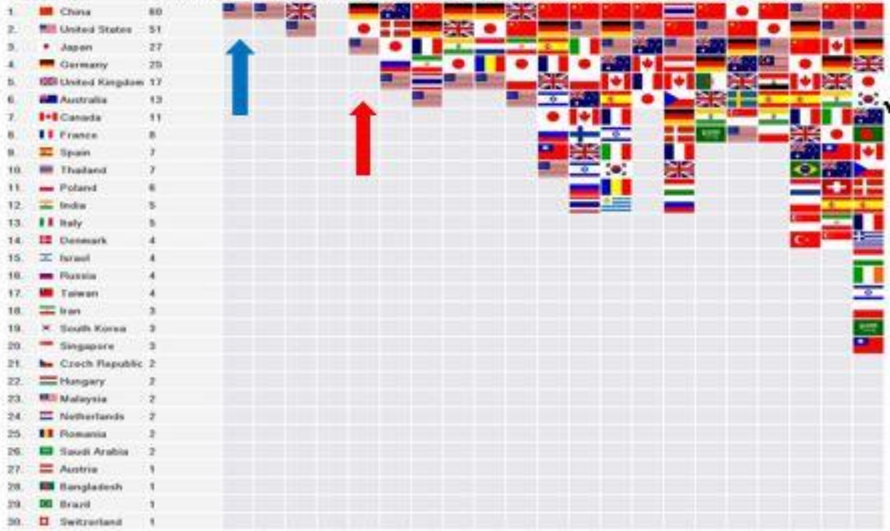
Quantum Network Coding



Emerging

Yes
[✓ No]
Unclear

Relation to U.S.

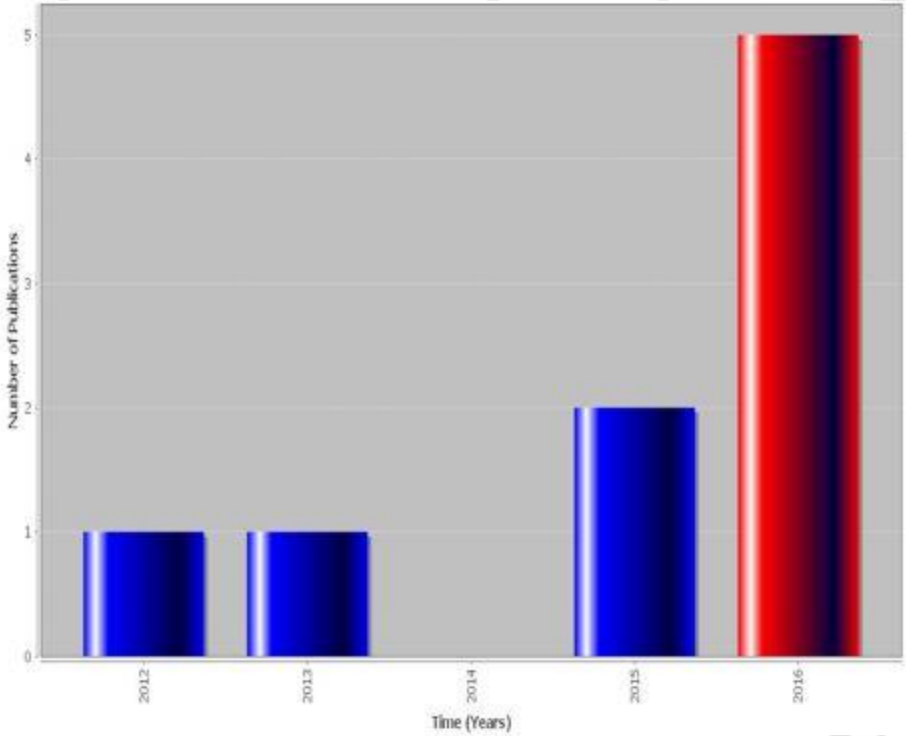


Rank	country	# Documents
1.	China	60
2.	United States	51
3.	Japan	27
4.	Germany	25
5.	United Kingdom	17
6.	Australia	13
7.	Canada	11
8.	France	8
9.	Spain	7
10.	Thailand	7
11.	Poland	6
12.	India	5
13.	Italy	5
14.	Denmark	4
15.	Israel	4
16.	Russia	4
17.	Taiwan	4
18.	Iran	3
19.	South Korea	3
20.	Singapore	3
21.	Czech Republic	2
22.	Hungary	2
23.	Malaysia	2
24.	Netherlands	2
25.	Romania	2
26.	Saudi Arabia	2
27.	Austria	1
28.	Bangladesh	1
29.	Brazil	1
30.	Switzerland	1

Before
[✓ After]
Same

Japan →
U.S. →

Quantum Network Coding AND Repeater

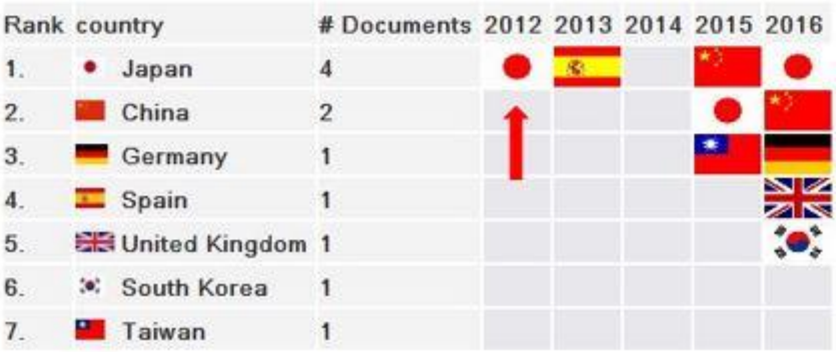


Emerging

Yes
No
✓ Unclear

Relation to U.S.

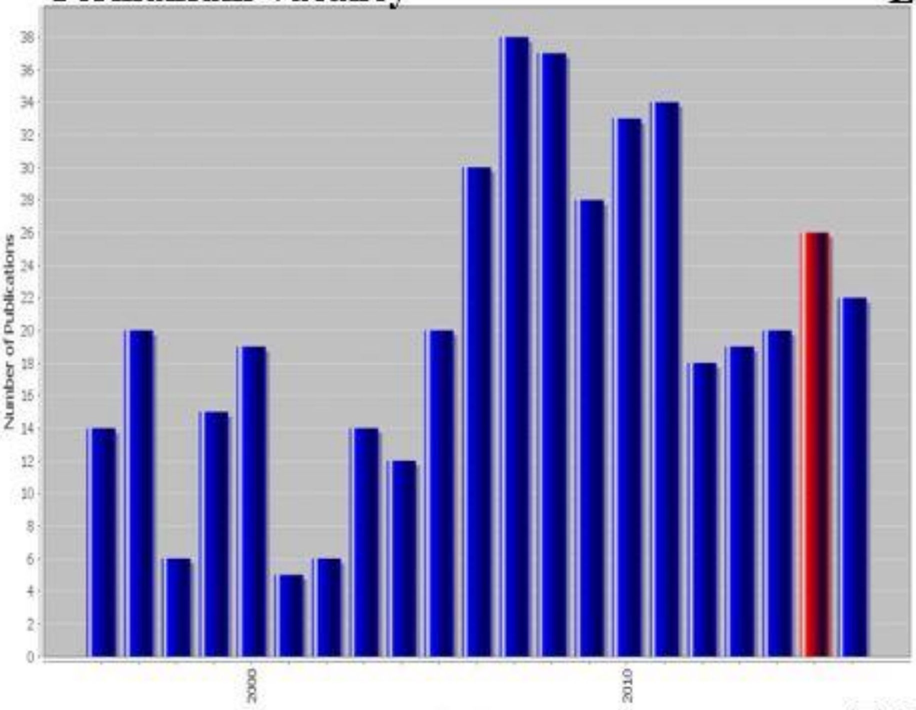
✓ Before
After
Same



Rank	country	# Documents	2012	2013	2014	2015	2016
1.	🇯🇵 Japan	4	🇯🇵	🇪🇸		🇨🇳	🇯🇵
2.	🇨🇳 China	2	↑			🇯🇵	🇨🇳
3.	🇩🇪 Germany	1				🇹🇼	🇩🇪
4.	🇪🇸 Spain	1					🇬🇧
5.	🇬🇧 United Kingdom	1					🇰🇷
6.	🇰🇷 South Korea	1					
7.	🇹🇼 Taiwan	1					

Japan →
U.S. →

Germanium Vacancy



Emerging

Yes

[✓ No]

Unclear

Relation to U.S.

Before

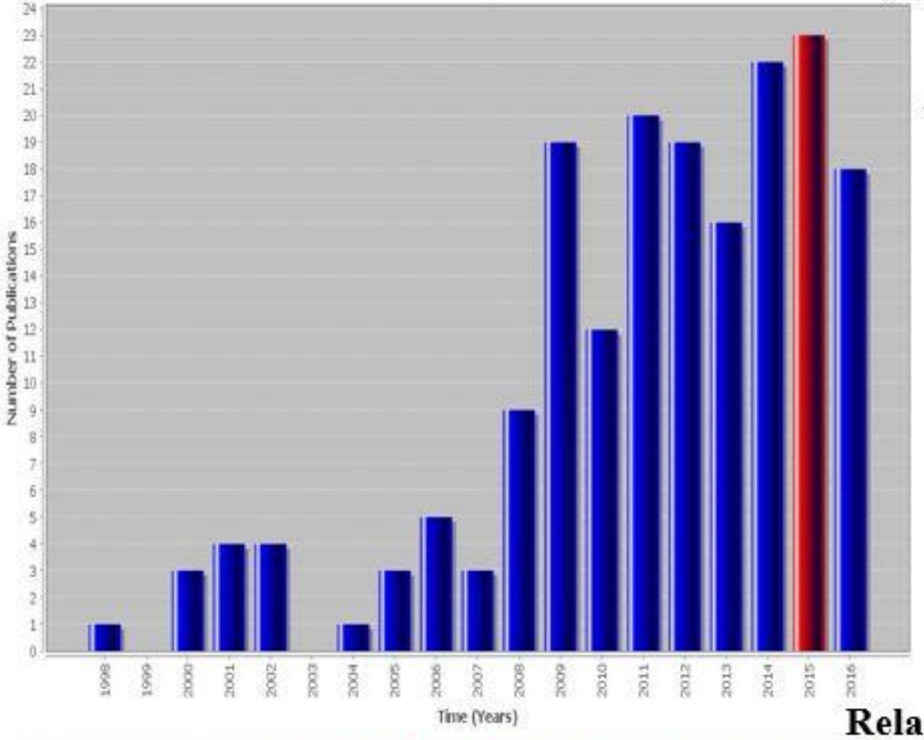
[✓ After]

Same

Rank	country	# Documents
1.	United Kingdom	92
2.	Germany	86
3.	United States	75
4.	Russia	48
5.	China	36
6.	France	31
7.	Japan	30
8.	Belgium	26
9.	Greece	23
10.	Poland	19
11.	Sweden	19
12.	Switzerland	18
13.	Denmark	18
14.	Finland	16
15.	Italy	13
16.	Portugal	13
17.	Canada	12
18.	South Korea	12
19.	Australia	11
20.	Belarus	10
21.	Brazil	7
22.	Spain	7
23.	India	7
24.	Saudi Arabia	7
25.	Ukraine	7
26.	South Africa	7
27.	Croatia	6
28.	Singapore	6
29.	Austria	5
30.	Norway	5

Japan →
U.S. →

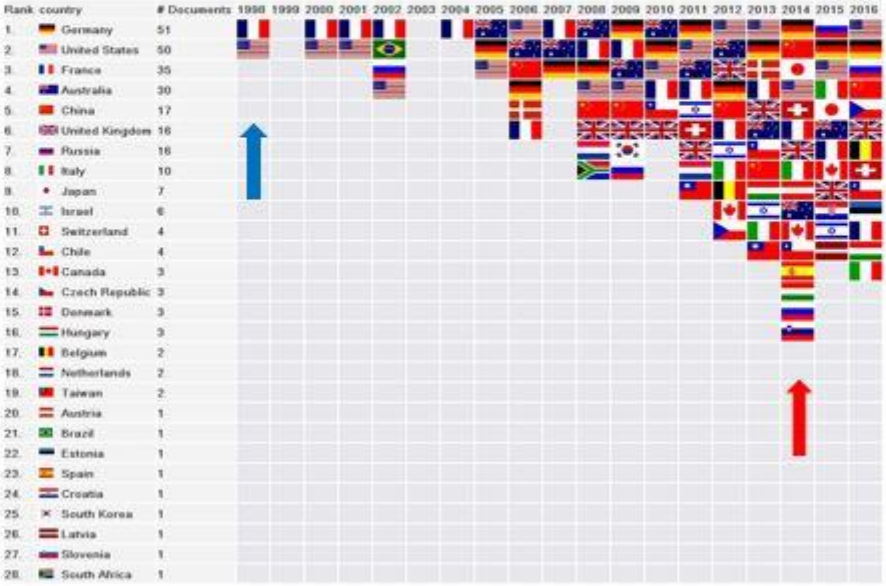
Single Color Centers AND Diamond



Emerging

Yes [✓ No] Unclear

Relation to U.S.

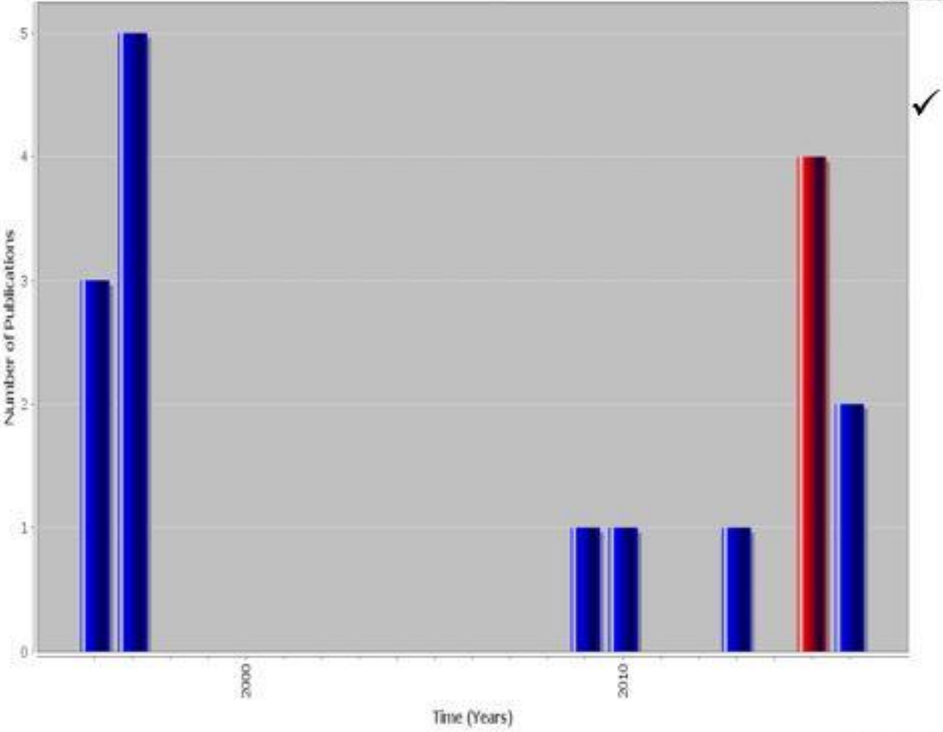


Rank	country	# Documents
1.	Germany	51
2.	United States	50
3.	France	35
4.	Australia	30
5.	China	17
6.	United Kingdom	16
7.	Russia	16
8.	Italy	10
9.	Japan	7
10.	Israel	6
11.	Switzerland	4
12.	Chile	4
13.	Canada	3
14.	Czech Republic	3
15.	Denmark	3
16.	Hungary	3
17.	Belgium	2
18.	Netherlands	2
19.	Taiwan	2
20.	Austria	1
21.	Brazil	1
22.	Estonia	1
23.	Spain	1
24.	Croatia	1
25.	South Korea	1
26.	Latvia	1
27.	Slovenia	1
28.	South Africa	1

Before [✓ After] Same

Japan →
U.S. →

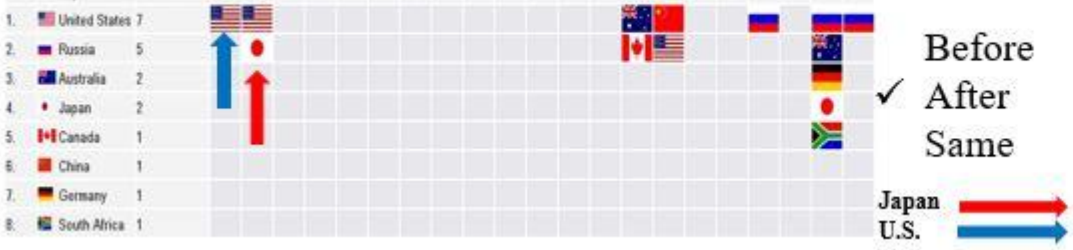
Germanium Vacancy AND Diamond



Emerging

Yes
✓ No
Unclear

Relation to U.S.



Rank	country	# Documents
1.	United States	7
2.	Russia	5
3.	Australia	2
4.	Japan	2
5.	Canada	1
6.	China	1
7.	Germany	1
8.	South Africa	1

Before
✓ After
Same

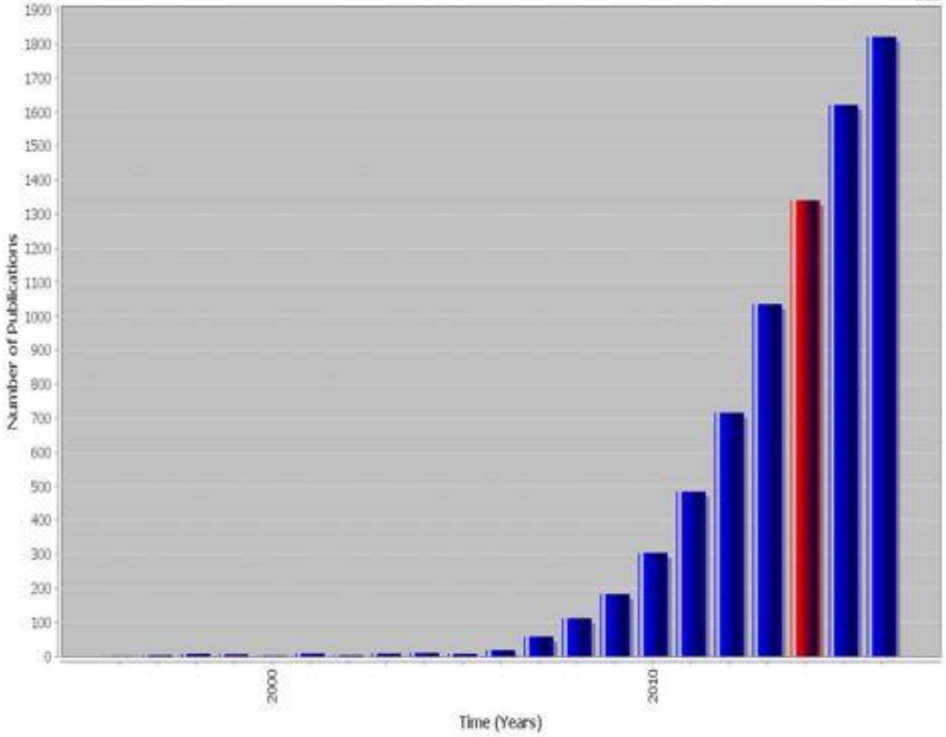
B-Doped AND Graphene

Emerging

Yes

✓ No

Unclear

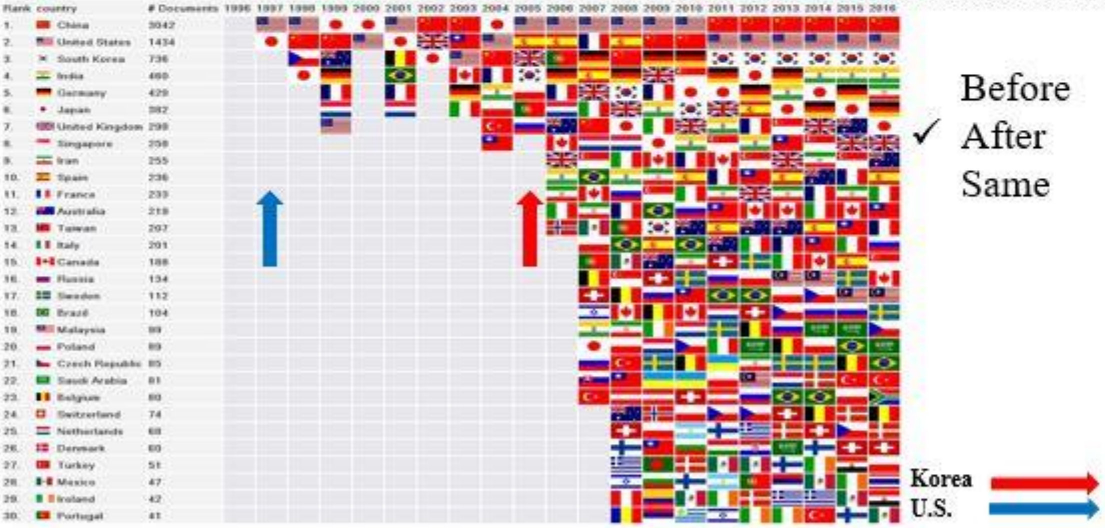


Relation to U.S.

Before

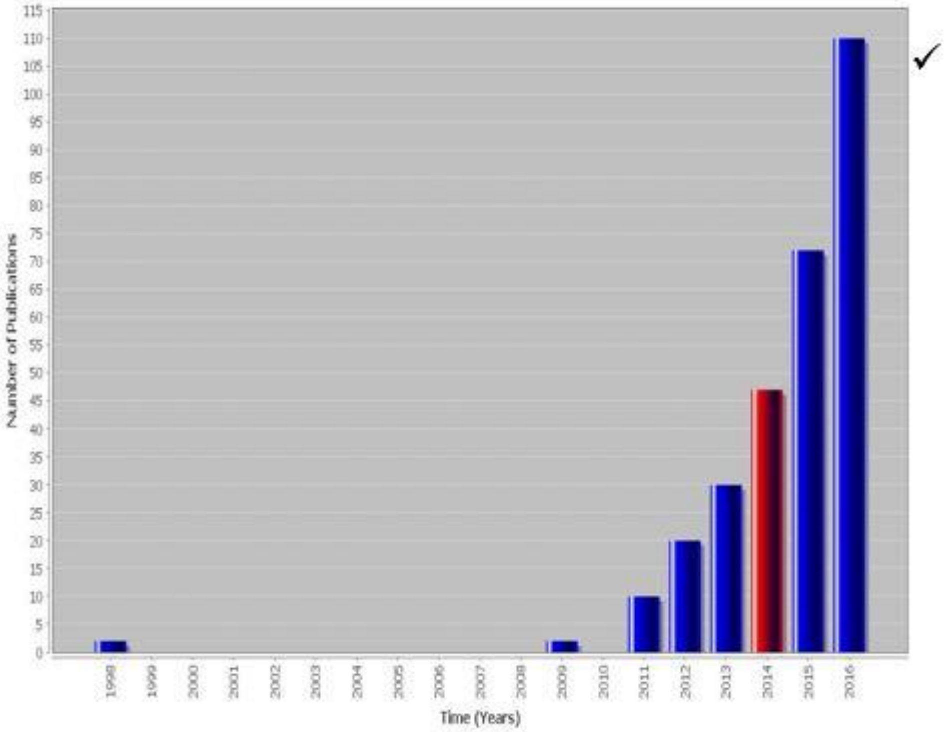
✓ After

Same



Rank	country	# Documents
1.	China	3042
2.	United States	1434
3.	South Korea	736
4.	India	460
5.	Germany	429
6.	Japan	382
7.	United Kingdom	298
8.	Singapore	258
9.	Iran	255
10.	Spain	236
11.	France	233
12.	Australia	218
13.	Taiwan	207
14.	Italy	201
15.	Canada	188
16.	Russia	134
17.	Sweden	112
18.	Brazil	104
19.	Malaysia	99
20.	Poland	89
21.	Czech Republic	85
22.	Saudi Arabia	81
23.	Belgium	80
24.	Switzerland	74
25.	Netherlands	68
26.	Denmark	60
27.	Turkey	51
28.	Mexico	47
29.	Ireland	42
30.	Portugal	41

B-Doped AND Graphene AND Cathode



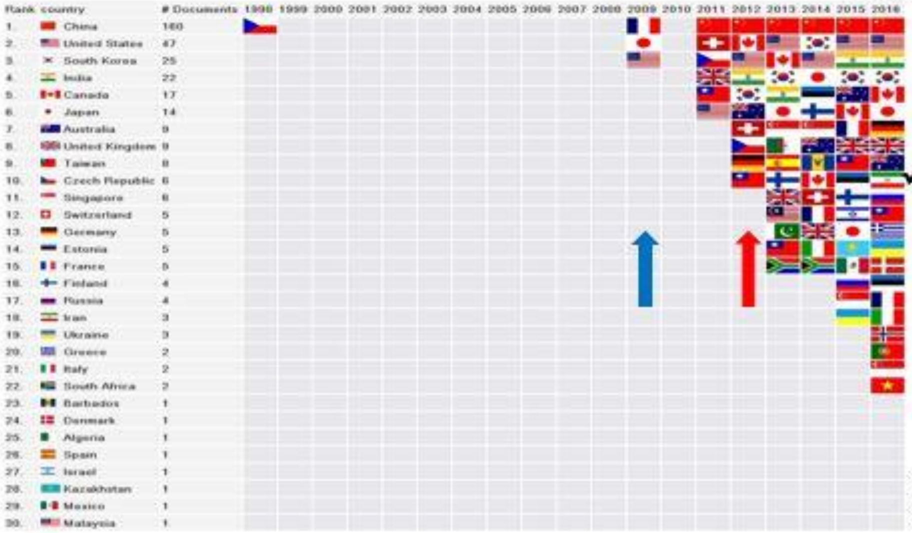
Emerging

✓ Yes

No

Unclear

Relation to U.S.



Rank	country	# Documents
1.	China	160
2.	United States	47
3.	South Korea	25
4.	India	22
5.	Canada	17
6.	Japan	14
7.	Australia	9
8.	United Kingdom	9
9.	Taiwan	8
10.	Czech Republic	6
11.	Singapore	6
12.	Switzerland	5
13.	Germany	5
14.	Estonia	5
15.	France	5
16.	Finland	4
17.	Russia	4
18.	Iran	3
19.	Ukraine	3
20.	Greece	2
21.	Italy	2
22.	South Africa	2
23.	Barbados	1
24.	Denmark	1
25.	Algeria	1
26.	Spain	1
27.	Israel	1
28.	Kazakhstan	1
29.	Mexico	1
30.	Malaysia	1

Before

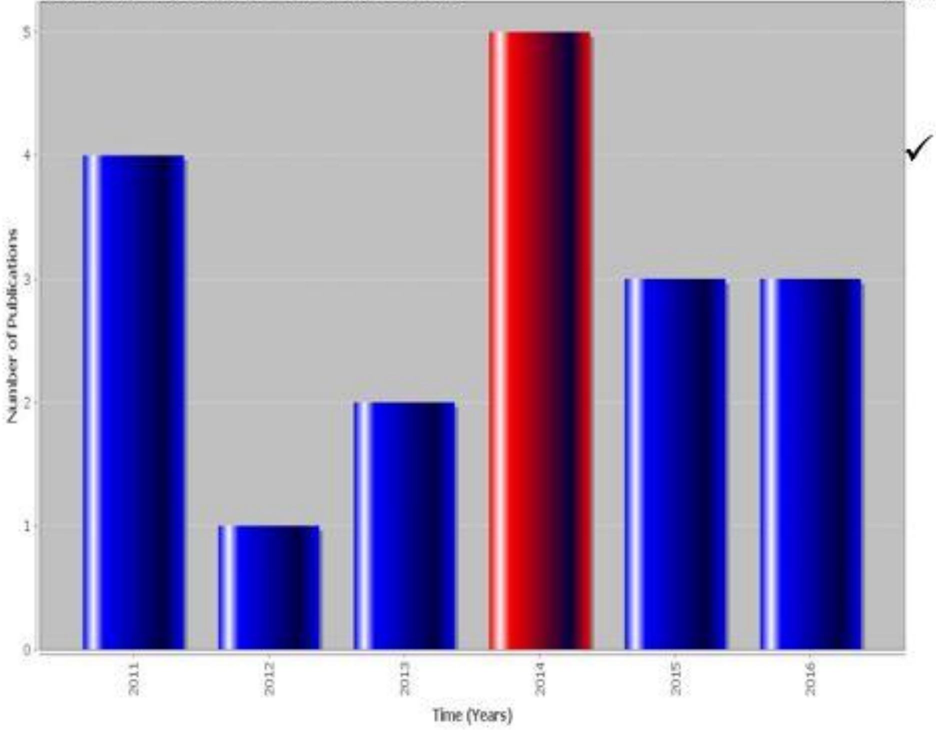
✓ After

Same

Korea →

U.S. →

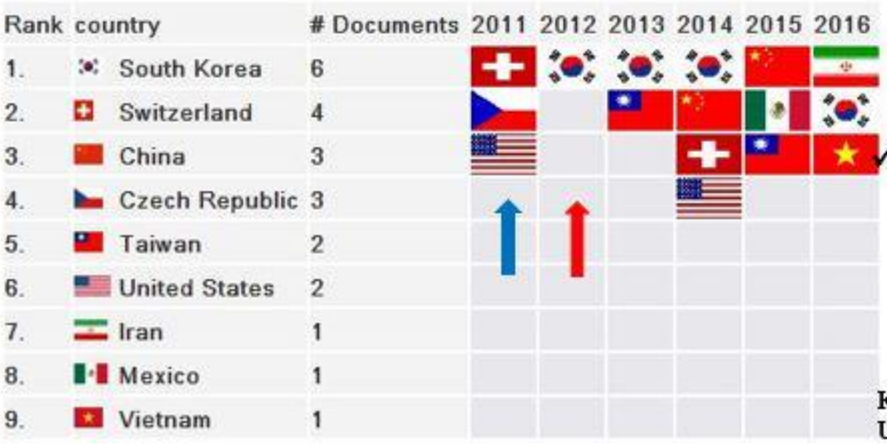
B-Doped AND Graphene AND Cathode AND Solar Cell



Emerging

Yes
No
✓ Unclear

Relation to U.S.

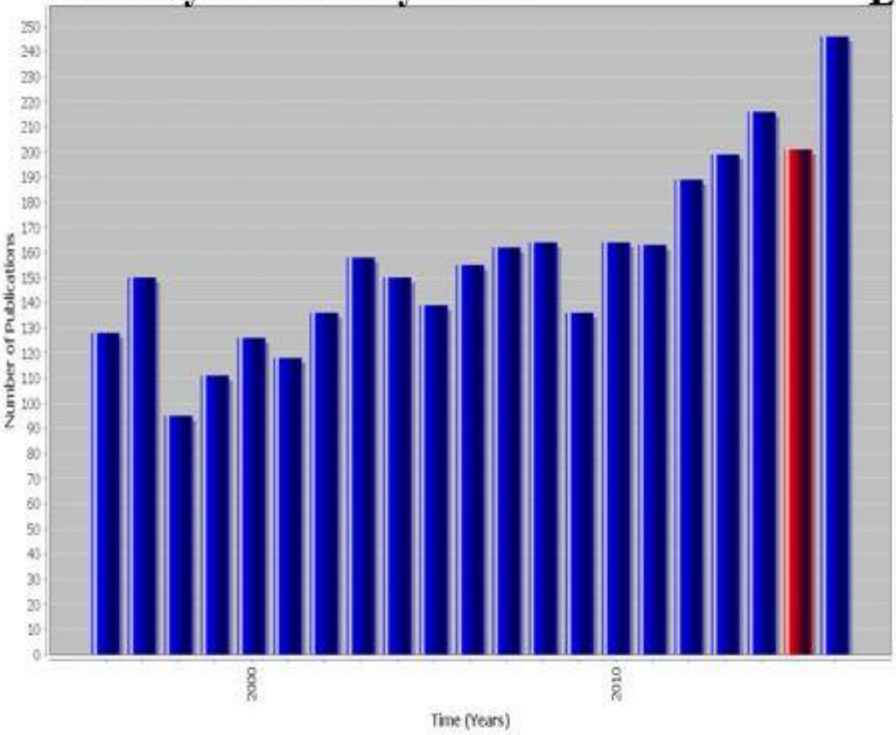


Rank	country	# Documents	2011	2012	2013	2014	2015	2016
1.	🇰🇷 South Korea	6	🇨🇭	🇰🇷	🇰🇷	🇰🇷	🇨🇳	🇮🇷
2.	🇨🇭 Switzerland	4	🇨🇿		🇹🇼	🇨🇳	🇲🇽	🇰🇷
3.	🇨🇳 China	3	🇺🇸			🇨🇭	🇹🇼	🇻🇳
4.	🇨🇿 Czech Republic	3	↑	↑		🇺🇸		
5.	🇹🇼 Taiwan	2						
6.	🇺🇸 United States	2						
7.	🇮🇷 Iran	1						
8.	🇲🇽 Mexico	1						
9.	🇻🇳 Vietnam	1						

Before
✓ After
Same

Korea →
U.S. →

Chirality Selective Synthesis



Emerging

Yes
[✓ No]
Unclear

Relation to U.S.

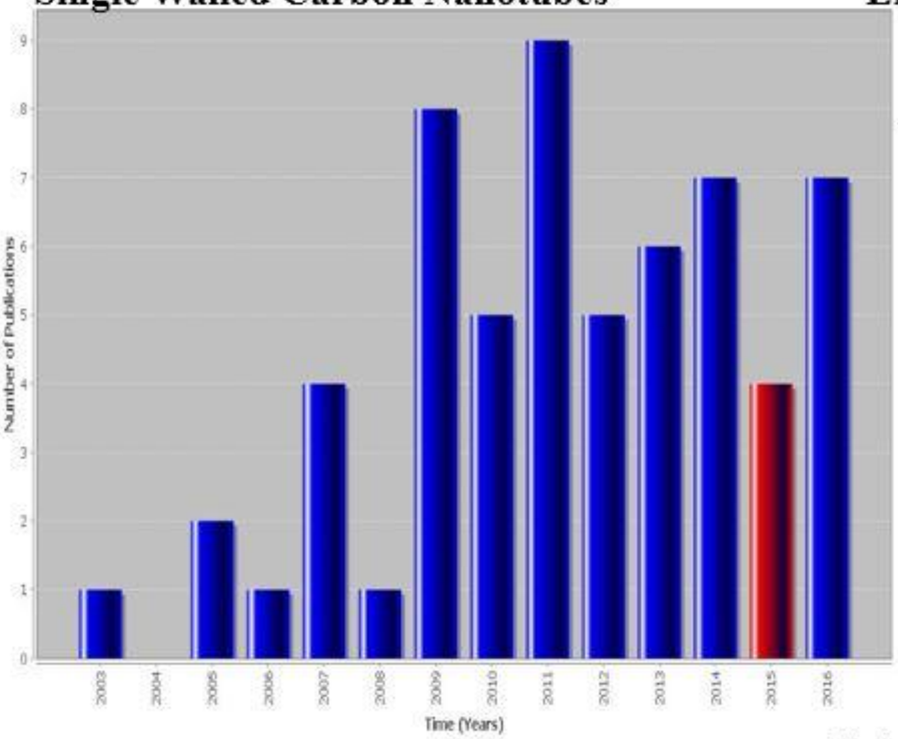
Rank	country	# Documents
1.	United States	632
2.	Japan	475
3.	China	387
4.	Germany	336
5.	France	219
6.	United Kingdom	202
7.	Spain	173
8.	Italy	164
9.	India	137
10.	Switzerland	89
11.	Canada	71
12.	Poland	66
13.	South Korea	58
14.	Sweden	53
15.	Netherlands	42
16.	Austria	40
17.	Singapore	35
18.	Denmark	34
19.	Belgium	33
20.	Hungary	33
21.	Brazil	31
22.	Turkey	31
23.	Portugal	30
24.	Ireland	26
25.	Russia	26
26.	Australia	25
27.	Czech Republic	25
28.	Israel	24
29.	Mexico	21
30.	Finland	17

Before
[✓ After]
Same

Singapore 🡆
U.S. 🡆

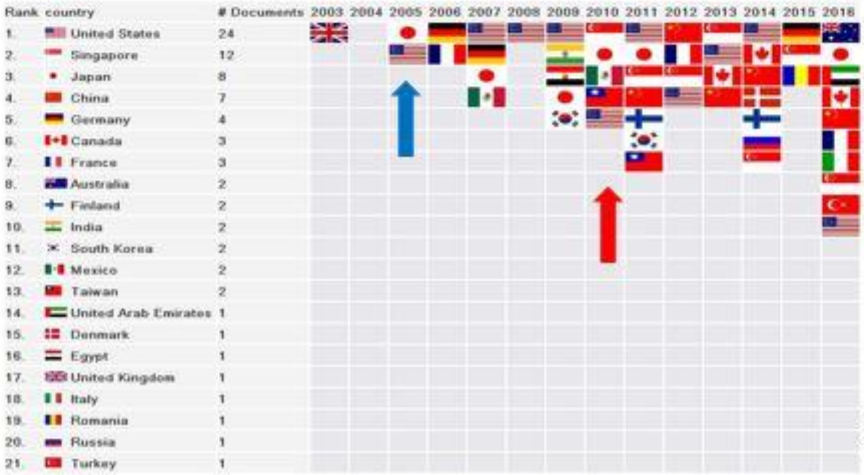
Chirality Selective Synthesis AND Single Walled Carbon Nanotubes

Emerging



Yes
[✓ No]
Unclear

Relation to U.S.



Rank	country	# Documents
1.	United States	24
2.	Singapore	12
3.	Japan	8
4.	China	7
5.	Germany	4
6.	Canada	3
7.	France	3
8.	Australia	2
9.	Finland	2
10.	India	2
11.	South Korea	2
12.	Mexico	2
13.	Taiwan	2
14.	United Arab Emirates	1
15.	Denmark	1
16.	Egypt	1
17.	United Kingdom	1
18.	Italy	1
19.	Romania	1
20.	Russia	1
21.	Turkey	1

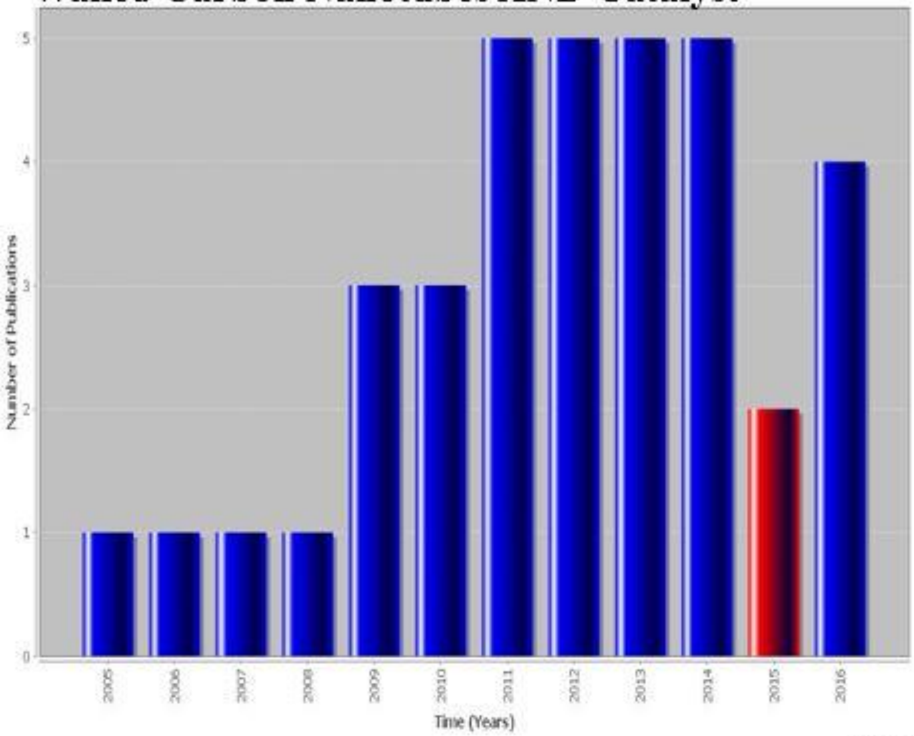
Before
[✓ After]
Same

Singapore 🟥
U.S. 🟦

Chirality Selective Synthesis AND Single Walled Carbon Nanotubes AND Catalyst

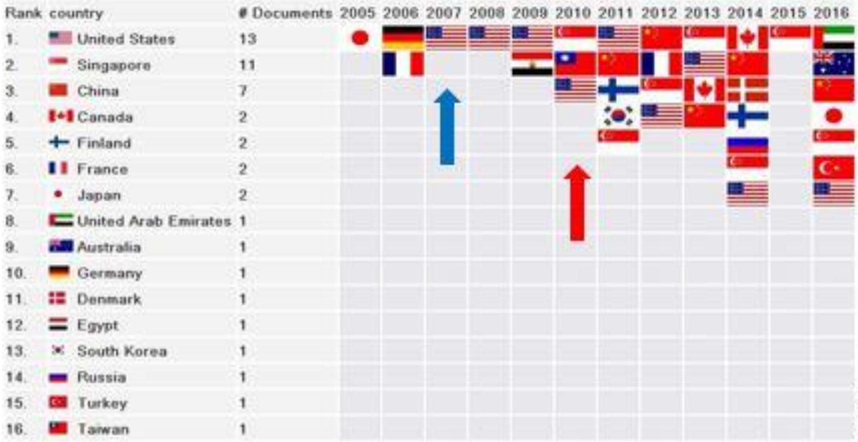
Emerging

Yes
✓ No
Unclear



Relation to U.S.

Before
✓ After
Same



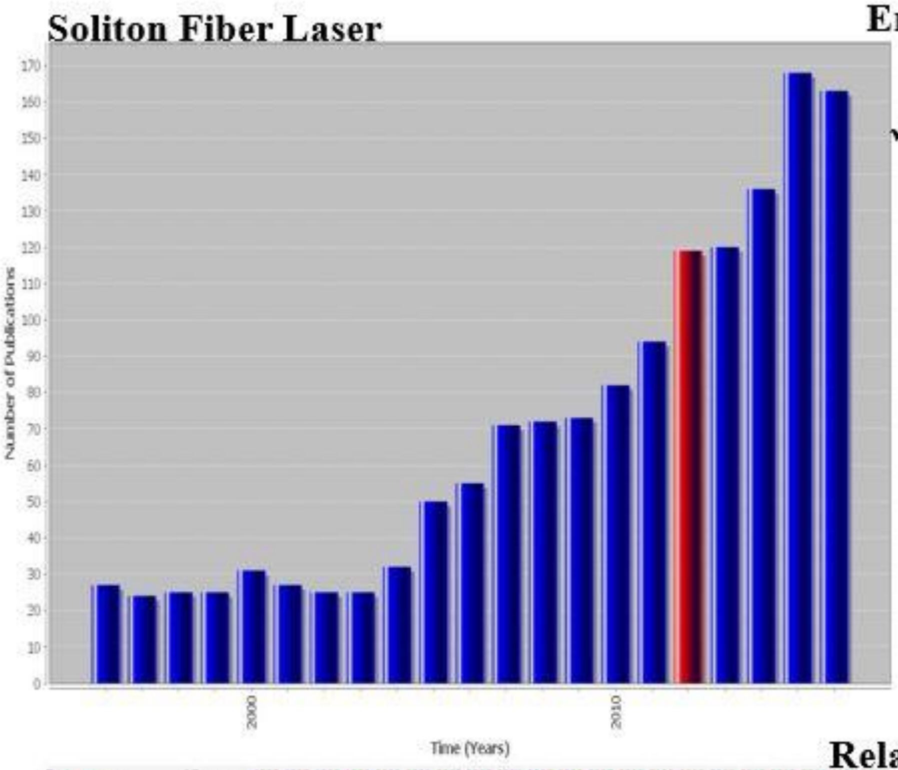
Rank	country	# Documents
1.	United States	13
2.	Singapore	11
3.	China	7
4.	Canada	2
5.	Finland	2
6.	France	2
7.	Japan	2
8.	United Arab Emirates	1
9.	Australia	1
10.	Germany	1
11.	Denmark	1
12.	Egypt	1
13.	South Korea	1
14.	Russia	1
15.	Turkey	1
16.	Taiwan	1

Singapore →
U.S. →

Soliton Fiber Laser

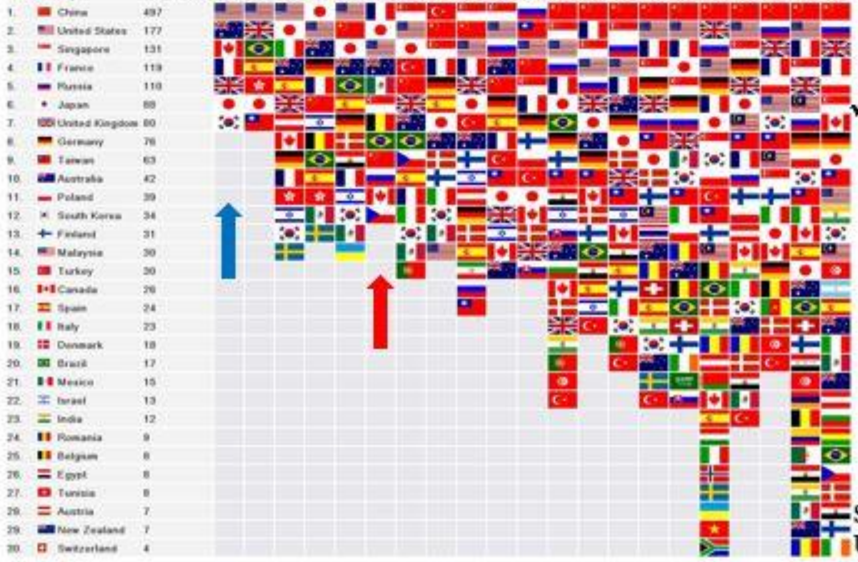
Emerging

Yes
✓ No
Unclear



Relation to U.S.

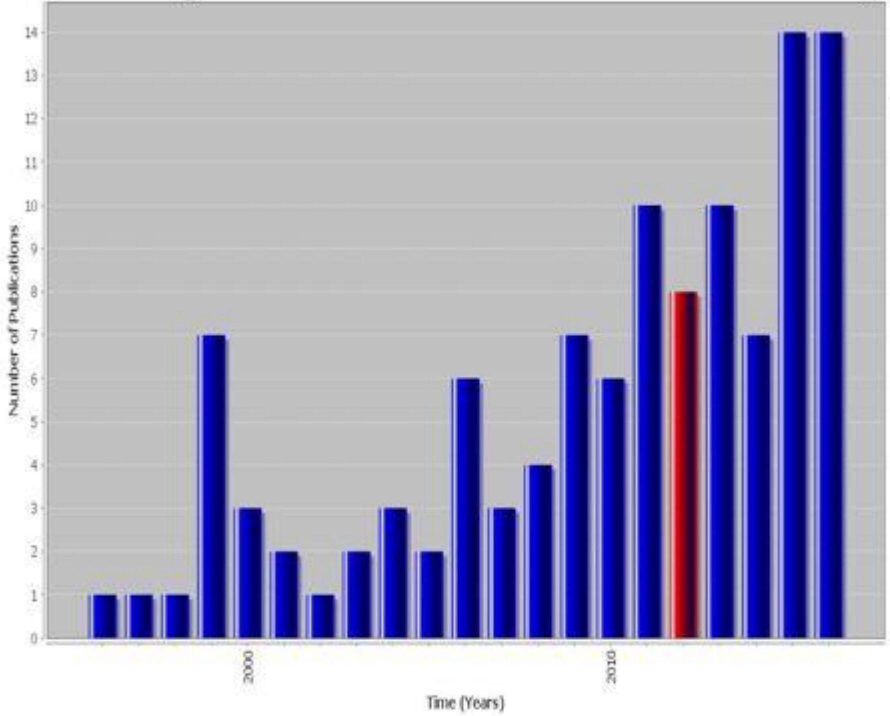
Before
✓ After
Same



Rank	country	# Documents
1.	China	497
2.	United States	177
3.	Singapore	131
4.	France	119
5.	Russia	110
6.	Japan	88
7.	United Kingdom	80
8.	Germany	76
9.	Taiwan	63
10.	Australia	42
11.	Poland	39
12.	South Korea	34
13.	Finland	31
14.	Malaysia	30
15.	Turkey	30
16.	Canada	26
17.	Spain	24
18.	Italy	23
19.	Denmark	18
20.	Brazil	17
21.	Mexico	15
22.	Israel	13
23.	India	12
24.	Romania	9
25.	Belgium	8
26.	Egypt	8
27.	Tunisia	8
28.	Austria	7
29.	New Zealand	7
30.	Switzerland	4

Singapore 🟥
U.S. 🟦

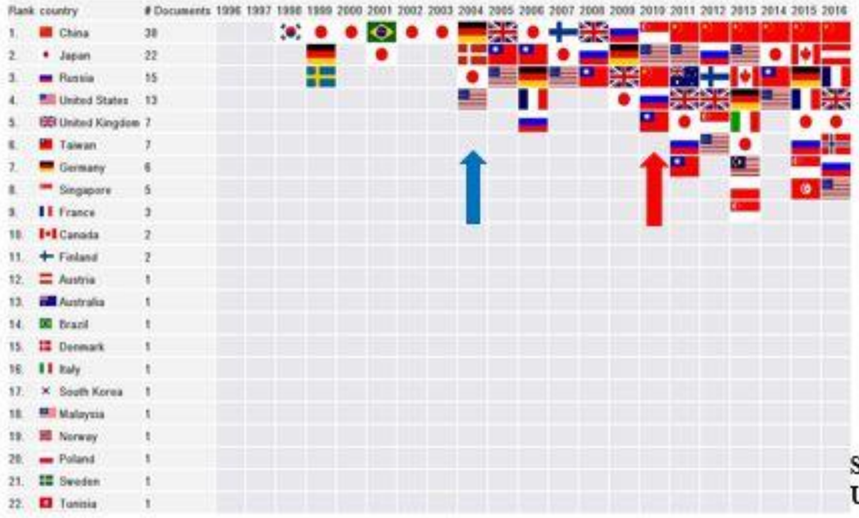
Soliton Fiber Laser AND Wavelength Tunable



Emerging

Yes
[✓ No]
Unclear

Relation to U.S.

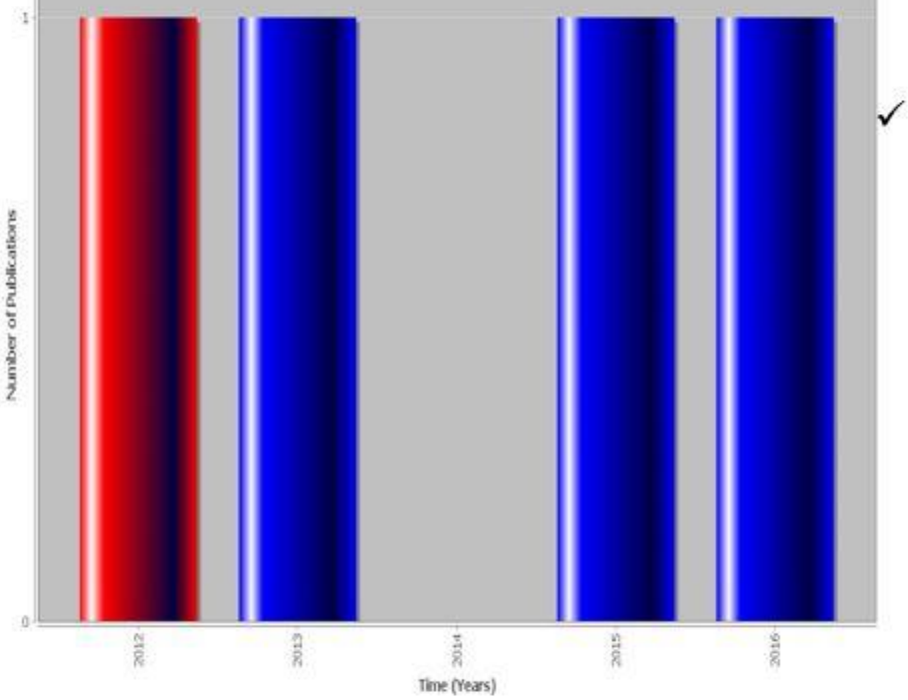


Rank	country	# Documents
1.	China	38
2.	Japan	22
3.	Russia	15
4.	United States	13
5.	United Kingdom	7
6.	Taiwan	7
7.	Germany	6
8.	Singapore	5
9.	France	3
10.	Canada	2
11.	Finland	2
12.	Austria	1
13.	Australia	1
14.	Brazil	1
15.	Denmark	1
16.	Italy	1
17.	South Korea	1
18.	Malaysia	1
19.	Norway	1
20.	Poland	1
21.	Sweden	1
22.	Tunisia	1

Before
[✓ After]
Same

Singapore →
U.S. →

Soliton Fiber Laser AND Wavelength Tunable AND Topological Insulator



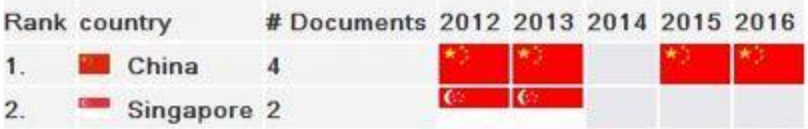
Emerging

Yes

No

✓ Unclear

Relation to U.S.



Rank	country	# Documents	2012	2013	2014	2015	2016
1.	🇨🇳 China	4	🇨🇳	🇨🇳		🇨🇳	🇨🇳
2.	🇸🇬 Singapore	2	🇸🇬	🇸🇬			

⬆

✓ Before

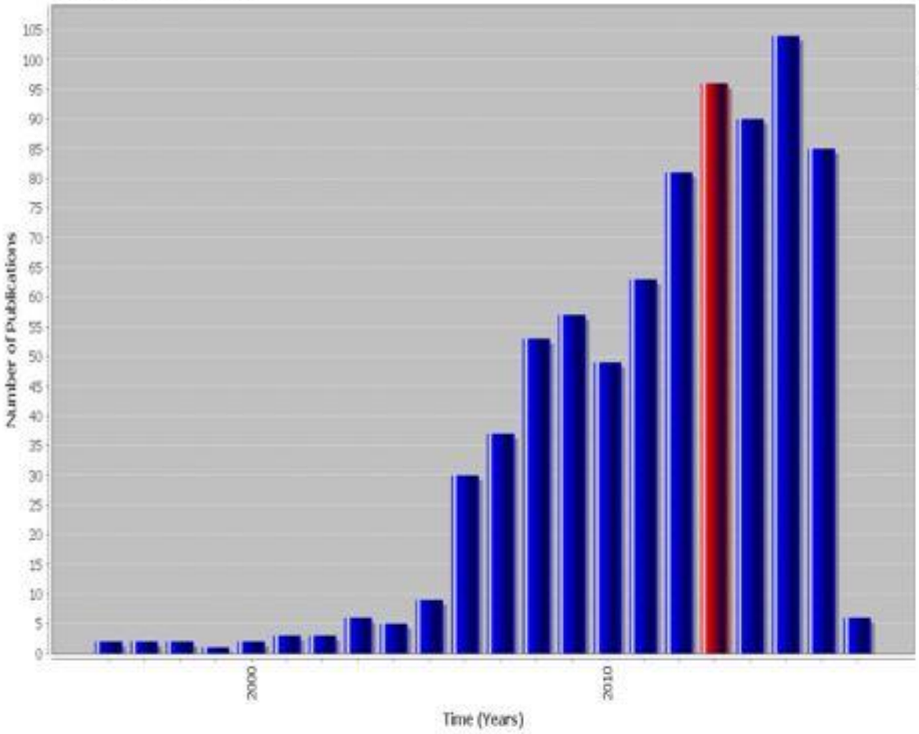
After

Same

Singapore ➡

U.S. ➡

Visual Slam

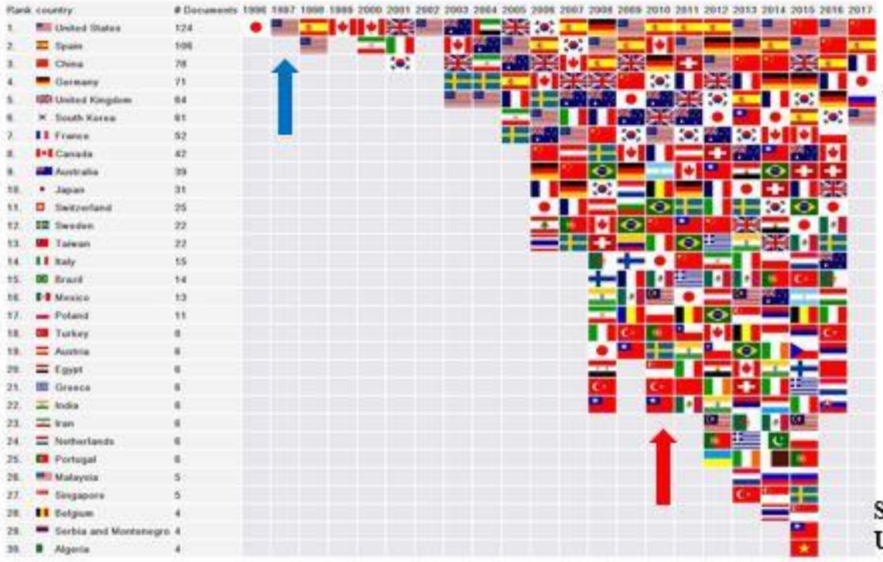


Emerging

Yes
✓ No
Unclear

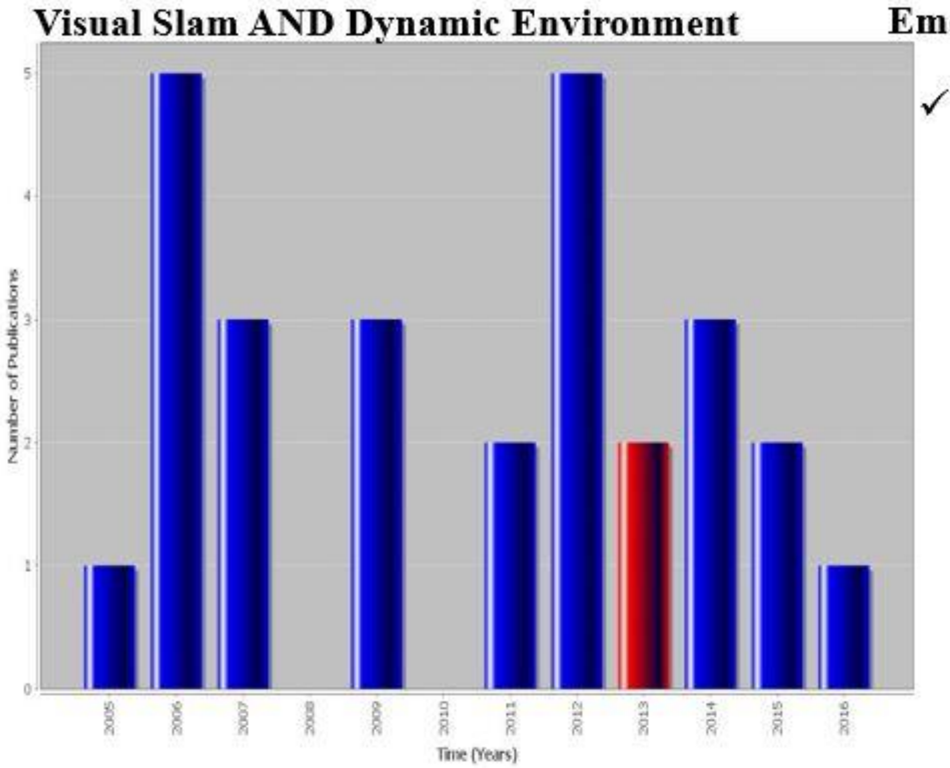
Relation to U.S.

Before
✓ After
Same



Rank	country	# Documents
1.	United States	124
2.	Spain	106
3.	China	78
4.	Germany	71
5.	United Kingdom	64
6.	South Korea	61
7.	France	52
8.	Canada	42
9.	Australia	39
10.	Japan	31
11.	Switzerland	25
12.	Sweden	22
13.	Taiwan	22
14.	Italy	15
15.	Brazil	14
16.	Mexico	13
17.	Poland	11
18.	Turkey	8
19.	Austria	6
20.	Egypt	6
21.	Greece	6
22.	India	6
23.	Iran	6
24.	Netherlands	6
25.	Portugal	6
26.	Malaysia	5
27.	Singapore	5
28.	Belgium	4
29.	Serbia and Montenegro	4
30.	Algeria	4

Singapore
U.S.



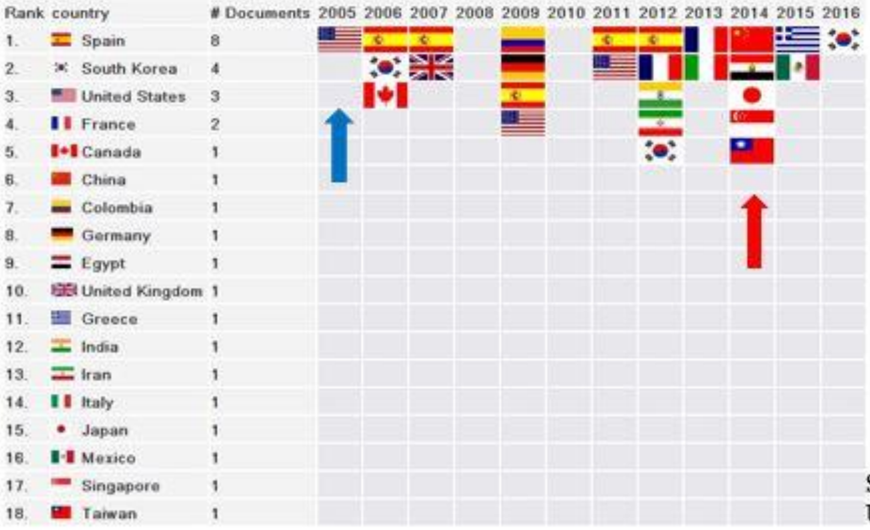
Emerging

Yes

✓ No

Unclear

Relation to U.S.



Rank	country	# Documents	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
1.	Spain	8												
2.	South Korea	4												
3.	United States	3												
4.	France	2												
5.	Canada	1												
6.	China	1												
7.	Colombia	1												
8.	Germany	1												
9.	Egypt	1												
10.	United Kingdom	1												
11.	Greece	1												
12.	India	1												
13.	Iran	1												
14.	Italy	1												
15.	Japan	1												
16.	Mexico	1												
17.	Singapore	1												
18.	Taiwan	1												

Before

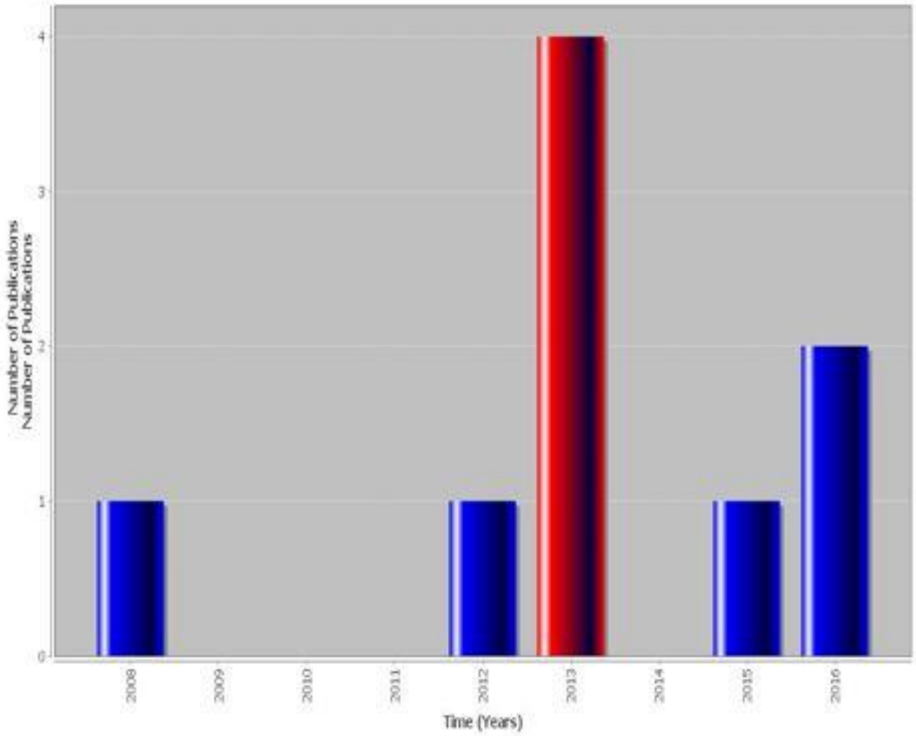
✓ After

Same

Singapore ➡

U.S. ➡

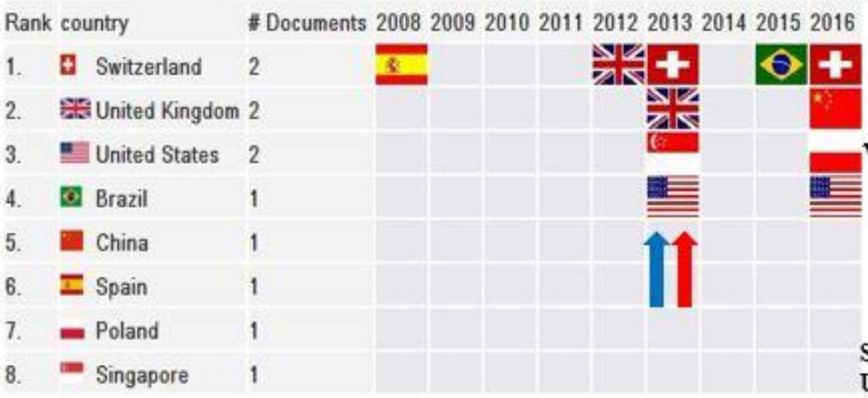
Collaborative AND Visual Slam



Emerging

Yes
✓ No
Unclear

Relation to U.S.



Rank	country	# Documents	2008	2009	2010	2011	2012	2013	2014	2015	2016
1.	🇨🇭 Switzerland	2	🇪🇸				🇬🇧	🇨🇭		🇧🇷	🇨🇭
2.	🇬🇧 United Kingdom	2						🇬🇧			🇨🇳
3.	🇺🇸 United States	2						🇸🇬			🇵🇱
4.	🇧🇷 Brazil	1						🇺🇸			🇺🇸
5.	🇨🇳 China	1						⬆⬆			
6.	🇪🇸 Spain	1									
7.	🇵🇱 Poland	1									
8.	🇸🇬 Singapore	1									

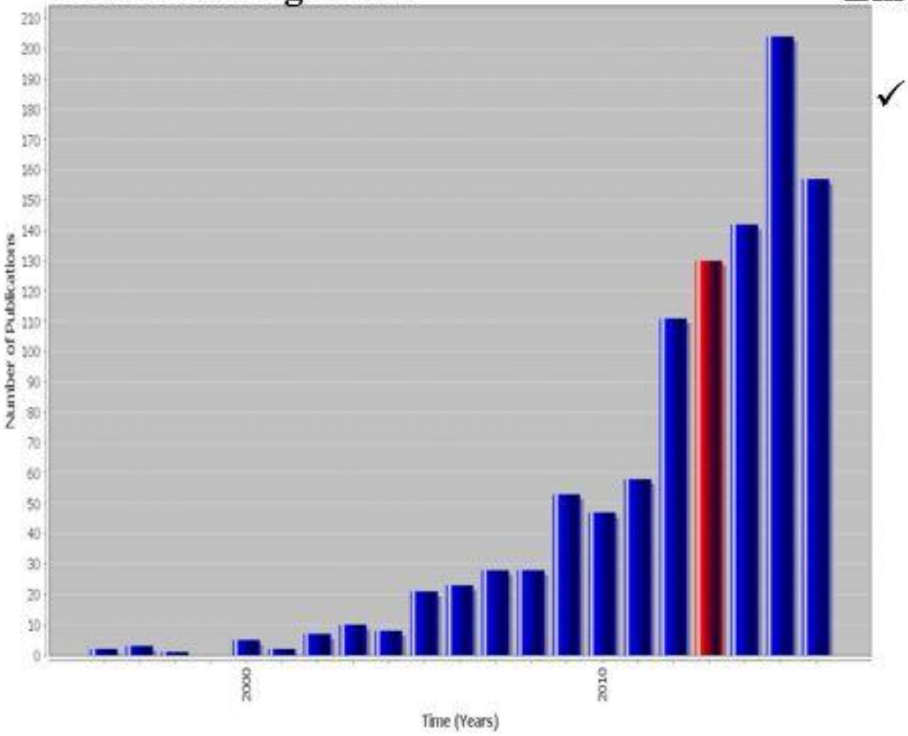
Before
After
✓ Same

Singapore ➡
U.S. ➡

Direct Power Conversion OR Grid Integration

Emerging

Yes [✓ No] Unclear

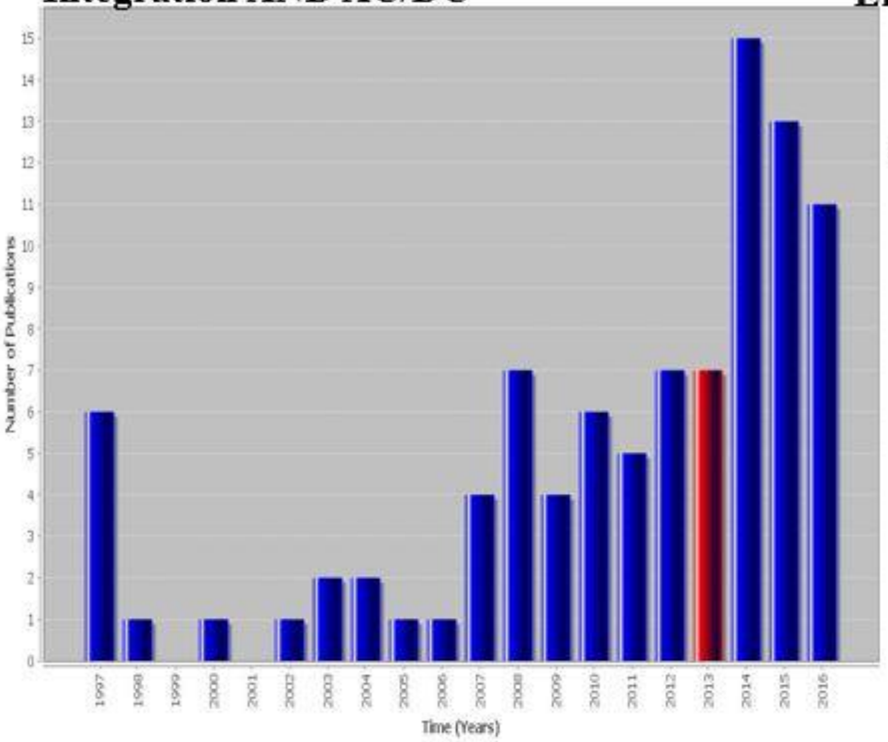


Relation to U.S.

Before [✓ After] Same

Rank	country	# Documents
1.	United States	203
2.	India	139
3.	China	134
4.	Germany	87
5.	Canada	48
6.	United Kingdom	43
7.	Denmark	42
8.	Spain	36
9.	Australia	30
10.	Japan	28
11.	France	27
12.	Italy	24
13.	South Korea	24
14.	Iran	20
15.	Netherlands	20
16.	Sweden	20
17.	Switzerland	18
18.	Norway	18
19.	Portugal	16
20.	Brazil	14
21.	Singapore	14
22.	Turkey	14
23.	South Africa	14
24.	New Zealand	13
25.	Egypt	12
26.	Ireland	11
27.	Pakistan	10
28.	Poland	9
29.	Croatia	8
30.	Taiwan	8

Direct Power Conversion OR Grid Integration AND AC/DC



Emerging

Yes

No

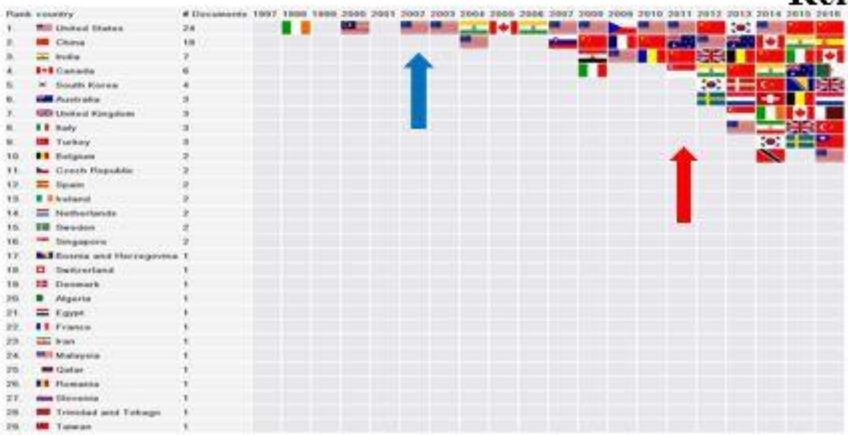
✓ Unclear

Relation to U.S.

Before

✓ After

Same



Rank	country	# Documents
1.	United States	24
2.	China	18
3.	India	7
4.	Canada	6
5.	South Korea	4
6.	Australia	3
7.	United Kingdom	3
8.	Italy	3
9.	Turkey	3
10.	Belgium	2
11.	Czech Republic	2
12.	Spain	2
13.	Ireland	2
14.	Netherlands	2
15.	Sweden	2
16.	Singapore	2
17.	Bosnia and Herzegovina	1
18.	Switzerland	1
19.	Denmark	1
20.	Algeria	1
21.	Egypt	1
22.	France	1
23.	Iran	1
24.	Malaysia	1
25.	Qatar	1
26.	Romania	1
27.	Slovenia	1
28.	Trinidad and Tobago	1
29.	Taiwan	1

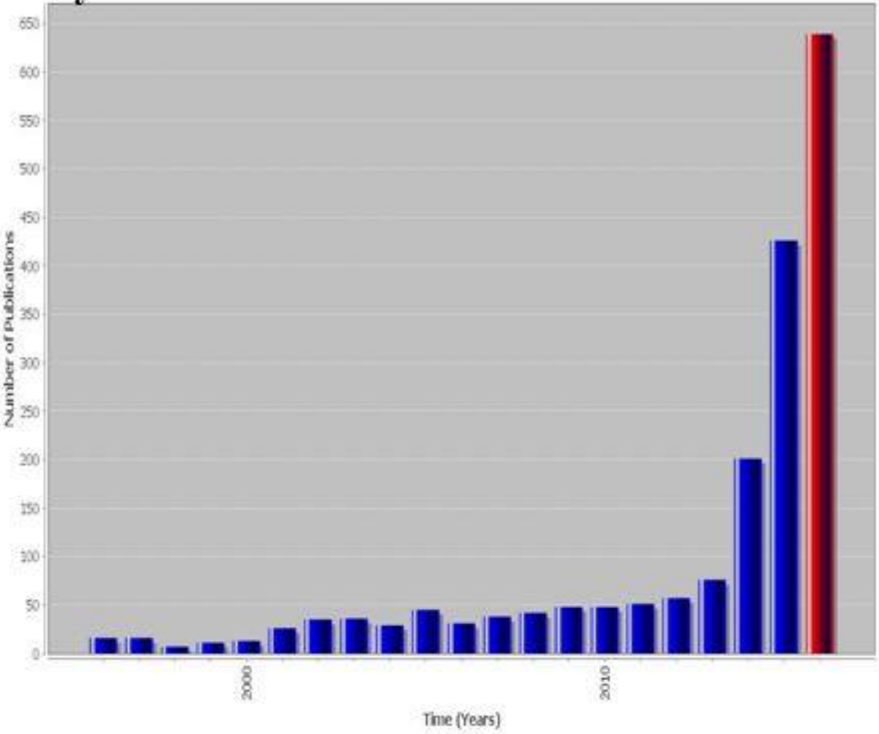
Singapore →

U.S. →

Hybrid Perovskites

Emerging

✓ Yes
No
Unclear

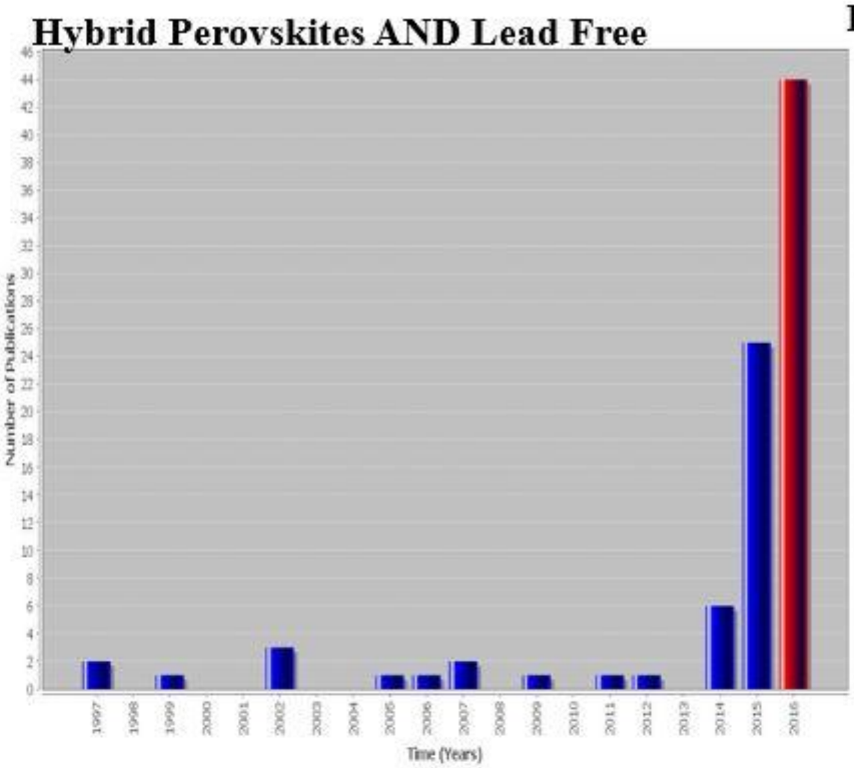


Relation to U.S.

Before
✓ After
Same

Rank	country	# Documents
1.	United States	467
2.	China	460
3.	Japan	212
4.	South Korea	147
5.	United Kingdom	143
6.	France	130
7.	Germany	109
8.	India	98
9.	Spain	83
10.	Italy	82
11.	Switzerland	61
12.	Saudi Arabia	51
13.	Taiwan	49
14.	Singapore	45
15.	Australia	37
16.	Israel	32
17.	Sweden	29
18.	Canada	28
19.	Netherlands	27
20.	Russia	27
21.	Latvia	21
22.	Poland	18
23.	Qatar	18
24.	Tunisia	16
25.	Austria	15
26.	Brazil	13
27.	Egypt	13
28.	Iran	13
29.	Belgium	12
30.	Malaysia	11

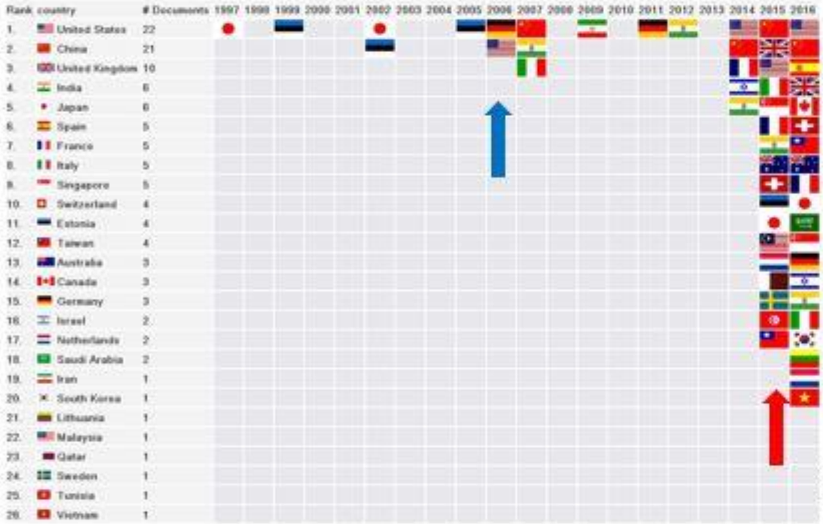
Hybrid Perovskites AND Lead Free



Emerging

[✓ Yes]
No
Unclear

Relation to U.S.

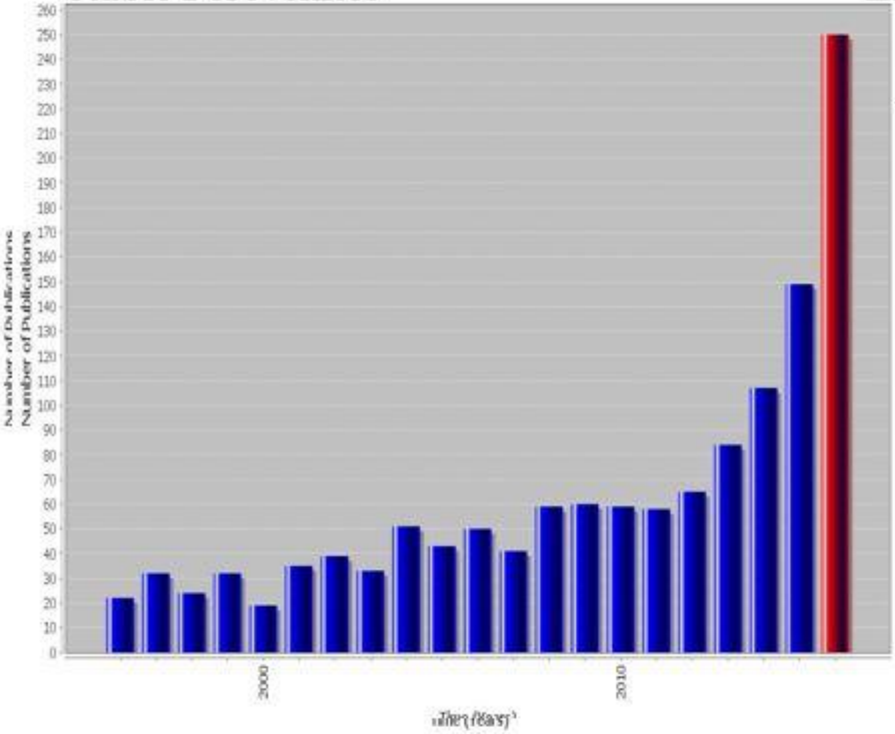


Rank	country	# Documents
1.	United States	22
2.	China	21
3.	United Kingdom	10
4.	India	6
5.	Japan	6
6.	Spain	5
7.	France	5
8.	Italy	5
9.	Singapore	5
10.	Switzerland	4
11.	Estonia	4
12.	Taiwan	4
13.	Australia	3
14.	Canada	3
15.	Germany	3
16.	Israel	2
17.	Netherlands	2
18.	Saudi Arabia	2
19.	Iran	1
20.	South Korea	1
21.	Lithuania	1
22.	Malaysia	1
23.	Qatar	1
24.	Sweden	1
25.	Tunisia	1
26.	Vietnam	1

Before
[✓ After]
Same

Singapore →
U.S. →

Stable Perovskites

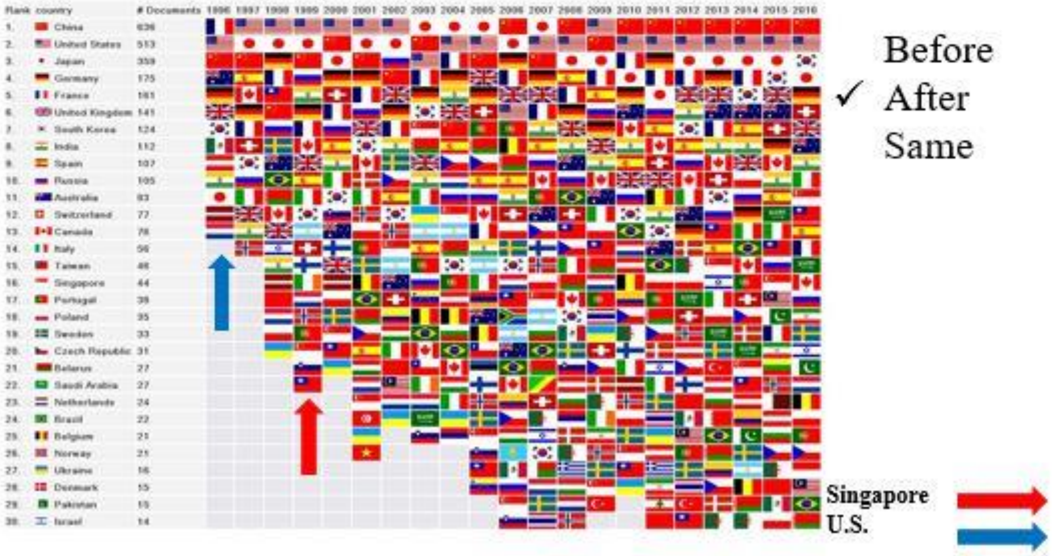


Emerging

Yes
[✓ No]
Unclear

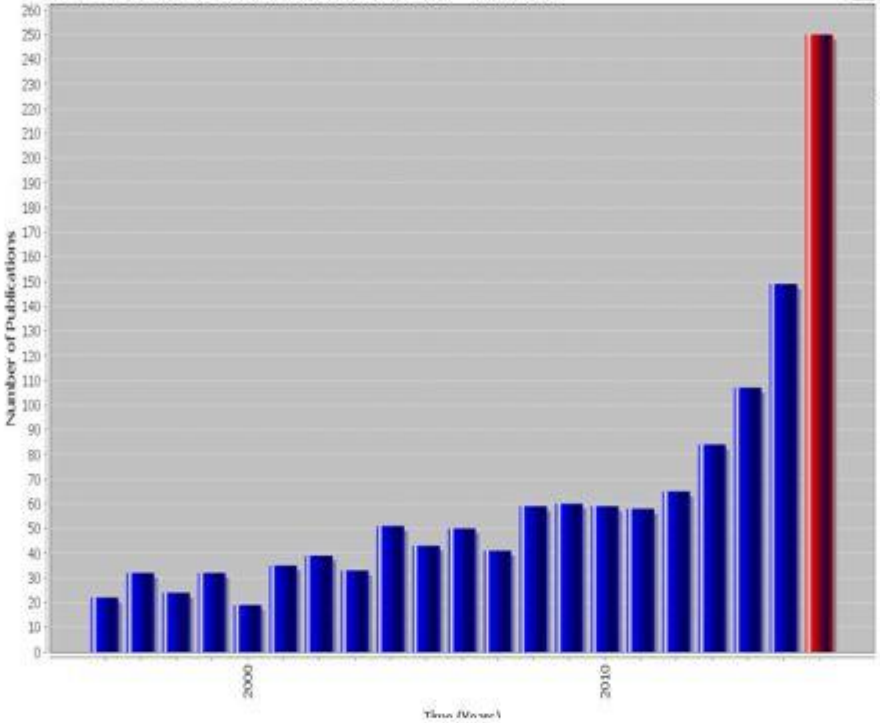
Relation to U.S.

Before
[✓ After]
Same



Rank	country	# Documents
1.	China	636
2.	United States	513
3.	Japan	359
4.	Germany	175
5.	France	161
6.	United Kingdom	141
7.	South Korea	124
8.	India	112
9.	Spain	107
10.	Russia	105
11.	Australia	83
12.	Switzerland	77
13.	Canada	76
14.	Italy	56
15.	Taiwan	46
16.	Singapore	44
17.	Portugal	39
18.	Poland	35
19.	Sweden	33
20.	Czech Republic	31
21.	Belarus	27
22.	Saudi Arabia	27
23.	Netherlands	24
24.	Brazil	22
25.	Belgium	21
26.	Norway	21
27.	Ukraine	16
28.	Denmark	15
29.	Pakistan	15
30.	Israel	14

Stable Perovskites AND Lead



Emerging

Yes

✓ No

Unclear

Relation to U.S.

Rank	country	# Documents
1.	China	108
2.	United States	64
3.	Japan	34
4.	France	30
5.	Germany	28
6.	United Kingdom	25
7.	Spain	23
8.	South Korea	22
9.	Russia	18
10.	Switzerland	17
11.	Australia	16
12.	India	16
13.	Italy	15
14.	Portugal	13
15.	Singapore	13
16.	Canada	12
17.	Belarus	8
18.	Israel	6
19.	Morocco	6
20.	Netherlands	6
21.	Sweden	6
22.	Taiwan	6
23.	Belgium	5
24.	Brazil	5
25.	Poland	5
26.	Saudi Arabia	5
27.	Czech Republic	4
28.	Malaysia	4
29.	Latvia	3
30.	Norway	3

Before

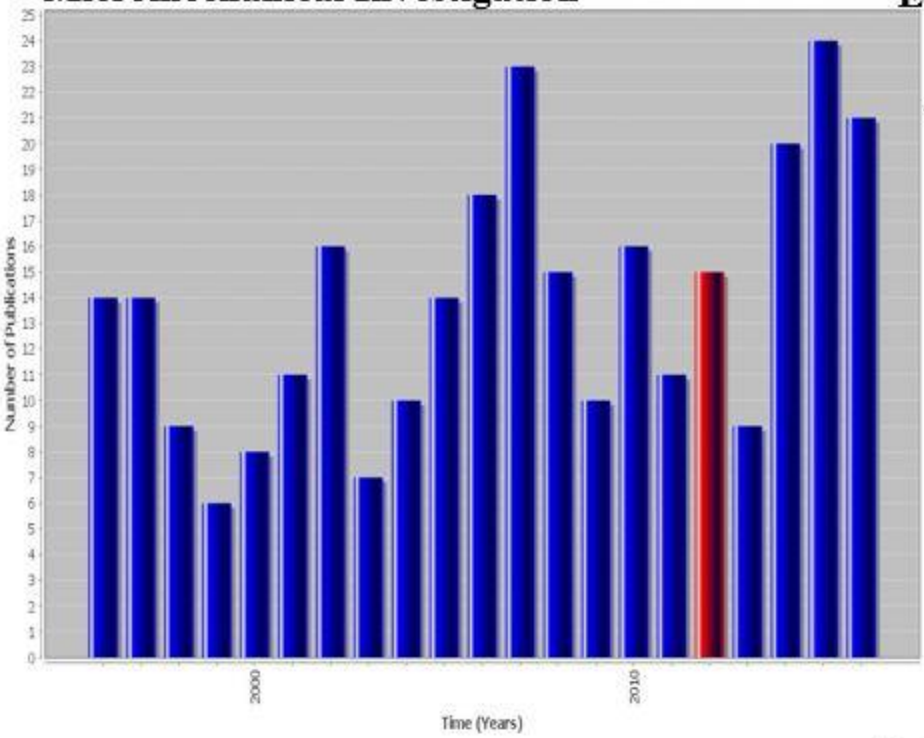
✓ After

Same

Singapore ➡

U.S. ➡

Micromechanical Investigation

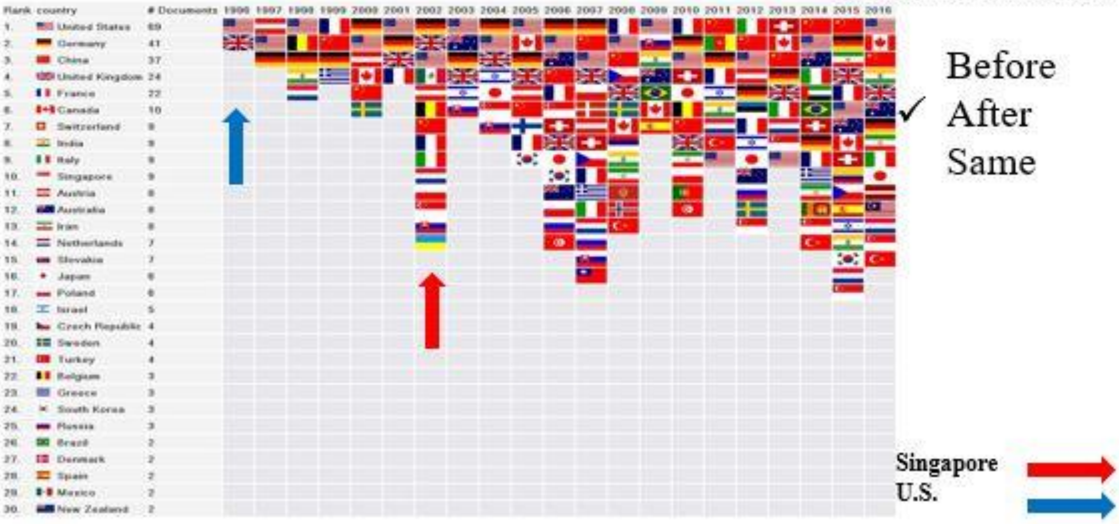


Emerging

Yes
[✓ No]
Unclear

Relation to U.S.

Before
[✓ After]
Same

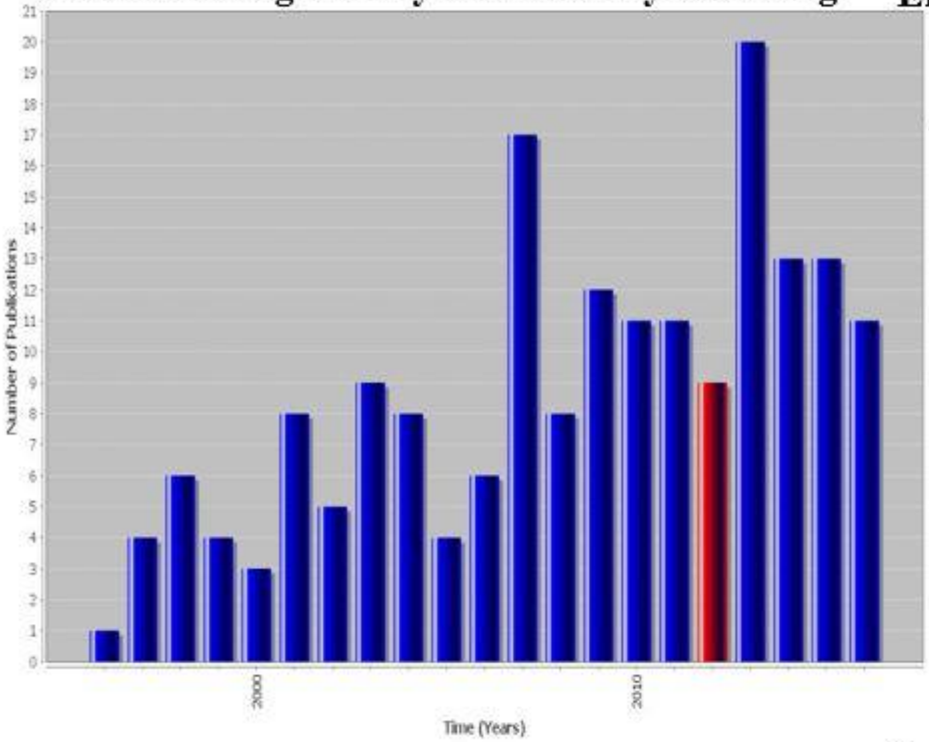


Rank	country	# Documents
1.	United States	69
2.	Germany	41
3.	China	37
4.	United Kingdom	24
5.	France	22
6.	Canada	10
7.	Switzerland	9
8.	India	9
9.	Italy	9
10.	Singapore	9
11.	Austria	8
12.	Australia	8
13.	Iran	8
14.	Netherlands	7
15.	Slovakia	7
16.	Japan	6
17.	Poland	6
18.	Israel	5
19.	Czech Republic	4
20.	Sweden	4
21.	Turkey	4
22.	Belgium	3
23.	Greece	3
24.	South Korea	3
25.	Russia	3
26.	Brazil	2
27.	Denmark	2
28.	Spain	2
29.	Mexico	2
30.	New Zealand	2

Phenomenological Crystal Plasticity Modeling

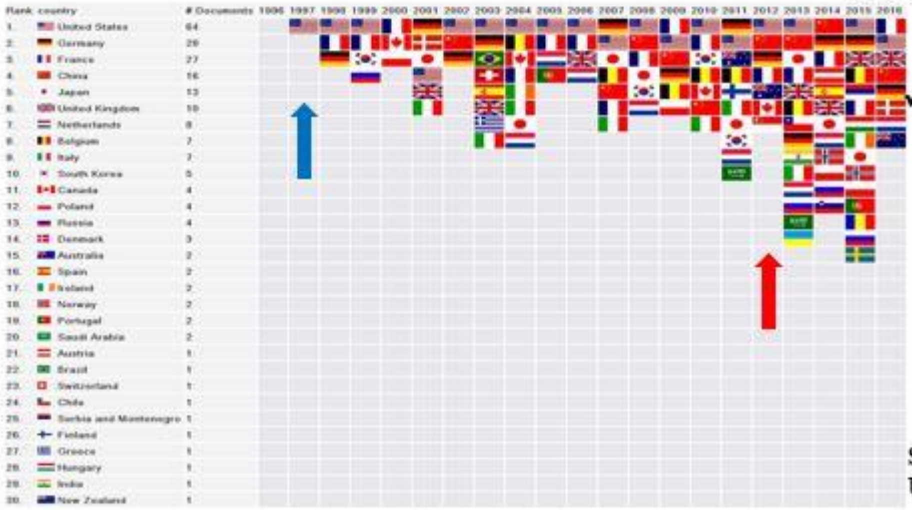
Emerging

Yes
✓ No
Unclear



Relation to U.S.

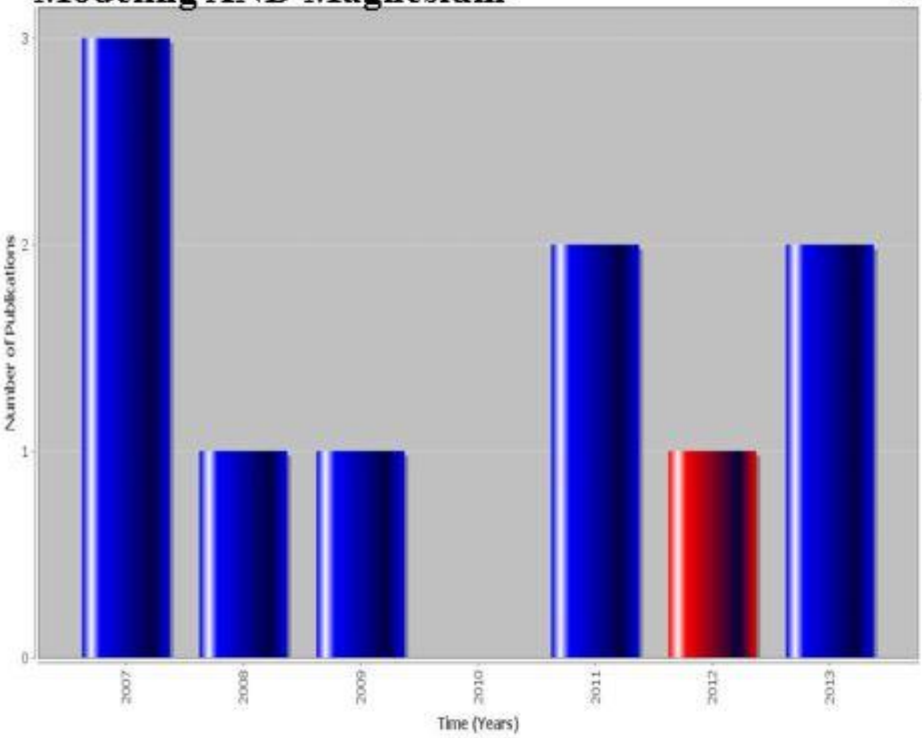
Before
✓ After
Same



Rank	country	# Documents
1.	United States	64
2.	Germany	28
3.	France	27
4.	China	16
5.	Japan	13
6.	United Kingdom	10
7.	Netherlands	8
8.	Belgium	7
9.	Italy	7
10.	South Korea	5
11.	Canada	4
12.	Poland	4
13.	Russia	4
14.	Denmark	3
15.	Australia	2
16.	Spain	2
17.	Ireland	2
18.	Norway	2
19.	Portugal	2
20.	Saudi Arabia	2
21.	Austria	1
22.	Brazil	1
23.	Switzerland	1
24.	Chile	1
25.	Serbia and Montenegro	1
26.	Finland	1
27.	Greece	1
28.	Hungary	1
29.	India	1
30.	New Zealand	1

Singapore →
U.S. →

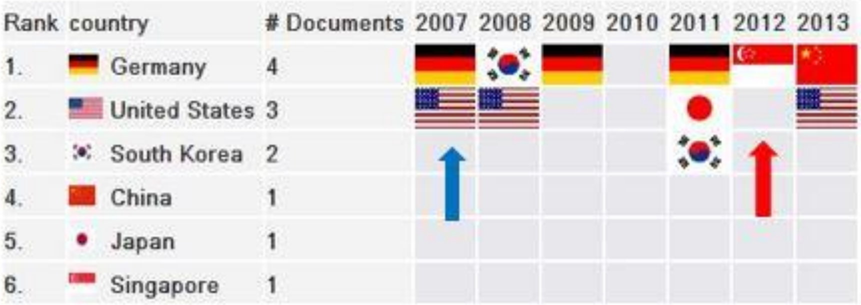
Phenomenological Crystal Plasticity Modeling AND Magnesium



Emerging

Yes [✓ No] Unclear

Relation to U.S.

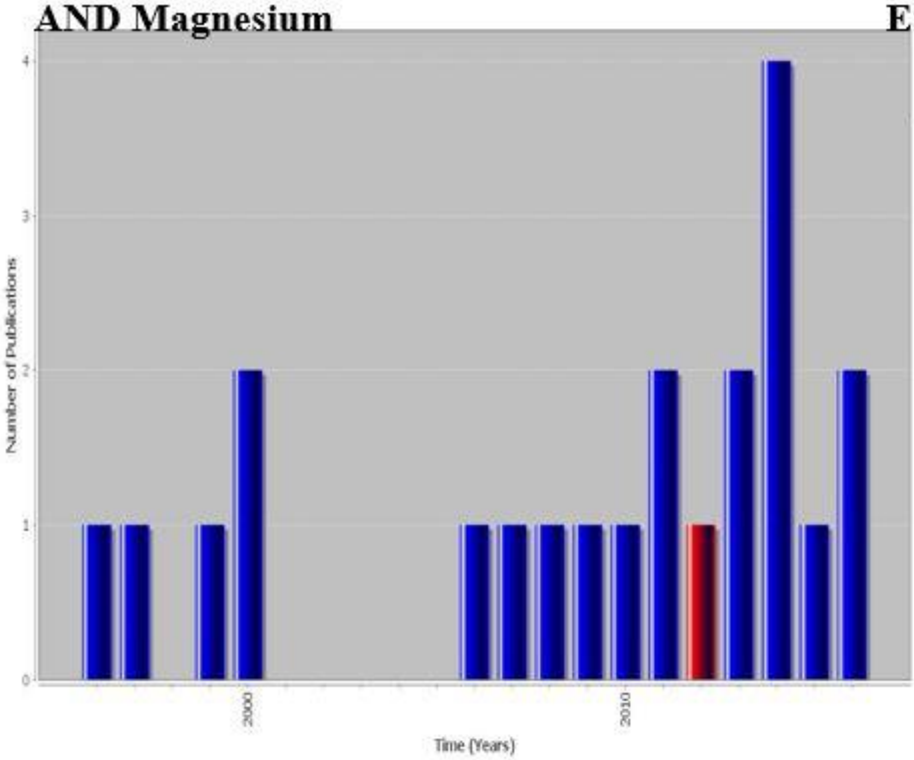


Rank	country	# Documents	2007	2008	2009	2010	2011	2012	2013
1.	🇩🇪 Germany	4	🇩🇪	🇰🇷	🇩🇪		🇩🇪	🇸🇬	🇨🇳
2.	🇺🇸 United States	3	🇺🇸	🇺🇸			🇯🇵		🇺🇸
3.	🇰🇷 South Korea	2	⬆				🇰🇷	⬆	
4.	🇨🇳 China	1							
5.	🇯🇵 Japan	1							
6.	🇸🇬 Singapore	1							

Before [✓ After] Same

Singapore ➡
U.S. ➡

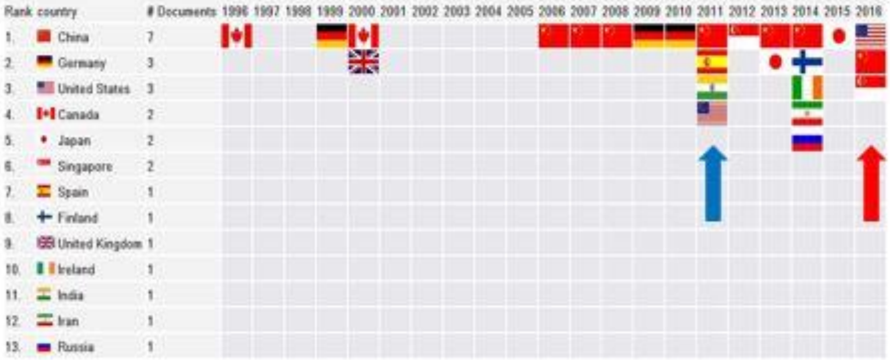
Micromechanical Investigation AND Magnesium



Emerging

Yes
✓ No
Unclear

Relation to U.S.

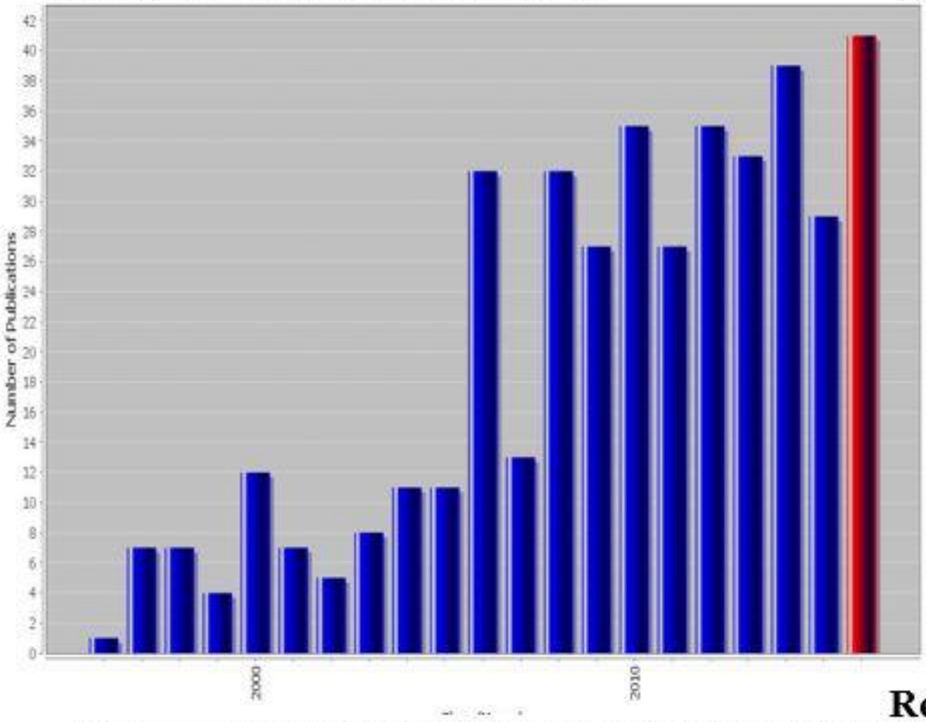


Rank	country	# Documents
1.	China	7
2.	Germany	3
3.	United States	3
4.	Canada	2
5.	Japan	2
6.	Singapore	2
7.	Spain	1
8.	Finland	1
9.	United Kingdom	1
10.	Ireland	1
11.	India	1
12.	Iran	1
13.	Russia	1

Before
✓ After
Same

Singapore 🡺
U.S. 🡺

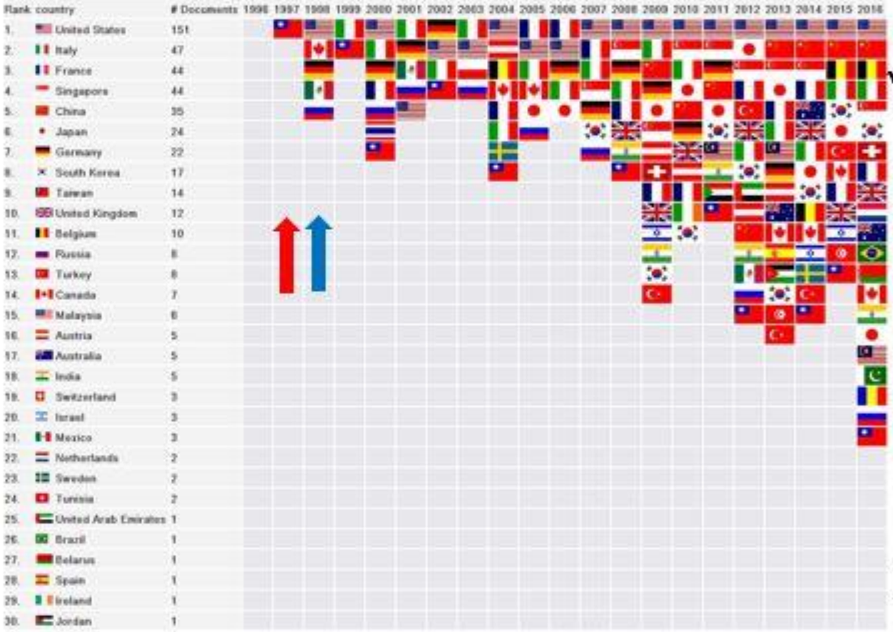
Germanium AND Photodetector



Emerging

Yes
✓ No
Unclear

Relation to U.S.

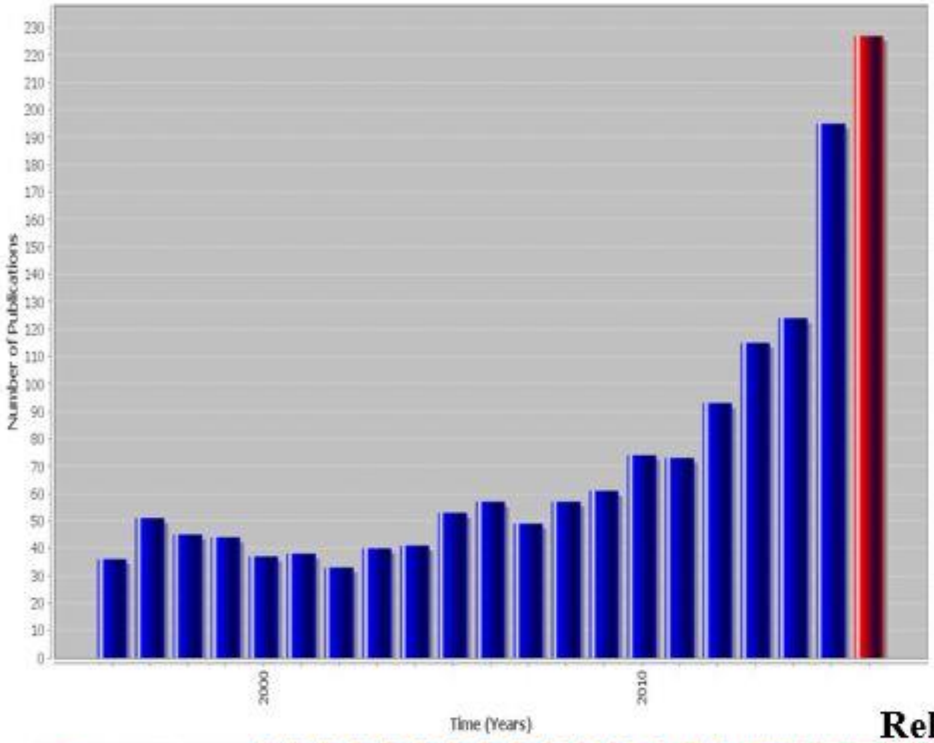


Rank	country	# Documents
1.	United States	151
2.	Italy	47
3.	France	44
4.	Singapore	44
5.	China	35
6.	Japan	24
7.	Germany	22
8.	South Korea	17
9.	Taiwan	14
10.	United Kingdom	12
11.	Belgium	10
12.	Russia	8
13.	Turkey	8
14.	Canada	7
15.	Malaysia	6
16.	Austria	5
17.	Australia	5
18.	India	5
19.	Switzerland	3
20.	Israel	3
21.	Mexico	3
22.	Netherlands	2
23.	Sweden	2
24.	Tunisia	2
25.	United Arab Emirates	1
26.	Brazil	1
27.	Belarus	1
28.	Spain	1
29.	Ireland	1
30.	Jordan	1

✓ Before
After
Same

Taiwan 🟥
U.S. 🟦

Backside AND Illumination AND Photodetector

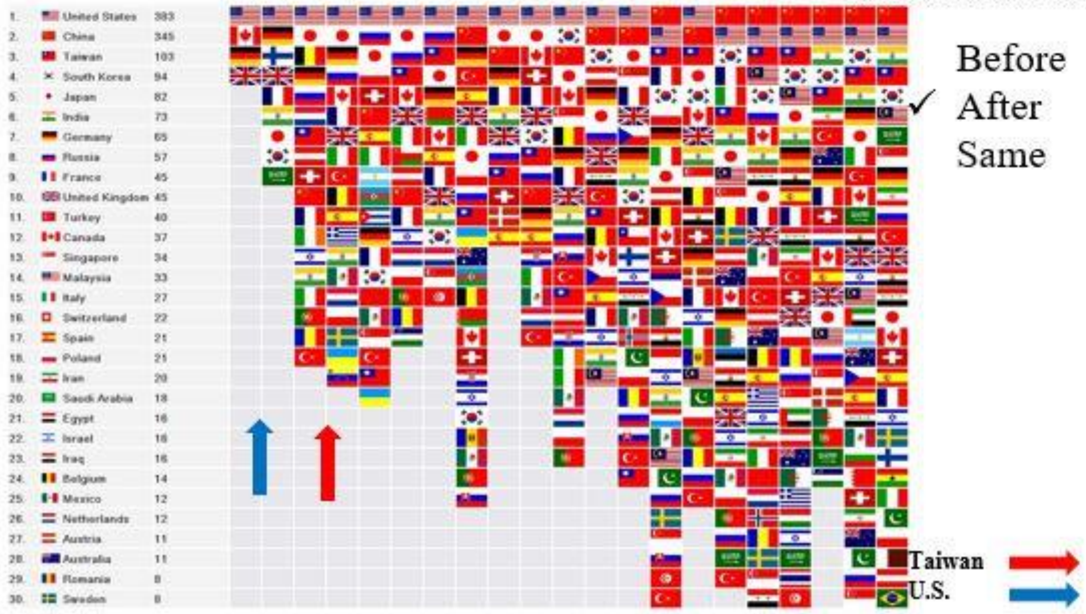


Emerging

Yes
✓ No
Unclear

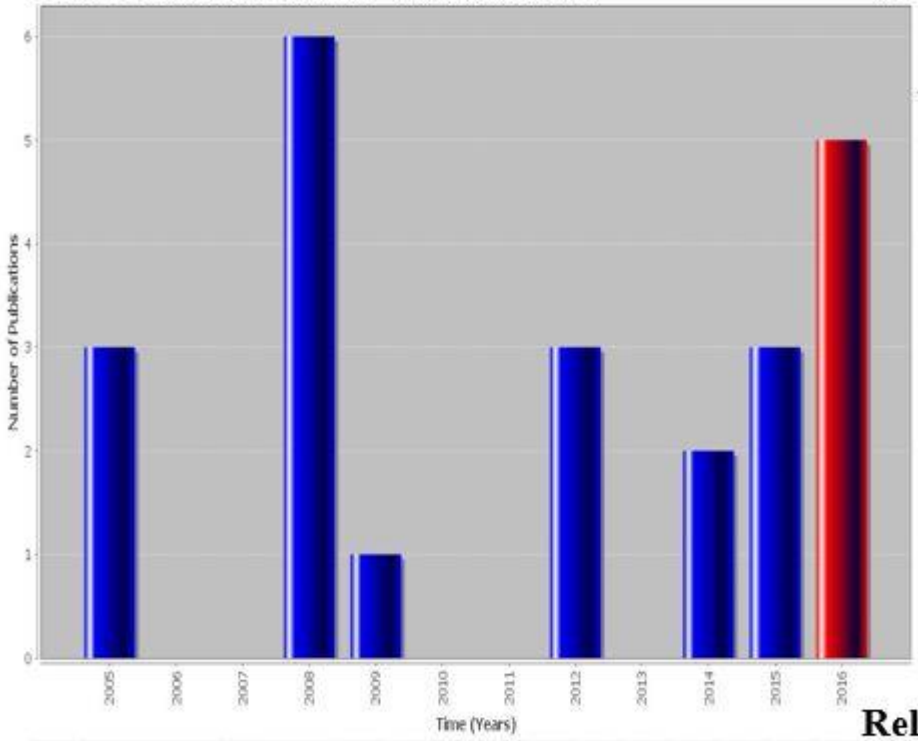
Relation to U.S.

Before
✓ After
Same



1.	United States	383
2.	China	345
3.	Taiwan	103
4.	South Korea	94
5.	Japan	82
6.	India	73
7.	Germany	65
8.	Russia	57
9.	France	45
10.	United Kingdom	45
11.	Turkey	40
12.	Canada	37
13.	Singapore	34
14.	Malaysia	33
15.	Italy	27
16.	Switzerland	22
17.	Spain	21
18.	Poland	21
19.	Iran	20
20.	Saudi Arabia	18
21.	Egypt	16
22.	Israel	16
23.	Iraq	16
24.	Belgium	14
25.	Mexico	12
26.	Netherlands	12
27.	Austria	11
28.	Australia	11
29.	Romania	8
30.	Sweden	8

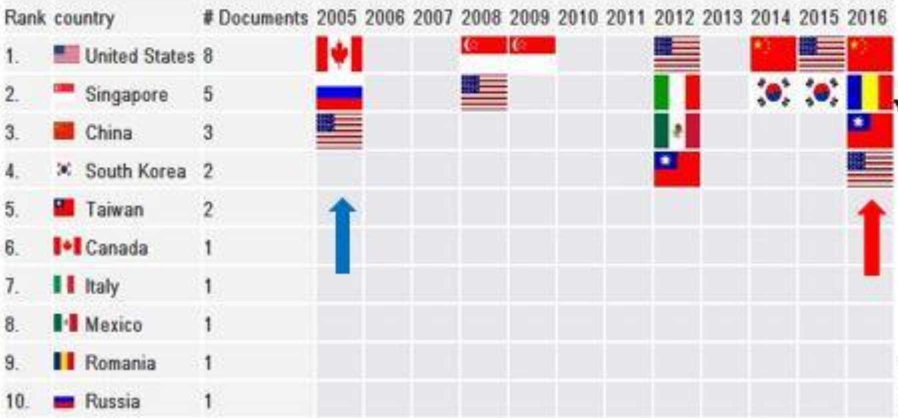
Backside AND Illumination AND Photodetector AND Germanium



Emerging

Yes
[✓ No]
Unclear

Relation to U.S.

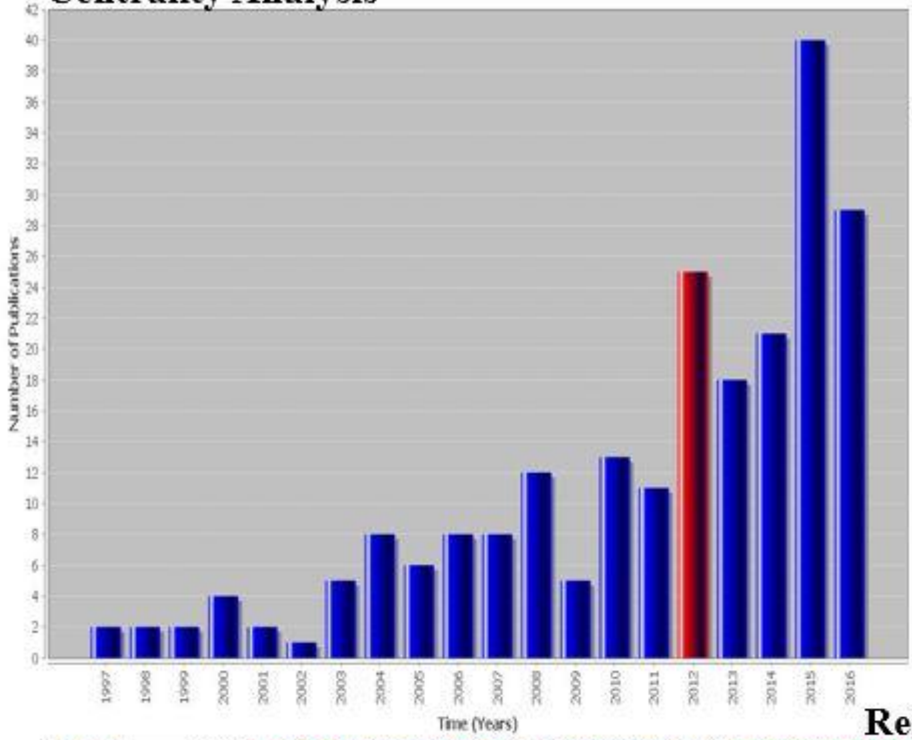


Rank	country	# Documents	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
1.	🇺🇸 United States	8	🇨🇦			🇸🇬	🇸🇬			🇺🇸		🇨🇳	🇺🇸	🇨🇳
2.	🇸🇬 Singapore	5	🇷🇺			🇺🇸				🇮🇹		🇰🇷	🇰🇷	🇷🇴
3.	🇨🇳 China	3	🇺🇸							🇲🇽				🇹🇼
4.	🇰🇷 South Korea	2								🇹🇼				🇺🇸
5.	🇹🇼 Taiwan	2	↑											↑
6.	🇨🇦 Canada	1												
7.	🇮🇹 Italy	1												
8.	🇲🇽 Mexico	1												
9.	🇷🇴 Romania	1												
10.	🇷🇺 Russia	1												

Before
[✓ After]
Same

Taiwan →
U.S. →

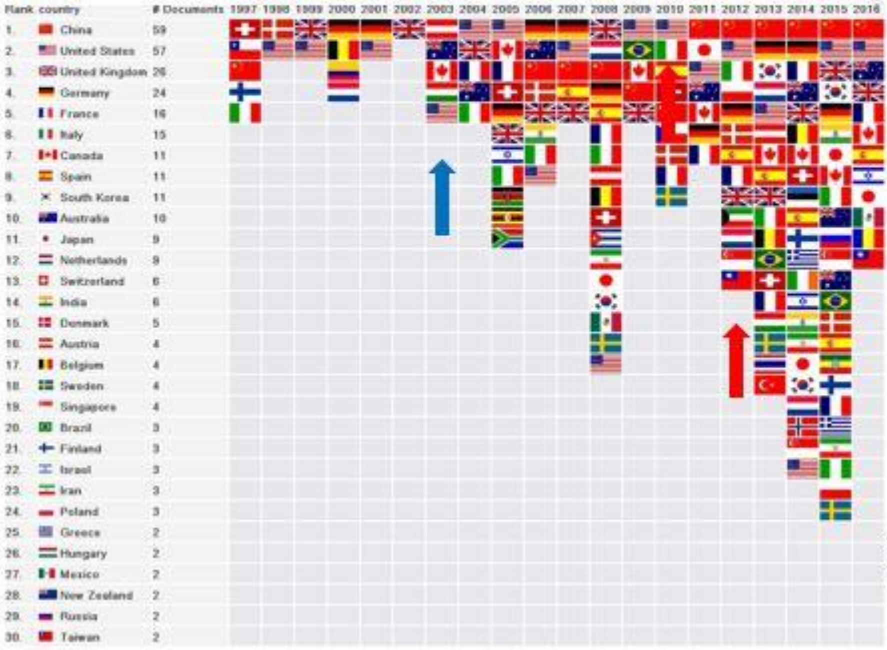
Centrality Analysis



Emerging

Yes
✓ No
Unclear

Relation to U.S.



Rank	country	# Documents
1.	China	59
2.	United States	57
3.	United Kingdom	26
4.	Germany	24
5.	France	16
6.	Italy	15
7.	Canada	11
8.	Spain	11
9.	South Korea	11
10.	Australia	10
11.	Japan	9
12.	Netherlands	9
13.	Switzerland	6
14.	India	6
15.	Denmark	5
16.	Austria	4
17.	Belgium	4
18.	Sweden	4
19.	Singapore	4
20.	Brazil	3
21.	Finland	3
22.	Israel	3
23.	Iran	3
24.	Poland	3
25.	Greece	2
26.	Hungary	2
27.	Mexico	2
28.	New Zealand	2
29.	Russia	2
30.	Taiwan	2

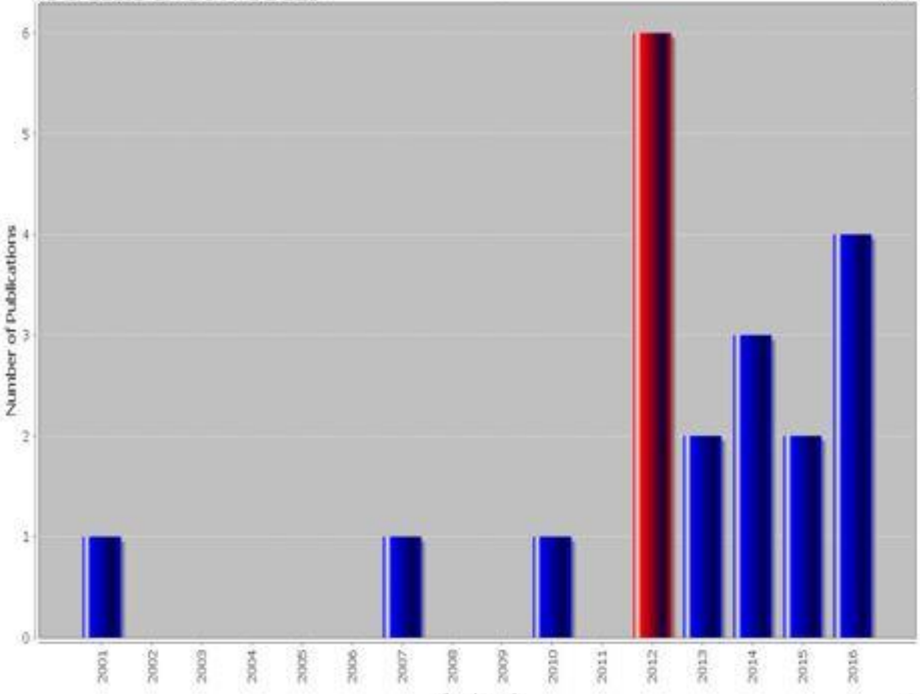
Before
✓ After
Same

Taiwan →
U.S. →

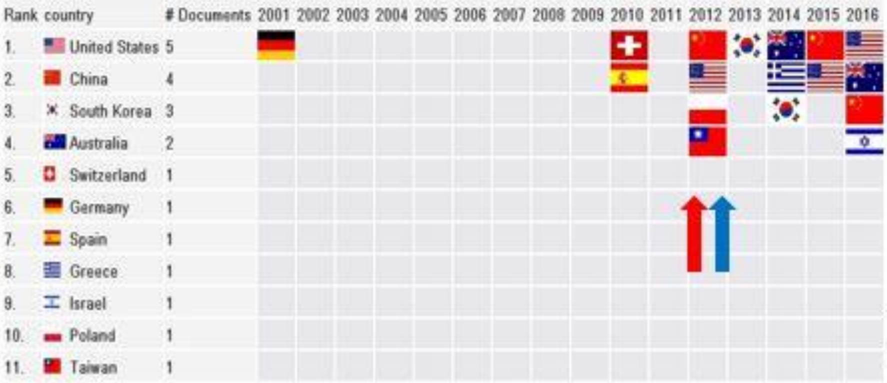
Centrality Analysis AND Social Networks

Emerging

Yes
✓ No
Unclear



Relative to U.S.

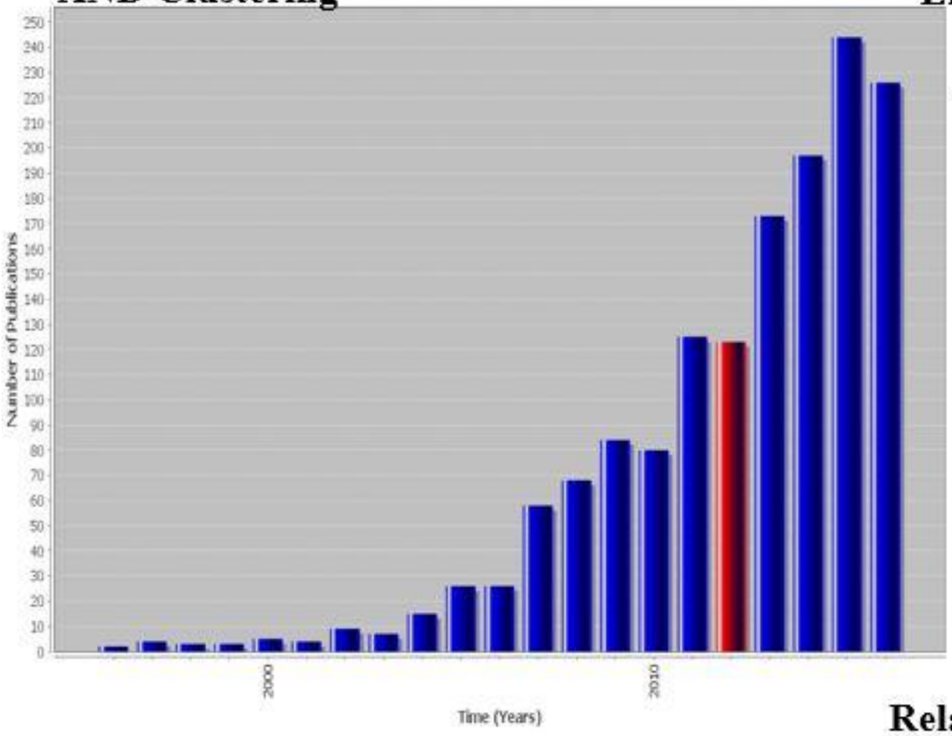


Rank	country	# Documents
1.	United States	5
2.	China	4
3.	South Korea	3
4.	Australia	2
5.	Switzerland	1
6.	Germany	1
7.	Spain	1
8.	Greece	1
9.	Israel	1
10.	Poland	1
11.	Taiwan	1

Before
After
✓ Same

Taiwan →
U.S. →

Analysis AND Social Networks AND Clustering



Emerging

Yes

✓ No

Unclear

Relative to U.S.

Rank	country	# Documents
1.	United States	423
2.	China	288
3.	United Kingdom	130
4.	Germany	78
5.	Australia	77
6.	Italy	73
7.	Canada	63
8.	Spain	61
9.	India	50
10.	South Korea	50
11.	Taiwan	46
12.	France	35
13.	Japan	35
14.	Netherlands	34
15.	Brazil	28
16.	Poland	24
17.	Switzerland	23
18.	Sweden	22
19.	Singapore	22
20.	Czech Republic	18
21.	Israel	17
22.	Hungary	16
23.	Iran	16
24.	Belgium	14
25.	Greece	13
26.	New Zealand	13
27.	Portugal	12
28.	Slovenia	11
29.	Finland	10
30.	Mexico	10

Before

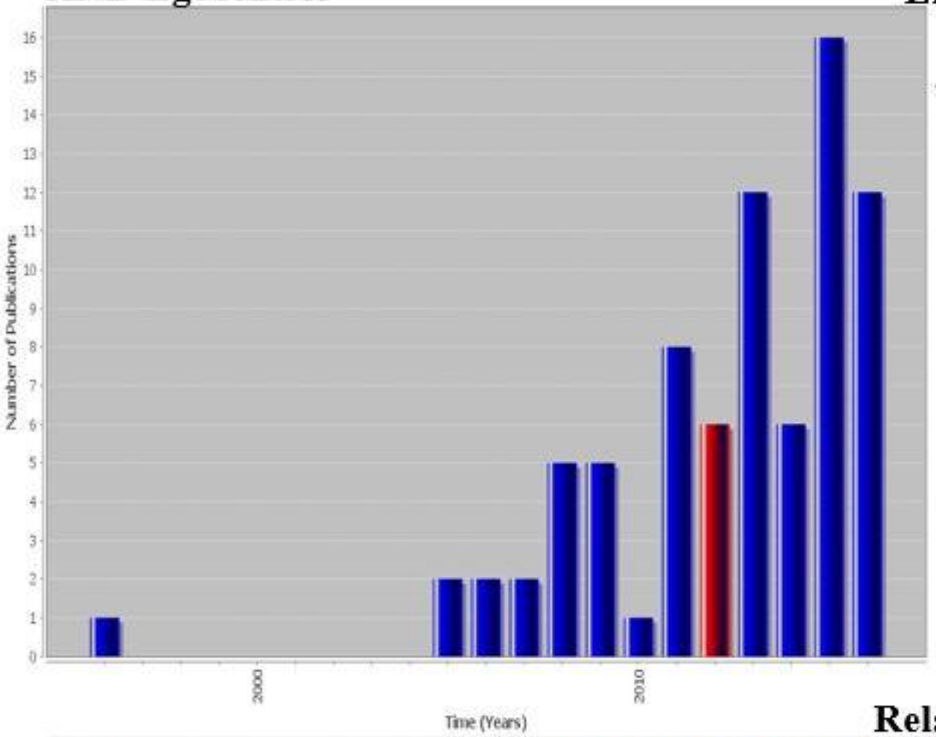
✓ After

Same

Taiwan 🡒

U.S. 🡒

Analysis AND Social Networks AND Egocentric



Emerging

Yes

✓ No

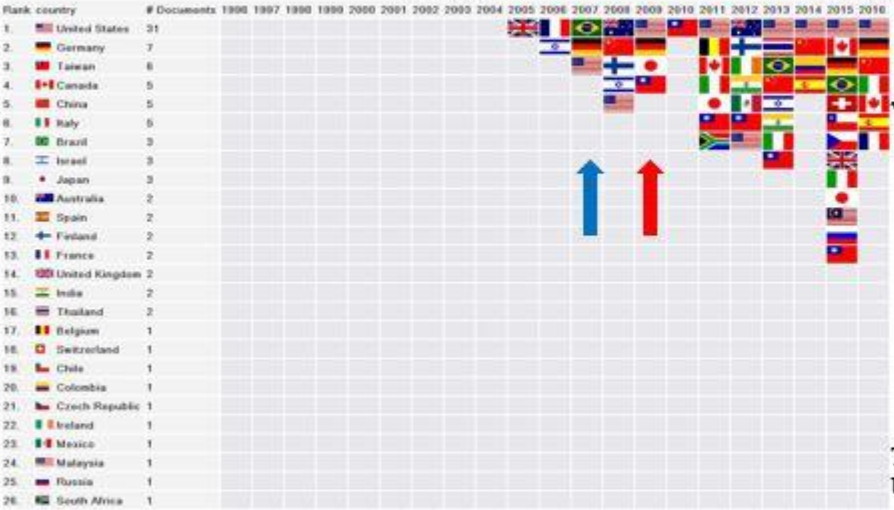
Unclear

Relative to U.S.

Before

✓ After

Same

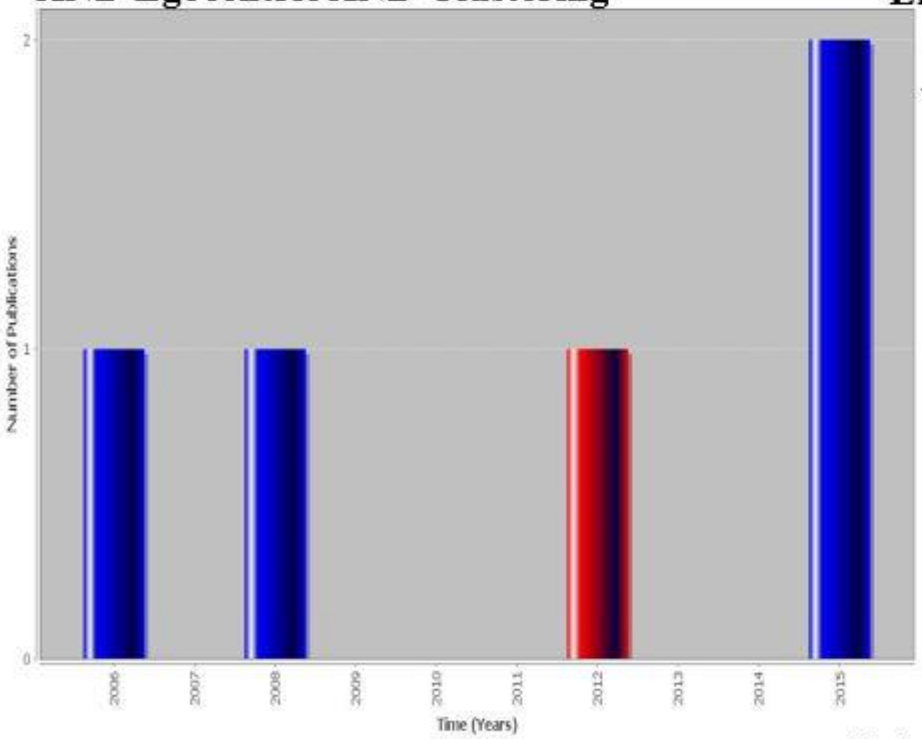


Rank	country	# Documents
1.	United States	31
2.	Germany	7
3.	Taiwan	6
4.	Canada	5
5.	China	5
6.	Italy	5
7.	Brazil	3
8.	Israel	3
9.	Japan	3
10.	Australia	2
11.	Spain	2
12.	Finland	2
13.	France	2
14.	United Kingdom	2
15.	India	2
16.	Thailand	2
17.	Belgium	1
18.	Switzerland	1
19.	Chile	1
20.	Colombia	1
21.	Czech Republic	1
22.	Ireland	1
23.	Mexico	1
24.	Malaysia	1
25.	Russia	1
26.	South Africa	1

Taiwan →

U.S. →

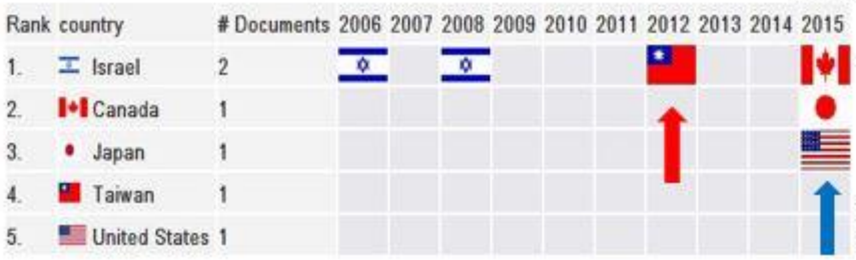
Analysis AND Social Networks AND Egocentric AND Clustering



Emerging

Yes
✓ No
Unclear

Relative to U.S.

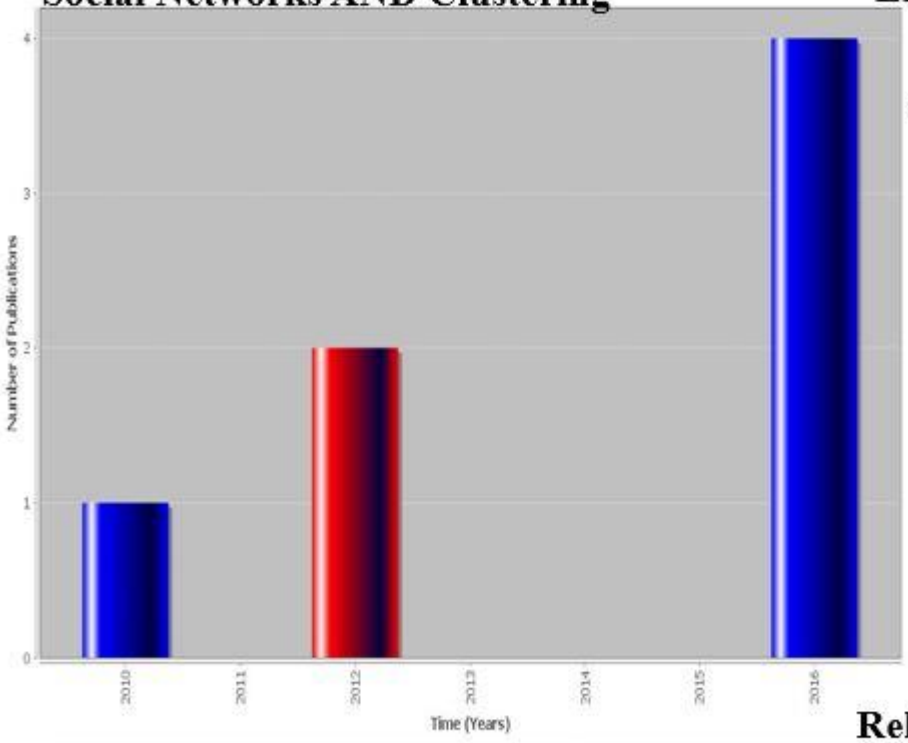


Rank	country	# Documents	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
1.	🇮🇱 Israel	2	🇮🇱		🇮🇱				🇹🇼			🇨🇦
2.	🇨🇦 Canada	1							↑			🇯🇵
3.	🇯🇵 Japan	1							↑			🇺🇸
4.	🇹🇼 Taiwan	1										↑
5.	🇺🇸 United States	1										↑

✓ Before
After
Same

Taiwan →
U.S. →

Centrality Analysis AND Social Networks AND Clustering



Emerging

Yes
✓ No
Unclear

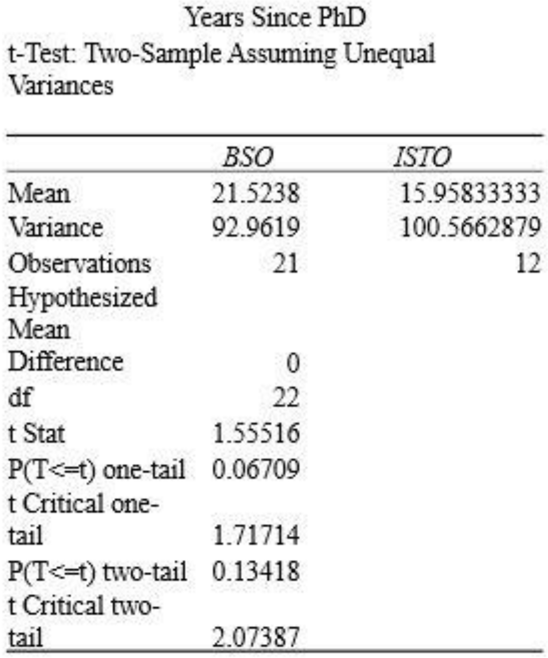
Relation to U.S.

Rank	country	# Documents	2010	2011	2012	2013	2014	2015	2016
1.	🇨🇳 China	2			🇰🇼				🇨🇳
2.	🇹🇼 Taiwan	2			🇹🇼				🇦🇺
3.	🇦🇺 Australia	1							🇮🇱
4.	🇮🇱 Israel	1			⬆				🇹🇼
5.	🇰🇼 Kuwait	1							

✓ Before
After
Same

Taiwan ➡
U.S. ➡

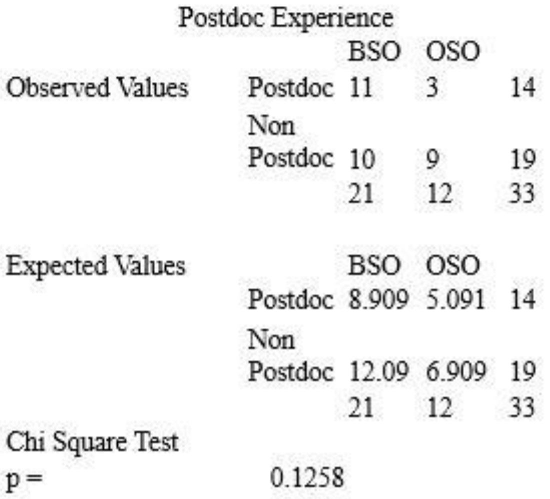
Appendix 2 – Demographic Comparisons Basic Science Office & International S&T Office



Years Since PhD

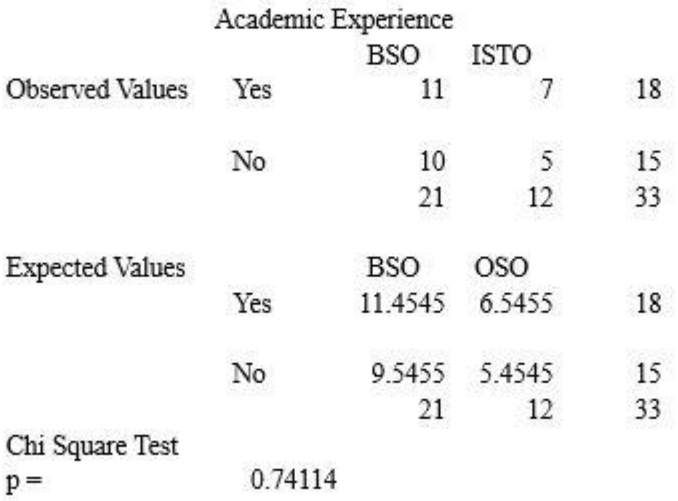
t-Test: Two-Sample Assuming Unequal Variances

	BSO	*ISTO*
Mean	21.5238	15.95833333
Variance	92.9619	100.5662879
Observations	21	12
Hypothesized Mean Difference	0	
df	22	
t Stat	1.55516	
P(T<=t) one-tail	0.06709	
t Critical one-tail	1.71714	
P(T<=t) two-tail	0.13418	
t Critical two-tail	2.07387	



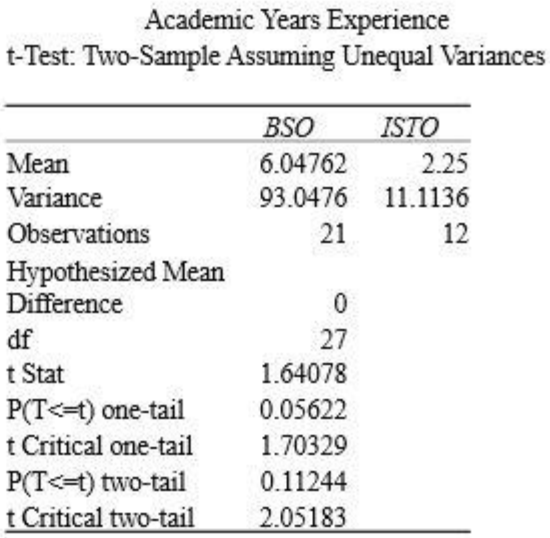
Postdoc Experience

		BSO	OSO	
Observed Values	Postdoc	11	3	14
	Non Postdoc	10	9	19
		21	12	33
Expected Values		BSO	OSO	
	Postdoc	8.909	5.091	14
	Non Postdoc	12.09	6.909	19
		21	12	33
Chi Square Test				
p =	0.1258			



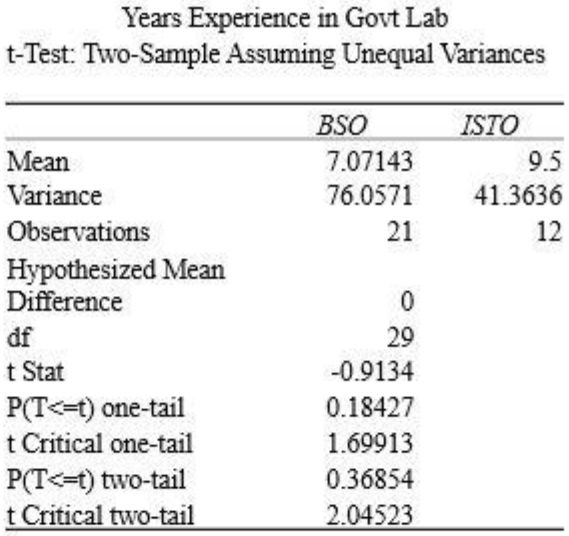
Academic Experience

		BSO	ISTO	
Observed Values	Yes	11	7	18
	No	10	5	15
		21	12	33
Expected Values		BSO	OSO	
	Yes	11.4545	6.5455	18
	No	9.5455	5.4545	15
		21	12	33
Chi Square Test				
p =	0.74114			



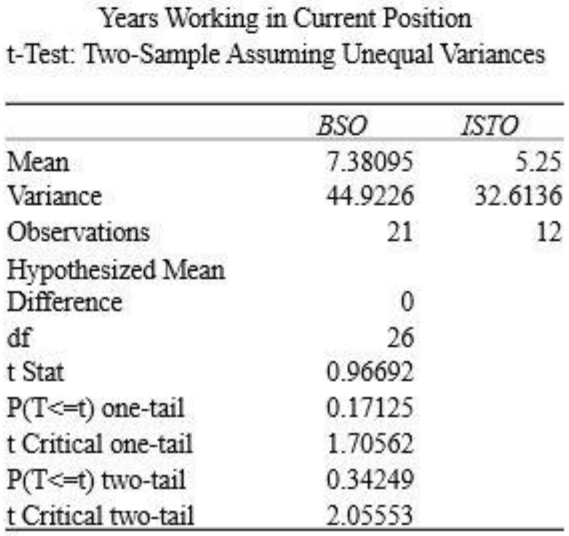
Academic Years Experience
t-Test: Two-Sample Assuming Unequal Variances

	BSO	*ISTO*
Mean	6.04762	2.25
Variance	93.0476	11.1136
Observations	21	12
Hypothesized Mean Difference	0	
df	27	
t Stat	1.64078	
P(T<=t) one-tail	0.05622	
t Critical one-tail	1.70329	
P(T<=t) two-tail	0.11244	
t Critical two-tail	2.05183	



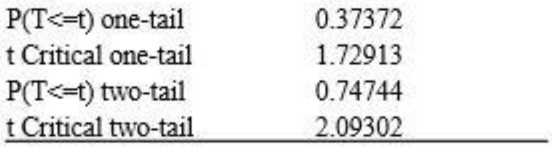
Years Experience in Govt Lab
t-Test: Two-Sample Assuming Unequal Variances

	BSO	*ISTO*
Mean	7.07143	9.5
Variance	76.0571	41.3636
Observations	21	12
Hypothesized Mean Difference	0	
df	29	
t Stat	-0.9134	
P(T<=t) one-tail	0.18427	
t Critical one-tail	1.69913	
P(T<=t) two-tail	0.36854	
t Critical two-tail	2.04523	



Years Working in Current Position
t-Test: Two-Sample Assuming Unequal Variances

	BSO	*ISTO*
Mean	7.38095	5.25
Variance	44.9226	32.6136
Observations	21	12
Hypothesized Mean Difference	0	
df	26	
t Stat	0.96692	
P(T<=t) one-tail	0.17125	
t Critical one-tail	1.70562	
P(T<=t) two-tail	0.34249	
t Critical two-tail	2.05553	



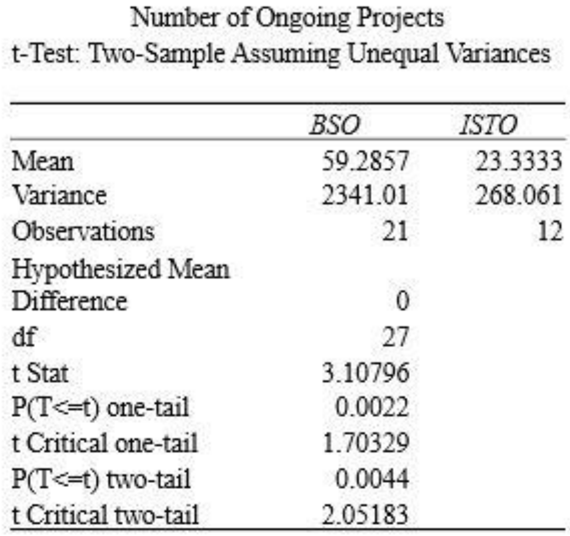
P(T<=t) one-tail	0.37372
t Critical one-tail	1.72913
P(T<=t) two-tail	0.74744
t Critical two-tail	2.09302

Peer Review Publications
t-Test: Two-Sample Assuming Unequal Variances

	BSO	*ISTO*
Mean	53.5238	16.25
Variance	6463.86	111.841
Observations	21	12
Hypothesized Mean Difference	0	
df	21	
t Stat	2.0931	
P(T<=t) one-tail	0.02433	
t Critical one-tail	1.72074	
P(T<=t) two-tail	0.04866	
t Critical two-tail	2.07961	

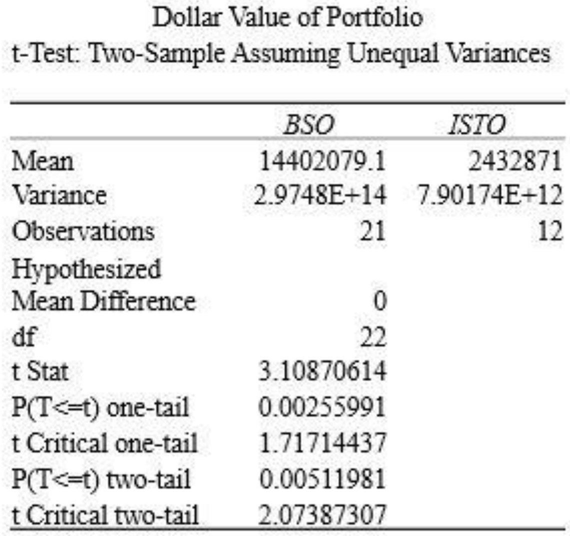
Conference Presentations Given
t-Test: Two-Sample Assuming Unequal Variances

	BSO	*ISTO*
Mean	41.8095	29.9167
Variance	2210.26	1264.81
Observations	21	12
Hypothesized Mean Difference	0	
df	28	
t Stat	0.81942	
P(T<=t) one-tail	0.20974	
t Critical one-tail	1.70113	
P(T<=t) two-tail	0.41947	
t Critical two-tail	2.04841	



Number of Ongoing Projects
t-Test: Two-Sample Assuming Unequal Variances

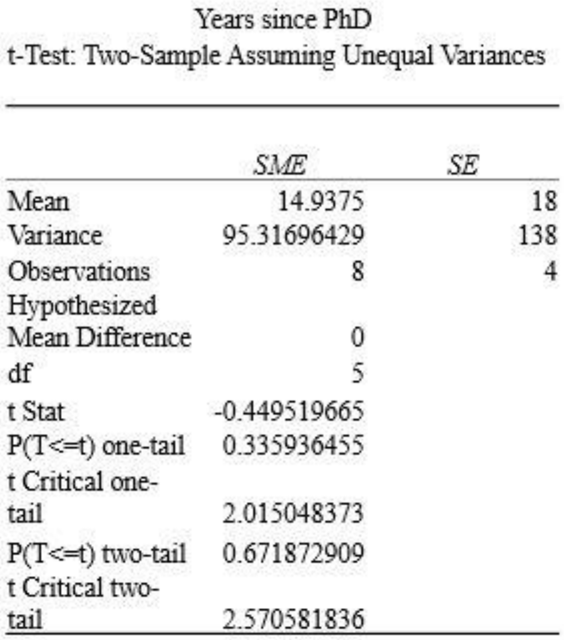
	BSO	*ISTO*
Mean	59.2857	23.3333
Variance	2341.01	268.061
Observations	21	12
Hypothesized Mean Difference	0	
df	27	
t Stat	3.10796	
P(T<=t) one-tail	0.0022	
t Critical one-tail	1.70329	
P(T<=t) two-tail	0.0044	
t Critical two-tail	2.05183	



Dollar Value of Portfolio
t-Test: Two-Sample Assuming Unequal Variances

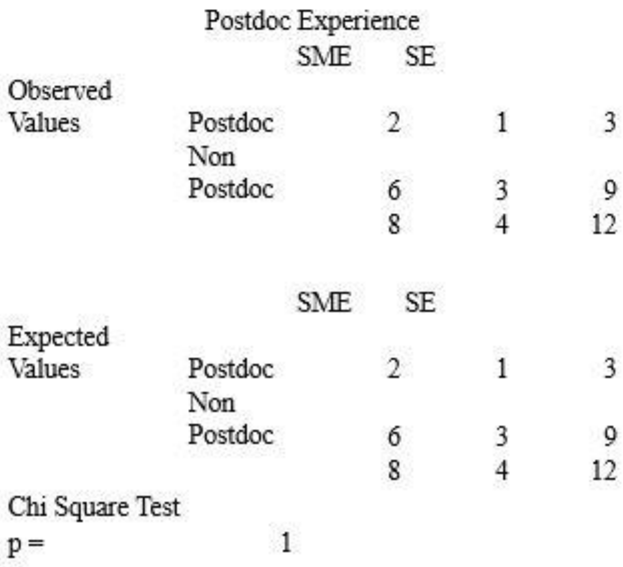
	BSO	*ISTO*
Mean	14402079.1	2432871
Variance	2.9748E+14	7.90174E+12
Observations	21	12
Hypothesized Mean Difference	0	
df	22	
t Stat	3.10870614	
P(T<=t) one-tail	0.00255991	
t Critical one-tail	1.71714437	
P(T<=t) two-tail	0.00511981	
t Critical two-tail	2.07387307	

Appendix 3 – Demographic Comparison Subject Matter Expert & Share Equity



Years since PhD
t-Test: Two-Sample Assuming Unequal Variances

	SME	*SE*
Mean	14.9375	18
Variance	95.31696429	138
Observations	8	4
Hypothesized Mean Difference	0	
df	5	
t Stat	-0.449519665	
P(T<=t) one-tail	0.335936455	
t Critical one-tail	2.015048373	
P(T<=t) two-tail	0.671872909	
t Critical two-tail	2.570581836	

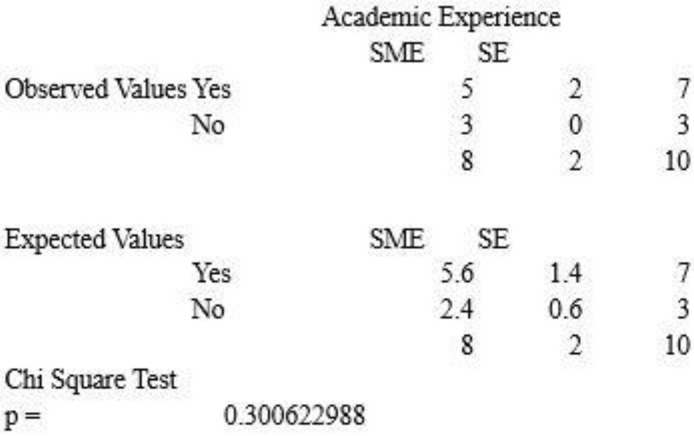


Postdoc Experience

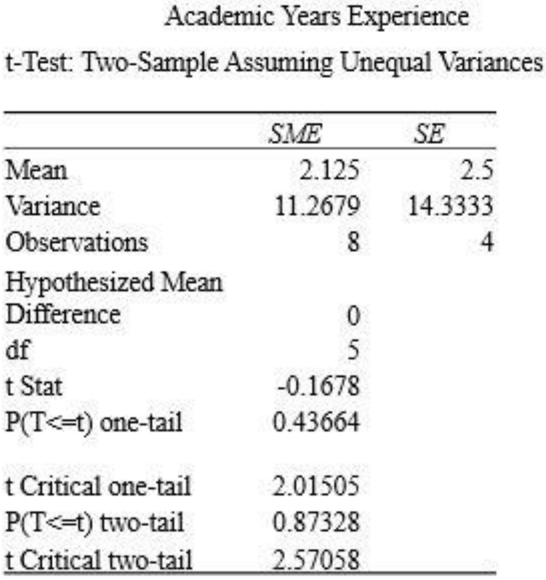
		SME	SE	
Observed Values	Postdoc	2	1	3
	Non Postdoc	6	3	9
		8	4	12

		SME	SE	
Expected Values	Postdoc	2	1	3
	Non Postdoc	6	3	9
		8	4	12

Chi Square Test
p = 1



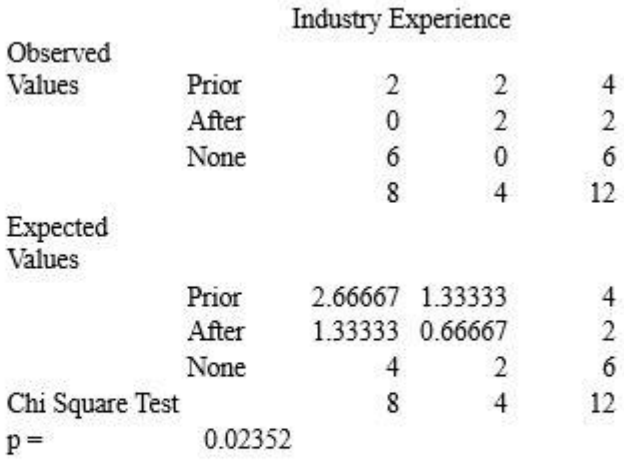
		Academic Experience		
		SME	SE	
Observed Values	Yes	5	2	7
	No	3	0	3
		8	2	10
Expected Values		SME	SE	
	Yes	5.6	1.4	7
	No	2.4	0.6	3
		8	2	10
Chi Square Test				
p =	0.300622988			



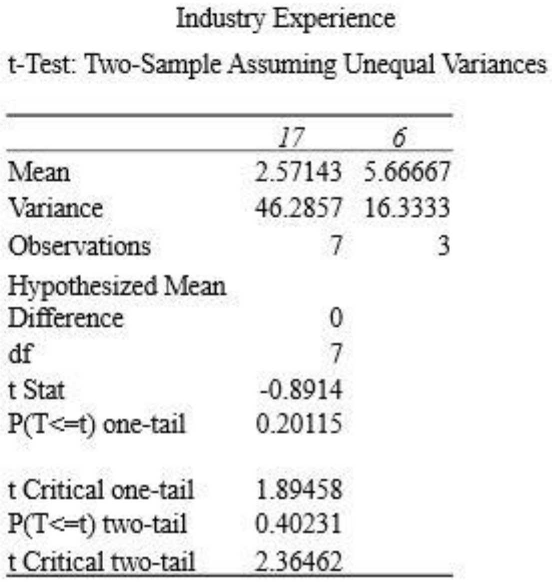
Academic Years Experience

t-Test: Two-Sample Assuming Unequal Variances

	SME	*SE*
Mean	2.125	2.5
Variance	11.2679	14.3333
Observations	8	4
Hypothesized Mean Difference	0	
df	5	
t Stat	-0.1678	
P(T<=t) one-tail	0.43664	
t Critical one-tail	2.01505	
P(T<=t) two-tail	0.87328	
t Critical two-tail	2.57058	



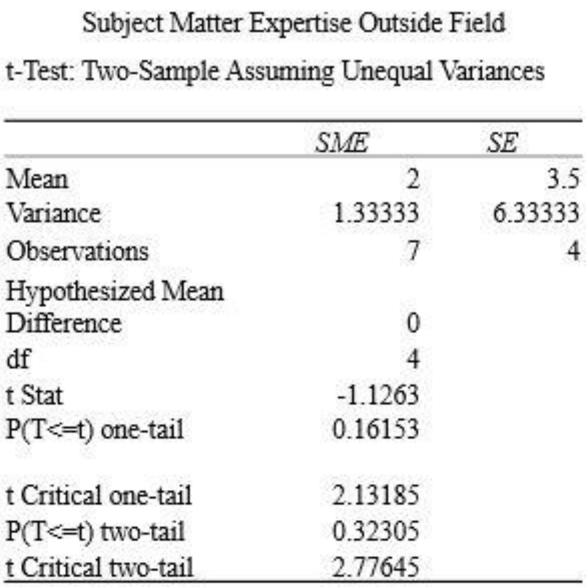
		Industry Experience		
Observed Values	Prior	2	2	4
	After	0	2	2
	None	6	0	6
		8	4	12
Expected Values				
	Prior	2.66667	1.33333	4
	After	1.33333	0.66667	2
	None	4	2	6
Chi Square Test		8	4	12
p =	0.02352			



Industry Experience

t-Test: Two-Sample Assuming Unequal Variances

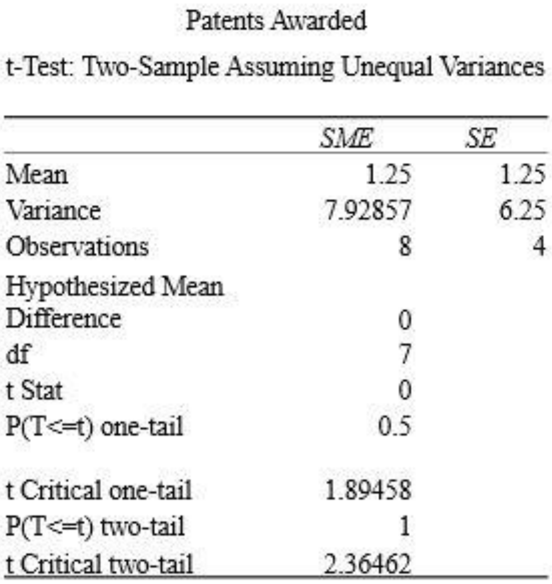
	17	*6*
Mean	2.57143	5.66667
Variance	46.2857	16.3333
Observations	7	3
Hypothesized Mean Difference	0	
df	7	
t Stat	-0.8914	
P(T<=t) one-tail	0.20115	
t Critical one-tail	1.89458	
P(T<=t) two-tail	0.40231	
t Critical two-tail	2.36462	



Subject Matter Expertise Outside Field

t-Test: Two-Sample Assuming Unequal Variances

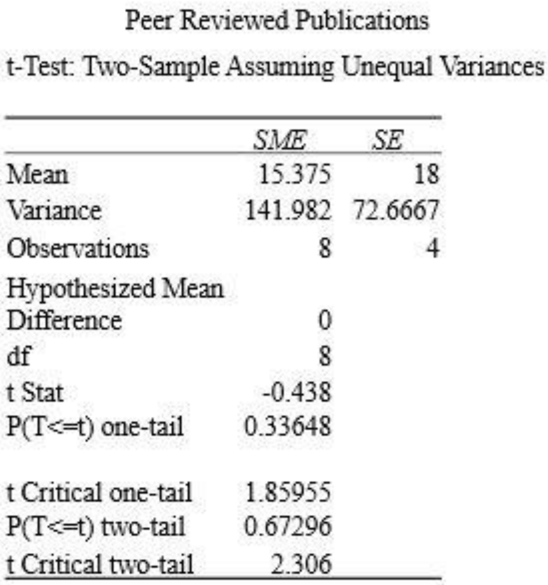
	SME	*SE*
Mean	2	3.5
Variance	1.33333	6.33333
Observations	7	4
Hypothesized Mean Difference	0	
df	4	
t Stat	-1.1263	
P(T<=t) one-tail	0.16153	
t Critical one-tail	2.13185	
P(T<=t) two-tail	0.32305	
t Critical two-tail	2.77645	



Patents Awarded

t-Test: Two-Sample Assuming Unequal Variances

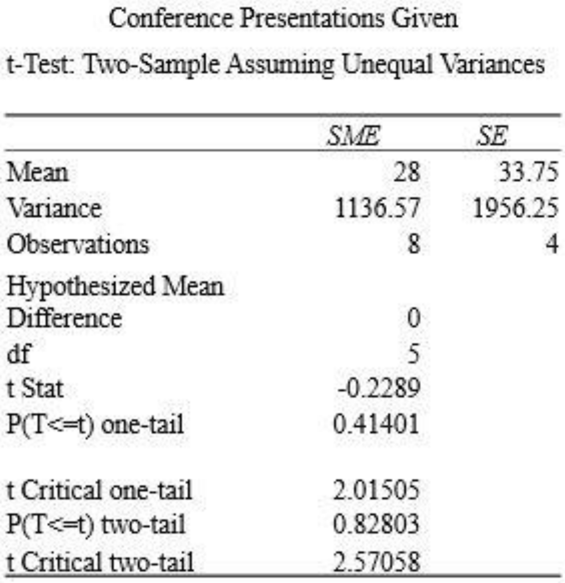
	SME	*SE*
Mean	1.25	1.25
Variance	7.92857	6.25
Observations	8	4
Hypothesized Mean Difference	0	
df	7	
t Stat	0	
P(T<=t) one-tail	0.5	
t Critical one-tail	1.89458	
P(T<=t) two-tail	1	
t Critical two-tail	2.36462	



Peer Reviewed Publications

t-Test: Two-Sample Assuming Unequal Variances

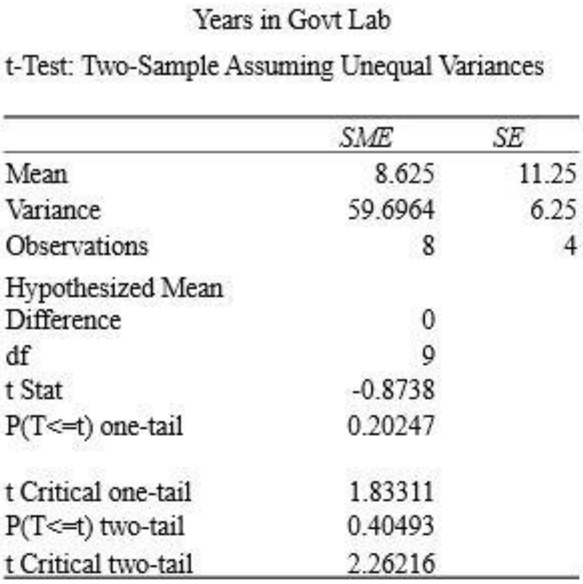
	SME	*SE*
Mean	15.375	18
Variance	141.982	72.6667
Observations	8	4
Hypothesized Mean Difference	0	
df	8	
t Stat	-0.438	
P(T<=t) one-tail	0.33648	
t Critical one-tail	1.85955	
P(T<=t) two-tail	0.67296	
t Critical two-tail	2.306	



Conference Presentations Given

t-Test: Two-Sample Assuming Unequal Variances

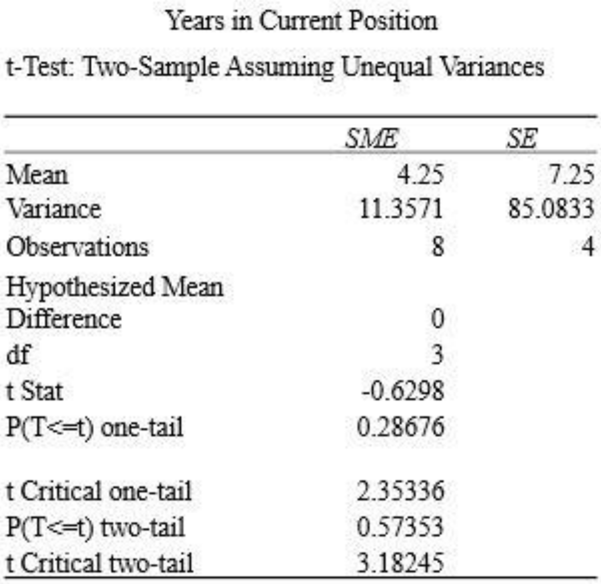
	SME	*SE*
Mean	28	33.75
Variance	1136.57	1956.25
Observations	8	4
Hypothesized Mean Difference	0	
df	5	
t Stat	-0.2289	
P(T<=t) one-tail	0.41401	
t Critical one-tail	2.01505	
P(T<=t) two-tail	0.82803	
t Critical two-tail	2.57058	



Years in Govt Lab

t-Test: Two-Sample Assuming Unequal Variances

	SME	*SE*
Mean	8.625	11.25
Variance	59.6964	6.25
Observations	8	4
Hypothesized Mean Difference	0	
df	9	
t Stat	-0.8738	
P(T<=t) one-tail	0.20247	
t Critical one-tail	1.83311	
P(T<=t) two-tail	0.40493	
t Critical two-tail	2.26216	

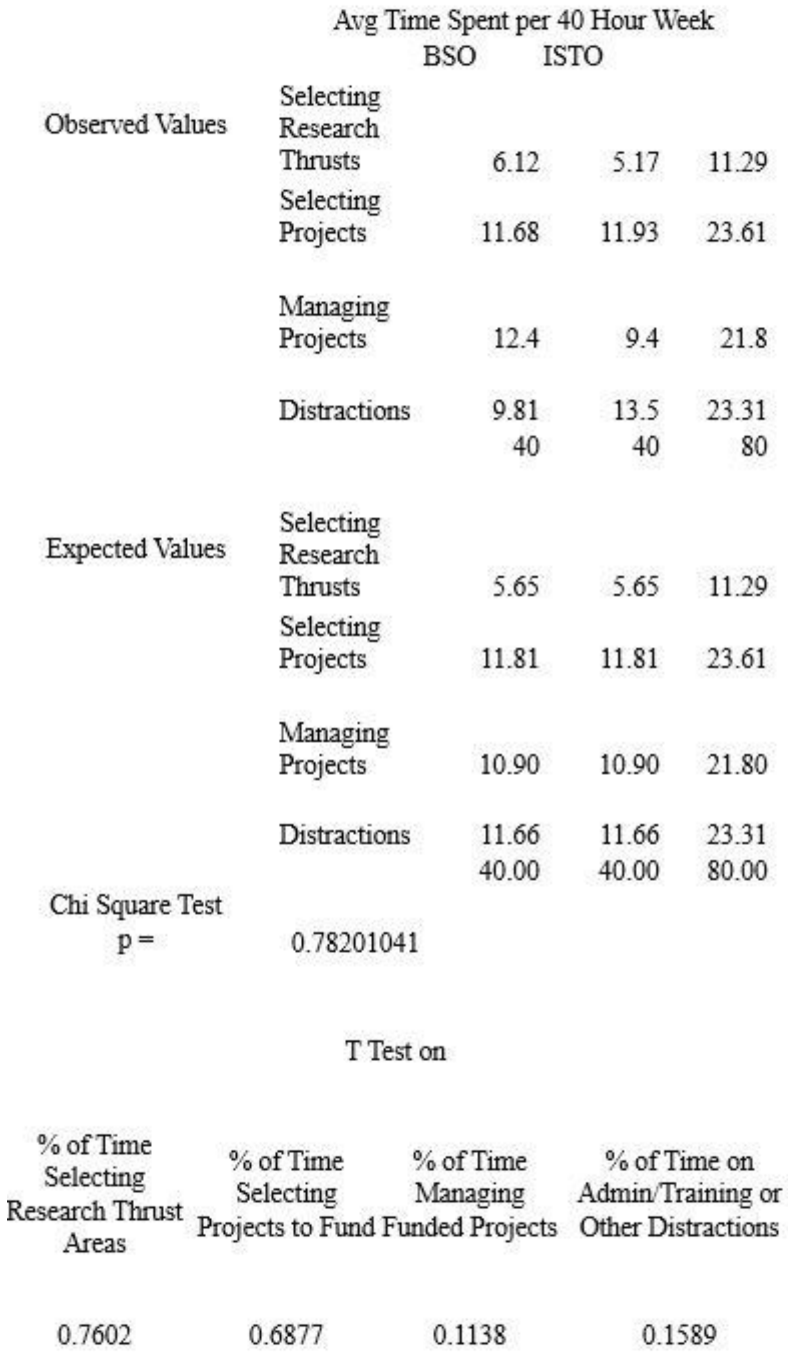


Years in Current Position

t-Test: Two-Sample Assuming Unequal Variances

	SME	*SE*
Mean	4.25	7.25
Variance	11.3571	85.0833
Observations	8	4
Hypothesized Mean Difference	0	
df	3	
t Stat	-0.6298	
P(T<=t) one-tail	0.28676	
t Critical one-tail	2.35336	
P(T<=t) two-tail	0.57353	
t Critical two-tail	3.18245	

Appendix 4 – Major Task Time Allocations



Avg Time Spent per 40 Hour Week

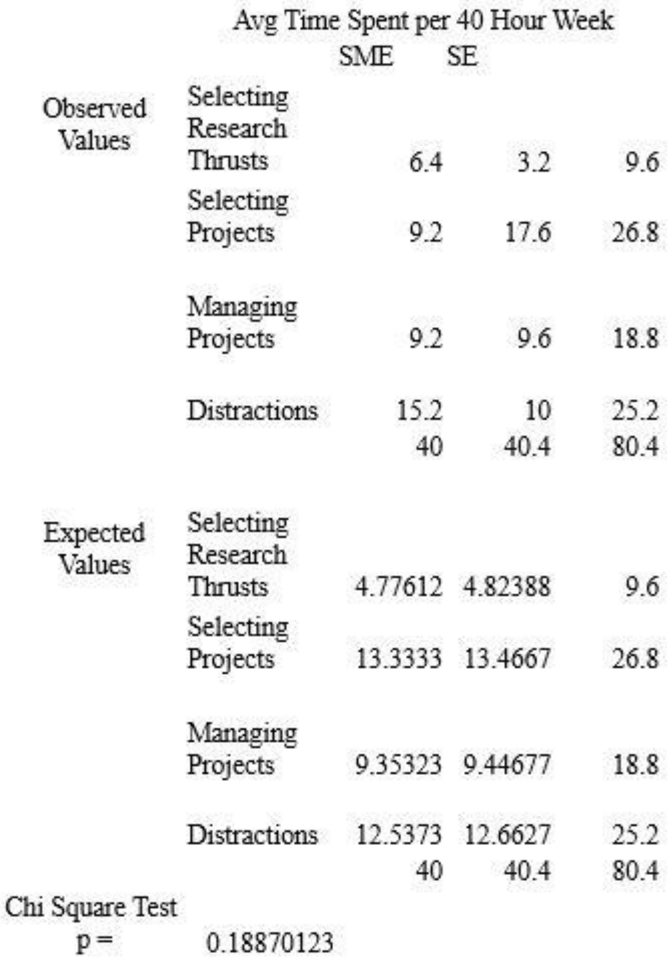
		BSO	ISTO	
Observed Values	Selecting Research Thrusts	6.12	5.17	11.29
	Selecting Projects	11.68	11.93	23.61
	Managing Projects	12.4	9.4	21.8
	Distractions	9.81	13.5	23.31
		40	40	80
Expected Values	Selecting Research Thrusts	5.65	5.65	11.29
	Selecting Projects	11.81	11.81	23.61
	Managing Projects	10.90	10.90	21.80
	Distractions	11.66	11.66	23.31
		40.00	40.00	80.00

Chi Square Test

p = 0.78201041

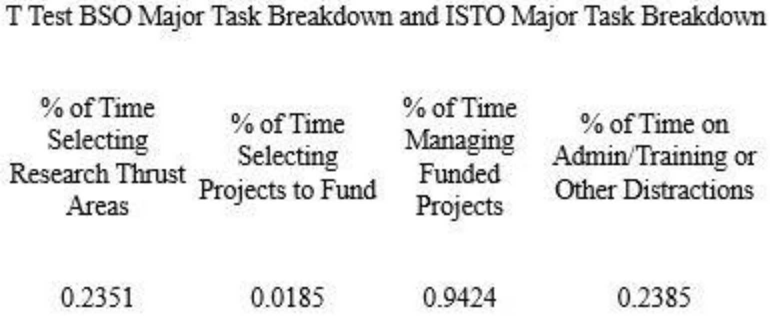
T Test on

% of Time Selecting Research Thrust Areas	% of Time Selecting Projects to Fund	% of Time Managing Funded Projects	% of Time on Admin/Training or Other Distractions
0.7602	0.6877	0.1138	0.1589



Avg Time Spent per 40 Hour Week

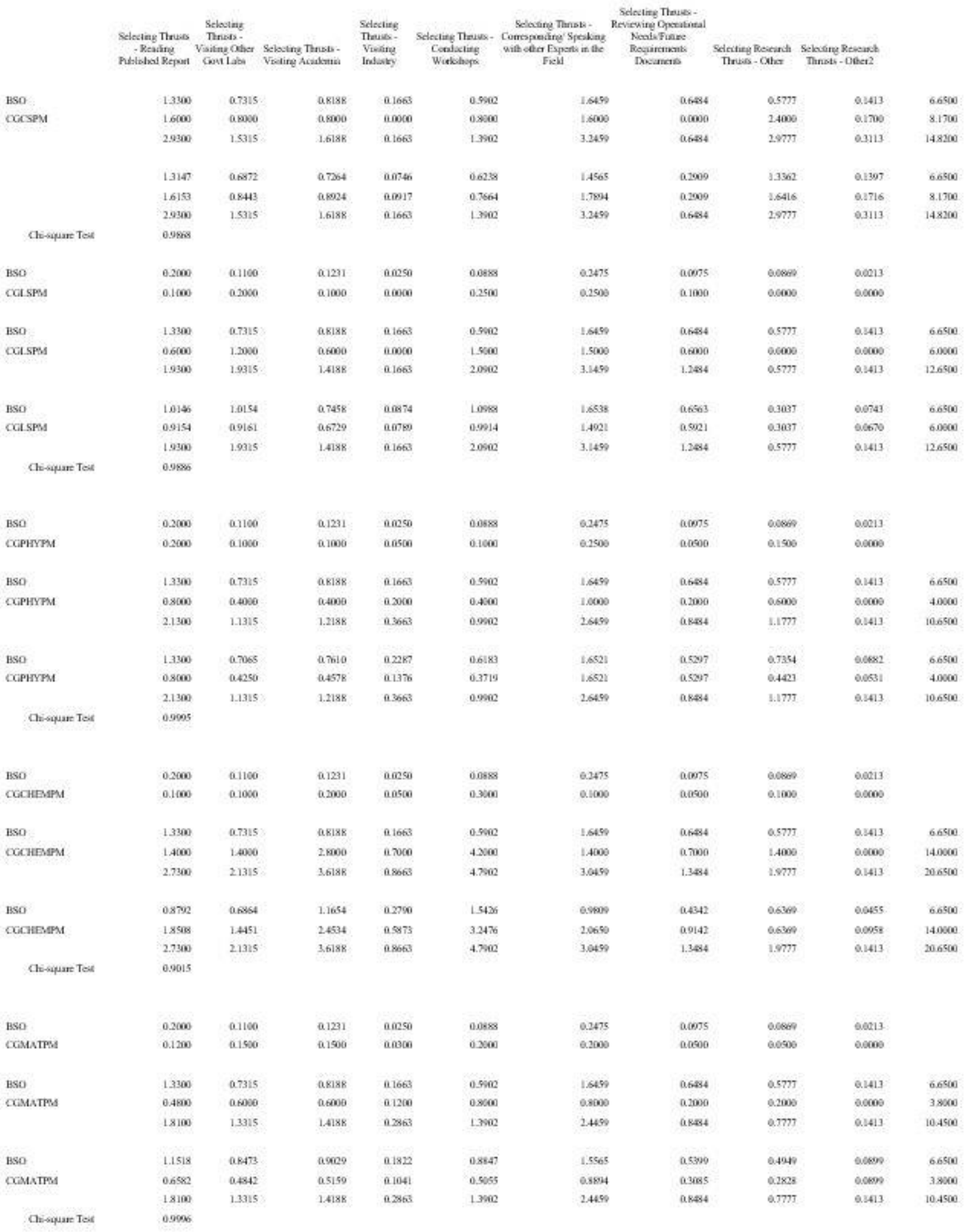
		SME	SE	
Observed Values	Selecting Research Thrusts	6.4	3.2	9.6
	Selecting Projects	9.2	17.6	26.8
	Managing Projects	9.2	9.6	18.8
	Distractions	15.2	10	25.2
		40	40.4	80.4
Expected Values	Selecting Research Thrusts	4.77612	4.82388	9.6
	Selecting Projects	13.3333	13.4667	26.8
	Managing Projects	9.35323	9.44677	18.8
	Distractions	12.5373	12.6627	25.2
		40	40.4	80.4
Chi Square Test				
p =	0.18870123			



T Test BSO Major Task Breakdown and ISTO Major Task Breakdown

% of Time Selecting Research Thrust Areas	% of Time Selecting Projects to Fund	% of Time Managing Funded Projects	% of Time on Admin/Training or Other Distractions
0.2351	0.0185	0.9424	0.2385

Appendix 5 – Subtask Time Allocations



	Selecting Thrusts - Reading Published Report	Selecting Thrusts - Visiting Other Govt Labs	Selecting Thrusts - Visiting Academia	Selecting Thrusts - Visiting Industry	Selecting Thrusts - Conducting Workshops	Selecting Thrusts - Corresponding/ Speaking with other Experts in the Field	Selecting Thrusts - Reviewing Operational Needs/Future Requirements Documents	Selecting Research Thrusts - Other	Selecting Research Thrusts - Other2	
BSO	1.3300	0.7315	0.8188	0.1663	0.5902	1.6459	0.6484	0.5777	0.1413	6.6500
CGCSPM	1.6000	0.8000	0.8000	0.0000	0.8000	1.6000	0.0000	2.4000	0.1700	8.1700
	2.9300	1.5315	1.6188	0.1663	1.3902	3.2459	0.6484	2.9777	0.3113	14.8200
	1.3147	0.6872	0.7264	0.0746	0.6238	1.4565	0.2909	1.3362	0.1397	6.6500
	1.6153	0.8443	0.8924	0.0917	0.7664	1.7894	0.2909	1.6416	0.1716	8.1700
	2.9300	1.5315	1.6188	0.1663	1.3902	3.2459	0.6484	2.9777	0.3113	14.8200
Chi-square Test	0.9868									
BSO	0.2000	0.1100	0.1231	0.0250	0.0888	0.2475	0.0975	0.0869	0.0213	
CGLSPM	0.1000	0.2000	0.1000	0.0000	0.2500	0.2500	0.1000	0.0000	0.0000	
BSO	1.3300	0.7315	0.8188	0.1663	0.5902	1.6459	0.6484	0.5777	0.1413	6.6500
CGLSPM	0.6000	1.2000	0.6000	0.0000	1.5000	1.5000	0.6000	0.0000	0.0000	6.0000
	1.9300	1.9315	1.4188	0.1663	2.0902	3.1459	1.2484	0.5777	0.1413	12.6500
BSO	1.0146	1.0154	0.7458	0.0874	1.0988	1.6538	0.6563	0.3037	0.0743	6.6500
CGLSPM	0.9154	0.9161	0.6729	0.0789	0.9914	1.4921	0.5921	0.3037	0.0670	6.0000
	1.9300	1.9315	1.4188	0.1663	2.0902	3.1459	1.2484	0.5777	0.1413	12.6500
Chi-square Test	0.9886									
BSO	0.2000	0.1100	0.1231	0.0250	0.0888	0.2475	0.0975	0.0869	0.0213	
CGPHYPM	0.2000	0.1000	0.1000	0.0500	0.1000	0.2500	0.0500	0.1500	0.0000	
BSO	1.3300	0.7315	0.8188	0.1663	0.5902	1.6459	0.6484	0.5777	0.1413	6.6500
CGPHYPM	0.8000	0.4000	0.4000	0.2000	0.4000	1.0000	0.2000	0.6000	0.0000	4.0000
	2.1300	1.1315	1.2188	0.3663	0.9902	2.6459	0.8484	1.1777	0.1413	10.6500
BSO	1.3300	0.7065	0.7610	0.2287	0.6183	1.6521	0.5297	0.7354	0.0882	6.6500
CGPHYPM	0.8000	0.4250	0.4578	0.1376	0.3719	1.6521	0.5297	0.4423	0.0531	4.0000
	2.1300	1.1315	1.2188	0.3663	0.9902	2.6459	0.8484	1.1777	0.1413	10.6500
Chi-square Test	0.9995									
BSO	0.2000	0.1100	0.1231	0.0250	0.0888	0.2475	0.0975	0.0869	0.0213	
CGCHEMPM	0.1000	0.1000	0.2000	0.0500	0.3000	0.1000	0.0500	0.1000	0.0000	
BSO	1.3300	0.7315	0.8188	0.1663	0.5902	1.6459	0.6484	0.5777	0.1413	6.6500
CGCHEMPM	1.4000	1.4000	2.8000	0.7000	4.2000	1.4000	0.7000	1.4000	0.0000	14.0000
	2.7300	2.1315	3.6188	0.8663	4.7902	3.0459	1.3484	1.9777	0.1413	20.6500
BSO	0.8792	0.6864	1.1654	0.2790	1.5426	0.9809	0.4342	0.6369	0.0455	6.6500
CGCHEMPM	1.8508	1.4451	2.4534	0.5873	3.2476	2.0650	0.9142	0.6369	0.0958	14.0000
	2.7300	2.1315	3.6188	0.8663	4.7902	3.0459	1.3484	1.9777	0.1413	20.6500
Chi-square Test	0.9015									
BSO	0.2000	0.1100	0.1231	0.0250	0.0888	0.2475	0.0975	0.0869	0.0213	
CGMATPM	0.1200	0.1500	0.1500	0.0300	0.2000	0.2000	0.0500	0.0500	0.0000	
BSO	1.3300	0.7315	0.8188	0.1663	0.5902	1.6459	0.6484	0.5777	0.1413	6.6500
CGMATPM	0.4800	0.6000	0.6000	0.1200	0.8000	0.8000	0.2000	0.2000	0.0000	3.8000
	1.8100	1.3315	1.4188	0.2863	1.3902	2.4459	0.8484	0.7777	0.1413	10.4500
BSO	1.1518	0.8473	0.9029	0.1822	0.8847	1.5565	0.5399	0.4949	0.0899	6.6500
CGMATPM	0.6582	0.4842	0.5159	0.1041	0.5055	0.8894	0.3085	0.2828	0.0899	3.8000
	1.8100	1.3315	1.4188	0.2863	1.3902	2.4459	0.8484	0.7777	0.1413	10.4500
Chi-square Test	0.9996									

	Managing Projects - Visiting PI	Managing Projects - Corresponding/Speaking on the Phone with PI	Managing Projects - Reviewing Progress, Interim and Final Reports	Managing Projects - Administratively Monitoring Project Records	Managing Projects - Preparation for Program Reviews	Managing Projects - Other	Managing Projects - Other 2	
BSO	2.3532	2.5180	2.3870	2.3109	2.2038	0.6270	0.0000	12.4000
CGCSPM	0.8000	1.6000	1.5400	1.4909	1.4218	0.0000	0.0000	6.8527
	3.1532	4.1180	3.9270	3.8018	3.6256	0.6270	0.0000	19.2527
BSO	2.0309	2.6523	2.5292	2.4486	2.3351	0.4039	0.0000	12.4000
CGCSPM	1.1223	1.4658	1.3978	1.3532	1.2905	0.2232	0.0000	6.8527
	3.1532	4.1180	3.9270	3.8018	3.6256	0.6270	0.0000	19.2527
Chi-square Test	0.9891							
BSO	0.1898	0.2031	0.1925	0.1864	0.1777	0.0506	0.0000	
CGLSPM	0.1500	0.2500	0.2000	0.2000	0.2000	0.0000	0.0000	
BSO	2.3532	2.5180	2.3870	2.3109	2.2038	0.6270	0.0000	12.4000
CGLSPM	3.0000	5.0000	4.0000	4.0000	4.0000	0.0000	0.0000	20.0000
	5.3532	7.5180	6.3870	6.3109	6.2038	0.6270	0.0000	32.4000
BSO	2.0487	2.8773	2.4444	2.4153	2.3743	0.2400	0.0000	12.4000
McElhinny	3.3044	4.6408	3.9426	3.8956	3.8295	0.3871	0.0000	20.0000
	5.3532	7.5180	6.3870	6.3109	6.2038	0.6270	0.0000	32.4000
Chi-square Test	0.9462							
BSO	0.1898	0.2031	0.1925	0.1864	0.1777	0.0506	0.0000	
CGPHYPM	0.1000	0.2500	0.1000	0.1500	0.2000	0.2000	0.0000	
BSO	2.3532	2.5180	2.3870	2.3109	2.2038	0.6270	0.0000	12.4000
CGPHYPM	1.2000	3.0000	1.2000	1.8000	2.4000	2.4000	0.0000	12.0000
	3.5532	5.5180	3.5870	4.1109	4.6038	3.0270	0.0000	24.4000
BSO	1.8057	2.8043	1.8229	2.0892	2.3396	1.5383	0.0000	12.4000
CGPHYPM	1.7475	2.7138	1.7641	2.0218	2.2642	1.4887	0.0000	12.0000
	3.5532	5.5180	3.5870	4.1109	4.6038	3.0270	0.0000	24.4000
Chi-square Test	0.8610							
BSO	0.1898	0.2031	0.1925	0.1864	0.1777	0.0506	0.0000	
CGCHEMPM	0.4000	0.1000	0.2000	0.2000	0.1000	0.0000	0.0000	
BSO	2.3532	2.5180	2.3870	2.3109	2.2038	0.6270	0.0000	12.4000
CGCHEMPM	4.8000	1.2000	2.4000	2.4000	1.2000	0.0000	0.0000	12.0000
	7.1532	3.7180	4.7870	4.7109	3.4038	0.6270	0.0000	24.4000
BSO	3.6352	1.8895	2.4327	2.3941	1.7298	0.3187	0.0000	12.4000
CGCHEMPM	3.5180	1.8285	2.3543	2.3168	1.6740	0.3187	0.0000	12.0000
	7.1532	3.7180	4.7870	4.7109	3.4038	0.6270	0.0000	24.4000
Chi-square Test	0.8160							
BSO	0.1898	0.2031	0.1925	0.1864	0.1777	0.0506	0.0000	
CGMATPM	0.2000	0.2000	0.2500	0.1500	0.1500	0.0500	0.0000	
BSO	2.3532	2.5180	2.3870	2.3109	2.2038	0.6270	0.0000	12.4000
CGMATPM	2.0000	2.0000	2.5000	1.5000	1.5000	0.5000	0.0000	10.0000
	4.3532	4.5180	4.8870	3.8109	3.7038	1.1270	0.0000	22.4000
BSO	2.4098	2.5011	2.7053	2.1096	2.0503	0.6239	0.0000	12.4000
CGMATPM	1.9434	2.0170	2.1817	1.7013	1.6535	0.5031	0.0000	10.0000
	4.3532	4.5180	4.8870	3.8109	3.7038	1.1270	0.0000	22.4000
Chi-square Test	0.9995							

	Selecting Thrusts - Reading Published Report	Selecting Thrusts - Visiting Other Govt Labs	Selecting Thrusts - Visiting Academia	Selecting Thrusts - Visiting Industry	Selecting Thrusts - Conducting Workshops	Selecting Thrusts - Corresponding/Speaking with other Experts in the Field	Selecting Thrusts - Reviewing Operational Needs/Future Requirements Documents	Selecting Research Thrusts - Other	Selecting Research Thrusts - Other2	
SME	0.1000	0.1450	0.2750	0.0425	0.1375	0.1375	0.1125	0.0250	0.0250	
CGCSPM	0.2000	0.1000	0.1000	0.0000	0.1000	0.2000	0.0000	0.3000	0.0000	
SME	0.6250	0.9063	1.7188	0.2656	0.8594	0.8594	0.7031	0.1563	0.1563	6.2500
CGCSPM	1.6000	0.8000	0.8000	0.0000	0.8000	1.6000	0.0000	2.4000	0.1700	8.1700
	2.2250	1.7063	2.5188	0.2656	1.6594	2.4594	0.7031	2.5563	0.3263	14.4200
SME	0.9644	0.7395	1.0917	0.1151	0.7192	1.0660	0.3048	1.1079	0.1414	6.2500
CGCSPM	1.2606	0.9667	1.4271	0.1505	0.9402	1.3934	0.3984	1.4483	0.1848	8.1700
	2.2250	1.7063	2.5188	0.2656	1.6594	2.4594	0.7031	2.5563	0.3263	14.4200
Chi-square Test	0.8795									
SME	0.1000	0.1450	0.2750	0.0425	0.1375	0.1375	0.1125	0.0250	0.0250	
CGLSPM	0.1000	0.2000	0.1000	0.0000	0.2500	0.2500	0.1000	0.0000	0.0000	
SME	0.6250	0.9063	1.7188	0.2656	0.8594	0.8594	0.7031	0.1563	0.1563	6.2500
CGLSPM	0.6000	1.2000	0.6000	0.0000	1.5000	1.5000	0.6000	0.0000	0.0000	6.0000
	1.2250	2.1063	2.3188	0.2656	2.3594	2.3594	1.3031	0.1563	0.1563	12.2500
SME	0.9536	0.9543	0.7010	0.0821	1.0327	1.5543	0.6168	0.2854	0.0698	6.2500
CGLSPM	0.9154	0.9161	0.6729	0.0789	0.9914	1.4921	0.5921	0.2740	0.0670	6.0000
	1.9300	1.9315	1.4188	0.1663	2.0902	3.1459	1.2484	0.5777	0.1413	12.6500
Chi-square Test	0.9064									
SME	0.1000	0.1450	0.2750	0.0425	0.1375	0.1375	0.1125	0.0250	0.0250	
CGPHYPM	0.2000	0.1000	0.1000	0.0500	0.1000	0.2500	0.0500	0.1500	0.0000	
SME	0.6250	0.9063	1.7188	0.2656	0.8594	0.8594	0.7031	0.1563	0.1563	6.2500
CGPHYPM	0.8000	0.4000	0.4000	0.2000	0.4000	1.0000	0.2000	0.6000	0.0000	4.0000
	2.1300	1.1315	1.2188	0.3663	0.9902	2.6459	0.8484	1.1777	0.1413	10.6500
SME	1.2500	0.6640	0.7152	0.2149	0.5811	1.5527	0.4979	0.6911	0.0829	6.2500
CGPHYPM	0.8000	0.4250	0.4578	0.1376	0.3719	0.9938	0.3186	0.4423	0.0531	4.0000
	2.1300	1.1315	1.2188	0.3663	0.9902	2.6459	0.8484	1.1777	0.1413	10.6500
Chi-square Test	0.9331									
SME	0.1000	0.1450	0.2750	0.0425	0.1375	0.1375	0.1125	0.0250	0.0250	
CGCHEMPM	0.1000	0.1000	0.2000	0.0500	0.3000	0.1000	0.0500	0.1000	0.0000	
SME	0.6250	0.9063	1.7188	0.2656	0.8594	0.8594	0.7031	0.1563	0.1563	6.2500
CGCHEMPM	1.4000	1.4000	2.8000	0.7000	4.2000	1.4000	0.7000	1.4000	0.0000	14.0000
	2.7300	2.1315	3.6188	0.8663	4.7902	3.0459	1.3484	1.9777	0.1413	20.6500
SME	0.8263	0.6451	1.0953	0.2622	1.4498	0.9219	0.4081	0.5986	0.0428	6.2500
CGCHEMPM	1.8508	1.4451	2.4534	0.5873	3.2476	2.0650	0.9142	1.3408	0.0958	14.0000
	2.7300	2.1315	3.6188	0.8663	4.7902	3.0459	1.3484	1.9777	0.1413	20.6500
Chi-square Test	0.9654									
SME	0.1000	0.1450	0.2750	0.0425	0.1375	0.1375	0.1125	0.0250	0.0250	
CGMATPM	0.1200	0.1500	0.1500	0.0300	0.2000	0.2000	0.0500	0.0500	0.0000	
SME	0.6250	0.9063	1.7188	0.2656	0.8594	0.8594	0.7031	0.1563	0.1563	6.2500
CGMATPM	0.4800	0.6000	0.6000	0.1200	0.8000	0.8000	0.2000	0.2000	0.0000	3.8000
	1.8100	1.3315	1.4188	0.2863	1.3902	2.4459	0.8484	0.7777	0.1413	10.4500
SME	1.0825	0.7964	0.8486	0.1712	0.8315	1.4628	0.5074	0.4651	0.0845	6.2500
CGMATPM	0.6582	0.4842	0.5159	0.1041	0.5055	0.8894	0.3085	0.2828	0.0514	3.8000
	1.8100	1.3315	1.4188	0.2863	1.3902	2.4459	0.8484	0.7777	0.1413	10.4500
Chi-square Test	0.9767									

	Selecting Projects - Reviewing Proposals	Selecting Projects - Visiting Primary Investigator	Selecting Projects - Corresponding/Speaking on the Phone with PI	Selecting Projects - Corresponding/Speaking on the Phone with Other Experts about a Proposal	Selecting Projects - Organizing and Obtaining Peer Review	Selecting Projects - Completing and Submitting Project Approval Packets	Selecting Projects - Other	Selecting Projects - Other2	
SME	0.1750	0.1938	0.0875	0.0913	0.1213	0.2938	0.0375	0.0000	
CGCSPM	0.4000	0.0000	0.1000	0.1000	0.3000	0.1000	0.0000	0.0000	
SME	1.6013	1.7728	0.8006	0.8349	1.1094	2.6878	0.3431	0.0000	9.1500
CGCSPM	3.2000	0.0000	0.8000	0.8000	2.4000	0.8000	0.0000	0.0000	8.0000
	4.8013	1.7728	1.6006	1.6349	3.5094	3.4878	0.3431	0.0000	17.1500
SME	2.5616	0.9458	0.8540	0.8723	1.8724	1.8608	0.1831	0.0000	9.1500
CGCSPM	2.2397	0.8270	0.7466	0.7627	1.6371	1.6270	0.1601	0.0000	8.0000
	4.8013	1.7728	1.6006	1.6349	3.5094	3.4878	0.3431	0.0000	17.1500
Chi-square Test	0.6649								
SME	0.1750	0.1938	0.0875	0.0913	0.1213	0.2938	0.0375	0.0000	
CGLSPM	0.2000	0.0000	0.1000	0.1000	0.3000	0.3000	0.0000	0.0000	
SME	1.6013	1.7728	0.8006	0.8349	1.1094	2.6878	0.3431	0.0000	9.1500
CGLSPM	2.0000	0.0000	1.0000	1.0000	3.0000	3.0000	0.0000	0.0000	10.0000
	3.6013	1.7728	1.8006	1.8349	4.1094	5.6878	0.3431	0.0000	19.1500
SME	2.1848	0.4246	1.2596	0.8874	1.9554	1.5075	0.9307		9.1500
CGLSPM	2.3878	0.4641	1.3766	0.9698	2.1371	1.6476	0.9307		10.0000
	5.1413	0.9992	2.9642	2.0882	4.6014	3.5475	2.1900	0.0000	21.5317
Chi-square Test	0.1580								
SME	0.1750	0.1938	0.0875	0.0913	0.1213	0.2938	0.0375	0.0000	
CGPHYPM	0.3500	0.0000	0.3500	0.1000	0.1000	0.1000	0.0000	0.0000	
SME	1.6013	1.7728	0.8006	0.8349	1.1094	2.6878	0.3431	0.0000	9.1500
CGPHYPM	4.2000	0.0000	4.2000	1.2000	1.2000	1.2000	0.0000	0.0000	12.0000
	7.3413	0.9992	6.1642	2.2882	2.8014	1.7475	2.1900	0.0000	23.5317
SME	2.8546	0.3885	2.3969	0.8897	1.0893	0.6795	0.8516		9.1500
CGPHYPM	3.7437	0.5095	3.1434	1.1668	1.4286	0.8911	1.1168		12.0000
	7.3413	0.9992	6.1642	2.2882	2.8014	1.7475	2.1900	0.0000	23.5317
Chi-square Test	0.0205								
SME	0.1750	0.1938	0.0875	0.0913	0.1213	0.2938	0.0375	0.0000	
CGCHEMPM	0.1000	0.0500	0.3000	0.1000	0.1500	0.3000	0.0000	0.0000	
SME	1.6013	1.7728	0.8006	0.8349	1.1094	2.6878	0.3431	0.0000	9.1500
CGCHEMPM	0.6000	0.3000	1.8000	0.6000	0.9000	1.8000	0.0000	0.0000	6.0000
	3.7413	1.2992	3.7642	1.6882	2.5014	2.3475	2.1900	0.0000	17.5317
SME	1.9526	0.6781	1.9646	0.8811	1.3055	1.2252	1.1430		9.1500
CGCHEMPM	1.2804	0.4446	1.2882	0.5777	0.8561	0.8034	0.7495		6.0000
	3.7413	1.2992	3.7642	1.6882	2.5014	2.3475	2.1900	0.0000	17.5317
Chi-square Test	0.2805								
SME	0.1750	0.1938	0.0875	0.0913	0.1213	0.2938	0.0375	0.0000	
CGMATPM	0.3000	0.0000	0.2500	0.1000	0.1000	0.0500	0.2000	0.0000	
SME	1.6013	1.7728	0.8006	0.8349	1.1094	2.6878	0.3431	0.0000	9.1500
CGMATPM	7.2000	0.0000	6.0000	2.4000	2.4000	1.2000	4.8000	0.0000	24.0000
	10.3413	0.9992	7.9642	3.4882	4.0014	1.7475	6.9900	0.0000	35.5317
SME	2.6630	0.2573	2.0509	0.8983	1.0304	0.4500	1.8000	0.0000	9.1500
CGMATPM	6.9850	0.6749	5.3794	2.3561	2.7028	1.1804	1.8000	0.0000	24.0000
	10.3413	0.9992	7.9642	3.4882	4.0014	1.7475	6.9900	0.0000	35.5317
Chi-square Test	0.0001								

	Managing Projects - Visiting PI	Managing Projects - Corresponding/Speaking on the Phone with PI	Managing Projects - Reviewing Progress, Interim and Final Reports	Managing Projects - Administratively Maintaining Project Records	Managing Projects - Preparation for Program Reviews	Managing Projects - Other	Managing Projects - Other 2	
SME	0.2438	0.1813	0.1563	0.2438	0.1250	0.0500	0.0000	
CGCSPM	0.1000	0.2000	0.2000	0.2500	0.2500	0.0000	0.0000	
SME	1.7531	2.1856	2.0336	1.4025	1.4493	0.5259	0.0000	9.3500
CGCSPM	0.8000	1.6000	1.5400	1.4909	1.4218	0.0000	0.0000	6.8527
	2.5531	3.7856	3.5736	2.8934	2.8711	0.5259	0.0000	16.2027
SME	1.4733	2.1845	2.0622	1.6697	1.6568	0.3035		9.3500
CGCSPM	1.0798	1.6011	1.5114	1.2237	1.2143	0.2224		6.8527
	2.5531	3.7856	3.5736	2.8934	2.8711	0.5259	0.0000	16.2027
Chi-square Test	0.9843							
SME	0.2438	0.1813	0.1563	0.2438	0.1250	0.0500	0.0000	
CGLSPM	0.1500	0.2500	0.2000	0.2000	0.2000	0.0000	0.0000	
SME	1.7531	2.1856	2.0336	1.4025	1.4493	0.5259	0.0000	9.3500
CGLSPM	3.0000	5.0000	4.0000	4.0000	4.0000	0.0000	0.0000	20.0000
	4.7531	7.1856	6.0336	5.4025	5.4493	0.5259	0.0000	29.3500
SME	1.5448	2.1696	1.8432	1.8212	1.7903	0.1810		9.3500
CGLSPM	3.3044	4.6408	3.9426	3.8956	3.8295	0.3871		20.0000
	5.3532	7.5180	6.3870	6.3109	6.2038	0.6270	0.0000	32.4000
Chi-square Test	0.9328							
SME	0.2438	0.1813	0.1563	0.2438	0.1250	0.0500	0.0000	
CGPHYPM	0.1000	0.2500	0.1000	0.1500	0.2000	0.2000	0.0000	
SME	1.7531	2.1856	2.0336	1.4025	1.4493	0.5259	0.0000	9.3500
CGPHYPM	1.2000	3.0000	1.2000	1.8000	2.4000	2.4000	0.0000	12.0000
	3.5532	5.5180	3.5870	4.1109	4.6038	3.0270	0.0000	24.4000
SME	1.3616	2.1145	1.3745	1.5753	1.7642	1.1600		9.3500
CGPHYPM	1.7475	2.7138	1.7641	2.0218	2.2642	1.4887		12.0000
	3.5532	5.5180	3.5870	4.1109	4.6038	3.0270	0.0000	24.4000
Chi-square Test	0.8728							
SME	0.2438	0.1813	0.1563	0.2438	0.1250	0.0500	0.0000	
CGCHEMPM	0.4000	0.1000	0.2000	0.2000	0.1000	0.0000	0.0000	
SME	1.7531	2.1856	2.0336	1.4025	1.4493	0.5259	0.0000	9.3500
CGCHEMPM	4.8000	1.2000	2.4000	2.4000	1.2000	0.0000	0.0000	12.0000
	7.1532	3.7180	4.7870	4.7109	3.4038	0.6270	0.0000	24.4000
SME	2.7411	1.4247	1.8344	1.8052	1.3043	0.2403		9.3500
CGCHEMPM	3.5180	1.8285	2.3543	2.3168	1.6740	0.3084		12.0000
	7.1532	3.7180	4.7870	4.7109	3.4038	0.6270	0.0000	24.4000
Chi-square Test	0.7975							
SME	0.2438	0.1813	0.1563	0.2438	0.1250	0.0500	0.0000	
CGMATPM	0.2000	0.2000	0.2500	0.1500	0.1500	0.0500	0.0000	
SME	1.7531	2.1856	2.0336	1.4025	1.4493	0.5259	0.0000	9.3500
CGMATPM	2.0000	2.0000	2.5000	1.5000	1.5000	0.5000	0.0000	10.0000
	4.3532	4.5180	4.8870	3.8109	3.7038	1.1270	0.0000	22.4000
SME	1.8171	1.8859	2.0399	1.5907	1.5460	0.4704	0.0000	9.3500
CGMATPM	1.9434	2.0170	2.1817	1.7013	1.6535	0.5031	0.0000	10.0000
	4.3532	4.5180	4.8870	3.8109	3.7038	1.1270	0.0000	22.4000
Chi-square Test	0.9994							

	Selecting Thrusts - Reading Published Report	Selecting Thrusts - Visiting Other Govt Labs	Selecting Thrusts - Visiting Academia	Selecting Thrusts - Visiting Industry	Selecting Thrusts - Conducting Workshops	Selecting Thrusts - Corresponding/Speaking with other Experts in the Field	Selecting Thrusts - Reviewing Operational Needs/Future Requirements Documents	Selecting Research Thrusts - Other	Selecting Research Thrusts - Other2	
SE	0.1125	0.0875	0.2000	0.0750	0.0500	0.1125	0.0500	0.0500	0.0125	
CGCSPM	0.2000	0.1000	0.1000	0.0000	0.1000	0.2000	0.0000	0.3000	0.0000	
SE	0.3375	0.2625	0.6000	0.2250	0.1500	0.3375	0.1500	0.1500	0.0375	2.2500
CGCSPM	1.6000	0.8000	0.8000	0.0000	0.8000	1.6000	0.0000	2.4000	0.1700	8.1700
	1.9375	1.0625	1.4000	0.2250	0.9500	1.9375	0.1500	2.5500	0.2075	10.4200
SE	0.4184	0.2294	0.3023	0.0486	0.2051	0.4184	0.0324	0.5506	0.0448	2.2500
CGCSPM	1.5191	0.8331	1.0977	0.1764	0.7449	1.5191	0.1176	1.9994	0.1627	8.1700
	1.9375	1.0625	1.4000	0.2250	0.9500	1.9375	0.1500	2.5500	0.2075	10.4200
Chi-square Test	0.9752									
SE	0.1125	0.0875	0.2000	0.0750	0.0500	0.1125	0.0500	0.0500	0.0125	
CGLSPM	0.1000	0.2000	0.1000	0.0000	0.2500	0.2500	0.1000	0.0000	0.0000	
SE	0.3375	0.2625	0.6000	0.2250	0.1500	0.3375	0.1500	0.1500	0.0375	2.2500
CGLSPM	0.6000	1.2000	0.6000	0.0000	1.5000	1.5000	0.6000	0.0000	0.0000	6.0000
	0.9375	1.4625	1.2000	0.2250	1.6500	1.8375	0.7500	0.1500	0.0375	8.2500
SE	0.2557	0.3989	0.3273	0.0614	0.4500	0.5011	0.2045	0.0409	0.0102	2.2500
CGLSPM	0.6818	1.0636	0.8727	0.1636	1.2000	1.3364	0.5455	0.1091	0.0273	6.0000
	0.9375	1.4625	1.2000	0.2250	1.6500	1.8375	0.7500	0.1500	0.0375	8.2500
Chi-square Test	0.9844									
SE	0.1125	0.0875	0.2000	0.0750	0.0500	0.1125	0.0500	0.0500	0.0125	
CGPHYPM	0.2000	0.1000	0.1000	0.0500	0.1000	0.2500	0.0500	0.1500	0.0000	
SE	0.3375	0.2625	0.6000	0.2250	0.1500	0.3375	0.1500	0.1500	0.0375	2.2500
CGPHYPM	0.8000	0.4000	0.4000	0.2000	0.4000	1.0000	0.2000	0.6000	0.0000	4.0000
	1.1375	0.6625	1.0000	0.4250	0.5500	1.3375	0.3500	0.7500	0.0375	6.2500
SE	0.4095	0.2385	0.3600	0.1530	0.1980	0.4815	0.1260	0.2700	0.0135	2.2500
CGPHYPM	0.7280	0.4240	0.6400	0.2720	0.3520	0.8560	0.2240	0.4800	0.0240	4.0000
	1.1375	0.6625	1.0000	0.4250	0.5500	1.3375	0.3500	0.7500	0.0375	6.2500
Chi-square Test	0.9998									
SE	0.1125	0.0875	0.2000	0.0750	0.0500	0.1125	0.0500	0.0500	0.0125	
CGCHEMPM	0.1000	0.1000	0.2000	0.0500	0.3000	0.1000	0.0500	0.1000	0.0000	
SE	0.3375	0.2625	0.6000	0.2250	0.1500	0.3375	0.1500	0.1500	0.0375	2.2500
CGCHEMPM	1.4000	1.4000	2.8000	0.7000	4.2000	1.4000	0.7000	1.4000	0.0000	14.0000
	1.7375	1.6625	3.4000	0.9250	4.3500	1.7375	0.8500	1.5500	0.0375	16.2500
SE	0.2406	0.2302	0.4708	0.1281	0.6023	0.2406	0.1177	0.2146	0.0052	2.2500
CGCHEMPM	1.4969	1.4323	2.9292	0.7969	3.7477	1.4969	0.7323	1.3354	0.0323	14.0000
	1.7375	1.6625	3.4000	0.9250	4.3500	1.7375	0.8500	1.5500	0.0375	16.2500
Chi-square Test	0.9989									
SE	0.1125	0.0875	0.2000	0.0750	0.0500	0.1125	0.0500	0.0500	0.0125	
CGMATPM	0.1200	0.1500	0.1500	0.0300	0.2000	0.2000	0.0500	0.0500	0.0000	
SE	0.3375	0.2625	0.6000	0.2250	0.1500	0.3375	0.1500	0.1500	0.0375	2.2500
CGMATPM	0.4800	0.6000	0.6000	0.1200	0.8000	0.8000	0.2000	0.2000	0.0000	3.8000
	0.8175	0.8625	1.2000	0.3450	0.9500	1.1375	0.3500	0.3500	0.0375	6.0500
SE	0.3040	0.3208	0.4463	0.1283	0.3533	0.4230	0.1302	0.1302	0.0139	2.2500
CGMATPM	0.5135	0.5417	0.7537	0.2167	0.5967	0.7145	0.2198	0.2198	0.0236	3.8000
	0.8175	0.8625	1.2000	0.3450	0.9500	1.1375	0.3500	0.3500	0.0375	6.0500
Chi-square Test	0.9999									

	Selecting Projects - Reviewing Proposals	Selecting Projects - Visiting Primary Investigator	Selecting Projects - Corresponding/Speaking on the Phone with PI	Selecting Projects - Corresponding/Speaking on the Phone with Other Experts about a Proposal	Selecting Projects - Organizing and Obtaining Peer Review	Selecting Projects - Completing and Submitting Project Approval Packets	Selecting Projects - Other	Selecting Projects - Other2	
SE	0.1875	0.1375	0.1125	0.1250	0.0875	0.2000	0.1500	0.0000	
CGCSPM	0.4000	0.0000	0.1000	0.1000	0.3000	0.1000	0.0000	0.0000	
SE	3.2813	2.4063	1.9688	2.1875	1.5313	3.5000	2.6250	0.0000	17.5000
CGCSPM	3.2000	0.0000	0.8000	0.8000	2.4000	0.8000	0.0000	0.0000	8.0000
	6.4813	2.4063	2.7688	2.9875	3.9313	4.3000	2.6250	0.0000	25.5000
SE	4.4479	1.6513	1.9001	2.0502	2.6979	2.9510	1.8015	0.0000	17.5000
CGCSPM	2.0333	0.7549	0.8686	0.9373	1.2333	1.3490	0.8235	0.0000	8.0000
	6.4813	2.4063	2.7688	2.9875	3.9313	4.3000	2.6250	0.0000	25.5000
Chi-square Test	0.5126								
SE	0.1875	0.1375	0.1125	0.1250	0.0875	0.2000	0.1500	0.0000	
CGLSPM	0.2000	0.0000	0.1000	0.1000	0.3000	0.3000	0.0000	0.0000	
SE	3.2813	2.4063	1.9688	2.1875	1.5313	3.5000	2.6250	0.0000	17.5000
CGLSPM	2.0000	0.0000	1.0000	1.0000	3.0000	3.0000	0.0000	0.0000	10.0000
	5.2813	2.4063	2.9688	3.1875	4.5313	6.5000	2.6250	0.0000	27.5000
SE	3.3608	1.5313	1.8892	2.0284	2.8835	4.1364	1.6705	0.0000	17.5000
CGLSPM	1.9205	0.8750	1.0795	1.1591	1.6477	2.3636	0.9545	0.0000	10.0000
	5.2813	2.4063	2.9688	3.1875	4.5313	6.5000	2.6250	0.0000	27.5000
Chi-square Test	0.5519								
SE	0.1875	0.1375	0.1125	0.1250	0.0875	0.2000	0.1500	0.0000	
CGPHYPM	0.3500	0.0000	0.3500	0.1000	0.1000	0.1000	0.0000	0.0000	
SE	3.2813	2.4063	1.9688	2.1875	1.5313	3.5000	2.6250	0.0000	17.5000
CGPHYPM	4.2000	0.0000	4.2000	1.2000	1.2000	1.2000	0.0000	0.0000	12.0000
	7.4813	2.4063	6.1688	3.3875	2.7313	4.7000	2.6250	0.0000	29.5000
SE	4.4380	1.4274	3.6594	2.0095	1.6202	2.7881	1.5572	0.0000	17.5000
CGPHYPM	3.0432	0.9788	2.5093	1.3780	1.1110	1.9119	1.0678	0.0000	12.0000
	7.4813	2.4063	6.1688	3.3875	2.7313	4.7000	2.6250	0.0000	29.5000
Chi-square Test	0.3585								
SE	0.1875	0.1375	0.1125	0.1250	0.0875	0.2000	0.1500	0.0000	
CGCHEMPM	0.1000	0.0500	0.3000	0.1000	0.1500	0.3000	0.0000	0.0000	
SE	3.2813	2.4063	1.9688	2.1875	1.5313	3.5000	2.6250	0.0000	17.5000
CGCHEMPM	0.6000	0.3000	1.8000	0.6000	0.9000	1.8000	0.0000	0.0000	6.0000
	3.8813	2.7063	3.7688	2.7875	2.4313	5.3000	2.6250	0.0000	23.5000
SE	2.8903	2.0153	2.8065	2.0758	1.8105	3.9468	1.9548	0.0000	17.5000
CGCHEMPM	0.9910	0.6910	0.9622	0.7117	0.6207	1.3532	0.6702	0.0000	6.0000
	3.8813	2.7063	3.7688	2.7875	2.4313	5.3000	2.6250	0.0000	23.5000
Chi-square Test	0.8366								
SE	0.1875	0.1375	0.1125	0.1250	0.0875	0.2000	0.1500	0.0000	
CGMATPM	0.3000	0.0000	0.2500	0.1000	0.1000	0.0500	0.2000	0.0000	
SE	3.2813	2.4063	1.9688	2.1875	1.5313	3.5000	2.6250	0.0000	17.5000
CGMATPM	7.2000	0.0000	6.0000	2.4000	2.4000	1.2000	4.8000	0.0000	24.0000
	10.4813	2.4063	7.9688	4.5875	3.9313	4.7000	7.4250	0.0000	41.5000
SE	4.4198	1.0147	3.3603	1.9345	1.6578	1.9819	3.1310	0.0000	17.5000
CGMATPM	6.0614	1.3916	4.6084	2.6530	2.2735	2.7181	4.2940	0.0000	24.0000
	10.4813	2.4063	7.9688	4.5875	3.9313	4.7000	7.4250	0.0000	41.5000
Chi-square Test	0.3181								

	Managing Projects - Visiting PI	Managing Projects - Corresponding/Speaking on the Phone with PI	Managing Projects - Reviewing Progress, Interim and Final Reports	Managing Projects - Administratively Maintaining Project Records	Managing Projects - Preparation for Program Reviews	Managing Projects - Other	Managing Projects - Other 2	
SE	0.1250	0.1875	0.2750	0.2000	0.0625	0.1500	0.0000	
CGCSPM	0.1000	0.2000	0.2000	0.2500	0.2500	0.0000	0.0000	
SE	1.1875	1.7813	2.6125	1.9000	0.5938	1.4250	0.0000	9.5000
CGCSPM	0.8000	1.6000	1.5400	1.4909	1.4218	0.0000	0.0000	6.8527
	1.9875	3.3813	4.1525	3.3909	2.0156	1.4250	0.0000	16.3527
SE	1.1546	1.9643	2.4124	1.9699	1.1709	0.8278		9.5000
CGCSPM	0.8329	1.4169	1.7401	1.4210	0.8446	0.5972		6.8527
	1.9875	3.3813	4.1525	3.3909	2.0156	1.4250	0.0000	16.3527
Chi-square Test	0.8767							
SE	0.1250	0.1875	0.2750	0.2000	0.0625	0.1500	0.0000	
CGLSPM	0.1500	0.2500	0.2000	0.2000	0.2000	0.0000	0.0000	
SE	1.1875	1.7813	2.6125	1.9000	0.5938	1.4250	0.0000	9.5000
CGLSPM	3.0000	5.0000	4.0000	4.0000	4.0000	0.0000	0.0000	20.0000
	4.1875	6.7813	6.6125	5.9000	4.5938	1.4250	0.0000	29.5000
SE	1.3485	2.1838	2.1294	1.9000	1.4793	0.4589	0.0000	9.5000
CGLSPM	2.8390	4.5975	4.4831	4.0000	3.1144	0.9661	0.0000	20.0000
	4.1875	6.7813	6.6125	5.9000	4.5938	1.4250	0.0000	29.5000
Chi-square Test	0.5378							
SE	0.1250	0.1875	0.2750	0.2000	0.0625	0.1500	0.0000	
CGPHYPM	0.1000	0.2500	0.1000	0.1500	0.2000	0.2000	0.0000	
SE	1.1875	1.7813	2.6125	1.9000	0.5938	1.4250	0.0000	9.5000
CGPHYPM	1.2000	3.0000	1.2000	1.8000	2.4000	2.4000	0.0000	12.0000
	2.3875	4.7813	3.8125	3.7000	2.9938	3.8250	0.0000	21.5000
SE	1.0549	2.1126	1.6846	1.6349	1.3228	1.6901	0.0000	9.5000
CGPHYPM	1.3326	2.6686	2.1279	2.0651	1.6709	2.1349	0.0000	12.0000
	2.3875	4.7813	3.8125	3.7000	2.9938	3.8250	0.0000	21.5000
Chi-square Test	0.8614							
SE	0.1250	0.1875	0.2750	0.2000	0.0625	0.1500	0.0000	
CGCHEMPM	0.4000	0.1000	0.2000	0.2000	0.1000	0.0000	0.0000	
SE	1.1875	1.7813	2.6125	1.9000	0.5938	1.4250	0.0000	9.5000
CGCHEMPM	4.8000	1.2000	2.4000	2.4000	1.2000	0.0000	0.0000	12.0000
	5.9875	2.9813	5.0125	4.3000	1.7938	1.4250	0.0000	21.5000
SE	2.6456	1.3173	2.2148	1.9000	0.7926	0.6297	0.0000	9.5000
CGCHEMPM	3.3419	1.6640	2.7977	2.4000	1.0012	0.7953	0.0000	12.0000
	5.9875	2.9813	5.0125	4.3000	1.7938	1.4250	0.0000	21.5000
Chi-square Test	0.5859							
SE	0.1250	0.1875	0.2750	0.2000	0.0625	0.1500	0.0000	
CGMATPM	0.2000	0.2000	0.2500	0.1500	0.1500	0.0500	0.0000	
SE	1.1875	1.7813	2.6125	1.9000	0.5938	1.4250	0.0000	9.5000
CGMATPM	2.0000	2.0000	2.5000	1.5000	1.5000	0.5000	0.0000	10.0000
	3.1875	3.7813	5.1125	3.4000	2.0938	1.9250	0.0000	19.5000
SE	1.5529	1.8421	2.4907	1.6564	1.0200	0.9378	0.0000	9.5000
CGMATPM	1.6346	1.9391	2.6218	1.7436	1.0737	0.9872	0.0000	10.0000
	3.1875	3.7813	5.1125	3.4000	2.0938	1.9250	0.0000	19.5000
Chi-square Test	0.9546							