U.S. and China Science and Technology Policies, Competitive Advantages, and Strategic Ambitions

by

Michael Spencer, Ph.D, MBA, MIM
Halcyon Institute

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Abstract

The US and China have vastly different strategic objectives when it comes to science and technology policy (S&T). The US government's role in policy creation is to enact policy that helps develop, manage, and support the nation's technological advancements through direct public investment and/or by providing resources and financial incentives to private sector businesses (Branscomb, 1995). It has been successfully used to maintain US technological hegemony in the post-Cold War era despite an environment of administration changes and congressional partisan resistance to administrative policy direction and strategies. China's science and technology policies in contrast are aimed at transforming China into an international leader in S&T, R&D and high-tech industrial production (Suttmeier, 2018). China's S&T policy is being successfully used to transform China into a global leader in S&T R&D and high-tech manufacturing that is challenging the US for technological dominance. The driver for this transformation is China's senior leadership who strongly believe that aggressive S&T policies, concerted investments in STI, and indigenous high-tech industrial development are the key to ensuring China's long-term economic growth and national security interests. If US and Chinese S&T policies and strategic ambitions continue at their current pace, they will increase leadership misgivings as to the true nature of each nation's science, technology and innovation objectives. Action-reaction cycles are already creating negative feedback loops of tension and distrust between the two nations. The results will draw the US and China into a high technology rivalry and inevitable geopolitical conflict.

Introduction

The US science and technology policy or technology policy (terms used interchangeably) implies the utilization of technology and its applications to create useful products and services that benefit US national and economic security (Branscomb, 1995). S&T research and development (R&D) occurs and flows simultaneously between the various government agencies, national laboratories, industries, nonprofits, non-government organizations (NGOs), and academic research universities. The government's role in policy creation is to enact policy that helps develop, manage, and support the nation's technological advancements through direct public investment and/or by providing resources and financial incentives to private sector businesses. Good S&T policies should also generate stable regulatory environments, trade policies, tax regimes, and patent and intellectual property right protections. When policy has been enacted correctly it was instrumental in stimulating innovation, economic development, national security, and improving the lives of US citizens (de la Mothe & Dufour, 1995).

US technology policy in the modern era began in the Cold War and was focused on providing government support for near term defense requirements. Research funding flowed unencumbered throughout the military-academic-industrial complex. By the end of the Cold War, dramatic shifts were occurring in US S&T policy. Technology policies were forced to evolve to account for a rise in international competitive pressures, increased importance of commercial product development, and changing leadership perspectives. If the US intended to retain its technological hegemony deemed vital for its economic and national security interests, then significant changes in policy direction would be necessary. In addition, US policy creation, in the post-Cold War era, would become increasingly more dependent on domestic politics, the administration in the White House, its policy advisors, and a reliance on the political party in control of Congress. (Lubell, 2019).

I argue that S&T policy has been successfully used to maintain US technological hegemony in the post-Cold War era despite an environment of administration changes and congressional partisan resistance to administrative policy direction and strategies. It has also set the foundation for a geopolitical struggle between the US and other technologically advanced developed nations in Europe and North East Asia over technology driven international competitiveness, and a growing rivalry between China and the US over technological hegemony that could result in an arms race and contribute to a security dilemma between the nations. Due to the vast variety of technologies researched and developed by technologically advanced nations and the complex and interconnected nature of technology integration, I will focus on those technologies that provide the greatest impact in achieving US economic and national security priorities, i.e. dual use technologies.

China's science and technology strategies and policies in contrast are aimed at transforming China into an international leader in S&T, R&D and high-tech industrial production. Chinese leadership established a new era of S&T reform in 2006 with policies directed at increasing R&D spending to rates comparable with other technologically advanced developed nations (Suttmeier, 2018). China's senior leaders realize that S&T and innovation (STI) are the keys to China's future economic growth. They realize that the era of relying on foreign technology through tech transfer and intellectual property acquisition will not meet China's economic expansion needs. Beijing realizes that economic growth is critical for ensuring its national security interests and China's prior manufacturing and export model cannot account for China's falling growth rates, depletion of indigenous resources, rapidly aging population, or indefinitely provide for the growing needs of its resource-intensive middle classes and their evolving consumption habits (Keller, 2016; Beckley, 2019). China's leaders have grown less satisfied on China's low value large-scale manufacturing prowess. They intend to promote indigenous innovation and make a leap from producing low-to-medium quality goods up to manufacturing and exporting high tech products and developing high-value supply chains (Keller, 2016; Legarda, 2018).

In China's drive for STI advancements, strategies and policies have been ongoing since 2006 and have resulted in a rapid increase in investments aimed at S&T R&D and in the development of high-tech industrial sectors. These policies and strategic initiatives have raised China from a developing country just a few decades ago to an international competitor in STI with a rate of investment growth exceeding all other nations (Veugelers, 2017).

In the same manner that I proposed that US S&T policy was successfully used to maintain technological hegemony, I argue that China's S&T policy is being successfully used to transform China into a global leader in S&T R&D and high-tech manufacturing that is challenging the US for technological dominance. The driver for this transformation is China's senior leadership who strongly believe that aggressive S&T policies, concerted investments in STI, and indigenous high-tech industrial development are the key to ensuring China's long-term economic growth and national security interests. This technological ascension is also setting the stage for geopolitical tension and a S&T rivalry between China and the US, leading both nations towards a potential arms race, and contributing to a complex technology driven security dilemma.

To present this analysis, I will utilize a five-step process for both the US and China. In the first step, I will provide an assessment as to how US technological developments are setting the foundation for a defensive realism-based security dilemma, and to what degree US S&T policies are contributing to a growing rivalry between the US and China. The second step will describe the US S&T and innovation (STI) environment, its vast network of interrelated agencies, policymaking process, and the complexity involved in enacting policy. I will also discuss the prior administrations process for enacting policies. Third, I will provide a historical overview of US Technology policy in the post-cold war era concentrating on policy differences between the Ronald Reagan, George H. W. Bush, Bill Clinton, George W. Bush, Barack Obama, Donald Trump, and the Joe Biden administrations. I will introduce the policymaking agencies and key policy making decision makers. I will describe how US technology-based strategies and policies differed from administration to administration. Fourth, I will discuss how domestic and geopolitical conditions influenced each US administration's policy recommendations. I will analyze how different administrations prioritize technology policies and which fields were given the greatest level of budgetary attention. I will explain how leadership perceptions influenced each administration's policy making. Finally, I will assess current government programs and their ability to coordinate between government agencies, industries, and academic institutions; their effectiveness in collecting relevant data and their ability to accurately measure policy success.

In Chana's case, the first step will explain how China's S&T policies are also rooted in defensive realism theory, and How China's technological advancements and economic growth are not being used for aggressive purposes but to gradually enhance China's position within the international order, how these actions are perceived by other nations as a threat, and how an action – reaction scenario is creating a technology driven security dilemma between the US and China. In step two, I will provide a description of China's political system, its five government branches, and the key positions within those branches. I will describe the principal policymakers and the policymaking process. Third, I will discuss the historical background leading up to China's technological and economic rise. I will explain how China used western expertise and knowledge, foreign direct investment (FDI), and its own research institutes, universities, state-owned enterprises to close the gap on US's STI dominance. I will describe how China successfully reformed its STI ecosystem through medium to long term strategic initiatives and short-term S&T policy directives. I will discuss the importance of China's senior leadership perceptions and how they were instrumental in setting the course of China's S&T policymaking reforms. Fourth, I will explain China's overall S&T strategies, policies, and policy making environment. I will evaluate China's centralized command and control policymaking methods, comparing its advantages and disadvantages to Western policymaking models. ~~In conclusion, I~~ The fifth step will assess if China's S&T policies meet senior leadership expectations and are consider a value to China's long-term objectives.

Throughout this five-step process I will use both qualitative and quantitative data for analysis to explain US and China's S&T policy environment and internal policy making process, provide a historical overview of their technology policies, explain the differences between US and Chinese strategic initiatives and S&T policy objectives and how these strategies and policies both influence and are affected by domestic and geopolitical conditions, outline how leadership perspectives and other contributing factors influence policymaking, and determine whether policies have been successful or not. The ultimate goal of this study is to present the differences between each nations S&T policies and objectives, identify any strategic advantages one nation may have over the other, assess if US and Chinese technological developments and competitiveness are setting the foundation for a defensive realism-based security dilemma, and ascertain to what degree are their S&T policies are contributing to a high technology rivalry between the US and China.

Technology Policy, Defensive Realism and the Security Dilemma – Step One

Defensive realism claims that the international system's anarchic nature will cause a nation to assume a defensive posture and implement strategies designed to ensure its national security. Nations are not inherently aggressive or constantly seeking to maximize their power but are instead more concerned with securing their position within the international system (Waltz, 1979: 118-120). However, the means by which a nation uses to secure its national security can be perceived as a threat to other security seeking nations provoking them to respond in kind. This downward spiral of unintended hostility, where no aggression was originally intended, represents a quandary referred to as the security dilemma. (Jervis, 1978: 169-170).

Defensive realists also claim that "structural modifiers" such as technology, geography, elite beliefs, etc. act as mechanisms that can further aggravate a security dilemma or can be catalysts unto themselves to promote possible aggression towards other nations. (van Evera, 1999: 7-8) Technological progress and new weapons systems development is perhaps the most prominent structural modifiers and can easily be perceived by other nations as an aggressive action; making other nations feel less secure and prone to advance their own technological development (Harris, 2016).

US S&T Policy and the Security Dilemma

In the case of the US, dual use technology development is used to not only ensure economic and national security but to sustain technological hegemony against rising international competition. This has created uneasiness among other technologically advanced developed nations because of how much money the US spends on defense, weapons platform superiority, and how often the US has used advanced weapons in wartime theaters over the past few decades (The White House, 2015).

Technological advancements and dual use R&D have contributed significantly to US long-term economic growth; enabling the US to further develop its military and reinvest in ongoing rounds of R&D. Europe and East Asia want to counterbalance against the perceived US threat by enhancing their own technological progress which also strengthens their economies and national security. (Lubell, 2019). As these nations narrowed the technology gap, especially in the commercial sectors, US leadership (administration) perceived this growing international competition as a threat to its technological and economic hegemony and has created new strategic directives and technology policies to ensure it retains its current dominant geopolitical position. All these technologically advanced developed nations are escalating their technological development and devising new strategic initiatives and supportive policies to be on the cutting-edge of a new generation of technologies, so they don't fall behind. (National Academy of Engineering, 1993; Lubell, 2019).

The US Government Accountability Office (GAO) identifies the new generations of cutting-edge technologies in these categories: genome editing, AI and AI embedded automation, quantum information science, brain/augmented reality, and cloud-based block chains. They are all known to have dual use capabilities and are currently in prototype development (GAO, 2019). What is becoming abundantly clear to these nations is that if they wish to maintain their current economic position in the international system, or be able to counterbalance against perceived threats, it will require innovation and good supporting policy. Innovation has become the economic lifeline for these nations and technological advances from dual use technologies are the key (Romer, 1986).

However, the complexity and rapid integration of new technologies makes it difficult for US policymakers and their counterparts to implement technology policy in a timely manner or to suitably address all the possible ramifications technology policies must account for. This complexity also convolutes the perceptions of each nation's leadership making strategic course changes difficult to ascertain, subject to partisan or standing committee politics, and increasingly hard to implement (Clark, 2013). These factors all contribute to rising international competition and are increasing the threat of a trade war. The current rivalry between the US, the current economic and technological hegemon, and China, the emerging technological powerhouse is a prime example of this (NSS, 2017: 2-3).

China S&T Policy and the Security Dilemma

China's policies are also ingrained in defensive realism. China's primary objective is to ensure its security by maintaining or incrementally improving its position in the anarchical international system (Waltz, 1979: 114- 116). Despite China's rapid technological and economic growth, there have been no serious attempts to become an offensive or aggressive global power. China appears more concerned with sustaining the balance of power which has been very beneficial to it economically. There have also been no overt attempts to counter or revise the international order with a multipolar system with China as a major power broker. Instead, China's leadership has sought to remain largely a status quo power focused on economic growth and avoid any expansionists strategies that could result in unbeneficial Western counter balancing measures. China's leaders are purposely exercising a defensive security strategy with an emphasis on the appearance of restraint, integration, and international cooperation. (Johnston, 2003; Tang, 2003).

Regardless of the US and other technologically advanced developed nations' fears, China has not demonstrated any outright intentions for role as regional or global hegemon. Instead, China seems more concerned with stabilizing its regional interests. However, China's senior leadership are troubled by the increasing US influence in Southeast Asia and Western attempts to contain its technological and economic growth (Jalil, 2019). China's leaders consider its long overdue military modernization and recent economic policies aimed at Taiwan and legislative actions against Hong Kong as balancing measures against unpredictable US regional actions, such as, increasing US naval and air military presence in the South China Sea, providing aid to Taiwan's independence efforts in the form of arms sales, and democratic rights support to Hong Kong protesters (Johnston, 2003; Meyers, 2019). China has demonstrated regional restraint and not engaged in any overt military activities. Nor does China appear interested in sacrificing its economic development or its relationship with its largest Western trading partners. China's long-term goals to become a technological and economic global power supersede any desires to challenge US military hegemony in Southeast Asia or globally. This could change in the future (Johnston, 2003).

China's leadership is also keenly aware that any attempt, military modernization efforts or to further development of its technological and economic prowess for national security and international competitiveness purposes, made to balance against what it perceives as a growing US influence in South East Asia region will be interpreted by the US as another escalation of hostilities. Threatening a US counter-response in a similar fashion or with another round of containment measures. This action-reaction spiral of perceived hostilities is contributing to the growing threat of a security dilemma between China and the US regardless of China's desire to avoid or mediate it (Jervis, 1999: 49; Jalil, 2019).

In addition to considering the components leading to a security dilemma, its potential severity can be attributed to the influence of structural modifiers or material factors. These modifiers include geography, technology, military, and nation's social structure, etc. (Taliaferro, 2001: 131, 137). The structural modifier of greatest impetus to China is its successful development of STI which has proven to be a major catalyst for its economic growth and for advancing its military modernization objectives. China's senior leadership realized that any nation rapidly modernizing its military, with advanced weaponry, increases security concerns among its surrounding nations or nations with a vested interest in the region. This in turn encourages those nations to pursue regional alliances and/or to develop technologies to guarantee their own national security (Van Evera, 1999: 112, 160; Tang, 2003; Harris, 2016). Fears of diminishing national security do not have to be based on actual actions (and are usually not) but on the perceptions of threat from the senior leadership (Van Evera, 1998).

China's senior leadership strongly believes that aggressive S&T strategic policies are necessary if China intends to become a dominant technological and economic power (Veugelers, 2017). China's prior S&T strategies and policies, beginning in 2006, established the foundations for China's technological progress and helped close the STI gap with the US and other technologically advanced developed nations. In contrast, the US did not devote the same level of attention to STI and this has resulted in a diminishing effect on its S&T R&D and high-tech manufacturing superiority, a mistake the Trump Administration attempted to remedy with an increase in investments, and the Biden Administration pursued in greater earnest by allocating almost $300 billion towards (Veugelgers, 2017; Edelman & Roughead, 2018; Chen & Lee, 2022). China’s leaders believe that Western neglect in STI and in high tech product conception presents an opportunity for China to surpass the US and other technologically advanced developed nations through state supported R&D and industrial development programs concentrating on emerging dual use / leapfrog technologies and private sector industrial development. Success in these emerging fields would reduce the need to compete directly against the US’s established technology dominance (Bey, 2018; Kaplan, 2019).

China’s pursuit of cutting-edge dual use / leapfrog technologies combined with its desire to wean itself from dependence on foreign technologies and advance its indigenous manufacturing capabilities and high-tech export capacity has raised alarms among many world leaders. The US and other technologically advanced developed nations remain unconvinced that China is simply trying to bolster its position in the international order or that it simply intends to gradually become a major international competitor in STI. Instead, these countries view China’s rapid technological ascension as part of an overall strategy designed to attain first regional, then usurp global technological hegemony (techno – hegemony) (Freeman, 2017a; Motohiro, 2019).

Circumstances are deteriorating to the point that China’s leaders believe that any advancement made to develop key emerging technologies (i.e. quantum computing, 5G, and AI integration) and their dual use capacity will be met with US counter balancing measures to slow China’s technological growth and increase investments into cutting edge R&D and high tech industry incentives (Motohiro, 2019, Edelman and Roughead, 2018). Each of these maneuvers from both sides further aggravates their leaderships’ fear and distrust that their counterparts have underlying hostile intentions. This in turn increases tensions between the nations and further encourages each to rush in and dominate these emerging technologies to safeguard their national security interests. This cycle contributes to a US – China technology rivalry and is becoming a growing catalyst for a broader security dilemma (Tang, 2009: 590-591; Kania, 2018).

Another major challenge facing China is similar to the one that is confronting the US. The complexity, integration capabilities, and rapid pace of integration, makes it difficult for China's leadership to gain a thorough understanding of what these new generations of technologies are capable of, how to integrate them properly, and how to enact policy accordingly. This level of STI complexity and vast integration possibilities can confuse and distort leadership and policy advisors' perceptions making strategic course directions or alterations difficult to agree upon and open to political and/or bureaucratic infighting. It can also create an even greater level of distrust between the two nations as their leadership questions the use and underlying motives behind S&T research and its product development (Clark, 2013; Kluz & Firlej, 2015).

Science, Technology & Innovation (STI) and Policy Making Environment – Step Two

US STI Environment and Policy Making Process

Throughout the technologically advanced developed nations, S&T policymaking occurs in only a few departments and/or ministries. This is not the case in the US, where close to 20 major agencies, offices, and departments exist that have advisory and/or policymaking capability. This fragmented bureaucracy makes US S&T policy creation cumbersome and difficult to manage. Attempts to coordinate and simplify technology policymaking operations has proven to be challenging. (Lubell, 2019).

The US system of innovation is a large and complex government structure embedded throughout the US economy (see Figure 1, page 72). The federal government directly supports innovation by developing infrastructure, providing a legal framework, conducive regulatory environment, and by directly sponsoring basic and applied research through specific executive agencies. More than half of this basic and applied research goes to the DOD, followed by the NIH, DOE, NASA, NSF, and then to other smaller agencies (Hummel, Cheatham & Rossi, 2012). However, the largest percentage of overall government support for R&D and innovation programs is indirectly channeled through private sector businesses and research institutions (Shapira & Youtie, 2010).

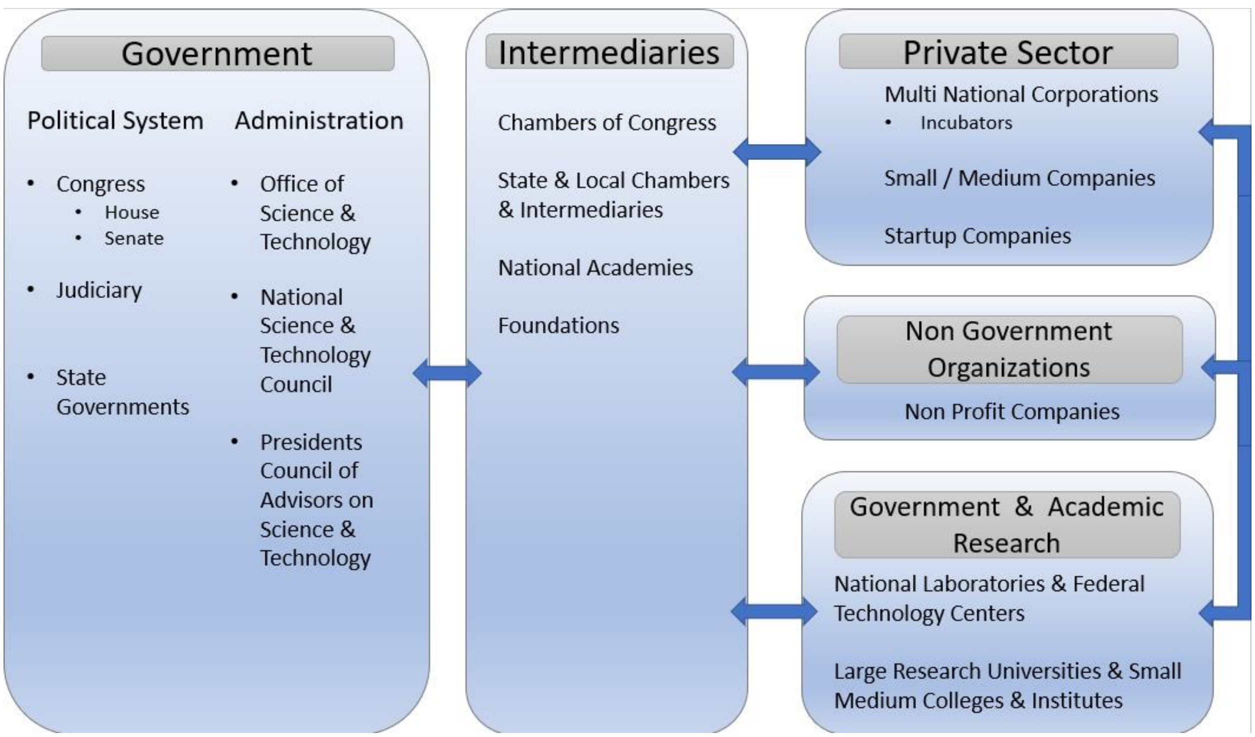

Figure 1. Organizational Chart of the US National Innovation Governance System

**Source: Fraunhofer ISI from Youtie and Shapira (2007)*

The innovation system is comprised of multiple interconnected elements consisting of 1) The federal government: current administration, Congress, judiciary branch, and state governments. 2) Private sector: technology based MNCs and incubators, small/medium size tech companies, and startup companies. 3) Large academic research institutions and smaller S&T based colleges. 4) Government research institutions: National Laboratories and Federal Technology Centers. 5) Nonprofit and nongovernment organizations (NGOs). 6) Intermediary institutions: Chambers of congress, academic and private sector research alliances, and think tanks and foundations. US state governments are also becoming more involved in innovation initiatives targeted to regional or state based economic development and job growth programs (Shapira & Youtie, 2010).

At the federal government level, the principal player is the Administration, consisting of the President and senior cabinet members. The President heads the executive branch which is comprised of numerous agencies and departments all with specific missions. Many of these federal agencies have vested interests in STI, but the three primary agencies, which report directly to the President and are responsible for directly advising the President on S&T policy formulation, are the Office of Science and Technology Policy (OSTP), National Science and Technology Council (NSTC), President's Council of Advisors on Science and Technology (PCAST). (see Figure 2 page 74) (Shapira & Youtie, 2010).

The OSTP directly advises the President on all matters dealing with STI, it coordinates budgetary allowances for all agencies under its purview and identifies and manages the nation's long-term innovation opportunities or competitive weaknesses. The NSTC is responsible for integrating and coordinating S&T activities and strategies throughout the various agencies. It also establishes goals and objectives for future S&T government support and investments. The PCAST performs as an advisory board to the President and is made up of highly respected and influential representatives from the private sector, academic institutions, and nonprofit/NGOs. Its purpose is to advise the President on the commercial sector technologies to pursue. Both the

OSTP and the NSTC have many offices and directorships that report directly to them and are outlined in Figure 2. These offices provide the OSTP and NSTC with valuable policy recommendations according to their areas of expertise (Sargent & Shea, 2017).

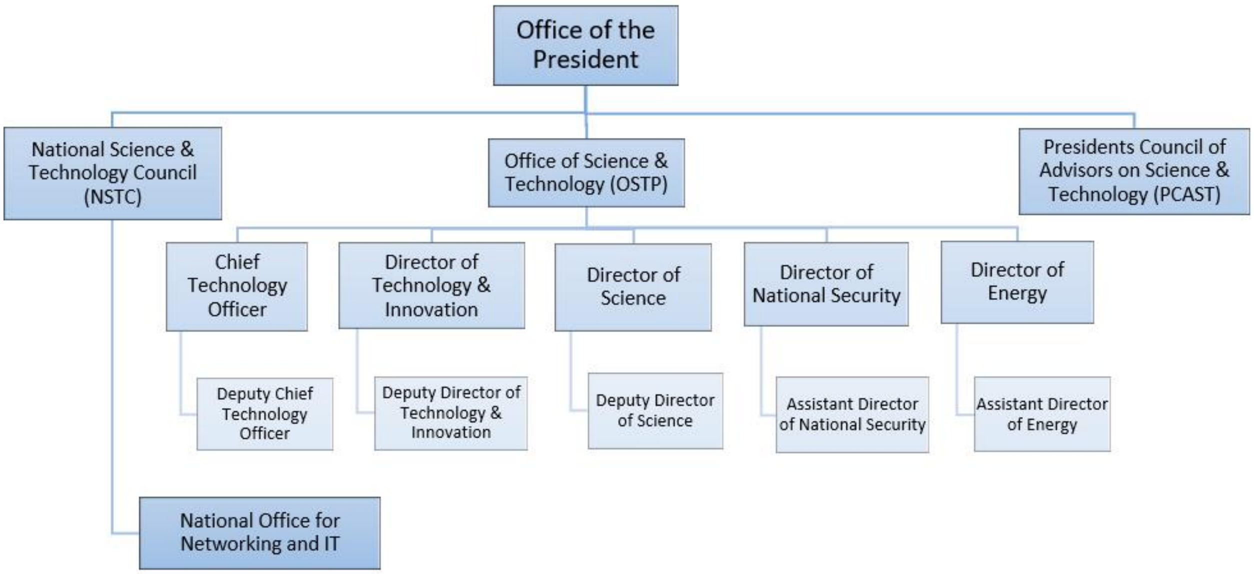

Figure 2. Selected White House Science and Technology Policy Organizations

Source: *Office of Science and Technology Policy, Executive Office of the President*

Policy creation is subject to the checks and balances between the different branches of the federal government. Partisan disagreements between the administration and Congress over the direction S&T policy should pursue are common, and the growing numbers of specific policies that come up for review each year complicate the matter further. There is also the problem of private sector appointments to the policymaking councils like the PCAST. Recommendations from business leaders have long been criticized for being to short-term and profit motivated than for advancing long-term interests of US innovation. Perhaps the biggest concern, in measuring and evaluating policies, is the difficulty in establishing suitable guidelines and metrics from which to measure success (Shapira & Youtie, 2010). This complex and arguably convoluted system allows for large-scale, multi-agency examination and assessment of numerous S&T

policies but reduces the chances of getting policy enacted in a timely manner and subjects the policy to obscure priorities and dilution from its original intended purpose. These factors hamper the success of technology policymaking and implementation, something that many other developed countries do not experience (OMB, 2019: 233, 235).

China's STI Environment, Government Structures, and Policy Making Process

There are five divisions of power that make up The People's Republic of China's (PRC): The Communist Party of China (CPC), the executive branch (government), and military branch are most relevant to S&T policy making. (see Figure 3 - China's Divisions of Government).

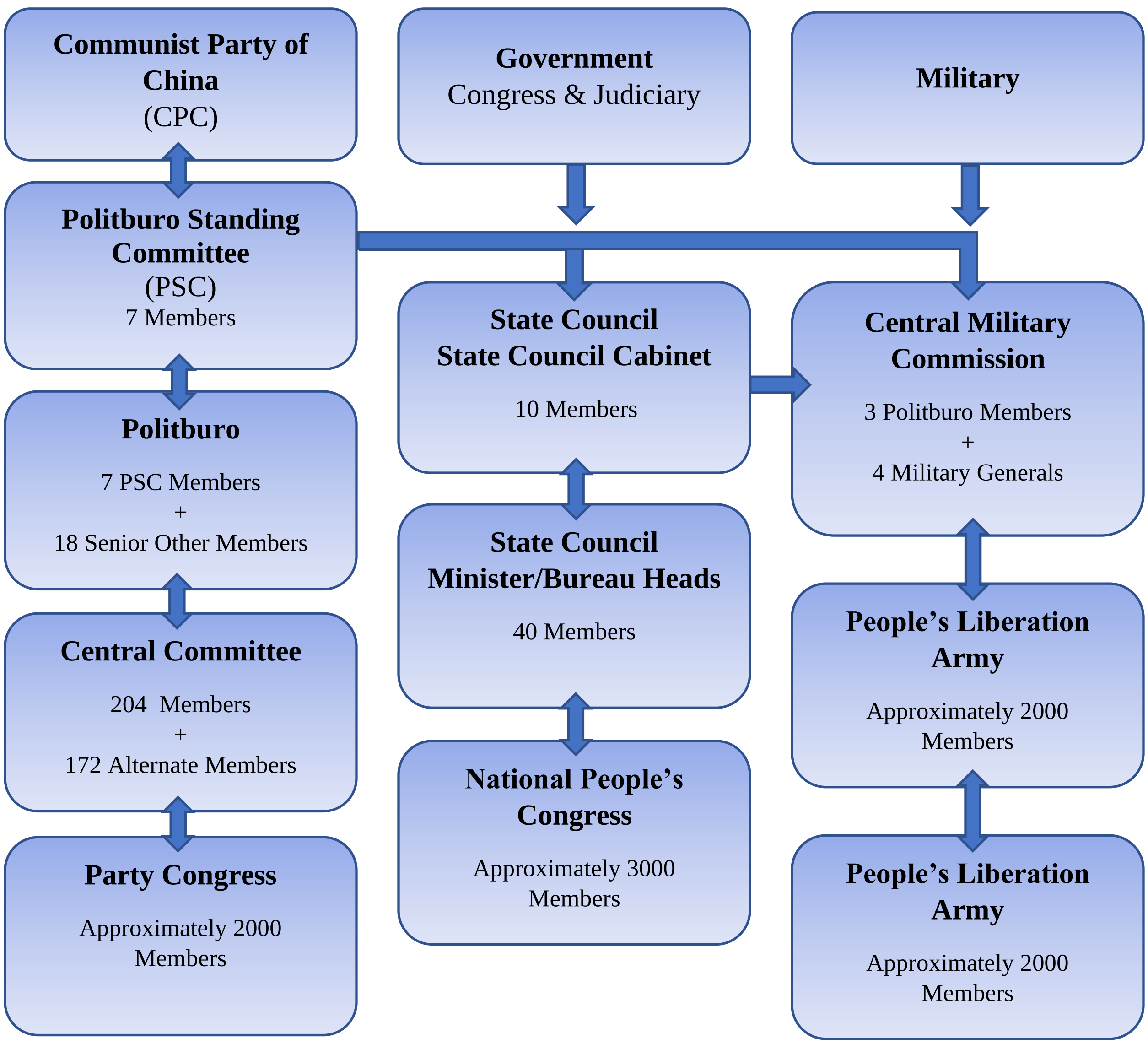

Figure 3. China's Divisions of Government

**Source: Chinese–Leaders: China's Political System*

China's Government System

The 2000 plus members of the CPC's Party Congress is China's highest political body and meets once every five years to review the Party's Constitution and elect the Central Committee. The Central Committee's 204 active members and 172 alternates in turn meets once per year to announce and validate the polices or make changes to policies, it is responsible for a greater body of laws than the greater Party Congress since it is in office for longer periods of time (McGovern & Rubio, 2018). Its most important function is to select and elect the 25-strong Central Politburo of the CPC or simply the Politburo. The Politburo is the chief political decision-making arm of the CPC and meets approximately once a month. It selects and elects the Politburo Standing Committee (PSC) from its own ranks. The Politburo's power resides in its members holding the most senior positions in the other branches of the PRC. The seven member PSC meets once per week and is the recognized top leadership of the CPC and is responsible for all major policy decisions. The General Secretary is the leader of the Standing Committee and shares the ceremonial title of President (Amebar, 2017; USCBC, 2013).

I define China's senior leadership as consisting of the CPC's elite seven-member Politburo Standing Committee (PSC), combined with 18 other senior Communist party officials who make up the Politburo. For the US it consists of the US Administration's President, Vice President and approximately 20 senior Cabinet members. Some Administrations include additional personnel: National Security Advisor, Director of OSTP, etc. (Huang, 2017; The White House, 2019c).

The executive branch consists of the State Council, Premier, and President (Figure 1). The State Council is officially referred to as the Central People's Government and was created in 1954. The approximately 35 members of the State Council. It is the chief executive or administration body of the PRC and is comprised of the 10-member Standing Committee also known as the State Council Cabinet and approximately 25-members comprising heads of ministries or bureau/agency chairs. The State Council's 25 (non-Standing Committee) members also hold senior positions and direct activities in the provincial governments. The State Council meets every six months and the Standing Committee meets weekly. The Premier is the head of the State Council. The President is the ceremonial head of state with little power unless the individual holding the title also holds another title such as the Secretary-General (Chinese-Leaders, 2018; Amebar, 2017). The State Council's purpose is to ensure laws passed through the NPC are appropriately executed and to supervise the PRC's vast bureaucracies (McGovern & Rubio, 2018).

The Military branch contains the 11-member Central Military Commission (CMC) which directs the People's liberation Army, People Armed Forces, and China's Militia (Figure 1). The PLA includes both active forces of the standing Army, Navy, and Air Force, and the reserve forces. The People's Armed Forces is responsible for maintaining the PRC's internal security and social order. The militia provides combat service and operational support for the PLA and helps the People's Armed Forces manage social order. The CMC and its 15 functional sections are managed by the NPCSC which is considered the militaries policymaking body. Its chairman or commander-in-chief is elected by the NPC. However, as is the case in most branches of the PRC, the PLA and its 2.5 million strong Armed Forces are ultimately controlled by the CPC's Central Committee (Amebar, 2017; Pike, 2017).

China's S&T policy creation has been a complex evolutionary process involving every major branch of the PRC and numerous subordinate organizational structures. Realizing that the old Soviet S&T R&D model under Mao Zedong needed reform if China was to ever open their secluded nation to learn advanced S&T from other countries and become internationally competitive (Xiaoping, 1978). To meet these objectives, the new paramount leader of the PRC Deng Xiaoping, set out in 1978 to institute a period of "reform and openness" and create a S&T renaissance in China. Deng Xiaoping's reforms began with the "Four Modernizations" which focused on agriculture, industry, science, and defense. Science and defense were to have an especially important relationship. Deng's vision was to utilize foreign technological achievements and R&D processes to modernize the PLA and better protect China's national security and political stability (JI, 2015). To solidify the drive for S&T reform both the Party's Central Committee and the State Council initiated major policy and structural changes to accelerate the restructuring process. New S&T strategic objectives were also established to improve the old bureaucratic systems operational function and capacity and to create a more efficient organizational structure and system of management (Dolla, 2015a).

China's S&T Organizational Structure

The two major organizations responsible for policy making were the Science and Technology Leading Group (STLG) and the State Science and Technology Commission (SSTC) later renamed to the Ministries of the People's Republic of China (MOST) (see Figure 4 page 119). The STLG became an instrument of the Party but remained under control of the State Council and was headed by the Premier (Dolla, 2015a). It was created to be the highest body in charge of China's S&T strategies, plans, and policies, and to bring economic and S&T development closer together and under the control of the Premier. This way the S&T policy creation process could be established and controlled at the highest levels of government (Simon, 1983). The STLG principal functions include the creation and management of China's S&T organizational structure and infrastructure, providing leadership and authority for long-term S&T planning and goals, acting as a decision-making body for the most relevant S&T policies, coordinating R&D activities between the various ministries and regional provinces, and assessing foreign technologies for their assimilation possibilities within China's S&T ecosystem (Xiaobin,1984).

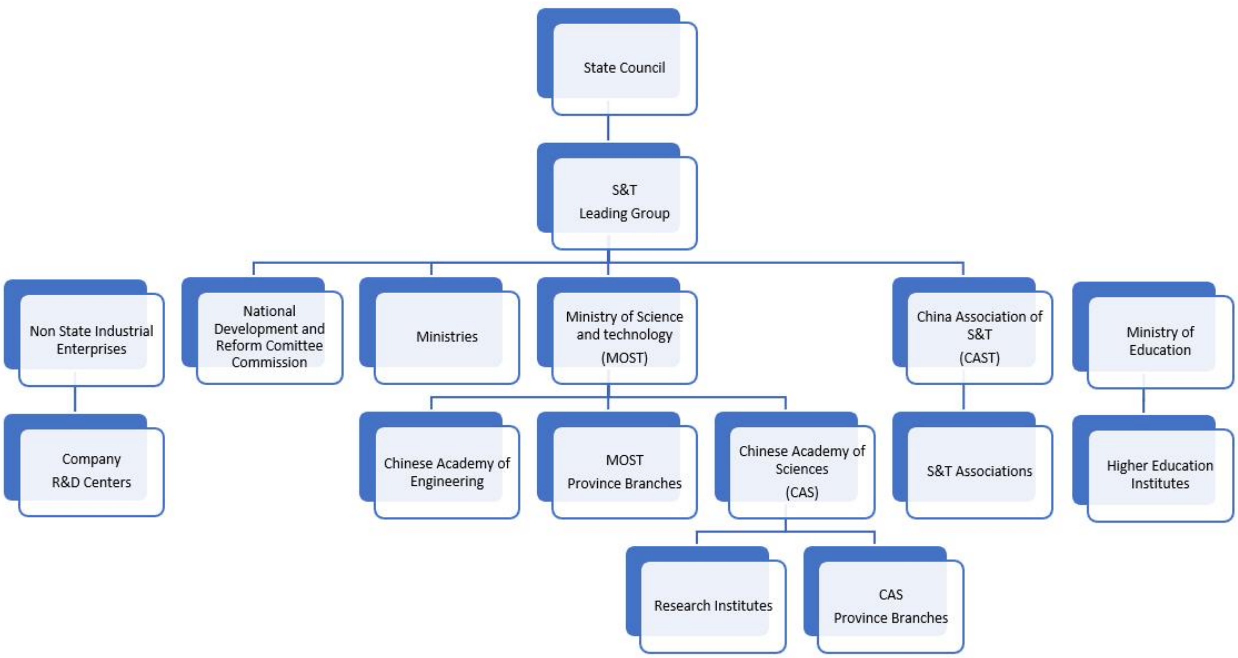

Figure 4 - Organizational Chart of the Science & Technology System in China

**Source: Science and Technology in Contemporary China: Part Three – Science & Technology Policy and Progress in Contemporary China*

The MOST is responsible for creating specific S&T policies, fashioning national S&T plans, coordinating S&T departments, identifying S&T R&D and project/program priorities, and the day to day management of those projects/programs and their R&D funding requirements (Xiaobin, 1984). The MOST was set up to be the equal of major agencies like the State's Planning

Commission (SPC), State Economic Commission (SEC), State Education Commission (SEDC), etc.in order to have the authority to coordinate S&T policy developments and actions under those agencies purview (Dolla, 2015a). The MOST is considered the functional body of the State Council and can operate, monitor activities, and implement policies throughout all the various levels of the administration and within the vast network under the State Council while also being closely associated with and answerable to the CPC (Xiaobin, 1984).

The MOST's policy formation generally occurs at the national level and involves seeking out recommendations from an extensive segment of the scientific community. This is done by organizing scientists into expert groups, obtaining recommendations from these groups or other S&T professionals, conducting meetings with these individuals/groups, preparing policy drafts, advising respective personnel within S&T R&D departments and major corresponding agencies (SPC, SEC, SEDC, etc.), and submitting policy recommendations to the State Council for final approval (Conroy, 1992). Even though the majority of MOST activities are conducted at the national level it can also engage in S&T policy development at the provincial and local government level through the Science and Technology Committee (STC). Most of the overall S&T policymaking and supervision legwork is conducted by the STC at these levels. This STC like the MOST is also directly associated with and monitored by the CPC (Dolla, 2015a).

The overall organizational structure for China's S&T R&D is wide-ranging and interconnected. It is composed of state-owned (collective) and non-state owned (private sector) organizations (Figure 2). State-owned organizations are well established and exist at the national level mostly in large cities and in the provinces. They consist of the Chinese Academy of Sciences (CAS), Production Ministries and their research institutes, large to medium size enterprises (LMEs), and higher education institutes (Dolla, 2015a). The CAS and the specialized research institutes residing with the Production Ministries are China's primary state-owned research institutions. The CAS is China's largest Academy and is responsible for conducting basic and applied research in the natural sciences. The chief purpose of CAS is to accumulate research conducted at the universities and state-owned research institutes and disseminate the findings to state owned enterprises. These enterprises repurpose the discoveries for new product/service generation and possible export, which in turn contributes to China's long-term economic development. The Academy also helps formulate basic research policy and provides scientific training and educational resources to research institutes, their research teams or individual researchers. CAS often provides a S&T consulting and advisory roles upon request for the MOST, SEC, and SPC (Suttmeier, 1980).

The Production Ministries are state-controlled production units managed by approximately 30 different government ministries. Each ministry creates specialized research institutes and R&D programs according to specific needs. The primary emphasis is on applied research focused on prototype generation and improving plant / facility operations, modifying technologies for different uses (dual use), and streamlining processes (Conroy, 1992). In total, there are well over 2000 of these research institutes with the majority occurring at the local (county) level. In addition to the research institutes there are also specialized Academies assigned to each of the 30 different government ministries, for example, the Chinese Academy of Geology (CAG) would be associated with the Ministry of Geology and provide additional research assistance and support to production units (research institutes) also affiliated with the Ministry of Geology. These research institutes and their corresponding academies received greatest allocations of PRC funding (Suttmeier, 1980; Conroy, 1992).

The vast majority of China's large to medium size enterprises are state owned Enterprise's (SOEs) and represent an integral part of China's economic development. China's SOEs are predominantly owned by the PRC and occasionally partially owned under certain circumstances. SOEs are generally created for specific industry purposes. China's LME SOEs do not have to follow market principles as their non-state owned (private sector) counterparts nor do they perform as well, being generally overleveraged and organizationally less efficient (Lo, 1997; Guluzade, 2019). Most LME SOEs have specialized research institutes dedicated to advancing research within their industry and product lines. China's senior leadership is devoted to growing their LME's and making them more efficient especially in the aerospace defense, energy production, IT, and transportation sectors where they believe direct state control is vital to China's long-term interests (Guluzade, 2019).

Higher education institutions (HEIs) are the last category of state-owned organizations and is made up of major universities, affiliated research institutions, and smaller technical colleges. HEIs fall into three categories: comprehensive HEIs with a large range of program availability (similar to Western liberal arts universities), technical HEIs which are dedicated to engineering, and specialized HEIs with concentrations in specific technologies and engineering programs. An equally important role for HEI's is the education of the next generation of scientists and engineers. Most HEI's have S&T oriented research institutions directly linked to them and have strong associations with provincial STC's and education bureaus (Suttmeier, 1980).

The second part of China's S&T R&D organizational structure consists of the rapidly growing non-state owned or private sector research institutes (Figure 2). China's non state-owned research institutions are adept at development (or experimental) research, which turns

S&T R&D into viable commercial products/services. This has been a significant structural problem in China's STI ecosystem for decades (Conroy, 1992). Funding for these private sector research institutes comes from their research lines and product development. As a result, they are generally better funded and have more state-of-the-art research equipment than state owned institutions (Convoy, 1992; Deyong & Cinnan, 1992). They do receive some local government administrative support which makes them subject to local or provincial government monitoring and in some circumstances direct control should a product under development be deemed a requirement of the state (GCSTP, 1985). Private sector institutes also provide higher wages which is attracting more scientists and engineers away from state-owned institutions and universities. The growth and success of private sector research have placed considerable pressure on the CAS, state-owned universities, and enterprises to remain competitive and adapt to changing market conditions (Dolla, 2015b).

Other organizations contribute to S&T R&D and innovation. One of the most prominent of these organizations is China's Association of Science and Technology (CAST) (Figure 2). It operates as an encompassing organization of academic societies across multiple levels of China's S&T ecosystem and as a trade union for the growing numbers of scientific and engineering professionals (Yaobang, 1980). These societies form professional networks between state and provincial governments, major universities, and non-state-owned research institutes to enhance China's S&T research and product development (GCSTP, 1985). CAST's primary duties include exchanging academic and research information between the various institutions, publish academic journals, articles, and books, provide consulting advice to non-state-owned enterprises, guarding the legal rights of S&T institutions, and providing favorable S&T research and industry knowledge to the Chinese populace (Dolla, 2015b).

The Institute of Science and Technical Information of China (ISTIC) is another organization that plays an important role in S&T development by acting as a comprehensive information hub. It operates directly under the MOST by collecting, storing, and servicing S&T literature, building databases for R&D programs, conducting analysis and its own supporting research, building and maintaining network infrastructure, and providing training and media services for S&T researchers and managers (ISTIC, 2013). One final organization that deserves mention is China's Center for Techno-Economic Research (CTER) which is responsible for analyzing the feasibility of new policies and programs that require large capital and technical outlays. The CTER draws upon the expertise of social and natural scientists, engineers, and business to assess the viability of large-scale S&T development projects and their economic benefits (Dolla, 2015b).

China's S&T Policymaking Process

China's S&T policy making process is much like the US, a convoluted hierarchical system involving numerous branches of government, ministries, and local / provincial institutions (Springnut, Schlaikjer & Chen, 2011). The ultimate authority in macro policymaking resides in the CPC, with the greatest level of authority residing in the PSC and its top three positions, the president / Secretary-General (Xi Jinping), the Premier (Li Keqiang), and the chairman of the NPC (Li Zangshu). Through the Premier, the PSC can control China's government bureaucracies. CPC members beholden to the PSC also hold the most important state, provincial, and local decision-making positions. The PSC has traditionally proposed most of China's long-term strategies, and plans. With of the rising importance of S&T policy it is the PSC or its proxy who set the course for important S&T strategies and policies and who make the final approvals or changes in strategy/policy initiatives proposed by the bureaucracies (Anderson, 2013).

With Xi Jinping's successful attempt at consolidating power, many of the broader policy concepts including S&T initiatives are now channeled through a proxy commission like the Central Comprehensive Deepening Reforms Commission. These commissions' members are handpicked by the Politburo and under its direct control. This all but guarantees that no "career ending" challenges by a lower-level bureaucrat / technocrat will occur (Shih, 2016).

China's S&T policies are part of and supported by a strategic broad-based national plan. This 15-year "Medium to Long Term Plan" (MLP) is designed to serve China's social, economic, and political goals. It also sets the course for China's S&T policy agenda. While this broader strategic plan is considered invaluable and draws from prior policy initiatives and successes from the past 25 years, in the rapidly evolving fields like S&T many of its recommendations became outdated requiring modifications or entirely new strategic initiatives (Cao, Suttmeier & Simon, 2006). To address these concerns China also creates National Five-Year Plans (FYP). The most recent 13th Five Year Plan was largely focused on STI and the issues-based subsection titled National Five-Year Plan for Science and Technology will provide a great example on how of China's policy making occurs (Trivium, 2018).

The process begins with the National Development and Reform Commission (NDRC) which is responsible for taking senior leadership recommendations (or directives) as well as the recommendations of technocrats and professional from ministerial government bodies, provincial governments, research institutes, universities, SOEs, and private sector MNCs and creates the national FYP draft which is presented the State Council and the Premier for assessment (USCBC, 2018). Once it the National FYP is deemed viable, the detailed goals are set, and it is approved, the national FYP will be broken down into issue-based goals. One of these is the FYP for S&T. This new plan is then sent to the various S&T ministries/agencies (i.e. MOST, CAST, CAS, etc.) and their associated ministries/agencies (i.e. SPS, SEC, SEDC, etc.) for further input and approval. Once these new S&T targeted goals are approved, the next step is the creation of S&T implementation notices and measures which are more narrowly focused action plans that will be carried out by the respective state and provincial agencies responsible for implementation. There may be additional steps if S&T sub-issue-based goals are needed (usually the case), in this case, a S&T sub-issues based FYP with additional specific goals would be generated, and another round of the process would occur (Trivium, 2018).

The process is not as simple as previously outlined. Policies and sub-issues often conflict with one another and funding requirements can become convoluted as different ministries and provincial governments occasionally have incompatible mandates. There are also internal political conflicts between the ministries / agencies and political officials or prominent local bureaucrats / technocrats which could have differing agendas and/or objectives (Trivium, 2018).

For individual S&T policies the process is similar. Once the FYP for S&T or a new strategic directive aimed at a specific emerging S&T is established by the State Council and meets the approval of the PSC the new policy making process begins. STI policy ideas or requests are proposed to the State Council from a variety of sources (Politburo, State Council, ministries, etc.) (Anderson, 2018). These new proposals go to the State Steering Committee on Science and Technology and Education which operates directly under the State Council for assessment as to their value and compliance with existing national priorities. The State Steering Committee is the highest body in S&T legislative policymaking and also assists the Premier in the final approving and managing new S&T policies (Xinghua, 2009).

If the new policy proposal is deemed viable, the State Steering Committee will either assign it directly to a corresponding ministry, assign it to leading Small Group (LSG) which acts as a coordinator between multiple ministries, or if it is deemed urgent and/or critically important handle it in-house. These ministries acting alone or coordinated will seek out advice and recommendations from among relevant research institutes, universities, SOEs, academies, etc**.** Once enough pertinent data is collected the ministry / ministries will draft a new policy and send it over to the State Council's Legislative Affairs Office (SCLAO) for an evaluation of its quality and legality (Ahrens, 2013:4; Anderson, 2018). If the policy is considered satisfactory it is sent to the State Council or the NPC (if it is in session) for a vote and final approval. If the policy is considered incomplete or doesn't meet quality and/or legal requirements it goes back to the original ministry / ministries for another round of re-drafting. Once the policy is finally approved, it goes back to the ministry, ministries, or State Steering Committee for implementation and funding. S&T policies are always subject to input from the PSC at any stage (Anderson, 2018).

Among the 10 ministries involved in S&T policymaking, the most influential ministry is the MOST. MOST responsibilities include drafting policy recommendations, funding and managing the national R&D programs, supervising state owned research institutions and their incubators, and assisting small and medium size enterprises (SMEs) and entrepreneurs/start-up companies to develop and/or upgrade key technologies. R&D funding and policy support for key technologies has become MOST's most significant role over the past few years (Ministry of Commerce, 2009).

There are many other important policymaking/funding ministries/agencies that influence China's S&T, some of the more prevalent include: CAS which oversees the state-owned research institutes, the Chinese Academy of Engineering (CAE) which coordinates industrial and academic engineers and helps sponsor large-scale international engineering projects, and the Ministry of Education which makes policy recommendations for research universities and professional development programs (Campbell, 2013).

Historical Overview of STI Policies – Step Three

US S&T Historical Overview

Cold War Era

Prior to the collapse of the Soviet Union and the emergence of the post-Cold War era, the US had already attained global scientific and technological superiority. This technological advantage had not only helped propel the US to become the world's strongest economy and military force, but also left US high-tech defense companies virtually unchallenged competitively (Branscomb & Florida, 1998). The foundations for this technological hegemony were established a few short years after World War II when Vannebar Bush, the then Director of the Office of Science and Research Development (OSRD), published his momentous report titled *Science: The Endless Frontier*. Bush had asserted that scientific and engineering-based R&D efforts were essential to the Allies wartime success and would remain a requirement for future US security and economic prosperity. He argued that federally funded research should be conducted primarily at major US universities to take advantage of cutting-edge research that was already occurring and where future generations of scientists and engineers would be educated. This report was instrumental in establishing large US academic research universities and combining formal education with national security research needs. The report also contributed to the creation of the NSF in 1950. The NSF's principal role was to bolster university research and education programs (Lane, 2008).

In the decade following the establishment of the NSF the US Congress would create or re-structure several more research-based agencies. These agencies included the Atomic Energy Commission (AEC), later renamed the Department of Energy (DOE), the National Institutes of Health (NIH), National Aeronautics and Space Agency (NASA), and four military specific agencies: The Office of Naval Research (ONR), Air Force office of Scientific Research, Army Research Office, and the Defense Advanced Research Projects Agency (DARPA) (de la Mothe and Dufour, 1995). Major universities and government agencies were not the only US institutions to receive federal support. The government also developed, operated, and funded the US National Laboratories i.e. Lawrence Livermore, Sandia, Los Alamos, etc., Intramural Research Laboratories located at the NIH and NASA, Federal Funded R&D Centers (FFRDC), The Jet Propulsion Laboratory (JPL), Fermi National Accelerator laboratory (Fermilab), The National Center for Atmospheric Research (NCAR), and a large number of smaller DOE weapons and multipurpose research centers. These government agencies, national laboratories, and research centers would complement the research universities by providing large basic and applied research facilities manned with an exceptional cadre of scientists and engineers dedicated to maintaining US technology dominance and national security interests (Lane, 2008).

The US government's S&T R&D investment programs focused on basic research and meeting the needs of a multitude of government mission specific objectives. Allocations were primarily directed at defense and space–based programs and were in response to the threats associated with the US vs Soviet Union Cold War and space race. Funding was also allocated towards health, energy, agriculture, and several other fields that required basic research (Mitchell, 1997). With all the increases in federal funding available, and the support of new government agencies, the Cold War era provided dramatic increases in technological innovation and scientific discoveries. The greatest concentrations of government support were in the field of physics and electronics leading to significant advancements in laser, transistor, and integrated circuit technologies. These technologies, would in time, revolutionize telecommunications and enabled the modern globalization of commerce (Lubell, 2019).

Private industry would also make large financial contributions towards R&D investments creating their own large-scale research laboratories, like the highly successful Bell Laboratories. MNCs also developed dedicated corporate research divisions focused on both basic and applied research programs, such as the ones at General Electric, IBM, Westinghouse, Hewlett-Packard, and Texas Instruments (Lane, 2008). The Cold War era became a particularly profitable time period for private sector companies working in the military-industrial-defense complex; especially those companies developing technologies for government mission priorities that could in time "spin off" into the private sector for commercialization, otherwise known as dual use technologies (Mitchell, 1997).

Despite the rapid technological advances generated by public and private sector collaborations during the Cold War, policy makers were beginning to realize that international competitive pressures were eroding US technological superiority and high-tech trade balances. This increasing commercial threat from other technologically advanced developed nations, in Europe and East Asia, forced Cold War era policy makers to reevaluate their long-held technology policies and strategies. The problem was twofold. First, policies had become overly concentrated on mission-based advanced technologies with funding priorities concentrated in the DOD and other federal agencies with defense-related ties. Second, government-based research support was directed almost solely at basic sciences (physics, chemistry, and mathematics) (Branscomb & Florida, 1998).

To counter the threat of rising international high-tech competition, the US Congress enacted the National Science and Technology, Organization, and Priorities Act of 1976. This Act ensured federal advisory and coordination for future administrations, provided a convincing rationale for S&T development, and required that technology policy would become a permanent fixture in the White House. The Act also outlines the connections and interrelations that STI has on US society and its impact on national security and economic growth. From this Act emerged the three executive branch agencies responsible for executing legislative actions (Lubell, 2019).

Of these three new executive branch agencies, the Office of Science and technology (OSTP) is the most prominent. Its function was to advise the Executive Office of the President (EOP) which science, technology, and engineering research lines and programs were of greatest benefit to US economic and national security interests. The office would also provide the EOP with scientific and technical analysis of major policies / programs currently in place. It would also provide an annual review to the Office of Management and Budget (OMB) of government sponsored R&D budgeting requirements. (OSTP, 2019c).

The second office was the President's Committee on Science and Technology referred to as the "committee". This committee consists of the Director of the OSTP and eight to fourteen distinguished and qualified individuals from various fields in science, technology, engineering, IT, and public policy that were appointed by the President. The purpose of the "committee" was to examine and analyze all pertinent missions, goals, funding requests, facility and personnel needs, and requirements associated with government sponsored S&T and engineering objectives. Another "committee" purpose was to ascertain and account for the interests of all individuals and groups that would be affected by the introduction of a new government-sponsored R&D program or the roll out of a new technology (Govregs, 2016).

The final office was the Federal Coordinating Council for Science, Engineering and Technology (FCCSET). The FCCSET was responsible for analyzing ongoing problems and new developments affecting Federal agencies in the S&T and engineering fields. It also provided additional layers of planning and administrative support for programs to help better identify research needs, allocate resources, provide for infrastructure (facilities), and foster international cooperation (Lubell, 2019).

The US Congress enacted additional Acts during this period to further offset the threat of foreign high-tech competition. These Acts were focused on accelerating R&D and technology development into the private sector. The Stevenson–Wydler Act of 1980 sought to strengthen collaborations between research universities and industry. The Bayh-Dole Act, also in 1980, allowed government agencies to provide exclusivity licenses for inventions made with government funding, The National Cooperative Research Act of 1984 lowered the risk of antitrust suits for firms engaging in collaborative government R&D programs (EPA, 2018). The Technology Transfer Act of 1986 established incentive structures for both government agencies and national laboratories to engage in cooperative R&D agreements with private sector companies. The Act was set in place to transfer government owned and/or originated technology patents to commercial companies for further development (Branscomb & Florida, 1998).

Just prior to the fall of the Berlin Wall and during the post-cold war era, different administrations played critical roles in the mechanisms that determined the direction of US S&T policy. There is no clearer indicator of how technology policy will be enacted and supported than by a President and senior cabinet members (administration). If STI is valued by a White House Administration, it becomes a principle foundation for long-term economic growth and national security. In this vein, S&T policies' importance becomes elevated to be on par with other critical federal policies & activities. Such an administration quickly assigns and authorizes the Director of the OSTP (Science Advisor), council members to PCAST, and other key policy advisors to significant positions of authority. This level of administration support was inconsistent in the post-Cold War era but did occur to varying degrees in the latter part of the George H.W. Bush presidency, Bill Clinton's second term, and throughout much of Barack Obama's first and second terms (Lubell, 2019). However, an administration's support alone was not always enough to ensure long-term stable policy creation. Bipartisan commitment and strategies are required to overcome domestic pressures and partisan resistance (Branscomb & Florida, 1998).

Ronald Reagan, January 20, 1981 - January 20, 1989

In 1988, the final year of the Reagan presidency, with democrats in control of Congress, the Omnibus Trade and Competitiveness Act of 1988 was passed. This Act restructured the way federal agencies accounted for technology development and technologies role in economic performance. It also established regional centers to assist small and medium-size companies to utilize technology developed by government agencies (Branscomb & Florida, 1998).

In addition to the Acts passed by Congress, new federal agency goals and missions were either developed or restructured in 1988. The Commerce Department was expanded to include the National Institute for Standards and Technology (NIST) and Technology Administration (TA) with a newly assigned undersecretary position created to direct them. The purpose of this restructuring was to provide the executive office greater control over STI objectives (Branscomb & Florida, 1998). During this same period, the NSF increased its investments in science and engineering research at major universities. Two new centers were also created at the NSF, these included the Engineering Research Centers and Science and Technology Centers, these Science and Technology Centers (STCs) promoted joint partnerships between research universities and technology focused companies. Their purpose was to support complex and potential transformative research projects with long term funding across multiple disciplines (NSF, 2018b).

With events leading to the fall of the Berlin Wall (June 1989) and the fading threat of Cold War conflict, the need for a heavy concentration on defense related military R&D was diminishing. International competitive pressures focused on technology development were accelerating faster than expected and the US was experiencing its first negative high-tech trade imbalances (Flynn, 2019). Foreign competitors were not simply investing in more R&D initiatives but also on downstream supply chain functions to improve manufacturing efficiency, quality control and to increase the pace of product cycles. This rise in commercial high-tech competition represented a clear threat to the US's global technological and economic hegemony. If the US wanted to maintain its economic dominance and military superiority, it would have to shift its strategic R&D pursuits and technology policy away from predominately DOD and federal agency mission objectives to include a greater emphasis on commercial R&D and technology related product/service development (Branscomb & Florida, 1998).

George H. W. Bush, January 20, 1989 - January 20, 1993

At the onset of the George H.W. Bush administration, US S&T policies were still heavily vested and highly proficient in defense research programs but lacked a clear strategic plan of how to penetrate the emerging commercial sectors, especially the rapidly growing computer hardware, IT and software development fields (The White House, 2001). The Bush presidency realized early that remaining focused solely on defense related R&D allowed international competitive pressures to deteriorate US technological hegemony. New S&T policy was required to offset this threat. Policies geared to the expansion of the government – industrial – academic programs, from the cold war era, into the rapidly growing commercial technology sectors. To invigorate private sector innovation the administration needed to maintain the traditional defense-oriented collaborations while also establishing new long-term alliances between private sector industries and government funded national laboratories and research universities. These long-term agreements were necessary to counterbalance the short-term investment tendencies of most businesses and their suppliers. In addition, this required fostering of long-term commercial sector commitments to basic research in STI, which the private sector generally shies away from in favor of more applied R&D (Branscomb & Florida, 1998).

To address these new concerns the Critical Technologies Institute (CTI) was established as a Federally Funded Research and Development Center (FFRDC). Its purpose was to analyze and evaluate critical and emerging technologies and report the findings to the OSTP. The OSTP, using these findings, implemented major changes to critical technologies research that favored commercial sector expansion and provided additional funding and support for it. Within a few short years, a balance was struck between military and civilian R&D expenditures that resulted in considerable growth in government-sponsored private sector R&D programs and US technology competitiveness (Branscomb & Florida, 1998; Pitcher, 1996).

To further meet the challenges of emerging international commercial sector competitiveness, what I ~~am~~ refer~~ring~~ to as a changing "geopolitical environment", the Bush administration released a new technology policy declaration: a government cost-sharing investment program, with private sector companies, to generate "precompetitive generic technology". This led to the creation of the Advanced Technology Program (ATP) within the Department of Commerce. These were technology lines that ~~would~~ could be useful to multiple users and platforms but were not yet ready for commercialization and would therefore not

~~otherwise~~ receive federal funding (Branscomb & Florida, 1998). These investment structures were meant to be applied directly to commercial businesses to develop “precompetitive generic” technologies, a form of government sponsored basic research directed at increasing private sector research and innovation (Helm, 1995).

Technology policy creation and maintenance was not limited to Congressional Acts or newly created or re-designed federal agencies and offices. The strategic and political objectives of administrations were also heavily influenced by the Executive Office’s chief policy advisors and their influence on the committees and boards they directed (Sargent & Shae, 2017). One of the most prominent of these chief policy advisors was the Director of the OSTP, also referred to as the President’s Science Advisor. Upon taking office, President Bush realized that a new direction regarding technology policy was necessary and appointed D. Allan Bromley as Director of the OSTP. The expressed intent and authorization of his position was to raise the importance of S&T policy within the administration. Bromley renamed the PCST to the President’s Council of Advisors on Science and Technology (PCAST) and restructured it so that the Council reported directly to the President instead of to the OSTP. Bromley was also tasked to reinvigorate the FCCSET and both Councils were permanently established in the White House. The FCCSET would later be renamed the National Science and Technology Council (NSTC). Under Bromley’s leadership, and despite fiscal constraints on federal discretionary budgets, groundwork was established which integrated S&T initiatives throughout the highest levels of the federal government and enabled the OSTP to grow into a major coordinating policy hub by the end of Bush’s presidency (Lubell, 2019).

Bill Clinton, January 20, 1993 - January 20, 2001

In January of 1993, William J Clinton took office and immediately set out to make S&T policy a primary emphasis of his administration's strategic objectives. Civilian research funding was increased by more than 43% and expanded to include programs engaged in national health and environmental concerns. The research and experimentation tax credits were extended to account for multiyear projects (The White House, 2001). The administration also created or re-structured a variety of technology-based programs designed to strengthen long term private sector investments to accelerate US economic growth. These programs included streamlining the Commerce Department's ATP to increase the pace of private sector, new technology development. The Manufacturing Extension Program (MEP) was created to give States the right to provide financial support to small/medium sized high-tech businesses so they could retool their manufacturing processes and implement new industry best practices. The EPA established the Environmental Technology Initiative (ETI) to encourage the redesign of manufacturing facilities for greater efficiency and less pollution. It also expanded the scope of the FCCSET, renaming it to the National Science and Technology Council (NSTC) (Branscomb and Florida, 1998). Even the DOD experienced significant restructuring with only minor reductions to defense-related spending. The DOD's Technology Reinvestment Project (TRP) was formed to shift defense spending away from traditional military R&D into dual use technologies and to increase the numbers and pace of commercialization conversion programs (Branscomb & Florida, 1998).

Within just a few years, the Clinton administration had successfully increased military to civilian R&D spending to a near 50:50 ratio. This was accomplished despite considerable neglect and underfunding that had occurred in many of the programs and the mounting political resistance from both Republicans and Democrats with close ties to the military-industrial complex. The rapid pace, scope, and success of these initiatives marked a dramatic shift in policy priorities over the programs from the Cold War era (Branscomb & Florida, 1998).

However, while President Clinton expanded upon S&T policy changes inherited from the Bush administration, he himself did not take on an active or engaged role in policymaking or even attend any PCAST meetings. He also assigned Vice President Al Gore as his S&T policy coordinator. Gore focused almost exclusively on applied technology development and climate change, neglecting many other lines of basic research. This caused consternation among many prominent scientists, and many scientists became advocates demanding a return to basic research for the potential long-term benefits (Lubell, 2019).

Midway through President Clinton's first term (January 1995), the Republican Party gained the majority of the congressional seats and took over both houses of Congress. Fiscal Conservatives immediately rejected the idea of "corporate welfare programs" and perceived large-scale civilian R&D spending as a threat to their proposed tax cuts and budget balancing objectives (Branscomb & Florida, 1998). I refer to this as influencing "domestic conditions". Intense debates and political wrangling were already commonplace in both the last years of the Bush administration and throughout Clinton administration's first term. With Republicans in control of Congress, conservatives wanted nothing more to do with federal spending excesses in the discretionary budget and put severe restrictions on additional funding programs like government-sponsored commercial investments and other similar large-scale civilian R&D programs. All future civilian R&D investment programs were either postponed or cut by 20 to 30%. This is a clear illustration of how different political perspectives can be instrumental in creating or putting the brakes on S&T policy initiatives (Helm, 1995; Branscomb & Florida, 1998).

It was not until 1997 and the start of the 105th Congress that bipartisan strategies for long-term solutions to international competitive pressures were demanded by moderates from both sides of the political spectrum. It was not until the 105th Congress (Jan 1997), and its receptiveness to building consensus and pursuing a bipartisan strategy, that enabled S&T policy ~~would~~ to be pursued in earnest again. Moderates from both parties argued strongly for nonpartisan consensus and were able to successfully rally Congress around the premise that US strength and prosperity is a product of its R&D and technological innovation. Its commercial S&T policy is what drives innovation which strengthens economic prosperity. (Branscomb & Florida, 1998). The Clinton administration shifted to offense and onboarded several new policy advisors to assist the OSTP Director Jack Gibbons and help further support congressional moderates sell the value of long-term commercial R&D to the House and Senate and to House Speaker Newt Gingrich (Lubell, 2019).

In addition, support for these assertions came from Edwin Mansfield's publication explaining how more than one tenth of new commercial products were dependent on academic research. Additional evidence was provided in Michael Boskin and Lawrence Lau's study, which concluded that technical progress was significantly more important than capital and labor in accelerating economic growth (Boskin & Lau. 1991). D. Allan Bromley also reemerged into the public light and called for President Clinton and Congress to renew their commitments to funding scientific and academic research. He argued for pegging government research support directly to the gross domestic product (GDP) and proposed a 10-year plan to restore federal funding to the level of GDP that had been attained during the Cold War era (Lubell, 2019).

Republicans, and some ultra-conservatives, already had a natural affiliation for private sector competition and with additional information understood the need for government support for commercial S&T R&D and innovation would not only ensure economic growth but increase business profits (AIP, 1996). As a result of this new bipartisan support, the 1998 Federal Research Investment Act was created. The Act's general findings claimed that federal investment in research produces significant benefits to both the public and private sector by increasing the number of new goods and services, providing new jobs, and raising capital. It also directly benefited the US by ensuring global competitiveness and increasing the American standard of living and quality of life. Funding for this landmark Act would have to wait until the following year where it would be tied into the 1999 HR 1625 Omnibus bill (Lubell, 2019).

The result was a shift in perspective among enough members of Congress to allow Senator Phil Gramm, a Texas Republican, to pass an authorization bill that would essentially double non-defense-related basic research spending over a 10-year period. This was a far cry from previous conservative demands for shrinking non-military R&D by 20 to 30% to meet their budget balancing objectives. The increase in private sector "precompetitive generic" research would turn out to be vital in countering the mounting international competitive pressures coming from Europe and East Asia. This was a prime example of how a small group of highly respected and influential members of Congress could form a bipartisan caucus and change congressional perceptions to the point where a new course for S&T policy would occur (Branscomb & Florida, 1998).

With a new assertion of the importance of commercial technology R&D, established between the Republicans and Democrats in both houses of Congress, President Clinton and Neal Lane, the new White House Science Advisor, the last few years of the Clinton presidency was dedicated to prioritizing dual use technologies. The administration would push a heavy emphasis on electronics, computer systems, IT, and biomedicine (Lubell, 2019). The Commerce

Department was tasked for organizing and managing joint funded R&D and project development programs between various government agencies and private sector companies. These programs combined government and private sector resources, shared risks, and reduced costs and funding requirements, while providing products that would meet the needs of both the government/military and commercial businesses (Ham & Mowery, 1995).

The Clinton administration strongly believed that technology development would not only strengthen the economy but improve Americans lives. To ensure that significant inroads would be made towards this objective, government funding for civilian R&D was increased by 43% without any substantial loss to defense research, and funding support for research universities was increased by 53%. The administration would also go on to invest over $10 billion in a variety of S&T programs during his two terms (The White House, 2001). By the end of President Clinton's second term, S&T policy and research funding priorities had shifted once again to account for the interdependence of scientific disciplines and include a greater emphasis on dual use technologies and their products and services. All these measures initiated by the Clinton administration did contribute to US economic growth and help the US retain its technological hegemony, but Europe and East Asia were quickly closing the gap (Lubell, 2019).

George W. Bush, January 20, 2001 - January 20, 2009

The George W Bush presidency began in 2001 under a widely accepted belief that S&T policy and R&D support was crucial for economic growth and ensuring US national security. This sentiment did spark initial interest in the Bush administration and a new PCAST was launched to provide policymakers direct access to the President. The Clinton administration's private sector R&D programs were also still supported and funded. However, this outlook would soon change with the destruction of the Twin Towers and the onset of the second Gulf War.

Neoconservatives (neocons) within the Bush administration, like Vice President Cheney, Andy Card, and John Bolton, shifted the country's S&T policy and budgetary allowances towards a wartime footing with a heavy emphasis on weapons development and computer / IT driven surveillance programs. The administration rarely got involved in any civilian R&D endeavors and the rapidly growing Silicon Valley firms, the Clinton administration had worked so hard to support, were largely ignored (McCullagh & Condon, 2009; Lubell, 2019). This lack of interest in civilian R&D, the growing neglect in basic research, and the administration's general distrust of the scientific community, was countered by prominent scientists who accused the administration of undermining science through censorship, alterations of data, and promoting unscientific claims. The scientific community was also growing frustrated with the increasing lack in leadership in many S&T agencies/offices and decreases in funding for many technology programs especially those in the private sector (Britt, 2008).

One of the biggest criticisms directed at the Bush administration was its apparent lack of technology expertise from the very beginning. The science community and prior policy advisors had grown concerned over a general lack of technology-oriented personnel within the administration, and those few that were present lacked any clout or substantial expertise to really influence decision-making. To aggravate the problem, the White House had begun to defer to Congress or other federal agencies staffed during the Clinton administration for routine technology policy matters rather than retaining authority within the Office of the President (McCullagh & Condon, 2009). President Bush had even considered outright abolishing the OSTP early in the administration, but Congress had warned it would overrule the decision. This disregard for the OSTP and properly staffing technology policy agencies/offices eventually created new problems in attracting proper talent from among the scientific community to fill important senior policymaker advisory positions. To make matters even worse, when President Bush finally selected Jack Marburger for OSTP Director, Marburger found that his office was no longer in the White House but had been moved several blocks away and his directorship no longer had a seat at the Cabinet table (Lubell, 2019).

Marburger grew to understand all too well the shortfalls of a predominantly wartime technology policy in the current modern age. He unsuccessfully attempted to convince the administration that as a percentage of US GDP government funded R&D, which peaked at 1.86% in 1963, was rapidly declining. By the end of President Bush's first term, it had dropped to 0.74%. Marburger was persistent and by 2006 had convinced some of the neocons that growing international competition in technology from Europe and East Asia, and the emerging threat from China, represented a real challenge to US technological dominance. This trend represented a serious threat to the US' economic growth and national security which is strongly dependent on STI (Lubell, 2019). Due to international competitive pressure, the Bush administration created the American Competitive Initiative (ACI) (February 2006) which authorized additional budgetary allocations for S&T R&D and education programs in the commercial sector. The ACI reintroduced basic research and funding back into the physical sciences especially concerning dual use technologies. It also reestablished government support for private sector R&D investment. Finally, it provided the OSTP Director improved standing at both the White House and among the scientific community. (Britt, 2008; Lubell, 2019).

Congress supported the ACI but introduced its own S&T policy objectives as well. With the Democrats in control of both houses of Congress, representative Nancy Pelosi introduced the Democrats "Innovation Agenda: a Commitment to Competitiveness to Keep America Number One" which called for strengthening STEM education, enhancing nationwide broadband access, promoting clean energy and energy independence, doubling the budget for basic research, and providing more support for small business innovation (Lubell, 2019). The result the combined ACI and Innovation Agenda was an increase of billions of dollars over a 10-year period for basic R&D, education, and entrepreneurship support. However, the Bush administration's lack of strong focus caused initial funding delays and concentrated an overabundance of funding and resources into the biosciences (stem cell research, genomic sciences, etc.), NASA, and to a few other departments (Britt, 2008).

These two initiatives represented a shift away from the Bush administration's previous hands-off approach and would set the stage for the next piece of legislation which would establish a new course for technology policy (The White House, 2004; Lubell, 2019). The America Creating Opportunities to Meaningfully Promote Excellence in Technology, Education, and **S**cience or COMPETES Act: 1) required the President to create a Council on Innovation and Competitiveness to strengthen government, academic, and private sector research collaborations concerning US innovation and competitiveness, 2) directed the NSTC to identify research deficiencies in US national laboratories and associated research universities, make it a priority that these national laboratories and research universities be readily accessible to US researchers involved in authorized research projects, and 3) required the OSTP to work with the National Academy of Sciences to conduct an ongoing series of studies that mitigate financial risks associated with private sector innovation, and encourage more students to adopt careers in STEM (Lubell, 2019).

The George W. Bush administration did not aid or restrict private sector innovation-based companies and technology-dependent industries. The reduction in regulations, access to global markets and free trade, and corporate tax cuts created a thriving economy and productive environment for almost all commercial businesses. These benefits were more pronounced in the technology sectors which experienced rapid growth without supporting technology policies. However, it would also lead to exorbitant risk-taking in the financial sectors which culminated in the 2008 financial crisis and a global economic turn down, all of which would play a major factor in the next administration (McCullagh, 2009).

Barack Obama, January 20, 2009 - January 20, 2017

In 2009 the Barack Obama administration took over the US Presidency along with Democratic control of both the House and Senate. One of the first acts of the administration and Congress was to enact the American Recovery and Reinvestment Act (ARRA). The Act provided a large-scale, short-term stimulus in response to the 2008 global credit crisis. The goal of the AARA was not simply to provide short-term financial relief to banks and large MNCs but to stimulate long-term job growth and business opportunities through innovation endeavors (Shapira & Youtie, 2010). Of the $787 billion allocated towards the ARRA roughly 13% (101.9 billion) was dedicated towards R&D and technology development. The breakdown was as follows: 45.1 billion for renewable energy, 19.6 billion for healthcare IT, 11 billion for smart energy grids, 7.2 billion broadband Internet expansion, and 19 billion for commercial sector R&D investment in basic and applied research (Shapira & Youtie, 2010).

The administration then set out to reestablish Clinton era policy objectives by creating its Strategy for American Innovation otherwise known as the Obama Innovation Plan. The Obama Innovation Plan stressed the importance of integrating high technology into traditional industrial sectors to achieve high levels of productivity growth for the nation, higher wages for workers, and a higher standard of living for US citizens. The initial strategy focused on developing high-technology manufacturing but had little concern for lower skilled manufacturing jobs that had already been lost in the US. The plan emphasized the new emerging industries as having the greatest potential for new job creation and economic growth (Cozzens, 2011).

The Obama administration immediately set out to reaffirm the OSTP and re-charter PCAST as its principal technology advisory boards. It also sought out knowledgeable representatives from the private sector and academic research institutions to advise on research priorities, STEM education, and new technology development. The administration believed that technology policy was an inter-agency effort made up of the combined policy advisory roles from the major federal agencies: NSF, DARPA, NASA, NIH, FCC, EPA, NSA, etc. (Flynn, 2019).

Two of the most promising fields the administration was interested in were nanotechnology and IT/networking, the latter of which would turn out to redefine how technology would be integrated throughout the public and private sectors. Support for rapidly growing IT/networking technologies came from the reinvigorated High-Performance Computing Act originally enacted in 1991, and the Next Generation Internet Research Act of 1998. These Acts provided large inter-agency standards and programs that would become the guideposts for all future government interactions in the country’s computer, networking and IT fields (NITRD, 2013).

Even with the resurgence of importance in technology policy in the latter part of the Bush administration (ACI and COMPETES Act), the new Obama Innovation Plan, and Democrats in control of both the House and Senate, the US STI was still in trouble. The ongoing issues plaguing the Obama administration included: large commercial sector projects that had been neglected for years, receiving little government support and funding; S&T policy making was hindered by major partisan ideological disagreements; ARRA funding for non-defense R&D or for the renewable energy investment programs was only $20 billion spread over a three-year timeline; and Republicans who were already unhappy with the ARRA and the unpopular Wall Street bailout consistently resisted any serious attempts to increase long term private sector R&D funding initiatives (Lubell, 2019). To compound the issues, the Obama administration was mired in the 2008 credit crisis and the economic downturn, and its attempts to mitigate climate change by regulating carbon dioxide through the American Clean Energy and Security Act 2009, also known as the Waxman – Markley Bill. This bill would eventually be defeated due to the nationwide unpopularity of creating a carbon cap and trade system in the US and the outright rejection of the Republican Party for the program (Sheppard, 2010). John Holdren who was a staunch supporter of climate change reduction and President Obama's pick for Director of the OSTP became a sharp critic of Republican dissent for the Waxman – Markley Bill and this made further compromises with Republicans difficult. This contention with Republicans would carry on throughout both of Obama's administrations (Neefus, 2011).

With the Republicans in control of the House in 2011 and the encompassing fight the administration was engaged in to deliver the Affordable Care Act or Obama Care to the public, there was little energy left to push S&T policy beyond what already had been established with the ARRA (Lubell, 2019). The Budget Control Act of 2011 tightened the fiscal budget and the Republican congressional hawks' push for budget sequestration in 2013 kept federal R&D allocations flat at around $150 billion for much of President Obama's second term. Funding matters would be made worse by the loss of both the House and Senate in 2014, and the administration was forced to rely on regulatory authority and executive orders to achieve any additional fiscal policy objectives (Thomas, 2017).

What the Obama administration was not able to do through direct funding measures it was able to accomplish through other means. There was considerable success with its Innovation Plan and the framework it developed for directing strategic investments into growth sectors such as clean energy, IT/networking, and healthcare while at the same time increasing the number of targeted interagency R&D programs. It also sought to strengthen the nation's innovation ecosystem by building up P3 collaborations that had diminishing support under the previous Bush administration. President Obama also made the R&D tax credit a permanent fixture to incentivize private sector investment into commercial R&D (Thomas, 2017). Despite Republican resistance, President Obama's Innovation Plan, during his two terms in office, was able to re–invigorate the Clinton era expansionists strategy by incentivizing the private sector. Incentives were provided for: R&D and technology investment; developing human capital through STEM programs; funding new energy programs and infrastructure; and sponsoring large-scale national goals programs. These investments contributed to long-term economic growth and reinstated confidence in the scientific community (Kalil, 2019).

Donald Trump, January 20, 2017 - January 20, 2021

Where the Obama administration focused on reestablishing S&T policy, the Donald J Trump administration mirrored the George W Bush administration and appeared less than enthusiastic on matters of commercial innovation choosing instead to allocate most of the R&D spending on weapons development (Thompson, 2019). Intent on being a disruptor, President Trump eradicated many of the regulatory policies and executive orders established by the Obama administration, and commercial sector STI was not immune to these changes. Recognized for pursuing a nationalistic policy that appealed to his voting base, he drew the ire of much of the scientific community who felt threatened by the potential removal of interactions amongst the global scientific community. In the 2017 tax package, Trump proposed cutting government-based research funding up to 30% and attempted to eliminate commercial sector research and experimentation (R and E) tax credits altogether. These measures were decisively rejected by Congress (Lubell, 2019). Perhaps one of the clearest indicators of President Trump's lack of initial S&T policy interest was that it took more than 18 months to name an OSTP Director. This attitude would quickly change as US-China tensions over trade imbalances, intellectual property theft to patent violations, and unfair trading practices emerged in 2018 (AIP, 2019).

Much of the science community and prior administration's policy makers were once again growing frustrated with what they described as typical Republican S&T policy. Republican technology policy doctrine they believed could be summed up as follows: the US government should invest in long-term basic R&D efforts that support military objectives or reside outside the scope of commercial businesses while applied R&D should remain in the domain of the private sector (Lubell, 2019).

After demonstrating lackluster interest in commercial S&T policy the administration's perception regarding US private sector competitiveness drastically shifted in the second year, providing another example of how geopolitical and domestic pressures can become major influencing factors (The White House, 2018b). China's emergence as a technologically dominant player combined with its escalating attempts to appropriate US intellectual property and trade secrets caused President Trump and congressional Republicans to re-define China as a direct threat towards American competitiveness and innovation. Realizing that China's intent was to expand its manufacturing process into the technology sectors and that this action would threaten US technological dominance and global competitiveness, President Trump announced that his administration would be conducting investigations and taking actions designed to defend against

Chinese improprieties and unfair competitive practices harmful to American innovation and the American worker (AIP, 2018; The White House, 2018b).

In August 2018, the US Trade Representative (USTR) launched an investigation under Section 301 of the Trade Act of 1974 to examine China's unfair trade practices which had been generating large trade deficits for the US and creating a burden on its commerce. Seeking out expertise and advisory roles from American technology companies, trade associations, law firms, research academics, American research institutions, and think tanks, the investigation determined that China was using foreign ownership restrictions and licensing agreements to pressure US tech companies into transferring proprietary technologies to Chinese companies or risk losing access to lucrative Chinese markets (Noonan, 2019).

The USTR uncovered that China had been routinely engaging in foreign ownership restrictions, eliciting facilities investments and acquisition strategies that generate large-scale tech transfers from US companies to Chinese companies, and engaging in cyber warfare penetrations into US businesses to acquire patents and trade secrets. The investigation also concluded that China was engaging in perhaps its most egregious offense, supporting cyber security attacks into US companies that provided China access to sensitive proprietary and trade secrets (The White House, 2018a; Noonan 2019). To confront these infractions, the administration implemented safeguard tariffs on billions of dollars of Chinese goods (Bulloch, 2018).

Joe Biden, January 20, 2021 – Incumbent

The Biden administration retained many of the Trump administration's counterbalancing initiatives and attached more significance to developing US STI initiatives. To ensure this, a cabinet level position was created for the assistant to the president for science and technology, PCAST advisors were selected from among a pool of highly qualified high-tech executives out of Silicon Valley, the America Creating Opportunities for Manufacturing Pre-Eminence in Technology and Economic Strength (America COMPETES) Act of 2022 was enacted in February 2022 and immediately established nearly $300 billion worth of funding for US S&T programs. $52 billion of those funds were dedicated to grants and subsidies for semiconductor manufacturers (Chen & Lei, 2022). The Biden administration also made pledges to support and unite the U.S. technology industries to better compete with CPC subsidized Chinese companies (Chen, 2022).

The Biden administration took a more moderate overall position on counterbalancing China's S&T policy ambitions. However, while the administration shifted the US stance towards one of attempting to deliberate, cooperate, and even engage the CPC on matters related to technology policy, it remained confrontational towards China's high tech companies and supporting entities (venture capital and private equity), especially among China's military-industrial-complex and large telecommunication giants like Huawei where export controls were increased (Chen & Lei, 2022) The administration recognized that they are engaged in technology rivalry but their emphasis would not be a focus primarily on trade and trade imbalances, but rather on technology itself, and if there is going to be a decoupling with China it will reside there. (Chen & Lei, 2022; Reed 2022).

To address the strategic shift towards technology, the administration outlined six principles that would guide their S&T policy framework. These principles include: "promoting competition in the technology sector; providing robust federal protections for Americans' privacy; stronger privacy and online protections for kids; removing legal protections for large tech platforms; increasing transparency about platforms' algorithms and content moderation decisions; and stopping discriminatory algorithmic decision-making" (Conner,2022). The emphasis is on critical technology development in the fields of: advancements in cybersecurity for vital infrastructure, policies oriented towards promoting competition (home and abroad), international standards for domestic and international settings, the Affordable Connectivity Program (ACP) to ensure affordable broad band access, and large-scale investments for semiconductor production detailed in the CHIPS and Science Act (Simpson & Conner, 2021; Conner 2022). This emphasis on competition, transparency, and privacy while still placing countervailing measures directed at Chinese companies and strengthening ties with Asian partners is what the administration believes is a more robust way of dealing a rising China. The strategic impetus is to outcompete China in critical technologies, especially digital technologies, while cooperating with Beijing on technology matters related to climate change, pollution, food production, renewable energy and research (Conner, 2022; Kuo, 2022).

China S&T Historical Overview

China has a long history of S&T inventions beginning early in the Tang dynasty with what modern historian refer to as the "Four Great Inventions": paper, printing, the compass, and gunpowder. These inventions are recognized as some of the most significant technological discoveries in world history. They would have a great impact on the development of Chinese civilization and would not be replicated in Europe for over a thousand years (China.org.cn, 2007). The Tang Dynasty (618 AD – 907 AD) and Song dynasty (960 AD – 1279 AD) provided substantial periods of innovation and engineering achievements introducing discoveries like: ceramics, porcelain, fireworks, rockets, cast iron, the iron plough, dry docks, suspension bridges, the propeller, metal drills, locks, matches and many others (Needham, 1962; Needham, 1985) .

The Chinese civilization would go on to make numerous advances in metallurgy, mathematics, pharmacology, agriculture, and warfare throughout the centuries but fell short of developing its own scientific revolution as much of Europe experienced by the 18th century. The reasons behind China's scientific and technical stagnation during European renaissance were attributed to numerous causes: political systems hostile to scientific advances, cultural factors resistant to scientific achievement, and philosophical and religious beliefs among Chinese intellectuals were not accommodating to testing the laws of nature (Needham & Wang, 1954).

This lack of S&T progress and innovation would change with the establishment of the Republic of China (ROC) in 1912 and the introduction of the Western scientific method. The Nanjing decade or Golden decade (1927 – 1938) was the most significant period during the ROC for S&T. Its average 3.9% GDP growth helped spark an explosion of modernization, industrialization, and scientific growth in China (Maddison, 1998: 57). Unfortunately, the second Sino Japanese war (1937 – 1945) followed by the resurgence of the Chinese Civil War between the ROC and CPC (1940 – 1949) were intellectual unproductive periods with limited research funding availability and a time where most research scientists were forced into teaching or government jobs (Maddison, 1998: 27).

The formation of the People's Republic of China in 1949 reorganized many of the remaining scientific institutions developed during the Golden decade under a new Soviet model organized around a bureaucratic rather than research-based system (Allrefer, 1987). The most important of these institutions included the new Chinese People's Political Consultative Conference (acting legislative branch of the PRC) which produced the Common Program (de facto constitution until 1954) and established specialized research institutes that prioritized applied S&T research projects focused mainly on the natural sciences. The concentrations included: agriculture, industry, and military applications. The Chinese Academy of Science was another of these institutions, created in 1949, it combined the numerous state-owned research institutes under the Beijing Research Academy. The Academy then assigned the research institutes to regional production centers according to their needs (DeGlopper, 1988) The final reorganized institution was the State Science and Technology Commission later renamed the Ministry of Science and Technology (MOST) which became the principle agency responsible for formulating S&T research policies, developing and coordinating China's R&D and innovation system, and their activities (most.gov.cn, 2019).

China's First Five Year Plan (1953 – 1957) organized the PRC's economy according to the Soviet model of economic development (DeGlopper, 1988). The Soviet Union aid program provided China with massive capital investment allocations and the largest technology transfer of that era. 156 industrial sectors with concentrations in power generation, heavy industry, chemicals, and equipment manufacturing were targeted. Chinese industries were forced to adopt the Soviet bureaucratic model that separated research from production and regulated all elements of China's S&T R&D to government control. China's production capabilities drastically improved and a large workforce was trained to operate the new Soviet style factories. (Allrefer, 1987). China's S&T progress also improved but progress was slow due to the soviet style bureaucratic policies and when the CPC shifted its focus to the Great Leap Forward (1958 – 1960) and the cultural Revolution (1966 – 1976) S&T progress ground to a halt. Despite the lack of R&D progress and the publics persecution of the scientific community during the anti-intellectual cultural revolution, programs with a military capability like nuclear weaponry, rockets systems, and satellites would go on to achieve considerable scientific success (DeGlopper, 1988).

After Chairman Mao's death in 1976 and the culmination of the cultural revolution, the new CPC leadership under the guidance of Deng Xiaoping reinvigorated S&T development. However, the new CPC leadership remained focused on only applied R&D in agriculture, industry, and defense for its economic growth and national security purposes (Shinn & Worden, 1988). Throughout the early 1980s China's senior leadership promoted major reform efforts and institutional policy changes directed at China's cumbersome S&T R&D system. The goal was address shortcomings in: industrial innovation, assimilation of new technologies, shortages of trained scientists and engineers, research facilities regulated to outdated soviet style research institutions, limitations in academic and professional freedom, prioritization of research concentrations and funding given to military projects, and lack of clarity regarding the ideal proportion of basic versus applied research (Baum, 2018).

By 1985 the communist party's Central Committee had decreed that major reforms were required for China's S&T research System. The Central Committee restructured the state-owned research institutions by changing their method of funding, required the commercialization of technology and the creation of new technology markets, and established a reward system for scientists for breakthroughs in research (DeGlopper, 1988). The purpose for these reforms was to ensure that Chinese S&T would better meet the needs of industry and reduce the level of program compartmentalization common the old Soviet style R&D structure. Direct funding for research institutions was slowly phased out and replaced with a competitive market system. Research institutes engaged in applied research would need to work directly with state-owned and private sector enterprises on a contractual level. This meant providing consulting services to enterprises or selling their services in the growing technology market systems to support their programs. Research institutes involved in direct research would have to compete with other institutes for grants from the newly created National Natural Science Foundation (1986) (Springnut, Schlaikjer & Chen, 2011).

The push for commercializing technology and creating new technology markets was to inspire technology transfer between research institutes and the growing numbers of private sector enterprises and to increase the pace of new products and services development. By the late 1980s Chinese technology markets and the commercialization of new technologies efforts had grown at a steady pace. It was decided that China needed additional market institutions to for patent transfers, consulting contracts, and for pricing and sales of new technologies. To bolster foreign technology transfer interest new policies were also implemented to renovate factories, improve facilities, and encouraged the importation of technology instead of just raw materials and finished goods (DeGlopper, 1988). Foreign MNCs were encouraged to transfer technology by entering into licensing agreements and/or joint ventures with Chinese private sector or state-owned enterprises to gain access to emerging Chinese markets, relaxed regulatory environment, and low-cost labor. Foreign MNCs were also encouraged to establish their own research centers and manufacturing facilities in China and hire local workers/managers. This would create skilled workforce communities enabling Chinese labor to gain knowledge and work experience that could be transferred back to indigenous state-owned enterprises (Springnut, Schlaikjer & Chen, 2011). China also established Economic and Technical Development Zones modeled after the already successful Special Economic Zones. The purpose for the zones was to provide supportive environments for foreign direct investment (FDI), strengthen China’s high-tech industries and create job opportunities, increase export opportunities, and stimulate local / provincial economic growth (GDP) (Swiss Business Hub China, 2016).

China's senior leadership introduced another round of regulations favorable to FDI in the 1990s. These regulations were designed to create a more conducive environment for western MNCs and increase the rate of foreign technology transfer to help China catch up to the more established technologically advanced developed nations. China's entry into the World Trade Organization (WTO) in 2001 was supposed to put a stop to these practices, but China managed to circumvent every restriction placed upon it by the WTO (Springnut, Schlaikjer & Chen, 2011). In 1995 the Central Committee issued a "decision" that China's state-owned and private sector R&D programs would receive funding equivalent to 1.5% GDP by 2000 in order to accelerate China's S&T progress and meet the needs of its growing market economy and middle class. The goal was to and shift S&T research away from state-owned research institutions towards China's increasing number of private enterprises since these had better access to FDI (US Embassy Beijing, 1996). In support of this "decision", the CAS also reformed its outdated Soviet model's R&D emphasis on government research institutions by drastically reducing them and encouraging instead the development of China's academic research institutions. The results of the "decision" were that investments in private and state owned enterprise R&D grew rapidly reaching US$10 billion by 2003 and equating to 60% of the total PRC's S&T investment, the R&D workforce for private and state owned enterprises totaled over 650,000 roughly 60% of the PRC R&D employment total, and patents created by China's enterprises increased 48% approaching 55,000 (Baogao & Chubanshe. 2005).

2005 marked a milestone for China's S&T progress. The Central Committee's National S&T development strategy had successfully shifted China from a nation depended on the technologically advanced developed nations for its technological progress and innovation to a nation that was becoming internationally competitive in several key high-tech S&T research and product development fields. China's advances in S&T since the "decision" included: over 55 million personnel working in private sector /state-owned enterprises and research institutions, the budget for S&T appropriations had increased to 97.5 billion Yuan and 184.3 billion yuan for R&D representing 1.35% of GDP, patent awards exceeded 190,000, the China Natural Science Foundation established cooperative agreements and joint research projects and 36 different countries, and 30,000 enterprises were operating in high-tech development zones in 53 Chinese states with an average growth rate in China's major economic indicators exceeding 60% (enacademic.com, 2010). China's senior leadership had reached a strong consensus that STI was a critical component of preserving their strategic economic ambitions, political security interests, and enhancing China's international status. They also realize that there remained a lack of significant indigenous innovation and intellectual property creation, and that China was still dependent on foreign technology in the majority S&T fields. This represented a major hurdle to achieving and sustain China's strategic STI goals (Kang & Segal, 2006).

To address these mounting concerns China's senior leadership directed the State Council of the People's Republic of China (State Council) to issue in 2006 a series of policy guiding principles or guidelines on the National Medium-and Long-Term Program for Science and Technology Development (2006-2020) (China.org.cn, 2006; State Council, 2006: 9). These guidelines were put in place in part to ensure that medium and long-term S&T R&D allocations would increase to 2.5% of GDP by 2020. To accomplish this objective the guidelines required S&T development was to focus on 11 major industrial sectors: energy, mining, manufacturing, transportation, urban development, water services, environmental, health services, electronics and information technology, communications, and national defense. In addition, new emerging technologies were to be thoroughly explored and developed. These included: biotech and genetics, super/quantum computing, material sciences and nanotechnology, robotics, deep sea exploration, space sciences and astronautics (China.org.cn, 2006; enacademic, 2010). The State Council guidelines also stipulated that China's large enterprises (equivalent of western MNCs) were required to set up their own R&D institutes, engineering labs, and joint R&D initiatives with universities and state-owned research institutes. New banking policies would be designed and implemented to financially support STI and tech-oriented startup businesses. A secondary capital market system would be established dedicated to advancing S&T industrialization and investment. Further reform of the existing STI management system to better coordinate civilian and PLA R&D partnerships allowing private sector enterprises and research institutes greater ease of access to defense projects (China.org.cn, 2006).

The 2006 Guidelines were met with incremental successes, by 2009 China S&T appropriations and R&D expenditures had reached 1.54% of GDP exceeding expectation (Battelle, 2011). The amount of state and private enterprise funding allocated to Chinese universities continued to grow as did the university national research output, China's share of S&T patents continued to rise, and the number of undergraduate/graduate students increased from 1 million to 5.4 million over the past decade, and the growth rate of the number of R&D scientists and engineers working in the STI ecosystem increased. All these factors demonstrated that China was closing the S&T gap with the other technologically advanced developed nations (Battelle, 2011; UNESCO, 2010).

Steady progress continued in 2010 with the number of foreign MNCs research centers expanding to 1200 (including 400 out of the top US Fortune 500 companies). These MNCs were involved in a wide variety of research foci and employed growing numbers of Chinese scientists and engineers (Springnut, Schlaikjer & Chen, 2011). This provided both benefits and problems for China. Chinese scientist, engineers, and project teams were able to work with and gain experience from large western MNCs engaged in cutting-edge S&T R&D and project development. However, the proximity and numbers these MNCs allowed China's state-owned and private sector companies to easily purchase their foreign technology instead of indigenously developing the technology themselves. This perpetuated China's lack of indigenous innovation, new product development, and intellectual property creation (Baogao & Chubanshe, 2005). To remedy these problems the Central Committee proposed policies requiring foreign MNCs selling their products/services in China would be required to promote Chinese innovation and their products/services sold in China would be devoid of any intellectual property protections (Segal, 2010). Despite withdrawing the later condition under international rebuke, China would routinely engage in actions aimed at acquiring foreign intellectual property, replicating and repackaging it, and claiming it as their own innovations and intellectual property (Segal, 2010).

By 2011 China had become the nation with the greatest number of patent applications, but the still trailed the US and Japan for the number of actual patents awarded. In addition, many of China's patents involved small incremental improvements to already existing designs not new innovative products or processes (Yee, 2011). China had also become through the Ministry of Science and Technology the number two academic publisher of scientific research papers, behind only the US. Unfortunately, most China's science organizations were self-publishing their journals and were either owned outright or largely funded by the Chinese government. This system was strongly criticized as having a "publish or perish" model and resulted in low quality, rarely cited, plagiarized, and/or completely fraudulent journals and articles. Responding to this criticism the Chinese government vowed to increase quality control, ensure a more thorough peer evaluation process, and create large independent publishing groups (Jha, 2011, Sharma, 2011).

Moving forward to 2015, China had clearly made greater inroads into S&T R&D investments than any other nation. China's senior leadership was now convinced that narrowing the US S&T dominance was critical for its economic prosperity, workforce creation, and national security (NSF, 2018a). The National Science Board (NSB) in its global Science and Engineering Indicators Report described the US as remaining the number one global R&D investor with $7.1 trillion invested between 1995 to 2015. In the final 2015-year, US investments in total R&D had reached $496 billion, captured 26% of the global R&D total, and spent 2.8% of its GDP on R&D efforts. However, China was rapidly catching up to the US in R&D spending despite having invested only $2.8 trillion from 1995 to 2015. China's 2015 total R&D investments had reached $408 billion and accounted for 21% of global R&D. What is significant here is China's rate of spending increases. China had averaged an 18% annual growth rate in R&D spending for the past five years, far in excess to that of the US and other technologically advanced developed nations (NSF, 2018a; NSB, 2018).

The Indicators Report also outlined how US had provided the greatest number of advanced S&T doctoral degrees in 2015 with 40,000, while China provided only 34,000. Yet when considering undergraduate science and engineering degrees China was by far producing more undergraduates at 1.65 million versus the US at US's 750,000. These degrees are crucial for knowledge intensive high-tech industries and developing a knowledge base economy (NSF, 2018a; NSB, 2018).

Other noteworthy comparisons from the Indicators Report included attracting venture capital and private equity investment. This is critical for STI startups / incubators especially in the key emerging technology fields. The US still dominated in 2016 attracting $70 billion in investments and 54% of global total. China had enticed $34 billion invested and 26% of global total but also achieved a $3 billion investment increase in just three years. Once again, it is China's growth rate (5%) that is significant and is much greater than any of the western nations (NSF, 2018a; NSB, 2018). The US still leads in developing knowledge in high-tech intensive businesses / industries with 34% of global total and in providing financial and information services for those businesses with 31% of global share. China has reached 17% in both categories, but China is again growing at a much faster 19% annual growth rate than other country (NSF, 2018a). The US also maintains its number one position in high-tech manufacturing (computers, aircraft, pharmaceuticals, etc.) with 31% of global share. China in second place at 24%. China is again growing at a faster pace than the US more than doubling its market share in the past decade (NSF, 2018a; NSB, 2018).

In 2018, one of the most significant indicators of China's S&T R&D success was provided by Boston Consulting Group (BCG). The BCG report explained how the US remains the leader in total R&D (basic, applied, and development research) and is the clear leader in front-end R&D which comprises both basic research which is used to acquire or expand scientific knowledge, and applied research which is instrumental in using existing technologies to solve specific problems usually for military and industrial applications. However, China recently surpassed the US in later stage or development research (Sirkin, 2017).

Development research is where inventions / technologies are converted to industrial production and/or commercialized products preferably with dual use capabilities (Sirkin, 2017). The US still invents more new technologies and devotes 33% of its total R&D expenditures in retaining its global leadership in basic and applied R&D while allocating 67% of its R&D expenditures towards later stage development research. China, on the other hand, is investing 84% of its total R&D expenditures on development research and has converted those investments to industrial and commercial products at a much faster rate. China is basically free riding on US R&D basic and applied research investments. (Davidson, 2017).

China enjoys another advantage over the US and other technologically advanced developed nations in that its state-owned tech companies and to a lesser extent its private sector enterprise doesn't need to worry about large-scale R&D losses should a product not be suitable for commercialization. Chinese government subsidies can reduce these losses and lessen the risk associated with investing in potentially high yield but financially perilous research and product development lines (Davidson, 2017).

China's unabated growth in STI has not gone unnoticed. The Trump administration had grown frustrated with China's unfair trade practices, technology transfer requirements, and intellectual property theft announced a series of trade sanctions and other counter measures (counterbalancing) in 2018 and 2019 aimed at stifling China and its enterprises unchecked growth. (Mourdoukoutas, 2019). The Biden administration kept most of these countermeasures in place and added to them with measures such as the CHIPs and Science Act which would allocate $280 billion in research funding and semiconductor manufacturing for critical infrastructure and key weapons and intelligence collection systems (Shepardson & Mason, 2022). Whether anticipating these counterbalancing efforts or reacting to them China has prepared a series of S&T strategic reforms and policies. Ji Jinping and the CPC are accelerating their efforts to become more self-reliant promoting five prominent scientists into the policy making positions with the politburo and increasing investments in innovative startup companies and venture capital firms focused on technology (Ruthwitch, 2023).

Domestic and Geopolitical Influences on S&T Policy – Step 4

US Geopolitical and Domestic Concerns and Leadership Perceptions

Geopolitically, the first serious retaliatory measure began with the Trump administration's tariffs on China. This forced the CPC to respond by reducing purchases on their largest US purchase items, such as, Boeing jets and millions of tons of soybeans. China's big stick retaliatory approach was surprising to foreign policy analysts and caused the Trump administration to initiate another larger round of tariffs, this time on $250 billion worth of exports (Bulloch, 2018). Once again, China quickly retaliated with their own tariffs and increased the range of some of their tariffs as much as 25%. These actions between the two countries have been construed by the World Trade Organization (WTO) and the global trading community as precursors to a trade war. Global financial markets have been operating in an environment of uncertainty ever since and have attempted to pressure both countries to resolve the matter before a severe trade war happens and there are long-term negative impacts on foreign exchange markets, monetary policies, and global trade flows (Holland & Sam, 2019).

Along with confronting unfair trade practices, the Trump administration was essentially forced to reevaluate its position on S&T policy in order to counter China's intent to become the dominant technology player on the global scene (Lawless, 2018; Droegemeier, 2019). The administration realized that for the US to remain the global technological hegemon will require: 1) Advancing US R&D and innovation by providing a conducive environment for private sector businesses, research universities, government agencies, and national laboratories collaborations. 2) Create a pro-worker agenda that creates a workforce capable of working with cutting-edge technologies by establishing lifelong learning pathways into the STEM fields. 3) Promoting core US values and principles including scientific integrity, freedom of inquiry, transparency, collaborations, and networks to ensure that the US provides both an open research environment while at the same time protects its intellectual property and patent rights (Droegemeier, 2019).

To safeguard US technological dominance, President Trump assigned Kelvin Droegemeier OSTP Director in mid-2018 with a renewed fervor to retain global STI leadership. The OSTP under Droegemeier immediately set out to reestablish US space exploration and R&D initiatives through the revival of the National Space Council and the creation of the new US Space Force. Trump also launched the American Artificial Intelligence Initiative to guarantee that China does not overtake the US in AI development. The White House then established a National Strategy on STEM Education directing over $200 million per year of grant funding which was matched by another $300 million by the private sector (Droegemeier, 2019).

Geopolitical stresses associated with a potential trade war were not the only problem. Domestically, the Trump administration was feeling pressure on multiple political fronts. Midwest farmers, a staunch Trump voting pool and supplier to China of soybeans and corn were growing deeply concerned that Brazil, the number two soybean producer, would step in and capture the lucrative Chinese soybean contracts. Democrats took this as an opportunity to slam the Trump administration over what they claim were poorly thought out trade policies and a blatant disregard for American farmers and American consumers (Daniels, 2018). However, Democrats perspectives on China were about to change as well. With ongoing criticism from the Trump administration, Republicans, and mounting evidence from the USTR report regarding unfair trade practices and intellectual property theft, top Democratic leaders began expressing their own concerns and bipartisan support took shape against China (Lawder & Wroughton, 2017).

The US scientific community represented another concern for the Trump administration's development of S&T policies. While there have been some promising advances towards S&T policy, skepticism among the scientific community remains prevalent. It remains uncertain whether President Trump is simply reacting towards China's unfair trade policies or truly intends to maintain US technological dominance (Lawless, 2018; AIP, 2019). One thing became clear, President Trump was clearly interested in programs such as AI, quantum information science, and STEM education, and most recently 5G. Basic research also became a priority, in addition to applied research, and the commercial sector did receive as much R&D support and funding as it has in prior administrations. (AIP, 2019).

The Biden Administration followed suit with sweeping export controls designed to cut off access to US semiconductors and other digital technologies, provide large-scale investment allowances in US innovation, and limit Chinese student access to STEM research (Reed, 2022). The administration is also working to establish a coalition of ally nations to take actions "against China in the name of democracy in science and technology" where Chinese companies will be confronted and sanctioned determined by their activities in relation cyber espionage and human rights abuse (Chen & Lei, 2022). President Biden intends to engage in a form of integrated deterrence where the US reinforces Asian alliances and draws upon broad array of technological proficiencies and economic capabilities for new round of great power competition (Kuo,2002)

Leadership Perceptions

Leadership perceptions are also critical in the creation and initiation of S & T policy. Almost equally as important, is how these perceptions get formed within their psyche. Consider that in the case of a democracy like the US, leadership decision-making is usually regulated by constitutional and regulatory constraints and by the domestic political pressures and international environment that defines the nation's status. Leaders define these constraints and pressures according to their preconceived perceptions and interpretations (Hermann & Hagan, 2013). While it is true that preconceived perceptions and interpretations are influenced by the leader's generation, culture, gender, beliefs, and political affiliations (party and the election process), they can also be shaped by aspiring ideologies (causes), relying on environmental cues (mirroring), and strategic approaches (testing the waters). From these factors, leaders will establish expectations, initiate strategies/planning, and engage in activities designed to enact some form of legislation, policy, or regulation and/or to guarantee their current political position and power. However, democracies require consensus, and before leaders can initiate change in a democracy, they must achieve varying degrees of consensus building. If disagreement is likely, this will require compromise (Hermann & Hagan, 1998: 131-133).

When it comes to politics specifically, perceptions associated with political affiliations are the key drivers of political behavior. Evolved psychological or "cognitive mechanisms" are responsible for shaping all group-based behaviors and this includes partisan behaviors. These mechanisms in humans are derived from evolutionary forces which direct humans to form social groups (partisan identities) and then engage in influencing behaviors such as in group favoritism, outgroup denial, or political group preference. It is this partisan identity that functions as a perceptual screen, one that influences how leaders judge and interacts with their environment and how they make decisions (Campbell, 1982: 432; Brewer, 1999: 28-29; Schmitz & Murray, 2017: 60).

Given the descriptions above, consider the basic differences between the Republican and Democrat perspectives concerning private sector S&T policy (Bush and Clinton commercial R&D example). Republicans, and especially conservatives, believe strongly in the power of competition. Competition encourages businesses to invest in R&D to ensure new generations of commercial products and to remain competitive. Most conservatives realize that market failures do occur and that some form of government intervention may be necessary. They are also widely supportive of government-based R&D for military and government (intelligence collection) purposes. Their problem resides in government interventions to remedy market failures which they believe should be left to its own devices. Since market failures are the primary reason for private sector R&D underinvestment, it too should be left to its own consequences. Conservatives are also strongly opposed to any federal spending for seemingly partisan (Democrat) purposes (Branscomb & Florida, 1998). This preconceived conservative perspective is what led to resistance in funding the government-sponsored, cost-sharing R&D investments program. This occurred even though conservatives (and many liberals) supported government funded basic research and defense related R&D programs, of which, private sector dual use technology and R&D is a part of. It took the combined influence of the Obama administration, congressional Democrats, and some influential moderate Republicans to present this in such a way that a preconceived conservative perspective evolved, and a beneficial policy change was implemented (Branscomb & Florida, 1998, Flynn, 2019).

The second example (Trump–China trade war), extended beyond domestic concerns and into the geopolitical arena. Increasing evidence of China's unfair business practices and intellectual property theft represented a growing risk to US technological hegemony and forced the Trump administration to change its perception of China as a valuable trading partner to that of an economic and national security threat. This potential threat to US national security triggered in the Republican party its partisan identity and its perceptual bias. This influences how it judges and interacts in a changing geopolitical environment. In this case, the administration's need to investigate "if or when" infractions are uncovered, and its response of initiating tariffs to protect the country's national interests (Schmitz & Murray, 2017). Democrats, who have generally been resistant to anything the Trump administration puts forth, were initially reluctant to condemn China's actions and in some cases, went so far as to defend China. However, once public sentiment towards China shifted, the Republicans used the Democrats reluctance to condemn China as a political tool. They portrayed Democrats as weak, against national security, and uncaring about the economic damage China was causing the US from ongoing trade deficits and job losses. Under this scrutiny, Democrats including the Biden Administration when it took office in 2021 were quick to change their perspective in order to preserve their political position and power (Hermann & Hagan, 2013; Chen & Lei, 2022).

There is another matter concerning perceptions that presents problems in policymaking. It has been stated that "politics is always about perception", and perceptions are what can get a candidate elected or defeated. However, a problem exists with political perceptions in that what the politician or policymaker perceives isn't necessarily within their grasp to control or in some cases even adequately understand (Clark, 2013). This is the case with current partisan perceptions which are having great difficulty keeping up with the rapid pace of technological changes. This issue is growing more prevalent in the civilian sectors and will require Republicans and Democrats alike to relinquish some funding control over private sector technology development. To compensate for this limitation, politicians need to listen to businesses and their expertise regarding research requirements and focus more on smaller innovation driven companies. In addition, give more support to large MNCs and their university and national laboratory collaborations. This will require a major shift in both party's perceptions and funding prioritization, but one that is necessary if the US intends to remain the global technological hegemony. (Branscomb & Florida, 1998).

What becomes evident from the history of US technology policy and from these examples is that technology policy was heavily influenced by geopolitical and domestic pressures and by the political perceptions of the nation's leaders. These perceptions were the product of preconceived beliefs, generational culture, and political in-group preferences, all of which became self-reinforcing mechanisms for partisan support. These perceptions were altered when leadership was presented with crisis scenarios or when the threat of resistance to change could result in a loss of current political power (Hermann & Hagan, 1998: 127-129). What can confuse even resolute political perceptions, like those an administration has for S&T policy, is that technological change is occurring so rapidly and is so broad in scope that decision-makers cannot gain an adequate understanding of the situation, much less on how to control it (Morrison, 2017; Malan, 2018).

China's Geopolitical and Domestic Expansionary Strategies, Policies, and Influences

China's S&T Strategies

China's current long-term strategic S&T objective is to become the world's leader in global S&T R&D, innovation, and high-tech manufacturing (McBride & Chatzky, 2019). These STI strategic objectives are an integral part of China's greater ambitions regarding "the great rejuvenation of the Chinese nation" and President Xi Jinping's vision and pursuit of the "China Dream". To meet these objectives China's senior leadership developed three overarching strategies: The Belt and Road Initiative, "Made in China 2025", and the military modernization program of the PLA (Panda, 2019). These strategies, especially the Belt and Road Initiative were also drafted to help mitigate US counterbalancing efforts against China's rapid technological progress (Cai, 2017).

The Belt and Road Initiative (BRI) originally termed the One Belt One Road strategy was created in 2013 by Xi Xinping as China's global development strategy. It seeks to integrate Asia, the Middle East, Europe, Africa, and Australia into a massive continental superstructure where

China can increase its international influence by offering billions of dollars of infrastructure investments and long-term binding trade agreements to mostly developing nations that lacked their own economic resources (Cavanna, 2018, Panda, 2019). China is investing US $150 billion annually and has already contracted with 68 countries which accounts for almost 70% of the world's population. The State Council has raised some concerns that the strategy may not have been properly conceived and total costs would approach US$4 -8 trillion by the time it is fully implemented. Xi Xinping has countered these concerns claiming that benefits will override costs. The BRI will provide Chinese companies guaranteed access to new developing markets, allow China to export its excess production capacity (i.e. steel and cement) and its underutilized heavy construction equipment, and to reinvest (dump) much of its portfolio in low interest-bearing US securities into those countries and their regional markets (Wo-Lap, 2016; J.P., 2017). The BRI has raised global alarms and strong condemnation from the Trump administration's NSS which states it is an attempt by China to assert its technological influence on the developing world. The NSS warns that the BRI will require developing countries to purchase Chinese technology, subject them to electronic surveillance, allow China access to their energy and natural resource reserves, and reduce the need for Western economic institutions (Cavanna, 2018).

The second strategy is China's "Made in China 2025", a 10-year plan to update China's extensive global manufacturing base by developing ten strategic high-tech industries and then become a dominant high-tech global manufacturer in each prior to 2049 (Panda, 2019). China's senior leadership selected these 10 strategic technology sectors because they believe these sectors are vital for China's long-term technological and economic growth objectives, its military modernization plans, for guaranteeing China a foremost position in the emerging fourth industrial revolution. These technology sectors include aviation and aerospace engineering, electric and hydrogen vehicles, rail infrastructure and transportation, maritime transportation, renewable energy, material sciences, new medical equipment and biomedicine, agriculture and farming technologies, next generation IT, and advanced robotics systems and AI. (McBride & Chatzky, 2019). China's leaders are already investing vast resources towards developing technology champions (companies and product lines) in each of these sectors (Kang & Rappeport, 2018).

China senior leadership realizes that they can no longer rely on their old economic growth models to accomplish the "Made in China 2025" strategy. China will have to reduce its reliance on foreign technology and promote their own high-tech product lines in these high value emerging markets. This in turn will require utilizing subsidized state-owned enterprises, providing additional support to private sector companies, recruiting STEM personnel from rival Western tech companies already proficient in these sectors, and engaging in more sophisticated foreign intellectual property acquisition tactics, (Kang & Rappeport, 2018; McBride & Chatzky, 2019). The "Made in China 2025" strategy is also receiving international condemnation from some of the technologically advanced developed nations who are growing increasingly concerned with China's flagrant attempts to acquire their countries high-tech MNCs and innovative startup companies, access their nations intellectual property, ignore their patent and copyright laws, and recruit their top scientist and engineers (Oh, 2018).

The final overarching strategy involves China's military modernization program and China's ambitions to "effectively secure China's overseas interests". China's senior leadership has plans to modernize its outdated military by developing and utilizing state-of-the-art military weapons systems and support structures generated through its civil – military fusion initiatives and integrating into every branch of the PLA (Panda, 2019). The goal is to modernize China's military by 2035 and a create world-class military by 2050. China's leaders have allocated substantial investments into state owned and private sector industries focused on the next generation of high-tech dual use technologies to improve the PLA's: warfighting capabilities, force projection, nuclear deterrence, space operations, and cyber warfare (USCC, 2018a: 205-206). China's immediate goals of this modernization program is to develop anti-access/aerial denial (A2/AD) hypersonic missiles with capabilities designed to "to attack, at long ranges, adversary forces that might deploy or operate within the western Pacific Ocean in the air, maritime, space, electromagnetic, and information domains", modernize naval capabilities for maritime operations in the disputed waters of the South and East China seas, and update Army and Air Force weapons platforms for land warfare operations along its land borders or in regions beyond those borders (USCC, 2017: 200).

China's senior leaders and PLA's CMC's major modernization goals revolve around the pursuit leapfrog technologies for a new generation of high proficiency military weapon systems developed indigenously within China's civil – military fusion landscape and acquired through its ongoing manipulation of the "US innovation economy" which enables China access US technology and intellectual property without proper authorization (Almond, 2018; Report to Congress, 2018). The CMC has specifically targeted weapon systems directed at counterspace and satellite weapons, unmanned aerial and terrestrial drones, hypersonic missiles, electromagnetic and kinetic rail guns, directed energy weapons, and AI embedded weapon systems (USCC, 2018a: 219, 222). China's high-tech industries with dual use production capabilities still lag behind the US's high tech oriented military industrial complex's approach to modern warfare weapons development. It also has a history of significant quality control issues for large military weapon systems such as jet engines. China has made rapid strides in some weapon systems like drone technology and cyber warfare systems, the latter has the added benefit of perpetuating industrial espionage in key technologies of its interests (Roblin, 2018).

China's S&T Policies

To help China achieve its greater strategic ambitions and meet its social and economic development goals, its senior leadership created a series of policies designed to reform China out of the old bureaucratic labor-intensive manufacturing model and into a new STI model capable of surpassing US technological dominance in advance high-tech R&D and manufacturing (mfa.gov.hu, 2018). The purpose of these techno-industrial policies is to create a union between China's S&T R&D programs and its high-tech industries sectors and their corresponding state owned / private sector tech enterprises. This rapid expansion of China's high-tech industry sector has become one of China's most important recent policy objectives (Springnut, Schlaikjer & Chen, 2011). These S&T R&D and innovation driven policies included: The National Medium- and Long-term Science and Technology Development Program (2006-2020), China's 13th Five Year Plan: Science Technology and Innovation, and State Council's Decision to Accelerate the Development of Strategic Emerging. (mfa.gov.hu, 2018).

The 2006 National Medium – and Long-Term Science and Technology Development Plan (2006 – 2020) also referred to as the MLP provided an outline for how China will become an "Innovation Oriented Society" by 2020 and a global S&T leader by 2050 (Springnut, Schlaikjer & Chen, 2011). The MLP requires total S&T R&D investments to reach 2.5% of GDP, technological progress to exceed 60%, and the call for the reliance on all imported technology to be less than 30%, all by 2020. The MLP also calls for China to become one of the top five countries in S&T awarded patents and for its publications to be the most cited in the world (Cao, Suttmeier & Simon, 2006). To attain these goals, China's senior leadership is committed to enhancing China's "indigenous innovation" with a specified interest in leapfrog technologies into key high-tech industrial fields and frontier, pioneering, or emerging (generally used interchangeably) technologies (Springnut, Schlaikjer & Chen, 2011).

"Indigenous innovation" which China's leadership believes must become a central focus of all S&T activities, requires fashioning a national strategy executed at the national, provincial, and local levels in every relevant industrial sector. The goal is to concentrate on generating original innovation, properly integrating that innovation into industry for product development, and evaluating the innovation for assimilation effectiveness in the broader commercial sectors and the PLA. For "indigenous innovation" to also be successful requires a favorable ecosystem capable attracting, educating, and utilizing talented S&T professionals, business leaders, entrepreneurs (Cao, Suttmeier & Simon, 2006; State Council, 2006: 9-10).

The MLP identified 11 key industries, 8 emerging technologies, and 8 "cutting edge" emerging sciences that were considered priorities for immediate S&T R&D project development and investments (Springnut, Schlaikjer & Chen, 2011). The most important of these project priorities involved: advancing core technologies in IT and equipment manufacturing, increasing agricultural output and productivity levels, achieving R&D breakthroughs in clean energy and efficient energy production, reducing natural resource requirements and environmental protection measures, conducting research into new pharmaceuticals and advanced medical equipment, modernizing military weapons and support systems, and establishing state-of-the-art R&D research institutes, universities, and industrial research centers and staffing them with world-class scientists, engineers, and research teams (see Table 1) (State Council, 2006: 10-11; Springnut, Schlaikjer & Chen, 2011).

Table 1 – China's Targeted Key Industries, Technologies, and Sciences

11 Key Industries	8 Emerging Technologies	8 Emerging Sciences
• Agriculture • Energy • Environment • IT • Industrial Manufacturing • Defense • Health Services • Public Security • Transportation • Urban Development • Water Resources	• Advanced Energy • Aerospace • Biotechnology • IT and Cellular • Advanced Manufacturing • Lasers • Material Sciences • Ocean Technologies	• Cognitive Sciences • Molecular Sciences • Core Mathematics • Natural Resources and Environmental • Lifecycle Processes • Condensed Matter • New Experimental Approaches • Advanced Research Techniques

** Source: China's Program for Science and Technology Modernization: Implications for American Competitiveness: R&D Projects*

To guarantee the MLP goals would be achieved called for formulation of seven additional supporting polices and measures. These polices included: 1) financial incentives and pretax deductions for S&T R&D expenditures geared at private sector SMEs; 2) improve or change existing industrial policies to strengthen the absorption, assimilation rate, and the effectiveness of importing foreign technologies and any backward reengineering and/or re-innovation processes; 3) amend the "PRC Government Procurement Law" and launch a government "first – buy" program catered to prioritizing purchases for domestic companies engaged in developing high-tech innovative products or intellectual property rights; 4) establish international property rights (IPR) and technology standards designed to reduce the loss of China's proprietary IPR (limit IPR piracy), while creating a system of laws and regulations that protects China's IPR and improves its technology standards; 5) develop venture capital investment schemes for China's private sector enterprises creating frontier or emerging technologies, build a second stock exchange specifically for technology, and create a dedicated capital market system for accelerating private sector S&T investing; 6) accelerate the pace of high-tech industrialization, optimize the high-tech environment with dedicated research institutions, and increase funding for widescale diffusion of advanced and enabling technologies; 7) reformulate and fortify the integration of the civil – military sectors, create a new S&T management system dedicated to identifying dual use technologies with military applications, and expand defense procurement processes to provide greater access into civilian research institutions and private sector enterprises (State Council, 2006: 46-49; Cao, Suttmeier & Simon, 2006).

The second policy that China's senior leadership believes is crucial for China's social and economic development and for becoming an international competitor in STI is the 2010 State Council's Decision to Accelerate the Development of Strategic Emerging Industries or simply Strategic Emerging Industries policy. The Strategic Emerging Industries policy requires China's S&T ecosystem to "accelerate cultivation and development of strategic emerging industries" to guarantee China's global international competitiveness (State Council, 2010: 2). This policy expands the development of private sector innovation in high-tech industries and their enterprises on a grand scale. It calls for enhancing programs and extending industrial support into seven major emerging industrial sectors where China's leadership believes cutting-edge breakthroughs are likely (Springnut, Schlaikjer & Chen, 2011). These new sectors include: 1) energy and environmental conservation with a focus on energy saving products, energy saving monitoring services, pollution reduction, and waste recovery systems; 2) next generation IT and broadband infrastructure development, Internet of Things (IOT) conductivity, cloud computing advancements, and new display circuitry including virtual reality; 3) biotechnology advances in pharmaceuticals, diagnostics, medical equipment, and genetic engineering for agricultural crops;

4) high-end equipment manufacturing including aerospace technologies, rail transport, oceanographic exploration equipment, and intelligent automated robotic manufacturing; 5) clean energy production involving solar, wind, nuclear, biomass, and intelligent grid integration; 6) new material technologies and rare earth material utilization with concentrations in new alloys, engineered plastics, membrane materials, advanced ceramics, super conductor materials, nanotechnologies, and materials capable of rudimentary intelligence; 7) electric, hybrid, and hydrogen vehicles with new generation of high-efficiency batteries (State Council, 2010: 5-6; Springnut, Schlaikjer & Chen, 2011).

The Strategic Emerging Industries policy was initiated in response to China's leaders realizing that private sector high-tech enterprises have outperformed China's state-owned research institutes and represent the clearest path to technological progress and international competitiveness (Schumpeter, 2018). A significant requirement of this policy initiative is to ensure adequate government funding is available for the launch some of these fledgling industries. To meet these requirements China would need to: increase government R&D allowances into private sector industry and enterprises engaged in research and product development in these strategic emerging sectors, rapidly expand its basic research in these strategic technologies, create cutting-edge research establishments, develop large-scale engineering projects utilizing these strategic technologies, assist in the commercialization of these technologies, generate supporting tax structures, guaranteed government procurement programs, and provide recruitment assistance in support of these emerging industry/enterprises. Many of these technologies are also of critical value to military weapons systems and national defense (State Council, 2010: 8-10; Springnut, Schlaikjer & Chen, 2011). Even with the Strategic Emerging Industries policy in place funding goals could not be reached strictly government allocations of capital which are expected to cover no more than 8% to 15% of the $1.5 trillion (spread over five years) in total costs, the rest will have to come from private sector investments (USCBC, 2013; Lai & Deng, 2017).

The third and most recent S&T policy was China's 2016 13th Five-Year Plan (2016 – 2020) also referred to as 13th FYP. The 13th FYP emphasized STI as the cornerstone for China's social and economic development and its future role as a global STI leader. The FYP stated that "China's future development must be based on innovation" (Ou, 2016). It also called for additional increases in STI funding and ongoing reforms to streamlining China's S&T funding processes. Funding increases would be used to; incentivizing large scale industrial innovation and entrepreneurship, establish profit-sharing guarantees that allow scientists and research teams to profit from their discoveries, reduce academic publishing fraud, and overhaul the subsidies evaluation processes for research institutes, research projects, and research professionals (European Commission, 2018a). The 13th FYP also sought to improve China's sustainable development capabilities. To achieve this goal, STI was used to: modernize agricultural production, integrate IT throughout all major industrial sectors, enhance high-tech manufacturing capabilities, and create a high-tech ecosystem supportive of entrepreneurship. The 13th FYP essentially calls for China to establish itself as a dominant player in the emerging high-tech industries with specific concentrations on key strategic technologies and large-scale production possibilities (cistc.gov.cn, 2016; Ou, 2016).

The 13th FYP for S&T clearly states that China's goal is to become an "innovation nation" by 2020. The focus of this STI sub issues-based section is on development R&D and increasing the pace of commercialization in the 11 major industrial sectors outlined by the State Council in the 2006 MLP and on the seven major emerging industrial sectors described in the

2010 Strategic Emerging Industries Policy. In addition to these industrial sectors, 13^{th} FYP for S&T emphasizes placing the greatest development R&D focus and commercialization efforts on a new group emerging technology. These include: AI, quantum computing, 5G communications, integrated circuitry, new materials, bioengineering/bio farming, satellites, and spacecraft. It also calls for the creation of new industrial research clusters to concentrate on these technologies and their commercialization potentials (Xinhua, 2017). To support these emerging industry sectors and account for insufficient government funding greater access to foreign capital was required. In 2019 China launched its new, less volatile, and better governed Nasdaq-style Science and Technology Innovation Board. This provided access to new equity markets and was targeted specifically towards these high-tech industries and their strong growth potential (Cheng, 2019a).

Internet+ Strategy which appeared in a 2015 Government Work Report and was recently updated to account for recent technological advances is the latest evolution of Chinese high-tech policies. Internet+ expands upon the Strategic Emerging Industries Policy and the 13^{th} FYP for S&T calls for China to not only become a global leader in the emerging technologies and their industrial sectors (IT networks, new materials, biotechnology, aeronautical and space platforms, etc.) but requires China become a dominant presence in the new rapidly advancing high-tech digital technologies and associated industry sectors (Xu, 2015).

These new generation emerging technologies will require a high degree of complex integration between 5G Internet networks, enhanced cloud computing storage, big data access, AI integration, IOT interconnectivity. and automated manufacturing processes (Xu, 2015). China’s private sector enterprises are central to this initiative and have already demonstrated success by numerous Chinese SMEs and startup companies integrating mobile internet capabilities into industrial agriculture systems and high-tech manufacturing facilities (Gu, 2016).

What becomes evident is that there is broad political and legislative leadership support for S&T R&D strategies and policies. China S&T environment has expanded from a two-tier strategy where basic research was gradually expanded while applied research was purposely strengthened, to a multi-tiered approach focused on basic, applied, and development research, and for the need take full advantage of private sector enterprises and their concentration on specialized research and product development (GCSTP, 1985; Jiaxi, 1986). This process further evolved over the past 15 years to include STI strategic initiatives, S&T R&D policy foci, and their associated industry concentrations in emerging high value technologies, the most recent of which is in the high-tech digital fields (China.org.cn, 2014).

Domestic and Geopolitical Influencers

China does not have internal bipartisan or multiparty political disputes that many Western democratic nations must deal with. It does have strong internal dynamics that can create disputes over policy direction, and this has an effect on policymaking. Even with President Xi Jinping tightening up the CPC's centralized control, China's S&T policy creation is subject to a vast array of internal political interests between the branches of government, ministries, agencies, and offices, all vying for power, influence, and program funding directly beneficial to their programs. This can become especially prevalent at the provincial and local levels. The PLA is by far the strongest force in determining the future course of S&T R&D and project investments. The PLA and can literally demand research lines and dual use technology development from any corner of China's STI ecosystem in any matter that concerns national security (Zhu, 2011).

Other significant internal influencer guiding the direction of S&T policy include China's growing number of think tanks, research universities, and the CAS, all of which are big providers of basic research. China's state own and growing private sector enterprises which have become increasingly more important in China’s recent S&T policy shift towards indigenous innovation and industry development in the emerging high-tech leapfrog technologies. (Zhu, 2011). The private sector’s growing array of entrepreneurs and high-tech startups which add a much-needed innovation impetus in the emerging tech fields and product development. These two last categories are also becoming the greatest contributors of development research. A final category influencing STI policy is China’s populace and their growing acceptance and use of technology. This increased public support for technology bleeds over to a public demand for, new commercial products, improved processes, and S&T policies, especially in the new digital technologies. The technologies with the highest demand are new e-commerce programs, mobile payment systems, internet financing options, and social media platforms (World Economic Forum, 2015).

Geopolitically China’s S&T strategic initiatives, policies, and policymaking processes are influenced by a number of factors. One of China’s senior leaderships’ biggest concerns are the unresolved territorial disputes with the Philippines, Malaysia, Indonesia, Vietnam, Japan, and India. Almost 90% of China’s energy (oil, natural gas, coal), raw material, and basic goods imports pass through these contested regions in South China Sea and China does not yet believe it has a blue water navy sufficient enough to protect these interests (Zhu, 2011). Should tensions rise between the China and the US or between an alliance consisting of the US and one or more of these aforementioned nations it could escalate to the point of military conflict and would most likely occur as a naval confrontation in the South China, East China, and Yellow Sea regions or as a coastal invasion. A land invasion would be to problematic since China is surrounded by geographical buffer regions. China biggest worry is that superior US naval forces could bottleneck up sea lanes vital for China's imports. Overcoming this concern is one of the main reasons Chinese leaders are seeking to advance leapfrog technologies (Friedman. 2017).

Perhaps the most significant external geopolitical influencer is US counterbalancing measures against China. The Trump administration attempted to strengthen alliances with Australia, Japan, South Korea, Thailand, and the Philippines and encouraging them to spend more on their militaries and the regions defense (Jennings, 2017). The Biden administration went even further in rebuilding regional coalitions intended to stifle Chinese aggressions in East Asia and encourage a buildup in military preparations and readiness (Kuo, 2022). China's leadership perceive these actions as part of a series of activities designed to contain China's economic growth and have made their own attempts to balance against the US. China sought to establish alliances with the Philippines and Indonesia, but this has proven difficult since China has already asserted its power in the disputed waters and its aggressive stance does not foster cooperation. (Friedman. 2017). Other US counterbalancing efforts include imposing tariffs on key Chinese products, limiting Chinese investments and acquisition strategies aimed at US companies, restricting US access to certain Chinese companies (and vice versa), and decreasing FDI to China**.** All these endeavors have slowed China's rapid STI and economic growth to varying degrees and have had a significant impact on China's most recent S&T policies (Tayal, 2019; Borzykowski, 2018).

A final major geopolitical influencer concerns international competition. The technologically advanced developed nations have become less trustful of China repeated trade infractions and they too have realized that increasing S&T R&D, high-tech industrialization, and high-value exports are the key to their future economic growth. Thus, these nations are all taking actions to increase their competitive positions (Friedman. 2017). This could prove very problematic for China since its STI is currently dependent on foreign technology and foreign direct investment (FDI). China's commerce ministry reported that FDI has been climbing 17.4% each year for the past decade and is currently at US $105.74 billion. This rate of increase in FDI is crucial for China's growth objectives in its private sector enterprises / industries in the emerging high-tech fields. Should foreign investment led by US counterbalancing measures ignore China and choose instead to focus on the western or northeast Asian countries, China's efforts to promote indigenous S&T R&D, generate high-tech production, and to export high value products abroad could fall short of expectations. China needs to ensure FDI remains consistent, but this will require serious concessions. Such concessions include providing political and economic stability, granting foreign investors access to Chinese markets, ensuring a favorable regulatory environment remains in place, and openness to international trade (reduction in trade barriers, tariffs, and bans on goods) (Bloomenthal, 2019).

<u>Government Coordination S&T Policymaking Effectiveness - Step 5</u>

US S&T Policymaking Assessment

Assessing the strength of US S&T policy creation is difficult due to a lack of established methods used to gauge S&T policies but important nonetheless due to the strong correlations between STI with economic growth. There have been some general studies and assessments done on the impact innovation has on economic growth. Lederman and Maloney analyzed over 53 countries between 1975 - 2000 and found that "a one percentage point increase in the ratio of total R&D expenditure to GDP increases the growth rate of GDP by 0.78 percentage points" (Lederman & Maloney, 2003, 3, 32; Chen & Dahlman, 2005). In addition, Guellec & van Pottelsberghe investigated the long-term effects that business, government, private sector, and foreign R&D had on multifactor productivity growth among economically developed countries from 1980 – 1998 (Guellec & van Pottelsberghe, 2001, 104). They found that all four types of R&D investments had statistically significant positive outcomes for a country's productivity growth (Guellec & van Pottelsberghe, 2001, 104 115; Chen & Dahlman, 2005).

Edwin Mansfield's 1991 publication provided an in-depth analysis on the impact that US academic basic research can have on private sector innovation. He discovered that across seven major manufacturing sectors, greater than 10% of all new products developed were fundamentally reliant on academic research (Hines, 2017: 7). Mansfield's conclusions indicate that both the return on investment (ROI) and the social rate of return to society on research conducted predominantly at universities but in collaboration with private sector was 28%. When Mansfield expanded his analysis, he found that the rate could be as high as 40% depending on the industrial sector. What these three studies indicate to S&T policy makers and the commercial sector is that basic research, whether conducted at universities, national laboratories, or private sector startups/incubators, has a greater impact on industrial productivity than either traditional commercial product development or applied R&D endeavors regardless of the product or product line (Lubell, 2019).

While these studies pointed out correlations between R&D and economic growth and commercial sector productivity, there have been few reliable S&T studies aimed at determining whether a policy or program met the expectations of policymakers. The only ways to assess the value of US S&T policies is to look at large-scale federal, congressional, or agency specific evaluations which have been largely partisan, subject to bias, and dependent on the current administration or congresses political perspectives (Shapira & Youtie, 2010: 26). The second method is to consider country specific technology policy evaluations conducted by independent sources and/or industry consulting reports which generally focus on industry specific policies. Despite subjectivity or a narrow focus, many of these policy evaluations have come with some degree of accuracy and while not entirely reliable or limited in scope most have determined that overall US S&T policies while inconsistent and dependent on administration have been of considerable value to establishing and maintaining global leadership in a number of technological fields (Shapira & Youtie, 2010: 26; Attri, 2016: 5).

China S&T Policymaking Assessment

There are few definitive clear-cut ways to assess China's S&T policy making. One of the best ways is to look at the outcomes of major STI strategic initiatives and policies and ascertain whether they meet objectives. Since China's leadership introduced major S&T policy reforms in 2006 with the MLP and more recently in 2016 with the 13th FYP China's rate of R&D investments, technological progress, and contributions to societal and economic development have outpaced all other nations (Veugelers, 2017).

China's aggressive S&T strategic initiatives and multilevel policies have helped China become the second largest spender of R&D accounting for 21% of the global US $2 trillion total, the rate of R&D spending from 2010 to 2015 grew an average of 18% per year outpacing the US by a fourfold factor (Harris, 2018). China became the world's leading producer of scientific publications reducing much of its academic publishing fraud, and the number one producer of science and engineering undergraduates (359,000 in 2000 to 1.65 million in 2014) and PhD degrees. FDI in the form of venture capital and private equity has risen from US$3 billion in 2006 to over US$34 billion in 2013 garnering 27% of global FDI. The US still remains number one at US$131 billion and 50% of global FDI but its share of the global total is dropping (Veugelers, 2017; Harris, 2018).

Another excellent indicator that China was meeting its S&T policy objectives was demonstrated by China exceeding its goals in their 2010 Strategic Emerging Industries Policy and 2015 Internet+ Strategy regarding the quantity and percentage rate increases in the flow of FDI into pioneering dual use, emerging high-tech, and integrated digital technologies, industries, and their markets (USCC, 2017: 514; Xinhua, 2019). FDI investment going into China in 2018 was US$134.6 billion and within the first eight months of 2019 had already reached US$ 89.3 billion a 3.2% year on year in investment increase. FDI investments into the emerging high-tech industries had climbed 39% capturing 29% of global FDI and FDI investments in high-tech services climbed an astounding 58.4% over the prior year (Trading Economics, 2019; Xinhua, 2019). These figures indicate that China's Strategic Emerging Industries Policy Internet+ Strategy, 13th FYP for S&T exceeding policy expectations (Trading Economics, 2019).

Additional examples of policies meeting senior leadership expectations included new policy measures in 2018 designed to attract FDI and mitigate US counterbalancing efforts. These policies were largely responsible for the rapid percentage increases in high-tech related FDI over the past year. These policies and government directives included expanding market access into China (including markets that compete against China's high-tech enterprises), fast-tracking environmental impact assessments for ease of entry, and infrastructure development and logistics support. China also cut tariffs on 1585 manufacturing and industrial item imports and streamlined customs import clearance by reducing almost half of the previous requirements (Koty, 2018).

In addition to achieving S&T policy objectives, China reformed its policy making process. China's senior leadership made certain that S&T policies received fervent support at the highest CPC levels. This support coupled with China's centralized government command-and-control enabled rapid policy creation and implementation without cumbersome partisan in-fighting experienced by western nations. These advantages have allowed China to quickly identify technology advancements, target emerging high-tech development research and corresponding industrial sectors, and pursue the new integrated digital technologies for immediate investments much faster than the other technologically advanced developed nations. *(*McBride & Chatzky, 2019). China's senior leadership can at any time introduce S&T policy they deem as pertinent and essentially push it through the process (Veugelers, 2017).

Despite China's lack of policy evaluation tools, China's policy value is clearly evident by third party analysis which provide assessments that indicate a rapid expansion in S&T R&D and industrial development (CRS, 2019b). The bottom line is that China's Strategies and policies generally meet or exceed senior leadership expectations and represent a significant to China's long-term goals (CRS, 2019b: 33-37). China's long-term strategies and plans are also showing promising results along with some of the drawbacks and problems that have set the stage for a high-tech rivalry that could last decades.

Conclusion

US S&T policy creation is a complex and drawn-out process involving up to 20 federal agencies, offices, and departments. This makes enacting technology policy cumbersome, difficult to coordinate, and reliant on political objectives occurring between the administration and Congress. In most administrations, effective policymaking required a bipartisan commitment to enact and fund substantial S&T policies.

The history of modern US S&T can be divided into two eras. The Cold War era which was focused on government support and funding for near-term defense related programs within the military – academic – industrial complex, and the post-Cold War era which experienced the emergence of international competition and the increased importance of commercial sector dual use technology development. Post-Cold War era can be further divided according to White House administrations. Republican administrations, George H.W. Bush, George W. Bush, and Donald Trump remained focused on Cold-War era defense related R&D and technology policy preferences. These administrations determined late in their administrations, the need to account for rising international competitive pressures and belatedly moved to reinvigorate private-sector commercial innovation by creating long-term alliances between technology industries and government sponsored national laboratories and major research universities. The Democratic administrations, Clinton, Obama, and Biden established broad-based strategies for shifting S&T policy objectives thoroughly into high-tech commercial sectors in order to enhance economic growth, increase worker wages, and provide for a higher standard of living for the populace. The strategies also involved creating high-tech manufacturing for global trade and attempts to rescale the workforce. These endeavors were generally met with considerable resistance from the Republican counterparts; reluctance due to views on corporate welfare programs.

Throughout the post-Cold War era S&T policy creation was strongly influenced by geopolitical and domestic pressures and the preconceived beliefs, cultures, and political in-group pressures, all of these were influencing factors on the perceptions of US Administration and Congressional leaders. Convoluting matters were the highly complex and rapidly changing dynamics of the S&T and innovation environment which policymakers were generally not prepared to deal with. Of equal concern, is the lack of reliable methods, processes, and metrics necessary from which to measure the effectiveness and success of S&T policy.

When comparing China's S&T strategic initiatives and policies I find the driving force behind China's goal of becoming a global leader in STI and producer of high-tech goods/services. China's senior leadership realizes that technological progress is directly linked to economic growth and that economic growth is crucial for China's ambitions to modernize its military, protect its regional interests, and meet the needs of its growing resource intensive middle class (Keller, 2016; Veugelers, 2017). China's leaders also understand that maintaining their low value manufacturing and export strategies will no longer be sufficient to achieve its goals. China's most recent S&T policies are leading China towards indigenous innovation and R&D, and into high-tech high-value manufacturing focused on dual use leapfrog technologies. These policies also require a drastic reduction on the dependence on foreign technology (Freeman, 2017a; Motohiro, 2019).

China's senior leadership have provided considerable support for S&T policies and the centralized command-and-control structure provides advantages in streamlining policy processes that result in faster and arguably more efficient policy creation methods than of Western models (Anderson, 2018). China's recent S&T policies have successfully reformed China's old bureaucratic manufacturing model into a vibrant STI model (mfa.gov.hu, 2018). These policies have enabled China to close the gap in S&T R&D spending and become the number one producer in science and engineering publishing, STEM graduates, and development research. They have also led China to become an international competitor in STI even surpassing western high-tech manufacturing capabilities in several different sectors, (Harris, 2018)

The other technologically advanced developed nations, with the US at the head, do not believe that China's only ambitions are to become a major international competitor in STI or simply to protect its national security and regional interests. Their leadership is becoming more convinced that China is making a move at global technological and economic hegemony and will use dual use technologies to become a dominant military power in Asia (Freeman, 2017b). The US is taking the lead and is engaged in counterbalancing measures to slow China's rapid growth, protect its intellectual property, and counter decades of trade infractions. China's senior leadership perceives US counterbalancing measures as an attempt to contain China and have enacted their own strategic initiatives designed to mitigate these attempts (Ji, 2015; Cai, 2017).

The bottom line is that if the US and China's S&T policies continue on their current trajectories, they will help contribute to ongoing leadership misgivings as to the true purpose of each nation's STI ambitions. Action-reaction cycles are already establishing negative feedback loops of tension and distrust between the two nations and drawing the US and China into a technology driven security dilemma (Jervis, 1999: 49; Jalil, 2019). The competitive intricacies in their S&T policy formation are setting the foundations for an emerging US-China high tech rivalry and technology-based arms race and we are only experiencing the early stages of what could be an inevitable large scale geopolitical conflict.

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