Fundamental Research Security

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Contents

1 EXECUTIVE SUMMARY

The National Science Foundation (NSF) celebrates its 70th anniversary this year (2019). Over seven decades it has transformed U.S. fundamental research and enabled a world-leading scientific enterprise built upon open intellectual exchange, collaboration, and sharing. Several incidents in recent years have led to concern that the openness of our academic fundamental research ecosystem is being taken advantage of by other countries. This sense of unfair competition is entwined with concerns about U.S. economic and national security in a rapidly changing world. The NSF wishes to assess these concerns and respond to them where appropriate, while also adhering to core values of excellence, openness, and fairness.

NSF has charged JASON to produce an unclassified report that can be widely disseminated and discussed in the academic community, providing technical or other data about specific security concerns in a classified appendix.

JASON was asked:

1. What is the value and what are the risks of openness generally associated with fundamental research?

2. How should the principles of scientific openness be affirmed or modified?

3. Are there areas of fundamental research that should be more controlled rather than openly available? What are those areas?

4. What controls, if any, could be placed on particular types of information, and how can this be managed in a way that maintains the maximum benefit of the open research environment for fundamental research?

5. What good practices could be put into place by academic researchers to balance the open environment of fundamental research with the needs for national (and economic) security?

6. What good practices could be put into place by funding agencies such as NSF to balance the open environment of fundamental research with the needs for national (and economic) security?

To address these questions, JASON engaged with NSF leadership, senior university administrators, the intelligence community, and others. This report details the results from the ensuing inquiry, discussions, and debates engaged with NSF, senior university administrators, the intelligence community, law enforcement, and others.

Four main themes emerged from the study:

- The value of, and need for, foreign scientific talent in the United States,
- The significant negative impacts of placing new restrictions on access to fundamental research,
- The need to extend our notion of research integrity to include disclosures of commitments and potential conflicts of interest,
- The need for a common understanding between academia and U.S. government agencies about how to best protect U.S. interests in fundamental research while maintaining openness and successfully competing in the global marketplace for science talent.

Our Findings and Recommendations amplify these themes and propose steps the NSF can take to improve the security of fundamental research.

1.1 Findings

1. There is a long and illustrious history of foreign-born scientists and engineers training and working in the United States, and they make essential contributions to our preeminence in science, engineering and technology today. Maintaining that leading position will require that the United States continues to attract and retain the best science talent globally.

2. The United States upholds values of ethics in science, including objectivity, honesty, accountability, fairness and stewardship (NAS 2017 *Fostering Integrity in Research*). These values protect research integrity, upon which credibility of the fundamental research enterprise, and the entire academic system, is based.

3. Actions of the Chinese government and its institutions that are not in accord with U.S. values of science ethics have raised concerns about foreign influence in the U.S. academic sector. JASON reviewed classified and open-source evidence suggesting that there are problems with respect to research transparency, lack of reciprocity in collaborations and consortia, and reporting of commitments and potential conflicts of interest, related to these actions.

4. The scale and scope of the problem remain poorly defined, and academic leadership, faculty, and front-line government agencies lack a common understanding of foreign influence in U.S. fundamental research, the possible risks derived from it, and the possible detrimental effects of restrictions on it that might be enacted in response.

5. Conflicts of interest and commitment in the research enterprise can be broader than those that are strictly financial, including those that might occur in foreign research

collaborations or result from required reporting obligations for scholarships or grants.

6. There are many stakeholders with responsibility for the integrity of fundamental research, from U.S. government agencies to individual scholars, each with particular perspectives, roles and responsibilities. Universities and research funding agencies have policies and guidelines regarding some of these responsibilities, but these are often insufficient for individuals to assess risk and take appropriate actions.

7. National Security Decision Directive (NSDD) 189, established in 1985 a clear distinction between fundamental research and classified research. This remains a cornerstone to the fundamental-research enterprise, as officially reaffirmed in 2001 and 2010 and it continues to inform policy today.

8. Universities have mechanisms to handle Controlled Unclassified Information (CUI) under existing categories, such as HIPAA, FERPA, Export control, and Title XIII. CUI protection is difficult, but suited to these tasks, however it is ill-suited to the protection of fundamental research areas.

9. International researchers in the United States are partners in our research enterprise, and, consequently, in the effort to strengthen research integrity nationally and globally.

1.2 Recommendations

1. The scope of expectations under the umbrella of research integrity should be expanded to include full disclosure of commitments and actual or potential conflicts of interest.

2. Failures to disclose commitments and actual or potential conflicts of interest should be investigated and adjudicated by the relevant office of the NSF and by universities as presumptive violations of research integrity, with consequences similar to those currently in place for scientific misconduct.

3. NSF should take a lead in working with NSF-funded universities and other entities, as well as professional societies and publishers to ensure that the responsibilities of all stakeholders in maintaining research integrity are clearly stated, acknowledged, and adopted. Harmonization of these responsibilities with those of other federal research-funding agencies is encouraged.

4. NSF should adopt, and promulgate to all stakeholders, project assessment tools that facilitate an evaluation of risks to research integrity for research collaborations, and for all non-federal grants and research agreements.

5. Education and training in scientific ethics at universities and other institutions performing fundamental research should be expanded beyond traditional research integrity issues to include information and examples covering conflicts of interest and commitment.

6. NSF should support reaffirmation of the principles of NSDD-189, which make clear that fundamental research should remain unrestricted to the fullest extent possible, and should discourage the use of new CUI definitions as a mechanism to erect intermediate-level boundaries around fundamental research areas.

7. NSF should engage with intelligence agencies and law enforcement to communicate to academic leadership and faculty an evidence-based description of the scale and scope of problems posed by foreign influence in fundamental research, as well as to communicate to other government agencies the critical importance of foreign researchers and collaborations to U.S. fundamental research.

8. NSF should further engage with the community of foreign researchers in the United States to enlist them in the effort to foster openness and transparency in fundamental research, nationally and globally, as well as to benefit from their connections to identify, recruit and retain the best scientific talent to the United States

9. NSF and other relevant U.S. government agencies should develop and implement a strategic plan for maintaining our competitiveness for the top science and engineering talent globally, taking advantage of new opportunities for engagement that might arise, even as others become more challenging.

1.3 Conclusion

JASON concludes that many of the problems of foreign influence that have been identified are ones that can be addressed within the framework of research integrity, and that the benefits of openness in research and of the inclusion of talented foreign researchers dictate against measures that would wall off particular areas of fundamental research. We expect that a reinvigorated commitment to U.S. standards of research integrity and the tradition of open science by all stakeholders will drive continued preeminence of the United States in science, engineering, and technology by attracting and retaining the world's best talent.

2 INTRODUCTION

The National Science Foundation (NSF) celebrates its 70th anniversary this year (2019). Over seven decades it has transformed U.S. fundamental research and enabled a world-leading scientific enterprise built upon open intellectual exchange, collaboration, and sharing. Several incidents in recent years have led to concern that the openness of our academic fundamental research ecosystem is being taken advantage of by other countries. This sense of unfair competition is entwined with concerns about U.S. economic and national security in a rapidly changing world. NSF wishes to assess these concerns and respond to them where appropriate, while also adhering to core values of excellence, openness, and fairness.

NSF has charged JASON to produce an unclassified report that can be widely disseminated and discussed in the academic community, providing technical or other data about specific security concerns in a classified appendix. Although much of the recent concern has focused on the actions of China, JASON has largely taken a nation-agnostic approach to potential solutions and has sought to provide recommendations that would broadly strengthen the U.S. fundamental research enterprise against foreign influence.

In this report we review the recent history of U.S. fundamental research and the important role that foreign-born researchers have played in it, the basis for open science in U.S. fundamental research and current mechanisms controlling access to that research, and address U.S. values of science ethics and specific features of foreign programs that transgress those values. We then consider these transgressions in the context of the current understanding of research integrity and of the expectations of collaborative agreements, and provide advice concerning maintaining openness, tools for stakeholders in research integrity, and the means to increase awareness of the scale and scope of the problem. We conclude with detailed Findings and Recommendations. Appendices include the charge to JASON from NSF, the text of National Security Decision Directive 189, and a brief classified section.

In performing this study, JASON was briefed by the following individuals:
Rebecca Keiser, NSF; James Ulvestad, NSF; Arthur Bienenstock, National Science Board (NSB); Steven Binkley, Department of Energy; Suresh Garimella, University of Vermont; Michael Lauer, National Institutes of Health; Michael McQuade, Carnegie Mellon; Sethuraman Panchanathan, Arizona State University; Emilda Rivers, National Center for Science and Engineering Statistics; Tobin Smith, Association of American Universities; Maria Zuber, Massachusetts Institute of Technology; and representatives of the intelligence community and law enforcement.

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3 HISTORY AND CONTEXT

3.1 Post-WWII Rise of U.S. Science and Technology

Science and technology are international enterprises, characterized by global collaboration, as well as by global competition. No nation better epitomizes the international character of these enterprises than the United States. Technological progress in the United States at the start of the 20th century was closely associated with foreign-born inventors who emigrated here from abroad, with familiar names including Alexander Graham Bell (Scotland), Nicola Tesla (Croatia), Chien-Shiung Wu (China) and Guglielmo Marconi (Italy). The rise of Fascism and National Socialism prior to the Second World War resulted in a further efflux of human capital to the United States, bringing to our shores an entire generation of European refugees that included world-class scientists and mathematicians, such as Albert Einstein and Hans Bethe, Maria Goeppert-Mayer (Germany), Enrico Fermi and Emilio Segré (Italy), Rita Levi-Montalcini (Italy), John von Neuman, Leo Szilard, Eugene Wigner and Edward Teller (Hungary)—and many others. A number of these scientific refugees subsequently contributed in vital ways to the Allied war effort, including critical work on the Manhattan Project that led to the development of the atomic bomb.

Buoyed by the economic climate that prevailed at the end of the war, and by the influx of so many top scientists, the United States ascended to a preeminent world role in science and technology during the immediate postwar era. The report by Vannevar Bush (Director of the Office of Scientific Research and Development) in 1945, entitled "*Science, The Endless Frontier*[1] made the case for an increased emphasis on basic research. It expounded a series of fundamental principles and recommendations that were to guide U.S. science for many years to come, including concepts of openness, dissemination of information via publication, and freedom of inquiry. It called on government to support scientific research in the name of public welfare, and for lowering the barriers to advanced education for U.S. citizens. Importantly, it also called for lifting of many of the restrictions implemented during the war years, which were assessed to hamper the overall cause of national security. Although written nearly 75 years ago, *Science, The Endless Frontier* still carries impressive currency today. Not long thereafter, in 1950, Congress established the National Science Foundation, "*To promote the progress of science; to advance the national health, prosperity, and welfare; and to secure the national defense*."[2]

The 1950s and 60s continued to attract intellectual capital to the United States from abroad, further boosting the strength of American science and technology. During this time, prominent scientists arrived on our shores from a growing pool of countries, including war-ravaged European countries[3], war-time allies, particularly the United Kingdom and British Commonwealth countries, as well as from Asia, including Japan, China, and Korea. The flight of human capital from Great Britain to North America during the Cold War era, in particular, led to the coining of the term "*brain drain*[4]". There can be little doubt that the United States has benefitted enormously from brain drain right up to the present day, attracting some of the best talent in the world. It's notable that, as of the start of 2019, 16 Nobel Prizes garnered by U.S. scientists, post-WWII, have been won by ethnic Asians: five by Japanese-Americans[5], eight by Chinese-Americans[6] (in addition to two Fields Medalists), and three by Indian-Americans[7]. As of 2018, fully 30% of U.S. Nobel laureates in the hard sciences were won by individuals born on foreign soil[8]. In 2019, eight Americans were awarded Nobel Prizes – half were foreign born.

3.2 Advanced Education in the United States

In parallel with the continued influx of world-class scientists from abroad, domestic research was boosted after WWII by significantly increased funding, available from federal granting agencies, most of which were created postwar, including the NSF, DOE, and several new institutes of the NIH. For example, the NIH budget soared from $52.7 million in 1950 to $388 million by 1960, and it is approximately $39.2 billion today. In 1950, in its first full year of operations, the NSF's budget was a mere $3.5 million. The launch of Sputnik in Oct. 1957 by the U.S.S.R. stimulated the U.S. Congress to increase the NSF budget to $40 million in 1958, and it is approximately $8.1 billion today[9]. The national response to Sputnik also led to the creation in 1957 of the Advanced Research Projects Agency in the Department of Defense (ARPA, now DARPA), which funds research on the frontiers of technology and science for national security purposes. As the U.S. research establishment blossomed, so too did our attractiveness as a global center for higher education. Among the top-20 universities in the world in 2019, U.S. universities routinely occupy the overwhelming majority of the highest rankings (from 11 to 16 out of 20, depending on the rating source)[10].

By 2017, in excess of 800,000 foreign students were here in the United States pursuing an advanced degree or postdoctoral training. Of that number, roughly 272,000 came from the People's Republic of China[11]. Foreign students are critical to our domestic research enterprise, filling an otherwise unmet demand for high-level talent. To cite one striking example, in computer science in 1995, there were nearly equal numbers of U.S. and international full-time graduate students. Between 1995 and 2015, the number of U.S students increased by 45% (8,627 to 12,539), while the number of international students soared by 480% (7,883 to 45,970)[12]. During the same period, the number of U.S. graduate students in electrical engineering (EE) actually *decreased* by 17%, while the number of foreign students rose 270%[13]. These numbers reflect the dramatic change in size and scope of technology programs in the United States, necessary to maintain our national competitiveness and to keep up with global demand. Our domestic production of well-qualified students, however, has not managed to keep up with this growth, and that is a source of ongoing concern. Today, foreign nationals account for the majority of graduate students in many technology fields, including electrical, civil, mechanical, industrial, chemical, and petroleum engineering. They also dominate in fields including computer science and economics, and some universities graduate programs likely could not maintain their high level of excellence without foreign students[14].

A similar situation obtains for many branches of science. As of 2017, foreign students represented 35% of graduate students throughout the science, health, and engineering fields. In the physical sciences, over 30% of master's and over 40% of Ph.D. students were foreign[15]. The top three countries earning doctorates in the United States were China, India, and South Korea, respectively, and these account for 54% of the total foreign doctorates, with China alone accounting for 34% of this total[16].

It is important to realize that foreign students receiving post-graduate training in the United States often choose to stay once they receive their degree is complete, thereby adding to our expert workforce. The retention rates are impressive. Overall, ~80% of all science and engineering doctoral students coming from abroad report a definite postgraduate commitment to remain in the United States for employment or further training (89% for India; 83% for China)[17]. The long-term stay rates, defined as remaining 10 years or more in the United States, stood around 70% in computer science and mathematical sciences, life sciences, and physical sciences in 2015, and long-term stay rates exceeded 75% in engineering[18].

In the case of China, there are indications that this imbalance in favor of the United States may be shifting. The drivers of this change include large increases in pay packages offered by China at all levels (for example, postdoctoral salaries now reach 600,000 yuan, or $87,827, topping the U.S. average of $47,000), stricter visa restrictions on students, and perception of "increasing hostility against Chinese researchers"[19]. Whether the Chinese brain drain has actually been reversed is still unclear, but the numbers of science and technology (S&T) trainees coming from China, as well as the numbers staying, have recently dropped in response to a greater "pull" by China and a greater "push" from the United States[20].

3.3 The Vulnerability of U.S. Science and Technology Primacy

The global preeminence achieved by U.S. science and technology in the postwar era, through the end of the Cold War in 1991, has not gone unchallenged. The first decade of the 21st century, in particular, saw a major shift in the global landscape, and the apparent loss of U.S. primacy in S&T areas. Many factors are responsible for this shift, and these have been well described in various reports[21]. There are no easy metrics by which to measure success in science or technology, but multiple indicators suggest that China, in particular, may now be gaining an upper hand. Although we continue to spend more on research and development (R&D) than any other nation, the United States is currently being outspent by China in certain areas. Battelle reported in 2012 that "*China's march to prominence in the global R&D arena remains constant and strong, accounting for $23 billion on the coming year's projected growth*"[22]. By 2013, China had surpassed the United States in the number of scientific publications in Physics and Astronomy, considered as fraction of world production[23]. China also took the publication lead in many other S&T fields, including chemistry, renewable energy, computer science, quantum computation, artificial intelligence, electrical engineering, nanotechnology, nuclear engineering, materials science, and biotechnology, among others. Of course, quantity does not imply quality, and it might be argued that China's apparent lead is illusory in certain ways.

Chinese growth in S&T has continued more-or-less unabated, but there is some question about whether the recent rate of growth is sustainable. By 2017, Battelle noted:

> "The shifting of R&D investments to Asia is a trend that started several years ago, and it has continued with 44% of all R&D monies in 2018 being spent in that region—a significant trend expected to continue into the future. As noted over the past ten years in these forecasts, the overall growth in global R&D investments is being driven by the substantial increases in Asian countries and especially in China, which for many years increased its R&D investments by *more than 10% per year*. Over that many years, the Chinese rate increases are basically unsustainable—and its current R&D growth rate is now in the 6.7% growth rate range, which is still more than twice that of the United States and most European countries. Asia accounts for nearly 44% of all global R&D investments. Its share rate continues to increase each year at the expense of all the other countries investing in R&D. The United States continues to be the country with the largest investments in R&D, a title it has held for the past 50 years. The U.S. share of the global R&D pie continues to shrink due to the higher growth rates in Asia, however, at a slowing rate over the past five years."[24]

However, there is little doubt that China is a world leader in fields that are increasingly important to U.S. national security, including artificial intelligence and hypersonics. Furthermore, PRC leadership has been quite open about its desire to become a global leader in S&T, and the 13th Five-Year Plan now in effect places a strong emphasis on innovation in S&T[25].

3.4 Intellectual Capital as a Global Commodity

Given the international character today's science and technology enterprise, top-tier talent, or "intellectual capital," has become something of a global commodity. Both developed and developing nations compete to attract the brightest academic minds, particularly high-profile investigators who can nucleate domestic research programs or offer specialized knowledge. These developments correspond to what a report from the National Science Board has termed "*brain circulation*," as opposed to brain drain[26]. As global competition in science and technology increases, the desire to repatriate citizens while simultaneously attracting additional foreign-national talent has led to a proliferation of recruitment programs.

Science, technology, engineering and mathematics (STEM)-focused recruitment programs are not new and come in many forms. Scholarships, established by governments or private foundations, that fund academics for sabbaticals and longer-term visits have long existed. In

Germany the Alexander von Humboldt Fellowship brings internationally renowned researchers to Germany for up to 18 months. In the United States, the Fulbright Scholar Program sponsors the largest international exchange program for students. The John Simon Guggenheim Foundation awards competitive fellowships for study abroad to young faculty in both the arts and sciences. The United Kingdom recently established the Rutherford Fund, with a $130 million initial allocation, to attract the best foreign researchers, for stays ranging from a few months to 10 years. Canada has budgeted $94 million to fund international researchers to take up research chairs that it has established at top universities. France has committed $50 million to attract climate scientists to work in France, citing current U.S. climate policies as a motivation[27].

In general, STEM-focused recruitment programs target one or more of four classes of individual: (1) domestic students sent to study abroad, with the goal of repatriating them after their education (these are essentially scholarship programs); (2) foreign students imported to study in the homeland of the program, with the goal of capitalizing on their research efforts and possibly retaining a fraction of them after their studies are completed; (3) established foreign scientists with common cultural or familial ties to the country offering the recruitment program, with the goal of bringing them back to the homeland (recruited individuals may be nationals, citizens of the foreign country, or dual citizens); and (4) established foreign scientists with no particular ties to the homeland, but who nevertheless might be persuaded to immigrate by professional and personal enticements.

Brain circulation is a two-way street. Several foreign countries have successfully wooed some top American academics: over the past decade, a number of researchers based in the United States have moved overseas (or split their research programs between here and abroad), lured by the promise of prestigious positions, increased laboratory space, new equipment, improved funding, a ready supply of students, job security, etc. The number of such American expatriates is comparatively small, for the time being.

It is important to note that many of the recent concerns about foreign influence in the U.S. fundamental research enterprise derive from features of Chinese recruitment programs. China has many such programs, but the Thousand Talents Plan in particular has been the focus of recent scrutiny. This program was established in 2008 with the goal of recruiting "strategic scientists or leading talents who can make breakthroughs in key technologies or can enhance China's high-tech industries and emerging disciplines[28]." The ways in which execution of this plan has, in some cases, resulted in transgressions against U.S. values of science are covered in Section 5 of this report. In addition, the Senate Homeland Security and Governmental Affairs Permanent Subcommittee on Investigations released on November 19, 2019 a staff report *Threats to the U.S. Research Enterprise: China's Talent Recruitment Plans*[29]. This report provides substantial details of the workings of the Thousand Talents Plan, including recruitment contracts and case studies of the actions of individuals engaged in talent program activities.

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4 OPEN SCIENCE IN FUNDAMENTAL RESEARCH

Open science relies on the free exchange of information between scientists around the world. Since the start of the Second World War, open science has come into tension with the need for secrecy for technology surrounding the military uses of technology. Following the Second World War, the classification system was created to restrict access to sensitive information, including scientific information deemed sensitive, to those with the need-to-know. As time passed, the prevailing view was that fundamental research would remain unclassified whereas specific, usually national security related, applications of fundamental research could be classified. This section describes two government actions – NSDD-189 from 1985 and CUI from 2008 – that attempted to codify aspects of the openness of fundamental research.

4.1 National Security Decision Directive 189 (NSDD-189)

On September 21, 1985, President Ronald Reagan issued National Security Decision Directive 189 (NSDD-189)(included as Appendix B), with the explicit aim to "*establish a national policy for controlling the flow of science, technology, and engineering information produced in federally funded research at colleges, universities, and laboratories*[30]."

NSDD-189 was intended to specifically address "*the acquisition of advanced technology by Eastern Bloc nations for the purpose of enhancing their military capabilities* [which poses] *a significant threat to our national security.*" The overarching goal was to safeguard "*our leadership position in science and technology*," which was deemed to be "*an essential element in our economic and physical and security*." NSDD-189 recognized that *"The strength of American science requires a research environment conducive to creativity, an environment in which the free exchange of ideas is a vital component*."

NSDD-189 established a national policy of openness, by default, for the conduct of "fundamental research," which it defined by contrast with proprietary research, as follows:

> *"'Fundamental research' means basic and applied research in science and engineering, the results of which ordinarily are published and shared broadly within the scientific community, as distinguished from proprietary research and from industrial development, design, production, and product utilization, the results of which ordinarily are restricted for proprietary or national security reasons."*

The controlling words of the policy are as follows:

> *"It is the policy of this Administration that, to the maximum extent possible, the products of fundamental research remain unrestricted. It is also the policy of this Administration that, where the national security requires control, the mechanism for control of information generated during federally-funded fundamental research in science, technology and*

engineering at colleges, universities and laboratories is classification. ... No restrictions may be placed upon the conduct or reporting of federally-funded fundamental research that has not received national security classification, except as provided in applicable U.S. Statutes.”

Some 34 years on, NSDD-189 is still operative as our national policy. It was reaffirmed post 9/11 by the Bush Administration, in a letter dated November 1, 2001, from Secretary of State Condoleezza Rice to Harold Brown, Co-Chair of the Center for Strategic and International Studies[31], who noted that “*The key to maintaining U.S. technological preeminence is to encourage open and collaborative basic research. The linkage between the free exchange of ideas and scientific innovation, prosperity, and U.S. national security is undeniable.*” It was reaffirmed again in 2010 by Undersecretary of Defense Ashton Carter[32], who wrote that “*NSDD-189 makes clear that the products of fundamental research are to remain unrestricted to the maximum extent possible. When control is necessary for national security reasons, classification is the only appropriate mechanism.*”

NSDD-189 indicates that when it comes to government-sponsored research of the type conducted by universities, a policy of openness should prevail, with the smallest possible number of exceptions to be carved out for those cases where security concerns dominate. Furthermore, the exceptions are to be handled by our existing classification mechanisms, and not by some other protection schemes.

The fundamental principles embraced by NSDD-189, along with much of its original wording, were subsequently incorporated into the Federal Acquisition Regulations (FAR) and are therefore the law of the land. This has created some issues, because there have been instances of the inclusion of publication and access restrictions in various grants and cooperative agreements in universities[33], and because federal granting agencies sometimes impose restrictions on foreign nationals in their research contracts to universities when the research complies with NSDD-189. Furthermore, other federal regulations, such as the Export Administrations Regulations (EAR) and International Traffic in Arms Regulations (ITAR), seem to be at odds with the principles of NSDD-189. A previous NRC report has addressed many of these issues and offered recommendations[34].

4.2 Controlled Unclassified Information

In the study charge, JASON was asked to consider whether there are areas of fundamental research that should be controlled rather than openly available, what types of control might be used, and how they would be managed. Particularly relevant to addressing these questions is the establishment of the category of “Controlled Unclassified Information (CUI)” in a memorandum issued by the Bush administration on May 9, 2008, seven years after the Rice letter reaffirming NSDD-189. CUI was intended to replace a hodge-podge of earlier, informal categories of protected information, with names like “For Official Use Only (FUOU),” “Sensitive But

Unclassified (SBU)," and "Law Enforcement Sensitive (LES)." This attempt at consolidation emerged from a proposal initiated by the Department of Homeland Security in 2004, and was placed under the auspices of the National Archives and Records Administration (NARA), which was responsible for overseeing the CUI framework[35]. The original Bush memorandum was later rescinded on Nov. 4, 2010, and replaced under the Obama administration by Executive Order 13556, which decried the proliferation of federal agency policies and regulations that had come to be associated with controlled information:

> *"This inefficient, confusing patchwork has resulted in inconsistent marking and safeguarding of documents, led to unclear or unnecessarily restrictive dissemination policies, and created impediments to authorized information sharing. The fact that these agency-specific policies are often hidden from public view has only aggravated these issues[36]."*

Executive Order 13556 maintained the designation "Controlled Unclassified Information" for federal use, but imposed further restrictions on its use, and required all agencies to review the categories, subcategories, and markings of CUI, with an eye towards removing CUI designations wherever feasible. It also reminded parties that CUI designations need to maintain consistency with existing laws and policies:

> *"The CUI categories and subcategories shall serve as exclusive designations for identifying unclassified information throughout the executive branch that requires safeguarding or dissemination controls, pursuant to and consistent with applicable law, regulations, and Government-wide policies[37]."*

Executive Order 13556 also attempted to contain, and to harmonize, the ever-increasing number of CUI categories, by designating that the Executive Agent shall:

> *"…approve categories and subcategories of CUI and associated markings to be applied uniformly throughout the executive branch and to become effective upon publication in the registry established."*

In addition, Order 13556 called for interagency meetings to discuss matters pertaining to the CUI program, and to maintain a public CUI registry of categories. Despite the good intentions, the number of CUI categories has continued to proliferate, and now stands at 125[38], grouped into 20 divisions. These include such diverse category names as "Pesticide Producer Survey," "Taxpayer Advocate Information," "Consumer Complaints," and "Campaign Funds." The CUI Registry also subsumes a large number of categories of traditionally protected, personal information that are already covered by applicable federal statutes, such as medical records (HIPAA regulations), genetic information (GINA regulations), taxpayer information (Title 26), census data (Title 13), electronic funds transfers and personal finances (Federal banking regulations), student records (FERPA regulations). Also included are some categories with comparatively less well-defined scope, such as “Unclassified Controlled Nuclear Information,” “Sensitive Personally Identifiable Information,” and “Railroad Safety Analysis Records.”

It seems fair to say that despite the attempt of Executive Order 13566 to regularize the concept of Controlled Unclassified Information, confusion reigns with respect to many of the categories that have been established, particularly those that are not otherwise covered by dedicated federal statutes.

Importantly, there is no division or category within the CUI Registry directly concerned with the conduct of academic research, and this appears to be broadly consistent with the principles laid out in NSDD-189. However, two categories of export controls, namely, “Export Controls” and “Export Controlled Research,” come into play for novel technologies and software that could be considered dual use, or which might adversely affect U.S. national security or nonproliferation objectives. Restrictions associated with these categories can – and do – affect foreign researchers carrying out advanced work at U.S. universities. Among the CUI categories, the official definition of “Export Controlled Research” seems especially vague, being only described as:

> “*Related to the systematic investigation into and study of materials and sources in order to establish facts and reach new conclusions (*sic*)*[39].”

Unfortunately, this type of description provides little in the way of guidance and seems destined to lead to precisely the type of “*unnecessarily restrictive dissemination policies and created impediments to authorized information sharing”* criticized by Executive Order 13556.

For the time being, the handling practices associated with the categories of CUI are many, and in a state of flux. For the most part, these remain to be fully reconciled with NSDD-189. Given the current state of affairs, JASON cannot recommend adoption of a CUI mechanism to secure additional categories of information generated by U.S. universities, beyond those currently covered by applicable laws designed to protect personal information (e.g., HIPAA, GINA, FERPA, Title 13, etc.). Rather, the general principle of creating high walls, i.e., classification, around narrowly defined areas should be adhered to, minimizing conflicts that might adversely affect U.S. open science practices.

5 RESEARCH INTEGRITY AND FOREIGN INFLUENCE

This Section considers how specific methods of exerting foreign influence impact the research integrity of the U.S. fundamental research enterprise. Subsection 5.1 describes the U.S. core values of research integrity, subsections 5.2–5.6 present a taxonomy of different means of foreign influence and how they compromise research integrity, subsection 5.7 discusses specific aspects of China's influence with a focus on potentially relevant cultural differences, and subsection 5.8 addresses the nature of the information provided to JASON by the intelligence community and law enforcement.

5.1 Research Integrity

Research integrity is a set of ethical standards that undergirds the U.S. research enterprise. Historically the primary focus of research integrity concerns has been on scientific misconduct. In 1992, the National Academy of Sciences (NAS) stated "*Misconduct in science is defined as fabrication, falsification, or plagiarism, in proposing, performing, or reporting research*[40]." This definition specifically excluded research errors, differences of opinion, and misconduct unrelated to research. In addition, the NAS definition excluded questionable research practices defined as "*...actions that violate traditional values of the research enterprise and that may be detrimental to the research process.*" The NAS concluded that, at that time, there was not agreement or consensus on the seriousness of such actions.

In 2000, a unified federal policy on research misconduct was promulgated, largely drawing from the 1992 NAS report, and concerned with fabrication, falsification and plagiarism[41]. The reporting policies of the National Science Foundation and Department of Health and Human Services (including NIH) on research integrity have focused on these same topics[42]. In 2017, NAS returned to these issues in the report *Fostering Integrity in Research*[43]. After reaffirming the 1992 recommendations on scientific misconduct, this report noted that research integrity depends on a much broader set of practices by individuals and institutions, including dishonesty and avarice, both pertinent to the topic of this JASON study. The report concluded by urging research institutions, publishers, professional societies, and public and private funding agencies to support a broader landscape of research integrity.

The 2017 *Fostering Integrity in Research* report defined six core values that underlie research integrity: objectivity, honesty, openness, accountability, fairness and stewardship. It also stated that "practicing integrity in research means planning, proposing, performing, reporting, and reviewing research in accordance with the [core] values …" These core values are the foundation of what is referred to as the "responsible conduct of research." We note that many training tools are available to help practitioners adhere to these values in the conduct of their research[44].

5.2 Modes of Influence

JASON reviewed evidence from the intelligence community for foreign influence in the U.S. research enterprise that might run counter to U.S. values of science ethics. We have divided the types of influence into four types: *reward, deception, coercion and theft*. Reward is the offering of material or social goods in exchange for desired behavior; deception is providing incomplete, incorrect information on an application, proposal, or publication for the purpose of hiding or directing attention away from some activity; coercion is the threat of harm or disadvantage for the purpose of enforcing compliance with a demand; and theft is the taking of a physical object or protected idea without permission of the owner. Different engagements, recruitment programs (e.g. the Thousand Talents Plan), scholarships, etc., may make use of some or all of the influence types.

5.3 Rewards

Rewards as a means of influence can come in many forms. Recruitment programs may entice a foreign researcher working in the United States with cash, a high salary, living accommodations, prominent title, or research funds or facilities to encourage them to return to their home country or to apply their skills towards improving the research enterprise there. A prominent U.S. researcher may receive the same kinds of offers from a foreign country, without a requirement for full-time residence in that country. Recruitment programs are well-documented; many countries have made use of them and there is nothing intrinsically wrong with recruiting talent in this way (see Section 3). U.S. academic institutions have been highly successful in attracting the best science and engineering faculty, including many foreign researchers, using a combination of named chairs, substantial startup funds, housing assistance programs and attractive compensation and benefits packages.

Scholarships that provide tuition and stipend support for graduate students attending U.S. universities, and fellowships that provide salary and research allowances for postdoctoral scholars to work at U.S. universities are also common forms of rewards. In the United States, NSF and DOE have Graduate Research Fellowships, NIH and NASA offer postdoctoral fellowships and several foundations have research fellowships for early career faculty. These scholarships and fellowships carry both prestige and the expectation that the awardees will continue to do excellent work in their fields and acknowledge the support of the awarding organization. In some cases, the granting agency requires the recipient to submit an annual report of their activities supported by the scholarship or fellowship. These requirements are publicly stated as a condition of the reward.

Rewards may also be used to encourage activities that compromise research integrity, such as unauthorized sharing of information, theft of material goods (e.g. samples or prototypes), placement of foreign students into a U.S. research group, or other deceptive practices. Some rewards carry the requirement that the receipt of the reward not be disclosed to the recipient's home institution, a practice that may violate the rules of host institution.

5.4 Deceptive Practices

Deceptive practices in the research context include deliberate concealing or omission of information to gain advantage and constitutes the most widespread type of influence. Many parts of the U.S. fundamental research enterprise rely on accurate and complete self-reporting of information to fulfill their responsibilities. These include graduate admission committees, faculty assessing post-doctoral scholars, committees considering hiring and promotion of faculty, officials granting visas, and program officers awarding grants. Deception by omission refers to failure to report rewards or gifts, institutional affiliation, courses completed, or other pertinent information. Deception by falsification refers to communication of false information. Both types of deception appear to occur relatively frequently in graduate and undergraduate applications[45]. JASON was not able to assess the prevalence of the problem for postdoctoral and more senior positions for lack of relevant data.

For foreign scholars seeking a position in the U.S., deception by omission can take the form of not reporting an affiliation with an institution operated by the military or state security in the home country[46] or not reporting courses taken that a visa official may deem sensitive (e.g. hypersonics, acoustics)[47]. Some universities have chosen not to accept students through scholarship programs that require that the student return to the home country after completing their studies. This likely creates an incentive not to report those terms and others that are perceived by foreign scholars as being detrimental to their chances of admission.

Failure to disclose foreign or domestic affiliations, rewards in the form of cash, lodging, or material goods, or time commitments are examples of deception by omission. Some of these are potentially conflicts of interest which also must be disclosed. Use of a second name for an affiliation to mask its true purpose – for example a military university with a non-military name[48] – verges on deception by omission. Deception by falsification can occur in applications, proposals, and other reporting when a scholar or U.S.-based researcher purposely provides incorrect information.

The frequency of deceptive practices in the fundamental research enterprise is difficult to determine – federal agencies, universities, and other institutions have only occasional auditing and usually find deceptive information when alerted by others or as part of a broader investigation. Importantly, the NIH reports their caseload of unreported conflicts is rising as a result of greater attention to foreign engagements[49]. With respect to unreported affiliations and reporting obligations by foreign scholars, a study of co-authorship to identify scholars in the United States with undisclosed military connections found 188 scholars in the U.S. affiliated with foreign military institutions[50]. Anecdotal evidence from several JASON members at different institutions suggests that foreign student networks have advised foreign scholars desiring entry into the U.S. against mentioning coursework or an intent to study topics such as hypersonics, acoustics, or artificial intelligence (AI) on their visa applications to increase their chances of getting a visa.

5.5 Coercive Practices

Coercion is the practice of forcing an individual to do something by force or threat. The threat may be implicit or explicit and can range from social condemnation to physical harm. Implicit coercion has a significant cultural dimension – an individual "knows what can happen" if they do not comply, based on cultural experience. For a foreign scholar, coercion may take the form of withholding scholarship or fellowship funds if the scholar does not report on their activities, gather requested information, or agree to return to their home country after completing their studies. A U.S.-based researcher may be coerced by the threat of loss of resources, prestige, or privileges in the foreign country. For scholars and U.S.-based researchers who have engaged in deception, exposure of their failure to report may be used to coerce certain behaviors. Loss of privileges or social standing for families of scholars in the United States may also provide a coercive element. Finally, laws requiring citizens of a foreign country to cooperate with the intelligence and security services of that country when asked are a legal form of coercion.

JASON heard accounts of the use of coercion from the intelligence community and examined examples of coercive talent contracts (also see the HSGAC report referred to in Section 3[51]). Although the frequency of such events is not well-established, there clearly are potentially coercive mechanisms in place. For example, a recruitment program contract that contains the requirement that affiliation with a recruitment program not be disclosed, facilitates coercion by threat of exposure to the U.S.-based scholar for failure to disclose that affiliation.

5.6 Theft

In this context, theft is the taking of intellectual property (IP) without permission of the principal investigator or host institution. Samples[52], prototypes, software, written documents, and ideas all constitute IP and, in fundamental research, these are the currency of academic achievement and their loss can effect promotions, tenure and grant decisions. In contrast with private sector IP loss, financial considerations are usually secondary, but can be substantial to the university and investigator if an invention to be patented is compromised.

Inadvertent IP theft can occur when a scholar communicates the research group's activities outside the group. Most U.S. scholars have an intuitive sense of what they should and should not discuss outside their group and how they should react when they hear something that could be confidential from another group, but a foreign scholar may not have the same sense. Research group leaders should develop a culture in which sharing information is explicitly discussed – a culture that is best developed by individual principal investigators and their collaborators, as norms vary by subfield. Professional societies could play a role in developing and promulgating the norms for different subfields.

A scholar can be coerced into intentional theft through a reporting condition attached to their support, or the promise of a reward, or out of loyalty to a former colleague or supervisor. The U.S. research enterprise relies on peer review for selection of papers for publication and grants for support. A peer reviewer will have access to confidential information in advance of publication or grant award and can, from loyalty, coercion, or the promise of a reward, transmit IP to others; doing so is intentional theft. Violations of common peer review practices appear to happen regularly, causing concern at the NIH and other agencies[53]. Most publications and granting agencies give clear instructions forbidding the sharing of materials for peer review[54].

Many research groups provide samples, prototypes, or software to other groups either individually or to the community at large. Typically, the principal investigator, with the guidance or instruction of their home institution, sets the conditions for sharing and a group member providing materials outside this guidance is engaged in theft. A researcher running a lab or group in a foreign country who provides materials from their home institution to their foreign lab outside the rules or guidance of both institutions is also committing theft – the researcher may have developed the IP, but the institution where the work was carried out owns the IP and must agree to share with another lab or group, even if the lab or group is run by the researcher.

There are reports of journals that solicit articles from researchers, especially early career researchers, primarily to harvest and share the content prior to publication[55].

Anecdotes abound of foreign scholars in research groups passing on sensitive information, and some JASON members had experienced this in their own research groups. Usually it is not known what rules were in place in these groups. In addition, we note that some examples of what has been interpreted by the intelligence community and law enforcement as theft by foreign researchers actually appears to be the collegial sharing of academic work that occurs between, for example, investigators and the postdoctoral scholars they mentor and assist in starting their own research groups, which might be in another country.

The NSF[56] and NIH[57] have reported and acted upon cases of the violation of the confidentiality of the peer review of proposals, but the nature of the theft makes gathering statistics on its prevalence difficult.

5.7 China and Foreign Influence in Fundamental Research

The efforts of the Chinese government and its institutions to acquire U.S. science and technology information have been cause for concern in the intelligence community for some years. These efforts, particularly in the context of industrial technology, are covered in detail in *Chinese Industrial Espionage*, a 2013 monograph by U.S. government analysts with expertise in this area[58]. With respect to fundamental research, JASON assesses that some of these efforts violate the U.S. values of science ethics that contribute to research integrity, through the use of unethical modes of influence described in Section 5. The Chinese government is not unique in engaging in information collection and influence in the U.S. academic research enterprise, but they are probably the largest and best organized and their efforts are well documented (see reference 59 for related material).

China's society differs from that of the United States in many ways. Particularly relevant is the relationship between Chinese academic institutions, the government of the PRC and the Chinese Communist Party (CCP). In China these are intertwined in a way that is entirely different from the United States, where higher education institutions are largely independent of the government[60]. In 2018, Chen Baosheng, China's Minister of Education, described plans for restructuring the curriculum of universities to bring it into line with current ideological thought[61]. It is common for CCP officials to be represented in university administration[62] and in granting agencies. Anecdotally, many academic scientists in China report that they do not typically experience interference in their work from the party or government, but that it is an ever-present concern.

As a totalitarian nation, the PRC government requires a degree of cooperation from its citizens in ways the United States does not. For example, the National Intelligence Law[63], most recently updated in 2017, requires citizens and organizations to render assistance to the security and intelligence services when asked. Further, the phrasing of the National Intelligence Law implies that citizens should not disclose that they have assisted intelligence and security services. Many U.S. citizens would view this law as particularly vexatious and some, perhaps many, would refuse to comply. However, China has a different history and different imperatives and its citizens may view the National Intelligence Law as a fact of life and find a U.S. citizen's view of the law strange. When a Chinese scholar comes to an American graduate school to study, the scholar may not be aware that the norm in our research community is that information regarding the research group's activities might not be routinely shared with government or university officials – this is something left up to the head of the research group (except for required reporting associated with grants).

A third important consideration is the CCP and Chinese government view that China, after centuries of outside oppression, is seeking to assume its rightful place in the world as a major power. Chinese citizens who are proud of their country and its achievements may agree with the CCP and Chinese government's ambitions, but may not agree with its methods or policies, just as a U.S. citizen may not agree with aspects of U.S. foreign policy. However, in China, the means of dissent are typically different, perhaps making a Chinese scholar reluctant to express any view at all, which may be taken as agreement when discussing cultural norms of science ethics.

Finally, many Chinese scholars study in the United States and choose to remain and become U.S. residents. However, that does not mean they have given up strong feelings for their home country or have adopted U.S. views or cultural norms. Those who have emigrated from China to the United States frequently continue to be closely tied to China and may actively seek to help their home country's progress in legal ways. It is important to note that the many scholars in the United States who are Chinese citizens or U.S. citizens originally from China are typically not acting as representatives of the CCP or the Chinese government and are not necessarily in agreement with the aims, methods, or policies of those institutions. Like any émigrés, such individuals must be treated as fellow residents or citizens of our country and should be judged on their personal actions and not by profiling based on the actions of the government and political institutions of their home country.

5.8 The Nature and Limitations of Intelligence Information

Intelligence agencies gather information, both open and classified, in an attempt to inform decision makers. In general, their imperative is to provide a picture of the situation at hand sufficiently early that decision makers can begin formulating a response. In a multi-faceted situation such as foreign influence of the U.S. fundamental research ecosystem, a detailed picture and meaningful statistics are seldom available – what the intelligence community (IC) is able to provide is a partial picture with some assessment of confidence and extrapolations across areas with sparse data, along with some assessment of the confidence of the accuracy of the parts and the whole of the picture. Decision makers must then craft their response based on the that picture and assessment of its accuracy. The strength of the response should be proportional to the degree of the threat and to the IC's assessment of the accuracy of their assessment.

Finally, the IC provides information and assessment of its accuracy, not policy suggestions. The IC has not provided us with any specific suggestions for possible responses during any of our discussions. The IC typically provides information only to U.S. government policy makers and is not prepared to present open source documentation of problematic issues of foreign influence to the broad academic research community. Similarly, law enforcement agencies typically only make detailed information public once cases have been prosecuted. This lack of effective engagement with the academic community by the IC and law enforcement, combined with a corresponding lack of understanding of the IC and law enforcement agencies on the part of the academic community, has resulted in a lack of effective communication of the problem of foreign influence in fundamental research to academic leadership and faculty.

5.9 Summary

JASON's assessment of the landscape of foreign influences through rewards, deception, coercion, and theft indicates that all occur to some degree. How frequently they occur is not clear, but the mechanisms for such actions are in place and there are enough verified instances to warrant concern and action. The IC and law enforcement continue to collect information on activities in foreign countries and in the U.S. and the information JASON received has allowed us to connect this information with the activities we have described. The picture of foreign influence in fundamental research is far from complete, but JASON does see a developing situation that appears to be worsening and that represents a threat to our fundamental research enterprise and, in the longer run, our economic security and national security.

6 INTERESTS, COMMITMENTS AND COLLABORATIONS

The modes of influence discussed in Section 5 point to a need to expand the concept of research integrity, beyond fabrication, falsification, and plagiarism. This need is amplified by the highly collaborative nature of research today. In subsection 6.1 we discuss conflicts of interest and commitment and consider in subsection 6.2 issues that arise with respect to collaborations.

6.1 Conflicts of Interest and Commitment

Guidance on the definitions and management of conflict of interest (COI) and conflict of commitment (COC) can be found in the writings of professional societies[64-66]. The publication *Recommended Principles to Guide Academy-Industry Relationships* from the American Association of University Professors[65] offers concise definitions of these conflicts:

> "A conflict of interest is a set of circumstances that creates a risk that professional judgment or actions regarding a primary interest will be unduly influenced by a secondary interest."
>
> A Financial COI "… may be broadly defined as a situation in which an individual or a corporate financial interest has a tendency to interfere with the proper exercise of judgment."
>
> "A 'conflict of commitment' arises whenever a faculty member's or administrator's outside consulting and other activities have the potential to interfere with their primary duties, including teaching, research, time with students, or other service and administrative obligations to the university."

Institutions receiving federal funding are required to develop written policies to govern such conflicts[66,67]. The University of Texas at Austin provides a comprehensive example of such policy statements[68].

> *"Conflict of Interest* – A significant outside interest of a university employee or one of the employee's immediate family members that could directly or significantly affect the employee's performance of the employee's institutional responsibilities. The proper discharge of an employee's university responsibilities could be directly or significantly affected if the employment, service, activity or interest: (1) might tend to influence the way the employee performs his or her university responsibilities, or the employee knows or should know the interest is or has been offered with the intent to influence the employee's conduct or decisions; (2) could reasonably be expected to impair the employee's judgment in performing his or her university responsibilities; or (3) might require or induce the employee to disclose confidential or proprietary information acquired through the performance of university responsibilities."
>
> *"Conflict of Commitment* – A state in which the time or effort that a university employee devotes to an outside activity directly or significantly interferes with the employee's fulfillment of university responsibilities, or when the employee uses state property without authority in connection with the employee's outside employment, board service or other activity. Exceeding the amount of total time permitted by UT System or

university policy for outside activities creates the appearance of a conflict of commitment."

In summary, a conflict of interest or commitment (COI/COC) can arise when one simultaneously serves two or more interests that do not align. A COI/COC can arise when a person fills two different roles: for example, that of a principal investigator for a university and an outside consultant for another university or company, a student that is also reporting on their activities to a foreign government, or a regulator with a financial stake in that which they are regulating.

Of specific concern are COI's that arise in the U.S research enterprise when a principal investigator operates a laboratory at their own institution supported by federal or foundation funds while also operating a laboratory in another country supported by that country's funds that carries out related research, unknown to the principal investigator's home institution. In this case, the conflict is not financial, but academic – information generated in one laboratory may find its way to the other laboratory in order to secure funding. In this case, the first laboratory does not benefit from its own work while the second laboratory benefits from work it did not do. A second example of a COI not related to financial matters occurs when a foreign student divulges information about work being done at their U.S. institution to their former mentor in their home country as part of an obligatory report. Here, the former mentor gains access to information they did not play a role in developing.

Existing laws and regulations are in place to address many of the issues associated with full and transparent disclosure of any COI obligations. For example, the federal False Claims Act (FCA), states, in an example specifically provided on the NSF's web site regarding a training grant, that "*material statements that are made or omitted, where the Term 'material,' within the meaning of the FCA, means having a natural tendency to influence, or be capable of influencing, the payment or receipt of money or property*" by the government, constitutes a violation of the law[69]. Civil FCA violations can involve substantial financial penalties including treble damages for the full amount of the federal award as well as penalties for each paid false invoice. FCA violations can also be prosecuted in conjunction with wire fraud and mail fraud. Hence, full disclosure requirements for perceived and/or actual conflict of interest, as well as any other contractually binding non-financial obligations associated with federal financial assistance, fall under existing laws and regulations, and involve both institutional and individual exposure in instances of material non-compliance.

Universities should promote increased awareness of the institutional and individual obligations for compliance and insure full disclosure of all material statements in all federal financial assistance applications, (e.g., grants and contracts). As noted above, U.S. research institutions have requirements to develop policies on COI reporting[67]. Similar to the FCA case described above, these policies tend to be linked to reporting on what would be a financial conflict of interest. Today, clear financial conflicts are not always obvious and new guidance recommends reporting all conflicts, hence the language *potential* conflicts of interest.

Assessment of conflicts of commitment (COC) is based on the notion that the sum of one's commitments of time and effort must not exceed the allowable work hours. The Department of Health and Human Services defines COC as follows:

> "*Conflicts of commitment are generally situations in which a researcher is dedicating time to personal [professional, ed.] activities in excess of the time permitted by institutional policy, or to other activities that may detract from his or her primary responsibility to the institution. The issue here is not necessarily financial or bias in one's judgment, but rather whether one's commitment of time and effort are inconsistent with one's commitment to the institution and its interests.*[70]"

Another aspect of COC can arise from a researcher exercising asymmetric authority over a subordinate (e.g., student, or postdoc). This can happen by giving extra work or exerting undue pressure for various work to be completed related to the researchers external consulting or activities. Even if these junior colleagues have interest in the external work, the conflict of commitment arises when these activities are delaying the junior colleague's own research or degree requirements. This can frequently be subtle and the monitoring non-existent. But, as with reporting potential COI, such situations should be reported and evaluated.

Required reporting with respect to fellowships and awards is also an important area. Responsible conduct of research training highlights the importance of sharing with the principal investigator and research team *all* materials related to the research that is to be transmitted outside of the research team. This ensures proper attribution of results and proper protection of intellectual property. As noted in the discussion of talent programs, students (both undergraduate and graduate) and postdoctoral fellows often are required to report on their progress to sponsors of their scholarships/fellowships. Sometimes these reports constitute public disclosures that would affect securing intellectual property rights to the research results, and other times they might constitute release of information prior to publication, vetting by co-workers in the laboratory, peer-review, and/or review for accuracy by the principal investigator.

COI and COC can be addressed and managed if the potential conflicts are first disclosed to all interested parties. In the case of a principal investigator running two labs, disclosure requirements would ensure that the individual made clear to both laboratories the scope of their respective projects and that these projects did not substantially overlap. In the case of the foreign student obligated to report on their activities, the expectations should include disclosure to the principal investigator of the reporting requirement and direction from the principal investigator on what may be reported from the research group.

Most universities and laboratories require annual disclosure of COI and commitments, as well as updating the information when submitting new grant applications. Senior administrators typically then review the disclosures and consult with Department chairs. What should be reported is not always clear: JASON heard from academic leaders that some faculty are under the mistaken impression that money paid as consulting fees does not need to be reported, as the work often takes place outside of academic business hours. It is evident that the requirements for disclosure of COI and commitments must be clearly communicated to all stakeholders in maintaining research integrity.

6.2 Challenges Posed by Collaborative Agreements

Within the broad range of activities and policies of U.S. research institutions are collaborations between individual U.S. and foreign researchers, large international science and engineering collaborations, large facilities involving international participation, and open data access policies. Upholding the tenets of research integrity can be particularly challenging in the context of such collaborative arrangements. Broadly considered, participants in collaborations should practice transparency, reciprocity, and adherence to norms of research integrity, and should expect the same from other participants.

Transparency. An open science environment requires transparency between all partners. Although the meaning of "transparency" is likely to be context-dependent, at a minimum, it should include openly declaring all funding sources, individuals, and organizations involved in the collaboration as well as agreed upon requirements for flow of information and documents within the collaboration and between participants and their governments.

Reciprocity. Trustful and respectful collaboration is central to the responsible conduct of research. This includes equitable exchange of ideas, information, and data and ensuring that the research environment encourages a shared commitment to values and practices that support the integrity of the research. The expected degree of reciprocity with respect to data sharing in collaborative projects will also be context-dependent

Adherence to Norms of Research Integrity. Most collaborations, national or international, are based on widely accepted principles of research integrity and openness. Adherence to these principles should be required of all partners in a collaboration.

Research integrity within collaborations is compromised when researchers withhold information from the rest of the research team or collaboration and/or research findings are disseminated externally without discussion and concurrence with the team. Asymmetry in data sharing or access to collaborative facilities degrades reciprocity and the ability to maintain open and trustful relationships. Differences in scientific field and social cultural norms can add to the challenge of maintaining respectful communication within and across teams.

Often the agreements for international collaborations are made by individual U.S. universities without significant input from the NSF or other U.S. funding agency. The definition of what constitutes an acceptable reciprocal arrangement may be very different for an individual U.S. university than it may be for the NSF, particularly if the NSF has invested heavily over years to develop a particular research capability in the United States. This can be particularly problematic if the reciprocity involves a monetary contribution in return for technical expertise. Some guidelines for reciprocity might include:

- Access to data should be comparable between a foreign partner and a U.S. partner.
- Transparency should be reciprocal.
- To the extent possible, contributions should be "in kind," in addition to monetary contributions.

These principles, coupled with the core values discussed in Section 5, provide an unambiguous set of ethical standards for defining research integrity. It should not be taken for granted that every researcher from every country interprets these standards the same way. Research teams, collaborators, and educators should be proactive in having frequent discussion and review of what it means to conduct research responsibly, sharing the responsibility for maintaining research integrity.

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7 SECURING THE U.S. FUNDAMENTAL RESEARCH ENTERPRISE

Because of the integral nature of foreign research talent to our fundamental research enterprise, JASON assesses that retaliatory responses such as restricting the number of foreign students in the United States would likely do more harm to the United States than good. Diplomatic solutions, such as reciprocal agreements concerning foreign students in the United States could be negotiated, but still leave the U.S. research enterprise vulnerable to many of the practices we have described, and such treaties would be difficult to negotiate. Some academics believe that foreign students, educated in U.S. values, and other engagement will bring adversarial nations around to the U.S. way of thinking. This could be true, but there are few signs of progress.

JASON concludes that the most effective U.S. responses that could be put into place in the near term are: requirement of rigorous disclosure of affiliations and commitments, continued adherence to NSDD-189 as a framework for control of information, development and deployment of project assessment tools to assist stakeholders in securing fundamental research, and education of both the U.S. academic and research community as to the nature of the threat and the intelligence and law enforcement communities about the norms of fundamental research.

7.1 Disclosure

Disclosure of activities presents our main defense against foreign influence, especially that involving rewards, deception, and coercion. JASON recommends that applications for foreign scholars require disclosure of all affiliation, academic degrees, and courses completed. Applications are usually considered to be confidential, which will encourage accurate disclosures. Once at the U.S. host institution, foreign scholars should disclose any reporting requirements required by their fellowships or other conditions their home country attaches to their permission to study or work abroad. Income or rewards a foreign scholar receives should also be disclosed annually. Foreign scholars coming to work or study at U.S. universities or research institutions should be required to disclose the all the terms of the contract or fellowship supporting them, including any reporting or non-disclosure requirements.

U.S. faculty and research staff usually disclose their outside professional activities (OPA) to their employer annually. This is for the assessment of potential conflicts of interest and commitment at the institutional level. Requirements of OPA disclosure policies vary by institution but should include, at a minimum, listing and describing all positions and affiliations, including foreign positions and affiliations, each year. Foreign compensation and research support should also be reported. Most federal grant applications require disclosure of all current and pending research support and what is being supported by other agencies and foundations. NSF should continue to insist on reporting of foreign research support as part of the grant application process, making it clear that all support must be disclosed as part of the award process.

In the case of foreign research support or participation in a talent program, the full contract of the program should be disclosed to the granting agency or university. JASON finds that failing to disclose any aspect of a foreign engagement, either a foreign scholar coming to the United States or a U.S. researcher conducting funded research in a foreign country, compromises the integrity of the U.S. research enterprise. A failure to make the proper disclosure must then be treated as a violation of research integrity and should be investigated and adjudicated in the same way as, for example, falsification of data or plagiarism (i.e., research misconduct). In most U.S. research institutions, punishments for research misconduct can include demotion, loss of privileges, or dismissal. Granting agencies, such as NSF, can bar an individual from receiving further grant support, typically for a defined period. It is important to note that some forms of failure to make proper disclosure can also involve legal punishments, for example, willfully supplying incorrect information as part of a disclosure.

7.2 Adherence to NSDD-189

National Security Decisional Directive 189 (NSDD-189) is included in Appendix B and described in Section 3. NSDD-189 sets out the definition of fundamental research and specifies that research should be open unless it is deemed to be sensitive from a national security point of view, in which case it could be classified in the manner described in Executive Order 12356 and subsequent orders.

In the study charge, JASON was asked:

- Are there areas of fundamental research that should be more controlled rather than openly available?

- What controls, if any, could be placed on particular types of information and how can they be managed in a way that maintains the maximum benefit of the research of the open research environment for fundamental research?

In response, JASON concludes that it is neither feasible nor desirable to control areas of fundamental research beyond the mechanisms put in place by NSDD-189. Responding to the first question, it is not possible to draw boundaries around broad fields of fundamental research and define what is included and what is excluded (government controlled) in that discipline of inquiry. Artificial intelligence, for example, permeates broadly entire disciplines, including biology, chemistry, physics, materials science, mechanical engineering, and social science. Robotics similarly broadly impacts a wide swath of research endeavors, from biomedical engineering and drug discovery to advanced manufacturing and space exploration. Novel battery technologies involve fundamental studies of electrochemistry, surface science, materials science, physical chemistry, applied physics, and theory. The work in these broad areas is furthermore interconnected, making it even more difficult to define where one aspect of research stops, and another starts.

Fields of research change with time and can be fluid as technology evolves. In a time of extremely rapid discovery and technological change, it is difficult to make useful predictions of the future from past research. Students trained and performing research in one area, for example fundamental materials chemistry, today may take jobs in another field, for example an AI-based field that can make use of their broad problem-solving skills and analytical training and the ability to code. Vigorous investment and attractive opportunities in the private sector in many fields of research are blurring the boundaries of what defines a professional career in a particular field of endeavor.

Even if it were possible to crisply define specific fields of fundamental research that might be restricted, the costs of imposing restrictions on researchers that can work in those areas will deleteriously affect the available talent pool required to advance that strategic field of interest. For example, in the Department of Energy (DOE) laboratories primarily supported by the DOE Office of Science, the work that is being performed frequently exploits unique capabilities and/or infrastructure that is available at the laboratories. This infrastructure has been developed to serve the entire research community through collaboration, both national and international. Joint projects include Energy Frontier Research Centers, Energy Innovation Hubs, and Energy Materials Networks. A fluid exchange of people routinely occurs involving, for example, graduate students who are jointly supervised by national laboratory personnel and students who continue their work as post-doctoral fellows either formally appointed under the supervision of the national laboratory personnel or jointly supervised by them with non-laboratory personnel. These collaborations greatly leverage the limited personnel expertise and resources associated with the national laboratory and thus benefit the entire research ecosystem. Restrictions on personnel that can work with the national laboratories would impact the strength of the laboratories themselves.

The established, implemented categorization of research involves differentiation between fundamental research, classified research, or imposition of export control regulations (on certain types of advanced engineering-related applications of research). The fundamental research exemption is based on the idea that the general nature of the knowledge produced in fundamental research cannot be controlled. The main impetus for the control of information is usually considered to be prevention of the transmission of information that *might* be economically valuable from U.S. research labs to competitor nations. The uncertainty about the value of any fundamental research information stems from its fundamental nature. Making the case, for classification reasons, that a new technology might be of national security value is far simpler than assessing its potential economic impact, even if economic security is equated in some way with national security.

An intermediate layer of control already exists called controlled unclassified information (CUI) that might seem useful in fundamental research situations. However, new CUI categories for particular research areas will not solve this problem unless broad areas of fundamental research are deemed “born controlled” – subject to control until review removes the control. Such control would run counter to the notion that fundamental research is intended for open publication and would severely hinder the U.S. research enterprise. Universities and the U.S. government already have the means of protecting intellectual property through the patent process and non-disclosure agreements. They should be used as needed to protect information and modified if more protection is needed.

JASON concludes that the framework set forth in NSDD-189 continues to be relevant, creating a clear definition for fundamental research, declaring that most such research should be open and specifying when a specific application of knowledge from fundamental research should be classified.

7.3 Assessment Tools

The fundamental research ecosystem has a wide range of participants and stakeholders, each responsible for their own actions. The stakeholders include:

- The public
- Political leadership, e.g. members of U.S. Congress and the Executive Branch
- Federal funding agencies (e.g., NSF, NIH, DOD)
- Research Institutions (e.g., Universities, National Laboratories, Think Tanks)
- Research group leaders (e.g., department heads, institute and center directors
- Professional societies
- Publishers
- Principal investigators
- Scholars (e.g., research collaborators, staff, students, postdoctoral fellows)

JASON assesses that a powerful countermeasure against foreign influence would be the careful consideration of foreign engagements by stakeholders before they are initiated. This could be facilitated by a set of assessment tools in the form of a series of questions, tailored to the level of the stakeholder in question. These can be thought of as a catechism for fundamental research, a series of instructive questions upon which one is to reflect when making decisions about research engagements. Within the U.S. government the Heilmeier Catechism for assessing DARPA projects is well known[71]. For a principal investigator (PI) considering engaging with a foreign research entity, such a series of questions might be:

- Describe the engagement succinctly and without jargon. Is it fundamental research? If not, what are the institution's policies around creating the engagement?

- Are the terms of the engagement made clear in writing? Have all the participants been identified? Are all participants known to the PI and the PI's institution?

- Are all the participants conflicts of interest and commitment documented? Are there any aspects of the engagement that are not to be disclosed to any of the participants? If so, what is the reason?

- Is there any aspect of the engagement that seems unusual, unnecessary or poorly specified?

- Where does the funding and other resources needed for the activity come from? Is it clear what each party is providing?

- Are all of the tangible assets of the engagement, existing or to be generated (e.g., data, metadata, profits, equipment, etc.), known? How will they be shared? Who decides how they are allocated?

- How does a participant end their engagement?

- Are scholars expected to reside away from their home institutions as a part of the engagement? If so, how are they chosen for participation in the engagement?

- What are the reporting requirements back to home institutions or organizations?

- Who will control the dissemination of the resulting fundamental research?

These questions can be thought of as an assessment tool, meant to develop a fuller understanding of the engagement before a decision is made. A representative of a university or laboratory may consider a similar set of questions, modified to reflect the risks such institutions face. An example, based on that developed by the MIT Office of the Vice President for Research[72]:

- Is there a risk to U.S. national security?

- What are the political, civil and human rights risks?

- Is there a risk to U.S. national competitiveness?

- Will export control compliance be assured?

- What are the intellectual property risks?

- Are there clear data and publication policies?

- What is the early termination risk?

- What is misrepresentation risk?

- Is there a risk to the institution's community and core values?

- What is the risk to institution of *not* engaging?

Each stakeholder would have their own set of questions or guidelines based on relevance to a decision they are likely to be making – for scholars or institutions to engage or not to engage, for a journal, to publish or not to publish, for a funding agency, to fund or not to fund. The NSF and professional societies, both central to the U.S. research enterprise, could lead the development and promulgation of these tools. Table 1 presents examples of perceived rewards, perceived risks and obligations for the stakeholders in the U.S. research enterprise.

Table 1. U.S. researcher enterprise stakeholder rewards, risks and obligations in assessing engagements.

Stakeholders	Perceived rewards	Perceived Risk	Obligation
Public	Improved quality of life	Misinformation	Expect valid communication of science
Political Leadership	Advancement of science and the economic competitiveness through attracting top talent	Loss of economic advantage, IP loss, and infiltration	Top level guidance to agencies and national labs balancing risks and rewards
Federal funding agencies	Advance science through collaboration and ability to attract top talent	Compromise of research integrity	Develop clear policies and guidelines that enables responsible conduct of research
Research Institutions	Advancing their institutions' reputation through scholarship and attracting top talent	Reputational risks, IP loss, loss of talent, and loss of opportunity	Develop clear policies and guidelines that enables responsible conduct of research
Research group leaders	Advancing careers of faculty and students through opportunities and attracting top talent	Reputational risks, loss of access to talent and facilities	Foster a culture of reseach integrity and adherence to new policies
Professional societies	Advancing their field and attracting top talent	Being left behind	Developing workable guidelines specific to their field, statistics on activities
Publishers	Enhancing reputation	Good science published elsewhere	Fair and safe rigoruous review process
Principal Invesitgators	Access to research support, facilities, data and top talent	Loss of access to unique data, research funds, and talent	Ensure and educate about research integrity, insist on workable agreements in collaborations
Scholars	Access to facilities, data, mentors, and collaborators	Loss of jobs, degrees, and careers	Responsible conduct of research

7.4 Education and Outreach

Foreign influence of the U.S. research enterprise is an emerging threat and the research community must understand the nature of the threat and our responses to it. The typical academic researcher in a U.S. university has little contact with the U.S. intelligence community (IC) or law enforcement, but does have daily contact with foreign scholars, particularly graduate students and postdocs, and frequent contact with faculty peers in other nations. Academics value these contacts – even though nations may be at odds over substantial issues, broad-based scientific discourse brings academics together over the common desire to develop scientific knowledge.

The IC, law enforcement, and university administrations have the complex task of communicating an emerging threat that is relatively diffuse and vague to a largely unreceptive audience. Part of the problem has been the cultural differences between academics and those with the deepest knowledge of the threat. Representatives of the IC are used to briefing audiences that understand that the IC cannot openly share much of the information it holds. Academic audiences often do not understand the IC's function as providing early warning to policy makers, rather than provers of fact. Similarly, the IC and law enforcement agencies lack an understanding of how academic research labs operate, and the advising and mentoring relationships that exist between faculty members and the range of researchers who work with them. Consequently, briefings from the IC, law enforcement, and university administrations have been met with disbelief and derision by their academic audiences. Requests from academics for further supporting information are often met with the refrain "I can't tell you; it's classified.", frustrating those used to having full access to information and data in their research. The IC and law enforcement briefers may feel distrusted and dismissed by those they believe they are trying to help.

In the course of many interactions on a range of topics, JASON has found that IC and law enforcement members are receptive to these concerns; a concerted effort to improve communication is likely to have both short-term benefit for the current situation, and long-term benefit for future challenges. JASON concludes that NSF should be the facilitator of more effective communication between the academic community and IC and law enforcement. This might take several forms, including encouraging the declassification of information related to foreign influence in fundamental research, and convening meetings between interested parties from all sides.

The IC and law enforcement have given a partial picture of foreign influences on the U.S. fundamental research enterprise. JASON has assessed that there is indeed a threat that appears to be growing in scale, requiring a response. In this section, we have recommended a response that is proportional to our assessment of the threat. A useful question to ask at this point is, "What risk to research do the recommended solutions pose if the picture assessment from the IC is not correct, and there is in fact no substantial threat?" JASON believes our recommended course presents little threat to the functioning of the U.S. fundamental research enterprise. We have suggested that the problem of foreign influence can be met by a combination of more robust research integrity measures, careful consideration of risks before entering into foreign engagements and better information exchange between the IC, law enforcement, and academia – all of which are good in any circumstance. We note in particular that expanded expectations with respect to reporting conflicts and commitments would have the strong benefit of making the academic system fairer for all.

8 SUMMARY

Foreign scholars are a boon to the U.S. research enterprise and economy, and the United States need to continue to recruit and cultivate the best international talent to maintain the preeminent position of the United States in science and technology. Many foreign scholars stay in the United States and contribute to our scientific enterprise and those that return remain colleagues and help to build trust between nations engaged in what is increasingly an international scientific enterprise. However, it cannot be ignored that some foreign scholars in the United States participate in programs of the governments and institutions of their home countries that violate U.S. norms of science ethics and research integrity. These actions pose a threat to the U.S. fundamental research enterprise.

JASON concludes that many of the problems of foreign influence that have been identified are ones that can be addressed within the framework of research integrity, and that the benefits of openness in research and of the inclusion of talented foreign researchers dictate against measures that would wall off particular areas of fundamental research. We expect that a reinvigorated commitment to U.S. standards of research integrity and the tradition of open science by all stakeholders will drive continued preeminence of the United States in science, engineering, and technology by attracting and retaining the world's best talent.

JASON presents the following Findings and Recommendations in response to the study charge from NSF.

8.1 Findings

1. There is a long and illustrious history of foreign-born scientists and engineers training and working in the United States, and they make essential contributions to our preeminence in science, engineering and technology today. Maintaining that leading position will require that the United States continues to attract and retain the best science talent globally.

2. The United States upholds values of ethics in science, including objectivity, honesty, accountability, fairness and stewardship (NAS 2017 *Fostering Integrity in Research*). These values protect research integrity, upon which credibility of the fundamental research enterprise, and the entire academic system, is based.

3. Actions of the Chinese government and its institutions that are not in accord with U.S. values of science ethics have raised concerns about foreign influence in the U.S. academic sector. JASON reviewed classified and open-source evidence suggesting that there are problems with respect to research transparency, lack of reciprocity in collaborations and consortia, and reporting of commitments and potential conflicts of interest, related to these actions.

4. The scale and scope of the problem remain poorly defined, and academic leadership, faculty, and front-line government agencies lack a common understanding of foreign influence in U.S. fundamental research, the possible risks derived from it, and the possible detrimental effects of restrictions on it that might be enacted in response.

5. Conflicts of interest and commitment in the research enterprise can be broader than those that are strictly financial, including those that might occur in foreign research collaborations or result from required reporting obligations for scholarships or grants.

6. There are many stakeholders with responsibility for the integrity of fundamental research, from U.S. government agencies to individual scholars, each with particular perspectives, roles and responsibilities. Universities and research funding agencies have policies and guidelines regarding some of these responsibilities, but these are often insufficient for individuals to assess risk and take appropriate actions.

7. National Security Decision Directive (NSDD) 189, established in 1985 a clear distinction between fundamental research and classified research. This remains a cornerstone to the fundamental-research enterprise, as officially reaffirmed in 2001 and 2010, and it continues to inform policy today.

8. Universities have mechanisms to handle Controlled Unclassified Information (CUI) under existing categories, such as HIPAA, FERPA, Export control, and Title XIII. CUI protection is difficult, but suited to these tasks, however it is ill-suited to the protection of fundamental research areas.

9. International researchers in the United States are partners in our research enterprise, and, consequently, in the effort to strengthen research integrity nationally and globally.

8.2 Recommendations

1. The scope of expectations under the umbrella of research integrity should be expanded to include full disclosure of commitments and actual or potential conflicts of interest.

2. Failures to disclose commitments and actual or potential conflicts of interest should be investigated and adjudicated by the relevant office of the NSF and by universities as presumptive violations of research integrity, with consequences similar to those currently in place for scientific misconduct.

3. NSF should take a lead in working with NSF-funded universities and other entities, as well as professional societies and publishers to ensure that the responsibilities of all stakeholders in maintaining research integrity are clearly stated, acknowledged, and adopted. Harmonization of these responsibilities with those of other federal research-funding agencies is encouraged.

4. NSF should adopt, and promulgate to all stakeholders, project assessment tools that facilitate an evaluation of risks to research integrity for research collaborations, and for all non-federal grants and research agreements.

5. Education and training in scientific ethics at universities and other institutions performing fundamental research should be expanded beyond traditional research integrity issues to include information and examples covering conflicts of interest and commitment.

6. NSF should support reaffirmation of the principles of NSDD-189, which make clear that fundamental research should remain unrestricted to the fullest extent possible, and should discourage the use of new CUI definitions as a mechanism to erect intermediate-level boundaries around fundamental research areas.

7. NSF should engage with intelligence agencies and law enforcement to communicate to academic leadership and faculty an evidence-based description of the scale and scope of problems posed by foreign influence in fundamental research, as well as to communicate to other government agencies the critical importance of foreign researchers and collaborations to U.S. fundamental research.

8. NSF should further engage with the community of foreign researchers in the United States to enlist them in the effort to foster openness and transparency in fundamental research, nationally and globally, as well as to benefit from their connections to identify, recruit and retain the best scientific talent to the United States

9. NSF and other relevant U.S. government agencies should develop and implement a strategic plan for maintaining our competitiveness for the top science and engineering talent globally, taking advantage of new opportunities for engagement that might arise, even as others become more challenging.

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APPENDIX A: Statement of Work

Fundamental Research and National Security
National Science Foundation (Jim Ulvestad, Rebecca Keiser)
28 February 2019

Statement of the Problem: Historically, the national security and economic well-being of the United States have benefited from an open scientific ecosystem, as laid out in *Science, the Endless Frontier* (Vannevar Bush) and in numerous National Academies efforts such as the 2009 National Research Council Committee on Science, Security and Prosperity's "Beyond Fortress America" consensus study.

NSF seeks an exploration by JASON of the approach reflected in the documents cited above and whether to recommend any policy changes in the current international environment.

What has Changed? The wide variety of communication methods, mobility of people and investments in science in today's world have made it challenging to understand all the uses for that information. Government security organizations say that the "paradigm has shifted" and that our open system is being used by others in detrimental ways. White House documents about economic aggression from China, proposed legislation, and communications to/from university groups and government agencies focus on security concerns of fundamental research, much of it at our nation's universities, colleges, and research institutions (see Works Cited). Recent reports from the U.S.-China Economic and Security Review Commission and the Hoover Institution have described security issues relating to students from China, and student associations, at U.S. universities. Research funding agencies and the academic community are trying to assess and evaluate this paradigm shift and whether it should motivate policy changes in the traditional U.S. ecosystem.

What Expertise is Needed? JASON is uniquely qualified to explore the issues related to the U.S. science ecosystem because of its connection to that ecosystem and its background in national security issues. Individuals with the following expertise should be involved in the assessment:

- Historical understanding of the benefits and risks of the U.S. science ecosystem with regard to economic development and national security.
- Understanding of the definitions of fundamental and applied research, how they are distinguishable, and how they overlap.
- Understanding of the U.S. research ecosystem and its dependence on non-U.S. talent.

- Knowledge in key areas of particular interest for national security, such as artificial intelligence, quantum information science, genomics, synthetic biology, and space situational awareness.

- Awareness of methods used by other nations to exploit the U.S. fundamental research ecosystem, as well as specific threats, and U.S. efforts to counter that exploitation.

Objectives and Deliverables: NSF seeks an assessment of the topics listed below.

- **Fundamental Research:** What is the value and what are the risks of openness generally associated with fundamental research? How should the principles of scientific openness on which the NSF was founded in 1950 be affirmed or modified?

- **Fundamental and Applied Research:** Where do the boundaries lie between fundamental research that should remain open and more applied research whose distribution may be restricted? How should NSF assist the academic community in understanding those boundaries?

- **Risk Areas:** Are there particular areas of fundamental research for which information should be controlled rather than openly available? What are those areas, what controls should be placed on information, and how can this be managed in a way that maintains the maximum benefit of the traditional open environment for fundamental research?

- **Good Practices:** What good practices should be followed by academic researchers in all disciplinary areas, and perhaps institutionalized by NSF, to balance the open environment of fundamental research with the needs for national (and economic?) security?

Key Questions: NSF would like an unclassified report that can be widely disseminated and discussed in the academic community, possibly with a classified version or appendix that provides technical or other data about specific security concerns.

This report should address, at minimum, the following questions. These questions may be revised or modified as the study is undertaken:

1. What is the value and what are the risks of openness generally associated with fundamental research?

2. How should the principles of scientific openness be affirmed or modified?
3. Are there areas of fundamental research that should be more controlled rather than openly available? What are those areas?

4. What controls, if any, could be placed on particular types of information, and how can this be managed in a way that maintains the maximum benefit of the open research environment for fundamental research?

5. What good practices could be put into place by academic researchers to balance the open environment of fundamental research with the needs for national (and economic) security?

6. What good practices could be put into place by funding agencies such as NSF to balance the open environment of fundamental research with the needs for national (and economic) security?

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APPENDIX B: Text of NSDD-189

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September 21, 1985

NATIONAL POLICY ON THE TRANSFER OF SCIENTIFIC, TECHNICAL AND ENGINEERING INFORMATION

I. PURPOSE

This directive establishes national policy for controlling the flow of science, technology, and engineering information produced in federally-funded fundamental research at colleges, universities, and laboratories. Fundamental research is defined as follows:

> "'Fundamental research' means basic and applied research in science and engineering, the results of which ordinarily are published and shared broadly within the scientific community, as distinguished from proprietary research and from industrial development, design, production, and product utilization, the results of which ordinarily are restricted for proprietary or national security reasons."

II. BACKGROUND

The acquisition of advanced technology from the United States by Eastern Bloc nations for the purpose of enhancing their military capabilities poses a significant threat to our national security. Intelligence studies indicate a small but significant target of the Eastern Bloc intelligence gathering effort is science and engineering research performed at universities and federal laboratories. At the same time, our leadership position in science and technology is an essential element in our economic and physical security. The strength of American science requires a research environment conducive to creativity, an environment in which the free exchange of ideas is a vital component.

In 1982, the Department of Defense and National Science Foundation sponsored a National Academy of Sciences study of the need for controls on scientific information. This study was chaired by Dr. Dale Corson, President Emeritus of Cornell University. It concluded that, while there has been a significant transfer of U.S. technology to the Soviet Union, the transfer has occurred through many routes with universities and open scientific communication of fundamental research being a minor contributor. Yet as the emerging government-university-industry partnership in research activities continues to grow, a more significant problem may well develop.

III. POLICY

It is the policy of this Administration that, to the maximum extent possible, the products of fundamental research remain unrestricted. It is also the policy of this Administration that, where the national security requires control, the mechanism for control of information generated during federally-funded fundamental research in science, technology and engineering at colleges, universities and laboratories is classification. Each federal government agency is responsible for: a) determining whether classification is appropriate prior to the award of a research grant, contract, or cooperative agreement and, if so, controlling the research results through standard classification procedures; b) periodically reviewing all research grants, contracts, or cooperative agreements for potential classification. No restrictions may be placed upon the conduct or reporting of federally-funded fundamental research that has not received national security classification, except as provided in applicable U.S. Statutes.

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Notes

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[1] Full report, "*Science, The Endless Frontier,*" available at https://www.nsf.gov/about/history/nsf50/vbush1945.jsp.

[2] Full act, "*National Science Foundation Act,*" available at https://legcounsel.house.gov/Comps/81-507.pdf.

[3] Examples include Nobel laureates George Palade (Romania), Albert Szent-Györgyi (Hungary), and Joachim Frank (Germany), who spent the war years in Europe. Nobel laureate Yoichiro Nambu (Japan) worked in Tokyo on radar research, but later emigrated to the U.S. The American space program famously benefitted from the assimilation of former Nazi rocketeer Wernher von Braun. Source: "List of Nobel laureates by country."

[4] See: Cervantes, M. and D. Guellec. "The brain drain: Old myths, new realities," https://oecdobserver.org/news/archivestory.php/aid/673/The_brain_drain:_Old_myths,_new_realities.html.

[5] Japanese-American Nobel laureates include Yoichiro Nambu and Shuji Nakamura (Physics), who are Japanese-born U.S. citizens, along with Susumu Tonegawa (Physiology or Medicine), Osamu Shimomura and Ei-ichi Negishi (Chemistry), who are permanent U.S. residents. Source: "List of Nobel laureates by country."

[6] Chinese-American Nobel laureates include Chen Ning Yang, Tsung-Dao Lee, Samuel C.C. Ting, Steven Chu, Daniel Chee Tsui, and Charles K. Kao (Physics), and Yuan T. Lee and Roger Tsien (Chemistry). All hold (or held) U.S. citizenship. C.N. Yang, T.-D. Lee, D.C. Tsui, and C. Kao were born in China; Y.T. Lee was born in Taiwan. R. Tsien, S. Chu, and S. Ting were born in the U.S. to Chinese émigré parents. Fields Medals were won by Terence Chi-Shen Tao and Shing-Tung Yau. Tao was born in Australia to Chinese émigrés from Hong Kong and is now a U.S. citizen; Yau was born in China and is now a U.S. citizen. Source: "List of Nobel laureates by country."

[7] Indian-American Nobel laureates include Har Gobind Khorana and Venkatraman "Venki" Ramakrishnan for Physiology or Medicine; and Subrahmanyan Chandrasekhar in Physics. All three were born in India and subsequently became U.S. citizens. Ramakrishnan holds dual U.S. and U.K. citizenship. Source: "List of Nobel laureates by country."

[8] The hard science categories are Chemistry, Physics, and Physiology or Medicine. There have been 288 Nobel laurates in science since the first U.S. recipient in 1914 (Theodore Richards, Chemistry), 85 of whom were born outside this country. In addition, one U.S. dual national (Michael Levitt, Chemistry, 2013) chose to accept the Nobel Prize as an Israeli. Source: "List of Nobel laureates by country."

[9] See: NIH, "Appropriations History by Institute/Center (1938 to Present)," at https://officeofbudget.od.nih.gov/approp_hist.html and NSF "NSF Funding by Account" https://dellweb.bfa.nsf.gov/NSFFundingbyAccount.pdf

[10] QS World University Rankings places 11 U.S. universities among the top 20; see https://www.topuniversities.com/university-rankings/world-university-rankings/2019. U.S. News & World Report Best Global University Rankings places 16 U.S. universities among the top 20; see: https://www.usnews.com/education/best-global-universities/rankings. The Best Schools places 16 U.S. universities among the top 20; see: https://thebestschools.org/rankings/best-universities-world-today. The Times Higher Education World University Rankings survey places 15 U.S. universities among the top 20; see: https://www.timeshighereducation.com/world-university-rankings/2019/world-ranking#!/page/0/length/25/sort_by/rank/sort_order/asc/cols/stats.

[11] National Science Board, National Science Foundation. *Higher Education in Science and Engineering. Science and Engineering Indicators 2020*. Available at https://ncses.nsf.gov/pubs/nsb20197/.

[12] National Foundation for American Policy. *The Importance of International Students to American Science and Engineering*. NFAP Policy Brief, available at https://nfap.com/wp-content/uploads/2017/10/The-Importance-of-International-Students.NFAP-Policy-Brief.October-20171.pdf.

[13] Ibid.

[14] Ibid.

15 Source: National Science Board, National Science Foundation. *Higher Education in Science and Engineering. Science and Engineering Indicators 2020*. NSB-2019-7. Available at: https://ncses.nsf.gov/pubs/nsb20197/.

16 Source: National Science Foundation, National Center for Science and Engineering Statistics. *Doctorate Recipients from U.S. Universities: 2017.* NSF 19-301. Available at: https://ncses.nsf.gov/pubs/nsf19301/data.

17 Ibid.

18 Source: National Science Foundation, National Center for Science and Engineering Statistics. "Survey of Doctorate Recipients, 2015." Available at: https://ncsesdata.nsf.gov/doctoratework/2015/.

19 Source: Chen, Stephen. "China's Brain Drain to the U.S. is Ending, Thanks to Higher Salaries and Donald Trump." Available at: https://www.scmp.com/news/china/science/article/2163001/chinas-brain-drain-us-ending-thanks-higher-salaries-and-donald.

20 Source: Zhou, Youyou. "Chinese students increasingly return home after studying abroad." Available at: https://qz.com/1342525/chinese-students-increasingly-return-home-after-studying-abroad/.

21 For example: "*International Science and Engineering Partnerships: A Priority for U.S. Foreign Policy and Our Nation's Innovation Enterprise*"; "*2012 Global R&D Funding Forecast*"; "*2018 Global R&D Funding Forecast*"; *SCImago Journal & Country Rank*.

22 Source: Battelle. "Battelle-R&D Magazine Release Newest Global Research Funding Forecast." Available at: https://www.battelle.org/newsroom/press-releases/press-releases-detail/battelle-r-d-magazine-release-newest-global-research-funding-forecast.

23 Ibid.

24 Source: R&D Magazine. *2018 Global R&D Funding Forecast*. Available at: https://www.rdworldonline.com/2018-global-rd-funding-forecast-snapshot/.

25 Full text of, "*The 13th Five-Year Plan For Economic And Social Development Of The People's Republic Of China (2016–2020),*" available at: http://en.ndrc.gov.cn/newsrelease/201612/P020161207645765233498.pdf.

26 Source: National Science Board, National Science Foundation. *International Science and Engineering Partnerships: A Priority for U.S. Foreign Policy and our Nation's Innovation Enterprise.* NSB-08-4. Available at: https://www.nsf.gov/pubs/2008/nsb084/nsb084.pdf.

27 See: Redden, Elizabeth. "Ready to Go Expat?" Available at: https://www.insidehighered.com/news/2017/07/26/several-countries-launch-campaigns-recruit-research-talent-us-and-elsewhere.

28 See: *The Thousand Talents Plan*. Available at: http://www.1000plan.org.cn/en/plan.html.

29 Full text of, Portman, Rob. *Threats to the U.S. Research Enterprise: China's Talent Recruitment Plans,* available at: https://www.hsgac.senate.gov/imo/media/doc/2019-11-18%20PSI%20Staff%20Report%20-%20China's%20Talent%20Recruitment%20Plans%20Updated2.pdf.

30 NSDD-189. Full text available at: https://fas.org/irp/offdocs/nsdd/nsdd-189.htm. Original text at: https://catalog.archives.gov/id/6879779.

31 Full letter available at: https://fas.org/sgp/bush/cr110101.html.

32 Full memorandum available at: https://www.acq.osd.mil/dpap/dars/pgi/docs/2012-D054%20Tab%20D%20OUSD%20(ATL)%20memorandum%20dated%20May%2024%202010.pdf.

33 See: National Research Council, *Science and Security in the Post 9/11 World: A Report Based on Regional Discussions Between Science and Security Communities*, available at: https://www.nap.edu/catalog/12013/science-and-security-in-a-post-911-world-a-report.

34 Ibid.

35 See: "Controlled Unclassified Information." Available at: https://en.wikipedia.org/wiki/Controlled_Unclassified_Information.

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