VISITING COMMITTEE ON ADVANCED TECHNOLOGY
National Institute of Standards and Technology

2018 Annual Report

Visiting Committee on Advanced Technology of the National Institute of Standards and Technology

U.S. Department of Commerce

April 2019

Preface

The Visiting Committee on Advanced Technology (VCAT or the Committee) of the National Institute of Standards and Technology (NIST or the Institute) was established in its present form by the Omnibus Trade and Competitiveness Act of 1988 and updated by the America COMPETES Act in 2007 and the American Innovation and Competitiveness Act of 2017. The VCAT is a Federal Advisory Committee Act (FACA) committee and its charter includes reviewing and making recommendations regarding general policy for NIST, its organization, budget, and programs within the framework of applicable national policies as set forth by the president and the Congress. This 2018 annual report covers the period from the beginning of March 2018 through February 2019.

The Committee reviews the Institute's strategic direction, performance and policies, and provides the Secretary of Commerce, Congress, and other stakeholders with information on the value and relevance of NIST's programs to the U.S. science and technology base and to the economy. At the first meeting of each year, the Director of NIST proposes areas of focus to the Committee and agreement is reached on a program for the year. Over the past year, the Committee has been active in assessing NIST's contributions to and progress in the following areas:

- NIST programs in emerging technologies and national priorities
  - Quantum Information Science
  - Artificial Intelligence
  - Advanced Communications
  - Cybersecurity
  - Advanced Manufacturing
- NIST efforts to strengthen Technology Transfer
  - The Return on Investment Initiative
  - The NIST-on-A-Chip Program
- NIST facility needs and ongoing renovation projects in both Gaithersburg and Boulder

The Committee reviews a significant portion of NIST programs through direct discussion with NIST leaders, scientists, and engineers. Reactions and observations of the Committee members are presented candidly to the NIST senior management and other attendees at each meeting. This feedback encourages continuous improvement in key areas in the overall operation. The Committee also visits various NIST laboratories and satellite facilities to discuss research projects directly with the technical staff. These laboratory tours help the Committee to assess the impact of NIST research, progress towards achieving research goals, the quality of the staff, institutional culture – especially related to safety and security - and the efficacy of the facility infrastructure.

Under the Committee charter, the Director of NIST appoints the VCAT members. Members are selected on a clear, standardized basis, in accordance with applicable Department of Commerce guidance. Members are selected solely on the basis of established records of distinguished service; provide representation of a cross-section of traditional and emerging U.S. industries; and are eminent

in fields such as business, research, new product development, engineering, labor, education, management consulting, environment, and international relations. No employee of the Federal Government can serve as a member of the Committee. Members are appointed for staggered three-year terms.

Seven new members were appointed during the period covered by this report: Mr. Jay Alexander (Keysight Technologies), Mr. George Fischer (Verizon Enterprise Solutions), Dr. Dana (Keoki) Jackson (Lockheed Martin), Ms. Katharine Ku (Stanford University), Dr. Mehmood Khan (PEPSICO), Dr. Eric Kaler (University of Minnesota), and Dr. Vinton Cerf (Google); three members were reappointed to a second term: Dr. Theodore (Tod) Sizer (Nokia Bell Labs), Dr. Allen Adler (HRL Laboratories, LLC), and Dr. Waguih Ishak (Corning Incorporated); and one member served two complete terms: Mr. William Holt (Intel Corporation Retired).

This report highlights the Committee's observations, findings and recommendations. Detailed meeting minutes and presentation materials are available on the NIST web site at www.nist.gov/director/vcat.

VCAT Members during the Period Covered by this Report

Dr. Rita R. Colwell, Chair
University of Maryland at College Park
Term: January 6, 2014 – January 5, 2020

Dr. Allen Adler
HRL Laboratories, LLC
Term: January 25, 2016 – January 24, 2022

Mr. Jay Alexander
Keysight Technologies
Term: May 22, 2018 – May 21, 2021

Dr. Rodney Brooks
Rethink Robotics
Term: June 1, 2014 – May 31, 2020

Dr. Vinton G. Cerf
Google
Term: December 21, 2018 – December 20, 2021

Mr. George Fischer
Verizon Enterprise Solutions
Term: May 22, 2018 – May 21, 2021

Mr. Michael Garvey
M-7 Technologies
Term: January 23, 2015 – January 22, 2021

Dr. Waguih Ishak
Corning Incorporated
Term: January 25, 2016 – January 24, 2022

Dr. Dana (Keoki) Jackson
Lockheed Martin
Term: May 22, 2018 – May 21, 2021

Dr. Eric Kaler
University of Minnesota
Term: December 21, 2018 – December 20, 2021

Dr. Mehmood Khan
PEPSICO
Term: November 13, 2018 – November 12, 2021

Ms. Katharine Ku
Stanford University, Emerita
Term: May 22, 2018 – May 21, 2021

Ms. Hemma Prafullchandra
Microsoft
Term: October 27, 2014 - October 26, 2020

Dr. Theodore Sizer
Nokia Bell Labs
Term: August 28, 2015 – August 27, 2021

Mr. David Vasko
Rockwell Automation
Term: February 2, 2017 – February 1, 2020

Dr. Gail Folena-Wasserman
MedImmune
Term: January 30, 2017 – January 29, 2020

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1. VCAT Focus in 2018

In 2018, the work of the VCAT was centered around three major themes, the role of NIST in emerging technologies and area of national priority, technology transfer, and the facility and infrastructure requirements of NIST. The VCAT has long been engaged with NIST's work in cybersecurity and advanced manufacturing and were updated on NIST's efforts in these areas. Additionally, with the administration placing high-priority on areas of emerging technology that impact national security and economic competitiveness the VCAT felt it essential to focus on the role that NIST is playing in Quantum Information Science, Artificial Intelligence, and Advanced Communications. The VCAT received detailed programmatic briefings in all these areas, toured the unique NIST facilities and met with key policy makers. In the area of technology transfer NIST has undertaken a major effort to strengthen and enhance the transfer of technology from federal laboratories, which is known as the Return on Investment Initiative (ROI). The VCAT was briefed on NIST's ROI-related efforts as well as programs to improve the transfer of NIST-developed technologies. To continue to track these efforts and bring in additional relevant expertise the VCAT formed a subcommittee on Technology Transfer. The VCAT was also briefed on the status of NIST's physical infrastructure and laboratory facilities, as well as ongoing renovation projects in both Gaithersburg and Boulder. The VCAT believes that the deteriorating state of many of NIST's facilities, the majority of which are over 50 years old could have significant impacts on NIST's ability to remain at the cutting edge of measurement science research. This 2018 Annual report summarizes the VCAT's work, observations, and recommendations related to these topics.

2. NIST Programs in Emerging Technologies and National Priorities

NIST is well positioned to play a key role in supporting the advancement of multiple emerging technologies that will be critical to future national security and economic competitiveness for the U.S. The VCAT reviewed NIST plans, which build upon the planning work that the VCAT was briefed on in 2017, and its efforts focused on the development of administration R&D priorities and policies in the areas of Quantum Information Science, and Artificial Intelligence. In addition, the VCAT had the first-hand opportunity to review NIST's research programs, facilities, partnerships, and industry services targeting advanced communications, including efforts focused on public safety communications when it visited the NIST Boulder labs in October. Additionally, the VCAT was updated on NIST's continuing efforts to advance and support work in advanced manufacturing and cybersecurity. The work of the VCAT on these issues is summarized below.

2a. NIST and Quantum Information Science

Leadership in Quantum Information Science is a key priority for the nation that will have lasting impact on national security and our long-term economic competitiveness. NIST's world-leading expertise in quantum science, conducted with academic and industry partners, is furthering the development of new quantum measurement technologies upon which U.S. companies can build new businesses and services and has positioned NIST to be a key player in the National effort to achieve "quantum supremacy". In 2018 the VCAT reviewed NIST's engagements in the development of a

National Quantum Initiative, and in the ongoing and planned NIST programmatic efforts in this space.

Over the past year it was clear to the VCAT that NIST has been effectively working with interagency partners in OSTP, DOE, NSF, DOD and other agencies to build a comprehensive National Quantum Initiative. The VCAT is pleased to see that NIST's role in developing the scientific and technical foundation upon which a quantum industry can be built is recognized and called out in both the National Strategic Overview for Quantum Information Science developed and released by OSTP, as well as in the National Quantum Initiative Act which codifies much of NIST's ongoing role. The NQI, which passed the House in September calls on NIST to:

- Continue and expand QIS research and the development of measurement and standards infrastructure
- Train scientists in QIS
- Establish or expand existing partnerships or consortia
- Provides OTA for the NQI related activities
- Hold within 1 year a workshop that convenes stakeholders on future measurements and standards
- Report to Congress not later than 2 years the results of that workshop

The VCAT believes that NIST is well positioned to succeed in this field, but to ensure that the U.S. is able to attain "quantum supremacy" additional resources will be needed. NIST has laid out a very well thought out plan for its future work in the area of QIS that focus on the following three elements:

- Quantum Engineering: NIST will develop the measurement tools to engineer materials, structures, and devices that will be the core building blocks for a broad collection of future quantum technologies, including a true quantum computer. With additional resources NIST would be able to grow new capabilities at NIST and also expand existing and establish new joint institutes and centers of excellence in quantum engineering. NIST's efforts in quantum engineering will help accelerate the establishment of capabilities in quantum-based sensors, quantum enabling technologies (e.g. transducers, interconnects), and quantum engineering (fabrication and characterization methods). The new metrological tools developed by NIST will underpin a robust quantum engineering framework and enable an entire industry to tackle core challenges of developing and manufacturing quantum technologies. Program elements will fast-track the application of quantum science, leverage advances in quantum technology for standards and measurements, and provide U.S. leadership in fundamental research into quantum phenomena.
- Foundational Quantum (Information) Science and Metrology: NIST is positioned to build upon its foundational quantum successes such as the quantum logic clock, near quantum-limited amplification of weak signals, and characterization of quantum many-body systems,

and the pioneering of quantum simulation. NIST needs the capability to exploit the benefits of quantum information science for improved measurement capabilities.

- Quantum SI (Système International d'Unités): Quantum breakthroughs will allow NIST to redefine how weights and measures are disseminated, improving accuracy and precision while eliminating the costly and time-consuming calibration chains. With the 2019 redefinition of the SI to one based on laws of nature instead of physical artifacts, additional resources will position NIST to exploit its leadership in quantum science to deliver a new suite of measurement technologies upon which U.S. companies can build new businesses and services.

The VCAT believes that NIST's focus on quantum engineering will be of significant benefit to overall U.S. efforts. In establishing themselves as a world leader in Atomic, Molecular, and Optical science, NIST researchers have built unique competencies in quantum engineering and technology. As the field matures and opportunities are identified to transition scientific breakthroughs to the marketplace, NIST is well positioned to facilitate such transitions. The VCAT believes that at this point in the evolution of Quantum Science, pre-competitive consortia would be helpful, and we are glad to see that NIST is participating in the establishment of the Quantum Economic Development Consortia (QED-C) in partnership with SRI. The QED-C will play an important role in helping expand U.S. leadership in global quantum R&D and the emerging quantum industry in computing, communications and sensing. With funding from both the government and private-sector member organizations, the consortium fosters public-private sector coordination and will help determine workforce needs, provide access to technology platforms and processes, foster sharing of intellectual property, and other developments required to support the quantum economy. However, the VCAT also recognizes that engagement in rapidly developing new markets carries certain reputational risks. We are pleased to see that NIST leadership is mindful of these risks and is committed to managing them proactively.

RECOMMENDATIONS:

- Quantum SI (Système International d'Unités): NIST has played a crucial role in redefining weights and measures allowing improved accuracy and precision while eliminating the costly and time-consuming calibration chains. We encourage NIST to work to transfer these technologies to industry where they can be leveraged in the next generation of self-calibrating sensors.

2b. Artificial Intelligence

Advances in artificial intelligence (AI) promise transformative technologies and scientific breakthroughs that will improve our lives in myriad ways, such as driverless cars, smart buildings, automated health diagnostics, and improved security monitoring. This disruptive technology will also bring with it significant challenges related to workforce, security, privacy, and a host of other issues. It is therefore no surprise that this technology area has been identified as a top technological priority by the Trump administration.

The economic impacts of poorly designed or implemented AI and data systems could be devastating to our nation, as skepticism and distrust may cause the U.S. to collectively neglect the potential advantages and lose out on the economic gains from AI. To overcome this, we must address the widespread concerns about reliability in applications of AI, from self-driving cars to automated health diagnostics. Agreed upon measures for AI systems and methods for assessing performance are lacking and must originate from a neutral and reputable source. NIST can play an important role in the development of these needed tools. The VCAT reviewed NIST's plans to provide this foundation of trust for AI systems and technologies.

NIST efforts in AI are focused on 2 primary lines of effort:

1. Improving confidence in AI: NIST is working to grow and expand its technical capabilities in order to develop the rigorous scientific testing necessary for trustworthy and safe AI, by both recruiting new FTEs, establishing a visiting fellows program, and working to provide training opportunities to NIST staff. NIST will establish trust and confidence in AI by creating datasets, testing procedures, and associated tools that allow AI developers and users to assess the performance of their systems. Working in close partnership with industry will be important to the success of these activities.
2. Drive applications of AI to meet the NIST mission: Scientists across NIST are applying AI and machine learning solutions in areas such as Novel materials discovery, biosciences (e.g. protein folding), and medical imaging. For instance, AI techniques were recently applied by NIST that made possible the computational prediction and discovery of new metal-glass material hybrids at speeds 200 times faster than typically possible. The application of AI will be further advanced in other NIST research areas, such as the use of AI to improve the agility of robots to safely learn and quickly adapt to manufacturing environments in U.S. factories. These expanded NIST research capacities will be targeted at building the confidence and trust in AI systems necessary for American businesses to take full advantage of these transformational technologies.

The VCAT was provided in-depth briefings on NIST highlighting NIST efforts to date in each of these areas. NIST efforts to improve confidence in AI are largely built around the newly established NIST Fundamental and Applied Research and Standards for AI (FARSAI) program that is led by the Information Technology Laboratory. This program, in the short term, is designed to build the machine learning and AI expertise at NIST through AI training, the development of AI computing platform, the creation of an AI community of interest, and an AI visiting fellows program. The VCAT was particularly impressed with the AI community of interest that has been organized over the past year that represents over 50 distinct research projects across all the NIST labs. In long term, the FARSAI program will provide the tools and infrastructure necessary to measure and enhance the security and trustworthiness of AI systems and machine learning and augment capabilities in cybersecurity.

The VCAT's exploration of NIST efforts to apply AI and machine learning solutions to different NIST mission areas primarily focused on NIST work in advanced materials. An area where AI and

machine learning are having a particular impact, NIST has already begun to apply and utilize AI and machine learning tools is the Materials Genome Initiative (MGI) program. Early examples of success include improved materials modeling, enhanced classification of microscopy images, efficient phase diagram measurements, and enabling new materials measurements like strain tensor.

The VCAT is pleased to see the level of engagement and visibility that NIST has had in the development of the administration's priorities around AI, with key roles on the Office of Science and Technology Policy's Select Committee on Artificial Intelligence, as well as being a co-chair of the National Science and Technology Council's Subcommittee on Artificial Intelligence.

RECOMMENDATIONS:

Concerns regarding trust and safety of AI could limit adoption and place the US at a competitive disadvantage. NIST work to improve confidence is crucial to the well-planned adoption of AI. To accelerate research, increase utility for practitioners, and instill public confidence, NIST could play an important role in providing a framework and standards for validation of developing and existing Free and Open Source Software libraries in the AI/ML domain (currently this is done via crowdsourcing). NIST could also create new and credible ideas for evaluating the reliability of AI/ML processes, to include demonstrations of detection of ML failure modes.

2c. Advanced Communications

The VCAT held its October meeting at NIST's Boulder campus and as such had the opportunity to do an in-depth exploration of NIST's newest research laboratory, the Communications Technology Laboratory (CTL). The VCAT was briefed on the programs of the CTL and toured the unique facilities that NIST has developed to support advanced spectrum measurements.

Secure, reliable, high-speed wireless communications are critical to the economic and national competitiveness of the United States. Advanced communications are enabling dramatic changes in how consumers, manufacturers, governments and others provide and consume information, transact business, provide and use essential services, and shop, among other tasks. Gartner forecasts that there will be approximately 20.8 billion connected devices by 2020, up from the estimated 6.4 billion connected devices currently in place. This insatiable societal demand for connectivity will require significant advancements in communication technologies.

NIST's role in advanced communication includes:

- the National Advanced Spectrum and Communications Test Network (NASTCN), which is organizing a national network of Federal, academic and commercial test facilities that will provide the testing, modeling and analyses needed to develop and deploy spectrum-sharing facilities;
- the Public Safety Communications Research (PSCR) program, which is leading the development of the standards and performing the associated research, development and testing to provide the public safety community access to a dedicated, nationwide LTE broadband network (FirstNet);

- Developing and improving the measurement tools and technologies that will improve spectrum utilization, and the novel spectrum sharing techniques, to address the current spectrum crunch; and

- Providing the measurements and data needed for the development of the next generation of wireless communications systems and the improvement of optical communication technologies.

While CTL is NIST's smallest lab, the VCAT feels strongly that the role it plays in advancing spectrum sharing and enabling next generation communications technologies to take hold (like 5G communications) is of critical importance now, and the need will only continue to grow in the future.

2d. Advanced Manufacturing

A partner to the U.S. manufacturing sector for more than a century, NIST has a proven track record in delivering useful tools and technical assistance that existing manufacturers and aspiring start-ups need. Timely technical assists from NIST can help the nation's manufacturers to invent, innovate and create new products and services more rapidly and more efficiently than their competitors around the world. NIST works with the nation's manufacturers to invent, innovate, and create through precision measurements, development of advanced materials, and collaborative partnerships. In FY2018 the VCAT was provided an update on NIST activities focusing on advanced manufacturing, specifically examining the collaboration between the NIST programs.

The estimated support of manufacturing in the laboratory programs is $172 million, which is over 20 percent of the Scientific and Technical Research and Services budget and combined with $155 million from the Hollings Manufacturing Extension Partnership Program (MEP), it is approximately one-third of the total non-construction budget. The following NIST programs all contribute to NIST's support for advanced manufacturing:

- **NIST Laboratory Programs** collaborate with industry, academia, and other government agencies to develop the measurement and standards solutions to accelerate the development of the next generation of manufacturing technologies. A few key areas of NIST activity include robotics, Materials Genome Initiative, emerging technologies, and smart manufacturing.
- The **Hollings Manufacturing Extension Partnership (MEP)** facilitates and accelerates the transfer of manufacturing technology in partnership with industry, universities and educational institutions, state governments, NIST and other federal research laboratories and agencies.
- **Manufacturing USA** consists of linked Manufacturing Innovation Institutes with common goals, but unique concentrations. Here industry, academia, and government partners are leveraging existing resources, collaborating, and co-investing to nurture manufacturing innovation and accelerate commercialization.

The VCAT was pleased to see examples of collaborations between the NIST research programs and the MEP and Manufacturing USA programs, which showcases the increased impact that NIST can have on an area when it takes a "One NIST" approach, although the VCAT would note that there is still room for enhanced two-way collaboration and partnership. One particular area of opportunity is in workforce development. A number of the emerging technology areas that NIST is engaged in will have significant implications for the U.S. workforce, either requiring retraining in the case of mitigating the impacts of automation and AI, or in helping ensure the availability of a technically focused workforce in the case of microelectronics or quantum science and technology. Partnerships with MEP and Manufacturing USA give NIST a unique asset to potentially address these unique workforce challenges and NIST could contribute to filling the need for improved standards in certification and credentialing in advanced manufacturing.

RECOMMENDATIONS:

US Advanced Manufacturing branding: The US lacks a single program to focus advanced manufacturing, such as Germany's Industrie 4.0, and China's China 2025. There are dozens of advanced manufacturing programs around the world and the US seems alone in not having a common focus, even though the significant contributions NIST has done on Manufacturing USA, MEP, National Strategic Plan for Advanced Manufacturing, NIST Cyber security framework and the "Current Standards Landscape for Smart Manufacturing Systems" exceeds the body of work of nearly every national program. A common program focus would increase the impact, collaboration and consistency of US efforts and enable the US to be more competitive worldwide.

2e. Cybersecurity

In 2018 the VCAT reviewed NIST's ongoing efforts in cybersecurity and discussed the potential ramifications of attempts to expand NIST's roles in cybersecurity, including legislation that would give NIST an audit and quasi regulatory function.

NIST cultivates trust in technology through cybersecurity through a program that revolves around research, development, and transition to practice with industry. The VCAT was briefed on the progress that NIST has made in cryptography, risk management, and IOT cybersecurity:

- In cryptography NIST is leading a world-wide competition in quantum resistant cryptographic standards. NIST has received and is reviewing with industry and academia worldwide about 70 algorithms and supporting technical packages. To adequately review these standards, NIST has increased its capabilities through additional funding and hiring of eight new cryptographers. NIST has also been updating its cryptography testing and accreditation program to keep pace with the growing number of requests. NIST has also been growing cryptography capabilities as they relate to blockchain applications and lightweight cryptographic algorithms.
- In the area of risk management, NIST is building better mechanisms to understand and manage cybersecurity risks. NIST has been working to incorporate privacy and security controls throughout its risk management program. NIST continues to build its system lifecycle to support strong risk management. Supply chain is another area of importance, to

understand not only what, but also where the parts and pieces came from that are being employed into digital capabilities.

- In the area of IoT cybersecurity the NIST's laboratories are working on definitions, guidelines, and best practices, as well as coordination of standards across sectors of the digital economy. In addition, the NIST Cybersecurity Center of Excellence is working on IoT use cases. For example, the NCCoE staff worked with over 80 percent of the manufacturers in the U.S. on security, architectures, and capabilities for IoT in health care environments with wireless infusion pumps.

It is clear that NIST continues to have significant impact in the area of cybersecurity. It is the VCATs position that NIST's ability to have this success is directly linked to its ability to convene and work directly with stakeholders across the entire industry. The VCAT is extremely concerned that adding auditing, and other more regulatory responsibilities to NIST, will damage the trust that the community has in NIST will ultimately jeopardize NIST's ability to work effectively with all stakeholders.

Additionally, the VCAT is concerned that the NIST programs in this space are already overstretched, and that NIST will not be able to keep up with the increasing demands to assess and mitigate the ever-changing cyber threat without additional resources.

RECOMMENDATIONS:

NIST's ability to have this success is directly linked to its ability to convene and work directly with stakeholders across the entire industry. Auditing, and regulatory responsibilities may undermine NIST ability to work with stakeholders.

While NIST utilizes a robust public comment process for the cybersecurity standards it develops, the process is relatively inflexible and would benefit by bringing trusted industry partners into the development and review process earlier, enabling more timely, targeted and balanced products that account for the most current threats and adopt the latest approaches to cyber defense, resilience and risk mitigation within the operations of the engineering and production enterprise. This landscape is ever changing and transforming in the digital enterprise.

3. NIST Efforts to Strengthen Technology Transfer

Enhancing and improving the processes and policies that govern technology transfer both for the federal system and for NIST specifically remains a top NIST priority. In 2018 the VCAT was actively engaged in the launch and implementation of NIST's Return on Investment Initiative. The VCAT was also briefed on a new pilot project being launched at NIST to enhance the transfer and commercialization of highly advanced quantum-based NIST measurement technologies – the NIST on A Chip Program.

To provide further advice on both of these issues the VCAT established a subcommittee on technology transfer at the request of Dr. Copan to review and provide recommendations on NIST's

technology transfer-related programs. The subcommittee is chaired by Ms. Katharine Ku and addresses the following charge:

1. Review NIST's current technology transfer policies and practices, and provide their individual technical assessments on the principles that should drive these policies and practices for effectively engaging the business community and communicating with stakeholders;
2. Assess NIST's performance in the development and dissemination of work products and knowledge and recommend improvements. Specific areas that the visiting technical experts should address include the development and use of intellectual property and collaborative research.

3a. Return on Investment Initiative

In 2018 Dr. Copan outlined for the VCAT his vision for the Return on Investment (ROI) Initiative. For NIST the Return on Investment Initiative objectives are to assess, streamline, and accelerate the transfer of technology from Lab-to-Market by identifying critically needed improvements to federal technology transfer policies, practices, and efforts. The federal research and development investment is approximately $150 billion per year, with one-third invested in 300 federal laboratories and two-thirds invested at university and industry R&D institutions. To produce economic gain and expand a strong national security innovation base, the results of this investment must be put to productive use through applied research and services to the public as well as tech transfer to private companies to create new products and services.

Over the course of the year NIST conducted broad stakeholder outreach with a kick off meeting in May at the U.S. Institute of Peace, a request for information, and a series of 4 listening sessions across the country to gather input on the policy, regulatory, and legislative changes that would have the most impact on strengthening and making the U.S. technology transfer system more efficient and effective. Based on this community feedback NIST plans to publish a Green paper outlining a series of recommended potential actions for public comment in December.

In August 2018, a VCAT Subcommittee on Technology Transfer was established. The subcommittee developed recommendations focused on strengthening NIST's delivery of advanced technology to enhance national security and improve our Nation's economic competitiveness and quality of life. The Subcommittee was specifically charged to:

- Review NIST's current technology transfer policies and practices, and provide the Subcommittee's recommendations on the principles that should drive these policies and practices for effectively engaging the business community and communicating with stakeholders;
- Assess NIST's performance in the development and dissemination of work products and knowledge and recommend improvements. Specific areas that the Subcommittee should address include the development and use of intellectual property and collaborative research.

One of the first task undertaken by the subcommittee was to review and provide feedback on the Draft ROI Green Paper. The VCAT was briefed on the work and recommendations of the subcommittee at the February 2019 meeting. The full report of the subcommittee is attached as Appendix A. The VCAT voted unanimously to adopt the subcommittee's report and endorse its recommendations to NIST.

RECOMMENDATIONS:

- The VCAT recommends that NIST consider the recommendations of the VCAT Subcommittee on Technology Transfer as it develops its plans to implement the recommendations outlined in the Return on Investment Green Paper.

3b. NIST-on-A-Chip Program

During the October meeting the VCAT was provided with an overview of the NIST on A Chip (NoAC) program, an effort NIST is making to transfer the breakthroughs that it has made in quantum metrology into commercially viable technologies that can be manufactured at scale providing NIST quality standards and sensors directly where our customers need them, thereby eliminating the need for a costly calibration chain. Currently NIST calibrates about 14,000 artifacts per year for industry. NIST must be able to maintain traceability chain over time to ensure measurement certainties, which is a very expensive modality. Being able to move into quantum-based chip scale standards will be transformative both for NIST and industry. NIST has already had some initial successes with developing and commercializing chip scale technology. The chip-scale atomic clock created in Boulder has been commercialized and now it sits in cell phone towers all over the country. This one component plays a critical role, directly providing the accurate timing needed for a multi-trillion-dollar industry. Currently NIST has 24 different quantum SI chip-scale devices in development. Some are more mature than others, but NIST either has existing CRADAs with industry or is negotiating partnerships for all of these technologies. The current portfolio of NIST efforts covers a broad range of measurement needs including resistance, voltage, temperature, radiometry, pressure, vacuum, humidity, and laser power.

To more effectively and intentionally facilitate the transfer and commercialization of these NoAC-based technologies NIST has created a portfolio management-based approach that will bring together expertise from the labs, the Technology Partnerships Office, the newly formed Technology Discovery Office, and the Business Operations Office. This team will be building an R&D roadmap, conducting targeted outreach to potential users, putting in place the necessary agreements, and creating the process management tools and systems to enable efficient workflow across the different organizations involved. NIST will be evaluating the performance of this pilot over the course of the next year, and if successful will apply it more broadly across NIST.

The VCAT is excited about NIST efforts in this area and looks forward to reviewing progress during the coming year.

RECOMMENDATIONS:

Tech transfer of NIST developed technology though tech transfer programs, such as NIST on a Chip, are critical to US adoption of these technologies and serves as a feedback mechanism to ensure NIST is working on technologies that can have real world application.

4. NIST Facility Needs and Ongoing Renovation Projects in Gaithersburg and Boulder

In 2018 the VCAT was briefed on the state of NIST's physical infrastructure, NIST's ongoing renovation projects in both Boulder and Gaithersburg, and the master site plans for future construction projects. The VCAT was pleased to see that 2018 enacted budget for NIST provided the necessary funds to complete the renovation of the Radiation Physics building in Gaithersburg. However, the VCAT remains extremely concerned with the deteriorating infrastructure in both Boulder and Gaithersburg. The $40M requested for construction and renovation of facilities in the President's FY 2019 budget is woefully inadequate. The majority of NIST's facilities were constructed in the sixties and decades of deferred maintenance due to chronically low renovation and repair budgets have led to accelerated facility deterioration.

The long-term facility renovation plans presented to the VCAT for the Boulder and Gaithersburg campuses are sound. The VCAT strongly urges Congress to provide funding at a level that can both support substantial progress in ongoing NIST Construction projects as well as provide adequate funding for maintenance and major repairs. Based on the current facility footprint it is estimated that NIST should be spending close to $120 M a year to keep up with facility maintenance costs., and to complete a major portion of ongoing renovations in Boulder, an additional $69M in FY2019 would allow NIST to complete renovation of Wing 5 in Boulder.

5. NIST Budget

NIST Budget (Dollars in Millions) (Under Continuing Resolution)

	FY 2018 Enacted		FY 2019 President's Budget Request	FY 2019 House Mark		FY 2019 Senate Mark
STRS	**$724.5**		**$573.4**	**$720.0**		**$724.5**
Laboratory Programs	628.0		516.6	647.7		628.0
Corporate Services	17.3		11.6	17.3		17.3
Stds Coord & Special Pgms	79.2	*	45.2	55.0		79.2
ITS	**$155.0**		**$15.1**	**$145.0**	**	**$155.0**
Hollings Mfg Ext Partnership	140.0		0.0	140.0		140.0
Manufacturing USA	15.0		15.1	5.0		15.0
CRF	**$319.0**		**$40.5**	**$120.0**		**$158.0**
Construc & Major Renovations	255.0		0.0	TBD		94.0
Saf, Cap, Maint & Maj Repairs	64.0		40.5	TBD		64.0
Total, NIST Discretionary	**1,198.5**		**629.0**	**985.0**		**1,037.5**

* Includes $2.2M Baldrige Performance Excellence Program funding.

** With $2M recission of prior year unobligated balance.

The VCAT was briefed on the FY 2019 President's Request for NIST and updated on budget discussions with Congress. Unfortunately, no progress has been made on the enactment of a 2019 budget at the time of this report. The VCAT again offers the following observations:

- Operating on continual resolutions for prolonged periods of time makes planning difficult and as no new programs can be initiated. It makes it extremely difficult to meet increasing demands from stakeholders in industry and across government.
- As the VCAT has noted in the past NIST is under resourced compared to the increasing number of important measurement and standards challenges it must address in areas like quantum science, AI, cybersecurity, IoT, etc. that will directly impact the future competitiveness of the U.S. With a 47:1 return on investment[1], adding resources to NIST is sound long-term investment for the U.S.
- The Committee is concerned about the decreasing support for the NIST infrastructure and facilities. As previously noted, recommended support for facility maintenance is more than double that in the FY 2019 Budget Request. Without adequate support, NIST facilities will fall further into disrepair, undermining the science and engineering work of the NIST staff and causing increased safety risks. The Committee also notes that it is likely that repair and maintenance funds are needed but also funds for renovation to bring in the latest technologies and methods. Without additional funds, resources will be increasingly pulled from programmatic resources, compounding the already steep cuts outlined in the FY2019 request.
- In our experience, uncertainty and the threat of decreasing resources is likely to cause high-performing staff to look for other opportunities. Because of this, the Committee is concerned about attrition of NIST's outstanding research staff, which is so critical to its success and mission delivery. In addition, since NIST's exceptional scientists are a significant recruiting tool, losing those top researchers because of budget uncertainty would likely have significant long-term effects.

The VCAT was briefed by NIST leadership on the effects of the Government Shutdown and the steps that the agency was taking to bring operations back to normal. The VCAT applauds the resilience that NIST has shown during this unfortunate situation. Shutdowns like this are highly disruptive. For example, NIST leads US participation in critical international standards setting forums and events for technologies such as 5G. Failure of the US to engage in a timely manner could result in US industry, economy and national security being significantly disadvantaged vs. foreign competitors and adversaries. We recommend that critical engagements be identified and permitted under policy and statute to continue during government shutdown periods.

[1] https://www.nist.gov/director/summary-nist-laboratory-economic-impact-studies

Appendix A

Subcommittee on Technology Transfer
NIST Visiting Committee on Advanced Technology (VCAT)

The Return on Investment (ROI) Initiative for Unleashing American Innovation is a bold move by NIST and the Department of Commerce to begin a national conversation about how to maximize the benefits of Federal investments in science and technology. NIST's goal is to remove barriers, reduce friction, and create incentives to innovation. Innovation expands the U.S. entrepreneurial ecosystem and attracts private sector investment in new products, businesses, and industries. These benefits create value for Americans and improve the human condition for people all over the world.

The VCAT Subcommittee on Technology Transfer commends NIST on a very well organized, clear draft Green Paper based on the feedback from the U.S. stakeholder community. It identifies both short-term and long-term goals, and implementation strategies that would enable these goals to be met. The Green Paper is an important contribution to NIST's efforts to develop a roadmap for increasing the outcomes from the Federal government's investment in research and development.

General Comments:

The Subcommittee believes that the overriding–and perhaps most difficult–goal of the ROI initiative is to align incentives so that all stakeholders have a strong interest in maximizing the transfer of Federally funded science and technology to the private sector.

- Companies see the potential value of accessing the significant intellectual and physical assets that Federal laboratories and universities possess in order to be able to develop new and improved products. Regrettably, companies–from small to large–often find it challenging to engage Federal laboratories and universities in technology transfer. The proposed changes detailed in the Green Paper should make it easier for the companies to obtain the benefits of Federally funded research.
- Universities believe that formal technology transfer is part of their mission to transfer the results of their research to the public for society's benefit. Universities recognize that effectively licensing inventions and building an entrepreneurial ecosystem can help regional economic development and provide jobs for graduates. Royalty revenues are returned to the inventors, and to universities to fund further research and education. Clarification of Bayh-Dole provisions will make it easier for universities to engage with companies.
- The National Competitiveness Technology Transfer Act (NCTTA) of 1989 explicitly establishes technology transfer as a mission of Federal laboratories. Execution of that mission needs to be an important part of the laboratories' performance evaluation in order to maximize the transfer of Federal laboratory science and technology to companies. The desired essential culture change is to create a more entrepreneurial, flexible environment that supports and encourages effective technology transfer. New flexible partnering models are critical for increased private sector engagement with the Federal laboratories. These models should be crafted after there is clear articulation and consensus on what the

intended outcomes from these new approaches should be and should be consistently adopted across the Federal laboratory system.

Equally important, Federal laboratories need to create a more entrepreneurial environment. In recent years, universities have recognized that to do technology transfer well, they must embrace and encourage entrepreneurial activity at all levels of the organization. In tandem, they have learned how to manage both individual and institutional conflicts of interest. Federal laboratories should do the same: develop Federal employee educational entrepreneurship programs, encourage entrepreneurial activity and manage conflicts of interest. Most Federally funded technologies are very early stage and inventor participation in transferring the technology to the private sector is critical to successful technology development. If the Federal Laboratories can develop a flexible mechanism to enable inventors to be actively involved in technology transfer, there would be a much higher return on investment of our Federal research dollars.

Priorities:

The Subcommittee felt that the following proposed actions should be the highest priority to address:

1. **Strategy 1. Identify regulatory impediments and administrative improvements in Federal technology transfer policies**

   Intended Action 6 – Strengthen Technology Transfer at Federal Laboratories.
   a. **The Secretary of Commerce must have authority to issue regulations and implement policies government-wide, under Stevenson-Wydler.**
   b. **The Secretary of Commerce needs to confirm the mission requirement for all Federal entities engaged in research and development to contribute to US innovation.**

The Subcommittee unanimously believes this Intended Action is the most important priority. The Federal R&D agencies must truly believe that effective technology transfer is a priority for the country and make strategic cultural changes to show their commitment. The ability of these entities to make this cultural change will be the driver of success. Prior, good faith efforts to fundamentally change how Federal laboratories engage with outside groups have failed due to the lack of support and flawed approaches to garner such needed support. Failure to achieve cultural change and buy-in will undermine or, at the very least, dilute the potential impact of the other Intended Actions.

2. **Strategy 3. Build a more entrepreneurial R&D workforce.**

   a. **Intended Action 11 – Technology Entrepreneurship Programs.**
      i. **Establish government-wide technology entrepreneurship programs at all Federal R&D agencies.**

The Subcommittee believes that enthusiastic and genuine support by Federal laboratory leadership is critical to the success of changing the culture of the Federal laboratories to be more entrepreneurial. We recognize that a program like iCorps, for example, requires a significant time commitment of researchers, and therefore recommend that a system-wide iCorps-lite program be developed and implemented. We encourage synergistic partnerships between the Federal laboratories and academia in leveraging the entrepreneurial programs already mature at some universities.

b. Intended Action 12 - Managing Conflicts of Interest.

i. Authorize scientists and engineers at Federal Laboratories to engage in entrepreneurial activities that support technology transfer and commercialization. Implement harmonized and consistent requirements for managing conflicts of interest.

The Subcommittee believes the country will see a much better return on their Federal research dollars if Federal laboratory researchers can help transfer their technology to industry. They should be able to receive a financial benefit for their inventive contributions. The Subcommittee also recognizes that while it may seem easier to prohibit rather than manage conflicts of interest (as is currently the case), prohibition merely dissuades entrepreneurial initiative and leads to inefficient or ineffective technology transfer. The Federal government should therefore develop balanced conflict of interest requirements and systems to manage conflicts in a transparent way, and all agencies must agree to the same requirements and systems. Many Universities have developed robust conflict of interest management systems that can be used as models to develop Federal laboratory conflict of interest requirements/systems. Actions 11 and 12 go hand-in-hand and must be addressed at the same time.

3. Strategy 2. Increase Engagement with Private Sector Technology Development Experts and Investors.

a. Intended Action 8 -- Streamline Partnership Mechanisms.

i. Implement streamlined, transparent, and balanced partnership agreements.

ii. Develop cross-agency consistent and balanced indemnification terms.

The Subcommittee believes that the best way to increase engagement with the private sector is for the Federal laboratories to be able to move quickly with minimal transaction delays. While large firms have a bevy of lawyers, small firms do not, and they typically cannot afford to spend the time or money to negotiate with the Federal laboratories. The private sector is very clear that transactional delays hinder potential partnerships. The Federal laboratories need to have greater creativity and flexibility at the local level to tailor specific licensing terms to a particular situation. The Subcommittee recognizes that each Agency engages with the private sector differently; this makes it very difficult for private sector partners because there is no government-wide consistency. Harmonized, pre-determined indemnification terms, clear and consistent terms for company trade secret protection, etc. for all Federal laboratories will help decrease transaction time.

b. Intended Action 9 -- New/Expanded Partnership Mechanisms.

As mentioned above, industry partners will greatly appreciate any/all mechanisms that will speed up and simplify the establishment of partnership agreements. We encourage all interested parties to meet and discuss desired outcomes for any new partnering agreements, and then seek to develop agreements that are consistent with these motivations. Too often, one party creates agreements without the other side's input and this unnecessarily delays collaboration opportunities.

c. Intended Action 10 -- Technology Maturation Funding.

The biggest challenge for university and Federal laboratory technology transfer is that many technologies are considered to be "too early stage" for companies to take on. The ability of Federal laboratories to locally deploy flexible government funding to accelerate technology maturation will increase technology transfer–and the return on investment--to the private sector. Many universities are establishing such funds and the Federal laboratories should follow suit.

Noteworthy Intended Actions:

The Subcommittee supports:

- Intended Action 1 -- Government Use license
- Intended Action 2 -- March-In Rights
- Intended Action 13-15 – Reporting Systems. With respect to Intended Action 15, we encourage NIST to work with Association of University Technology Managers (AUTM) to coordinate and expand upon AUTM's ongoing efforts to establish metrics and benchmarks.

Concerns:

Intended Action 3 – Preference for U.S. Manufacturing. Expansion of the preference for U.S. manufacturing to nonexclusive licenses is of concern to the Subcommittee. In general, we are skeptical that this will increase U.S. competitiveness. We understand, and are supportive of, encouraging manufacturing in the U.S. However, the additional requirement of substantial U.S. manufacture to nonexclusive licenses will discourage nonexclusive licensing of widely used, ubiquitous technologies by multinational or non-U.S. companies. We want to encourage such companies to recognize university and Federally owned patents and to take nonexclusive licenses--and pay royalties to the U.S. entity--to patents as appropriate. In many cases, broad, worldwide dissemination of technology will be in the best interest of America and will provide economic growth and robust competitiveness. Some universities are already finding companies choosing to license competing, non-government funded technologies to avoid the U.S. manufacture requirements. If these requirements are extended to nonexclusive licenses, university technology transfer may be detrimentally impacted.

The Subcommittee feels that **Intended Action 4 – Software Copyright** needs to be clarified as to whether or not this is intended for the Federal laboratories only or also includes universities. Most

universities have copyright policies that allow for copyright protection, notwithstanding Bayh-Dole. This Action may be more useful to the Federal laboratories to enable them to license copyrighted software. Additionally, today, Government Owned Contractor Operated (GOCO) laboratories are able to assert copyright and license software with the approval of the Federal funding agency. To achieve maximum impact from Federally funded software, we recommended that the GOCO laboratories be authorized to assert copyright and license software without case-by-case agency approval under a process similar to that for electing title to patentable inventions.

The Subcommittee believes that **Intended Action 8 – Streamline Partnership Mechanisms** should be applied to the Federal laboratories only; we do not see a need to modify Bayh-Dole. The Subcommittee further believes that the Federal laboratories should retain local control of negotiating financial terms for license agreements to maximize flexibility and responsiveness to partner needs.

Additional comments:

Several of the private sector Subcommittee members feel that it is difficult to easily identify the capabilities and assets available at the Federal laboratories. While the Federal Laboratory Consortium (FLC) provides a mechanism for publicizing Federal laboratory technologies, the private sector often does not have the time to search technologies on the website. One suggestion was to have a "concierge," or explore other ways to expand and make it easier for companies to understand what the laboratories have to offer.

We note Federal laboratories are very different from universities and to compare technology transfer metrics (especially royalties) between the two sectors may not be reasonable.

We encourage universities and Federal laboratories to continue to develop exclusive and nonexclusive licensing programs in the public interest, always with the goal of increasing the probability of commercialization by the private sector.

The Subcommittee appreciates the opportunity to comment on the draft Green Paper. We suggest communicating real results from the proposed actions to industry, universities, and the Federal laboratories through workshops and progress reports so that the public knows that the final Intended Actions are being taken, and not just sitting dormant as a report. We look forward to hearing about NIST's success in bringing about a greater Return on Investment of our Federal research dollars.

Respectfully submitted,

The Subcommittee on Technology Transfer
NIST Visiting Committee on Advanced Technology

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