# Chapter 11: Accelerating AI Innovation

## Blueprint for Action

The United States remains the world's artificial intelligence (AI) leader. However, trends within the United States indicate underlying weaknesses. The Federal Government holds the responsibility to provide strategic direction and long-term resources to strengthen the nation's foundation for AI innovation. The United States—through government leadership, and in partnership with industry and academia—must increase the diversity, competitiveness, and accessibility of its AI innovation environment to ensure continued leadership.

Recommendation

### *Recommendation: Scale and Coordinate Federal AI R&D Funding*

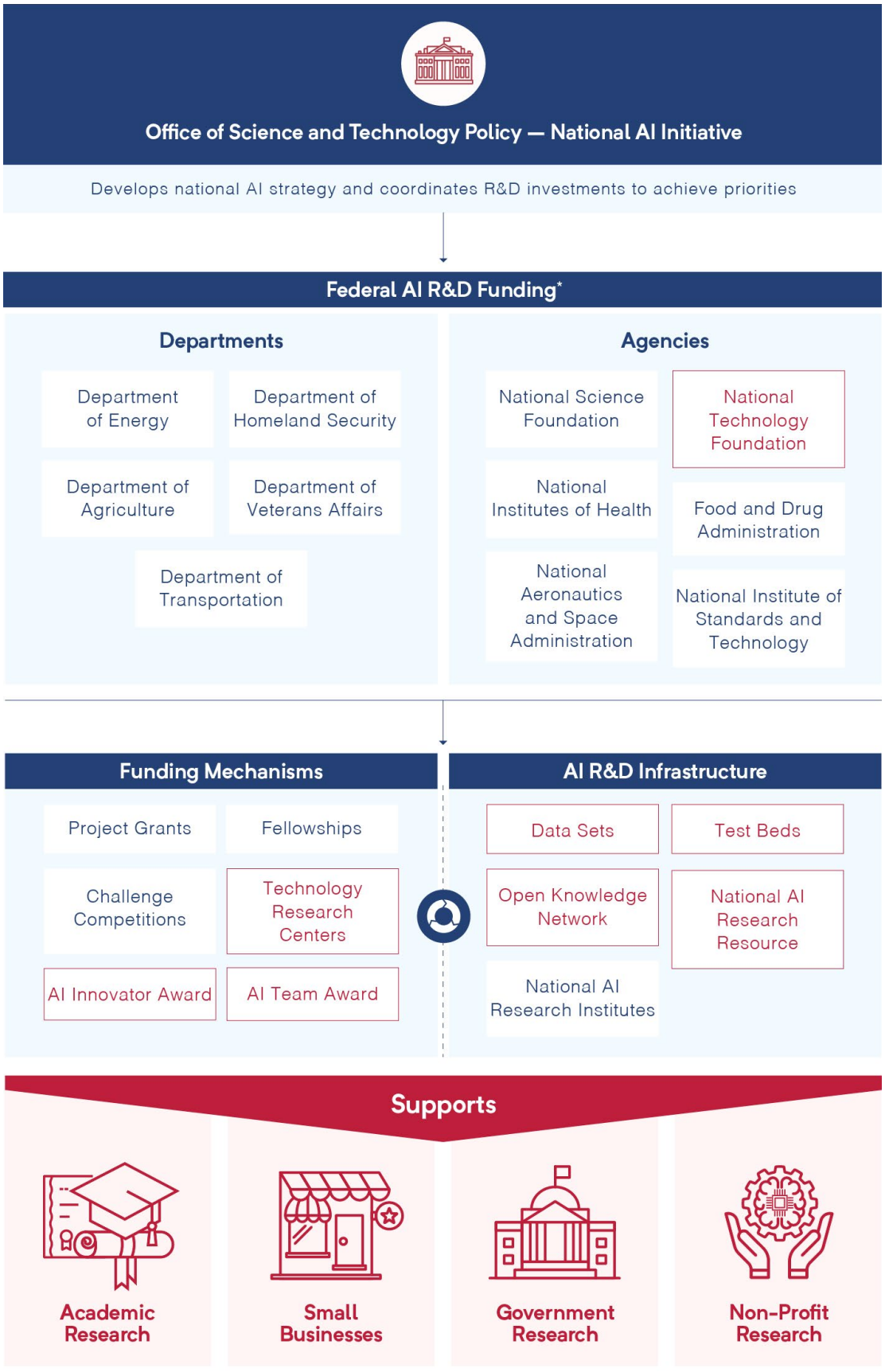
The United States must reinforce the foundation of technical leadership in AI by enacting a bold, sustained federal push to invest in AI R&D to foster a nationwide landscape of AI innovation and drive breakthroughs in the next generation of AI technologies by establishing a National Technology Foundation, funding AI R&D at compounding levels, establishing additional National AI Research Institutes, and making big bets on talent and innovative ideas.

#### *Component 1: Establish a National Technology Foundation*

In the wake of Russia's successful launch of the Sputnik satellite in 1957, Congress made significant investments in the National Science Foundation (NSF) to shore up U.S. leadership in science and technology.[1] Since then, the NSF has supported research across the frontiers of science and engineering, funding efforts that contributed to the development of the Internet, smartphones, and additive manufacturing.[2] However, in today's heightened geopolitical technology competition, even bolder action is needed to meet the promise of emerging and disruptive technologies like AI, drive U.S. innovation toward the national interest, and secure our economic future.

The Commission recommends the creation of a National Technology Foundation (NTF) as an independent federal agency and sister organization to the NSF to provide the means to move science more aggressively into engineering and scale innovative ideas into reality. This will require an organization that is structured to accept higher levels of risk and empowered to make big bets on innovative ideas and people. It also demands an emphasis on the transition of technology from the lab to the market.

Federal AI R&D Ecosystem.




☐ NSCAI Recommendation

*Representing the current top 10 federal funders of non-defense AI R&D

The current federal R&D posture lacks an organization that provides the level of investment and focus in applied research and technology engineering commensurate with the benefit that technology breakthroughs could bring to the U.S. economy, society, and national security. In contrast to fundamental science, technology development embodies a more costly undertaking,[3] requires the support of a diverse base of researchers and developers—including private-sector partners—and involves regular risk-taking. The Defense Advanced Research Projects Agency (DARPA) does this effectively, but for specific national security–focused ends and primarily through a prescribed program-based approach.

The NTF would drive technology progress at a national level by focusing on generating value at intermediate levels of technical maturity, prioritizing use-inspired concepts,[4] establishing infrastructure for experimentation and testing, and supporting commercialization of successful outcomes. It would work in close concert with the NSF, DARPA, and other interagency partners to strengthen investment in domestic science and technology (S&T), providing the fuel for the development and delivery of AI and other technologies on which future economic progress and national security advantages rely.

To provide the level of attention to advance technologies of strategic importance, the NTF should focus efforts around a set of routinely updated priority research areas, such as those the Commission has identified as technologies critical to U.S. national competitiveness[5]:

1. Artificial Intelligence
2. Biotechnology
3. Quantum Computing
4. Semiconductors and Advanced Hardware
5. Robotics and Autonomy
6. 5G and Advanced Networking
7. Advanced Manufacturing
8. Energy Technology

We do not underestimate the challenge of establishing a new institution; however, we see it as a strategic imperative. The NTF represents a long-term investment in America's ability to lead in AI and other disruptive technologies and apply technology toward efforts of societal importance. It would provide access to the resources and tools that could promote a national culture of experimentation and invention with new technology.

Given the criticality of holistically strengthening the national R&D landscape, the NTF should not detract from the level of appropriations for NSF, DARPA, or other existing federal R&D efforts. Rather, it should be instantiated as part of a broader approach that bolsters NSF as an institution of enduring, critical importance and amplifies federal support for technology R&D through existing channels as the organization gets off the ground.

Action for Congress:

- **Authorize and appropriate funding to support the establishment of the NTF.**
    - To match the envisioned enlargement of U.S. technology efforts, federal investment

in the NTF should gradually increase from Fiscal Year 2022 to Fiscal Year 2026 for an ultimate estimated operating budget of $20 billion per year.

    - Additional funds for facilities and equipment necessary for the Foundation's creation, estimated at around $30 million, should be made available starting in Fiscal Year 2022.

- A National Technology Board—with members appointed by the President—should be created to provide policy direction to the NTF, supervise the Foundation's major initiatives, and ensure that its research focus areas are updated to reflect technology trends. The Board's directives and actions should be informed by the National Technology Strategy proposed by the Commission and, when necessary, coordinated with the Technology Competitiveness Council—both of which are separately recommended in this report.[6]
- Jointly, a Director and Deputy Director appointed by the President should coordinate programming across the Foundation's directorates and with external organizations.
- The NTF should be empowered to implement a portfolio of responsibilities:
    - Distribute funding through grants, cooperative agreements, and contracts awarded through competitive, risk-acceptant processes to academic and private-sector researchers, nonprofits, and consortia.
    - Manage a component of its funding through an innovation unit modeled on DARPA in which independent program managers would fund proposals from both industry and academia to advance solutions to forward-looking research questions.
    - Promote the transfer of technology advancements to the government as well as the commercial sector.
    - Run prize competitions to catalyze research around significant technology challenge problems.
    - Manage national technology resources and infrastructure that democratize an ability to build, test, and experiment.
    - Contribute to the success of the regional innovation clusters envisioned by the Commission by participating in the proposed technology program office and liaising with industry at Technology Research Centers.
    - Contribute to international R&D collaborations and standards-setting dialogues that strengthen U.S. strategic partnerships.

*Component 2: Increase Federal Funding for Non-Defense AI R&D at Compounding Levels and Prioritize Key Areas of AI R&D*

Research is the linchpin of America's global leadership in AI. However, current federal funding is not adequate to meet the growth of the field, let alone support its continued expansion.[7] The Trump Administration's proposed budget for non-defense AI R&D in Fiscal Year 2021 was $1.5 billion,[8] a growth from around $1 billion spent in Fiscal Year 2020.[9] Further building on this investment, Congress included the National AI Initiative

Act of 2020 in the National Defense Authorization Act for Fiscal Year 2021, which creates a structure for a more strategic approach to harnessing AI and includes authorization for additional investments in AI at the NSF, Department of Energy (DoE), National Institute of Standards and Technology (NIST), and the National Oceanic and Atmospheric Administration (NOAA).[10]

### National AI Initiative Act of 2020

- Created an executive branch entity within the Office of Science and Technology Policy to coordinate federal support for AI research and development, education and training, research infrastructure, and international engagement in order to achieve national priorities as defined in a regularly updated strategic plan for AI.[11]
- Included provisions that established a National AI Research Resource task force, formalized the National AI Research Institute effort, and authorized funding for AI research at the National Science Foundation, the National Institute of Science and Technology, the Department of Energy, and the National Oceanic and Atmospheric Administration.

The government should build on these first moves and invest in AI R&D at compounding levels. Federal research funding holds the power to change the trends that are degrading the ability of the U.S. to continue to lead in AI, namely that academic research is weakening as a result of brain drain of professors and diversion of graduate students to industry, the domestic AI talent pipeline is not keeping up with government and industry needs, and national technical and ethical standards for development are lagging behind the technology.[12] Furthermore, federal support can spur the application of AI to other fields of science and engineering, which holds the potential for significant returns on investment.

Through sustained investments, federal support can serve to holistically strengthen AI R&D by embracing a range of initiatives—to include support for basic and applied research, shared research infrastructure, a network of AI R&D institutes, fellowships, and challenge competitions. Flowing investments through a diversity of agencies will create a vibrant fabric of funding, both mission-oriented and investigator-driven, that balances sustainment of evolutionary progress with big bets on revolutionary breakthroughs and supports innovation in academia and the private sector.

Actions for Congress:

- **Double annual non-defense AI R&D funding to reach $32 billion by Fiscal Year 2026.**
    - Congress should support compounding levels of federal funding for AI R&D, doubling investments annually from the baseline of $1 billion in Fiscal Year 2020.
    - Investments should be made across federal R&D funding agencies, notably the

proposed National Technology Foundation, DoE, NSF, the National Institutes of Health (NIH), NIST, and the National Aeronautics and Space Administration (NASA).

- Significant funds should be appropriated to expand fellowship and scholarship programs.[13] Augmented funding through these vehicles would support additional undergraduate and graduate students to pursue AI-related fields of study, helping to strengthen academia, grow the domestic talent pipeline, and provide pathways into government for technical talent. Similarly, career/faculty fellowship vehicles supporting researchers in academia would serve to stem the flow of researchers to industry and invest in top talent to pursue big ideas.

- **Commit to spending at least 1% of GDP on federally funded R&D.**
  - To maintain a strong base of innovation across S&T, Congress should pair AI-specific investments with an overall federal commitment to annually fund R&D at a level that reaches at least 1% of gross domestic product (GDP). This could be accomplished through steady growth over the next five years, at a rate of about $15 billion per year.

Actions for the Office of Science and Technology Policy:

- **Balance Interagency AI R&D Investment Portfolios.**
  - The National AI Initiative should coordinate federal investments in AI R&D toward annual doubling benchmarks, through amplified research funding, fellowships, and establishment of research infrastructure.
  - The National AI Initiative should ensure that growth in funding occurs across multiple agencies and embodies a portfolio approach that leverages a diverse set of mechanisms, focused on a range of outcomes—advancement of basic science, solving specific challenge problems, and facilitating commercialization of breakthroughs.

- **Prioritize Critical AI Research Areas.**
  - Research investments should prioritize areas critical to advance AI technology that will underpin future national security and economic growth but may not receive significant private-sector investment, such as:
    - *Novel machine learning (ML) directions.* To further non-traditional approaches to supervised ML in an unsupervised or semi-supervised manner as well as the transfer of learning from one task or domain to another.[14] Other directions include exploration of hybrid AI techniques that combine data-centric AI with different forms of model-based representations and inference methodologies to capitalize on complementary strengths.[15]
    - *Test and evaluation, verification and validation (TEVV) of AI systems.* To develop a better understanding of how to conduct TEVV and build checks and balances into the entire life cycle of an AI system,[16] including improved methods to explore, predict, and control individual AI system behavior so that when AI systems are composed into systems-of-systems their interaction does not lead to unexpected negative outcomes. Understand context-specificity and degradation of performance in new and unseen environments.

- *Robust and resilient ML.* To cultivate more robust methods that can overcome adverse conditions and advance approaches that enable assessment of types and levels of vulnerability and immunity. Addressing challenges of multiple classes of adversarial ML attacks. Includes research on fairness.
- *Complex multi-agent scenarios.* To advance the understanding of interacting cohorts of AI systems, including research into adversarial vulnerabilities and mitigations, along with the application of game theory to varied and complex scenarios.
- *AI for modeling, simulation, and design.* To progress the use of rich simulations as a source of synthetic data and scenarios for training and testing AI systems, and to use AI to solve complex analytical problems and serve as a generative design engine in scientific discovery and engineering.
- *Advanced scene understanding.* To evolve perceptual models to incorporate multi-source and multi-modal information to support enhanced actionable awareness and insight across a range of complex, dynamic environments and scenarios.
- *Preservation of personal privacy.* To assure personal privacy of individuals is protected in the acquisition and use of data for AI system development and operation through advancements in anonymity techniques and privacy-preserving technologies such as homomorphic encryption, differential privacy techniques, and multi-party federated learning.
- *AI system risk assessment.* Advance capabilities to support risk assessment including standard methods and metrics for evaluating degrees of auditability, traceability, interpretability, explainability, and reliability.
- *Enhanced human-AI interaction and teaming.* To advance the understanding of human-AI teaming, including human-AI complementarity, methods for augmenting human reasoning abilities, and fluid handoffs in mixed-initiative systems. Also includes bolstering AI technologies to better perceive and understand human intention and communications, including comprehension of spoken speech, written text, and gestures. Advances in human-machine teaming will enable human interactions with AI-enabled systems to move from the current model of interaction where the human is the "operator" to a future in which humans have a "teammate" relationship with machines.
- *Autonomous AI systems.* To advance a system's ability to accomplish goals independently, or with minimal supervision, from human operators in environments that are complex and unpredictable.
- *Toward more general AI.* Research persistent challenging problems and mysteries of human intellect, including ability to learn efficiently in an unsupervised manner; amass and apply commonsense knowledge; build causal models that provide robust explanations; exercise self-awareness, assessment, and control; and generalize and leverage knowledge learned about specific tasks to become proficient at another task.

*Component 3: Triple the Number of National AI Research Institutes*

NSF awarded grants for the first National AI Research Institutes in 2020, supporting seven university-based, multi-institution consortia organized around fundamental and applied areas of AI research—topics for which were determined through coordination with interagency and community stakeholders.[17] NSF plans to fund a second round of institutes in 2021, coordinating support not only with interagency partners but also with private-sector stakeholders to launch eight additional institutes.[18] Congress took steps to support the initiative through the National AI Initiative Act of 2020, which formalizes the effort, provides all agencies the authority to financially support formation of a National AI Research Institute, and directs NSF to bring together the institutes as an "Artificial Intelligence Leadership Network."[19]

Expansion of this initiative would create a nationwide network of AI innovation that supports a breadth of AI research initiatives—advancing basic AI science, solving domain-specific challenges, and applying AI to other fields of science and engineering. Their establishment would increase training opportunities for students and research opportunities for academic faculty, national lab researchers, and non-profit research organizations; help grow the field outside of leading private universities and regional technology hubs; and strategically steer research toward areas that could advance the science of AI and applications that serve broader society and the national interest.

Action for Congress:

- **Direct and appropriate funds to expand the network of AI institutes.**
    - Congress should direct and appropriate funds to NSF to expand the network of AI institutes three-fold over the course of the next three years—ideally resulting in a broad diversity of participating institutions, regions, and research concentrations.
    - This investment would encompass 30 additional institutes, totaling $600 million to sustain the additional institutes for the five-year duration of the grant awards. This would entail appropriations of $200 million in Fiscal Year 2022, Fiscal Year 2023, and Fiscal Year 2024.

Action for the Office of Science and Technology Policy:

- **Integrate the network of institutes with national AI R&D infrastructure investments.**
    - The National AI Initiative should ensure alignment of the National AI Research Institutes with strategic research priorities and integration with the national network of open AI test beds and the National AI Research Resource (see discussion of a National AI Research Infrastructure below).

*Component 4: Invest in Talent that Will Transform the Field*

Top talent in AI is a scarce commodity, and investing in talent holds the potential to not only unlock breakthroughs in the science and application of AI but also to attract and retain top talent in the United States.[20] Similarly, investing in research initiatives conducted by integrated, multidisciplinary teams is a proven mechanism to prompt breakthroughs, address complex problems, and challenge the status quo.[21]

The launch of an AI Innovator Award and complementary team-based AI award would strengthen the ability of federal AI research funding to push the boundaries of the field, providing a mechanism to complement ongoing investments in incremental progress with bets on revolutionary breakthroughs.

Actions for Congress:

- **Direct and fund establishment of an AI Innovator Award.**
    - Congress should direct and fund NSF to establish an AI Innovator Award, loosely modeled on the NIH Pioneer Award[22] and the Howard Hughes Medical Institute Investigator Program[23] to create a mechanism that provides top researchers the flexibility to pursue big ideas without prescribed outcomes over the course of a five-year, renewable grant award.
        - Totaling around $5.5 million per awardee for the five-year term, the awards would cover the full salary and benefits of the researchers at their respective institutions as well as a research budget that would support equipment and staff.[24]
        - At its height, the program would support a maximum of 100 researchers at a time, reaching an annual funding level of around $125 million for research support, with additional funds available for major equipment support.
        - Eligible researchers would be those at any career stage based at U.S. universities or research institutions who commit to spending 75% of their time on research.[25]
        - Attention should be paid by the selection committee to the need for diversity among awardees in terms of gender, race, age, location, and primary focus area of study, as well as on the communication and leadership skills of applicants.
    - Congress should authorize NSF to:
        - Fund an external organization to administer the program.[26]
        - Annually select 10 to 20 recipients for five-year, renewable terms and conduct selection through a small, rotating panel of AI experts.[27]
        - Ensure selection of innovative candidates through an advocacy model process in which candidates are ranked in accordance with the maximum scores provided by reviewers, thereby placing priority on their upside potential.[28]
        - Hold an annual meeting in which all awardees would share their work, providing a venue for meaningful feedback between review cycles and helping build a community of innovation among the top U.S.-based minds in AI.

  - Congress should require NSF to assess the program after seven years of operation to determine whether the program should continue to expand or operate at a lower number of awards and to evaluate the impact of the funding level and award term on the research conducted by participants.

- **Direct and fund establishment of a team-based AI research award.**
  - Congress should direct and fund NSF to work with the same external organization as the AI Innovator Award to create a team-based award to support bold, interdisciplinary research initiatives that apply AI to solve complex challenge problems or pursue use-inspired basic research efforts.
    - The program should begin with an annual budget of $50 million, growing to a sustained annual budget of $250 million by its fifth year of operation.
  - Congress should authorize the NSF to:
    - Fund an external organization to administer the program.
    - Select five to 10 teams annually for non-renewable, five-year terms, awarding $4 million to $10 million per year for the five-year term of the award.[29]

Recommendation

*Recommendation: Expand Access to AI Resources through a National AI Research Infrastructure*

If not addressed, the growing divide between "haves" and "have nots" in AI R&D will degrade the long-term research and training functions performed by U.S. universities, limit the ability of small businesses to innovate, and exacerbate the lack of diversity in the field.[30] While developments in the past five years have dramatically increased access to baseline ML tools and cloud-based computation, progress on the cutting edge of many important AI approaches requires significant amounts of data and computing power, expensive infrastructure, and substantial hardware and software engineering.

The United States should foster the world's leading environment for AI innovation through democratized access to AI R&D that supports more equitable growth of the field and expansion of AI expertise across the country; enables application of AI to a broad range of fields of science and engineering, commercial sectors, and public services; and fuels the next waves of innovation.

*Component 1: Launch the National AI Research Resource*

Since the explosion of deep learning in 2012 and accompanying growth in use of specialized hardware for AI computing, there has arisen what some have termed the "compute divide"—a disparity in access between large technology companies and elite universities and mid- and lower-tier universities to the resources necessary for cutting-edge AI research.[31] Availability and type of compute resources have been found to levy "outsized" influence in the direction of research pursued by researchers, as has the ascendency of the well-equipped firms in shifting the overall direction of AI research toward applied, "narrow AI" efforts.[32]

To bridge the compute divide, the Federal Government should establish a National AI Research Resource (NAIRR) to provide verified researchers and students with access to compute resources, co-located with AI-ready government and non-government data sets, educational tools, and user support.[33] This infrastructure should leverage public-private partnerships and cutting-edge private-sector technology and build on existing government efforts[34]—avoiding high startup costs of a government-run data center. Congress has taken the first step in the Fiscal Year 2021 National Defense Authorization Act, implementing a component of the Commission's prior recommendation to create a task force to develop a roadmap for a NAIRR.[35] The result of this effort will be due to Congress 18 months after appointment of task force members.

Action for Congress:

- **Authorize and appropriate $30 million for implementation of the NAIRR roadmap.**
    - Congress should authorize and appropriate funds to immediately implement the roadmap developed by the NAIRR task force.
        - The resource should be sustained at an initial level of $30 million annually, amplified by contributions from private-sector partners, and scaled as it matures and gains users.
        - Funding would support staffing of the program and the cloud resources, augmented through public-private partnerships. Staff would be responsible for maintaining and improving the architecture solution, curating data sets, building interfaces and tools, and providing support to researchers.

*Component 2: Create a Network of National AI Testbeds to Serve the Academic and Industry Research Communities*

Sponsored through various federal agencies, this network of national AI testbeds would provide real-world, domain-specific resources open to the academic, business, and government research communities to drive basic and applied research to address complex problems and develop robust, usable AI systems ripe for commercialization (for example, a self-driving vehicle test range, an instrumented humanitarian aid and disaster relief test site, or an instrumented home environment). Such resources would help establish and maintain benchmarking standards that enable measurable research progress through comparable approaches and reproducibility testing.

Testbeds should support experimentation with both novel software and hardware, equipped with rich simulation capabilities to model the physical world. Supported by simulated, live, and blended environments, these platforms would support research and experimentation that tackles open-ended, real-world problems. Furthermore, they should be architected to collect valuable data that could be made accessible to the community for training and evaluation, providing additional fuel for progress.

Action for the Office of Science and Technology Policy:

- **Coordinate agency investments in AI R&D testbed facilities.**
    - The National AI Initiative should coordinate agency investments in AI testbed facilities through the annual budget process, aligning investments with research priorities issued in the initiative's strategic plan. Attention should focus on modernizing existing resources to support data-driven and AI-enabled technologies.[36]

Action for Federal Agencies:

- **Invest in domain-specific AI R&D testbeds through upgraded or purpose-built facilities.**
    - Investment in the suite of national AI testbeds should be made across multiple federal agencies, facilitating creation of domain-specific resources open to the broader research community. Focus areas of each testbed should be aligned with priority AI research areas and in support of existing federal AI investments.
    - Testbeds should be set up as "user facilities" that maintain a hybrid approach of awarding grants for use and charging fees to those not selected for grant funding. User fees would assist in maintaining the testbeds and supplementing the amount of funding available for grants.

Action for Congress:

- **Support agency funding requests for establishment of AI R&D testbeds.**

*Component 3: Invest in Large-Scale, Open Training Data*

Data is critical currency for today's popular AI approaches. Promising work in the realm of low-shot learning, semi-supervised learning, and learning from synthetic data provides glimpses of a future in which performance of an AI system is not directly tied to big data, and the Federal Government should continue to prioritize funding for research in these areas. However, balancing these bets on the future with investments in resources to further U.S. leadership in the current leading AI approaches would strengthen the foundation of both current and future AI-based technology and applications.

Building AI systems and solutions for new domains and application areas relies on availability of specialized data that have been cleaned and organized for use. Federal support for well-designed, publicly-available data sets and provision of AI-ready government data sets would help drive research progress in AI and its application to other fields of study. Currently, a sizable amount of government data that is legal to share with trusted non-government researchers is not being shared due to a lack of confidence in cybersecurity and privacy-protecting technologies and a lack of willingness to accept risk.

Responsibly creating pipelines for the curation, hosting, and maintenance of complex data sets would set the foundation for future AI capabilities, help strategically steer the research community toward issues in the public interest, and advance technology around data set lifecycle maintenance.

These data investments could be further augmented by and created in support of the domain testbeds recommended above and hosted through the NAIRR. This integration could foster creation of data sets to support benchmarks within the testbeds as well as generate rich data from testing that could be provided back out to serve the research community. Access to resources should be granted to researchers with verified research efforts and governed by appropriate compliance controls based on the type of data and metadata contained in the data set.

Actions for the Executive Branch:

- **Issue a common policy and set of best practices.**
    - Leveraging the work of NIST,[37] the U.S. Chief Data Officer should issue a common policy and set of best practices to support release of AI-ready government data to the public and work with industry and academia to adopt compatible policies and best practices for reciprocal sharing and documentation.
- **Provide incentives to industry and academia to make available select data sets.**
    - The U.S. Chief Data Officer should develop incentives for industry and academia to make available select data sets on the NAIRR that would be managed and accessed alongside government-owned data sets.
- **Support NSF-funded cybersecurity and privacy researchers to make government data accessible for research purposes.**
    - The National AI Initiative should coordinate NSF-funded cybersecurity and privacy researchers to undertake rotational assignments at federal agencies[38] and work closely with agency personnel and data stewards to responsibly unlock access to more of the government's data holdings for the purpose of stimulating AI research and innovation.
    - Researchers would apply promising methodologies for protecting data and privacy in a controlled manner, providing a proving ground for new approaches and objective evidence to justify evolving data-sharing policies and practices. This could include creating secure environments for verified researchers to access more sensitive government-held data.

Actions for Congress:

- **Unlock public data for AI R&D.**
    - Congress should fund teams of data engineers and data scientists organized through the U.S. Digital Service to unlock public data currently held by the government for use by the AI research community.[39]

  - These teams would prioritize, clean, and curate non-sensitive public data sets to make them AI-ready and structure enduring processes to capture, clean, and regularly update data that would be hosted on a platform such as NAIRR, accessible by verified U.S.-based researchers.

- **Fund an AI data program at the Department of Energy.**
  - Congress should appropriate $25 million[40] per year for the next five years to DoE to administer an AI data program that would create exemplar, complex data sets and maintain them as living, regularly updated resources. These could include specialized data sets in physical, biological, earth, and engineering sciences, as well as social sciences.[41]
  - The program should be coordinated through the National AI Initiative to ensure data sets created steer the research community in desired directions.
  - Congress should direct DoE to work closely with NIST to develop standards for the data—to include standards for documentation, data modeling, data engineering, and data formats—as well as to advance the methods and tools necessary to support the data lifecycle.

*Component 4: Sponsor an Open Knowledge Network*

Open knowledge networks (or repositories) with massive amounts of world knowledge could fuel the next wave of AI exploration, driving innovations from scientific research to the commercial sector. Today, only the biggest tech companies have the resources to develop significant knowledge graphs and networks.

Various federal agencies have invested in specialized, domain-specific knowledge networks that could provide a starting point for an open knowledge network.[42] Beginning with a push to federate and map together existing specialized knowledge networks and government data platforms, and then building in real-world knowledge and context, the government could sponsor an Open Knowledge Network that would serve verified U.S.-based companies and researchers of all backgrounds to use world knowledge to develop AI systems that operate effectively and efficiently. This type of resource, particularly if paired with the complementary research infrastructure above, could unlock frontiers of technology yet unexplored.

Action for the Office of Science and Technology Policy:

- **Hold an innovation sprint to build an open knowledge network roadmap.**
  - Leveraging prior work undertaken through the Networking and Information Technology Research and Development (NITRD) program Big Data Interagency Working Group,[43] the Office of Science and Technology Policy should hold an innovation sprint to build a roadmap to establish an open knowledge network in a phased manner.

Action for Congress:

- **Direct and fund implementation and management of the open knowledge network.**
    - Congress should direct and fund the NSF to implement and manage the open knowledge network, appropriating $25 million per year for the next five years and encouraging NSF to leverage partnerships with industry stakeholders where possible.[44]

Recommendation

*Recommendation: Leverage Both Sides of the Public-Private Partnership*

U.S. companies are at the forefront of AI R&D, and their investments benefit consumers globally through the rapid development and adoption of AI-enabled products. But the impact of AI-enabled products on U.S. society and national security has largely come as an afterthought. The speed of technology development by the private sector has vastly outpaced federal policies and regulations. To address these challenges, the public and private sector must share responsibility for the safety, security, and well-being of Americans. The following recommendations would make the government a better partner for industry, broaden the benefits of strategic emerging technologies like AI through regional innovation clusters, and expand opportunities to access AI research and education through private-sector philanthropy.

*Component 1: Create Markets for AI and Other Strategic Technologies*

The government's buying power cannot compete with a global consumer market, but it can influence investment decisions in technologies essential to overall U.S. technical leadership.[45] Many potential public-sector applications of AI, such as education and labor, fall under agencies with limited R&D budgets. As the government increases investment in basic research, it must also fully leverage its purchasing power to support AI and other strategic technologies.[46] The scale of government funding can influence the research priorities and viability of early-stage startups, which often succeed or fail in the first year; and, if leveraged collectively, it can draw private-sector resources toward areas of strategic priority. This makes investors and technology companies important partners for AI R&D that can build future defense and national security capabilities.

Yet the government remains a difficult customer—especially for small and medium-sized businesses—because of its complex contracting process and unique requirement. Making the U.S. government a more compelling customer and effective buyer of commercial technology will help drive technology development in the commercial sector that is in the national interest. It will also assist the government in almost every aspect of its mission, from providing basic public services to driving economic policy and protecting national security.

Actions for the General Services Administration (GSA):

- **Promote the application of AI across the U.S. Government.**
    - In fulfilling its mandate to facilitate the adoption of AI technologies in the Federal Government,[47] the AI Center of Excellence (AI CoE) should look first to readily available commercial off-the-shelf (COTS) technology that can be tailored for government use.
        - AI CoE should work with Federal technical leadership,[48] including the U.S. Chief Technology Officer, Chief Information Officer Council, and the National AI Initiative,[49] to identify government needs and opportunities and expedite the adoption of commercial AI applications across federal agencies.
        - The AI CoE should leverage existing digital governance efforts across the Executive Branch, including GSA's 18F and the U.S. Digital Service, and technical talent exchange programs, including GSA's Presidential Innovation Fellowship, to bring sufficient technical expertise and commercial proficiency to this effort.[50]
- **Communicate federal AI capability priorities to the private sector.**
    - The AI CoE should add federal procurement priorities and agency capability needs to its publicly available website, which contains information regarding programs, pilots, and other initiatives.[51]

Actions for the U.S. Small Business Administration:

- **Publish a digital technology "playbook" for small businesses.**
    - A playbook for small businesses should outline paths for companies interested in doing business with the U.S. government and explain in a single place[52] how to navigate challenges like obtaining access cards to government facilities. Such a resource would make the acquisitions process more transparent and reduce the need for companies to hire outside help.
        - The playbook should be developed and reviewed by personnel with technical and commercial proficiency, for example Presidential Innovation Fellows or staff from the U.S. Digital Service, and written in language that technology startups with no prior government experience can understand.
        - The playbook should be aggressively publicized to increase its visibility.
- **Bridge public and private investment through the Small Business Innovation Research (SBIR) Program.[53]**
    - Support the efforts of participating federal agencies to modernize SBIR to more effectively develop and deploy AI solutions and encourage broader participation of American technology startup and small-business companies.
        - Expand pilot programs that offer supplemental funding to bridge the gap between current SBIR/Small Business Technology Transfer (STTR) Phase II awards and Phase III scaling efforts.[54]

        - Expand pilot programs that offer larger funding amounts[55] and private-sector matching opportunities to support higher technology readiness levels common in DoD SBIR contracts.[56]
    - Update SBIR Policy Directive to allow programs to require matching private-sector funds as early as Phase II.[57]

Actions for Department of Defense and Intelligence Community:

- **Adopt a "hoteling" model to allow small- and medium-sized technology companies to access classified facilities on a flexible basis.**
    - The Digital Ecosystem described in Chapter 2 of this report would establish prototypical platform environments for contributors and users, including cleared personnel from AI companies. Flexible access to classified spaces would speed development cycles and help companies more regularly engage with current or potential customers within the national security enterprise, leading to more tailored and effective solutions delivered more quickly.
- **Simplify the contracting process to attract non-traditional vendors.**
    - Amend the Defense Federal Acquisition Regulation to allow commercial performance to be considered more widely in the contracting process. The U.S. government can benefit from broader adoption of best-in-class commercial AI software.
    - Allow for pilot use of commercially available digital application tools and access portals for SBIR and other non-traditional contracting vehicles.[58]
- **Commit to growing the national security innovation base.**
    - DoD should set a target of increasing its contracts with early-stage technology firms by four times over the five-year Future Years Defense Program.[59] This will also require growing the budgets of successful but nascent innovation initiatives such as the Defense Innovation Unit.[60]
        - To this point, DoD has focused on a large number of small bets without following up with larger later-stage investments. Larger contracts for later-stage companies would help scale validated solutions that meet military requirements.
    - The Under Secretary of Defense for Acquisition and Sustainment and the Service Acquisition Executives should encourage Acquisition Category programs of all sizes to solicit bids from at least one non-traditional contractor per program.
- **Strengthen return on SBIR investments.**
    - Review, modernize, and streamline SBIR processes to encourage broader participation of American technology startup and small-business companies.[61]
        - Program officers should clearly communicate pathways to transition, including milestone criteria and dollar amounts, to SBIR awardees so that they can plan and resource accordingly.
        - Explicitly allow SBIR contracts to leverage any "color of money" as matching funds up to the amount of SBIR funding.

- Enable successful prototypes to scale through sufficient funding, early access to customers and operators, and better due diligence on the commercialization prospects of a company.[62]
  - Military Service and Office of the Secretary of Defense (OSD) SBIR programs should allocate a portion of SBIR funding for scaling successful SBIR projects through Phase II enhancements.[63]
  - Program Offices should provide program dollars alongside matching SBIR funds to increase the likelihood of transition.
- Continue efforts to align SBIR program with Department technology priorities to focus investments on subsets of key technologies on which private-sector R&D can help advance.[64]
  - The Office of the Under Secretary of Defense for Research and Engineering should introduce a special solicitation on AI that invites solutions across a diversity of AI approaches[65] and a range of technology readiness levels.[66]

*Component 2: Form a Network of Regional Innovation Clusters Focused on Strategic Emerging Technologies*

Competition is critical to a vibrant national security innovation base.[67] If a strategic industry lacks competition, one wrong bet by an incumbent can place the nation's technological leadership in jeopardy.[68] The U.S. government should create an environment in which innovative startups are able to disrupt inefficient or outdated ways of doing business and grow into industry leaders themselves. The right mix of policies and incentives can help firms overcome mounting barriers to entry at the cutting edge of emerging technologies like AI.[69] This approach will promote innovation in industries that are essential to U.S. leadership in AI and the nation's economic and technological competitiveness more broadly.[70]

As the Commission noted in its *2019 Interim Report*, the clustering of technology firms in regions like Silicon Valley yields a more dynamic and globally competitive industry by expediting knowledge sharing and sharpening domestic rivalry.[71] However, this trend has benefited some regions and demographics more than others.[72] To spur regional innovation across a broader swath of the nation, the U.S. government should support the growth of technology clusters in regions with latent innovation potential. Broader in mission and scope than existing models within the U.S. government, such an initiative would democratize access to federal R&D resources so that small firms could compete in industries with high barriers to entry like AI. By facilitating the exchange of technology and talent between the public and private sectors, the U.S. government would also be well positioned to establish new contracts and intellectual property sharing agreements for commercial technologies that are critical to U.S. national security.

Actions for Congress:

- **Establish an interagency program office responsible for coordinating a network of regional innovation clusters focused on R&D and commercialization of strategic emerging technologies.**
    - The program office should be hosted by the Department of Commerce at NIST and staffed by representatives from U.S. departments and agencies with experience in and missions related to strategic emerging technologies.[73] The program office should also draw on expertise from the private sector and academia through talent-exchange programs and external advisory arrangements.
    - Congress should authorize $5 million for the creation of the program office and task it with designating regional innovation clusters in qualified locations throughout the United States via a competitive process, as described below in detail. As a first step, the program office should solicit bids for financial assistance from applicants focused on the R&D and commercialization of strategic emerging technologies. In assessing bids, the program office should consider the following criteria:
        - *Location.* Clusters should be equitably distributed throughout the United States in regions with latent innovation potential, taking into account factors such as proximity to federal R&D facilities, the level of support from state and local governments, the presence of and value proposition for leading firms and research institutions, and the size and education level of the local workforce.[74]
        - *Subject area.* Clusters should be organized around the research, development, and commercialization of strategic emerging technologies that are critical to U.S. national competitiveness. Of particular interest are technologies that enable advances in adjacent sectors and whose domestic production would directly benefit U.S. national security, such as microelectronics.[75]
        - *Economic feasibility.* To maximize the impact of federal resources and ensure self-sustainability of the clusters, financial assistance should only be awarded to applicants that demonstrate the existence of a nascent cluster in their region.[76]
    - The program office should establish Technology Research Centers (TRCs) for each cluster to facilitate collaboration between participants. By forming sustained partnerships with anchor institutions, each TRC should strive to advance the research, development, and commercialization of strategic emerging technologies.[77]
        - *Leverage talent.* TRCs should host researchers on temporary assignments from U.S. departments and agencies, establish talent exchanges with local firms and research institutions, and fund multi-year, postdoctoral fellowships for the commercialization of research.[78]
        - *Encourage technology transfer.* TRCs should host program managers from U.S. departments and agencies responsible for transitioning basic research into commercially viable technologies, identifying national security use cases and end users within the U.S. government, and initiating new government contracts for those products.
        - *Generate intellectual property.* TRCs should establish intellectual property—sharing agreements with cluster participants to encourage government adoption of commercial technologies. When appropriate, research should be

published in the open-source domain to encourage advances in the broader science and technology community.

- *Bring government resources to bear.* TRCs should facilitate participants' access to federal computing resources, curated government data sets, testing infrastructure and ranges, and other R&D facilities at low cost.[79]

- The program office should play a high-level coordination role that includes supervising the operation of TRCs, facilitating R&D collaboration between clusters, and promoting the commercialization of technologies with national security use cases.

- **Enact a package of provisions that incentivizes industry and academia to participate in clusters.**
  - Provisions should include tax incentives to locate near the cluster, competitive research grants, loan guarantees, and seed funding. A complementary approach should be taken by state and local governments. These policies could be modeled on Opportunity Zones, which have stimulated investment in regional economies.[80]
    - *Investment tax credits.* To compete with incentives offered by foreign countries, Congress should establish investment tax credits for firms participating in regional innovation clusters. While the details of these tax credits will vary by sector, one example is the investment tax credit for semiconductor manufacturing facilities and equipment proposed in Chapter 13 of this report.
- **Provide funding to each cluster for at least five years, with matching investments from public- and private-sector partners.**
  - Within one year, the program office should request from Congress the necessary funding for the designation of up to 10 clusters. This funding should be matched at least 1:1 by investment from private companies, state and local governments, and federal agencies, with a target of each cluster initially receiving a total of $50 million annually. This annual amount should increase as demand and capacity at each cluster expands over time.[81] These funds would be used to operate the TRCs, maintain R&D facilities, issue research grants, and seed startups.

*Component 3: Establish a Private Sector–Led Competitiveness Consortium*

The private sector shares responsibility with the government to strengthen the foundations of the R&D ecosystem that underpins breakthroughs they will commercialize and the training pipeline needed to meet their increasing demand for technical talent.

Companies are already struggling to find these qualified applicants for technical roles, with one estimate showing more than 400,000 open computing jobs nationwide.[82] Furthermore, as described above, researchers in academia who will undertake the high-risk, high-gain research that will push the frontiers of the field are finding themselves locked out from the computing and data resources needed to fuel this work. How well the nation addresses this looming challenge has widespread implications for the economy, society, and U.S. global competitiveness.

Chapter 10 of this report describes in detail recommendations to revamp the U.S. educational system to equip Americans for the jobs of the future, and this chapter details the extensive investments the Federal Government should make in AI R&D. However, corporations should also consider their responsibility to prepare citizens for the future they are inventing and maintain the strong foundation of national innovation from which they benefit. Toward that end, many firms are already having a positive impact beyond their bottom lines through corporate social responsibility efforts. STEM education programs and job training feature prominently in the charitable-giving arms of leading tech firms.[83] Yet the scale of the challenge is too broad for individual firms to address in insolation, despite their generosity.

Actions for the Private Sector:

- **Donate $1 billion over five years.**
    - Providing every American an opportunity to increase their technical proficiency requires bold action from government, academia, and industry to coordinate, prioritize, and scale programs that broaden AI research opportunities and instill digital proficiency.[84] For the private sector to meet this call to action, the Commission calls upon industry to donate $1 billion over the next five years to support AI education and upskilling and provide data and compute resources to democratize and fuel best-in-class AI research efforts.
    - These funds would lay the foundation for broader digital transformation and economic empowerment. Government officials should publicly highlight the impact of this effort and the role of the firms contributing to it.
    - Similar to the Partnership on AI's work coordinating development of best practices across AI firms,[85] this effort should be managed by an independent non-profit organization that can link and scale firms' efforts to build digital skills and democratize AI research. The U.S. Digital Service Academy proposed by the Commission could also contribute expertise, volunteers, curriculum development, and other in-kind support.[86]
- **Expand research exchanges between industry and academia.**
    - Leading technology firms should invest in or expand exchange programs designed to combine top academic talent with world-class private-sector computing resources. Rotational exchanges of this type would both democratize computing access for researchers and simultaneously shed light on new pathways for next-generation AI products that could be commercialized by industry.

Action for the U.S. Bureau of Labor Statistics:

- **Standardize and report data on digital skills in the job market.**
    - The U.S. Bureau of Labor Statistics should lead an effort in coordination with other agencies such as the Department of Education to collect and regularly update statistics on the digital proficiency of demographic groups and regions, with entries describing specific digital skills needed by firms with job openings. This will enable

academic institutions, firms, and other organizations to prioritize their efforts for educating, reskilling, upskilling, and digital transformation.

Recommendation

*Recommendation: Tackle Some of Humanity's Biggest Challenges*

If the investments detailed above are implemented, they will set the conditions to harness AI to tackle some of the biggest challenges in science, society, and national security.

Examples of promising initiatives that could improve societal well-being and advance scientific frontiers include, but are not limited to:

- *Enable long-term quality of life.* AI technology that can help the elderly live independently longer, assisting in managing health and daily tasks and improving the quality of life. This can include application of AI to biomedicine to address acute and chronic illnesses and enhance healthy aging.
- *Revolutionize education and lifelong learning.* AI tools that personalize education, training, and retraining at appropriate challenge levels and intuitively evaluate development to optimize standard curricula to promote individual learning success.
- *Transform energy management.* Smart infrastructure for cities that can effectively respond to surges in energy demand and emergencies (both man-made and natural disasters).
- *Effectively predict, model, prepare for, and respond to disasters.* Accurate, near—real time weather, earthquake, and fire line detection and prediction of escalation to aid in emergency response and planning for optimized deployment of limited resources. Autonomous robots for search, rescue, and cleanup in the wake of natural or man-made disaster, providing force-multiplying support to first responders and hazardous materials professionals.

Action for the Office of Science and Technology Policy:

- **Direct the National AI Initiative to align federal investments in AI R&D to tackle significant scientific, technological, and societal challenges.**
    - The National AI Initiative should identify and oversee realization of opportunities to harness federal R&D investments to take on audacious scientific and technological challenges that could lead to breakthroughs that benefit society and national security.[87]
    - Prioritization of these efforts should be coordinated with the national security research community and informed by the Technology Competitiveness Council proposed by the Commission[88] to define areas of research where the application of AI could contribute to progress that provides strategic advantages.

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[1] *The National Science Foundation: A Brief History*, National Science Foundation (July 15, 1994), https://www.nsf.gov/about/history/nsf50/nsf8816.jsp#chapter3 ("In fiscal year 1958, the year before Sputnik, the Foundation's appropriation had leveled at $40 million. In fiscal 1959, it more than tripled at $134 million, and by 1968 the Foundation budget stood at nearly $500 million.").

[2] *12 Irreplaceable Innovations Made Possible by NSF*, National Science Foundation (last accessed Feb. 11, 2021), https://www.nsf.gov/news/special_reports/btyb/innovation.jsp. A recent report produced by Computer Science and Telecommunications Board of the National Academies of Sciences, Engineering, and Medicine traces the interplay between fundamental research in information technology (IT) in academia and industry and its effects on capabilities of IT and non-IT sectors. For an illustration of the how the research funded by NSF and others has influenced the technologies that have transformed our everyday lives, see *Information Technology Innovation: Resurgence, Confluence, and Continuing Impact*, National Academies of Sciences, Engineering, and Medicine at 14 (2020), https://doi.org/10.17226/25961.

[3] We recommend an estimated operating budget of $20 billion per year. For comparison, NSF has an annual budget of $8.5 billion (FY 2021), while five U.S. technology firms—Alphabet, IBM, Facebook, Microsoft, and Amazon—spent an estimated $80.5 billion on AI R&D alone in 2018. See *About the National Science Foundation*, National Science Foundation (last accessed Feb. 11, 2021), https://www.nsf.gov/about/; Martijn Rasser, et al., *The American AI Century: A Blueprint for Action*, CNAS (Dec. 17, 2019), https://www.cnas.org/publications/reports/the-american-ai-century-a-blueprint-for-action.

[4] As argued by Donald Stokes in 1997, research should be conceived not as a dichotomy between basic and applied research, but on a quadrant along the axes of "quest for fundamental understanding" and "considerations of use." Research in the upper-right quadrant is defined as use-inspired basic research—research that advances fundamental knowledge but is driven by a clear purpose. Stokes calls this "Pasteur's quadrant" after the work of Louis Pasteur, whose research pushed scientific boundaries and had practical applications. See Cherie Winner, *Pasteur's Quadrant*, Washington State Magazine (2009), https://magazine.wsu.edu/web-extra/pasteurs-quadrant/.

[5] See Chapter 16 of this report for additional details on each of these technologies and why the Commission believes they are critical to future U.S. national competitiveness.

[6] For additional details on the Commission's proposed National Technology Strategy and the Technology Competitiveness Council, see Chapter 9 of this report.

[7] For example, NSF, which provides 85% of federal funding for computer science, funded $188 million in core AI research in 2019 but did not have room in the budget to fund another $178 million worth of highly rated proposals. This was an improvement from 2018, when it funded $165 million but left $185 million of highly rated work unfunded. Furthermore, NSF (in partnership with the Department of Agriculture) funded seven National AI Research Institutes in 2020 but was unable to fund the more than 30 that were judged worthy of supporting. NSF presentation to NSCAI (January 2020).

[8] *The Networking & Information Technology Research & Development Program Supplement To The President's FY2021 Budget*, National Science & Technology Council at 4 (Aug. 14, 2020), https://www.nitrd.gov/pubs/FY2021-NITRD-Supplement.pdf.

[9] *The Networking & Information Technology Research & Development Program Supplement To The President's FY2020 Budget*, National Science & Technology Council at 11 (Sept. 2019), https://www.nitrd.gov/pubs/FY2020-NITRD-Supplement.pdf.

[10] Pub. L. 116-283, William M. (Mac) Thornberry National Defense Authorization Act for Fiscal Year 2021, 134 Stat. 3388 (2021).

[11] The legislation tasks an interagency committee overseen by the National AI Initiative Office to develop every three years a strategic plan for AI that determines and prioritizes areas of AI R&D requiring Federal Government leadership and investment; supports long-term funding for interdisciplinary AI research; provides or facilitates the availability of curated, standardized, secure, representative, aggregate, and privacy-protected data sets for AI R&D; provides or facilitates the necessary computing, networking, and data facilities for AI R&D; supports and coordinates Federal education and workforce training activities; and supports and coordinates the network of AI Research Institutes.

[12] See *Interim Report*, NSCAI at 24-28 (Nov. 2019), https://www.nscai.gov/previous-reports/; Craig Willis, *Analysis of Current and Future Computer Science Needs via Advertised Faculty Searches for 2019*, CRA Bulletin (Dec. 7, 2018), https://cra.org/analysis-of-current-and-future-computer-science-needs-via-advertised-faculty-searches-for-2019/.

[13] Expanded funding could go through programs across federal agencies, notably the following. For NSF: CAREER fellowship; Graduate Research Fellowship Program; CyberCorps: Scholarship for Service; Historically Black Colleges and Universities Undergraduate Program; and Research Traineeship. For DoE: Early Career Research Program; Computational Science Graduate Fellowship. For NASA: Space Technology Research Fellowship program. For DoD: DARPA Young Faculty Award; Vannevar Bush Faculty Fellowship; Science, Mathematics, and Research for Transformation Scholarship for Service Program; National Defense Science and Engineering Graduate Fellowship Program; and Historically Black Colleges/Universities and Minority-Serving Institutions Research and Education Program. See Chapter 10's recommendation for the passage of a National Defense Education Act.

[14] Learning techniques such as unsupervised, semi-supervised, self-supervised, one- or zero-shot, and reinforcement learning enable training AI models with less reliance on large data sets of labeled data, albeit often with lower accuracy than with using supervised learning. See Dr. Bruce Draper, *Learning with Less Labeling*, DARPA (last accessed Dec. 19, 2020), https://www.darpa.mil/program/learning-with-less-labeling. Reducing reliance on large amounts of labeled data is important when supporting applications where data is scarce or labeling data is cost prohibitive. See *NSCAI Interim Report - Beyond Deep Learning*, NSCAI at 55 (Nov. 20100), https://www.nscai.gov/wp-content/uploads/2021/01/NSCAI-Interim-Report-for-Congress_201911.pdf.

[15] Hybrid AI approaches include integrating statistical machine learning with other techniques such as symbolic AI, knowledge representations, game theory, search, and planning. Hybrid AI approaches are often used in applications of robotics, battle management systems, and resilient systems. NSCAI Staff Correspondence with DARPA (Feb. 22, 2021).

[16] This is a particular challenge for long-lived, autonomous AI systems operating over long durations of time. These systems will likely continuously evolve their mission sets and capabilities, utilizing dynamic learning, along with in-field, in situ updating. All this requires advancing the discipline of TEVV to continuously monitor and ensure such a system's operation remains compliant to performance requirements over its missional lifetime.

[17] The topics were Trustworthy AI, Foundations of Machine Learning, AI-Driven Innovation in Agriculture and the Food System, AI-Augmented Learning, AI for Accelerating Molecular Synthesis and Manufacturing, and AI for Discovery in Physics. The Department of Agriculture teamed with NSF to provide funding toward two of the institutes to support AI research on developing the next generation of and resilience in agriculture. *Artificial Intelligence at NSF*, NSF (Aug. 26, 2020), https://www.nsf.gov/cise/ai.jsp.

[18] Around the topics of Human-AI Interaction and Collaboration, Advances in Optimization, AI and Advanced Cyberinfrastructure, Advances in AI and Computer and Network Systems, Dynamic Systems, AI-Augmented Learning, AI to Advance Biology, and AI-Driven Innovation in Agriculture and the Food System. The institutes are funded at a rate of $4 million per year for five years, totaling $20 million. See *Id.*

[19] Pub. L. 116-283, sec. 5201(b), William M. (Mac) Thornberry National Defense Authorization Act for Fiscal Year 2021, 134 Stat. 3388 (2021).

[20] A 2019 evaluation of the grants made as a component of the National Institutes of Health (NIH) high-risk, high-reward program—which include large, longer-term investments in talent through the NIH Director's Pioneer Award, NIH Director's New Innovator Award, and the NIH Director's Early Independence Award—found that these awards funded highly productive research compared to the work funded under traditional NIH research grants and that they result in a higher technological impact. The high-risk, high-reward program was created to accelerate the pace of biomedical, behavioral, and social science discoveries by supporting creative scientists with highly innovative research. See *Report of the ACD Working Group on High-Risk, High-Reward Research*, National Institutes of Health Advisory Committee to the Director (June 2019), https://www.acd.od.nih.gov/documents/presentations/06132019HRHR_B.pdf.

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[21] Studies have found that research that effectively combines diversity of knowledge is more likely to prompt breakthroughs and that interdisciplinary research lends itself to complex problem-solving, developing new research thrusts, and challenging the status quo. See Lee Fleming, *Recombinant Uncertainty in Technological Search*, Management Science (Jan. 2001), https://funginstitute.berkeley.edu/wp-content/uploads/2012/10/Recombinant-Uncertainty-in-Technological-Search.pdf; Andrew Barry, et al., *Logics of Interdisciplinarity*, Economy and Society (Feb. 2008), http://users.sussex.ac.uk/~ir28/IDR/Barry2008.pdf.

[22] The NIH Director's Pioneer Award supports researchers at any career stage who propose bold research projects with unusually broad scientific impact. The program supports awardees with $3.5 million over five years and requires 51% of time spent on research in the first three years. See *NIH Director's Pioneer Award*, National Institutes of Health (last accessed Jan. 1, 2021), https://commonfund.nih.gov/pioneer. Competition for participation in the program is high; reportedly the success rate for applicants is just 1%. See Roberta B. Ness, *The Creativity Crisis*, Oxford University Press at 87 (2015).

[23] Established in 1978, the Howard Hughes Medical Institute (HHMI) supports more than 250 investigators across the United States. Thirty current or former HHMI investigators have been awarded the Nobel Prize. The HHMI Investigator Program is organized around the core belief in the power of individuals to make breakthroughs over time. Through the program, which selects 20 investigators per year, HHMI aims to expand a community of basic researchers and physician scientists who catalyze discovery research in basic and biomedical sciences, plant biology, evolutionary biology, biophysics, chemical biology, biomedical engineering, and computational biology. See *Investigator Program*, HHMI (last accessed Feb. 3, 2021), https://www.hhmi.org/programs/biomedical-research/investigator-program; see also *Competition to Select New HHMI Investigators*, HHMI (2020), https://www.hhmi.org/sites/default/files/programs/investigator/investigator2021-program-announcement-200714.pdf.

[24] This mirrors the HHMI structure and cost model, with HHMI awarding $8 million over a seven-year term. HHMI updated the length of their award in 2018, extending the term from five to seven years. See *HHMI Bets Big on 19 New Investigators*, HHMI (May 23, 2018), https://www.hhmi.org/news/hhmi-bets-big-on-19-new-investigators.

[25] Should researchers move institutions over the course of the program, the award would move with them.

[26] This could be conducted through a cooperative agreement, mirroring the relationship NSF formed with the Computing Research Association to launch the Computing Innovation Fellows program in 2009 to support postdoctoral PhDs imperiled in finding academic appointments by the downturn of the economy. See *CIFellow*s, Computing Community Consortium (last accessed Jan. 1, 2021), https://cra.org/ccc/leadership-development/cifellows/. Furthermore, this entity would be able to accept supplemental funding from individuals, corporations, or other non-profits to further strengthen and expand the program.

[27] They would provide meaningful feedback to selectees throughout their participation in the program. The quality of feedback provided by reviewers was identified by researchers as a key factor in the success of HHMI investigators. Pierre Azoulay, et al., *Incentives and Creativity: Evidence from the Academic Life Sciences*, NBER (Dec. 2011), https://www.nber.org/papers/w15466.

[28] Pierre Azoulay & Danielle Li, *Scientific Grant Funding*, MIT & NBER (March 4, 2020), https://mitsloan.mit.edu/shared/ods/documents/?PublicationDocumentID=6296. See also the "gold award" model used by the Gates Foundation. *How Grand Challenges Explorations Grants Are Selected*, Bill & Melinda Gates Foundation Global Grand Challenges (last accessed Feb. 3, 2021), https://gcgh.grandchallenges.org/how-grand-challenges-explorations-grants-are-selected.

[29] The amount of the award would be adjusted in accordance with the specificities of the project. Eligible teams would be composed of researchers based in U.S. academic or research institutions proposing innovative work related to AI.

[30] The annual Taulbee Survey that tracks the field of computer science (CS) found that women make up 21.0% of CS bachelor graduates and 20.3% of CS doctoral graduates, and domestic underrepresented minorities account for 14.7% of CS bachelor graduates and only 3.1% of doctoral graduates. Stuart Zweben & Betsy Bizot, *2019 Taulbee Survey*, Computing Research Association at 4-5, 22, (May 2020), https://cra.org/wp-content/uploads/2020/05/2019-Taulbee-Survey.pdf.

[31] Nur Ahmed & Muntasir Wahed, *The De-democratization of AI: Deep Learning and the Compute Divide in Artificial Intelligence Research*, ArXiv (Oct. 22, 2020), https://arxiv.org/abs/2010.15581.

[32] Joel Klinger, et al., *A Narrowing of AI Research?* ArXiv (Nov. 18, 2020), https://arxiv.org/pdf/2009.10385.pdf.

[33] This program may be realized as a single cloud resource or a federation of resources, the pros and cons of which should be considered by the task force with determinations made within their resulting roadmap.

[34] Such as the NSF's CloudBank, which brokers cloud access to specific NSF-funded researchers, and the COVID-19 High Performance Computing Consortium, a public-private partnership that grants access to a range of computing resources to serve COVID-19–related research. See CloudBank (last accessed Jan. 2, 2021), https://www.cloudbank.org/; the COVID-19 High Performance Computing Consortium (last accessed Jan. 2, 2021), https://covid19-hpc-consortium.org/.

[35] Pub. L. 116-283, sec. 5106, William M. (Mac) Thornberry National Defense Authorization Act for Fiscal Year 2021, 134 Stat. 3388 (2021).

[36] For example, AI testbeds could be hosted by DoE's existing national laboratory facilities and high-performance computing resources, by DoD's existing testing and evaluation infrastructure, or by facilities managed by the Department of Transportation, NIH, NIST, or the Department of Agriculture.

[37] The National AI Initiative Act of 2020 tasks NIST to develop standards for AI data sharing and documentation. See Pub. L. 116-283, William M. (Mac) Thornberry National Defense Authorization Act for Fiscal Year 2021, 134 Stat. 3388 (2021).

[38] Through such mechanisms as the Intergovernmental Personnel Act mobility program. *Intergovernmental Personnel Act*, U.S. Office of Personnel Management (last accessed Feb. 1, 2021), https://www.opm.gov/policy-data-oversight/hiring-information/intergovernment-personnel-act/.

[39] Executive Order 13859 on AI called on federal agencies to "enhance access to high-quality federal data, models, and computing resources to increase their value for AI R&D." See Donald J. Trump, *Executive Order on Maintaining American Leadership in Artificial Intelligence*, The White House (Feb. 11, 2019), https://trumpwhitehouse.archives.gov/presidential-actions/executive-order-maintaining-american-leadership-artificial-intelligence/.

[40] This would provide for creation of five initial data sets, as well as maintenance over their lifetime and creation of additional data sets as the program matures.

[41] The DoE is well placed to manage such a program, leveraging the cross-disciplinary expertise resident throughout the laboratory network, the unique computing and user facilities housed at the 17 laboratories, and the ability to create and maintain secure data environments. *User Facilities at a Glance*, U.S. Department of Energy: Office of Science (last accessed Jan. 2, 2021), https://science.osti.gov/User-Facilities/User-Facilities-at-a-Glance#0. The program could build on the pathfinder Open Data Initiative launched by Lawrence Livermore National Laboratory in partnership with the University of California San Diego, which hosts complex, labelled data sets for testing solutions for scalable ML platforms. See *New Partnerships Results in Increased Access to Compelling "Real World Data,"* UC San Diego (April 21, 2020), https://library.ucsd.edu/news-events/new-partnership-results-in-increased-access-to-compelling-real-world-data/; *Open Data Initiative*, Lawrence Livermore National Laboratory (last accessed Jan. 2, 2021), https://data-science.llnl.gov/open-data-initiative.

[42] For example, NSF, NASA, NIH, and DARPA have all sponsored or created data resources relevant to an open knowledge network. In addition, government and community-led efforts to pool data to build solutions to the COVID-19 pandemic could be leveraged.

[43] *Open Knowledge Network: Summary of the Big Data IWG Workshop*, National Science & Technology Council (Nov. 2018), https://www.nitrd.gov/pubs/Open-Knowledge-Network-Workshop-Report-2018.pdf.

[44] This would build on ongoing efforts through NSF's Convergence Accelerator track on Open Knowledge Networks. *NSF Convergence Accelerator Awards Bring Together Scientists, Businesses, Nonprofits to Benefit Workers*, NSF (Sept. 10, 2019), https://www.nsf.gov/news/special_reports/announcements/091019.jsp.

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[45] For additional details and recommendations on technologies associated with AI that are important to U.S. technology leadership, see Chapter 16 of this report. A strategic industry is considered by the government to be very important to a country's economy or safety. In the national security context, it is considered critical to the country's competitive advantage over an adversary. While the United States' 16 critical infrastructure sectors refer to large segments of the economy "whose assets, systems, and networks, whether physical or virtual, are considered so vital to the United States," a strategic industry refers to a much more specific group of companies or businesses. See *Critical Infrastructure Sectors*, Cybersecurity and Infrastructure Agency (last accessed Jan. 4, 2020), https://www.cisa.gov/critical-infrastructure-sectors; see also *Strategic Industry*, Cambridge Dictionary (last accessed Jan. 4, 2020), https://dictionary.cambridge.org/dictionary/english/strategic-industry.

[46] U.S. federal agencies collectively have an annual information technology (IT) budget of $90 billion—one-tenth the annual revenue of the top five U.S. tech firms—yet the majority of government systems are "outdated and poorly protected." *An American Budget*, U.S. Office of Management and Budget at 9 (Feb. 2018), https://trumpwhitehouse.archives.gov/wp-content/uploads/2018/02/budget-fy2019.pdf.

[47] Congress, in the Consolidated Appropriations Act, 2021, called on the General Services Administration (GSA) to create a five-year program to be known as the "AI Center of Excellence" to "(1) facilitate the adoption of artificial intelligence technologies in the Federal Government; (2) improve cohesion and competency in the adoption and use of artificial intelligence within the Federal Government; and (3) carry out paragraphs (1) and (2) for the purposes of benefiting the public and enhancing the productivity and efficiency of Federal Government operations." *Rules Committee Print 116-68, Text of the House Amendment to Senate Amendment to H.R. 133*, U.S. House Committee on Rules at 378 (Dec. 21, 2020), https://rules.house.gov/sites/democrats.rules.house.gov/files/BILLS-116HR133SA-RCP-116-68.pdf (referring specifically to section 103 of the Consolidated Appropriations Act, 2021).

[48] The Consolidated Appropriations Act, 2021, outlines AI CoE's duties to include "advising the Director of the Office of Science and Technology Policy on developing policy related to research and national investment in artificial intelligence." *Rules Committee Print 116-68, Text of the House Amendment to Senate Amendment to H.R. 133*, U.S. House Committee on Rules at 380 (Dec. 21, 2020), https://rules.house.gov/sites/democrats.rules.house.gov/files/BILLS-116HR133SA-RCP-116-68.pdf.

[49] The National AI Initiative Act of 2020 directs the Director of OSTP to establish a "National Artificial Intelligence Initiative Office" within OSTP to "(1) provide technical and administrative support to the Interagency Committee and the Advisory Committee; (2) serve as the point of contact on Federal artificial intelligence activities carried out under the Initiative for Federal departments and agencies, industry, academia, nonprofit organizations, professional societies, State governments, and such other persons as the Initiative Office considers appropriate to exchange technical and programmatic information; (3) conduct regular public outreach to diverse stakeholders, including through the convening of conferences and educational events, the publication of information about significant Initiative activities on a publicly available website, and the dissemination of findings and recommendations of the Advisory Committee, as appropriate; and (4) promote access to and early adoption of the technologies, innovations, lessons learned, and expertise derived from Initiative activities to agency missions and systems across the Federal Government, and to industry, including startup companies." Pub. L. 116-283, sec. 5102, William M. (Mac) Thornberry National Defense Authorization Act for Fiscal Year 2021, 134 Stat. 3388 (2021).

[50] The Consolidated Appropriations Act, 2021, outlines AI CoE's duties to include "advising the Administrator, the Director, and agencies on the acquisition and use of artificial intelligence through technical insight and expertise, as needed." *Rules Committee Print 116-68, Text of the House Amendment to Senate Amendment to H.R. 133*, U.S. House Committee on Rules at 379 (Dec. 11, 2020), https://rules.house.gov/sites/democrats.rules.house.gov/files/BILLS-116HR133SA-RCP-116-68.pdf.

[51] The Consolidated Appropriations Act, 2021, outlines AI CoE's duties to include "(1) regularly convening individuals from agencies, industry, Federal laboratories, nonprofit organizations, institutions of higher education, and other entities to discuss recent developments in artificial intelligence, including the dissemination of information regarding programs, pilots, and other initiatives at agencies, as well as recent trends and relevant information on the understanding, adoption, and use of artificial intelligence; (2) collecting, aggregating, and publishing on a publicly available website information regarding programs, pilots, and other initiatives led by other agencies and any other information determined appropriate by the Administrator." *Rules Committee Print 116-68, Text of the House Amendment to Senate Amendment to H.R. 133*, U.S. House Committee on Rules at 378-79 (Dec. 21, 2020), https://rules.house.gov/sites/democrats.rules.house.gov/files/BILLS-116HR133SA-RCP-116-68.pdf.

[52] The digital playbook should consider recent upgrades made to Acquisition.gov. An important element of the development of an effective playbook is ensuring its interface and content accounts for different user profiles. Critical among those user profiles is that of a small-business or non-traditional government contractor that may be unfamiliar with the process to even begin eligibility for a government contract. *Access the Federal Acquisition Regulation*, U.S. General Services Administration (last accessed Feb. 18, 2021), https://www.acquisition.gov/.

[53] The SBIR program is one of the largest and longest-standing programs for federally funded R&D in small businesses. It was established in 1982 as part of the Small Business Innovation Development Act, and Federal agencies with extramural research and development budgets that exceed $100 million set aside 3.2% of their budgets to fund the SBIR program. The program is structured in three phases: Phase I awards of approximately $50,000 to $250,000 for six months to vet "technical merit, feasibility, and commercial potential"; Phase II awards of $750,000 to $1,700,000 for two years to support successful efforts initiated in Phase I; and Phase III, which is not funded by SBIR dollars, to pursue commercialization. The program issues a higher number of Phase I awards but allocates more funding toward Phase II, with the goal of placing many small bets on novel technologies and only scaling those that show real promise. NSCAI Engagement (Sept. 25, 2020); see also *About*, Small Business Innovation Research (last accessed Feb. 3, 2021), https://www.sbir.gov/about.

[54] For example, AFWERX's Supplemental Funding Pilot Program (TACFI and STRATFI) and USD(R&E)'s Accelerated Transition funding program.

[55] "As of November 2020, agencies may issue a Phase I award (including modifications) up to $259,613 and a Phase II award (including modifications) up to $1,730,751 without seeking SBA approval. Any award above those levels will require a waiver." *About*, Small Business Innovation Research (last accessed Feb. 3, 2021), https://www.sbir.gov/about. See also *Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR) Program Policy Directive*, U.S. Small Business Association (May 2, 2019), https://www.sbir.gov/sites/default/files/SBIR-STTR_Policy_Directive_2019.pdf.

[56] The Air Force, in partnership with Air Force Research Lab (AFRL) and the National Security Innovation Network (NSIN), developed Open SBIR Topics, which includes a "few big bets" (strategic financing): rewards of up to $15 million, with 1:1:2 Program-SBIR-Private Matching options. *SBIR Open Topics*, U.S. Air Force AFWERX (last accessed Feb. 3, 2021), https://www.afwerx.af.mil/sbir.html.

[57] Specifically, on page 74 of the SBA SBIR/STTR Policy Directive, the line "For example, some agencies administer Phase IIB awards that differ from the base Phase II in that they require third party matching of the SBIR/STTR funds." could be changed to "For example, some agencies administer Phase II or IIB awards that require third party matching of the SBIR/STTR funds." *Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR) Program Policy Directive*, U.S. Small Business Administration at 74 (May 2, 2019), https://www.sbir.gov/sites/default/files/SBIR-STTR_Policy_Directive_2019.pdf.

[58] The current application portals for beta.sam.gov and the "Defense SBIR/STTR Innovation Portal" are significant barriers to entry for non-traditionals trying to work with the DoD. NSCAI staff engagement (Feb. 9, 2021).

[59] *Future of Defense Task Force Report 2020,* U.S. House Committee on Armed Services at 68 (Sept. 23, 2020), https://armedservices.house.gov/_cache/files/2/6/26129500-d208-47ba-a9f7-25a8f82828b0/424EB2008281A3C79BA8C7EA71890AE9.future-of-defense-task-force-report.pdf.

[60] For more examples of innovation initiatives and recommendations to scale their impact, see Chapter 2 of this report and its associated Blueprint for Action.

## Blueprint for Action: Chapter 11 - Endnotes

[61] Contracts must be easier to understand and fill out, review periods shortened and clearly communicated, and oversight streamlined to keep pace with the current rate of technology innovation.

[62] Phase II and supplemental awards should be based on a broader diligence process that includes the long-term health and viability of the company. This assessment should consider as a starting point the firm's technical capabilities, financial structure, management structure, and the larger commercial market opportunities.

[63] Phase II enhancements, sometimes called Phase IIB/II.5 contacts, have become a common method to extend SBIR dollars to promising projects that fail to secure Phase III funding. The Navy Commercialization Readiness Program oversees the distribution of Phase II.5 contracts "to further develop SBIR technologies and to accelerate transition for existing Phase II projects." *Navy Phase II.5 Structure and CRP*, U.S. Navy (last accessed Feb. 3, 2021), https://www.navysbir.com/cpp.htm. The Air Force's AFWERX, Army, and DARPA, as well as several Federal agencies outside the DoD, also use Phase IIB awards. The Office of the Secretary of Defense (OSD) Transitions SBIR Technology Pilot Program provides SBIR awardees the opportunity to apply for Phase II Enhancement (e) and Accelerated Transition funding for the funding sponsor. However, current funding limits set by SBA reduce their efficacy by including Phase II enhancements under the Phase II cap of SBIR dollars. NSCAI staff engagement (Sept. 23, 2020). For further detail, see *Interim Report and Third Quarter Recommendations*, NSCAI at 52-57 (Oct. 2020), https://www.nscai.gov/previous-reports/.

[64] This effort would be informed by the Technology Annex to the National Defense Strategy recommended in Chapter 2 of this report.

[65] The future will likely be defined by a fusion of many different AI approaches including expert systems, model-based AI, symbolic-based AI, statistical ML, and new and evolving AI approaches such as neurosymbolic AI. See *Neuro-Symbolic AI*, MIT-IBM Watson AI Lab (last accessed Feb. 3, 2020), https://mitibmwatsonailab.mit.edu/category/neuro-symbolic-ai/.

[66] DARPA's SBIR program, for example, is unique in its long time horizon. Most of its investments are pre-commercial and will take another eight to 10 years to develop before results can be scaled for military or commercial use.

[67] David E. Cooper, *Defense Industry Consolidation: Competition Effects of Mergers and Acquisitions*, Statement before the U.S. Senate Committee on Armed Services Subcommittee on Acquisition and Technology (March 4, 1998), https://www.gao.gov/assets/110/107240.pdf.

[68] For example, Intel's recent chip missteps have jeopardized U.S. leadership in the design and manufacturing of advanced semiconductors. See Michael Kan, *Intel: Sorry, But Our 7nm Chips Will Be Delayed to 2022, 2023*, (July 23, 2020), https://www.pcmag.com/news/intel-sorry-but-our-7nm-chips-will-be-delayed-to-2022-2023.

[69] For example, small firms have difficulty affording the cost of compute resources and data for training sophisticated ML models. Nur Ahmed & Muntasir Wahed, *The De-democratization of AI: Deep Learning and the Compute Divide in Artificial Intelligence Research*, arXiv (Oct. 22, 2020), https://arxiv.org/abs/2010.15581.

[70] Michael Porter, *The Competitive Advantage of Nations*, Harvard Business Review (1990), https://hbr.org/1990/03/the-competitive-advantage-of-nations.

[71] *Interim Report*, NSCAI at 26 (Nov. 2019), https://www.nscai.gov/previous-reports/; see also Michael Porter, *Clusters and the New Economies of Competitio*n, Harvard Business Review (1998), https://hbr.org/1998/11/clusters-and-the-new-economics-of-competition.

[72] William R. Kerr & Frederic Robert-Nicoud, *Tech Clusters*, Journal of Economic Perspectives at 63 (2020), https://pubs.aeaweb.org/doi/pdfplus/10.1257/jep.34.3.50.

[73] The program office could be modeled on the Advanced Manufacturing National Program Office that coordinates Manufacturing USA, a network of manufacturing innovation institutes. See Manufacturing USA (last accessed Feb. 3, 2021), https://www.manufacturingusa.com/.

[74] For example, proximity to research facilities operated by the departments of Defense and Energy or access to technically oriented military installations should be prioritized.

[75] See the Chapter 13 Blueprint for Action for more details on the importance of U.S. access to trusted and assured microelectronics for national security use cases. The Commission also proposes a preliminary list of strategic emerging technologies that are critical to U.S. national competitiveness in Chapter 16 of this report.

[76] The existence of a nascent cluster suggests industry has already passed the market test. Mark Muro & Bruce Katz, *The New "Cluster Moment": How Regional Innovation Clusters Can Foster the Next Economy*, The Brookings Institution (Sept. 21, 2010), https://www.brookings.edu/research/the-new-cluster-moment-how-regional-innovation-clusters-can-foster-the-next-economy/. Resources like the U.S. Cluster Mapping Project will also be essential to identify which locations are economically viable. See U.S. Cluster Mapping (last accessed Feb. 3, 2021), http://clustermapping.us/.

[77] Anchor institutions are firms, not-for-profit institutions, and research universities that locate near the cluster and pursue joint R&D with federal agencies or other cluster participants.

[78] *Overview: The New Federal Role in Innovation Clusters, Clustering for 21st Century Prosperity: Summary of a Symposium*, The National Academies Press (2012), https://www.nap.edu/read/13249/chapter/3#31.

[79] For example, the clusters may be co-located with DoE's national laboratories or military test ranges.

[80] According to the Council of Economic Advisors, Opportunity Zones (OZs) incentivize private investment in low-income communities by lowering capital gains taxes on businesses investing in the region, which could be a revenue-neutral way of lifting people out of poverty due to the expected reduction in transfer payments. Investors receive tax benefits for investing in Qualified Opportunity Funds, which can be used to make equity investments in partnerships or corporations that operate in an OZ. The funds can also be used to purchase tangible property for use in the fund's trade or business. See *The Impact of Opportunity Zones*, The Council of Economic Advisors (Aug. 2020), https://trumpwhitehouse.archives.gov//wp-content/uploads/2020/08/The-Impact-of-Opportunity-Zones-An-Initial-Assessment.pdf.

[81] Private-sector contributions may comprise cost sharing in joint R&D projects, donations, or membership dues, if such a model is adopted.

[82] CODE Advocacy Coalition (last accessed Jan. 2, 2021), https://advocacy.code.org/.

[83] See, e.g., *Microsoft Philanthropies: TechSpark*, https://query.prod.cms.rt.microsoft.com/cms/api/am/binary/RE4s6AL; Carolina Milanesi, *STEM Education as a Diversity Driver in Tech*, Amazon (Sept. 14, 2020), https://www.aboutamazon.com/news/community/stem-education-as-a-diversity-driver-in-tech; *Applied Digital Skills: Teach and Learn Practical Digital Skills*, Google (last accessed Jan. 2, 2021), https://applieddigitalskills.withgoogle.com/s/en/home.

[84] Michael Wade, *Corporate Responsibility in the Digital Era*, MIT Sloan Management Review (April 28, 2020), https://sloanreview.mit.edu/article/corporate-responsibility-in-the-digital-era/.

[85] Partnership on AI has a mission to shape best practices, research, and public dialogue about AI's benefits for people and society, with partners from more than 100 companies and research organizations. *Partnership on AI* (last accessed Feb. 3, 2021), https://www.partnershiponai.org.

[86] See Chapter 6 of this report for further discussion of the Commission's proposed U.S. Digital Service Academy.

[87] One way this could be enacted is by assigning "national mission managers" to oversee each opportunity identified.

[88] As recommended in Chapter 9 of this report.