CHAPTER 7: CONCLUSIONS AND FUTURE NEEDS, GAPS, AND CHALLENGES

The pilot activities highlight that there is both an art and a science to effective critical technology assessment, and that such assessment is essential to ensure that the country smartly invests and enacts necessary policies to achieve short- and long-term security, prosperity, and broad-based social well-being. Effective assessment is not top-down coordination or optimization of investments that copies competitor nations' style and approach, nor can it be solely a curiosity- (for science) or market- (for technology) driven approach that fails to acknowledge the stakes and the outcomes for the nation and its people.

As Congress recognized in the creation of TIP, something disruptive is needed in how we fund the pathway from translational discovery to commercialization. In addition, for TIP to be effective in fulfilling its charge, something novel and organizationally disruptive is also needed in how the nation conducts critical technology assessment (CTA): the federal government will need to intentionally design a rapid CTA function for Congress and the executive branch alike. This program must embrace the accelerating pace of innovation, draw on the nation's rich variety of institutions, disciplines, and agencies, and exploit their analytic power and technical expertise. Such work will be best led by a single organizational unit charged to think across national objectives and technology interdependencies, engaging topic-specific program managers trained in the art of critical technology assessment to identify the most important problems, match methods to problems, and mobilize and orchestrate the distributed national capabilities both within and outside government.

The NNCTA pilot year activities demonstrate that data and analytics can meaningfully inform national technology strategy, but the necessary capabilities do not sit with one discipline, investigator, or type of organization. The novel pairings and cross-disciplinary collaborations that were effective in this pilot year had to be orchestrated (a hallmark of the efforts undertaken by DARPA program managers). This orchestration is an "art" that, if done well, yields a whole greater than the sum of the parts: creating a dynamic exchange between a 30,000-foot machine-driven and a bottom-up expert-driven perspective to benefit from both; combining data across scholarly areas and institutions to transcend gaps; marshaling different disciplines and methods to solve different aspects of a policy problem; setting up different perspectives on the same policy problem to enhance understanding through complementary or contradictory insights; creating teams to combine disciplines and models in a way that produces otherwise unavailable novel findings; identifying transition partners; and transparently engaging throughout and communicating the final findings across the variety of relevant stakeholders. The analytic methods leveraged in specific fields are the frontiers of science—whether economics, computer science, sociology, political science, psychology and decision science, or engineering.

The pilot year investigations also revealed that the most appropriate methods and data are not static but closely linked with (i) the status of a technology's discovery, diffusion, and adoption; (ii) US global competitiveness in the knowledge, production, and use relevant to the technology; and (iii) the state of the policy process with respect to the technology. Understanding the most important problems to tackle in a particular area, and how to match methods across disciplines to those problems, requires deep knowledge of the industrial, technological, and policy contexts. Program managers with the talent to identify and understand national challenges as well as top researchers' activities across disciplines, and to provide the orchestration needed to address those challenges, are rare. The nation should cultivate them by investing in nontraditional educational

programs and professional fellowships to build human capital with problem-oriented policy skills that leverage analytic rigor, interdisciplinary methods, and contextual and phenomenological depth—in short, to develop a community of practice in (rapid) critical technology assessment.

A number of cross-cutting insights for critical technology assessment can be drawn from the area demonstrations:

Advanced analytics today can be used to inform

- US global competitiveness in scientific funding and its collaboration networks
- US domestic funding biases that are failing to leverage the full bench of talent
- Technology commercialization pathways, including policy, investment, and other interventions—technical, human capital, infrastructure, regulatory, and citizen awareness and participation—to overcome bottlenecks. Following are examples of options identified this year to overcome technology commercialization bottlenecks:
  - Identify infrastructure gaps and increase access to that infrastructure to boost innovation;
  - Identify skill gaps in specific regions and training or worker mobility interventions to overcome these gaps;
  - Identify public, technical, and regulatory bottlenecks to the introduction of new technologies in commodity products, and opportunities to overcome those bottlenecks.
- Investment and policy interventions that could reduce supply chain vulnerabilities, and the value of that reduced vulnerability for national objectives in security, the economy, and social well-being.

US CTA capability is hampered by the following gaps:

- Building situational awareness of global technology and production capabilities is much more challenging than analyzing scientific and inventive capabilities through publications and patents: the data currently don't exist, and therefore few scholars or practitioners are rigorously addressing these problems. A CTA function must invest in these capabilities and develop a framework to determine where and how frequently they should be applied.
- The data needed for analytics to inform policy and investment in a timely fashion for rapidly moving critical technologies such as AI are lacking. Public-private partnerships must be established to create these datasets to inform critical questions in national technology strategy. There are analogous needs to coordinate data across the private sector and government in a timely fashion in certain critical technology supply chains.
- The inclusion of equity in each analysis requires resources. Equity is not a single field of study, and experts with complex analytic, technical, and phenomenological knowledge are needed to address issues in algorithmic bias, energy equity, health equity, and equity and discrimination in labor and training (e.g., conscious and unconscious recruiting bias, macro- and microaggressions in STEM fields), among others. CTA leadership (the director, government director, and technical director) will also need to ensure that program managers maintain a cross-mission focus involving all three dimensions of criticality (security, the economy, social well-being) and that all analyses include the geographic and demographic implications of policies and investments.

US CTA capability will require the following institutional innovations:

- Leveraging the best of the nation's analytic capabilities to address the full portfolio of CTA challenges, opportunities, and needs will require integration of capabilities across a range of performers from academia, industry, and nonprofits such as FFRDCs.
- To scale this year's project and performer selection and orchestration activities, area-specific program managers should have deep contextual (technical and industrial) expertise in their topic area, experience in a diversity of institutions (academia, industry, and government), and an ability to understand leading analytic capabilities. There is a shortage of this type of human capital.

- To ensure policy relevance and impact of selected projects, program managers should be charged with (i) scanning globally and domestically for US challenges and gaps and (ii) scanning the nation's top talent for analytics to address those challenges, identifying multiple stakeholder agencies to partner with on specific analytic projects, and ensuring government transition partners for the outcomes.
- To simultaneously maintain relevance to policy and develop buy-in from relevant government stakeholders in the legislative and executive branches, members of Congress, the executive branch, and government agencies should be allowed to cofund analytic undertakings.
- The lack of a field of critical technology assessment means there is also a lack of human capital with the skills necessary both to perform the analytics needed for national technology strategy development and to serve as program managers of the work conducted across the country in each area. New education programs and professional fellowships are needed to invest in building this human capital.

Across demonstration areas, many scholars, government labs, and nonprofits (including FFRDCs) have a deep bench of data and models. The US government must develop a disruptive new program to tap into and integrate this expertise.

Based on these observations and our pilot year demonstrations, we recommend that the United States invest in a rapid critical technology assessment entity to provide the executive and legislative branches with the tools needed to inform national technology strategy. This CTA program would, as part of its primary functions, support NSF TIP in its annual roadmapping and OSTP in its Quadrennial National Technology Strategy, serve Congress and the executive branch with analytics to inform critical technology strategy across national (and agency-specific) missions writ large, and serve as a trusted source of technology assessment capability to government, industry, nonprofits, and the public. The program should focus on problems that span national missions, taking account of technology and policy interdependencies and of win-wins or tradeoffs across national objectives (or individual agency missions).

The CTA program would in many ways serve as an "analytic ARPA" to orchestrate the analytics necessary to inform national technology strategy. The program should draw heavily from the DARPA model in terms of its dynamism, and the independence and discretion of talented program managers to choose problems and orchestrate top performers to address those problems. It should also, like DARPA, push the frontier of analytic capabilities, then transfer those capabilities eventually into the executive and legislative branches. Unlike DARPA, however, the program should not undertake high-risk analyses but be grounded in a simultaneously disciplined and innovative analysis process, pushing the frontier of scientific and analytic capabilities.

The core CTA function would be conducted by a program manager with both area-specific expertise (e.g., technical depth, such as in AI or semiconductors) and institutional and disciplinary breadth. Program managers would, as at DARPA, have limited terms to help keep the organization nimble and up-to-date and also to facilitate these positions as a stepping stone to follow-up leadership positions. The CTA entity would involve and draw on agency and organizational expertise across the government. It would fund problem-oriented research and also serve a business development role in supplementing nonspecific funds with matching contracts from relevant executive or legislative branches (e.g., for issues that cross departmental missions in semiconductors, involving the Departments of Commerce, Defense, and Energy; or, in the case of novel data infrastructure, NCSES, the International Trade Commission, and/or the US Census Bureau). In addition to the CTA entity's advisory board, which should include leaders from government agencies as well as from academia and industry, each program manager should have an area-specific advisory committee, and run workshops that bring together relevant thought leaders and stakeholders from academia, industry, government, and nonprofits to launch and inform analytic programs.

Overseeing the program managers, in a way similar to DARPA office directors' integrational role, would be a government director and a technical director. The government director would identify relevant national challenges across

departments for which there likely is particular value in analytics, including in quantifying tradeoffs or win-wins across missions. The technical director would identify opportunities for collaboration or integration across the topic areas. The government and technical directors, along with the CTA program director, would together be responsible for one of the most challenging and important functions: where to focus the limited analytic resources—identifying the topic areas for program managers, reducing or eliminating funding of some areas as appropriate, and bringing on new program managers and funding in newly needed topics.

The CHIPS and Science Act calls for a new federal capacity to fortify the nation's leadership and ability to determine policies and investments that will ensure national security, global competitiveness, economic prosperity, and social well-being. To effectively operationalize this mandate will require something truly disruptive. This report of the pilot National Network for Critical Technology Assessment provides evidence of what analytics can accomplish, and the critical components for a path forward as effective and disruptive as legislators envisioned.