CHAPTER 6: A VISION FOR THE FUTURE

NETWORK SUSTAINABILITY

As explained in the preceding chapters, a nongovernmental body for science and technology (S&T) analysis, such as this year's pilot National Network for Critical Technology Assessment, could help Congress and agencies sift through and evaluate information bearing on numerous national issues. To survive any length of time the program will have to identify unfilled policymaking needs, satisfy them, and continue to do so while building and maintaining trusted relationships. It will have to determine whether and how it can provide policy-relevant findings for what are inevitably political decisions. And it will have to establish both credibility and usefulness among policymakers, stakeholders, and the public.

A number of analytical groups in the federal government (e.g., the Census Bureau, NSF, Energy Information Administration, Bureau of Economic Analysis, and Bureau of Labor Statistics) have established and sustained reputations for reliable data gathering and presentation. In addition, the Congressional Budget Office, Congressional Research Service, and Government Accountability Office are valued sources of digestible information for Congress.

As discussed in chapter 2, the Office of Technology Assessment (OTA) was specifically established to provide objective S&T analysis to Congress, but was closed in 1995 after little more than 2 decades.[1] Despite the perceived quality and usefulness of its reports, OTA did not have a sufficiently broad and deep support structure among congressmembers, committees, and their staffs to be sustained. OTA studies generally sought to address the socioeconomic implications of emerging technologies; although questions about critical technologies were discussed in several OTA studies, no OTA studies focused on them. Practically all of its studies were requested by members of Congress and approved by its Congressional Board, but, unlike CBO and GAO, its work was not grounded in federal spending and what taxpayers get for their money, an abiding consideration for congressmembers.

A reputation for reliable information and analysis requires nonpartisan independence and transparency, including acknowledgment of uncertainties. Usefulness for policymakers who must make difficult decisions comes in part from clear communication, relevance, and consistency in approach over time. During its pilot year, the Network demonstrated these qualities as well as technical depth and breadth, and resourcefulness and innovation in its use of available data and tools to yield clear, substantiated insights. These qualities are evidenced by the number of demonstrations that attracted agency and industry attention and influenced outcomes therein (situational awareness—DARPA; semiconductors—DARPA, DOD, and Commerce as well as industry and universities; generic drugs—the White House; and energy—DOE and OMB).

But by many indications, more and more US residents now reject the findings of competent scientists, engineers, and physicians, who were once but no longer are widely accepted as experts. Experiences and behaviors during the COVID-19 pandemic as well as the 2020 election and its aftermath revealed the impacts of widespread misinformation, mistrust, and manipulation. In addition, many Americans simply adopted different views of the pandemic and associated choices: dollars vs. deaths, PPE vs. personal autonomy, inoculation vs. individualism, one risk vs. another…. The skeptics and their values were often confounding to the scientists and technocrats who staffed and advised government agencies. Beyond COVID, Americans are similarly divided over climate change, alternative energy, public education, and much else. This

[1] A good deal has been written about OTA since its closure. See, for example, *Technology in Society* 42(2-3) (1997), "Special Issue: Technology Assessment: The End of OTA"; Sadowski (2015), Graves and Schuman (2020), and Blair (2013).

suggests that whatever analytical findings emerge from a CTA effort might come under attack. An effective CTA program will have to anticipate such reactions and seek to counter them as best it can by recognizing when potential policy options would implicitly be based on values that may not be universally held and by establishing its political neutrality, openness to evidence, thorough analysis, and evenhandedness. To avoid backlash, the CTA program should incorporate a diverse set of representatives of civil society organizations (e.g., consumer advocates, environmentalists, trade unionists, chambers of commerce, professional associations, civil rights groups), much as OTA did with its advisory panels, to listen to their concerns and suggestions, enlist their support, and defuse charges of elitism. In addition, to earn both agency and public trust it will be essential to elicit public perceptions and early public input, document the geographic and demographic distribution of impacts, and engage experts in science communication to make as much data as possible publicly available in an interactive, easily digestible form.

Coordination of this sort may be more difficult in a decentralized network, where participants have distinct roles, identities, and organizational homes, than in a single agency. But to the extent that the coalitions that emerge from a more inclusive planning process are likely to be broader than their predecessors, the results are likely to be more sustainable as well. If the CTA program is going to prove viable and make the most of its resources and political capital, it needs to build bridges not only among the so-called experts of different disciplines but also with policymakers and the broader US population.

LONG-TERM OPERATIONS MODEL AND ORGANIZATIONAL FORM: LESSONS FROM THE PILOT YEAR

Building a national capability in critical technology assessment involves formidable challenges: the analytical tools are not clearly defined, the cross-disciplinary work involved is not academically recognized, the problems require interdisciplinary talent not easily attracted by individual agencies, and the problems are both interdependent and cross-mission in nature, spanning multiple departments and agencies (cf. Fuchs 2020, 2021a,b, 2022). The ideal analytic capability to inform national technology strategy would

- **Be strategic and forward-looking,** conducting work on timelines of 6 months to 2 years, while thinking about problems on the 1- to 50-year timeline. For example, the critical technology analytics program would focus not on building long-term data infrastructure but on providing strategic and quantitative guidance for building such capabilities and on demonstrating what capabilities are possible.
- **Integrate insights across disciplines and institutions,** bringing together technical expertise in engineering, the physical sciences, modern data analytics (e.g., machine learning, operations research, natural language processing), and the social sciences (e.g., economics, political science, sociology, history) as well as practitioners with experience in policy implementation.
- **Work on interagency projects,** including work from multiple agencies on one topic. Such work might reflect, for example, national security objectives per the Department of Defense; economic objectives per the Departments of Commerce or Treasury; and labor, health, and equity objectives per the Departments of Labor or Health and Human Services.
- **Be a neutral third party across stakeholder, agency, or political interests,** or have the capability to spin off public-private partnerships to serve as neutral third parties.
- **Operate through a highly flexible, distributed model** capable of rapidly mobilizing and reconfiguring outstanding private sector, government, and academic talent, data, and resources (e.g., through contracts or other mechanisms as necessary).

This year-long pilot was an exceptional opportunity for the nation to begin to operationalize this vision, with lessons about next steps necessary to more fully develop and realize it.

Organizational Form and Investment

PROGRAM MANAGEMENT: DIMENSIONS OF INTEGRATION

Operating in a Flexible, Distributed Model That Orchestrates Integrated Interdisciplinary Insight from Top Talent Nationwide

Submitting to NSF Technology Innovation and Partnerships' Broad Area Announcement meant that the NNCTA pilot year consisted of demonstrations *proposed by academics* of the potential for analytics to inform investments in science and innovation. With just 4 weeks to submit, the individuals engaged were leading academics in science and innovation policy of which the director was aware, and others enlisted by those individuals or suggested to the director during the 1- to 2-week search period. Given the limited search and organization period, the director and the small operational support team helped define the demonstration areas, sought and paired multidisciplinary talent for the demonstration areas, and managed and facilitated the interactions between performers. The scanning, orchestration, and management were similar to the collaboration and community orchestration done by DARPA program managers (Fuchs 2010).

To scale the above activities in future years, the ideal would be for program managers with expertise in the individual area demonstrations to assume responsibility for the relevant scanning (of government needs), orchestration (e.g., identification and funding of university faculty), and project management, all of which were done in the first year by the director and executive technical director. This scale-up will have benefits: Topic experts will do a better job of scanning in their area of expertise and will be focused specifically on critical technology assessment and what's needed to inform national investment.

In the long term it would be ideal for analytical talent to be drawn not just from academia but also from industry, nonprofits (e.g., RAND, MITRE), and government (especially government labs). That said, the pilot year's orchestration of academic talent from multiple disciplines offered important insights into management approaches to yield a whole that is greater than the sum of its parts (**box 6-1**).

Facilitating "Co-Optition" across Complementary Analytic Outcomes and Data

In the context of AI, three Network groups undertook analytics with similar or complementary objectives, using data sources that were different (surveys, job postings, patents, publications, depending on the group) and in some cases highly complementary (e.g., due to different foci, for US and Chinese data). Management involved facilitating engagements and interactions across the groups and identifying opportunities for collaboration. In the longer term, potentially important managerial roles might include offering neutral third parties or contexts to manage data or algorithm comparison or sharing, or bringing external incentives for cross-team engagement and collaboration. In the pilot year the groups compared outcomes across data sources, each with different limitations, and benefited from seeing where they pointed in the same direction. Future efforts will benefit from further staffing for facilitation, extramural fund raising, and the engagement of a neutral third party for data or analytic comparisons to bring about, for example, the sharing of US and China labor data held by different parties.

Orchestrating Analytics by a Nonacademic Leader with Technical, Industry, and Analytic Expertise

Unlike the other pilot year topic areas, the semiconductor lead was not a professor. Instead, he had experience working at a semiconductor startup and at a firm consulting to the semiconductor industry and in the introduction of new microelectronics products. For this project he orchestrated analytic research led by professors in four areas: economic analyses of the potential market value of emerging technologies and the optimal investment portfolio, expert interviews about technical bottlenecks to the commercialization and scale-up of emerging technologies, situational awareness of global semiconductor capabilities, and analytics of labor and skill requirements for and gaps in new semiconductor facility investments.

BOX 6-1

Consideration of an Alternative Organizational Form

An alternative organizational form discussed by Network members was a less top-down but gated membership organization that was organizationally more similar to a "network" like the Jasons and the Santa Fe Institute, both of which vote in new members. Concerns included lack of flexibility to call on whoever might be most suited to a particular problem and lack of dedicated staff to build the field of critical technology assessment. To build in flexibility, Network members discussed funds for emergent issues to be allocated by the director, with approval by the academic research council; and project reallocation by a board and the academic research council at the end of each year. This organizational model was eventually not favored because of the cited limitations and concerns about "involution," "group think," and incentives for existing members to sustain their funding and exclusive position.

He also oversaw his own project that led to an "early win" in terms of identifying an immediate gap in US access to what was needed for emerging technology commercialization, not yet addressed in the CHIPS and Science legislation. He was hired by the Department of Commerce to implement insights derived from the analyses he led. For this group the Network director was able to have less of a managerial role as the research topic identification, orchestration, and management were handled by the nonacademic lead.

Orchestrating Separate Analytic Perspectives in Parallel

The pharmaceuticals and public awareness teams each had important research insights in this area: what pharmaceuticals (especially generics) were most vulnerable to shortages, and what interventions may be most effective for public communication, understanding, and acceptance of policies to address the shortages. Close collaboration was not necessary for the two research activities; indeed, there was value in their being undertaken separately, resulting in independent analysis of criticality from the perspective of data, and rigorous academic analysis of expert and public perceptions of medicine criticality and potential solutions. From a managerial perspective, the most important function was to guide the two teams in parallel and to engage a neutral third party in writing the final integrated summary of the topic area. This function is not that different from a DARPA program manager funding complementary or competing technical solutions to a problem facing the Department of Defense.

Facilitating Teaming and Analytic Collaboration across Complementary Expertise

The energy storage and critical minerals PIs together proposed the most interconnected collective analysis, and required the least management of any team. The primary orchestration and management role of the director was in introducing the PIs to each other and asking them to work together in the pilot year. From there, the teams managed the project on their own. The director's only additional management involvement was in facilitating integration of the equity team's work, by identifying a broker across the highly integrated group and the equity team, which was conducting an energy equity survey.

Being Strategic and Forward-Looking

Because the academics were invited to propose the analytics, the projects were by definition on a longer time horizon than, for example, White House timelines. Given the normal multiyear timelines for many academics in S&T research and the focus of academic work on pushing the knowledge frontier, it was particularly impressive that the initial demonstrations were completed in just 6 months and integration across demonstrations in 9 months. The open multilateral conversations with government decision makers about academic work in progress, at the midway and third-quarter meetings, is also uncommon but was welcomed by the government and academics alike. The full benefits of drawing these two groups closer, including throughout the analytic process, may yet emerge.

Some aspects of the original vision were more challenging than others to realize. First, a national technology strategy must by definition span multiple government departments, each with specific, singular national objectives (e.g., defense, commerce, labor). The pilot year activities focused on demonstrating the potential for analytics to inform national technology strategy writ large (e.g., across departmental missions); because mission optimization is the job of each agency, and given the lack of coordination of activities across agencies, analytics that identify win-wins and tradeoffs across national objectives will continue to be an important focus for future CTA activities.

Second, the focus on how analytics could inform national technology strategy meant less research on what is a critical technology and how to measure a technology's criticality. While workshops and surveys elicited structured responses from the PIs and Advisory Council on these questions, in the longer term the Network would benefit from a small number of integrational research scientists dedicated to these types of research activities.

Finally, in the future the ideal approach to launch to new projects might be some combination of dedicated program managers whose job it is to scan government needs and academic, industry, and nonprofit capabilities, and the pilot year workshop that convened academia, industry, and government to launch the biopharmaceutical activity. Building on the concept behind our own advisory board, which had experts in each topic area pursued this year, program managers should also have area-specific expert advisory groups, which engage in these launch and stakeholder feedback workshops and serve as advisors on important topics. These advisory groups and workshops might serve a similar function in launching new projects to the Information Science and Technology (ISAT) advisory group for DARPA.

EXCHANGE: LESSONS ON INFORMING ANALYTIC PROJECTS THROUGH MULTILATERAL DIALOGUE BETWEEN ACADEMIA, INDUSTRY, AND GOVERNMENT

NSF TIP's 1-year $4M pilot award for a National Network for Critical Technology Assessment enabled the first step of bringing together top *academics* from across the country to define a vision for critical technology assessment, considering current capabilities, gaps, and the national investment and organizational form needed to realize that vision. But to be successful, a CTA vision must also involve practitioners from industry, government, and nonprofits. Industry and government stakeholders are essential contributors who need to inform not only the data and analytics but also the questions asked. Moreover, in multiple cases industry has essential data or analytic capabilities not available in government or academia.

Network leads sought and received an award from the Alfred P. Sloan Foundation for a series of workshops or other mechanisms to convene and engage in a multilateral dialogue with practitioners in industry, government, and nonprofits. The workshops provided a forum to discuss the proposed demonstrations and an opportunity for the practitioners to comment on the associated data, analytics, questions, and policy problems, to potentially team up with the academics in solving challenges, and to inform the vision for the future of critical technology assessment. In total we held eight workshops: one workshop for each area demonstration, one cross-cutting workshop for labor and equity, and two workshops where we engaged in multilateral dialogue on the analytic results with industry and government leaders as well as building a cross-area vision of critical technology assessment with performers.

The area workshops yielded important insights into long-term operations of a national network. By coincidence, the area leaders ended up experimenting with the timing of the workshops, which were held at three different stages of the analytic enterprise: during problem formulation before the use of substantial analytics (the biopharmaceuticals team led this workshop), roughly midway through the proposed analytic endeavor when stakeholder response had high value (the semiconductor team), and toward the end of the 1-year demonstration when red teaming of the results helped inform interpretation and future work (the situational awareness team). We propose that the three prototyped workshop functions would be valuable for future network projects to ensure robust dialogue between academia, industry, and government.

Problem Formulation (Biopharmaceuticals)

This workshop served as a prototype for convening industry, government, and academic leaders (both those doing the analytics and those conducting research in pharmaceutical science and technology, S&T) early in the analytic process. When the workshop took place data had arrived for one PI team and before analyses had begun for the other two PI teams. For two of the pharmaceuticals analytic experts, the workshop discussions provided qualitative data on technologies that could be used to overcome supply chain bottlenecks. For the other two teams, the discussions framed their research process. A main takeaway of this workshop was the value of convening government, industry, and academia to launch the analytic process. Similar to how Information Science and Technology (ISAT) workshops can launch ARPA programs, project funding would ideally follow (rather than, as this year, precede) these launch workshops.

Midway Stakeholder Feedback (Semiconductors)

The semiconductor workshop was held roughly midway through the analytic process. Once again, it convened leaders from industry, government, and academia (the latter were leaders in both analytics and relevant semiconductor S&T). Having read many public papers on what the government should do in this area, the lead PI had an early insight and recommendation for policy action—and also preliminary results on a second analysis that was different from the published positions. The PIs didn't know how stakeholders would respond, and expected potential opposition from industry on one recommendation and from university stakeholders on another. Surprising to the PIs, the workshop's industry participants were in favor of the early recommendation for policy action and among the academic stakeholders there was greater consensus (than in public statements) about the technical and human capital constraints to optimal capital investment to support R&D activities in this area. Last, a new direction of research emerged at the workshop related to workforce constraints, which the analytic team added to the analyses over the next 3 months.

Red Teaming (Situational Awareness)

A red-teaming workshop on situational awareness was held toward the end of the pilot year's analyses to deepen understanding of the results and build on them to inform the focus of future research. Again, leaders from industry, government, and academia were assembled, but instead of the workshop being run by the PI, the Network supported the event by assembling the experts and enlisting an outside contractor deeply engaged in relevant topics to identify additional experts and run the workshop. Area experts from NSF, ONR, DARPA, and a defense contractor took area demonstrations into the results that China was more disruptive than the United States in specific topics, to begin to unpack the source and validity of the results. For example, the experts agreed that the publication-based finding that Chinese researchers appear to be outpacing their US counterparts in selected beyond-CMOS technologies, specifically insulators, could be valid. At the same time, experts felt that the most important next steps for this research would be to do more analysis, specifically comparing independent expert assessments with the publication-based indicators or measures, in terms of (i) what were the most disruptive, prescient, and emergent publication (and nonpublication) scientific discoveries over the past 2–3 decades, and (ii) where China was and was not leading the United States in scientific discovery.

Cross-Area Workshops (Labor and Equity)

The labor and equity workshop highlighted the value of bringing together scholars with common interests across areas and methods, and should be replicated in the future on this topic as well as other cross-area themes to build both community and intellectual foundations. The workshops that created structured, multilateral interactions between industry, government, and the academic performers were particularly valuable in understanding stakeholder interests, needs, and support or lack thereof.

Overall Workshop Takeaways

As one Network PI said, "The demonstrations and workshops should by definition be different. This whole undertaking is a grand experiment. If we all did the same thing, we wouldn't be learning anything." The multiple workshop formats experimented with in the pilot year should continue in future years, and be run by the CTA program, both to standardize format and to learn lessons across them.

The area workshops were similar to those typically run by White House entities to convene industry leaders, academic experts, and government representatives across agencies, except with the goal of building analytics to inform the policy actions considered by those stakeholders. If all four types of workshops—launch, midway feedback, end-of-project red teaming, and cross-area community building—were run for all projects, this approach would have significant analogues to existing workshops associated with programs at DARPA: ISAT workshops, which likewise have multiple stages (for ISAT often three sequential workshops) and which often lead to program managers' decisions about funding directions for research. The cross-area workshops had community-building and direction consensus characteristics similar to DARPA workshops (such as the Electronics Resurgence Initiative annual meetings). While perhaps slightly different from the NNCTA midway or red-teaming workshops, DARPA program managers' multiple workshops also bring together performers to share information and influence the direction of their projects as they evolve. The diverse leadership of some of our most successful area workshops — by an Advisory Council member (who had previously been in the White House), the semiconductor lead (who had previous multi-institutional experience including in industry and consulting), and an external contractor (who had previous experience at WTEC and the NNCO) — speak to the large advantages for a CTA program creating a standard format for and facilitating future workshops.

Toward a Rapid Critical Technology Assessment Program

The pilot year 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 the necessary policy to achieve short- and long-term security, prosperity, and broad-based social well-being. This 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 nation and its people as stakeholders in outcomes (such as access to semiconductors, whether for national security or for societal well-being). As Congress recognized in the creation of TIP, something disruptive is needed. However, to be effective in fulfilling its charge, TIP as a funding agency and more broadly the federal government will need to intentionally design a rapid CTA function for Congress and the executive branch alike. This program must embrace the pace of innovation today, draw on the nation's variety of institutions, disciplines, and agencies (which, with different missions, don't all easily talk to one another), and exploit the analytic power and technical expertise of institutions across the nation. Such work will be best led by program managers trained in the art of critical technology assessment to select the most important problems, match methods to problems, and coordinate the distributed national capability.

STAFFING

We recommend that a program manager orchestrate talent from across the nation to perform analytics to inform critical technology strategy in each key technology area (**figure 6-1**). The core CTA function would be conducted by the program manager.

Topic area program managers, as at (D)ARPA (Fuchs 2010), would scan for global and domestic challenges and the state of government response to them. They would coordinate national talent to address the challenges, on contracts that would typically last 6 months to 2 years but could extend to 4 years for undertakings requiring sustained effort.

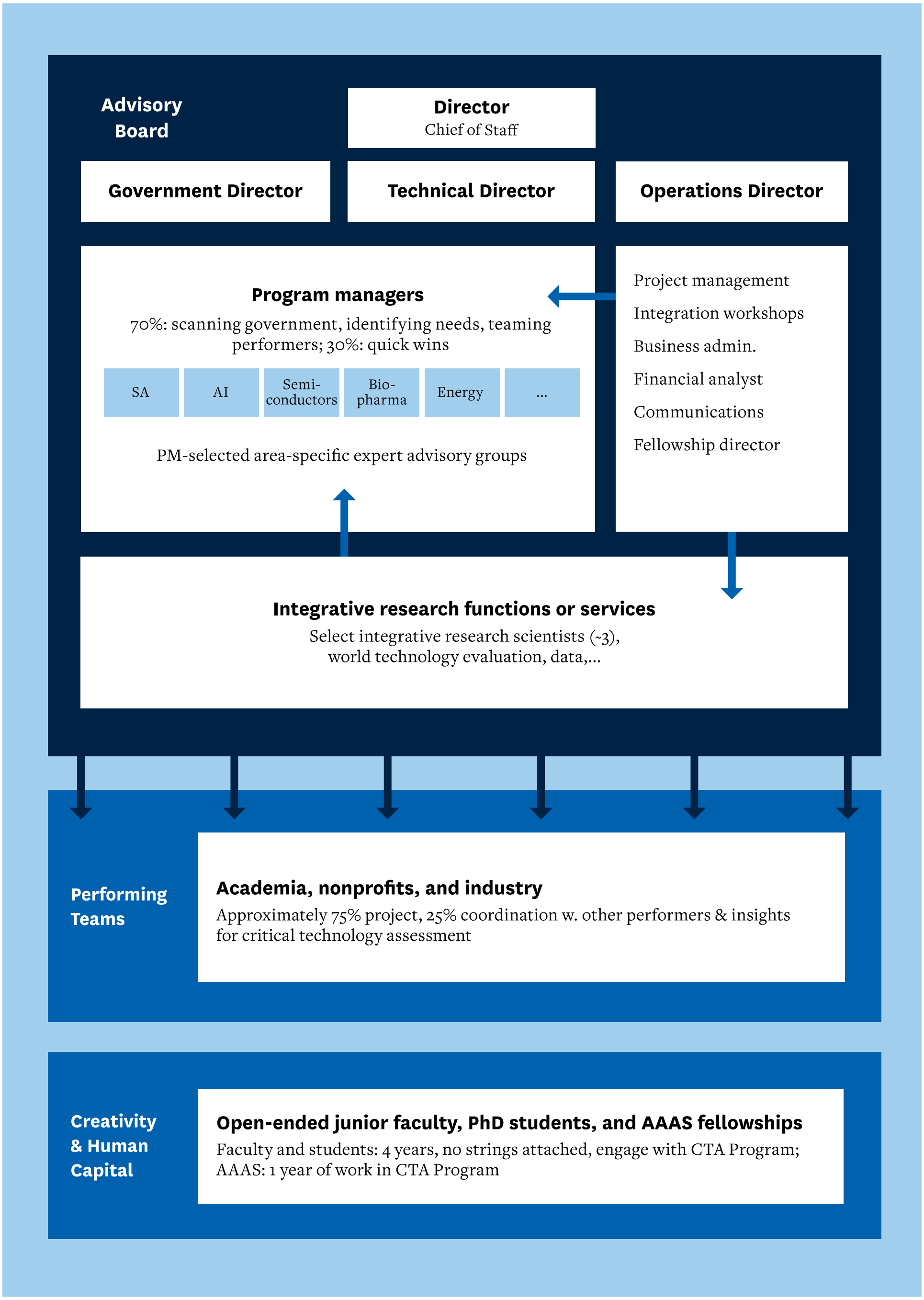

FIGURE 6-1. Proposed organization of a national Critical Technology Assessment Program. PM = program manager

The area program managers would focus on pushing the frontier of analytics to inform CTA and on transitioning the recommendations and findings to government stakeholders and supporting select government agencies in moving closer to the analytic frontier by transitioning select relevant data infrastructure or modeling capabilities. Since the objective would be to inform government technology strategy, funds would not be well spent on a high-risk portfolio of potential failures or on long-term data infrastructure, which would be better housed in established government entities. Funding would instead support efforts to transform the possibility frontier in terms of data and analytics (and data infrastructure) and to assist governmental adoption of those capabilities.

As outlined in this chapter's appendices (particularly, **appendix 6A-1**), the CTA program manager would identify not only important national problems needing to be solved but also the dimensions of integration to address those problems. Critical qualities to successfully execute these responsibilities are sufficient depth in a technology area complemented by "multilingual" ability across disciplinary and institutional contexts to bring together performers across disciplines and institutions to serve national needs.

The area program managers would also have responsibilities in the synthesis, interpretation, integration, and translation of project findings into recommendations for government. This synthesis within and across areas was led in the pilot by the leadership team. With a smaller amount of funding, synthesis and integration would be the primary function of the program managers, with smaller-scale contracts for academics and others to inform their work. With more funding, the integration might be done by supporting integrational research scientists or staff comparable to ARPA's science and engineering technical advisors.

Finally, in their translation role, similar to the semiconductor policy lead's activities in the pilot year, the area program managers would look for "quick wins" with immediate implications for policy, drawing from either existing academic and industry knowledge or funded projects (possibly even before project completion). As in our semiconductors case, the program manager might put staff directly on these topics, identify needed policy actions, and/or rotate into government to help implement the activity findings. The program managers would split their time between scanning for policy challenges in need of analytic capabilities, scanning for national knowledge and talent to address those challenges, managing and orchestrating the distributed talent, and synthesizing lessons for government, including quick wins for immediate policy implementation. It would be appropriate and expected for the particular allocation of effort to vary by topic area and program manager.

The program managers would, as at DARPA, have limited terms: given the timeline of the project contracts, we recommend 1- to 3-year terms, instead of the more typical 3- to 5-year terms of DARPA program managers. These limited terms would both help keep the organization nimble and up-to-date and facilitate the positions as a stepping stone to leadership positions.

The program managers would ideally have diverse institutional experience—in academia, industry, and government—along with experience in analytics to inform science and innovation policy (in the pilot year this diversity of experience was uniquely, and beneficially, held by the semiconductor project lead). Such multi-institutional background harkens to the Japanese model (Fransman 1999) and is quite important because of the multiple perspectives it affords, associated adaptability, and increased likelihood that the program manager will be able to serve as a broker between institutional forms.

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 government challenges across departments where there may be 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. Both the government and technical director, along with the Network director, would be responsible for identifying the topic areas for program managers, reducing or eliminating funding of lower-priority topic areas in favor of higher-priority ones, and bringing on new program managers and raising funding in newly needed topic areas.

In addition to the program managers, a small number (at first, perhaps only 3–5) of integrational research scientists should be housed at the hub. They would focus on the big picture of what is a critical technology, build the intellectual foundations across areas, and continually push the frontier of the data and analytic tools possible to inform critical technology strategy. They may fund, in consultation with the directors, a few grants to build the emerging field of critical technology assessment as the academic community grows. The integrational research scientists would also play a lead role, in coordination with the program managers, in writing the annual report of the state of critical technology assessment.

FUNDING STRUCTURE

Effectively mobilizing, synthesizing, and integrating capabilities distributed across the country's rich variety of researchers, disciplines, and institutions will require that a rapid CTA program spend the majority of its funds on external contracts. When functioning at a smaller scale (e.g., potentially in the early days of a staged ramp-up), no less than 50% and as much as 80% of funds should go to external contracts, with the remaining funds focused on the operations of the program itself (director, technical director, government director, program managers, integrational research scientists, and the necessary operations functions). In this early phase, the internal operations will focus on synthesis of distributed capabilities and smaller-scale external contracts. Once established, 80–90% of funding should go to external contracts.

The CTA program's funds should not be assigned to specific projects or technologies; rather, the most important technologies and problems on which to focus should be the explicit task of the director, government director, technical director, and program managers, in consultation with OSTP, NSF TIP leadership, and the interagency working group. The director, along with the government and technical directors, will maintain the focus and balance of the overall activity portfolio, ensuring that new areas grow and less vibrant areas are discontinued. Similar to DARPA, the director and deputy directors will determine (i) how the unassigned funds should be distributed across the program managers and integrational research scientists and (ii) the projects most important for funds to address.

Given the all-of-government, cross-mission nature of identifying a national technology strategy and the legislation's charge to identify key US challenges and technologies to address them "in consultation with the interagency working group," an interagency advisory mechanism should be set up for the CTA program. Without a direct sponsor (as Congress was for OTA), it will be essential to have other departments and arms of government (the executive and legislative branches) as, in essence, "clients" of the CTA program's activities that are relevant to them. A sign of the CTA program's success would be government entities' recognition of value in the analytic functions offered. Such recognition could be embodied in liaisons or personnel assigned to the rapid CTA program from other labs or agencies, requests through the interagency advisory mechanism for analytics on challenges particularly cross-mission in nature (such as, for example, the relevance of access and leadership in semiconductors to DOD, DOC, DOE, and DOT missions), or possibly even the cofunding of project topics central to their specific mission but spanning multiple agency missions.

OPERATIONS: STANDING SUPPORT FUNCTIONS

In association with the program management, the CTA program should support not only administrative and other business activities but also workshops to convene PIs on related topics (as done by DARPA PMs) and other representatives from academia, industry, and government for multilateral dialogue on the analytics at various stages (launch, middle, and close to the end) of the analytic process (**appendix 6A-2**). Separate from the Advisory Council, program managers would likely keep formal or informal topic-specific expert panels spanning industry, academia, and government to support these activities.

CTA CAPACITY BUILDING

Given the relative short-term problem orientation of a CTA program, it will be important to fund activities that encourage creativity and big-picture thinking, as well as high-risk work that may be impossible for the CTA program itself to undertake. In our engagement with policymakers and even venture capitalists, they commented on the rarity of the analytic capability offered and advanced by the NNCTA, and the need to build the human capital with this capability. The technical breadth, matched with disciplinary and institutional breadth, required for program managers was noted by multiple Network members as even rarer. This capacity may best be developed in industry or other private sector positions, in the AAAS S&T policy and similar fellowship programs, and in a handful of S&T policy, computer science or telecom policy, or engineering and public policy programs across the country. Building human capital in critical technology assessment will benefit not only staffing of the CTA program but also decision making in government, industry, and across the country.

We believe this human capital development is best undertaken through three types of foundation-funded fellowships: AAAS fellowships to work with the CTA program (which has precedent from the days of the OTA), no-strings-attached 4-year fellowships (similar to Howard Hughes Medical Institute Fellowships or the MacArthur Genius Grants) for junior faculty, and no-strings-attached 4-year fellowships for PhD students (similar to NSF's graduate research fellowships). All would involve doing professionally daring, interdisciplinary, policy-problem-oriented research on critical technology strategy, with the AAAS fellowships being more applied than the other two. These fellowships will be particularly valuable given the lack of an academic field associated with critical technology assessment or national technology strategy and the corresponding career risks and lack of academic incentives to undertake the associated interdisciplinary, phenomenologically driven research on real-world technology policy problems. Recipients, ideally selected by a rotating independent fellowship committee convened by the CTA program, would be invited to participate in CTA program activities and benefit from associated community-building activities and resources.