Received: 12 November 2021 | Revised: 28 December 2021 | Accepted: 17 February 2022

DOI: 10.1111/ropr.12474

RPR REVIEW OF POLICY RESEARCH

ORIGINAL ARTICLE

Government-led innovation acceleration: Case studies of US federal government innovation and technology acceleration organizations

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Funding information
This work was supported by the Acquisition and Development Program of the Homeland Security Operational Analysis Center, a federally-funded research and development center operated by the RAND Corporation.

Abstract

How can agencies that have operational activities as a primary focus improve the procurement and transition of innovative technologies, particularly from the private sector? This study seeks to inform scholars and public-sector managers about organizational design for innovation and technology acceleration using a systems approach. It examines three organizations responsible for mission-oriented innovation: In-Q-Tel, stood by up the Central Intelligence Agency; the FBI's Operational Technology Unit; and the National Institute for Occupational Safety and Health (NIOSH). It finds that collaboration and mission-inspiration can bridge public–private sector divides, but that distance from operators can slow technology adoption. It recommends establishing metrics for innovation investments and outcomes and gaining a better understanding of end user needs. Venture capital characteristics in quasi-government innovation organizations show promise but are untested outside of defense and intelligence. This study contributes to the literature by analyzing technology acceleration rather than initiation, development, adoption, or diffusion. It also adds to the study

of technology acceleration in mission-oriented agencies that are less often the focus of R&D scholarship on big science.

KEYWORDS

biotechnology, governance, high-tech, innovation, national governance

INTRODUCTION

Increasing numbers of government agencies, like private-sector enterprises, face demands to undertake or accelerate technological innovation (Fisher & Mahajan, 2006). This has led to as many as 125 government innovation and policy labs now operating worldwide (Apolitical, 2021). Improving government's adoption of technological innovation requires first asking what agencies are trying to do—do they want to access commercial technology in an area such as information technology in which the private sector is a leader? Or are they working in an area such as military weapons systems in which government is the primary funder and user? In most cases, government organizations with operational activities as a primary focus will want to access a mix of commercial technology, custom-developed technology, and in-house government expertise. In determining the appropriate mix of these sources of technology to advance operational objectives, innovation acceleration organizations often act as boundary spanners between users, stakeholders, and technologists in and outside of government.

To accelerate the uptake of technology within government, managers face a bewildering array of options—from innovation incubators to in-house laboratories to venture capital-like organizations. This paper asks how mission-oriented agencies seek to accelerate the uptake of innovations by their operational users (Cunningham et al., 2020; Nakashima, 2015; Reinert, 2012). It breaks new ground by focusing on mission-oriented agencies rather than broad-focused science and technology (S&T) agencies such as the National Science Foundation (NSF) or agencies following the Defense Advanced Research Projects Agency (DARPA) model (e.g., "big science" (Jacob & Hallonsten, 2012). Innovation organizations and programs within agencies with operational components remain understudied and may operate according to a different model (Belanger, 1998; Bonvillian, 2018). For example, the relationship between end-users and technology developers is particularly important for mission-oriented agencies, whereas the more frequently studied "big science" agencies may define innovation according to breakthroughs in various science and engineering technology fields rather than according to user needs. Scholars lack theory and empirical data about how mission-oriented agencies engage in technology acceleration. This article provides guidance to scholars and public-sector managers as they consider designs for programs to accelerate the uptake of technological innovation to their organizations.

The research approach is a comparison of three government agencies which have received attention for leading change through technological innovation in their mission areas. The organizations are: In-Q-Tel; the FBI's Operational Technology Division; and the National Institute for Occupational Safety and Health (NIOSH). While each of them seeks to accelerate technological innovation for operational ends, they vary in important ways. Some pursue near-term outcomes, while others aim at the long-term. Two operate primarily according to annual budget cycles, while another pursues a venture capital model, modified for the public sector. Two work

primarily in classified spaces, while one conducts unclassified work. The NIOSH case helps draw out the challenges of boundary spanning across private companies, universities, nonprofits, and government when working in classified spaces. Defense and security agencies have moved toward greater classification over time (e.g., Shane, 2005), and the contrasts among the cases are intended to highlight, in part, the costs of classification, as well as the benefits.

This article, in eight sections, begins by positioning tech-accelerating agencies in the scholarly context of "systems of innovation." The article finds that these agencies seek to remove barriers to knowledge and information flow in the innovation systems they aim to serve. Section 3 defines mission-oriented innovation, and Section 4 describes the major organizational design options for government agencies seeking to augment their technological capacity. Section 5 describes this article's research design and methods. Section 6 presents three case studies. Section 7 compares the cases, yielding insights on the determinants of agency efficacy. Section 8 concludes by describing two areas for future investigation.

SYSTEM OF INNOVATIONS AND GOVERNMENT INNOVATION ORGANIZATIONS

The design and behavior of government innovation-accelerating organizations can be informed using a "systems of innovation" lens (Edquist, 2004; Freeman, 1987; Lundvall, 1992; Nelson, 1993). Scholars of innovation have rejected the idea that innovation proceeds linearly: basic research leading to applied research, leading to development and testing, leading to an eventual application. They have also rejected the notion that information and knowledge pass automatically between innovation processes and organizations (Balconi et al., 2010, 7).

In place of the linear model, contemporary innovation scholars tend to understand innovation as a knowledge-centric process undertaken by and within a system that is comprised of functionally distinct types of organization that are embedded within a particular institutional and policy environment.[1] A system's efficacy in producing or diffusing innovation depends on the character of its system components, inter- and intracomponent flows, and the associated institution and policy context. Other essential features of the systems of innovation approach include taking a holistic rather than a reductionist explanatory approach, recognition of historical contingency, and rejection of the notion of an optimal innovation system, emphasizing instead constant system evolution within a dynamic and idiosyncratic context (Edquist, 1997).

Systems of innovation research has yielded practical insights pertinent to government innovation-accelerating organizations. For example, agencies may wish to take note of the scholarly finding that improving the flow of knowledge between system components improves innovation, adoption, and diffusion outcomes. This might lead organizations to attack bottlenecks associated with the transmission of information across organizational boundaries and between the stages of innovation. In the absence of positive measures or "boundary spanning mechanisms" to promote interorganization information exchange, information will tend to remain static (Youtie & Shapira, 2008, p. 1191). Examples of boundary spanning roles include building channels or tools to enable inter-organization knowledge exchange, serving as a liaison or broker, or garnering participation from individuals from distinct sides of organizational boundaries to serve in roles outside of their home organization (Michelson, 2013; Schmid et al., 2017; van Meerkerk & Edelenbos, 2018; Youtie & Shapira, 2008).

Several features of the defense and law enforcement technology environment make intermediaries that engage in boundary spanning particularly important in facilitating these flows. With

defense technology, input from warfighters has proved essential to the development and gradual improvements of defense technology (Bellais & Guichard, 2006). Failure to account for these nonlinear flows, or the iterative character of innovation, may result in technology that is divorced from the end-user and of limited operator utility.

The provision of boundary spanning mechanisms is particularly important in facilitating out-of-sequence flows for defense and law enforcement systems, which may be unfamiliar to many private firms. First, the character of the demand signal from warfighters and law enforcement officers is obscure to most firms; many entrepreneurs simply lack an understanding of what products or product features would appeal to a defense and law enforcement client. As one government science-and-technology leader put it, "To be innovative, you have to have an understanding of the operational problems."[2] Further, the process to determine the eventual features of a product differs in government and commercial systems (Schmid, 2018). In government, for example, a purchasing agency may disseminate product requirements to technology providers; in the private sector, product features develop in an iterative, market-based process. In all cases, however, a demand signal is an important first step (Edler & Boon, 2018).

Finally, the process of doing business with government agencies requires specialized knowledge. Contracting with the federal government often requires adherence to the Federal Acquisition Regulation (FAR) and associated regulations and procedures that are intended to ensure fairness but are sometimes burdensome. This specialized knowledge already is possessed by defense primes and other large government contractors. This provides an incumbency advantage to firms with government contracting experience and existing relationships with government clients (Greenstein, 1993). These firms may also have strong information links with their government clients, meaning they possess a clearer understanding of the demand signal. Beyond information, the existence of legacy technology systems may provide a path-dependent process in some cases where it is easier to maintain or replace a system than start afresh (Greenstein, 1993, p. 19).

Government innovation-accelerating organizations can be a means of removing these barriers. Each of the organizations we studied seeks to facilitate information sharing across organizational boundaries. That is, each of them serves a boundary-spanning function within the innovation systems in which they operate. Indeed, as will be shown, these organizations emphasize the articulation of the demand signal for agencies or stakeholders that these innovation-accelerating organizations serve. Finally, these organizations try to help unfamiliar parties navigate the process of how to do business with the government, including by creating new, streamlined ways to contract.

MISSION-ORIENTED INNOVATION

This study contributes to new knowledge by focusing on how agencies with operational components can acquire or accelerate technological innovations. Robinson and Mazzucato define such mission-oriented innovation as, "the development of specific technologies in line with state-defined goals (missions)" (Robinson & Mazzucato, 2019, p. 938). Broad, research-oriented government agencies like the NSF and NIH are more tolerant of long-investment timelines and high-risk investments than agencies with operational components. Such agencies tend to evaluate investments based on their broad scientific and social impact (National Science Foundation, 2018). But even they face political scrutiny and are compelled to justify their impact and investment strategies (Mervis, 2013).

Operational agencies judge their innovations on whether the funded technologies advance operational priorities. Inventing a new tool or contributing to knowledge is insufficient, if the "advance" fails to make its way into practice. Because success for an innovation-accelerating organization is defined based on the extent to which the technology advances mission objectives, the metrics to evaluate them are distinct from those for more broad-focused S&T promotion organizations. In the case studies that follow, this study identifies metrics for specific organizations' short- and long-term "success."

SOURCES OF INNOVATION FOR GOVERNMENT AGENCIES

Government agencies seeking to fill future or present capability gaps using technological solutions confront a series of decisions.[3] Figure 1 shows a stylized version of this decision process. Once a precise understanding of the required capabilities is attained, the agency must decide: Should they undertake R&D, or buy a given technology "as is," purchasing commercial off-the-shelf technologies (COTs) or licensing existing tech? If the latter option is selected, the vendors may include firms, universities, and other government agencies. This option can be attractive for government agencies, as it may eliminate or minimize the risk associated with undertaking an uncertain, and possibly long, research, and development process. This also assumes the agency has accurately understood the technology in question; the technical risk with COTs purchases and technology licensing are low, relative to engaging in R&D.

But if technologies do not exist or fail to match the government agency's performance requirements, more R&D may be required. This may include custom builds or adaptions of COTs to suit mission needs. Once officials determine this will be necessary to attain a desired capability, the agency must decide whether its R&D should be internal or external. Internal R&D may be preferred, if the agency has internal capability in the field in question that exceeds that of plausible partners. While myriad variables will affect an agency's decision, this study found that recent decisions to externalize R&D activities were driven by pragmatic concerns. Specifically, agencies that seek to increase their technological capabilities by leveraging external innovation tend to explain this decision by observing that the bulk of contemporary R&D and tech innovation occurs outside of government.

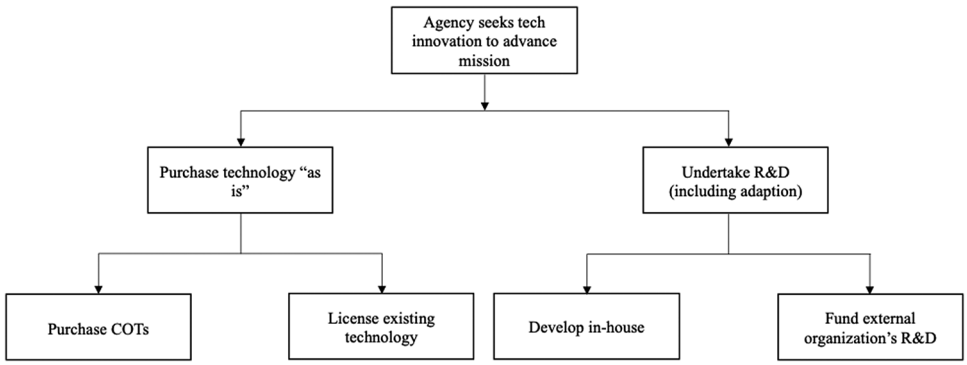

FIGURE 1 Technological innovation options for government agencies

TABLE 1 Characteristics of three mission-based innovation organizations

Organization	Type	Basic or applied	Location of funded R&D	Users of technical innovations	Organizational degrees of separation from end users	Metrics process	Typical funding mechanism	Classification status
In-Q-Tel	Non-profit, non-governmental venture fund legally independent from CIA	Applied	External; within invested firms	CIA	Some	Number of investment deals made, number of pilots, and number of adoptions	Equity investment and work program (prototyping contracts)	Classified
OTD	Government agency (under FBI)	Applied	Internal and external	FBI, state and local law enforcement, national security agencies	Few	Frequent project review; annual budgeting	Contracts	Classified and unclassified
NIOSH	Government agency (part of CDC under HHS)	Applied	Internal and external	Private sector businesses, workers, government agencies	Many	Sector-specific metrics; funding competition; process tracing backwards from a particular outcome to the research and translation that produced it	Grants and contracts	Unclassified

COMPARING INNOVATION AGENCIES

To provide guidance for government managers considering design options for technology innovation and acceleration organizations, we combined a fresh look at select organizations with insights from the peer-reviewed literature. We began by reviewing the scholarly literature on innovation and organizational design. Then we selected three organizations responsible for innovation that we encountered in a combination of the literature, our own government experience, and the experience of colleagues. The three organizations had received positive attention for their work, and they varied in design features including:

- Their degree of engagement with the private sector, universities, and in their in-house research capacity
- Time horizon for defining success and measuring outcomes (long vs. medium vs. short)
- Distance from use and outcomes (e.g., some serve customers directly and others serve intermediaries)
- Resource allocation strategies (driven by operational unit demands vs. strategy including entities inside and outside of government)
- Internal metrics of performance
- Mission (intelligence vs. domestic and social policy clients)
- Degree of use of classified information and security clearance access.

We began our study with an interest in In-Q-Tel's novel venture fund model, and we sought cases that would provide relevant contrast. We chose one organization from the security and intelligence field that operates through a more traditional within-agency R&D laboratory but uses private sector technology. We chose another case from outside the intelligence and security fields in order to bring into relief the distinctive features of technology acceleration in intelligence and security agencies.

We undertook a theoretically informed case study analysis combining the intuitions of within-case process tracing and cross-case analysis (Gerring, 2006; Levy, 2008). Process tracing is a method for providing a more precise account of critical junctures in individual cases (Givel, 2010; Hall, 2013; Pierson, 2000). We did not conduct a full process tracing analysis of each case, but we used the detective-like approach of process tracing to identify critical steps in the innovation process, and we posed counterfactual claims during our case construction to find turning points that mattered for innovation design. We were also explicit about our prior beliefs outside the case where relevant (e.g., Google and Apple have access to proprietary technology that the government would like to access in present and future law enforcement and intelligence cases).

The cases considered here are all located within the United States' innovation system, which is highly decentralized, characterized by high organization-type diversity, and is highly-market oriented (Shapira & Youtie, 2010). In recent years, new US government innovation acceleration organizations such as ARPA-H, ARPA-E, and IARPA have tended to emulate the DARPA model of innovation and organizational design (Bonvillian, 2018; Tollefson, 2021). One aim of this study is to expand scholarly scrutiny beyond the DARPA model and highlight alternative modes of government-led innovation acceleration.

While most of the sources for case study data came from government reports, peer-reviewed articles, and news articles, we also conducted interviews by telephone, video, and e-mail with eight people who now work in, have worked in, or have worked with our case study organizations. These were semi-structured interviews of senior subject matter experts, using open-ended

questions. The median length of the interviews was 1 h, but some interviews were shorter, and had follow-up by email. The interviews provided context for our cases, illuminated perspectives on government innovation, and offered illustrations. We did not approach the interviews as a systematic or unbiased data source. We used them to illuminate public documents (e.g., annual reports, official strategies, news articles, and secondary literature) and to help validate our claims. Table 1 shows that the three organizations studied all aim at applied research but they differ in other ways.

CASES IN INNOVATION AND TECHNOLOGY ACCELERATION

Case 1: In-Q-Tel's approach to stimulating private sector R&D for use in the intelligence community

In-Q-Tel was chartered by the Central Intelligence Agency (CIA) in February 1999, as a private nonprofit venture fund to serve the intelligence community (IC).[4] While the CIA is its primary funder, In-Q-Tel is legally independent from the agency and also works with other government agencies. In-Q-Tel's mission is "to identify and deliver cutting edge technologies to the U.S. intelligence community to enable IC agencies to carry out their national security missions" (Mission, In-Q-Tel). In-Q-Tel's primary office is in Arlington, but it has smaller offices in Menlo Park, Waltham, London, and Sydney.

In 2019, In-Q-Tel took in $133 million in total revenue (Open 990). Total assets under management have increased substantially in recent years. In FY2014, the fund held assets of $340 million. In FY2015, it held $419 million. In FY2017, FY2018, and FY2019 In-Q-Tel had assets of $535 million, $591 million and $625 million, respectively.[5]

At least three factors are cited as motivating In-Q-Tel's creation. First, leaders in the IC, including George Tenet and Ruth David, perceived that relevant innovation in information technology had moved to the private sector.[6] Previously, government sources had funded a generation of transformative intelligence technologies, like the U2 reconnaissance aircraft and the Corona reconnaissance satellite. But the bulk of relevant innovation activity in the 1990s was thought to occur in the private sector. Tenet, who was appointed Director of Central Intelligence (DCI) in 1997 and was DCI during In-Q-Tel's creation, described the detriments of the private–public gap in tech capability on CIA operations, stating, "Private-sector technology was far outstripping our ability to keep pace with our targets" (Tenet & Harlow, 2007, p. 16). A primary function of In-Q-Tel was to create linkages to the private sector (Ulvick & Tighe, 2008, p. 1), notably starting at a time when public sector tech advances seemed scant.

Second, In-Q-Tel's leadership identified specific capability deficits in the emerging areas of information technology (IT) and information communication technologies (ICTs) (Reinert, 2013, p. 686). In 2008, Sydney Ulvick and Donald Tighe, two employees from In-Q-Tel, wrote, "By the late 1990s, the pace of commercial IT innovation was outstripping the ability of government agencies—including the CIA—to access and incorporate the latest information technology" (Ulvick & Tighe, 2008, p. 1). In fact, In-Q-Tel's Certificate of Incorporation is explicit in placing the organization's focus on IT, stating that In-Q-Tel shall, "Perform and promote research and related scientific endeavors in the field of IT" (quoted in Report of the Independent Panel on the CIA In-Q-Tel Venture, 2001). Several years after formation, In-Q-Tel's area of focus was extended

beyond IT to technologies that would fill an identified operational need (Ulvick & Tighe, 2008, p. 1).

Third, besides trying to leverage commercial IT technology, Belko observes that In-Q-Tel's formation was driven by leadership's frustration regarding the traditional government procurement process. As technological change in IT and ICT was perceived to be racing ahead in the private sector, CIA leadership anticipated that old and slow government procurement processes would prevent the agency from fielding technologies fast enough to keep and win advantage over adversaries. Belko, describing the hope that In-Q-Tel would accelerate the fielding of technology, explained that the organization sought to, "overcome the hurdles of the federal acquisition system ... the CIA sought a way to identify new technologies before they became commercialized, so that once a technology became available for use, the agency could quickly incorporate it into its arsenal of technology solutions" (Belko, 2004, p. 27).

Approach to innovation acceleration

Often characterized as a venture capital firm, In-Q-Tel has two features that distinguish it from its private-sector counterparts. First, In-Q-Tel's primary objective is to advance the CIA's strategic objectives, rather than to realize profit. This aim was succinctly articulated by Gilman Louie, the organization's first CEO, who stated, "The most important thing is the technology return ...of secondary importance is the financial return" (Johnson, 2001 June 25, p. E5).

A second relevant distinction between venture capital firms and In-Q-Tel relates to the principal destination of the funded technology. In a venture capital firm, the technology is marketed to external consumers. With In-Q-Tel, the technology is principally used to advance the objectives of the agencies it serves.[7] Given these distinctions, In-Q-Tel may be understood as a corporate strategy venture fund like Google Ventures, GE Ventures, Microsoft Ventures, and Intel Capital.

In-Q-Tel is mission-driven (Wanzenböck et al., 2020, p. 3); it seeks to invest in technology that fills a "pressing problem" for the CIA (Tenet & Harlow, 2007, p. 26). The identification and articulation of capability gaps is conducted by the In-Q-Tel Interface Center (QIC). It solicits stakeholders in the CIA about tech needs, and then refines, ranks, and declassifies them into a problem set consumable by potential solution providers (Molzahn, 2003, p. 51). The QIC also manages the contractual relationship between CIA and In-Q-Tel and is responsible for guiding the process of technology transition into the CIA.

In-Q-Tel seeks solutions that are relatively mature, defined as yielding benefits within 36 months (Reinert, 2013, p. 679). Its investment process is based on the performance of the firm and associated technology on three dimensions: the firm's financial soundness; a technical evaluation of the solution in question; and the closeness of match between the solution and the QIC-defined problem set (Lucid Imagination, 2009). Most firms In-Q-Tel works with have not previously done business with the federal government (How we work, In-Q-Tel, 2021). Indeed, partnering with it increased the reported likelihood that an In-Q-Tel portfolio company would anticipate selling to the government (Mara, 2011, p. 5).

Once a potential commercial source for a technology is identified, In-Q-Tel makes two types of investments: equity and work program. Its equity investments resemble those of a venture capital firm: In-Q-Tel takes an ownership position in the company. Its work program support resembles prototyping investments, with In-Q-Tel typically funding late-stage R&D required to make a product adhere to its specifications.

In-Q-Tel currently makes roughly 50 investments per year each of $500,000 to $3 million (How we work, In-Q-Tel, 2021). Of these investments, only 20% or so are of the equity variety, with the rest going to R&D projects or licensing (Reinert, 2013, p. 698). In-Q-Tel has frequently augmented its investments by encouraging other venture capital firms to simultaneously invest in their portfolio of firms (Ulvick & Tighe, 2008, p. 2).[8]

When In-Q-Tel invests in a company, it is typically provided an advisory spot on the Board of Directors. Board access provides early information about corporate problems and eases the exchange of information between parties. Returns from investments flow back into In-Q-Tel.

Lerner et al. also noted that, compared with a traditional model of government procurement in which a single solution is selected, the In-Q-Tel model allows the government to hedge. Louie, In-Q-Tel's first CEO, made this point on the value of diversified investment in fast-moving IT, stating, "As a result, the CIA didn't have to pick a single winner or loser. Now they could bet on three or four companies in a given product space without having to go through the process of a single procurement, which was good because it was extremely hard to pick winners in new technologies, and the cycle times were very short, particularly in the IT space" (Lerner et al., 2004).

Besides investing in companies, In-Q-Tel attempts to broadly articulate government demand to the commercial sector. It seeks to inform relevant parts of the commercial sector about the intelligence community's future needs. Ulvick and Tighe (2008) described this function, stating, "In-Q-Tel is also able to strengthen situational awareness in the commercial and entrepreneurial markets regarding the technology needs of the U.S. Intelligence Community" (Ulvick & Tighe, 2008, p. 3).

Investment staff, performance metrics, and a cultural distinction vis-à-vis its government clients

There are four principal investment staff roles for a given In-Q-Tel deal. Investment team members lead the financial assessment of potential investments (i.e., firms in which In-Q-Tel might invest) and draft and negotiate the terms of investment deals. Technology architects are charged with assessment of the technology that underlies the investment. Both investment team members and technology architects play active roles during the investment search process, attending conferences, using market research resources such as those provided by Forrester and Gartner, and using their personal networks to identify promising firms. As with other areas of innovation, the social capital of team members is an important resource (Fountain, 1998). The principal performance metric for investment team members and technology architects is number of deals completed. Secondary performance metrics for these roles are pilots completed and adoptions (i.e., completed technology transitions to a government agency).

Following the completion of a deal, program managers and project engineers play pivotal roles. The former coordinate the overall effort and manage technology transition to recipient government agencies; the latter conduct additional hands-on testing of the technology in question. The principal performance metrics for program managers and project engineers are pilots completed and adoptions.

While In-Q-Tel is legally independent of the CIA and its other government clients, it also tries to maintain a cultural distinction from its government clients in terms of organization, staffing, speed of action, and compensation (Reinert, 2013, p. 694). Louie, its first CEO,

explained that such characteristics facilitates understanding between In-Q-Tel and the firms it intends to work with, stating that In-Q-Tel seeks to, "structure ourselves in a manner that will be familiar to many information technology companies we hope to attract as partners" (Gordon, 2000, p. S10).

One means by which In-Q-Tel maintains a cultural distinction from the CIA and its other government clients is through its hiring practices. In-Q-Tel's senior investment staff typically have experience working for other venture capital firms and startups, rather than experience in the IC.[9] Similarly, investment team members tend to have educational and professional background similar to private VC investment staff, rather than intelligence, defense, or government backgrounds.

Case 2: FBI's operational technology division (OTD) as a bridge builder within the bureau and to commercial firms

The FBI's OTD aims to "deliver technology-based solutions that enable and enhance the FBI's intelligence, national security, and law enforcement operations" (FBI, 2019a). It is physically located in Quantico, Va., next to the famed crime lab, and it is a division of the FBI's Science and Technology (FBI S&T) branch. FBI S&T has the largest budget of any branch in the FBI—between $600 and $800 million annually, according to a 2015 Washington Post estimate (Nakashima, 2015). More recent budget reports do not provide an exact number, but the estimate seems plausible based on the FBI's account of its budget priorities (FBI, 2021). FBI S&T's mix of public and private technology, used for law enforcement and national security intelligence purposes, makes it a bridge-builder across sectors.

The OTD has a lofty vision statement: "to counter current and emerging threats through applied technology." Much of its most publicized work involves technology related to the collection and analysis of electronic communications (Tromblay, 2016, p. 82; U.S. Department of Justice, 2014, pp. 4–9). Its customers are within the FBI and outside of it. It provides technology for FBI operational divisions as well as federal, state, and local law enforcement, the US intelligence community, and US Attorneys' offices (FBI, 2019a, 2019b; IG, 2018).

The OTD is organized into several divisions. The Cryptologic and Electronics Analysis group analyzes cryptic communications. The Remote Operations Unit (ROU) provides tools for accessing data from computers and phones (O'Neill, 2018). The Data Intercept Technology Unit (DTU) develops and employs technology like devices that capture Internet and phone traffic. The DTU has sub units, including the Collections Operations Group, which focuses on cyber data. A response to a *Forbes* magazine FOIA request noted that the COG's mission "is to provide tools, expertise and solutions to effect lawfully authorized electronic surveillance of data communications on today's evolving local area network and Internet technologies" (Brewster, 2018). The COG is involved from the procurement stage through the development and deployment of surveillance equipment to field offices. It also links the FBI with other agencies that might seek bureau services in analyzing cyber data. As of 2018, there was a unit created to address difficulties with electronic devices and encryption that the FBI cannot easily access—the "going dark" problem (O'Neill, 2018).

OTD divisions are called on to develop or adapt technology to address a range of criminal and intelligence missions. Its technicians, for example, examine cell phones captured from the battlefield and look for clues in terrorist materials from overseas. Others test radio functioning in various operational environments. Some process DNA samples and add them to biometric

databases, while still others reverse-engineer fragments of improvised explosive devices (IEDs) from overseas battlefields. Another part of the division analyzes biometric data from Al Qaeda prisoners looking for leads in terrorism cases (Weiner, 2012, p. 823). Another cracks codes and supports investigative technologies for domestic crimes.

Innovation model is driven by mission area needs

OTD supports technology development for national security and law enforcement applications for collecting information for criminal or investigative activities over the short term, responding to immediate needs, as well as the medium term horizon planning for new investigative technologies. The broad conditions for innovation are set by law and FBI policy. Law and policy shape the agenda (e.g., terrorism after 9–11), and the technology available in the private market shapes the threats and the available tools for response (e.g., tools to conduct and defend against cyber-crime and cyber terrorism). The division, for example, has developed special expertise over time in biometric data and electronic communication in response to operational demand for these capabilities.

The budgeting system drives OTD work at a high level. The FBI allocates a budget to OTD divided according to a measure of workload for each major mission area: Intelligence; Counterterrorism/Counterintelligence (CT/CI); Criminal Enterprises/Federal Crimes (CEFC); Criminal Justice Services. If 20% of OTD's workload supports counterterrorism investigations, then 20% of the OTD budget is allocated to CT/CI projects (U.S. Department of Justice, 2019, pp. 1–5). The workload-based budgeting model does not fully explain how technologies are prioritized, however.

Typically, an operational division will pose a question or seek help for a problem from OTD. In 2015, for example, 14 people were killed in a San Bernardino, Calif., terrorist attack that included a mass shooting and attempted bombing. The FBI recovered an iPhone from the shooter, Rizwan Farook, but could not unlock it because of the phone's security features. When faced with the locked phone, Amy Hess, the assistant director of the Science and Technology branch, asked her subordinates "does OTD know of a solution, have a solution?" (IG, 2018, p. 8).

OTD typically responds to an inquiry by reviewing if it has a solution, or a technology already developed in-house or near development. If it does not, it may ask its subunits to develop the technology on their own or ask trusted private sector vendors to do so. Through "the nature of their work, both CEAU and ROU have engineers and vendors who attempt to develop techniques that can exploit mobile devices, with legal authorities appropriate for the types of matters in which they are involved" (IG, 2018). The FBI faces the same choice to pursue in-house R&D or go to a private sector vendor that many other innovation and technology acceleration organizations face, as shown in Figure 1.

The Farook iPhone case illustrates how OTD often interacts with the private sector. In cases in which commercial vendors supply technology that the FBI seeks access to, such as a mobile phones or computer operating systems, OTD and its divisions use long-standing relationships to access the technology. For example, the DTU regularly meets with major US telecom providers (Harris, 2013). For cases in which the FBI seeks new capabilities that are not commercially available, it will look in house and scan the private sectors for commercial firms that may be able to help develop the technology in full or in part. While the purposes for engaging the private sector vary, from gaining access to commercial technology to developing a new technology to further an operation, in all cases the division prefers to work closely with commercial firms in an interactive

development process. Sometimes firms provide technologists for direct support to the division and bureau to fulfill a task order (Qbase, 2020a, 2020b).

Metrics

OTD's large and diverse portfolio includes numerous context-specific metrics. At a general level, the organization measures performance through frequent project reviews with its customers and through the budgeting cycle. Its customers in the FBI or other organizations send a demand signal for OTD's service by requesting and sometimes paying for work. One former OTD manager recalled that: "If your customer isn't happy, you heard about it quickly. There's usually a conversation between the program level, unit level, and out to the field office. The field office would push their concerns, if they weren't getting what they needed from technical engineers. That was rare...".[10]

After the terrorist attacks of Sept. 11, 2001, the FBI developed a strategic management system (SMS) that drew on the principles of the balanced scorecard, which attempts to combine measures of past performance with predictors of future performance (Kaplan & Norton, 2001). Its pillars are:

> "Provide a common framework to ensure that executive leadership clarifies and gainsconsensus around a single, unified strategyLink strategic and operational decision-makingProvide a balanced set of measures to monitor strategic performance (FBI, 2008, pp. 1–4)"

The SMS offered a way to explicitly balance priorities, even between the occasionally conflicting goals of supporting the intelligence community and supporting domestic law enforcement. The SMS took various forms over time, including a one-page strategy map that could be shared widely, as well as strategy depicted as pillars and snapshots. The strategy map contained 25 strategic objects (e.g., "leveraging technology and science"), and objects were connected with context-specific performance measures, though many of the specific metrics for OTD are classified (FBI, 2010).

Siloed and specialized organizational structure, and a domestic and overseas divide

The siloed and specialized organizational structure of the Science and Technology Branch (STB), and OTD in particular, sometimes makes collaboration and information sharing within the STB difficult. Different OTD units have different missions, expertise, and sponsors. When one sponsor wants a technology from a new unit or combined from multiple units, OTD divisions may not have a clear mechanism to collaborate. A 2018 IG report quoted former assistant director Hess saying that S&T "sections and units grew out as individual trees or stovepipes without much integration. She said it always concerned her that individual units do not always know all the capabilities other units have, and that the units are so big that unit chiefs may not even know the full capabilities of their own units. Further, she said that sometimes assumptions are made that 'if there was another solution out there, I would know,' or sometimes questions are asked, but they are not directed to the right people" (IG, 2018).

The principal organizational divide is between domestic criminal investigative technology and national security technology directed overseas. A 2018 IG report found "a dividing line discouraging collaboration between the units that predominately do criminal and national security"

work in OTD (IG, 2018, p. 9). The IG report also found a lack of clarity about when the OTD would look to vendors and when it would pursue internal technology development solutions (IG, 2018, p. 9). Further, there was also a lack of clarity about whether to: seek unclassified-only technology solutions for domestic investigations; pursue unclassified solutions first; or look at all possible solutions (IG, 2018, p. 9). The search for a technology to read the contents of Farook's locked iPhone is one example of the tension among divisions. Electronic crimes, cyber security, and international terrorism bridge the divides between domestic investigative work and international investigations.

Case 3: NIOSH's process for innovation in the complex field of worker health and safety

The National Institute for Occupational Safety and Health (NIOSH) is the federal agency responsible for ensuring safe and healthy working conditions (CDC, 2019). NIOSH is part of The Centers for Disease Control and Prevention, which itself is part of the Department of Health and Human Services. The agency conducts research through 10 industry-sector programs and seven programs based on a public–private cross-sectoral research agenda identifying the most serious health and safety problems. There also are 20 core and specialty programs distributed throughout the agency. Research and implementation activities are carried out by more than 1300 employees with backgrounds in engineering, and the physical, natural, and social sciences (CDC, 2019).

NIOSH is not primarily a regulatory agency, but it has statutory authority to develop new knowledge, provide recommendations, and encourage cross-sector (e.g., public, nonprofit and private) cooperation in worker safety and health. The principal sources of its statutory authority are the Federal Coal Mine Health and Safety Act of 1969 (Pub. L. No. 91–173, amended by Pub. L. No. 95–164 in 1977 or MSHAct; also known as the Coal Act) and the Occupational Safety and Health Act of 1970 (Pub. L. 91–596; also known as the OSHAct). Since its founding in 1970, NIOSH has contributed to better monitoring of and protection against lead, asbestos, dioxin, coal mine dust, traumatic injuries, and workplace violence, among other successes.

At an organizational level, NIOSH is divided into divisions, laboratories, and offices. Some units focus on specific diseases or injuries (e.g., respiratory), others are devoted to a particular expertise (e.g., lab research or surveillance and field studies), and others are industry-specific (e.g., mining). NIOSH leadership resides in Washington, D.C., but its units are geographically dispersed, and locations usually focus on specific issues (e.g., mining safety).

Within the agency, research programs are spread across units in a matrix approach, rather than housed in a specific S&T division. For example, at least four divisions carried out research for the Hearing Loss Prevention program (Williams et al., 2009). NIOSH also funds applied research by others through grants and contracts. Other NIOSH programs invest in translation efforts to move basic and applied research into workplace practice.

Outcomes for improved worker safety and health depend on businesses, consultants, insurance company loss executives, and universities as much or more than NIOSH (Miller et al., 2017, p. 1). Scholars refer to process of a mix of public and private groups contributing to a widely-beneficial social outcome as “co-production” (Bovaird, 2007). NIOSH's contribution to health and safety is realized when users outside of NIOSH use the technology or adopt a standard. NIOSH also aims at a long-term impact on society, which is hard to measure because so many factors outside the agency's control influence worker health and well-being.

Since NIOSH is only one part of a larger occupational safety and health field, part of its job is to coordinate others outside the organization. The National Occupational Research Agenda (NORA) is the principal attempt to coordinate the entire research community and improve workplace practices. NORA began in 1996 through a collaborative process designed to identify the most pressing issues in workplace safety and health. Collaborative groups involving government, businesses and worker organizations, and universities worked to identify goals and tasks for addressing those issues (Rosenstock et al., 1998; Williams et al., 2009, p. 13). The NORA agenda allocates resources and attention according to the number of workers at risk for a particular injury or illness, the seriousness of a hazard, and the chance that new data can make a difference.[11] Various cross-sector committees tackle issue or sector areas (e.g., construction) by meeting regularly and feeding into the strategic planning process.[12] Each year there is a new internal funding cycle, and NIOSH researchers compete for funds by submitting NORA proposals for new projects, subject to evaluation by internal and external panels.[13] The NORA process, in turn, shapes the NIOSH research agenda along with other private, non-profit, and university contributions (Chari et al., 2018).

Metrics

The organization tracks bibliometrics using citation analysis, keeps portfolio assessments built from subject matter expert valuations (CDC, 2016), and conducts case studies of particular innovations, using process tracing backwards from a particular outcome to the research and translation process that produced it (Miller et al., 2017, p. 1). One challenge is that the benefits of investments in innovation are sometimes realized far in the future and after many organizations other than NIOSH have been involved. Therefore, outputs and activities are easier to measure than outcomes—a measurement difficulty found in many complex policy areas.

Innovation priorities shaped by analysis of burden, need, and impact

NIOSH allocates resources based on the number of workers at risk for a particular injury, the seriousness of the hazard, and the likelihood that research can make a difference in outcomes—a process called "Burden, Need, and Impact (BNI)" (CDC, 2019; Felknor et al., 2019). The BNI method establishes research priorities by identifying the health, safety and economic burden of workplace hazards and risks. Burden is another way of conceptualizing the risk of bad outcomes. The process first includes estimating the burden or risk of bad outcomes from emerging issues and understudied populations by examining *potential* risks (e.g., injury, illness, or death) where historical data are scant. Second, the process analyzes relative need, identifying where research could fill a gap, and considering the comparative advantage NIOSH has in filling the gap. For example, NIOSH is a leader in coal mining safety and a natural source of new knowledge. For improvements to safety for military pilots, however, the issue might fall to the Department of Defense.

The third part of the research prioritization process is estimating impact. Direct interventions to improve safety or health as well as creating new knowledge that could lead others (e.g., a business or industry) to act count as impact. The ultimate goal is decreased illness or death or

enhanced worker well-being. The BNI process provides a return on investment (ROI) calculation tailored to the NIOSH mission and capabilities.

Collaborations with the private sector and universities

NIOSH undertakes frequent collaboration with the private sector and universities on specific health and safety issues informed by the NORA strategy. As one NIOSH manager put it, "Since stakeholder buy in is so critical to having a practice/technology implemented, it usually helps to partner early on in the development process even if NIOSH is the initiator."[14] Other research has found that the "triple helix" of government, industry, and business can be effective in promoting innovation across sectors of society (Leydesdorff & Etzkowitz, 1996). In some cases, the collaborations organize private sector input. The primary aim is to build knowledge, and only later that knowledge finds its way into NIOSH work in diffuse ways.

Albers et al. (2005) report on a meting NIOSH organized with representatives of the construction industry. Construction managers said that they felt like it was difficult for them to invest in safety innovations because they were unable to control the nature of their work environment in a fragmented industry. As one construction manager put it, "We don't own the real estate." According to participants at the meeting, managers felt like they lacked control over safety innovations, so the innovations they did adopt came through regulation and manufacturer innovations, often in response to regulations. This collaboration added to the understanding of policy tools and the private sector's perspective on worker safety improvements.

University partnerships are important to many of NIOSH's research programs. A program to provide noise control technology to prevent worker hearing loss illustrates how the partnerships work (Hayden, 2004). NIOSH wanted to measure noise from power tools and make recommendations for appropriate noise levels. However, there was relatively little peer-reviewed literature on the subject, and NIOSH knew little about the population of workers who used hand tools. It knew of specific examples, but not about the frequency, extent, and type of use across a variety of industries. Therefore, NIOSH funded a university project to reduce noise emissions from power tools. While at a safety conference, NIOSH officials met university researchers who were interested in the power tools problem. NIOSH provided funding to student teams who worked on the problem under the supervision of faculty and delivered a report and presentation to the agency. The NIOSH–university relationship supports an ongoing partnership with Iowa State University's noise control center.

NIOSH responds to criticism with new metrics

NIOSH is embedded in a web of relationships in health and safety research, including active private sector and university R&D programs. The decentralization of functions and responsibility made it vulnerable to critics who wonder why it exits at all. In the mid-1990s, critics in conservative think tanks and some industry organizations wondered whether the agency should continue to exist if the private sector and the Occupational Health and Safety Administration (OSHA) in the Department of Labor handled many workplace safety issues. The critics pressed NIOSH on the value added by its research, and some industry critics focused on highlighting the cost of regulation and compliance. In particular, industry critics charged that NIOSH's research was impractical and too pro-labor while excluding the perspective of business, and unsynchronized

with OSHA's regulatory work (Figura, 1995). The criticism from conservative budget hawks and business gave urgency to the agency's efforts to organize its mission through the NORA cross-sector planning process, bringing together other government agencies, business, and labor. It also provided an impetus for the agency to invest in evaluating its impact over the long-term and communicating impact to stakeholders. Measuring near and long-term impact is now a routine part of its evaluation and resource allocation process. Contextually specific measures may be important in evaluating policy impact in mission-driven social policy areas where more general measures such as the number of patents generated (Link, 2019) are not sufficiently close to intended outcomes.

CROSS-CASE COMPARISONS AND CONSIDERATIONS FOR ORGANIZATION AND PROGRAM DESIGNS

Taken together, this article analyzes how institutions are designed to accelerate innovation within government agencies by focusing on an understudied group of mission-oriented agencies. These agencies rely on private sector technology in different ways, and they act as boundary-spanning organizations linking the government with commercial firms, universities, and government labs.

Our study contributes to the literature on innovation along two dimensions. In the first, studying three organizations through the systems lens captures how these organizations relate to their environment to accelerate innovation. The basic science and much of the technology is developed elsewhere, but these organizations accelerate user-tailored development and adoption. In contrast, much of the literature focuses on the organization level (e.g., Damanpour, 1991; Hansen & Nørup, 2017) or the local or national government level (e.g., Feeney & Wang, 2016), whereas the systems approach spans the public and private sectors (e.g., Fountain, 2001; Mergel et al., 2019). We use the systems approach as a starting point to analyze three organizations in their environment and develop insights of use to managers. Second, we contribute new analysis of technology acceleration. We define technology acceleration as actions taken by a third-party (i.e., not the primary technology developer or the final technology user) that seek to accelerate the end-to-end process of ideation to a technology's eventual use and upgrading. The bulk of the literature focuses on initiation and development (Lee et al., 2011), adoption (Whitford et al., 2020), or diffusion (Dearing & Cox, 2018). We add to the development of theory about technology acceleration, as well as specific considerations for managers.

Each of the three organizations studied provides design and process options that could be adopted by other government organizations seeking to incorporate innovations into their operational work. In-Q-Tel seeks to increase the flow of mission-relevant commercial technology into the hands of operators. In-Q-Tel also seeks to streamline the procurement process for its clients. Unlike the other organizations considered here, however, In-Q-Tel is not a government agency. Rather In-Q-Tel falls in the category of quasi-government organizations that comingle aspects of government and the private sector (Congressional Research Service, 2011; Koppell, 2006; Moe, 2001).

While legally independent from the CIA, In-Q-Tel's mission and funding are intrinsically tied to that of the CIA. It is formally incorporated as a non-profit, but its organizational structure and operations resemble a corporate strategy venture fund. This quasi-governmental model offers several attributes of relevance to other government organizations seeking to accelerate innovation.

Because In-Q-Tel is not a government agency, it has enjoyed latitude in terms of its approach to compensation, contracting, and investment type. With regard to the former, In-Q-Tel is able

to tie employee compensation to its portfolio's performance in a way unavailable to government agencies. To the extent that this incentivizes an improved investment selection process, it should be considered by other government agencies. With regard to investment type, In-Q-Tel's status as a non-profit that is legally independent from the CIA also allows it to make equity investments.

The FBI's OTD is designed to foster a close and recursive relationship with the users of its technology in the Bureau and elsewhere. It is a boundary spanning organization, but its span is tightly connected to its customers. In the short term, FBI operational divisions drive OTD priorities. Over the long term, a combination of law and policy driven by events and technological developments shape OTD priorities. The division's budget has ebbed and flowed according to congressional priorities, and the FBI allocates a budget to OTD divided according to a measure of workload for each major mission area.

Since much of the innovation in electronic communication occurs in the private sector, OTD relies on private sector partners for technological solutions. This reliance makes OTD vulnerable when private sector organizations are unwilling to cooperate. The FBI's trouble accessing the locked iPhone of a San Bernardino terrorist attack perpetrator in 2015 is one example. OTD faces a dilemma in deciding when it should look to vendors and when it should pursue internal technology development solutions.

OTD also faces another dilemma: should it seek unclassified-only technology solutions for domestic investigations, seek unclassified solutions first then look to classified options, or look at all possible solutions from the beginning? The siloed and specialized organizational structure of the Science and Technology Branch, and OTD in particular, makes collaboration and information sharing across parts of the organization difficult. Different units within OTD have different missions, expertise, and sponsors. When one sponsor wants a technology from a new unit or combined from multiple units, the OTD divisions lack a clear mechanism to collaborate. The principal organizational divide in OTD has been between domestic criminal investigative technology and national security technology directed overseas. These are two cultures that are not easily bridged at an operational level.

NIOSH offers a contrast to OTD and In-Q-Tel because it does not use classified information or require security clearances in its work. Therefore, its boundary spanning reach to external organizations is more fluid. NIOSH is a compelling model for organizations implementing social policy because its outcomes are broad and depend on users far down the chain of innovation—in particular private companies, managers, and workers whose health and safety NIOSH seeks to improve. NIOSH is only one organization out of many that contributes to these outcomes. Its distance from the outcomes it aims at and its interrelationship with a web of organizations that have the same goals make it vulnerable to critics who want more evidence of its effectiveness and think its efforts are duplicative. This same vulnerability prodded the agency to seek more cross organizational collaboration and a greater evidence base for its performance in the 1990s.

To make the case for the value of its investments, NIOSH maintains metrics that analyze the long and incremental innovation process. The National Occupational Research Agenda (NORA) is the principal attempt to coordinate the entire research community—including NIOSH, other agencies, universities and the private sector—to improve workplace practices. A similar cross-sector stakeholder process could be used in other policy areas. NIOSH allocates resources based on the number of workers at risk for a particular injury, the seriousness of the hazard, and the likelihood that research can make a difference in outcomes—a process called "Burden, Need, and Impact" (BNI).

Beyond co-location to bridging the public–private sector divides through collaboration and mission inspiration

The bulk of innovation in the United States measured through R&D spending and new products now comes from the private sector. The digital technology sector is at the leading edge of US global competitiveness (Schwab, 2018). The increasing importance of "tech" to innovation has led to a school of thought that equates innovation with Silicon Valley and the digital economy. To meet the pull of the technology sector, government organizations including the Department of Defense (via Defense Innovation Unit stood up in 2015) and the DHS (in 2015) have opened offices in Silicon Valley (U.S. Department of Homeland Security, 2019). Other innovation leaders in government recommend flexible hiring authorities so that the government can hire computer scientists, roboticists, and Silicon Valley executives at a higher pay scale and with less red tape than typically accompanies government work.

While reaching out to Silicon Valley is an important step, some interview subjects cautioned that hanging a shingle in the Bay Area of California was not sufficient for gaining access to mission-relevant technology. Instead, multiple subjects recommended strengthening connections between operators or users of technology and the technology developers in Silicon Valley or elsewhere. The methods discussed below including conferences, regular meetings, and trusted long-term relationships can help.

Inspiring the cooperation of technical experts in the private sector by emphasizing the importance of the mission. Some defense and intelligence missions have met with resistance from the technical community (e.g., the Farook iPhone case and the FBI), In other cases, however, technical experts were inspired by the idea that they could make a distinctive contribution to national and global service. After the September 11, 2001 terrorist attacks, one government manager said that "When we put the word out for what we needed we immediately got help from Google, etc. We immediately got expertise to do innovation of the fly."[15] An expert said that DARPA initially struggled to persuade some technical companies to cooperate in robotics problems. But when its robotics challenge was framed as about contributing to the public good through better disaster response, more private sector technical experts said they wanted to participate.[16]

Distance from operators can slow technology adoption

The further they are from operators, the more innovation organizations struggle with facilitating the adoption of new technology by operators. One interview subject said that, "NIOSH has both intramural and extramural research programs to facilitate the development of innovative safety and health technologies. But as a government agency it has little influence over the commercialization and adoption of these innovations in the private market, and it often finds that no one in the private market wants to take them on and produce them."[17]

Another interview subject told the story of a rail car monitoring device that one government innovation organization developed at a cost of millions of dollars to provide an unparalleled ability to track cars and resist removal.[18] Though technically advanced the device did not find a willing operational user in government because it did not solve a problem that an operator faced. This incident raises the question of whether the money would have been better spent on a technology that was more likely to be adopted and that met a user's needs in the near term.

The remedy to potential failures to adopt new technology developed at high cost is to build a close relationship between technical experts and the users of technology so that the learning

will be mutual. Henry Ford's most famous apocryphal quote is "If I had asked people what they wanted, they would have said a faster horse." The quote may not be accurately attributed, but the sentiment conveys a truth that innovators know: users themselves cannot always articulate what they might want or need. Therefore, users can benefit from mutual exchange with technical experts about possibilities for the future. The FBI's relationship with its field offices is one example of a productive relationship. One former FBI OTD manager said "they [the field offices] knew they could call me anytime, anywhere."[19]

A close relationship with users may not function the same way in fields where users are more diffuse and less expert (e.g., the general public). NIOSH serves workers, broadly, but it engages intermediaries in the innovation process as a boundary spanner in its particular domain. NIOSH organizes a system of conferences and meetings in which its ongoing relationships with business and academia, and its strategic planning process, are tools to limit the possibility that technical solutions will not solve a problem in the field. The system of ongoing relationships and mutual learning also reduces the risk that operators will not see the problem they should be solving or the need they should be addressing with a new way of doing things.

Establish metrics for innovation investments and track outcomes

Some policymakers in defense and national security advocate looking to start-up firms and leading commercial technology companies for innovation. Others find that the existing defense industry will best be able to lead military and security-related technology development and innovation (Dombrowski & Gholz, 2006). The answer for which path to innovation is best may depend on the operational needs, the technology, and the time pressures and budget.

Establishing metrics for measuring return on investment could help guide decision-making. Metrics for complex decisions are unlikely to be composed of a single measure but may be part of a process involving subjective and objective data. Metrics also vary by time horizons. For example, In-Q-Tel seeks solutions for operational needs that yield benefits within 36 months. NIOSH seeks to influence worker health and safety outcomes that may show improvement anywhere from a year to many years later, or even across decades. The NIOSH evaluation process includes some intensive, long-term evaluations.

There is likely no single best organizational design, but understanding end users, learning, and good metrics should improve outcomes

Even among operationally oriented government agencies, innovation is heterogenous, cumulative, path-dependent, and context-dependent. Therefore, there is no single optimal organizational design for innovation promotion. Innovation depends on organizational design, but also users, the technical expert community, the pace of technical development, and the political environment (Predd et al., 2021; Sanchez & Mahoney, 1996).

The lack of a single best organizational design does not mean that approach and organizational design do not matter. Managers still have to make choices and foster new and better ways of achieving their goals. Broad concepts such as linkages between experts and users, boundary spanners, and the exchange and quality of information, including metrics, appear to be important. For operationally specific innovations, knowledge of user needs and requirements is important. For general purpose innovations among the non-expert public such as worker safety and

health or public disaster preparedness, less so. In either case, a process for recursive learning between innovators and users is important. Each of our cases shows some recursive learning, through different means.

Venture capital characteristics show promise in defense and intelligence but are untested in domestic and social policy spaces

In-Q-Tel has some of the characteristics of a venture capital firm—seeking to hedge its investments, taking an equity stake, receiving a return on investments, seeking employee contributions to a fund, and gaining access to Boards of Directors. The approach allows for market signals to influence investments and allows In-Q-Tel to hold a diversified portfolio in a fast-changing space.

It is difficult to make sweeping claims about innovation based on three case studies of government support for innovation for national security or domestic public policy. All of these programs are subject to lobbies asking government for support for their industries, often with a high degree of secrecy in military or intelligence fields. Therefore, commercial market constraints are less pronounced and there is the potential for the government to commit to designs earlier than a market process might, leading to premature lock in (Pavitt, 2005, p. 99). The venture capital model is one way to address these challenges in government innovation and embrace a diversity of R&D projects and experimentation. It remains to be seen whether this model will suit government agencies outside of the defense and intelligence space. Would a venture model work in areas where technical progress is slow and incremental or where experiments are costly (e.g., nuclear power or fighter aircraft)? The viability of venture capital models for other domains should be explored.

IMPLICATIONS FOR FUTURE RESEARCH

Our investigation points to at least two areas when future research is warranted. First, we recommend the study of organizations that—in form, context, or approach—differ from the set of organizations that, at any given time, are drawing the lion's share of policy or scholarly attention. Innovation acceleration can be faddish as illustrated by the multi-fold emulation of DARPA in the United States and the rush by government agencies to establish offices in technology clusters such as Silicon Valley. Our research suggests that lessons can be extracted from organizations that take alternative, or even countertrend, tacks to innovation acceleration.

Second, scholars have noted a shift from an era in which big science and breakthroughs occurred in the public sector—with the Manhattan project being a paradigmatic example—to an era in which many scientific breakthroughs occur in or with the scientific and technical capacity of the private sector (Sachs, 2017; Tether & Tajar, 2008). Future research should explore how public organizations make use of private sector expertise for technology acceleration. We observed the use of the private commercial market in multiple cases, the development of structured, long-term public–private networks in the case of NIOSH, OTD's use of focused relationships with trusted private-sector companies, and emerging "venture capital" model of the public sector. There may be other models worth documenting, analyzing, and ultimately evaluating for their efficiency and fit with different organizational missions.

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ENDNOTES

[1] Since the foundational work by Freeman (1987), Lundvall (1992), and Nelson (1993), variations on the systems of innovation (SI) model have proliferated. Variants of the SI model include national innovation systems (Nelson, 1993), regional innovation systems (Cooke et al., 1997), and sectorial innovation systems (Carlsson, 1995).

[2] Authors' interview (September 23, 2019).

[3] This decision process described here begins after the identification of capability gaps. That is, it is assumed that by the time an agency has begun the decision process described in Figure 1, the agency has carefully specified either current or future organizational needs and formulated these gaps into a set of requirements.

[4] The focus of the In-Q-Tel case study is on In-Q-Tel, the strategic investor arm of IQT, the parent organization, which encompasses IQT Policy, IQT Labs, IQT International, and IQT Emerge.

[5] FY2016 were not available on Open 990.

[6] The impetus for externalizing a portion the CIA's technology acquisition strategy came from the head of the CIA's Directorate of Science and Technology (DST) Ruth David.

[7] If In-Q-Tel funds are used to improve a commercial product, as is often the case, the company and its other customers also benefits from the improved technology.

[8] In a 2008 article, Ulvick and Tighe observe that on average for every dollar In-Q-Tel invests in a company, other venture capital firms invest eight dollars (Ulvick & Tighe, 2008, p. 2).

[9] Typical of the background of senior In-Q-Tel investment staff are Katie Gray, a Stanford MBA with extensive expertise working with Silicon Valley tech startups and George Hoyem, who has extensive Silicon Valley VC experience.

[10] Authors' interview (September 23, 2019).

[11] https://www.cdc.gov/nora/about.html.

[12] https://www.cdc.gov/nora/pdfs/NORA-FY-2018-report_final_508.pdf.

[13] Authors' interview, September 26, 2019.

[14] Authors' interview, September 26, 2019.

[15] Authors' interview (September 23, 2019)

[16] Authors' interview (September 23, 2019).

[17] Authors' interview (September 27, 2019).

[18] Authors' interview (September 23, 2019).

[19] Authors' interview (September 23, 2019).

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How to cite this article: Roberts, P. S. & Schmid, J. (2022). Government-led innovation acceleration: Case studies of US federal government innovation and technology acceleration organizations. *Review of Policy Research*, 39, 353–378. https://doi.org/10.1111/ropr.12474