Testimony
Before the Committee on Science, Space, and Technology, House of Representatives

SCIENCE AND TECHNOLOGY

Overview of GAO’s Enhanced Capabilities to Provide Oversight, Insight, and Foresight

Accessible Version

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For Release on Delivery Expected at 10:00 a.m. ET Thursday, December 5, 2019
SCIENCE AND TECHNOLOGY

Overview of GAO’s Enhanced Capabilities to Provide Oversight, Insight, and Foresight

GAO provides a variety of science and technology (S&T) products and services to Congress. Over the decades, GAO has grown its S&T portfolio by adding technology assessments, engineering/project controls best practices guides, and, most recently, the Science & Tech Spotlight series. Together, these products are designed to address key congressional interests on S&T issues by providing foresight on the consequences of advances in S&T, oversight of the federal S&T enterprise and S&T-centric programs and projects, and insight into emerging issues and topics of congressional interest.

GAO has the expertise, independence, and access to data to provide authoritative, nonpartisan advice to Congress in a manner that complements other sources of S&T advice.

- **Expertise:** GAO’s new Science, Technology Assessment, and Analytics (STAA) team has 59 staff members with masters’ degrees and/or doctorates, as of November 2019. Fifty-six staff members have at least one degree in a science, technology, engineering, and mathematics field. GAO’s technology assessments are informed by appropriate S&T expertise, including external experts across academia, think tanks, and industry. GAO integrates subject and policy knowledge from across its 15 mission teams to develop rigorous methodological approaches to expertly analyze quantitative and qualitative data.

- **Independence:** GAO has a robust quality assurance framework to help ensure its independence and has congressional protocols to help ensure GAO is responsive to Congress in a nonpartisan manner.

- **Access to data:** GAO’s legal authorities grant it unique access to an extensive range of agency information and data, including classified information and other information that is not available to the public.

GAO will continue to build its capacity to respond to congressional demand. STAA’s current staff level is about one-half of what was outlined in the April 2019 plan submitted to Congress. GAO’s key S&T activities are shown in the figure below.
Chairwoman Johnson, Ranking Member Lucas, and Members of the Committee:

Thank you for the opportunity to discuss GAO’s science and technology (S&T) support to Congress. As you are aware, rapid developments in S&T are transforming multiple sectors of society, including medicine, transportation, communication, defense, commerce, and even culture itself. Like all technological change, each of these developments brings both opportunities—for economic growth and improved quality of life, for example—and the potential for unintended consequences. The ability of Congress to understand, evaluate, and prepare for such changes will be critical for the United States to remain safe, secure, innovative, and globally competitive.

We at GAO provide Members of Congress and their staffs with an array of professional services in the domains of oversight, insight, and foresight to help them carry out their Article I constitutional responsibilities as they relate to the nation’s science and technology enterprise. Our expertise, research, and analyses help address a number of specific congressional needs, including:

- Evaluation of the impacts of science, technology, and innovation—including programmatic and/or policy implications
- Development of policy options concerning science, technology, and innovation issues in the context of actual or hypothesized congressional policy goals
- Proactive and/or on-demand, “just-in-time” scientific/technical assistance on science, technology, and innovation issues

The 2019 Legislative Branch Appropriations Bill Conference Report encouraged GAO to reorganize and enhance its S&T function by creating a new office. In January 2019, the Comptroller General directed the creation of the Science, Technology Assessment, and Analytics (STAA) team to build on and expand our decades-long work providing Congress with S&T analysis. GAO also enhanced its Information Technology and Cybersecurity team’s existing capabilities with the hiring of 32 additional information technology (IT) and cybersecurity experts during fiscal year 2019. In addition, last year GAO inaugurated its Center for Strategic Foresight to identify and explore major emerging issues affecting
government and society—including areas involving science and technology—such as personal identity and privacy, space policy, deepfake video, and other emerging technologies.

In my testimony today, I will discuss (1) our S&T products and services for Congress; (2) how we are structured to provide S&T advice to Congress; and (3) our plan to continuously improve our S&T advising capabilities.

GAO Provides Congress a Variety of S&T Products and Services

GAO has been successfully conducting science and technology-related work for close to 50 years—including technology assessments for almost two decades—providing Members of Congress and their staffs with a variety of products and services on S&T topics. This work addresses key congressional interests on S&T issues by providing foresight on the consequences of S&T advancement; oversight of the federal S&T enterprise; and insight into specific challenges and topics of congressional interest. Recent examples of these are included in table 1. Our products include traditional GAO reports such as S&T-related performance evaluations and testimonies. Over the decades, however, we have grown our portfolio of S&T products to include technology assessments (TAs), best practices guides, and most recently, our Science & Tech Spotlight series—the latter being designed to provide a brief overview of an emerging technology area and its possible implications for policy (see app. I for a list of technology assessments and related products, app. II for Spotlights, and app. III for a broader list of selected S&T products).
Table 1: Examples of GAO Products and Services that Provide Science and Technology Foresight, Oversight, or Insight

<table>
<thead>
<tr>
<th>Category</th>
<th>Products and Services</th>
<th>Approx. Time frame</th>
<th>Examples</th>
</tr>
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<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Science &amp; Tech Spotlight: Opioid Vaccines, GAO-19-706SP</td>
</tr>
<tr>
<td>FORESIGHT</td>
<td>Evaluations and Testimonies</td>
<td>2 weeks to 2 years</td>
<td>Biodfense: The Nation Faces Long-Standing Challenges Related to Defending Against Biological Threats, GAO-19-63ST</td>
</tr>
<tr>
<td></td>
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<td></td>
<td>Science and Technology: Considerations for Maintaining U.S. Competitiveness in Quantum Computing, Synthetic Biology, and Other Potentially Transformational Research Areas, GAO-18-656</td>
</tr>
<tr>
<td>FORESIGHT</td>
<td>Technology Assessments</td>
<td>8 to 16 months</td>
<td>Irrigated Agriculture: Technologies, Practices, and Implications for Water Scarcity, GAO-20-128SP</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Technology Assessment: Artificial Intelligence: Emerging Opportunities, Challenges, and Implications, GAO-18-142SP</td>
</tr>
<tr>
<td>FORESIGHT</td>
<td>S&amp;T Horizon Scanning</td>
<td>Continuous</td>
<td>GAO’s Center for Strategic Foresight, in partnership with STAA, is doing work on Deep Fakes, Deep Space, 5G and Cellular Agriculture.</td>
</tr>
<tr>
<td>OVERSIGHT</td>
<td>Briefings and Technical Assistance</td>
<td>Days to weeks</td>
<td>In April 2019, we briefed congressional staff on National Institute of Standards and Technology’s measurement services and standards development activities.</td>
</tr>
<tr>
<td>OVERSIGHT</td>
<td>Evaluations and Testimonies</td>
<td>2 weeks to 2 years</td>
<td>Sexual Harassment in STEM Research: Preliminary Observations on Policies for University Grantees and Information Sharing among Selected Agencies, GAO-19-583T</td>
</tr>
<tr>
<td>OVERSIGHT</td>
<td>Cross-cutting and Domain-specific Reporting</td>
<td>2 weeks to 2 years</td>
<td>Critical Infrastructure Protection: Actions Needed to Address Significant Cybersecurity Risks Facing the Electric Grid, GAO-19-332</td>
</tr>
<tr>
<td></td>
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<td></td>
<td>Nuclear Waste: Opportunities Exist to Reduce Risks and Costs by Evaluating Different Waste Treatment Approaches at Hanford, GAO-17-306</td>
</tr>
<tr>
<td>INSIGHT</td>
<td>Briefings and Technical Assistance</td>
<td>Days to weeks</td>
<td>In October 2019, our Chief Scientist participated as a subject matter expert in a Data Roundtable for the House Veterans’ Affairs Committee to discuss data portability, use of electronic health records, and privacy and security concerns, among other things.</td>
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<tr>
<td></td>
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<td></td>
<td>Columbia Class Submarine: Overly Optimistic Cost Estimate Will Likely Lead to Budget Increases, GAO-19-497</td>
</tr>
<tr>
<td>INSIGHT</td>
<td>S&amp;T Issue Tracking</td>
<td>Continuous</td>
<td>Gene Editing; AI and Automation; Quantum Information Science; Brain/Augmented Reality; Cryptocurrencies</td>
</tr>
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</table>

Source: GAO | GAO-20-306T

Note: Time needed is dependent on the scope and methodologies chosen. We are continuously working to decrease the amount of time taken to issue GAO reports and TAs.

In addition to written products, we provide S&T-related services to Members and their staffs, including briefings on our products or on our
areas of expertise, and short-term analyses and reviews. Each product and service requires a different level of effort and time, tailored to the current and anticipated needs and interests of the requesters. Significant to STAA’s long-term, sustainable service to the Congress is the shift in our strategic posture from a product-centered to an agile, content-centered operation in order to capitalize on newer information channels (e.g., podcasts, interactive/visualized data, mobile platforms) and in a manner that fits today’s legislative operational tempo.

Foresight of Scientific and Technological Advancement

Members and their staffs need to understand how new technologies will shape our world. We provide foresight into technological opportunities and risks with thorough and balanced assessments of critical innovations that affect society, the environment, and the economy. GAO foresight products include TAs, Science & Tech Spotlights, and S&T-related evaluations and testimonies, while foresight services include S&T horizon-scanning and issue tracking in partnership with GAO’s Center for Strategic Foresight. Having multiple product types and services allows us to respond in an appropriate time frame with the information Congress needs.

Technology assessments. Our TAs analyze the latest developments in science and technology, draw attention to implications of technological change, and make core concepts accessible to policymakers. The content of TAs varies. They may:

- Highlight potential short-, medium-, and long-term impacts of scientific advancement and/or technological development
- Elaborate on and communicate the risks and benefits associated with a technology, including early insights into the potential impacts of technology
- Highlight the status, viability, and relative maturity of a given technology—especially in the context of a complex acquisition program
- Describe federal investments in S&T
- Present policy options designed to inform decision makers on potential courses of action and the opportunities and challenges associated with each option.
TA time frames depend on their scope, but they can be completed within several months. Figure 1 highlights some recent TAs, and appendix I shows a full list of our TAs and related products.
<table>
<thead>
<tr>
<th>Topic</th>
<th>Description</th>
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</thead>
<tbody>
<tr>
<td>Irrigated Agriculture:</td>
<td>Provides an overview of irrigation technologies and practices that could reduce water usage. Also discusses factors that influence the adoption of efficient irrigation technology and how efficient irrigation technologies impact water conservation. Provides policy options in the area.</td>
</tr>
<tr>
<td>Critical Infrastructure Protection:</td>
<td>Reports on the potential effects of geomagnetic disturbances on the U.S. electric grid, and technologies to prevent or mitigate a disturbance. Also discusses factors that could affect the development and implementation of these technologies.</td>
</tr>
<tr>
<td>Artificial Intelligence:</td>
<td>Discusses how artificial intelligence (AI) has evolved over time, the opportunities and future promise, as well as the principal challenges and risks. Report includes the policy implications and research priorities resulting from advances in AI.</td>
</tr>
<tr>
<td>Chemical Innovation:</td>
<td>Assesses selected technologies that are available or in development to make chemical processes and products more sustainable. Describes the contributions of the federal government, industry, and others to the development and use of such technologies.</td>
</tr>
<tr>
<td>Medical Devices:</td>
<td>For multiplex point-of-care technologies, describes performance and costs. Discusses challenges and potential benefits of these technologies.</td>
</tr>
<tr>
<td>Internet of Things:</td>
<td>Describes the state of the Internet of Things, the purposes and uses of the technologies, along with potential implications.</td>
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Source: GAO. | GAO-20-306T
Science & Tech Spotlights. We also provide Congress with foresight through our Science & Tech Spotlights. Launched in 2019, Spotlights are two-page overviews for policymakers and the public. Each describes an emerging S&T development, the opportunities and challenges it brings, and the relevant policy context. Spotlights are designed to inform Congress of key developments in a timely and efficient manner, generally before congressional requests for deeper inquiries. Spotlights are completed in a few to several weeks. Our first four Spotlights, included in appendix II, address blockchain, hypersonic weapons, opioid vaccines, and probabilistic genotyping software—with the latter topic now requested as part of a full technology assessment project.

Evaluations and testimonies. Some GAO evaluations identify key technologies and their risks and opportunities, and provide policy options to decision makers. For example, in a series of reports from December 2009 through March 2019, we identified options for policy or structural changes that could help the Department of Homeland Security better fulfill its biosurveillance integration mission. More generally, since 2013, we have released 13 reports that included identification and assessment of policy options in a variety of technical and non-technical contexts. In addition, we addressed a range of S&T topics in testimonies before Congress. For example, in June 2019 we testified before the House Committee on Oversight and Reform on biological threats and biodefense efforts. In June 2019, we testified in front of the House Committee on Oversight and Reform on the privacy and accuracy of FBI’s use of facial recognition. We also testified on a range of information technology and cybersecurity topics in fiscal year 2019, such as IT challenges at the Department of Veterans Affairs, systems development and cybersecurity efforts in preparation for the 2020 Census, and federal cybersecurity workforce issues.

S&T horizon scanning and issue tracking. In addition to working on specific foresight-related products, our staff continually perform horizon-scanning to support Congress. Further, awareness and evaluation of trends in S&T are part of our ongoing strategic planning efforts. In GAO’s 2018-2023 Strategic Plan for Serving Congress and the Nation, we outline a number of technologies and scientific advances that will potentially transform society, among them genome editing, artificial intelligence and automation, quantum information science, brain-computer interfaces and augmented reality, and cryptocurrencies and
blockchain (see app. IV).\textsuperscript{1} Our staff track advancements in these areas to inform our current and future products and services. The issues we focus on will change over time as our horizon-scanning identifies new priority issues.

**Oversight of the Federal S&T Enterprise and S&T-centric Programs and Projects**

Members and their staffs need trusted, nonpartisan information on the performance of federal programs and their outcomes for Americans. This work has increasingly focused on S&T as it has become more important to the efficient and effective performance of federal programs. GAO provides oversight through products, such as performance evaluations, and through technical assistance services, such as briefings on our prior work or short-term analysis of agency programs or activities.

**Cross-cutting evaluations of S&T.** We conduct cross-cutting work that evaluates the management and coordination of research and development across the federal government. This work addresses issues related to topics such as basic science, innovation, manufacturing, and S&T’s role in economic competitiveness. For example, in fiscal year 2019 we issued products on advanced manufacturing, scientific integrity, and sexual harassment in Science, Technology, Engineering, and Mathematics (STEM) research.

**Domain-specific performance evaluations.** In addition, we evaluate a number of domains where S&T is critical, including defense, space, energy and the environment, nuclear, health care, and IT, as is shown in figure 2. The development of S&T-intensive systems, delivery of technology-dependent services, and development and application of technologies to solve problems are just some of the topics addressed in this work. Recent work in this area has examined topics such as synthetic biology, environmental cleanup technologies, critical infrastructure cybersecurity, and quantum computing. Time frames for this work, including testimonies and evaluations, typically average less than a year, but may range from 2 weeks to 2 years, depending on the scope of the work and congressional needs.

Figure 2: GAO Examines Science and Technology in Many Domains

Defense and homeland security
We evaluate technology readiness and risks for complex weapons and homeland security systems, such as missiles, radar, ships, and border security systems.

Space
We assess federal military and civilian space programs and efforts to support and oversee telecommunications in the public interest.

Energy and the environment
We evaluate developing and deployed technologies in a range of activities, including environmental monitoring, renewable energy, cleanup of hazardous sites, and civilian nuclear power.

Nuclear
We evaluate programs, infrastructure, technology readiness, and operations for the maintenance and management of nuclear weapons, as well as the aircraft and submarines designed to carry and deliver them.

Health care
We assess new technologies for emerging infectious diseases, such as technologies that can simultaneously test for multiple infectious diseases at or near the site of patient care, and the impacts of new technology on human health, disease prevention, and the delivery of health care.

Information technology and cybersecurity
We evaluate the management and operation of the government's substantial IT investments and assess efforts to protect federal systems, emerging technologies, critical infrastructure, and individual privacy from cyber threats.

Sources (top left to right): DoD, NASA/Kennedy, and GAO; (bottom left to right) GAO, GAO, and Social Security Administration.
Series of performance evaluations. A third area in which we support congressional S&T oversight is long-term monitoring of agency operations and factors that could affect these operations. For example, GAO first designated federal information security as a government wide high risk area almost 22 years ago in 1997 and our cybersecurity work has been critical to informing and assisting Congress. Our work informed Congress as it considered major legislation on information security, such as the Federal Information Security Management Act of 2002 (FISMA), its successor, the Federal Information Security Modernization Act of 2014, and the Cybersecurity and Infrastructure Security Agency Act of 2018. We have also undertaken a series of reports evaluating the planning, design, and construction of large facilities sponsored by the National Science Foundation, such as telescopes and research vessels, and a series of reports on oversight of high-containment laboratories.

We also regularly provide services to Congress related to our oversight work, including briefings on past and ongoing work or technical assistance to provide additional data or context to our work. For example, informed by our bodies of work, we have provided overview briefings to committees, such as “Defense Space Systems 101” and “NIST 101.”

Insight into Priority Issues

Members and their staffs need partners to help ensure efficiency and accountability in government. We provide guidance to federal managers and employees to help S&T-intensive programs operate at their best. We developed a series of best practices guides that lay out proven and effective approaches and decision-making tools for federal managers. We developed these guides to respond to persistent challenges in managing the cost, schedule, and performance of the federal government’s significant investments in research and development and complex technical acquisition programs. Our guides currently cover cost, schedule, and technology readiness, with an additional guide planned for Agile software development. Our cost, schedule, and technology readiness assessment guides have improved project management practices across the federal government and spurred congressional action on technology risks. We have also used our expertise in these areas to review federal programs and identify targeted interventions to improve federal acquisitions, such as our December 2017 and April 2019 reports concerning, respectively, the technology readiness and cost estimate of the Navy’s Columbia class submarine. These guides are described in figure 3.
### Figure 3: GAO Best Practice Guides

<table>
<thead>
<tr>
<th>Title</th>
<th>Summary</th>
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<tbody>
<tr>
<td>Cost Estimating and Assessment Guide</td>
<td>• Provides 12-step process to develop high-quality, reliable program cost estimates applicable across government and industry.</td>
</tr>
<tr>
<td><em>Currently being updated</em></td>
<td>• Provides a detailed link between cost estimating and earned value management (EVM).</td>
</tr>
<tr>
<td>Best Practices for Developing and Managing Capital Program Costs GAO-09-3SP, Mar. 2, 2009</td>
<td></td>
</tr>
<tr>
<td>Schedule Assessment Guide</td>
<td>• Provides 10 best practices to help managers and auditors ensure that a program schedule is reliable.</td>
</tr>
<tr>
<td>Best Practices for Project Schedules GAO-16-89G, Dec. 22, 2015</td>
<td>• Develops standard criteria to determine the extent to which agency programs and projects meet industry scheduling standards.</td>
</tr>
<tr>
<td>Technology Readiness Assessment Guide</td>
<td>• Provides six-step outline of a reliable technology readiness assessment process and associated best practices to evaluate technology maturity across the federal government.</td>
</tr>
<tr>
<td><em>Update forthcoming</em></td>
<td>• Provides a framework for better understanding technology maturity, conducting credible technology readiness assessments, and developing plans for technology maturation efforts.</td>
</tr>
<tr>
<td>Agile Guide</td>
<td>• Provides nine adoption best practices sorted into team activities, program processes, and agency environment.</td>
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</table>

Source: GAO | GAO-20-306T
We also provide Members and their staffs immediate access to a trusted source of nonpartisan information to gain insight into S&T topics and programs, ranging from answering technical questions by phone, to providing a comprehensive written and oral briefing on a complex issue. Depending on the need and topic, turnaround time can range from days to a few weeks. Some of our methods for providing technical assistance to Congress include:

- We frequently provide informal briefings and other assistance to Members of Congress and congressional staff on a very short time frame based on our expertise, prior work, and analysis. We have provided numerous technical briefings on request, such as on biodetection systems, big data, artificial intelligence, IT, and cybersecurity issues, among others. Our technical assistance also supports hearings. For example, we provided information on fentanyl and fentanyl analogs for a hearing on the opioid crisis. We developed a briefing on sustainable chemistry for a committee.

- We have briefed new committee staff on topics or agencies within their portfolios, highlighting our recent reporting and our understanding of the major issues involved.

- We also draw on our in-house expertise and prior reporting to provide context and issues to consider regarding draft legislation.

Our ongoing work develops S&T content across a mixture of product types, key topics, and for a variety of congressional committees. Figure 4 shows selected current work in S&T.
Figure 4: Selected Ongoing GAO Science and Technology (S&T) Work

<table>
<thead>
<tr>
<th>Topic (Product Type)</th>
<th>Congressional Clients</th>
</tr>
</thead>
<tbody>
<tr>
<td>CRISPR gene editing and surrounding policy context (Science &amp; Tech Spotlight)</td>
<td>Biomedical, Agriculture, and National/Homeland security-related committees and caucuses</td>
</tr>
<tr>
<td>Information on deepfake video technology (Science &amp; Tech Spotlight)</td>
<td>Technology-related committees and caucuses</td>
</tr>
<tr>
<td>Nuclear microreactors technology (Science &amp; Tech Spotlight)</td>
<td>Energy-related committees and caucuses</td>
</tr>
<tr>
<td>Artificial intelligence in drug development (Technology Assessment)</td>
<td>Senate Committee on Health, Education, Labor, and Pensions, and House Committee on Energy and Commerce</td>
</tr>
<tr>
<td>Performance, usage, and challenges of 5G wireless networks (Science &amp; Tech Spotlight and Technology Assessment)</td>
<td>House Committee on Armed Services, House Permanent Select Committee on Intelligence, House Committee on Science, Space, and Technology, and Senate Select Committee on Intelligence</td>
</tr>
<tr>
<td>Artificial intelligence in the delivery of health care services (Technology Assessment)</td>
<td>Senate Committee on Health, Education, Labor, and Pensions, and House Committee on Energy and Commerce</td>
</tr>
<tr>
<td>Algorithms used in forensics, including DNA fingerprints and facial recognition (Technology Assessment)</td>
<td>Security and technology-related committees and caucuses</td>
</tr>
<tr>
<td>Infectious disease modeling as it relates to public health decisions (Performance Evaluation)</td>
<td>House Committee on Energy and Commerce</td>
</tr>
<tr>
<td>Federal efforts to address antibiotic resistance (Performance Evaluation)</td>
<td>Senate Committee on Health, Education, Labor, and Pensions, and House Committee on Energy and Commerce</td>
</tr>
<tr>
<td>The National Science Foundation’s large facilities construction (Performance Evaluation)</td>
<td>House Appropriations Subcommittee on Commerce, Justice, Science, and Related Agencies</td>
</tr>
<tr>
<td>The Department of Veterans Affairs research into veterans’ health care needs (Performance Evaluation)</td>
<td>House Committee on Veterans’ Affairs</td>
</tr>
<tr>
<td>Intellectual property assistance for small businesses (Performance Evaluation)</td>
<td>House Committee on Small Business</td>
</tr>
<tr>
<td>Department of Homeland Security’s new biodetection technology system (Technology Assessment and/or Performance Evaluation)</td>
<td>Senate Committee on Homeland Security and Governmental Affairs, House Committee on Energy and Commerce, House Committee on Homeland Security, House Committee on Science, Space, and Technology</td>
</tr>
<tr>
<td>Identify and describe Agile software development best practices (Best Practice Guide)</td>
<td>Appropriations, Budget, and technology-related committees and caucuses</td>
</tr>
<tr>
<td>An update to GAO’s 2009 Cost Estimating and Assessment Guide (Best Practice Guide)</td>
<td>Appropriations, Budget, and oversight-related committees and caucuses</td>
</tr>
</tbody>
</table>

Source: GAO. | GAO-20-306T
GAO Has the Expertise, Independence, and Access to Data to Provide Authoritative, Nonpartisan Advice to Congress

GAO is uniquely positioned to provide fact-based, non-ideological, nonpartisan and authoritative S&T advice to Congress in a manner that complements advice provided by the National Academies of Sciences, Engineering, and Medicine (National Academies) and the Congressional Research Service. Authoritative S&T advice requires distilling technical and policy expertise into clear, concise, and independent descriptions and recommendations. GAO has the in-house talent, access to external expertise, and employs the methodological rigor to do so, although we are not yet staffed up as intended in our April 2019 STAA plan. GAO has a strong reputation for independent, high-quality, nonpartisan analysis. In addition, we have unique access to expertise and information in the federal government, as well as significant access to external expertise, be it through our standing relationship with the National Academies or through our own convening and access to academic, nonprofit, and private-sector expertise.

GAO Staff Are Well Qualified to Provide Congress a Variety of S&T Products and Services

Although we have expanded our technical expertise substantially over the past year, we have not yet fully staffed up as intended in our April 2019 STAA plan. Nevertheless, we have a well-trained and diverse talent pool. Our STAA team now has 59 staff members with masters’ degrees and/or doctorates. Fifty-six staff members have at least one degree in a STEM field. The team currently includes engineers (e.g., biomedical, electrical and electronics, systems, petroleum, aerospace), chemists (e.g., analytical, environmental, inorganic, organic, theoretical), biologists, and physical scientists (e.g., nuclear physics, environmental science, geology), and others. STAA also has operations research analysts/project controls engineers who specialize in lifecycle cost estimating, scheduling, earned value management, technology readiness assessment, and Agile software development. In addition to these fields, STAA team members also hold advanced degrees in public policy, rounding out the team to expertly advise on the nexus of technology and policy. In October 2019, we hired our first Chief Data Scientist to lead innovative data analytics
efforts for all of GAO. A team of attorneys within GAO’s Office of the General Counsel provides support to STAA as well.

STAA staff also benefit from collaboration with GAO’s broader workforce of subject-area policy analysts, economists, social scientists, methodologists, and attorneys across our 14 other mission teams. Some of the other mission teams that address S&T topics typically have their own dedicated, in-house S&T expertise on topics related to their missions. Examples include expertise in engineering, chemistry, biology, physics and cybersecurity. Figure 5 shows a representation of S&T expertise within STAA and GAO more broadly.

Figure 5: GAO Has Extensive Science and Technology Expertise

![Figure 5: GAO Has Extensive Science and Technology Expertise](image)

Examples of how this expertise is used:

- Biological/life sciences for emerging infectious diseases, epidemiology, synthetic biology, biosafety, and biosecurity work
- Computer/systems/electrical engineering for digital and communications technologies (e.g., 5G wireless, blockchain, quantum cryptography, artificial intelligence/machine learning systems)
- Applied math/engineering/computer science for advanced analytics/data science/data engineering
- Nuclear physics for nuclear nonproliferation, waste management, weapons systems analysis, and radiation/nuclear detection systems
- Quantum computing
- Physics/aerospace engineering for advanced weapons systems, space systems, and unmanned systems

Source: GAO | GAO-20-306T
Our Information Technology and Cybersecurity (ITC) team, for example, has extensive knowledge of key IT domains, including IT and cybersecurity risk management, software development, system administration, and computer networking. Many ITC team members have one or more specialized certifications, such as Certified Information Systems Security Professional (CISSP), Certified Information Privacy Professional (CIPP), and Certified Ethical Hacker (CEH).

Furthermore, we have 11 field offices across the country, giving us deeper links throughout the federal community, access to talent from different regions, and connecting us with a diverse set of universities, research institutions, and industries. This access to a well-trained and diverse talent pool brings a powerful and sophisticated perspective to our work as we conduct TAs and analyze the policy implications of a range of technical and scientific topics for Members and their staffs.

**GAO Work Is Fact-Based and Undergoes a Rigorous Technical Review Process**

We employ rigorous methods to produce fact-based information, ensuring that all statements presented in our products are based on sufficient and credible evidence. Further, we integrate a wealth of knowledge from across GAO’s 14 other mission teams to develop rigorous methodological approaches for expertly analyzing quantitative and qualitative data. We also tailor our methodologies to suit particular products and meet congressional needs.

We have designed our TA process to ensure that our work is informed by appropriate S&T expertise, including external experts across academia, think tanks, and industry. We involve experts throughout our studies. To do so, we draw expertise from scientists, engineers, and physicians through routine engagement with the National Academies of Sciences, Engineering, and Medicine. Since 2001, we have maintained a standing contract that allows National Academies personnel to help GAO identify experts and assist with convening expert meetings for GAO. Once we have selected a group of experts that represents the needed cross-sector expertise (e.g., government, university, industry, and nonprofit), we traditionally convene a meeting of these experts to highlight and discuss

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the latest research in the field. We use an experienced moderator to encourage discussion that can result in new thoughts and ideas. We then contact the experts over the course of our work to gain additional input as needed. Once we have developed a draft report, the experts who participated in our meeting of experts then review our TAs for technical and scientific accuracy to ensure the assessments are of the highest quality. Involvement of these experts throughout the process is reflected in figure 6 and in more detail in appendix V. As described in our April 2019 STAA Plan, our TA portfolio is based on our well-established quality assurance framework and is at times above and beyond how it is applied to our evaluation work.

Figure 6: GAO Involves Experts Throughout Its Technology Assessments

We collaborate with many other S&T entities as well. For example, we engage with federally funded research and development centers, such as the MITRE Corporation, the Institute for Defense Analyses, and the Carnegie-Mellon Software Engineering Institute. We are also building key academic partnerships with universities that have specialized programs in science, technology, and public policy, such as Arizona State University, Carnegie-Mellon University, the Georgia Institute of Technology, the Massachusetts Institute of Technology, and University of Maryland College Park, among others. By maintaining a diverse network, we are able to connect Members and their staffs with other relevant experts when needed.

GAO Responds to Congressional Priorities

Our work directly supports congressional interests. In fiscal year 2019, we devoted 96 percent of our engagement resources to work requested
directly by Members and committees or required by Congress in statute. Prioritization of this work is guided by our congressional protocols, which we designed in consultation with Congress and which provide a sequence of internal controls that allows us to efficiently and effectively receive, prioritize, and respond to congressional requests. These protocols help ensure we work constructively with Congress and conduct our work in accordance with congressional priorities to meet the needs of both parties. These protocols also ensure that we are consistent in dealing with all committees and individual members. Although we prioritize mandates and requests from Chairs and Ranking Members of congressional committees over individual member requests, we may also provide technical assistance and briefings in response to individual member requests.

In addition, we may undertake work that is not directly tied to requests. This can be useful for topics that are of broad interest in Congress, generally longer-range, crosscutting, and transformational issues. The ability to conduct such work under “Comptroller General Authority,” is also beneficial because it allows us to bring to Congress’s attention important emerging S&T issues that may affect the nation’s future. For example, we developed our Science & Tech Spotlights under this authority to quickly inform Congress of S&T topics of broad interest. Examples of some of our ongoing work—including requests and Comptroller General Authority work—were previously shown in figure 4.

Examples of our more recent S&T work to support Congress include our July 2019 testimony before the Subcommittee on Research and Technology on the technologies for making chemical products and processes more sustainable. Also in July 2019, before the Subcommittee on Research and Technology and the Subcommittee on Investigations and Oversight, we testified on federal research, and strengthening scientific integrity policies. This hearing helped inform Members of the subcommittees as they considered the Scientific Integrity Act. In October 2019, our Chief Scientist participated as a subject matter expert in a Data Roundtable for the House Veterans’ Affairs Committee to discuss data

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31 U.S.C. § 717(b)(1) grants the authority to evaluate the “results of a program or activity” of the Government on the initiative of the Comptroller General. This work, conducted under “Comptroller General Authority,” can be beneficial as we identify emerging S&T issues.

portability, use of electronic health records, and privacy and security concerns, among other things. Also, we provided a briefing of 5G technologies to Members and their staffs from the House Science, Space, and Technology Committee and staff from the House Armed Services Committee.
GAO Work Is Independent and Nonpartisan by Design

We ensure our independence both in our work and as an independent agency that works for Congress. We are careful to ensure that our opinions, findings, conclusions, judgments, and recommendations will be impartial and will be viewed as such by third parties. GAO has a robust quality assurance framework and systems to help ensure our independence. For example, GAO employees must disclose their personal financial holdings and other interests annually. In addition, employees must certify every two weeks that they remain independent with respect to their work. If any conflict or concern arises, supervisors, in conjunction with our Office of Ethics, take immediate and appropriate action.

As an agency, we efficiently use available resources to maximize our ability to meet the Congress’s needs and consistently exercise the independence necessary to ensure that our products and work conform to professional standards and our core values of accountability, integrity, and reliability. While we work closely with Congress to understand their needs and to conduct work that will address those needs, we do so in a manner that enables us to demonstrate our independence throughout all aspects of our work to ensure credibility. For example, we make the final determination of the specific questions our work will address, the scope of those questions, and the methods we will use to answer them.

GAO Has Unique Access to Federal Agency Data

We are also well-positioned to address Congress’s S&T needs because our legal authorities grant us unique access to an extensive range of agency information and data, including classified information and other information that is not available to the public. This gives us a unique ability to provide well-informed, high-quality S&T advice. For example, in the technology assessment Irrigated Agriculture: Technologies, Practices, and Implications for Water Scarcity, we used nonpublic data from the U.S. Department of Agriculture to create an econometric model examining the effects irrigation technology had on how much water farms were using.5 We found that use of efficient irrigation technologies alone may not

conserve water, and provided two policy options designed to address that concern.

**GAO Plans to Continue to Expand Its S&T Capacity to Respond to Congressional Demand**

In January 2019, we created the STAA team and since then have dramatically enhanced our ability to provide Congress with thorough and balanced analyses of technological and scientific developments that affect society, the environment, and the economy. Since that time, we have built significant capacity to produce S&T products and services, but more needs to be done. We will work to continuously enhance our products and services by exploring additional product types, and expanding our staff by attracting additional world-class talent.

**Future Content-Centric Plans to Meet Congressional S&T Needs**

Using a content-centric strategy, we are implementing a number of steps that take into account the unique requirements of TAs and related S&T work to meet the needs of Members of Congress and their staffs. As we build on our existing capabilities and grow the new STAA team, we will:

- Develop and refine content development and delivery formats designed to issue clear and concise communication on technical topics in accordance with the current and projected congressional operational tempo
- Develop additional methods and standards that are appropriate to TAs and separate from those covering our evaluation work
- Designate staff whose primary focus will be TAs and the provision of direct technical assistance to the Congress
- Continue engaging with external experts and advisory boards, as appropriate
We are exploring and anticipate making future changes. While still in the exploratory phase, these may include preparing an annual horizon scanning report and establishing an S&T advisory board.\(^6\)

**Future Staffing Plans to Enhance S&T Work**

To ensure Members and their staffs continue to receive high-quality, independent, and nonpartisan advice and analysis on technological and scientific topics, we organized our S&T activities into four key groups, as is shown in Figure 7. We plan to continue to build capacity in those areas to respond to greater congressional demand.

![Figure 7: Key Science and Technology Activities](image)

**Technology Assessment**
Provides foresight on key technologies and the policy implications for the federal government.

**Innovation Lab**
Explores, pilots, and deploys advanced analytics, information assurance auditing, and emerging technologies to improve auditing practices.

**Evaluations**
Oversight of research programs, cybersecurity, defense, intellectual property protection, health care, and all other science and technology functions of government.

**Engineering Sciences**
Provides best practices, including for cost, schedule, earned value, and technology readiness assessment.

Across our work we aim to augment our core products with a range of timely, high-value technical assistance services for our congressional clients.

STAA’s current staff level is about one-half of what was outlined in the plan submitted to Congress, so we will grow our current S&T workforce

\(^6\)Though not finalized yet, the S&T advisory board may consist of external S&T policy experts from industry, academia, nonprofits, and former senior government officials.
over the next few years. Depending on congressional priorities through the normal authorization and appropriations process, we aspirationally plan to grow STAA to 140 full-time equivalent total staff as we adapt to meet future congressional demand. We anticipate that at least half of STAA staff will have advanced degrees across the physical, life, and computational sciences as well as most variants of engineering. We will continually assess optimum staffing levels for the team based on congressional needs and product demand. As we continue to assess anticipated future work and S&T issues that will be of interest to the Congress, we have hired and plan to continue hiring to add expertise in areas such as:

- Biological/life sciences for emerging infectious diseases, epidemiology, synthetic biology, biosafety, and biosecurity work
- Computer/systems/electrical engineering for digital and communications technologies (e.g., 5G wireless, blockchain, quantum cryptography, artificial intelligence/machine learning systems)
- Applied math/engineering/computer science for advanced analytics/data science/data engineering
- Nuclear physics for nuclear nonproliferation, waste management, weapons systems analysis, and radiation/nuclear detection systems
- Quantum computing
- Physics/aerospace engineering for advanced weapons systems, space systems, and unmanned systems

In addition to permanent staff, we are exploring actively recruiting temporary or limited-term staff to meet project-specific needs, particularly around the latest S&T advances. Such staff could include experts from the National Academies or Intergovernmental Personnel Act detailees.\footnote{The Intergovernmental Personnel Act Mobility Program provides for the temporary assignment of personnel between the federal government and state and local governments, colleges and universities, Indian tribal governments, federally funded research and development centers, and other eligible organizations. Assignment agreements can be made for up to two years, and may be intermittent, part-time, or full-time.} The exact number of such staff will vary based on our hiring authority, project needs, and congressional demand for our work. We will seek additional authorities if necessary to obtain needed expertise. As discussed during meetings with external stakeholders, there is a strong interest within the S&T community in opportunities to participate in and

The exact number of such staff will vary based on our hiring authority, project needs, and congressional demand for our work. We will seek additional authorities if necessary to obtain needed expertise. As discussed during meetings with external stakeholders, there is a strong interest within the S&T community in opportunities to participate in and
contribute to analysis of S&T issues on behalf of the Congress, and to enhance their own work on S&T issues through an understanding of the broader policy context.

Thank you, Chairwoman Johnson, Ranking Member Lucas, and Members of the Committee, this concludes my prepared statement. I would be pleased to answer any questions.
For further information on this testimony, please contact Timothy Persons, Chief Scientist, GAO, and Managing Director, Science, Technology Assessment, and Analytics who may be reached at (202) 512-6888. Contact points for our Congressional Relations and Public Affairs offices may be found on the last page of this statement. Other individuals making key contributions to this work include: Karen Howard (Director), Laura Holliday (Assistant Director), Jenn Beddor (Analyst-in-Charge), Will Bauder, Anika McMillon, Jon Menaster, Tind Shepper Ryen, and Ben Shouse.
## Appendix I: List of GAO Technology Assessments and Science Forum Highlights

<table>
<thead>
<tr>
<th>Title</th>
<th>Publication Details</th>
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<tr>
<td>Irrigated Agriculture: Technologies, Practices, and Implications for Water Scarcity</td>
<td>GAO-20-128SP (Nov. 12, 2019)</td>
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<tr>
<td>Technology Assessment: Artificial Intelligence: Emerging Opportunities, Challenges, and Implications</td>
<td>GAO-18-142SP (Mar. 28, 2018)</td>
</tr>
<tr>
<td>Medical Devices: Capabilities and Challenges of Technologies to Enable Rapid Diagnoses of Infectious Diseases</td>
<td>GAO-17-347 (Aug. 14, 2017)</td>
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<td>Internet of Things: Status and Implications of an Increasingly Connected World</td>
<td>GAO-17-75 (May 15, 2017)</td>
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<td>Technology Assessment: Municipal Freshwater Scarcity: Using Technology to Improve Distribution System Efficiency and Tap Nontraditional Water Sources</td>
<td>GAO-16-474 (Apr. 29, 2016)</td>
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<td>Highlights of a Forum: Data and Analytics Innovation—Emerging Opportunities and Challenges</td>
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<td>Technology Assessment: Municipal Freshwater Scarcity: Survey of Technology Adoption by Municipal Water Utilities</td>
<td>GAO-16-588SP, Apr. 29, 2016, an e-supplement to GAO-16-474</td>
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Source: GAO | GAO-20-306T
Appendix II: Examples of GAO Science and Technology Spotlight Series
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SCIENCE & TECH SPOTLIGHT

PROBABILISTIC GENOTYPING SOFTWARE

THE TECHNOLOGY

What is it? Probabilistic genotyping software (PGS) is used in criminal investigations to help link a genetic sample — such as a sample from crime-scene evidence — to a person of interest (POI). It facilitates genetic analysis in complicated situations, such as when a sample is partially degraded or contains DNA from more than one person.

How does it work? The usual first step is to gather genetic material from both the evidence and the POI. Both samples are then separately analyzed using a process that examines multiple regions of DNA whose length varies among individuals. Investigators can then create genetic profiles that allow them to distinguish among individuals using this variability.

Next, laboratories compare the genetic profile of the evidence with that of the POI. They often do this with a computer simulation of many different scenarios (fig. 1). PGS provides a probability that the evidence gathered would have led to the evidence profile that was obtained, if the POI were — or were not — a contributor to the sample. Investigators can use the relative values of these two probabilities to establish the strength of the evidence in favor of, or against, the POI.

How mature is it? PGS was available by the late 1990s, yet it is not fully mature. There are several software packages for PGS, some open source, some commercial. About 100 laboratories in the United States reportedly use PGS. PGS analyses are used by law enforcement offices, crime or forensics laboratories, defense attorneys, and law offices at the county, city, state, and federal levels. For example, according to a President's Council of Advisors on Science and Technology (PCAST), the FBI started using a PGS package called STRmix in 2015.

PCAST stated that, in order to establish the scientific validity of PGS, outside groups need to conduct scientific evaluation studies, in addition to the developers and affiliated laboratories that typically conduct such studies currently. PCAST also recommended publication of study results.

OPPORTUNITIES

- Usable on a variety of samples. PGS allows for interpretation of genetic material that is degraded, comes from multiple people, or is present at low concentrations, such as when a person only touched a piece of evidence (instead of leaving blood behind, for example).
- Scenario analysis. PGS also could facilitate analysis of a large number of scenarios and help ensure consistency in laboratory methodology.

CHALLENGES

- False negatives. When a genetic marker is present but at a concentration too low to detect, it may produce a false negative result (fig. 2).
- False positives. Conversely, when contamination or random “noise” gives the appearance of a marker that is not actually present, it can lead to a false match.
Appendix II: Examples of GAO Science and Technology Spotlight Series

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Limited information content. PGS cannot attribute a DNA sample to a particular event. For example, a high likelihood of matching the PDI does not mean the PDI handled the object at a particular time or during a particular incident.

Lack of clarity. It can be challenging to present results in a way that is meaningful to a lay audience. For example, if the test shows that the PDI match is 50,000 times more likely than another random person, how a non-specialist would interpret this statistic is unclear.

Lack of consistency. Different software packages may yield different results from the same sample. In some cases, even the same software package can yield varying results, although this may not invalidate the results. One of the causes for lack of consistency is the lack of standards for using and interpreting PGS results.

Lack of validation. It is challenging to validate PGS for certain scenarios, such as when a sample contains DNA from more than three people, or if the amount or quality of DNA decreases. If outside parties cannot validate the methods or examine how validation was conducted, legal questions could arise. For example, one news report suggested that results from a single PGS were used as the sole physical evidence in a trial that ended in conviction. However, the defense argued that the software company did not make its source code available for examination. Additionally, without validation, one may not know specifically why different methods produce different results.

Policies context and questions.

PGS use in forensic analyses is increasing, but PGS results reportedly can be used with only limited confidence under certain circumstances. Some key questions for consideration include:

- In what situations is PGS useful, and when should it be avoided or used with caution?
- What are the gaps in empirical evidence that need to be filled to increase confidence in PGS results for use in criminal or civil trials, and what is the cost and feasibility of addressing these gaps?
- How are federal agencies evaluating and using PGS, and what should the federal role be?
- What additional validation work is needed to expand use of PGS?

Selected GAO work.

- DNA Evidence: DOJ Should Improve Performance Measurement and Property Design Controls for Nationwide Grant Program. GAO-18-572T
- DNA Evidence: Preliminary Observations on DOJ’s DNA Capacity Enhancement and Backlog Reduction Grant Program. GAO-18-561T
- Technology Assessment: Artificial Intelligence: Emerging Opportunities, Challenges, and Implications. GAO-18-452SP

References.

- Academy Standards Board “Validation Standards for Probabilistic Genotyping Systems Draft.”
- President’s Council of Advisors on Science and Technology “Forensic Science in Criminal Courts: Ensuring Scientific Validity of Forensic-Comparison Methods.” (Washington, D.C., September 2016).

Ga o Support:

GAO meets congressional informational needs in several ways, including by providing oversight, insight, and foresight on science and technology issues. GAO staff are available to brief on completed bodies of work or specific reports and answer follow-up questions. GAO also provides targeted assistance on specific science and technology topics to support congressional oversight activities and provide advice on legislative proposals.

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Staff Acknowledgments: Saurabh Sharma (Assistant Director), Hayden Huang (Analyst-in-Charge), Anika McNiff, Ben House, and Jessica Smith.

This document is not an audit product and is subject to revision based on continued advances in science and technology. It contains information prepared by GAO to provide technical insight to legislative bodies or other external organizations. This document has been reviewed by the Chief Scientist of the U.S. Government Accountability Office.

Source: GAO. | GAO-20-306T  Part 2 of 2
Appendix II: Examples of GAO Science and Technology Spotlight Series

SCIENCE & TECH SPOTLIGHT:

OPOID VACCINES

THE TECHNOLOGY

What is it? Opioid vaccines are medical therapies designed to block opioids, such as heroin and fentanyl, from entering the brain or spinal cord, thus preventing addiction and other negative effects. While none are approved for use yet, they could be useful for at-risk individuals, patients in drug recovery programs, or first responders who might accidentally come into contact with deadly opioids that can be absorbed through the skin. This approach offers advantages over some current treatment methods, including requiring minimal medical supervision and no potential for abuse.

SEPTEMBER 2019

WHY THIS MATTERS

The ongoing opioid epidemic in the United States impacts lives on both a personal and national level. More than 10 million people abused opioids in 2017, with more than 47,000 opioid-related deaths — a nearly six-fold increase since 1999. Opioid vaccines could offer advantages over current treatment options.

After the body has learned to target an opioid molecule, it naturally forms antibodies that can bind to it. These opioid-specific antibodies stick to opioid molecules in the bloodstream, forming a unit that is too large to enter the central nervous system.

Without entering the central nervous system, the molecule is not able to produce the negative effects associated with opioids. The antibody-bound opioid will eventually be excreted via urine without harming the exposed individual.

How mature is it? As of 2019, the Food and Drug Administration (FDA) has not approved any opioid vaccines for use. While opioid vaccines studies were initially proposed as early as the 1970s, clinical trials have thus far been unsuccessful. Currently, at least three early-stage clinical trials of potential opioid vaccines are underway, including one that the Walter Reed Army Institute of Research is conducting on a heroin vaccine.

Recently the National Institutes of Health and the National Institute of Allergy and Infectious Diseases released a broad agency announcement to fund the development of opioid vaccines against heroin and fentanyl. This funding is set to begin in August 2020. Other academic researchers continue to publish studies focusing on development and preclinical testing of opioid vaccines.

OPPORTUNITIES

- Treat at-risk patients. Unlike some current treatment options, opioid vaccines do not carry the risk of abuse. This could allow for more effective treatment of patients at high risk of abusing another medication, such as methadone.
- Medical advantages. The vaccines have a long duration (months to years) of action and require limited medical supervision.
- Compatible with other therapies. Vaccines currently in development are targeted to limit use of opioids such as heroin and fentanyl, and therefore do not interfere with most drug treatment or pain management therapies.
- Protection against accidental exposure. Vaccines could be administered prophylactically to individuals at risk of accidental exposure to opioids, such as law enforcement, military, and first responders.

CHALLENGES

- Lack of broad-based effect. Current opioid vaccines are designed against the specific chemical structure of each opioid; therefore, multiple vaccines would be needed to provide broad-spectrum

Source: GAO | GAO-20-306T

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Figure 1: When an opioid enters the bloodstream (top), it crosses into the brain, where it can act on the target receptors to cause psychotropic effects, addiction, and overdose. Opioid vaccines (bottom) trigger the body to create antibodies that bind to opioid molecules and prevent them from entering the central nervous system, thus preventing negative effects.

How does it work? When opioid molecules bind to receptors in the central nervous system (the brain and spinal cord), they can cause psychotropic effects (e.g., hallucination, euphoria), addiction, and overdose. Opioid molecules have specific chemical structures. Opioid vaccines are designed to trigger an immune response to these structures when injected into a patient. Similar to vaccines for infectious diseases, such as polio or measles, when a patient is treated with an opioid vaccine, their immune system learns to identify the targeted opioid as a dangerous foreign substance so it can respond if that opioid enters the bloodstream in the future.

Source: GAO | GAO-20-306T
immunity. In addition, opioids such as fentanyl can be easily altered into a series of similar molecules called analogs, further complicating vaccine development.

- **Less effective in immune-compromised patients**: Patients with opioid use disorders often have other infections and altered immune responses that may limit the effectiveness of vaccines.
- **Mechanism not well understood**: The current biological mechanism of opioid vaccines is not as well understood as that of vaccines for infectious diseases.
- **Patient consent**: Consent issues could arise for people who might receive an opioid vaccine. For example, some might question a parent’s right to compel their child to take a vaccine against a non-infectious agent, or an addicted patient’s ability to understand potential long-term effects of an opioid vaccine.
- **Interference with medical care**: If vaccines were developed against legal opioids that are used for pain management, vaccinated individuals would have a reduced risk of addiction but would also be unable to use those medications as effective treatments.
- **Insurance and payment**: Recent refusals to provide insurance to individuals who carry naloxone, used to counter opioid overdose, highlight the insurance issues surrounding opioid-related treatments. Would insurance cover an opioid vaccine? What might be the baseline costs?

**GAO SUPPORT:**

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Staff Acknowledgments: Karen Howard (Assistant Director), Elise Rether (Analyst-in-Charge), Anika McMillon, Ben Husee, and Jessica Smith.

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Appendix II: Examples of GAO Science and Technology Spotlight Series

GAO Science, Technology Assessment, and Analytics

SCIENCE & TECH SPOTLIGHT: HYPERSONIC WEAPONS

THE TECHNOLOGY

What is hypersonic? Hypersonic weapons fly at least Mach 5—five times the speed of sound, or approximately 3,800 mph. Unlike ballistic missiles, which can reach similar speeds but have a relatively fixed flight path, hypersonic weapons, once developed, would fly at lower altitudes, be highly maneuverable, and may be able to change targets during flight. This will make them extremely difficult to defend against.

How does it work? Most hypersonic weapons fall into two categories: hypersonic glide vehicles (HGVs) and hypersonic cruise missiles (HCMs).

SEPTEMBER 2019

WHY THIS MATTERS

Hypersonic weapons, once developed, would fly faster than 3,800 mph and be extremely difficult to defend against. Advances in hypersonic technologies have significant implications for national security, as well as for transportation and space systems. Research and development of offensive and defensive capabilities in hypersonics is and will remain critically important.

The air enters the inlet at a speed greater than Mach 1. It is then compressed by the engine geometry, and combustion occurs at supersonic speeds.

Hypersonic weapons would likely enable U.S. warfighters to penetrate existing adversary anti-aircraft and anti-missile systems because of their speed, maneuverability, and altitude (above typical anti-aircraft defenses and below interception points for ballistic reentry vehicles).

Targeting. A traditional missile needs to be launched with a target in mind, but a hypersonic weapon can be maneuvered later in flight. This could provide U.S. decision-makers more time and make it extremely difficult for adversaries to prepare.

High travel speed. Hypersonic vehicles would allow for very short travel times and may have commercial applications. Such vehicles would essentially be limited to certain spacecraft reentering the atmosphere and experimental aircraft.

Source: GAO. | GAO-20-306T

Figure 1. Ballistic Reentry Vehicle (RV) versus HGV Trajectories. An RV follows a ballistic trajectory determined mainly by its launch characteristics, its target, and gravity. An HGV can take a variety of trajectories and have its final destination ambiguous.

HGVs are unpowered and glide to their targets from a high altitude after initial launch by a rocket. They are expected to fly at altitudes between 26 and 60 miles. HCMs are powered by high-speed engines during their entire flight. They are expected to fly at altitudes between 12 and 19 miles.

For most HCMs, a nosetip would accelerate the missile to Mach 3 or 4, and then the HCM’s own ramjet or supersonic combustion ramjet (scramjet) engine would take over. A scramjet uses the speed of the vehicle to “ram” and compress air with fuel, which is burned to produce thrust. A scramjet is similar, with air moving at supersonic speed.

Source: GAO. | GAO-20-306T

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Appendix II: Examples of GAO Science and Technology Spotlight Series

/// CHALLENGES

- **Heat-tolerant materials.** At hypersonic speeds, the exterior temperature of a hypersonic vehicle or weapon can exceed 2,000°F, necessitating advanced materials that will protect interior electronics. Such materials also need to be mechanically strong and efficient.

- **Propulsion technology.** Refinement of engine technology is needed for HCMs. This includes increasing the reliability and efficiency of scramjet engines. New types of engines that allow for propulsion from standoff to hypersonic speeds are also being developed, which would eliminate the need for rockets to provide the initial launch.

- **Weapon tracking.** Defense against a hypersonic weapon would involve tracking and intercepting it, but current radar and satellite systems are inadequate for this task.

- **Limited testing resources.** There are limited places to perform ground tests and flight tests of hypersonic weapons and vehicles in the United States. Currently, there are limited wind tunnel facilities in the country capable of running propulsion tests of hypersonic weapons and vehicles.

- **Safety and control.** Hypersonic velocities require additional improvements of aircraft control and guidance to help ensure the accuracy of hypersonic weapons and to avoid in-flight accidents or loss of control of hypersonic vehicles.

/// POLICY CONTEXT AND QUESTIONS

Within the Department of Defense (DOD), multiple programs by the Defense Advanced Research Projects Agency (DARPA), the Air Force, the Navy, and the Army are leading research or developing hypersonic weapons for a variety of applications and launch methods.

NACA also conducts work related to hypersonics for vehicles and spacecraft reentry into the atmosphere, both for NASA programs and in support of DOD. This includes research to safely control and guide hypersonic vehicles.

With U.S. investment in hypersonics increasing, and key technologies not yet mature, some questions for consideration include:

- **What is the status of U.S. efforts to advance the science and technology needed to develop hypersonic weapons and vehicles?**

/// SELECTED GAO WORK

- **DOD Acquisition Reform: Leadership Attention Needed to Effectively Implement Changes to Acquisition Oversight.**

- **National Security: Long-Range Emerging Threats Facing the United States As Identified by Federal Agencies.**

- **Technology Readiness Assessment Guide.**

/// REFERENCES


/// GAO SUPPORT:

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Staff Acknowledgments: Laura Holloway (Assistant Director), Richard Hornsby (Assistant Director), R. Scott Fletcher (Assistant Director), Aricka McMillon, Ben Shouse, Jessica Smith, and Spencer Barnes.

GAO-19-505SP Hypersonic Weapons

Source: GAO. | GAO-20-306T
Appendix II: Examples of GAO Science and Technology Spotlight Series

Science & Tech Spotlight: Blockchain & Distributed Ledger Technologies

**THE TECHNOLOGY**

What is it? Distributed ledger technologies (DLT) like blockchain are a secure way of conducting and recording transfers of digital assets without the need for a central authority. DLT is “distributed” because multiple participants in a computer network (individuals, businesses, etc.) share and synchronize copies of the ledger. New transactions are added in a manner that is cryptographically secured, permanent, and visible to all participants in near real-time.

How does it work? Distributed ledgers do not need a central, trusted authority because as transactions are added, they are verified using what is known as a consensus protocol. Blockchain, for example, ensures the ledger is valid because each “block” of transactions is cryptographically linked to the previous block so that any change would alert all other users. With an agreement on that history, users may then conduct a new transaction with a shared understanding of who has which resource.

Distributed ledgers can be either “permissioned” or “unpermissioned.” With unpermissioned ledgers, which are generally public, any participant can conduct a transaction. Permissioned ledgers may or may not be public, but only trusted users can conduct transactions.

How mature is it? Businesses have been using ledgers to record transactions for thousands of years, and a defining characteristic of such ledgers was their reliance on central management. Furthermore, DLT is not a new technology, but an innovative way of using existing, mature technologies. In October 2008, an unknown author using the name Satoshi Nakamoto published a white paper called “Bitcoin – A Peer-to-Peer Electronic Cash System,” which is credited as the first theoretical framework of a DLT. In January 2009 the service the paper described was launched.

**WHY THIS MATTERS**

Distributed ledger technology (e.g., blockchain) allows users to carry out digital transactions without the need for a centralized authority. It could fundamentally change the way government and industry conduct business, but questions remain about how to mitigate fraud, money laundering, and excessive energy use.

**SEPTEMBER 2019**

Cryptocurrencies like Bitcoin are a digital representation of value and represent the best-known use case for DLT. The regulatory and legal frameworks surrounding cryptocurrencies remain fragmented across countries, with some implicitly or explicitly banning them, and others allowing them.

In addition to cryptocurrencies, there is a number of other efforts underway to make use of DLT. For example, Hyperledger Fabric is a permissioned and private blockchain framework created by the Hyperledger consortium to help develop DLT for a variety of business applications. The consortium is made up of companies such as Airbus, Cisco, American Express, IBM, and Intel.

**OPPORTUNITIES**

- **Transparency.** Because any user can view the ledger, DLT may result in benefits such as reduced corruption.
- **Reduced labor costs.** DLT reduces or eliminates the need for human workers to track data.
- **Data quality and reliability.** Transaction information is automatically generated by a computer, which may reduce errors.
- **Wide applicability.** DLT is being explored for use across many sectors, including supply chain and logistics, news, energy, healthcare, and government. For example, Target built a system now known as CoreSource to verify products are sourced sustainably.

Source: GAO | GAO-20-306T

Part 1 of 2
CHALLENGES

- **Excessive energy usage.** Some uses of DLT can be costly to operate. For example, cryptocurrencies using “proof-of-work” consensus protocols (also known as “mining”) require large amounts of computing power and energy to generate new units of currency.
- **Collusion.** Security of the network relies on the consensus protocol that maintains the ledger, and research has shown that users who collude can gain enough influence to manipulate the ledger to their benefit and gradually disrupt the protocol.
- **Security.** Entities using DLT will need to ensure data stored on a permissioned distributed ledger is not accessible to outside actors. Additionally, holders of cryptocurrency can have their digital wallets hacked and their currency stolen.
- **Permanence.** While the permanence of transactions may be a core strength of DLT, it can also be a weakness should an entity find that it needs to regularly correct errors in its ledger, as it would be unable to easily do so with DLT.
- **Lack of transparency.** Because DLT can be used without a central authority, governments may feel uncomfortable allowing cryptocurrencies (or other DLT) to be used as a method of exchange or contracting, since they cannot easily be tracked and could be used to facilitate illicit activity (such as tax evasion and money laundering).

**POLICY CONTEXT AND QUESTIONS**

DLT use across many sectors is increasing, but challenges remain to widespread adoption. Some key questions for consideration include:

- In what situations is DLT useful, and when should it be avoided or used with caution?
- To what extent can DLT be used to facilitate illegal activities, and how might policymakers mitigate such use?
- How are federal agencies evaluating and using DLT?

**SELECTED GAO WORK**

- Financial Technology: Information on Subsectors and Regulatory Oversight. [GAO-17-381]

**REFERENCES**


**GAO SUPPORT:**

GAO needs congressional information needs in several ways, including by providing oversight, insight, and insight on science and technology issues. GAO staff are available to brief on completed bodies of work on specific reports and answer follow-up questions. GAO also provides targeted assistance on specific science and technology topics to support congressional oversight activities and provide advice on legislative programs.

Timothee M. Parsons, Ph.D., Chief Scientist, parsons@gao.gov

Staff Acknowledgments: William Carrey (Assistant Director), Jon Menard (Analyst-in-Charge), Anika Moffitt, Ben Sloop, and Jessica Smith.

This document is not an audit product and is subject to revision based on continued advancements in science and technology. It contains information prepared by GAO to provide technical insight to legislative bodies or other external organizations. This document has been reviewed by the Chief Scientist of the U.S. Government Accountability Office.

GAO-19-704SP Blockchain & Distributed Ledger Technologies

Source: GAO. GAO-20-306T Part 2 of 2
Appendix III: Selected GAO Science and Technology Products, Fiscal Years 2018 and 2019

## Defense and Space

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## Biology and Medicine

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<td>Illicit Opioids</td>
<td>While Greater Attention Given to Synthetic Opioids, Agencies Need to Better Assess Their Efforts.</td>
<td>GAO-18-205. Washington, D.C.: Mar. 29, 2018</td>
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## Physical Sciences and Engineering

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### Appendix III: Selected GAO Science and Technology Products, Fiscal Years 2018 and 2019

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Source: GAO.  

### Computer Science and Data

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Source: GAO.  

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Special thanks to GAO-20-306T for making this information widely available.
Appendix IV: Science and Technology Trends from GAO’s 2018-2023 Strategic Plan
Appendix IV: Science and Technology Trends from GAO’s 2018-2023 Strategic Plan

SCIENCE AND TECHNOLOGY

WHERE ARE WE?

Five emerging technologies will potentially transform society

1. Gene Editing
   *Gene editing*: A technique used to make specific and intentional additions, deletions, or alterations to genetic material. It could:
   - prevent, treat, or cure medical conditions
   - create unintended and unforeseen genetic changes in the population

2. Artificial Intelligence and Automation
   *Artificial intelligence* (AI) could:
   - produce smarter machines that perform more sophisticated tasks
   - disrupt the job market by eliminating jobs and creating others with new skill requirements
   
   While its use is expected to grow, AI that is as intelligent as a human is not expected to occur in the next 20 years.

3. Quantum Information Science
   *Quantum information science*: uses the behavior of atoms or molecules to obtain and process information in ways that existing systems cannot. It could:
   - drastically improve information acquisition, processing, and transmission

4. Brain/Augmented Reality
   *Brain-computer interfaces*: systems that connect the human brain to an external device. Research is ongoing to create implantable versions that could, for example, compensate for vision loss or hearing impairment.
   *Augmented reality*: superimposing a digital image onto a view of the real world through a device, such as a smartphone camera. It is a new trend in entertainment, education, and healthcare.

5. Cryptocurrencies and Blockchain
   *Cryptocurrencies*: virtual currencies—digital representations of value that are not government-issued—that operate online and verify transactions using a public ledger called *blockchain*.
   Cryptocurrencies offer:
   - benefits such as anonymity and lower transaction costs
   - drawbacks such as making it harder to detect money laundering and other financial crimes

Blockchain could:
   - reshape financial services
   - have more security vulnerabilities as quantum computing, an area of quantum information science, develops

WHAT ARE THE IMPLICATIONS?

Continued *debate, study, and evaluation* are needed in the public sector to consider the potential implications:

- Economic
- Ethical
- Privacy
- Safety
- Security
- Societal

Source: GAO. | GAO-20-306T
Appendix V: For Technical Reviews, GAO Involves External Experts Throughout the Engagement Process
Appendix V: For Technical Reviews, GAO Involves External Experts Throughout the Engagement Process

GAO’s technology assessments (TA) draw on external experts throughout the process, including for technical reviews of the draft report

**Initiation**
- Discussions with congressional requesters regarding scope and focus of project

**Design agreement**
- Agreement is informed by
  - Initial research
  - Relevant sections of GAGAS (Generally Accepted Government Auditing Standards)
  - GAO Methodology Guides
  - GAO stakeholders (e.g., economists, social scientists, subject matter experts)
- Independent expert group facilitated by the National Academies of Sciences, Engineering, and Medicine
- Discussions with other independent and/or agency experts

**Message development**
- Assess evidence and research results
- Ongoing engagement with experts
  - Develop draft observations and identify policy gaps
  - When warranted, identify and assess policy options
- Writing and design assistance while drafting
- Draft review using relevant parts of GAO Quality Assurance Framework

**External review**
- Review by National Academies-facilitated expert group
- Review by other individual experts and/or relevant federal agency experts (as appropriate)

Source: GAO. | GAO-20-306T
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