

TECHNOLOGY ASSESSMENT DESIGN HANDBOOK

**Handbook for Key Steps and Considerations
in the Design of Technology Assessments**



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Abbreviations

AI	artificial intelligence
CRS	Congressional Research Service
EMS	Engagement Management System
OTA	Office of Technology Assessment
S&T	science and technology
STAA	Science, Technology Assessment, and Analytics
TA	technology assessment
TRL	technology readiness levels

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Preface

GAO provides Congress, federal agencies, and the public with objective, reliable information to help the government save money and work more efficiently. Science and technology (S&T) issues figure prominently in problems that Congress confronts, and one component of the assistance GAO provides to Congress is the production of technology assessments (TAs). This TA Design Handbook provides GAO staff and others with tools to consider for supporting robust and rigorous assessments. This handbook is particularly important given the need for GAO to provide insight and foresight on the effects of technologies and corresponding policy implications related to a wide range of S&T issues. While other organizations—including, previously, the Office of Technology Assessment (OTA) and a number of TA organizations elsewhere, such as in Europe—conduct TAs, each has different relationships with its stakeholders and government bodies. While their TA approaches and considerations may vary, some may still find portions of this handbook useful. We are seeking comments on this draft of the handbook.

This handbook elaborates on GAO’s approach to TA design and outlines the importance of TA design (Chapter 1), describes the process of developing TA design (Chapter 2), and provides approaches to select TA design and implementation challenges (Chapter 3). The handbook generally follows the format of the 2012 GAO methodology transfer paper, *Designing Evaluations*.¹ Given that GAO is likely to learn from its current expansion of TA work, GAO will review and update this draft handbook as needed, based on experience gained through ongoing TA activities and external feedback.

GAO has defined TA as the thorough and balanced analysis of significant primary, secondary, indirect, and delayed interactions of a technological innovation with society, the environment, and the economy and the present and foreseen consequences and impacts of those interactions.² The effects of those interactions can have implications. Recognizing this, GAO has in some of its products included policy options, which

¹*Designing Evaluations* describes designs of program evaluations. See GAO, *Designing Evaluations: 2012 Revision*, [GAO-12-208G](#) (Washington, D.C.: Jan. 2012).

²There is no single agreed-upon typology/taxonomy of or approach to TAs. Examples of different TA approaches found in the literature include: strategic, early-warning, future-oriented, classical or expert, and participatory. Expert TAs may emphasize expert knowledge, and participatory TAs may emphasize stakeholder and public involvement.

policymakers could consider in the context of a given technology and policy goal. In this context, policy goals serve to guide the development of policy options by stating the overall aim of the policy options, and helping to identify the landscape and scope of policy options. Policy options can be defined as a set of alternatives or menu of options (including the status quo) that policymakers, such as legislative bodies, government agencies, and other groups, could consider taking. GAO is exploring approaches to making policy options a more standard feature or component of TAs. In this handbook, we include considerations related to the development of policy options that TA teams may wish to consider at each phase of TA design.

Technology Assessments at GAO

GAO has a history of doing S&T related work, including audits of federal S&T programs. In fiscal year 2018, GAO provided 34 congressional committees with nearly 200 products, including technology assessments, covering a wide range of science, technology, and information technology issues, including cybersecurity. In 2018, Congress encouraged the formation of a Science, Technology Assessment, and Analytics (STAA) team within GAO, recognizing that the scope of technological complexities continues to grow significantly and there is need to bolster capacity of, and enhance access to, quality, independent science and technological expertise for Congress. STAA was formally created on January 29, 2019.

Source: STAA Initial Plan. | GAO-20-246G

In the United States, the Technology Assessment Act of 1972 established OTA, which was an analytical support agency of the Congress, but was defunded in 1995. In 2002, Congress asked GAO to begin conducting TAs, and in 2008, a permanent TA function was established at GAO. In 2019, the Science, Technology Assessment, and Analytics (STAA) team was created at GAO. STAA has taken a number of steps to account for the unique requirements of TAs and related S&T work to meet the needs of Congress.

GAO TAs share some common design principles with GAO's general audit engagement process, which is centered around intentional and purpose-driven design.³ While general design principles are shared across GAO's product lines, TAs are distinct from other GAO product lines, such as performance audits, financial audits, and other routine non-audit products. The specialized content of TAs, their scope, and their purpose, warrant some different considerations. Table 1 highlights some similarities and differences between TAs and other GAO product lines, including where TAs follow aspects of GAO's general audit engagement process, and where TAs may further emphasize certain steps or require

³For example, GAO's general audit engagement process includes a robust initiation and design processes that consider factors such as: stakeholder interests, the current state of knowledge, and relevant and appropriate methodological considerations in defining and investigating appropriate research questions. Also part of GAO's general audit engagement process is internal message development and agreement, along with external review processes. Design decisions are implemented and revisited throughout the audit engagement process.

additional steps during the engagement process.⁴ Not all steps have been included in Table 1.

Table 1: Summary of GAO's Technology Assessment Process

Steps in plain text are process steps for both general audit and TA products. Steps in **bold italics** are either additional process steps or a particular emphasis for TAs.

Phase	Steps
Initiation	<ul style="list-style-type: none"> • Discussion with congressional requesters regarding scope and focus of the engagement • Consideration of technology state, breadth of stakeholder expertise, and potential policy implications • Consideration of whether policy options are appropriate for inclusion
Design	<ul style="list-style-type: none"> • Performance of initial research • Consideration of relevant sections of GAO's Quality Assurance Framework and GAO methodological and technical standards and guides • Consultation with GAO subject matter experts and internal stakeholders, as needed • Discussion with agency officials • Identification of and consultation with external experts, such as science, policy, and industry experts, who may also serve as external reviewers^a • Identification of initial policy options, if appropriate
Message development	<ul style="list-style-type: none"> • Collection and analysis of evidence • Assessment of evidence and research results • Development of draft findings • Ongoing engagement with external experts • Performance and discussion of the results of policy options assessment, if appropriate^b
External review	<ul style="list-style-type: none"> • Request views from relevant third parties, if applicable, and request comments from relevant federal agencies, as appropriate • Request comments from external experts

Source: GAO analysis of GAO's product line processes. | GAO-20-246G

^aGAO has a standing task order contract with the National Academies of Sciences, Engineering, and Medicine. GAO can interact with National Academies personnel to help GAO identify experts on various scientific topics and also can leverage National Academies assistance to convene GAO expert meetings.

^bInstead of recommendations, TAs may consider the inclusion of policy options.

We expect to continue to regularly seek input and advice from external experts related to the TA Design Handbook initiative, as well as throughout the conduct of GAO TAs. While the primary audience of this handbook is GAO staff, we expect that other organizations engaged or interested in TAs will find portions of this handbook useful. For example,

⁴Products from other product lines may emphasize these elements as well, depending on engagement needs.

these organizations could use the handbook to gain insight into GAO's TA design approaches, as well as use aspects of GAO's TA design approaches that they deem helpful. We will accept comments on this handbook at TAHandbook@gao.gov for approximately 1 year after publication. The handbook seeks to affirm and document GAO's approach, and we expect to modify and refine this handbook, as needed, based both on comments received and further experience in conducting TAs that include policy options. We anticipate that the final handbook will contain additional information and details related to TA design, such as elaborating on specific methodologies that could be applied within this general design framework, including those designed to identify policy options.

Below is a summary of the approach we used to identify and document TA design steps and considerations for this handbook. For more information, please refer to Appendix I: Objectives, Scope, and Methodology.

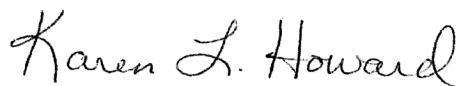
- Reviewed select GAO documents, including *Designing Evaluations* ([GAO-12-208G](#)), published GAO TAs, select GAO products utilizing policy analysis approaches to present policy options, and other GAO reports
- Reviewed select Office of Technology Assessment reports
- Reviewed select Congressional Research Service reports
- Reviewed select literature regarding TAs and related to development and analysis of policy options
- Held an expert forum to gather experts' input regarding TA design
- Considered experiences of GAO teams that have successfully assessed and incorporated policy options into GAO products, as well as GAO teams that are incorporating policy options into their TA design
- Collected input from GAO staff who provided key contributions to GAO TAs, regarding challenges to TA design and implementation and possible solutions

We conducted our work to develop this handbook from April 2019 to December 2019 in accordance with all sections of GAO's Quality Assurance Framework that are relevant to our objectives. The Framework requires that we plan and perform the engagement to obtain sufficient and appropriate evidence to meet our stated objectives and to discuss

any limitations in our work. We believe that the information and data obtained, and the analysis conducted, provide a reasonable basis for any findings and conclusions in this product.



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Chapter 1: The Importance of Technology Assessment Design

This chapter underscores the importance of technology assessment (TA) design, outlining reasons for performing TAs and for spending time on the design of TAs. The information presented in this chapter is based on review of results of a literature search, an expert forum, select GAO reports, and experiences of GAO teams and technical specialists. For more information, please refer to Appendix I: Objectives, Scope, and Methodology.

1.1 Reasons to Conduct and Uses of a Technology Assessment

TAs are significant given their increasing importance to policymakers, and the growing effects of S&T on society, economy, and other areas. While technological changes can be positive, they can also be disruptive. Therefore, it is critical for Congress to be able to understand and evaluate these changes, to ensure, for example, national security and global competitiveness. Examples of potential uses of TAs related to enhancing knowledge and awareness to assist decision-making include:

- Highlight potential short, medium, and long-term impacts of a technology
- Elaborate on and communicate the risks and benefits associated with a technology, including early insights into the potential impacts of technology¹
- Highlight the status, viability, and relative maturity of a technology
- Plan and evaluate federal investments in S&T

GAO TAs are most commonly requested by congressional committees, which may use them to, among other things, make decisions regarding allocating or reallocating resources to address research gaps, support

¹This may include analyzing and providing information on the costs and benefits of a specific technology or set of technologies, and their present and potential future challenges.

updated rulemaking for a regulatory agency, or inform a legislative agenda or the development of a national strategy.²

Technologies present opportunities and challenges that may vary, depending in part on the policy context in which they are evaluated. Therefore, part of a TA is considering the policy context surrounding a given technology. GAO may, where appropriate, identify and analyze policy options as part of its TAs, which may also include: clarifying and summarizing policy-related issues and challenges, and providing information that can be used for decision-making. In this situation, policy options can be defined as a set of alternatives or menu of options (including the status quo) that policymakers, such as legislative bodies, government agencies, and other groups, could consider taking. Policy options can be used to articulate a range of possible actions a policymaker could consider in the context of a given technology and policy goal. Policy options do not state what policymakers should do in a given circumstance with a certain technology. Policy options do not endorse or recommend a particular course of action; they are not recommendations or matters for congressional consideration, which GAO makes in its audits. In addition, policy options are addressed to

²Examples of research questions and objectives from published GAO TAs include: (1) what is known about the potential effects of geomagnetic disturbances on the U.S. electric grid; what technologies are available or in development that could help prevent or mitigate the effects of geomagnetic disturbances on the U.S. electric grid, and how effective are they; and what factors could affect the development and implementation of these technologies? GAO, *Critical Infrastructure Protection Protecting the Electric Grid from Geomagnetic Disturbances*, [GAO-19-98](#) (Washington, D.C.: Dec. 19, 2018); (2) how has artificial intelligence (AI) evolved over time, and what are important trends and developments in the relatively near-term future; according to experts, what are the opportunities and future promise, as well as the principal challenges and risks, of AI; and according to experts, what are the policy implications and research priorities resulting from advances in AI? GAO, *Artificial Intelligence: Emerging Opportunities, Challenges and Implications*, [GAO-18-142SP](#) (Washington, D.C.: Mar. 28, 2018); and (3) Identify biometric technologies currently deployed, currently available but not yet deployed, or in development that could be deployed in the foreseeable future for use in securing the nation's borders; determine how effective these technologies are for helping provide security to our borders currently or are likely to be in the future; determine the economic and effectiveness trade-offs of implementing these technologies; and identify the implications of biometric technologies for personal security and the preservation of individual liberties. GAO, *Technology Assessment: Using Biometrics for Border Security*, [GAO-03-174](#) (Washington, D.C.: Nov. 15, 2002). Examples from GAO TA reports were included here given our familiarity with GAO products; numerous non-GAO examples of research objectives and questions exist.

policymakers more broadly, and are not addressed to a specific federal agency or entity.³

1.2 Importance of Spending Time on Design

Developing a written TA design helps TA teams agree on and communicate a clear plan of action to the project team and the team's advisers, requesters, and other stakeholders. Written TA designs also help guide and coordinate the project team's activities and facilitate documentation of decisions and procedures in the final report. In addition, focusing the TA on answering specific researchable questions can assist teams to define and select the appropriate scope, approach, and type of product, ensuring usefulness of the product to the intended users. More specific reasons for spending time on systematically designing a TA include:

- Enhance its quality, credibility, and usefulness
- Ensure independence of the analysis
- Ensure effective use of resources, including time

Data collection and quality assurance of data can be costly and time-consuming. A thorough consideration of design options can ensure that collection and analysis of the data are relevant, sufficient, and appropriate to answer the researchable question(s), and helps to mitigate the risk of collecting unnecessary evidence and incurring additional costs.

³The term "policymaker" is context-specific and may vary from TA to TA.

Chapter 2: Technology Assessment Scope and Design

This chapter highlights design phases, cross-cutting considerations, and GAO TA design examples for sound technology assessment (TA) design. To ensure that the information and analyses in TAs meet policymakers' needs, it is particularly useful to outline the phases and considerations involved in sound TA design, while remaining aware of the iterative and nonlinear process of designing a TA. The information presented in this chapter is based on review of results of a literature search, an expert forum, select GAO reports, and experiences of GAO teams and technical specialists. For more information, please refer to Appendix I: Objectives, Scope, and Methodology.

2.1 Sound Technology Assessment Design

Below are questions to consider for a sound TA design. Reflecting on these questions may help teams make important decisions (like selecting an appropriate design) and ensure quality TAs.

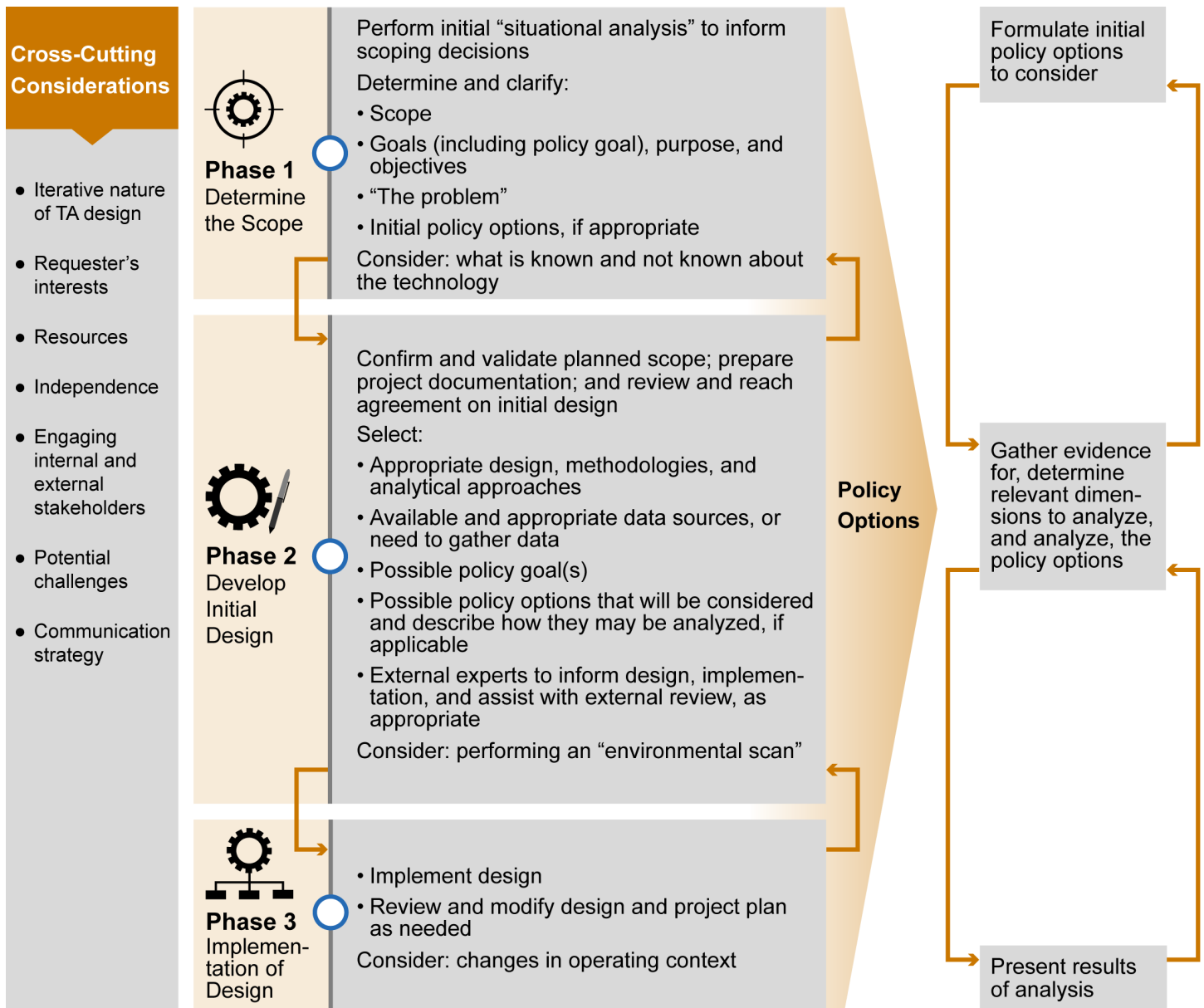
- Does the design address the needs of the congressional requester?
- Will the design yield a quality, independent, balanced, thorough, and objective product?
- Will the design likely yield information that will be useful to stakeholders?
- Will the design likely yield valid conclusions on the basis of sufficient and credible evidence?
- Will the design yield results in the desired time frame?
- Will the design likely yield results within the constraints of the resources available?
- How will policy options be identified and assessed, if applicable?

2.2 Phases and Considerations for Technology Assessment Design

Figure 1 outlines three phases and seven considerations for TA design. While Figure 1 presents TA design as a series of phases, actual execution is highly iterative and nonlinear. Teams may need to be prepared to re-visit design decisions as information is gathered or circumstances change.¹

¹Refer to Appendix II for a summary of the typical GAO engagement process, of which design is a part.

Figure 1: Summary of Key Phases and Considerations of Technology Assessment Design



Source: GAO analysis of expert forum, select literature, and GAO's Designing Evaluations. | GAO-20-246G

Phase 1: Determine the Scope

During this phase, TA teams will make scoping decisions,² informed by an initial “situational analysis” that may be used to:

Cross-Cutting Considerations

Below are some considerations for the team to think about while designing a TA and throughout the process of performing the TA. This list is not exhaustive, and some of the considerations may not be unique to TAs.

The iterative nature of TA design: As circumstances change and new information comes to light, it may be necessary to revisit scope and design.

Requester’s interests: Discuss needs and interests with the requester(s), as applicable.

Independence: This includes potential or perceived threats to independence, including conflicts of interest, bias, and implicit bias.

Resources: These include staff availability, staff expertise, and time available. Trade-offs may need to be considered, such as between resources and potential scope.

Engaging internal and external stakeholders: Consider and consult with relevant internal and external stakeholders as early as possible and during all design phases.

Potential challenges: Consider potential challenges to design and implementation of the TA, such as: (1) possible changes in operating environment; (2) characterizing or quantifying anticipatory factors, uncertainty, and future condition(s); and (3) lack of or limitations with data. See Chapter 3 for more specific examples.

Communication strategy: Consider potential users of the product(s) and how information regarding the TA will be communicated. How results are communicated can affect how they are used, so it is important for TA teams to discuss communication options.

Source: GAO analysis of expert forum and select literature. | GAO-20-246G

- Develop an initial understanding of the technology (such as the state of the technology) and context of the technology (such as social, political, legal, and economic factors)
- Identify internal and external stakeholders
- Identify other preliminary activities

The initial situational analysis may also be used to:

- Inform the goal(s), purpose, and objectives (also known as researchable questions)
- Identify the problem to be addressed
- Identify initial policy options, if applicable

TA teams will identify policy goal(s) and develop policy goal statements, as applicable, based on the congressional request and other factors. Teams will need to think about whether the policy goal statement is balanced (does not bias a potential course of action) and should document how the policy goal statement is derived. In this context, policy goals serve to guide the development of policy options by stating the overall aim of the policy options, and helping to identify the landscape and scope of policy options. TA teams may develop a list of possible policy options based on an initial literature search, initial discussion with experts, and other factors.³ TA teams may also find it necessary at this stage to initially group policy options, such as by similar themes, or eliminate some options as being beyond the scope of the TA and its policy goal

²Teams may find it useful to define and delineate scope according to: type or part of the technology; timeframe; economic sector(s); policy goal(s); institutional considerations, such as previous work by GAO and other organizations; types of impact; geography; availability of information, including possible proprietary nature of information; and degree of knowledge, lack of information, or prevalence of conflicting information related to the technology. Scoping decisions ultimately affect the conclusions a TA can draw, as well as the policy options it can consider. Therefore, areas that have been scoped out should be documented, along with any related limitations or considerations that provide context to the conclusions.

³Initial policy options may appear to be more like preliminary policy concepts, until more evidence is collected and analysis is performed.

statement.⁴ TA teams will need to think about whether the initial policy options are appropriate to the size and scope of the TA, as well as whether they are in line with the policy goal and the overall TA purpose and objectives. In keeping with the iterative nature of TA design and execution, any initial policy option list will be revisited, modified, or refined, as needed, as the work progresses and more information is gained. TA teams may also need to plan to include policy analysis and exploration of the ramifications of each policy option during subsequent design and implementation phases.

During this phase, and as early as possible, teams identify and may start engaging with relevant internal and external stakeholders, including those related to policy options. Such stakeholders include:

- Internal stakeholders, such as: individuals or units with relevant subject matter, technical, methods, or other types of expertise⁵
- External stakeholders, such as: academic researchers and industry or nonprofit groups who have knowledge and interest in the specific topic⁶

Phase 2: Develop Initial Design

During this phase, TA teams continue to build on the situational analysis work and gather more background information. In addition, TA teams:

- Confirm and validate the scope from phase 1
- Prepare project documentation
- Reach agreement with stakeholders on the initial design
- May perform an “environmental scan” to further highlight limitations, assumptions, divergent points of view, potential bias, and other factors that may help the team select a design⁷

⁴Themes for grouping of policy options may include: subject matter, type of policy, or phase of technology.

⁵For example: mission teams may have performed work in the related area(s), and have subject matter and agency-related knowledge and expertise; the Office of General Counsel may have insight regarding questions relating to ethical, legal, or regulatory context of the technology; communications analysts can support product development; and other internal experts, such as biologists, chemists, physicists, engineers, statisticians, information technology specialists, economists, social scientists, and data scientists, who can provide valuable context and information.

⁶This includes relevant stakeholders for each policy option, some of whom may or may not benefit from a policy option.

Other specific activities that take place during this phase include:

Examples from GAO Technology Assessments

Examples of data collection and analytical techniques used in GAO TAs to date include: interviews, literature review, expert forums, site visits, technology readiness assessments, surveys, conceptual models, small group discussion, content analysis such as Delphi, among others. OTA reported using similar methodologies for its TAs (OTA, *Policy Analysis at OTA: A Staff Assessment*, 1983).

Source: GAO analysis of GAO TA and OTA reports. | GAO-20-246G

- Identify and select appropriate design, methodologies, and analytical approaches (refer to the next section of this chapter for example TA design approaches and App. III for examples of TA methods)
- Identify and select appropriate data sources, or the need to gather data
- Identify, select, and possibly develop appropriate dimensions of analysis, if applicable
- Develop possible policy goal(s)
- Clarify the possible initial policy options that will be considered and describe how they may be analyzed, if applicable
- Identify and consult with external experts to inform design and implementation, and assist with external review, as appropriate⁸

If policy options are being considered, it is important to determine the relevant dimensions along which to analyze the options. The dimensions will be highly context- specific, vary from TA to TA, and depend on the scope and policy goal statement of the TA.⁹

⁷An environmental scan is the process of gathering information about a subject and its relationship with other subjects and actors.

⁸External review, also called “peer review,” may include review of draft products by external subject matter experts that TA teams may have engaged with during earlier design phases. The external review process can be used to ensure that the information presented in TAs is accurate, balanced, and of high quality.

⁹Dimensions for analyzing policy options may include: relevance to the policy goal statement, stakeholder impacts, cost/feasibility, legal implications, magnitude of impact, ease of implementation, time frames, degree of uncertainty, and potential for unintended consequences.

Phase 3: Implementation of Design

During this phase, the design and project plan are being implemented, potentially while aspects of phase 2 are still underway. It is important to consider changes in the operating context—such as changes in the operating environment, understanding of the issues, and access to information—and review and make changes to the design and project plan accordingly.

Examples from Other GAO Products

We reviewed select GAO products that used policy analysis to present policy options. We found that these products used a variety of data collection and analytical approaches, such as: interviews, literature review, survey, expert forum, site visits, case studies, analysis of secondary data, content analysis, among others.

Source: GAO analysis of GAO reports. | GAO-20-246G

If an initial policy options list was developed earlier in design, it may be necessary to revisit the list as work progresses. During this phase, TA teams may gather additional information regarding the policy options, further analyze policy options, and present the results of the analysis. Policy options are to be presented in a balanced way, including presentation of opportunities and considerations, and not resulting in a single overall ranking of policy options.

2.2.1 GAO Technology Assessment Design Examples

We found that GAO TAs used a variety of design approaches and methodologies to answer various categories of design objectives (researchable questions). GAO TAs generally include one or more of the following categories of design objectives, which are not mutually exclusive: (1) describe status of and challenges to development of a technology; (2) assess opportunities and challenges arising from the use of a technology; and (3) identify and assess cost-effectiveness, other policy considerations, or options related to the use of a technology. Provided below are example questions, design approaches, and GAO TAs, for each of these categories of objectives. GAO TA examples were used given our familiarity with GAO products, though numerous non-GAO TA design examples exist. This is not intended to be a comprehensive list of design examples. For more examples of methodologies, please refer to App. III.

Describing the status and challenges to the development of a technology. Table 2 provides example questions, design approaches, and GAO TAs, for design objectives related to describing the status and challenges to the development of a technology. Questions may address, for example, what the current state of the technology is, and may involve identifying and describing the status of the technology, which GAO TAs have done using a variety of methods.

Table 2: Examples for Technology Assessment Objectives that Describe Status and Challenges to Development of a Technology

Example questions	Example design approaches	Examples from GAO technology assessments
<ul style="list-style-type: none"> What is the current state of the technology? What are alternative applications of the technology? Does the status of technology vary across different applications or sectors where technology is being developed? 	<ul style="list-style-type: none"> Identify and describe status of select applications of the technology Assess technical capabilities of select applications or sectors where technology is being developed 	<ul style="list-style-type: none"> A TA team reported on current state, examples, and technical status of different applications of climate engineering technologies, based on: review of literature; interviews with scientists, engineers, government officials, and other relevant stakeholders; an expert meeting; and assignment of technology readiness levels (TRLs)^a (GAO-11-71)
<ul style="list-style-type: none"> What are technical challenges to the development of the technology? 	<ul style="list-style-type: none"> Review and observe applications of technology Gather and analyze reports or other evidence of technical challenges to development of technology 	<ul style="list-style-type: none"> To identify and consider technical challenges associated with technologies to enable rapid diagnoses of infectious diseases, a GAO team reviewed select agency documentation and scientific literature; interviewed agency officials, developers, and users of these technologies; conducted site visits to select developers; and convened an expert group to provide technical assistance and review the GAO draft report (GAO-17-347)
<ul style="list-style-type: none"> What technologies are available or under development that could be used to address a specific problem or issue? What challenges do these technologies face? 	<ul style="list-style-type: none"> Gather and analyze documentary and testimonial evidence of technologies in use or that could be put to use to address problem of interest Identify challenges and potential approaches addressing both the problem of interest and challenges in developing technology 	<ul style="list-style-type: none"> A TA team identified technologies that could mitigate the effects of large-scale electromagnetic events, along with issues and challenges associated with development of these technologies by reviewing and synthesizing technical reports and interviewing federal agency officials (GAO-19-98)

Source: GAO review of GAO technology assessments. | GAO-20-246G

^aTRLs provide a standard tool for assessing the readiness of emerging technologies. The team adopted an existing categorization of technologies aimed generally at either carbon dioxide removal or solar radiation management. The team then rated and compared TRL levels of select technologies within these categories.

Assessing opportunities and challenges that may result from the use of a technology. Table 3 provides example questions, design approaches, and GAO TAs, for design objectives related to assessing opportunities and challenges that may result from the use of a technology. Questions may address, for example, what are the expected or realized benefits of the technology, and may involve gathering and assessing evidence on the results from using the technology, which GAO TAs have done using a variety of methods.

Table 3: Examples for Technology Assessment Objectives that Assess Opportunities and Challenges that May Result from the Use of a Technology

Example questions	Example design approaches	Examples from GAO technology assessments
<ul style="list-style-type: none"> What are the expected or realized benefits of the technology? What unintended consequences may arise from using the technology? 	<ul style="list-style-type: none"> Gather and assess existing reports or other evidence on results from using technology 	<ul style="list-style-type: none"> A TA team determined expected and realized benefits and unintended consequences from use of artificial intelligence in select areas by: reviewing relevant literature; interviewing select experts, developers and other stakeholders (including to inform a pre-forum reading package); convening an expert forum; and seeking review of the draft report from members of the expert forum and two additional experts (GAO-18-142SP)
<ul style="list-style-type: none"> Do uses or outcomes of the technology differ across geographic, economic or other social groups or sectors? 	<ul style="list-style-type: none"> Gather and analyze information to assess potential differences in use or impacts (e.g. to employment, health, or the environment) across different economic or other social sectors or groups, either quantitative or qualitative, depending upon available information 	<ul style="list-style-type: none"> To assess differences in use and impacts of sustainable chemistry technologies across different sectors, a TA team reviewed key reports and scientific literature; convened a group of experts; interviewed representatives of state and federal agencies, chemical companies, industry and professional organizations, academic institutions, nongovernmental organizations, and other stakeholders; conducted site visits to federal laboratories; attended two technical conferences; and conducted a survey of selected chemical companies (GAO-18-307)

Source: GAO Review of GAO technology assessments. | GAO-20-246G

Assessing cost-effectiveness, policy considerations, or policy options related to the use of a technology. Table 4 provides example questions, design approaches, and GAO TAs, for design objectives related to assessing cost-effectiveness, policy considerations, or policy options related to the use of a technology. Questions may address, for example, what are the economic trade-offs of a technology, and may involve gathering and analyzing evidence related to cost, which GAO TAs have done using a variety of methods.

Table 4: Examples for Technology Assessment Objectives that Assess Cost-Effectiveness, Policy Considerations, or Options Related to the Use of a Technology

Example questions	Example design approaches	Examples from GAO technology assessments
<ul style="list-style-type: none"> What are the economic and effectiveness impacts of implementing specified technologies? 	<ul style="list-style-type: none"> Gather and analyze information on the costs, benefits, and risks associated with the implementation of alternative technologies or systems involving specific technologies Compare cost-effectiveness of alternative technologies or systems 	<ul style="list-style-type: none"> A TA team developed four scenarios for using biometric technologies in border security by reviewing relevant statutes and regulations; interviewing government officials; reviewing test documentation from academic, government, and industry sources; and analyzing Immigration and Naturalization Service statistics, among other things. For each scenario, the team analyzed select costs, benefits, and risks associated with implementation (GAO-03-174)
<ul style="list-style-type: none"> What are policy implications resulting from advances in the technology? 	<ul style="list-style-type: none"> Gather and analyze reports, test results, developer and stakeholder perspectives, and other relevant information on the legal, economic, equity or other relevant implications resulting from advances in the technology 	<ul style="list-style-type: none"> To examine policy issues and potential effects of several policy options for federal government use of cybersecurity for critical infrastructure protection, a TA team analyzed federal statutes and regulations that govern the protection of computer systems; reviewed relevant literature; conducted interviews; convened a group of experts; and obtained comments on the draft report from the Department of Homeland Security and the National Science Foundation (GAO-04-321)
<ul style="list-style-type: none"> What policy options could address challenges to the use of a technology to achieve a specified outcome? 	<ul style="list-style-type: none"> Gather and analyze reports, test results, stakeholder perceptions or other relevant information to identify and synthesize policy options Analyze policy options on dimensions such as cost-effectiveness or ease of implementation Use quantitative and qualitative approaches to analyze and display relevant information 	<ul style="list-style-type: none"> To identify and analyze policy options that federal policymakers could consider to reduce the impact of irrigated agriculture in areas facing water scarcity in the United States, a TA team reviewed scientific literature; convened an expert meeting; interviewed farmers, academics, industry representatives, federal officials; modeled water use in an illustrative watershed; and performed regression analysis on U.S. Department of Agriculture irrigation, crop, and technology data (GAO-20-128SP)

Source: GAO review of GAO technology assessments. | GAO-20-246G

Chapter 3: Approaches to Selected Technology Assessment Design and Implementation Challenges

This chapter describes select challenges regarding technology assessment (TA) design and implementation, as well as possible strategies to mitigate those challenges. The information in this chapter is based on review of results of a literature search, an expert forum, select GAO reports, and experiences of GAO teams and technical specialists. The tables provided below are not intended to be a comprehensive list of challenges or strategies. For more information, please refer to Appendix I: Objectives, Scope, and Methodology.

During our review, we identified a variety of TA design and implementation challenges. The following four general categories of TA design and implementation challenges were frequently found:

- Ensuring TA products are useful for Congress and others
- Determining policy goals and measuring impact
- Researching and communicating complicated issues
- Engaging all relevant stakeholders

3.1 Ensuring Technology Assessment Products are Useful for Congress and Others

To be useful, TA assessment products must be readable and timely, among other things, which may present a challenge for numerous reasons. Table 5 provides examples of potential mitigation strategies to address these challenges.

Table 5: Challenges to Ensuring Technology Assessment Products are Useful for Congress and Others

Specific example of a challenge	Potential mitigation strategies
Writing simply and clearly about technical subjects	<ul style="list-style-type: none"> • Allow sufficient time for writing and revising • Engage communication specialists • Use “cold readers”
TAs do not have a uniform design approach	<ul style="list-style-type: none"> • Review TA literature and discuss approaches with a broad variety of government, academic, and private sources, to get a sense of what others have done • Engage methodologists and other subject matter experts early
Threats to independence	<ul style="list-style-type: none"> • Ensure transparency and discuss threats (potential and real) early and often • Regularly consult with stakeholders
Determining scope for a technology with broad applications or implications	<ul style="list-style-type: none"> • Review literature to get a firm understanding of what has and has not been done • Prepare an initial document with a list of potential scope(s), outline trade-offs associated with each, and discuss with stakeholders • Consider performing a situational analysis to make decisions about scope, refer to Chapter 2
Length of time required to conduct, draft, and publish TAs	<ul style="list-style-type: none"> • Continue to explore other approaches to designing TAs, and learn from past work • Publish findings as they become available

Source: GAO analysis of literature, expert forum, and GAO staff input. | GAO-20-246G

3.2 Determining Policy Goals and Measuring Impact

Another challenge in TA design arises from determining policy goals and policy options, and estimating their potential impacts. Many of the effects of policy decisions may be distant, and policy outcomes may be uncertain at the time of the TA. Table 6 provides examples of potential mitigation strategies to address these challenges.

Table 6: Challenges to Determining Policy Goals and Measuring Impact

Specific example of a challenge	Potential mitigation strategies
Policy goal and options may be difficult to identify	<ul style="list-style-type: none"> Determine and communicate scope early on Perform a literature search and engage internal and external experts Conduct an analysis of the social and political context
Effects of policy options can be uncertain and difficult to estimate	<ul style="list-style-type: none"> Perform and document regular monitoring of the TA subject area, such as by ongoing review of literature and engagement of relevant stakeholders, to ensure knowledge is current and sufficiently comprehensive Make assumptions and limitations clear for each policy option Assess and communicate level of uncertainty (e.g., high-, mid-, and low-range estimates or “best case,” “likely case,” “worst case” scenarios) Consider and select appropriate prediction models Refer to results tracking tools and other resources, as appropriate

Source: GAO analysis of literature, expert forum, and GAO staff input. | GAO-20-246G

3.3 Researching and Communicating Complicated Issues

TAs are complex and interdisciplinary, and emerging technologies are inherently difficult to assess. Table 7 provides examples of potential mitigation strategies to address these challenges.

Table 7: Challenges to Researching and Communicating Complicated Issues

Specific example of a challenge	Potential mitigation strategies
Interdisciplinary nature of TAs can present challenges to effective communication and shared understanding	<ul style="list-style-type: none"> Manage staffing effectively, and collaborate and consult among disciplines frequently Consider how best to obtain expert and other stakeholder input and share information, such as through expert meetings, surveys, and interviews
Assessing complex systems	<ul style="list-style-type: none"> Carefully scope the work to respond to Congressional interest in a comprehensive manner, while considering multiple products or means of communication, if necessary Every few years, review current body of work to assess effectiveness of prior work and consider revisiting previous assessments
Assessing emerging technologies	<ul style="list-style-type: none"> Determine what is known and not known Leverage existing tools and data analyses if they exist. If not, extrapolate, where possible Consider roadmapping, among other tools

Source: GAO analysis of literature, expert forum, and GAO staff input. | GAO-20-246G

3.4 Engaging All Relevant Stakeholders

An additional challenge in conducting TAs is engaging all relevant internal and external stakeholders, ensuring none are overlooked. Table 8 provides examples of potential mitigation strategies to address this challenge.

Table 8: Challenges to Engaging All Relevant Stakeholders

Specific example of a challenge	Potential mitigation strategies
Ensuring all relevant internal stakeholders are engaged	<ul style="list-style-type: none">• Consider if and how the different types of internal stakeholders will be engaged• Speak with internal subject matter experts to determine which, if any, other stakeholders may need to be engaged. Also, review previous work related to the technology
Ensuring all relevant external stakeholders are engaged	<ul style="list-style-type: none">• Review literature and ask external experts which other external experts should be engaged• Use a systematic approach to identifying and engaging with experts known to have particular knowledge and insight. Consider reaching out to a variety of groups, such as: nongovernmental organizations, industry (e.g., inventors, manufacturers, and vendors), and professional associations• Seek out stakeholders who have different points of view, including international perspectives, where appropriate• Consider providing a communication channel or process whereby diverse stakeholders can regularly provide input. For example, this may be an email address or point of contact. This may also include using “open innovation” approaches such as crowdsourcing¹

Source: GAO analysis of literature, expert forum, and GAO staff input. | GAO-20-246

¹Crowdsourcing is the practice of obtaining information or input into a task or project by enlisting the services of a large number of people, either paid or unpaid, typically via the Internet. For more information, see: GAO, *Open Innovation: Executive Branch Developed Resources to Support Implementation, but Guidance Could Better Reflect Leading Practices*, [GAO-17-507](#) (Washington, D.C.: June 8, 2017) and GAO, *Open Innovation: Practices to Engage Citizens and Effectively Implement Federal Initiatives*, [GAO-17-14](#) (Washington, D.C.: Oct. 13, 2016).

Appendix I: Objectives, Scope, and Methodology

This handbook identifies key steps and considerations in designing technology assessments (TAs). Below is a summary of methodologies used for all chapters of the handbook.

Review of GAO Documents

We reviewed GAO documents, including:

- Designing Evaluations ([GAO-12-208G](#))
- GAO TAs
- select GAO products utilizing policy analysis approaches to identify and assess policy options
- other GAO documents

We reviewed and analyzed 14 GAO TAs,¹ including their designs and considerations, using a data collection instrument that contained fields regarding each report's purpose, methodologies, and key considerations for each methodology used (such as strengths and weaknesses). The data collection instrument also contained fields regarding whether policy considerations were presented or if specific policy options were identified and assessed in each TA report, what methodologies were used to identify and assess policy options, and key considerations associated with the methodologies used.

We also reviewed GAO reports from non-TA product lines that utilized policy analysis approaches to assess policy options. An initial pool of 56 GAO reports was generated based on a keyword search of GAO's reports database. Of the 56 GAO reports, 12 were selected for review based on the following criteria: (1) the reports were publicly released after January 1, 2013 and (2) the reports included identification and assessment of policy options (not solely a presentation of agency actions related to policy options or general policy considerations). Testimonies and correspondence were excluded. We analyzed each of these selected GAO reports according to a data collection instrument that contained the following fields regarding policy options in the report: purpose, methodologies, and key considerations for each methodology used (such

¹All technology assessment reports on GAO's technology assessment web page (https://www.gao.gov/technology_and_science#t=1) were selected for review, as of October 2019. Since then, the following GAO TA was published: GAO, *Irrigated Agriculture: Technologies, Practices, and Implications*, [GAO-20-128SP](#) (Washington, D.C.: Nov. 12, 2019).

as strengths and weaknesses). A list of GAO documents reviewed is provided below.

GAO Documents
Reviewed for Preparing
this Handbook

Retirement Security: Some Parental and Spousal Caregivers Face Financial Risks. [GAO-19-382](#). Washington, D.C.: May 1, 2019.

GAO Science Technology Assessment, and Analytics Team: Initial Plan and Considerations Moving Forward. Washington, D.C.: April 10, 2019.

Retirement Savings: Additional Data and Analysis Could Provide Insight into Early Withdrawals. [GAO-19-179](#). Washington, D.C.: March 28, 2019.

Critical Infrastructure Protection: Protecting the Electric Grid from Geomagnetic Disturbances. [GAO-19-98](#). Washington, D.C.: December 19, 2018.

Postal Retiree Health Benefits: Unsustainable Finances Need to Be Addressed. [GAO-18-602](#). Washington, D.C.: August 31, 2018.

Data Collection Seminar Participant Manual. Washington, D.C.: March 2018.

Artificial Intelligence: Emerging Opportunities, Challenges and Implications. [GAO-18-142SP](#). Washington, D.C.: March 28, 2018.

Chemical Innovation: Technologies to Make Processes and Products More Sustainable. [GAO-18-307](#). Washington, D.C.: February 8, 2018.

Federal Regulations: Key Considerations for Agency Design and Enforcement Decisions. [GAO-18-22](#). Washington, D.C.: October 19, 2017.

Medical Devices: Capabilities and Challenges of Technologies to Enable Rapid Diagnoses of Infectious Diseases. [GAO-17-347](#). Washington, D.C.: August 14, 2017.

U.S. Postal Service: Key Considerations for Potential Changes to USPS's Monopolies. [GAO-17-543](#). Washington, D.C.: June 22, 2017.

Internet of Things: Status and Implications of an Increasingly Connected World. [GAO-17-75](#). Washington, D.C.: May 15, 2017.

Flood Insurance: Comprehensive Reform Could Improve Solvency and Enhance Resilience. [GAO-17-425](#). Washington, D.C.: April 27, 2017.

Flood Insurance: Review of FEMA Study and Report on Community-Based Options. [GAO-16-766](#). Washington, D.C.: August 24, 2016.

Medicaid: Key Policy and Data Considerations for Designing a Per Capita Cap on Federal Funding. [GAO-16-726](#). Washington, D.C.: August 10, 2016.

Municipal Freshwater Scarcity: Using Technology to Improve Distribution System Efficiency and Tap Nontraditional Water Sources. [GAO-16-474](#). Washington, D.C.: April 29, 2016.

GAO Memorandum: Quality Assurance Framework Requirements for Technology Assessments. Washington, D.C.: April 6, 2016.

Biosurveillance: Ongoing Challenges and Future Considerations for DHS Biosurveillance Efforts. [GAO-16-413T](#). Washington, D.C.: February 11, 2016.

Social Security's Future: Answers to Key Questions. [GAO-16-75SP](#). Washington, D.C.: October 2015.

Water in the Energy Sector: Reducing Freshwater Use in Hydraulic Fracturing and Thermoelectric Power Plant Cooling. [GAO-15-545](#). Washington, D.C.: August 7, 2015.

Nuclear Reactors: Status and Challenges in Development and Deployment of New Commercial Concepts. [GAO-15-652](#). Washington, D.C.: July 28, 2015.

Veterans' Disability Benefits: Improvements Needed to Better Ensure VA Unemployability Decisions Are Well Supported. [GAO-15-735T](#). Washington, D.C.: July 15, 2015.

Debt Limit: Market Response to Recent Impasses Underscores Need to Consider Alternative Approaches. [GAO-15-476](#). Washington, D.C.: July 9, 2015.

Temporary Assistance for Needy Families: Potential Options to Improve Performance and Oversight. [GAO-13-431](#). Washington, D.C.: May 15, 2013.

Private Pensions: Timely Action Needed to Address Impending Multiemployer Plan Insolvencies. [GAO-13-240](#). Washington, D.C.: March 28, 2013.

Designing Evaluations: 2012 Revision. [GAO-12-208G](#). Washington, D.C.: January 2012.

Neutron Detectors: Alternatives to Using Helium-3. [GAO-11-753](#). Washington, D.C.: September 3, 2011.

Climate Engineering: Technical Status, Future Directions, and Potential Responses. [GAO-11-71](#). Washington, D.C.: July 28, 2011.

Technology Assessment: Explosives Detection Technologies to Protect Passenger Rail. [GAO-10-898](#). Washington, D.C.: July 28, 2010.

Technology Assessment: Protecting Structures and Improving Communications during Wildland Fires. [GAO-05-380](#). Washington, D.C.: April 26, 2005.

Technology Assessment: Cybersecurity for Critical Infrastructure Protection. [GAO-04-321](#). Washington, D.C.: May 28, 2004.

Technology Assessment: Using Biometrics for Border Security. [GAO-03-174](#). Washington, D.C.: November 15, 2002.

Review of Experiences of GAO Teams and Technical Specialists

We spoke with and gathered input from GAO teams that are in the process of or have successfully assessed and incorporated policy options into GAO products. In addition, to augment our understanding of TA design and implementation challenges, we collected input from GAO staff who had provided key contributions to GAO TAs. Specifically, we asked for their thoughts regarding: (1) the strengths and limitations of TA methodologies and (2) challenges they faced, and strategies to address those challenges.

Review of Select Office of Technology Assessment Reports

A GAO librarian performed a search for relevant Office of Technology Assessment (OTA) reports, using keyword searches.² From this initial list of OTA reports, we selected 17 reports to review that were frameworks, guides, models, or other compilations. We also reviewed the methodologies of the OTA reports selected for review. A list of OTA reports reviewed is included below.

Office of Technology Assessment Reports Reviewed for Preparing this Handbook

Office of Technology Assessment. *Insider's Guide to OTA*. Washington, D.C.: January 1995.

Office of Technology Assessment. *Policy Analysis at OTA: A Staff Assessment*. Washington, D.C.: May 1993.

Office of Technology Assessment. *Research Assistants Handbook*. Washington, D.C.: June 1992.

Office of Technology Assessment. *Strengths and Weaknesses of OTA Policy Analysis*. Washington, D.C.: 1992.

Office of Technology Assessment. *The OTA Orange Book: Policies and Procedures of the Office of Technology Assessment: Communication with Congress and the Public*. Washington, D.C.: February 1986.

Office of Technology Assessment. *What OTA Is, What OTA Does, How OTA Works*. Washington, D.C.: March 1983.

Office of Technology Assessment. *Draft: An OTA Handbook*. Washington, D.C.: June 7, 1982.

Office of Technology Assessment. *Draft: A Management Overview Methodology for Technology Assessment*. Washington, D.C.: February 2, 1981.*

Office of Technology Assessment. *Draft: Technology Assessment in Industry: A Counterproductive Myth*. Washington, D.C.: January 30, 1981.*

²Websites searched for OTA reports included: http://ota.fas.org/technology_assessment_and_congress/, <https://www.princeton.edu/~ota/>, and <https://digital.library.unt.edu>.

Office of Technology Assessment. *Draft: Technology Assessment Methodology and Management Practices*. Washington, D.C.: January 12, 1981.*

Office of Technology Assessment. *Draft: Technology Assessment in the Private Sector*. Washington, D.C.: January 9, 1981.*

Office of Technology Assessment. *Draft: A Process for Technology Assessment Based on Decision Analysis*. Washington, D.C.: January 1981.*

Office of Technology Assessment. *Draft: Technology as Social Organization*. Washington, D.C.: January 1981.*

Office of Technology Assessment. *A Summary of the Doctoral Dissertation: A Decision Theoretic Model of Congressional Technology Assessment*. Washington, D.C.: January 1981.*

Office of Technology Assessment. *Report on Task Force Findings and Recommendations: Prepared by the OTA Task Force on TA Methodology and Management*. Washington, D.C.: August 13, 1980.

Office of Technology Assessment. *Phase I Survey Results: Draft Papers Prepared for the Task Force on TA Methodology and Management*. Washington, D.C.: April 10, 1980.

Office of Technology Assessment. *Staff Memo: Notes and Comments on Staff Discussion of Task Force on TA Methodology and Management*. Washington, D.C.: December 14, 1979.

*Special reports prepared at the request of the OTA

Review of Select Congressional Research Service Reports

We identified a pool of 29 Congressional Research Service (CRS) reports to consider reviewing that were technology assessments or included an analysis of policy options, based on a keyword search of CRS's website.³ We also interviewed CRS officials. Of the initial 29 CRS reports we identified, we selected six CRS reports to review, based on the following criteria: (1) published within the past 15 years (2004-2019) and (2) if a

³The following CRS website was used: <http://www.loc.gov/crsinfo/>.

review of technology (technology assessment) and/or policy options was included. Reports were excluded based on the following criteria: (1) for technology assessment related reports—if they represented a summary of a technology assessment that was included in our review or (2) for policy options related reports—the report did not indicate how CRS arrived at the policy options (no methodology to review or analyze). A list of CRS reports reviewed is included below.

Congressional Research Service Reports Reviewed for Preparing this Handbook

Congressional Research Service. *Advanced Nuclear Reactors: Technology Overview and Current Issues*. Washington, D.C.: April 18, 2019.

Congressional Research Service. *Drug Shortages: Causes, FDA Authority, and Policy Options*. Washington, D.C.: December 27, 2018.

Congressional Research Service. *Policy Options for Multiemployer Defined Benefit Pension Plans*. Washington, D.C.: September 12, 2018.

Congressional Research Service. *Shale Energy Technology Assessment: Current and Emerging Water Practices*. Washington, D.C.: July 14, 2014.

Congressional Research Service. *Carbon Capture: A Technology Assessment*. Washington, D.C.: November 5, 2013.

Congressional Research Service. *Energy Storage for Power Grids and Electric Transportation: A Technology Assessment*. Washington, D.C.: March 27, 2012.

Review of Literature

A GAO librarian performed a literature search based on keyword searches for two areas—TA and policy options. For TA literature, the team selected 29 documents to review that were frameworks, guides, models, or other compilations, based on a review of the literature titles and abstracts. In general, we excluded specialized types of TAs, such as health-related TAs, as we focused on TA design more broadly. For policy options literature, the team selected 14 documents to review that were frameworks, guides, models, or other compilations and focused on policy options related to science and technology. We also asked experts we consulted to suggest literature for our review; these suggestions confirmed the literature list noted below. A list of literature reviewed is included below.

Literature Reviewed for
Preparing this Handbook

Grunwald, Armin. *Technology Assessment in Practice and Theory*. London and New York: Routledge, 2019.

Armstrong, Joe E., and Willis W. Harman. *Strategies For Conducting Technology Assessments*. London and New York: Routledge, 2019.

Noh, Heeyong, Ju-Hwan Seo, Hyoung Sun Yoo, and Sungjoo Lee. "How to Improve a Technology Evaluation Model: A Data-driven Approach." *Technovation*, vol. 72/73 (2018): p. 1-12.

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Ibrahim, O., and A. Larsson. "A Systems Tool for Structuring Public Policy Problems and Design of Policy Options." *Int. J. Electronic Governance*, vol. 9, nos. 1/2 (2017): p. 4-26.

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Berg, M., K. Chen, and G. Zissis. "A Value-Oriented Policy Generation Methodology for Technology Assessment." *Technological Forecasting and Social Change*, vol. 4, no. 4 (1976): p. 401-420.

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Consultation with External Experts

We held a forum to gather experts' opinions regarding TA design. An initial list of experts was prepared based on a review of GAO TA reports, literature, and referral by other experts. Experts were selected based on their knowledge and expertise in the subject, including: (1) prior participation on a National Academy of Sciences panel or other similar meeting; (2) leadership position in one or more organizations or sectors relevant to technology research and development implementation or policy; and (3) relevant publications or sponsorship of reports. Care was also taken to ensure a balance of sectors, backgrounds, and specific areas of expertise (e.g., science, technology, policy, information technology, and law). We also asked the experts to suggest literature for our review; these suggestions confirmed the literature list noted above. A list of external experts consulted is included below.

External Experts Consulted for the Handbook

Dr. Jeffrey M. Alexander, Senior Manager, Innovation Policy, RTI International

Dr. Robert D. Atkinson, President, Information Technology and Innovation Foundation

Mr. David Bancroft, Executive Director, International Association for Impact Assessment

Mr. Duane Blackburn, S&T Policy Analyst, Office of the CTO, MITRE

Dr. Peter D. Blair, Executive Director, Division of Engineering and Physical Sciences, National Academies of Sciences, Engineering, and Medicine

Ms. Marjory Blumenthal, Acting Associate Director, Acquisition and Technology Policy Center; Senior Policy Researcher, RAND Corporation

Mr. Chris J. Brantley, Managing Director, Institute of Electrical and Electronics Engineers, Inc., USA

Dr. Jonathan P. Caulkins, H. Guyford Stever University Professor of Operations Research and Public Policy, Carnegie Mellon University

Mr. Dan Chenok, Executive Director, Center for The Business of Government, IBM

Dr. Gerald Epstein, Distinguished Research Fellow, Center for the Study of Weapons of Mass Destruction, National Defense University

Dr. Robert M. Friedman, Vice President for Policy and University Relations, J. Craig Venter Institute

Mr. Zach Graves, Head of Policy, Lincoln Network

Ms. Allison C. Lerner, Inspector General, National Science Foundation

Mr. Mike Molnar, Director of Office of Advanced Manufacturing, National Institute of Standards and Technology

Dr. Michael H. Moloney, CEO, American Institute of Physics

Dr. Ali Nouri, President, Federation of American Scientists

Dr. Jon M. Peha, Professor, Engineering and Public Policy; Courtesy Professor, Electrical and Computer Engineering, Carnegie Mellon University

Dr. Stephanie S. Shipp, Deputy Director and Professor, University of Virginia, Biocomplexity Institute and Initiative, Social and Decision Analytics Division

Dr. Daniel Sarewitz, Co-Director, Consortium for Science, Policy & Outcomes Professor of Science and Society, School for the Future of Innovation in Society, Arizona State University

Ms. Rosemarie Truman, Founder and CEO, Center for Advancing Innovation

Dr. Chris Tyler, Director of Research and Policy, Department of Science, Technology, Engineering and Public Policy (STEaPP), University College London (UCL)

Mr. David E. Winickoff, Senior Policy Analyst and Secretary of the Working Party on Bio-, Nano- and Converging Technology, Organisation for Economic Co-operation and Development

Appendix II: Summary of Steps for GAO's General Engagement Process

As part of GAO's Quality Assurance Framework, GAO's general design and project plan templates contain five phases that are followed in sequential order, with modifications or changes as needed. GAO technology assessments (TAs) use these templates, as applicable. Throughout the phases, the status of the work, including decisions, is communicated to stakeholders and congressional committees that requested the work. Provided below is a summary of the activities GAO staff undertake during each of the phases, and is based on a review of GAO documentation related to engagement phases.¹

- Phase I: Acceptance
 - Engagement characteristics such as risk level or internal stakeholders are determined at a high-level Engagement Acceptance Meeting.
 - Engagement teams obtain a copy of and review the congressional request letter(s), as applicable.
- Phase II: Planning and Proposed Design
 - Staff are assigned to the engagement and set up the electronic engagement documentation set folders.
 - Staff enter standard information regarding the engagement in GAO's Engagement Management System (EMS),² which is used to monitor the status of the engagement throughout the engagement process and regularly updated.
 - Engagement teams hold an initiation meeting with engagement stakeholders to discuss potential research questions, design options, and stakeholder involvement.
 - Engagement teams clarify engagement objectives and approach through discussions with the congressional requesters, as applicable.

¹"Engagement" is the term GAO uses for its audit and non-audit work and for producing reports, testimonies, technology assessments, and other products. Engagements are generally performed at the request of Congressional Committee(s) or the Comptroller General.

²EMS is a web-based system that provides information on GAO engagements, such as job code, engagement title, risk level, project milestones, assigned staff, costs, and narratives related to background, scope/methodology, key questions, and potential impact/results.

- Engagement teams obtain background information. For example, to gather information about the topic and any work already performed, teams may conduct a literature review, search prior and ongoing GAO work related to the topic, or consult with external stakeholders, outside experts, and agency officials, including the Congressional Research Service, Congressional Budget Office, and Inspectors General of federal agencies.
- Engagement teams formally notify agencies of the engagement through a notification letter, and hold an entrance conference, as applicable.
- Engagement teams prepare a design matrix, project plan, risk assessment tool, data reliability assessment, and all participants on engagements, including stakeholders, affirm their independence. The design matrix is a tool that describes: researchable questions; criteria; information required and sources; scope and methodology; and limitations. The project plan identifies key activities and tasks, dates for completing them, and staff assigned.
- Engagement teams secure approval to move forward with engagement approach at a high-level Engagement Review Meeting.
- Phase III: Evidence Gathering, Finalizing Design, and Analysis
 - Engagement teams finalize design: teams work with internal stakeholders to confirm soundness and reach agreement on proposed initial design. If engagement teams and stakeholders conclude that additional work is needed or the design faces significant implementation challenges, design is reviewed and modified, as needed.
 - Engagement teams collect and analyze evidence: teams may collect and analyze evidence using a variety of methodologies including document review, interviews, surveys, focus groups, and various forms of data analysis. For example, engagement teams may meet with agency officials and outside experts, as applicable, to gather evidence.
 - Engagement teams assess evidence and agree on conclusions: teams assess whether the evidence collected is sufficient and appropriate to support findings and conclusions reached for each objective. Once sufficient evidence is collected and analyzed, the team discusses how the evidence supports potential findings and shares these findings with stakeholders, generally in the form of a formal message agreement meeting.

- Engagement teams update congressional requesters, as applicable, on the engagement status and potential findings.
- Phase IV: Product Development
 - Engagement teams draft product: after drafting the product, teams send draft to internal stakeholders for review. Teams also send draft to relevant external parties, including relevant agencies, to confirm facts and obtain their views.
 - Teams identify sources of all information in the draft and an independent analyst (not on the team) verifies the sources through a process called indexing and referencing.
 - Engagement teams perform exit conferences with agencies, as applicable, to discuss findings and potential recommendations. Agencies and external parties are given the opportunity to comment on the draft, as applicable.
 - Engagement teams communicate findings and potential recommendations, as well as timeframes for issuing the product, to congressional requesters, as applicable.
 - The draft product is copy-edited, prepared for issuance, and publicly released on GAO's website, as applicable.
- Phase V: Results
 - Engagement documentation is closed out.
 - Engagement teams conduct follow-up, track the results, and prepare reports on the status of recommendations and financial and non-financial benefits, as applicable, using GAO's results tracking system.

Appendix III: Example Methods for Technology Assessment

This appendix provides examples of methods and analytical approaches that GAO technology assessment (TA) teams can use to examine different types of evidence. Also included in this appendix are considerations of the strengths, limitations, and synergies among evidence types and methods, which can be useful to consider throughout design to ensure that evidence is sufficient and appropriate to answer the researchable questions. Examples from GAO TAs were used given our familiarity with GAO products, though numerous other (non-GAO) examples of TA methods exist. This appendix included a review of GAO reports and select literature, and is not intended to be comprehensive. This is a simplified presentation of methods, and there is variation in the levels of structure of the example methods.

This appendix is divided into several sections, including by evidentiary types: Testimonial, Documentary, and Physical. For each of these types of evidence, example methods are presented with low and high levels of structure, and include examples of considerations (such as general benefits and limitations) that analysts may consider. In general, more highly structured approaches generate increased consistency and comparability of results that allows for stronger quantification. Less structured approaches tend to provide more flexibility and context, and richer illustrative evidence.

Examples of Methodologies for Testimonial Evidence

Testimonial evidence is elicited from respondents to understand their experience, opinions, knowledge, and behavior, and it can be obtained through a variety of methods, including inquiries, interviews, focus groups, expert forums, or questionnaires. Testimonial evidence can be gathered from individuals who may be responding personally based on their own experience in an official capacity to represent agencies or other entities, or groups, who may share individual level responses, or may present a single group response. Group testimony enables interactions that can be used to explore similarities and differences among participants, to identify tensions or consensus in a group, or to explore ideas for subsequent research and collaboration. It is important to evaluate the objectivity, credibility, and reliability of testimonial evidence. Analysts may use a combination of approaches to gather testimonial evidence, depending on the relevant population(s) of respondents, intended analytical approach(es), likely respondent burden, and resource considerations. Table 9 provides more examples.

Table 9: Select Examples of Methodologies for Testimonial Evidence

Level of structure	Example methods	General benefits	General limitations	Examples from GAO technology assessments
Low	<ul style="list-style-type: none"> Interviews Small group discussions Diary methods 	<ul style="list-style-type: none"> Qualitative data is descriptive, good for examples and anecdotal information Semi-structured and unstructured can be developed fairly quickly Data collected to answer “how” and “why” kinds of questions Can be appropriate for explanatory or early design work, to inform further data collection later in the engagement (such as survey development) or to help interpret results at the end of the assignment Can allow the team to gather lots of information and allows for follow-up questions Allows for spontaneity and probing during interviews Can elicit opinions of key informants, corroborate evidence from other sources, and provide leads on audits 	<ul style="list-style-type: none"> Conducting interviews, data reduction, and analysis of data collected from semi-structured and unstructured interviews can be time consuming May be tempting to generalize results beyond the cases selected, which would only be appropriate when interviewing a sample designed to be generalizable A relatively small number of cases may result in extreme responses skewing analysis Unstructured and semi-structured items may introduce inconsistencies that make reporting very difficult Data summary/reduction and analysis can be difficult and time consuming May not obtain results that demonstrate a consensus of opinion, common themes, or patterns 	<ul style="list-style-type: none"> A TA team identified how effective biometric technologies may be applied to current U.S. border control procedures, by interviewing government officials, among other methods (GAO-03-174)
High	<ul style="list-style-type: none"> Focus groups Expert panels Surveys 	<ul style="list-style-type: none"> Data collected may help answer “to what extent” kinds of questions Precise estimates (with confidence intervals) can be provided when using a generalizable sample design Techniques such as the Delphi Method may be able to identify areas of consensus 	<ul style="list-style-type: none"> Can be more time intensive to develop structured approach May require more technical expertise in question development, facilitation, or statistical methods May require pre-testing of instruments to achieve reliability Low response/collection rate can limit generalizability Once fielded, can be hard to change 	<ul style="list-style-type: none"> A TA team used an expert forum comprised of individuals from academia, industry, government, and nonprofit organizations to identify and analyze emerging opportunities, challenges, and implications of artificial intelligence (GAO-18-142SP)

Source: GAO review of GAO design documentation. | GAO-20-246G

Examples of Methodologies for Documentary Evidence

Documentary evidence is existing information, such as letters, contracts, accounting records, invoices, spreadsheets, database extracts, electronically stored information, and management information on performance. It is important to evaluate the objectivity, credibility, and reliability of documentary evidence. Analysts may use a combination of approaches to gather documentary evidence, depending on the relevant sources and types of documents, intended analytical approach(es), and resource considerations. Table 10 provides more examples.

Table 10: Select Examples of Methodologies for Documentary Evidence

Level of structure	Example methods	General benefits	General limitations	Examples from GAO technology assessments
Low	<ul style="list-style-type: none"> Document summary Background research Article review 	<ul style="list-style-type: none"> Quantitative and qualitative, numeric and narrative information that can help to provide background knowledge or illustrate a point Can be appropriate in early design work to help shape researchable questions and identify relevant stakeholders 	<ul style="list-style-type: none"> May not fully reflect important aspects of the document May not reflect the broader population of knowledge 	<ul style="list-style-type: none"> A TA team reviewed key reports and scientific literature to establish background related to chemical innovation (GAO-18-307)
High	<ul style="list-style-type: none"> Data collection instrument Administrative data Systematic literature review Evaluation synthesis Content analysis 	<ul style="list-style-type: none"> Enables systematic data collection and gives ability to systematically analyze information from written material Results of analysis can be easily summarized and understood Improves ability for researchers to more easily analyze collected data Multiple staff can collect data at the same time, if appropriately trained Can be generalizable 	<ul style="list-style-type: none"> Requires preparation and testing of protocol and instrument to ensure reliability of measurement and coding Availability and location of source records sometimes a problem Limited flexibility during fieldwork Abstraction and reduction of data collection can lose valuable context Requires knowledge of method and data collection methods expertise Can be labor- and time-intensive May require training of coders May require inter-coder (rater) agreement 	<ul style="list-style-type: none"> A TA team conducted a literature review to summarize the known potential effects of geomagnetic disturbances on the U.S. electric grid (GAO-19-98)

Source: GAO review of GAO design documentation. | GAO-20-246G

Examples of Methodologies for Physical Evidence

Physical evidence is obtained by direct inspection or observation of people, property, or events. The appropriateness of physical evidence depends on when, where, and how the inspection or observation was made and whether it was recorded in a manner that fairly represents the facts observed. Common considerations for physical evidence include the reliability of site selection, intended analytical approaches, and resource considerations. Table 11 provides more examples.

Table 11: Select Examples of Methodologies for Physical Evidence

Level of structure	Example methods	General benefits	General limitations	Examples from GAO technology assessments
Low	<ul style="list-style-type: none"> Post-visit summary of observation Site visit Individual photos, videos, or other recordings 	<ul style="list-style-type: none"> Quick generation of compelling and engaging illustrative observations 	<ul style="list-style-type: none"> Not generalizable May be hard to establish reliability 	<ul style="list-style-type: none"> A TA team conducted site visits with developers to interview their staff and observe their facilities, including the developers' multiplex point-of-care technologies (GAO-17-347)
High	<ul style="list-style-type: none"> Case study Ethnographic methods (such as field studies, participant observation, and tester audits) 	<ul style="list-style-type: none"> Multiple sources of information can be used to help compare, contrast, and combine different perspectives of the same process, increasing reliability and validity of findings. Qualitative, rich descriptions of behavior and in-depth information about a topic Often used to answer complex "how" and "why" questions Typically qualitative, but could include quantitative data 	<ul style="list-style-type: none"> Small number of cases may prohibit generalizability Training of observers of testers may be necessary. Reduction of voluminous qualitative data can be difficult. May be difficult to develop appropriate scripts, questions, and data collection instruments 	<ul style="list-style-type: none"> A TA team conducted case studies of six states to identify and assess different approaches to address risks associated with wildland fire, interoperability of communications, or use of military resources (GAO-05-380)

Source: GAO review of GAO design documentation. | GAO-20-246G

GAO may also rely on agency and other secondary data. Considerations for those secondary data are dependent on the type, source, and collection method, and could include all of the considerations above. Use of secondary data is usually more efficient than collecting new data on a topic, and administrative records (a form of documentary evidence) are generally not as prone to self-reporting biases that may be present in testimonial evidence. However, when secondary data are used, more work may be required to assess whether data are reliable and appropriate for a given purpose. For example, analysts will gather all appropriate

documentation, including record layout, data element dictionaries, user's guides, and data maintenance procedures. Depending on the database, procedures and analysis can be very complex—and it would be important to note assumptions, limitations, and caveats pertaining to the data, which may affect the conclusions that can be drawn based on the analyses.

Examples of Analytical Approaches

Examples of analytical approaches found in the literature to analyze data include:

- Interpretive structural modeling: shows a graphical relationship among all elements to aid in structuring a complex issue area, and may be helpful in delineating scope.
- Trend extrapolation: is a family of techniques to project time-series data using specific rules, and may be helpful in forecasting technology.
- Scenarios: is a composite description of possible future states incorporating a number of characteristics, and may be helpful in policy analysis.
- Scanning methods, such as checklists: is listing factors to consider in a particular area of inquiry, and may be helpful in identifying potential impacts.
- Tracing methods, such as relevance trees: includes identifying sequential chains of cause and effect or other relationships, and may be helpful in identifying potential impacts.
- Cross-effect matrices: are two-dimensional matrix representations to show the interaction between two sets of elements, and may be helpful in analyzing consequences of policy options.
- Simulation models: are a simplified representation of a real system that is used to explain dynamic relationships of the system, and may be helpful in identifying impacts and forecasting technology.
- Benefit-cost analysis: is a systematic quantitative method of assessing the desirability of government projects or policies when it is important to take a long view of future effects and a broad view of possible side effects.
- Decision analysis: is an aid to compare alternatives by weighing the probabilities of occurrences and the magnitudes of their impacts, and may be helpful in determining impacts and assessing policy options.

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- **Scaling:** is an aid that may include developing a matrix that identifies potential impact related to an activity and stakeholder group, and qualitatively or quantitatively assesses the potential impact, and may be helpful analyzing potential impacts, including of policy options.

Appendix IV: GAO Contact and Staff Acknowledgments

GAO Contact

Timothy M. Persons (202) 512-6888 or PersonsT@gao.gov and Karen L. Howard (202) 512-6888 or HowardK@GAO.gov

Staff Acknowledgments

In addition to the contacts named above, key contributors to this report were R. Scott Fletcher (Assistant Director), Diantha Garms (Analyst-in-charge), Nora Adkins, Colleen Candrl, Virginia Chanley, Robert Cramer, David Dornisch, John De Ferrari, Dennis Mayo, Anika McMillon, SaraAnn Moessbauer, Amanda Postiglione, Steven Putansu, Oliver Richard, Meg Tulloch, Ronald Schwenn, Ben Shouse, Amber Sinclair, Ardith Spence, Andrew Stavisky, David C. Trimble, and Edith Yuh.

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