GAO Best Practice Guides: Cost Estimating, Scheduling, and Technology Readiness Assessments

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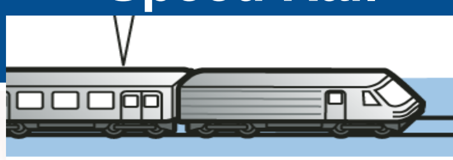
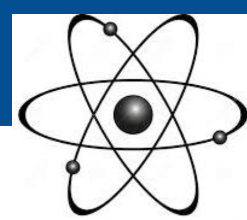
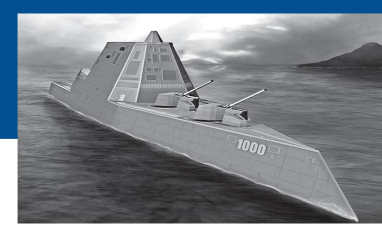
Agenda

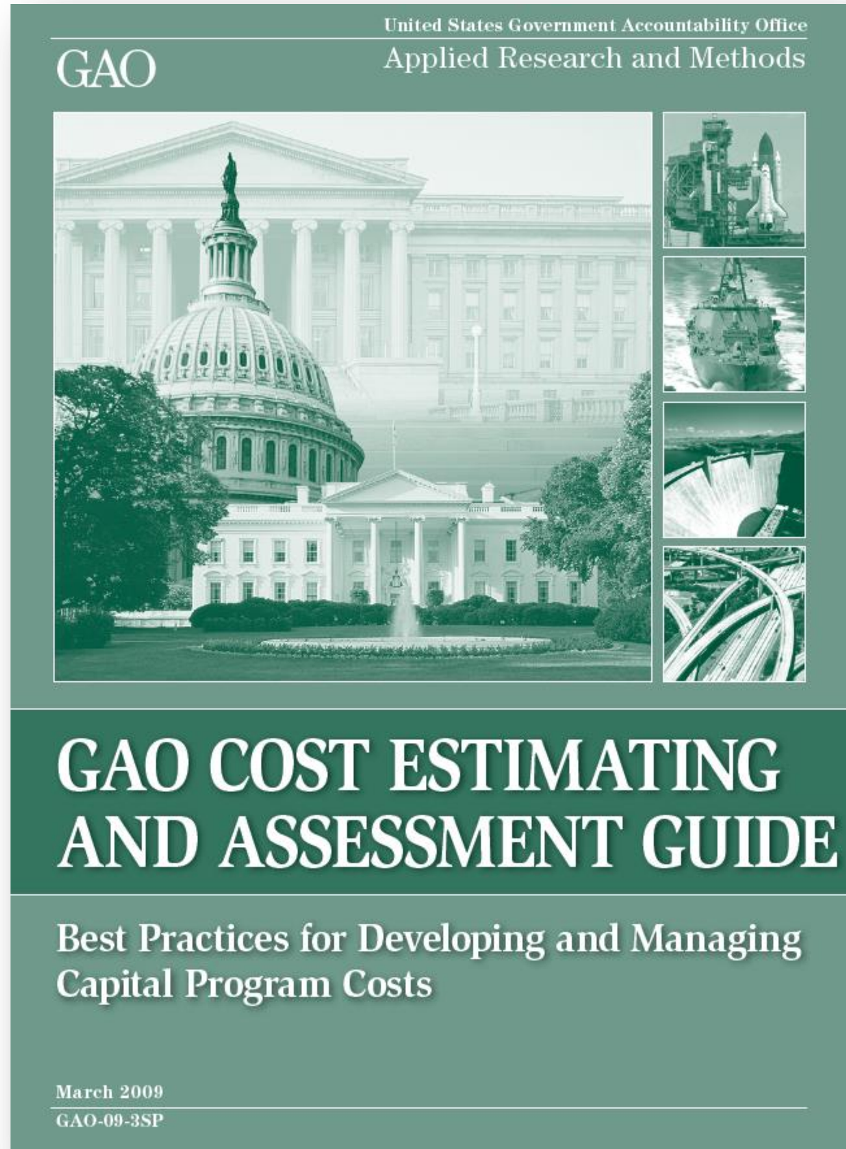
- Overview of GAO Criteria to Review Cost and Schedule on Acquisition Programs
  - Cost Estimating and Assessment Guide (“Cost Guide”)
  - Schedule Assessment Guide (“Schedule Guide”)
  - Technology Readiness Assessment Guide (“TRA Guide”)
- Examples of GAO Reviews of Large Technical Projects

California High-Speed Rail	ITER, UPF	DDG-1000
		

- TRA for Technology Assessment/Foresight Studies
- Conclusions

Cost Estimating and Assessment Guide

- Drafted 2005-2007, published in 2009
- Outlines GAO's criteria for assessing cost estimates during audits
- Contains 20 chapters with supporting appendixes
- Chapters 1-17: developing credible cost estimates and the 12-step cost estimating process for developing high quality cost estimates
- Chapters 18-20 address managing program costs once a contract has been awarded and discuss Earned Value and risk management
- Also provides case studies of prior GAO audits to show typical findings related to the cost estimating process



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Characteristics of Reliable Cost Estimates

Are all costs included?

Comprehensive

- Develop the estimating plan
- Determine the estimating approach

Is the estimate unbiased?

Accurate

- Develop the point estimate
- Compare the point estimate to an independent estimate
- Update the estimate with actual costs

What is the uncertainty?

Credible

- Create an independent cost estimate
- Conduct sensitivity analysis
- Conduct risk and uncertainty analysis

Can the estimate be recreated?

Well Documented

- Define the program
- Identify ground rules and assumptions
- Obtain data
- Document the estimate
- Present estimate to management

California High-Speed Rail: Background

- 520-mile high-speed rail system
- May be one of the most expensive transportation projects in the U.S. Estimated cost $68.4 billion
- GAO assessed:
  - Project costs using GAO Cost Guide
  - Reasonableness of ridership and revenue estimates
  - Risks of project financing plan
  - Comprehensiveness with which project economic impacts were identified

Sources: California High Speed Rail Authority and GAO.

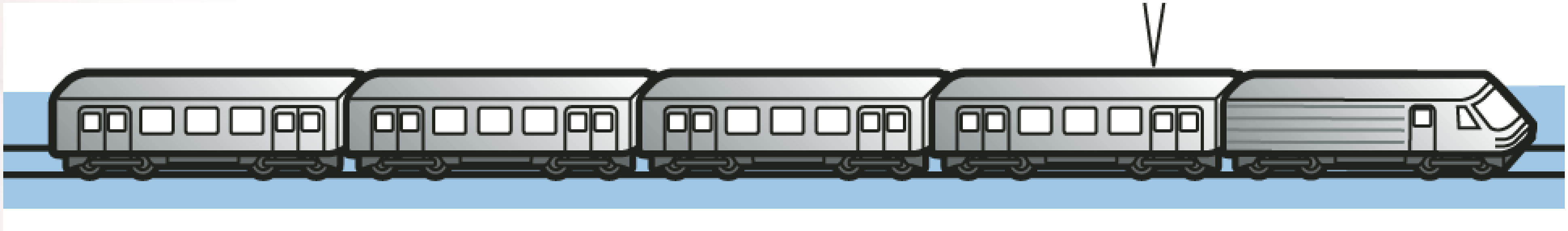
California High-Speed Rail: Key Findings

- Met some, but not all, Cost Guide practices:
  - Costs accurate but operating costs not well detailed (comprehensive)
  - Costs not sufficiently explained (well documented)
  - No assessment of cost risks performed (credible)
- Ridership and revenue estimates reasonable for the early stage of the project but continuous updates are required
- Project funding faces uncertainty and obtaining almost $40 billion in federal funding is biggest challenge
- Economic impacts were comprehensively identified

California High-Speed Rail: Implications and Recommendations

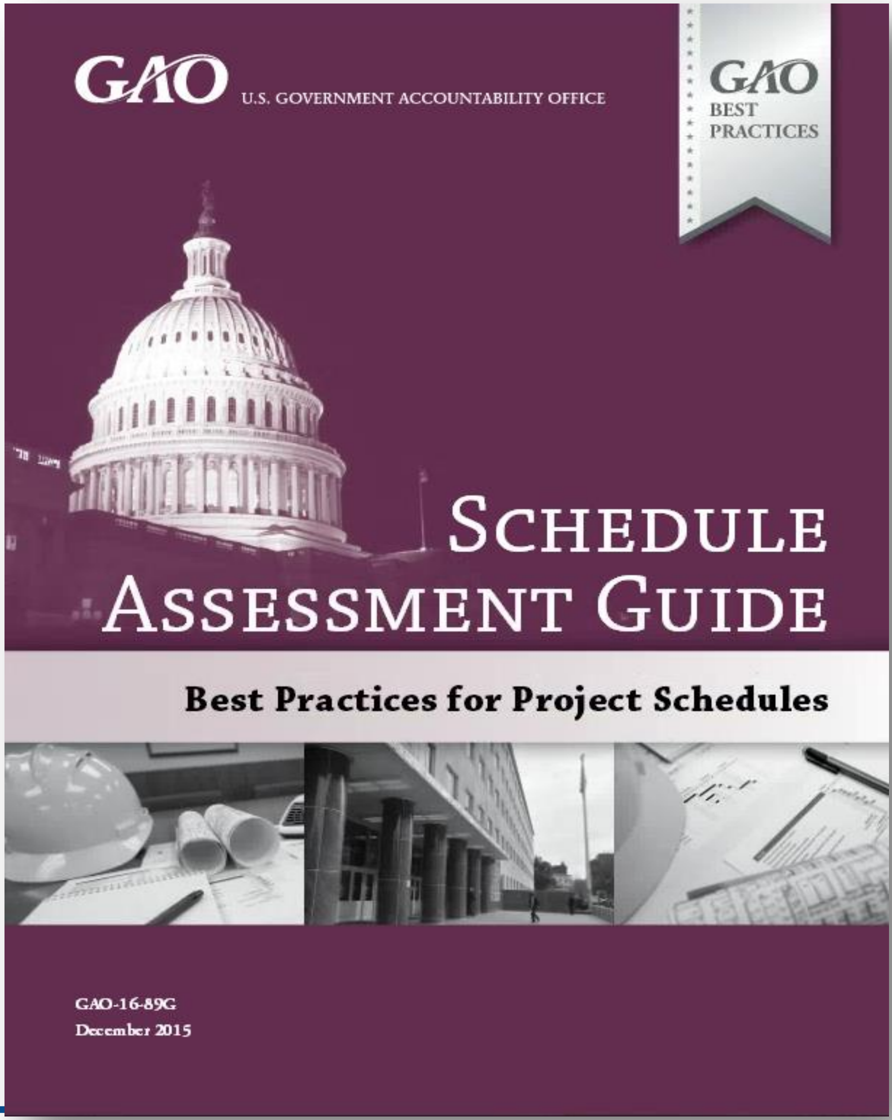
- Implications of GAO's findings:
  - Increased risk of cost overruns
  - Potential missed deadlines
  - Possible unmet performance targets

- Recommendation:
  - Federal Railroad Administration should improve project guidance so it is in line with GAO Cost Guide



Schedule Assessment Guide

- Public exposure draft released May 2012, final version released December 2015
- Expands on schedule best practices introduced in Cost Guide
- Outlines GAO's criteria for assessing master schedules
- Contains chapters for each of the 10 best practices plus supporting appendixes
- Provides case studies of prior GAO audits to show typical findings related to the scheduling process

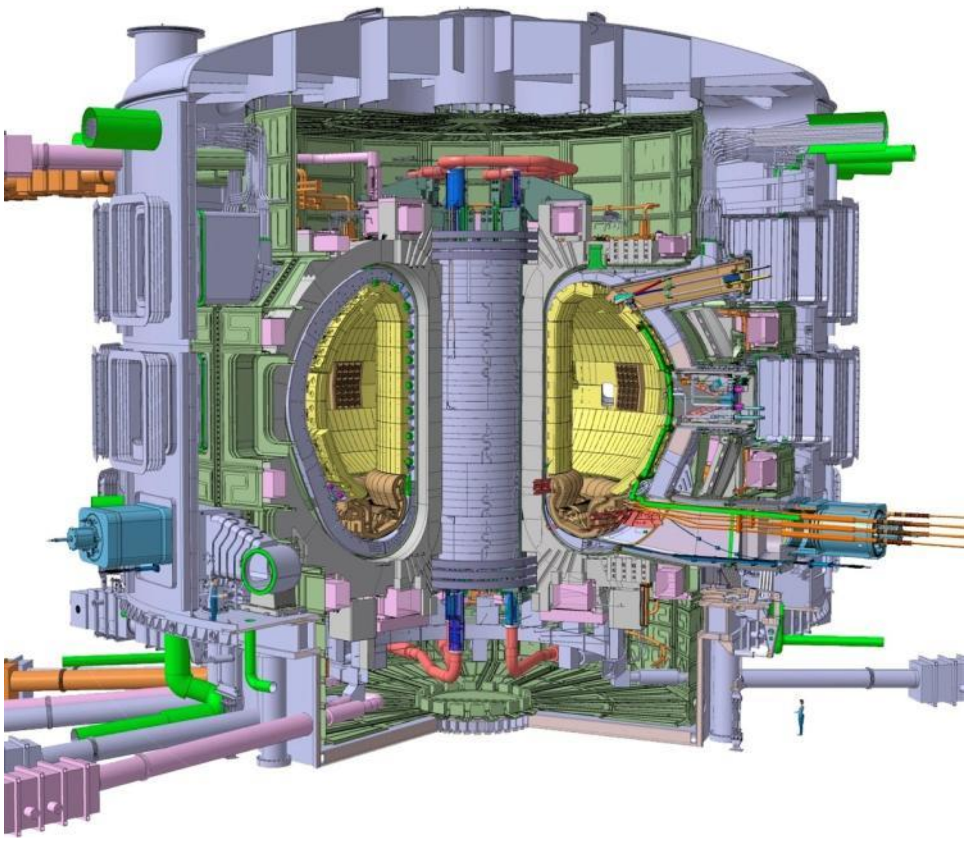


Four Characteristics of a Reliable Schedule

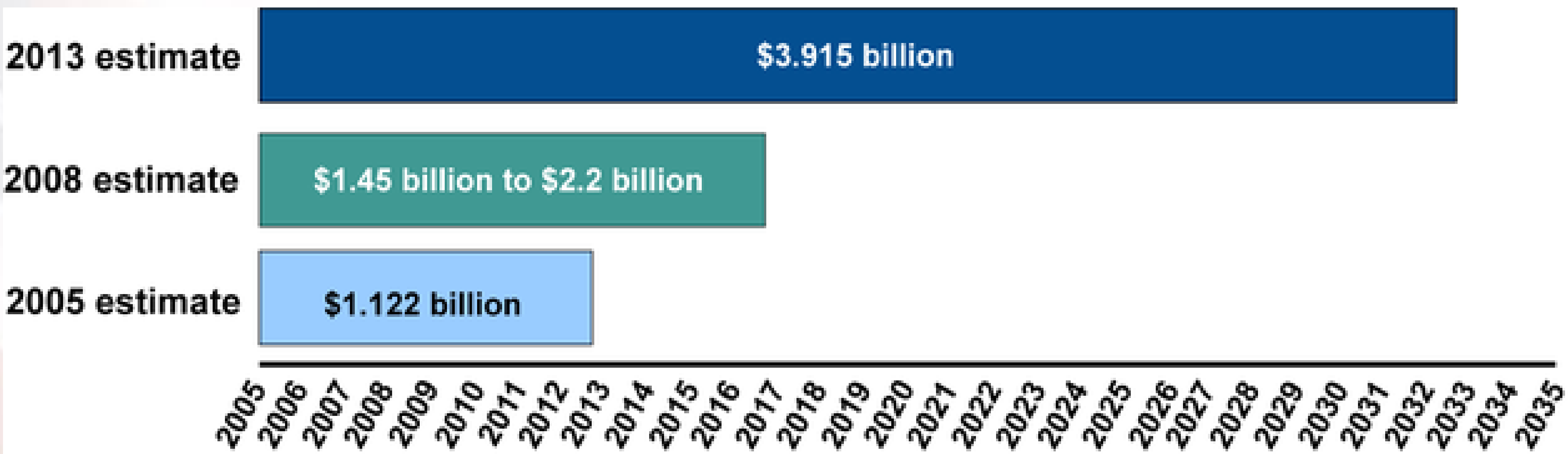
Is all effort included?	Is the network logical?	What is the uncertainty?	Is progress measured?
Comprehensive	**Well Constructed**	**Credible**	**Controlled**
• Capture all activities • Assign resources to all activities • Establish durations for all activities	• Sequence all activities • Confirm the critical path • Confirm reasonable float (slack)	• Confirm vertical and horizontal traceability • Conduct a schedule risk analysis	• Update the schedule with progress • Maintain a schedule baseline

International Thermonuclear Experimental Reactor (ITER) Project: Background

- ITER is an international research facility being built in France to demonstrate the feasibility of fusion energy.
- Other countries involved in ITER include Russian Federation, Japan, European Union, People's Republic of China, Republic of Korea, and India.
- The United States has committed to providing about 9 percent of ITER's construction costs through contributions of hardware, personnel, and cash, and DOE is responsible for managing those contributions, as well as the overall U.S. fusion program.
- GAO reviewed costs and schedules in 2014 (GAO-14-499)



ITER: Cost Estimates of U.S. Contribution



Source: GAO analysis of DOE data. | GAO-14-499

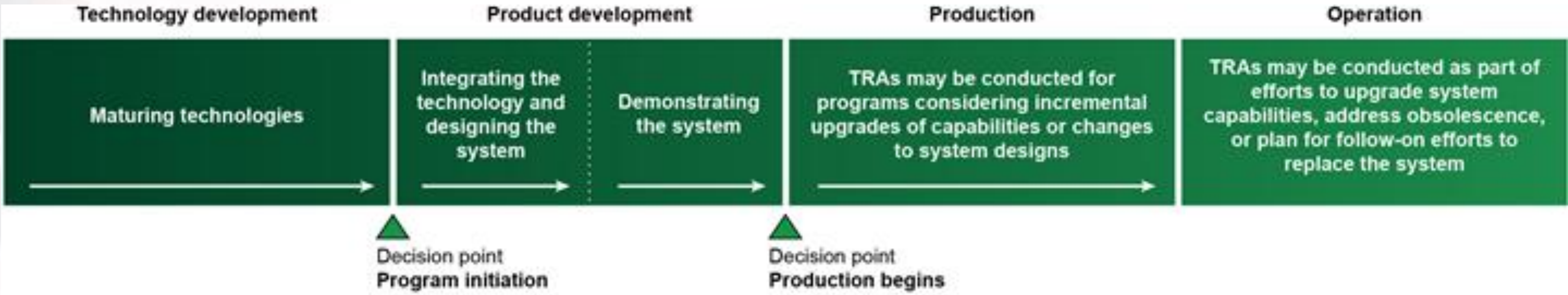
ITER: Key Findings

- ***Cost:*** Estimate of U.S. contribution has grown by almost $3 billion
- ***Schedule:*** Estimated completion date has slipped by 20 years
- ***Causes:*** 1) refined design and requirements of U.S. hardware; 2) changes to the international schedule; 3) changes to ITER design; 4) U.S. funding constraints and associated inflation; 5) increased ITER construction costs
- ***Assessment***:
  - U.S. schedule estimates substantially met best practices
  - U.S. cost estimates substantially met best practices, but were only partially credible because they did not develop a sensitivity analysis or independent cost estimate
  - DOE has been unable to set a cost and schedule baseline in part because the international schedule has not been set

ITER: Recommendations

- Revise U.S. ITER Project Office to develop a sensitivity analysis for the cost estimate and compare to an independent cost estimate
- Develop proposal describing what actions are necessary to create a reliable international schedule and improve ITER Organization program management
- Once ITER Organization creates a reliable master schedule, use that schedule to update the U.S. schedule
- Develop strategic plan to address DOE’s fusion program priorities

Phased Acquisition Cycle with Decision Points



Source: GAO simplification of agency documents. | GAO-16-410G

- The four-phased acquisition process: technology development, product development, production, and operations.
- Each broad phase may contain a number of activities designed to increase knowledge about the technologies and product being developed, built, and eventually operated.
- Transition to the next phase should involve a documented evidence-based review that demonstrates the knowledge gained during the prior phase as well as progress in development compared to goals/exit criteria.

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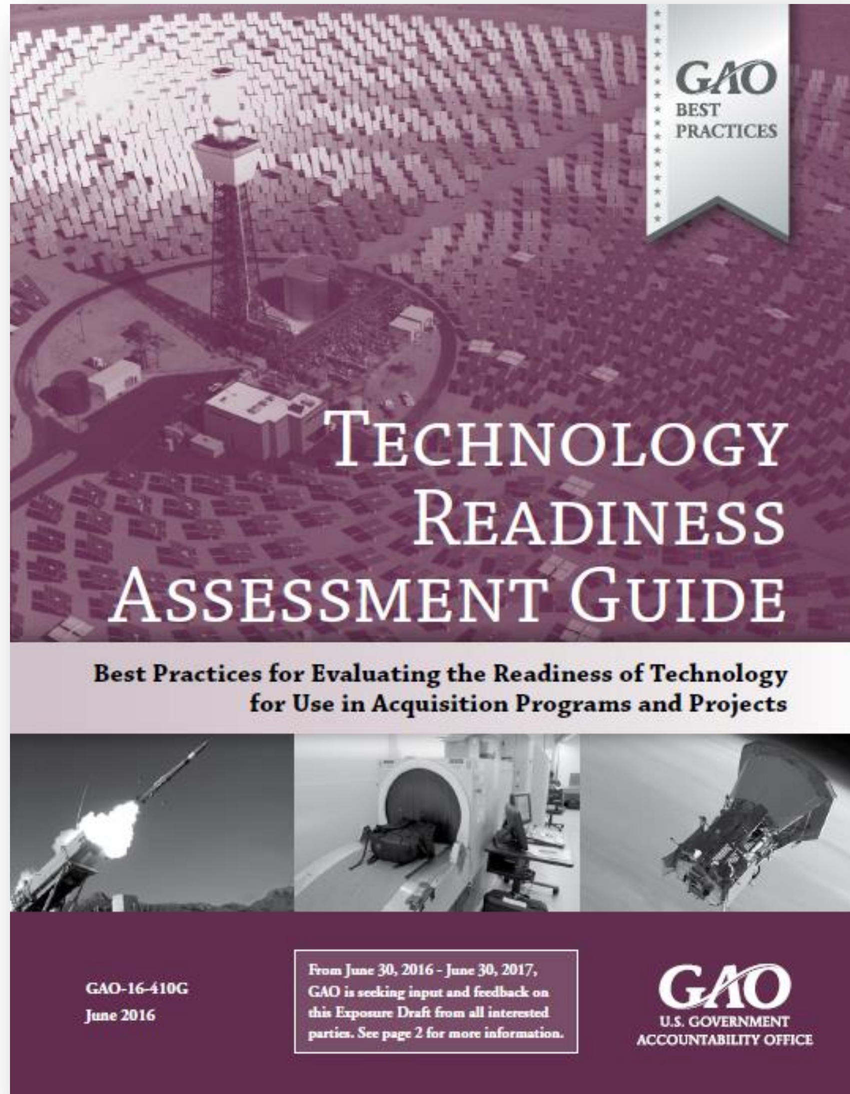
TECHNOLOGY READINESS LEVELS

Technology readiness level (TRL)		Description
1	**Basic principles observed and reported**	Lowest level of technology readiness. Scientific research begins to be translated into applied research and development. Examples include paper studies of a technology's basic properties.
2	**Technology concept and/or application formulated**	Invention begins. Once basic principles are observed, practical applications can be invented. Applications are speculative, and there may be no proof or detailed analysis to support the assumptions. Examples are limited to analytic studies.
3	**Analytical and experimental critical function and/or characteristic proof of concept**	Active research and development is initiated. This includes analytical studies and laboratory studies to physically validate the analytical predictions of separate elements of the technology. Examples include components that are not yet integrated or representative.
4	**Component and/or breadboard validation in laboratory environment**	Basic technological components are integrated to establish that they will work together. This is relatively low fidelity compared with the eventual system. Examples include integration of ad hoc hardware in the laboratory.
5	**Component and/or breadboard validation in relevant environment**	Fidelity of breadboard technology increases significantly. The basic technological components are integrated with reasonably realistic supporting elements so they can be tested in a simulated environment. Examples include high fidelity laboratory integration of components.
6	**System/subsystem model or prototype demonstration in a relevant environment**	Representative model or prototype system, which is well beyond that of TRL 5, is tested in its relevant environment. Represents a major step up in a technology's demonstrated readiness. Examples include testing a prototype in a high-fidelity laboratory environment or in a simulated operational environment.
7	**System prototype demonstration in an operational environment**	Prototype near or at planned operational system. Represents a major step up from TRL 6 by requirement demonstration of an actual system prototype in an operational environment (e.g., in an aircraft, a vehicle, or space).
8	**Actual system completed and qualified through test and demonstration**	Technology has been proven to work in its final form and under expected conditions. In almost all cases, this TRL represents the end of true system development. Examples include developmental test and evaluation of the system in its intended weapon system to determine if it meets design specifications.
9	**Actual system proven through successful mission operations**	Actual application of the technology in its final form and under mission conditions, such as those encountered in operational test and evaluation. Examples include using the system under operational mission conditions.

Source: GAO simplification of agency documents. | GAO-16-410G

Technology Readiness Assessment Guide

- Drafted 2015-2016, public exposure draft released today for one year
- Outlines GAO's criteria for evaluating technological readiness assessments
- Contains 10 chapters with supporting appendixes
- Chapters 1 & 2 define TRAs and describe their importance and limitations
- Chapter 3 outlines a reliable process for conducting TRAs
- Chapters 4-10 address the associated best practices
- Provides case studies of prior GAO audits to show typical findings related to the scheduling process



Six Steps to Develop a High Quality TRA

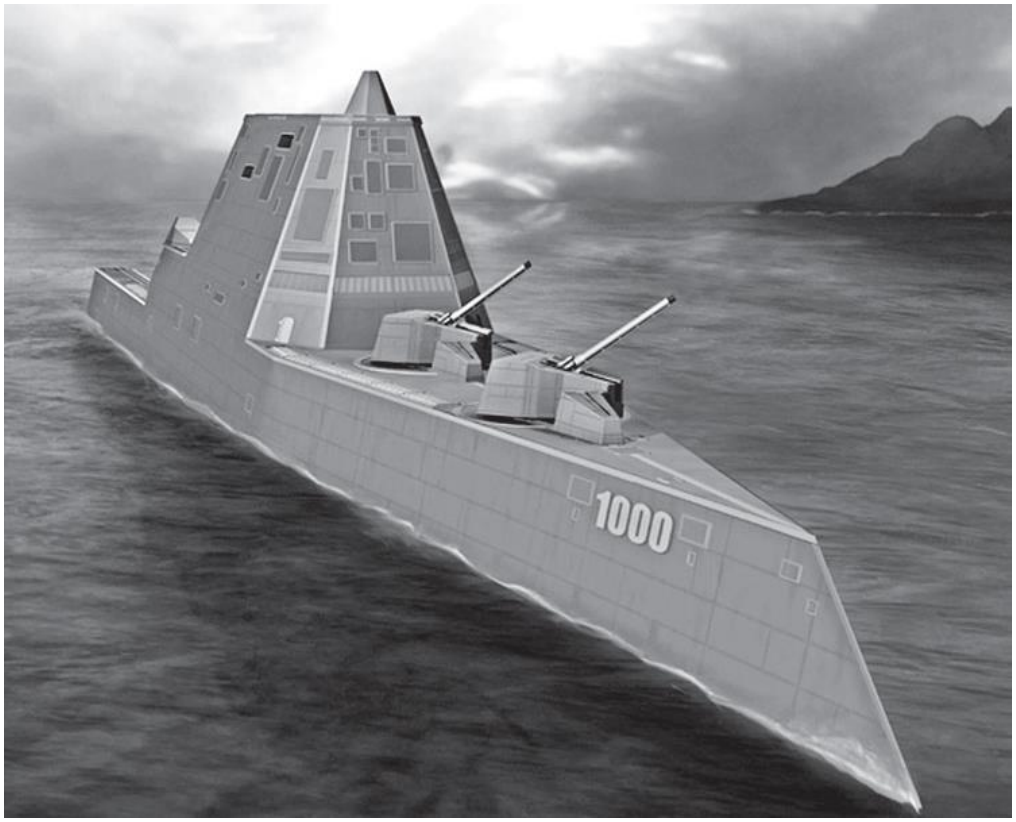
Define Purpose	• Determine purpose, level of detail, scope, TRL definition • Obtain pertinent information • Align assessment strategy to SE management plan
Develop Strategy, Plan, and Assemble Team	• Develop schedule and events • Determine specific team members and needed expertise • Outline the approach • Identify a plan for handling dissenting views
Select Critical Technologies	• ID purpose, system, and performance characteristics in a technology baseline document • Use a Work Breakdown Structure that characterizes the system to select critical technologies • Use key questions and environment to determine if a technology is critical

Six Steps to Develop a High Quality TRA

Evaluate Critical Technologies	• Determine TRL definitions and required evidence prior to assessment • Determine acceptability of test articles and environments • Determine if testing results are sufficient and acceptable • Document all relevant information
Prepare and Submit the TRA Report	• Prepare an official report that documents actions from previous steps • Obtain report comments and explain dissenting views
Use TRA Results and Develop a Technology Maturation Plan	• Use TRA results to make decisions about the program's development priorities • Program management identifies TRA-related concerns and risks, including potential effects on cost and schedule estimates • Develop a technology maturation plan to track progress

DDG-1000: Background

- The Navy's Zumwalt-class (DDG-1000) destroyers are multi-mission surface combatant ships that provide advanced land attack capability and contribute to dominance in shallow coastal waters.
- The program had challenging multi-mission requirements, resultant numerous technologies, and a tight construction schedule.
- GAO reviewed key systems and design maturity in 2008 (GAO-08-804)

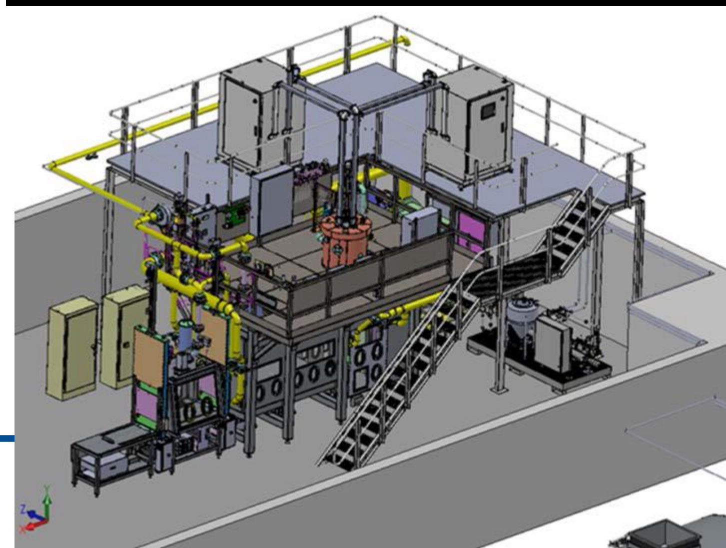


DDG-1000: Key Findings and Recommendations

- While the Navy faced significant technical and design challenges, they conceived a thoughtful acquisition strategy to:
  - develop key systems, and
  - mature the design before starting to build the ship.
- Several of the ship's key systems that depended on new technologies were successfully demonstrated; however, other key systems' demonstrations had been delayed
- GAO recommended:
  - Reduce program risk by requiring detail design completion prior to start of construction
  - Defer contract award for follow-on ships until lead ship costs better understood

Uranium Processing Facility: Background

- The National Nuclear Security Administration (NNSA) conducts enriched uranium activities—including producing components for nuclear warheads and processing nuclear fuel for the U.S. Navy—at the Y-12 National Security Complex in Tennessee.
- NNSA has identified key shortcomings in the Y-12 plant's current uranium operations, including rising costs due to the facility's age. In 2004, NNSA decided to build a more modern facility—the UPF—which will use nine new technologies that may make enriched uranium activities safer and more efficient.



Uranium Processing Facility: Findings

New technology	Description	May 2013 TRL assigned by UPF contractor	August 2013 TRL assigned by UPF independent peer review report
Phase I			
Microwave casting	A process that uses microwave energy to melt and cast uranium metal into various shapes	6	Less than 6[a]
Special casting	A custom process for casting uranium into various shapes	3	3
Bulk metal oxidation	A process that converts bulk uranium metal to oxide	7	7
Uranyl nitrate hexahydrate (UNH) calcination	A process that converts impure solutions into a stable, storable condition	5	5[b]
Saltless direct oxide reduction[c]	A process that converts uranium dioxide into metal	6	4 or 5
Recovery extraction centrifugal contactors	A process that uses solvent to extract uranium for purposes of purification	7	Not above 6[d]
Phase II			
Agile machining	A system that combines multiple machining operations—for fabricating metal into various shapes—into a single process	5	4
Chip management	An automated process that reduces operator interactions with machining process and improves worker safety by minimizing exposure to radioactive metal chips. It is one of the multiple operations to be performed through agile machining	6	5
Alternate processing of pins	A process to form uranium metal into custom shapes	7	6

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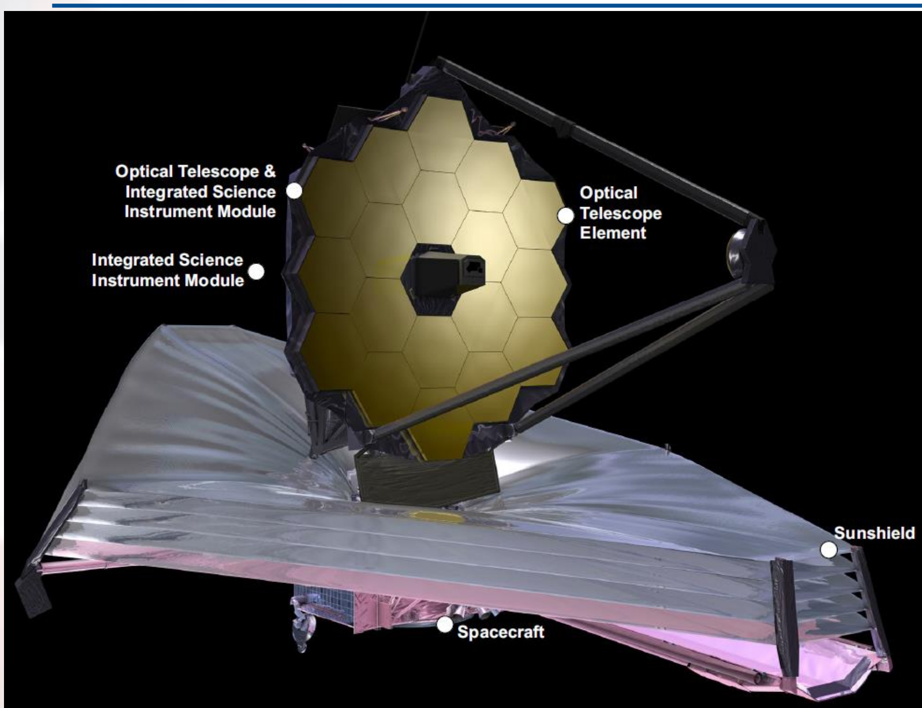
UPF: Key Recommendations

- DOE should fully adhere to best practices in its technology development activities by achieving a TRL 7 – the level where a prototype is demonstrated in an operational environment, has been integrated with other key supporting subsystems, and is expected to only have minor design changes – at the start of construction.
- NNSA's oversight of technology development efforts should continue to include independent peer review to help identify and respond to some technology development issues.

Many More Case Studies for TRA



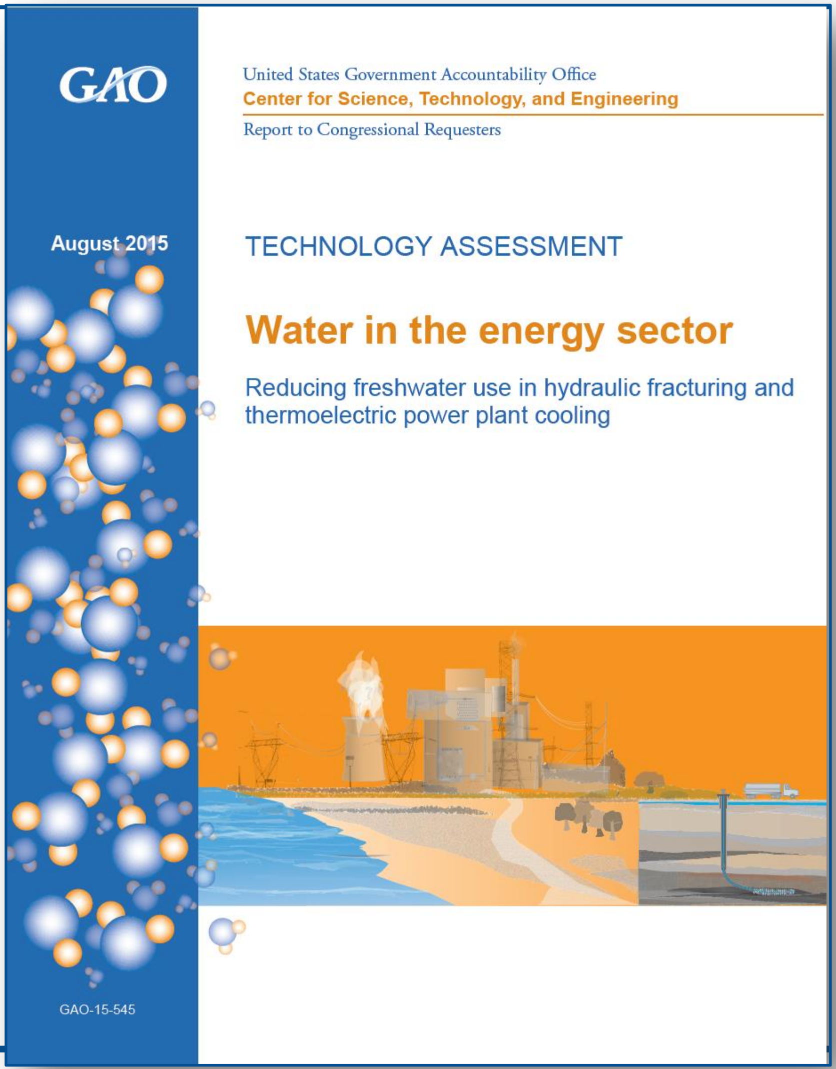
TRAs Used in Technology Assessments

Objectives

1. Assess advanced and emerging technologies that can reduce water use in hydraulic fracturing (HF) and thermoelectric power plant cooling.
2. Examine the impact of regional differences in thermoelectric power generation on water use in water-stressed versus unstressed areas in the United States.

Findings

1. Waterless and water-efficient fracturing technologies can reduce freshwater use in HF, although the main benefit is enhanced hydrocarbon recovery.
2. Dry and hybrid cooling systems reduce freshwater use but are less efficient than water cooling. Most emerging technologies are in the early stages of development.
3. Regional distribution of electricity generation reflects water stress conditions to a certain extent. In the most water-stressed regions, new construction of natural gas power plants has tended to use dry cooling technology.



Assessment of Advanced Cooling Tech

Maturity[a]	Potential effectiveness[b]	Cost factors[c]	Potential challenges and consequences
Hybrid wet-dry cooling			
High (TRL 9): • Hybrid systems with separate wet and dry cooling modes are operating at a few plants in the United States and many more abroad • A prototype configured as a single structure housing both wet and dry cooling systems is being tested at a power plant • Limited commercial operation at full-scale power plants in the United States, though more abroad	**Medium:** • Ability to save water is highly variable depending on ambient temperature, humidity, and plant operating conditions • Approximately 20-90 percent annual reduction in make-up water could be achieved. A 55 percent representative reduction would equate to an savings of 1.0 billion gallons per year (equivalent to 330 gals/MWh) compared to traditional wet cooling tower systems, while still retaining efficiency and capacity advantages during hot weather's peak load periods, compared to an all-dry system	• May cost more than wet recirculating cooling systems • Viability may depend on the cost of water versus the site-specific capital and operations and maintenance costs and the associated energy penalty	• More complex than wet cooling systems • Up to 10 percent more power production on the hottest days compared to an air-cooled condenser of an all-dry system • Existing dry cooled plants could be retrofitted with a separate wet cooled unit to improve cooling performance during hot days

Conclusions

- The GAO Cost Guide, Schedule Guide, and TRA Guide can provide criteria to evaluate many types of large technology-oriented and/or capital acquisition projects.

- Risk assessments such as technology readiness assessments, and independent cost and schedule assessments are often not performed – or are incomplete or lacking in independence, resulting in significant program risk and cost overruns.

- GAO recommendations have been aimed at improving oversight to keep projects on cost and schedule and to risk manage critical technologies in complex acquisitions.

- Programs/projects which do follow the best practices tend to demonstrate greater success in terms of outcomes and resource utilization.

Thank you- Any Questions?

Guides Available Online and Downloadable in PDF:

- GAO Cost Estimating and Assessment Guide:
  http://www.gao.gov/products/GAO-09-3SP

- GAO Schedule Assessment Guide:
  http://www.gao.gov/products/GAO-15-89G

- GAO Technical Readiness Assessment Guide:
  http://www.gao.gov/products/GAO-16-410G