GAO
and
Accountability in Technology Development

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The Government Accountability Office

A. Organization:

- **Mission:** The U.S. GAO is an independent agency in the legislative branch of the federal government. It exists to help Congress improve the performance and accountability of the federal government for the benefit of the American people.
- On July 13, 2004, law was passed changing its name from the General Accounting Office to the Government Accountability Office.
- Almost all of GAO's work is done at the request of committees or members, mandated by public laws or committee reports. GAO also undertakes its own research and development work under Comptroller General's authority.

The Government Accountability Office

- **Core Values:**
  - **Accountability:** Helping the Congress oversee federal programs and operations to ensure effective and efficient government
  - **Integrity:** Ensuring our work is professional, objective, fact-based, nonpartisan, non-ideological, fair and balanced
  - **Reliability:** Providing high-quality information that is timely, accurate, useful, clear, and candid
- **GAO staff issue reports, brief Members of Congress and their staff, and testify at congressional hearings**

- **A GAO audit normally assesses the business case:**
  - **Requirements management**
  - **Technology maturity**
  - **Realistic cost estimates**
  - **Risks management, and**
  - **Stability of funding**

- **In sum, GAO's work:**
  - **Oversight:** Ensuring performance
  - **Insight:** Deep knowledge of programs and operation**s**
  - **Foresight:** High-risk issues, emerging challenges

B. Accountability in Technology Programs

- Audits of defense acquisition programs involve assessment of science and technology developments.
- The focus is on applied technology being implemented in federal computing and information systems.
- Accountability in technology development is assessed through maturity, or technology readiness levels (TRLs).
- For software developments and acquisitions, the framework to asses maturity is the Capability Maturity Model (CMM).
- Both frameworks emphasize tests and evaluations.

Recall: TRLs and CMM

- TRL framework was developed at NASA in 1990s with the focus on quality control of space systems, especially in hardware qualifications.
- DARPA adopted and refined the framework for both hardware and software.
- In general, TRLs are structured framework for quality control, adopting common sense approaches such as Total Quality Management.
- CMM framework can be characterized as the model for software quality control. It is developed by CMU's Software Engineering Institute (SEI) for the DoD. It is now integrated with system engineering approaches.

Technology Readiness Levels (NASA)

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1. **Basic principles observed and reported**: Lowest level of technology readiness. Scientific research begins to be translated into applied research and development. Examples might include paper studies of a technology basic's 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 is no proof or detailed analysis to support the assumptions. Examples are limited to analytical studies.

3. **Analytical and experimental critical functions and/or characteristic proof of concept**: Active research and development are initiated, which include analytical and laboratory studies to physically validate analytical predictions of separate technology elements. Examples include components that are not yet integrated or representative.

Technology Readiness Levels

4. **Component and/or breadboard validation in laboratory environments:** Basic technology components are integrated to establish that they will work together. This is a relatively low fidelity compared to the eventual system. Examples include integrating *ad hoc* hardware in the laboratory.

5. **Component and/or breadboard validation in relevant environments:** Fidelity of breadboard technology increases significantly. The basic technology components are integrated with reasonably realistic supporting elements so they can be tested in a simulated environment. Examples include high fidelity integration of components in a laboratory.

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 a relevant environment, which represents a major step up in the technology's demonstrated readiness. Examples include testing a prototype in a high-fidelity laboratory or simulated operational environment.

Technology Readiness Levels

7. **System prototype demonstration in an operational environment**: Prototype is near or at planned operational system. This is a major step up from TRL 6 and requires demonstrating an actual system prototype in an operational environment such as an aircraft, vehicle, or in space. Examples include testing the prototype in a test-bed aircraft.

8. **Actual system completed and "flight 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 is the end of true system development. Examples include developmental test and evaluation of the system in its intended weapon system to see if it meets design specifications.

9. **Actual system "flight 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. In almost all cases, this is the end of the bug-fixing aspect of true system development. Examples include using the system in operational mission conditions.

Capability Maturity Model (CMM)

- Developed by SEI for software quality control.
- Establish a 5-level maturity framework in software development and acquisition.
- Integrating with system engineering practices, the model is currently known as CMM-I:
  - Level 0: Ad-hoc, incomplete
  - Level 1: Performed
  - Level 2: Locally Managed
  - Level 3: Defined
  - Level 4: Institutionally managed
  - Level 5: Optimizing
- Each level has its own goals and practices.
- Emphasis is in process management.

Accountability in Technology Development

- Focus on the TRLs and risk reduction programs in capital programs.
- Software maturity and manufacturing readiness have been persistent challenges.
- Technology maturity may be a component of project risks, i.e., schedule delay, technical challenges and cost overrun.
- Technical risks could be the basis for recommendation to terminate or restructure programs, e.g., need breakthroughs in some discipline or incremental progress is too costly.
- Developing operational guides for assessing TRLs in capital programs.
- GAO is exploring the possibility of developing a Technology Readiness Assessment Guide that builds on the success of the GAO Cost Estimating and Assessment Guide (http://www.gao.gov/products/GAO-09-3SP) and the upcoming Schedule Assessment Guide.

OBJECTIVES

- Raise awareness about the importance of technology readiness outside of the DOD and NASA. Reinvigorate interest in technology readiness assessments at DOD.
- Give program managers and decision makers tools to put them in a better position to assess technology maturity and manage risks.
- Provide a common language on how to talk about technology-related issues.
- Improve technology investment decisions and outcomes in light of budget constrained environment and decreased federal spending.
- Increase likelihood that science and technology projects are successfully transitioned from the lab to acquisition programs.
- Provide an audit tool for GAO analysts and others examining these issues.

OBJECTIVES

- **The proposed "*GAO Technology Readiness Assessment Guide*" would describe best practices for conducting technology readiness assessments of hardware and software for projects using established criteria and methodologies. It would also discuss best practices for managing technology maturation and manufacturing readiness - key issues that have been the focus of GAO's work for more than a decade.**

- **The initial phase of the project will focus on: (1) What is the appropriate scope for the guide? (2) Who are the leading thinkers and organizations in technology-related issues as they relate to acquisitions? (3) To what extent does consensus exist among those thinkers and organizations on how to evaluate technology readiness and manage technology insertion?**

Software Readiness Levels (DARPA)

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1. **Basic principles observed and reported**: Lowest level of software readiness. Basic research begins to be translated into applied research and development. Examples might include a concept that can be implemented in software or analytical studies of an algorithm'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 is no proof or detailed analysis to support the assumptions. Examples are limited to analytical studies.

3. **Analytical and experimental critical functions and/or characteristic proof of concept**: Active research and development are initiated, which include analytical studies to produce code that validates analytical predictions of separate software elements. Examples include software components that are not yet integrated or representative, but satisfies an operational need. Algorithms run on a surrogate processor in a laboratory environment.

Software Readiness Levels

4. **Component and/or breadboard validation in laboratory environment:** Basic software components, which are relatively primitive with regard to efficiency and reliability compared to the eventual system are integrated to establish that they will work together. System software architecture development initiated includes interoperability, reliability, maintainability, extensibility, scalability, and security issues. Software is integrated with simulated current and legacy elements as appropriate.

5. **Component and/or breadboard validation in relevant environments:** Reliability of software ensemble increases significantly. The basic software components are integrated with reasonably realistic supporting elements so that they can be tested in a simulated environment. Examples include high-fidelity laboratory integration of software components. Algorithms run on a processor(s) with characteristics expected in the operational environment. Software releases are “alpha” versions and configurations and configuration control is initiated. Verification, validation, and accreditation (VV&A) is initiated.

6. **System/subsystem model or prototype demonstration in a relevant environment:** Representative model or prototype system, which is well beyond that of SRL 5, is tested in a relevant environment, which represents a major step up in the software’s demonstrated readiness. Examples include testing a prototype in a live or virtual experiment or in a simulated operational environment. Algorithms run on a processor(s) in an operational environment that is integrated with actual external entities. Software releases are “beta” versions and configuration is controlled. Software support structure is in development; VV&A is in process.

Software Readiness Levels

7. **System prototype demonstration in an operational environment**: Represents a major step up from SRL 6 and requires demonstrating an actual system prototype in an operational environment such as a command post or an air or ground vehicle. Algorithms run on a processor(s) that is part of the operational environment and is integrated with actual external entities. Software support structure in place; software releases are distinct versions. Frequency and severity of software deficiency reports do not significantly degrade functionality or performance. VV&A is completed.

8. **Actual system completed and "flight qualified" through test and demonstration**: Software has been demonstrated to work in its final form and under expected conditions. In almost all cases, this SRL is the end of system development. Examples include software test and evaluation in its intended system to see if it meets design specifications. Software releases are production versions and configuration is controlled in a secure environment. Software deficiencies are rapidly resolved through the support structure.

9. **Actual system "flight proven" through successful mission operations:** Actual application of the software in its final form and under mission conditions such as those encountered in operational test and evaluation. In almost all cases, this is the end of the bug-fixing aspect of system development. Examples include using the system in operational mission conditions. Software releases are production versions and configuration is controlled. Frequency and severity of software deficiencies are minimal.

Manufacturing Readiness Levels

1. **Basic manufacturing implications identified:** Lowest level of manufacturing readiness. The focus is to address manufacturing shortfalls and opportunities needed to achieve program objectives. Basic research, i.e., funded by a budget activity 6.1, starts with studies.

2. **Manufacturing concepts identified**: Describing the application of new manufacturing concepts. Applied research, i.e., 6.2 funding, translates basic research results into solutions to broadly defined applications. Typically this level of readiness in the S&T environment includes identification, paper studies and analysis of material and process approaches. An understanding of manufacturing feasibility and risk is emerging.

3. **Manufacturing proof of concept developed**: This level begins the validation of laboratory experiments. Typical of technologies in the S&T funding categories of Applied Research and Advanced Development, i.e., 6.3 funding. Materials and/or processes have been characterized for manufacturability and availability but further evaluation and demonstration is required. Experimental hardware models have been developed in a laboratory environment that may possess limited functionality.

Manufacturing Readiness Levels

4. **Capability to produce the technology in a laboratory environment:** Typical for S&T programs in 6.2 & 6.3 categories; should be at TRL 4 and ready for Technology Development Phase of acquisition. Requirements such as manufacturing technology development have been identified.

5. **Capability to produce prototype components in a production relevant environment:** Typical of the mid-point level in the TDP of acquisition, or of the Advanced Technology Demonstration; should be at TRL level 5. A manufacturing strategy has been refined and integrated with the risk management plan.

6. **Capability to produce a prototype subsystem or system in a production relevant environment:** Associated with a decision to initiate an acquisition program; typically at TRL 6. In the S&T environment, it is at the level of completion of development and acceptance into a preliminary system design. An initial manufacturing approach has been developed. The majority of manufacturing processes have been defined and characterized, but there a still significant engineering and/or design changes in the system itself.

Manufacturing Readiness Levels

7. **Capability to produce system, subsystem, or components in a production representative environment:** Typical for the mid-point of the Engineering and Manufacturing Development (EMD) phase; technologies should be at TRL 7. System design review is underway. Materials specifications have been approved and materials are available to to meet the planned pilot line build schedule.

8. **Pilot line capability demonstrated; Ready to begin Low Rate Initial Production:** Typically associated with an entry into LRIP; technologies involved should be at TRL 8. Detailed system design is essentially complete.

9. **Low rate production demonstrated; Capability in place to begin Full Rate Production:** At this level, the system, component or item has been previously produced, or has successfully achieved LRIP; technologies are at TRL 9. This level also enables entry into FRP. All system engineering/design requirements should have been met such that there are minimal system changes.

Manufacturing Readiness Levels

10. **Full Rate Production demonstrated and lean production practices in place:** This is the highest level of production readiness, normally associated with the Production or Sustainment of the product acquisition cycle; technologies should be at TRL 9.

Some Definitions

- **Production relevant environment:** An environment with some shop floor production realism present (such as facilities, personnel, tooling, processes, materials etc.). There should be minimum reliance on laboratory resources during this phase. Demonstration in a production relevant environment implies that contractor(s) must demonstrate their ability to meet the cost, schedule, and performance requirements of the EMD Phase based on their production of prototypes. The demonstration must provide the program with confidence that these targets will be achieved. Furthermore, there must be an indication of how the contractor(s) intend to achieve the requirements in a production representative and pilot environments.
- **Production representative environment:** An environment that has as much production realism as possible, considering the maturity of the design. Production personnel, equipment, processes, and materials that will be present on the pilot line should be used whenever possible. The work instructions and tooling should be of high quality, and the only changes anticipated on these items are associated with design changes downstream that address performance or production rate issues. There should be no reliance on a laboratory environment or personnel.

Some Definitions

- **Pilot line environment:** An environment that incorporates all of the key production realism elements (equipment, personnel skill levels, facilities, materials, components, work instructions, processes, tooling, temperature, cleanliness, lighting etc.) required to manufacture production configuration items, subsystems or systems that meet design requirements in low rate production. To the maximum extent practical, the pilot line should utilize full rate production processes.

Some Definitions

- **Manufacturability:** The characteristics considered in the design cycle that focus on process capabilities, machine or facility flexibility, and the overall ability to consistently produce at the required level of cost and quality. Associated activities may include some or all of the following:
  - Design for commonality and standardization - fewer parts
  - Perform comprehensive technology assessment, including commercial industrial applications and the supplier base
  - Design for multi-use and dual-use applications
  - Design for modularity and plug compatible interface/integration
  - Design for flexibility/adaptability or use “robust design”
  - Utilize reliable processes and materials
  - Utilize monolithic and determinant assembly
  - Design for manufacturing and assembly
  - Achieve production yield

- **Producibility:** The relative ease of producing an item that meets engineering, quality and affordability requirements.

- Back-up Slides

I. OVERVIEW OF THE U.S. GOVERNMENT

II. THE CONGRESS

A. Organization

B. The Legislative Process

C. The 112th Congress

III. The U.S. Government Accountability Office

A. Organization

B. Accountability in Technology Development

I. OVERVIEW OF THE U.S. GOVERNMENT

A. The Three Branches
   1. Legislative branch: Makes laws
   2. Executive branch: Enforces
   3. Judicial branch: Interprets laws

B. Checks and Balances
   1. Congress: Appropriations, oversight, filibuster
   2. Executive: Privileges, foreign policy
   3. Judicial: Jurisdiction & The Courts, nomination & confirmation, constitutionality

C. Modus operandi: Government accountability and transparency

II. THE CONGRESS

A. Organization

1. Senate: 100, 2 from each state: advise and consent
2. House: 435, from districts based on populations: power of the purse
3. Committees with jurisdictions. Some committees are more important than others: Appropriations, Budget, Ways and Means, Armed Services, etc.
4. Senate confirmation hearings of federal judges and executive officials, House's "power of the purse"

B. The Legislative Process

- Legislation (bill) to take place in both houses
- Conference resolves differences between Senate's and House's bills
- Conference report sent to the President
- If signed, bill becomes law; if not,
  - If vetoed, 2/3 votes needed to override in both houses
  - If not vetoed, law takes effect after 10 days if Congress is in session; if Congress has adjourned, "pocket veto"!
- Give-and-take between lawmakers during drafting/markup or conference of legislation
- Constituents' interests and professional lobby weigh heavily in deliberation and resultant legislation

C. The 112th Congress

- House: 435 members: 242 Republicans; 190 Democrats; 0 Independent; 3 vacancies; majority needed to pass a bill: 218 ayes
- Senate: 100 senators; 51 Democrats, 47 Republicans, 2 Independents; majority: 51, VP votes if tied 50-50! Majority decides agenda

- Compromise essential to pass bills
- An administration's agenda depends on the composition of the Congress
- Some legislations become laws with 1 vote difference.