DEPARTMENT OF DEFENSE

Technology Readiness Assessment Deskbook

September 2002

Prepared by the
Deputy Under Secretary of Defense for Science and Technology (DUSD(S&T))

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I. INTRODUCTION

1.1 BACKGROUND

The recently revised Department of Defense (DoD) acquisition system is documented in Department of Defense Directive (DoDD) 5000.1,[1] Department of Defense Instruction (DoDI) 5000.2,[2] and DoD 5000.2-R,[3] all of which are available on Internet Web Site http://dod5000.dau.mil/index.htm.

A central theme of the acquisition system is that the technology employed in system development should be "mature" before system development begins.[4] Normally, for technology to be considered mature, it must have been applied in a prototype article (a system, subsystem, or component), tested in a relevant or operational environment, and found to have performed adequately for the intended application. This implies a need for a way to measure maturity and for a process to ensure that only sufficiently mature technology is employed. The DoD 5000 series of documents establish a requirement for Technology Readiness Assessments (TRAs) and provide an outline of the process and responsibilities for performing TRAs. These documents introduce Technology Readiness Levels (TRLs) as an accepted way to describe technology maturity. The National Aeronautics and Space Administration (NASA) has defined and used TRLs in its program reviews, and the NASA definitions are the basis for the definitions being used in DoD. A readiness level of TRL 6 or, preferably, TRL 7 is normally achieved before a technology is used in system development.

To carry out TRAs, DoD 5000.2-R assigns responsibilities to Program Managers (PMs), Component Science and Technology (S&T) Executives, Component Acquisition

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1 DoDD 5000.1, *The Defense Acquisition System,* October 23, 2000 (Administrative Reissuance Incorporating Change 1, January 4, 2001).

2 DoDI 5000.2, *Operation of the Defense Acquisition System,* April 5, 2002.

3 DoD 5000.2-R, *Mandatory Procedures for Major Defense Acquisition Programs (MDAPS) and Major Automated Information System (MAIS) Acquisition Programs,* April 5, 2002.

4 This reflects a major conclusion of a study performed by the Government Accounting Office (GAO). See Appendix B.

Executives (CAEs), and the Director of Defense Research and Engineering (DDR&E).[5] TRAs must be carried out before Milestone B and Milestone C of acquisition programs categorized as Acquisition Category One (ACAT I): ACAT ID[6] or ACAT IAM.[7]

1.2 PURPOSE OF THIS DOCUMENT

The current document is intended as a "TRA Deskbook" that will aid PMs, Component S&T Executives, CAEs, and their respective staffs and will serve as a guide to support everyone involved in the TRA process. Appendix A contains Points of Contact (POCs) for various TRA activities.

1.3 ORGANIZATION OF THIS DOCUMENT

The body of this document is a concise description of the responsibilities and procedures for meeting the TRA requirements of the Defense Acquisition System (DAS). The intent is to provide a working appreciation of the overall process and of where and how the TRAs fit into defense acquisition, including enough detail to allow a participant to get to work quickly. A set of appendixes provides the details of procedures, formats, templates, and so forth.

The expectation is that the basic architecture of the TRA process will remain relatively stable over time, whereas the details implementing the process will evolve, grow, or

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5 The current editions (as of 30 August 2002) of DoDI 5000.2 and DoD 5000.2-R assign this responsibility to the Deputy Under Secretary of Defense for Science and Technology (DUSD(S&T)). A pending memorandum from the Under Secretary of Defense for Acquisition, Logistics, and technology (USD(AT&L)) (see Appendix D of this document) assigns this responsibility to the Director of Defense Research and Engineering (DDR&E). The Office of the Director of Defense Research and Engineering (ODDR&E) staff proponent for TRAs is the DUSD(S&T).

6 An ACAT ID is a subcategory of the ACAT I program. ACAT I programs are Major Defense Acquisition Programs (MDAPs) or programs that the Milestone Decision Authority (MDA) designates ACAT I. An MDAP is an acquisition program that is not a highly sensitive classified program (as determined by the Secretary of Defense) and is designated by the USD(AT&L) as an MDAP or is estimated to cost more than certain specified amounts. The MDA for ACAT ID programs is the USD(AT&L). The "D" refers to the Defense Acquisition Board (DAB), which advises the USD(AT&L) at major decision points.

7 An ACAT IAM is a subcategory of the ACAT IA program. ACAT IA programs are Major Automated Information Systems (MAISs) or programs designated by the Assistant Secretary of Defense for Command, Control, Communications, and Intelligence (ASD(C3I)) to be ACAT IA. The MDA for the ACAT IAM programs is the DoD Chief Information Officer (CIO), who is ASD(C3I). The "M" in ACAT IAM refers to MAISs.

perhaps even become simpler over time. As changes occur, adapting the appendixes will provide an effective way for the deskbook to accommodate these changes.

1.4 ACQUISITION PROCESS OVERVIEW

Figure I-1 shows the architecture, or framework, of the defense acquisition process. An acquisition program is normally established in response to a recognized user need, but it could also be established to exploit a technological opportunity that might result in a new military capability, a reduced cost, or other benefit.

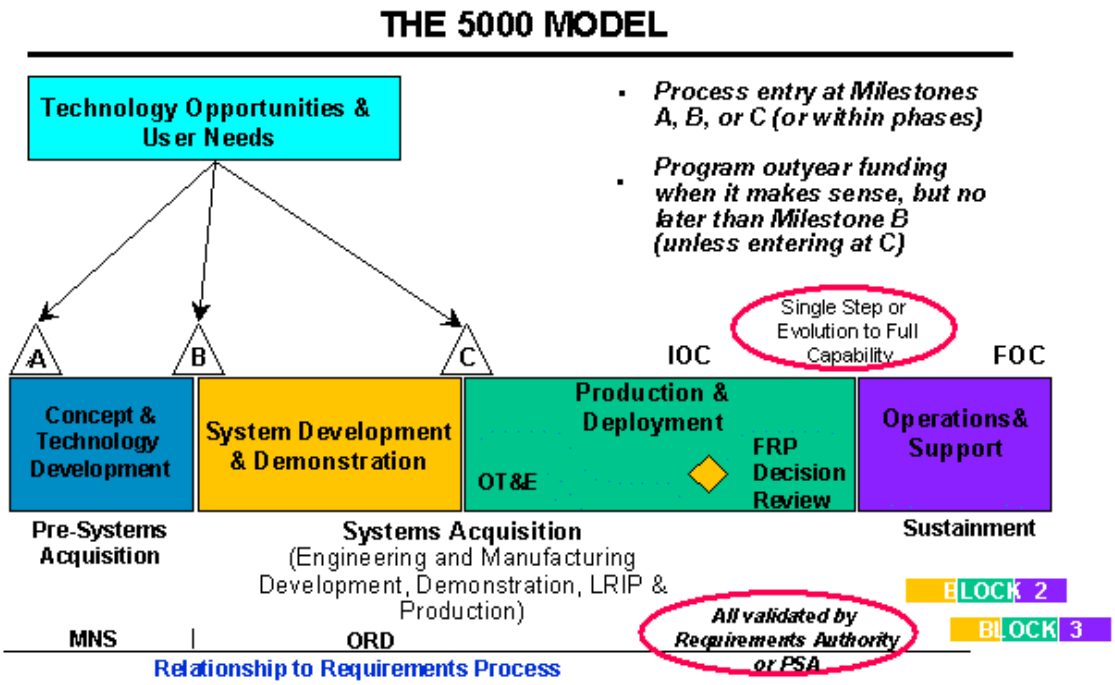

Figure I-1. Defense Acquisition Management Framework (Source: DoDI 5000.2)

During the first phase [Concept and Technology Development (CTD)], various system concepts, operational concepts, and technologies are examined to arrive at a system architecture. This is often a competitive phase that ends with the selection of a preferred system concept and a contractor. Most of the technologies needed to realize the system concept can be identified during this phase. A TRA is required before the Milestone B decision. The purpose of the Milestone B TRA is to ensure that the critical technologies on which the concept is based are sufficiently mature (or have acceptable risk-mitigation plans in place) so that the system development will not be delayed, overly costly, or unsuccessful.

Milestone B authorizes the program to proceed to the System Development and Demonstration (SDD) phase. During this phase, the system design and the manufacturing processes are developed, and developmental testing and operational testing are carried out to prove the functionality and operational effectiveness of the system. Prototypes demonstrated in an operational environment during the later part of SDD should be close to the production design and should be produced with final production processes wherever possible. A TRA is also required before the Milestone C decision, which authorizes the system for production and deployment.

The framework just described can be tailored to the specific acquisition program structure. For example, the program does not have to start at Milestone A. It can start at Milestone B or some other place between Milestone A and Milestone C. If it starts at or beyond Milestone B, a TRA will be conducted to ensure that the technology is ready for the upcoming phase of development.

The DoD 5000 series of documents encourage the use of an evolutionary acquisition strategy, and they require this strategy if the Operational Requirements Document (ORD) has time-phased requirements. An evolutionary acquisition strategy is one in which development, test, production, and deployment are conducted for two or more blocks of capability. The first block (Block 1) provides a useful, supportable capability. Each subsequent block provides greater capability until the objective capability of the ORD is realized. Normally, each successive block introduces later technology. To ensure that the technology is mature, a TRA is required for each block before the program has a Milestone B or Milestone C review.

Software is developed using a special process. This is an iterative, cyclical process of build-test-fix-test-deploy, often referred to as spiral development. Each release builds on the lessons of the previous release. There can be several releases during the acquisition and deployment of a system or system block. In the TRA process, software is considered an integral part of the system or subsystem in which it operates.

II. KEY RESPONSIBILITIES

Before an acquisition program can enter SDD (at Milestone B) or low rate initial production (LRIP) (at Milestone C), technology maturity must be assessed (paragraph C7.5.2, DoD 5000.2-R). DoDI 5000.2 establishes as acquisition policy that "… Unless some other factor is overriding in its impact, the maturity of the technology will determine the path to be followed" (paragraph 4.7.3.2.2.1). It further states that "… If technology is not mature, the DoD Component shall use alternative technology that is mature and that can meet the user's needs" (paragraph 4.7.3.2.2.2).

The PM is especially important in defense acquisition. He/she is responsible for planning and managing each program. The PM reports to a Program Executive Officer (PEO), who oversees several PMs. The PEO reports directly to the CAE, who reports through the Component Secretary to the Under Secretary of Defense for Acquisition, Technology, and Logistics (USD(AT&L)).

The Component S&T Executive also reports to the CAE. The Component S&T Executive is responsible for developing the noncommercial technologies that will be needed to meet future operational requirements and for directing the Component TRAs. These TRAs are submitted to the CAE for approval, and an information copy is sent to the DDR&E. Subsequently, the CAE transmits the action version to the DDR&E. The DDR&E reports to the USD(AT&L) and is responsible for managing the overall Science and Technology (S&T) program within DoD and for evaluating each TRA received from a Component.

Determining a technology's maturity involves the participation of the PM, the Component S&T Executive, and the DDR&E.[8] The following paragraphs elaborate on these responsibilities. Figure II-1 is a nominal timeline for the required TRA activities. Figure II-2 displays the principal activities/responsibilities of the DDR&E Action Officer (AO). Section IV discusses the process.

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[8] Appendix C includes extracts from the DoD 5000 series of documents that assign TRA responsibilities.

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Pages II-3 and II-4 are holder pages for an 11 × 17” figure that will be supplied.

2.1 Program Manager (PM)

2.1.1 Determining System Architecture and Identifying Technologies

Before Milestone B (during Concept Exploration and Component Advanced Development), the system architecture is determined, and the technologies required to develop the system are identified. Whenever the system concept requires technologies that are still being developed by Component S&T organizations, the PM will negotiate Technology Maturity Agreements (TMAs) with the Component S&T Executive. These agreements specify activities to be conducted to mature the technologies, the expected resulting TRL, the schedule, and the funding. See paragraph 2.2.1. Appendix F of this document contains a suggested TMA format.[9]

2.1.2 Requesting Milestone Review Meetings

The PM is responsible for requesting milestone review meetings. For ACAT ID programs, the Defense Acquisition Board (DAB)[10] conducts the review. For ACAT IAM programs, a group assembled by DoD's Chief Information Officer (CIO)[11] conducts the review. Concurrently with scheduling a milestone review meeting, the PM establishes a schedule for the submission of critical technologies. When establishing the schedule for submitting critical technologies, coordinating with the Component S&T Executive and, for ACAT ID and ACAT IAM programs, with the DDR&E is important so that each organization will have ample time to complete its respective TRA activities.

2.1.3 Determining Critical Technologies and Disseminating Information

The PM is charged with the fundamental task of determining which technologies are critical. A technology is "critical" if the system being acquired depends on this technology to meet the system operational requirements (including key performance parameters and cost) in development, production, and operation *and* if the technology or its application is either new or novel. Said another way, a new or novel technology is critical if it is

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9 The TMA format in Appendix F is an Army version. The reader will notice that the Army refers to a TMA as a "Technology Maturity Assessment."

10 The DAB is chaired by the USD(AT&L), who is the MDA for ACAT ID programs. The Vice Chairman of the Joint Chiefs of Staff (VCJCS) serves as the vice chairman.

11 The meeting is chaired by the ASD(C3I), who is the DoD CIO and MDA for ACAT IAM programs.

necessary to achieve the successful development of a system, its acquisition, and its operational utility.

Before identifying the critical technologies, the PM should send the DDR&E and the Component S&T Executive a memorandum that describes the process that will be used. About 16 weeks before a milestone review (see Figure II-1), on the schedule agreed to with the DDR&E and the Component S&T Executive, the PM should identify the critical technologies and compile the status, test results, and other information necessary to assess the maturity of these technologies.

After determining the critical technologies, the PM provides this information to the Component S&T Executive and sends an information copy to the DDR&E. Preferably, the identification of critical technologies will have been vetted and agreed upon between the PM and Component S&T Executive. In addition to the list of critical technologies, the PM should explain the function of each technology in the system and provide information on the status of each technology. This could include records of tests or applications of the technology. The PM should provide additional information as requested by the Component S&T Executive or the DDR&E. This identification of critical technologies is a critical step in the TRA process. For a readiness assessment to be useful, it must include all the critical technologies.

If an ACAT ID or ACAT IAM program integrates critical systems that are being developed in other programs, the PM of the higher order program (the "system-of-systems" program) is responsible for the technologies—including interface technologies—used on his/her side of the interfaces for the TRA. This PM should request (through the appropriate PEO or CAE, as necessary) and obtain the identification of any critical technologies on which the lower order programs depend.

If a program has competing designs at the time of the Milestone B or Milestone C review, the critical technologies of each design must be identified separately.

2.2 COMPONENT SCIENCE AND TECHNOLOGY (S&T) EXECUTIVE

2.2.1 Providing the Required Technology

The Component S&T Executive is responsible for developing the noncommercial technologies that will be needed to meet future operational requirements. In addition to advising PMs regarding the status and applicability of technologies, the Component S&T Executive will enter into TMAs with the PMs to establish how technologies will be matured

to support system development programs. These agreements are coordinated among all the stakeholders and reviewed by the DDR&E. They obligate the Component S&T Executive and the PM to a best-efforts commitment to meet a technology maturation schedule.

2.2.2 Directing the TRA

The Component S&T Executive directs the TRA and decides how it will be conducted. The TRA must include all critical technologies identified by the PM and can include additional technologies that the Component S&T Executive considers critical. Typically, much of the information used in a TRA comes from the PM, but the assessment *must be independent* of the PM.

The TRL definitions (see Section III, Table III-1) provide a convenient and unambiguous nomenclature for a technology's maturity status. The Component should use TRLs to relate TRA findings unless the DDR&E has approved alternative means beforehand. Willoughby charts are a possible alternative. An explanation of the assessed maturity status is required.

2.2.3 Processing the TRA Results

For ACAT ID and ACAT IAM programs, the Component S&T Executive signs the TRA (or accompanying memorandum) and accepts responsibility for its accuracy. He/she then submits the TRA to the CAE and, at the same time, sends an information copy to the DDR&E.

2.3 COMPONENT ACQUISITION EXECUTIVE (CAE)

For ACAT ID and ACAT IAM programs, the CAE submits a report to the DDR&E with an assessed TRL (or some equivalent measure) for each critical technology. This report can consist of a cover letter or memorandum endorsing the Component TRA and officially transmitting that TRA. This should be accomplished according to the agreed-upon schedule—normally, at least 6 weeks before a scheduled Milestone B or Milestone C. See Figure II-1.

2.4 DIRECTOR OF DEFENSE RESEARCH AND ENGINEERING (DDR&E)

2.4.1 Preparation and Oversight

The DDR&E has both oversight and evaluation responsibilities for the TRA. An Action Officer (AO) assists as directed (see Figure II-2). Before the TRA is officially received from the Component, the AO reviews the critical technologies and the identification process, negotiates any perceived deficiencies, and provides oversight while the Component TRA is conducted. In addition, the AO participates in the TRA to the extent mutually agreed upon with the Component S&T Executive.

2.4.2 Evaluating the Component TRA

The DDR&E evaluates the Component TRA in cooperation with the Component S&T Executive and the PM. There is no rigid requirement that every critical technology has to be at a pre-specified TRL by Milestone B or Milestone C. However, for Milestone B, readiness levels of at least TRL 6 are typical (TRL 7 preferred), and, for Milestone C, readiness levels of at least TRL 8 are typical (TRL 9 preferred). At Milestone B, the DDR&E might conclude that a readiness level of TRL 5 is adequate for a critical technology if there is in place a planned and funded program to mature the technology quickly or if there is a mature backup technology that meets the program requirements and schedule. If the Component expects such a conclusion, the supporting information must be provided along with the TRA. At Milestone C, a similar situation could arise—most likely with respect to the manufacturing process technology required to achieve required production rates or cost goals.

After evaluating the Component TRA, the DDR&E either concurs with the findings or conducts an independent TRA. The DDR&E forwards either a concurrence with the findings of the Component TRA or the findings of the independent TRA to the Overarching Integrated Product Team (OIPT) and the DAB or CIO Review Group. This takes place at least 15 days before a Milestone B or Milestone C decision meeting (see Figure II-1). If this 15-day window is not possible, the date of the decision meeting should be reconsidered so the OIPT and DAB members or CIO Review Group members have ample time to review all the relevant information.

2.4.3 Preparing the National Defense Authorization Act (NDAA) Reports for the Secretary of Defense

Sec. 804 of the NDAA for Fiscal Year 2002, Conference Report, requires the Secretary of Defense to submit reports on the implementation of the DoD technology readiness policy. The DDR&E is responsible for preparing these reports. Paragraph 2.7 describes the responsibilities and procedures in more detail.

2.5 CHAIRMAN, OVERARCHING INTEGRATED PRODUCT TEAM (OIPT)

The OIPT [or, in the case of an ACAT IAM program, the Information Technology Overarching Integrated Product Team (IT OIPT)] is led by the appropriate Office of the Secretary of Defense (OSD). It is composed of

- The PM
- The PEO
- The representatives of the Component staff, the USD(AT&L) staff, the Assistant Secretary of Defense for Command, Control, Communications, and Intelligence (ASD(C3I)) staff, and the Joint Staff
- Other OSD principals involved in the oversight and review of a particular ACAT ID or ACAT IAM program.

The OIPT or IT OIPT provides strategic guidance for the early resolution of issues and conducts oversight and review as a program proceeds through its acquisition life cycle.

2.6 MILESTONE DECISION AUTHORITY (MDA)

The MDA is the individual designated in accordance with criteria established by the USD(AT&L)—or the ASD(C3I) for Automated Information System (AIS) acquisition programs—to approve the entry of an acquisition program into the next phase. The DAB or CIO Review Group provides a recommendation to assist the MDA in the decision.

2.7 SECRETARY OF DEFENSE

For each of the calendar years 2002 through 2005, the Secretary of Defense is required to report to Congress on the implementation of DoD policy regarding technology

maturity at the initiation of Major Defense Acquisition Programs (MDAPs)[12]. According to Sec. 804 of the NDAA for Fiscal Year 2002, Conference Report, the reports must

> identify each case in which a major defense acquisition program entered system development and demonstration [i.e., passed MS B] during the preceding calendar year and into which key technology has been incorporated that does not meet the technological maturity requirement [i.e., that technology must have been demonstrated in a relevant environment or, preferably, in an operational environment, to be considered mature enough to use for product development in systems integration] described in subsection (a) and provide a justification for why such technology was incorporated; and
>
> identify any determination of technological maturity with which the Deputy Under Secretary of Defense for Science and Technology[13] did not concur and explain how the issue has been or will be resolved.

The report for each calendar year must be submitted to the Committees on Armed Services of the Senate and the House of Representatives by March 1 of the following year (i.e., March 1 of years 2003 through 2006).

At the conclusion of each MDAP milestone review, an office designated by the DDR&E will compile the necessary information for these reports. At the beginning of each calendar year (2003 through 2006), the designated office will prepare the report for the Congressional committees. The DDR&E will submit the report to the USD(AT&L) for concurrence and forwarding to the immediate office of the Secretary of Defense. The Secretary of Defense will sign the report or cover letter and submit it to the Congressional committees as required.

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12 This requirement is contained in Sec. 804 of the National Defense Authorization Act for Fiscal Year 2002, Conference Report. Appendix D of this document contains the complete text. The policy to which the Conference Report refers is in DoDI 5000.2, paragraph 4.7.3.2.2.2. Appendix D also provides various policy statements, directives, and so forth relevant to the TRA process.

13 In light of the change to DoD 5000.2-R contained in the pending USD(AT&L) memorandum (see Appendix D), DDR&E should bear this responsibility.

III. TRL DEFINITIONS

DoD 5000.2-R establishes technology maturity expressed in TRLs as the centerpiece for the TRAs required for ACAT ID and ACAT IAM programs. Other means to accomplish a TRA are allowed but only when approved in advance by the DDR&E. Willoughby charts are a possible alternative; however, no alternatives to the TRL-based process have been approved thus far (as of September 2002).

It is important to have a strong grasp of the TRL concept. The tables in this section give the TRL fundamentals. Appendix E provides greater detail and examples.

Using TRLs to describe the maturity of technologies considered for use in a new system originated with NASA in the early 1980s. The levels ran from the earliest stages of scientific investigation (level 1) to successful use in a system (level 9), which equates to space flight for NASA. DoD has adopted the NASA definitions—with only minor modifications—for the nine TRLs.

Table III-1 defines and describes the DoD TRL levels. It also lists typical documentation that should be extracted or referenced to support a TRL assignment. Table III-2 includes a set of additional definitions that help provide a uniform interpretation of the levels.

Software is likely to be an important element in many TRAs. Since the TRL definitions in Table III-1 reflect a systems approach in which software is treated as a part of a component or system, software TRLs are not spelled out specifically in these definitions. However, because some guidelines would be useful in determining the TRLs of the software parts of components and systems, Table III-3 provides a set of software TRL definitions developed by the Army.

Table III-1. TRL Definitions, Descriptions, and Supporting Information (Source: DoD 5000.2-R, dated April 5, 2002)

TRL	Definition	Description	Supporting Information
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's basic properties.	Published research that identifies the principles that underlie this technology. References to who, where, when.
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.	Publications or other references that outline the application being considered and that provide analysis to support the concept.
3	Analytical and experimental critical function and/or characteristic proof of concept	Active research and development (R&D) is initiated. This includes analytical studies and laboratory studies to physically validate analytical predictions of separate elements of the technology. Examples include components that are not yet integrated or representative.	Results of laboratory tests performed to measure parameters of interest and comparison to analytical predictions for critical subsystems. References to who, where, and when these tests and comparisons were performed.
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 to the eventual system. Examples include integration of "ad hoc" hardware in the laboratory.	System concepts that have been considered and results from testing laboratory-scale breadboard(s). References to who did this work and when. Provide an estimate of how breadboard hardware and test results differ from the expected system goals.
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.	Results from testing a laboratory breadboard system are integrated with other supporting elements in a simulated operational environment. How does the "relevant environment" differ from the expected operational environment? How do the test results compare with expectations? What problems, if any, were encountered? Was the breadboard system refined to more nearly match expected system goals?

Table III-1. TRL Definitions, Descriptions, and Supporting Information (Continued) (Source: DoD 5000.2-R, dated April 5, 2002)

TRL	Definition	Description	Supporting Information
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. Represents a major step up in a technology's demonstrated readiness. Examples include testing a prototype in a high-fidelity laboratory environment or in simulated operational environment.	Results from laboratory testing of a prototype system that is near the desired configuration in terms of performance, weight, and volume. How did the test environment differ from the operational environment? Who performed the tests? How did the test compare with expectations? What problems, if any, were encountered? What are/were the plans, options, or actions to resolve problems encountered before moving to the next level?
7	System prototype demonstration in an operational environment	Prototype near, or at, planned operational system. Represents a major step up from TRL 6, requiring demonstration of an actual system prototype in an operational environment such as an aircraft, vehicle, or space. Examples include testing the prototype in a test bed aircraft.	Results from testing a prototype system in an operational environment. Who performed the tests? How did the test compare with expectations? What problems, if any, were encountered? What are/were the plans, options, or actions to resolve problems encountered before moving to the next level?
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.	Results of testing the system in its final configuration under the expected range of environmental conditions in which it will be expected to operate. Assessment of whether it will meet its operational requirements. What problems, if any, were encountered? What are/were the plans, options, or actions to resolve problems encountered before finalizing the design?
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.	Operational Test and Evaluation (OT&E) reports.

Table III-2. Additional Definitions of TRL Descriptive Terms (Source: DoD 5000.2-R, dated April 5, 2002)

Term	Definition
Breadboard	Integrated components that provide a representation of a system/subsystem and that can be used to determine concept feasibility and to develop technical data. Typically configured for laboratory use to demonstrate the technical principles of immediate interest. May resemble final system/subsystem in function only.
High Fidelity	Addresses form, fit, and function. High-fidelity laboratory environment would involve testing with equipment that can simulate and validate all system specifications within a laboratory setting.
Low Fidelity	A representative of the component or system that has limited ability to provide anything but first-order information about the end product. Low-fidelity assessments are used to provide trend analysis.
Model	A functional form of a system, generally reduced in scale, near or at operational specification. Models will be sufficiently hardened to allow demonstration of the technical and operational capabilities required of the final system.
Operational Environment	Environment that addresses all the operational requirements and specifications required of the final system to include platform/packaging.
Prototype	A physical or virtual model used to evaluate the technical or manufacturing feasibility or military utility of a particular technology or process, concept, end item, or system.
Relevant Environment	Testing environment that simulates the key aspects of the operational environment.
Simulated Operational Environment	Either (1) a real environment that can simulate all of the operational requirements and specifications required of the final system or (2) a simulated environment that allows for testing of a virtual prototype; used in either case to determine whether a developmental system meets the operational requirements and specifications of the final system.

Table III-3. Army Software TRL Definitions

TRL	Definition	Description
1	**SW**: Functionality conjectural	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 analytic studies of an algorithm's basic properties.
2	**SW**: Technology concept and/or application formulated	Invention begins. Once basic principles are observed, practical applications can be invented. Applications may be speculative, and there may be no proof or detailed analysis to support the assumptions. Examples are limited to analytic studies.
3	**SW**: Analytical and experimental critical functions and/or characteristic proof of concept	Active R&D is initiated. This includes analytical studies to produce code that validates the analytical predictions of separate software elements. Examples include software components that are not yet integrated or representative but satisfy an operational need and algorithms run on a surrogate processor in a laboratory environment.
4	**SW:** Functionality demonstrated in a laboratory environment	Basic software components are integrated to establish that they will work together. They are relatively primitive with regard to efficiency and reliability compared with the eventual system. System software architecture development is initiated to include interoperability, reliability, maintainability, extensibility, scalability, and security issues. Software is integrated with simulated current/legacy elements as appropriate.
5	**SW:** Functionality and performance demonstrated in a relevant environment	Reliability of the software ensemble increases significantly. The basic software components are integrated with reasonably realistic supporting elements so that the software can be tested in a simulated environment. Examples include "high-fidelity" laboratory integration of software components. System software architecture is established. Algorithms are run on a processor(s) that has characteristics expected in the operational environment. Software releases are "Alpha" versions, and configuration control is initiated. Verification, Validation, and Accreditation (VV&A) is initiated.

Table III-3. Army Software TRL Definitions (Continued)

TRL	Definition	Description
6	**SW:** Functionality and performance demonstrated in a realistic simulated (live/virtual) operational environment	Representative model or prototype system, which is well beyond that of TRL 5, is tested in a relevant environment. Represents a major step up in software-demonstrated readiness. Examples include testing a prototype in a live/virtual experiment or in simulated operational environment. Algorithm is run on a processor or in the simulated operational environment. Software releases are “Beta” versions and are configuration controlled. Software support structure in development. VV&A in process.
7	**SW:** Functionality and performance demonstrated in an operational test environment	Represents a major step up from TRL 6, requiring the demonstration of an actual system prototype in an operational environment, such as a command post or air/ground vehicle. Algorithms are run on processor of the operational environment integrated with actual external entities. Software support structure in place. Software releases are in distinct versions (e.g., Version 2.0). Frequency and severity of software deficiency reports do not significantly degrade functionality or performance. VV&A completed.
8	**SW:** Functionality, performance, and quality attributes validated in an operational environment	Software has been demonstrated to work in its final form and under expected conditions. In most cases, this TRL represents the end of system development. Examples include test and evaluation of the software in its intended system to determine whether it meets design specifications. Software releases are production versions and are configuration controlled in a secure environment. Software deficiencies are resolved rapidly through the support structure.
9	**SW:** Functionality, performance, and quality attributes proven in an operational environment through successive, successful accomplishment of 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 last "bug fixing" aspects of system development. Examples include using the system under operational mission conditions. Software releases are production versions and are configuration controlled. Frequency and severity of software deficiencies are at a minimum.

IV. THE TRA PROCESS

4.1 ACTION SEQUENCE FOR A TRA

Figure IV-1 graphically portrays the steps normally expected by the DDR&E in the assessment of technology readiness for an MDA. These steps[14] are as follows:

A. During CTD, the PM develops a system concept and a concept of operation. A functional analysis establishes the functions and performance levels necessary to meet the needs expressed in a Mission Needs Statement (MNS). For the system, the PM develops an Acquisition Program Baseline (APB) and a Work Breakdown Structure (WBS) and conducts a risk assessment, which includes technology risk. Technology choices will be made on the basis of risk, cost, and other factors. If some components or subsystems are not sufficiently mature to support a Milestone B decision, a component advanced development program and risk-reduction program will be planned, as necessary. The TMA is an appropriate means for reducing risk. The degree of detail is necessarily limited in CTD but becomes far greater in SDD.

B. From the WBS, the risk assessment, and the functional analysis, the PM identifies those technologies that are not already fully mature but that are critical to the accomplishment of goals for program cost and schedule and for system producibility, cost, and operational effectiveness. These will be listed as *critical technologies*.

   To support the TRA required before an upcoming Milestone B or Milestone C, the PM prepares a list of the critical technologies and an assessment of the maturity of each critical technology. Substantiating information normally consists of describing the status of components or subsystems, the testing that has been accomplished, and the results of this testing. Test environments and results are described in relation to the functional needs of the system concept. At least 16 weeks before a scheduled Milestone B or Milestone C (see Figure II-1), the list of critical technologies and the supporting information are sent to the Component S&T Executive, with a request for a TRA. At the same time, an information copy is sent to the DDR&E.

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[14] The steps that follow (A–J) are marked accordingly in Figure IV-1.

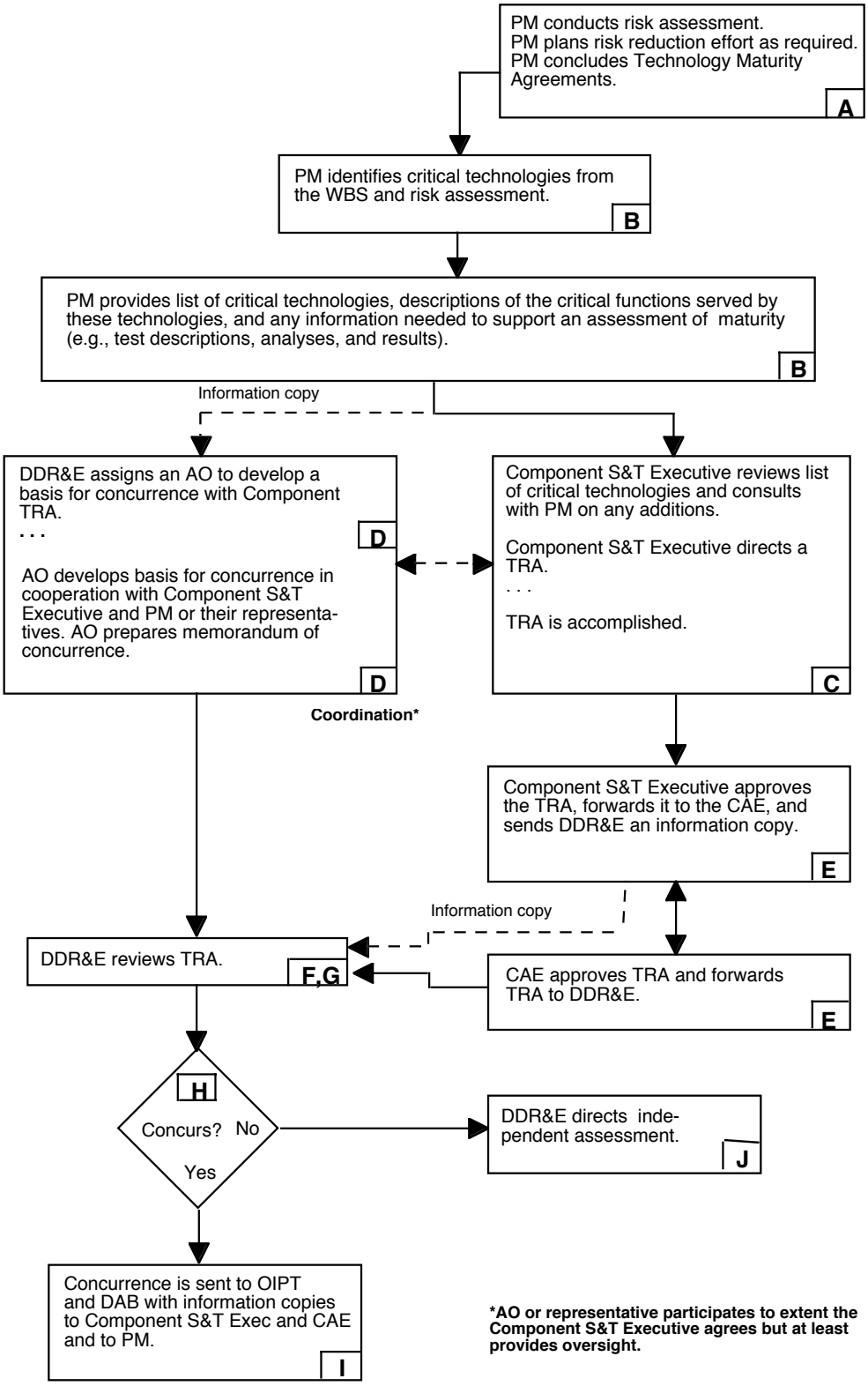

Figure IV-1. Flow Diagram for the TRA Process

C. The Component S&T Executive coordinates with the PM on any additions to the list of critical technologies and on any additional information needed for the TRA.

The Component S&T Executive directs and schedules the accomplishment of a TRA based on the PM's request and submission of the critical technologies information.

The TRA is conducted in accordance with Component guidelines and procedures. Appendix F provides sample procedures from the Components.

D. The DDR&E normally appoints a member of his/her staff to act as AO to develop a basis for the DDR&E to concur with the Component TRA. This basis must be sufficient to fulfill the DDR&E oversight responsibilities, but it should not be a duplication of the Component TRA.

The AO should review the critical technologies and the identification process, negotiate any perceived deficiencies, and provide oversight while the Component TRA is conducted. The AO should coordinate with the Component S&T Executive to determine to what extent the AO or technology specialists of the DDR&E staff could or should monitor or participate in the Component TRA. The Component S&T Executive is not required to agree to any such monitoring or participation beyond oversight.

E. When the Component TRA is completed, the Component S&T Executive approves it and forwards it to the CAE. At the same time, the Component S&T Executive sends an information copy to the DDR&E.

Subsequently, the CAE forwards the approved TRA to the DDR&E. Appendix G contains several actual TRAs that have been submitted for milestone decisions.

F. The AO develops a basis for DDR&E concurrence. The approach can be tailored to the specific situation (see paragraph 4.2, which describes one approach). The AO should minimize the impact on the PM and the Component S&T organization but still provide a sound basis for DDR&E concurrence. Monitoring or participating in the Component TRA will likely facilitate a quick concurrence. If the AO deems any critical technology to be insufficiently mature for the coming milestone, he/she tells the Component S&T Executive and the PM so that all involved have an opportunity to reach agreement on appropriate action.

G. Upon receiving the report and official TRA from the CAE, the AO confirms that it is consistent with the information copy.

H. The AO prepares a memorandum of concurrence or nonconcurrence for signature, presents the staff evaluation of the TRA to the DDR&E, provides whatever backup information is needed, and acts on the DDR&E's decision.

I. If the DDR&E concurs, the concurrence memorandum is transmitted to the OIPT and the DAB or to the IT OIPT and CIO Review Group. This must occur at least 2 weeks before the milestone meeting.

J. If the DDR&E does not concur, an independent assessment is required. The AO recommends a course of action and prepares a memorandum directing this action. The independent assessment should be a positive contribution to the acquisition program. For example, it could result in a revised, more realistic schedule, in the use of an alternative technology, or in a revised, evolutionary acquisition strategy. The independent assessment should be conducted as quickly as possible—whether this requires 1 day or several months. Typically, the Component funds the independent assessment.

Paragraph 4.2 offers an approach to developing the basis for DDR&E concurrence.

4.2 DDR&E CONCURRENCE

The DDR&E is required to evaluate the Component TRA before Milestone B and Milestone C of ACAT ID and ACAT IAM programs. An AO, designated by the DDR&E, will normally lead the evaluation effort.

It is recommended that the AO secure DDR&E concurrence as follows:

- When the DDR&E designates an AO, a memorandum is sent to his/her staff Directors. This memorandum alerts them to a possible need to provide assistance in their respective technology areas and requests them to designate a POC within their Directorates.
- The AO provides copies of the Component TRA to the designated POCs and invites comments by a certain date.
- The AO reviews the TRA and calls for assistance, as necessary, to obtain a competent assessment of the critical technologies or to determine whether all the critical technologies have been identified.
- If a disagreement with the Component TRA emerges, this is noted in a memorandum to the DDR&E. If the disagreement would jeopardize a favorable decision by the USD(AT&L) or the ASD(C3I), the AO obtains a full explanation and concurrence from the cognizant Director.

- The AO conveys the evaluation results to the DDR&E in a briefing or memorandum. Key Directors attend or coordinate.
- If the DDR&E does not concur with the Component TRA, the AO prepares the action memorandum to conduct an independent TRA.
- The AO prepares a memorandum for DDR&E signature. This memorandum gives the evaluation results of the Component TRA and the independent TRA, if conducted. It is sent to the Chairman of the OIPT or IT OIPT and to the Executive Secretary of the DAB or the appropriate staff officer to the ASD(C3I).

V. SUBMITTING A TRA

5.1 SKELETAL TEMPLATE FOR A TRA SUBMISSION

The following outline is a skeletal template for anticipated TRA submissions:

1.0 Purpose of This Document

2.0 Program Overview

2.1 Program Objective

2.2 Program Description

2.3 System Description

3.0 Technology Readiness Assessment

3.1 Process Description

3.2 Critical Technologies

3.3 Assessment of Maturity

3.3.1 First Critical Technology or Category of Technology

3.3.2 Next Critical Technology or Category of Technology

3.4 Summary of TRLs by Technology

4.0 Conclusion

5.2 ANNOTATED TEMPLATE FOR A TRA SUBMISSION

The following outline is an annotated version of the TRA template.

1.0 Purpose of This Document

Should be short and should give the program name, the system name if different from the program name, and the milestone or other decision point for which the TRA was performed. For example, "This document presents an independent Technology Readiness Assessment (TRA) for the UH-60M helicopter program in support of the Milestone B decision. The TRA was performed at the direction of the Army Science and Technology (S&T) Executive."

2.0 Program Overview

2.1 Program Objective

States what the program is trying to achieve (e.g., new capability, improved capability, lower procurement cost, reduced maintenance or manning, and so forth). Refer to the MNS or ORD that states the need for this capability.

2.2 Program Description

Describes the program, not the system. Does the program provide a new system or a modification to an existing operational system? Is it an evolutionary acquisition program? What capabilities will be realized in Block 1? When is initial operational capability (IOC)? Does it have multiple competing prime contractors? Into what architecture does it fit? Is it a system-of-systems? Does its success depend on the success of other acquisition programs?

2.3 System Description

Describes the overall system, the major subsystems, and components, as necessary, to give an understanding of what is being developed and to show what is new, unique, or special about it. Should include the systems, components, and technologies that will later be declared "critical technologies." Describes how the system works (if this is not obvious).

3.0 Technology Readiness Assessment

3.1 Process Description

Tells who led the TRA and what organizations or individuals performed the TRA. Identifies the special expertise of participating organizations or individuals. This should establish the competence and the independence of the TRA. In this context, "independence" means that the assessors are not unduly influenced by the opinions of the developers (government or industry). Usually, the PM or the System Program Office (SPO) will provide most of the data and other information that form the basis of a TRA. Nevertheless, the assessment *should be independent* of the PM or SPO.

States the analyses and investigations that were performed when making the assessment (e.g., examination of test setups, discussions with test personnel, analysis of test data, review of related technology, and so forth). This section is only a broad description of the process. Section 3.3 presents an opportunity to include more detail.

3.2 Critical Technologies

Lists the technologies included in the TRA. A table with the technology name and a few words that describe the technology and its function is appropriate. The technologies can be organized according to the WBS, as provided by the PM. The names of these critical technologies should be used consistently throughout the remainder of the document.

The PM is required to identify the critical technologies. The TRA is required to assess at least these technologies; however, other technologies that the TRA considers critical can also be included.

3.3 Assessment of Maturity

3.3.1 First Critical Technology or Category of Technology

Describes the technology (subsystem, component, or technology). Describes the function it performs and, if needed, how it relates to other parts of the system. Provides a synopsis of technology development history and status. This can include facts about related uses of the same or similar technology, numbers or

hours of testing of breadboards, numbers of prototypes built and tested, relevance of the test conditions, and results achieved. Finally, applies the criteria for TRLs and assigns a readiness level to the technology. States the readiness level (e.g., TRL 5) and the rationale for choosing this readiness level.

For a complex system, if the critical technologies presented are in categories (e.g., airframe or sensors), the information specified in the previous paragraph (e.g., describing the technology, describing the function it performs, and so forth) should be provided for each critical technology within a category.

3.3.2 Next Critical Technology or Category of Technology

Assessments of the maturity of other critical technologies should present the same information as that in paragraph 3.3.1.

3.4 Summary of TRLs by Technology

Presents a table that lists critical technologies and assesses the TRL of each technology.

4.0 Conclusion

States the Component S&T Executive's position concerning the maturity of the technologies and whether this maturity is adequate for the system to enter the next stage of development. If the position is supportive of entering the next stage (even though some critical technologies are less mature than would ordinarily be expected), explains what circumstances or planned work justifies the positive position.

The TRA should be signed "Approved By" the Component S&T Executive, or it should be transmitted with a cover memorandum that clearly states that the TRA presents the position of the Component S&T Executive. In effect, the Component S&T Executive must certify that he/she stands behind the statements in the Conclusion section.

ACRONYMS

ACAT	Acquisition Category
AIS	Automated Information System
AO	Action Officer
APB	Acquisition Program Baseline
ASD(C3I)	Assistant Secretary of Defense for Command, Control, Communications, and Intelligence
CAE	Component Acquisition Executive
CIO	Chief Information Officer
CTD	Concept and Technology Development
DAB	Defense Acquisition Board
DAS	Defense Acquisition System
DDR&E	Director of Defense Research and Engineering
DoD	Department of Defense
DoDD	Department of Defense Directive
DoDI	Department of Defense Instruction
DUSD(S&T)	Deputy Under Secretary of Defense for Science and Technology
FOC	full operational capability
FRP	full-rate production
GAO	Government Accounting Office
IDA	Institute for Defense Analyses
IOC	initial operational capability
IT OIPT	Information Technology Overarching Integrated Product Team
LRIP	low rate initial production
MAIS	Major Automated Information System
MDA	Milestone Decision Authority
MDAP	Major Defense Acquisition Program
MNS	Mission Needs Statement
NASA	National Aeronautics and Space Administration
NDAA	National Defense Authorization Act
NSIAD	National Security and International Affairs Division (GAO)
ODDR&E	Office of the Director of Defense Research and Engineering

OIPT	Overarching Integrated Product Team
ORD	Operational Requirements Document
OSD	Office of the Secretary of Defense
OT&E	operational test and evaluation
PEO	Program Executive Officer
PM	Program Manager
POC	Point of Contact
PSA	Principal Staff Assistant
R&D	research and development
S&T	Science and Technology
SDD	System Development and Demonstration
SPO	System Program Office
TMA	Technology Maturity Agreement
TRA	Technology Readiness Assessment
TRL	Technology Readiness Level
USD(AT&L)	Under Secretary of Defense for Acquisition, Technology, and Logistics
VCJCS	Vice Chairman of the Joint Chiefs of Staff
VV&A	Verification, Validation, and Accreditation
WBS	Work Breakdown Structure