

# Technology Readiness Levels<sup>1</sup>

## 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.

## 2. Technology concept and/or application formulated

Invention begins. Once basic principles are observed, practical applications can be invented. The application is speculative and there is no proof or detailed analysis to support the assumption. Examples are still limited to paper 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 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 the pieces will work together. This is relatively "low fidelity" compared to the eventual system. Examples include integration of "ad hoc" hardware in a 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 that the technology 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 the breadboard tested for 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.

## 7. System prototype demonstration in an operational environment

Prototype near or at planned operational system. Represents a major step up from TRL 6, requiring the demonstration of an actual system prototype in an operational environment with representatives of the intended user organization(s). Examples include testing the prototype in structured or actual field use.

## 8. Actual system completed and operationally qualified through test and demonstration.

Technology has been proven to work in its final form and under expected operational 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 or pre-production configuration to determine if it meets design specifications and operational suitability.

## 9. Actual system, proven through successful mission operations.

Actual application of the technology in its production configuration 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 true system development. Examples include using the system by operational users under operational mission conditions.

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<sup>1</sup> Adapted from GAO/NSIAD99-162 Best Practices Appendix I Technology Readiness Level Descriptions