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# On the Practical Application of Technology Readiness Levels

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# Outline

What are technology readiness levels (TRLs)

- Background
- History
- References

Technology Readiness Assessment: TRA handbook – a brief view of the TRA process used by DOD; provides context for the work presented here

Assessing the maturity of a technology

- AFRL Transition Readiness Calculator
- Proposed tool
- Understanding the details by looking at the “valley of death” (TRL 4-6)

Conclusions

# What are TRLs?

**Question of readiness:** *when a new technology is invented or conceptualized, it is typically not ready/suitable for immediate inclusion into a system or subsystem; its generally not ready for immediate application*

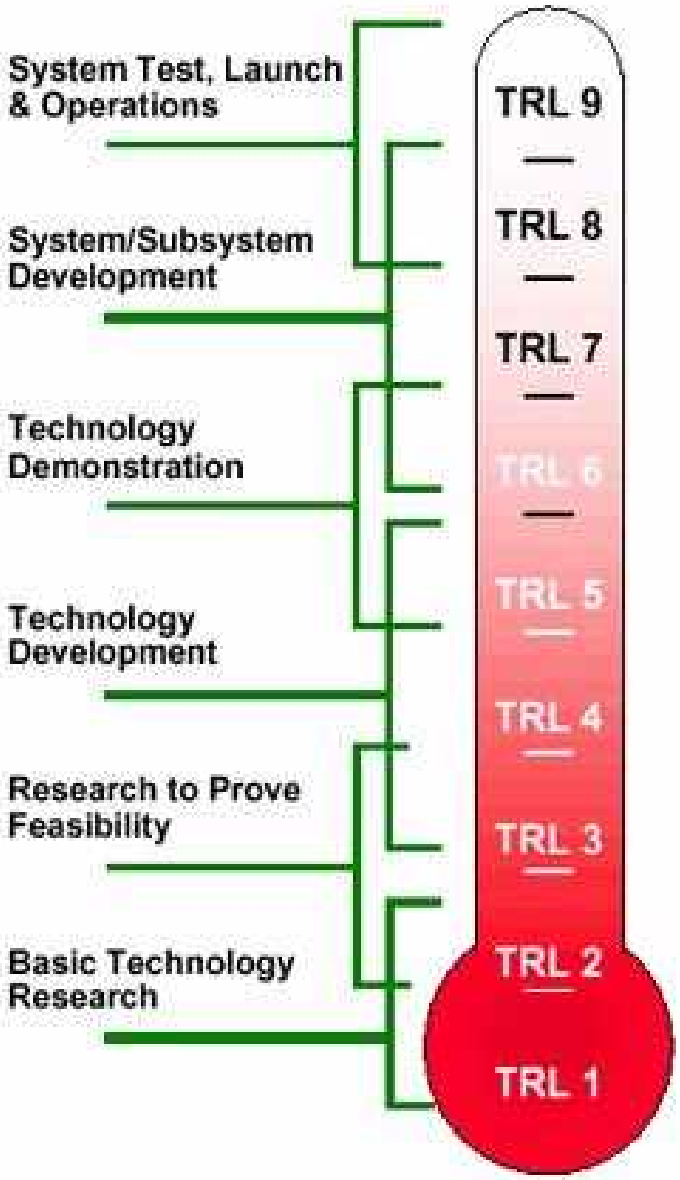
**Technology Readiness Levels (TRL):** *a measure used to assess maturity of evolving technologies prior to incorporating them into a larger system or subsystem*

**Definitions:** *A 9-Level Scale is used to describe technology maturity. See next slide for a description of the 9 levels.*

**Brief History**

- *1980's: TRLs were originally developed by NASA*
- *1990's: USAF adopted the use of TRLs*
- *1995: John C. Mankins proposed descriptions of each TRL in a white paper*
- *1999: GAO recommended that DOD adopt the use of NASA's TRLs*
- 2001: *Deputy Under Secretary of Defense for Science and Technology issued a memorandum that endorsed use of TRLs in new major programs*
- *2003: DOD first developed the Technology Readiness Assessment Deskbook*
- *2003: Sandia Technology Readiness Working Group*
- *2005: NSSE Valley of Death Workshop*
- *2007: Sandia officially adopted the 9-Level TRL scale as a project management tool*

# TRL Definitions




Operational use of deliverable

Actual deliverable qualified through test and demonstration

Final development version of the deliverable demonstrated in operational environment

Representative of the deliverable demonstrated in relevant environments

Key elements demonstrated in relevant environments

Key elements demonstrated in laboratory environment

Concepts demonstrated analytically or experimentally

Concept and/or application formulated

Basic principles observed and reported

# TRL: reference information

## Websites

•http://en.wikipedia.org/wiki/Technology_Readiness_Level

•*http://trl.sandia.gov* – *[only available via the internal restricted network]*

## Documents

•*Mankins, John C., (6 April 1995), Technology Readiness Levels: A White Paper, NASA, Office of Space Access and Technology, Advanced Concepts Office.*

•GAO, (July 1999), *Best Practices: Better Management of Technology Can Improve Weapon System Outcomes*, GAO/NSIAD-99-162

•DOD, (24 July 2006), *Defense Acquisition Guidebook*

•DOD, (May 2005), *Technology Readiness Assessment (TRA) Deskbook*

•Mitchell, John A. and Bailey, Beatriz R., On the Integration of Technology Readiness Levels at Sandia National Laboratories, Sandia Report SAND2006-5754, Sandia National Laboratories, 2006.

## Tools

•Nolte, William L., et. al., (20 October 2003), *Technology Readiness Level Calculator, Air Force Research Laboratory*, presented at the NDIA Systems Engineering Conference.

# Technology Readiness Assessment

## Reference TRA handbook (DOD)

**Central Theme of DOD Acquisition:** Technologies employed in system development should be mature before system development begins

**Conceptual Definition of Maturity:** technology must have been applied in a prototype article, tested in a relevant or operational environment, and found to have performed adequately

**DOD TRA Definition:** a systematic, metrics-based process that assesses the maturity of certain technologies

**TRA Purpose:** surface data and assess information relevant to the maturity of CTEs in acquisition programs

# Technology Readiness Assessment

## Reference TRA handbook (DOD) [continued]

**Implication**

A need exists for measuring the maturity of a technology and for a process to ensure that only sufficiently mature technologies are employed – this is outlined in the DOD Defense Acquisition Guidebook

**TRA Process Implemented for System Acquisition**

- *Identify CTEs*
- *Assess CTE Readiness*

**CTE Definition**

A technology element is “critical” if the system being acquired depends upon this technology element to meet operational requirements and if the technology element or its application is either new or novel.

# Assessing the maturity of a technology:
## Assigning a TRL: Approach

**AFRL Transition Readiness Level Calculator, version 2.2**

### Hardware Calculator

| Technology Readiness Level Achieved | | | | | Technical: | | 4 | 3 |
|---|---|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |

**TRL 4 (Check all that apply or use slider for % complete)**

| | | |
|---|---|---|
| 100 | ✓ | Cross technology issues (if any) have been fully identified |
| 100 | ✓ | Ad hoc and available laboratory components are surrogates for system components |
| 100 | ✓ | Individual components tested in laboratory/by supplier (contractor's component acceptance testing) |
| 100 | ✓ | Piece parts and components in a pre-production form exist |
| 100 | ✓ | M&S used to simulate some components and interfaces between components |
| 100 | ✓ | Customer publishes requirements document |
| 100 | ✓ | Overall system requirements for end user's application are known |
| 100 | ✓ | System performance metrics have been established |

◉ Use Manufacturing
○ No Manufacturing

◉ Use Programmatics
○ No Programmatics

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# Assessing the maturity of a technology:
## Practical Application of TRLs: Approach

DOD and AFRL appear to agree that TRL is a good measure of maturity

Caveat

The real meaning of a TRL for a government agency is better understood by evaluating their approach for assigning the TRL

AFRL tool clearly defines approach for assigning TRL

DOD Deskbook provides TRL definitions but is less clear about specifics on assigning TRL

# Assessing the maturity of a technology:
## Proposed approach for assigning TRL

We consider two *use cases*

- *Self assessment* – check boxes: project level evaluation; conceptually similar to AFRL tool

- *Programmatic assessment* – Self assessment plus required supporting evidence: rigorous form of measuring the maturity of a particular technology;

Here the emphasis is on questions associated with check boxes and subsequent requirements for supporting evidence

# Assessing the maturity of a technology:
# TRL 4: Definition and concepts

*Definition*

Key elements demonstrated in laboratory environment

The key elements must be integrated to establish that the pieces will work together. The validation should be consistent with the requirements of potential applications but is relatively low-fidelity when compared to a final product. Examples include integration of ad-hoc hardware or software in the laboratory such as breadboards, low fidelity development components, and rapid prototypes.

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*Additional Concepts*

Small R&D teams mature technologies thru TRL 4. Development is principally driven by these teams; they demonstrate a solution to a particular problem. At this stage, end user customers do not significantly direct development. TRL 4 is about demonstrating proof of concept.

# Assessing the maturity of a technology:
## Proposed question(s) for TRL 4: Part 1

Have you developed a prototype which integrates all key elements necessary to address a particular problem?

Answering NO to this question terminates this branch; TRL 4 is not achieved and no further questions are presented to the user

<u>Supporting Evidence</u>

What problem does your prototype solve?

What key elements are integrated?

How does your prototype solve the problem?

# Assessing the maturity of a technology:
# Proposed question(s) for TRL 4: Part 2

Have you conducted a laboratory demonstration that integrates all key elements necessary to solve a particular problem and shown that functional aspects of the prototype operated according to what a customer would expect?

Answering NO to this question terminates this branch; TRL 4 is partially completed

Supporting Evidence

What key elements were part of the demonstration?

What functionality was demonstrated with the prototype?

What metrics did you use to conclude that the prototype worked as expected?

# Assessing the maturity of a technology:
## Proposed question(s) for TRL 4: Part 3

Do you have a customer or end user who has shown interest in this technology?

Answering NO to this question terminates this branch; TRL 4 is partially completed

Supporting Evidence

In what way does your technology and the problem that it solves correlate with the potential customer's needs?

# Assessing the maturity of a technology:
## Proposed question(s) for TRL 4: Part 4

Does your potential customer agree that you have successfully conducted a laboratory demonstration integrating all key elements necessary to solver their problem?

Answering NO to this question terminates this branch; TRL 4 is partially completed

Supporting Evidence

On what basis did your potential customer conclude you have successfully conducted a laboratory demonstration integrating all key elements required to solve their problem?

# Assessing the maturity of a technology:
# TRL 5: Definition and concepts

*Definition*

Key elements demonstrated in relevant environments

Fidelity of the key elements increases significantly. Key elements are integrated with realistic supporting elements so that the technology can be tested and demonstrated in simulated or actual environments.

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*Additional Concepts*

Less research and more development; Technology begins to take on a product focus; Resources required for development are higher than those previously required; End-user customer interactions and requirements gathering becomes critical to maturing the technology;

# Assessing the maturity of a technology:
## Proposed question(s) for TRL 5: Part 1

Do you have an end user customer for you technology?

Answering NO to this question terminates this branch; TRL 5 is not achieved and no further questions are presented to the user

Supporting Evidence

Who is your customer?

# Assessing the maturity of a technology: Proposed question(s) for TRL 5: Part 2

Are you working with your customer to document and define functional requirements?

Supporting Evidence

Please summarize functional aspects and requirements for your product and describe how they solve your customer's problem?

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Are you working with your customer to document and define integration requirements?

Supporting Evidence

Please summarize the integration requirements and explain how your product integrates within the customer's system.

# Assessing the maturity of a technology:
## Proposed question(s) for TRL 5: Part 2

Are you working with your customer to document and define environmental requirements?

Supporting Evidence

Please summarize the environmental requirements.

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Are you working with your customer to document and define abnormal environments or extrema events?

Supporting Evidence

Please summarize the abnormal environments and the expectations for your product after exposure to these environments.

# Assessing the maturity of a technology:
## Proposed question(s) for TRL 5: Part 2

Have you integrated the key elements of your technology in a way that is consistent with your customer's integration requirements?

Supporting Evidence

- How do you plan to integrate and demonstrate your technology within the customer's system?

# Assessing the maturity of a technology:
## Proposed question(s) for TRL 5: Part 3

Can you demonstrate the key elements and functional aspects of you technology individually when they are exposed to your customer's environmental conditions?

Supporting Evidence

What key elements and/or functional aspects of your product have you tested?

What metrics did you use to conclude that key elements operated as expected during and/or after exposure to environmental conditions?

# Assessing the maturity of a technology:
## TRL 6: Definition and concepts

*Definition*

**Representative of the deliverable demonstrated in relevant environments**

Represents a major step in a technology's demonstrated readiness. Examples include testing a prototype or representative of a deliverable in a high fidelity laboratory environment or in a simulated operational environment.

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*Additional Concepts*

Working with the customer to finalize requirements; fabricating a representative deliverable;

# Assessing the maturity of a technology:
## Proposed question(s) for TRL 6: Part 1

Working with your customer, have you collected and agreed upon a complete set of requirements for your product?

Answering NO to this question terminates this branch; TRL 6 is not achieved and no further questions are presented to the user

Supporting Evidence

Please provide documentation for the agreed upon requirements.

# Assessing the maturity of a technology:
## Proposed question(s) for TRL 6: Part 2

Have you successfully demonstrated a development version of your product in your customer's required environments?

Answering NO to this question terminates this branch; TRL 6 is not achieved and no further questions are presented to the user

Supporting Evidence

How was the demonstration representative of your customer's specific needs?

What metrics did you use to conclude that the demonstration was successful?

# Assessing the maturity of a technology:
## Proposed question(s) for TRL 6: Part 3

Does the customer agree that the demonstration was representative of their requirements and that it was successful?

Answering NO to this question terminates this branch; TRL 6 is not achieved and no further questions are presented to the user

Supporting Evidence

What metrics did the customer use to make this conclusion?

How do the metrics used by the customer to verify the demonstration was a success correlate with the agreed upon requirements?

# Conclusions

What are technology readiness levels (TRLs)

Discussed a process where assigning a TRL is required: very briefly reviewed the TRA deskbook

Reviewed AFRL Transition Readiness Calculator

Proposed an approach and outline a tool for assigning TRLs

- Examined details of our approach using TRLs 4 thru 6

Our philosophy for assigning a TRL

The maturity of a technology is independent of the processes used to mature the technology.