Technology Readiness Levels Adapted for Use in IM Development

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Joint Insensitive Munitions Technology Program

Purpose – Provide a S&T base to ensure that munitions under development or in procurement are safe throughout their lifecycle when subjected to unplanned stimuli to the maximum extent practicable

Goal – Develop joint enabling technologies that can be used by the Services for their weapon programs

Strategy – Counteracting the IM threats is a complex task that requires extensive planning. Three factors shaped the JIMTP strategic direction:

- **Policy and regulation requiring IM compliance**
- **Needs identified by Acquisition Officials**
- **Near, mid and far term goals/objectives from SMEs**

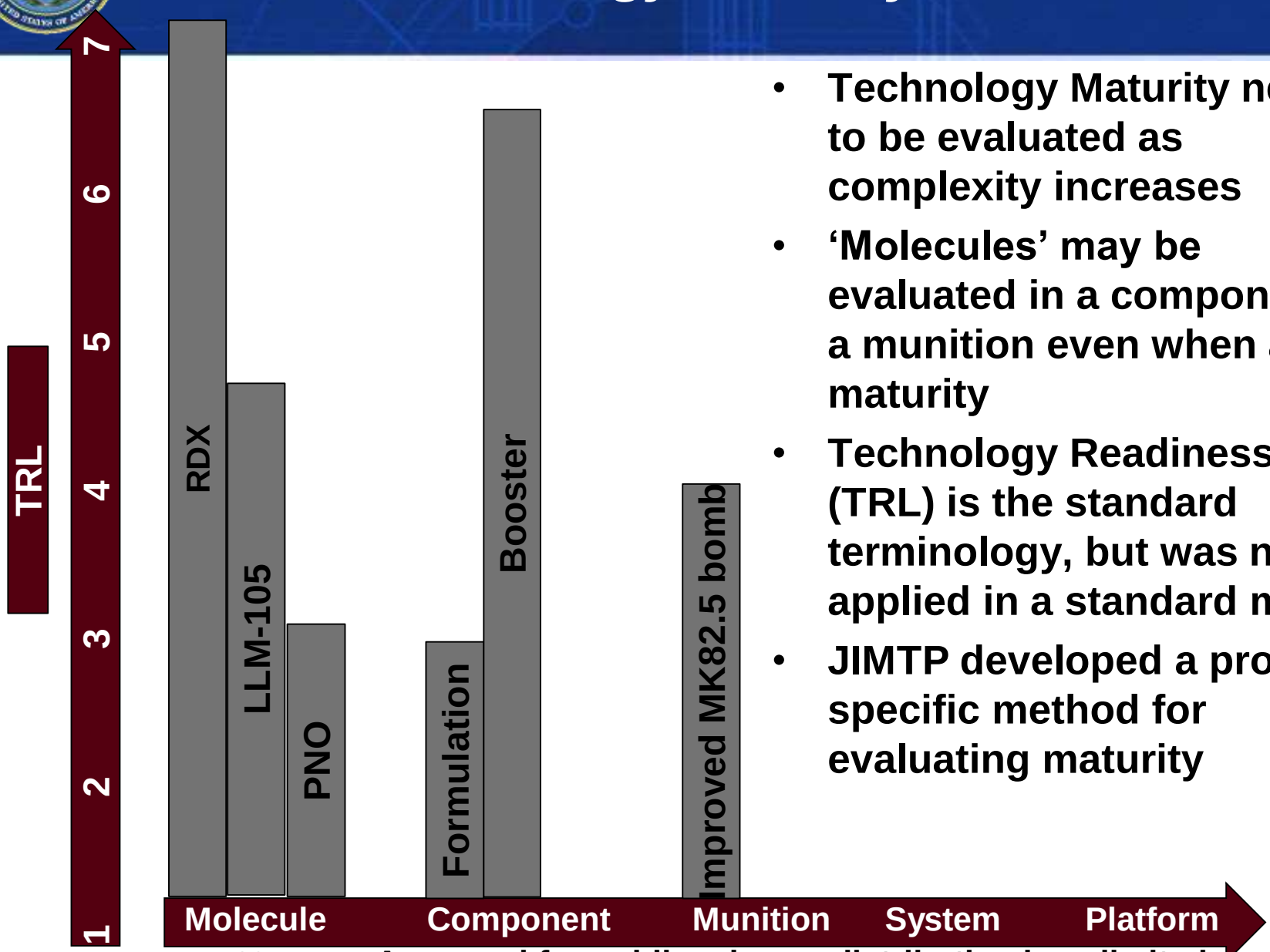
JIMTP Process

- **Annual request for New Ideas to Industry and Government Labs based on the gaps, goals, and roadmaps**
- **JIMTP leadership selects best New Ideas for full proposals**
- **Proposals evaluated and selected based on:**
  - **IM Improvement**
  - **Technology Maturity (TRL) and Approach**
  - **Programmatics and Transition Potential**
  - **Relevance to MATG roadmaps and goals**
  - **Overall portfolio balance (e.g., innovation, risk, payoff, maturity)**
- **All currently funded projects compete with new idea proposals for funding**

JIMTP Metrics and TRLs

- **In the JIMTP, applied research needs to be developed to TRL 4-5 and transition to advanced technology demonstrations**
- **Advanced technology development tasks need to be developed to TRL 6-7**
- **TRLs also used in the JIMTP Risk Assessment process**

Technology Maturity



- Technology Maturity needs to be evaluated as complexity increases
- 'Molecules' may be evaluated in a component or a munition even when at low maturity
- Technology Readiness Level (TRL) is the standard terminology, but was not applied in a standard manner
- JIMTP developed a program-specific method for evaluating maturity

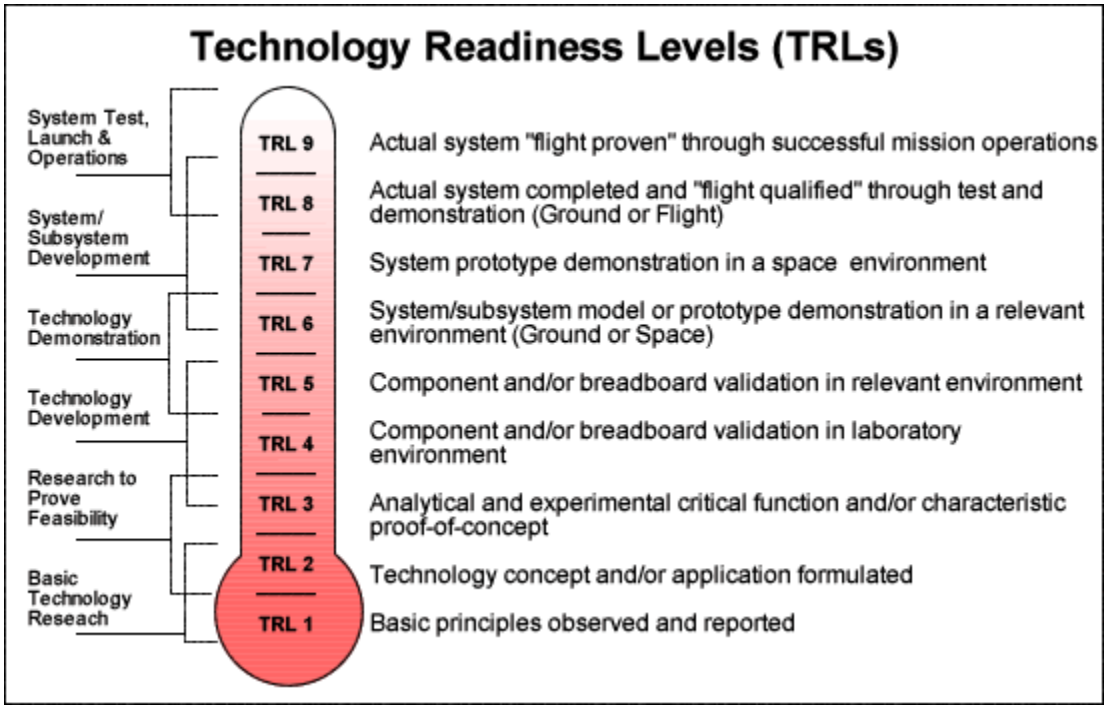
The TRL Problem

"TRL level definitions were developed as a communication tool. They can be very useful--if well defined. The problem in all communication is that the recipient often receives a different message than what the sender thought he sent. So it is important to have as many people on the same page with respect to definitions as possible, minimizing differences in understanding and establishing a meaningful reference for additional discussion" – David Dean, Naval Air Warfare Center Weapons Division, 2007

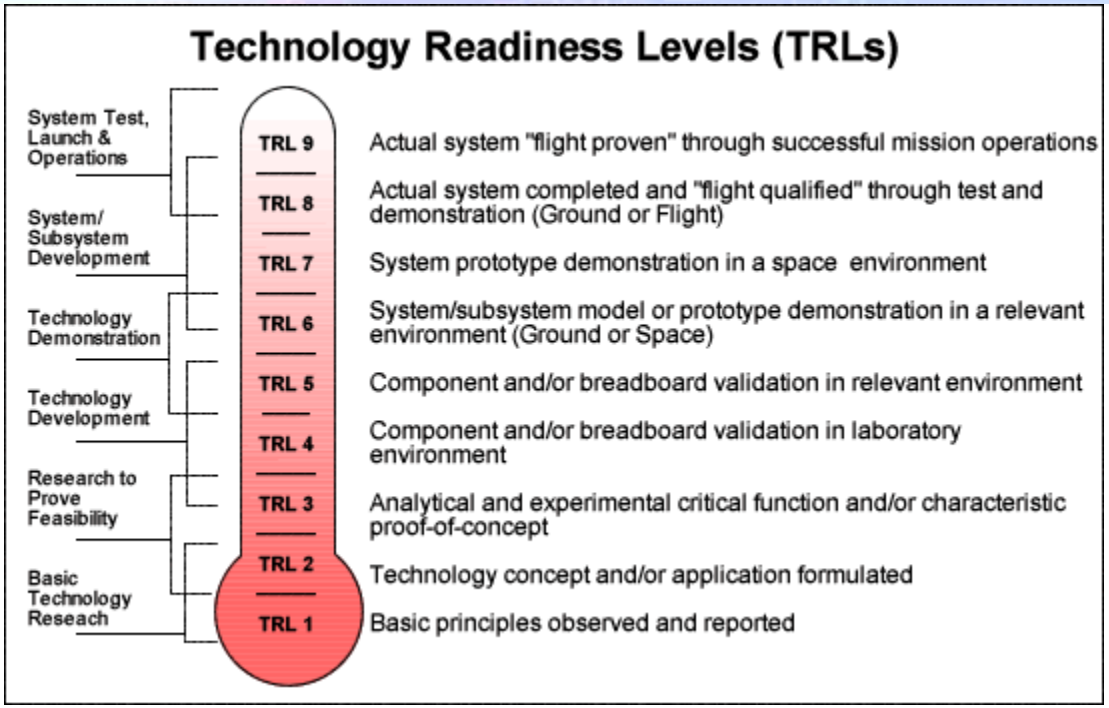
TRL Evolution

TRL concept originated by NASA

- **Top level ready for flight on Shuttle**
- **Bottom level was idea that could be used to control or improve control**
- **Concept built on (electronic) subsystems that integrate into the Shuttle flight system**



TRL Evolution



- **System devised for essentially large-scale system**
- **Initially tried to apply them to everything from new ingredients, to formulations, to rocket motors and warheads, to full missile systems and to systems of systems!**

TRL Evolution

- **Variety of definitions developed and used**
- **DoD Technology Readiness Assessment (TRA) Deskbook – May 2005**
  - **Hardware TRL Definitions, Descriptions, and Supporting Information (Source: *Defense Acquisition Guidebook)***
  - **Software TRL Definitions, Descriptions, and Supporting Information (Source: IT TRL *Working Group Minutes,* November *9,2004)***
  - **Manufacturing Technology TRL Definitions, Descriptions, and Supporting Information (Source: *Joint Defense Manufacturing Technology Panel (JDMPT) Manufacturing Readiness Level Subgroup)***

TRL Evolution

- 2006 – Technology Readiness Levels for Insensitive Munitions Programs – Rich Bowen/Ken Tomasello – Navy IM Office
- 2007 – Technology Readiness Levels for Propellants – Chris Michienzi – NSWC Indian Head
- 2007 – Component Readiness Levels – David Dean
- 2008 – Recommendation from Propulsion IPT – "Establish criteria for technology and manufacturing readiness levels"
- 2009 – JANNAF Workshop
- 2010 – "Propellant Readiness Level: A Methodological Approach to Propellant Characterization" – AIAA 2010-6732 – Bossard and Rhys

TRL Evolution

- **2014 – Stuart Blashill asked by JIMTP Program Manager to develop a set of TRLs specific to the program**
- **Based drafts on what had come before, adjusting values as thought appropriate**
- **Presented at JIMTP Strategic Planning Meeting and team established to refine**
- **Final version incorporated into JIMTP Strategic Plan and presented to the Technical Advisory Committee in August**

JIMTP TRLs

TRL	Ingredient	Formulation	Mitigation Device	Weapon Subsystem

JIMTP TRLs Examples

TRL	Ingredient	Formulation	Mitigation Device	Weapon Subsystem
	Molecule X	Explosive containing Molecule X	Venting Mechanism	Warhead

These could all be at different TRLs!

JIMTP TRL 1

TRL	Ingredient	Formulation	Mitigation Device	Weapon Subsystem
Basic principles Observed and Reported (6.1)	Fundamental research to develop new ingredient concepts. Technical publication or report reviewed and recognized by the technical community.	Formulation(s) conceived using literature search of ingredients and their properties.	Design/concept studies of a technology's basic properties. Applications are speculative and there may be no proof or detailed analysis to support the assumptions. Examples are limited to analytic studies.	Identification of available component technologies, design/trade studies and analysis of approaches.

JIMTP TRL 2

TRL	Ingredient	Formulation	Mitigation Device	Weapon Subsystem
Technology concept and/or application formulated (6.1/6.2)	Ingredients synthesized and produced at 5 gram level. Safety characterization tests	Thermochemical calculations performed. First mixes (hand or mechanical): thermal and mechanical sensitivity/safety data, ingredient compatibility / solubility, demonstrate processing and cure.	Early laboratory studies to physically validate analytical predictions. Parts are not yet integrated or representative.	Concept development. Component studies. Theoretical performance analyses. Bench-top testing.

JIMTP TRL 3

TRL	Ingredient	Formulation	Mitigation Device	Weapon Subsystem
Analytical and experimental critical function and/or characteristic proof of concept (6.2)	Synthesis is optimized at laboratory level to ~50 gram level. Material is completely characterized and the synthesis yields consistent results at this scale.	Mixes up to 1lb: experiment with formulation, determine processability, burning rate (strand burn, closed bomb), mechanical properties, small-scale vulnerability testing for thermal and/or impact response.	Parts are integrated to establish that they will work together in the device. Bench-top testing.	Components selected. Fabrication and integration begins.

JIMTP TRL 4

TRL	Ingredient	Formulation	Mitigation Device	Weapon Subsystem
Component validation in pilot plant, laboratory or simulated environment (6.2/6.3)	Scale-up begins. Quantities of reproducible material are available and sufficient for 6.2-level formulation efforts.	Mixes to 10lb: formulation refined optimized, repeat testing from TRL3. Sub-scale performance testing. Consistent mix quality and performance results.	Realistic components are integrated. Device tested in a simulated environment.	Sub-scale, analog and/or surrogate testing to validate IM and performance.

JIMTP TRL 5

TRL	Ingredient	Formulation	Mitigation Device	Weapon Subsystem
Component validated in relevant environment (6.3)	Scale-up is demonstrated. Quantities of reproducible material are available and sufficient for 6.3-level formulation efforts.	Mixes to 50 lb with pilot plant grade ingredients. Formulations evaluated at full scale. Large scale testing is initiated.	Fabrication and testing of the device on sub-scale weapon components to validate performance.	Full-scale fabrication and testing begins, often with some simulated components.

JIMTP TRL 6

TRL	Ingredient	Formulation	Mitigation Device	Weapon Subsystem
System / subsystem model or prototype demonstration in a relevant environment. (6.3/6.4)	Advanced development of material is conducted at simulated production levels and evaluated for safety/IM and performance. Procurement draft specifications are developed.	Qualification of explosives / propellants / compositions begins.	Representative full-scale system is tested in a relevant environment.	Full-scale fabrication and testing completed on representative item.

JIMTP TRL 7

TRL	Ingredient	Formulation	Mitigation Device	Weapon Subsystem
System prototype demonstration in an operational environment (6.4/6.5)	Material routinely available: sustainable, reliable supply.	Composition routinely available. Qualification complete. PM demonstrates formulation in end item hardware.	PM demonstrates device in end item hardware.	System prototype demonstration by PM.

Summary

- **The system engineer can argue that a well characterized component is nothing more than a component, and until it is utilized in a subsystem, there is no TRL at all.**
- **Conversely, the chemist or materials engineer can say that his new compound or material is completely characterized and manufactured at the ton level and is clearly mature, meaning some high TRL level.**
- **The JIMTP TRL definitions attempt to take both of these views into account and provide a means of gauging the maturity of a proposed technology and assessing the risk.**

Questions