The International Project on Innovative Nuclear Reactors and Fuel Cycles (INPRO)

The INPRO Dialogue Forum

Technology Readiness Levels

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INPRO Dialogue Forum Workshop
February 1-4, 2010

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International Atomic Energy Agency

Technology Readiness

Introduction to Technology Readiness and Its Role in Successful Commercialization

What is the technology development plan?

1. **Will the program be concept to commercial?**
2. **Will the program use the technology nationally?**
3. **Will the program license the technology (patents) or will it be transferred from / developed with a strategic partner?**
4. **Will the program export the technology?**

How do we determine when and how technology is ready?

Technology Readiness Session Objectives:

1. Provide a basic understanding of Technology Readiness terms and definitions and an overview of several national experiences

2. How mature does the technology need to be before a Member State can consider it ready for inclusion in their National Nuclear Energy System (NES) Development and Deployment Plan?

3. What kinds of “proof”, data, or validating information is required for a Member State to make a determination of technology readiness?

The Problem: Technical Risk

In the US many technology development programs were going ahead with less knowledge at critical junctures than suggested by best practices. These critical junctures are known as “Knowledge Points” and include:

- **Technology maturity**
- **Design maturity**
- **Fabrication maturity**

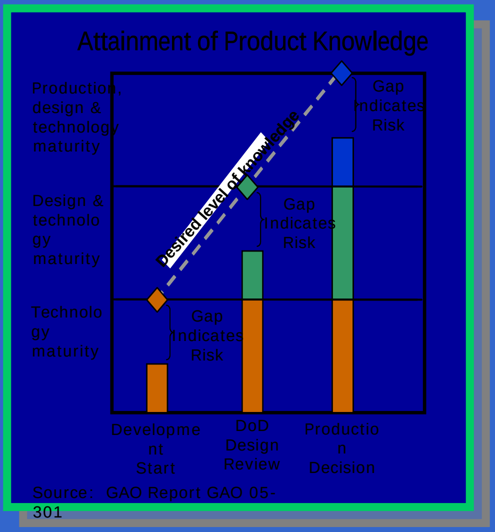
What are Knowledge Points?

Knowledge Points and associated indicators are defined as follows and all basically look at the maturity levels at a critical juncture:

- **Technology is mature.** This means that technologies need to meet essential performance requirements and have been demonstrated to work in their intended environment. **A gap between industry best practices and actual technology maturity indicates potential technical risk.**

- **Component / Facility design is stable.** This means that the design is stable at the system-level during design review. **A gap between industry best practices and actual design stability indicates potential technical risk.**

- **Production / Fabrication processes are mature.** This means that all key manufacturing processes are repeatable, sustainable and demonstrated at the start of production. **A gap between industry best practices and actual production maturity indicates potential technical risk.**



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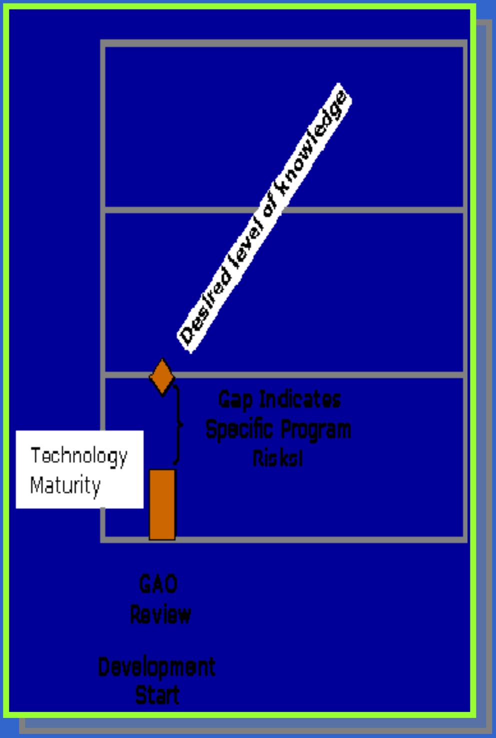
What Were the Problems?

The US study found - Immature Technologies:

Eighty-five percent of the programs that were over budget or behind schedule began development not having demonstrated all of their technologies as mature. There was a major gap between what they should have known at the decision point and what they knew. Going forward required a "leap of faith" that somehow a miracle would occur to solve technology gaps.

More often than not, programs expected to mature technologies through technology development when they should have been focusing on maturing the system design and preparing for production. These programs moved forward before the technologies were mature, but the miracle failed to appear and it caused problems- technical failure.



Program acquisition cost:

- Rose an average of **21 percent** for those programs that preceded with immature technologies.

- Rose an average of only **one percent** for programs with mature technologies!

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What Were the Problems? (continued)

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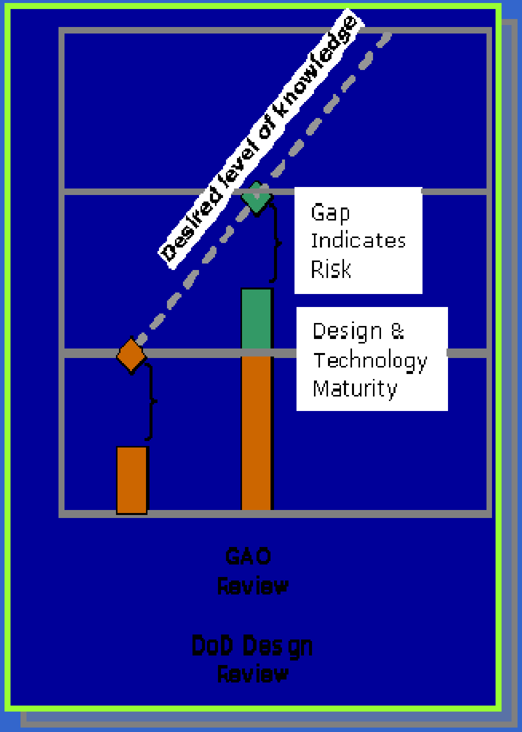
The US study found - Design Instability:

Only 42 percent of programs held design reviews after achieving design stability. The majority moved forward with unstable designs. There was a major gap between what they should have known at the decision point and what they knew. Going forward required a "leap of faith" that somehow a miracle will occur to solve these gaps. These programs moved forward before the design was mature, the miracle did not occur and it caused problems.



The **mature programs** experienced:

- A 6 percent increase in development costs and a schedule increase of 11 months

Immature programs, those that did not achieve design stability by Design Review experienced:

- A **46 percent increase** in cost and a schedule slip of 29 months

It should be noted that design stability cannot be attained if key technologies are not mature.

One way to determine Technology Readiness uses TRLs Developed by NASA for the USG

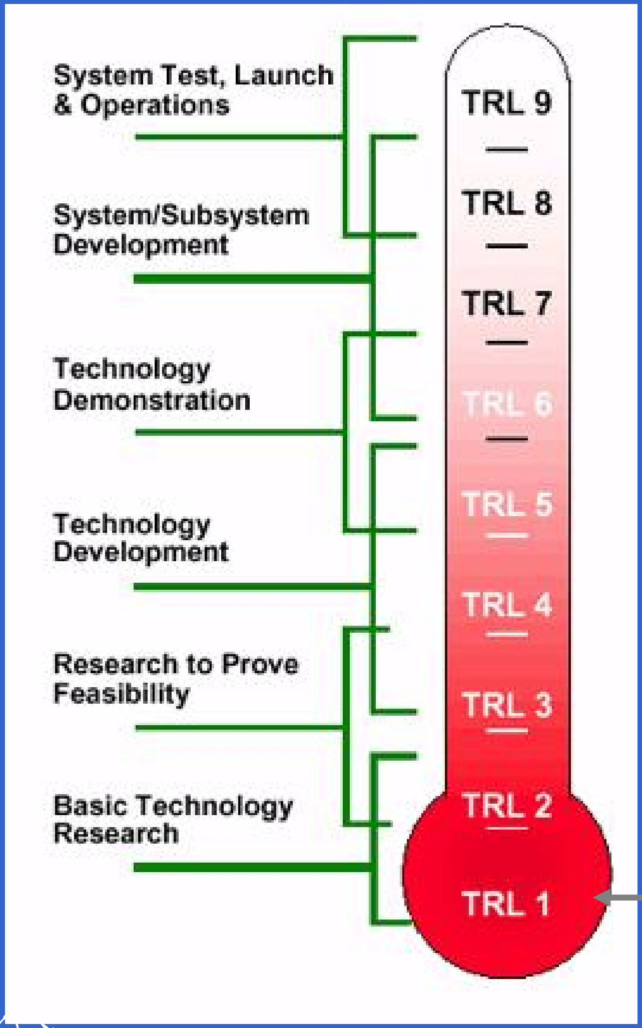
- In response to the high cost and risks associated with constantly pushing the technological envelope, NASA developed and began using Technology Readiness Levels (TRLs) in the 1980's.

- The Technology Readiness Levels were a scale for assessing the maturity of a particular technology.

- The original scale consisted of seven levels and this was later expanded to nine levels of technology development maturity as seen in the next slides.

- NASA's use of TRLs has led to it's widespread adoption by other government agencies including the Department of Energy.

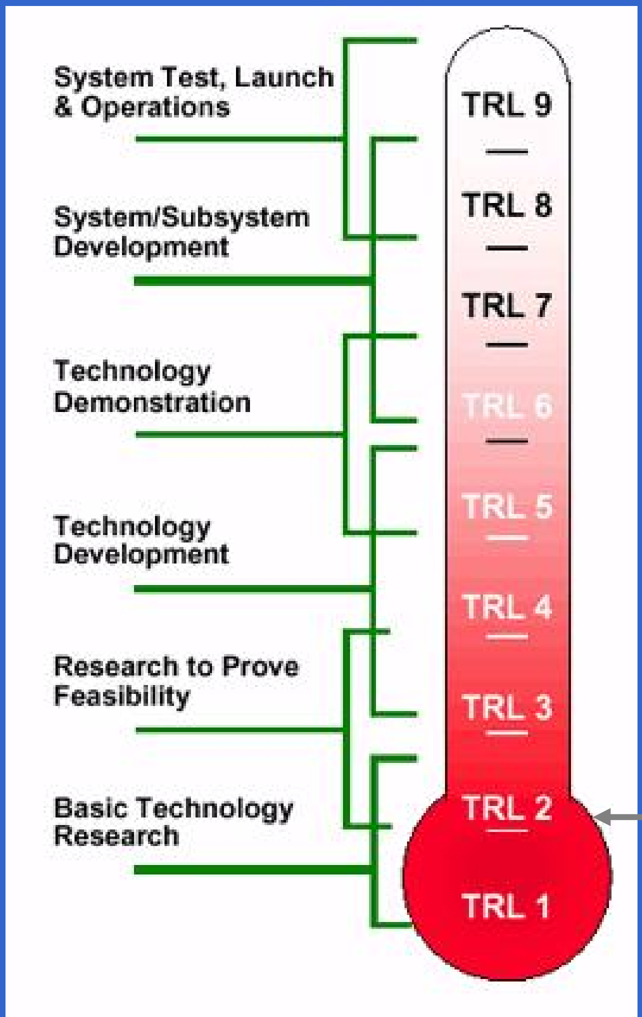
TRLs Described: TRL-1



TRL 1:

Basic principles observer and reported. This is the lowest "level" of technology maturation. At this level scientific research begins to be translated into applied research and development.

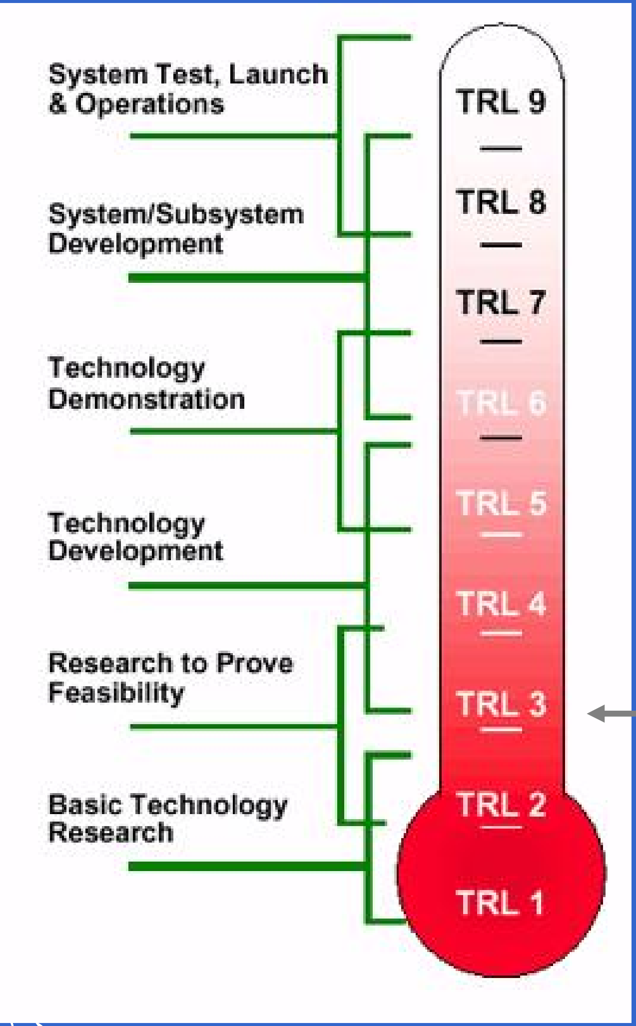
TRLs Described: TRL-2



TRL 2:

Technology concept and/or application formulated. Once basic physical principles are observed, the organization identifies practical applications of those characteristics for the next level of maturation. At this level, the application is still speculative: there is not experimental proof or detailed analysis to support the conjecture.

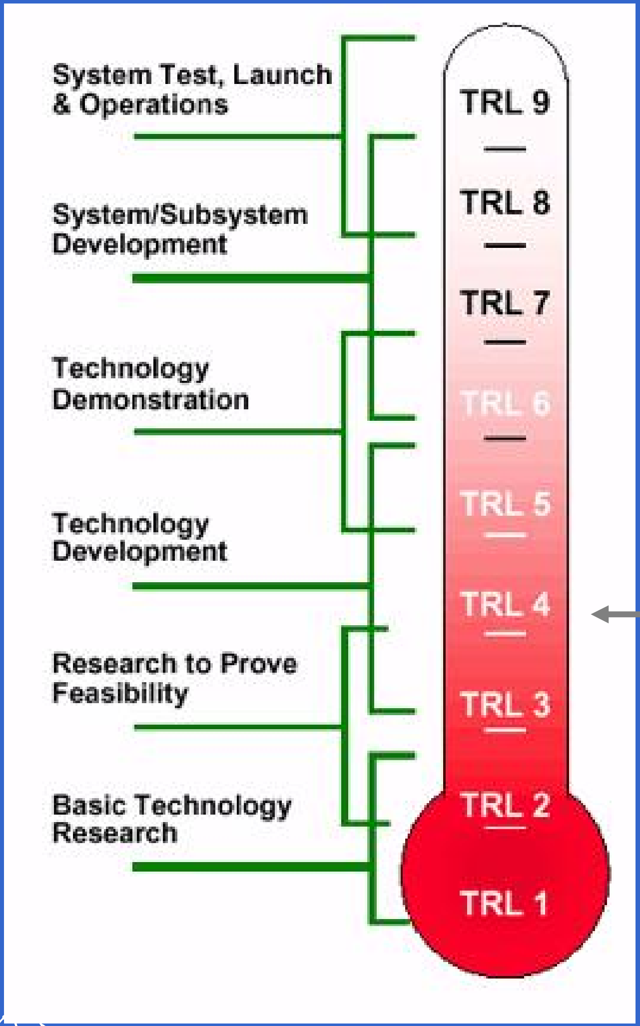
TRLs Described: TRL-3



TRL 3:

Analytical and experimental critical function and / or characteristic proof of concept. At this step in the maturation process, the organization initiates active research and development (R&D). This must include both analytical studies and laboratory-based studies to physically validate that the analytical predictions are correct.

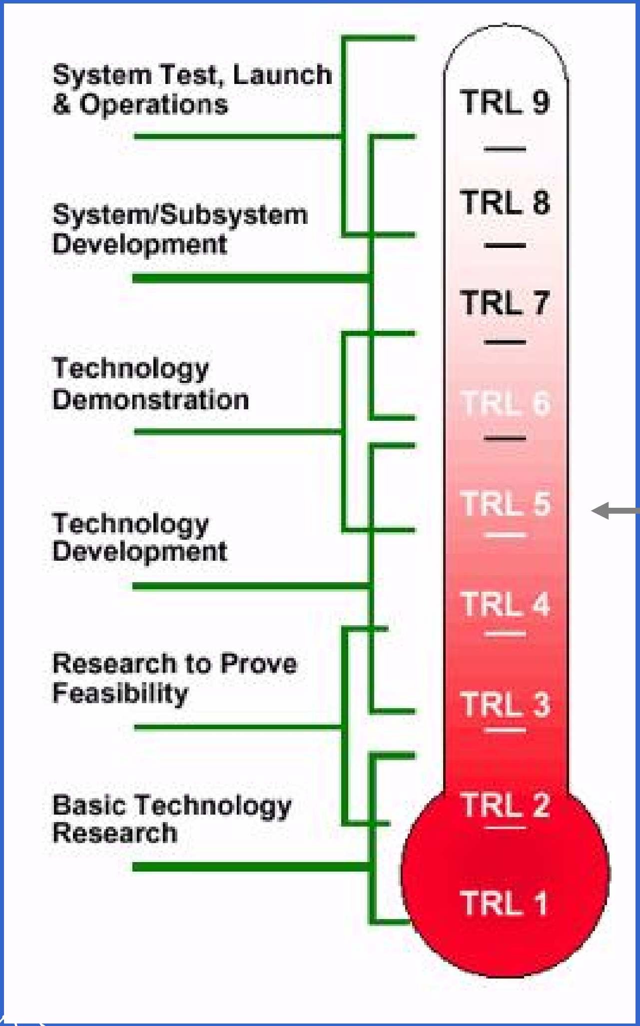
TRLs Described: TRL-4



TRL 4:

Component and/or breadboard validation in laboratory environment. Following successful "proof-of-concept" work, the organization must integrate basic technological elements. This is to establish that the "pieces" will work together to achieve concept-enabling levels of performance for a component and/or breadboard.

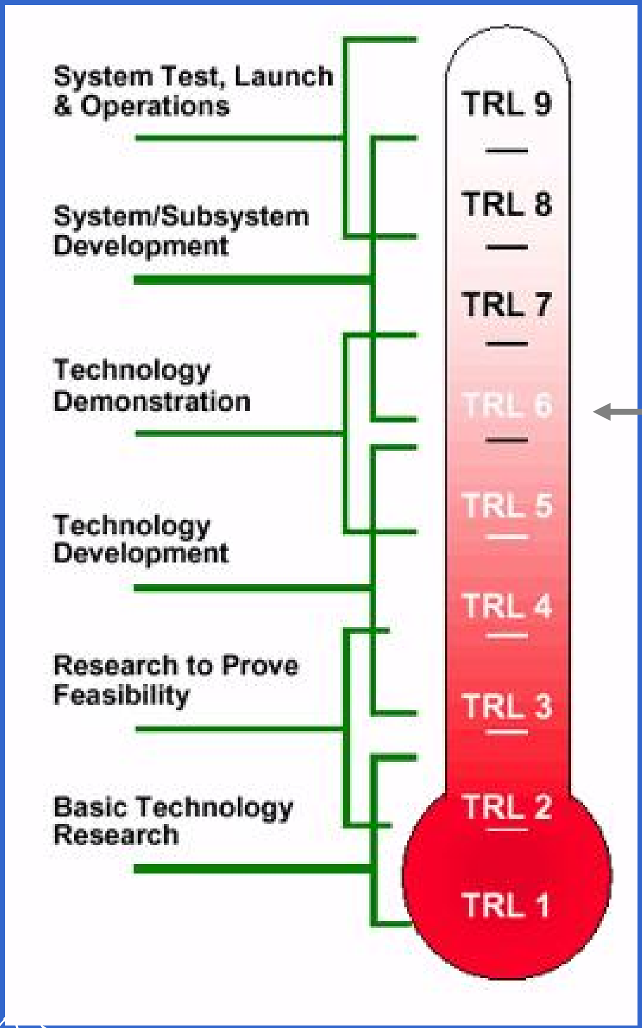
TRLs Described: TRL-5



TRL 5:

Component and/or breadboard validation in relevant environment. At this level, the fidelity of the component and/or breadboard being tested has to increase significantly and tested in a 'simulated' or somewhat realistic environment.

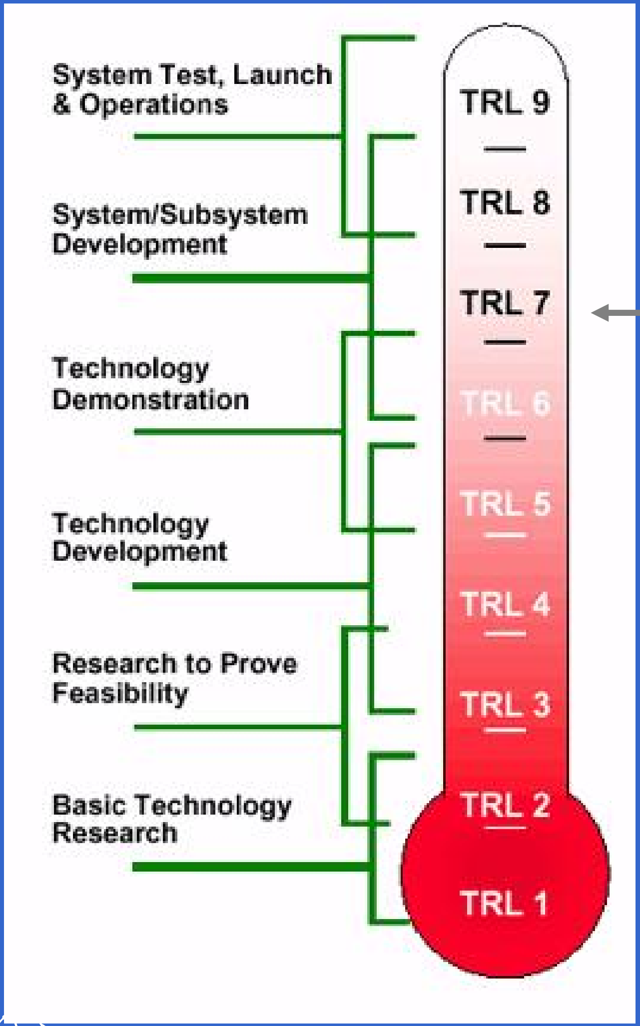
TRLs Described: TRL-6



TRL 6:

System / subsystem model or prototype demonstration in a relevant environment (ground or space). At TRL 6, the organization tests a representative model or prototype system or system in a relevant environment.

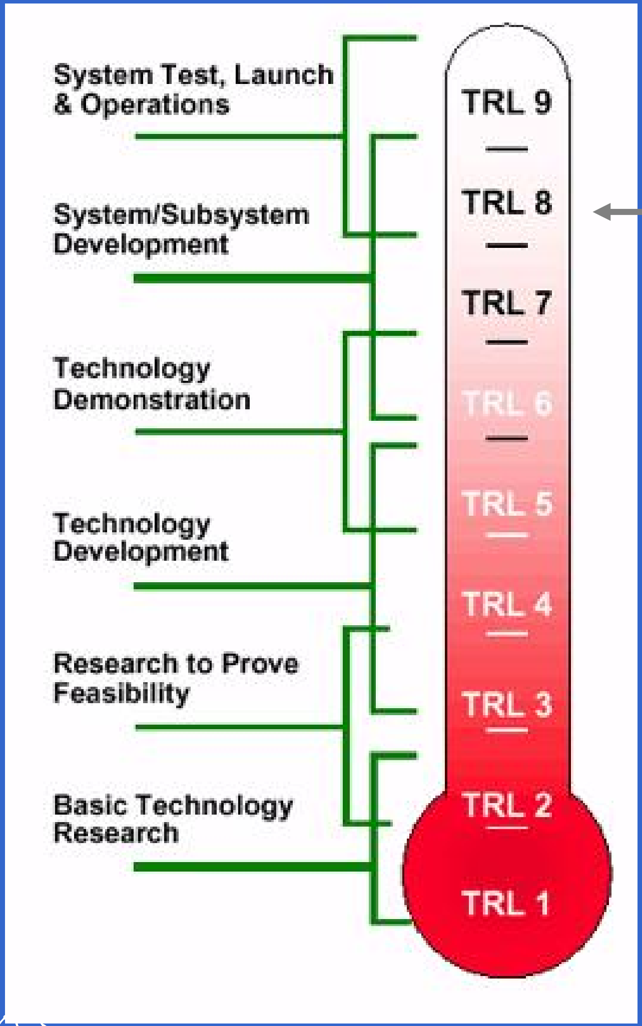
TRLs Described: TRL-7



TRL 7:

System prototype demonstration in a space environment. TRL 7 is a significant step beyond TRL 6, requiring an actual system prototype demonstration in a actual environment. The prototype should be near or at the scale of the planned operational system.

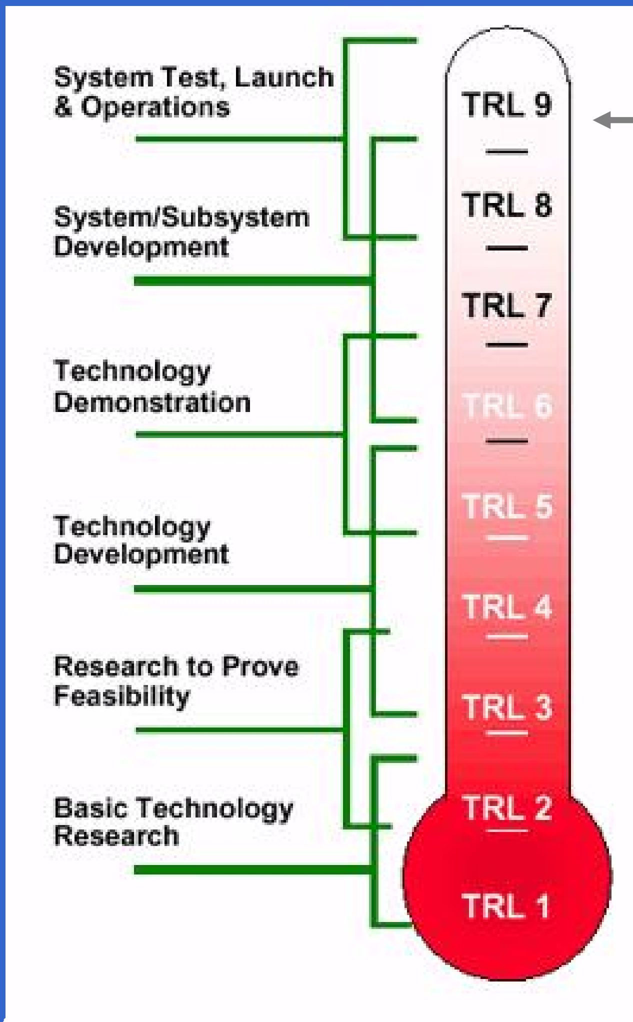
TRLs Described: TRL-8



TRL 8:

Actual system completed and demonstrated through testing and operation in actual conditions. In almost all cases, this level is the end of true 'system development' for most technology elements. This might include integration of new technology into an existing system.

TRLs Described: TRL-9



TRL 9:

Actual system operation. In almost all cases, the end of true 'system development'. This might include integration of new technology into an existing system. This TRL does *not* include planned product improvement of ongoing or reusable systems.

TRLs Developed by NASA

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TRLs are designed to:

- Measure technology maturity, and
- Indicate what has been accomplished in the development of that technology;
    1. Theory / Laboratory / Field
    2. Relevant Environment / Operational Environment
    3. Subscale / Full Scale
    4. Breadboard / Brassboard / Prototype
    5. Reduced Performance / Full Performance

TRLs are *not* designed to assess whether:

- The technology is the right answer for the job.
- The application of the technology will result in the successful development and deployment of a system.
- The manufacturing capability exists to produce or repeatably produce the item.

Proven Technology Speakers

- Opening remarks by session chair *R. Beatty (INPRO)*
- Proven technology for the APR1400's development, licensing and deployment *C-H Song (ROK)*
- The EPR TM reactor : evolution to Gen III+ based on proven technology

  A. Teller (France)
- Perspective from Japan in the area of proven technology *M. Koyama (Japan)*
- Role of R&D from early development to commercialization *R. Speranzini (Canada)*
- Break
- Proven Technology: CAREM approach *D. Delmastro (Argentina)*
- Proven technology: perspective from Indonesia *B. Suprawoto (Indonesia)*

Questions??

Thank you for your attention.

Please contact for further information:

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