Status of the development of an International Standards Organization (ISO) definition of the Technology Readiness Levels (TRL) and their criteria of assessment

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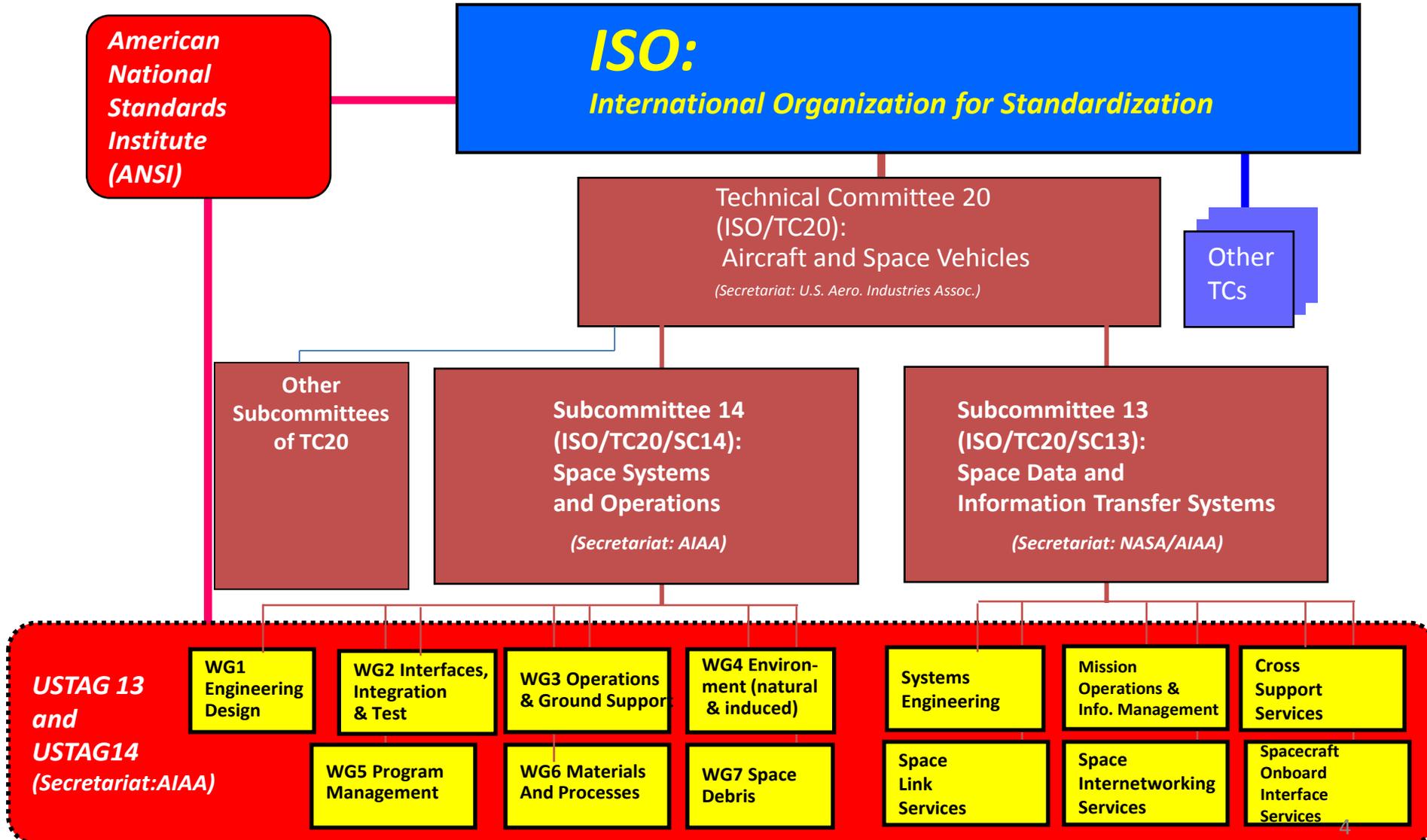
Status of Proposed ISO TRL Handbook

- What is ISO?
- What is TRL?
- The DoD TRL Process
- The NASA TRL Process
- Current Status
- What documents are being considered as inputs for the Handbook?
- The Way ahead

International Standards Organization (ISO)

- "ISO (International Organization for Standardization) is a global network that identifies what International Standards are required by business, government and society, develops them in partnership with the sectors that will put them to use, adopts them by transparent procedures based on national input and delivers them to be implemented worldwide."
  - ISO is not a Government or treaty Organization; like IEC, ITU
  - **Members: 157** national standards bodies (e.g. ANSI)
  - **208** technical committees, **531** subcommittees
- ISO TC20/SC14 Space Systems and Operations– Estab. 1992
  - 12 Participating countries ; 7 Observers ; 7 Liaison Orgs.
  - May 18-22, 2009, Berlin, Germany : 19th Plenary, 31st WG1 meeting,
  - ~100 attendees, 11 countries represented

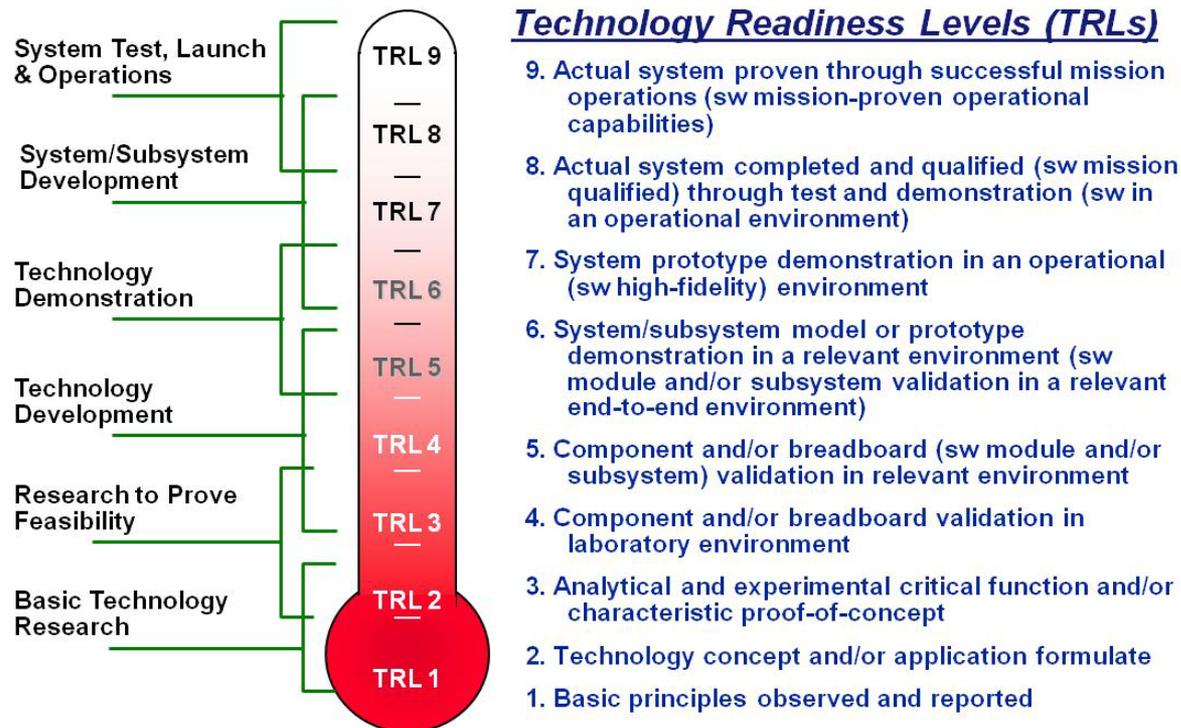# International Standards Organization (ISO)

American National Standards Institute (ANSI)

ISO:
International Organization for Standardization

Technical Committee 20
(ISO/TC20):
Aircraft and Space Vehicles

(Secretariat: U.S. Aero. Industries Assoc.)

Other TCs

Other Subcommittees of TC20

**Subcommittee 14
(ISO/TC20/SC14):
Space Systems
and Operations**

(Secretariat: AIAA)

**Subcommittee 13
(ISO/TC20/SC13):
Space Data and
Information Transfer Systems**

(Secretariat: NASA/AIAA)

USTAG 13 and USTAG14
(Secretariat:AIAA)

WG1 Engineering Design

WG2 Interfaces, Integration & Test

WG3 Operations & Ground Support

WG4 Environ-ment (natural & induced)

WG5 Program Management

WG6 Materials And Processes

WG7 Space Debris

Systems Engineering

Mission Operations & Info. Management

Cross Support Services

Space Link Services

Space Internetworking Services

Spacecraft Onboard Interface Services

International Standards Organization (ISO)

International harmonized stage codes

STAGE	SUB-STAGE						
	00	**20**	**60**	**90** Decision			
	Registration	**Start of main action**	**Completion of main action**	**92** Repeat an earlier phase	**93** Repeat current phase	**98** Abandon	**99** Proceed
00 Preliminary stage	**00.00** Proposal for new project received	**00.20** Proposal for new project under review	**00.60** Close of review			**00.98** Proposal for new project abandoned	**00.99** Approval to ballot proposal for new project
10 Proposal stage	**10.00** Proposal for new project registered	**10.20** New project ballot initiated	**10.60** Close of voting	**10.92** Proposal returned to submitter for further definition		**10.98** New project rejected	**10.99** New project approved
20 Preparatory stage	**20.00** New project registered in TC/SC work programme	**20.20** Working draft (WD) study initiated	**20.60** Close of comment period			**20.98** Project deleted	**20.99** WD approved for registration as CD
30 Committee stage	**30.00** Committee draft (CD) registered	**30.20** CD study/ballot initiated	**30.60** Close of voting/comment period	**30.92** CD referred back to Working Group		**30.98** Project deleted	**30.99** CD approved for registration as DIS
40 Enquiry stage	**40.00** DIS registered	**40.20** DIS ballot initiated: 5 months	**40.60** Close of voting	**40.92** Full report circulated: DIS referred back to TC or SC	**40.93** Full report circulated: decision for new DIS ballot	**40.98** Project deleted	**40.99** Full report circulated: DIS approved for registration as FDIS
50 Approval stage	**50.00** FDIS registered for formal approval	**50.20** FDIS ballot initiated: 2 months. Proof sent to secretariat	**50.60** Close of voting Proof returned by Secretariat	**50.92** FDIS referred back to TC or SC		**50.98** Project deleted	**50.99** FDIS approved for publication
60 Publication stage	**60.00** International Standard under publication		**60.60** International Standard published				
90 Review stage		**90.20** International Standard under periodical review	**90.60** Close of review	**90.92** International Standard to be revised	**90.93** International Standard confirmed		**90.99** Withdrawal of International Standard proposed by TC or SC
95 Withdrawal stage		**95.20** Withdrawal ballot initiated	**95.60** Close of voting	**95.92** Decision not to withdraw International Standard			**95.99** Withdrawal of International Standard

What is a TRL?

- A Technology Readiness Level (TRL), describes the maturity of a given technology relative to its development cycle.

- At its most basic, it is defined at a given point in time by what has been done and under what conditions.


Technology Readiness Levels (TRLs)

9. Actual system proven through successful mission operations (sw mission-proven operational capabilities)

8. Actual system completed and qualified (sw mission qualified) through test and demonstration (sw in an operational environment)

7. System prototype demonstration in an operational (sw high-fidelity) environment

6. System/subsystem model or prototype demonstration in a relevant environment (sw module and/or subsystem validation in a relevant end-to-end environment)

5. Component and/or breadboard (sw module and/or subsystem) validation in relevant environment

4. Component and/or breadboard validation in laboratory environment

3. Analytical and experimental critical function and/or characteristic proof-of-concept

2. Technology concept and/or application formulate

1. Basic principles observed and reported

System Test, Launch & Operations — TRL 9, TRL 8

System/Subsystem Development — TRL 7

Technology Demonstration — TRL 6

Technology Development — TRL 5, TRL 4

Research to Prove Feasibility — TRL 3

Basic Technology Research — TRL 2, TRL 1

The Beginning of TRL's

- The idea of ascribing levels of maturity to technology was first documented in a paper "***THE NASA TECHNOLOGY PUSH TOWARDS FUTURE SPACE MISSION SYSTEMS,***" (Saden, Povinelli & Rosen, 1989).

- This was a significant change in emphasis on the part of NASA, where technology had previously been viewed as merely having a supporting role.

- The change in role was the result of a revision in the National Space Policy stating that NASA's technology program "--*shares the mantle of responsibility for shaping the Agency's future--.*"

Who uses TRL's?

- CNES
- DLR
- DOD
- DOE
- DHS
- UK MOD
- Canada
- Australia
- JAXA
- ESA
- NATO
- And of course NASA

DoD Acquisition Milestones
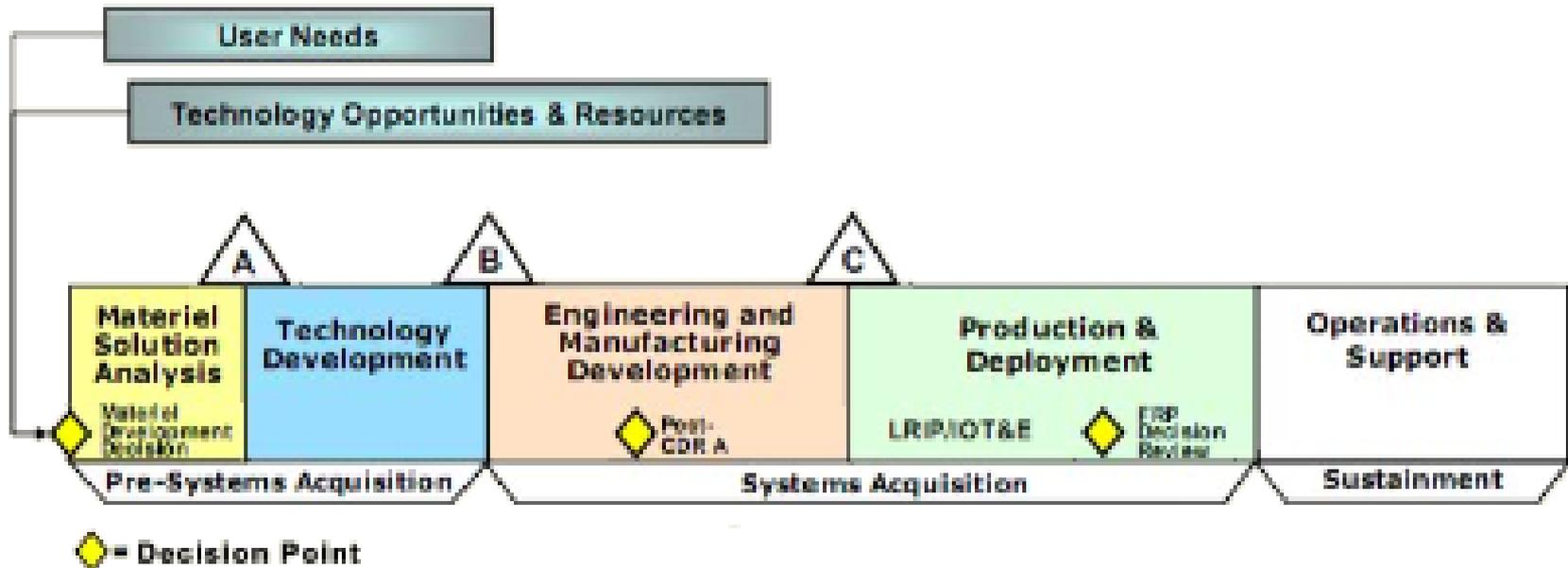
MS A approves entry into the Technology Development (TD) phase;

MS B approves entry into the Engineering and Manufacturing Development (EMD) phase;

MS C approves entry into the Production and Deployment (P&D) phase.

TRA required at MS B (Congressional mandate) and MS C (DoD Regulatory mandate)

DOD Technology Readiness Assessment (TRA) Deskbook July 2009 provides guidance

What is a TRA?

- A systematic, metrics-based process and accompanying report that
  - Assesses the maturity of Critical Technology Elements (CTEs) used in systems
  - Uses TRLs as the metric
- Regulatory information requirement for *all* acquisition programs at MS B and C
  - Submitted to oversight for ACAT ID and MAIS programs, including space programs

ACAT (Acquisition Category) I - Major Defense Acquisition Programs	MAIS - Major Automated Information Systems Programs

- Demonstrates
  - How the CTEs are identified
  - Why the CTEs are important to the program
  - An *independent* (from the program) assessment of their maturity
- Adequate performance to meet program requirements must be demonstrated in the appropriate environment

What are CTEs?

- A technology element is "critical" (CTE)
  - If the system being acquired depends on this technology element to meet operational requirements
    - Within acceptable cost and schedule limits *and*
  - If the technology element or its application is
    - Either new or novel, or
    - In an area that poses major technological risk during detailed design or demonstration

DoD Technology Maturation Policy Leading To Milestone Decisions

Milestone B   **TRL 6**

- Technology developed in science and technology (S&T) or procured from industry or other sources shall have been demonstrated in a relevant environment or preferably, in an operational environment to be considered mature enough to use for product development

- Technology readiness assessments, and where necessary, independent assessments, shall be conducted

- If technology is not mature, the DoD Component shall use alternative technology that is mature and that can meet the user's needs

Milestone C   **TRL 7**

- Entrance Criteria. Entrance into this phase depends on the following criteria:

  - ✓ Acceptable performance in developmental test and evaluation (DT&E) and operational assessment
  - ✓ Mature software capability
  - ✓ No significant manufacturing risks
  - ✓ Acceptable interoperability
  - ✓ Acceptable operational supportability

Source: Department of Defense Instruction (DoDI) 5000.02, *Operation of the Defense Acquisition System,* December 8, 2008, Enclosure 2, paragraph 5.d.(4) and paragraph 7.b

NASA TRL Assessment Process

How often do you do a Technology Assessment (TA) ?

As defined by NPR 7120.5d,
NASA Space Flight Program and Project Management Requirements

- **KDP A – Transition from Pre-Phase A to Phase A:**
  Requires an assessment of potential technology needs versus current and planned technology readiness levels, as well as potential opportunities to use commercial, academic, and other government agency sources of technology. Included as part of the draft integrated baseline.

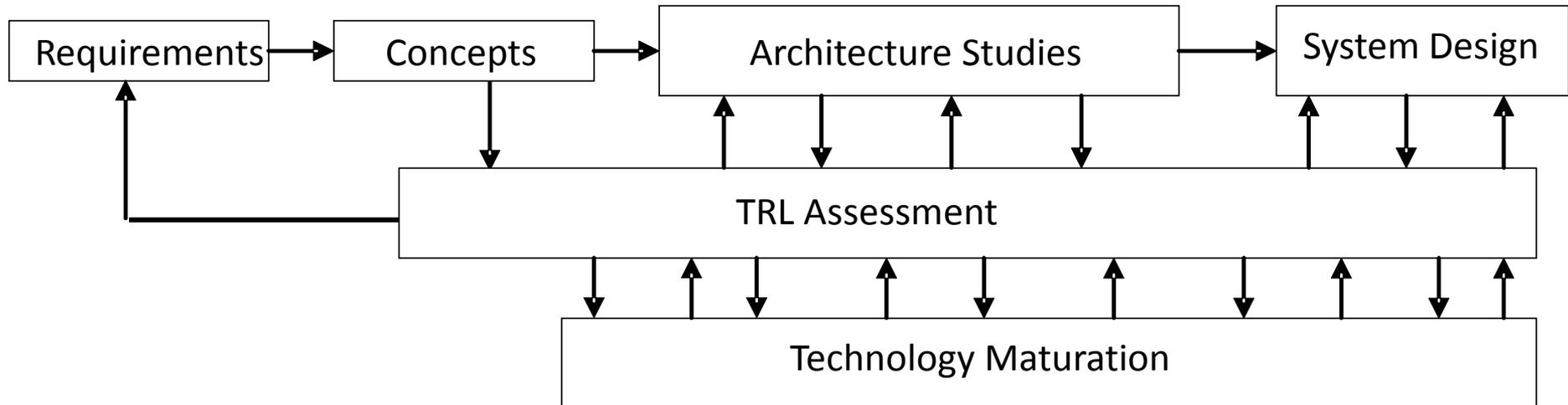- **KDP B – Transition from Phase A to Phase B:**
  Requires a Technology Development plan identifying technologies to be developed, heritage systems to be modified, alternate paths to be pursued, fall back positions and corresponding performance de-scopes, milestones, metrics and key decision points. Incorporated in the preliminary Project Plan.

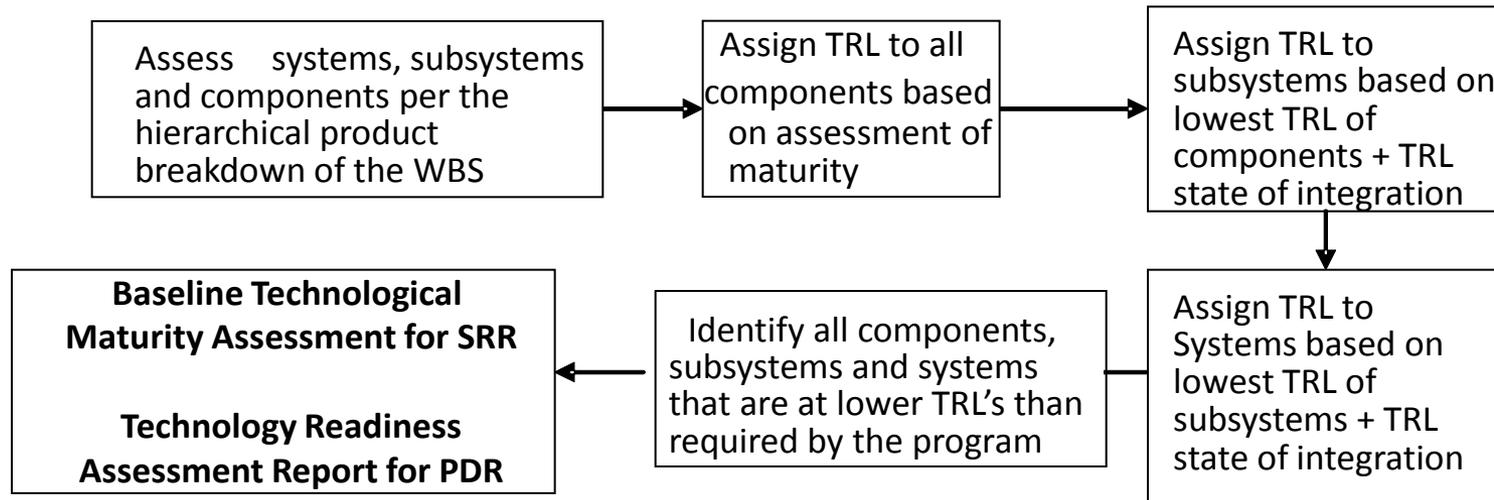- **KDP C – Transition from Phase B to Phase C/D:**
  Technology Readiness Assessment Report (TRAR) demonstrating that all systems, subsystems and components have achieved a level of technological maturity with demonstrated evidence of qualification in a relevant environment.

NASA TRL Assessment Process

Architectural Study & Technology Assessment Interaction

NASA TRL Assessment Process

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┌─────────────────────────┐     ┌─────────────────────┐     ┌─────────────────────────┐
│ Assess    systems,      │     │ Assign TRL to all   │     │ Assign TRL to           │
│ subsystems              │     │ components based    │     │ subsystems based on     │
│ and components per the  │ ──► │ on assessment of    │ ──► │ lowest TRL of           │
│ hierarchical product    │     │ maturity            │     │ components + TRL        │
│ breakdown of the WBS    │     │                     │     │ state of integration    │
└─────────────────────────┘     └─────────────────────┘     └─────────────────────────┘
                                                                          │
                                                                          ▼
┌─────────────────────────┐     ┌─────────────────────┐     ┌─────────────────────────┐
│ Baseline Technological  │     │ Identify all        │     │ Assign TRL to           │
│ Maturity Assessment     │     │ components,         │     │ Systems based on        │
│ for SRR                 │ ◄── │ subsystems and      │ ◄── │ lowest TRL of           │
│                         │     │ systems             │     │ subsystems + TRL        │
│ Technology Readiness    │     │ that are at lower   │     │ state of integration    │
│ Assessment Report for   │     │ TRL's than          │     │                         │
│ PDR                     │     │ required by the     │     │                         │
│                         │     │ program             │     │                         │
└─────────────────────────┘     └─────────────────────┘     └─────────────────────────┘
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NASA TRL Definition Example
(R&T NPR 7120.8)

Level	Definition	Hardware Description	Software Description	MRL Description	Exit Criteria
5	Component or breadboard validation in a relevant environment	A mid-level fidelity system/component brassboard is built and operated to demonstrate overall performance in a simulated operational environment with realistic support elements that demonstrates overall performance in critical areas. Performance predictions are made for subsequent development phases.	End-to-end Software elements implemented and interfaced with existing systems/simulations conforming to target environment. End-to-end software system, tested in relevant environment, meeting predicted performance. Operational Environment Performance Predicted. Prototype implementations developed.	Manufacturing Process Development. Trade studies and lab experiments define key manufacturing processes and sigma levels needed to satisfy CAIV targets. Initial assessment of assembly needs conducted. Process, tooling, inspection, and test equipment in development. Significant engineering and design changes. Quality and reliability levels not yet established. Tooling and machines demonstrated in lab. Physical and functional interfaces have not been completely defined.	Documented test performance demonstrating agreement with analytical predictions. Documented definition of scaling requirements.
6	System/subsystem model or prototype demonstration in a relevant environment	A high-fidelity system/component prototype that adequately addresses all critical scaling issues is built and operated in a relevant environment to demonstrate operations under critical environmental conditions.	Prototype implementations of the software demonstrated on full-scale realistic problems. Partially integrate with existing hardware/software systems. Limited documentation available. Engineering feasibility fully demonstrated.	Critical Manufacturing Processes Prototyped. Critical manufacturing processes prototyped, targets for improved yield established. Process and tooling mature. Frequent design changes still occur. Investments in machining and tooling identified. Quality and reliability levels identified. Design to cost goals identified.	Documented test performance demonstrating agreement with analytical predictions.

NASA TRL Supporting Definition Example

Relevant Environment:

Not all systems, subsystems and/or components need to be operated in the operational environment in order to satisfactorily address performance margin requirements. Consequently, the relevant environment is the specific subset of the operational environment that is required to demonstrate critical "at risk" aspects of the final product performance in an operational environment.

Status of Proposed ISO TRL Handbook

First Meeting of the ISO TRL Working Group (WG) held at the British Standards Institute in London, UK on May 11, 2010

Status of Proposed ISO TRL Handbook

ISO TRL WG objectives

14N665 *Definition of the Technology Readiness*

Levels (TRL) and their criteria of

assessment

The scope of this project is to standardize the definition of the Technology Readiness Levels (TRL) and of their criteria of assessment.Those criteria are presented as key questions to be adressed to assess each level. Related management guidelines are not addressed in this document.

Status of Proposed ISO TRL Handbook

Project Leader: Frédéric Safa (ESA/ESTEC)

WG members – Country Leads

US: Jim Bilbro

FR; Franck Durand-Carrier

Japan: Satoshi Kikuchi

UK: Nicolas Chesher

DE: Andreas Jain (represents also WG5)

Brazil: Paulo Roberto Sakai

Ukrainian: Yuriy Stryzhak

Status of Proposed ISO TRL Handbook

Kick-off meeting objectives

1- Reviewing/understanding of the Terms of Reference

2- Reviewing the documents provided as inputs, and providing feedback/comments

3- Providing a summary of current needs/practices/examples in respective countries/institutes for TRL assessment

4- Initiating reflection on TRL use and need

Status of Proposed ISO TRL Handbook

- US Team Members:
  - ❖ Jim Bilbro, JB Consulting International – Team Lead
  - ❖ Tim Barth - NASA
  - ❖ Cornelius Dennehy – NASA
  - ❖ Prasun Desai – NASA
  - ❖ Oscar Gonzalez – NASA
  - ❖ John Kelly – NASA
  - ❖ Corinne Kramer – DOD
  - ❖ Steve Kapurch – NASA
  - ❖ Bill Nolte – DOD
  - ❖ Sandra Smalley – NASA
  - ❖ Dick Weinstein (Consultant) – Working Group 1
  - ❖ Rich Widman (Boeing) – Working Group 5

Status of Proposed ISO TRL Handbook

- CNES TRL Handbook is the basis of the ISO proposal
- Additional Documents recommended by participants to date
  - DLR TRL Handbook
  - DOD TRA Deskbook
  - NASA SE TRA Process
  - NASA TRL Description & Definitions
- ISO document will draw on all sources to develop a consensus Handbook
- Participation of interested organizations/companies is welcome & encouraged

Status of Proposed ISO TRL Handbook

Results of the first meeting:

Definition of the end point

- **Mature** Technology:
  Set of reproducible processes for the design, manufacture and test of an element, which meets a set of performance requirements.

  Process = material, tools, human factor/skills, manufacturing techniques

Status of Proposed ISO TRL Handbook

- Second Meeting planned for Paris, October 25, 26, 2010
- Proposed activities:
  - concentrate on the Definitions of the TRLs
  - initiate the discussion on the TRL evaluation
  - initiate the activity on the WG report: outline, work distribution
- Expected Completion Date: May 2011

Status of Proposed ISO TRL Handbook

- Issues to address (from US Perspective):
  - How to resolve differences between submitted documents:
  - Expansion of document to include other than space
  - Inclusion/exclusion of software
  - Inclusion/exclusion of exit criteria
  - Creation of a dictionary of terms beyond TRLs

Status of Proposed ISO TRL Handbook

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