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Technology maturity level assessment

Why, when and how to evaluate the maturity of your research results?

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PROGRAM DAY 1

- Intro, objectives of the course
- What is TRL
- Origin
- Relevance to Innovation and Exploitation
- TRL in H2020
- TRL in the HBP context
- The TRL assessment guide
- Checklist
- Relevance for the Innovation Radar (IR)

PROGRAM DAY 2

- Assessing maturity of Hardware
- Assessing maturity of Software
- Assessing maturity of Services
- Assessing maturity of Datasets
- Assessing maturity of Models
- Practical examples

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OBJECTIVES OF THE COURSE

- To learn why and how the progress of scientific and technologic processes must be evaluated
- To understand the importance of the technology maturity level (TRL) assessment
- To identify opportunities that TRL may bring in terms of innovation
- To acknowledge how close are your results to end-users markets and learn how these markets could be more quickly and efficiently approached

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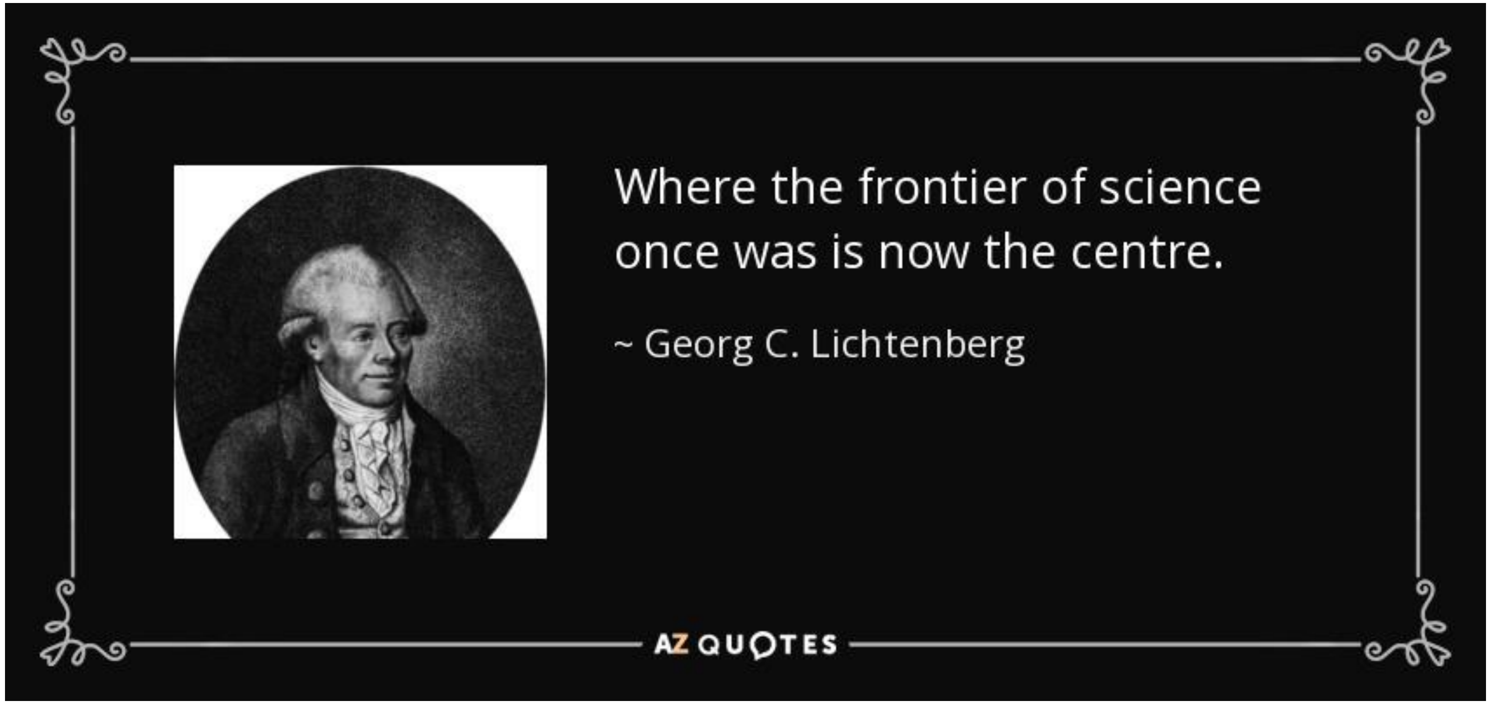
Scientific progress is an endless process

Despite the endless frontiers of Science, researchers work to develop finite solutions, i.e. tools with a “final form”



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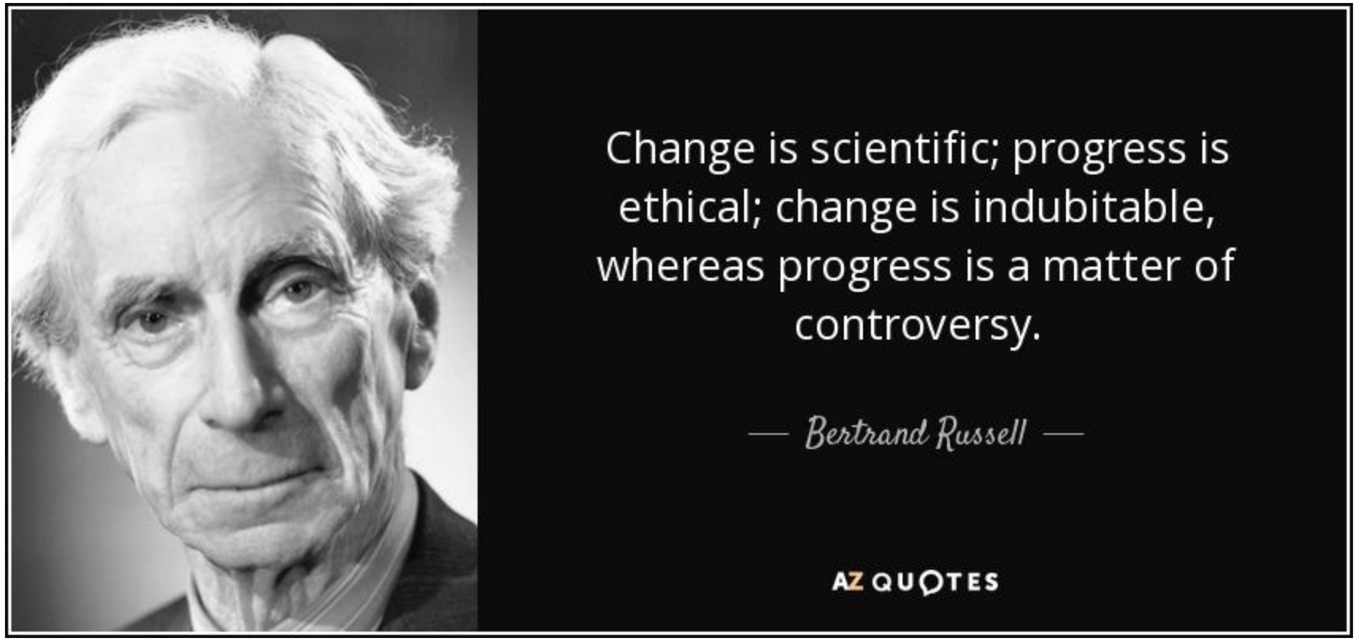
Scientists have to reflect, therefore, on how their progress could be measured and when their solutions will adopt such a “final” form

In fact, measuring the progress and results of Science and Technology efforts is not an easy task



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What is TRL? Measuring technology development progress

"Technology Readiness Levels (TRLs) are a systematic metric/measurement system that supports assessments of the maturity of a particular technology and the consistent comparison of maturity between different types of technology."

Mankins, J. C. 1995. "Technology readiness levels".Houston, TX: NASA (National Aeronautics and Space Administration).

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TRL INFLUENCES…

Technology discussions: common language

Funding decisions (start & finalise): risk reduction

Commercial strategy

Communication with stakeholders

IP strategic plans

Design decisions & integration

Ideas generation & Innovation

Technical acquisitions, public procurement

Quality aspects, awareness

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Consequences of implementing immature technologies

Technology maturing increases planned costs

Distorted schedules and plans

Failed technologies, undesired performance

Projects failing to meet requirements

Programs cancelled

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Origins and evolution of the TRL concept

- **NASA PRE-FLIGHT RITUALS: CHECKING WHETHER THE VEHICLE IS READY TO FLY**
- APOLLO PROGRAM (1969) AND POST APOLLO SPACE STATIONS PLANS: WERE TECHNOLOGIES READY FOR IT?
- THE CONCEPT ENDURED FOR TWO DECADES …
- REAGAN DIRECTIVE ON NATIONAL SPACE POLICY (1988): WIDER COOPERATION BEWTEEN NASA, CIVIL AND COMMERCIAL PARTNERS
- 1979: NASA CONCEIVED TRL IN 1979 BUT THE CONCEPT WAS FLESHED OUT IN A WHITE PAPER ONLY IN 1989 (SEVEN LEVELS)
  Sadin, S. R., Povinelli, F. P. &R. Rosen. 1989. The NASA technology push towards future space mission systems. Acta Astronautica, 20: 73-77
- INFLUENCE OF THE "CHALLENGER" DISASTER: (1986): STRONG RESONS FOR SAFER SPACE TECHNOLOGY
- **FROM A PROGRAM MODEL DRIVEN BY LARGE SPACE PROGRAMS TO A TECHNOLOGY PUSH STRATEGY THAT ENCOURAGES TECHNOLOGIES WITH NO SPACE PROGRAM BEHIND**
- A PRECISE ASSESSMENT OF MATURITY AS THE INVENTORY OF NEW TECHNOLOGIES INCREASED, SOME OF THEM WITH NO CLEAR FEASIBILITY
- THE USE OF TECHNOLOGY READINESS LEVELS SUPPORTED THE DIALOGUES BETWEEN MILITARY AND COMMERCIAL ORGANIZATIONS
- IN 1990 THE US AIR FORCE APPLIED THE TRL
- **1991 NASA INTEGRATED TECHNOLOGY PLAN (ITP) IS THE MODEL OF TRL USAGE (NINE LEVELS)**
  OAST (Office of Aeronautical and Space Technology). 1991. Integrated Technology Plan for the Civil Space Program. Houston: NASA(National Aeronautics and Space Administration).
- 1999-2001: GOVERNMENT ACCCOUNTABILITY OFFICE (GAO) RECOMMENDED THE USE OF TRL.
  DoD: DEFENCE ACQUISITION GUIDEBOOK, TRL ASSESSMENT DESKBOOK

REMEMBER

- SPACE SAFETY. APOLLO SUCCESS
- CHALLENGER DISASTER
- FROM MILITARY TO COMMERCIAL GOALS
- PARADIGM CHANGE: TECHNOLOGY PUSH
- LARGE TECHNOLOGY INVENTORY
- GOVERNMENT SUPPORT: ACCOUNTABILITY

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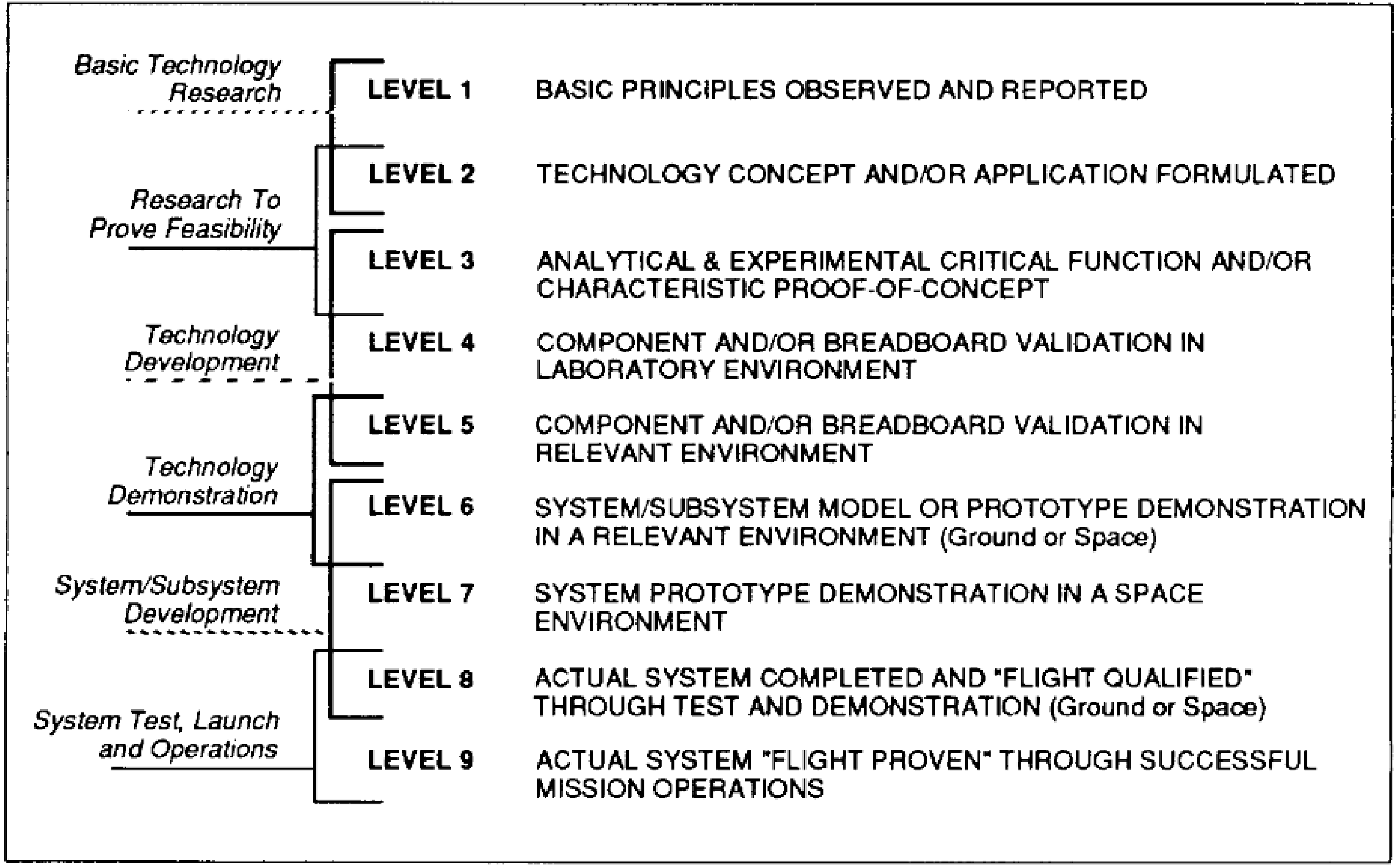
The nine-levels TRL scale as originally conceived (1991)



OAST (Office of Aeronautical and Space Technology). 1991. Integrated Technology Plan for the Civil Space Program. Houston: NASA(National Aeronautics and Space Administration).

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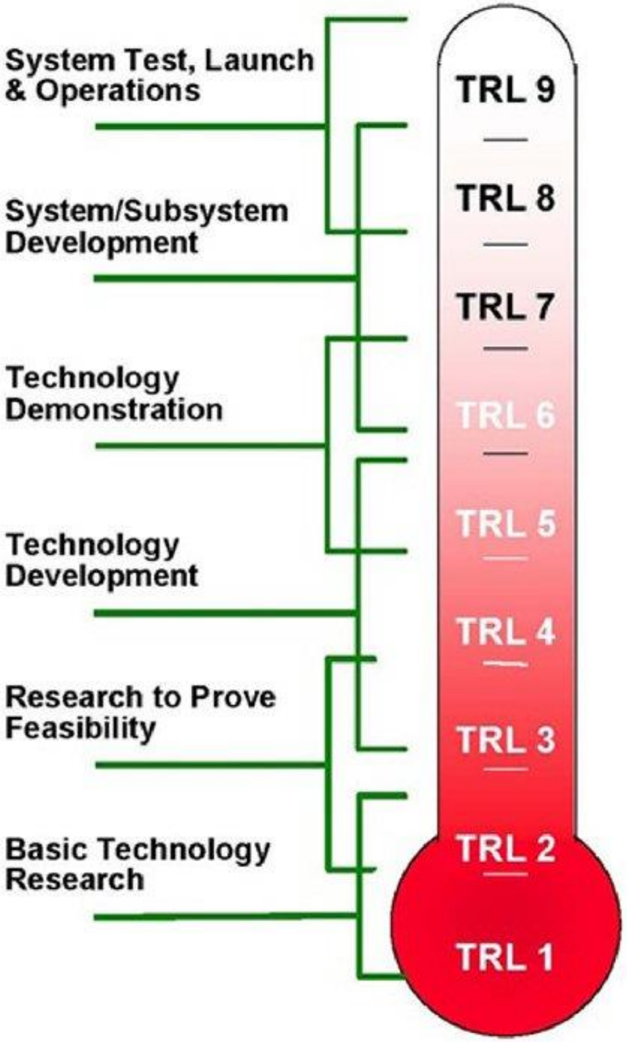
TRL scale (European Commission, 2014)



TRL 9 – actual system proven in operational environment

TRL 8 – system complete and qualified

TRL 7 – system prototype demonstration in operational environment

TRL 6 – technology demonstrated in relevant environment

TRL 5 – technology validated in relevant environment

TRL 4 – technology validated in lab

TRL 3 – experimental proof of concept

TRL 2 – technology concept formulated

TRL 1 – basic principles observed

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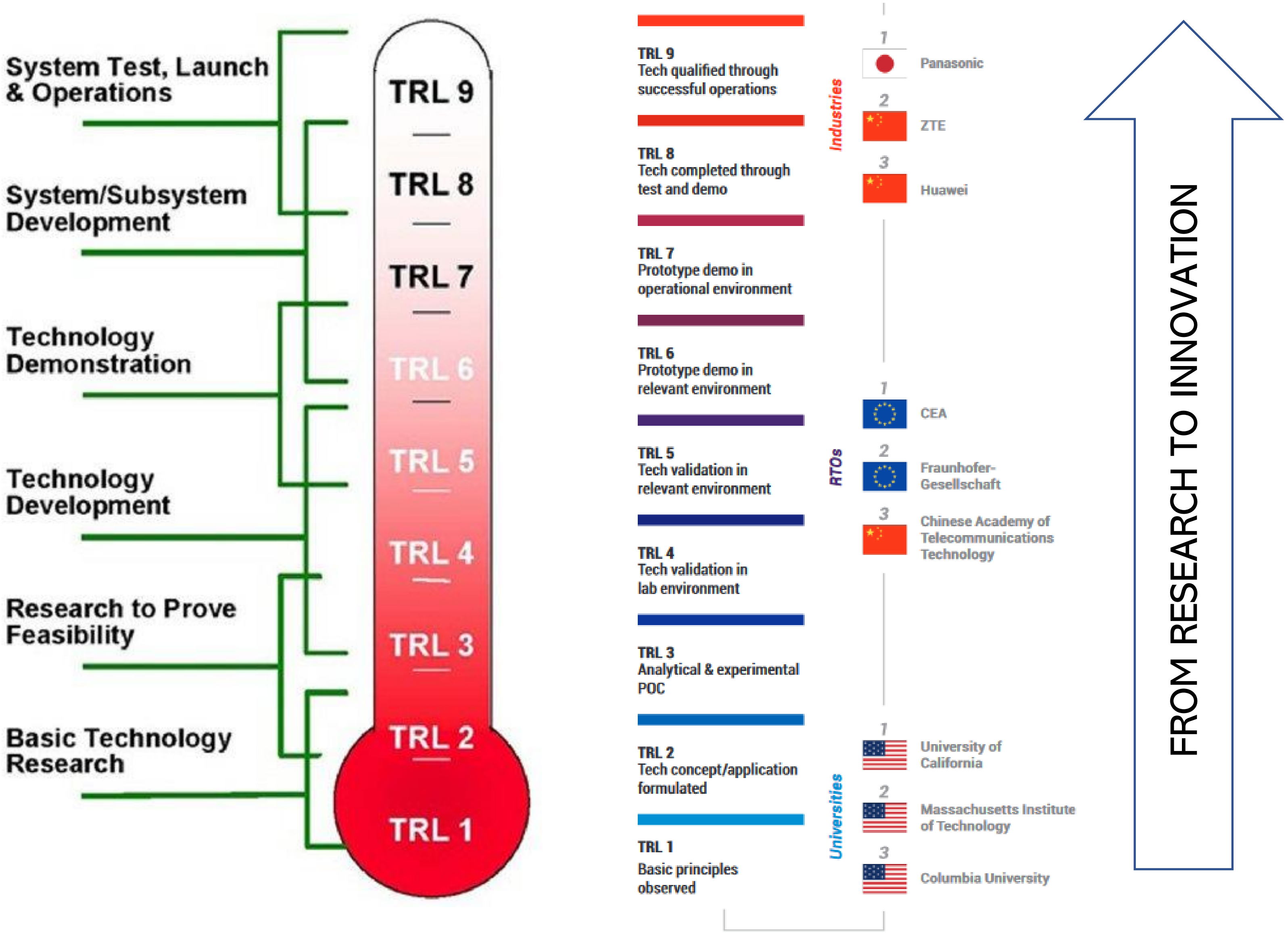
Research and Innovation actors from a TRL perspective



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Innovation

INNOVATION *is the implementation of a new or significantly improved* ***product*** *(good or service), or* ***process****, a new* ***marketing*** *method, or a new* ***organisational*** *method in business practices, workplace organisation or external relations.*

The minimum requirement for an innovation is that the product, process, marketing method or organisational method must be ***new (or significantly improved)*** *to the firm. This includes products, processes and methods that firms are the first to develop and those that have been adopted from other firms or organisations.*

A common feature of an innovation is that it must have been ***implemented****. A new or improved product is implemented when it is introduced on the market. New processes, marketing methods or organisational methods are implemented when they are brought into actual use in the firm's operations.*

Oslo Manual
A joint publication of OECD and Eurostat
The Measurement of Scientific and Technological Activities
GUIDELINES FOR COLLECTING AND INTERPRETING INNOVATION DATA.
Third edition (2005)

REMEMBER

- PRODUCT, PROCESS, SERVICE, METHODS
- NEW OR IMPROVED RESULT
- FISRT DEVELOPMENT OR FIRST ADOPTION
- IMPLEMENTATION
- OSLO MANUAL

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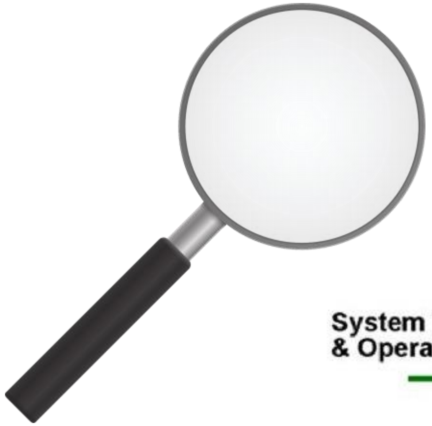
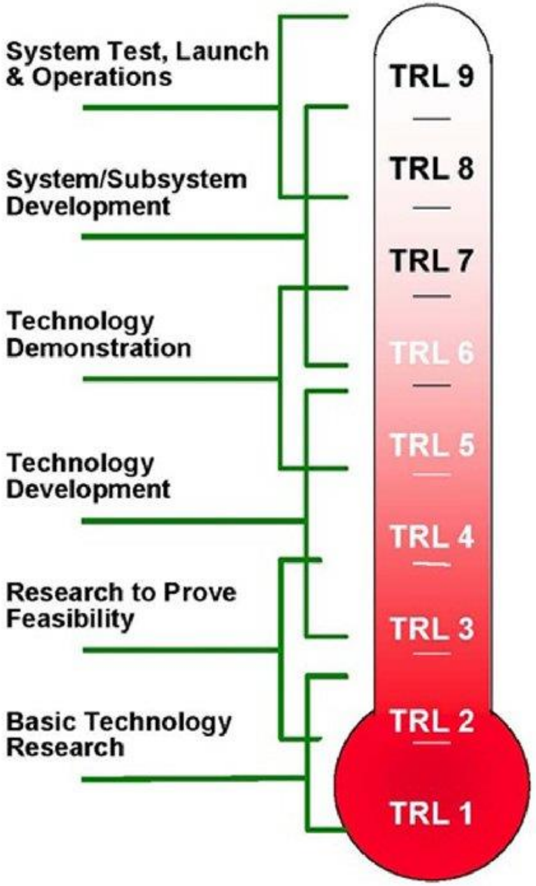
TRL to support an Innovation strategy



- Some organizations only pay attention to ***well consolidated technologies*** because the intended goal is to incorporate them through products or services available in the market in short periods of time (technology as a "commodity")

- In other cases, the interest is focused on ***emerging technologies*** which are immature, but they could support a new generation of products or services in the short or medium term and the organization is anticipating its positioning in the market

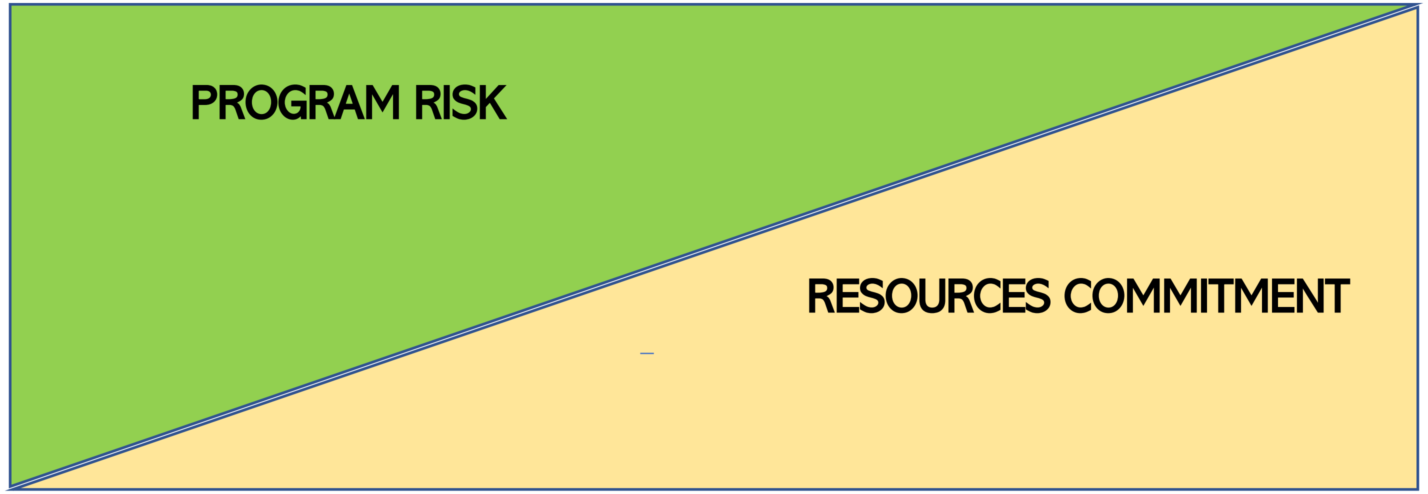


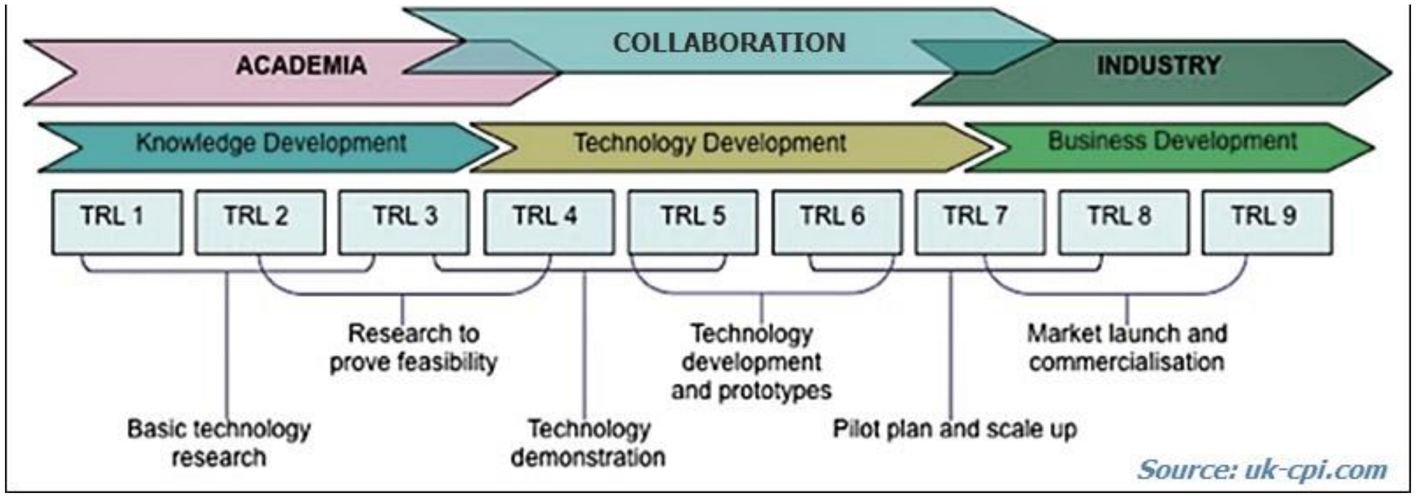
TRL to recognise the costs along the maturity process

A study by Boeing revealed that 10% of the total funds of the projects are committed up to TRL 6 (Whelan, 2008).

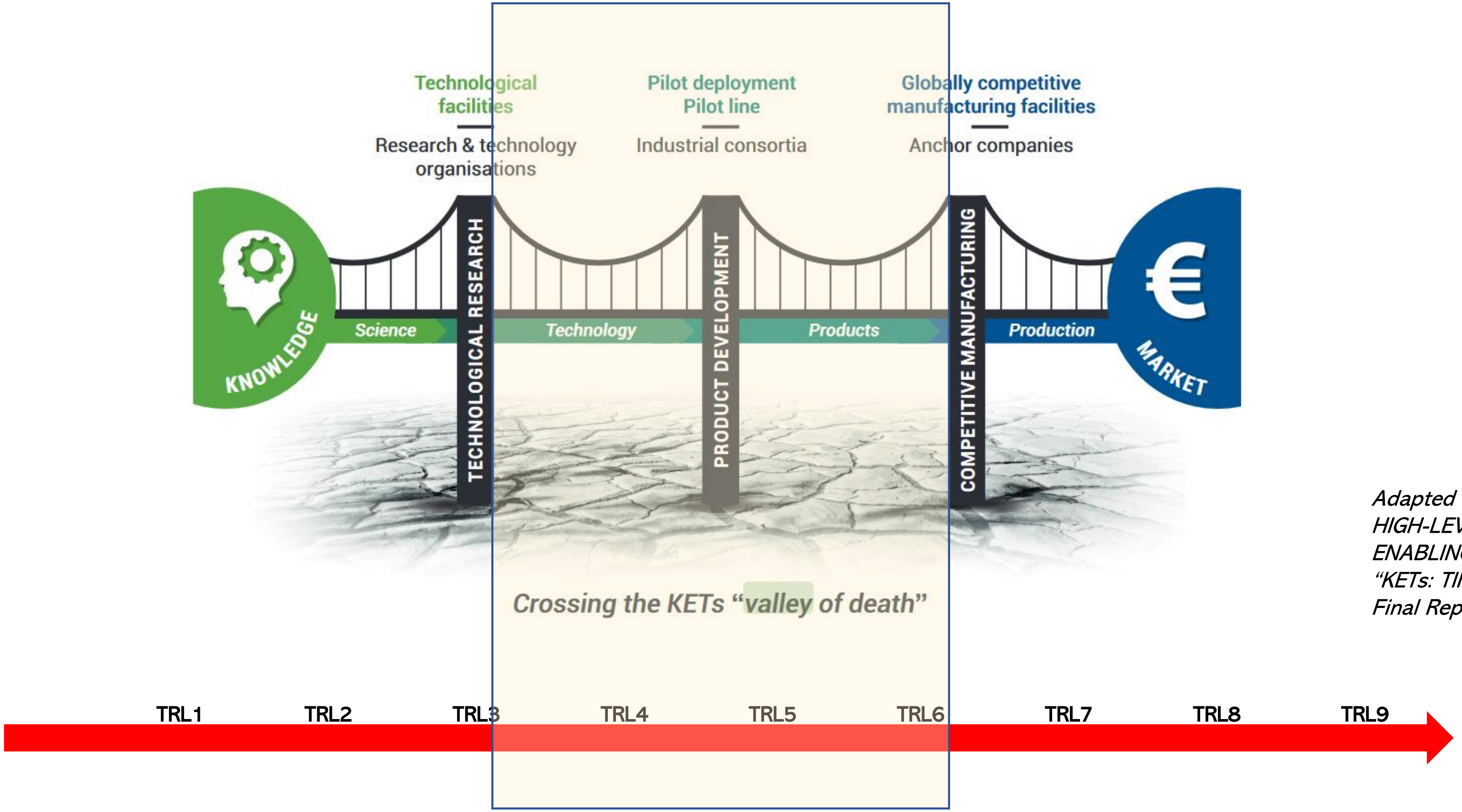
The 90% of the total cost are therefore allocated to the TRL 6 to 9 stages.

The first HLG-KET report (EC) indicates that pilot line activities are 5-10x higher than R&D activities.



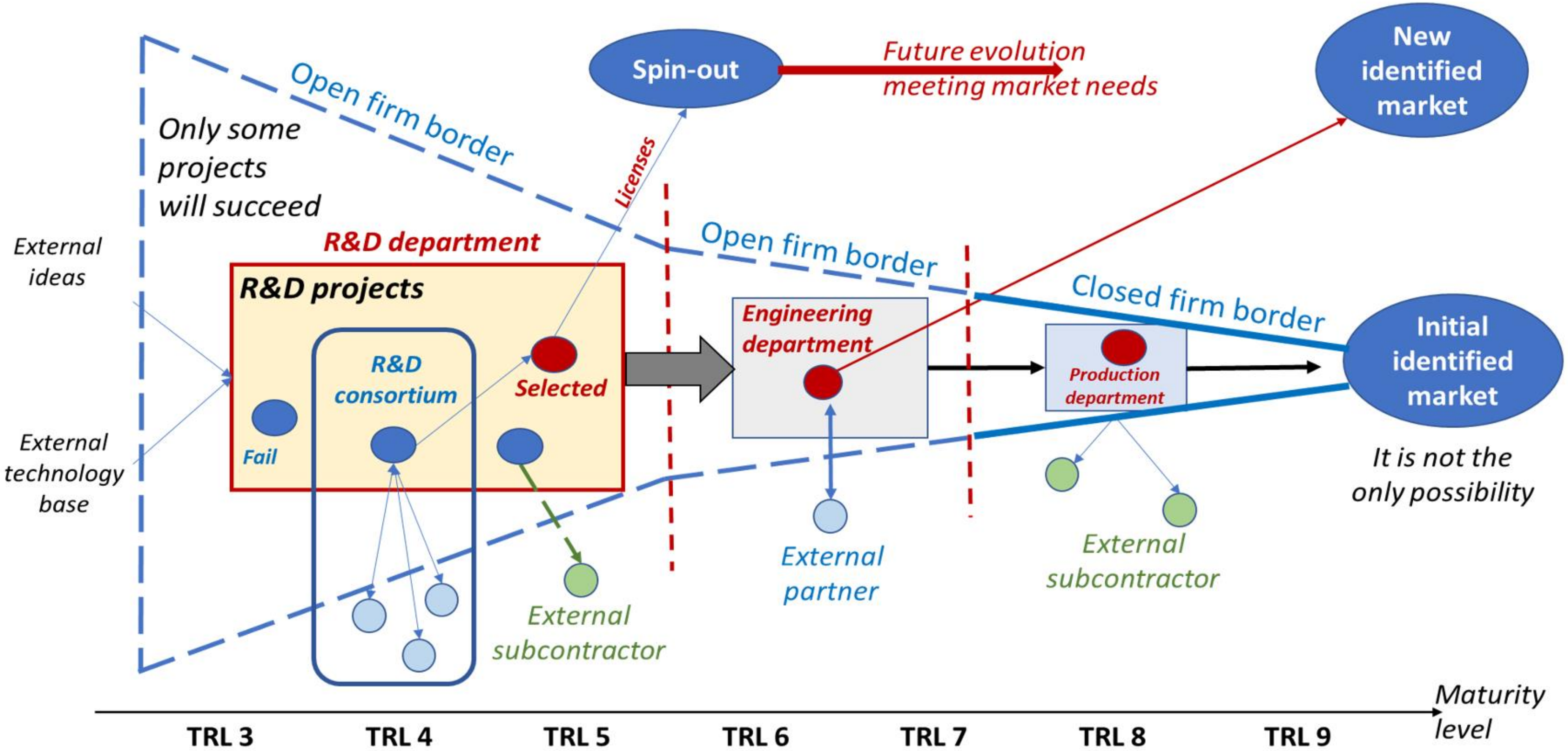


TRL to acknowledge our position in the way from Knowledge to Market

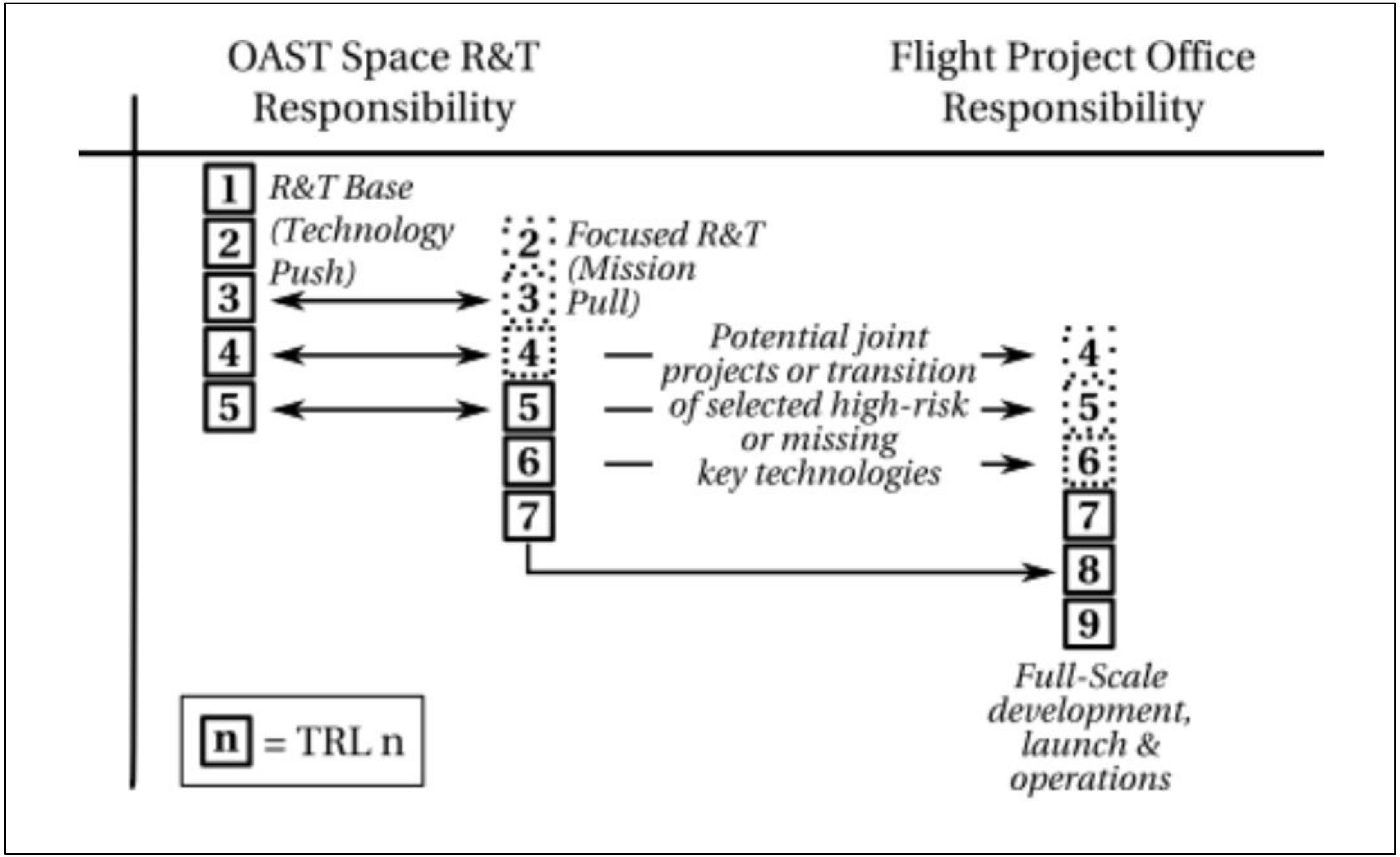


Adapted from:
HIGH-LEVEL EXPERT GROUP ON KEY ENABLING TECHNOLOGIES
"KETs: TIME TO ACT"
Final Report June 2015

TRL to guide Open innovation strategies



TRL to allocate project responsibilities



Mihály Héder (2017) “From NASA to EU: the evolution of theTRL scale in Public Sector Innovation” The Innovation Journal: The Public Sector Innovation Journal, Volume 22(2), 2017, article 3.

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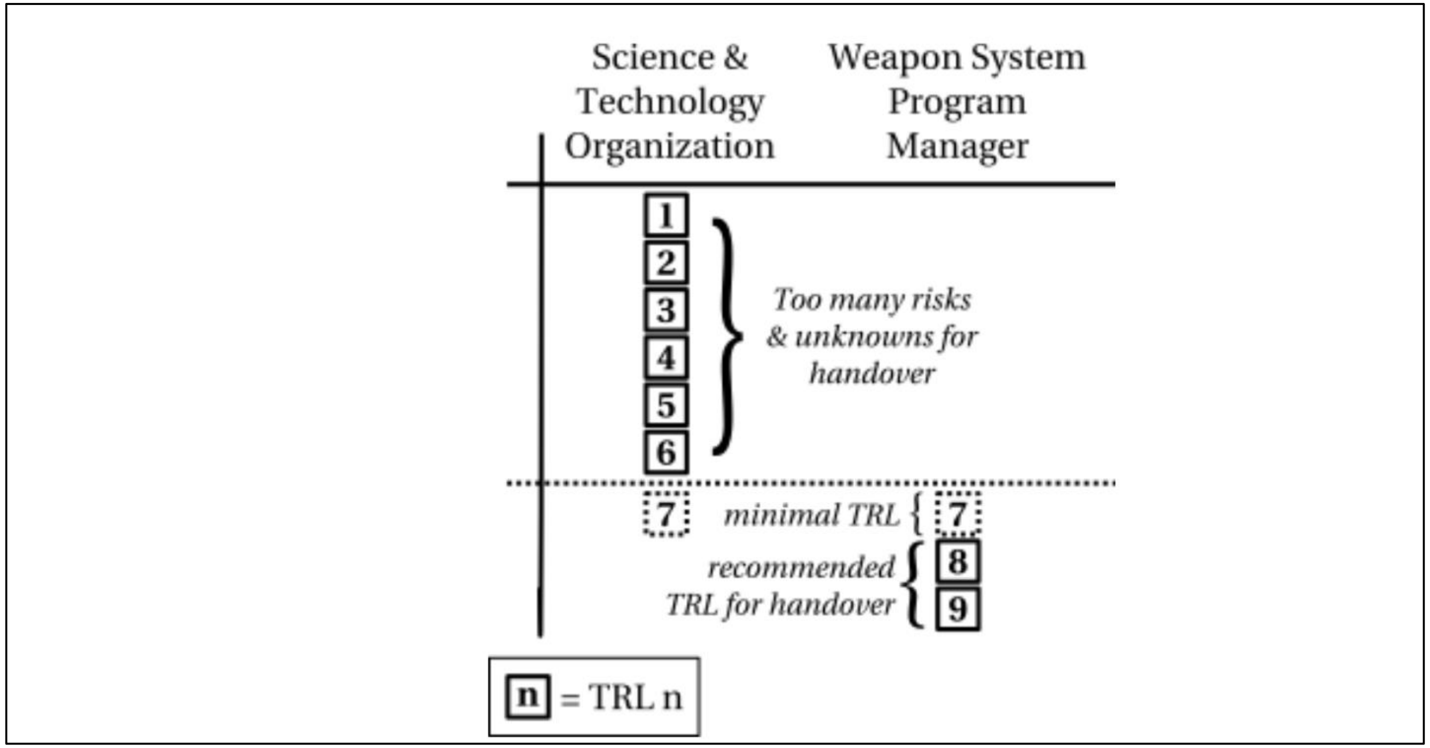
TRL to support Technology acquisition

GAO recommendation to the DoD: only technologies over TRL 7 could be acquired



Mihály Héder (2017) "From NASA to EU: the evolution of theTRL scale in Public Sector Innovation" The Innovation Journal: The Public Sector Innovation Journal, Volume 22(2), 2017, article 3.

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TRL assessment to evaluate Commercial Readiness ?

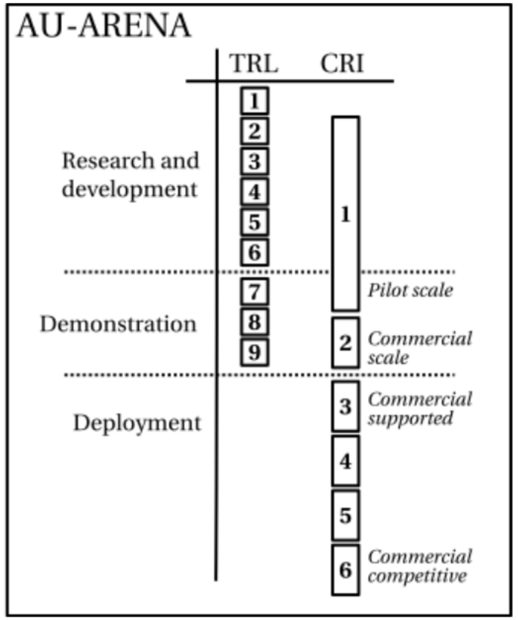
Does TRL 9 mean that the solution is commercially ready?

The EC interprets the path from TRL 1 to TRL 9 as the road from “idea to market”.

However, the EC Innovation Radar initiative seems to assume that TRL 9 just implies “Tech ready” and business-oriented actions (e.g. market analyses) are needed to achieve “Market ready” conditions.

The Commercial Readiness Index (CRI) was created in Australia (ARENA, 2014) to address that problem:

Level 1 -Hypothetical commercial proposition
Level 2 -Commercial trial
Level 3 -Commercial scale up
Level 4 -Multiple commercial applications
Level 5 -Market competition driving widespread deployment
Level 6 -"Bankable" grade asset class



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TRL in the EC

"Preparing for our future: Developing a common strategy for key enabling technologies in the EU" (European Commission, 2009).

This communication introduced the concept of **Key Enabling Technologies (KETs) i.e.** foundational technologies on which industrial progress depends: Nanotechnology, advanced materials, biotechnology, micro-and nano-electronics (including semiconductors), and photonics.

The High-Level Expert Group on Key Enabling Technologies identified the problem of the Valley of Death as one that particularly hinders the European Union. **They explained it in terms of TRLs.**

The communication also recommended the use of the TRL o include technological research, product development and demonstration activities within its RDI portfolio

THE COMMUNICATYION MEANS A TURN TOWARDS A MORE INDUSTRY DRIVEN RESEARCH POLICY. THE USE OF THE TRL WAS THEREFORE CONSEQUENCE OF THE INDUSTRIAL TURN IN THE EC STRATEGY

TRL in the Horizon 2020 program

The TRL1-9 scale has been used by Horizon2020.

The definitions of the TRL levels can be found in the General Annexes / annex G (European Commission, 2014).

Some chapters of the 2014-15 work program documentation of Horizon 2020 use TRLs to set boundaries for the funded projects on some topics.

The maturity levels (staring and targeted) requested for funding research proposals in H2020 differ across the multiple areas of the program (e.g. while nanotechnology ask for projects at TRL 4-5 and targeting TRL 6, “Fast track to Innovation” required TRL 7 and targeted TRL9

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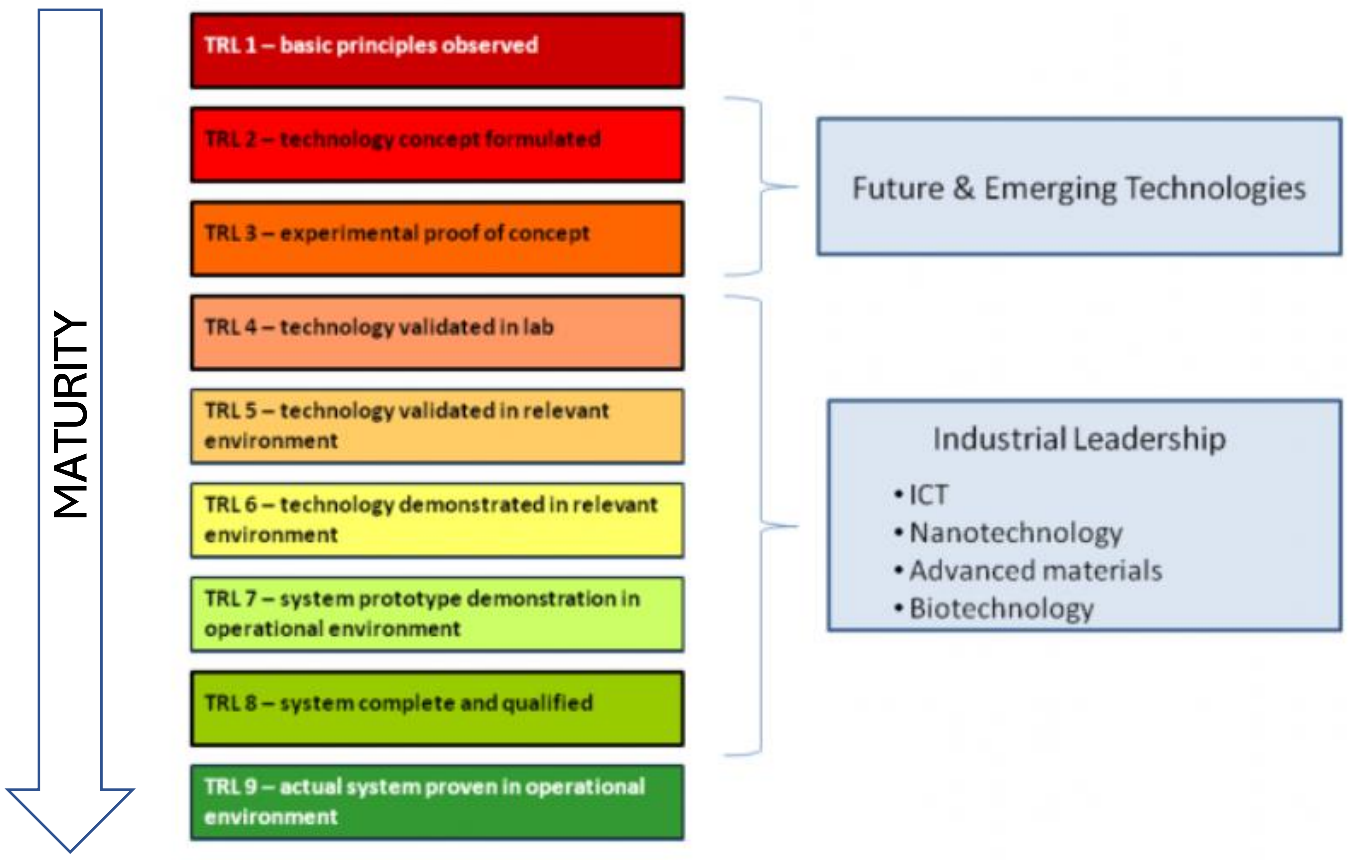
TRL in the Horizon Europe program

Horizon Europe



- Future and Emerging Technologies section of the Horizon Europe Work Programs is funded with low TRL levels
- 'Leadership in enabling and industrial technologies' (LEITs) are funded with higher TRLs
- Funding form: Innovation Actions (IA) or Research and Innovation Actions (RIA).
- Normally it is required a TRL for the proposal implementation an a specific TRL target at the end of the action.

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TRL in the HBP context

- During the first 5 years of the project (RU & SGA1), the HBP markedly showed a research–driven (technology push) orientation
- In RU and SGA1 the TRL was unevenly evaluated: coexistence of different evaluation scales
- In SGA2 the HBP started a gradual change towards a more user-oriented (technology pull) approach
- In SGA2 the Innovation team of HBP developed a guide for assessing homogeneously the maturity of HBP results

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A guide for TRL assessment in HBP: difficulties found

- THE PROJECT DEVELOPS RESULTS OF VERY DIFFERENT NATURE
- THE PROBLEM OF USING THE NASA SCALE IN OTHER AREAS IS RECOGNISED IN THE LITERATURE
- EARTO POSED THE NECESSITY OF TAILORING THE TRL (EARTO, 2014)
- EACH SCIENTIFIC AREA HAS PROBLEMS RELATED TO TIME AND ENVIRONMENT CHANGES
- CAPACITIES AND RESOURCES CHANGE OVER TIME (E.G. MOORE´S LAW)
- ASSESSING THE MATURITY OF SYSTEMS IS NOT OBVIOUS: TECHNOLOGY COMPONENTS

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Why the TRL assessment guide of HBP is innovative?

- There are been little attempts in the literature that try to adapt the NASA TRL scale to results of very different nature
- The Innovation team of HBP has created – with the support of some other HBP groups – five customized checklists that aim to help HBP researchers to evaluate the maturity of:
  - Hardware
  - Software
  - Services
  - Datasets
  - Models

Such an adaptation has been recognized by the Project officer as innovative and useful for other research communities and EC projects

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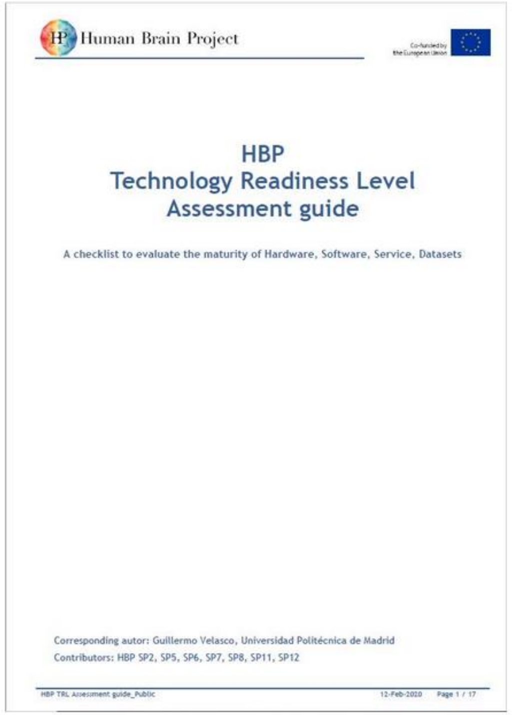
The Innovation team helps you to assess the maturity of your results

The maturity of HBP results can be evaluated with the support of the TRL assessment guide: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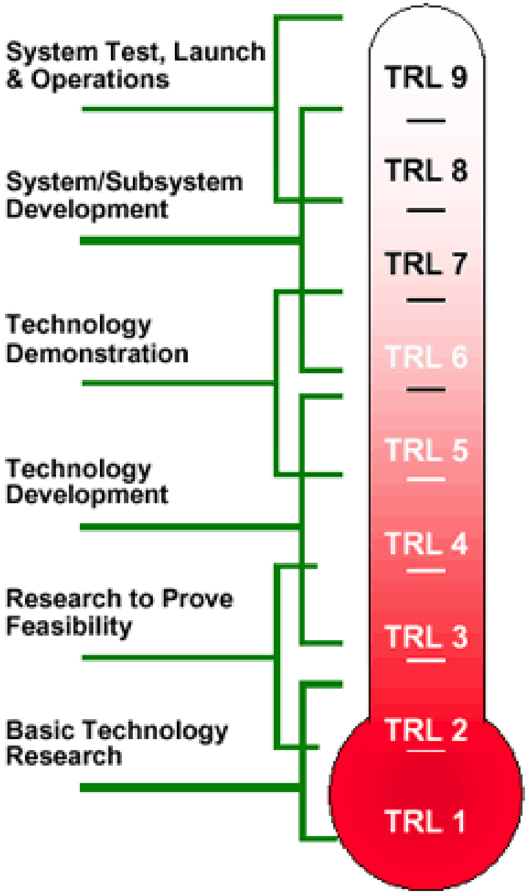
HBP
Technology Readiness Level
Assessment guide

A checklist to evaluate the maturity of Hardware, Software, Service, Datasets

Corresponding autor: Guillermo Velasco, Universidad Politécnica de Madrid
Contributors: HBP SP2, SP5, SP6, SP7, SP8, SP11, SP12



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TRL 1 – basic principles observed

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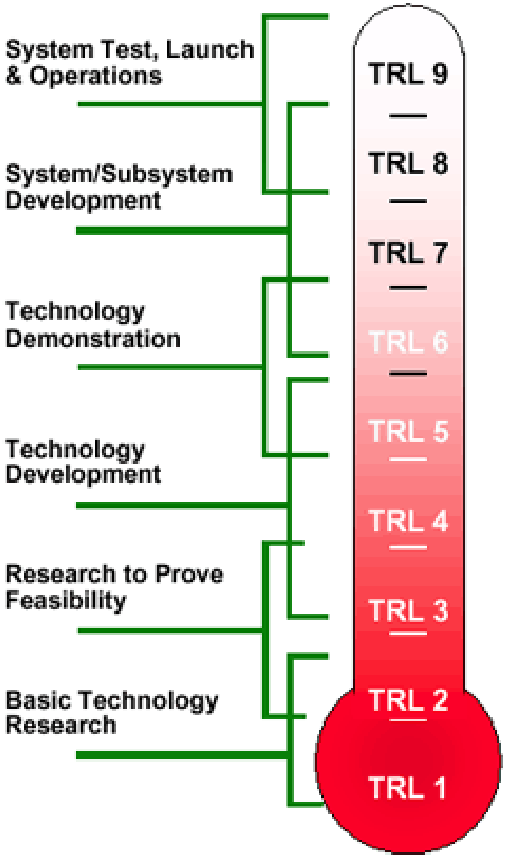
https://sos-ch-dk-2.exo.io/public-website-production/filer_public/34/8f/348f734a-9401-4ad6-a0ec-c8eeb3cca358/hbp_trl_assessment_guide_public.pdf

The three key blocks of the TRL scale



9. Actual system proven in operational environment 8. Deployment, qualification 7. Prototype proven in operational environment	DEPLOYMENT	SYSTEM FUNCTIONALITIES PROVED, OPERATIONAL FEASIBILITY AND PRODUCTION
6. Demonstration in relevant environment 5. Validation in relevant environment 4. Prototype component	DEVELOPMENT	ENGINEERING FEASIBILITY AND TECHNICAL DEVELOPMENT
3. Proof of concept implementation 2. Conceptualisation 1. Project initiation	RESEARCH	SCIENCE FEASIBILITY BLOCK: SCIENTIFIC KNOWLEDGE UNDERPINNING THE IDEA

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Example of a TRL checklist

TRL1 Project initiation
- ☐ Basic technology processes and scientific knowledge underpinning hardware applications are known.
- ☐ Technology principles and high-level objectives are defined.
- ☐ Supporting Information includes published research or other references that identify the principles.
- ☐ Ethical aspects for hardware production and operation are addressed and compliant with EU policies
- ☐ Use case definitions (includes target users and activities)

TRL2 Conceptualisation
- ☐ Practical applications are identified. However, applications are speculative, and there may be no proof or detailed analysis to support the assumptions.
- ☐ Most of the work is analytical or paper studies with the emphasis on understanding the science better.
- ☐ Experimental work is designed to corroborate scientific principles, including validation criteria for critical components.
- ☐ PoC (proof-of-concept) is being planned.

TRL3 Proof of concept implementation
- ☐ Analytical studies and laboratory-scale studies to validate the analytical predictions of separate elements of the technology have been performed (modelling and simulation may be used to complement experiments).
- ☐ Critical components of the technology are validated, but there is no attempt to integrate the components into a complete system.

TRL4 Prototype component
- ☐ Basic technological components are integrated to establish a load testing of elements or components.
- ☐ This is a "low fidelity" system to demonstrate basic functionality and critical test environments.
- ☐ Supporting information includes the experimental components and experimental test results differing from the expected system performance goals.

TRL5 Prototype integration
- ☐ The technological components are integrated so that the system configuration is similar to (matches) the final application in almost all respects.
- ☐ Supporting information includes results from the laboratory scale testing, analysis of the differences between the laboratory and eventual operating system/environment and analysis of what the experimental results mean for the eventual operating system/environment.
- ☐ Increased fidelity of the system and environment to the actual application.

TRL6 Pilot-scale prototype to real-world integration
- ☐ Integrated systems or engineering-scale prototypes are tested in a relevant environment.
- ☐ The operating environment for the testing should closely represent the actual operating environment
- ☐ This includes initial system documentation and initial user documentation.

TRL7 Operational integration
- ☐ Validation of a full-scale, integrated system in a relevant real-world environment.
- ☐ Supporting information includes results from the full-scale testing and analysis of the differences between the test environment.
- ☐ Final design is virtually complete.

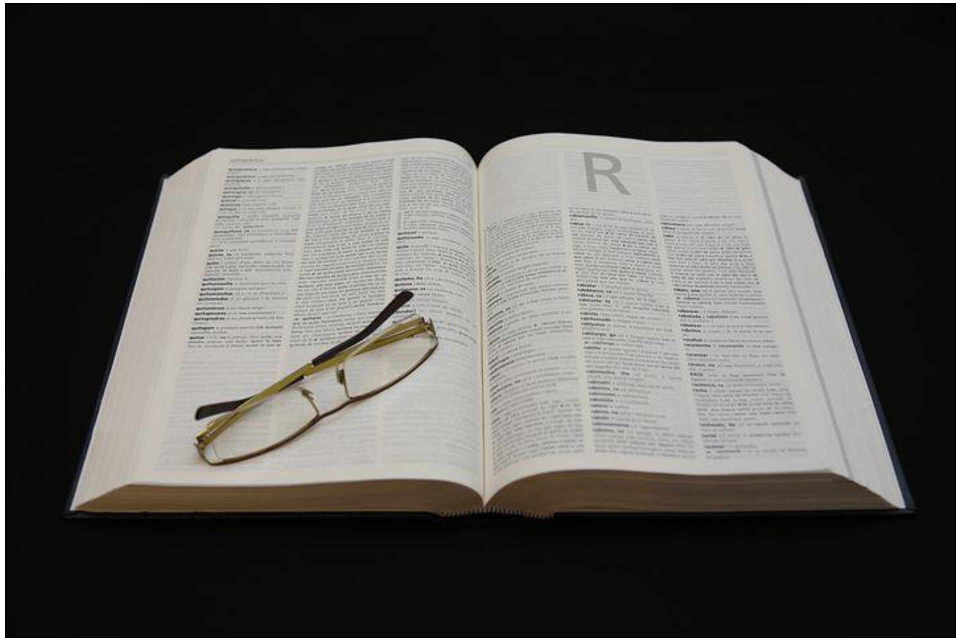
TRL8 Deployment
- ☐ Integrated system has been proven to work in its final form and under expected conditions.
- ☐ The final product in its final configuration is successfully demonstrated through test and analysis for its intended operational environment.
- ☐ all user documentation, training documentation and maintenance documentation completed.

TRL9 Production
- ☐ System is in its final form and operated under the full range of operating conditions.
- ☐ Final product operates over the full range of expected conditions.

Some tips and notes on the utilization of the TRL checklist

- Choose the category (Hardware, Software, Service, Dataset or Model) that corresponds to the result whose TRL is going to be evaluated.
- Note that RL (Readiness level), instead of TRL, is the acronym used in assessment of the Services, Datasets and Models maturity
- Every exploitable (commercially and/or non-commercially) result need to be evaluated separately. You can copy/paste the specific checklist and make the evaluation in a separate document.
- Some check-list statements, within the same TRL level, could look to be describing similar requirements with different wording. This just helps to clarify the actual meaning of the requirement and to corroborate (double-check) some important aspects of the assessment.
- Some solutions may include a variety of tools and services (e.g. platforms), each of them presenting different levels of maturity. When more than one level of maturity is present within a solution, we should consider the lowest one as the technology level of the whole.
- A specific TRL is achieved when all the conditions required for that level are met. Otherwise, the TRL of the technology would be the highest one on which all conditions are fulfilled.

Some preliminary definitions to assess TRL



Source: DoD (Department of Defense). U. S. 2009. Technology Readiness Assessment (TRA) Deskbook. Washington, WA:Prepared by Deputy Undersecretary of Defense for Science and Technology (DUSD (S&T)).

BREADBOARD	Integrated components that provide a representation of a system/subsystem and that can be used to determine concept feasibility and to develop technical data. Typically configured for laboratory use to demonstrate the technical principles of immediate interest. May resemble final system/subsystem in function only.
HIGH FIDELITY	Addresses form, fit, and function. A high-fidelity laboratory environment would involve testing with equipment that can simulate and validate all system specifications within a laboratory setting.
LOW FIDELITY	A representative of the component or system that has limited ability to provide anything but first-order information about the end product. Low-fidelity assessments are used to provide trend analysis.
MODEL	A functional form of a system, generally reduced in scale, near or at operational specification. Models will be sufficiently hardened to allow demonstration of the technical and operational capabilities required of the final system.
OPERATIONAL ENVIRONMENT	Environment that addresses all the operational requirements and specifications required of the final system to include platform/packaging.
PROTOTYPE	A physical or virtual model used to evaluate the technical or manufacturing feasibility or military utility of a particular technology or process, concept, end item, or system.
RELEVANT ENVIRONMENT	Testing environment that simulates both the most important and most stressing aspects of the operational environment.
SIMULATED OPERATIONAL ENVIRONMENT	Either (1) a real environment that can simulate all the operational requirements and specifications required of the final system or (2) a simulated environment that allows for testing of a virtual prototype. Used in either case to determine whether a developmental system meets the operational requirements and specifications of the final system.

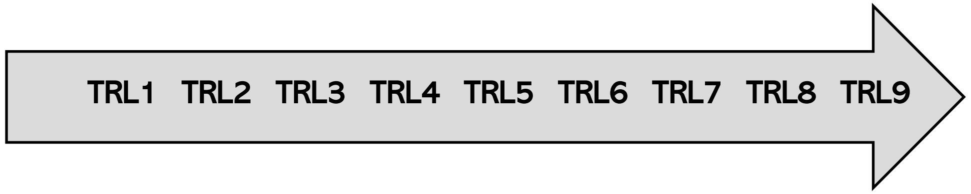
Contents

Innovation Radar

The Innovation Radar is a European Commission initiative to identify high potential innovations and innovators in EU-funded research and innovation framework programmes

Looking for inspiration? Explore by maturity levels ...

Exploring	Tech Ready	Business Ready	Market Ready
Innovations actively exploring value creation opportunities.	Progressing on technology development process (e.g. pilots, prototypes, demonstration)	Putting concrete market-oriented ideas together (e.g. market studies, business plans, end-user engagement)	Outperforming in innovation management and innovation readiness. Considered "Ready for market"
Explore	Explore	Explore	Explore



MARKET READY: Innovations that are technologically mature and show high commitment of the project consortium to bring them to the market.

BUSINESS READY: Innovations for which concrete market-oriented ideas have been put together (e.g. market studies, business plans, end-user engagement). They are considered advanced on market preparation but further progress on technology development is required

TECH READY: Innovations that are progressing on the technology development process (e.g. pilots, prototypes, demonstration). Further action in terms concrete market-oriented actions (e.g. market studies, business plans, end-user engagement) are required to capitalise on the market potential of these innovations

EXPLORING: Innovations that are actively explore value creation opportunities. These innovations are in the early phases of technological readiness, but already show high commitment levels from the organisations developing them. Their commercialisation requires efforts in transforming technology into marketable products

Source: https://www.innoradar.eu

Questions

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TRL checklist for Hardware (1/2)

TRL1 Project initiation

- ☐ Basic technology processes and scientific knowledge underpinning hardware applications are known.
- ☐ Technology principles and high-level objectives are defined.
- ☐ Supporting Information includes published research or other references that identify the principles.
- ☐ Ethical aspects for hardware production and operation are addressed and compliant with EU policies
- ☐ Use case definitions (include target users and activities)

TRL2 Conceptualisation

- ☐ Practical applications are identified. However, applications are speculative, and there may be no proof or detailed analysis to support the assumptions.
- ☐ Most of the work is analytical or paper studies with the emphasis on understanding the science better.
- ☐ Experimental work is designed to corroborate scientific principles, including validation criteria for critical components.
- ☐ PoC (proof-of-concept) is being planned.

TRL3 Proof of concept implementation

- ☐ Analytical studies and laboratory-scale studies to validate the analytical predictions of separate elements of the technology have been performed (modelling and simulation may be used to complement experiments).
- ☐ Critical components of the technology are validated, but there is no attempt to integrate the components into a complete system.

TRL4 Prototype component

- ☐ Basic technological components are integrated to establish a load testing of elements or components.
- ☐ This is a "low fidelity" system to demonstrate basic functionality and critical test environments.
- ☐ Supporting information includes the experimental components and experimental test results differing from the expected system performance goals.

TRL5 Prototype integration

- ☐ The technological components are integrated so that the system configuration is similar to (matches) the final application in almost all respects.
- ☐ Supporting information includes results from the laboratory scale testing, analysis of the differences between the laboratory and eventual operating system/environment and analysis of what the experimental results mean for the eventual operating system/environment.
- ☐ Increased fidelity of the system and environment to the actual application.

TRL checklist for Hardware (2/2)

TRL6 Pilot-scale prototype to real-world integration

- ☐ Integrated systems or engineering-scale prototypes are tested in a relevant environment.
- ☐ The operating environment for the testing should closely represent the actual operating environment
- ☐ This includes initial system documentation and initial user documentation.

TRL7 Operational integration

- ☐ Validation of a full-scale, integrated system in a relevant real-world environment.
- ☐ Supporting information includes results from the full-scale testing and analysis of the differences between the test environment.
- ☐ Final design is virtually complete.

TRL8 Deployment

- ☐ Integrated system has been proven to work in its final form and under expected conditions.
- ☐ The final product in its final configuration is successfully demonstrated through test and analysis for its intended operational environment.
- ☐ all user documentation, training documentation and maintenance documentation completed.

TRL9 Production

- ☐ System is in its final form and operated under the full range of operating conditions.
- ☐ Final product operates over the full range of expected conditions.

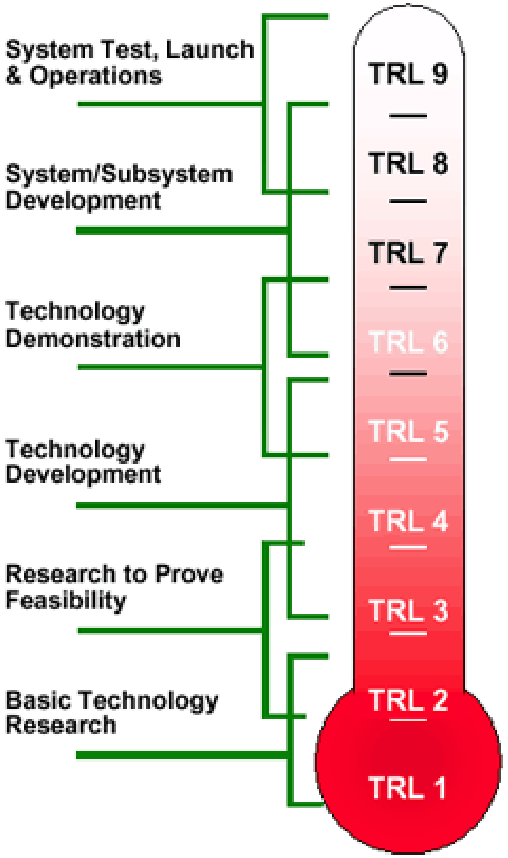
REMEMBER

- USE CASES
- PROOF OF CONCEPT
- PROTOTYPE
- RELEVANT ENVIRONMENT
- OPERATIONAL ENVIRONMENT
- TESTING
- DOCUMENTATION

Human Brain Project

Contents

How does TRL can be applied to Software development? (1/2)

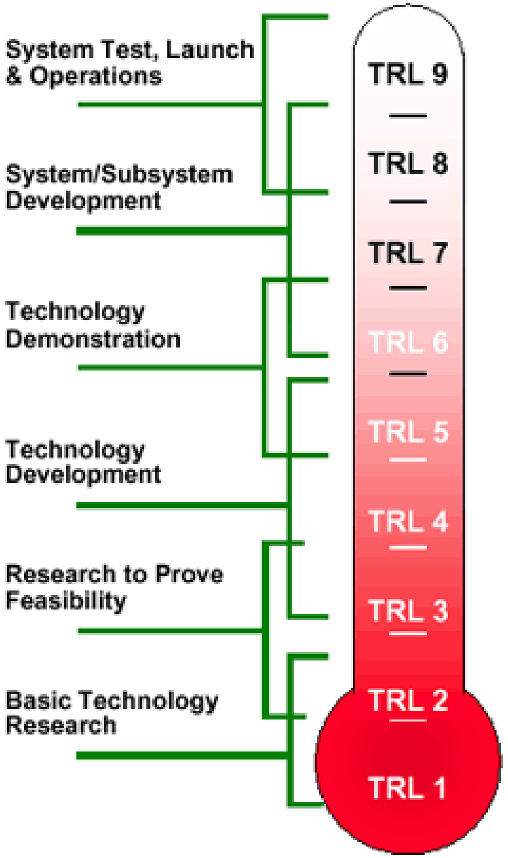


9. Actual system proven in operational environment 8. Deployment, qualification 7. Prototype proven in operational environment	From a well integrated hardware/software system demonstrating operational feasibility to a final product that operates over the full range of expected conditions
6. Demonstration in relevant environment 5. Validation in relevant environment 4. Prototype component	From an alpha prototype to demonstrate basic functionality and critical test environments to an integrated system or prototype implementation of the software tested in a relevant environment
3. Proof of concept implementation 2. Conceptualisation 1. Project initiation	From preliminary idea/concept to the validation of analytical predictions of separate components of the software.

SOFTWARE DEVELOPMENT

Human Brain Project

How does TRL can be applied to Software development? (1/2)

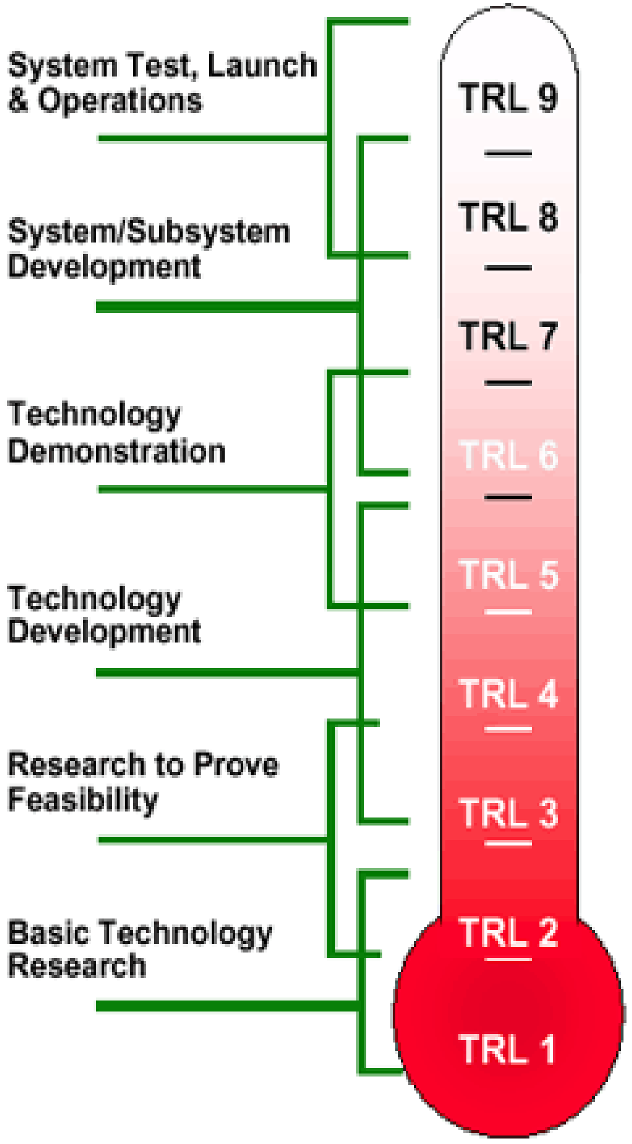


Software stage	TRL range description
Continuous development of released versions	From a well integrated hardware/software system demonstrating operational feasibility to a final product that operates over the full range of expected conditions
Stable version of the software for end users	
Open beta testing – black box (internal structure/ design/ implementation are not known by the tester)	
Open beta testing – black box - for selected users	From an alpha prototype to demonstrate basic functionality and critical test environments to an integrated system or prototype implementation of the software tested in a relevant environment
Alpha testing – black box – for selected ext/int users	
Alpha testing – white box – for few internal testers	
Concept/abstract idea, coding starts, functionalities change, pre-alpha drafting stage	From preliminary idea/concept to the validation of analytical predictions of separate components of the software.

SOFTWARE DEVELOPMENT

Human Brain Project

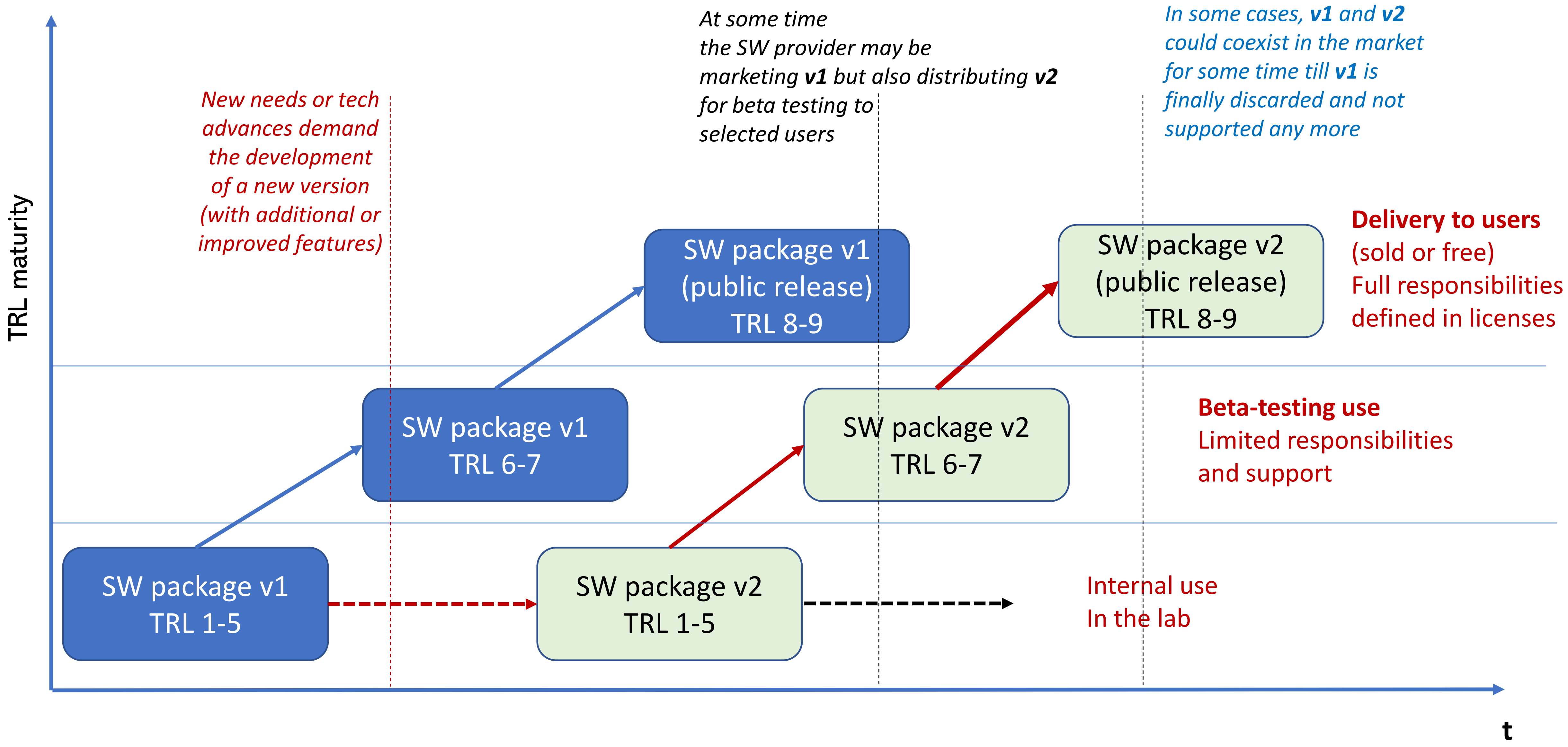
Supporting information in the TRL assessment of Software



9. Actual system proven in operational environment	Production configuration management reports. Technology integrated into a reuse "wizard."
8. Deployment, qualification	Published documentation and product technology refresh build schedule. Software resource reserve measured and tracked.
7. Prototype proven in operational environment	Critical technological properties measured against requirements in operational environment
6. Demonstration in relevant environment	Results from laboratory testing of a prototype package that is near the desired configuration in terms of performance, including physical, logical, data, and security interfaces. Comparisons between tested environment and operational environment analytically understood. Analysis and test measurements quantifying contribution to system-wide requirements such as throughput, scalability, and reliability. Analysis of human-computer (user environment) begun.
5. Validation in relevant environment	System architecture diagram around technology element with critical performance requirements defined. Processor selection analysis, Simulation/Stimulation (Sim/Stim) Laboratory buildup plan. Software placed under configuration management. Commercial-of-the-shelf/government-off-the-shelf (COTS/GOTS) components in the system software architecture are identified
4. Prototype component	Advanced technology development, stand-alone prototype solving a synthetic full-scale problem, or standalone prototype processing fully representative data sets.
3. Proof of concept implementation	Algorithms run on a surrogate processor in a laboratory environment, instrumented components operating in a laboratory environment, laboratory results showing validation of critical properties.
2. Conceptualisation	Applied research activities, analytic studies, small code units, and papers comparing competing technologies
1. Project initiation	Basic research activities, research articles, peer-reviewed white papers, point papers, early lab model of basic concept may be useful for substantiating the TRL

DoD (Department of Defense). U. S. 2009. Technology Readiness Assessment (TRA) Deskbook. Washington, WA:Prepared by Deputy Undersecretary of Defense for Science and Technology (DUSD (S&T)).

How does TRL can be applied to Software development? (2/2)



TRL checklist for Software (1/2)

TRL1 Project initiation

- ☐ Basic technology processes and scientific knowledge underpinning software applications (architecture, formulation) are known.
- ☐ Technology principles and high-level objectives are defined.
- ☐ Supporting Information includes published research or other references that identify the principles.
- ☐ Ethical aspects for software production and operation are addressed and compliant with EU policies
- ☐ Use case definitions, including target users and activities.

TRL2 Conceptualisation

- ☐ Practical applications are identified. However, applications may be still speculative, and there may be not yet a detailed analysis to support the assumptions.
- ☐ Most of the work is analytical or paper studies with the emphasis on understanding the concept better.
- ☐ Experimental work is designed to corroborate scientific principles, including validation criteria for critical components and basic properties of algorithms.
- ☐ PoC (proof-of-concept) being planned, starting with preliminary simulations with synthetic data.

TRL3 Proof of concept implementation

- ☐ Analytical studies and small-scale studies to validate the analytical predictions of separate components of the software have been performed (modelling and simulation may be used to complement experiments).
- ☐ Software components are validated, but there is no attempt yet to integrate the components into a complete system.

TRL4 Prototype component

- ☐ Key software modules are integrated, functionally validated, and tested with a range of data sets, to establish interoperability and begin architecture development.
- ☐ It is an alpha prototype integrated locally and containing key components to demonstrate basic functionality and critical test environments against expected system performance goals.
- ☐ Supporting information includes the experimental components and experimental test results differing from the expected system performance goals.
- ☐ Initial architecture documentation available

TRL5 Prototype integration

- ☐ End-to-end software elements integrated with key components, as well as implemented and interfaced with existing systems/simulations conforming to target environment.
- ☐ Supporting information includes results from the laboratory scale testing, analysis of the differences between the laboratory and eventual operating system/environment, and analysis of what the experimental results mean for the eventual operating system/environment.
- ☐ All required data formats have been specified.
- ☐ Increased fidelity of the system and environment to the actual application.
- ☐ The medium-fidelity prototype has been tested at laboratory scale system to demonstrate overall performance in a relevant environment.

TRL checklist for Software (2/2)

TRL6 Pilot-scale prototype to real-world integration

- ☐ Integrated systems or high-fidelity prototype implementations of the software are tested in a relevant environment under expected load, being demonstrated on full-scale realistic problems.
- ☐ The operating environment for the testing closely represents the actual operating environment.
- ☐ Initial system documentation, user documentation and final architecture documentation are available.

TRL7 Operational integration

- ☐ Validation of a prototype software with all key functionality available in a relevant real-world environment.
- ☐ Well integrated with operational hardware/software systems demonstrating operational feasibility.
- ☐ Most software bugs removed.
- ☐ No expected data format or application programming interfaces changes.
- ☐ Supporting information includes results from the full-scale testing and analysis of the differences between the test environment.
- ☐ Final design is virtually complete.

TRL8 Deployment

- ☐ Full software system has been proven to work in its final form and under expected conditions, i.e. the end-to-end system has been already created with all components
- ☐ All functionality successfully demonstrated in simulated operational scenarios.
- ☐ End-to-end system tested and integrated in a real-world environment with a small number of real users.
- ☐ Software has been thoroughly tested (user-acceptance and performance) and debugged.
- ☐ Software has been fully integrated with all operational hardware and software systems.
- ☐ All user documentation, training documentation and maintenance documentation completed, including software/system requirements and architecture/design related descriptions.

TRL9 Production

- ☐ System is in its final form and operated under the full range of operating conditions.
- ☐ Tested in a real-world environment with a target number of real users.
- ☐ Sustaining software engineering support is in place (e.g. forum, issue tracking, help desk, bug reporting email, etc.)
- ☐ Final product operates over the full range of expected conditions.

REMEMBER

- ALPHA PROTOTYPE
- BETA PROTOTYPE
- DEBUGGING
- COHABITING VERSIONS
- WHITE BOX TEST
- BLACK BOX TEST
- SOFTWARE ENGINEERING SUPPORT

Contents

RL checklist for Services (1/2)

RL1 Project initiation

- ☐ Basic principles of the service are known.
- ☐ High-level objectives defined.
- ☐ Supporting information includes published research or other references that identify the principles.
- ☐ Ethical aspects for service operation are addressed and compliant with EU policies
- ☐ Use case definitions (includes target users and activities)

RL2 Conceptualisation

- ☐ Practical applications of the service are identified. However, applications are speculative, and there may be no proof or detailed analysis to support the assumptions.
- ☐ Most of the work is analytical with the emphasis on understanding the service better.
- ☐ Validation work is designed to corroborate principles.
- ☐ PoC (proof-of-concept) is being planned, starting with preliminary service simulations.

RL3 Proof of concept implementation

- ☐ It includes analytical studies to validate the performance of separate elements of the service.
- ☐ These elements are validated (modelling and simulation may be used to complement the validation) but there is no attempt to integrate them into a complete service system.

RL4 Prototype component

- ☐ Key service elements are integrated, and functionally validated, to establish interoperability.
- ☐ Supporting information includes validation of elements and those results that differ from the expected service performance goals.
- ☐ Initial version of the service to demonstrate basic functionality and testing critical environments ready

RL5 Prototype integration

- ☐ End-to-end service elements integrated, as well as implemented and interfaced with existing systems conforming to target environment.
- ☐ Supporting information includes results from the testing, analysis of the differences between the test and eventual operating system/environment and analysis of what the tested results mean for the eventual operating system/environment.

RL checklist for Services (2/2)

RL6 Pilot-scale prototype to real-world integration

- ☐ Integrated service is tested in a relevant environment being demonstrated on full-scale realistic problems.
- ☐ This is a step up from tests to operational real-world scale and the determination of scaling factors that will enable design of the service system.
- ☐ The operating environment for the testing should closely represent the actual operating environment.
- ☐ System monitoring points identified.
- ☐ Initial service documentation and initial user documentation are available.

RL7 Operational integration

- ☐ Validation of the service with all key functionality available in a relevant real-world environment.
- ☐ Well integrated with other systems and services demonstrating operational feasibility.
- ☐ Supporting information includes results from the full-scale testing and analysis of the differences between the test environment.
- ☐ System monitoring points implemented.
- ☐ SLA monitored.
- ☐ No expected service changes.
- ☐ Final design is virtually complete.

RL8 Deployment

- ☐ Full service has been proven to work in its final form and under expected conditions.
- ☐ All functionality successfully demonstrated in simulated operational scenarios.
- ☐ Tested in a real-world environment with a small number of real users.
- ☐ SLA enforced.
- ☐ The service has been fully integrated with all operational systems.
- ☐ all user documentation, training documentation and following-up documentation is completed.

RL9 Production

- ☐ Service is in its final form and running under the full range of operating conditions.
- ☐ It has been thoroughly depurated and fully integrated with all operational systems.
- ☐ Tested in a real-world environment with a target number of real users.
- ☐ All documentation has been completed.
- ☐ Service engineering and following-up support is in place.
- ☐ Final service operates over the full range of expected conditions

REMEMBER

- USE CASES
- SERVICE LEVEL AGREEMENTS
- MONITORING POINTS
- SERVICES DOCUMENTATION
- SERVICE SUPPORT

Contents

Brief glossary of terms used in the TRL for HBP Datasets

ATLAS INTEGRATION	Data anchored to an appropriate anatomical location in a reference atlas, allowing data to be findable through spatial search and by search for brain structures
BASIC METADATA	The basic information needed to make data findable and accessible
CURATION	Management of data throughout its life cycle and translating an independently created data source into a unified system
CURATION SUPPORT	Service that deals with questions related to metadata and data management
DATA LICENCE	Describes under which conditions data are shared
DERIVED DATA	Data that have been generated from a primary data source or data that have been created from a disseminated dataset
FAIRNESS SCORE	Quantitative measurement of the FAIR (findable, accessible, interoperable and re-usable) principles
IN-DEPTH METADATA	Enrichment of metadata for the purpose of data re-use
MINDS	Basic metadata schema that includes Minimum Information for Neuroscience Data Sets
METADATA	Data that describe information about other data
PROVENANCE	A historical recording trail of the data and their origin
QUALITY CHECK	A process by which entities review the quality of the data
RAW DATA	Primary data that has not been subjected to processing
REPOSITORY	Storage location of data

RL checklist for Datasets (1/2)

RL1: Project initiation

☐ High-level objectives of the data are defined, including SMART requirements (Specific, Measurable, Achievable, Relevant, Time-bound)
☐ Acquisition methods are identified
☐ Processing methods are identified
☐ Ethical procedures for data production and handling are addressed and compliant with EU policies
☐ Component created in the project management tool (PLUS, in the Human brain project)

RL2: (Meta)data management concept

☐ File formats of (meta) data community standards were followed
☐ Repository concept is designed (standardised repository solutions are considered)
☐ Local storage concept is designed (guaranty of long-term preservation and integrity of data)

RL3: Validation of project execution

☐ Acquisition methods are validated and refined
☐ (Meta)data formats are validated and refined
☐ Storage/repository concepts are validated and refined
☐ Processing methods are validated and refined
☐ Quality check on test raw and/or derived data are developed and optimised

RL4: Data production

☐ Raw (meta)data are produced
☐ Quality check of raw data is applied according to: completeness, accessibility, consistency, accurateness, comprehensiveness, quantity, credibility, readability, relevance, timeliness, uniqueness, usefulness, validation possible, standard based processed, reproducibility, privacy and security observed (applicable to derived data, e.g. patient data)
☐ Derived data and corresponding metadata are produced
☐ Quality check of derived data is applied
☐ (Meta)data production is documented

RL checklist for Datasets (2/2)

RL5: Data findability / Curation initiation

☐ Data repository is (re)located onto a long-term storage system
☐ DataDescriptor is completed and accompanies the data
☐ Email with curation request is sent to curation team (curation-support@humanbrainproject.eu)
☐ Basic metadata (MINDS: Minimum Information for Neuroscience Data Sets) are collected and reviewed
☐ Metadata are clearly and explicitly linked to corresponding data it describes via a unique identifier (URL)
☐ Metadata are registered into a searchable resource (KnowledgeGraph) and assigned with a unique and persistent identifier (DOI)
☐ Metadata are released

RL6: Data interoperability

☐ (Meta)data are enriched with references to other (registered) (meta)data
☐ Metadata entries follow community standards (terminologies or ontologies) if applicable

RL7: Data publishing (via HBP Knowledge Graph)

☐ Data license is defined in compliance with the HBP open data policy
☐ (Derived)Data are released and assigned with a persistent DOI (on request of the data provider)
☐ Basic (meta)data are retrievable by their identifier from a searchable resource (KnowledgeGraph)
☐ Software for accessing data is provided

RL8: Data (re)usability

☐ Approach to integrate data into the HBP atlas viewers is identified
☐ Data and KnowledgeGraph are enriched with spatial metadata and guiding materials
☐ Data representation in atlas viewer is confirmed
☐ Data and KnowledgeGraph are enriched with in-depth metadata
☐ In-depth metadata are tested to be sufficient for software applications
☐ Data are integrated into the HBP atlas viewers (release of spatial metadata if possible)
☐ Data are accessible via software applications (release of in-depth metadata if possible)

RL9: Real-world application of Data

☐ Data are cited and used by 3rd parties
☐ Data achieve a high FAIRness score/ data are proven to be FAIR

REMEMBER

- CURATION SUPPORT
- RAW DATA
- METADATA
- REPOSITORY
- DERIVED DATA
- FAIRness

Contents

RL checklist for Models (1/3)

RL1 Model incubation: conception

- ☐ Basic principles and high-level objectives are defined.
- ☐ Supporting Information includes published research or other references that identify the principles.
- ☐ Target users of the model are defined.
- ☐ Model development activities are planned.
- ☐ Preliminary definition of users and/or developers ´ collaboration communities
- ☐ Low level of detail represented, e.g. block representations of components and parts of the model.
- ☐ Ethical aspects for the model development and utilisation are addressed and compliant with EU policies.

RL2 Model incubation: conceptualisation

- ☐ Practical applications are identified. However, applications may be still tentative, and there are not yet a detailed analysis to support the assumptions.
- ☐ Most of the work is analytical or paper studies with the emphasis on understanding the concept better.
- ☐ Experimental work is designed to corroborate principles, including the design of validation criteria for critical components and basic properties of the model.
- ☐ Critical features and capabilities of the code, programs, protocols, if needed, are still missing or lack robustness.
- ☐ PoC (proof-of-concept) being planned, starting with very preliminary simulations.

RL3 Model incubation: proof of concept

- ☐ Small-scale studies to validate the analytical results of separate components of the model have been performed.
- ☐ Mathematical components and algorithms are defined, but their verification can be only made by judgment, as numerical errors can still pollute validation or application decisions.
- ☐ Uncertainty quantification and sensitivity of the model can be still only assessed by judgment.
- ☐ There is yet no attempt yet to integrate the model components into a complete system.

RL4 Model structuring: prototype demonstration on lab

- ☐ Code, programs, protocols, procedures, and/or any elements of the model are integrated in a prototype, and preliminary assessed against quality requirements.
- ☐ The model prototype demonstrates basic functionality and critical test with a range of data sets.
- ☐ Consolidation of users and/or developers ´ collaboration communities
- ☐ Sensitivity of mathematical components and algorithms parameters has been explored.
- ☐ Informal “what if” assessment is undertaken to analyse uncertainty of the model.
- ☐ Qualitative comparisons have been made of measurement to model predictions.
- ☐ Sustained regression testing made with significant coverage.
- ☐ Final form of the model is just empirically speculated or calibrated.
- ☐ Initial model documentation available.

RL checklist for Models (2/3)

RL5 Model structuring: prototype validation on real problem

☐ Model elements integrated and implemented with existing systems/simulations conforming to target environment.
☐ Supporting information includes results from testing, analysis of the differences between prediction and operating environment, and reflection of what testing results imply for the final utilisation.
☐ All required input formats have been specified.
☐ A medium-fidelity prototype of the model, without significant defeaturing and/or simplification, has been tested to demonstrate overall performance in real conditions.
☐ Medium fidelity prototype captures key aspects of the geometry (physical models).

RL6 Model structuring: system model prototype demonstration on real problem

☐ Code, programs, protocols, procedures, and/or any elements of the prototype model are fully assessed against quality requirements.
☐ High-fidelity prototype model is implemented and tested in a relevant environment.
☐ The operating environment for the model testing represents the final operating environment.
☐ Quantitative validation of the model is made yet without assessment of variability and uncertainties or made with extrapolation to application parameter space.
☐ Sustained regression and verification testing completed with significant coverage.
☐ Numerical errors of the model are already estimated and acknowledged.
☐ Initial documentation and user documentation are available.

RL7 Model exploitation: operational demonstration

☐ High fidelity version of the model with little to no defeaturing and/or simplification.
☐ The validation of the model is available in a relevant real-world environment.
☐ High degree of endorsement by users and/or developers ´ collaboration communities
☐ Model is well integrated with system elements demonstrating operational feasibility.
☐ No expected data format or model application changes.
☐ Initial attempts are made to formally quantify margins, uncertainty, and sensitivity of the model. With some judgment yet, or significant judgment as to what to include.
☐ Plausible physics-informed models can be alternated in operations, potentially with model calibration.
☐ Supporting information includes results and analysis from the full-scale testing and operational demonstrations.

RL checklist for Models (3/3)

RL8 Model exploitation: deployment

- ☐ Formal quantification assessment of margins, uncertainty, and sensitivity is completed and available, without significant judgment as to what to include and without significant extrapolation to the application parameter space.
- ☐ Numerical error bounds rigorously quantified.
- ☐ Sustained regression testing and verification have been completed with very significant coverage of high-order interactions.
- ☐ All functionalities of the model have been proven to work in its final form and under expected operational conditions.
- ☐ Model fundamentals and/or development process is available in the scientific literature
- ☐ Model utilisation and training documentation is completed, including configuration requirements and operational related descriptions.

RL9 Model exploitation: completed version in production use

- ☐ The model is in its final form and operated under the full range of operating conditions.
- ☐ The model has been tested in a real-world environment with a target number of real users.
- ☐ Supporting and assistance service is available for user of the model, e.g. issue tracking, training module, help desk.
- ☐ Model is fully available to the end-users ´ communities

REMEMBER

- INCUBATION, STRUCTURING, EXPLOITATION
- VERIFICATION BY JUDGMENT
- SIMULATION
- SENSITIVITY
- UNCERTAINTY
- REGRESSION TESTING
- QUANTIFICATION ASSESSMENT

Contents

Innovation

Innovation In The Human Brain Project

The HBP is achieving conceptual breakthroughs in neuroscience and computing, and developing new techniques, tools, services, models, datasets, many of which are shared with the academic community – non-commercial exploitation- while others may be commercially exploited. The new platform EBRAINS will facilitate future studies of the human brain, enhance neuroscience research and support the realisation of innovative and practical solutions to prevent, diagnose and treat brain-related diseases.

The Innovation and Technology Transfer Node

The Innovation & Technology Transfer Node (ITTN) provides a set of exploitation and technology transfer services to the HBP community to accelerate the impact of the project on society through innovation.

Some specific objectives of the ITTN are:

1. Identify HBP emerging brain technologies and services with market potential
2. Create and update a catalogue of technology sheets and make market analysis on

CONTACTS

- Task leader industrial engagement: Gonzalo León
- Task leader exploitation of EBRAINS: Guillermo Velasco
- Bryan Strange
- Bárbara Gasset

HBP INNOVATION NEWSLETTER

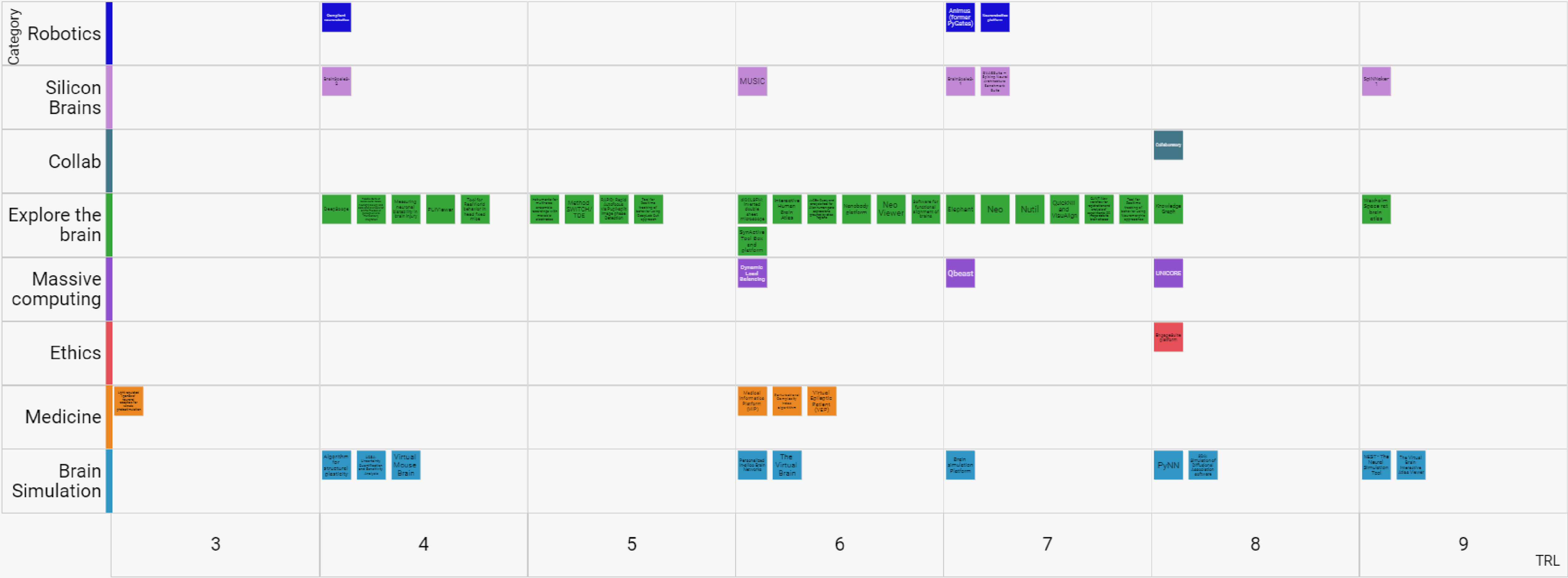
TECHNOLOGY CATALOGUE

TRL ASSESSMENT GUIDE

EDUCATION

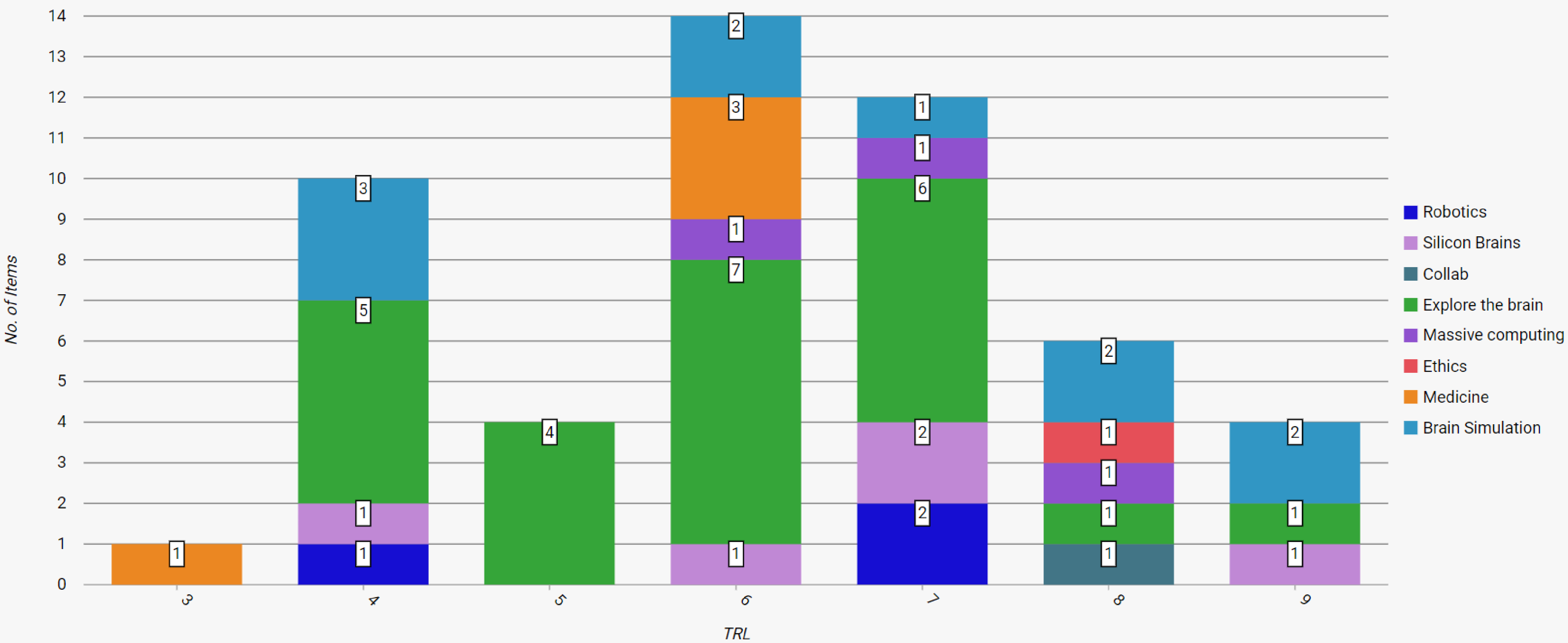
- TRL Assessment course
- HBP Curriculum online course on IPR, translation and exploitation of

How mature are the HBP developing tools?

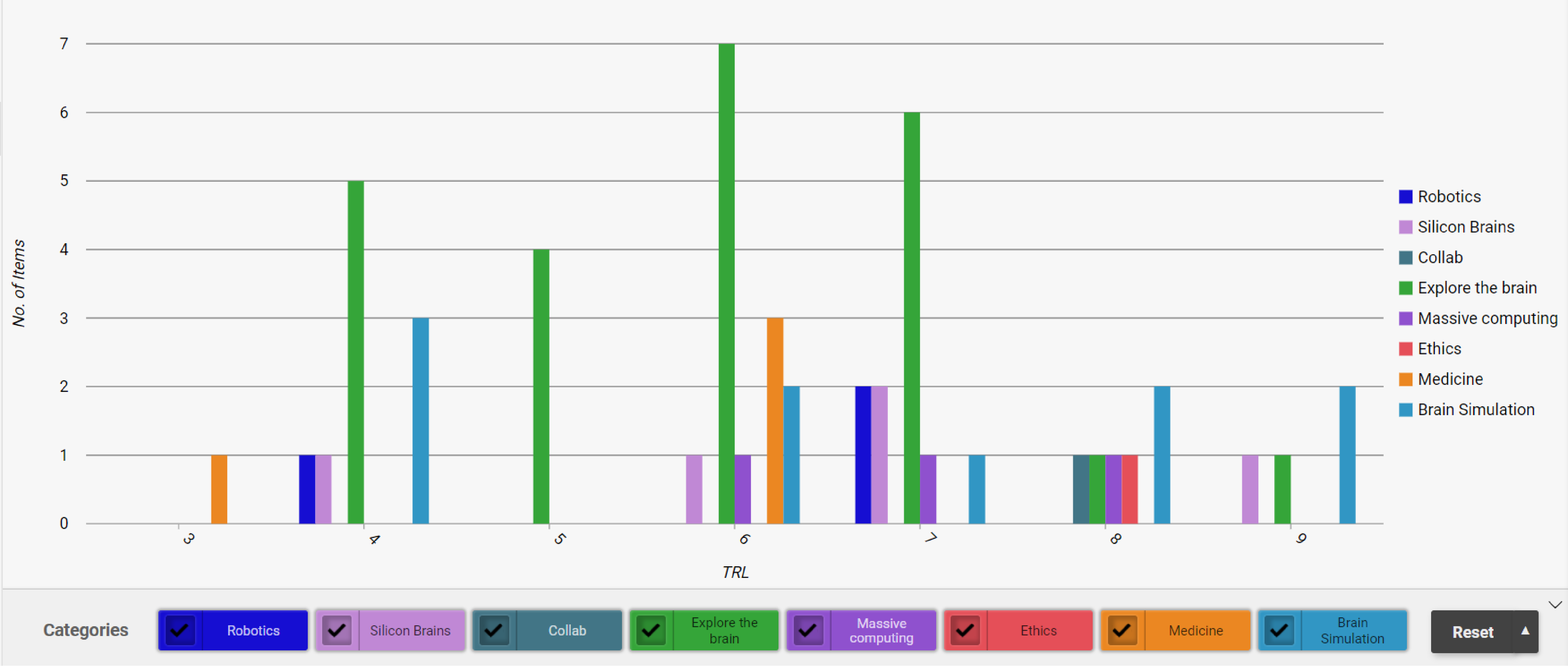


https://my.sharpcloud.com/html/#/story/126a9c22-3dcf-4212-83bc-46a7d4083e0a/view/ebfca8ed-84d8-4d82-a4d1-600d505b27ba

How mature are the HBP developing tools?

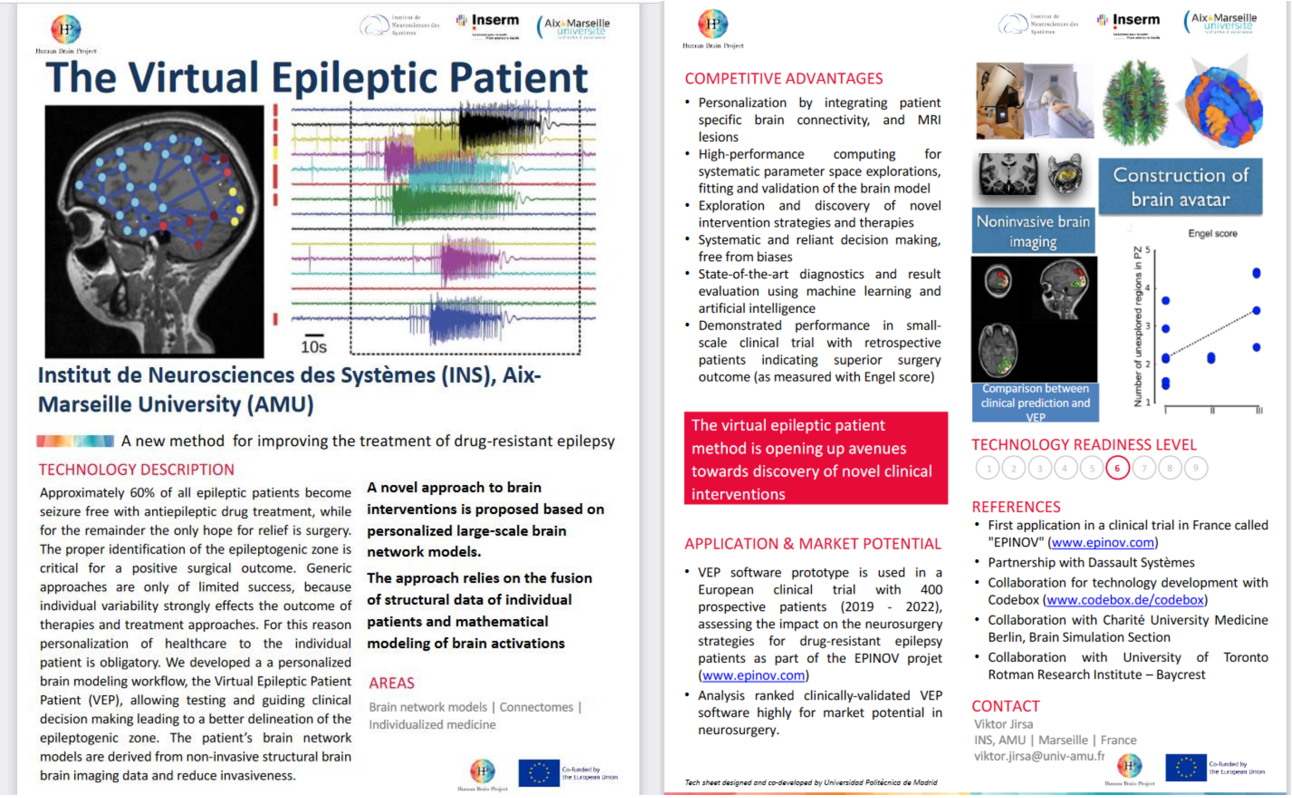


How mature are the HBP developing tools?



Example 1

Software demonstrated in relevant environment (TRL 6) and fully immersed in crinical trial (TRL 7)



The Virtual Epileptic Patient

Institut de Neurosciences des Systèmes (INS), Aix-Marseille University (AMU)

A new method for improving the treatment of drug-resistant epilepsy

TECHNOLOGY DESCRIPTION

Approximately 60% of all epileptic patients become seizure free with antiepileptic drug treatment, while for the remainder the only hope for relief is surgery. The proper identification of the epileptogenic zone is critical for a positive surgical outcome. Generic approaches are only of limited success, because individual variability strongly effects the outcome of therapies and treatment approaches. For this reason personalization of healthcare to the individual patient is obligatory. We developed a a personalized brain modeling workflow, the Virtual Epileptic Patient Patient (VEP), allowing testing and guiding clinical decision making leading to a better delineation of the epileptogenic zone. The patient's brain network models are derived from non-invasive structural brain brain imaging data and reduce invasiveness.

A novel approach to brain interventions is proposed based on personalized large-scale brain network models.

The approach relies on the fusion of structural data of individual patients and mathematical modeling of brain activations

AREAS

Brain network models | Connectomes | Individualized medicine

COMPETITIVE ADVANTAGES

- Personalization by integrating patient specific brain connectivity, and MRI lesions
- High-performance computing for systematic parameter space explorations, fitting and validation of the brain model
- Exploration and discovery of novel intervention strategies and therapies
- Systematic and reliant decision making, free from biases
- State-of-the-art diagnostics and result evaluation using machine learning and artificial intelligence
- Demonstrated performance in small-scale clinical trial with retrospective patients indicating superior surgery outcome (as measured with Engel score)

The virtual epileptic patient method is opening up avenues towards discovery of novel clinical interventions

APPLICATION & MARKET POTENTIAL

- VEP software prototype is used in a European clinical trial with 400 prospective patients (2019 - 2022), assessing the impact on the neurosurgery strategies for drug-resistant epilepsy patients as part of the EPINOV projet (www.epinov.com)
- Analysis ranked clinically-validated VEP software highly for market potential in neurosurgery.

Noninvasive brain imaging

Construction of brain avatar

Comparison between clinical prediction and VEP

TECHNOLOGY READINESS LEVEL

1 2 3 4 5 6 7 8 9

REFERENCES

- First application in a clinical trial in France called "EPINOV" (www.epinov.com)
- Partnership with Dassault Systèmes
- Collaboration for technology development with Codebox (www.codebox.de/codebox)
- Collaboration with Charité University Medicine Berlin, Brain Simulation Section
- Collaboration with University of Toronto Rotman Research Institute – Baycrest

CONTACT

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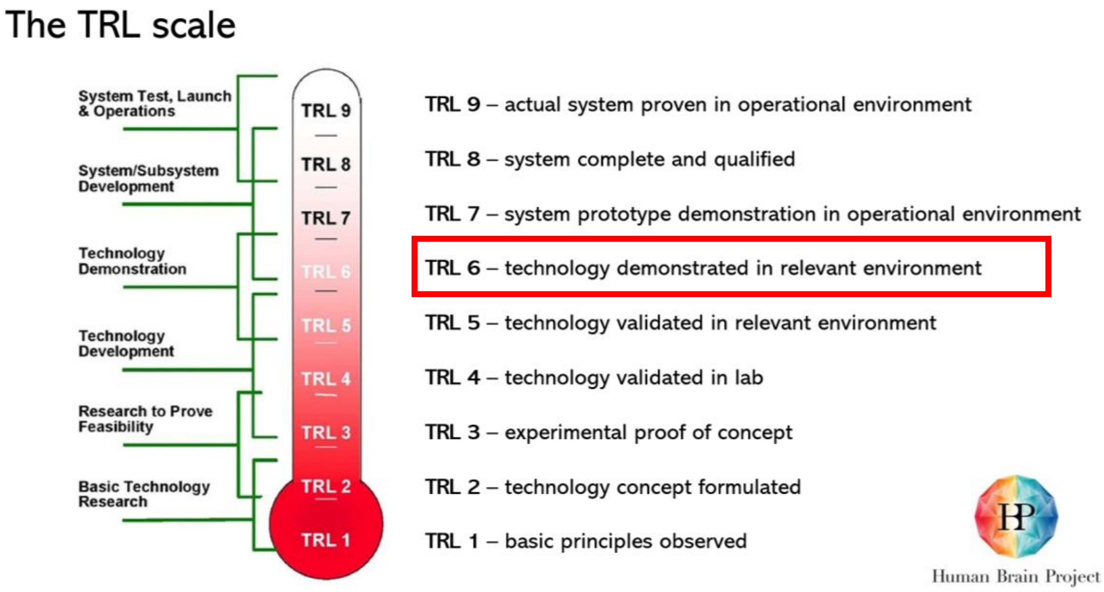
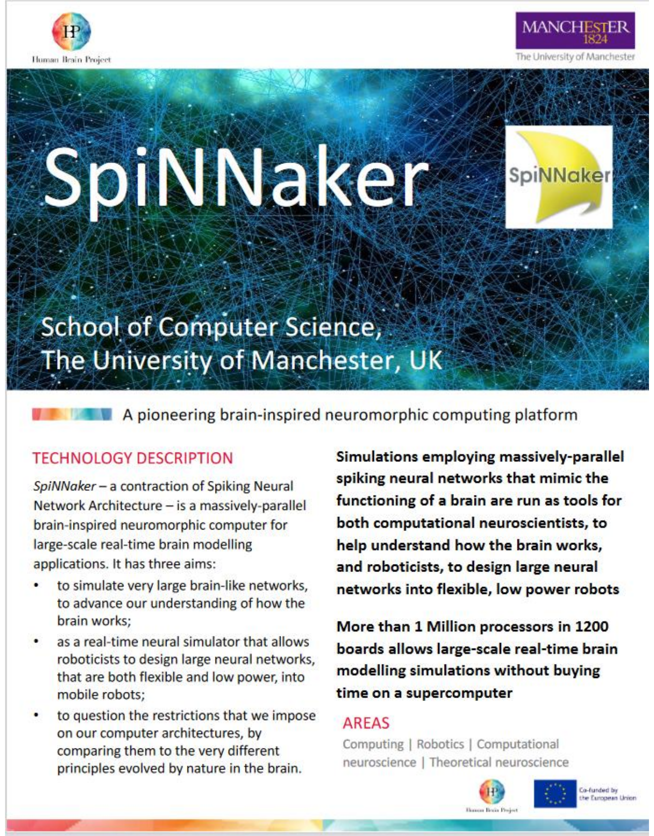
Tech sheet designed and co-developed by Universidad Politécnica de Madrid



Example 2

Hardware system proven in operational environment, more than 100 systems used worldwide



Human Brain Project

MANCHESTER 1824 The University of Manchester

SpiNNaker

School of Computer Science,
The University of Manchester, UK

A pioneering brain-inspired neuromorphic computing platform

TECHNOLOGY DESCRIPTION

SpiNNaker – a contraction of Spiking Neural Network Architecture – is a massively-parallel brain-inspired neuromorphic computer for large-scale real-time brain modelling applications. It has three aims:

- to simulate very large brain-like networks, to advance our understanding of how the brain works;
- as a real-time neural simulator that allows roboticists to design large neural networks, that are both flexible and low power, into mobile robots;
- to question the restrictions that we impose on our computer architectures, by comparing them to the very different principles evolved by nature in the brain.

Simulations employing massively-parallel spiking neural networks that mimic the functioning of a brain are run as tools for both computational neuroscientists, to help understand how the brain works, and roboticists, to design large neural networks into flexible, low power robots

More than 1 Million processors in 1200 boards allows large-scale real-time brain modelling simulations without buying time on a supercomputer

AREAS

Computing | Robotics | Computational neuroscience | Theoretical neuroscience

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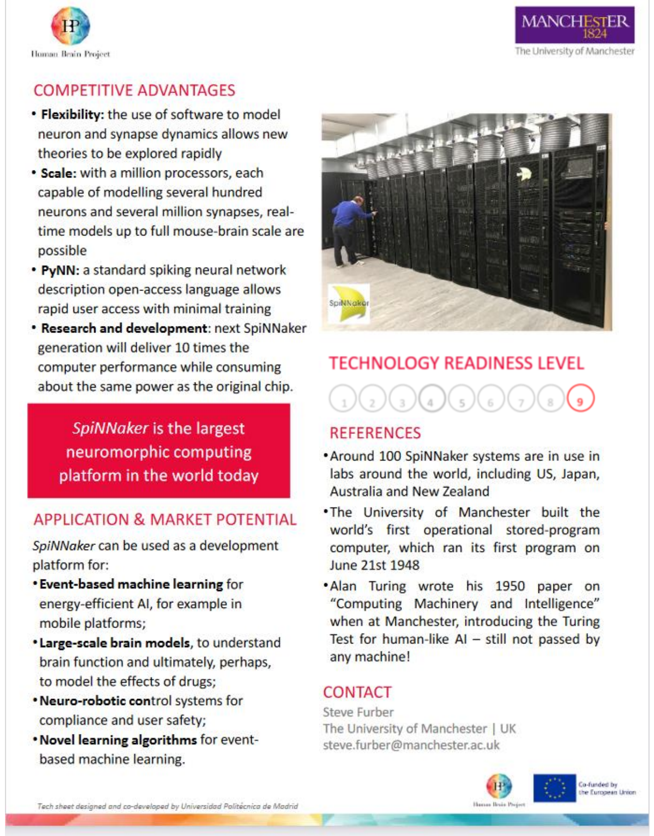

Human Brain Project

MANCHESTER 1824 The University of Manchester

COMPETITIVE ADVANTAGES

- **Flexibility:** the use of software to model neuron and synapse dynamics allows new theories to be explored rapidly
- **Scale:** with a million processors, each capable of modelling several hundred neurons and several million synapses, real-time models up to full mouse-brain scale are possible
- **PyNN:** a standard spiking neural network description open-access language allows rapid user access with minimal training
- **Research and development**: next SpiNNaker generation will deliver 10 times the computer performance while consuming about the same power as the original chip.

SpiNNaker is the largest neuromorphic computing platform in the world today

APPLICATION & MARKET POTENTIAL

SpiNNaker can be used as a development platform for:

- **Event-based machine learning** for energy-efficient AI, for example in mobile platforms;
- **Large-scale brain models**, to understand brain function and ultimately, perhaps, to model the effects of drugs;
- **Neuro-robotic control** systems for compliance and user safety;
- **Novel learning algorithms** for event-based machine learning.

TECHNOLOGY READINESS LEVEL

1 2 3 4 5 6 7 8 9

REFERENCES

- Around 100 SpiNNaker systems are in use in labs around the world, including US, Japan, Australia and New Zealand
- The University of Manchester built the world's first operational stored-program computer, which ran its first program on June 21st 1948
- Alan Turing wrote his 1950 paper on "Computing Machinery and Intelligence" when at Manchester, introducing the Turing Test for human-like AI – still not passed by any machine!

CONTACT

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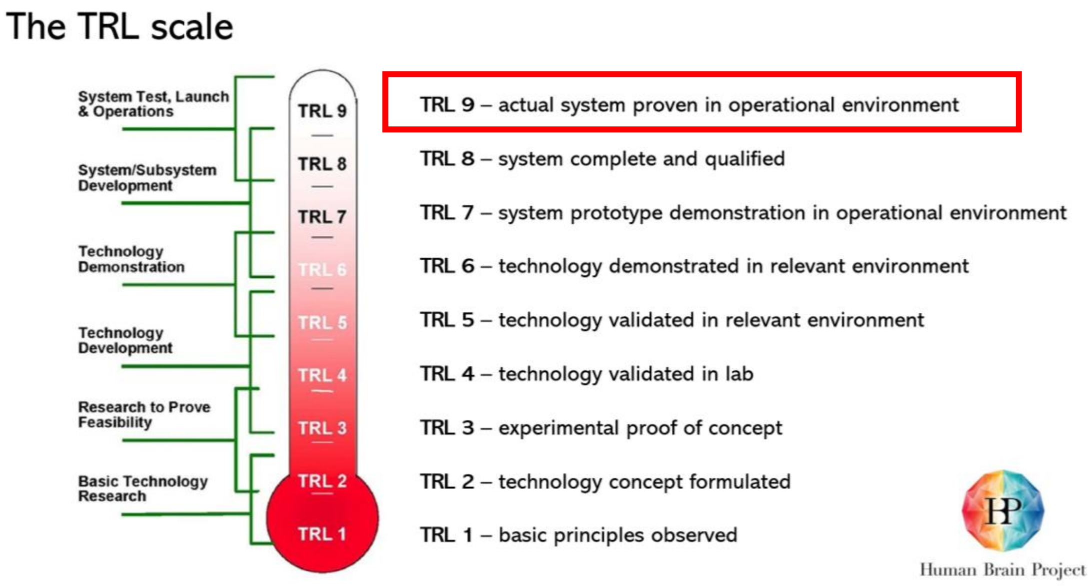

Example 3

Software demonstrated in relevant environment and being currently used in operational environment: computational neuroscientists, clinicians, etc (TRL 7)

Human Brain Project

JÜLICH Forschungszentrum

Interactive Human Brain Atlas

Forschungszentrum Juelich GmbH

Explore & analyze human brain data in 3D from a web browser

TECHNOLOGY DESCRIPTION

The Human Brain Project offers an interactive human brain atlas, which allows to explore 3D reference models and parcellations of the brain using only a web browser. This includes the BigBrain, a human brain model at microscopic resolution, which resolves individual cortical layers and large cells. Users can select different parcellations, navigate to specific brain regions, and interactively zoom and rotate to arbitrary viewpoints. In the sense of a spatial information system, the atlas allows to browse the comprehensive data repository of HBP for data and models related to selected brain locations, and retrieve descriptions of cytoarchitecture, connectivity, chemoarchitecture, genetics and brain function. Users can also map their own data to atlases to analyze them in context.

Exploring the 3D structure of the human brain, down to the level of 20 microns from a web browser

Finding and selecting brain regions, and using them to explore the Human Brain Project's comprehensive repository of brain data and models .

Adding custom tools for working with brain regions, by using an open plugin architecture

AREAS

Brain atlases | Neuroanatomy | Data repositories | 3D visualization

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Human Brain Project

JÜLICH Forschungszentrum

COMPETITIVE ADVANTAGES

- Efficient 3D navigation of a microscopic resolution brain atlas in a web browser
- Access to probabilistic maps that capture human brain variability, coupled with 3D maps at microscopic resolution
- Interactive access to a growing range of spatially organized multimodal brain data - **a spatial brain information system**
- Interactive functionality to project custom datasets to reference atlases for localizing and assessing neuroscientific findings
- Possibility to integrate and share custom data together with the HBP atlases

The interactive brain atlas allows instantaneous exploration of high resolution 3D brain models, as well as exploration and analysis of comprehensive neuroscience data by their location in the brain.

APPLICATION & MARKET POTENTIAL

- **Education:** Explore the anatomy of the brain in 3D, and learn more about different brain areas
- **Medical applications:** Localize brain areas affected by clinical findings
- **Neuroimaging:** Use different reference atlases to aggregate and assess results from neuroimaging studies
- **Simulation:** Retrieve region-specific multimodal properties of the brain to construct simulation models

TECHNOLOGY READINESS LEVEL

1 2 3 4 5 6 7 8 9

REFERENCES

- Atlas used by neuroanatomists, neuroimaging researchers, clinicians, and increasingly computational neuroscientists
- Based on the neuroglancer Project (https://github.com/google/neuroglancer)
- Includes interactive access to the "BigBrain" (http://bigbrain.humanbrainproject.org/) high-resolution human brain model (Amunts/Evans et al., Science 2013)

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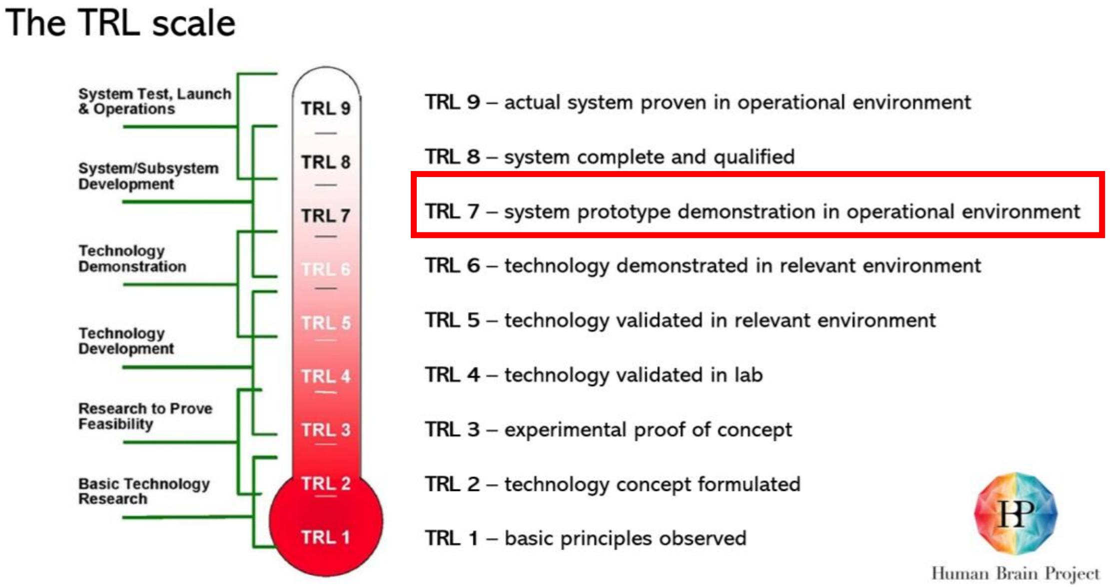

TRL assessment control and reporting

The process for the control of the TRL assessment is linked to the process of drafting and validating the WP specific exploitation plans and is summarized in the following steps:

1) For each exploitable result, a specific exploitation plan should be drafted by the developers; the Innovation Team provides a template and guidance for these plans.

2) Innovation team provides guidelines and training and is available to assist the developers of the results in the TRL assessment.

3) The corresponding TRL checklist (specific for hardware, software, service and dataset) is filled in by the developers of the results. The TRL resulting from this assessment should be included in the exploitation plan of each specific exploitable result.

4) The innovation team validates the TRL assessment done with the checklist, i.e. check that the completed checklist does correspond to the nature of result, and check that all the questions are correctly addressed.

5) The resulting TRL is considered official for reporting purposes, until a new assessment is done. If the technology is further developed, a new assessment of the TRL should be done, at least once per year. For the Technical Reports, the TRL levels should be updated along with the exploitation plans update.

Co-funded by
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Human Brain Project

Thanks

Questions ?

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