GUIDELINES FOR COBOTIC BASE CELL (CBC) DESIGN– OPEN CALL 2.1

CBC DESIGN OPEN CALL 2.1

Description: This document contains the guidelines and application procedure for S3C Open Call 2.1

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Intended for: S3C Partners

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COBOTIC BASE CELLS (CBC)

COBOTIC BASE CELLS (CBC) ARE THE HEART OF S3C

The heart of the S3C infrastructure will be a collection of state-of-the-art Cobotic Base Cells (CBCs). These are modular and reconfigurable machines that address a specific industrial process in the manufacturing sector.

To fulfill its task, CBC usually includes several components.

Cobot: A collaborative industrial robot (cobot) is an industrial robot that is designed in compliance with ISO 10218-1 and intended for collaborative use. Depending on the type of activity and safety requirements, a robot that does not comply with ISO 10218-1 may also be considered. Commercial cobots may be fitted with additional sensing capabilities and safety features, but rarely are these robots ready for use in a flexible production scenario without additional components.

Sensors: A CBC will usually include additional vision or sensor equipment. Typically, these sensors provide data about the robot's workspace, especially when a human is involved, allowing the workspace to be dynamic. This includes vision systems with 2D and 3D cameras proximity sensors, force and torque sensors, tactile sensors, inertial sensors, position and motion sensors, LiDAR etc.

Cognition: The data provided by the cobot, and workspace sensors need to be analyzed and fused. Information from the production activity (e.g. assembly components and steps) as well as from the user interfaces (see Interfaces below) are usually also available and need to be merged, processed, analyzed, understood, and converted into commands and actions for the robot. The robot uses this information to perform tasks autonomously adapting to changes in the environment. This cognitive process is crucial for transforming raw sensor inputs and user commands into precise, context-aware actions by the cobot. Cognition is the key element for a responsive human-robot collaboration with the robot understanding the intentions of human operators and learning adaptively from the collaboration.

Programming: Programming is a critical aspect of cobot deployment within a CBC constituting the software part enabling communication of all the components for an efficient task execution. This includes traditional teach pendant programming via user-friendly interfaces, brand-specific textual programming languages (TPL) visual programming languages (VPL) with code blocks, high-level language programming (e.g. Python, C++) with communication middleware (e.g. ROS, gRPC), learning from demonstration (LfD) (e.g. kinesthetic teaching), reinforcement learning (e.g. policy search), teleoperation, augmented/virtual reality programming (e.g. with wearable or mobile AR devices), offline simulation-based programming. CBCs should be programmed in a way that it can be easily adapted to different variations of the task without having to call for an expert.

Gripping and Feeding: Most tasks will require the cobot and human to interact with product components that need to be grabbed and released. Alternatively, the robot's end-effector may be a tool. The components must reach the robot workspace, this is either done by a human (e.g. bringing palettes of components into the workspace) or by using feeding systems. Grippers become a key element of the system as they must reliably handle the current production components, which may change several times a day. This includes parallel grippers, angular grippers, vacuum grippers, magnetic grippers, soft grippers, adaptive multi-fingered grippers, and custom 3D printed grippers.

Interfaces: Allow robots and humans to communicate with each other. Various interface modalities can facilitate this interaction. Manual interfaces include traditional methods like Teach Pendants (TP) with light displays and input buttons, as well as modern touch screens with graphical programming languages. Voice interfaces enable verbal communication, where the human provides commands through a microphone and the robot responds via a speaker. Kinesthetic interfaces allow the human to physically guide the robot, teaching it desired positions or trajectories through direct manipulation. Visual interfaces involve the human demonstrating tasks in front of a vision system, which the robot observes and learns from. Depending on the task, combining multiple interface modalities may yield the greatest benefits, allowing for more flexible and intuitive human-robot collaboration.

Safety: ISO/TS 15066 specifies safety requirements for collaborative industrial robot systems and the work environment, supplementing ISO 10218. To ensure compliance, the CBC must meet these standards, which may necessitate the integration of additional safety components such as safety cameras and sensors, protective barriers etc. A comprehensive risk assessment document according to ISO12100 that outlines the potential hazards and mitigation measures is required. This assessment needs to be conducted for each application programmed on the CBC, considering all the mechanical, electrical and software components. The electrical architecture of the CBC should comply with IEC/EN 62061 and IEC/EN 60204 standards, incorporating crucial safety features such as emergency stop circuits and safety relays to protect both human operators and robots, following ISO 13489-1 and EN/IEC 62061. Additionally, the CBC's mechanical design must reduce risks and enhance safety by ISO 10218, ensuring that the layout supports safe operations, and the selected robot configuration aligns with the mechanical requirements of each specific application.

Electrical Architecture: Electrical components are the foundation of CBC, providing the essential power, control, and connectivity needed for the system's operation. These components ensure the integration of all subsystems, from the cobot and sensors to the interfaces and safety mechanisms. Proper wiring, connectors, and real-time communication protocols like EtherCAT and Profinet ensure reliable data exchange and coordination across the system.

Mechanical Architecture: The mechanical architecture of CBC focuses on the design and integration of fixtures, custom-designed components, support structures, and the overall layout of the cell. This includes worktables, mounting fixtures, and any specially designed 3D components that are essential for securely holding parts and tools in place during operation. The mechanical layout must support the reconfigurability of the CBC, allowing quick adaptation to different tasks and production needs. The 3D design of the CBC should consider the reachability of the robot, or the robot needs to be chosen according to the mechanical design requirements.

Human-Robot Collaboration (HRC): Human-Robot Collaboration refers to the interaction between humans and robots working together in a shared environment to accomplish tasks. For example, in an assembly line, a robot might handle repetitive precise positioning of components, while a human operator handles the final adjustments and quality checks. HRCL (HRC levels) are defined as HRCL 0- Isolation, HRCL 1 - Coexistence, HRCL 2 - Synchronization, HRCL 3 - Cooperation and HRCL 4 – Collaboration. The primary objective of CBCs is to achieve and demonstrate high levels of HRC, particularly at HRCL 3 and 4, where humans and robots not only work together but also respond dynamically to each other's actions, enhancing productivity and safety.

Technology Readiness Level (TRL): Technology Readiness Level is a scale used to assess the maturity of a particular technology, ranging from basic research and conceptualization to fully developed and operational systems. The TRL scale typically ranges from TRL 1 (basic principles observed) to TRL 9 (actual system proven in an operational environment). CBCs should have at least TRL 6.

GENERAL INFORMATION

This section provides an overview of the open call for Cobotic Base Cell (CBC) design. It outlines the key details of the call, including the scope, available funding and application deadlines. This call invites S3C partners to propose innovative CBC designs that align with our strategic goals.

OBJECTIVES

The objective of CBC Design Open Call 2.1 is to advance the applied state-of-the-art cobotics technology in the industry. To achieve this, the call specifies the requirements given below. Each CBC shall

- address a specific manufacturing process, sector and/or branch to solve a challenge in the industry,
- be original and innovative favoring different processes and sectors than the already existing S3C Cells (see S3C Catalogue),
- enable flexible re-programming and adaptation to different tasks within the defined application with minimal intervention,
- achieve **at least TRL 6 and HRCL 3** (see Appendix for an explanation of TRLs and HRCLs),
- promote technology transfer from research to solve industrial manufacturing problems,
- promote collaboration of research and industry partners to innovate together,
- address sustainable development goals (SDG) (see here for an overview).

FUNDING

CBC Design Open Call 2.1 provides financial support to build **three large CBCs** and **three compact CBCs**. The funding details are as follows:

- A maximum of **200k CHF per large CBC** and **115k CHF per compact CBC** are allocated per CBC project.
- The funding will be distributed in two stages:
  - **60% upfront** upon acceptance of the proposal.
  - **40% upon successful commissioning** of the adapted CBC, verified by S3C and the consortium leader through the **CBC Checklist**.
- The consortium leader is responsible for distributing the funds according to the agreed budget plan outlined in the proposal.
- A minimum **in-kind contribution of 25-45%** is expected from consortium members to demonstrate commitment and ensure cost-effective solutions.

APPLICATION PROCEDURE AND DEADLINES

CBC Design Open Call 2.1 will address the partners within S3C and will allow an internal (and external) competition of state-of-the art technologies matching real industrial needs. The requirements for application are as follows:

- The S3C partners must apply for the CBC calls in a **consortium of at least three S3C partners**.
- The consortium should include **at least one research institution, one robot integrator** and **one technology provider.** The list of S3C research institutions, robot integrators and technology providers are given in Appendix 2.

- The proposal should include **at least 2 Letter of Intents (LOIs) from industrial end-users**, who will be invited to review the use-case during the live demonstration at the commissioning phase.
- The demonstrations of the **use-cases should be less than 5 minutes**, preferably around 2-3 minutes.
- The proposal should be written in the template given by **CBC_Design_Proposal_Template.docx**, converted to pdf, and renamed **XX_CBC_Design_Proposal.pdf** where **XX is the consortium leader partner institute**. The content and guidelines of the proposal are given in Section **GUIDELINES FOR PROJECT DESCRIPTION**. The minimum font size should be 10, and the font type is Arial. There is no need to put a table of contents, or table of figures nor table of tables. The proposal should be **maximum of 20 pages without the Appendix.**

Partners may optionally submit an **Expression of Interest (EoI)** during the period 01 December 2024 – 15 January 2025. This initiative aims to support partners in three ways:

1. If a partner is interested in participating in the call and has a technology offer but lacks a consortium or a finalized proposal idea.
2. If a partner has a proposal idea but has not yet formed a consortium.
3. If a partner has a consortium and a proposal idea and seeks preliminary feedback.

Activity	Call 2.1 – Deadlines
Submission for Expression of Interest (EoI) and full proposals opens.	01 December 2024
Submission closes for EoIs.	15 January 2025
Submission closes for full proposals.	**01 March 2025**
Notification of preliminary decisions with feedback from the S3C executive board. Resubmission period opens.	04 April 2025
Final submission incorporating feedback from the S3C executive board closes.	21 April 2025
Final funding decision by the S3C executive board is given.	01 May 2025
Project start date	**15 May 2025**
Latest CBC commissioning date.	**15 November 2025**

GUIDELINES FOR PROJECT DESCRIPTION

#	Section	Description
1	**Introduction**	
1.1	Problem definition	Describe the industrial challenge that you are trying to solve. Define the problem, motivation and objectives.
1.2	Industrial use-case(s)	Define the use-case(s) associated with the industrial challenge that the proposed CBC will try to solve. Provide the steps of the use-cases (of the current manual process, or of the current automatized process to be improved) using visual aids, describing challenges that each step contains in terms of cobotics.
1.3	Current state-of-the-art	Define the current state-of-the-art in the target process and in the target industry by citing existing commercial and academic automation efforts in the field. Define TRL and HRCL of the state-of-the-art that you would like to advance.
1.4	Proposed solution	Briefly explain how the proposed solution CBC in this proposal addresses the specific challenges in Section 1.2.
1.5	Innovative content	Define precisely the innovative content of your proposal referring to the state-of-the-art in Section 1.3. Describe the unique selling propositions (USPs) of your solution.
2	**CBC Plan**	
2.1	Overview of the concept	Describe the concept of the CBC using visual aids (e.g. 3D drawings, block-based diagrams). Briefly mention which hardware and software components exist and why are these components essential to the CBC.
2.2	Description of hardware	Describe each available hardware component: cobot, sensors, gripping, feeding, user-interfaces, electrical architecture. Justify the choice of each mechanical component. Hardware components need to be cited along with the applied safety standards.
2.3	Description of software	Describe each available software component: cognition, programming, user-interfaces, communication protocols with a process diagram. Justify the choice of each software component. How do you make sure that the software complies with the previously cited safety standards?
2.4	Adaptability	Discuss the adaptability of the CBC, particularly in terms of reconfiguring for different tasks, scalability, and integration with existing systems. Highlight how the CBC can be adjusted to meet varying industrial requirements and future challenges.
2.5	HRCL and TRL	Define the targeted Human-Robot Collaboration Level (HRCL) and Technology Readiness Level (TRL) of your CBC. Discuss the steps you will take to achieve these levels, including any incremental improvements over the current state-of-the-art.
3	**Project Plan**	
3.1	Consortium	Describe the consortium behind the project, including the roles and responsibilities of each partner
3.2	Workpackages, deliverables, milestones	Create a table with all the workpackages, deliverables and milestones for each workpackage. Explain how these tasks are distributed among the consortium members. Please consider the midterm review meeting with the S3C team.

3.3	Budget Plan	Provide a detailed budget plan, outlining the costs associated with each work package, including hardware, software, personnel, and other resources. Justify the expenses with offers.
3.4	Gantt Chart	Include a Gantt chart that visually represents the project timeline, showing the start and end dates of each work package, milestone, and deliverable
3.5	Risk Plan	Identify potential risks to the project and propose mitigation strategies for each. Discuss risks related to technical challenges, resource availability, timeline delays, and budget overruns, and describe how you plan to address them (in a table).
4.	**Results**	
4.1	Potential Customers	Identify potential customers or industries that would benefit from the CBC. Discuss the market potential and how the CBC addresses specific needs within these markets. Include any preliminary discussions or letters of intent from interested parties.
4.2	Demonstration use-cases	Detail the scenarios in which the CBC will be tested, the metrics for success, and how the results will be communicated to stakeholders. Briefly mention the expected impact on the target industry using this demonstration.
4.3	Environmental and Social Impact	(If any) Describe how the proposed solution contributes to sustainability, such as reducing energy consumption, minimizing waste, or enhancing worker safety. Additionally, discuss any potential social benefits, such as job creation or improving working conditions.
4.4	Future work	Outline the long-term vision for the CBC, including potential future developments, upgrades, or expansions. Discuss how the project will continue to evolve after the initial phase is complete.
§	**Appendix**	References and supplementary materials (e.g. offers, letter of intents etc.)

EVALUATION CRITERIA

The proposals to build CBCs will be evaluated following fixed criteria. First, each CBC proposal will be checked to make sure all formal requirements are met for funding. Proposals which are eligible will be evaluated by at least two experts following the criteria listed below. Each criterion will be rated between 1 (weak) to 5 (strong) by each expert. The three criteria will be summed up to an overall proposal score (maximum 15 points). An average overall score will be calculated for each proposal based on the two expert evaluations. This average score will be used to rank all proposals received. Proposals below a minimum quality threshold will not be considered for funding.

Excellence (40%)
Overall Concept 1: The concept is poorly defined, lacks clarity, does not align with the project's objectives, and does not meet TRL 6 or HRCL 3. 2: The concept is somewhat unclear, with limited structure and partial alignment to the project's objectives, falling short of TRL 6 or HRCL 3. 3: The concept is adequately defined, showing a reasonable understanding of the problem, a logical approach, and potential to reach TRL 6 or HRCL 3. 4: The concept is well-defined, clearly structured, aligns strongly with the project's objectives, and demonstrates readiness to meet at least TRL 6 or HRCL 3. 5: The concept is exceptionally well-defined and structured, perfectly aligned with the project's objectives, and fully meets or exceeds TRL 6 or HRCL 3. **Innovation** 1: The proposal lacks any innovative aspects, relying entirely on existing methods or technologies with no new ideas or advancements. 2: The proposal demonstrates minimal innovation, making only slight improvements or adjustments to existing technologies or methods. 3: The proposal is moderately innovative, introducing some new concepts or improvements but without substantial technological advancements. 4: The proposal is highly innovative, introducing new approaches or technologies that significantly improve upon the current state of the art. 5: The proposal is exceptionally innovative, presenting groundbreaking ideas or technologies that have the potential to revolutionize the field of cobotics. **Relevance to Industry** 1: The proposal does not address any significant industry needs and has minimal potential to solve relevant industrial challenges. 2: The proposal has some relevance to industry needs but does not fully align with pressing challenges or lacks clear potential to provide value. 3: The proposal addresses relevant industry challenges but may not fully capture all the critical issues or opportunities within the sector. 4: The proposal is strongly aligned with industry needs, providing a clear solution to a significant challenge with high potential impact. 5: The proposal is perfectly aligned with pressing industry challenges, offering a highly relevant, impactful solution that addresses core issues and creates substantial value for the sector. **Scalability and Adaptability**

1: The CBC design lacks scalability and is highly specialized, with limited ability to adapt to other processes or environments. 2: The design shows limited adaptability, with some potential for scalability but significant challenges to extend its application to different settings. 3: The design is moderately adaptable and scalable, with the potential to be applied to other processes or environments with some modifications. 4: The CBC design is highly adaptable and scalable, capable of being reconfigured or extended to various industrial environments with minimal effort. 5: The CBC design is exceptionally scalable and adaptable, offering modular, flexible solutions that can be easily applied to a wide range of industrial settings with little to no modification.
Impact (30%)
Originality and Differentiation 1: The proposal shows no significant difference from existing cells at S3C, lacking originality. 2: The proposal shows minimal differences from existing cells, with limited originality. 3: The proposal demonstrates moderate originality with some clear differences from existing cells. 4: The proposal is original, with significant differences from existing cells, offering new approaches. 5: The proposal is highly original, introducing groundbreaking ideas that strongly differ from existing cells at S3C. **Impactful Demonstrations** 1: The proposed demonstrations are unlikely to have any significant impact. 2: The proposed demonstrations have limited potential impact, lacking clear value. 3: The proposed demonstrations have moderate impact, with some potential for value. 4: The proposed demonstrations are impactful, with a clear and significant value proposition. 5: The proposed demonstrations are highly impactful, with exceptional potential to showcase value and achieve project objectives. **Impact for Swiss economy** 1: The project has minimal or no impact on the Swiss economy, with little relevance to national economic objectives. 2: The project offers limited economic benefits, with some relevance to the Swiss economy but lacking significant impact. 3: The project has moderate relevance to the Swiss economy, with the potential to contribute positively to economic growth and objectives. 4: The project significantly benefits the Swiss economy, with strong alignment to national economic objectives and clear potential for substantial impact. 5: The project has a highly positive impact on the Swiss economy, with strong alignment to national economic goals, and is likely to contribute to sustained economic growth.
Implementation (30%)
Consortium & responsibilities 1: The consortium lacks the necessary expertise, with poorly defined responsibilities, creating significant risk to achieving objectives. 2: The consortium has some relevant expertise, but responsibilities are not clearly defined, leading to potential challenges in meeting objectives. 3: The consortium is adequately skilled with reasonably defined responsibilities, capable of achieving most objectives with some risks. 4: The consortium is well-composed, with clear and complementary responsibilities, likely to meet objectives effectively. 5: The consortium has exceptional expertise, with well-defined and perfectly complementary responsibilities, ensuring a high probability of achieving all objectives.

Project Plan

1: The Gantt chart is poorly constructed with unrealistic timelines, hindering the achievement of objectives.

2: The Gantt chart is somewhat clear but has unrealistic timelines or missing milestones, impacting objective achievement.

3: The Gantt chart is clear with realistic timelines, adequately supporting objective achievement.

4: The Gantt chart is well-constructed with realistic timelines and milestones, strongly supporting objective achievement.

5: The Gantt chart is excellently structured with clear, realistic timelines and milestones, ensuring optimal support for objective achievement.

Cost Plan

1: The cost plan is incomplete, missing essential components, and unrealistic, with no inclusion of in-kind contributions, making it unsuitable for supporting the project.

2: The cost plan is partially complete, with some unrealistic or poorly justified elements, and includes less than 25% in-kind contributions, introducing financial risks.

3: The cost plan is complete, covering all necessary components with realistic and well-justified estimates, and includes in-kind contributions within the 25-35% range, ensuring basic financial feasibility.

4: The cost plan is thorough, providing detailed and carefully analyzed estimates, with clear justification for costs, and incorporates in-kind contributions between 35-44%, effectively aligning with the project's financial objectives.

5: The cost plan is exceptionally detailed and comprehensive, with highly accurate estimates and robust justification, demonstrating strategic alignment with financial objectives, and includes 45% or more in-kind contributions to ensure optimal resource use.

GUIDELINES FOR COMMISSIONING

A **Checklist Agreement** needs to be signed by the consortium leader and S3C to proceed with the payment of the remaining 40% funding.

The designed CBC must be delivered to S3C in **fully functional condition no later than the 15th of November**. Upon delivery, the **Checklist Agreement** must be signed to confirm that all components and functionalities meet the required standards. During the commissioning process, the applicants are expected to demonstrate the operation of the CBC, including the full implementation of the proposed use-case. This demonstration should involve the use-case or LOI providers, who will also be invited to observe and understand how the CBC addresses their specific needs. **The final 40% payment will be processed upon successful commissioning and demonstration, with payment completion to be made by the end of November.**

DOCUMENTATION AND MODELS

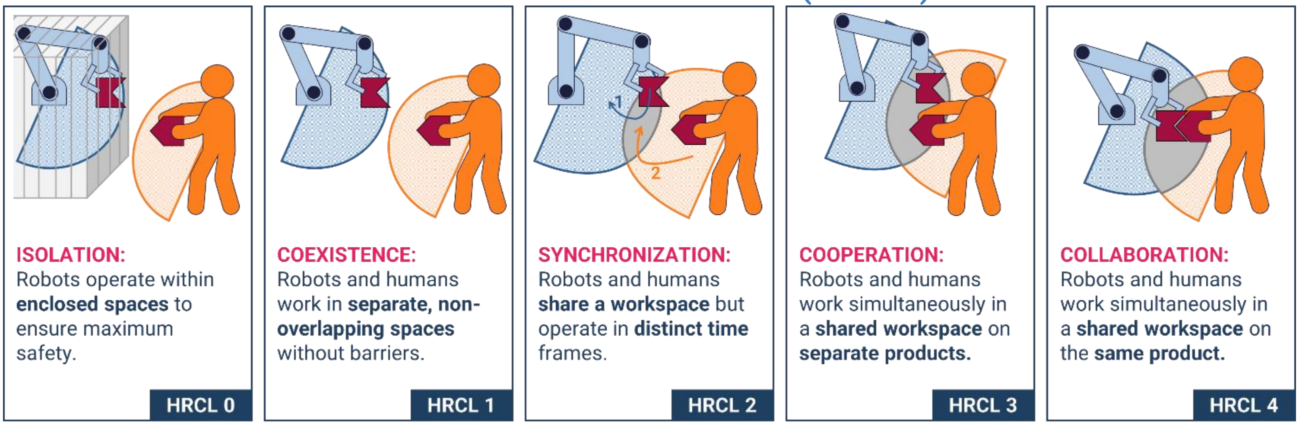
Please ensure that the following documentation and models will be delivered with the CBC.

Documentation:	• Instructions manual with a general description, operating instructions, transportation instructions, adaptations, error management and maintenance • Circuit diagrams, communication architecture • Risk assessment and safety documents • Test reports (running the task until completion many times to provide statistical error measures) • Process flowchart
Digital-twin models:	• CAD models • Simulation environments (optional)
Software	• Teach pendant instructions/programs that have been implemented with a description of created files, variables and functions. • Well commented code software package (e.g. zip, github, gitlab etc.) if applicable.
Promotion material:	• Basic video of the demonstration of the cell (no need for professional help) • Final photos of the commissioned cell at S3C and all the components.

PLEASE NOTE: BY SUBMITTING THE APPLICATION, THE S3C OPEN CALL CONDITIONS ARE ACCEPTED. THERE IS NO LEGAL ENTITLEMENT TO FUNDING.

APPENDIX

HUMAN-ROBOT COLLABORATION LEVEL (HRCL)



TECHNOLOGY READINESS LEVEL (TRL)

TRL #	Description
TRL 1: Basic Principles Observed **Stage**: Research	The lowest level of technology readiness. Scientific research begins to be translated into applied research and development.
TRL 2: Technology Concept Formulated **Stage**: Research	The technology concept and application are identified. Practical applications are still speculative, with no experimental proof or detailed analysis.
TRL 3: Experimental Proof of Concept **Stage**: Research	Active research and development (R&D) are initiated, including analytical and laboratory studies to validate predictions.
TRL 4: Technology Validated in Lab **Stage**: Validation	Basic technological components are integrated to establish that they will work together.
TRL 5: Technology Validated in Relevant Environment **Stage**: Validation	The technology is validated in a simulated environment that closely resembles the intended operational environment.
TRL 6: Technology Demonstrated in Relevant Environment **Stage**: Demonstration	The technology is demonstrated in a relevant environment, such as a pilot plant. Major subsystems are tested and validated.
TRL 7: System Prototype Demonstration in Operational Environment **Stage**: Deployment	A prototype system is demonstrated in an operational environment. The technology is close to being market-ready.
TRL 8: System Complete and Qualified **Stage**: Deployment	The technology is fully developed and qualified through testing and demonstration. It is ready for market introduction.
TRL 9: Actual System Proven in Operational Environment **Stage**: Commercialization	The technology has been successfully deployed and proven in the operational environment. It is fully commercialized and integrated into the market.