worldskills

Technical Description

Additive Manufacturing

WorldSkills International, by a resolution of the Competitions Committee and in accordance with the Constitution, the Standing Orders, and the Competition Rules, has adopted the following minimum requirements for this skill for the WorldSkills Competition.

The Technical Description consists of the following:

1 Introduction

1.1 Name and description of the skill competition

1.1.1 The name of the skill competition is

Additive Manufacturing

1.1.2 Description of the associated work role(s) or occupation(s)

Additive manufacturing is one of the newest and fastest developing branches of engineering. Traditional manufacturing methods, like milling and turning, are “subtractive” methods of manufacture: they start with a solid block of material, normally metal or an alloy, and cut away unwanted material until it forms the desired shape and size. Additive manufacturing adds, or “builds”, layer upon layer of material. It is more commonly known as 3D Printing.

Additive manufacturing has several advantages over milling and turning. For example:

- It can enable more complex shapes to be created
- although the materials may be more expensive, it is efficient and economical in their use, because items need be no more solid than is strictly necessary, and weight is minimized
- It can create stronger bonds between different materials
- It can produce complex units as single objects, removing the need for several parts to achieve the overall desired shape and function
- It can use a wider range of materials and composites
- It is especially quick and responsive for manufacturing design and development, including research, prototyping, and trials.

Despite its many strengths, additive manufacturing complements milling and turning; it is not a substitute for them. At least for the foreseeable future, 3D printers and new materials are relatively expensive. The printing process is also slow. Additive manufacturing therefore extends manufacturing’s capabilities and applications to a significant extent, especially where customization, lightness, complex shapes and functions, new materials, durability, and reliability are involved. As a result, additive manufacturing is being used very widely, with aerospace an early adopter, followed by medicine, transportation, energy, and consumer products.

Additive manufacturing allows us to redesign many objects around us, and rethink approaches to the design of new ones. In this way it is potentially transformative and disruptive across the manufacturing process. While the layer-on-layer process is relatively slow, additive manufacturing’s overall impact on design and manufacture will be to shorten the production cycle, improve quality, and improve customer benefits.

An additive manufacturing technician requires a wide range of knowledge, skill, and generic attributes. In relation to 3D, their role covers 3D scanning, metrology, scan-to-CAD redesigning, CAE, build process analysis, and post-processing. Beyond these, the role requires an appreciation of their properties and characteristics of materials, applied mathematics, and geometry in particular, and the ability to take advantage of the future possibilities of this new technology.

1.1.3 Number of Competitors per team

Additive Manufacturing is a single Competitor skill competition.

1.1.4 Age limit of Competitors

The Competitors must not be older than 25 years in the year of the Competition.

1.2 The relevance and significance of this document

This document contains information about the standards required to compete in this skill competition, and the assessment principles, methods, and procedures that govern the competition.

Every Expert and Competitor must know and understand this Technical Description.

In the event of any conflict within the different languages of the Technical Descriptions, the English version takes precedence.

1.3 Associated documents

Since this Technical Description contains only skill-specific information it must be used in association with the following:

- WSI – Code of Ethics and Conduct
- WSI – Competition Rules
- WSI – WorldSkills Occupational Standards framework
- WSI – WorldSkills Assessment Strategy
- WSI online resources as indicated in this document
- WorldSkills Health, Safety, and Environment Policy and Regulations
- WorldSkills Standards and Assessment Guide (skill-specific)

2 The WorldSkills Occupational Standards (WSOS)

2.1 General notes on the WSOS

The WSOS specifies the knowledge, understanding, skills, and capabilities that underpin international best practice in technical and vocational performance. These are both specific to an occupational role and also transversal. Together they should reflect a shared global understanding of what the associated work role(s) or occupation(s) represent for industry and business (www.worldskills.org/WSOS).

The skill competition is intended to reflect international best practice as described by the WSOS, to the extent that it can. The Standard is therefore a guide to the required training and preparation for the skill competition.

In the skill competition the assessment of knowledge and understanding will take place through the assessment of performance. There will only be separate tests of knowledge and understanding where there is an overwhelming reason for these.

The Standard is divided into distinct sections with headings and reference numbers added.

Each section is assigned a percentage of the total marks to indicate its relative importance within the Standards. This is often referred to as the “weighting”. The sum of all the percentage marks is 100. The weightings determine the distribution of marks within the Marking Scheme.

Through the Test Project, the Marking Scheme will assess only those skills and capabilities that are set out in the WorldSkills Occupational Standards. They will reflect the Standards as comprehensively as possible within the constraints of the skill competition.

The Marking Scheme will follow the allocation of marks within the Standards to the extent practically possible. A variation of up to five percent is allowed, if this does not distort the weightings assigned by the Standards.

2.2 WorldSkills Occupational Standards

Section		Relative importance (%)
1	**Work organization and management**	**5**
	The individual needs to know and understand: • Standards for environmental protection, safety, hygiene and accident prevention related to the use of ◦ optical and laser 3D scanners ◦ graphic work stations ◦ additive machines ◦ other machines, and post-processing equipment • The principles and applications of additive manufacturing (AM) • The principles and applications of related and replacement technologies • The importance of planning and time management during work • The importance of prioritizing	

Section		Relative importance (%)
	• The importance of cost accounting and analysis • Current internationally recognized standards (ISO), and standards currently used and recognized by industry • The role and significance of providing innovative and creative solutions to technical and design problems and challenges • The importance of maintaining a productive and professional demeanour • The importance of efficient, economical, and data rational work habits and performance	
	The individual shall be able to: • Provide and maintain a safe, tidy, and efficient work area • Promote health and safety legislation, best working practice, and environmental protection • Apply the internationally recognized standards (ISO) and standards currently used and recognized by industry; • Use planning and time management during the work; • Prioritize between work demands on a rational basis • Independently Interpret technical tasks • Estimate and plan the time, sequence, and duration of tasks and steps • Produce work that fully meets the technical specifications and standards; • Create and apply innovative and creative solutions to problems and challenges of AM • Maintain a productive appearance and demeanour • Work efficiently, economically, and data rationally	
2	**Communication and interpersonal skills**	**5**
	The individual needs to know and understand: • The importance of effective communication and inter-personal skills between co-workers, customers, and other related professionals • The range of purposes of documentation in both paper and electronic forms as well as instructions in any forms • Technical terminology and symbols • The importance of technical specifications • The importance of resolving misunderstandings and conflicting demands • The importance of gaining, retaining, and developing knowledge through log books, exhibitions, articles, and specialist internet resources	

Section		Relative importance (%)
	The individual shall be able to: • communicate effectively, using strong inter-personal skills with co-workers, clients, and other related professionals to ensure that developing projects meet requirements • Read, interpret, and extract technical data and instructions from any available sources • Use discretion and confidentiality when dealing with clients • Clarify terms of reference, specifications, and instructions, for the most accurate implementation of requirements • Maintain proactive continuous professional development in order to sustain knowledge and skill in new and developing technologies and practices	
3	**3D digitizing**	**15**
	The individual needs to know and understand: • The principles of equipment operation for 3D digitizing • The advantages and disadvantages of various types of equipment for 3D digitizing, and the technologies on which they are based • The requirements for ensuring the feasibility of work and its required quality and accuracy relative to dust, base vibration, stray light sources, mobility of objects, thermal expansion, etc • The importance of calibration of equipment, and the requirements for calibration and digitizing conditions • The requirements of each item's surface characteristics for optical 3D digitizing, relative to its purposes and uses such as fit, smoothness, transparency, translucence, glossiness • Methods and techniques for surface preparation for optical 3D digitizing, such as washing, sandblasting, and matting • The types of rejection of 3D digitizing, their sources, and ways to eliminate them • The types and range of measuring instruments and devices (probes, sensors, fixing devices, etc.) • Constructive and metrological characteristics of measuring instruments, including special ones (for measuring narrow grooves, gears, threads, etc.) • Factors influencing the reliability of the results of measurement (surface contamination, temperature imbalance, incorrect measuring force, etc.) • Measurements making methods • How to use specialized reference books, tables, or diagrams	
	The individual shall be able to: • Perform equipment's adjustment and calibration • Make decisions regarding the possibility of optical 3D digitizing, for technical reasons: ◦ Possible or impossible to perform	

Section		Relative importance (%)
	◦ The accuracy it is possible to attain for the object ◦ The required conditions for digitizing • Make decisions regarding pre-process works such as disassembly, washing, and painting • Perform pre-process actions for applying matting coating • Apply matting coating • Apply optical marks • Fix objects for subsequent digitization • Perform 3D digitizing for various objects with: ◦ different materials ◦ different surface characteristics ◦ different geometrical complexity • Save results in the required form • Prepare objects and measuring instruments for measurements • Calibrate, adjust, and align measuring instruments • Select correct measuring instruments and devices (styluses, probes, etc.), auxiliary and fixing devices (vices, V-blocks, clamps, etc.), relating to measurement strategy • Perform measurements using various control and measuring instruments • Read the indications of measuring instruments • Identify and estimate the correctness of measurements and the reliability of the data obtained, to minimize associated human factor errors • Find the required information in specialized reference books, tables, or diagrams • Carry out routine maintenance of measuring instruments • Transfer measuring data to CAD-models	
4	**Component optimization/structural optimization**	**25**
	The individual needs to know and understand: • What types and methods are available for software-supported component optimization • How the methods differ from each other • The results that the various methods deliver • The input variables that must be known for the procedures • The objectives pursued for structural optimization and the ways in which the results differ for the different optimizations • How optimization methods are selected and used • The valid and common rules to be followed for optimization in additive manufacturing	
	The individual shall be able to: • Select the right type of optimization for the task in hand. • Define and apply correct boundary conditions	

Section		Relative importance (%)
	• Carry out component optimizations by applying the given optimization objectives • Evaluate the results of the optimizations with reference to quality and compliance with the given input variables • Convert the optimized components into printable components with adapted geometry • Design components according to given manufacturing processes and exploit the potential of the process for design • Optimise designs with regard to the required number of components	
5	**Transfer-to-CAD and optimization**	**20**
	The individual needs to know and understand: • The purposes of Transfer-to-CAD processes in relation to additive technologies (the number of parts reducing, weight reducing, functions optimizing, etc) • Transfer-to-CAD software applications; CAD, CAE, and optimization software • Mathematics, especially geometry related to additive technologies • Polygonal models requirements for Transfer-to-CAD purposes • Methods of extracting primitives from polygonal models for the purpose of restoring CAD models and their optimization • Mechanical systems and operational principles • Fundamentals of technical drafts and drawings • The basics of component assembly • Comparative methods for CAD and polygonal modelling • The requirements for CAD models for AM purposes, post-processing, and subsequent use • AM and mechanical engineering materials' properties.	
	The individual shall be able to: • Create editable CAD models by digitized data (polygonal models) • Apply mathematics to additive technologies • Restore missing data of the elements of objects to be redesigned, from available data: ◦ Of polygonal models (for example, the gear wheel has only one preserved tooth, the worm has only one turn, or there is only one-third of the flange) ◦ Taken from connected parts ◦ Taken from existing objects by manual measuring (for example, the depth of a blind hole) • Change the geometry of created models according to task • Consider the features of AM and subsequent finishing processing • Analyse and optimize the structure of the model in accordance with the terms of reference	

Section		Relative importance (%)
	• Analyse the deviation of created models from the results of 3D scanning • Provide lattices' and surfaces' topology, with analysis and optimization according to task • Apply standards for conventional dimensioning and tolerances, and geometric dimensioning and tolerance appropriate to the ISO standard • Distinguish between, and mix, polygon meshing and standard b-rep functionalities in a smart way	
6	**Preparation and forming**	**25**
	The individual needs to know and understand: • Physics and chemistry related to additive technologies • Model preparation, simulation and analysis software • The advantages and disadvantages of the most common additive technologies (SLS, SLM, SLA/DLP, FDM/FFF and MJ) • Properties, advantages and disadvantages of industrial materials for 3D printing • Requirements for models in accordance with technologies and materials • Post-processing technologies, their capabilities and requirements for built models (fastening requirements, binding elements, post-processing allowances, stresses relieve operations sequence) • Technologies and processes that can used for AM parts (casting in SPF, burned or lost wax models casting, polymers moulding, etc.)	
	The individual shall be able to: • Choose the technology that best suits the task • Choose material that best suits the task • Prepare models for forming according to the selected technology and material (placement, orientation, supports, shrinkage) • Apply physics and chemistry as they relate to additive technologies • Simulate and analyse forming processes • Start and control the build process • Assign necessary post-processing processes and define their complexity.	

Section		Relative importance (%)
7	**Finalize and deliver work pieces**	**5**
	The individual needs to know and understand: • The processes and procedures of post processing • The importance of completing work pieces to the required standard to the extent of their responsibilities • The circumstances in which referral should be made to other appropriate personnel	
	The individual shall be able to: • Clean parts • Deliver parts to the appropriate locations and/or personnel as required by the organization • Evaluate and report on factors and outcomes relevant to requirements and expectations.	
	Total	**100**

3 The Assessment Strategy and Specification

3.1 General guidance

Assessment is governed by the WorldSkills Assessment Strategy. The Strategy establishes the principles and techniques to which WorldSkills assessment and marking must conform.

Expert assessment practice lies at the heart of the WorldSkills Competition. For this reason, it is the subject of continuing professional development and scrutiny. The growth of expertise in assessment will inform the future use and direction of the main assessment instruments used by the WorldSkills Competition: the Marking Scheme, Test Project, and Competition Information System (CIS).

Assessment at the WorldSkills Competition falls into two broad types: Measurement and Judgement. For both types of assessment, the use of explicit benchmarks against which to assess each Aspect is essential to guarantee quality.

The Marking Scheme must follow the weightings within the Standards. The Test Project is the assessment vehicle for the skill competition, and therefore also follows the Standards. The CIS enables the timely and accurate recording of marks; its capacity for scrutiny, support, and feedback is continuously expanding.

The Marking Scheme, in outline, will lead the process of Test Project design. After this, the Marking Scheme and Test Project will be designed, developed, and verified through an iterative process, to ensure that both together optimize their relationship with the Standards and the Assessment Strategy. They will be agreed by the Experts and submitted to WSI for approval together, to demonstrate their quality and conformity with the Standards.

Prior to submission for approval to WSI, the Marking Scheme and Test Project will liaise with the WSI Skill Advisors for quality assurance and to benefit from the capabilities of the CIS.

4 The Marking Scheme

4.1 General guidance

This section describes the role and place of the Marking Scheme, how the Experts will assess Competitors' work as demonstrated through the Test Project, and the procedures and requirements for marking.

The Marking Scheme is the pivotal instrument of the WorldSkills Competition, in that it ties assessment to the standard that represents each skill competition, which itself represents a global occupation. It is designed to allocate marks for each assessed aspect of performance in accordance with the weightings in the Standards.

By reflecting the weightings in the Standards, the Marking Scheme establishes the parameters for the design of the Test Project. Depending on the nature of the skill competition and its assessment needs, it may initially be appropriate to develop the Marking Scheme in more detail as a guide for Test Project design. Alternatively, initial Test Project design can be based on the outline Marking Scheme. From this point onwards the Marking Scheme and Test Project should be developed together.

Section 2.1 above indicates the extent to which the Marking Scheme and Test Project may diverge from the weightings given in the Standards, if there is no practicable alternative.

For integrity and fairness, the Marking Scheme and Test Project are increasingly designed and developed by one or more Independent Test Project Designer(s) with relevant expertise. In these instances, the Marking Scheme and Test Project are unseen by Experts until immediately before the start of the skill competition, or competition module. Where the detailed and final Marking Scheme and Test Project are designed by Experts, they must be approved by the whole Expert group prior to submission for independent validation and quality assurance. Please see the Competition Rules for further details.

Experts and Independent Test Project Designers are required to submit their Marking Schemes and Test Projects for review, verification, and validation well in advance of completion. They are also expected to work with their Skill Advisor, reviewers, and verifiers, throughout the design and development process, for quality assurance and in order to take full advantage of the CIS's features.

In all cases a draft Marking Scheme must be entered into the CIS at least eight weeks prior to the Competition. Skill Advisors actively facilitate this process.

4.2 Assessment Criteria

The main headings of the Marking Scheme are the Assessment Criteria. These headings are derived before, or in conjunction with, the Test Project. In some skill competitions the Assessment Criteria may be similar to the section headings in the Standards; in others they may be different. There will normally be between five and nine Assessment Criteria. Whether or not the headings match, the Marking Scheme as a whole must reflect the weightings in the Standards.

Assessment Criteria are created by the person or people developing the Marking Scheme, who are free to define the Criteria that they consider most suited to the assessment and marking of the Test Project. Each Assessment Criterion is defined by a letter (A-I). **The Assessment Criteria, the allocation of marks, and the assessment methods, should not be set out within this Technical Description. This is because the Criteria, allocation of marks, and assessment**

methods all depend on the nature of the Marking Scheme and Test Project, which is decided after this Technical Description is published.

The Mark Summary Form generated by the CIS will comprise a list of the Assessment Criteria and Sub Criteria.

The marks allocated to each Criterion will be calculated by the CIS. These will be the cumulative sum of marks given to each Aspect within that Assessment Criterion.

4.3 Sub Criteria

Each Assessment Criterion is divided into one or more Sub Criteria. Each Sub Criterion becomes the heading for a WorldSkills marking form. Each marking form (Sub Criterion) contains Aspects to be assessed and marked by Measurement or Judgement, or both Measurement and Judgement.

Each marking form (Sub Criterion) specifies both the day on which it will be marked, and the identity of the marking team.

4.4 Aspects

Each Aspect defines, in detail, a single item to be assessed and marked, together with the marks, and detailed descriptors or instructions as a guide to marking. Each Aspect is assessed either by Measurement or by Judgement.

The marking form lists, in detail, every Aspect to be marked together with the mark allocated to it. The sum of the marks allocated to each Aspect must fall within the range of marks specified for that section of the Standards. This will be displayed in the Mark Allocation Table of the CIS, in the following format, when the Marking Scheme is reviewed from C-8 weeks. (Section 4.1 refers.)

		CRITERIA								TOTAL MARKS PER SECTION	WSSS MARKS PER SECTION	VARIANCE
STANDARDS SPECIFICATION SECTION		A	B	C	D	E	F	G	H			
	1	5.00								5.00	5.00	0.00
	2		2.00					7.50		9.50	10.00	0.50
	3								11.00	11.00	10.00	1.00
	4			5.00						5.00	5.00	0.00
	5				10.00	10.00	10.00			30.00	30.00	0.00
	6		8.00	5.00				2.50	9.00	24.50	25.00	0.50
	7			10.00				5.00		15.00	15.00	0.00
TOTAL MARKS		5.00	10.00	20.00	10.00	10.00	10.00	15.00	20.00	100.00	100.00	2.00

4.5 Assessment and marking

There is to be one marking team for each Sub Criterion, whether it is assessed and marked by Judgement, Measurement, or both. The same marking team must assess and mark all Competitors. Where this is impracticable (for example where an action must be done by every Competitor simultaneously, and must be observed doing so), a second tier of assessment and marking will be put in place, with the approval of the Competitions Committee Management Team. The marking teams must be organized to ensure that there is no compatriot marking in any circumstances. (Section 4.6 refers.)

4.6 Assessment and marking using Judgement

Judgement uses a scale of 0-3. To apply the scale with rigour and consistency, Judgement must be conducted using:

- benchmarks (criteria) for detailed guidance for each Aspect (in words, images, artefacts, or separate guidance notes). This is documented in the Standards and Assessment Guide.
- the 0-3 scale to indicate:
  - 0: performance below industry standard
  - 1: performance meets industry standard
  - 2: performance meets and, in specific respects, exceeds industry standard
  - 3: performance wholly exceeds industry standard and is judged as excellent

Three Experts will judge each Aspect, normally simultaneously, and record their scores. A fourth Expert coordinates and supervises the scoring, and checks their validity. They also act as a judge when required to prevent compatriot marking.

4.7 Assessment and marking using Measurement

Normally three Experts will be used to assess each Aspect, with a fourth Expert supervising. In some circumstances the team may organize itself as two pairs, for dual marking. Unless otherwise stated, only the maximum mark or zero will be awarded. Where they are used, the benchmarks for awarding partial marks will be clearly defined within the Aspect. To avoid errors in calculation or transmission, the CIS provides a large number of automated calculation options, the use of which is mandated.

4.8 The use of Measurement and Judgement

Decisions regarding the choice of criteria and assessment methods will be made during the design of the competition through the Marking Scheme and Test Project.

4.9 Skill assessment strategy and procedures

WorldSkills is committed to continuous improvement including reviewing past limitations and building on good practice. The following skill assessment strategy and procedures for this skill competition take this into account and explain how the marking process will be managed.

The Marking Scheme developed by the Independent Test Project Designer will comprise Aspects with clear calculations and/or added detail.

The following is an example of the aspects.

Assessment
3D scanning and measurement • Equipment's adjustment and calibration; • Objects preparation; • Conformity of structure/texture of surfaces of the digitized model to the original part (here are not any ripples as well as over smoothing); • The absence of defects and mistakes in stitching (there are not any duplications, shifts, offsets, skews of surfaces of the polygonal model); • Data sufficiency for the geometry restoration (the data must allow determining the shape and mutual placement of all surfaces);

Assessment
• Equipment's choosing and using • Accuracy of measurements and calculations
Optimization and component design • Selection of the right optimization method • Determination of the correct input variables and boundary conditions • Achievement of the optimization goals • Quality of the achieved rework with regard to the input variables • Compliance with the valid design rules for the intended additive process • Degree of utilization of the potential of additive manufacturing
Transfer-to-CAD • Properness of alignment of a polygonal model; • Conformity of the restored parametric model to scanning data (polygonal model) or/and TP requirements; • Whether the restored model has all the necessary elements; • Whether the accuracy of the restored model according to task; • The restored parametric model has no redundant edges and artefacts; • Whether the restored model was redesigned or optimized according to task;
Preparation and forming • Equipment's adjustment and calibration; • Model preparation; • Material preparation; • Build providing;
Post-processing • Part removing • Part cleaning and post-processing • Cleaning of equipment and tools

There shall be a clear understanding that ONLY the finished result (the 3D model(s), printed part (s), electronic document, cleaned up working place) or a well-established fact (violation of the rules) is evaluated. Not the process.

The marking of the Test-Projects will take place daily.

After the Competitors finished a module, the Test Projects are collected, and the Chief Expert will permanently mark the collected Test Projects with a secret number. From now on nobody in the assessment teams will have any reference of the “secret number” to any of the Competitors.

The Chief Expert will divide the Experts into teams of three and assign the teams to specific criterion to evaluate. Having three Experts in an assessment team (EACH Expert must measure the aspect) shall ensure that no errors are made in assessment.

Besides the Expert teams there will also be selected criterion which is inspected by measurement machines and an independent technician of the sponsor of such machines. For these criteria a minimum of one Expert must witness the process of each assessment.

5 The Test Project

5.1 General notes

Sections 3 and 4 govern the development of the Test Project. These notes are supplementary.

Whether it is a single entity, or a series of stand-alone or connected modules, the Test Project will enable the assessment of the applied knowledge, skills, and behaviours set out in each section of the WSOS.

The purpose of the Test Project is to provide full, balanced, and authentic opportunities for assessment and marking across the Standards, in conjunction with the Marking Scheme. The relationship between the Test Project, Marking Scheme, and Standards will be a key indicator of quality, as will be its relationship with actual work performance.

The Test Project will not cover areas outside the Standards or affect the balance of marks within the Standards other than in the circumstances indicated by Section 2. This Technical Description will note any issues that affect the Test Project's capacity to support the full range of assessment relative to the Standards. Section 2.1 refers.

The Test Project will enable knowledge and understanding to be assessed solely through their applications within practical work. The Test Project will not assess knowledge of WorldSkills rules and regulations.

Most Test Projects and Marking Schemes are now designed and developed independently of the Experts. They are designed and developed either by the Skill Competition Manager, or an Independent Test Project Designer, normally from C-12 months. They are subject to independent review, verification, and validation. (Section 4.1 refers.)

The information provided below will be subject to what is known at the time of completing this Technical Description, and the requirement for confidentiality.

Please refer to the current version of the Competition Rules for further details.

5.2 Format/structure of the Test Project

The Test Project is a series of standalone modules.

5.3 Test Project design requirements

Test Projects should reflect the purposes, structures, processes, and outcomes of the occupational role they are based on. They should aim to be a small-scale version of that role. Before focusing on practicalities, SMTs should show how the Test Project design will provide full, balanced, and authentic opportunities for assessment and marking across the Standards, as set out in Section 5.1.

The Test Project may consist of the following modules:

1. Component digitization
2. Component optimization
3. Transfer-to-CAD and redesign
4. Component design, print preparation, implementation, and rework for metal SLM printing
5. Component design, print preparation, implementation, and rework for plastic FDM or MJF printing

6. Component design, print preparation, implementation, and rework for plastic DLP or SLA printing
7. Typical modules may include:
8. 3D scanning for various objects with:
   - Different materials;
   - Different surface characteristics;
   - Different geometrical complexity;
9. Restore missing data of the elements of objects to be redesigned, from available data:
   - Of polygonal models (for example, the gear wheel has only one preserved tooth, the worm has only one turn, or there is only one-third of the flange);
   - Taken from connected parts;
   - Taken from existing objects by manual measuring (for example, the depth of a blind hole;
10. Change the geometry of created models according to task
11. DLP/SLA, FDM/FFF, and SLM 3D printing

5.4 Test Project coordination and development

The Test Project MUST be submitted using the templates provided by WorldSkills International (www.worldskills.org/expertcentre). Use the Word template for text documents and DWG template for drawings.

5.4.1 Test Project coordination (preparation for Competition)

Coordination of the Test Project/modules will be undertaken by the Skill Competition Manager.

5.4.2 Who develops the Test Project/modules

The Test Project/modules are developed by an Independent Test Project Designer (ITPD) in collaboration with the Skill Competition Manager.

5.4.3 When is the Test Project developed

The Test Project/modules are developed according to the following timeline:

Time	Action
Ten (10) months prior to the Competition	The ITPD is identified and a Confidentiality Agreement between WSI and the ITPD is organized.
Five (5) months prior to the Competition	The Independent Test Project Designer starts to develop TP in accordance with this Technical Description and the Infrastructure List.
No later than one (1) month prior to the Competition	The Independent Test Project Designer completes the design of the Test Project and Marking Scheme. The Test Project documents are sent to the WorldSkills International Skills Competitions Administration Manager.
At the Competition on C-2	The Test Project/modules are presented to Experts and Competitors

5.5 Test Project initial review and verification

The purpose of a Test Project is to create a challenge for Competitors which authentically represents working life for an outstanding practitioner in an identified occupation. By doing this, the Test Project will apply the Marking Scheme and fully represent the WSOS. In this way it is unique in its context, purpose, activities, and expectations.

To support Test Project design and development, a rigorous quality assurance and design process is in place (Competition Rules sections 10.6-10.7 refer.) Once approved by WorldSkills, the Independent Test Project Designer (ITPD) is expected to identify one or more independent expert(s), and trusted individuals initially to review the Independent Test Project Designer's ideas and plans, and subsequently to verify the Test Project, prior to validation.

A Skill Advisor will ensure and coordinate this arrangement, to guarantee the timeliness and thoroughness of both initial review, and verification, based on the risk analysis that underpins Section 10.7 of the Competition Rules.

5.6 Test Project validation

The Skill Competition Manager coordinates the validation of the Test Project/modules and will ensure that it can be completed within the material, equipment, knowledge, and time constraints of Competitors.

5.7 Test Project circulation

The Test Project/modules are not circulated prior to the Competition. The Test Project/modules are presented to Experts and Competitors on C-2

Interpreters receive the documents, computers, and digital versions of the translation(s) on C-2. All documents, computers, and digital versions used for translation remain with the Skill Competition Manager.

5.8 Test Project change

Due to the Test Project being developed by an Independent Test Project Designer (ITPD), there is no change required to be made to the Test Project/modules at the Competition. Exceptions are amendments to technical errors in the Test Project documents and according to infrastructure limitations.

5.9 Material or manufacturer specifications

Specific material and/or manufacturer specifications required to allow the Competitor to complete the Test Project will be supplied by the Competition Organizer and are available from www.worldskills.org/infrastructure located in the Expert Centre. However, note that in some cases details of specific materials and/or manufacturer specifications may remain secret and will not be released prior to the Competition. These items may include those for fault finding modules or modules not circulated.

Free training on machine and software, where possible, must be provided at least four (4) months prior to the Competition. Travel, lodging, and food expenses for this training are to be carried by the Competitors or their sponsor. The scheduling of the training is to be done by the Competition Organizer. The Competitors are notified about the training at least six (6) months prior to the

Competition. Participating in the provided training is the choice of the Competitors and/or their sponsor.

Sponsors of additive machines and 3D printers, materials for 3D printing, 3D scanners, inspection equipment, and scan-to-CAD, CAD, CAE and build processing software must supply specialists and service staff in adequate numbers to ensure that the competition runs smoothly. These specialists should be available at any time prior to and during the competition, as well as during the marking of the Test Projects.

6 Skill management and communication

6.1 Discussion Forum

Prior to the Competition, all discussion, communication, collaboration, and decision making regarding the skill competition must take place on the WorldSkills skill-specific Discussion Forum. (http://forums.worldskills.org). Skill related decisions and communication are only valid if they take place on the WorldSkills Discussion Forum. The Chief Expert (or an Expert Lead appointed by the Skill Management Team) will be the moderator for this Discussion Forum. Refer to the Competition Rules for the timeline of communication and competition development requirements.

6.2 Competitor information

All information for registered Competitors is available from the Competitor Centre (www.worldskills.org/competitorcentre).

This information includes:

- Competition Rules
- Technical Descriptions
- Mark Summary Form (where applicable)
- Test Projects (where applicable)
- Infrastructure List
- WorldSkills Health, Safety, and Environment Policy and Regulations
- Other Competition-related information

6.3 Test Projects and Marking Schemes

Circulated Test Projects will be available from www.worldskills.org/testprojects and the Competitor Centre (www.worldskills.org/competitorcentre).

6.4 Day-to-day management

The day-to-day management of the skill competition during the Competition is defined in the Skill Management Plan that is created by the Skill Management Team. The Skill Management Team comprises the Skill Competition Manager, Chief Expert, and the Expert Leads. The Skill Management Plan is progressively developed in the six (6) months prior to the Competition and finalized at the Competition. The Skill Management Plan can be viewed in the Expert Centre (www.worldskills.org/expertcentre).

6.5 General best practice procedures

General best practice procedures clearly delineate the difference between what is a best practice procedure and skill-specific rules (section 9). General best practice procedures are those where Experts and Competitors CANNOT be held accountable as a breach to the Competition Rules or skill-specific rules which would have a penalty applied as part of the Issue and Dispute Resolution procedure including the Code of Ethics and Conduct Penalty System. In some cases, general best practice procedures for Competitors may be reflected in the Marking Scheme.

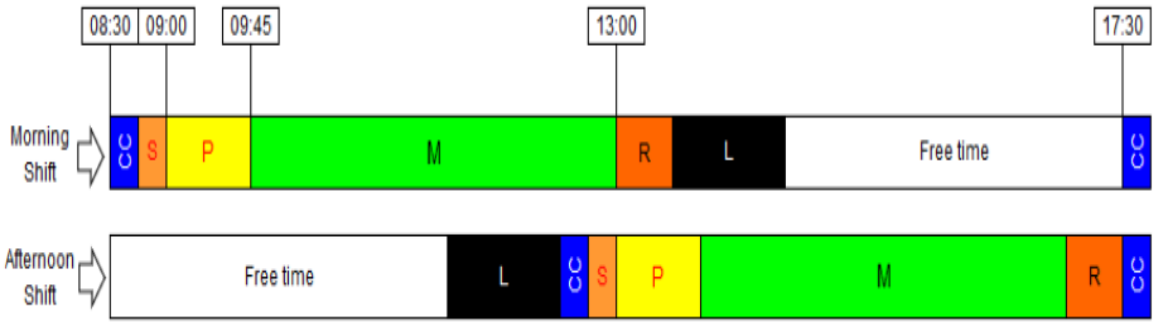
Topic/task	Best practice procedure
Equipment failure	• If equipment or tools which are brought by the Competitor fail, no extra time is allowed. • If equipment or tools supplied by the Competition Organizer fail extra time may be allowed only if the technician of the sponsor or supplying company specifies and proves it is not a “user error”, but truly an equipment failure without the fault of the user, e.g. power outage … this is in most cases is NOT the fault of the user.
Marking teams	• The Skill Management Team defines a sufficient amount of marking teams based on WorldSkills experience and mixture of cultures. Each group has a team leader assigned by the Skill Competition Manager and the Chief Expert and rotates their duties in the course of the different modules.
Time keeping	• A time keeping is provided for questions and interruptions in the ongoing competition. The start and end time of the interruption will be recorded. Following the interruption, Skill Competition Manager and the Chief Expert decide whether a make-up time will be granted. This can only be granted in case of an actual error in the Test Project/modules or in case of technical or health problems.
Release of Test Project	**Step 1** At C-3, the text of the Test Project is presented to Experts. Questions and ambiguities are clarified. The Interpreters are given time to translate the texts. The whole Test Project is NOT shown at this point! **Step 2** At each Competition Day, 15 minutes before the start the module, Competitors get the Test Project of this module (drawings, schemes, and files). After reading there is time for the Competitors to ask questions to the Skill Competition Manager or Independent Test Project Designer. **Step 3** Now the designated Marking Teams review the Test Project and their marking tasks assigned to them. **Step 4** SCM shares the TP with the entire group of Experts after the marking is finished.

In general, one module covers the tasks for a complete Competition Day (or a shift) and shall not be interrupted with work from other modules.

For example, the floor-space and/or the SLM machine requirements are so intensive, that it is impossible to get a working situation where Competitors have a SLM machine totally at their disposal.

Therefore, the shift rotation basis will apply, meaning Competitors have to share the SLM machine in a shift rotation (morning shift/afternoon shift). This reflects common industry situations.

Sequences example:



It is important to have the reset-time between shift changes. During this reset-time the control-unit is cleared, machine parameters are reset to original stage, and tools and tool holders are taken out. The machine is cleaned by the Competitor and made ready for the next shift to start their Test Project.

The sequence of a module is (example morning shift):

1: 8:30 Compatriot Communication (without Test Project)

Includes explanation of expectations with Independent Test Project Designer (Experts and Interpreters present)

2: 8:45 Competitors receive drawings and materials (including data transfer equipment e.g.

memory stick) and have 15 minutes for planning their work (without any other person except the Independent Test Project Designer for clarification).

3: 9:00 Buzzer will indicate the beginning of the preparation time.

Competitor can use the provided computer for slicing and build preparation for the SLM printing, no action at the machine is allowed.

4: 9:45 Buzzer will indicate beginning of the machining time.

At this point the Competitor is allowed to use both, the computer and the SLM machine.

5: 13:00 Buzzer will indicate the finishing of the module.

The reason that during the programming time (Slicing and build processing, indicated above in yellow) the Competitor is only allowed to use the computer and not the machine, is the shift rotation system. (equal situation for both shifts).

7 Skill-specific safety requirements

7.1 Personal Protective Equipment

Refer to WorldSkills Health, Safety, and Environment Policy and Regulations for Host country or region regulations.

Task	Safety glasses with side protection	Laboratory gloves (nitrile)	Laboratory coat (knee-length)	Heat proof gloves	Sturdy Shoes with closed toe and heel protective cap
General PPE for safe areas					√
During working time in the workshop	√				√
Working with machines and tool over 85 dB	√				√
Working with FFF/ FDM during build process	√			√	√
Operating SLM machine					√
During SLM metal powder changing		√	√		√
Operating DLP/SLA machine		√	√		√
	√				√

Task	Safety glasses with side protection	Laboratory gloves (nitrile)	Laboratory coat (knee-length)	Heat proof gloves	Sturdy Shoes with closed toe and heel protective cap
Working with pressure					

Task	Hearing protection	Full fasce protection mask	Hat or cap	Tight fitting clothes (long sleeves, no open ankles)
General PPE for safe areas				
During working time in the workshop				√
Working with machines and tool over 85 dB	√			√
Working with FFF/ FDM during build process				√
Operating SLM machine				√
During SLM metal powder changing		√	√	√
Operating DLP/ SLA machine		√	√	√
Working with pressure				√

8 Materials and equipment

8.1 Infrastructure List

The Infrastructure List details all equipment, materials, and facilities provided by the Competition Organizer.

The Infrastructure List is available at www.worldskills.org/infrastructure.

The Infrastructure List specifies the items and quantities requested by the Skill Management Team for the next Competition. The Competition Organizer will progressively update the Infrastructure List specifying the actual quantity, type, brand, and model of the items. Note that in some cases details of specific materials and/or manufacturer specifications may remain secret and will not be released prior to the Competition. These items may include those for fault finding modules or modules not circulated.

At each Competition, the Skill Management Team must review and update the Infrastructure List in preparation for the next Competition. The Skill Competition Manager must advise the Director of Skills Competitions of any increases in space and/or equipment.

At each Competition, the Technical Observer must audit the Infrastructure List that was used at that Competition for the upcoming WorldSkills Competition.

The Infrastructure List does not include items that Competitors and/or Experts are required to bring and items that Competitors are not allowed to bring – they are specified below.

8.2 Competitors toolbox

Competitors are not allowed to send a toolbox to the Competition. All tools are provided by the Competition Organizer.

8.3 Materials, equipment, and tools supplied by Competitors

It is not applicable for Competitors to bring materials, equipment, and tools to the Competition. However, Competitors are allowed to bring their own keyboards and mouse in the morning of C-2 on Familiarization Day. It is recommended that these be brought in the luggage of the Competitor.

Furthermore, Competitors are required to supply their own Personal Protective Equipment as specified in section 7 skill-specific safety requirements.

8.4 Materials, equipment, and tools supplied by Experts

Experts are required to supply their own Personal Protective Equipment as specified in section 7 skill-specific safety requirements.

Experts are responsible that Interpreters bring their PPE.

8.5 Materials and equipment prohibited in the skill area

Competitors and Experts are prohibited to bring any materials or equipment not listed in section 8.3 and section 8.4.

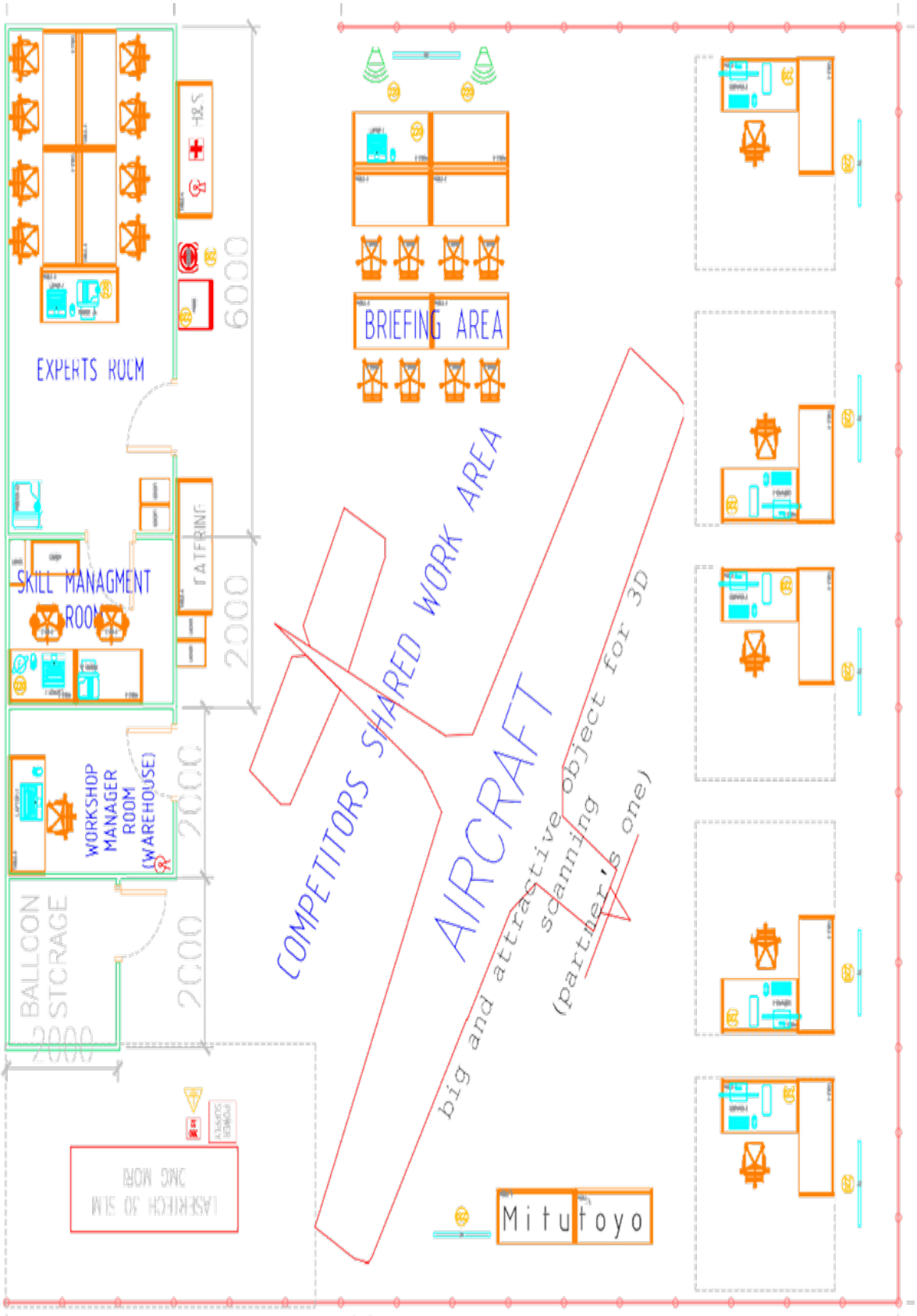
Competitors and Experts are prohibited to bring any materials or equipment not listed in section 8.3 and section 8.4.

3D space mouse is not permitted.

8.6 Proposed workshop and workstation layouts

Workshop layouts from previous competitions are available at www.worldskills.org/sitelayout.

Example workshop layout



The workstations must be equipped with a concrete, non-vibrating floor. Suitable vibration damping elements must be taken for the printers.

9 Skill-specific rules

9.1 General notes

Skill-specific rules cannot contradict or take priority over the Competition Rules. They do provide specific details and clarity in areas that may vary from skill competition to skill competition. This includes but is not limited to personal IT equipment, data storage devices, Internet access, procedures and workflow, and documentation management and distribution. Breaches of these rules will be solved according to the Issue and Dispute Resolution procedure including the Code of Ethics and Conduct Penalty System.

9.2 Skill-specific rules

Topic/task	Best practice procedure
Use of technology – digital memory devices (such as memory stick, CD or DVD Rom, Bluetooth or Wi-Fi devices, media players etc.)	• Competitors are only allowed to use digital memory devices provided by the Competition Organizer. No other memory devices are to be inserted into or connected with the Competitor computers or machines. • All provided digital memory devices are to be submitted to the Skill Competition Manager or Chief Expert at the end of each module (day) for safe keeping and must not be taken out of the workshop. • The Skill Competition Manager and Chief Expert, Competition Organizer IT team, and technicians from sponsors are allowed to insert their devices for checking or installation of software. • Headphones, wireless earbuds, or similar devices that would allow music, communication, or any other distraction are not allowed for the Competitors.
Use of technology – personal laptops, tablets and mobile phones	• Competitors are not allowed to bring personal laptops, tablets, or mobile phones into the workshop, including other communication devices such as smartwatches. In the event that Competitors do bring these to the competition they shall be locked in the personal locker and shall not be taken to the workstation. These can only be removed at the completion of the module for that day. This rule is valid for C-2 until the end of C4. • No Wi-Fi or Bluetooth is allowed at the workstations for Competitors • Skill Competition Manager, Chief Expert, Experts and Interpreters are allowed to use personal laptops, tablets, and mobile phones in assigned areas only from C-6 until C+1.
Use of technology – personal photo and video taking devices	• Skill Competition Manager, Chief Expert, Competitors, Experts, Workshop Managers, and Interpreters are allowed to use personal photo and video taking devices in the workshop. Restrictions may be set by the Skill Competition Manager and the Chief Expert in situations where sensitive information is in

Topic/task	Best practice procedure
	the area. Any photos or videos must be approved by the Skill Competition Manager and Chief Expert prior to taking. • This rule is valid for C-6 until C+1.

10 Visitor and media engagement

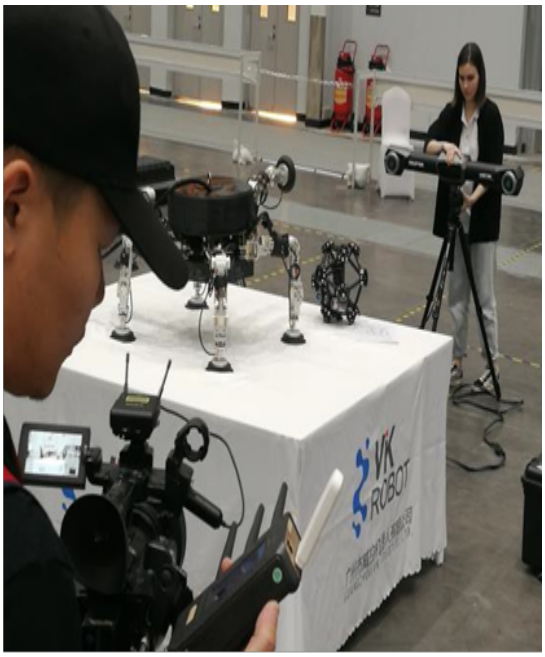
10.1 Engagement methods

Following is a list of possible ways to maximize visitor and media engagement:

Following is a list of possible ways to maximize visitor and media engagement.

From the very beginning, the Additive Manufacturing skill was developing as attractive exhibition product for media and visitors:

- 3D scanning gives bright pictures and attract photographers and videographers;
- Dynamic action - the digitized object immediately appears on the screen of the workstation
- The attractiveness of the object for scanning – an unusual car, a mysterious product, etc.;
- 3D printing is popular enough and seems rather clear. This attract because people like to feel that they able to understand complex processes.



11 Sustainability

11.1 Sustainable practices

This skill competition will focus on the sustainable practices below:

- Use of shift rotation system (i.e. shared workstations) to reduce floorspace.
- Recycling and waste management
- Smart management of Infrastructure List to safe resources
- Multiple use of offices to reduce needed floorspace (Expert-room is also Judgement Marking room, Competitor-room is also briefing room)
- Use of Team-Challenge outcome as present to the Competition Organizer of the competition.
- Better use of digital technology to reduce paper

12 References for industry consultation

12.1 General notes

WorldSkills is committed to ensuring that the WorldSkills Occupational Standards fully reflect the dynamism of internationally recognized best practice in industry and business. To do this WorldSkills approaches a number of organizations across the world that can offer feedback on the draft Description of the Associated Role and WorldSkills Occupational Standards on a two-yearly cycle.

In parallel to this, WSI consults three international occupational classifications and databases:

- ISCO-08: (http://www.ilo.org/public/english/bureau/stat/isco/isco08/)
- ESCO: (https://ec.europa.eu/esco/portal/home)
- O*NET OnLine (www.onetonline.org/)

12.2 References

Adjacent occupations may also be explored through these links.

ILO 3115

The following table indicates which organizations were approached and provided valuable feedback for the Description of the Associated Role and WorldSkills Occupational Standards in place for WorldSkills Lyon 2024.

Organization	Contact name
CESI	Jean-Daniel Penot, Head of R&D Deparment
Mavericks Holdings Pte Ltd	Benjamin Moey, Managing Director
Siemens	Martin Koczmann, Academic Programme Manager
Siemens Software France	Jonathan Frechard, Presales

13 Appendix

13.1 Appendix information

Not applicable.