

MANUFACTURING AND ENGINEERING TECHNOLOGY

# CNC Milling



## Technical Description

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:

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# 1 Introduction

## 1.1 Name and description of the skill competition

### 1.1.1 The name of the skill competition is

CNC Milling

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

Computer Numerical Control (CNC) technology has become omnipresent. Most people cannot imagine how important these technologies are in their lives. There is nothing that we use that hasn't in its manufacturing utilized CNC technology. It is present in products and objects of everyday life, such as cars, airplanes, components of machines of all types, moulds for tools used for household machines, medical prosthetics, cell phones, and toys.

CNC milling machines are machine tools used for the shaping of metal and other solid materials. These machines exist in two basic forms: horizontal and vertical. This refers to the orientation of the cutting tool spindle. Early milling machines were manually or mechanically automated, but technological advances have led to the development of Computer Numerical Control, such as the CNC machining centre. CNC refers to a computer-controlled device to read and store instructions. This numerical information, generally "G and M" codes (a programming language) is then used to control and drive a machine tool which is a powered mechanical device ("machining centre"). A machining centre is used to fabricate components using cutting tools for removing the material.

To form the finished part, the cutting process can be started from a solid block, pre-machined part, casting, or forgings. For those scenarios, the skill requires the highly skilled CNC milling machinist must read and interpret complex technical drawings and specifications, and work to a high degree of precision and detail. They must be proficient in metal work and understand how metals react to various processes. They must be a skilled computer operator and machine operator. The programs can be generated manually or using Computer Aided Design/Computer Aided Manufacture (CAD/CAM) software.

To achieve the finished part, the CNC milling machinist undertakes a sequence of essential activities, from interpreting engineering drawings to optimizing the machining process:

- Interpreting engineering drawings and following the specifications
- Generating the processes and programs with the CAD/CAM system and/or G and M-codes
- Setting up the tools, work holding devices, and work pieces on the CNC milling centre
- Manipulating cutting conditions, based on the properties of the material and tools
- Operating, inspecting, and maintaining the accuracy of dimensions within the specified tolerances
- Optimizing the process, taking into account the production type: whether large quantities of one part, small batches, or one-of-a-kind items.

Today a wide range of industries require CNC milling machinists to program, operate, and keep sophisticated machining centre's running in an efficient and reliable way. Large enterprises such as automobile plants, medium sized enterprises such as mould making, and small enterprises in the maintenance field, are some of many environments in which the CNC milling machinist plays a key, integral role to the success of the metalwork industries.

### 1.1.3 Number of Competitors per team

CNC Milling is a single Competitor skill competition.

### 1.1.4 Age limit of Competitors

The Competitors must not be older than 22 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.

## 2 The WorldSkills Occupational Standards (WSOS)

### 2.1 General notes on the WSOS

The WSOS specifies the knowledge, understanding, and specific skills that underpin international best practice in technical and vocational performance. It 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](http://www.worldskills.org/WSOS)).

The skill competition is intended to reflect international best practice as described by the WSOS, and to the extent that it is able to. 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 that are set out in the Standards Specification. 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, provided that this does not distort the weightings assigned by the Standards.

## 2.2 WorldSkills Occupational Standards

Section	Relative importance (%)
<b>1 Work organization and management</b>	<b>10</b>

The individual needs to know and understand:

- The extent and impact of CNC-milling on modern life and industry
- Quality standards for materials and quality of metals
- Standards for the environment, safety, hygiene, and prevention of accidents at work
- Computer operating systems
- Mathematics, especially accurate and detailed calculations, and trigonometry
- Properties of materials, especially steel and aluminium
- Principles of technical design and process planning
- CNC equipment technology (Vertical and Horizontal Machining Centre)
- Programming by hand or CAM system software
- Cutting technology according to the parameters, material, equipment and cutting tools
- Health and safety regulations, legislation, and best practice
- The importance of adhering to manufacturers' operating instructions
- Ways to ensure the maintenance of sophisticated milling machines to promote efficient and reliable working
- The importance of effective communications and teamwork
- The importance of effective working methods with other professionals related to the CNC milling process

The individual shall be able to:

- Use computer related professional software
- Interpret and apply quality standards and regulations
- Promote and apply health and safety regulations and best practice
- Use IT and related professional software
- Apply mathematical and geometrical principles accurately for the preparation and programming processes for CNC milling
- Develop creative solutions to complex design or technology challenges

<b>2 Interpret engineering drawings and follow the specification</b>	<b>10</b>
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The individual needs to know and understand:

- ISO 1 and/or ISO 3 (European and American) drawing representation
- Technical terms and symbols used in drawings and plans
- Standards, standards symbol, and tables
- Technical drawing legends

Section	Relative importance (%)
<p>The individual shall be able to:</p> <ul style="list-style-type: none"> <li>• Interpret and apply engineering drawings and follow specifications</li> <li>• Locate and identify main dimensions and secondary dimensions</li> <li>• Locate and identify ISO standards for surface finishes</li> <li>• Locate and identify ISO standards for geometrical form and positional tolerances</li> <li>• Locate and identify ISO standards for geometrical form and positional tolerances</li> </ul>	
<p><b>3 Process planning</b></p> <p>The individual needs to know and understand:</p> <ul style="list-style-type: none"> <li>• The importance of good planning for the successful execution of programming and operation/machining</li> <li>• How to plan, based on the type of operation and the sequence (machining strategy) of the data that must be specified</li> <li>• Types of machining tools used in CNC technology including lathes, multi-axis spindles, wire electrical discharge machines, and milling machines</li> <li>• Methods of work holding according to the shape of the base material</li> </ul>	15
<p>The individual shall be able to:</p> <ul style="list-style-type: none"> <li>• Identify and set the different machining features</li> <li>• Identify the most efficient work holding solution to clamp the base material into the machine</li> <li>• Select the right cutting tools for machining</li> <li>• Define the cutting parameters as a function of the operation sequence, material type, and type of operation</li> </ul>	
<p><b>4 Programming</b></p> <p>The individual needs to know and understand:</p> <ul style="list-style-type: none"> <li>• Programming as the creation of a logical process plan</li> <li>• Different methods and techniques to generate the programs (CAM/CAD or manual)</li> <li>• CAM system programming</li> <li>• Skill related software</li> </ul>	20
<p>The individual shall be able to:</p> <ul style="list-style-type: none"> <li>• Select the best methods according to the production type and part specification</li> <li>• Use skill specific software and related hardware</li> <li>• Generate programs by using the CAD/CAM system with the format of the initial data</li> <li>• Start with drawings in paper format to create the geometry in wireframe and/or surface and/or solid</li> </ul>	

Section	Relative importance (%)
<b>5 Metrology</b>	<b>10</b>

The individual needs to know and understand:

- The ranges of tools and gauging instruments and their applications
- Main measuring techniques

The individual shall be able to:

- Select and use appropriate measuring tools and instruments
- Make measurements on threaded elements

<b>6 Operating</b>	<b>15</b>
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The individual needs to know and understand:

- The different steps that lead to setup machines
- The different modes of machine operation

The individual shall be able to:

- Prepare measurements and cutting tools
- Identify and design the functional parameters for operation on the CNC milling machine

<b>7 Machining</b>	<b>20</b>
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The individual needs to know and understand:

- The different types of machine features
- The machining sequence

Section	Relative importance (%)
<p>The individual shall be able to:</p> <ul style="list-style-type: none"> <li>• Identify and designate the different machining processes on a CNC milling machine</li> <li>• Optimize the machining strategy</li> <li>• Define and adjust the cutting parameters as a function of the operation sequence, material type, type of operation, and CNC machine tool</li> <li>• Start the cutting process from the raw material</li> <li>• Solid block</li> <li>• Perform the following machining operations:               <ul style="list-style-type: none"> <li>• Facing</li> <li>• Roughing and finishing                   <ul style="list-style-type: none"> <li>• External contours</li> <li>• Island milling</li> <li>• Milling channels</li> <li>• Pocket (figurative)</li> <li>• Pocket (circular and rectangular)</li> <li>• Taper ribs</li> </ul> </li> <li>• Thread milling                   <ul style="list-style-type: none"> <li>• Internal</li> <li>• External</li> </ul> </li> <li>• Canned cycles                   <ul style="list-style-type: none"> <li>• Through hole boring</li> <li>• Blind hole boring</li> <li>• Reaming</li> <li>• Tapping</li> <li>• Drilling</li> </ul> </li> <li>• 3D machining operations                   <ul style="list-style-type: none"> <li>• Roughing</li> <li>• Finishing</li> </ul> </li> </ul> </li> <li>• Tapping</li> <li>• Drilling</li> <li>• 3D machining operations</li> <li>• Roughing</li> <li>• Finishing</li> </ul>	
<b>Total</b>	<b>100</b>

## 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, in order 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 people 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 Rules for further details.

Experts and Independent Assessors 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	
	A	B	C	D	E	F	G	H				
STANDARDS SPECIFICATION SECTION												
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)
- 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

WorldSkills is committed to continuous improvement. This particularly applies to assessment. The SMT is expected to learn from past and alternative practice and build on the validity and quality of assessment and marking.

### A – Main dimensions

Dimensions range from 0.02 to 0.04; Reamed bores: IT7; Hollow out bores: IT7; inside thread and outside thread: IT6, Tolerances according- ISO standards 286-2 (table provided to Competitors)

Form and positional tolerances as per DIN ISO 1101

### B – Secondary dimensions

Dimensions with general tolerance should be +/-0.04 oriented of the nominal size; e.g. 73.8 mm should be in between 73.76 mm and 73.84 mm.

Depth of hole and thread: 0/+2 mm; e.g. Depth size 16 should be 16.00 mm to 18.00 mm

Depth of bore: 0/+0.5 mm; e.g. Depth size 22 should be 22.00 to 22.50 mm

Radius: +/- 0.2; e.g. R12 should be R11.8 mm to 12.2 mm

Angle: +/-0.5°; e.g. 30° should be 29.5° to 30.5°

### C – Surface quality

Surface quality = Ra 0.8 to 3.2

## D – Judgement

Judgement aspects are described in Standards and Assessment Guide. In this guideline the Independent Test Project Developer can choose 11 aspects depending of the modules. The total mark for Judgement is 10 marks. As per module minimum amount of aspects must be 6. As per module maximum aspects can be 9.

Standards and Assessment Guide is to be provided.

## 4.10 Skill assessment procedures

Assessment and marking are an intense process that depends upon skilful leadership, management, and scrutiny.

The definitive Judgement and Measurement Marking Forms are finalized by the Independent Test Project Designer.

Makeup of the marking groups and use of data;

Measurement Marking - A, B, C, and E;

Coordinate measuring machine – CMM, measurement marking - A and B;

Judgement Marking - D

Three Experts for the evaluation

One spare Expert and minute keeping

For Judgement Marking the Experts are divided into three working groups.

Formation of Expert groups: The groups shall be nominated by the Chief Expert and the Deputy Chief Expert. The group must be a mix of experienced senior Experts and Experts who are new in their functions.

Each group is responsible for the complete assessment of one module realized by all Competitors.

CMM teamwork in the workshop; Experts can supervise their work.

A-Main dimensions +/- 0.003 mm tolerance compensation

### Assessment/Marking

Three Experts shall be assigned to assess each aspect of Judgement, whether or not attempted. Each Expert shall award a score between 0 and 3 displayed on flash cards based on the given benchmarks. To do this correctly, each Expert shall first assess the work by himself by comparing the Competitor's performance with these benchmarks and prepare the flashcard hidden. After, they display their scores at the same time as directed by the assessment team leader who is appointed by the Chief Expert.

## 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 Developer, 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 three (3) standalone modules.

## 5.3 Test Project design requirements

Details of module one MILLING		
<b>Initial Data</b>	<ul style="list-style-type: none"> <li>Material: Aluminium AIMG1SICU (6061-T6) HB90</li> <li>Maximum raw size: 150 mm x 100 mm x 50mm</li> <li>The minimum size for a finished part is not smaller than 50 mm x 50 mm x 30 mm</li> <li>Time Allowed: 4.15 hr</li> <li>2D finished drawing with a 3D shaded view (paper) or 3D step model (CAD) with 2D finished drawing (paper).</li> <li>Work on two or three faces.</li> </ul>	
<b>Machining Process:</b>	<b>The following features must be included:</b> Milling Channels, figurative pocket, external contour, through hole boring, internal or external thread milling	<b>The following features may be Included (optional):</b> circular pocket, rectangular pocket, Drilling, Reaming, and Tapping
<b>Additional Information</b>	<ul style="list-style-type: none"> <li>The total of aspects for criterion A- Main dimensions must be between 20 minimum - 23 maximum;</li> <li>The total of aspects for criterion B - Secondary dimensions must be between 17 minimum – 20 maximum (the remaining dimensions are assessed in criterion D - conformity to drawing).</li> <li>The total aspects for criterion C- Surface quality must be between 5 minimum – 8 maximum (must be possible to check all aspect with surface roughness tester similar to Mitutoyo - 178-954-3A)</li> </ul>	
<b>Tasks schedule</b>	<b>Part Programming and Machining 4 hours 15 minutes</b>	
	<b>Par CAM Activity Tool Preparation Machining</b> Competitors can access both CAM and CNC machine at all times during the complete module.	

Details of module two MILLING	
<b>Initial Data</b>	<ul style="list-style-type: none"> <li>Material: Steel C45E 1.1191</li> <li>Maximum raw size: 150 mm x 100 mm x 50 mm or</li> <li>2 off maximum raw size: 100 mm x 50 mm x 50 mm</li> <li>The minimum size for a finished part is not smaller than 50 mm x 40 mm x 30 mm</li> <li>Time Allowed: 6.15 hr</li> <li>2D finished drawing with a 3D shaded view (paper) or 3D step model (CAD) with 2D finished drawing (paper).</li> <li>Work on three faces</li> </ul>

Details of module two MILLING		
	<ul style="list-style-type: none"> <li>• Possible customer design.</li> <li>• Possible two components with mating features.</li> <li>• Possible production run.</li> </ul>	
<b>Machining Process</b>	<b>The following features must be included:</b> Milling channels, figurative pocket, external contour, through hole boring, nose, circular pocket, internal thread milling (M30 x 1.5), reaming	<b>The following features may be Included (optional):</b> Rectangular pocket, drilling sample, island milling, tapping
<b>Additional Information</b>	<ul style="list-style-type: none"> <li>• The total of aspects for criterion A- Main dimensions must be between 25 minimum - 28 maximum</li> <li>• The total of aspects for criterion B- Secondary dimensions must be between 20 minimum - 23 maximum (the remain dimensions are assessed in criterion D - conformity to drawing)</li> <li>• The total aspects for criterion C- Surface quality must be between 5 minimum – 8 maximum (must be possible to check all aspect with surface roughness tester similar to Mitutoyo - 178-954-3A)</li> </ul>	
<b>Tasks schedule</b>	<b>Part Programming</b>	<b>Machining</b>
	CAM Activity (2.30 hr)	Tool Preparation (15 min)
		Machining (3.30 hr)

Details of module three MILLING		
<b>Initial Data</b>	<ul style="list-style-type: none"> <li>• Material: Steel C45E 1.1191</li> <li>• Maximum raw size: 150 mm x 100 mm x 50 mm</li> <li>• The minimum size for a finished part is not smaller than 50 mm x 50 mm x 30 mm</li> <li>• Time Allowed: 7.00 hr</li> <li>• 2D finished drawing with a 3D shaded view (paper) or 3D step model (CAD) with 2D finished drawing (paper).</li> <li>• Work on three or four faces</li> </ul>	
<b>Machining Operations:</b>	<b>The following features must be included:</b> Drilling, Blind hole boring, external contour, figurative pocket, island milling, external thread milling (M42 x 1.5), tapping, Ribs (**).	<b>The following features may be Included (optional):</b> Circular pocket, rectangular pocket, gudgeon

Details of module three MILLING		
<b>Additional Information</b>	<ul style="list-style-type: none"> <li>The total of aspects for criterion <u>A - Main dimensions</u> must be between 30 minimum – 33 maximum</li> <li>The total of aspects for criterion <u>B - Secondary dimensions</u> must be between 20 minimum - 23 maximum (the remain dimensions are assessed in criterion D - conformity to drawing)</li> <li>The total aspects for criterion <u>C - Surface quality</u> must be between 5 minimum – 8 maximum (must be possible to check all aspect with surface roughness tester similar to Mitutoyo - 178-954-3A)</li> </ul> (**) Rib feature: Thickness = 6 mm – 8 mm; one or two ribs maximum	
<b>Tasks schedule</b>	<b>Part Programming</b>	<b>Machining</b>
	CAM Activity (2 hr 45 min)	Tool Preparation (15 min)
		Machining (4 hr)

#### Additional details for the modules

- Of the three modules at least one module must use 2D finished drawing with a 3D shaded view (paper)
- Of the three modules at least one module must use 3D step model (CAD) with 2D finished drawing (paper)
- The following additional details must be included in the module: machine chamfers 0.2 mm to 0.3 mm x 45 degrees;
- Every module must have a minimum of four geometric dimensioning tolerances criteria;
- It must be possible to complete the modules with the machining tools detailed in this Technical Description;
- It must be possible to check the modules with the measuring equipment and checking devices described in this Technical Description;
- Measurements of work pieces is performed on a coordinate measuring machine (CMM);
- The Competition Organizer will nominate a technician who is responsible for operating the coordinate measuring machine;
- The depth of the drilled or reamed hole will not be measured. The depth of the thread milling and tapped holes must be measured;
- For M6 and M10, core hole diameter 5.0 mm, 8.5 mm and the depth will not be measured;
- Tenons are not allowed under the machine vice. The Competitor must align the vice themselves. Machine stops on the vice are allowed;
- The Competition Organizer will try and supply the raw material + 0.15 mm/- 0, machined all six faces;
- Competitors can use Mastercam during the machining and tool preparation time.

## Tolerances

The following tolerances apply to the Modules:

- Main dimensions: range from 0.02 mm to 0.04 mm, IT<sub>7</sub>≥7;
- Reamed bores IT7;
- Hollow out bores IT7;
- Surface quality N6 to N8/average = Ra 0.8 to 1.6;
- Depth of thread 0+2 mm;
- Form and positional tolerances as per DIN ISO 1101.

## Customer change

Customer changes should come with a new 2D drawing or 3D model, the following changes can be made after the elapsed time;

- Features can be changed to cut more material away, such as a bore diameter being increased, or a boss diameter being reduced.
- Additional features machined into the original design, such as a pocket or drilled hole.
- Features must be “added” to the design, such as an additional bore where there was none before.

## Mating features

Mating features are to be judged on the fit between the two components; this is an additional Judgement criterion.

There can also be measurement criteria for an overall length or dimension.

## Production Run

Competitors will have two billets, the first is used to test the programme to the drawing and check the component dimensionally. Once finished the Competitor will receive the second billet. On the second billet, each side must be produced with one program only and no stopping.

The time for each cycle is recorded. A maximum and minimum mark is awarded for fastest and slowest times. All other results are graded between.

## Tool Preparation Time (15 minutes)

- Competitors can set up tool holders;
  - Competitors can change tools; Competitors can measure tool using the
    - CNC machine without cutting the material.
- Competitors can continue to work on Mastercam;
- Competitors **cannot** set up the vice.

## Additional design requirements

The modules must meet the following requirements:

- Drawing ISO 1/E (First Angle Projection), Original Inventor model and Inventor drawing;
- Drawing ISO 3/A (Third Angle Projection), Original Inventor model and Inventor drawing;
- Drawing annotation to ISO 8015.
- A STEP file (3D surface model);
- Component model made from Aluminium (conform to drawing);
- Measurement report checked by hand so that the Competitors are able to check all assessed marks;
- Judgement and Measurement Marking Aspect descriptions should list both ISO 1/E and ISO 3/A dimensions, with ISO 3/A placed in brackets e.g. C6 (C4);
- The modules must be created with filename conventions (including filename extensions);
- Prior to the Competition, the modules must NOT be accessible to the Competitors;

(\* ) The version is determined six (6) months prior to the Competition

### Important Note:

The list of tools and instruments described in section 8.3 is the reference for the development of the Test Project proposal; this means that it is of utmost importance that all project modules are made in strict accordance with the list of tools described. None of the project proposals submitted by the Expert may use different cutting tools and diameters than those defined in the Technical Description.

## 5.4 Test Project development

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

### 5.4.1 Who develops the Test Project or modules

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

### 5.4.2 When is the Test Project developed

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

Time	Activity
Prior to the Competition	The Test project/modules are developed.
Three (3) months prior to the Competition	Independent Test Project Designer completes the design of the Test Project and Marking Scheme. The final files and photos of the prototype are emailed to the WorldSkills International Skills Competitions Administration Manager.
At the Competition on C-4	The Test Project/modules are presented to Experts.
At the Competition on C1	The Test Project/modules are presented to 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 is expected to identify one or more independent, expert, and trusted individuals initially to review the 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 and will ensure that the Test Project/modules can be completed within the material, equipment, knowledge, and time constraints of Competitors.

The Marking Scheme and Test Project is developed by the Independent Test Project Designer and should be checked by an independent third party. They should also supply a detailed CMM procedure report and programme. The CMM Programme is made by MiCAT Planner Software by Mitutoyo.

## 5.7 Test Project selection

The Test Project/modules are selected by the Independent Test Project Designer in collaboration with the Skill Competition Manager.

## 5.8 Test Project circulation

If applicable, the Test Project is circulated via the website as follows:

The Test Project/modules are not circulated prior to the Competition. The Test Project/modules are presented to Experts on C-4 and to Competitors on C1.

## 5.9 Test Project coordination (preparation for Competition)

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

## 5.10 Test Project change

There is no 30% 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 to infrastructure limitations.

## 5.11 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](http://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 such items may include those for fault finding modules or modules not circulated.

The Competition Organizer provides information on the following equipment as per the Competition Rules:

- The machines;
- The machine control systems;
- The tool holders (e.g. Sk40 DIN 69871, BT 40, HSK A63);
- Release bolts for the tool holders;
- Machine vice;
- CAM programming station, software version, PC keyboard;
- Machine control training software;
- Possibility of practicing operating the machines intended for the Competition.

## 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 skill specific Discussion Forum (<http://forums.worldskills.org>). Skill related decisions and communication are only valid if they take place on the forum. The Chief Expert (or an Expert nominated by the Chief Expert) will be the moderator for this Forum. Refer to 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](http://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](http://www.worldskills.org/testprojects) and the Competitor Centre ([www.worldskills.org/competitorcentre](http://www.worldskills.org/competitorcentre)).

### 6.4 Day-to-day management

The day-to-day management of the skill during the Competition is defined in the Skill Management Plan that is created by the Skill Management Team led by the Skill Competition Manager. The Skill Management Team comprises the Skill Competition Manager, Chief Expert, and Deputy Chief Expert. The Skill Management Plan is progressively developed in the six months prior to the Competition and finalized at the Competition by agreement of the Experts. The Skill Management Plan can be viewed in the Expert Centre ([www.worldskills.org/expertcentre](http://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
Release of Test Projects	<ul style="list-style-type: none"> <li>The Test Projects modules are released at C-4 with the SMT and the all Experts together and no one can take the notes in any way.</li> </ul>
The translation for the Test Projects	<ul style="list-style-type: none"> <li>The Expert or Interpreter is allocated 10 minutes per module for translation.</li> <li>A dictionary can be used.</li> </ul>
Attend to the Competitor	<ul style="list-style-type: none"> <li>If the Competitor has the problems during the competition, the interpreter can accompany the technician or SMT to solve their question. The compatriot Expert can attend only with permission from the SMT.</li> </ul>
Templates, aids, etc.	<ul style="list-style-type: none"> <li>The Competitor may bring one sheet (A4 size) with tool speeds and feeds for information only.</li> <li>Blank paper can be provided at the competition.</li> </ul>
Spy software	<ul style="list-style-type: none"> <li>Spyware may be used on the computers</li> </ul>
Tools/infrastructure	<ul style="list-style-type: none"> <li>Competitors must use the mouse and keyboard provided by the Competition Organizers.</li> <li>Tenons are not allowed underneath the machine vice, the Competitor must align the machine vice manually.</li> <li>Competitors are not allowed to bring their own linear height gauges. There are some supplied by the Competition Organizer which can be used during the competition.</li> <li>The machine parameters must not be changed.</li> <li>The post processor cannot be changed by the Competitor.</li> </ul>
Equipment failure	<ul style="list-style-type: none"> <li>When a Competitor has an issue, their work must be checked for the correct process before looking for machine or software failure.</li> <li>In the event of CNC machine failure, the Competitors are moved onto one of the spare CNC Machines</li> <li>In the event of a computer failure, the Competitors may use one of the spare computers</li> </ul>
Assessment	<ul style="list-style-type: none"> <li>The Competitors part is engraved with their Member ISO code, then it is covered and assigned a random number during assessment</li> </ul>

## 7 Skill-specific safety requirements

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

Task	Safety glasses with side protection	Cut protection gloves (without breakage)	Sturdy shoes with closed toe and heel	Safety shoes with protective cap	Tight fitting work clothes (long trousers)	Hearing protection
General PPE for safe areas			√			
Programming				√	√	
Machining	√			√	√	√ (optional)
Material Handling	√	√		√	√	√ (optional)
Material Deburring	√	√		√	√	√ (optional)
Using Compressed Air	√	√		√	√	√

## 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](http://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 such 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.

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 may bring one toolbox with the total external volume not exceeding 1.2 m<sup>3</sup>.

(Volume = Length x Height x Width, or  $V = L \times H \times W$ )

Volume measurement does not include a packing crate, other protective packing material, palette for transportation, wheels, etc.

### 8.3 Materials, equipment, and tools supplied by Competitors

The following items are allowed to be carried in the toolbox:

Item	Description	Dimensions	EXAMPLE PHOTO
1	NC Centre Drills 90°	Ø10.00	
2	Drills (DIN338/345)	Ø5.00, Ø8.50, Ø9.80, Ø10.00, Ø11.80, Ø20.00	
3	Machine Reamer	Ø10H7, Ø12H7	
4	Machine Tap (Blind Holes)	M6 x 1, M10 x 1.5	

Item	Description	Dimensions	EXAMPLE PHOTO
5	Machine Tap (Through Holes)	M6 x 1, M10 x 1.5	
6	End Mill (roughing) (DIN844)	$\varnothing 6 \times 13$ , $\varnothing 8 \times 19$ , $\varnothing 10 \times 22$ , $\varnothing 12 \times 26$ , $\varnothing 16 \times 32$ , $\varnothing 20 \times 38$	
7	End Mill (finishing) (DIN844)	$\varnothing 6 \times 13$ , $\varnothing 8 \times 19$ , $\varnothing 10 \times 22$ , $\varnothing 12 \times 26$ , $\varnothing 16 \times 32$ , $\varnothing 20 \times 38$	
8	Ball Nosed End Mills	$\varnothing 12$	
9	Chamfering cutters 90°	$\varnothing 10$	
10	Internal thread mill, pitch 1.5 mm	M30x1.5 (maximum length = 1.5 x $\varnothing$ )	
11	External thread mill, pitch 1.5 mm	M42x1.5 (maximum length = 1.5 x $\varnothing$ )	
12	Boring head	$\varnothing 20$ mm to 30 mm	
13	Surface Milling Head	$\varnothing 63$	
14	Spare reversible carbide tips		

## Reference list for test and measurement instruments

Item	Description	dimensions
1	Vernier calliper DIN 862	0-150 mm
2	Depth micrometre	0-75 mm
3	Depth Vernier calliper	0-15 mm
4	Outside micrometres DIN 863/1	0-25, 25-50, 50-75, 75-100, 100-125, 125-150 mm
5	Inside micrometres	5-25, 25-50 mm
6	Disc micrometres	0-25, 25-50 mm
7	Three-point hole micrometres	5-25, 25-50 mm
8	(M30x1.5, M42x1.5)	
9	Thread plug gauges for good and rejected products	M6, M10, M30x1.5
10	Thread ring Gauges	M30 x 1.5, M42 x 1.5
10	Chamfering tester 45°	
11	Instrument for angular measurement, plain protractor	
12	Set of slip gauges	
13	Indicating micrometre with magnetic stand	
14	Dial indicator with magnetic stand	
15	Radius gauge R3-25 mm	
16	High-accuracy 90°angle, arm length 80 mm	
17	Straight edge 100 mm	

**Important Notes:**

A) Please note that Competitors must bring their own tooling (tool holder, cutting tools, test and measurement instruments) to the Competition. The Competition Organizer will not be providing these items for the Competitors. The same items described and available in Infrastructure List are only spares.

B) As mentioned in A) the Competitors must carry their own tool holders. Tool holders are limited to 20 per Competitor.

C) Competitor tooling length can be a maximum of 2 mm greater than the design maximum specified.

D) The Competition Organizer will supply pull studs for the CNC machine at the competition. But Competitors can bring additional pull studs if they wish.

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.

## 8.5 Materials and equipment prohibited in the skill area

The following IT-based information (e.g. data, programmes etc.) and equipment allowing wireless contact outside the skill area (mobile-phones, laptops, etc.) are:

- Prohibited for Competitors;
- May be used by Experts in the workshop as defined by the Chief Expert prior to the Competition.

The use of any other PC than that provided during the Competition is strictly prohibited.

Competitors must only work with the software provided.

Only the keyboards supplied by the Competition Organizer can be used.

### Important Information

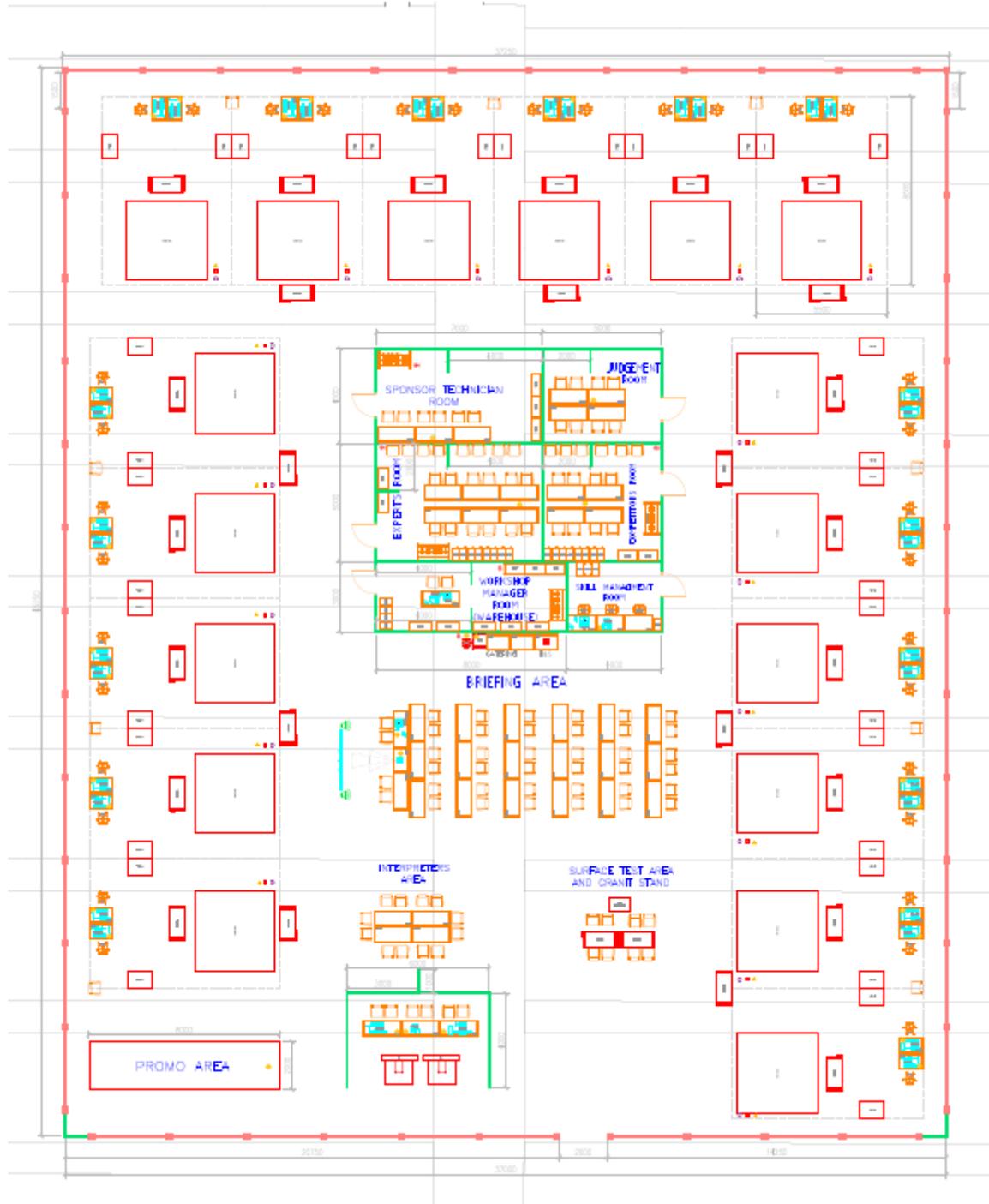
- The use of angular machine vices is NOT ALLOWED;
- The Competitors are only allowed to bring machine reamers for Dia.10H7 and Dia. 12H7;
- The Competitors are not allowed to bring their own linear height gauge or digital height gauges;

No external tool presetter is allowed in CNC Milling. The Competition Organizer does not provide this item and Competitors cannot bring external tool presetters.

## 8.6 Proposed workshop and workstation layouts

Workshop layouts from previous competitions are available at [www.worldskills.org/sitelayout](http://www.worldskills.org/sitelayout).

### Example workshop layout



## 9 Skill-specific rules

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.

Topic/task	Skill-specific rule
Use of technology – USB, memory sticks	<ul style="list-style-type: none"> <li>• Competitors must only use memory sticks provided by the Competition Organizer. No other memory sticks are to be inserted into the Competitor computers except with permission from the SMT.</li> <li>• Memory sticks or any other portable memory devices cannot be taken outside the workshop.</li> <li>• Memory sticks or other portable memory devices are to be submitted to the Chief Expert at the end of each day for safe keeping and must not be taken out of the workshop.</li> </ul>
Use of technology – personal laptops, tablets and mobile phones	<ul style="list-style-type: none"> <li>• Competitors, Experts, and Interpreters are not allowed to bring personal laptops, tablets or mobile phones into the workshop.</li> </ul>
Use of technology – personal photo and video taking devices	<ul style="list-style-type: none"> <li>• Competitors, Experts, and Interpreters are allowed to use personal photo and video taking devices in the workshop at the conclusion of the competition only.</li> </ul>
Drawings, recording information	<ul style="list-style-type: none"> <li>• No drawings or information regarding the Test Project can be taken out of the workshop.</li> <li>• The Competitor cannot bring their own drawings. During familiarization, drawings are supplied.</li> </ul>

## 10 Visitor and media engagement

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

- Display screens (video of CNC milling machining);
- A show spot with a complete Test Project (description, parts, and drawings) from past Competitions that make easy the understanding of Competitor activity;
- Competitor profiles - provide a sticker with the national flag, the name of the Competitor, and a brief description of their studies;
- Daily reporting of Competition status;
- A demonstration area for Competitors to interact with visitors to explain their skill;
- Demonstration videos provided by the machine and CAD/CAM sponsors showing parts machining which are of interests to visitors: aerospace, automotive, etc.;
- Small exhibits around the competition venue where various objects of everyday life such as a bottle; a mobile telephone; a toy; automotive part; aerospace part are exhibited with an explanation how it is produced and the role of CNC milling machines;
- A person who has detailed knowledge about CNC milling explains our competition with samples and videos. (Using former completed projects and technical drawings and a video showing a dry machining process of one module.);
- Terminals nearby the Competitors workplace showing the CAM activity;
- Live web cam in the machine with projection to a big screen. E.g. GoPro Cameras.

# 11 Sustainability

This skill competition will focus on the sustainable practices below:

- At the end of the Competition create several individual project sets (part, drawing and programmes) from the parts machined by the Competitors and donate them to vocational schools as teaching materials. (The programme is chosen from the highest scorer of each module);
- Demonstration parts;
- Each country/region is required to bring demonstration parts that the public can easily identify to be used during the demonstration time. (A geometric 3D file of the part is required as well.)

## 12 References for industry consultation

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/>) ILO 7223
- ESCO: (<https://ec.europa.eu/esco/portal/home> )
- O\*NET OnLine ([www.onetonline.org/](http://www.onetonline.org/))

The WSOS in section 2 appears most closely to relate to: *Milling and Planing Machine Setters, Operators and Tenders*:

<https://www.onetonline.org/link/summary/51-4035.00>

or *Milling Machine Operator*:

<http://data.europa.eu/esco/occupation/a1c9f8b7-c4ce-4b15-ac3c-3378c300d8f2>

These links also enable a review of adjacent occupations.

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 Shanghai 2021.

Organization	Contact name
GBR Mechanico Pte Ltd, (Asia)	Davizon Yee Khe Khum, Director
Hamilton Bonaduz AG, (Global)	Enrico Bellasi, Team Leader, Prototyping and Apprentices Mechanics
Prototyp-Werke GmbH (Global)	Wolfgang Lehmann, Team Leader Vocational Education
Sick Stegmann GmbH (Germany)	Stefan Mueller, Vocational Trainer
Siemens AG (Global)	Karsten Schwarz, Head of Training