SECTOR SKILLS STRATEGY
IN ADDITIVE MANUFACTURING

# D6.5 - New Professional Profiles / Qualifications and Competence Units/ Training Modules

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# Contents

## Executive summary

This report was developed under Work Package 6 - Implementation of SAM's final methodology for creating Professional Profiles, responding to Task 6.5 - New Professional Profiles/Qualifications and Competence Units/ Training Modules. It provides an overview on the creation/development process of new training guidelines.

Four new competence units (CU) were developed: one on "Metal AM sustainability and circularity", one new CU on "Aerospace and Part Quality Control", one CU on "Polymer AM sustainability and circularity", and the CU "Outlook of Professional Careers in Additive Manufacturing". In this document it's presented the information on the participating experts, the development process, the working sessions for validation with outcomes and the structure and content of the developed guidelines is presented.

The development of these new competence units is based in the methodology and templates developed in WP3 - Methodology for designing and revising professional profiles and developing skills, which have been used for the IAMQS update.

## 1. Introduction

This document reports on the creation process implemented in WP6 - Implementation of SAM's final methodology for creating Professional Profiles and results of D6.5 - New Professional Profiles/Qualifications and Competence Units/ Training Modules).

Based on the findings collected in D4.5 (3rd Report on the analysis and validation of needs), which resulted from the previous auscultations among industry, training organisations and RTOs , validated with the experts, and from the cross-check with what the IAMQS already foresees, it was concluded that it would be necessary to create the new 4 CUs:

- Metal AM Sustainability and Circularity
- Aerospace and Part Quality Control
- Polymer AM Sustainability and Circularity
- Outlook of Professional Careers in Additive Manufacturing.

In addition to D4.5 findings, a pilot of CU73 Introduction to Sustainability for Additive Manufacturing was delivered by IMR, with support from MTC and Lortek in March 2022 that further reinforced the need to develop two new CUs at advanced levels that could cover in more depth AM Sustainability, Recycling and Circularity subjects applied to both metals and polymers materials.

In the following sections, the development and validation processes of the new CUs, including the meetings, participants and contents details are described.

# 2. New competence unit on Metal AM Sustainability and Circularity

The following sections describe the working progress and outcomes of the of the new Competence Unit/Unit of learning outcomes on Metal AM sustainability and circularity at advanced level, in alignment with EQF level 6.

## 2.1. Background information

Under WP5, CU73 - Introduction to Sustainability for Additive Manufacturing was piloted. The course was led by IMR, with support from MTC and Lortek. Piloting of the course took place on the 24th, 29th&31st March 2022 with21 participants.

Details of CU73 are given in annex 1.

Here is presented the feedback from the attendees of CU73:

- The training was aligned with all participants expectation (100%) and would recommend it to someone else (100%).
- The knowledge and skills acquired in the training.
- Course structure, contents, coherence training tools and trainers' performance.
- Dynamics and interactions – breaks to allow break out rooms and discussion sessions.
- Use of examples in the form of case studies.
- Relevance of the course to your job activities.

The positive response to this course supported by the validated findings, lead to the to the development of two new CUs, the Metal AM Sustainability, Recycling and Circularity and Polymer AM Sustainability, Recycling and Circularity.

Also, this piloting action facilitated the design process of a new CU, the responsible partners were careful to avoid repetition of s topics already existent in the more this more generic unit.

## 2.2. Working sessions

The development and validation of the new CU on Metal AM Sustainability and Circularity took place between June and July of 2022 with SAM partners and experts in relevant thematic. Further details on the internal preparation and the validation session with the experts can be seen below:

### 2.2.1. Summary of meetings

| Meeting | Date/time | Attendees (organisation) | Output |
|---|---|---|---|
| MTC internal CU Design meeting | 22nd June 2022<br>12:00 – 13:00 (BST) | Ollie Hartfield (MTC)<br>Amanda Field (MTC)<br>Steven Hall (MTC)<br>Llyr Jones (MTC)<br>David Wimpenny (MTC) | CU description Draft 1 |
| Feed-back from EWF on Draft 1 | 1st July 2022<br>9:00-10:00 (BST) | Adelaide Almeida (EWF)<br>Ana Beatriz Lopez (EWF) | CU description Draft 2 |
| Review of Draft2 | 7th July 2022<br>12:3-14:00(BST) | Katrina Farrell (IMR)<br>Jon Aranzabe Zugasti (Lortek)<br>Raquel Maria Almeida (ISQ) | CU description Draft 3 |

| | | | |
|---|---|---|---|
| | | David Wimpenny (MTC) | |
| Review of Draft 3 | 8th July 2022<br>10:30-12:00 (BST) | Barbara Previtali (Polimi) Danny Lloyd (Arrival)<br>Mirko Kunowsky (AIJU)<br>Damjan Klobčar ( Ljubljana University)<br>David Wimpenny (MTC) | CU description Draft 4 |

### 2.2.2. MTC internal CU Design Meeting

| Nature of meeting | Date/time | Attendees |
|---|---|---|
| On-line via TEAMS | 22nd June 2022<br><br>12:00 – 13:00 (BST) | Ollie Hartfield (MTC)<br>Amanda Field (MTC)<br>Steven Hall (MTC)<br>Llyr Jones (MTC)<br>David Wimpenny (MTC) |

The design team was supplied with a copy of CU73 and the feedback from attendees prior to the design meeting. Each member of the design team was carefully selected to bring specialized expert knowledge to contribute to the design of the competence unit – as shown in the table below:

| MTC staff | Area of expertise relevant to the topic |
|---|---|
| Ollie Hartfield | Design for AM with focus on sustainability |
| Amanda Field | Metal AM process chain |
| Steven Hall | Feed-stock production, management and reuse/recycling |
| Llyr Jones | Design for AM – trainer for CU76 introduction to sustainability for AM |

At this meeting the duration, content of the CU was discussed, and the first draft (Annex 2) description was generated.

### 2.2.3. Meeting with EWF

| Nature of meeting | Date /time | Attendees |
|---|---|---|
| On-line via TEAMS | 1st July 2022<br>9:00-10:00 (BST) | Adelaide Almeida (EWF)<br>Ana Beatriz Lopez (EWF)<br>David Wimpenny (MTC) |

The first draft was shared with EWF, and a meeting was held on the 1st of July 2022 to gather some feedback.

The primary discussion points are listed below:

- Clarifying that completing CU73 Introduction to feasibility for AM should be a prerequisite for this course as this provides a significant amount of background information which should not be duplicated in the new course.
- The aim of the course was to inform attendees of the critical role that their decisions could make in respect of determining the sustainability of metal AM processes and the parts generated using it. For this reason, the course would only be offered as an advanced course to engineers, supervisors, coordinators and designers – as these grades of personnel are the decision makers. The course was not going to be open to operators, as generally speaking they must strictly adhere to process guidelines and thus have limited influence or decision-making powers.
- There was concern that there was potentially too much duplication between the Introduction to Sustainability and Metal AM sustainability, Recycling and Circularity courses. To reduce this risk the duration of the new course was reduced from 2 days (14 contact hours) to just 1 day (7 contact hours). As well as helping to ensure that the course focused on new material specifically related to metal AM, by reducing the duration it would potentially make the course more attractive to industry.

Based on this feedback a revised CU description was generated (annex 3).

### 2.2.4. Meeting for CU Draft 2 Description Review

Draft 2 of the CU description was then circulated to the review panel comprising of members of the AM sustainability WG and interested SAM partners:

- Katrina Farrell (IMR) - 7th July
- Jon Aranzabe Zugasti (Lortek) - 7th July
- Raquel Maria Almeida (ISQ) - 7th July
- Barbara Previtali (Polimi) - 8th July
- Danny Lloyd (Arrival) - 8th July
- Mirko Kunowsky (AIJU) - 8th July
- Damjan Klobčar (University of Ljubljana) - 8th July
- Gustavo Melo (RWTH-aachen) – unable to attend review
- Georg Schlick (Fraunhofer-IGCV) – unable to attend review
- Matthias Gieseke (Baker Hughes) – unable to attend review

It was not possible for everyone to attend the meeting and two sessions were set-up, the first on the 7th of July and the second meeting on the 8th of July.

| Nature of meeting | Date / time | Attendees |
|---|---|---|
| On-line via TEAMS | 7th July 2022<br>12:3-14:00(BST) | Katrina Farrell (IMR)<br>Jon Aranzabe Zugasti (Lortek)<br>Raquel Maria Almeida (ISQ)<br>David Wimpenny (MTC) |

In this meeting it was decided to eliminate the concept “Recycling” from the CU and many changes were made in the CU knowledge and skills, that can be consulted in annex 4 .

### 2.2.5. Meeting for CU Draft 3 Description Review

| Nature of meeting | Date/time | Attendees |
|---|---|---|
| On-line via TEAMS | 8th July 2022<br>10:30-12:00 (BST) | Barbara Previtali (Polimi)<br>Danny Lloyd (Arrival)<br>Mirko Kunowsky (AIJU) |

| | | |
|---|---|---|
| | | Damjan Klobčar (University of Ljubljana)<br>David Wimpenny (MTC) |

Draft 3 of the CU description was reviewed at a meeting on the 8th of July. There was the agreement that Draft 3 was good, but some suggestions were given to improve:

- Reuse of feedstock materials should include downcycling strategies.
- Circularity also needs to consider potential waste streams into AM from other processes, as well as output from AM in other manufacturing processes, for example significant work on using waste from other processes to generate AM feedstock in particular plastic waste in polymer AM (see Michael Hunt – 3D printing Cornwall).
- Sustainability should include a reminder that AM is important as a prototyping tool to support design process (leading to improved products and fewer manufacturing problems).

The comments from the meeting are shown in blue in annex 5.

## 2.3. Structure and content of the CU Metal AM sustainability and circularity

In this chapter, the result of the working and validation sessions is presented.

### 2.3.1. Competence Unit / Unit of Learning Outcomes

Competence Units (CU) /Units of Learning Outcomes (ULOs) cover the minimum requirements for education and training, in terms of Learning Outcomes (LOs) and contact (teaching) hours to be devoted to achieving them.

On each Competence Unit, objectives and scope are defined for a specific depth of knowledge and skills, which is described as “proficiency level”, in alignment with EQF. The same Competence Unit can also be part of different Qualifications, whenever its Learning Outcomes are necessary for the qualification´s expected results.

It will be revised periodically, by the Observatory Working Groups to take into account changes to reflect the "state of the art". Students successfully completing a Competence Unit/Unit of LOs and its examination will be expected to be capable of applying the achieved LOs at a level consistent with the related qualifications diplomas.General information about the new CU “ Metal AM sustainability and circularity”

- **Target**: Additive Manufacturing Professional Profiles /Occupations - Engineerscoordinators and designers.
- **Objectives:** - provide a detail insight into the sustainability of metal AM processes
- **Precedence:** CU00 Overview on AM process and CU73 Introduction to sustainability for AM
- **Entry level:** EQF level 6

| **Metal AM Sustainability and Circularity** | RECOMENDED CONTACT HOURS |
|---|---|
| **SUBJECT TITLE** | |
| Overview of sustainability | 0.5 |
| Concept & Practice of Circularity | 0.5 |
| Potential sustainability benefits of AM | 0.5 |

| | |
|---|---|
| Measuring, predicting and justifying sustainability | 0.5 |
| Overview of metal AM process chains and their impact on sustainability | 0.5 |
| Impact of AM feed-stock on sustainability | 0.5 |
| Impact of part design and material selection | 1.0 |
| Impact of AM process selection and build set-up on sustainability | 1.0 |
| Impact of Part post processing on sustainability | 0.5 |
| Impact of Metal AM facility design and operation | 0.5 |
| Repair, reuse & recycling approaches in metal AM | 0.5 |
| Recap on all topics covered, assessment and complete post CU survey | 0.5 |
| **Total** | 7 |
| **WORKLOAD** | 14 |

| **LEARNING OUTCOMES – Metal AM sustainability and circularity** | |
|---|---|
| **LEVEL** | **Advanced** |
| **KNOWLEDGE** | – Advanced knowledge and critical understanding of the theory, principles and applicability of: Sustainability - economic, climate change, critical raw materials, supply chain resilience/reshoring, government policy and standards<br>– Tools for sustainability assessment – Life Cycle Assessment (LCA)<br>– Impact of metal AM process chains on sustainability<br>– Circularity, repair and recycling in metal AM concepts |
| **SKILLS** | – Identify the different ways in which sustainability effects our lives<br>– Compare sustainable tools considering their advantages and limitations in Metal AM productionExplain the impact of metal AM process chains on sustainability<br>– Evaluate the metal AM process chain to optimize the sustainability process in each segment |

# 3. New competence unit on AM for Aerospace & Part Quality Control

The following sections describe the working progress and outcomes of the of the new Competence Unit/Unit of learning outcomes on AM for Aerospace & Part Quality Control at advanced level, in alignment with EQF level 6. Further detail on the internal preparation and the validation session with the experts can be seen below.

## 3.1. Working sessions

The development and validation of the new CU on AM for Aerospace & Part Quality Control took place between September and November 2022 with SAM partners, representatives of IAMQC and representatives of aerospace industry. The following sections describe the working progress and outcomes of the development leading to the finalised version of the CU.

### 3.1.1. Summary of meetings

| Meeting /consultation | Date/time/duration | Attendees (organisation) | Output |
|---|---|---|---|
| Initial discussion of the content of the course | 05/09/22<br>10:00-12:00<br>2 hours | David Wimpenny (MTC)<br>Amanda Field (MTC) | DW generated first draft of CU |

| | | | |
|---|---|---|---|
| Review of the 1st draft of the CU | 20/09/22<br>11:30-13:00<br>1.5 hours | David Wimpenny (MTC)<br>Amanda Field (MTC)<br>Nick Cruchley (MTC)<br>Ruaridh Mitchinson (MTC) | 2nd draft |
| Review of the 2nd draft of the CU | 24/10/22<br>11:00-12:30<br>1.5 hours | David Wimpenny (MTC) – DW<br>David Santos Gonzalez (Idonial) – DSG<br>Suresh Srinivansan (Ubrun) – SS<br>Ilka Zajons (LAK) – IZ<br>Emma Gil (Lortek) – EG (30mins)<br>Jon Aranzabe Zugasti (Lortek) – JAZ (52mins) | 3rd draft with more detail added |
| Review of the 3rd draft of the CU from an aerospace industry perspective | 16/11/22<br>15:00-16:00<br>1 hour scheduled (47 minutes actual) | Callum Raines<br>Production Engineering<br>Production Engineering Technical Support<br>Glenair | 4th draft with areospace industry input |
| Review of the 4th draft of the CU from an aerospace industry perspective | 21/11/22<br>16:30-15:30<br>1 hour | David Wimpenny (MTC) – DW<br>Scott Linthorpe (Parker Meggitt) – SL<br>Director AM<br>Cameron Ross (Parker Meggitt) – CR<br>Group Manufacturing Engineering & Technology Director<br>Parker Meggitt | 5th draft with further aerospace industry input |

### 3.1.2. 1st Meeting 05/09/22

The objective of this meeting was to discuss the aims and objectives of the course and identify the potential topics which should be covered in the course, resulting from this meeting the first draft presented in annex 6.

### 3.1.3. 2nd Meeting 20/09/22

In this meeting the main focus was to conduct an initial review of the draft content of the new competence unit based on the output from the meeting on the 5th of September, the comments and changes generated in the meeting can be seen in annex 7.

### 3.1.4. 3rd Meeting 24/10/22

The aim of this meeting was to review the Draft 2 of the CU description generated at the review meeting on the 20/9/22, including the detailed breakdown of the content, the comments and changes generated in the meeting can be seen in annex 8.

### 3.1.5. 4th Meeting 16/11/22

In this 4th meeting the goal was to review the Draft 3 of the CU description generated at the review meeting on the 24/10/22, including the detailed breakdown of the content. The comments and changes generated in the meeting can be seen in annex 9.

### 3.1.6. 5th Meeting - 21/11/22

A review of the draft of the CU description generated at the review meeting on the 16/11/22, including the detailed breakdown of the content was made, the comments and changes generated in the meeting can be seen in annex 10.

## 3.2. Structure and content of the CU AM for Aerospace & Part Quality Control

The new competence unit is intended to provide students who are working towards or have completed the AM engineer qualification. The aim is to provide specific information related to the requirements of the aerospace sector, particularly through the use of case studies. Students should have some prior knowledge of AM processes gained through completion of other competence units or through prior learning.

### 3.2.1. Competence Unit / Unit of Learning Outcomes

Competence Units (CU) /Units of Learning Outcomes (ULOs) covers the minimum requirements for education and training, in terms of Learning Outcomes (LOs) and contact (teaching) hours to be devoted to achieving them.

On each Competence Unit, objectives and scope are defined for a specific depth of knowledge and skills, which is described as “proficiency level”, in alignment with EQF. The same Competence Unit can also be part of different Qualifications, whenever its Learning Outcomes are necessary for the qualification´s expected results.

It will be revised periodically, by the Observatory Working Groups to consider changes to reflect the "state of the art". Students successfully completing a Competence Unit/Unit of LOs and its examination will be expected to be capable of applying the achieved LOs at a level consistent with the related qualifications diplomas.

General information about the new CU “AM for Aerospace & Part Quality Control”:

- **Target**: AM engineers/coordinators who are working towards or have completed AM engineer/coordinator qualification
- **Objectives:** address the specific requirements of the aerospace sector in adopting AM.
- **Precedence:** CU00, CU01 (DED-Arc), CU08 (DED-LB), CU15(PBF-LB), CU25 (post processing)
- **Entry level:** EQF level 6

| **AM for Aerospace & Part Quality Control** | RECOMENDED CONTACT HOURS |
|---|---|
| **SUBJECT TITLE** | |
| Introduction to AM in the Aerospace Sector<br>Metal AM processes | 1.5 |
| Polymer AM processes | 1.0 |
| Opportunities and challenges with AM for the aerospace sector | 1.0 |
| Adoption of AM in aerospace sector | 1.5 |
| Design for AM | 1.0 |
| Barriers to adoption of AM in the aerospace sector | 1.0 |
| Impact of certification, qualifications and standards in the aerospace sector | 1.5 |
| Aerospace relevant AM materials and their properties | 1.5 |

| | |
|---|---|
| Impact of feed-tock, build parameters and post processing on part quality & properties | 1.0 |
| Specifying & Assessing part quality | 1.0 |
| Sustainability & Circularity | 1.0 |
| Future perspective on AM in aerospace | 1.0 |
| Total | 14 |
| WORKLOAD | 28 |

| **LEARNING OUTCOMES – AM for Aerospace & Part Quality Control** | |
|---|---|
| **LEVEL** | **Advanced** |
| **KNOWLEDGE** | - Advanced knowledge and critical understanding of the theory, principles and applicability of: the different metal and polymer AM processes applied to the aerospace sector.<br>- the opportunities and challenges of AM, when applied to the aerospace sector.<br>- the history of AM adoption in the aerospace sector<br>- the certification & qualification process for aerospace parts.<br>- AM materials and the impact of build/post processing parameters on the quality and properties of parts.<br>- assessment of part quality to meet aerospace requirements. |
| **SKILLS** | Explain the opportunities and challenges for introduction of AM in the aerospace sector.<br>Relate the influence of the build and post-process parameters on the quality and properties of AM parts.<br>Explain the impact of the aerospace qualification, certification and standards on the deployment of AM including part categories and material quality sets.<br>Describe where AM is currently used in the aerospace sector and the reasons for its selection.<br>Select specific materials for different aerospace applications to meet part requirements.<br>Specify the inspection approach to be used to ensure part quality. |

# 4. New competence unit on Polymers AM - Sustainability & Circularity

## 4.1. Background information

The need for the development of this competence unit was also reinforced with the piloting of CU73 - Introduction to Sustainability for Additive Manufacturing, with the procedures already described above in the part of the document referring to the development of the new CU Metal AM Sustainability and Circularity.

Prior to the preparation of this document, IDONIAL had access to the work led by MTC, for the configuration of a CU on Sustainability, Recycling & Circularity, dedicated in this case to Metal AM technologies. To date, these works have reached the 4th draft version. Given the potential similarities between said competence unit and the present one, that 4th draft is used as a starting point, to analyse its current content and its adaptability to polymeric AM technologies.

## 4.2. Working sessions

The development and validation of the new CU on Polymers AM - Sustainability & Circularity took place between July 2022 and May 2023 by SAM partners. The following sections describe the working progress and outcomes of the development leading to the finalised version of the CU.

### 4.2.1. Summary of meetings

| Meeting | Date/time | Attendees (organisation) | Output |
|---|---|---|---|
| IDONIAL internal CU Design Meeting | 08/07/2022 | IDONIAL | Analysis of previous documents |
| Draft Definition CU Polymers AM– Sustainability, Recycling & Circularity | 27/07/2022 | David Santos González (IDONIAL)<br>Mario López Marlasca (IDONIAL)<br>Manuel Antonio García García (IDONIAL)<br>Paula Queipo Rodríguez (IDONIAL) | 1 st draft version |
| Revision after workshop evaluating | 17/05/2023 | David Santos González (IDONIAL)<br>Mario López Marlasca (IDONIAL)<br>Manuel Antonio García García (IDONIAL)<br>Paula Queipo Rodríguez (IDONIAL) | Sections 4 and 5 are added as a result. |

### 4.2.2. IDONIAL internal CU Design Meeting

The initial work consisted of the analysis of previous documents:

- Competence unit CU73 “Introduction to Sustainability for Additive Manufacturing”.
- The MTC´s document “SAM-WP6-Development of CU Metal AM Sustainability and Circularity (170222a)”, updated to the generation of its draft 4 (08/07/2022).

#### 4.2.2.1. Analysis of CU73 “Introduction to Sustainability for Additive Manufacturing”

Based on the current definition of CU73, this competence unit:

- It allows participants to obtain a general knowledge towards the relevance of sustainability from socio-economic perspectives.
- By introducing the concept of "product life cycle", it also aims to provide the trainee with the bases to understand how the product development, manufacturing and usage activities generate impact throughout its various stages, also delivering the bases to assimilate how additive manufacturing has limitations and opportunities in each of them.
- It shows how additive manufacturing can specifically influence the sustainability of a product, whether in its conception, production, use and disposal.

Thus, the main conclusion on the analysis of current CU73 is that its main aim is to provide trainees with insights into sustainability, an understanding of how it is related to a product, and significant key aspects and examples on how AM can be a tool when searching for reducing the environmental impact of products.

#### 4.2.2.2. Analysis of document CU73 "SAM-WP6-Development of CU Metal AM Sustainability and Circularity (170222a)", updated to the generation of its draft 4 (08/07/2022)

Led by MTC, a competence unit capable of going deeper and beyond the CU73, with a more specific focus on metal additive technologies has been defined. After several sessions, its 4th draft version was analysed (annex 11).

The main conclusions were that it could be argued whether the information to be provided to the trainee in described sections could be in a certain way repetitive with respect to the information already transferred to the trainee in the CU73, in which these concepts could have been partially covered, although under a different formulation and sequence. A possible exception or possibility of intensification could perhaps be raised regarding the information around the LCA impact quantification methodologies.

A presentation of an LCA example that could integrate design and production considerations could be beneficial. In this way, a quantitative example of the effect of possible alternatives on the impact of the product can be presented to the trainees, allowing them to better understand this procedure in a holistic and practical way.

### 4.2.3. Draft Definition CU Polymers AM – Sustainability & Circularity

Based on CU73, a first draft of a new CU is presented on 27/07/2022, aiming for targeted and in-depth training in the field of sustainability of design and manufacturing processes, supported by polymeric AM technologies (annex 12).

### 4.2.4. Evaluations and comments from workshop "AM SKILLS WORKSHOP & 25th AM-Platform meeting", 27th April 2023

On April 27, 2023, the "AM SKILLS WORKSHOP & 25th AM-Platform meeting" took place, providing an opportunity for different stakeholders to provide feedback on the CU proposal on "Polymer AM sustainability and circularity." Looking at the comments and ratings in detail, we can observe:

- All questions have a "suitable" + "very suitable" score greater than 65%:
- The topics "Subjects covered by the CU", "Adequacy of the subjects for the advanced level (EQF6)", "Adequacy of the expected level of knowledge (Learning outcomes)", "Adequacy of the expected level of skills (Learning outcomes)" and "Clarity of the detailed knowledge" get a "suitable" + "very suitable" mark greater than 80%.
- The topics "Overall duration of the UC considering its purpose", "Contact hours allocated to each subject" and "Allocation of contact hours for different contexts (A+B+C): Allocation of contact hours for different contexts (A+B+C)", get a "suitable" + "very suitable" mark lower than 80%.
- There were specific comments on aspects as:
    - Time dedicated to LCA could be increased.
    - The current duration of the CU could be insufficient.
    - Aspects such as material reuse, toxicity, or an increased perspective from materials science could be included in the CU.

These results could imply that, regarding the general structure and content, it does not seem that these results suggest that major modifications are necessary. On the other hand, the three aspects that reached the lowest levels, plus the specific comments, can be seen as different facets of the same issue, which is the total time dedicated to the CU and the specific time dedicated to some of the topics. Thus, potential changes to the draft CU could be the next ones:

- As long as CU duration should be a multiple of 3.5, the CU could benefit from a prolongation from 6 to 7 contact hours.

- This extra amount of time could be spent on the topics highlighted by the stakeholders´ feedback which are aligned with these subjects:
    - Impact of AM feedstock on sustainability (+0.5 hours).
    - Measuring, predicting, and justifying sustainability (+ 0.5 hour).
- As this would entail increasing the contact time in one hour, this would translate to 2 hours increase in workload time, up to 14 hours.
- These changes could be implemented in the "Course content and structure" section of the CU. A modification of the "detailed knowledge section" wouldn´t be strictly necessary, as long as the required topics are already present in the current description and the added time can be used to go further into some aspects (AM feedstock), or to provide more or more comprehensive examples (LCA).

### 4.2.5. CU Polymers AM – Sustainability, & Circularity Revision

In light of what was described in the previous section, it has been deemed appropriate to partially revise the CU draft. This first formulation of the CU "Polymers AM–Sustainability & Circularity" aims to reduce the possibilities of redundancy regarding the material presented in CU73, while increasing the intensification of this new CU on polymer-based AM processes.

Based on the above, it is proposed to henceforth link the subsequent development of the sustainability-focused CUs for metals and polymers. This will lead to a unified basic structure, minimizing redundancy, while simultaneously favoring specific and independent attention to both metallic and polymeric-based AM processes.

## 4.3. Structure and content of the CU Polymers AM – Sustainability & Circularity

In this chapter, the result of all the working sessions is presented.

### 4.3.1. Competence Unit / Unit of Learning Outcomes

Competence Units (CU) /Units of Learning Outcomes (ULOs) cover the minimum requirements for education and training, in terms of Learning Outcomes (LOs) and contact (teaching) hours to be devoted to achieving them.

On each Competence Unit, objectives and scope are defined for a specific depth of knowledge and skills, which is described as "proficiency level", in alignment with EQF. The same Competence Unit can also be part of different Qualifications, whenever its Learning Outcomes are necessary for the qualification´s expected results.

It will be revised periodically, by the Observatory Working Groups to consider changes to reflect the "state of the art". Students successfully completing a Competence Unit/Unit of LOs and its examination will be expected to be capable of applying the achieved LOs at a level consistent with the related qualifications diplomas.

General information about the new CU " AM – Sustainability, Recycling & Circularity":

- **Target:** Additive Manufacturing Professional Profiles /Occupations – Engineers, coordinators and designers.
- **Objectives: provide a detailed insight into the sustainability of polymer AM processes**
- **Precedence**:CU00 Overview on AM process and CU73 Introduction to sustainability for AM
- **Entry level:** EQF level 6

| Polymer AM sustainability and circularity<br>SUBJECT TITLE | RECOMENDED CONTACT HOURS |
|---|---|
| Overview of polymer AM process chains and their impact on sustainability | 0.5 |
| Impact of AM feed-stock on sustainability | 1.0 |
| Impact of part design and material selection | 1.0 |
| Impact of AM process selection and build set-up on sustainability | 1.0 |
| Impact of Part post processing on sustainability | 0.5 |
| Impact of Polymer AM facility design and operation | 0.5 |
| Repair, reuse & recycling approaches in polymer AM | 0.5 |
| Measuring, predicting, and justifying sustainability | 1.5 |
| Recap on all topics covered | 0.5 |
| Total | 7 |
| WORKLOAD | 14 |

| LEARNING OUTCOMES – Polymer AM sustainability and circularity | |
|---|---|
| **LEVEL** | **Advanced** |
| **KNOWLEDGE** | – Advanced knowledge and critical understanding of the theory, principles and applicability of: Sustainability - economic, climate change, critical raw materials, supply chain resilience/reshoring, government policy and standards<br>– Tools for sustainability assessment – Life Cycle Assessment (LCA)<br>– Impact of polymer AM process chains on sustainability<br>– Circularity, repair and recycling in polymer AM concepts |
| **SKILLS** | – Identify the different ways in which sustainability effects our lives<br>– Explain the impact of polymer AM process chains on sustainability<br>– Evaluate the polymers AM process chain to optimize the sustainability process in each segment |

# 5. New competence unit on Outlook of Professional Careers in Additive Manufacturing

Under WP6 a new competence unit, CU "Outlook of professional careers in additive manufacturing" was developed. The CU was led by FAN3D, with support from UBRUN, LAK, LMS, C Nantes, ISQ and EPMA. Development of the CU took place on the 6th of December, and 5th of May 2023. Two working sessions and one expert validation was held to develop the CU.

## 5.1. Working sessions

The development and validation of the new CU on Outlook of Professional Careers in Additive Manufacturing took place between December 2022 and May 2023 by SAM partners. The following sections describe the working progress and outcomes of the development leading to the finalised version of the CU.

### 5.1.1. Summary of meetings

| Meeting /consultation | Date/time/duration | Attendees (organisation) | Output |
|---|---|---|---|
| First Working Group Meeting (Creating of first draft) | 06.12.2022 | Begum Canaslan Akyar (FA)<br>Yvonne Johannsen (LAK)<br>Eujin Pei, (UBRUN)<br>Harrys BIKAS, (LMS)<br>Panagis Foteinopoulos (LMS)<br>Borzoo Pourabdollahian Tehran (EC Nantes)<br>Kenan Boz (EPMA)<br>Tânia Avelino (ISQ) | BCA developed the first draft of CU |
| Second working group meeting (Development of first draft ) | 09.01.2023 | Begum Canaslan Akyar (FA)<br>Kenan Boz, France (EPMA)<br>Henning Ahlers (LAK)<br>Panagis Foteinopoulos (LMS)<br>Borzoo Pourabdollahian Tehran (EC Nantes)<br>Tânia Avelino (ISQ) | 2nd draft was developed |
| Expert Validation | 03.04.2023 | Begum Canaslan Akyar (FA)<br>Mario López Marlasca (IDONIAL)<br>Panagis FOTEINOPOULOS (LMS)<br>Colin Meade (IMR)<br>Yvonne Johannsen (LAK)<br>Henning Ahlers (LAK)<br>Eujin Pei (UBRUN)<br>Adelaide Almeida (EWF) | Final draft developed |

### 5.1.2. First Working Group Meeting (06.12.2022)

During this first session it were discussed the following topics:

- Definition of the target group
- Decision on recommended contact hours
- Definition the scope of the CU
- Listing the subject titles
- Determination composition of contact hours

The target group was defined as youngsters and/or adults who have not enrolled in the manufacturing or technical fields yet.

The global aim of this CU was to provide an alternative career path to a target group without manufacturing and technical background.

Additionally, this CU will help professionals understand how they can utilize AM in their current careers, taking advantage of it to improve their competence and competitiveness in their current job. As the scope of the new CU, in order to promote AM appreciation this CU will emphasize the soft skills and daily-life related applications.

The first version of subject titles was:

- Introduction to Additive Manufacturing

- Using AM across fields (or Examples of AM applications in different sectors)
- Career Pathways
- Skills for the Additive Manufacturing Professional
- Case study

The meeting closed with the decision to discuss the CU title, the subject title after receiving feedback from the project partners, to work on learning outcomes, and to discuss contact hours as prior topics in the next meeting.

### 5.1.3. Second working group meeting (09.01.2023)

In the second meeting, it was discussed the following topics:

- Revisiting subject titles' order and structure
- Decision on learning outcomes

The gathered feedback from project partners who did not attend the working group session, namely Adelaide Almeida and Paula Queipo, was added to the previous draft.

And the working group members commented on the first draft of the new CU.

This session was dedicated to reviewing and closing comments. The revised subject titles and order was decided (annex 13).

The recommended contact hours were outlined as 2 hours for the introduction and professional applications and 1h30 for Career Pathways. In order to decide on the current CU title, was developed a collaborative exercise, using Slido. From the many alternatives offered by the members, the name Outlook at professional careers in AM was selected. In annex 14, all the alternatives can be consulted. It was agreed that, through SharePoint, members would evaluate learning outcomes and leave their comments on the file.

### 5.1.4. Expert Validation Session (04.03.2023)

The main aim of this session was:

- To discuss the covered subjects.
- To discuss the adequacy of the expected level of knowledge and skills to be achieved for the allocated teaching time.
- To discuss contact hours allocated to each subject and overall time for the CU.
- To discuss the appropriate assessment approach.
- Any other business.

One external expert from BBS.me also gave an opinion about the current CU however, could not join the expert validation session. Ilka Zajons from LAK met bilaterally. The meeting results were also included in the expert validation session. The subjects were presented to the members, and they agreed on the proficiency level of the CU is "Basic Level" according to the IAMQS framework, used to design CU using a modular system, it is aligned with level 2 on EQF.

In addition, they stated verbally that the first subject shouldn't overlap with the CU00, which deals with a general overview of AM. Additionally, the subject should not go into historical details, etc. There was also adjustment to the allocated time to the subjects, it was considered 1.5 hours to the second subject not enough and increased 2 hours. Moreover, the first subject was decreased and set as 1.5 hours.

The skills were also revised, as the first "Recognize AM as an innovative technology" and the second one "Recognize its possibilities for application in different sectors" overlapped, the second skill was removed. On the other hand, there is not any item referring to the education pathway so one skill should be added addressing these skills.

As a suggestion from BBS-me, the subject title namely “Advantages and disadvantages of AM” was edited as “Possibilities and limits of AM”.

An online collaborative activity was developed to collect feedback about the appropriate assessment approach, and since the IAMQS is based on a multiple-choice questions assessment method, the current CU multiple-choice question was approved. However, because of the nature of the CU, experts recommend interviews or open-ended questions to gather valuable information.

To have access to all the detailed inputs given in this validation session please check annex 15.

## 5.2. CU structure and content

The global aim of this CU was to provide an alternative career path to a target group without a manufacturing and technical background. In this chapter, the result of the working sessions is presented.

### 5.2.1. Competence Unit / Unit of Learning Outcomes

General information about the new CU “Outlook of Professional Careers in Additive Manufacturing”:

- **Target:** General public, ranging from students from Vocational Education and Training (VET), high school and higher education; to adults from non-manufacturing professional area
- **Objectives of the CU;**
  - To raise awareness of additive manufacturing
  - To introduce AM career opportunities in various sectors
  - To identify career paths to be pursued in AM
  - To navigate finding job opportunities
- **Precedence**:CU00 Overview on AM process (as optional)
- **Entry level:** EQF level 2 as suggestion

| **Outlook of Professional Career in Additive Manufacturing** | **RECOMMENDED CONTACT HOURS** |
|---|---|
| **SUBJECT TITLE** | |
| INTRODUCTION AND SECTORAL APPLICATIONS of AM | 1.5 |
| AM CAREER PATHWAYS | 2.0 |
| **Total** | 3.5 |
| **WORKLOAD** | **7** |

| **LEARNING OUTCOMES – Outlook of professional careers in AM** | |
|---|---|
| **Level** | **Basic** |
| **KNOWLEDGE** | Basic knowledge of :<br>- Main concept of Additive Manufacturing (AM)<br>- Career pathways in AM |
| **SKILLS** | -Recognize AM as an innovative technology<br>-Recognize educational pathways in AM<br>-Identify possible jobs positions in AM |

# 6. Conclusion

Advanced manufacturing, in which additive manufacturing is included, is one of the factors for the evolution of industries towards sustainable economic growth, creating competitiveness and long-term jobs. Since the use of additive manufacturing has had a great relevance in the last decade, it is necessary to have up-to-date training and consider new professional profiles that responds to the needs of the various sectors. In the previous Work Packages of SAM project the existing gaps in AM were identified and how to improve the actual trainings to upskilling the workforce. This report demonstrates the process of creation/development of the new competence units on the subjects:

- Metal AM sustainability and circularity
- Aerospace and Part Quality Control
- Polymer AM sustainability and circularity
- CU Outlook of Professional Careers in Additive Manufacturing

For the development and validation processes of the new Competence Units the contribution of many experts both from the field of additive manufacturing as from educational field, was considered, some were internal to the project, but with the majority were external participants that brought important insights for the work that was being developed.

The meetings undertaken show a long development and iterative process , until the final version learning outcomes, defined in terms of knowledge, skills, autonomy and responsibility in each competence unit.

As mentioned before, these competence units have been developed based in the methodology and templates developed in WP3 - Methodology for designing and revising professional profiles and developing skills) which have been used for the IAMQS

# 7. Annexes

ANNEX 1 - CU73 piloting course

ANNEX 2 - MTC internal CU Design Meeting

ANNEX 3 - Feedback from EWF – 01/07/2022

ANNEX 4 - CU Draft 2 Description Review 07/07/2022

ANNEX 5 - CU Draft 3 Description Review 08/07/2022

ANNEX 6 - Notes of meeting of 05/09/22

ANNEX 7 - Notes of meeting of 20/09/22

ANNEX 8 - Notes of Meeting - 24/10/22

ANNEX 9 - Notes of Meeting -16/11/22

ANNEX 10 - Notes of Meeting - 21/11/22

ANNEX 11 - Analysis of document CU73

ANNEX 12 – First Draft - CU Polymers AM–Sustainability, Recycling & Circularity

ANNEX 13 – Subjects in Outlook of Professional Career in Additive Manufacturing

ANNEX 14 – New CU title

ANNEX 15 - Expert Validation Session collaborative approach

# ANNEX 1 - CU73 piloting course

Details of CU73

**Introduction to sustainability for Additive Manufacturing**

**1. General information about the CU:**

- **Target:** All Additive Manufacturing Professional Profiles /Occupations (from Operator to Engineers);
- **Objectives of the CU are to raise awareness on the importance of Sustainability applied to AM**
- **Precedence**:CU00 Overview on AM process (as optional)
- **Entry level:** EQF level 3 (Secondary level) as suggestion

**2. Course content and structure**

| **CU 73 Sustainability for Additive Manufacturing** | RECOMENDED CONTACT HOURS |
|---|---|
| **SUBJECT TITLE** | |
| Economic and social context for Sustainability Policies | 1 |
| Product Life Cycle | 1.5 |
| Additive manufacturing within a sustainable production scheme | 3.5 |
| Case studies | 1 |
| Total | 7 |
| WORKLOAD | 14 |

| **LEARNING OUTCOMES – CU Sustainability for AM** | |
|---|---|
| **LEVEL** | **Basic** |
| **KNOWLEDGE** | Basic knowledge of:<br>– Economic and social context for Sustainability Policies (R Imperatives; Green Deal; Sustainable Development Goals)<br>– Sustainability along the product life cycle (Human Centred Design)<br>– AM role in sustainability (advantages and limitations)<br>– |
| **SKILLS** | – Spot ideas and opportunities on alternative and more sustainable simple solutions applied to the daily AM activities<br>– Name advantages and disadvantages of AM use towards sustainability<br>– Identify the cases/examples where AM can lead to more sustainable products<br>– Take the initiative to make suggestions for more sustainable choices along the AM product life cycle |

ANNEX 2 - MTC internal CU Design Meeting

**Metal AM–Sustainability, Recycling & Circularity (Draft 1)**

**General information about the CU:**

- **Target:** Additive Manufacturing Professional Profiles /Occupations - Engineers, supervisors, coordinators and designers;
- **Objectives of new CU Metal AM ustainability, recycling and circularity – provide a detail insight into the sustainability of metal AM processes**
- **Precedence**:CU00 Overview on AM process (as optional)
- **Entry level:** EQF level 4

## Course content and structure

| **Metal AM Sustainability, Recycling and Circularity** | RECOMENDED CONTACT HOURS |
|---|---|
| **SUBJECT TITLE** | |
| Overview of sustainability | 1 |
| Potential benefits of AM on sustainability | 1 |
| Life cycle analysis | 1 |
| Metal AM process chains and their impact on sustainability | 1 |
| Impact of feed-stock production, management and reuse/recycling | 1.5 |
| Impact of material & process selection | 1 |
| Impact of part design | 2 |
| Impact of AM build process | 1 |
| Impact of Post processing | 1 |
| Impact of Metal AM facility design and operation | 1 |
| Concept & practice of circularity | 1 |
| Repair & recycling approaches in metal AM | 1 |
| Resume and final words | 0.5 |
| Total | 14 |
| WORKLOAD | 28 |

## Learning outcomes

| **LEARNING OUTCOMES – Metal AM sustainability, recycling and circularity** | |
|---|---|
| **LEVEL** | **Advanced** |
| **KNOWLEDGE** | Detailed knowledge of:<br>– Sustainability - economic, climate change, critical raw materials, supply chain resilience/reshoring, government policy and standards<br>– Tools for sustainability assessment –LCA<br>– Impact of metal AM process chains on sustainability<br>– Concept of circularity, repair and recycling in metal AM |
| **SKILLS** | – Understand how sustainability effects our lives<br>– Comment on sustainable tools and their limitations<br>– Make informed decisions regarding the AM process chain with sustainability in mind |

ANNEX 3 - Feedback from EWF – 01/07/2022

**Metal AM–Sustainability, Recycling & Circularity (Draft 2)**

## General information about the CU:

- **Target:** Additive Manufacturing Professional Profiles /Occupations - Engineers, supervisors, coordinators and designers.
- **Objectives of new CU Metal AM Sustainability, Recycling and Circularity – provide a detailed insight into the sustainability of metal AM processes**
- **Precedence**:CU00 Overview on AM process and CU73 Introduction to sustainability for AM
- **Entry level:** EQF level 4

## Course content and structure

| **Metal AM sustainability, recycling and circularity** | RECOMENDED CONTACT HOURS |
|---|---|
| **SUBJECT TITLE** | |
| Overview of sustainability | 0.5 |
| Potential sustainability benefits of AM | 0.5 |
| Measuring and modelling sustainability | 0.5 |
| Overview of metal AM process chains and their impact on sustainability | 0.5 |
| Impact of feed-stock production, management and reuse/recycling | 0.75 |
| Impact of material & process selection | 0.5 |
| Impact of part design | 0.75 |
| Impact of AM build process | 0.5 |
| Impact of Post processing | 0.5 |
| Impact of Metal AM facility design and operation | 0.5 |
| Concept & practice of circularity | 0.5 |
| Repair & recycling approaches in metal AM | 0.5 |
| Recap , assessment and complete post CU | 0.5 |
| Total | 7 |
| WORKLOAD | 14 |

**Learning outcomes**

| LEARNING OUTCOMES – Metal AM sustainability, recycling and circularity | |
|---|---|
| LEVEL | Basic |
| KNOWLEDGE | **Advanced** and critical understanding of the theory, principles and applicability of:<br>– Sustainability - economic, climate change, critical raw materials, supply chain resilience/reshoring, government policy and standards<br>– Tools for sustainability assessment –LCA<br>– Impact of metal AM process chains on sustainability<br>– Concept of circularity, repair and recycling in metal AM |
| SKILLS | – Understand Recognise different ways in which sustainability effects our lives<br>– Comment on sustainable tools and their limitations Compare sustainable tools considering their advantages and limitations in Metal AM production<br>Make informed decisions regarding the AM process chain with sustainability in mind |

**Adelaide Almeida**
This is not an active verb according Bloom taxonomy

**Adelaide Almeida**
Alos we could add: Identify the different concepts related to sustainability for metal AM

**Adelaide Almeida**
Suggest to replace

**Adelaide Almeida**
Would it make sense to say: Evaluate the AM process chain to optimize the sustainability process in each segment

## ANNEX 4 - CU Draft 2 Description Review 07/07/2022

**Metal AM–Sustainability, ~~Recycling &~~ Circularity (Draft 3 generated 7th July review meeting)**

**General information about the CU:**

- **Target:** Additive Manufacturing Professional Profiles /Occupations - Engineers, supervisors, coordinators and designers.
- **Objectives of new CU Metal AM Sustainability, ~~Recycling~~ and Circularity – provide a detailed insight into the sustainability of metal AM processes**
- **Precedence**:CU00 Overview on AM process and CU73 Introduction to sustainability for AM
- **Entry level:** EQF level 4

**Course content and structure**

| Metal AM sustainability, recycling and circularity | RECOMENDED CONTACT HOURS |
|---|---|
| SUBJECT TITLE | |
| Overview of sustainability | 0.5 |
| Concept & Practice of Circularity | 0.5 |
| Potential sustainability benefits of AM | 0.5 |
| Measuring, predicting and justifying sustainability | 0.5 |
| Overview of metal AM process chains and their impact on sustainability | 0.5 |
| Impact of AM feed-stock on sustainability | 0.5 |
| Impact of part design and material selection | 1.0 |
| Impact of AM process selection and build set-up on sustainability | 1.0 |
| Impact of Part post processing on sustainability | 0.5 |
| Impact of Metal AM facility design and operation | 0.5 |
| Repair, reuse & recycling approaches in metal AM | 0.5 |
| Recap on all topics covered, assessment and complete post CU survey | 0.5 |
| Total | 7 |
| WORKLOAD | 14 |

AA **Adelaide Almeida**
Although it important part of the CU delivery, we can. not consider it as a subject of the CU. We can add a not on the implementation guideline

**Learning outcomes**

| LEARNING OUTCOMES – Metal AM sustainability, recycling and circularity | |
|---|---|
| LEVEL | Advanced |
| KNOWLEDGE | Detailed knowledge of:<br>– Sustainability - economic, climate change, critical raw materials, supply chain resilience/reshoring, government policy and standards<br>– Tools for sustainability assessment –LCA<br>– Impact of metal AM process chains on sustainability<br>– Concept of circularity, repair and recycling in metal AM |
| SKILLS | – Understand how sustainability effects our lives<br>– Comment on sustainable tools and their limitations<br>– Make informed decisions regarding the AM process chain with sustainability in mind |

AA **Adelaide Almeida**
Please see comments and changes to the knowledge and skills in Page 10

## ANNEX 5 - CU Draft 3 Description Review 08/07/2022

The comments from the meeting are shown in blue in the description below

**Metal AM–Sustainability, Circularity (Draft 4 generated 8th July review meeting)**

### General information about the CU:

- **Target:** Additive Manufacturing Professional Profiles /Occupations - Engineers, supervisors, coordinators and designers.
- **Objectives of new CU Metal AM Sustainability and Circularity – provide a detailed insight into the sustainability of metal AM processes**
- **Precedence**:CU00 Overview on AM process and CU73 Introduction to sustainability for AM
- **Entry level:** EQF level 4

### Course content and structure

| Metal AM sustainability and circularity | RECOMENDED CONTACT HOURS |
|---|---|
| SUBJECT TITLE | |
| Overview of sustainability | 0.5 |

| | |
|---|---|
| Concept & Practice of Circularity | 0.5 |
| Potential sustainability benefits of AM | 0.5 |
| Measuring, predicting, and justifying sustainability | 0.5 |
| Overview of metal AM process chains and their impact on sustainability | 0.5 |
| Impact of AM feedstock on sustainability | 0.5 |
| Impact of part design and material selection | 1.0 |
| Impact of AM process selection and build set-up on sustainability | 1.0 |
| Impact of Part post processing on sustainability | 0.5 |
| Impact of Metal AM facility design and operation | 0.5 |
| Repair, reuse & recycling approaches in metal AM | 0.5 |
| Recap on all topics covered, assessment and complete post CU survey | 0.5 |
| Total | 7 |
| WORKLOAD | 14 |

## Learning outcomes

| LEARNING OUTCOMES – Metal AM sustainability and circularity | |
|---|---|
| **LEVEL** | **Advanced** |
| **KNOWLEDGE** | Detailed knowledge of:<br>– Sustainability - economic, climate change, critical raw materials, supply chain resilience/reshoring, government policy and standards<br>– Tools for sustainability assessment –LCA<br>– Impact of metal AM process chains on sustainability<br>– Concept of circularity, repair and recycling in metal AM |
| **SKILLS** | – Understand how sustainability effects our lives<br>– Comment on sustainable tools and their limitations<br>– Make informed decisions regarding the AM process chain with sustainability in mind |

## ANNEX 6 - Notes of meeting of 05/09/22

Black text was prepared by DW prior to meeting and blue text was added at the meeting

**Course content and structure - discussion**

**1. AM process chain** – covered several existing CUs including CU36 (coordination of AM).

**2. AM processes;**

- Attendees should have taken CU00 + CU01 (DED-Arc) +CU08 (DED-LB) +CU15(PBF-LB)
- Resume of CU00,01, 05, 08 with a focus on aerospace materials/applications
- Provide an overview of other metal AM processes – PBF-EB, DED-EB, bind&sinter (binder jetting, metal MX, jetting metal filled resin)
- Overview of polymer AM processes

**3. Opportunities and challenges with AM;**

- Generic commercial/technical benefits but specifically aligned to the aerospace sector.
- Generic challenges/limitations of AM but presented in an aerospace context (ie what does it mean for aerospace parts)

**4. Adoption of AM in aerospace sector** – brief timelines through to present day to give a sense of the time it takes to gain approval, supported by aerospace case studies.

**5. Barriers to adoption and how they are being addressed**

- Need to mention aerospace parts classification /criticality .
- Standards / certification /qualification.

**6. Design for AM** (DfAM)

- Principles + software
- Aerospace case studies – focusing on the DfAM details
- Benefits and risks with DfAM

**7. AM Materials**

Introduction and warning that AM parts are different (microstructure & properties)

Metal AM

- PBF-LB materials & properties
- PBF-EB materials & properties
- DED- Arc/LB – materials and properties

Polymer AM

**8. Effect of Post processing** – perhaps part quality should come first ?

**9. Part quality**

- Issues and impact on performance (including fatigue) – surface finish, accuracy, defects.
- Defects - Sources in AM processes – PBF-LB (air flow, weld spatter etc), PBF-EB, DED-arc/LB , build interruptions (even M400 has 10 mins build pauses to automatically clean and swop filters).
- Inspection of AM parts and challenges

- Impact of process modelling, in-process measurement

**10. Quality management and traceability**

- Managing and assessing feed-stock
- Compliance with process plan
  Note: Lots of information in CU36 coordination
  Some design software (NTOPOLOGY sometimes introduced errors)

**11. Future opportunities**

- New processes
- Multi material AM
- In-process monitoring eliminating inspection – in-process NDT
- Dynamic process control (ie not a fixed process!!)

**12. Sustainability & circularity**

- AM for automated repair
- Repair of AM parts

Note: need to consider number of powder recycles, single versus multi melts, new powder recycling options (including 6K).

## ANNEX 7 - Notes of meeting of 20/09/22

Comments/changes generated in the meeting marked in brown text

Q- does this include space? – no

Q- civil and military aerospace – yes

**General information about the CU:**

- **Target:** AM engineers/coordinators
- **Objectives of new CU –** new competence unit will focus on the specific requirements of the aerospace sector in adopting AM. The course will target engineers/coordinators who are working towards or have completed AM engineer/coordinator qualification
- **Precedence**: CU00, CU01 (DED-Arc), CU08 (DED-LB), CU15(PBF-LB), CU25 (post processing) – see appendix for details

Q- is necessary that all of these CUs have been completed before undertaking CU?

This CU must build upon but not replace the existing AM process CUs

It may be acceptable to take one of the 2 DED CUs (either CU01 or CU08) but CU15 and CU25 are both essential

Q- is there sufficient information on polymer AM processes in CU00

Need to review the content of the polymer AM specific CUs to see if they can be skipped

- **Entry level:** EQF level 4

| **AM for Aerospace & Part Quality Control** | RECOMENDED CONTACT HOURS |
|---|---|
| **SUBJECT TITLE** | |
| AM processes and the process chain (generic and then refresh on metal and polymers<br><br>But with a focus on aerospace relevant processes, information and case studies | 1 ok |
| Overview of other metal AM processes – EB, binder jetting | 1 ok |
| Overview of polymer AM processes<br>We need to focus on the most appropriate processes (PBF-LB. MEXT, vat polymerization…) | 1 ok |
| Opportunities and challenges with AM<br>Needs to have an aerospace focus, what are the particular characteristics and requirements of the aerospace sector the problem to solve (short lead-time flexibility, supply chain, light weight etc, cost-perhaps) wider benefits……. | 1 ok |
| Sustainability & circularity<br>Not entirely sure that it should be here or later<br>Feed-stock recovery | 1 ok |

| | |
|---|---|
| Mention at the start<br>Issues about material waste/ spec etc… (once only virgin powder)<br>Repair…is it better or worse | |
| Adoption of AM in aerospace sector<br>Include history of adoption to show how long it takes to introduce things<br>Good and bad examples -Ewira etc.<br>Bad first – what are the lessons ?<br>Good last to finish on a positive note | 1 ok |
| Design for AM<br>Freedom and benefits<br>Software tools and approaches | 1 |
| Barriers to adoption of AM in the aerospace sector..<br>This is really important ..<br>Issues – low productivity, poor reliability, lack of material data, transfer of information, very fast moving, no history and approval part-by-part not process.<br>Material availability – even if the material can be processed the properties are different. Impact of down stream processing, surface finish, inspection etc.<br>Certification, qualification and standards; helps to reduce risk but slow down introduction. Need to change internal processes, system is designed for small, slow changes (not AM).<br>How to overcome …..the more we do the easier it gets and new approaches to inspection , certification and qualification…..<br>Is AM is the same as any other manufacturing process – potential group discussion ?<br>Polymer are simpler but have similar problems (cost is less, productivity is higher, applications currently less demanding) but this may change…new composite machines will change this. | 1.5 |
| Quality management & traceability<br>Is this in the right place ?<br>Useful information in several other CUs including coordinating | 1.5 ok |
| Certification, qualification and standards<br>Aerospace part categories<br>Material quality sets<br>Cost of qualifying material & limited read across materials<br>AMS 7003 – AM production for aerospace – any variation and build failures will condemn the process<br>Casting is often more variable than AM but this is ignored by aerospace companies<br>ASTM and SAE both has design variable standards<br>Adhere to current QCS process and then change the process based on the evidence | |
| AM Materials and their properties<br>Part categories to material quality link<br>Metals<br>polymers | 1.5 ok |
| Impact of Post processing<br>Polymers – infiltrate and finish<br>Metal – heat treatment, HIP, finishing, peening (heat treatment book) | 1 ok |
| Part quality<br>How/ when to inspect parts<br>100% inspection<br>Multiple inspection<br>In-process monitoring data to avoid / reduce or target inspection process<br>Need to look at polymer part testing | 1 ok |

| | |
|---|---|
| TAS to see what they do<br>Surface finish - Standards specify min surface finish for inspection | |
| Future perspective on AM in aerospace<br>Dramatic changes to aerospace sector;<br>Hydrogen fuel<br>Electrification<br>New opportunities<br>Number of flying parts made today<br>Future predictions of part production<br>New technolology;<br>• New processes<br>• Multi material AM<br>• In-process monitoring eliminating inspection – in-process NDT<br>• Dynamic process control (ie not a fixed process!!) | 0.5 ok |
| Total | 14 |
| WORKLOAD | 28 |

The information collected at the meeting was used to populate the knowledge / skills and detailed content description

| LEVEL | ADVANCED |
|---|---|
| KNOWLEDGE | Knowledge and critical understanding of the different metal and polymer AM processes which are particularly applicable to the aerospace sector.<br><br>Understand of the opportunities and challenges of AM, particularly when applied to the aerospace sector<br><br>Knowledge of the history of AM adoption in the aerospace sector and an insight context this knowledge brings<br><br>Knowledge of the particular requirements of the aerospace sector<br><br>– DED-Arc equipment, accessories, including build platform, feedstock and other consumables<br><br>– DED-Arc process parameters and variables, including post processing operations |
| SKILLS | Assess the possibility of manufacturing a specific part with DED-Arc based on the characteristics and limitations of the process<br><br>Relate the influence of the process parameters, build platform, feedstock and other consumables with the properties of the as built part.<br><br>Implement different methodologies related with to process parameters and deposition strategies for reducing distortion of as built parts<br><br>Distinguish the different regimes and processes of failure and describe the factors controlling them and the boundaries and limits between them.<br><br>Select specific materials for different applications to meet part requirements.<br><br>Identify specific metallurgical aspects of DED-Arc parts<br><br>Define DED-Arc parameters for manufacturing specific parts |

| LEVEL | ADVANCED |
|---|---|
| | Adjust process parameters, manufacturing strategy and set up to prevent part defects and process related issues |

## ANNEX 8 - Notes of Meeting - 24/10/22

Comments/changes generated in the meeting marked in blue text

**General information about the CU:**

- **Target:** AM engineers/coordinators
- **Objectives of new CU –** new competence unit will focus on the specific requirements of the aerospace sector in adopting AM. The course will target engineers/coordinators who are working towards or have completed AM engineer/coordinator qualification
- **Precedence**: CU00, CU01 (DED-Arc), CU08 (DED-LB), CU15(PBF-LB), CU25 (post processing) – see appendix for details
- **Entry level:** EQF level 4 should be level 6

Question IK? – do all of the listed CUs under precedence need to be undertake first?

Answer DW – yes although we may want to specify that just one of the DED CUs (either CU01 or CU08 will suffice). It is important that this module is not regarded as an alternative to taking the full CUs. However, if someone wants to take CU on its own, they will not be able to.

Note: the overview of the content was not reviewed at the meeting on 24.10.22, only the detailed content described later. However, the overview will need to be updated based on the recommended changes to the detailed description.

| **AM for Aerospace & Part Quality Control** | RECOMENDED CONTACT HOURS |
|---|---|
| **SUBJECT TITLE** | |
| **Metal AM processes**<br>Overview of metal AM processes of particular relevance to aerospace sector; | 1.5 |
| **Polymer AM processes**<br>Overview of polymer AM processes of particular relevance to aerospace sector; | 1 |
| **Ceramic AM processes**<br>Overview of ceramic AM processes of particular relevance to aerospace sector | 0.5 |
| **Opportunities and challenges with AM**<br>Overview of the benefits and limitations of AM.<br>Particular requirements of the aerospace sector and potential for AM to fulfil them | 1 |
| **Adoption of AM in aerospace sector**<br>where AM is used in fixed and rotary wing aircraft and why | 1 |
| **Design for AM**<br>How design for AM can give benefits for aerospace parts , including the software tools and manufacturing considerations | 1 |

| | |
|---|---|
| **Barriers to adoption**<br>Commercial, technical and regulatory barriers | 1.5 |
| **Certification, qualification and standards in the aerospace sector**<br>Overview of certification and qualification process in the aerospace industry including key topics of aerospace part categories, material quality sets, generation of design allowables and the impact of standards. | 1.5 |
| **AM Materials and their properties**<br>Metals<br>polymers | 1.5 |
| **Impact of build parameters and post processing on part quality & properties** | 1 |
| **Specifying & Assessing part quality**<br>Challenges and opportunities for part quality assessment for aerospace AM parts.<br>Inspection strategies including use of witness samples, final part inspection and the potential impact of in-process quality assessment. | 1 |
| **Sustainability & Circularity**<br>Environmental benefits from part performance and manufacturing, including feed-stock management and part repair and end of life considerations. | 1 |
| **Future perspective on AM in aerospace**<br>How changing requirements and manufacturing technology developments could impact on the use of AM in the aerospace sector | 0.5 |
| Total | 14 |
| WORKLOAD | 28 |

**Note: learning outcomes were <u>not</u> reviewed at the meeting**

DW – need to think about how the CU will be delivered (ie intensive days or ½ days?)

IK- We tend to do it normally in shorter intervals because industry are always ones. Of course, this discussion here all you might all have this discussion. IT industry wants everything in in at least. Best is one day. If we would offer the course we would tend to give it in one day. This is probably the best accepted course duration for an introduction to AM in Aerospace for industry.

## ANNEX 9 - Notes of Meeting -16/11/22

Comments/changes generated in the meeting marked in <u>red</u> text

**General information about the CU:**

- **Target:** AM engineers/coordinators
- **Objectives of new CU –** new competence unit will focus on the specific requirements of the aerospace sector in adopting AM. The course will target engineers/coordinators who are working towards or have completed AM engineer/coordinator qualification

- **Precedence**: CU00, CU01 (DED-Arc), CU08 (DED-LB), CU15(PBF-LB), CU25 (post processing)*
- **Entry level:** EQF level 6

Note: CU must build upon but not replace the existing AM process CUs but is it necessary that all of these CUs have been completed before undertaking CU? . Perhaps It may be acceptable to take one of the 2 DED CUs (either CU01 or CU08) but CU15 and CU25 are both essential

CR- Aim of the course is okay

CR-2 days is optimal 1 day is too short and 3 is too long

DW - is it better to do one day and then a space, let the people assimilate it, do a bit of homework and then come back for the second day or is it better just to do back-to-back days?

CR – depends on the persons circumstances. Concentrated block learning has the benefit of keeping the information fresh but if you split the days over two weeks it gives you time to do some homework ..for example looking at a part which the company makes to see if it is suitable for AM….

| **AM for Aerospace & Part Quality Control**<br>**SUBJECT TITLE** | RECOMENDED CONTACT HOURS |
|---|---|
| **Metal AM processes**<br>Overview of metal AM processes of particular relevance to aerospace sector;<br>OK | 1.5 |
| **Polymer AM processes**<br>Overview of polymer AM processes of particular relevance to aerospace sector;<br>OK | 1.5 |
| ~~**Ceramic AM processes**~~<br>~~Overview of ceramic AM processes of particular relevance to aerospace sector~~<br>~~CR- covering plastics as well as metals parts is okay, ceramics is really for the future and needs to be moved to the end~~ | 0 |
| **Opportunities and challenges with AM**<br>Overview of the benefits and limitations of AM.<br>Particular requirements of the aerospace sector and potential for AM to fulfil them<br>Need to emphasise the regulatory requirements | 1 |
| **Adoption of AM in aerospace sector**<br>where AM is used in fixed and rotary wing aircraft and why<br>OK | 1 |
| **Design for AM**<br>How design for AM can give benefits for aerospace parts , including the software tools and manufacturing considerations<br>OK | 1<br>Could be longer |
| **Barriers to adoption**<br>Commercial, technical and regulatory barriers | 1 |
| **Certification, qualification and standards in the aerospace sector**<br>Overview of certification and qualification process in the aerospace industry including key topics of aerospace part categories, material quality sets, generation of design allowables and the impact of standards.<br>Could be longer (or move 30 mins from previous session)<br>Note: lots of useful information in CU36 – coordination of AM | 1.5 |
| **AM Materials and their properties**<br>Metals<br>Polymers | 1.5 |

| | |
|---|---|
| OK | |
| **Impact of feed-tock, build parameters and post processing on part quality & properties**<br>This is a big and complex topic | 1 |
| **Specifying & Assessing part quality**<br>Challenges and opportunities for part quality assessment for aerospace AM parts. Inspection strategies including use of witness samples, final part inspection and the potential impact of in-process quality assessment.<br>OK | 1 |
| **Sustainability & Circularity**<br>Environmental benefits from part performance and manufacturing, including feed-stock management and part repair and end of life considerations.<br>OK | 1 |
| **Future perspective on AM in aerospace**<br>How changing requirements and manufacturing technology developments could impact on the use of AM in the aerospace sector<br><br>**Ceramic AM processes**<br>Overview of ceramic AM processes of particular relevance to aerospace sector<br>CR- covering plastics as well as metals parts is okay, ceramics is really for the future and needs to be moved to the end | 1<br>0.5 hr too short |
| Total | 14 |
| WORKLOAD | 28 |

DW- Do you have any questions?

CR -No this is familiar to me …I've have been reading a book about how to implement AM

It was actually a very interesting read because it deals with stakeholders and how people view things differently and also just how difficult it actually is in terms of process verification….is probably the best read when you're trying to do a technology introduction like this, and especially geared towards the more demanding engineering industries.

https://www.fabbaloo.com/2019/05/book-of-the-week-additive-manufacturing-change-management

"Additive Manufacturing Change Management: Best Practices" by David M. Dietrich, Michael Kenworthy, and Elizabeth A. Cudney.

CR- seems okay

| LEVEL | ADVANCED |
|---|---|
| KNOWLEDGE | Knowledge and critical understanding of the different metal and polymer AM processes which are particularly applicable to the aerospace sector.<br><br>Understand of the opportunities and challenges of AM, particularly when applied to the aerospace sector.<br><br>Knowledge of the history of AM adoption in the aerospace sector and the reasons for the relatively slow rate of uptake.<br><br>Understanding of the certification & qualification process for aerospace parts.<br><br>Knowledge of AM materials and the impact of build/post processing parameters on the quality and properties of parts.<br><br>Understanding how to assess part quality to meet aerospace requirements. |

| LEVEL | ADVANCED |
|---|---|
| SKILLS | Ability to “balance” the opportunities and challenges for introduction of AM in the aerospace sector.<br>Relate the influence of the build and post process parameters on the quality and properties of AM parts.<br>Able to explain the impact of the aerospace qualification, certification and standards on the deployment of AM including part categories and material quality sets.<br>Describe where AM is currently used in the aerospace sector and the reasons for its selection.<br>Select specific materials for different aerospace applications to meet part requirements.<br>Specify the inspection approach to be used to ensure part quality. |

CR- Overall view of course

I think it's a good introduction ….really good for managers and to an outline of what some of their engineers are looking to do.
Covers a lot of the process workflow.
You're saying up front this is what can be done…these are the challenges and I think this is a really good course for that.

## ANNEX 10 - Notes of Meeting - 21/11/22

Comments/changes generated in the meeting marked in green text
(comments from previous meetings are shown in red and blue text)

**General information about the Competence Unit (CU):**

- **Target:** AM engineers/coordinators
- **Objectives of new CU –** new competence unit will focus on the specific requirements of the aerospace sector in adopting AM. The course will target engineers/coordinators who are working towards or have completed AM engineer/coordinator qualification
- **Precedence**: CU00, CU01 (DED-Arc), CU08 (DED-LB), CU15(PBF-LB), CU25 (post processing) -CR need to explain what these CUs are – provide title in every case
- **Entry level:** EQF level 6

CR- Aim of the course is okay

CR-2 days is optimal 1 day is too short and 3 is too long

DW - is it better to do one day and then a space, let the people assimilate it, do a bit of homework and then come back for the second day or is it better just to do back-to-back days?

CR – depends on the persons circumstances. Concentrated block learning has the benefit of keeping the information fresh but if you split the days over two weeks it gives you time to do some homework ..for example looking at a part which the company makes to see if it is suitable for AM….

| **AM for Aerospace & Part Quality Control**<br>**SUBJECT TITLE** | RECOMENDED CONTACT HOURS |
|---|---|
| **Metal AM processes**<br>Overview of metal AM processes of particular relevance to aerospace sector;<br>OK | 1.5 |
| **Polymer AM processes**<br>Overview of polymer AM processes of particular relevance to aerospace sector;<br>OK | 1 |
| **Ceramic AM processes**<br>Overview of ceramic AM processes of particular relevance to aerospace sector<br>CR- covering plastics as well as metals parts is okay, ceramics is really for the future and needs to be moved to the end | 0.5 |
| **Opportunities and challenges with AM**<br>Overview of the benefits and limitations of AM.<br>Particular requirements of the aerospace sector and potential for AM to fulfil them<br>Need to emphasise the regulatory requirements | 1 |
| **Adoption of AM in aerospace sector**<br>where AM is used in fixed and rotary wing aircraft and why<br>OK | 1 |
| **Design for AM**<br>How design for AM can give benefits for aerospace parts , including the software tools and manufacturing considerations<br>OK | 1 |

| | |
|---|---|
| **Barriers to adoption**<br>Commercial, technical and regulatory barriers | 1.5 |
| **Certification, qualification and standards in the aerospace sector**<br>Overview of certification and qualification process in the aerospace industry including key topics of aerospace part categories, material quality sets, generation of design allowables and the impact of standards.<br>Could be longer (or move 30 mins from previous session) | 1.5 |
| **AM Materials and their properties**<br>Metals<br>Polymers<br>OK | 1.5 |
| **Impact of feed-tock, build parameters and post processing on part quality & properties**<br>This is a big and complex topic | 1 |
| **Specifying & Assessing part quality**<br>Challenges and opportunities for part quality assessment for aerospace AM parts.<br>Inspection strategies including use of witness samples, final part inspection and the potential impact of in-process quality assessment.<br>OK | 1 |
| **Sustainability & Circularity**<br>Environmental benefits from part performance and manufacturing, including feed-stock management and part repair and end of life considerations.<br>OK | 1 |
| **Future perspective on AM in aerospace**<br>How changing requirements and manufacturing technology developments could impact on the use of AM in the aerospace sector<br>Ceramics could go here | 0.5 |
| Total | 14 |
| WORKLOAD | 28 |

DW- Do you have any questions?

CR -No this is familiar to me …I've have been reading a book about how to implement AM

It was actually a very interesting read because it deals with stakeholders and how people view things differently and also just how difficult it actually is in terms of process verification….is probably the best read when you're trying to do a technology introduction like this, and especially geared towards the more demanding engineering industries.

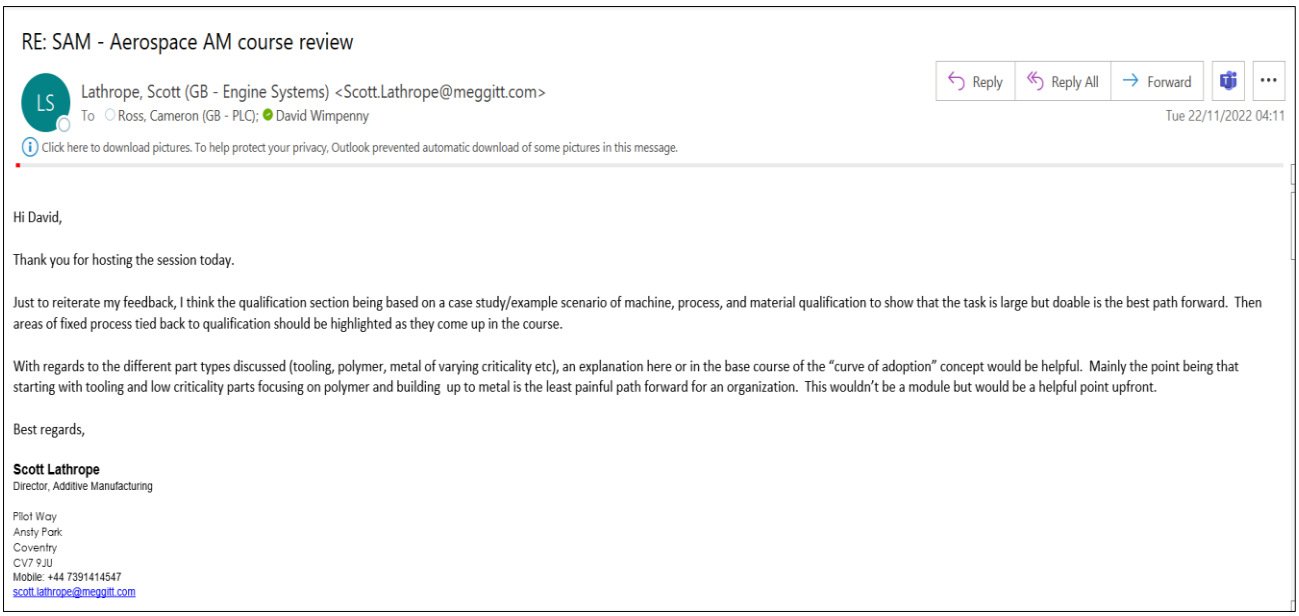
https://www.fabbaloo.com/2019/05/book-of-the-week-additive-manufacturing-change-management

"Additive Manufacturing Change Management: Best Practices" by David M. Dietrich, Michael Kenworthy, and Elizabeth A. Cudney.

CR- seems okay

| LEVEL | ADVANCED |
|---|---|
| KNOWLEDGE | Knowledge and critical understanding of the different metal and polymer AM processes which are particularly applicable to the aerospace sector.<br><br>Understand of the opportunities and challenges of AM, particularly when applied to the aerospace sector.<br><br>Knowledge of the history of AM adoption in the aerospace sector and the reasons for the relatively slow rate of uptake.<br><br>Understanding of the certification & qualification process for aerospace parts.<br><br>Knowledge of AM materials and the impact of build/post processing parameters on the quality and properties of parts.<br><br>Understanding how to assess part quality to meet aerospace requirements. |
| SKILLS | Ability to “balance” the opportunities and challenges for introduction of AM in the aerospace sector.<br><br>Relate the influence of the build and post process parameters on the quality and properties of AM parts.<br><br>Able to explain the impact of the aerospace qualification, certification and standards on the deployment of AM including part categories and material quality sets.<br><br>Describe where AM is currently used in the aerospace sector and the reasons for its selection.<br><br>Select specific materials for different aerospace applications to meet part requirements.<br><br>Specify the inspection approach to be used to ensure part quality. |

CR- Overall view of course
I think it's a good introduction ….really good for managers and to an outline of what some of their engineers are looking to do.
Covers a lot of the process workflow.
You're saying up front this is what can be done…these are the challenges and I think this is a really good course for that.



RE: SAM - Aerospace AM course review

Lathrope, Scott (GB - Engine Systems) <Scott.Lathrope@meggitt.com>
To Ross, Cameron (GB - PLC); David Wimpenny

Reply | Reply All | Forward

Tue 22/11/2022 04:11

Click here to download pictures. To help protect your privacy, Outlook prevented automatic download of some pictures in this message.

Hi David,

Thank you for hosting the session today.

Just to reiterate my feedback, I think the qualification section being based on a case study/example scenario of machine, process, and material qualification to show that the task is large but doable is the best path forward. Then areas of fixed process tied back to qualification should be highlighted as they come up in the course.

With regards to the different part types discussed (tooling, polymer, metal of varying criticality etc), an explanation here or in the base course of the "curve of adoption" concept would be helpful. Mainly the point being that starting with tooling and low criticality parts focusing on polymer and building up to metal is the least painful path forward for an organization. This wouldn't be a module but would be a helpful point upfront.

Best regards,

**Scott Lathrope**
Director, Additive Manufacturing

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CV7 9JU
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scott.lathrope@meggitt.com

## ANNEX 11 - Analysis of document CU73

### General information about the CU:

- **Target:** Additive Manufacturing Professional Profiles /Occupations - Engineers, supervisors, coordinators, and designers.
- **Objectives of new CU Metal AM Sustainability and Circularity – provide a detailed insight into the sustainability of metal AM processes**
- **Precedence**:CU00 Overview on AM process and CU73 Introduction to sustainability for AM
- **Entry level:** EQF level 6

### Course content and structure

| **Metal AM sustainability and circularity** | RECOMENDED CONTACT HOURS |
|---|---|
| **SUBJECT TITLE** | |
| Overview of sustainability | 0.5 |
| Concept & Practice of Circularity | 0.5 |
| Potential sustainability benefits of AM | 0.5 |
| Measuring, predicting and justifying sustainability | 0.5 |
| Overview of metal AM process chains and their impact on sustainability | 0.5 |

| Metal AM sustainability and circularity | RECOMENDED CONTACT HOURS |
|---|---|
| **SUBJECT TITLE** | |
| Impact of AM feed-stock on sustainability | 0.5 |
| Impact of part design and material selection | 1.0 |
| Impact of AM process selection and build set-up on sustainability | 1.0 |
| Impact of Part post processing on sustainability | 0.5 |
| Impact of Metal AM facility design and operation | 0.5 |
| Repair, reuse & recycling approaches in metal AM | 0.5 |
| Recap on all topics covered, assessment and complete post CU survey | 0.5 |
| Total | 7 |
| WORKLOAD | 14 |

## Learning outcomes

| LEARNING OUTCOMES – Metal AM sustainability and circularity | |
|---|---|
| **LEVEL** | **Advanced** |
| **KNOWLEDGE** | Detailed knowledge of:<br>– Sustainability - economic, climate change, critical raw materials, supply chain resilience/reshoring, government policy and standards<br>– Tools for sustainability assessment –LCA<br>– Impact of metal AM process chains on sustainability<br>– Concept of circularity, repair and recycling in metal AM |
| **SKILLS** | – Understand how sustainability effects our lives<br>– Comment on sustainable tools and their limitations<br>– Make informed decisions regarding the AM process chain with sustainability in mind |

As can be seen, there are 5 short sections (30 minutes each one), apparently related to general concepts on sustainability, circularity, potential influence of AM on sustainability, and its prediction and measurement. The exception is the section "*Overview of metal AM process chains and their impact on sustainability*", which is focused on metal technologies, although it is also a brief section.

It could be argued whether the information to be provided to the trainee in these sections could be in a certain way repetitive with respect to the information already transferred to the trainee in the CU73, in which these concepts could have been partially covered, although under a different formulation and sequence. A possible exception or possibility of intensification could perhaps be raised regarding the information around the LCA impact quantification methodologies. Even though they could be generally raised in the CU73, a more extensive description and exemplification could take place in this metal-AM focused CU.
On the other hand, and in view of the subjects that make up the following block, this draft develops different subjects from this point on, which are related to the design and production supported by metallic AM technologies. It should be considered whether the LCA-related

information should be placed in standalone final block, in the case that these subjects go deeper in various aspects of sustainability of the metal AM process. This way, the presentation of a developed metal LCA case could be much more illustrative than in the initial stages, especially if paired with a bigger time slot (1h or so).

- Second block of subjects:

| **SUBJECT TITLE** | |
|---|---|
| Impact of AM feed-stock on sustainability | 0.5 |
| Impact of part design and material selection | 1.0 |
| Impact of AM process selection and build set-up on sustainability | 1.0 |
| Impact of Part post processing on sustainability | 0.5 |
| Impact of Metal AM facility design and operation | 0.5 |
| Repair, reuse & recycling approaches in metal AM | 0.5 |

These blocks focus on analyzing and presenting stages related to the design and production supported by metallic AM. Thus, it could be said that they make up the "core" of the CU, in the sense that it is in these subjects that the most important sustainability related specificities of metallic AM technologies are dealt with. Thus, 4 hours of training are deemed appropriate.

- There is a last block, which would act as a summary of all the previous subjects, and would include the final evaluation and survey:

| **SUBJECT TITLE** | |
|---|---|
| Recap on all topics covered, assessment and complete post CU survey | 0.5 |

As previously mentioned, before this last section, a presentation of an LCA example that could integrate design and production considerations could be beneficial. In this way, a quantitative example of the effect of possible alternatives on the impact of the product can be presented to the trainees, allowing them to better understand this procedure in a holistic and practical way.

# ANNEX 12 – Polymer AM Sustainability and Circularity

## General information about the CU:

- **Target:** Additive Manufacturing Professional Profiles /Occupations - Engineers, supervisors, coordinators, and designers.
- **Objectives of new CU Polymer AM Sustainability and Circularity – provide a detailed insight into the sustainability of polymer AM processes**
- **Precedence**:CU00 Overview on AM process and CU73 Introduction to sustainability for AM
- **Entry level:** EQF level 6

## Course content and structure

| **Polymer AM sustainability and circularity** | RECOMENDED CONTACT HOURS |
|---|---|
| **SUBJECT TITLE** | |
| Overview of polymer AM process chains and their impact on sustainability | 0.5 |
| Impact of AM feed-stock on sustainability | 1.0 |
| Impact of part design and material selection | 1.0 |
| Impact of AM process selection and build set-up on sustainability | 1.0 |
| Impact of Part post processing on sustainability | 0.5 |
| Impact of Polymer AM facility design and operation | 0.5 |
| Repair, reuse & recycling approaches in polymer AM | 0.5 |
| Measuring, predicting, and justifying sustainability | 1.5 |
| Recap on all topics covered, assessment and complete post CU survey | 0.5 |
| Total | 7 |
| WORKLOAD | 14 |

## Learning outcomes

| **LEARNING OUTCOMES – Polymer AM sustainability and circularity** | |
|---|---|
| **LEVEL** | **Advanced** |
| **KNOWLEDGE** | Detailed knowledge of:<br>– Sustainability - economic, climate change, critical raw materials, supply chain resilience/reshoring, government policy and standards<br>– Tools for sustainability assessment –LCA<br>– Impact of polymer AM process chains on sustainability<br>– Concept of circularity, repair and recycling in polymer AM |
| **SKILLS** | – Get information on how polymer AM affects products sustainability<br>– Make informed decisions regarding the AM process chain with sustainability in mind |

## General information about the CU:

- **Target**: Youth and newcomers (e.g. students from Vocational Education and Training (VET), high school and higher education; adults from non-manufacturing professional such as art).
- **Objectives of new CU:**
  - To raise awareness of additive manufacturing
  - To introduce AM career opportunities in various sectors
  - To identify career paths to be pursued in AM
  - To navigate finding job opportunities
- **Precedence**: CU00 Overview on AM process (as optional)
- **Entry level:** EQF level 2 as suggestion

## Course content and structure

| **Polymer AM sustainability and circularity** | RECOMENDED CONTACT HOURS |
|---|---|
| **SUBJECT TITLE** | |
| Introduction and Sectoral Applications | 1.5 |
| Career Pathways | 2.0 |
| Total | 3.5 |
| WORKLOAD | 7.0 |

## Learning outcomes

| **LEARNING OUTCOMES – Polymer AM sustainability and circularity** | |
|---|---|
| **LEVEL** | **Advanced** |
| **KNOWLEDGE** | Basic knowledge of:<br>– Main concept of AM<br>– Career pathways in AM |
| **SKILLS** | – Recognize AM as an innovative technology<br>– Recognize educational pathways in AM<br>– Identify possible jobs positions in AM |

## ANNEX 14 – New competence unit on Outlook of Professional Careers in Additive Manufacturing

- In order to decide on the current CU title, Slido was used to gather alternatives from members, the Slido result was

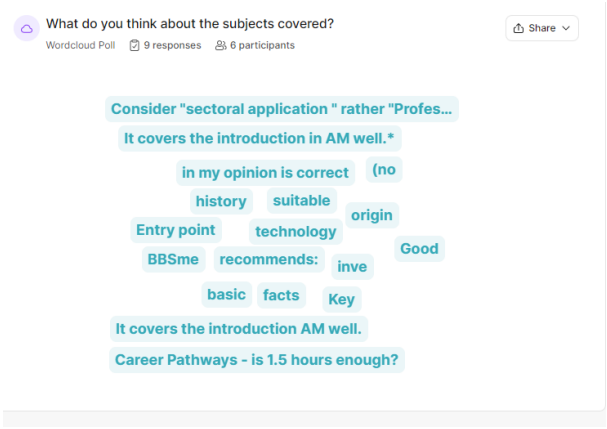

The alternatives were arranged;

1-Construct professional career in Additive Manufacturing X
2-Outlook on Additive Manufacturing
3-Careers in Additive Manufacturing
4-Professional Career in Additive Manufacturing: from a Beginner's to an Expert's Perspective
5-Additive Manufacturing for Beginners
6-Outlook and Careers in Additive Manufacturing
7- Outlook at professional careers in AM

- Among the options, number 7 got the highest vote from the members and was decided as the new CU's title.

## ANNEX 15 - Expert Validation Session collaborative approach

- To get members' opinions on the topics covered, a Slideo was shared. The results are shown below



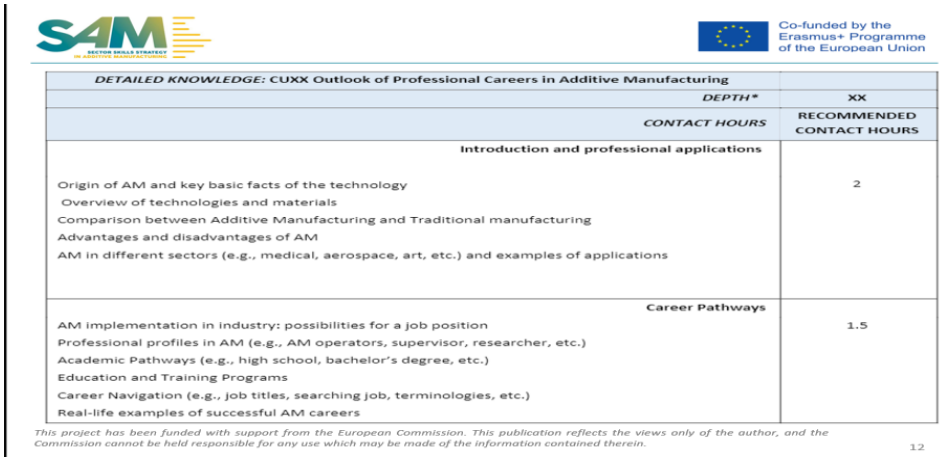

- The members agreed on the proficiency level of the CU is “Basic Level” according to EWF modular system and it is level 2 based on EQF.
- In addition, they stated verbally that the first subject shouldn't overlap with the CU00, which deals with a general overview of AM. Additionally, the subject should not go into history details etc.
- One of the members suggested that the first subject should be revised to “Introduction and Sectoral Implications”
- Based on the EWF modular system, CU proficiency is "Basic Level" and according to EQF level 2.



**Outlook of Professional Careers in AM**

| **LEARNING OUTCOMES –** Outlook of professional careers in AM | |
|---|---|
| **COMPETENCE UNIT/ULO** | **Basic** |
| **KNOWLEDGE** | Basic knowledge of :<br>-Main concept of AM<br>-Career pathways in AM |
| **SKILLS** | **-Recognize AM as an innovative technology**<br>**-Recognize its possibilities for application in different sectors**<br>**-Identify possible jobs positions in AM** |

*This project has been funded with support from the European Commission. This publication reflects the views only of the author, and the Commission cannot be held responsible for any use which may be made of the information contained therein.*



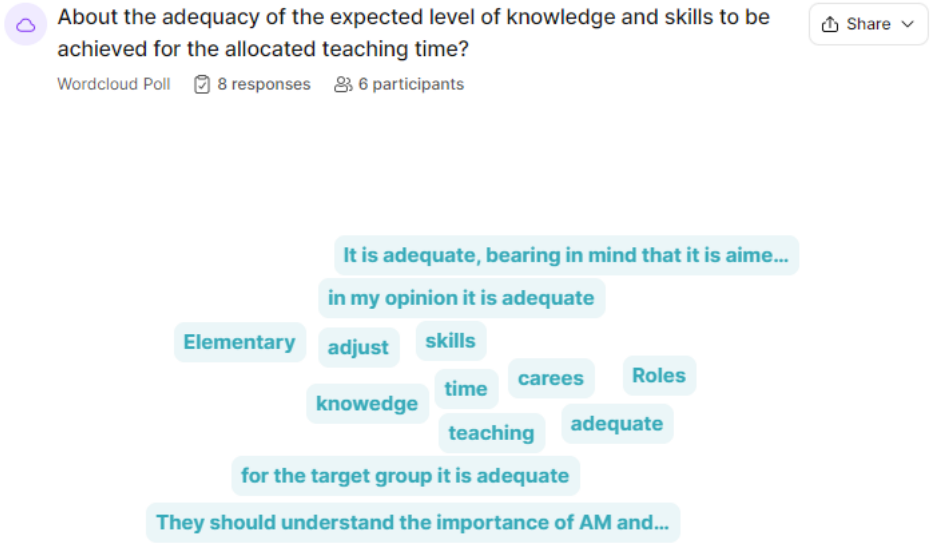
Co-funded by the Erasmus+ Programme of the European Union

| *DETAILED KNOWLEDGE:* CUXX Outlook of Professional Careers in Additive Manufacturing | |
|---|---|
| *DEPTH** | XX |
| *CONTACT HOURS* | RECOMMENDED CONTACT HOURS |
| **Introduction and professional applications**<br><br>Origin of AM and key basic facts of the technology<br>Overview of technologies and materials<br>Comparison between Additive Manufacturing and Traditional manufacturing<br>Advantages and disadvantages of AM<br>AM in different sectors (e.g., medical, aerospace, art, etc.) and examples of applications | 2 |
| **Career Pathways**<br><br>AM implementation in industry: possibilities for a job position<br>Professional profiles in AM (e.g., AM operators, supervisor, researcher, etc.)<br>Academic Pathways (e.g., high school, bachelor's degree, etc.)<br>Education and Training Programs<br>Career Navigation (e.g., job titles, searching job, terminologies, etc.)<br>Real-life examples of successful AM careers | 1.5 |

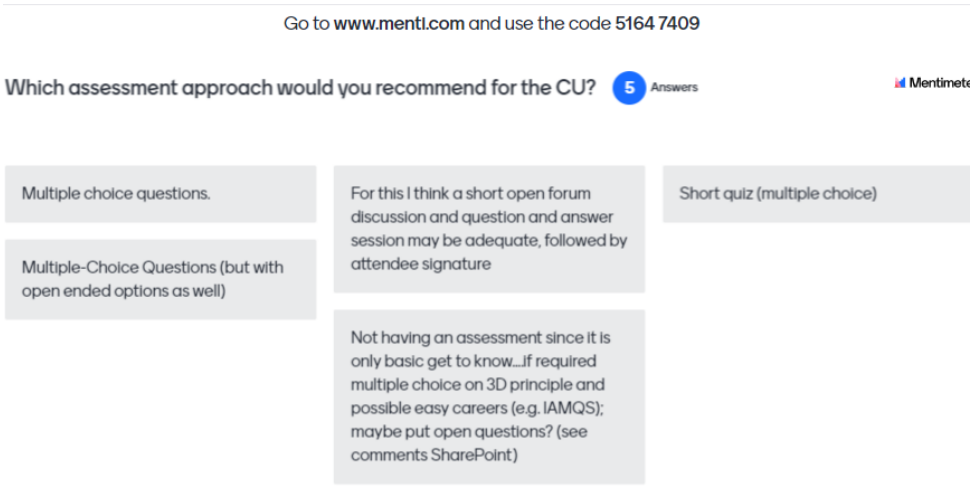
*This project has been funded with support from the European Commission. This publication reflects the views only of the author, and the Commission cannot be held responsible for any use which may be made of the information contained therein.*

12

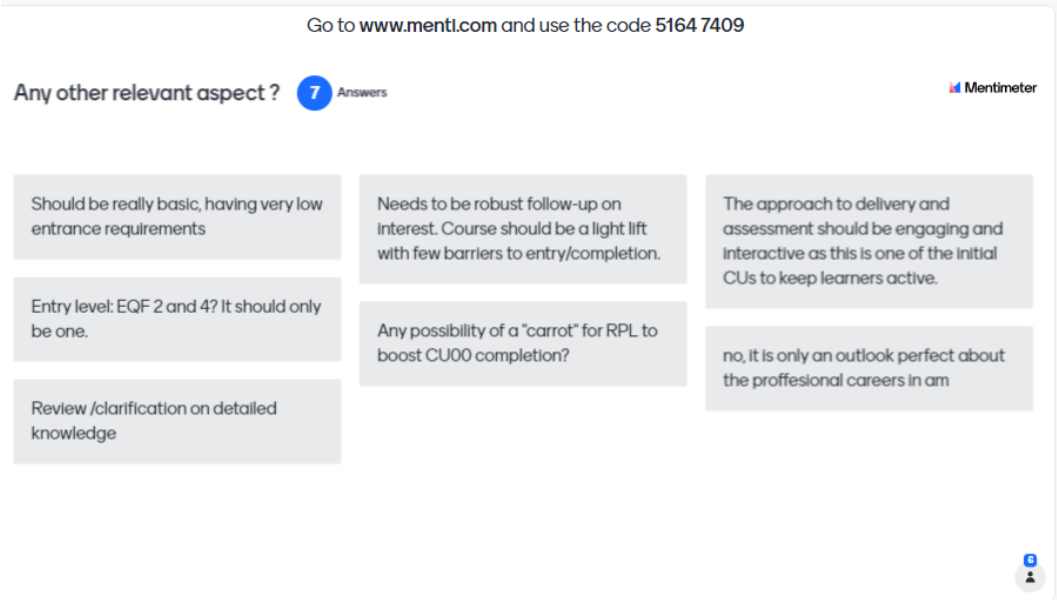
- Members were asked about the expected level of knowledge and skills required for the allocated teaching time. Their responses are shown below;




- Also stated verbally that the allocated time 1.5 hours to the second subject are not enough, it is better to increase as 2.00 hours. Moreover, the first subject can be decreased and set as 1.5 hours.
- The skills can be revised as the first "Recognize AM as an innovative technology" and the second one "Recognize its possibilities for application in different sectors" overlapping for this reason the second skills can be removed. On the other hand, there is not any item referring to the education pathway so one skill should be added addressing these skills.
- As a suggestion from BBS-me, the subject title namely "Advantages and disadvantages of AM" edited as "possibilities and limits of AM".
- The members put their opinions on Mentimeter about the appropriate assessment approach. The responds were given below;




- Since the IAMQS is based on a multiple-choice questions assessment method, the current CU multiple-choice question was approved. However, because of the nature of the CU, experts recommend interviews or open-ended questions to gather valuable information.
- Lastly, any other relevant questions were asked to the members, and the answers are shown below;




- One member suggested that CU00 could be a prerequisite of the current CU to boost CU00 completion.