Report on Curricula for Training and Knowledge Transfer

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Deliverable Datasheet

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Deliverable summary
This report presents the proposed curricula for training and knowledge transfer on AM research and education for UNIZAG FSB based on the mapping of all five partners (LTH, MUL, AIDIMME, UBRUN and UNIZAG FSB) on resources, expertise and projects in AM research delivered in D2.1.

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Nomenclature

Name	Description
INEX-ADAM	Increasing Excellence in Advanced Additive Manufacturing
EU	European Union
MUL	Montanuniversität Leoben
UNIZAG FSB	University of Zagreb, Faculty of Mechanical Engineering and Naval Architecture
UBRUN	Brunel University London
LTH	Lunds Tekniska Högskola
AIDIMME	Technology Institute on Metal-Processing, Wood, Furniture, Packaging and related industries
WP	Work package
SME	Small and medium-sized enterprise
R&D	Research and Development
CATeh	Centre for Additive Technology
AM	Additive Manufacturing
DfAM	Design for Additive Manufacturing
FGAM	Functionally Graded Additive Manufacturing
NDA	Non-Disclosure Agreement
SLS	Selective Laser Sintering
SLM	Selective Laser Melting
EBM	Electron Beam Melting
FFF	Fused Filament fabrication
PBF	Powder Bed Fusion
DSC	Differential Scanning Calorimetry
HPRC	High Pressure Capillary Rheometry
FEM	Finite Element Method
PSS	Product Service System
FGM	Functionally Graded Material
ISO	International Organization for Standardization
TC	Technical Committee of ISO

1. INEX-ADAM

Increasing Excellence in Advanced Additive Manufacturing (INEX-ADAM) is a 3-year European Union (EU) funded project to establish networking and synergy among the five research institutions through identification, planning and implementation of Additive Manufacturing (AM) research tracks. The project is coordinated by the University of Zagreb, Faculty of Mechanical Engineering and Naval Architecture (UNIZAG FSB) and supported by Brunel University London (UBRUN), Lunds Tekniska Högskola (LTH), Montanuniversität Leoben (MUL) and the Technology Institute on Metal-Processing, Wood, Furniture, Packaging and related industries (AIDIMME). The principle goal of this project is to widen the participation for collaborative research among the consortium partners and support the coordinating partner UNIZAG FSB with technical assistance and knowledge in the field of AM research.

The project consists of five Work packages (WP). UBRUN is leading WP2 for synergy strengthening and conducting the data mapping research. The purpose of WP2 is to establish the foundation for the project. The main objective of WP2 is to promote active networking of all consortium members by visiting the partners to carry out mapping of the member's capacities in AM research. The findings will enable a long-term view of synergy strengthening for cooperation in the field of AM. After mapping the level of knowledge, resources and expertise of each project partner, a high-level plan for knowledge transfer in the form of this report is documented the curricula for training and workshops proposed by each supporting partner LTH, MUL, AIDIMME and UBRUN. This will serve as a framework for WP3 about Raising Knowledge and Excellence on AM which will be led by LTH. The main deliverable from WP3 will be a compilation of the training materials for AM education which can be used for further teaching purposes.

2. Objective of Training and Knowledge Transfer

The purpose of this report serves to outline the proposed curricula from all four partners LTH, MUL, AIDIMME and UBRUN for a training and knowledge transfer programme for UNIZAG FSB. Based on the research competencies of each partner, a knowledge transfer and on-site training framework in Table 1 is used as a reference for the training plan. The completion of knowledge transfer activities such as training workshops will result in a number of valuable training materials being created. These materials will be systematically catalogued to support continuous knowledge transfer to other regional end users after the project. These activities will extend the knowledge from INEX-ADAM to other stakeholders, regional SMEs and start-ups. In addition, the knowledge transfer activities will also encourage end-users to develop joint projects with other industry and academic partners, thereby accelerating R&D investment in Croatia. At the end of the training session, each partner will evaluate the new level of knowledge of each participant through the use of surveys or questionnaires.

Table 1 Knowledge transfer and on-site training framework

Research area	Research domain / subject	LTH	MUL	AIDIMME	UBRUN
General area	Advanced Design (Topological Optimisation/lattice structure design and integration)	**X**		**X**	**X**
	Design for AM and process planning	**X**		**X**	**X**
	Material Modelling		**X**		
	Simulation	**X**	**X**		
	Functionally Graded Additive Manufacturing (FGAM)				**X**
	Protocols and procedures for AM Quality Management			**X**	
	Standardisation in AM				**X**
Transportation	Material/Process Qualification (how to control feedstock, process and built material)		**X**	**X**	
	Development of materials (methodologies of process parameters development for Metal AM - SLS, SLM, EBM; and Polymer AM - FFF)		**X**	**X**	
Mechanical engineering/ tool making	Development of the manufacturing plan (fabrication / post processing)			**X**	
	Conformal Cooling	**X**	**X**		
	Development of materials (methodologies of process parameters development for Metal AM - SLS, SLM, EBM)			**X**	
Medical	Medical Modelling	**X**			
	Material/Process Qualification (how to control feedstock, process and built material)		**X**	**X**	

3. Training Methodology

In cooperation with project partners, the training plan for knowledge transfer is presented in Table 2 showing the suggested partner, department, dates and location. The areas of training have been decided by mapping the expertise and competencies of each partner [1] in line with the framework presented in Table 1. The benefits of UNIZAG FSB to build up a sustainable ADAM platform within CATeh has also taken in to account which is realised from the mapping study [2].

Table 2 Timetable of training and knowledge transfer activities

Partner	Centre/Department involved	Training Date	Training Location
LTH	Department of Design Sciences	04-15 November 2019	Sweden
MUL	Institute of Polymer Processing	11 March-05 April 2019	Austria
AIDIMME	Department of New Manufacturing Processing	23 September-04 October 2019	Spain
UBRUN	Department of Design	03-12 June 2019	Croatia

LTH will organise knowledge transfer and training for three CATeh researchers for a duration of 2 weeks which will allow access to two metal AM machines. LTH has expertise in DfAM and Powder Bed Fusion (PBF) technique for metallic and polymeric material processing [3]. Before starting the knowledge transfer and training, experts from LTH will evaluate the existing knowledge of participants on topics related to AM and prepare the teaching curriculum. The training topics will be divided into three main topics: 1) DfAM for product design, 2) DfAM for tooling and 3) DfAM for medical applications. DfAM for product design will encompass topics the aspects of general guidelines, the application of lattice structures, product topology optimisation and design evaluation. DfAM for tooling will include general guidelines, conformal cooling and tool design evaluation. DfAM in medical applications will include medical imaging, medical scan data management and preparation for AM. At the end of the training, experts from LTH will evaluate the knowledge of each participant through the use of surveys or questionnaires.

MUL will organise training and knowledge transfer in Leoben (Austria), because MUL has installed all main equipment for compounding and AM facilities for making parts at one location in the Institute for Polymer Processing. Two CATeh researchers will visit MUL for 4 weeks to increase their experience and knowledge in the field of material compounding and producing new polymers, composites or metal materials for Fused Filament Fabrication (FFF) processes [4]. Training and knowledge transfer will cover topics including compounding systems, compounding processes, filament preparation, determination of AM parameters for processing new materials and the application of FFF for the production of parts for further testing. At the end of the training, experts from MUL will evaluate the knowledge of each participant through the use of a master report and a questionare.

AIDIMME will organise training and knowledge transfer during 2 weeks for three CATeh researchers to increase their knowledge in the field of developing new metallic powders for processing using powder-based AM. The equipment is installed at the AIDIMME site, therefore the training and knowledge transfer will be organised in the AIDIMME facility in Spain. Training and knowledge transfer will cover on advanced design of metal parts for AM, metal powder material systems, AM process planning, material/process qualification and AM Quality Management, based on their wide range of expertise and resourses [5]. At the end of the training, experts from AIDIMME will evaluate the knowledge of each participant through the use of surveys or questionnaires.

UBRUN experts from UK will travel to meet the UNIZAG FSB partner in Croatia for 2 weeks to deliver a series of lectures and workshops. UBRUN is expert on application of AM in design and product development [6]. The topics for UBRUN teaching plan include the possibilities and

benefits of creativity and design innovation, as well as functionally graded materials (FGM) in AM. In addition, there will be seminars on standardisation for AM regarding design guidelines and powder-bed fusion processes. The workshops will be practical projects so that the theoretical aspects of design guidelines can be better understood and put into practice. At the end of the training, experts from UBRUN will evaluate the knowledge of each participant through the use of surveys or questionnaires.

Upon completion of the training, all teaching material and detail reports of the topics will be documented as a handbook for future training. A summary of the training material in the form of a handbook will also be made available on the INEX-ADAM website for open access. All project consortium partners will have to create the teaching material in English and may have the option to translate the content into their own national language. The Steering Committee will also review the teaching material and determine whether a non-disclosure agreement (NDA) document is necessary to protect commercial interests and intellectual property, as defined in Consortium Agreement.

4.Teaching plan from LTH

Title of Teaching Plan

Design and Optimization for AM

Aims

To provide a general design methodology for AM and to introduce the participants to various analysis, optimization and build preparation software. The participants will also be introduced to the 3D-scanning, polymer PBF and metal PBF equipment installed at LTH.

Learning Objectives

- To be able to understand and use relevant design methods for AM
- To learn the use of software and equipment for DfAM
- To optimise, analyse and prepare for build and design in AM
- To optimise, analyse and qualify post processing techniques for building parts in AM

Teaching Material

Lecture slides, tutorial models and instructions, software and hardware manuals, and text book - *A Practical Guide to Design for Additive Manufacturing* developed by LTH.

Assessment / Evaluation Method

The assessment will be done through discussions and through the completion of two design projects.

Table 3 Topics of proposed curricula from LTH

Design and Optimization for AM				
Day	**Teaching Date**	**Topic**	**Materials and Activity**	**Instructor**
1	04.11.2019	Introduction to DfAM, AM process from design to printing part	Lecture, note taking and Q&A	Olaf Diegel Axel Nordin
2	05.112019	Design guidelines of polymer AM and post processing techniques, Economics of AM, Lattice structure exercise, Generative design in AM, Topology optimisation and Design for mass-customisation	Lecture, handouts, note taking and Q&A	Axel Nordin
3	06.11.2019	Design guidelines of metal AM, Tooling application of AM, Future of DfAM and Introduction to the first project: Redesign an existing metal component or design a new one for AM using topology optimization, lattice structures, design analysis, build simulation, distortion compensation	Lecture, handouts, note taking and Q&A	Olaf Diegel Axel Nordin
4	07.11.2019	Work on the first project	Handouts, software demonstration	Olaf Diegel Axel Nordin
5	08.11.2019	Work on the first project and initiate print	Practical session	Olaf Diegel Axel Nordin Jonny Nyman
6	11.11.2019	Part extraction and post-process	Practical session	Jonny Nyman
7	12.11.2019	Introduction to the second project: Design a customized polymer part using 3D scanning and mesh-based tools	Handouts, software demonstration	Olaf Diegel Axel Nordin Visitor
8	13.11.2019	Work on second project and initiate print	Practical session	Olaf Diegel Axel Nordin Jonny Nyman
9	14.11.2019	Part removal, post-processing and part validation	Practical session	Jonny Nyman
10	15.11.2019	Summary and discussion	Handouts, discussion and Questionnaire	Olaf Diegel Axel Nordin

5. Teaching plan from MUL

Title of Teaching Plan

Material development for Fused Filament Fabrication: Processing, characterisation and simulation

Aims

To demonstrate the strategy used to develop new materials for fused filament fabrication, to introduce the participants to the different processing techniques used to prepare these materials and the characterisation techniques needed to collect the data required for simulations of the extrusion process.

Learning Objectives

- To be able to understand and use a methodology to develop one new material for fused filament fabrication
- To be able to use equipment needed to produce the materials and filaments
- To be able to conduct characterisation of the rheological properties, the thermal conductivity and the transition temperatures for the process
- To be able to perform Finite Element Analysis simulations with the collected data

Teaching Material

Lecture slides, tutorials, equipment manuals, demonstrations and learning from a problem-based approach.

Assessment / Evaluation Method

The assessment will be done through discussions and through the completion of a master report. A scientific paper could be prepared from the results of the solved problem.

Table 4 Topics of proposed curricula from MUL

Material development for Fused Filament Fabrication: Processing, characterisation and simulation				
Day	**Teaching Date**	**Topic**	**Materials and Activity**	**Instructor**
1	11.03.2109	Introduction to Institute Safety instructions Lab tour of Polymer Processing	Handouts, note taking, lab tours and Q&A	Joamin Gonzalez Stephan Schuschnigg
2	12.03.2019	Compounding in Kneader Instruction Formulation calculation Compounding of compounds with copper	Lecture, handouts, note taking and Q&A	Ivica Duretek Joamin Gonzalez Santiago Cano
3	13.03.2019	Compounding of compounds with copper Lab tour Polymer Testing	Lecture, note taking, lab tour and Q&A	Sandra Petersmann
4	14.03.2019	Differential Scanning Calorimetry (DSC) Instructions DSC measurements Compounding of compounds with copper	Handouts and practical session	Sabrina Winkler
5	15.03.2019	Lab tour Design in Polymer DSC measurements Literature review on thermal conductivity and effect on FFF Compounding of compounds with copper	Tour, practical session, lecture, note taking and Q&A	Martin Pletz Joamin Gonzalez

Table 4 Topics of proposed curricula from MUL (cont.)

Material development for Fused Filament Fabrication: Processing, characterisation and simulation				
Day	**Teaching Date**	**Topic**	**Materials and Activity**	**Instructor**
6	18.03.2019	High Pressure Capillary Rheometry (HPRC) Instruction HPCR measurements Vacuum press instruction Preparing specimens for rotational rheometry in press	Handouts and Practical session	Julia Goesmann
7	19.03.2019	HPCR measurements Preparing specimens for thermal conductivity in press	Practical session	Ivica Duretek Sabrina Winkler
8	20.03.2019	Rotational rheometer instruction Rotational rheometry measurements	Handouts and Practical session	Julia Goesmann
9	21.03.2019	Thermal conductivity K-system instruction Thermal conductivity measurements	Handouts and Practical session	Julia Goesmann
10	22.03.2019	Thermal conductivity measurements	Practical session	Self-learning practice
11	25.03.2019	Thermal conductivity measurements Analysis of rheological data from capillary rheometry	Practical session	Ivica Duretek
12	26.03.2019	DSC measurements analysis of the data Analysis of rheological data from HPCR	Practical session	Ivica Duretek
13	27.03.2019	Instruction in HPCR with single barrel Production of filaments in HPCR	Handouts and Practical session	Julia Goesmann Santiago Cano
14	28.03.2019	HPCR measurements	Practical session	Self-learning practice
15	29.03.2019	HPCR measurements Preparation of report	Practical session and report writing	Self-learning practice
16	01.04.2019	FFF printer training FFF Printing	Practical session	Lukas Hentschel
17	02.04.2019	Lab tour of Processing of Composites FFF Printing	Lab tour and practical session	Gustavo Lorenco
18	03.04.2019	FFF printer Compounding of materials in extruder Extrusion of filaments in Extruder	Practical session	Santiago Cano
19	04.04.2019	Lecture about AM in Croatia FEM simulation with polymers lecture/exercise Preparation of master report	Lecture, note taking, report writing and Q&A	Stephan Schuschnigg
20	05.04.2019	FFF printing Preparation of master report	Practical session and report writing	Joamin Gonzalez

6. Teaching plan from AIDIMME

Title of Teaching Plan

AM Powder Bed Fusion (PBF) technologies and Workflow

Aims

To provide a training and knowledge transfer to increase the understanding of the field of the powder-based AM technologies, from the starting powder material to the final AM part validation. The participants will be introduced to metal PBF equipment at AIDIMME.

Learning Objectives

- To be able to understand the field of developing new materials with AM technologies
- To be able to execute a complete workflow of PBF techniques by evaluating the geometry, topological design, re-design for AM, etc.
- To be able to prepare machine and process material for AM production
- To attain knowledge and relevant skills needed for part extraction and post-processing treatment of built parts
- To be able to carry out part validation and qualification of AM technologies

Teaching Material

Lecture slides, tutorial models, instruction guides, software and hardware manuals.

Assessment / Evaluation Method

The assessment will be done through discussions, carrying out two complete workflows on PBF technologies, and by means of initial and final tests for evaluating the knowledge.

Table 5 Topics of proposed curricula from AIDIMME

AM Powder Bed Fusion (PBF) technologies and Workflow				
Day	**Teaching Date**	**Topic**	**Materials and Activity**	**Instructor**
1	23.09.2019	Initial test for knowledge evaluation Powder Bed Fusion Technologies-SLS, EBM and SLM	Lecture, note taking and Q&A	Julia Ureña Olga Jordá Mario Martínez
2	24.09.2019	Theoretical sessions about Selective Laser Sintering, SLS (Polyamide parts)	Lecture, note taking and Q&A	Julia Ureña Olga Jordá Mario Martínez
3	25.09.2019	Metallic Materials	Lecture, Note taking and Q&A	Julia Ureña Olga Jordá Mario Martínez
4	26.09.2019	Theoretical sessions about Electron Beam Melting, EBM (Metal parts)	Lecture, note taking and Q&A	Julia Ureña Olga Jordá Mario Martínez
5	27.09.2019	Parts characterizing and qualification	Lecture and practical session	Julia Ureña Olga Jordá Mario Martínez
6	30.09.2019	SLS complete workflow (Part 1)	Practical session	Julia Ureña Olga Jordá Mario Martínez
7	01.10.2019	SLS complete workflow (Part 2)	Practical session	Julia Ureña Olga Jordá Mario Martínez
8	02.10.2019	EBM complete workflow (Part 1)	Practical session	Julia Ureña Olga Jordá Mario Martínez
9	03.10.2019	EBM complete workflow (Part 2)	Practical session	Julia Ureña Olga Jordá Mario Martínez
10	04.10.2019	General conclusions of the training Open discussion Final test for the evaluation of knowledge transfer	Discussion, surveys and questionnaire	Julia Ureña Olga Jordá Mario Martínez

7. Teaching plan from UBRUN

Title of Teaching Plan

DfAM, FGAM and Standards in Additive Manufacturing

Aims

To provide knowledge in innovation management and Product Service System (PSS) business models to support DfAM, standards in AM, an overview of Functionally Graded Additive Manufacturing (FGAM) and modelling of metal AM.

Learning Objectives

- To be able to demonstrate innovation process and management systems for AM

- To be able to plan for future AM development in response to identified opportunities and potential requirements utilising strategic and creative tools via PSS and DfAM
- To be able to demonstrate the characteristics of business models and correlate them with innovation processes to tap on the potential of AM
- To be able to apply creative tools to envision and communicate business models for AM
- To be able to understand existing standards for AM and the work of ISO/TC261
- To be able to read, retrieve and apply the standards for AM
- To be able to understand the application of AM techniques in developing functionally graded parts and to identify key FGAM technologies
- To be able to demonstrate the modelling of metal AM techniques

Teaching Material

Lecture notes, handouts, creativity tools.

Assessment / Evaluation Method

The assessment will be done through discussions and problem solving activities.

Table 6 Topics of proposed curricula from UBRUN

DfAM, FGAM and Standards in AM				
Day	**Teaching Date**	**Topic**	**Materials and Activity**	**Instructor**
1	03.06.2019	Standardisation for AM regarding design guidelines	Lecture, handouts, note taking and Q&A	Eujin Pei
2	04.06.2019	Standardisation of powder-bed fusion processes	Lecture, handouts, note taking and Q&A	Eujin Pei
3	05.06.2019	Functionally Graded Materials (FGM) in AM	Lecture, note taking and Q&A	Giselle Loh
4	06.06.2019	Functionally Graded Materials (FGM) in AM	Lecture, software demonstration	Giselle Loh Israt Kabir
5	07.06.2019	Modelling of metal AM	Exercise and Q&A	Israt Kabir
6	10.06.2019	Introduction to innovation process, Interactive workshops	Lecture, handouts, templates, note taking and Q&A	Busayawan Lam Israt Kabir
7	11.06.2019	Introduction to circular business model, Distributed Manufacturing, Interactive workshop 1: Idea generation for DM-based business models	Lecture, handouts, tools, note taking and discussion	Fabrizio Ceschin
8	12.06.2019	Interactive workshop 2: Concept development, Interactive workshop 3: Communicating the concept	Handouts, tools and discussion	Fabrizio Ceschin

8. Summary

This report provides an outline of the proposed curricula from all four partners LTH, MUL, AIDIMME and UBRUN for a training and knowledge transfer programme for UNIZAG FSB. The curricula contents are proposed within the training framework and based on the expertise of the partners. The topics range from DfAM, Innovation Management, Product Service System (PSS), Development of AM processes and materials, Guidelines and standards of AM, FGAM, Material modelling and simulation and Process qualification. The application of knowledge transfer in AM will focus on transportation, tooling and medical sectors. These materials will be systematically catalogued in the next deliverable (D3.1) that will be led by LTH. Table 7 provides the summary of the training topics, in which duplication has been minimised and a better distribution of training is shared across the four partners to ensure that the research domains/subjects are fulfilled.

Table 7 Summary of Knowledge Transfer from Supporting Partners

Research area	Research domain / subject	LTH	MUL	AIDIMME	UBRUN
General area	Advanced Design (Topological Optimisation/lattice structure design and integration)	Design guidelines of polymer AM and post processing techniques, Economics of AM, Lattice structure exercise, Generative design in AM, Topology optimisation and Design for mass-customisation Design guidelines of metal AM,		SLS complete workflow (Part 1) and EBM complete workflow (Part 2): Topologic design with Altair software	
	Design for AM and process planning	Introduction to DfAM, AM process from design to printing part, Future of DfAM		SLS and EBM complete workflow (Part 1): Initial geometry evaluation, Re-design for Additive Manufacturing, Production preparation: nesting, machine and material preparation	Introduction to innovation process, Interactive workshops: Introduction to circular business model, Distributed Manufacturing, Idea generation for DM-based business models, Concept development, Communicating the concept
	Material Modelling				Modelling of Metal AM
	Simulation	Introduction to the first project: Design analysis, build simulation, distortion compensation	FEM simulation with polymers lecture/exercise		
	Functionally Graded Additive Manufacturing (FGAM)				Functionally Graded Materials (FGM) in AM
	Protocols and procedures for AM Quality Management			SLS and EBM complete workflow (Part 2): Part validation	
	Standardisation in AM				Standardisation for AM regarding design guidelines Standardisation of powder-bed fusion processes

Table 7 Summary of Knowledge Transfer from Supporting Partners (continued)

Research area	Research domain / subject	LTH	MUL	AIDIMME	UBRUN
Transportation	Material/Process Qualification (how to control feedstock, process and built material)		Compounding in Kneader Instruction, Formulation calculation, Compounding of compounds with copper, Compounding of materials in extruder Extrusion of filaments in Extruder FFF printer training, FFF Printing	Powder Bed Fusion Technologies (theoretical sessions), SLS (polyamide parts), EBM (metal parts), SLM (metal parts), Theoretical sessions about Selective Laser Sintering, SLS: Qualification of the production, Theoretical sessions about Electron Beam Melting, EBM: Qualification of the production	
	Development of materials (methodologies of process parameters development for Metal AM - SLS, SLM, EBM; and Polymer AM - FFF)		Differential Scanning Calorimetry (DSC) Instructions, DSC measurements (Data collection), High Pressure Capillary Rheometry (HPRC) Instruction, HPCR measurements, Vacuum press instruction, Preparing specimens for rotational rheometry in press, Preparing specimens for thermal conductivity in press, Rotational rheometer instruction, Rotational rheometry measurements, Thermal conductivity K-system instruction, Thermal conductivity measurements		

Table 7 Summary of Knowledge Transfer from Supporting Partners (continued)

Research area	Research domain / subject	LTH	MUL	AIDIMME	UBRUN
Mechanical engineering/ tool making	Development of the manufacturing plan (fabrication / post processing)	Part extraction and post-process (1st project) Part removal, post-processing and part validation (2nd project)		SLS and EBM complete workflow (Part 2): Part extraction, Post-processes	
	Conformal Cooling	Tooling application of AM, Introduction to the first project: Redesign an existing metal component or design a new one for AM using topology optimization, lattice structures			
	Development of materials (methodologies of process parameters development for Metal AM - SLS, SLM, EBM)		Refer to- Development of materials- *Transportation*	Theoretical sessions about Selective Laser Sintering, SLS: Processing parameters determination, Powder blending and recycling, Metallic Materials: Alloying design and techniques, Powder characterization for Additive Manufacturing, Powder characterization for AM: flowability and density, Theoretical sessions about Electron Beam Melting, EBM: Powder blending and recycling, Processing parameters determination	
Medical	Medical Modelling	Introduction to the second project: Design a customized polymer part using 3D scanning and mesh-based tools			
	Material/Process Qualification (how to control feedstock, process and built material)		Refer to - Development of materials- *Transportation*	Parts characterizing and qualification: Metallographic characterization: microstructure, densification and porosity evaluation of a metallic material (practical session), Part deformation, Technologies for parts qualification: CT Scan and 3D Scanner	

9. References

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End of report