



universidade de aveiro



theoria poiesis praxis

# DIGI3D

# Trainers Guide



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## **MOTIVATION**

In the rapidly evolving landscape of modern manufacturing, 3D printing has emerged as a transformative innovation, redefining design, production, and supply chain paradigms across a wide range of industries. Its ability to enable lightweight structures, complex geometries, and rapid prototyping has positioned it as a cornerstone technology in the ongoing digital manufacturing revolution. Moreover, its flexibility and efficiency allow for reduced material waste and shorter development cycles, further enhancing its industrial relevance. Recognizing the urgent need for engineers who are proficient in this emerging domain, the DIGI3D was conceived as a strategic initiative aimed at cultivating a digitally skilled, industry-ready workforce tailored to the evolving demands of the aerospace sector.

At its core, the DIGI3D represents a forward-looking commitment to bridging the gap between academia and industry. It introduces a curriculum framework anchored by a specialized course entitled “Digitalization in 3D Printing,” designed to equip students with the knowledge and technical competencies essential for the aerospace industry’s ongoing digital transformation. The course emphasizes not only the fundamental principles of additive manufacturing but also the integration of digital design, simulation, and advanced production workflows aligned with Industry 4.0 principles. In doing so, it prepares learners to effectively operate within increasingly automated, data-driven, and interconnected manufacturing environments.

The DIGI3D initiative is built around five key pillars:

- ***Introducing Novel Technology:***

As a cutting-edge manufacturing technology, 3D printing has become indispensable in the aerospace industry, demanding a new generation of skilled engineers. DIGI3D introduces students to the principles and applications of additive manufacturing, empowering them to innovate and adapt within this technologically dynamic environment.

- ***Industry Alignment:***

In direct response to the rapid expansion of the aerospace sector, DIGI3D seeks to address the existing skills gap by producing engineers who are not only theoretically proficient but also practically capable of implementing advanced digital manufacturing solutions.

- ***Practical Application:***

Traditional engineering education often emphasizes theoretical foundations over hands-on experience. DIGI3D bridges this gap by incorporating experiential learning, enabling students to apply design and manufacturing concepts in real-world aerospace scenarios through laboratory sessions and industry collaborations.

- ***Adapting to the Digital Age:***

As the aerospace industry increasingly embraces digital tools, data-driven decision-making, and automated production systems, DIGI3D prepares students to operate effectively within these environments. The program provides comprehensive training in digital design, simulation-based validation, and cyber-physical manufacturing systems.

- ***Environmental Advocacy:***

In an era defined by sustainability challenges and resource constraints, DIGI3D promotes an ethos of environmental responsibility. The program integrates awareness of eco-efficient manufacturing processes, material sustainability, and life-cycle assessment into its educational framework, encouraging students to adopt green manufacturing practices.

This guide provides a structured outline for trainers about the DIGI3D. It supports educators in delivering content effectively while ensuring alignment with learning objectives. The first section introduces the overall course framework, including its objectives, target groups, and teaching methodology. The second section presents the thematic modules in detail, describing their content, structure, and goals. Together, these sections serve as a practical reference for trainers, helping to ensure consistent course delivery and improving the overall quality and effectiveness of the learning experience across different training settings.

## **COURSE DESCRIPTION**

### **INTRODUCTION**

The course program on 3D printing applications in the aerospace industry has been developed within the framework of the Erasmus+ DIGI3D project. The primary objective of this project is to design and implement an innovative curriculum for engineering departments, addressing the growing need for digitalization in 3D printing applications. The aerospace sector, recognized as a global leader in adopting advanced manufacturing and digital technologies, serves as the target domain for this initiative. The course content has been collaboratively developed by partner institutions from Turkey, Portugal, and Lithuania, integrating multidisciplinary expertise to ensure both academic rigor and industrial relevance.

### **SHORT DESCRIPTION**

This course, developed under the DIGI3D project, focuses on 3D printing applications in the aerospace industry. It aims to establish an innovative, digitally oriented curriculum encompassing key topics such as Digital Manufacturing and 3D Printing, Materials in 3D Printing for Aerospace Applications, 3D Printing Processes in Aerospace Components and Maintenance, and Case Studies from Aerospace Applications. The program combines academic excellence with industrial relevance, equipping students with the knowledge and skills required to meet the evolving demands of the aerospace manufacturing sector.

## TARGET GROUPS

The main target group comprises students from the Aeronautical, Aerospace, Mechanical, and Materials Engineering departments, while research staff and industry professionals will also benefit from the project outcomes.

## OBJECTIVES

The DIGI3D aims to develop a comprehensive curriculum, textbook, and educational materials. The project promotes the digital tools in 3D printing, fostering a deeper understanding of sustainable manufacturing practices. Another key objective is to enhance applied engineering education, enabling students to engage directly with industry-relevant applications. Lastly, DIGI3D seeks to establish a strong consortium uniting academic and industrial partners, thereby strengthening collaboration in the 3D printing technologies.

## METHODOLOGY

The developed course supports both online and onsite learning, ensuring flexibility and accessibility. A textbook serves as the main reference, forming the basis for video lectures, reviews, practical assignments, and quizzes. All materials are freely available on an e-learning platform, providing easy access for the target groups. To enhance visibility, dissemination activities such as stakeholder visits, participation in events, and presentations at conferences are conducted by project partners to reach a broad audience and maximize impact.

The course adopts a learner-centered and competency-based pedagogical approach, combining theoretical knowledge with practical application. The instructional design is aligned with modern engineering education principles, emphasizing active learning, experiential learning, and problem-based learning.

To ensure effective knowledge transfer and skill development, the following pedagogical strategies are employed:

**Blended Learning Approach:** The course integrates online and face-to-face learning environments, allowing flexibility while maintaining interaction and engagement.

**Active Learning:** Students are encouraged to actively participate through discussions, problem-solving tasks, and collaborative activities rather than passive listening.

**Problem-Based Learning:** Real-world aerospace scenarios are introduced to help learners develop analytical and decision-making skills.

**Experiential Learning:** Hands-on laboratory sessions and simulation-based exercises enable learners to apply theoretical knowledge in practical contexts.

**Collaborative Learning:** Group projects and peer discussions foster teamwork, communication, and interdisciplinary thinking.

## CONTENT DELIVERY

The course content is delivered using a variety of instructional methods to address different learning styles:

**Video Lectures:** Structured and modular video content explaining key concepts.

**Interactive Presentations:** Visual and engaging slides integrated with questions and discussions.

**Practical Exercises:** Hands-on experience with 3D printing tools, software, and processes.

**Case-Based Learning:** Real aerospace applications are analyzed to connect theory with practice.

**Simulation and Digital Tools:** Computer-Aided Engineering (CAE) tools and process simulations are used to reinforce digital competencies.

**E-learning Platform:** All materials (videos, documents, assignments, quizzes) are accessible online to support self-paced learning.

**Guided Discussions:** Trainers facilitate discussions to deepen conceptual understanding.

## THEMATIC MODULES

**Module-1:** Digital Manufacturing and 3D Printing

**Module-2:** Materials in 3D Printing for Aerospace Applications

**Module-3:** 3D Printing Processes in Aerospace Components and Maintenance

**Module-4:** Case Studies from Aerospace Applications

## KEY LEARNING OUTCOMES

Upon completion of the training course, participants will be able to:

- Understand the principles of digitalization in 3D printing applications
- Identify and describe aerospace materials used in 3D printing processes
- Explain 3D printing applications in the production of aerospace components
- Recognize and evaluate practical 3D printing applications within the aerospace sector

## ASSESSMENT METHODS

The assessment strategy is designed to evaluate both theoretical knowledge and practical competencies, supporting continuous learning and feedback. A combination of formative and summative assessment techniques is used.

Assessment methods are used throughout the course to monitor learning progress and provide feedback:

**Quizzes:** Short quizzes after each module to reinforce key concepts.

**In-class Activities and Exercises:** Problem-solving tasks and discussions to assess understanding in real time.

**Assignments:** Individual or group assignments focused on design, analysis, or case studies.

**Instructor Feedback:** Continuous feedback is provided to guide improvement.

## COURSE CONTENT OVERVIEW

The course consists of four modules, with an overview of each module provided on the following pages.

## MODULE-1: Digital Manufacturing and 3D Printing

Short Description
<p>This module introduces the fundamental concepts of digital manufacturing and 3D printing, with particular emphasis on their application in the aerospace sector. It provides an overview of how digital technologies support the design, simulation, planning, production, and quality assurance of advanced aerospace components. The module addresses the principles of process digitalization and presents the principal software tools used throughout additive manufacturing workflows, including computer-aided design (CAD), simulation and analysis tools, slicing software, and process monitoring platforms. It also examines the role of process modelling and simulation in predicting thermal behaviour, residual stresses, distortion, and overall part performance. In addition, the module introduces design methodologies specifically developed for additive manufacturing, with particular focus on Design for Additive Manufacturing (DFAM). The key stages of the DFAM approach are discussed to illustrate how components can be optimized to exploit the unique capabilities of 3D printing, such as lightweight structures, part consolidation, and increased geometric complexity. The module further explores the integration of additive manufacturing into digitally driven and sustainable production systems, including concepts related to Industry 4.0, digital twins, and resource-efficient manufacturing. By combining theoretical foundations with aerospace-oriented examples, the module prepares learners to address the technical and strategic challenges associated with the digital transformation of additive manufacturing in aerospace applications. The detailed content of the module is presented below.</p> <ol style="list-style-type: none"> <li>1. Introduction</li> <li>2. Digital Tools for Additive Manufacturing</li> <li>3. Modelling, Simulation, and Print Preparation</li> <li>4. Digital Design Methodologies</li> <li>5. Integration of 3D Printing in Digital Production Systems</li> <li>6. Conclusions</li> </ol>
Learning Objectives
<p>Upon completion of this module, attendees will be able to:</p> <ul style="list-style-type: none"> <li>• Understand the fundamental concepts of digital manufacturing and 3D printing.</li> <li>• Recognize and apply digital tools (CAD/CAM/CAE) in additive manufacturing workflows.</li> <li>• Recognize digital design strategies to optimize 3D printed components.</li> <li>• Understand the influence of process parameters and their control on the printing quality of components for the aerospace industry.</li> <li>• Understand the complete digital workflow required to prepare parts for additive manufacturing.</li> <li>• Understand the integration of 3D printing into digitally enabled and sustainable production systems in the context of aerospace applications.</li> </ul>
Learning Resources
<ul style="list-style-type: none"> <li>• Scientific articles</li> <li>• Industrial reports</li> <li>• Books</li> <li>• Thesis</li> <li>• Tutorials</li> <li>• Instructional videos</li> </ul>

## MODULE-2: Materials in 3D Printing for Aerospace Applications

### Short Description

This module focuses on the selection, characterization, and effective utilization of materials in 3D printing processes. It provides a comprehensive overview of the material technologies currently employed in additive manufacturing, with particular emphasis on materials used in aerospace applications. The module examines the major classes of materials used in additive manufacturing, including polymers, metals, ceramics, and hybrid materials, and discusses their processing characteristics, advantages, limitations, and application areas. A central theme of the module is the relationship between material structure, processing conditions, and resulting properties. The influence of additive manufacturing parameters on microstructural development and defect formation is discussed. In addition to established material systems, the module explores emerging trends in additive manufacturing materials and material development. These include metal matrix composites and ceramic matrix composites. Practical examples and aerospace studies are incorporated throughout the module to demonstrate how material selection and process optimization influence component performance, and manufacturability. By integrating material science principles with additive manufacturing technology, this module provides a thorough understanding of how materials are selected, processed, and engineered to meet the demanding requirements of modern aerospace systems. The detailed content and organization of the module are outlined below.

1. Polymeric Materials for 3D Printing
2. Metallic Materials for 3D Printing
3. Ceramic and Hybrid Materials for 3D Printing
4. 3D Printing Technologies in Aerospace Applications
5. Conclusions

### Learning Objectives

Upon completion of this module, participants will be able to:

- Identify the material requirements specific to aerospace components.
- Explain current material technologies used in 3D printing.
- Classify materials suitable for 3D printing based on their properties and applications.
- Select appropriate 3D printing processes for aerospace-grade materials.

### Learning Resources

- Scientific articles
- Industrial reports
- Books
- Thesis

## MODULE-3: 3D Printing Processes in Aerospace Components and Maintenance

### Short Description

This module explores specific 3D printing processes, challenges, and opportunities in aerospace component production and maintenance. It introduces the fundamentals of 3D printing technologies in aerospace. It explains the types of technologies and materials, discuss the limitations and typical defects in 3D-printed parts, present experimental methodologies, and highlight key performance characteristics such as mechanical resistance and aerodynamic behaviour. The module is divided into six units:

1. Introduction
2. Additive Manufacturing Technologies
3. Limitations of Technologies and Common Defects in Products
4. Mechanical Strength and Performance Characteristics
5. Lightweight PLA Printing for UAV Structures
6. Boundary Layer and Specific Aerodynamics
7. Mechanical Characterization of Common LW-PLA Vase-Mode Structures
8. Other Features of Vase-Mode Printing
9. Conclusions

### Learning Objectives

Upon completion of this module, attendants will be able to:

- Identify the main 3D printing technologies applicable to UAV structure manufacturing.
- Select materials for 3D printing based on mechanical, thermal, and weight requirements.
- Recognize the limitations of different additive manufacturing methods and identify typical defects in 3D-printed parts.
- Apply fundamental research methodologies to evaluate the performance and quality of 3D-printed UAV components.
- Assess the mechanical strength, impact resistance, and structural integrity of 3D-printed UAV components.
- Understand how surface texture, material structure, and print quality affect boundary layer behaviour and aerodynamic performance.
- Integrate knowledge of materials, printing methods, and design constraints to develop optimized UAV components for real-world applications.

### Learning Resources

- UAV Laboratory
- Construction laboratory
- University Airfield Kyviškės
- Scientific articles

## MODULE-4: Case Studies from Aerospace Applications

### Short Description

This module focuses on the principles and practical applications of 3D printing design and manufacturing in the aerospace industry. It begins with an introduction to conventional digital design and then explains how these methods are adapted to address the unique opportunities and constraints associated with additive manufacturing technologies. Particular emphasis is placed on the concept of Design for Additive Manufacturing (DFAM), which is presented through its methodological framework and the fundamental stages of the design process: design requirements, conceptual design, embodiment design, detail design, and manufacturing. Each of these stages is discussed in detail to demonstrate how engineers can develop components that fully exploit the advantages of additive manufacturing, including weight reduction, part consolidation, geometric complexity, and functional integration. Throughout the module, the discussion is closely linked to aerospace applications, where stringent requirements for structural efficiency, reliability, and material performance make additive manufacturing an increasingly important manufacturing approach. In addition to the theoretical foundations, the module incorporates practical case studies involving both polymeric and metallic materials used in aerospace applications. The polymer-based case study examines the design and fabrication of lightweight structural components for unmanned aerial vehicles (UAVs), highlighting considerations such as topology optimization, material selection, and fabrication using material extrusion technologies. The metallic case study focuses on the additive manufacturing of aero-engine components, emphasizing issues related to powder-based processes, thermal effects, post-processing, and quality assurance. For each case study, appropriate additive manufacturing methods are selected and justified according to material characteristics, functional requirements, and production constraints. It also presents a step-by-step algorithm that outlines the complete workflow, beginning with design specification and concept development and continuing through simulation, and manufacturing. By combining theoretical principles, this module provides an understanding of how additive manufacturing can be effectively implemented in aerospace applications. The overall content and organization of the module are outlined below.

1. Introduction
2. Digital Product Design
3. Capabilities of 3D Printing in Digital Design and Manufacturing
4. Fundamental Steps in DFAM
5. Case Studies for Aerospace Components
6. Conclusions

### Learning Objectives

Upon completion of this module, participants will be able to:

- Identify process requirements specific to aerospace materials.
- Select appropriate process parameters for 3D printing operations.
- Design and sequence process steps involved in 3D printing workflows.
- Understand and apply digital tools used in 3D printing processes.

### Learning Resources

- Scientific articles
- Industrial reports
- Books
- Thesis
- Tutorials
- Application videos

*This document was prepared by the project team from Eskişehir Osmangazi University.*



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