Lightweight and Functionally Integrated Additive Manufacturing for Drone Components

The Purpose of the elaborated Case Studies

Case studies are structured examinations of real-world situations or challenges designed to bridge theory and practice. They are developed both as a research method and as a learning tool to strengthen analytical and problem-solving skills. By engaging with authentic industrial scenarios, students gain practical insight into complex professional environments.

The purpose of this case studies is to encourage active, learner-centred engagement. They support approaches such as problem-based learning by enabling students to work independently or collaboratively, with or without instructor guidance. Through analysing theoretical concepts within realistic contexts, students learn to interpret data and test results, evaluate alternative courses of action, and develop well-reasoned, creative solutions.

This approach is particularly valuable in sectors such as aerospace, defence, and advanced manufacturing, where challenges are multifaceted and solutions are rarely singular. Because multiple valid solutions often exist, guided facilitation is frequently beneficial to help students structure their reasoning, assess trade-offs, and justify their decisions effectively.

Lightweight and Functionally Integrated Additive Manufacturing for Drone Components

Author: Dr. Jens Kruse, Niels Janson
IPH – Institut für Integrierte Produktion Hannover gGmbH
https://www.iph-hannover.de

Background:

- Industrial facilities often contain confined spaces that are difficult or hazardous for human operators to access. To improve inspection efficiency and safety, a project was initiated to develop an autonomous drone capable of performing laser scanning missions inside industrial environments.
- Unlike conventional drones, the platform had to operate autonomously in narrow and cluttered areas while carrying sensitive and expensive equipment, including laser scanning systems and onboard computing hardware. Since contact with surrounding structures could not be completely avoided, the drone required a lightweight but highly impact-resistant protective structure.
- The innovative character of the project resulted in continuously evolving requirements throughout development. Rapid design iterations, efficient testing procedures, and flexible manufacturing technologies were therefore essential to achieve project objectives. Additive manufacturing became a key enabler for both product development and final component production.

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

Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the European Education and Culture Executive Agency (EACEA). Neither the European Union nor EACEA can be held responsible for them. PROJECT REFERENCE NO. 101103507

Lightweight and Functionally Integrated Additive Manufacturing for Drone Components

Illustration of the case study



Figure 1: Autonomous inspection drone during flight testing in an industrial environment

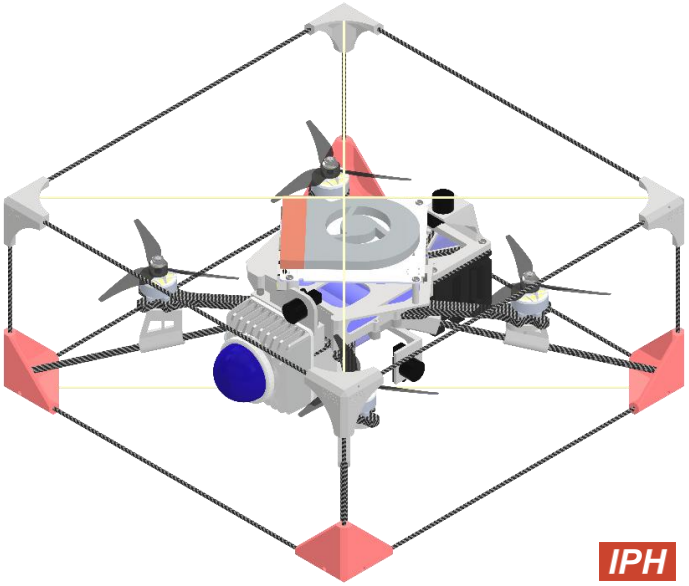


Figure 2: 3D CAD model of the autonomous inspection drone showing the protective cage and structural components

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

Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the European Education and Culture Executive Agency (EACEA). Neither the European Union nor EACEA can be held responsible for them. PROJECT REFERENCE NO. 101103507

Lightweight and Functionally Integrated Additive Manufacturing for Drone Components



Figure 3: CAD rendering of the additively manufactured corner connector used in the modular protective cage

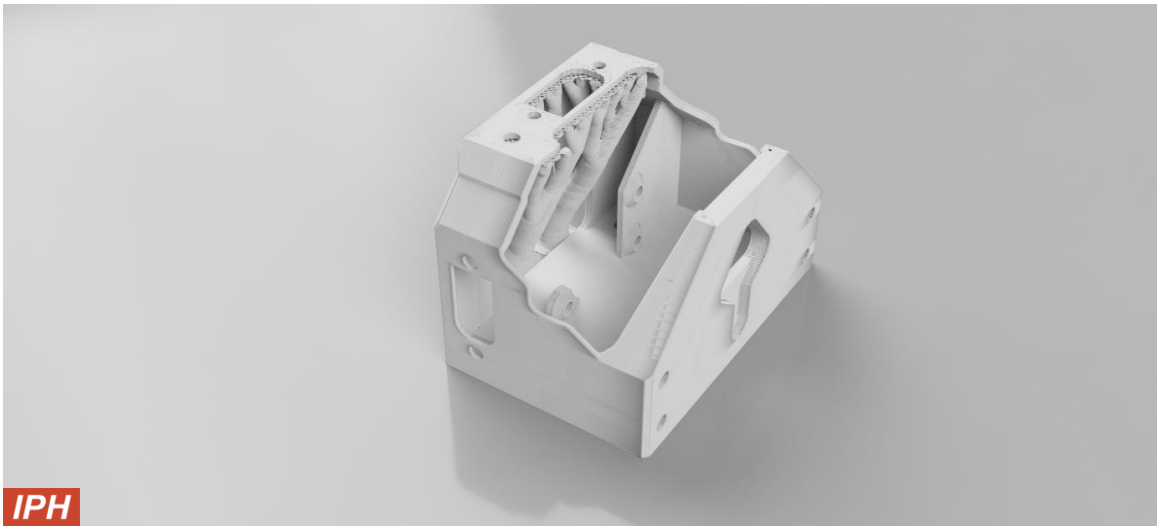


Figure 4: CAD rendering of the multifunctional 3D-printed LiDAR and battery mounting assembly

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

Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the European Education and Culture Executive Agency (EACEA). Neither the European Union nor EACEA can be held responsible for them. PROJECT REFERENCE NO. 101103507

Lightweight and Functionally Integrated Additive Manufacturing for Drone Components

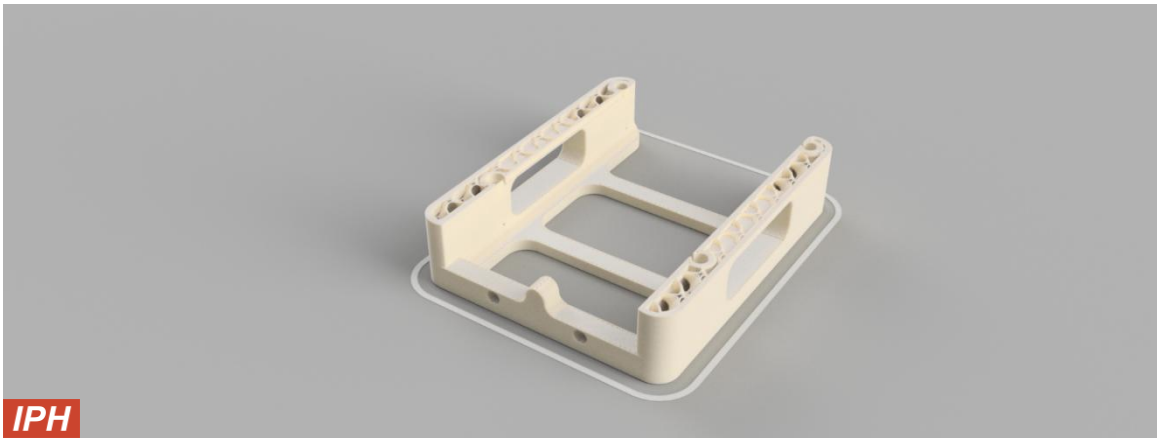


Figure 5: CAD model of the lightweight 3D-printed battery holder

Technical challenge

The engineering team had to address several challenges simultaneously:

- Continuously Evolving Design Requirements
  As testing progressed, new functional and operational requirements emerged. Mechanical designs had to be modified regularly, making conventional manufacturing methods too slow and expensive for efficient development.

- Rapid Validation of Design Concepts
  Multiple concepts needed to be evaluated before committing to costly manufacturing processes such as CNC machining or composite production. Functional prototypes had to be produced quickly and economically.

- Balancing Strength and Weight
  The drone structure had to withstand repeated impacts while remaining lightweight enough for autonomous flight and extended operating time.

- Cost-Effective Maintenance and Repair
  Because collisions were considered inevitable during development and potentially during operation, damaged components needed to be replaced quickly and at low cost.

- Realistic Crash Testing
  The protective cage had to be validated through realistic impact testing without exposing expensive sensors and electronics to damage.

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

Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the European Education and Culture Executive Agency (EACEA). Neither the European Union nor EACEA can be held responsible for them. PROJECT REFERENCE NO. 101103507

Lightweight and Functionally Integrated Additive Manufacturing for Drone Components

Detailed solution/ process

1 Lightweight and Modular Protective Cage

A modular protective cage was developed using a hybrid design approach.

The corner connectors were manufactured using 3D-printed nylon, selected because of its low weight, excellent impact resistance, and toughness. These properties enabled the connectors to absorb impact energy during collisions while maintaining structural integrity.

The cage framework itself was built from commercially available carbon-fibre rods. This approach reduced manufacturing costs and allowed damaged elements to be replaced rapidly after crashes.

To further improve stiffness, the structure was reinforced using UHMW-PE (Ultra High Molecular Weight Polyethylene) tension cords arranged diagonally throughout the cage. This significantly increased rigidity while adding minimal weight.

2 Hybrid Manufacturing of Structural Components

Several structural components followed a two-stage development process.

Initial versions of highly loaded components such as the central frame were produced using additive manufacturing. This enabled rapid evaluation of geometry, assembly, accessibility, and functionality. Once designs had matured, final versions were manufactured from machined carbon-fibre composite, providing superior strength-to-weight performance.

The same strategy was applied to the CPU mounting bracket. Early prototypes were 3D printed to support rapid iteration, while the final component was produced from CNC-machined aluminium to increase durability and precision.

3 Additive Manufacturing of Complex Functional Components

Several drone components integrated multiple mechanical interfaces and functions into single parts.

Due to their complex geometry, conventional manufacturing would have been difficult and economically unattractive. These parts were therefore manufactured using PETG fused filament fabrication (FFF). PETG provided an effective balance between strength, dimensional stability, manufacturability, and cost.

As project requirements evolved, these components could be redesigned and reproduced within hours, enabling continuous optimization and accelerated product development.

4 Realistic Crash Testing Without Risking Expensive Hardware

Validating the effectiveness of the protective cage was a critical part of the development process.

Instead of using the actual laser scanner and onboard computer during early testing, engineers produced 3D-printed dummy models with identical external geometry. The models were fitted with metal inserts to replicate the mass and weight distribution of the original equipment.

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

Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the European Education and Culture Executive Agency (EACEA). Neither the European Union nor EACEA can be held responsible for them. PROJECT REFERENCE NO. 101103507

Lightweight and Functionally Integrated Additive Manufacturing for Drone Components

This approach enabled repeated full-scale crash testing under realistic conditions while eliminating the risk of damaging costly hardware. Test results were subsequently used to optimize the cage design and improve impact resistance.

5 Results and benefits

The combination of additive manufacturing, composite materials, and conventional manufacturing technologies resulted in a highly efficient development process.

- Rapid implementation of design changes throughout the project.
- Fast validation of new concepts before investing in expensive manufacturing processes.
- Reduced development costs through extensive use of functional prototypes.
- Lightweight yet robust structures suitable for industrial operation.
- Cost-effective repair and replacement of damaged components.
- Safe and realistic crash-testing procedures without risking expensive electronics.
- Successful integration of additive manufacturing, carbon-fibre composites, and CNC machining to achieve optimum performance.

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

Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the European Education and Culture Executive Agency (EACEA). Neither the European Union nor EACEA can be held responsible for them. PROJECT REFERENCE NO. 101103507

Lightweight and Functionally Integrated Additive Manufacturing for Drone Components

Competence unit coverage:

	AILEEN competence units	Covered CU
AW_01	Welding: Advanced Metallic Materials in Aerospace and Defence Sectors	
AW_02	Welding: Advanced Welding Processes and Equipment in Aersopace and Defence Sectors	
AW_03	Welding: Advanced Welding Applications in Aerospace and Defence Sectors	
AW_04	Welding: Introduction to brazing technology Knowledge for quality brazed joints	
AW_05	Welding: Fundamentals of Industrial Brazing: Main Processes, Quality Standards & Applications	
AI_01	Inspection: Non-Destructive Testing (NDT) in Additive Manufacturing for metals and polymers	
AI_02	Inspection: Metrology in Additive Manufacturing for metals and polymers	
AI_03	Inspection: Inspection of AM parts. Material Quality	
AAM_01	AM: Qualification, Certification and Standards for AM in A&D	
AAM_02	AM: Quality Assurance & Quality Control for AM in Aerospace & Defence	✅
AAM_02/3	AM: Design of AM parts for A&D (2 courses - for DED & PBF)	
AD_01	Digital: Introduction to Digital Technologies in Advanced Manufacturing	
AD_02	Digital: Data Acquisition and Analysis	
AD_03	Digital: Industrial Internet of Things (IIoT) and Advantages in Advanced	
AD_04	Digital: Artificial Intelligence and Advantages in Advanced	
AD_05	Digital: Automation and Advantages in Advanced Manufacturing	✅
AD_06	Digital: Potentials of Advanced Simulation and Modelling in Advanced	
AD_07	Digital: Potentials of Digital Twins and Smart Factory Automation in Advanced Manufacturing	
AD_08	Digital: Unlocking the Potential of 3D Models Beyond Technical Drawings in the Aerospace and Defence Sector	✅
AG_02	Green: Sustainable Design and Environmental Compliance in Aerospace and Defence	
AAM_04	AM for Aerospace and Defenc	✅

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

Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the European Education and Culture Executive Agency (EACEA). Neither the European Union nor EACEA can be held responsible for them. PROJECT REFERENCE NO. 101103507