

## T5.5 Case study Problem- Based Learning (PBL)

### Title of Case Study / Problem-based learning case

#### Laser repair enhancement for Aero Engine components

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[Laser repair enhancement for Aero Engine | MTC](#)

### Background:

Within the aerospace industry, aero engines are often exposed to harsh conditions (temperature, mechanical stress and oxidation). Thus, the two main avenues for continual use of aircraft include repair or replacement of these parts. Industry is currently pushing further into repairing components where possible for maximising engine uptime and sustainability measures.

Therefore, the industry is experiencing a higher demand for through-life engineering (maintaining the design/component for the whole life cycle of the part from design to end-of-life). This industry has been projected to reach \$2.5 trillion over the next 20 years.

Thus, a key challenge and industry demand being addressed in this case study is addressing the repair technologies; these are currently limited due to inefficient pre and post processing treatments alongside a constrained supply chain. This hinders and restricts the maintenance strategies for the next generation of low emission engines.

- Material: Titanium Alloy (Ti-6Al-4V)
- Method: Direct Energy Deposition (DED) and Vertical Cavity Surface Emitting Laser (VCSEL) technology.
- Motivator: Improving the repair techniques for aero engines to maximise engine uptime and reliability.

Vertical Cavity Surface Emitting Laser is a method which uses a semiconductor laser diode which emits infra-red light vertically from its surface. A whole array of these diodes is placed in the head to create a wide heating area that is efficient and cost effective. It has been used in applications such as slurry drying for battery manufacture as a cost-effective way to dry slurries instead of traditional gas heaters. There is an opportunity to use this VCSEL heating for the pre and post-heat treatment of welded or repaired parts on gas turbine engines. This would be localised to the area being repaired and therefore would reduce off-wing down-time and reduce cost of heating the whole part. Figure 1 – example of a VCSEL set-up from Trumpf



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### Illustration of the case study

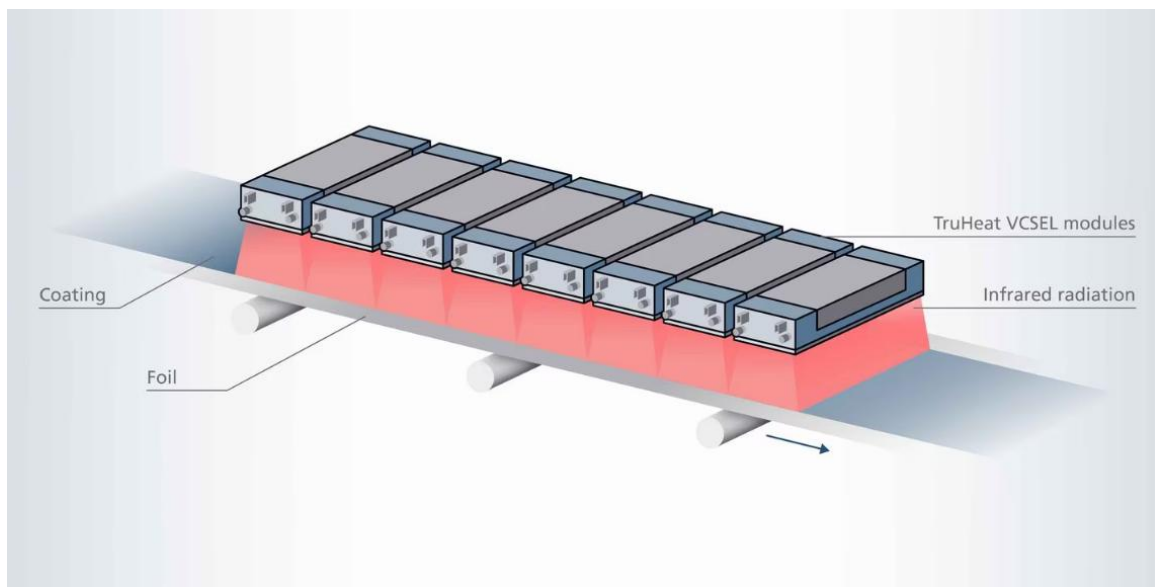
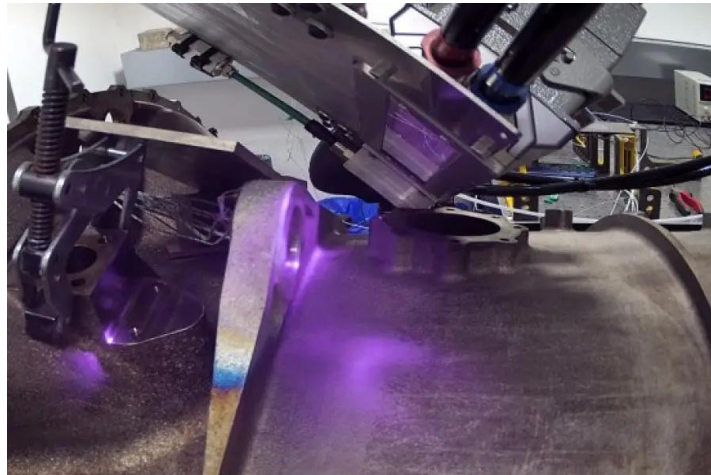


Figure 1. An example of a VCSEL set-up from Trumpf.

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*Figure 2 VCSEL laser in use on component part. Can see the different VCSEL modules arranged in an array at top of photo, and the light from the diodes on the part. The part is shown here which is due to be repaired. The bosses on the part will be re-welded or built up after damage. (Manufacturing Technology Centre, 2026)*

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*Figure 3: Image showing experimental set-up with VCSEL array at top of photo, and metal part with thermo-couples attached on heat-sink blocks at bottom of image. (Manufacturing Technology Centre, 2026)*

### Technical challenge

Main technical challenges:

- Insufficient pre and post processing
  - Current industry practises are not highly consistent.
  - The current repair techniques can limit the process quality and finished product.
- High variability in repair techniques based on cast or polished surfaces.
  - Different surfaces behave differently based on their finishing or manufacturing method.
  - These respond differently to heating and thus cannot consistently process the part.
- Low technology readiness levels
  - The technology to address this is still early in terms of progressing and development.
  - The repeatability and reliability of the process have its challenges in terms of certification.

Questions posed:

1. How could the VCSEL unit be used to improve current state of the art for pre and post repair heat-treat? How could this be measured and reported?
2. How to address the difference in treatment for cast vs polished surfaces when discussing repairing methods?

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### Detailed solution/ process

To address the technical challenges mentioned, the first step included conducting a detailed investigation of a downselected technology called VCSEL based on MTC knowledge and internal research. Once this was the technology decided upon, to address the variance in terms of the repair process, a temperature profiling and heat area analysis was conducted on different scenarios using a series of advanced sensors to build a better understanding of how these materials behave under repair processes. Thermo-couples were used initially on flat plates to understand how the specific Titanium material reacted to the VCSEL, and if heating was uniform. Parameters were adjusted to understand how quickly the part could be brought up to temperature and held at that temperature. Boundary conditions were of particular interest as well as different thickness plates. Plates were cut-up and metallurgy assessed following good results from the thermocouple data to support matching quality measures to temperature profiling.

Through a series of experimentation and profiling, stable conditions in terms of heat were achieved with only  $\pm 1^\circ\text{C}$  variation whilst covering a maximum effective heating area of 145 x 20 mm and a minimum of 8 x 10 mm. Geometries and thicknesses were reported and the impact on heating area and consistency was reported using thermocouple data and associated metallurgy (HAZ, grain size impact, repair depth)

Once the above was achieved, the VCSEL was trialled on a real part. Again, thermocouples were used to assess heating before and post a repair process. In this case, part access and the impact of part geometry was assessed using a design of experiment and thermocouple data as the measure. A real case study part was used to demonstrate viability on a gas turbine engine in the future. Some areas were machined and some were left as cast. The VCSEL was then applied to both surfaces and thermocouple data used to assess impact. This built a database of understanding and behaviour of this technology under these conditions. In total, temperature, geometry, HAZ depth, part geometry and thickness were all assessed.

As final application will involve a commercial off-the-shelf technology, both Trumpf VCSEL head was used as well as IPG laser diode heater to ensure the customer could understand the pros and cons of both heads for the specific application.

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### Competence unit coverage:

|          | AILEEN competence units                                                                                     | Covered CU |
|----------|-------------------------------------------------------------------------------------------------------------|------------|
| AW_01    | Welding: Advanced Metallic Materials in Aerospace and Defence Sectors                                       | X          |
| AW_02    | Welding: Advanced Welding Processes and Equipment in Aerospace and Defence Sectors                          | X          |
| AW_03    | Welding: Advanced Welding Applications in Aerospace and Defence Sectors                                     | X          |
| 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                             |            |

### 1 Bibliography

Manufacturing Technology Centre. (2026). *Laser repair enhancement for aero engine components*. Retrieved from <https://www.the-mtc.org/insights/laser-repair-enhancement-aero-engine-components>