Additive manufacturing (AM), commonly known as 3D printing, has become a powerful technology in recent years, especially for creating metal parts used in industries like aerospace, automotive, and biomedical fields. This technology allows for complex designs and more efficient use of materials. However, a significant challenge remains: ensuring that these printed metal parts are durable and resistant to fatigue, the process by which materials gradually weaken and fail under repeated loading. For metal components, such fatigue failures can lead to serious safety and operational risks. One of the biggest factors affecting the fatigue life of 3D-printed metal parts is the quality of the surface and subsurface areas, which are influenced by the printing parameters used.

This project aims to investigate how specific 3D printing parameters, such as contouring laser power and scanning speed, affect the fatigue life of steel produced by Laser Powder Bed Fusion (LPBF), a popular 3D printing method for metals. The research will specifically look at the effect of these parameters on surface quality and internal structures, with a focus on how the orientation of the printed surface impacts durability. While previous studies have examined some of these factors, there is a lack of understanding regarding how surface quality varies with different orientations and how this affects fatigue life.

In this study, two types of steel—18Ni300 maraging steel and 316L stainless steel—will be printed using different combinations of laser power, scan speed, and building angles. After fabrication, specimens will undergo a series of tests to measure surface roughness and internal pore features using advanced imaging methods like micro-computed tomography and optical profiling. Next, each specimen will undergo fatigue testing to measure its durability under repeated loads. The team will then use machine learning models, specifically Gaussian Process (GP) models, to identify relationships between the printing parameters, surface orientation, and fatigue life. These GP models will provide insights into how each parameter, and their combinations, affect fatigue life.

The results of this research are expected to have significant implications for both science and industry. Academically, it will contribute to a deeper understanding of how AM parameters impact material properties, helping researchers develop more accurate predictive models. Industrially, the findings will inform best practices for producing fatigue-resistant metal parts in sectors that require high durability, such as aerospace and automotive. Additionally, by advancing machine learning applications in materials science, this project may encourage more widespread use of data-driven methods to optimize 3D printing processes. Ultimately, the project seeks to enhance the safety, reliability, and lifespan of 3D-printed metal components.