Laser Powder Bed Fusion Process Challenges
Laser powder bed fusion (L-PBF) is an additive manufacturing process in which a three-dimensional product is built up layer by layer. During this process, the laser beam provides highly localized heating and repeated thermal cycles, inducing temperature gradients in the consolidated part. Cyclic thermal expansions and contractions induce residual stresses, which then cause deformation during processing or after heat treatment. Cracking, porosity, and lack of fusion can also be generated depending on the materials being used and process parameters such as laser power, travel speed, hatch spacing, and scan patterns. Minimizing distortion and other potential defects is a challenge to perform empirically and an opportunity for modeling.

Numerical Modeling of Laser Powder Bed Fusion
EWI has developed a transient thermal-mechanical analysis method to predict temperature, stress, strain, and deformation for L-PBF and other metal additive processes such as Laser and Arc Directed Energy Deposition processes. This analysis method includes a pre-processing module, a powder addition module, and a heat source module. The pre-processing module is used to slice a solid geometry into layers and create laser heat lines for each layer based on a designed scan pattern. The powder addition module is used to model the powder-to-solid transition by changing material properties based on the laser locations. The heat source module includes a moving line-heating model which works with ABAQUS to predict temperature by inputting laser power, travel speed, and the heat-line sequence. As an example, Figure 1 shows the predicted maximum principal stress distributions in a block model. Tensile stresses are predicted on the outer surface and compressive stresses are predicted inside the block, which explains why cracks that initiate on the surface stop propagating a certain depth during L-PBF with some crack-sensitive materials.

Optimizing the Laser Powder Bed Fusion Process
Numerical modeling can be used to optimize preheating temperatures, laser process parameters, hatch spacing, and scan patterns to improve overall L-PBF build quality. Determining the ideal preheating temperature can prevent cracking by reducing thermal gradients and thermal stresses. Laser process parameters including laser power and travel speed can be studied to predict the melt pool size and avoid lack of fusion. Hatch spacing and scan patterns can be selected to optimize heat input, further reducing thermal stresses and lowering the risk of cracking, as depicted in Figure 2.
Optimizing the Laser Powder Bed Fusion Process with Numerical Modeling

Benefits of Using Numerical Modeling
Numerical modeling is a powerful tool for evaluating the physics of L-PBF and linking process attributes to performance. It allows additive manufacturers to optimize process variables to reduce cracking, lack of fusion, residual stresses, and distortion. It can also be used to increase geometric accuracy while simultaneously reducing process development time and costs.

How EWI Can Help
EWI can help industrial customers model powder bed fusion and directed energy deposition metal 3D printing processes during new product and process development to efficiently and effectively optimize process parameters.

Yu-Ping Yang joined EWI in 2004 in the structural integrity and modeling group. His main area of expertise is computational modeling of thermal related processes to predict temperature, microstructure, residual stress, and distortion in large and complicated structures. He has extensive experience in finite-element analysis of welded structures including static, dynamic, creep, and fatigue simulation. Yu-Ping also has strong capabilities in welding and thermal forming software development, and in-depth knowledge in the mitigation of weld residual stress, distortion, and cracking.