Powder-Bed Additive Manufacturing (AM) through Direct Metal Laser Sintering (DMLS) or Selective Laser Melting (SLM) is being used by NASA and the Aerospace industry to "print" parts that traditionally are very complex, high cost, or long schedule lead items. The process spreads a thin layer of metal powder over a build platform, then melts the powder in a series of welds in a desired shape. The next layer of powder is applied, and the process is repeated until layer-by-layer, a very complex part can be built. This reduces cost and schedule by eliminating very complex tooling and processes traditionally used in aerospace component manufacturing.

To use the process to print end-use items, NASA seeks to understand SLM material well enough to develop a method of qualifying parts for space flight operation. Traditionally, a new material process takes many years and high investment to generate statistical databases and experiential knowledge, but computational modeling can truncate the schedule and cost - many experiments can be run quickly in a model, which would take years and a high material cost to run empirically. This project seeks to optimize material build parameters with reduced time and cost through modeling.

**Results & Discussion**

**Motivation**

- Model SLM Process and Microstructure Evolution of IN 718
- Optimize material build parameters with reduced time and cost
- Increase understanding of build properties & reliability of builds
- Decrease time to adoption of process for critical hardware
- Potential to decrease post-build heat treatments

**Background**

Overarching Goal: Model SLM Process and resulting material; calibrate and validate model using in-situ measurements and post-build metal evaluation.

Objectives & Approach

- Conduct single-track and coupon builds at various build parameters
- Record build parameter information and QM meltpool data
- Refine Applied Optimization powdered bed AM process model using data
- Report thermal modeling results
- Conduct metallography of build samples
- Calibrate STK models using metallography findings
- Run STK models using AO thermal profiles and report STK modeling results

**Background**

- AO has made good progress modeling single-track welds, and understanding the thermo-fluid mechanics involved in the SLM process.
- Single-track builds have been conducted and agree with the trends predicted in the AO model.
- Cube samples have been built and optical microscopy reveals identifiable weld bead geometry and verification of geometric parameters (such as hatch spacing)
- Cube sample metallography also reveals identifiable micro-cracking, porosity, surface deformations, non-uniform weld shapes, and other defects.

Conclusions

- AO has modeled double tracks which will be compared to double-track samples built at MSFC.
- AO is making predictions on weld defects in layers which will be compared to single-layer samples built at MSFC.
- Metallography of cube samples will be completed to calibrate Simultaneous Transformation Kinetics models and make predictions on microstructure evolution in SLM material.

Future Work

- AO Prediction of LENS process (Makiewicz Thesis) and MSFC block build, STK prediction (Makiewicz Thesis) and MSFC Microscopy of block
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- From Left to Right: Single track AO Prediction and MSFC build, Multi-layer AO Prediction of LENS process (Makiewicz Thesis) and MSFC block build, STK Prediction (Makiewicz Thesis) and MSFC Microscopy of block

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- Optical microscopy of printed cubes was conducted. The microscopy reveals parameters where the weld flattens on top (good spreading), or where it is too cold (limited spreading) or too hot (keyhole mode and micro-cracking). Top Left: Good parameters showing flat top surface and top layer of welds. Bottom Left: Cold parameters showing uneven top surface and top layer of welds. Right: Hot parameters showing keyhole shape weld.

- Above: AO Predictions compared with NASA samples

**Future Work**

- Single track, Double track and Single Layer samples in Laser Confocal Microscope
- DIC Optical Macro of AM Weld bead