

**SUCCESS STORY**

# Develop In-Process Monitoring Technology for Quality Assurance of Aerospace Parts

## Increasing Cost Effectiveness in Low Volume Part Production



*Sigma Labs PrintRite3D® provides a comprehensive package for certifying and qualifying metal, high-quality components produced via 3D printing.*

**PROBLEM**

Additive manufacturing (AM) in general, and direct metal laser melting (DMLM) in particular, are disrupting manufacturing technology, especially in the aerospace industry where cost-effective, highly complex components in low production volumes are required. There are a lack of commercially available, platform-independent, in-process measurement systems for quality assurance technology for AM production of aerospace components.

The ability to perform in-process quality assurance during a build would significantly improve the qualification and certification process for complex metal parts.

**OBJECTIVE**

The objective of this effort was to develop and advance in-process monitoring technology for DMLM quality assurance. Sigma Labs PrintRite3D® IPQA® (in-process quality assurance) technology served as the basis for this project which sought to implement IPQA into a system proptotype demonstration in an operational environment.

**TECHNICAL APPROACH**

The Sigma Labs PrintRite3D IPQA technology employs two photodiodes and a pyrometer to monitor melt pool optical emissions and a path toward rapid qualification, as well as in-process quality assurance through a proprietary classification algorithm to distinguish between features that are from a nominal process and those from an off-nominal process. The project team worked together to develop an experimental plan to:

- Install, verify, and validate process monitoring equipment
- Establish baseline critical-to-quality (CTQ) metrics and standard test plan
- Generate data for IPQA reference database
- Develop DMLM IPQA prototype tool

The repeatability of the measurement was assessed using multiple build platforms of an array of simple cylinder coupons with identical process parameters. The system sensitivity was quantified using a set of statistically designed experiments with different amounts of variation in the input process parameters to identify correlations between the CTQs and the in-process quality metric (IPQM®).



**AMERICA MAKES  
TECHNOLOGY  
DEVELOPMENT  
ROADMAP**

This project aligns to:



VALUE CHAIN

**ASTM  
PROCESS  
CATEGORY:**  
Powder Bed Fusion

**EQUIPMENT:**  
Concept M2  
EOSINT M280  
EOSINT M290

**MATERIAL:**  
Cobalt Chrome  
Alloy Inconel 625  
Alloy 718Plus

## ACCOMPLISHMENTS

Sigma Labs worked with the aerospace OEMs (GE Aviation, Honeywell International, and Aerojet Rocketdyne) to transition the IPQA technology into the preproduction environment at each of their facilities. PrintRite3D IPQA systems were installed at GE Aviation and Aerojet Rocketdyne while testing for Honeywell was completed using a PrintRite3D IPQA system at the Sigma Labs facility. To assist with development and commercialization efforts, the OEMs provided guidance in drafting functional and operational requirements for the technology.

A full factorial experimental design using simple cylindrical specimens was used to evaluate the sensitivity of the IPQA metric, a proprietary multivariate algorithmic approach to mine, fuse, and calculate quality metrics from one or more sensor outputs, to changes of  $\pm 20\%$  from nominal laser power, scan speed, and spacing. This showed that the IPQA metrics were a function of the material and the machine used as well as laser power and scan speed, but were not dependent on hatch spacing. Using the same factorial design, the IPQA metrics were discovered to be a weak predictor of porosity. They were also found to be a limited predictor of ultimate tensile strength and fracture toughness with evaluation of the latter somewhat limited by a small sample size. The program results provided data on the material properties that were researched and discovered to not be reliably related to the IPQA process, laying the groundwork for future investigation into other new tools and approaches for in-process monitoring of laser powder bed additive manufacturing.

## PROJECT END DATE

March 2017

## DELIVERABLES

- Report Documenting IPQA Analysis Validation and Verification
- Equipment Installation Report
- IPQATest Plan
- Material Specimen Raw Data and Test Data Analysis Results
- Report Detailing Ability of IPQA for Detection and Assessment
- Summary Report
- IPQA Sustainability Impact Report

*All downloadable deliverables are available to members of America Makes via the Digital Storefront.*

## FUNDING

**\$1.6M total project budget**

(\$822K public funding/\$804K private funding)

## PROJECT PARTICIPANTS

### Project Principal:

GE Aviation

### Other Project Participants:

Aerojet Rocketdyne  
Honeywell International Inc.  
TechSolve  
Burke E. Porter Machinery Co.  
B6 Sigma (Sigma Labs)  
Montana Tech of the University of Montana

### Public Participants:

U.S. Department of Defense  
National Science Foundation  
U.S. Department of Energy

4027 In-Process Quality Assurance (IPQA) for Laser Powder Bed Production of Aerospace Components

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