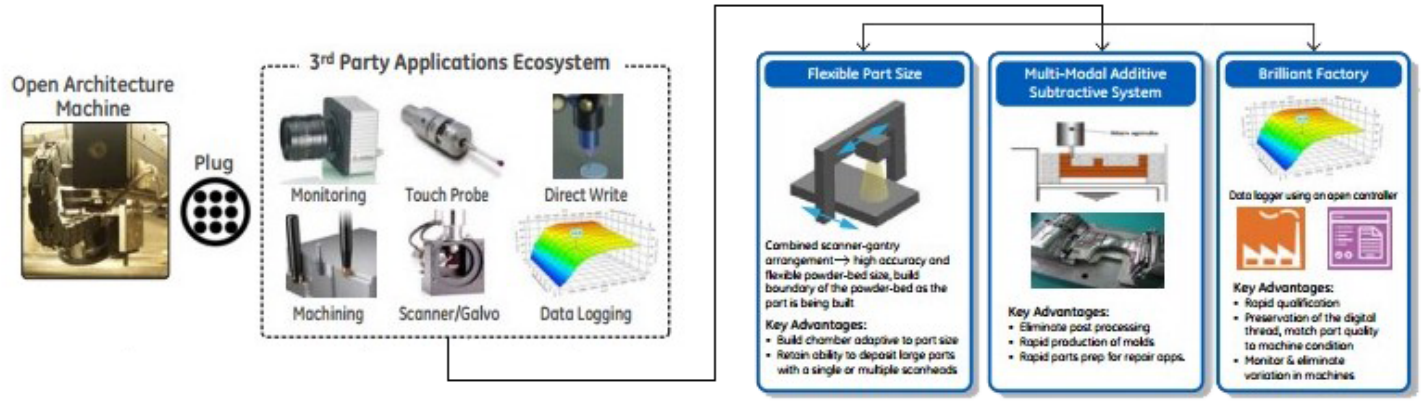
SUCCESS STORY

*An Open Architecture Framework Enables the Use of PBFAM for Development Opportunities and Custom Applications*

# Accelerating PBFAM Development and Use through Open Source Systems




*The open architecture concept creates the opportunity for third-party PBFAM hardware and ancillary processes to be easily integrated and adapted to PBFAM machines, contrary to current OEM machine technology and business development strategies.*

## PROBLEM

High volume production of critical metal components via powder bed fusion additive manufacturing (PBFAM) must meet rigid engineering and quality standards that exceed current capabilities. There are three key challenges in transitioning PBFAM from rapid prototyping to manufacturing: (1) machine robustness; (2) adaptation to custom applications; and (3) process monitoring and feedback. Industry demand to address these challenges is outpacing machine suppliers' and technology providers' ability to provide capable, robust solutions—an issue that has evolved in part because of the closed architecture approach of existing OEMs.

## OBJECTIVE

The objective of this project was to develop and demonstrate open architecture controls to foster third-party applications for PBFAM by establishing a design in which third-party developers would have ready access to standardized PBFAM control hardware. Specifically the team sought to accelerate the development of subsystems for process optimization and control of the thermal environment; multi-modal operation, such as using multiple energy sources or incorporating subtractive technology; flexibly-sized powder beds; and in-process measurement and feedback control.

## TECHNICAL APPROACH

The team planned to develop, demonstrate, and document a fully open architecture control system for PBFAM. The utility of the system along with several subsystems was tested and integrated on a research machine developed at Rensselaer's Center for Automation Technologies and Systems. The controller was implemented on a commercial Concept Laser PBFAM system at General Electric Global Research Center (GEGRC) which resulted in a truly open-architecture PBFAM machine. The team proposed to incorporate the work performed at the Pennsylvania State University in a parallel program, "Creating a High-Speed Protocol Enabling Process Control in AM Machines" into the open architecture system within this project. The control system included galvo scanning control for direction of the laser spot, a motion control system for control of various actuators such as part elevator and recoater, environmental controls including sensors and valves, a data acquisition system for logging appropriate data, and a computer vision system.

**AMERICA MAKES TECHNOLOGY DEVELOPMENT ROADMAP**

This project aligns to:

PROCESS

**ASTM PROCESS CATEGORY:** Powder Bed Fusion

**EQUIPMENT:** Concept Laser M2 Machine (commercial machine), RPI Research Machine

**MATERIAL:** Various Powdered Metals

## ACCOMPLISHMENTS

GEGRC and Rensselaer Polytechnic Institute (RPI) formed a research team that developed, demonstrated, and documented a fully open architecture control system for PBFAM. The control system included subsystems that were tested and integrated into a research PBFAM machine at Rensselaer's Center for Automation Technologies and Systems. The system was further demonstrated on a commercial Concept Laser M2 machine at GEGRC. The multi-spectral sensor developed by the Pennsylvania State University in a previous America Makes program was also demonstrated on the modified M2 machine. Demonstration parts were generated to show the full applicability of the open-source software (developed under the America Makes project 4039: Development and Demonstration of Open-Source Protocols for PBFAM) and the open architecture control system with full control of laser scan paths to generate PBFAM parts.

A full set of engineering documents, drawings, and block diagrams was transitioned to the America Makes consortium and is available as deliverables on the America Makes Digital Storefront. It is anticipated that this control system may be duplicated by consortium members of America Makes for their own research purposes.

As part of the Education and Outreach efforts of the program, Rensselaer integrated course modules using the PBFAM system into an additive manufacturing course held at Rensselaer and completed a student program to recommission a Phoenix system for use at the university.

RPI also leveraged the successful results of the open architecture control on the research machine developed within this project to win a $500K project through NASA for modeling analysis of microstructure prediction based on PBFAM process parameters.

## PROJECT END DATE

August 2018

## DELIVERABLES

- An overview of current relevant technologies and open efforts
- Design requirements for PBFAM laser scanning system
- Electrical schematic layouts complete with electrical power requirements, I/O requirements, buss specifications, and panel layout
- Dimensioned blueprints for any mechanical hardware needed for the implementation of the controller
- Block diagrams and control maps consistent with the expected functionality of the new system
- Working demonstrations of each of the subsystems
- Demonstration parts and a report documenting parts
- Education module for an AM course
- Modules on metal PBFAM incorporated into an AM course with a course project on PBFAM
- A GE-Rensselaer joint seminar on metal AM and Manufacturing Day tours at RPI's additive manufacturing center

## FUNDING

**$1.4M total project budget**
($678K public funding/$708K private funding)

## PROJECT PARTICIPANTS

**Project Principal:**
General Electric Global Research Center

**Other Project Participants:**
Rensselaer Polytechnic Institute
Pennsylvania State University

**Public Participants:**
U.S. Department of Defense
National Science Foundation
U.S. Department of Energy



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