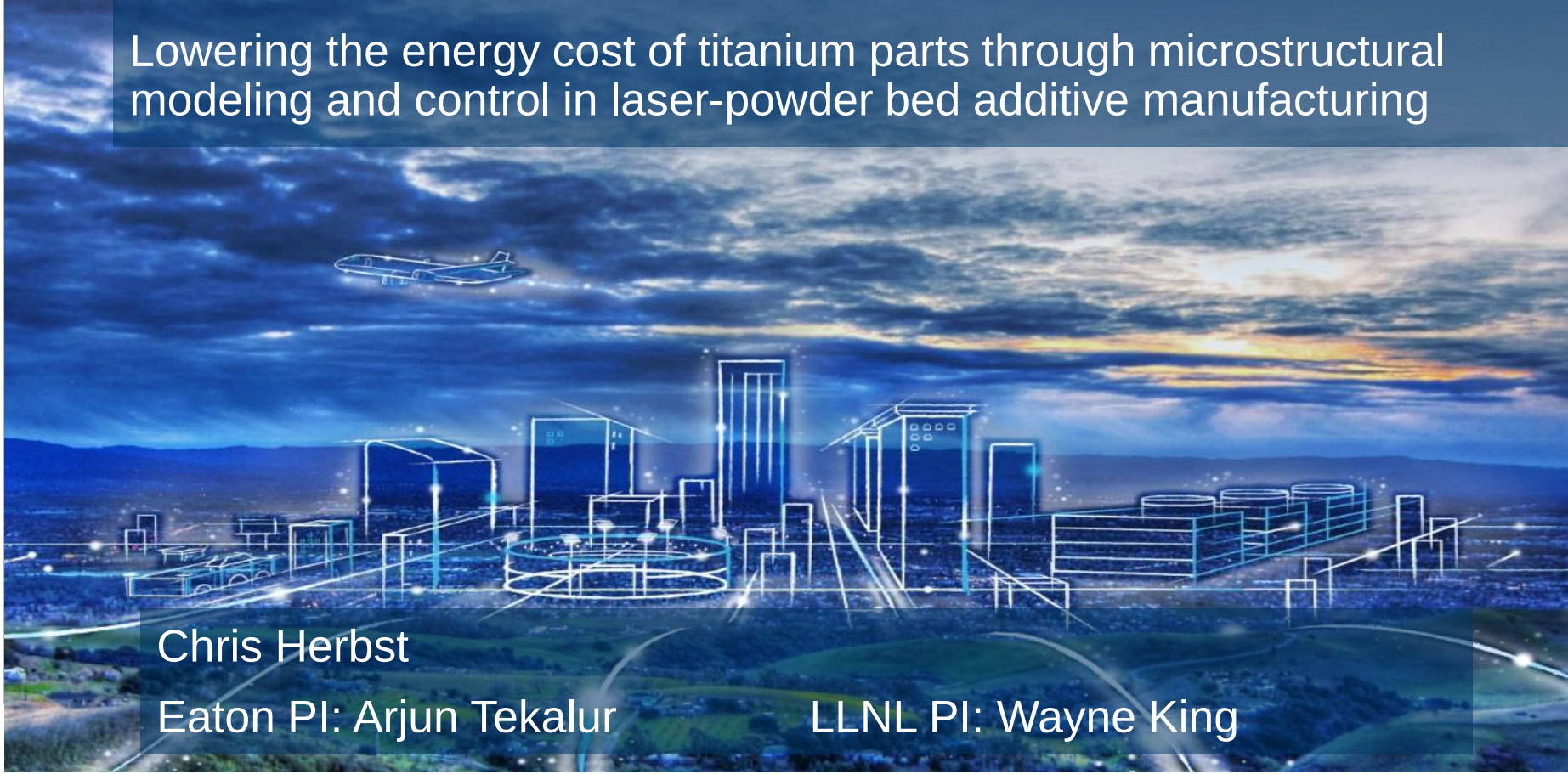
Lowering the energy cost of titanium parts through microstructural modeling and control in laser-powder bed additive manufacturing



Chris Herbst

Eaton PI: Arjun Tekalur LLNL PI: Wayne King

Powering Business Worldwide

We deliver safe, reliable, and efficient power management solutions

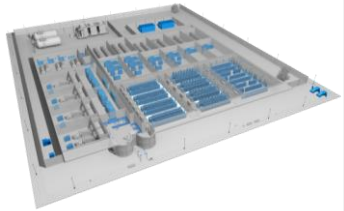
Electrical Sector

Products

2015 Sales: $7.0B

33% of sales

Systems and Services



2015 Sales: $5.9B

28% of sales

Providing safe and efficient electrical solutions from generation through distribution and control

Industrial Sector

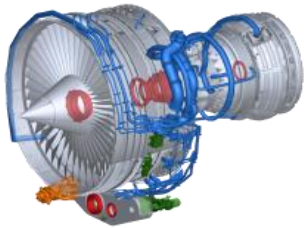
Hydraulics

2015 Sales: $2.5B

12% of sales

Solutions for the world's most demanding power needs

Aerospace



2015 Sales: $1.8B

9% of sales

Mission critical, safe, and reliable solutions

Vehicle

2015 Sales: $3.7B

18% of sales

Leader in fuel economy and emissions reduction

While helping our customers solve their most difficult challenges

Additive Manufacturing Center of Excellence
- Operating in Eaton's Innovation Center - Southfield, MI

- State-of-the-art 3D printing equipment for both metal and polymer applications
- Materials and metrology lab facilities
- Machine shop with an array of post-processing equipment
- Serving the businesses by developing complex high performance components, providing tools and fixtures for manufacturing operations, delivering rapid prototyping services for accelerating NPI/NTI initiatives, and advancing sustainable manufacturing efforts
- Collaborating with strategic external partners to accelerate internal developments

Powering Business Worldwide

America Makes

Lawrence Livermore National Laboratory

Oak Ridge National Laboratory

NextManufacturing Carnegie Mellon University

Our goal is microstructure control to minimize variation in mechanical & physical properties and expensive post-processing

- This one year program targets missing links between process variables and microstructure evolution in Ti-6Al-4V parts.
- Eaton responsibility:
  - Provide desired properties for representative Aerospace Ti-6Al-4V parts to LLNL.
  - Analyze coupons manufactured to validate LLNL models.

- LLNL HPC responsibility:
  - Phase field modeling: Build on existing AMPE code to model microstructure formation in alloys and predict local microstructure (grain size, composition, phase) in as-deposited components during a laser based AM powder bed fusion process.
  - Manufacture coupons using process parameters derived from model and provide to Eaton for analysis.

Powering Business Worldwide

HPC capabilities and laboratory expertise are filling gaps in knowledge and expediting commercialization

- Mean field approach requires proper selection of thermodynamic databases. As part of the program, the LLNL team provided inputs on selection of databases that served as excellent guidance for Eaton team.

- Phase field approach offers detailed insight into the microstructure. It requires specialized skill set and great computational capabilities. By partnering with LLNL, Eaton is learning the nuances of the simulation methodology. This is helping us in expediting the learning curve on phase field.

- The range of multi-physics and multiscale simulation that LLNL is performing for AM is helping Eaton to understand which aspects of that are relevant in an industrial setting. Then we focus only on those aspects and learn from LLNL on aspects that we do not undertake ourselves (e.g. powder level modeling).

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