

Immortal Machines

- AI Math that will positively impact all aspects of humanity
- ENGINEERS Algorithm developers of the machine that designs the products of the future
- SCIENTIST Discoverer of fundamental knowledge engineers use to optimize the machine

Jason W. Carroll, Ph.D.
Vice President, Global Technology
Eaton Corporation

How can we enable machines to design the products of the future?

Who is Eaton?

We are an **intelligent power management** company made up of approximately **85,000 employees**, doing business in more than **175 countries** with annual sales of over **\$19 billion USD**.

We make what matters work.*

We make delivering your best work.*

ELECTRICAL



Power distribution and circuit protection



Power quality, backup power and energy storage



Life safety and security



Structural solutions



Control and automation



Harsh and hazardous environments solutions

INDUSTRIAL



Aerospace



Filtration



Vehicle



eMobility

Immortal Machines

Future of Product Engineering

Intersection of:

- Multiscale materials design & materials informatics
- Multiphysics engineering simulation & reduced order modeling
- Artificial intelligence driven design & process automation
- Generative design
- Additive manufacturing

Autonomously designed & continually optimizing
Multi-scale, multi-physics optimized
Aware





Eaton Journey

2018 - present

2018 - “Hey Siri, design me a tank...”

2020 - First awarded phase Autonomous Digital Design program with the US Army

2021 - Built US and Pune, India Digital Design team - focused on PhDs in materials & mechanical engineering with scientific machine learning expertise

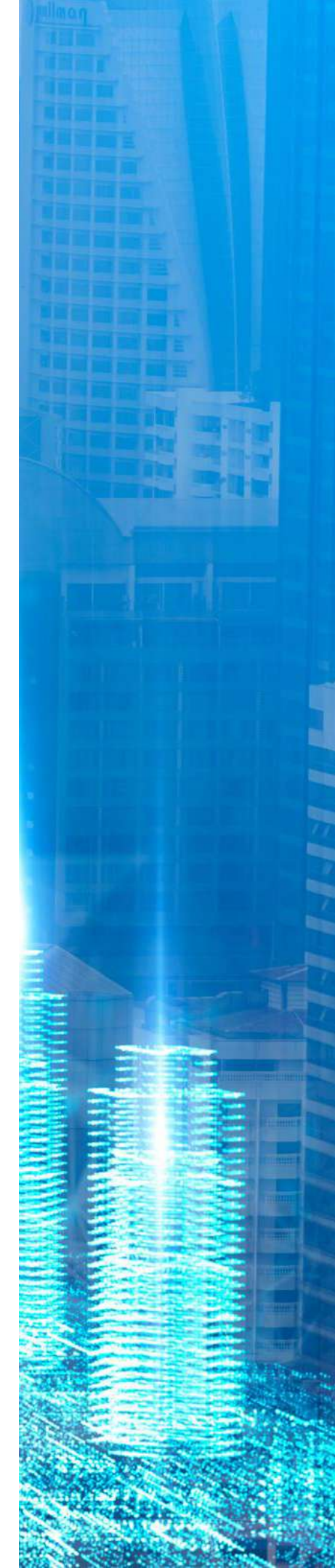
2022 - Hired global Digital Design leader for Eaton Research Labs; Kicked-off “Lighthouse” program in EV mechanical system due to deep domain expertise & digital knowledge

2022 - Expanded Pune, India team to broaden impact

2022 - Globally deployed Esteco ModeFrontier & Volta

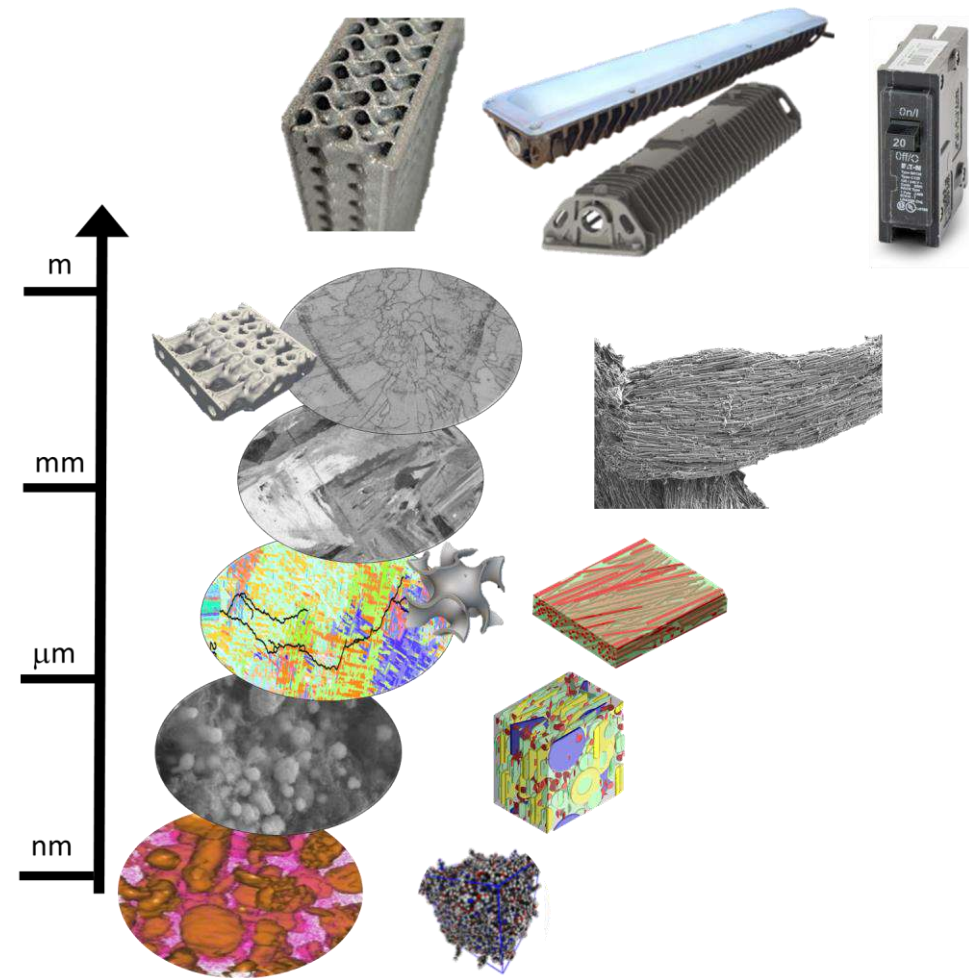
2023- 25 lead programs in Design automation globally

2023- Hired Global VP to drive to “Zero-Lead Time” engineering

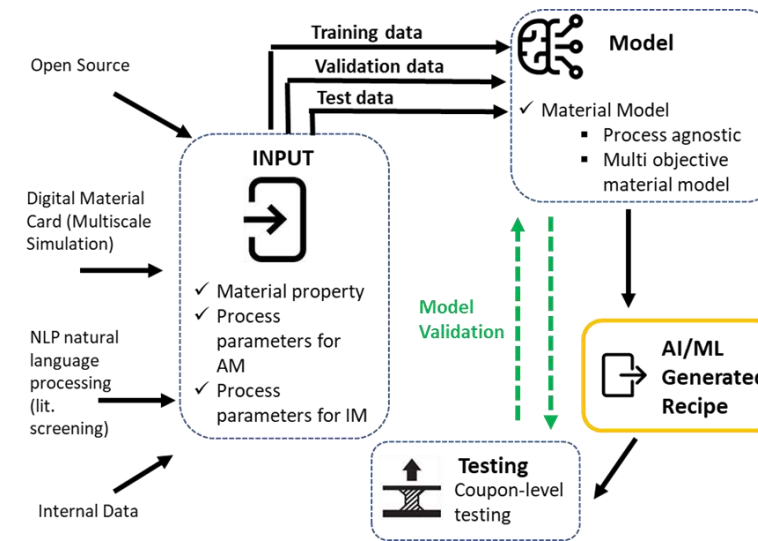


Materials Informatics

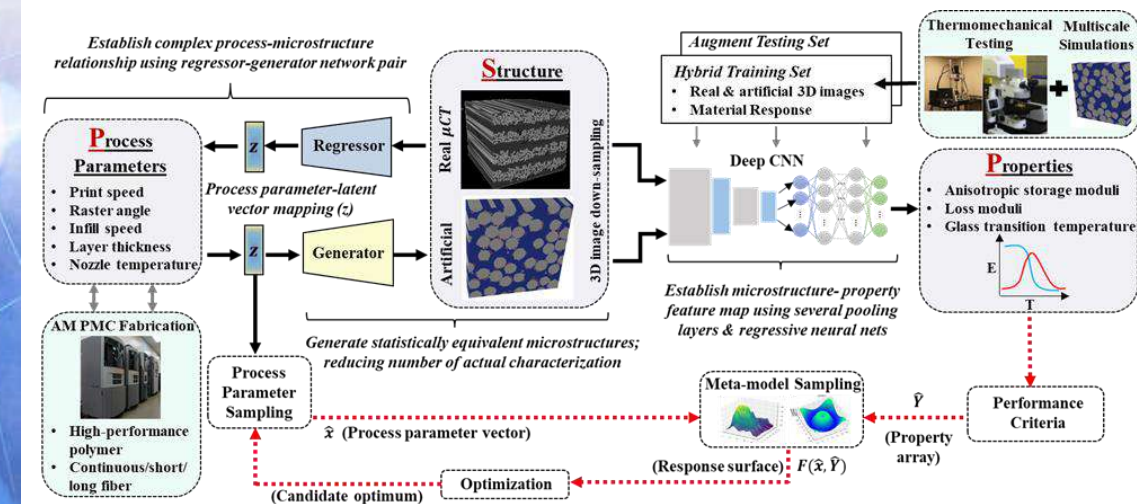
Develop bespoke metallic & polymer materials using multi-scale materials optimization to meet novel electrification applications



Use scientific machine learning to rapidly develop bespoke materials with novel properties






- Conductive polymers that are easy processed
- High thermal & electrically conductive metals



Multi-Physics Simulation & ROMs

Multi-physics optimization and reduced-order modeling of Champ Lighting

	7L Design (Manual)	7L Design (Digital)	11L Design (Digital)
Optimized lighting designs			
Design Lead Time	16 weeks	16 weeks	2 Weeks
Accuracy (from test)	>90% (CFD model)	>90% (AI/ML model)	>94% (AI/ML model)

87% reduction in design time

Electrical CTQs

- Voltage
- Power Factor
- Efficiency

Mechanical CTQs

- Wind load
- Corrosion resistance
- Structural load

Optical CTQs

- Lumens rating
- Optical distribution
- Color rendering index

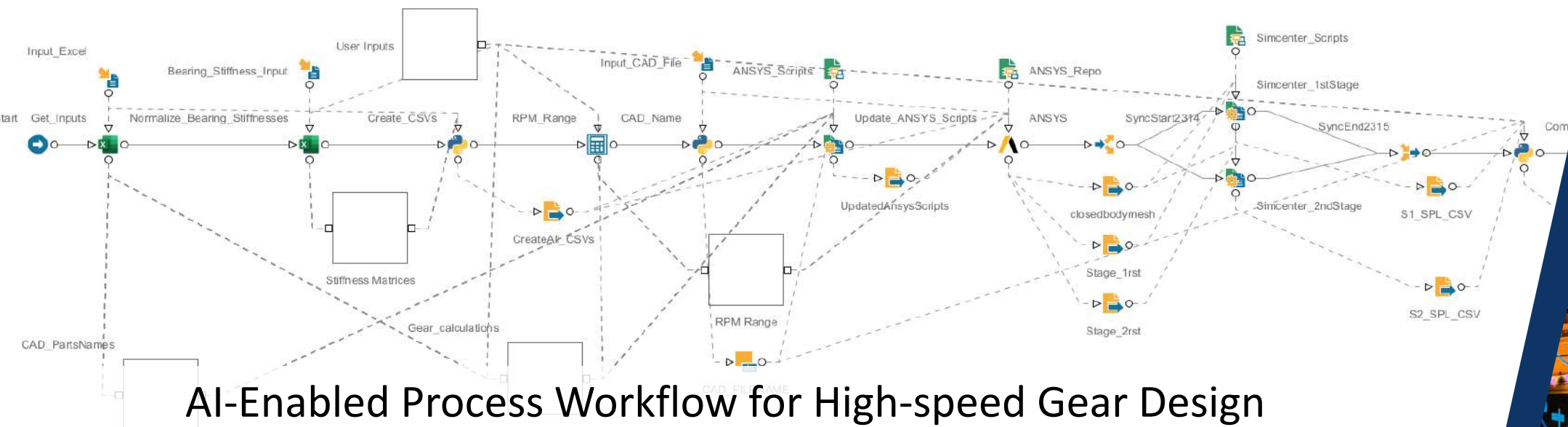
Thermal CTQs

- Thermal loading
- Heat transfer
- Correlated color temperature



AI-Driven Design & Process Automation

Orchestration of data and physics-informed AI models to automate the design of EV gears.



AI-Enabled Process Workflow for High-speed Gear Design

+65% reduction in design time



Generative Design

Intelligent design of liquid-to-air **heat exchangers** for Aerospace application with additive manufacturing constraints.



Optimized for cost, weight, heat load, efficiency, pressure drop

Four-fold increase in heat rejected per kilogram while also **reducing weight by 80%**.

Additive Manufacturing

Since its inception in late 2016, Eaton additive has developed expertise in many metal & polymer printing systems, additive material development & printed electronics with additive products launched at multiple customers in Aerospace & Energy systems



Two Corporate AM Centers of Excellence (USA, India)



Adv. Material, Additive Mfg, & Digital Design teams intimately linked



One Commercial Center of Excellence in Eaton Aerospace (SC, USA)



Focus on rapid qualification techniques



Production parts in metal & polymers



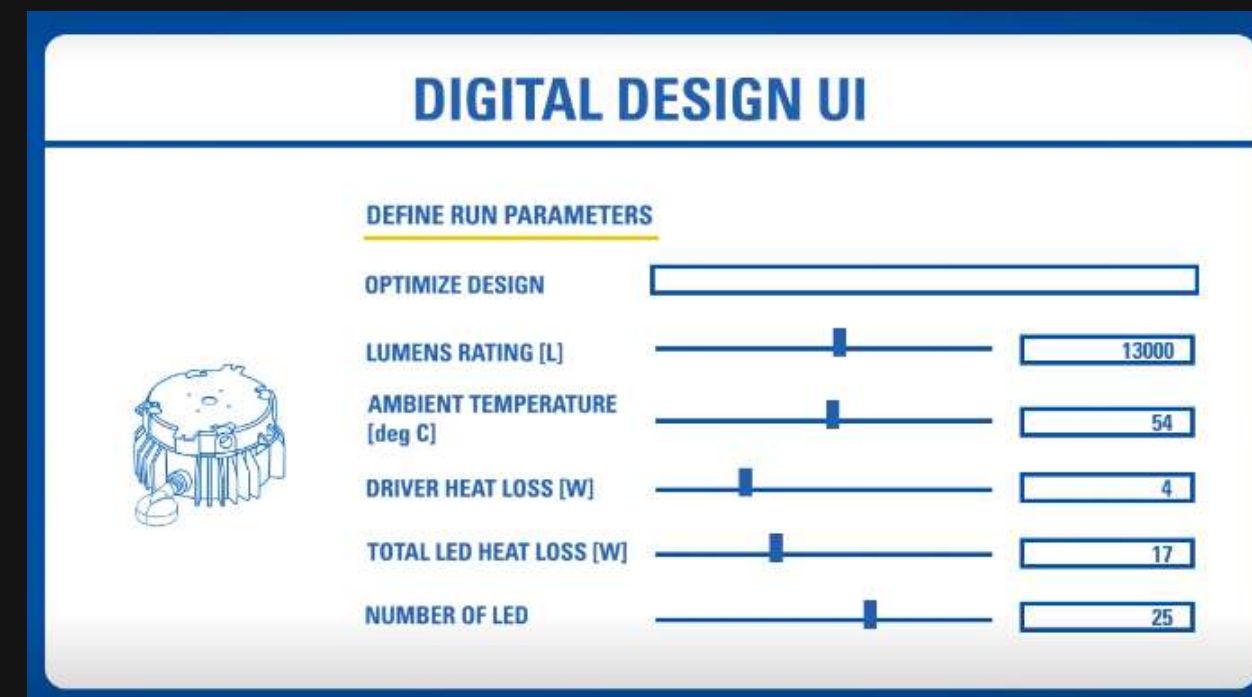
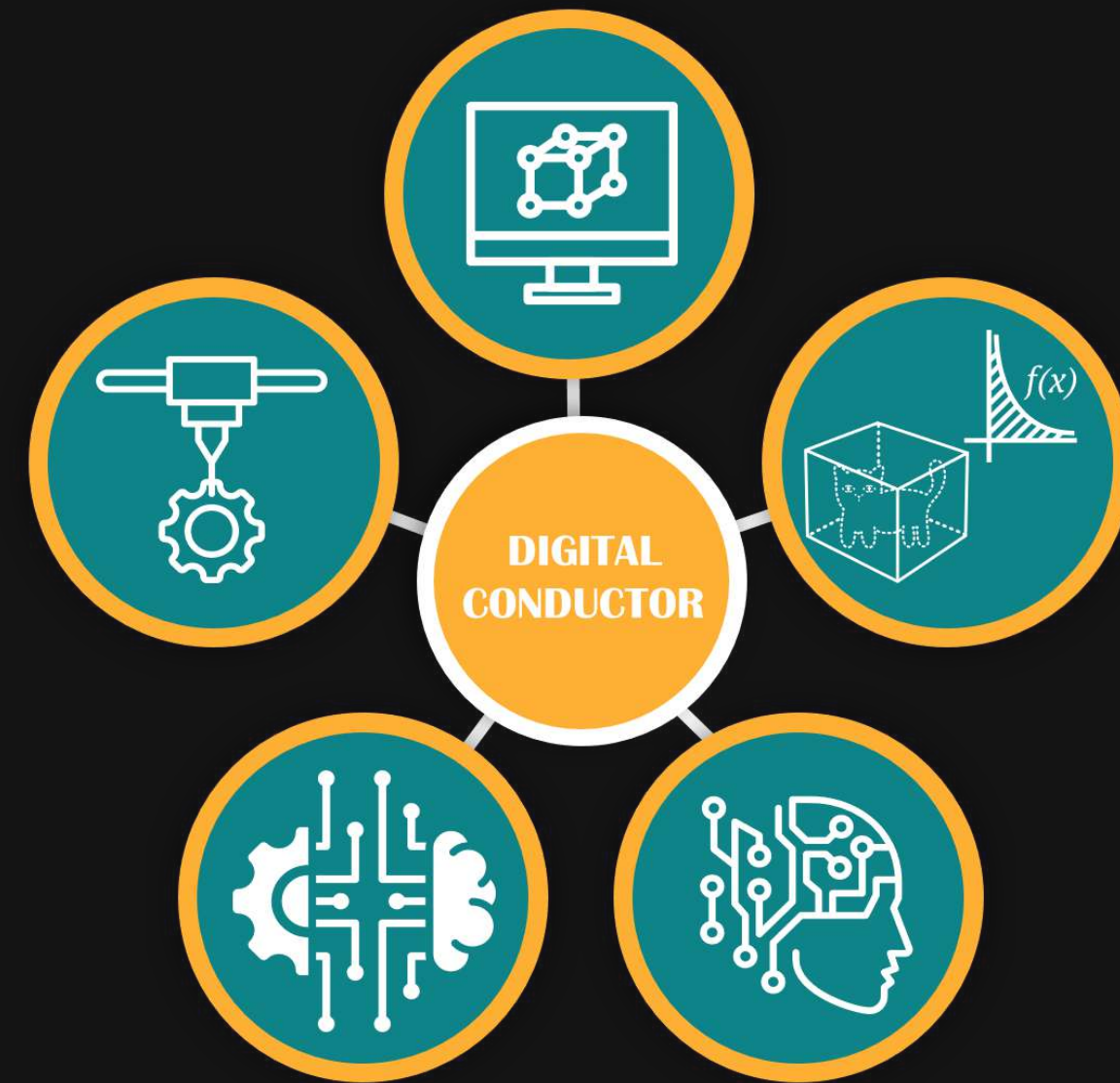
Global additive tooling



Bringing it all together

What Immortality looks like:

- developing products with new physics & digital design tools to create extraordinary life & value
- products that can fix themselves – *healable, tell you it's sick, aware*
- product design = “Hey Siri, Design me an X”
- no boundary between the digital & “real” world



EATON

Powering Business Worldwide