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Design and Modeling of Hybrid Manufacturing Processes : A Systems Perspective

Prepared for: Convergent Manufacturing A Future of Additive, Subtractive, and Transformative Manufacturing: A Virtual Workshop

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"A convergent manufacturing platform is defined as a system that converges heterogeneous materials and processes (additive, subtractive and transformative) in one platform, yielding functional devices and components for systems as an output, while equipped with unprecedented modularity, flexibility, connectivity, re-configurability, portability, and customization capability; all aided by Industry 4.0 principles."

What Constitutes a Hybrid Manufacturing System?

Systems Integration Perspective

- Systems integration activities have long benefited from and contributed to maturing modeling and simulation capabilities
  - Virtual to Virtual
  - Virtual to Physical

The evolution of systems integration can be characterized by technology, application, and problem

- Technology acts as a driver for requirements
- Applications act as a driver for scoping domain needs
- Problems evolve with new technologies and applications

Expanding on hybrid manufacturing through a systems perspective, key characteristics may include:

- Increased autonomy; multi-scale; multi-material; multi-laser; multi-scale, multi-machine

Optomec LENS 860


DMG Mori LASERTEC 65


BAE Systems

Additive Industries

Hybrid Manufacturing: Systems Technologies

As technologies continues to advance, hybrid enablers include:

- New laser systems and other processing technologies
- Advanced sensors and sensor networks
- New automation capabilities (hardware and software)
- New materials
- Faster communication with improved wireless access 5G(+)
- Improved computational capabilities (GPU, CPU, edge, cloud)
- New information paradigms (digital twin, blockchain)
- New data analytics including Machine learning/ AI

These advancements lead to new systems challenges, including:

- Increased "on demand" data access and storage
- Real time system to system communication
- Real time network (re)configurations
- Real time data analysis with explainable results
- Varying data structures with increased data heterogeneity
- Increased redundancies in instructions, observations, and behaviors

Platform characteristics:

Local, edge and cloud support; On demand access to relevant data; Transfer learning capabilities; Data compression; Information security; Established baseline "truths"; Unifying data structure for disparate data sources (captures convergence); Semantically unifiable structure

Hybrid Manufacturing: Systems Applications

As technology matures, digitalization progresses and new applications emerge, hybrid enablers include

- New tooling requirements (multi laser, tool exchange)
- New machine to machine interactions (robotics, printers, automated subsystems)
- Integrated inspection/ born qualified
- New (multi-)material delivery and removal systems
- Scaling of processes/deposition rates in real time
- Process monitoring,diagnostics, and feedback systems
- Accounting for human in the loop

These emerging applications introduce new systems challenges, including:

- Real time system to system communication
- Process interruption and control
- Machine health and prognostics monitoring and communication for machine, build and facility
- Providing awareness between systems' behaviors
- Local and global response control to changing behaviors

Platform characteristics:

Data and decision convergence support; Real time automatic reconfigurability- virtual and physical; Well characterized and integrated behavior models; Integrated safety features; Integrated security features; Standards-based communication between systems

Hybrid Manufacturing: Systems Problems

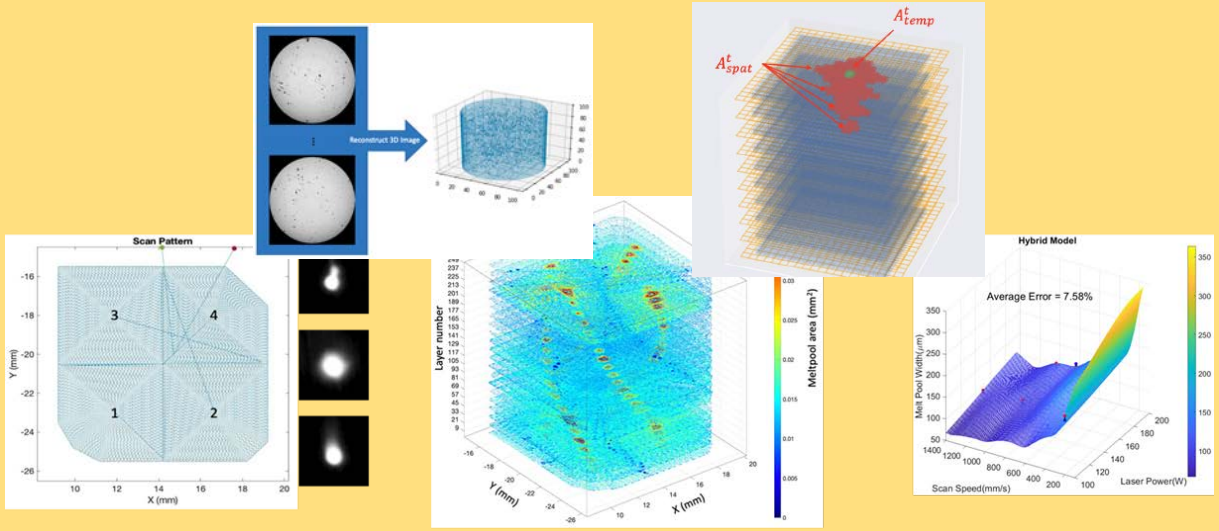
Advanced Hybrid Manufacturing Systems create unique systems challenges

Systems challenges can be overcome by solving evolving systems “problems”

- Systems problems can become increasingly complicated with hybrid manufacturing systems
- The “components” of the “system” continue to increase in size, complexity, and scope while increased demands are placed on control

  -Modeling and simulation are key enablers and key benefactors

  -Modeling and simulation are necessary for problem formulation and resolutions



Modeling and Simulation are key to solving systems problems, providing solutions through activities such as:

- Supporting systems integration
- Developing system interfaces
- Enabling communication between systems;
- Understanding and facilitating system scaling
- Performing system optimization;
- Defining system structure/definition
- Understanding and predicting system behavior;
- Assessing system performance