

Build strategies for additive manufacturing by cold spray

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National Research Council Canada

Cold Spray

- 23 dedicated PhDs, engineers and technicians
- 3 dedicated cold spray booths
- 7 state-of-the-art (high and low pressure) cold spray systems
- Helium recovery system
- Laser assisted cold spray
- Process diagnostics, monitoring and simulation
- Comprehensive testing and characterization capabilities

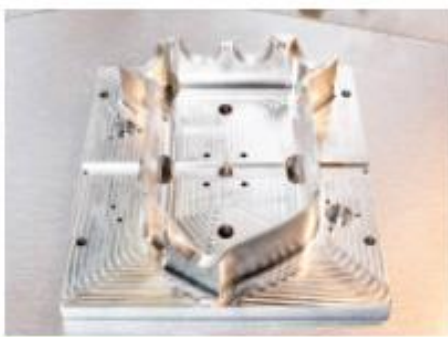


Cold spray additive manufacturing industrial R&D group objectives

1. Develop 3D build-up capabilities for cold spray
2. Extend the range of materials applicable for cold spray
3. Adapt the cold spray process to attain required deposited material properties for targeted applications



Part reinforcement
and consolidation



Advanced mold
and die fabrication

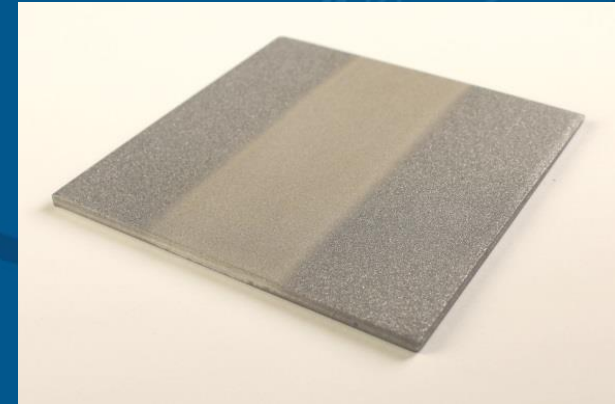
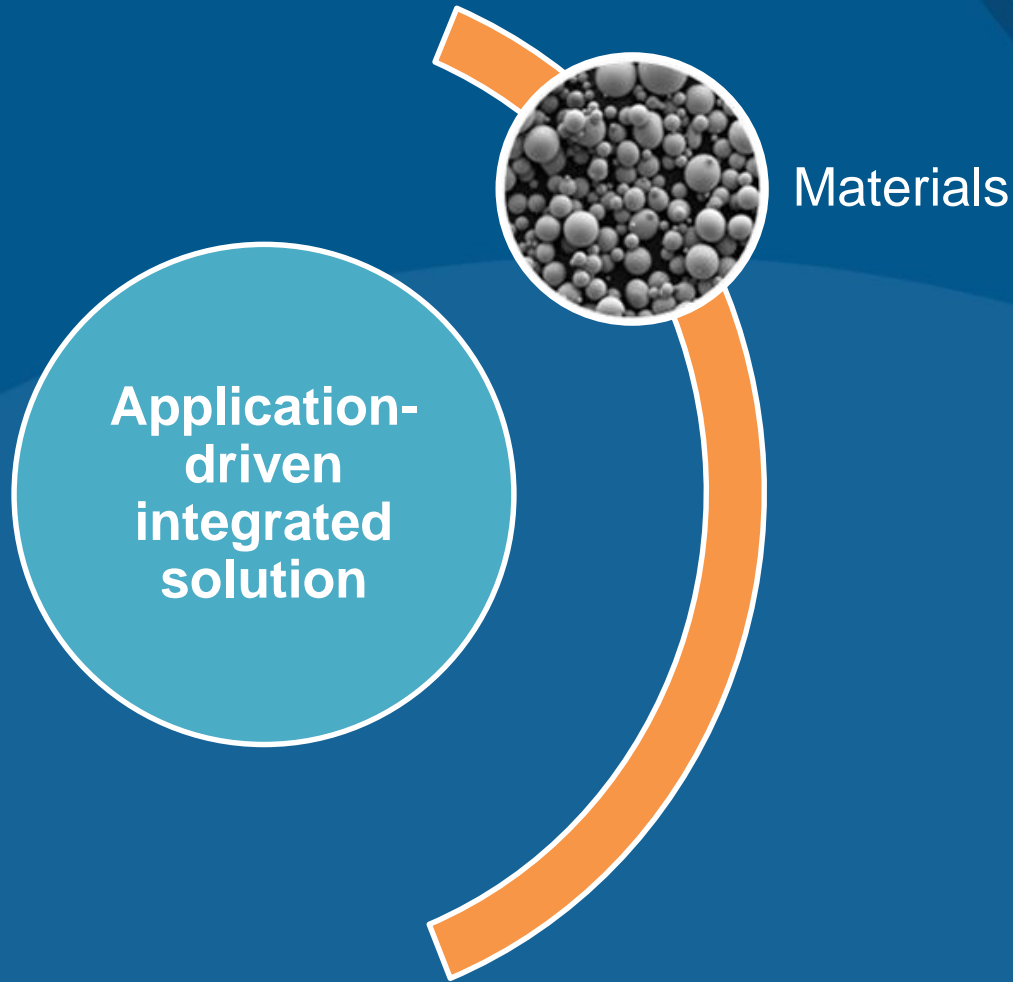


Rapid Prototyping
of Metal Parts

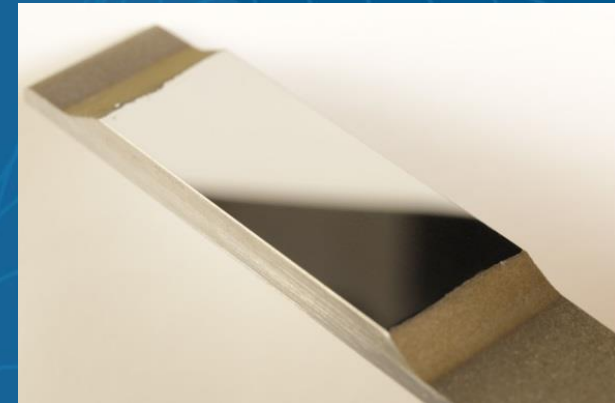


Dimensional
restoration and
structural repair

CSAM research axis and breakthrough development



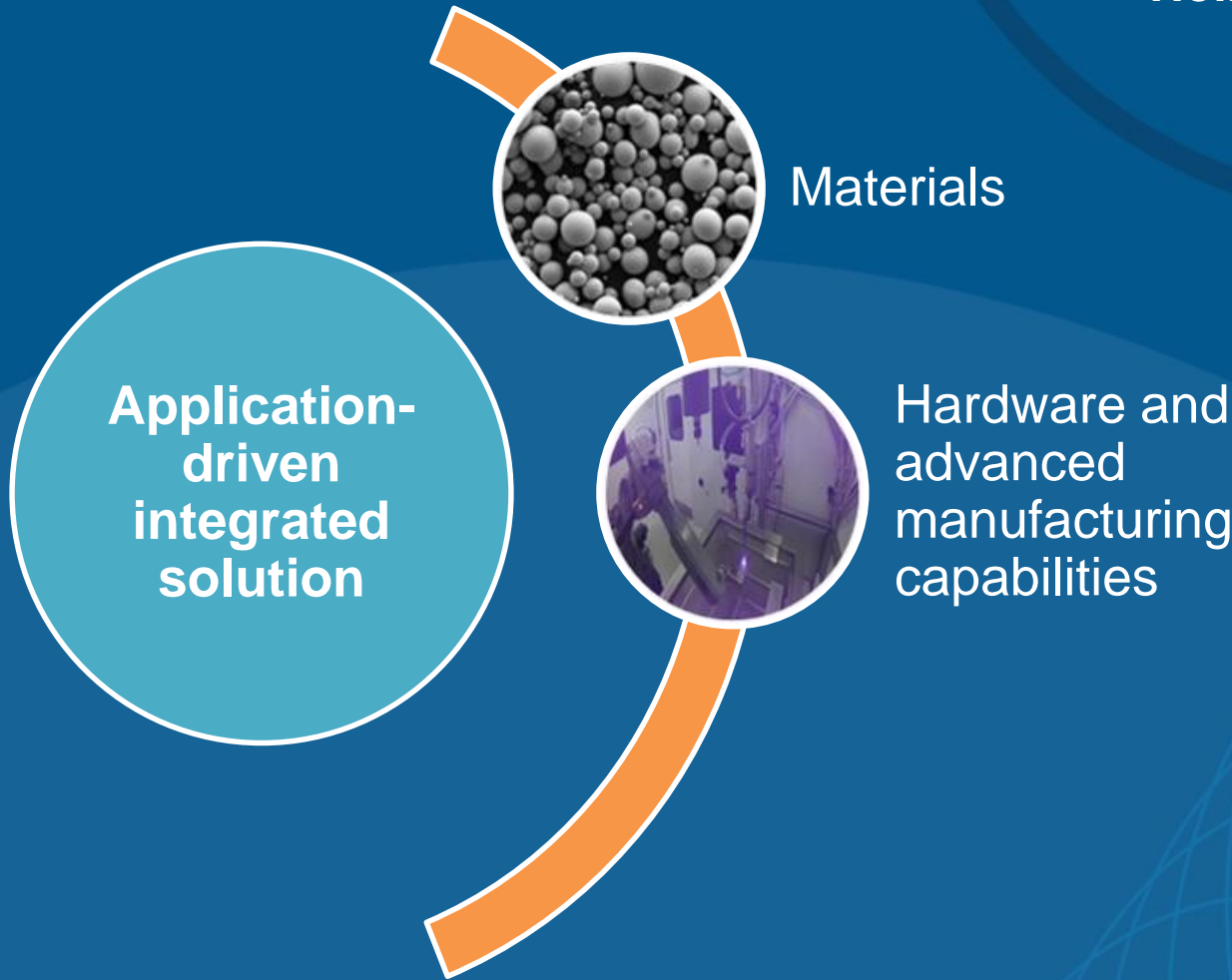
- Commercial H13 powder
- As received, different spray conditions tested



- Same commercial H13 powder
- Tailored powder

CSAM research axis and breakthrough development

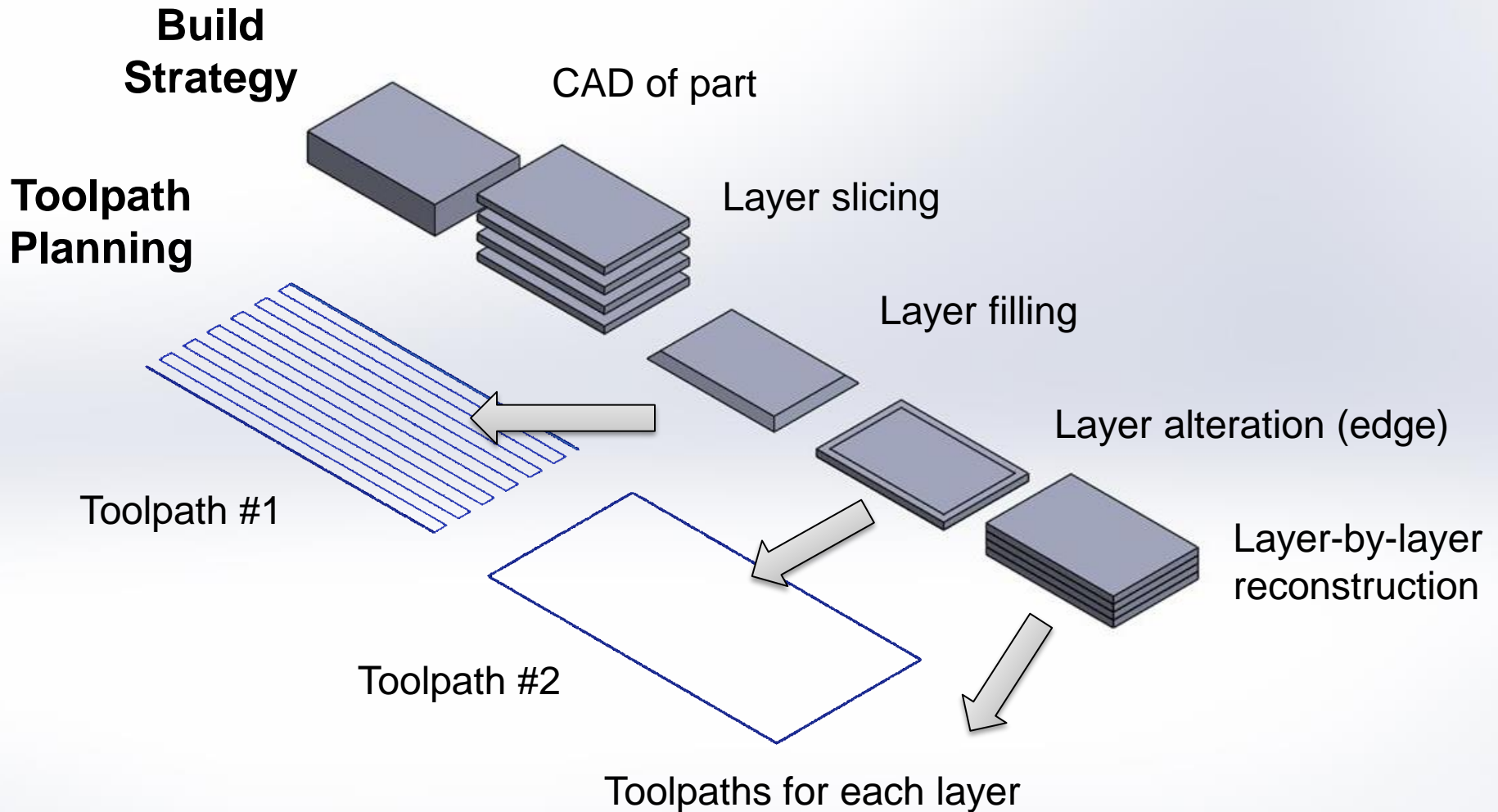
Hollow structure manufacturing
for conformal cooling



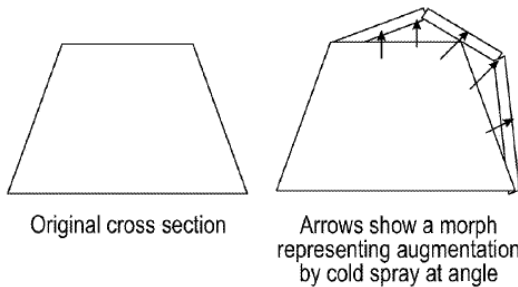
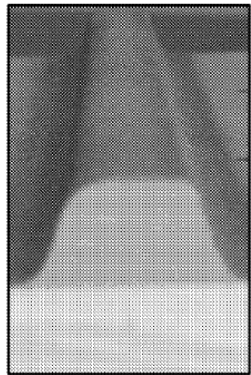
CSAM research axis and breakthrough development



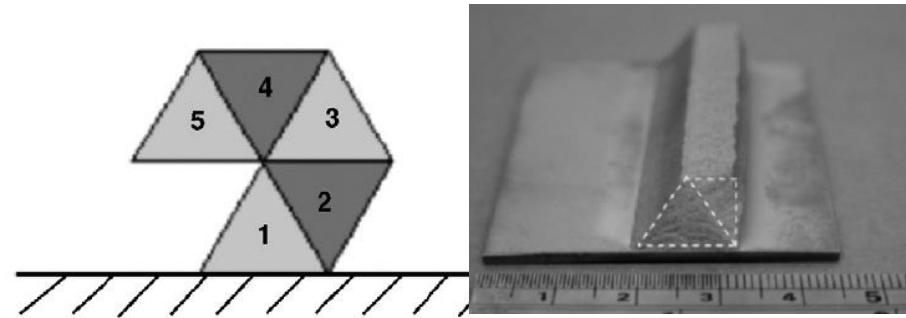
Toolpath and build strategy with cold spray AM



Selective deposition for shape control (literature)



Augmentation by cold spray at angle

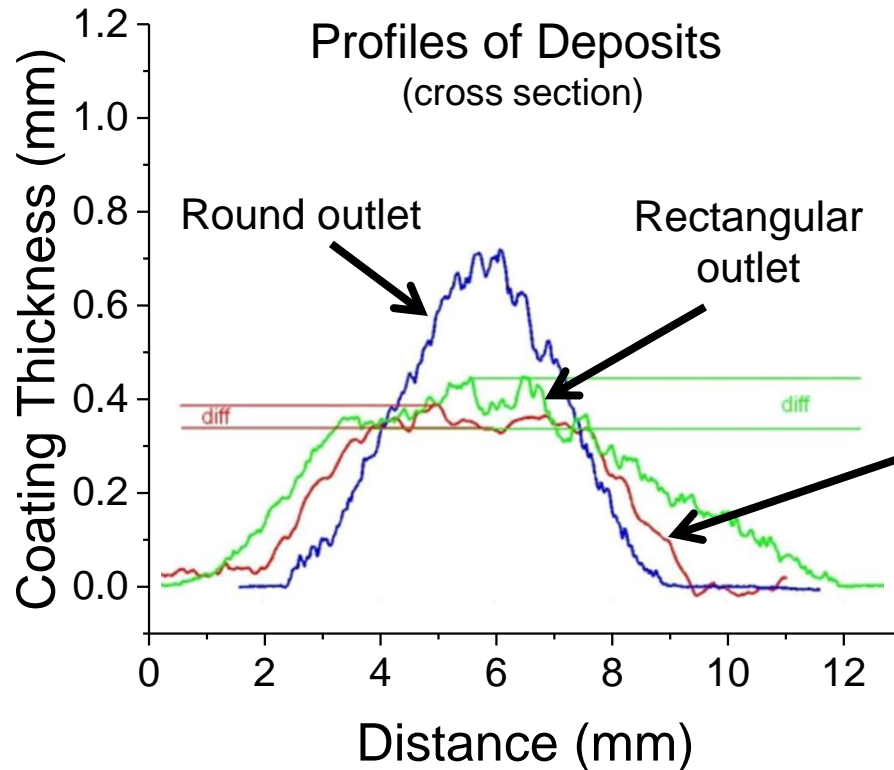


Triangular tessellation technique

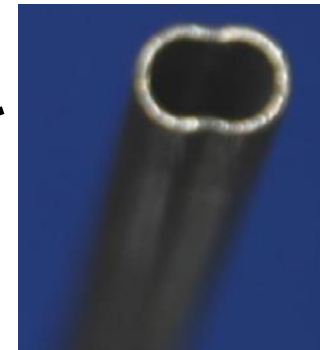
Patent# US 2014/0277669 A1
Sikorsky Aircraft Corp. (A. Nardi et al.)
Additive topology optimized manufacturing for multi-functional components

J. Pattison et al., *Cold gas dynamic manufacturing: A non-thermal approach to freeform fabrication*, Int. J. Machine Tools & Manufacture 47, 2007, 627-634

Nozzle design for shape control (NRC-London)



Nozzle designed for uniform deposition



Xue et al., *Direct manufacturing of net-shape functional components/test-pieces for aerospace, automotive, and other applications*, J. Laser Applications 23(4), 2011, 8p. (Patents US 9,168,546 B2 and CA 2,688,108 A1)

Considerations with cold spray AM

Build strategy

- Design parameters
- Transitions
- Support structures

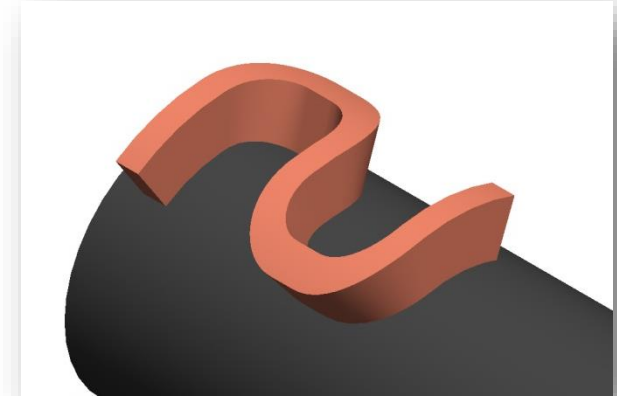
Fabrication

- Material-, hardware-, & process-specific

Toolpath

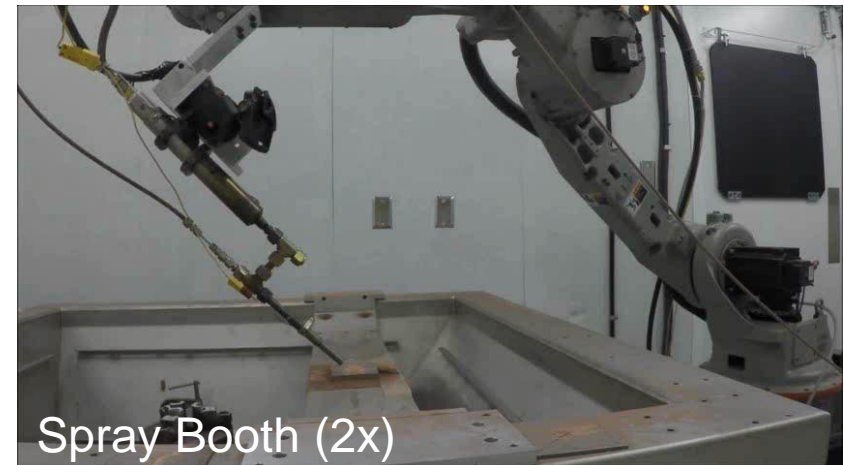
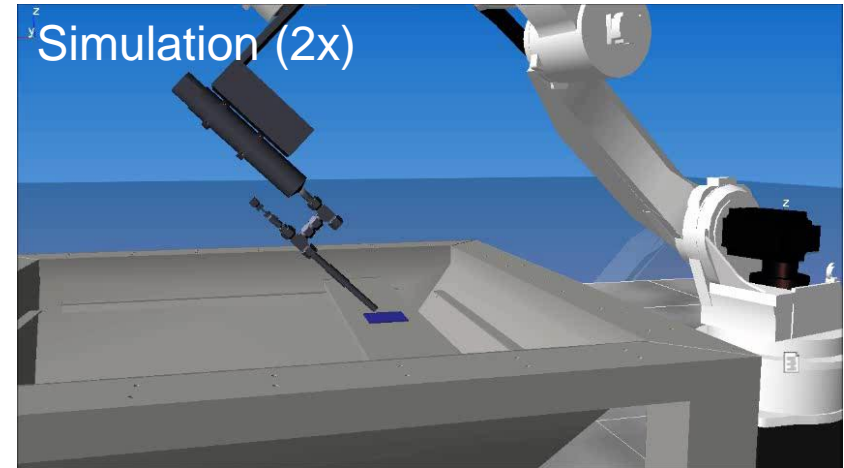
- Line-of-sight
- Precision and accuracy
- Integrated control

Cold Spray Build

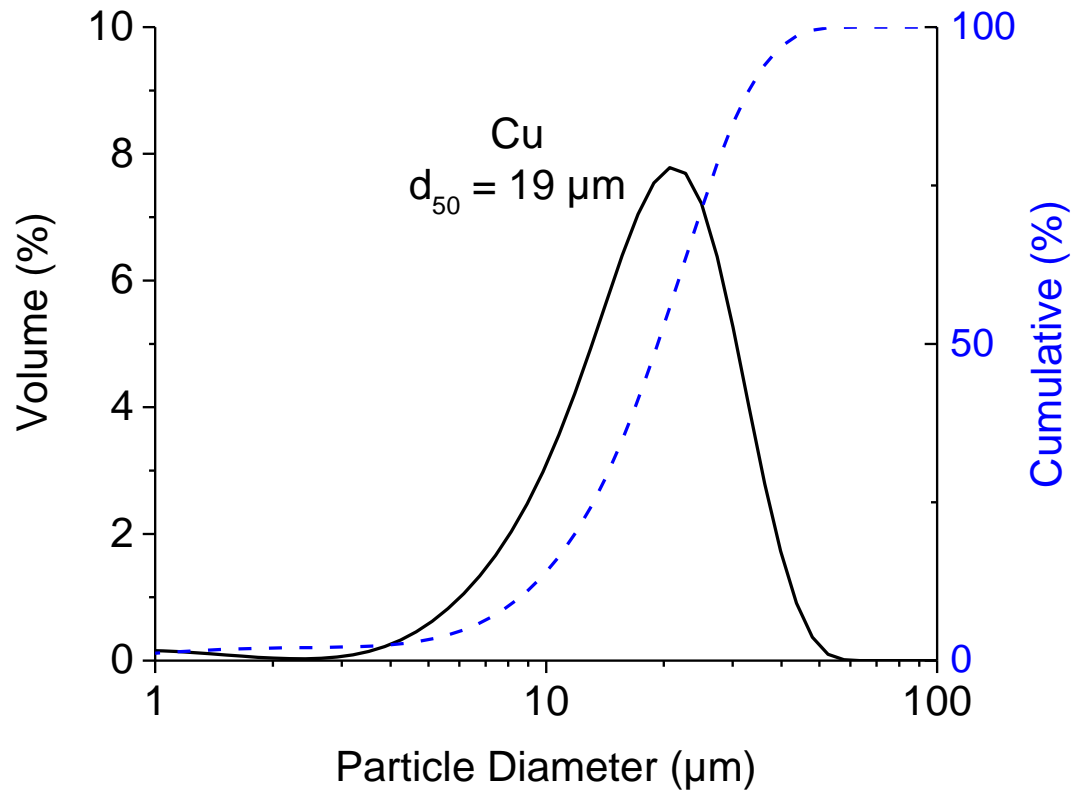


Toolpath generation

- Software-based robot programming
 - Complex toolpaths
 - Accurate, flexible, and efficient
 - Multiple toolpaths
 - Point density
- Simulation
 - Verification and troubleshooting



Cold spray powder and equipment



Inovati KM-CDS 2.2



Build strategy for shape control

- Resolution
 - ~4 mm outlet diameter for commercial nozzle
- Typical profile
 - Build-up at centre of particle jet greater than edges
- Altered profile
 - Consecutive passes at different spray angles

Typical Profile
Spray at 90° to substrate

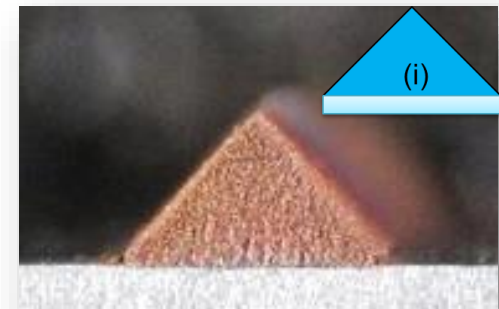


+ spray time

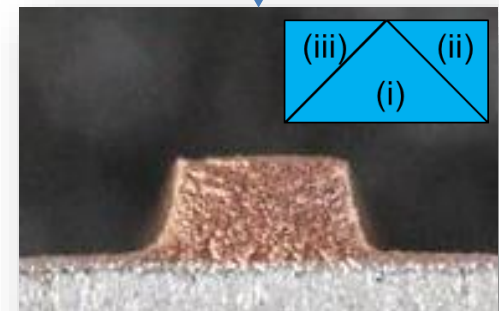


2 mm

Altered Profile
Spray at 90°



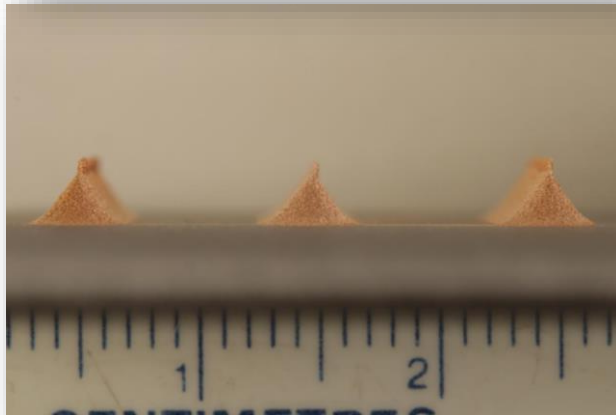
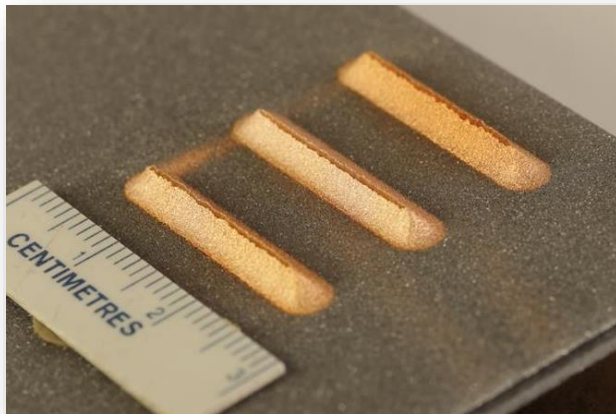
+ spray at
45° & 135°



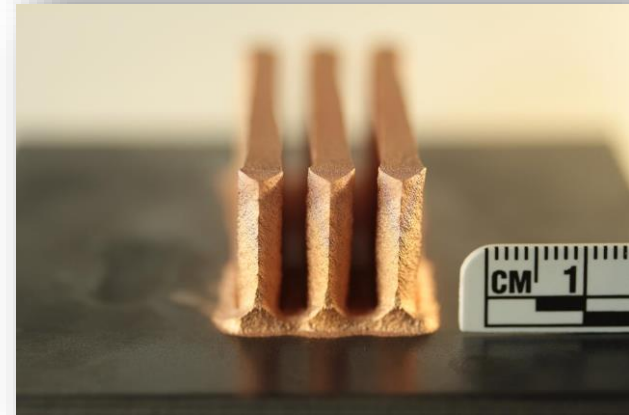
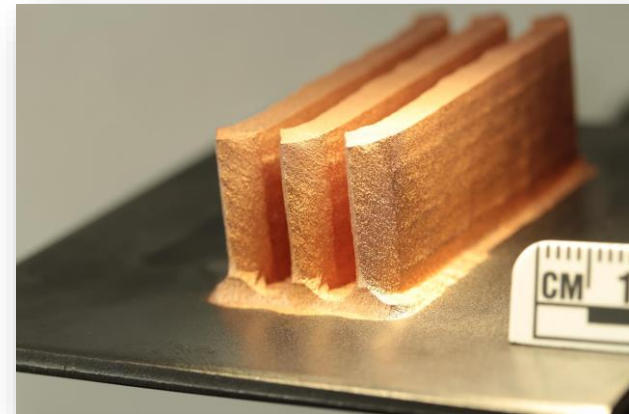
2 mm

Build strategy for shape control

Multiple passes with typical deposition profile

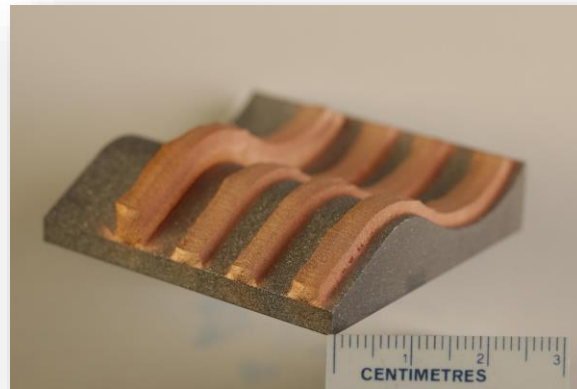


Multiple passes with altered deposition profile



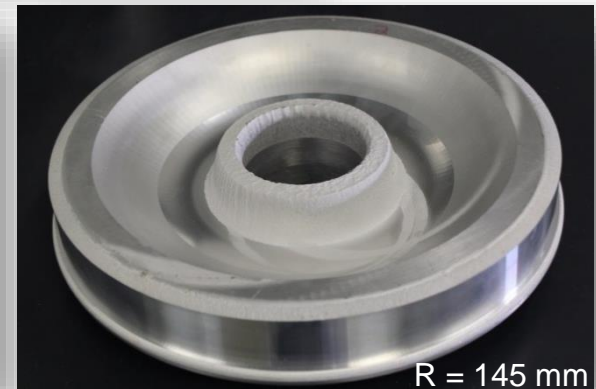
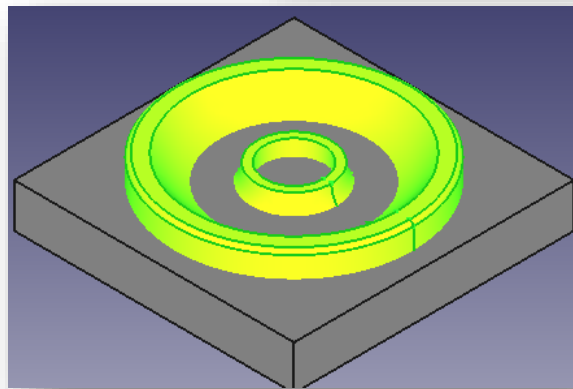
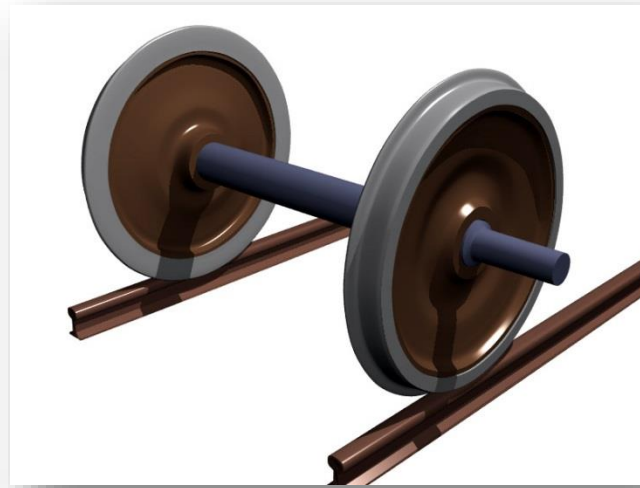
Layer-by-layer build considerations

- Design parameters
- Layering strategies
- Toolpath planning



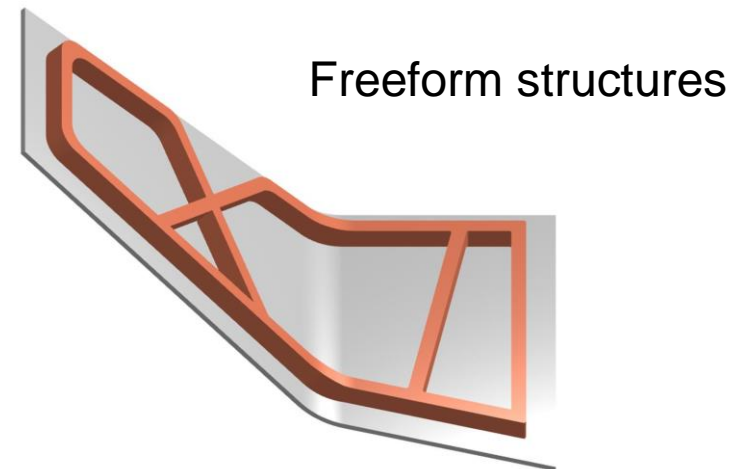
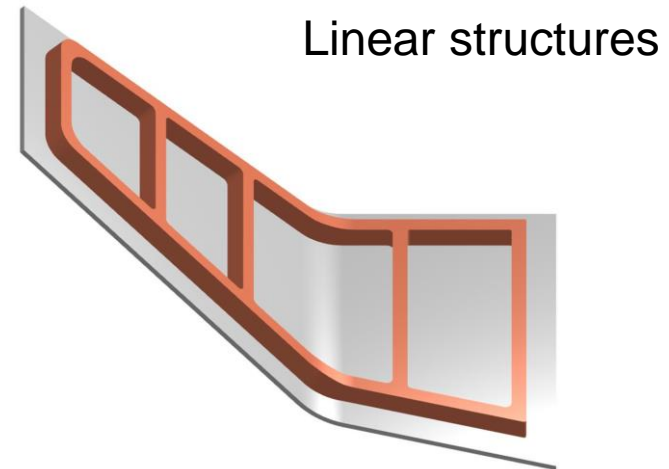
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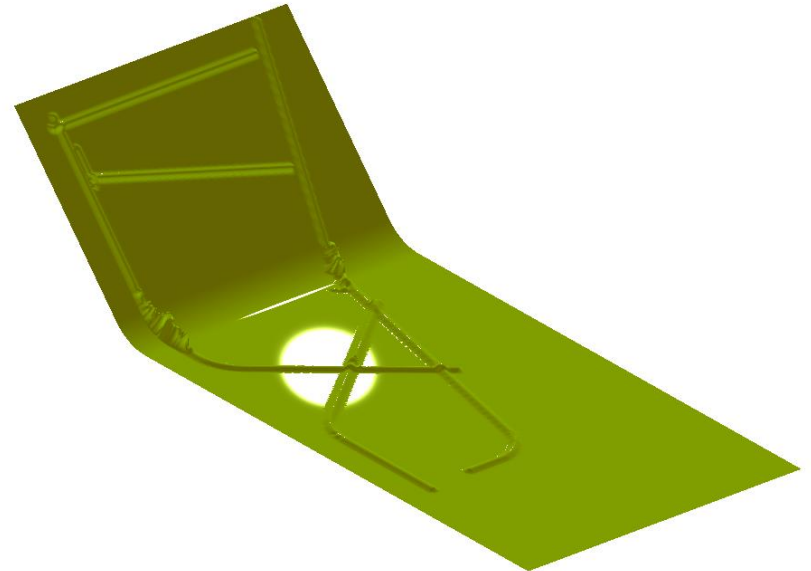
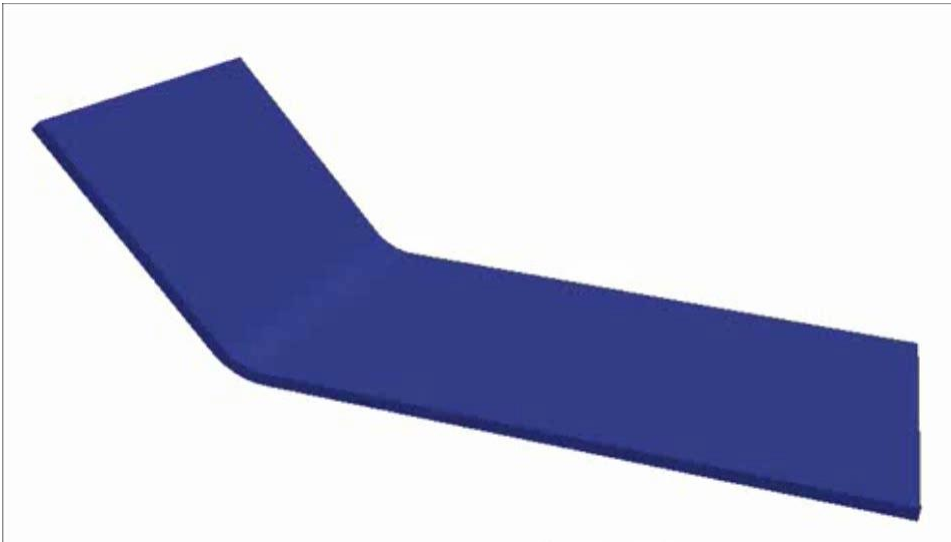
Design and build process

- Freeform stiffening structures
 - Design flexibility
- Toolpath planning
 - Build strategy
 - Robot considerations
 - Simulations
- Build process
 - Cold spray build
 - In-process machining

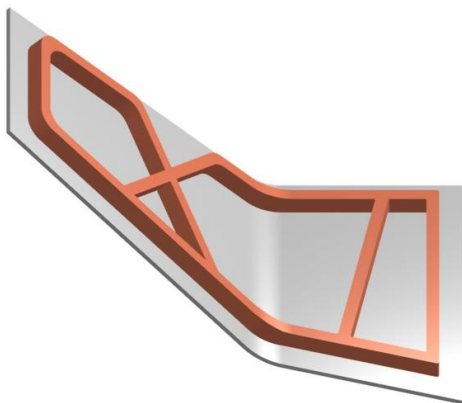


Toolpath planning

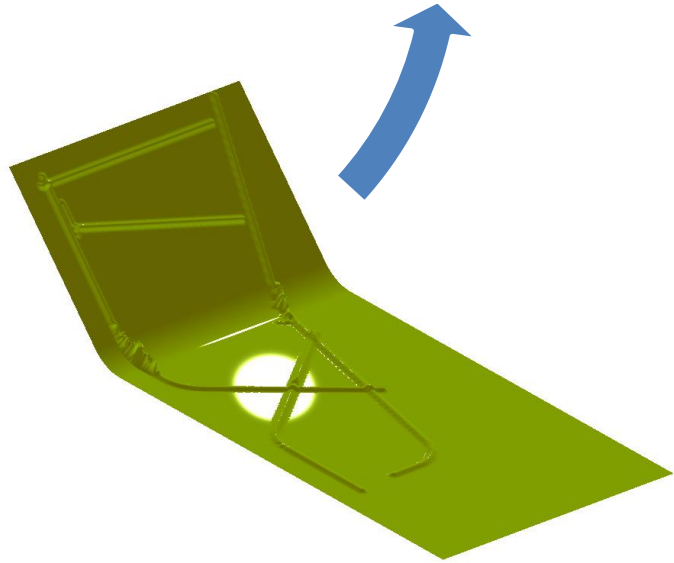
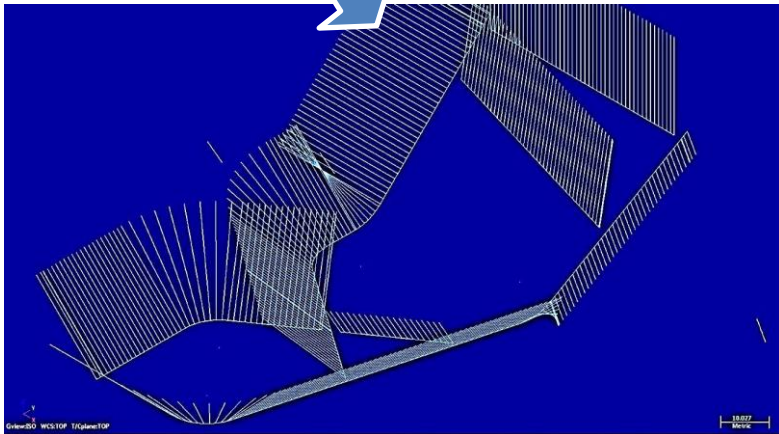
- Heat and mass transfer simulation



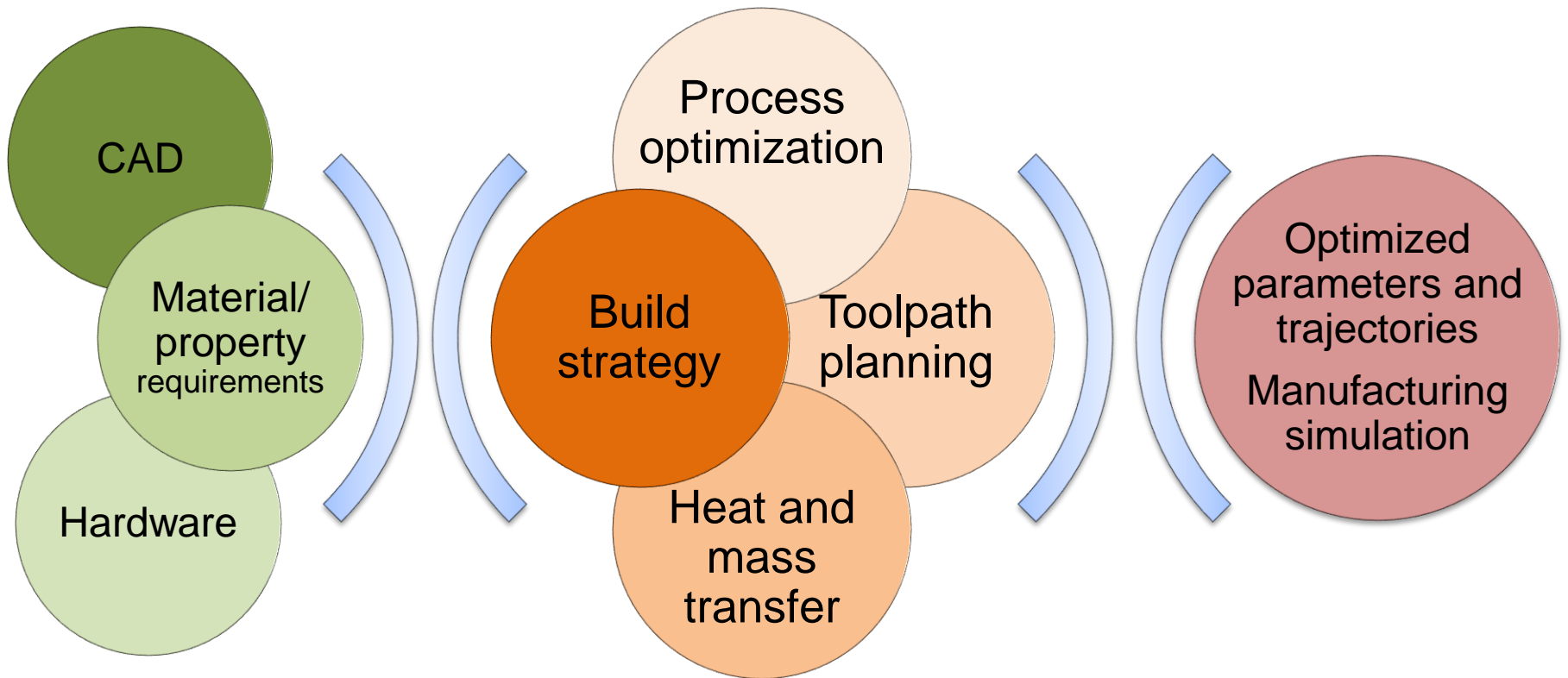
Manufacturing process



CSAM Solutions
Software



NRC Solutions software



Cold spray AM industrial R&D group – NRC team

40+
experts

Thermal Spray Team

•M. Aghasibeig, J.-F. Alarie, C. Cojocaru, D. de Lagrave, F.-D. Guenette, B. Guerreiro, B. Harvey, C. Hoang, E. Irissou, J.-M. Lamarre, M. Lamontagne, J.-G. Legoux, R. Lima, M. Martin, D. Poirier, J. Sykes, K. Theberge, J.-C. Tremblay, P. Vo, M. Zeman, Polly-Lee Moore

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Modeling & Simulation Team

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Ultrasonic Technology | Process Diagnostics Team

•A. Beauchesne, C. Bescond, S.E. Kruger, G. Lamouche, D. Lévesque, M. Lord, J.-P. Monchalain, D. Rocheleau, Z. Sun, J. Wu

Automation, Robotics and Intelligent Manufacturing Systems Team

•G. Côté, B. Monsarrat, M. de Montigny



Thank you

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