ADVANCED MANUFACTURING RESEARCH CLUSTER UBC

Canada is a manufacturing nation

- 11% of GDP, 1.7m employees, $7bn in annual R&D spend, 61% of goods exports
  Government of Canada "Strengthening Canada's Manufacturing Sector" 2014
- 80% of private sector R&D in Canada and two thirds of all goods & services exports.
  Canadian Manufacturers and Exporters
- In BC - $42bn in manufacturing sales, >7000 manufacturing establishments, 161,000 jobs
  "BC's manufacturing sector" Chartered Professional Accountant British Columbia 2016
- One of only 10 countries in the world where manufacturing is >10% of GDP
- Major federal government policy pillars:
  - CETA is a very important trade deals …that will create 80,000 jobs for Canadians
    Jason Myers, President & CEO Canadian Manufacturers and Exporters
  - $13bn in R&D funding over the last decade
  - Canada leads the G7 with the lowest tax rate on new manufacturing investments

A Revolution in Manufacturing Technologies

- Digital Revolution – Computing power growing exponent
- Industry 4.0 – Integration of cyber physical systems
- Advanced visualization, modelling and artificial intelligence
- Reconfigurable and integrated automation, sensors, robots, lasers and visual systems enabling product/ process monitoring & control, data collection both vertically (from shop floor to top floor) and horizontally (across the value chain)

- Internet of things – "Internet of Value" – Real time connection of products, processes, systems, customers, suppliers networks of value
- Big data an quantum computing – Data analysis enabling rapid decisions and new applications and services

- Additive manufacturing and 3D printing – Rapid prototyping and mass customization of complex parts
- Micromachining – Nano-machines, Bio-machines

- New materials – Lightweight, bio-nano-based, new alloys, printable electronics and smart materials
- New energy technologies –Generation, storage, propulsion, renewables

SCIENTIFIC VISION

The transformation of novel, exciting materials into the advanced products for the future

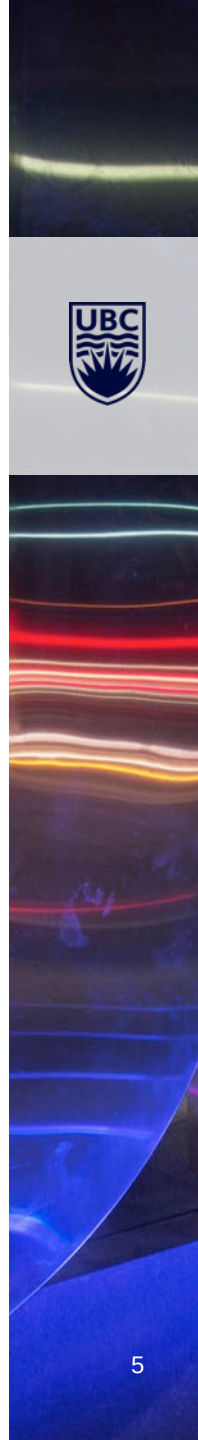
The challenge of massively complex problems

COMPETITIVE POSITIONING

Team of ≈ 30 researchers from both Vancouver and Kelowna

Nationally and internationally competitive

$90M	83,000	7 Canada	105
research income	citations	Research Chairs	Industrial partners



100+ INTERNATIONAL ELITE PARTNERS

- NASA
- Los Alamos National Laboratory
- Stanford
- DARPA
- US Air Force
- DLR (German Aerospace)
- Fraunhofer Society
- Max Planck Institute (Dussedorf)
- Universities of Grenoble, Lyon, Nantes
- Paris Tech

100+ INTERNATIONAL ELITE PARTNERS

INDUSTRY

Automotive

GM
Ford
Honda
Toyota
Magna
Montupet (Linamar)
Dicastal
Renault
Bosch
Caterpillar
Mercedes Benz

Aeropace

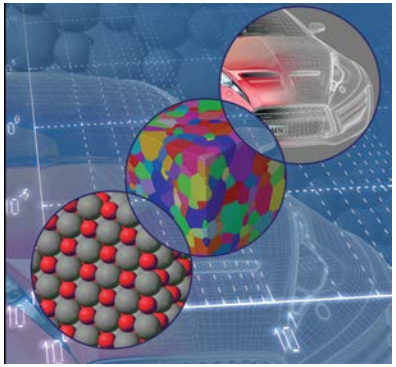
Boeing
Airbus
Bombardier
Rolls Royce
Pratt and Whitney
Lockheed Martin
NASA
3M
Dassault
Johnson Matthey
Dupont
BASF
Siemens

Material Suppliers

Rio Tinto Alcan
Arcelor-Mitall Dofasco
Teck
Posco
Dillenger Hutte
Kobe Steel
Evraz
US Steel
Novelis
Magnesium Elektron
Nippon Steel
JFE

THEME AREAS

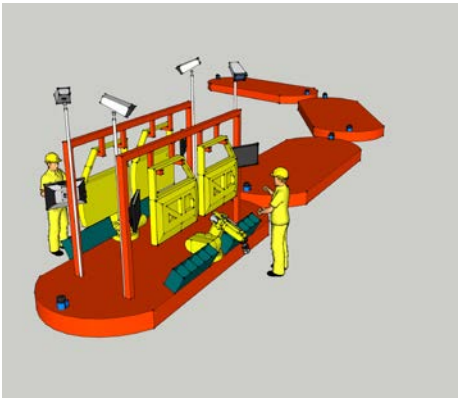
Multi-scale modelling



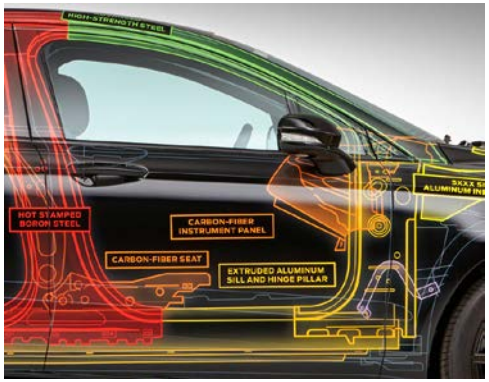
Advanced Metals Processing

Composites Manufacturing

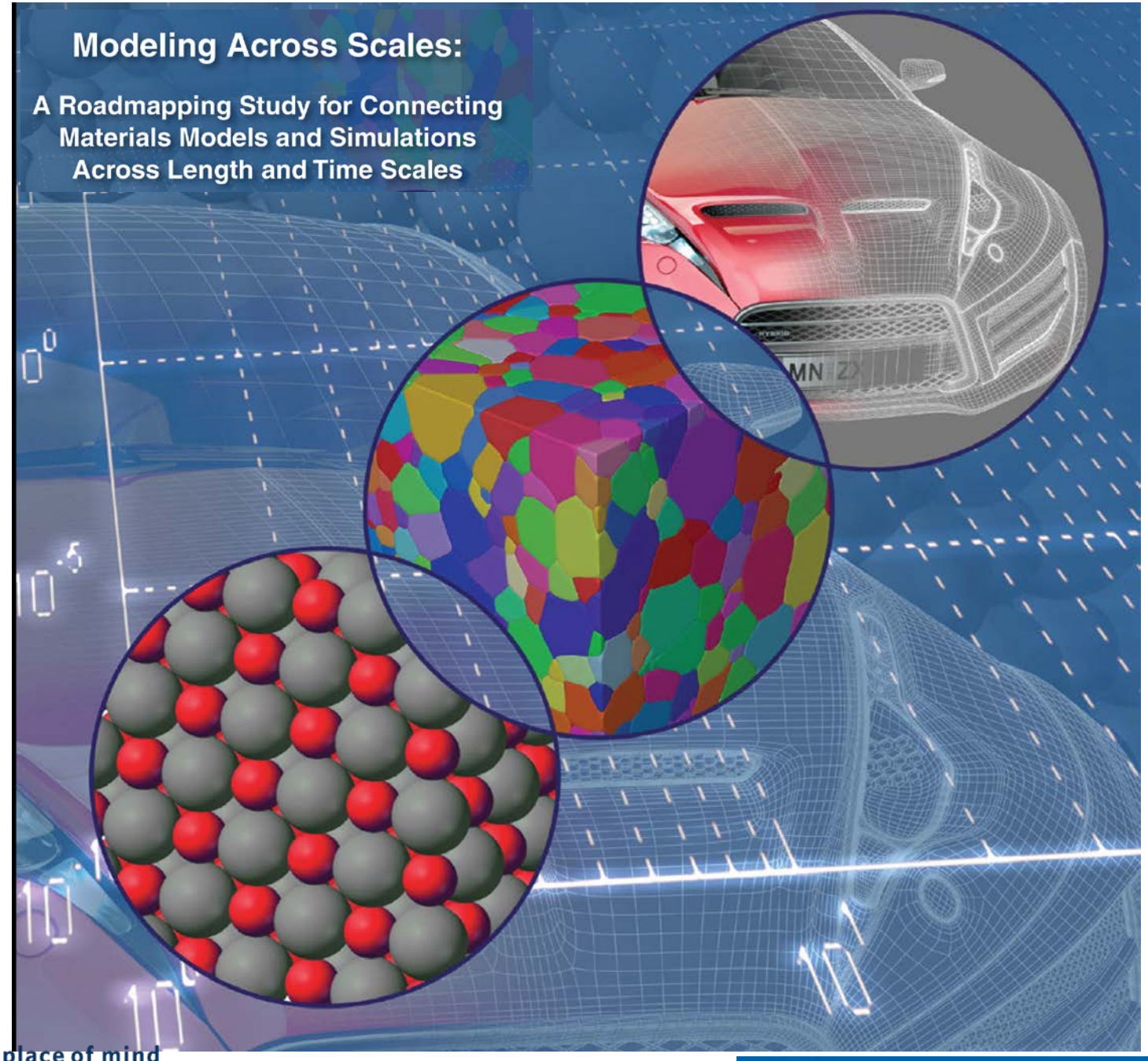
Automation and robotics



Multi-material solutions



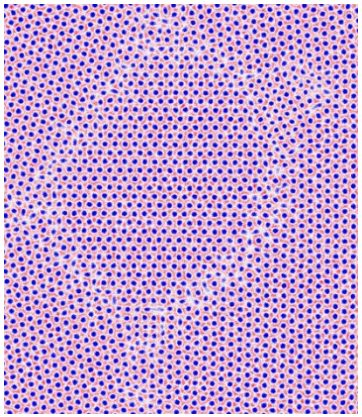
Additive manufacturing


Modeling Across Scales:
A Roadmapping Study for Connecting Materials Models and Simulations Across Length and Time Scales

Modelling Across Different Length Scales

Atomistic:
$10^{-9} – 10^{-10}$ m

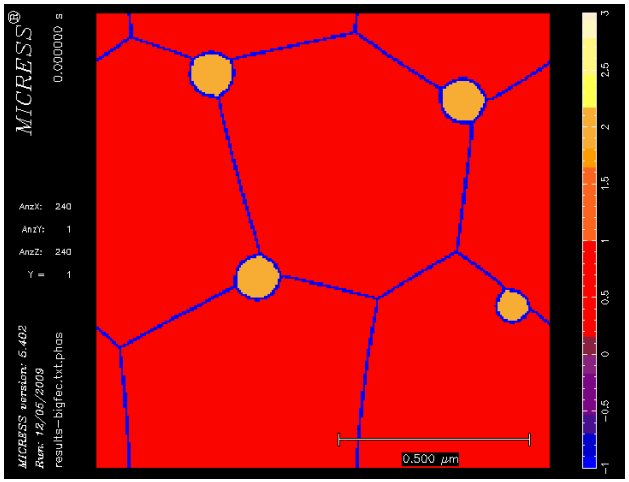
Scale of atom



- Density Functional Theory
- Molecular Dynamics
- Kinetic Monte Carlo
- Phase Field Crystal

Mesoscale:
$10^{-6} – 10^{-4}$ m

Scale of microstructure



- Phase Field Modelling
- Crystal plasticity
- Micromechanics

Macroscale:
0.01 – 10 m

Size of auto or airplane

- Finite element method
- CPFEM

UBCV Additive Manufacturing Activities

Chad Sinclair, MTRL
Daan Maijer, MTRL
Steve Cockcroft, MTRL
Yusuf Altintas, MECH
Rizhi Wang, MTRL
Rebecca Schaller, MTRL

UBC Program

1. NSERC Strategic Grant – Title: *Through-Process Modelling for Optimized Electron Beam Additive Manufactur*ing
2. CFI-JELF Award – Title: *High Performance Additive Manufacturing*
3. CFI-Innovation Fund - Title: *Canadian Additive Manufacturing Network (Can-AMN): A Network for Holistic Innovation in Additive Manufacturing*
4. NSERC Strategic Research Network – Title: *NSERC Network for Holistic Innovation in Additive Manufacturing (HI-AM)*
5. Collaboration with Deutsches Zentrum für Luft- und Raumfahrt e.V. (DLR) (Univ. Prof. Dr.-Ing. Heinz F. Voggenreiter)

NSERC Strategic Grant – Title: *Through-Process Modelling for Optimized Electron Beam Additive Manufactur*ing

NSERC Strategic Grant

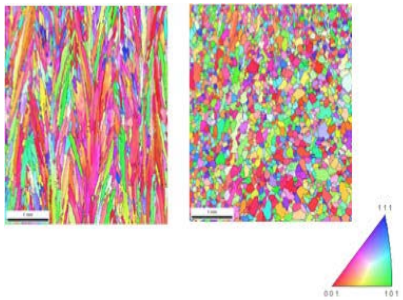
- $500,000 (2016-2019)
- Partnered with local company

APSC Innovation Grant

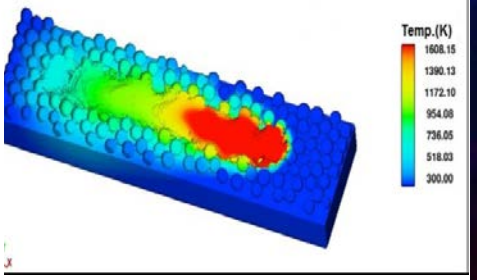
- $100,000
- Building of AM at UBC

The AM technologies involve important processes occurring at a range of length and time-scales that are dependent on multi-physics phenomena

Micro-scale (mm to ms)



Meso-scale (mm to s)



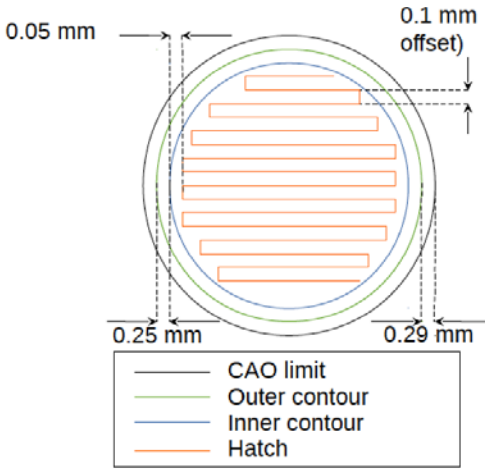
Macro-scale (m to hr)

Multi-Physics:

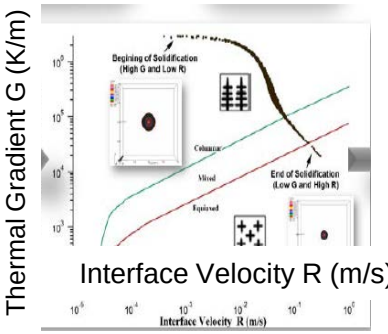
- thermal and mass diffusion and advection;
- radiation;
- evaporation and
- continuum mechanics

Micro-, Meso- and Macro-Scale Modelling of EB-Based AM Technology

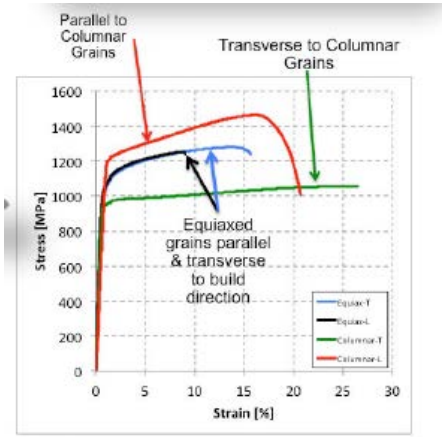
Process Parameters Pattern + Power + Scan Speed



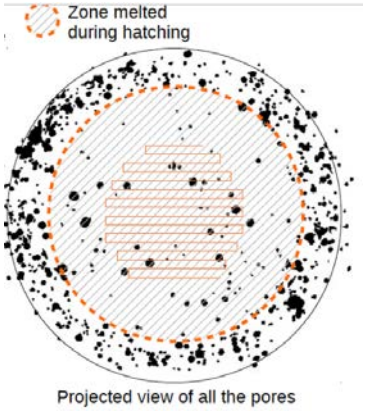
Microstructure



Mechanical Properties



Defect Population

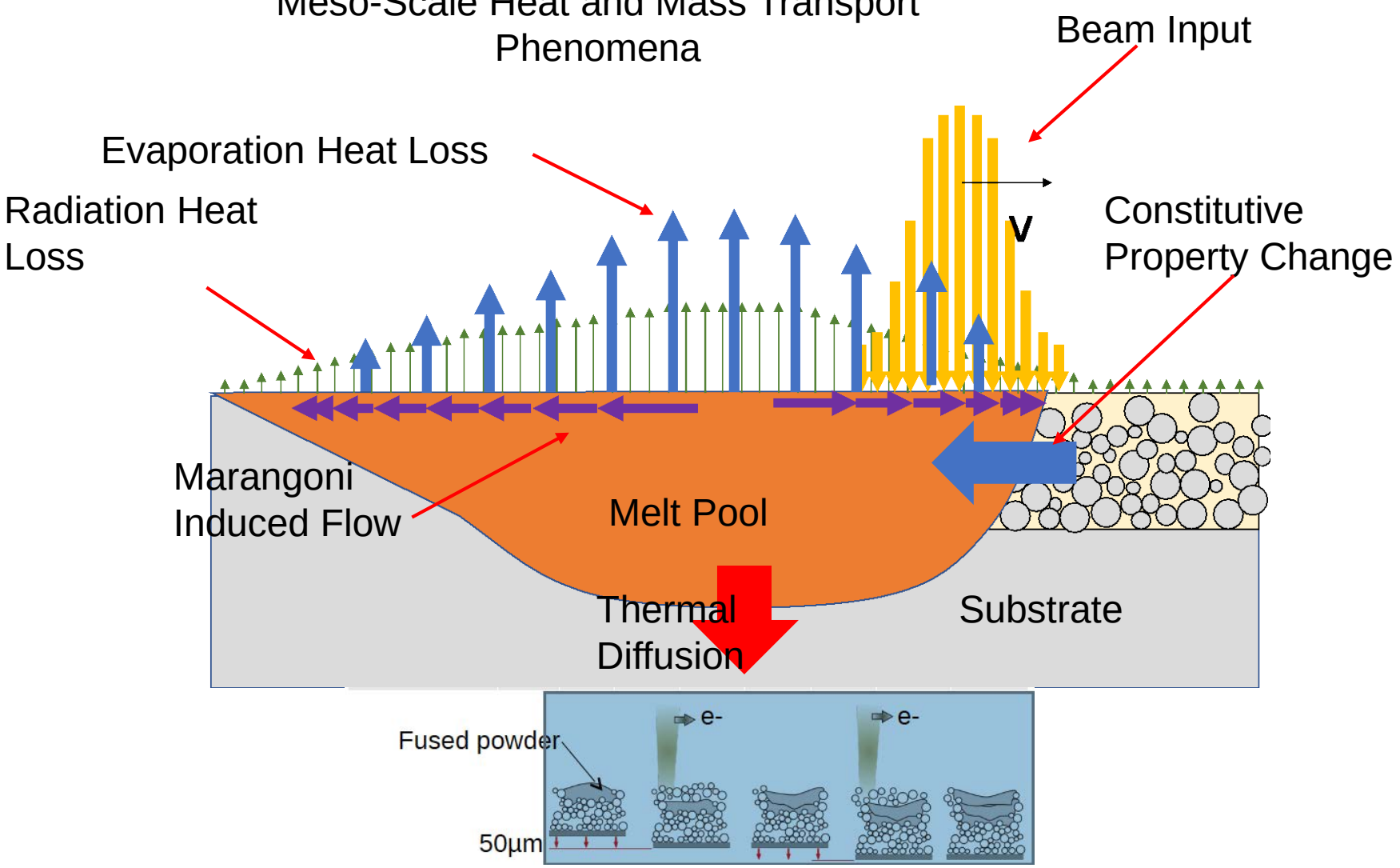


\+ Geometry Control

\+ Residual Stress

Micro-, Meso- and Macro-Scale Modelling

Meso-Scale Heat and Mass Transport Phenomena



NSERC Strategic Grant – Title: *Through-Process Modelling for Optimized Electron Beam Additive Manufactur*ing

Projects:

1. "Thermal & transport modelling of e-beam based AM"
   a. Meso-scale: E. Nishimura (Ph.D. Candidate) – Cockcroft/Maijer
   b. Macro-scale: N. Taylor (4 month intern) – Sinclair/Maijer

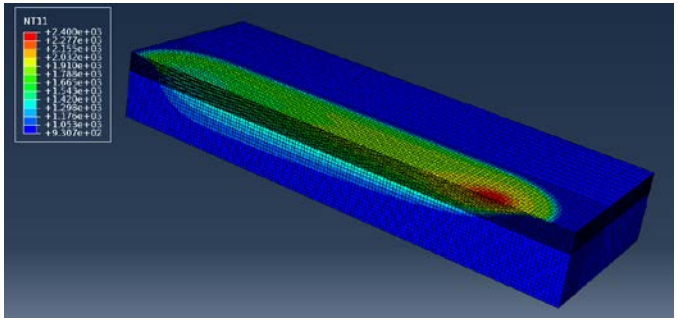
2. "Process Control for 3D-printing"
   - D. Sera Ertay (M.A.Sc. Graduate) – Altintas

3. "Solid-state Microstructure Control in e-beam AM"
   - W. Sparling (M.A.Sc. Candidate) – Sinclair

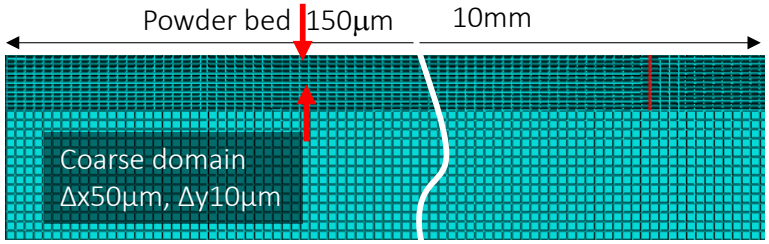
4. "Predicting & Controlling Solidification Microstructure in e-beam AM"
   - Dr. L. Wang (Post Doctoral Fellow) – Sinclair, Cockcroft, Maijer

Thermal Modelling

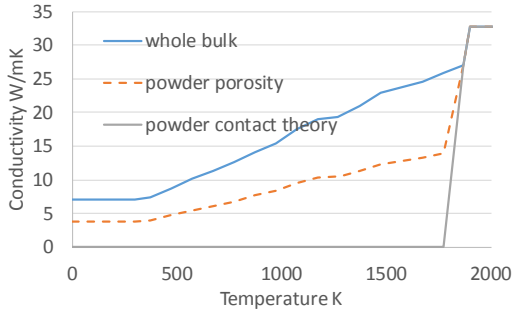
ABAQUS Based Thermal Model



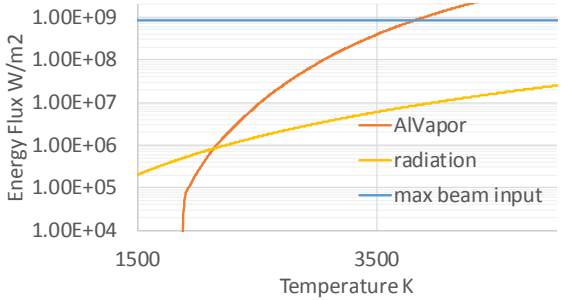
Thermal field, displacement field and stress prediction



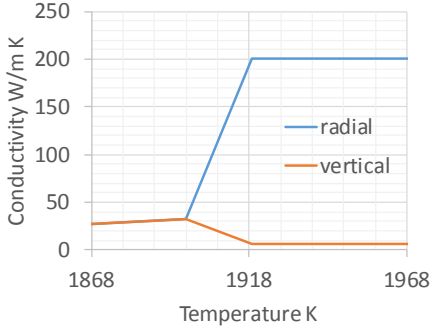
- Powder to bulk Conductivity shift



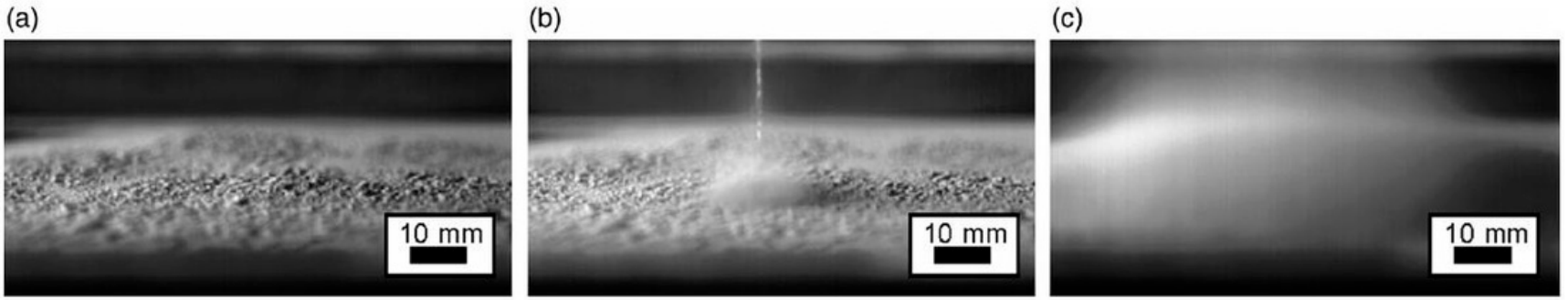
- Evaporation heat flux as function of temperature



- Marangoni effect as anisotropic conductivity



Pre-sintering of powder required to avoid “smoke”



T. R. Mahale: ‘Electron beam melting of advanced materials and structures’, PhD thesis, North Carolina State University, 2009.

Can we find ways to avoid long time/high temperature holds so as to allow more flexibility in microstructure control?

What conditions will give us high enough cooling rates to obtain Martensite in Ti-6-4?

CFI-JELF Award – Title: *High Performance Additive Manufacturing*

- Themes
  1. Advanced wiring feeding technology
  2. Functionally Graded Material Fabrication via Exploitation of Non-Equilibrium Phase Content
  3. Functionally Graded Material Deposition via Multi-Material Feeding

CFI-JELF Award – Title: *High Performance Additive Manufacturing*

- Vacuum chamber 3800x1500x2000mm and is lead shielded
- Electron beam gun is 150kV 15kW beam which can be run continuously and in pulsed mode
- Vacuum pumps included cryogenic pumps.

CFI-Innovation Fund - Title: *Canadian Additive Manufacturing Network (Can-AMN): A Network for Holistic Innovation in Additive Manufacturing*

- Awarded June 2017, Federal funding approved, Provincial approved Feb 2018, $CAN 3.6M
- THEME 1: Integrated Digital Topology Optimization and Accelerated Real-time Physics-based Modeling
- THEME 2: Material Development Tailored with Optimum AM Process Parameters
- THEME 3: Intelligent Process Control Strategies
- THEME 4: Next Generation AM Processes
- THEME 5: Innovative Products, Technology Transfer and Commercialization

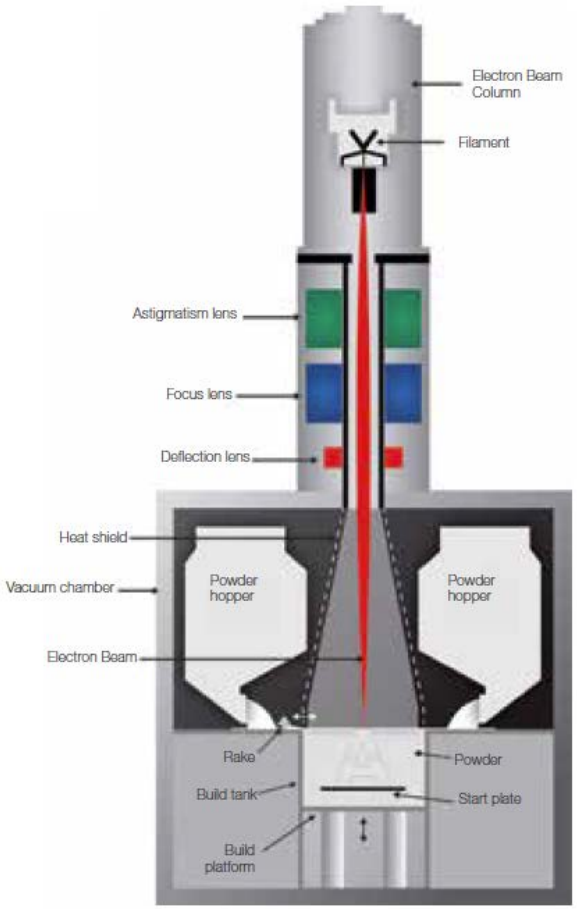
ARCAM Electron Beam Melting (EBM) Q20 Plus

Turn key, powder bed system for printing metals including Ti alloys, Ni-based super alloys, and Cr-Co alloys

ARCAM Electron Beam Melting

- Arcam EBM systems utilize a high power electron beam that generates the energy needed for high melting capacity and high productivity.

- It is built on state-of-the art deflection electronics, enabling extremely fast and accurate beam control. This allows melting at multiple points simultaneously, without compromising surface finish, precision or build speed. It is called Arcam MultiBeam.



Arcam EBM® systems, schematic architecture.

ARCAM Q20 PLUS

- For production of aerospace component such as turbine blades, structural airframe components and much more.

Arcam Q20plus build chamber.

Max. build size	350×380 mm (R/H)
Max. Beam Power	3000 W
Cathode type	Single crystalline
Min. beam diameter	140 µm
Max. EB translation speed	8000 m/s
Active Cooling	Water-cooled heat sink
Vacuum base pressure	5×10^{-3} mbar(chamber pressure before process starts)
Build atmosphere	4×10^{-3} mbar(partial pressure of He)
He consumption, build process	4 litter/h
He consumption, build cool down	100-150 litter/build
Power supply	3×400 V, 32 A, 7 kW
Size Approx.	2400×1300×2945 mm (W×D×H)
Weight	2900 kg

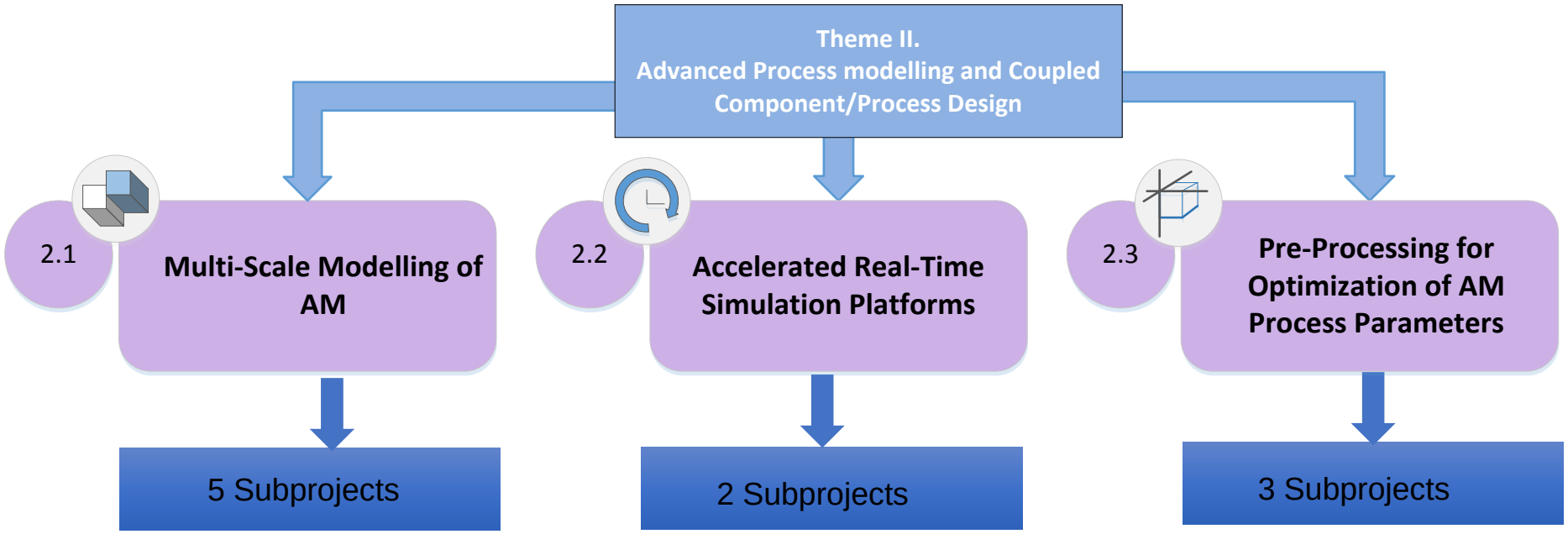
QUINTIS Hot Isostatic Press (HIP)

- 270 atm, 1400℃, Rapid quench
- The expected commissioning time would be January 2019.

NSERC Strategic Research Network
Holistic Innovation in Additive Manufacturing (HI-AM)

- Funded 2017 – Approved $5.5M total with Universities of Waterloo, McGill, Dalhousie, Alberta and others…
- Theme 1 – Material Development Tailored with Optimum Process Parameters: Three main Projects, ten Subprojects, training 4 Coop, 6 MASc, 15 PhD, 4 PDF
- **Theme 2 (UBC Lead)** – Advanced Process Modeling and Coupled Component/Process Design: Three main Projects with ten Subprojects, training 2 Co-op, 4 MASc, 6 PhD, 2 PDF; UBC 2 MASC, 2PhD, 1PDF
- Theme 3 – In-Line Monitoring/Metrology and Intelligent Process Control Strategies: Four Projects with ten Subprojects, training 4 Co-op, 4 MASc, 8 PhD
- Theme 4 – Innovative AM Processes and AM-made Parts: Four Projects with nine Subprojects, training 6 Co-op, 1 MASc, 9 PhD, 2 PDF

Theme II: Projects and Subprojects



DLR@UBC
Current Research Structure

DLR@UBC

Materials & Structures for Global Mobility

Further topics

1) Factory of the Future

- Human-Machine Interaction
- Virtual reality of DLR robot platform

2) Composite Technology

- Simulation of crash & impact behavior
- Thermoplastic technology
- Process simulation and producibility assessment for composite structures

3) Lightweight materials and technologies for automotive and rail applications

- Generic Part Design, Additive Manufacturing
- Multi Material Design Concepts

4) Sustainable Aero Engine

- 3D printing of accessories
- Automated assembly
- Research engine (with MTU)
- Engine tests
- Bio fuels

Topic in development

5) Clean flight UBC Okanagan

- Data analysis, management
- Automated production
- …

Topic in preparation

Research, acquisition, exchange of researchers and students, Ph.D. program, joint appointments

Cooperation with German, Canadian and further international industrial partners

Collaboration with Deutsches Zentrum für Luft- und Raumfahrt e.V. (DLR) (Univ. Prof. Dr.-Ing. Heinz F. Voggenreiter)

Project 1: Collaboration between UBC – DLR –MTU: Characterization of structure and properties of SLM aerospace component (Spring 2018)

Project 2: Joint Student: Characterization of correlation between process parameters and fatigue performance in SLM produced materials (Fall 2018)

Education Initiatives at UBC

New Undergraduate Program
Manufacturing Engineering (MANU)

The Vision

- New high-quality manufacturing engineering undergraduate degree
- Unique in the Canadian marketplace
- Tuned to the modern demands of employers
- Annual intake of ~100 students (50/campus)
- Delivered in parallel and partnership at UBCO & UBCV

Graduate Attributes

Strong grounding in engineering fundamentals

Focus on the acquisition of practical skill-sets

Readiness for the factory of the future

Trained across all the major manufacturing **processes**

Forging, cutting, forming, joining, AM…..

Trained across all the major manufacturing **platforms**

Robotics, automation, simulation, IOT, CAM….

Trained in production **management**

PROGRAM FEATURES

8 semesters & 160 credits Common 1st year in APSC

Equivalent Yr 1-3 programming @ UBCO & UBCV
(transfer opportunities)

Campuses offer Different 4th year programming

4 Co-op work terms

16 new MANU courses (60 credits)

6 semesters of project courses

9 credits of technical electives (bounded)

	UBCV		UBCO
Year 1	Common UBCV engineering		Common UBCO engineering
Year 2	Foundational stats & engineering data analysis, materials engineering and machine dynamics	Equivalent	Foundational stats & engineering data analysis, materials engineering and machine dynamics
Year 3	Advanced courses in engineering materials, measurement and instrumentation, industrial automation, mechatronics		Advanced courses in engineering materials, measurement and instrumentation, industrial automation, mechatronics
Year 4	**Production Stream** Advanced courses in manufacturing processes (traditional and non-traditional), advanced machining, control		**Management Stream** Advanced courses in production management, lifecycle management, design concepts and theory, supply chain tactics, digital enterprise management

ADVANCED MATERIALS MANUFACTURING

MEL | Master of Engineering Leadership

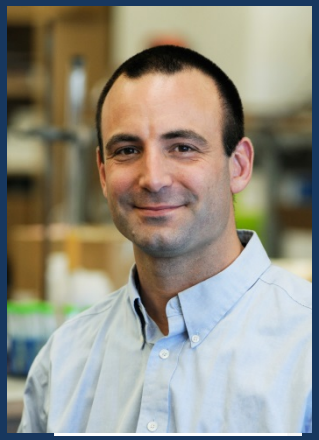
UBC Applied Science | SAUDER School of Business

Technical Skills

- MEL in Advanced Materials Manufacturing balances advanced engineering theory, interdisciplinary knowledge and real-world applications
- Participants will study advanced engineering technology, compare complex multi-material engineering processes and analyze the structure-property-process relationships inside materials manufacturing systems
- Multidisciplinary topics in engineering offer unique learning opportunities that mirror today's collaborative team-focused environments.

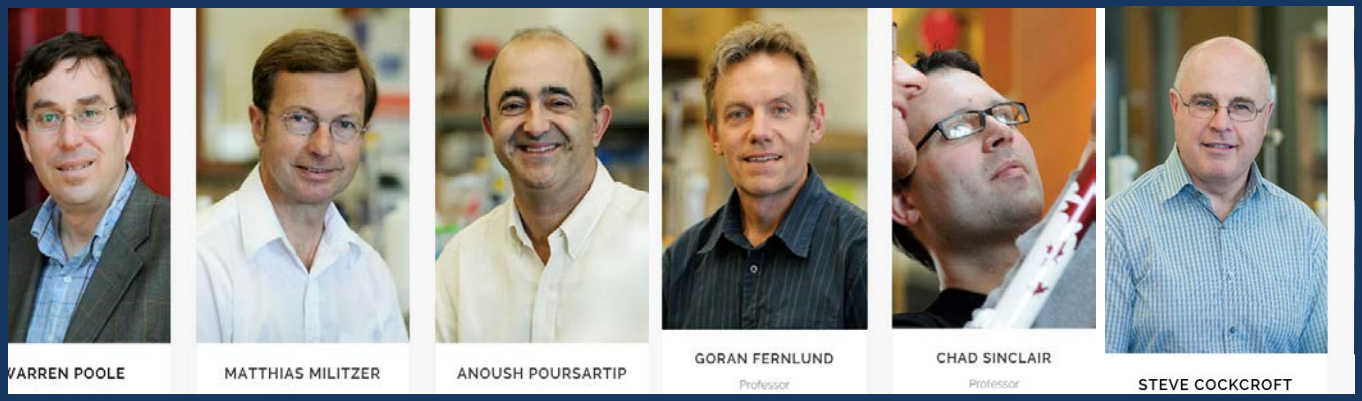
Advanced Materials Manufacturing curriculum follows the Industry Value Chain

Our Team

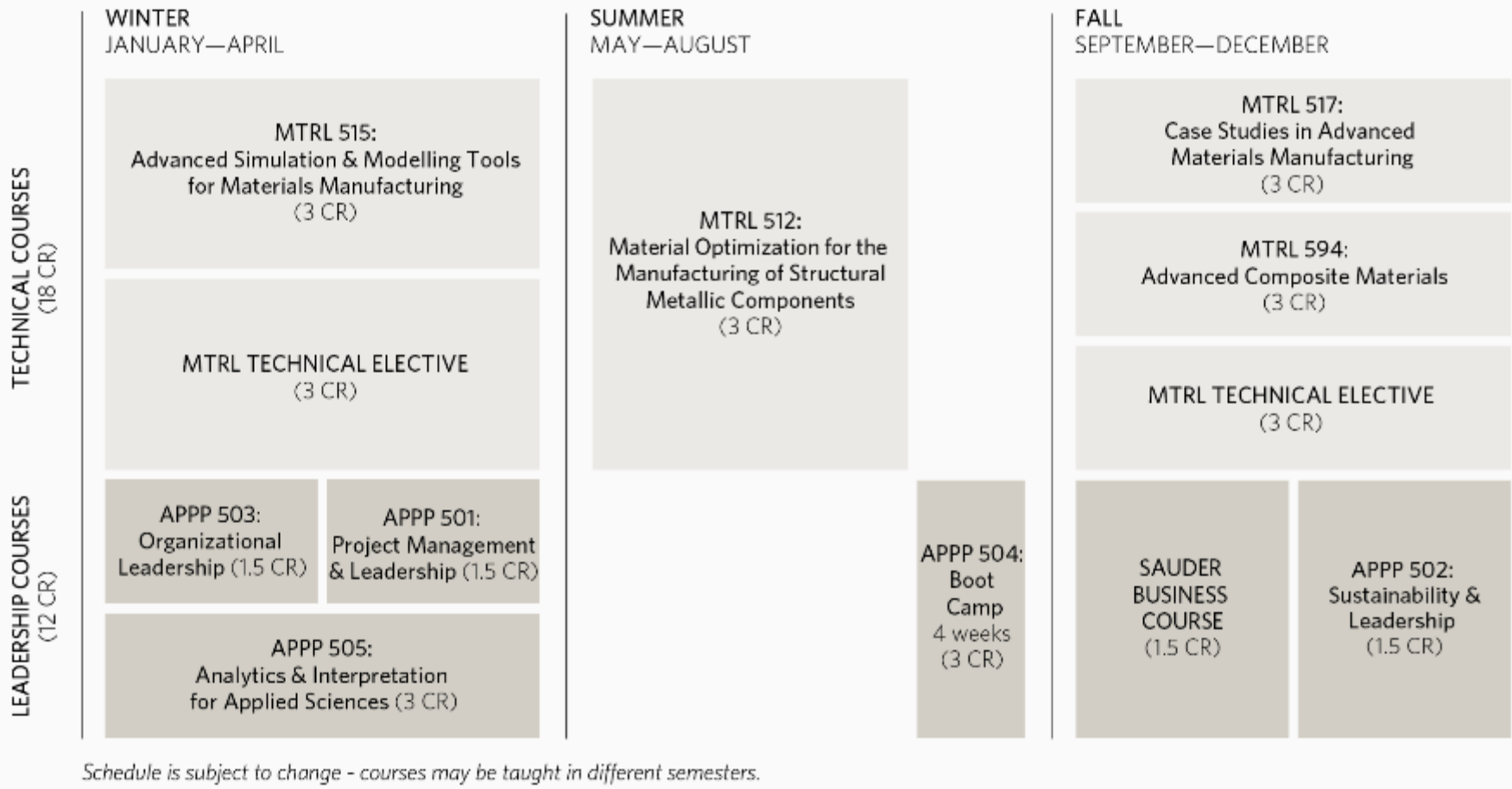


Daan Maijer
Director

World leading researchers in structural materials



Program



Schedule is subject to change - courses may be taught in different semesters.