Introduction

Wing Kam Liu

Walter P. Murphy Professor

Chair, USNC/TAM

Member, BISO

President, International Association for Computational Mechanics

Northwestern University

Evanston, IL 60208, USA

w-liu@northwestern.edu

The National Academies

Washington, DC

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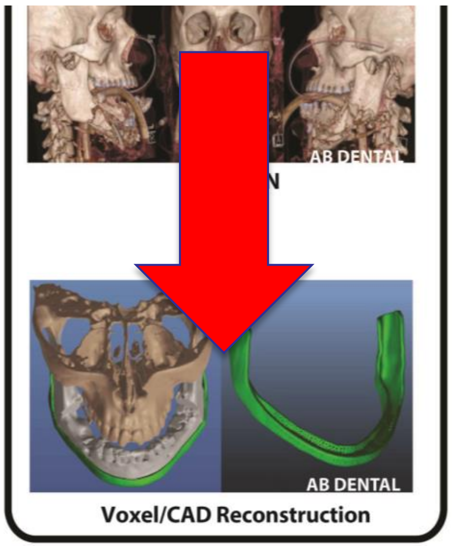
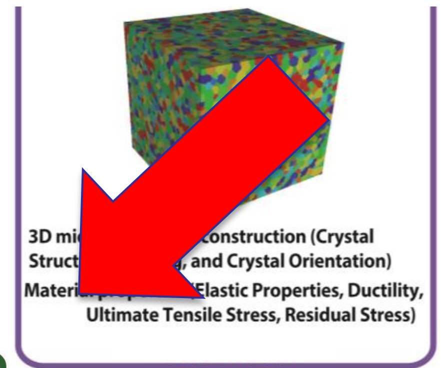
Original Model



- Custom/Patient Specific Product
- 3D scan technology
- CAD model generation software

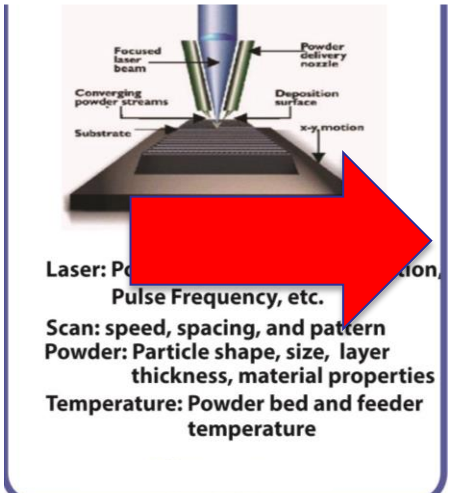
Mechanical Model



- Multiscale-Multiphysics analysis
- Fluid-Structure Interaction

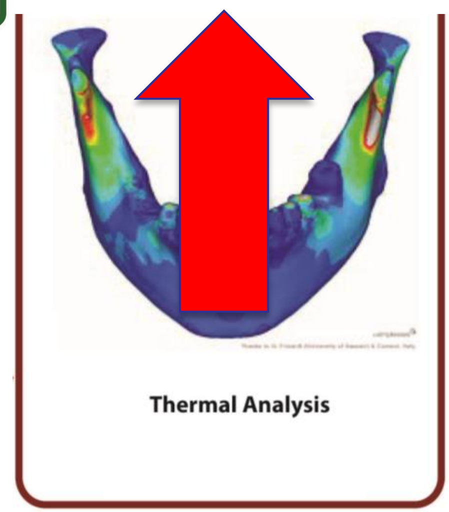
Final Product

Process Parameters

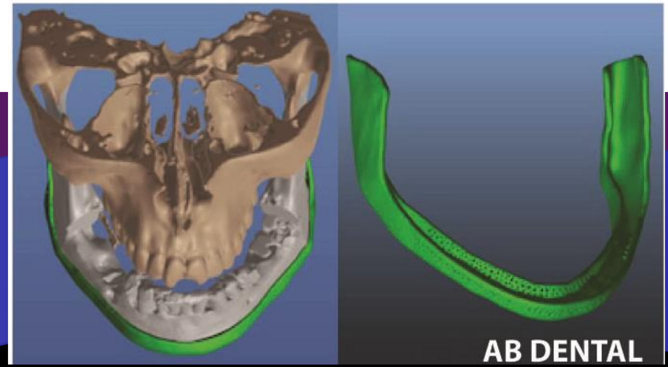


- Laser power/pulse frequency
- Powder size
- Powder Materials Selection

Process Model



- Multiscale
- Multiphysics
- Fluid-Structure Interaction
- Phase Transformation
- Quantum Mechanics
- Thermo-dynamics



Physical Experiments

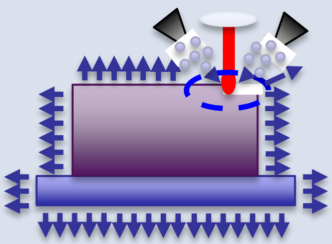
What theoretical and computational approaches can we use to get from CONCEPT to REALITY?

Uncertainty Quantification

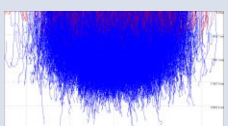
Verification and Validation

Process Modeling

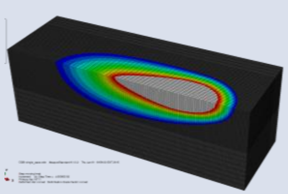
Simplifying Assumptions



Heat Source Model



Thermal analysis

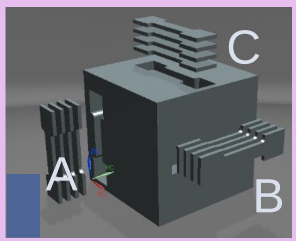


Cooling Rate Solidification & Melting Behavior

Mechanics

Residual Stress Distribution

Anisotropic Elastic-Plastic Analysis



Fatigue Life

Microstructure-based Fracture Toughness and Damage

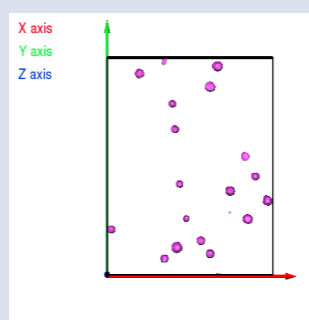
Materials Science

Powder Composition Selection

Materials design

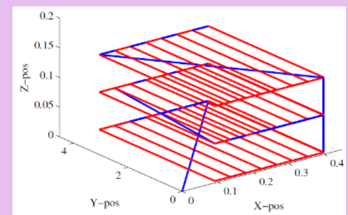
Phase Evolution

Microvoid and Precipitate Distribution

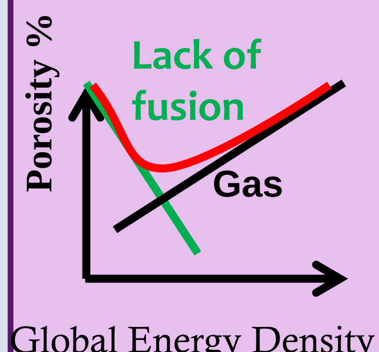


Process Optimization

Key Parameter Set Determination

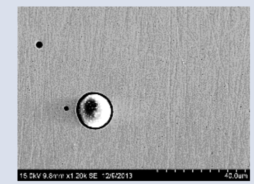


Key Parameter Set Optimization



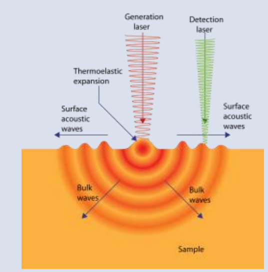
Final Product Characterization

Microstructure Characterization



Surface Topology Characterization

Non-destructive Microstructure Evaluation

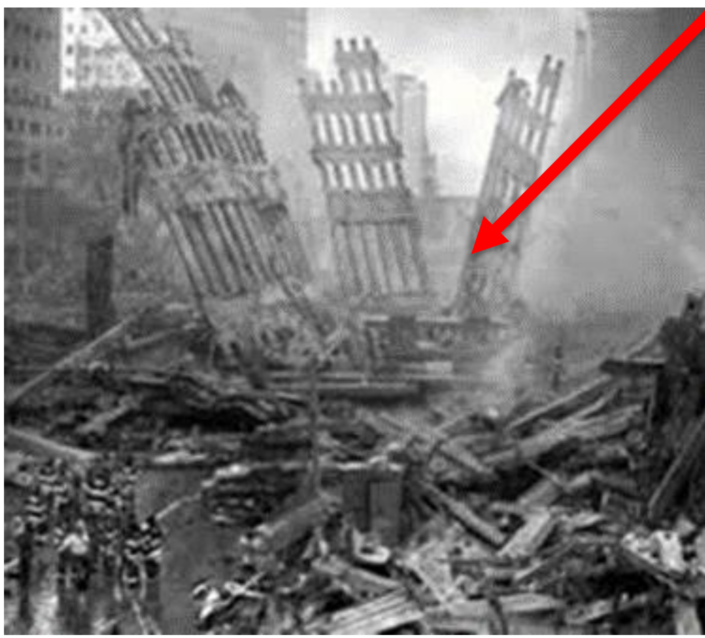


Strength and Fatigue Characterization

Disaster Prevention/Recovery

Extreme Loading Conditions

- Multi-scale Materials Testing
- Materials Selection & Design
- Damage Assessment
- Sensing & systems diagnostics
- Multi-scale Multi-physis Modeling
- Damage Mitigation and Retrofit



How to Effectively Protect Infrastructures Against Man-made Disasters?

Damage Assessment	New Materials Systems	Computational Methods	Testing Methods	Information Technology
a) Damage identification techniques, damage types of interest c) Sensors and placement strategies, types of sensors c) Systems diagnostics and image processing techniques d) Damage models for high strain rate & high temperature	a) Materials and material systems with desired performance under high strain rate b) Materials for effective damage mitigation/retrofit c) Active/sensitive structural material systems function in sufficiently fast manner d) Manufacturing of new materials and construction issue	a) Multi-scale and multi-physics mechanics b) Fast assessment of damages after disastrous events using reduced order method c) Computational techniques with the aid of sensor data and visualization information d) Multi-scale verification and validation	a) Characterization of damages high strain rates b) Sub-scale and near full-scale experimental investigation of damage/failure mechanisms c) Performance validation of mitigation/retrofit techniques d) Large-sale tests for threats estimation	a) Structural health monitoring and damage prognosis before events b) Critical infra-structure data, sensor and risk evaluation c) Systems to evaluate state of infrastructure after event: sensors, models, data display d) IT systems for first responders and policy makers

Tornados

Hurricanes

Earthquakes

Tsunami

Preventing **natural hazards** from

becoming **societal disasters**

Sustainable and Multi-Hazard-Resilient Communities

Hurricane Sandy (2012), $50 billion of damage, 285 fatalities

Nepal (2015), more than 5000 fatalities

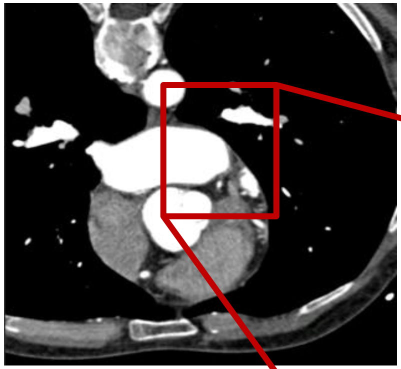
Oklahoma City tornado (2013), $3 billion of damage

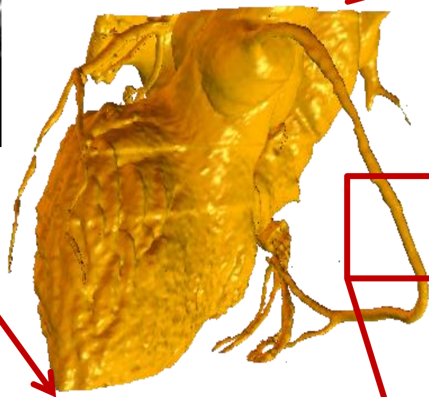
How do we build Sustainable and Multi-Hazard-Resilient Communities?

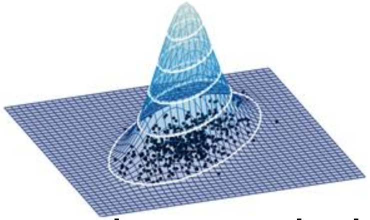
Loading Conditions	Infrastructure Aging	Analysis and Design	System Analysis	Policies
a) Determination of proper multiscale loading conditions associated with randomly recurring multi-hazards b) Developing accurate stochastic computational models (e.g. fluid dynamics models for tornados, hurricanes, and tsunamis) for the prediction of natural hazard effects	a) Infrastructure health monitoring b) Computational models for aging and deterioration evolution c) Destructive and non-destructive techniques for the assessment of current level of deterioration c) Experimental databases for validation activities	a) Multiscale mechanics, verification and validation (V&V) b) Engineered materials with multifunctional properties c) Techniques for the retrofitting of existing infrastructures d) Structural and process optimization e) Performance-based design	a) Combine resilience with sustainability a) Uncertainty quantification (UQ) and reliability analysis c) Systems and system interactions d) Interplay of conflicting objectives related to resilience and sustainability	a) Prioritization of resource allocation b) Community/city/region development planning c) Resource allocation for maintenance, rehabilitation, and retrofitting d) Disaster prevention and post-disaster recovery policies

Multiscale Drug Delivery Design

Image processing

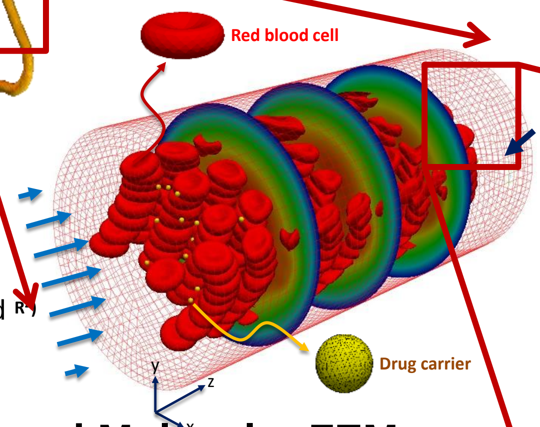






Bao et al. 2014. USNCTAM perspectives on mechanics in medicine. Journal of The Royal Society Interface 11 (97), 20140301

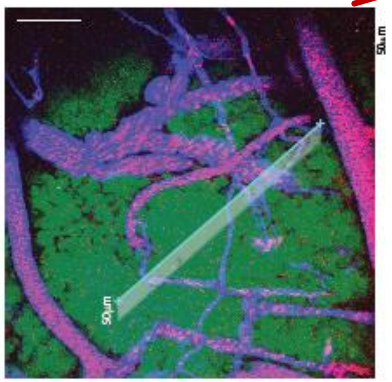
Uncertainty Quantification

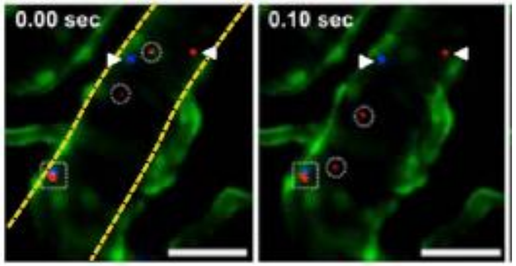


Isogeometric Analysis

Hughes, T. J., Cottrell, J. A., & Bazilevs, Y. (2005). Isogeometric analysis: CAD, finite elements, NURBS, exact geometry and mesh refinement. Computer methods in applied mechanics and engineering, 194(39), 4135-4195.

Immersed Molecular FEM





Experimental Validation

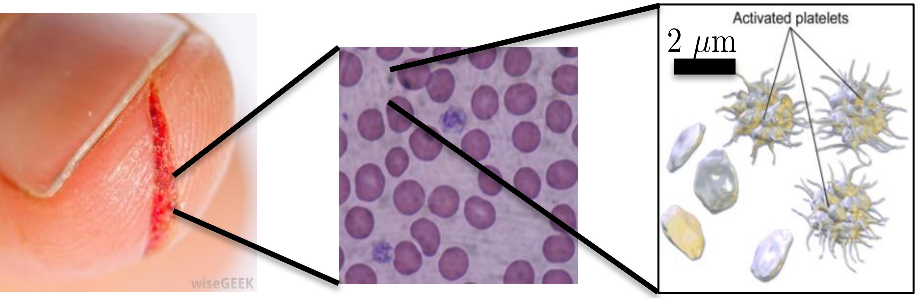
Nature methods. Simultaneous measurement of RBC velocity, flux, hematocrit and shear rate in vascular networks 7(8), 655, 2010

Microvasculature Modeling

Ven et al., J Controlled Release, 2007

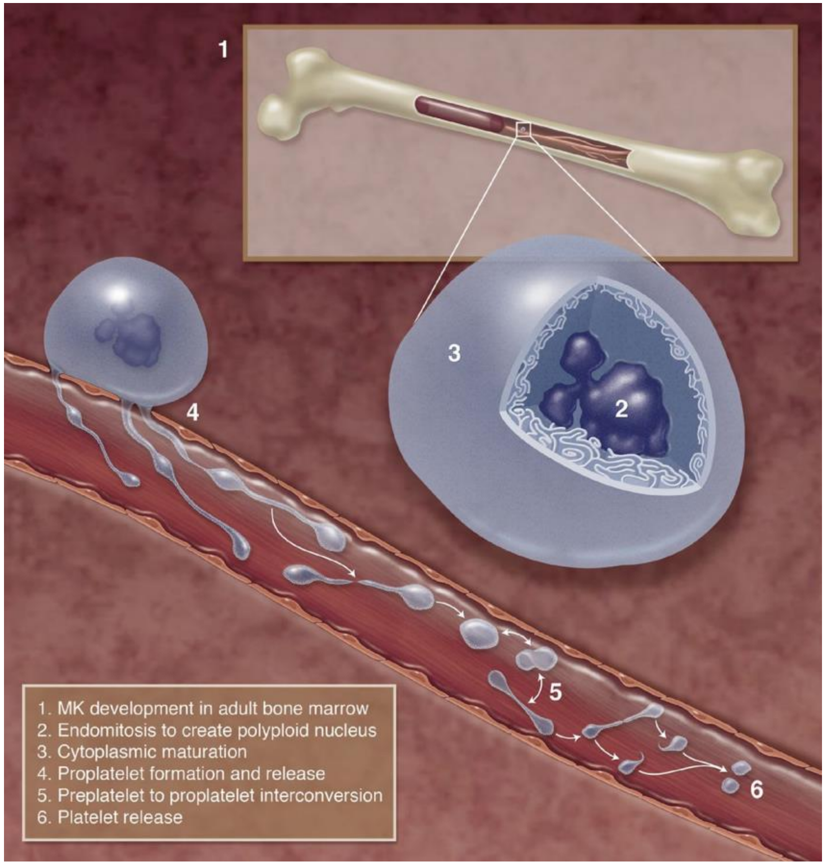
Platelet Biogenesis

Wound Healing

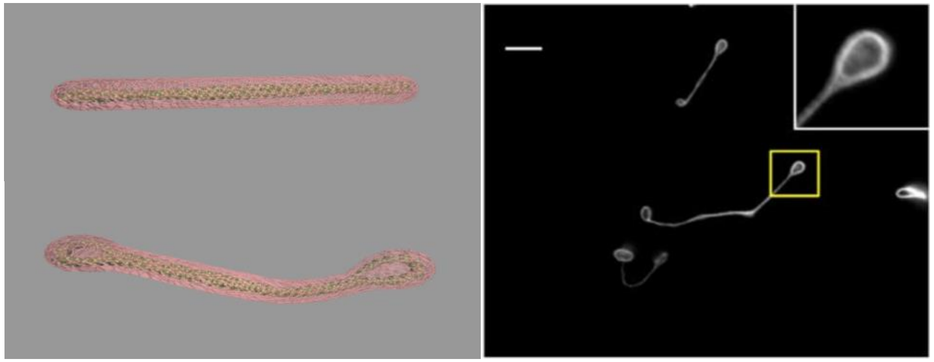


Disease

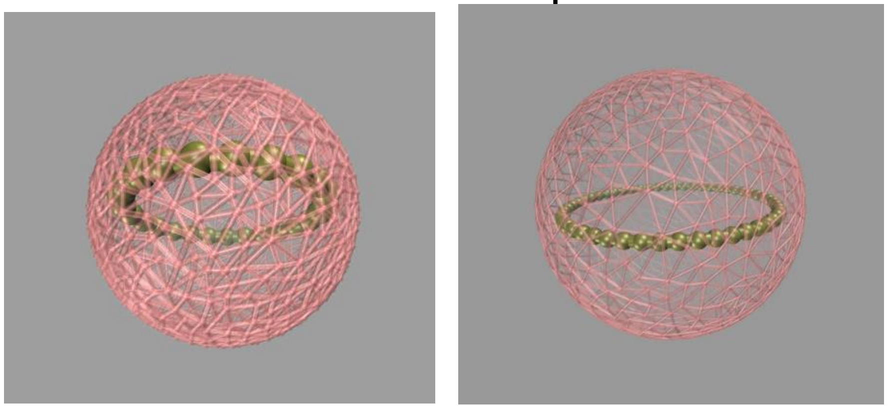
- Thrombocytopenia: Too few platelets, leads to poor clotting
- Thrombocytosis: Too many platelets, can lead to stroke
- Giant platelet syndrome



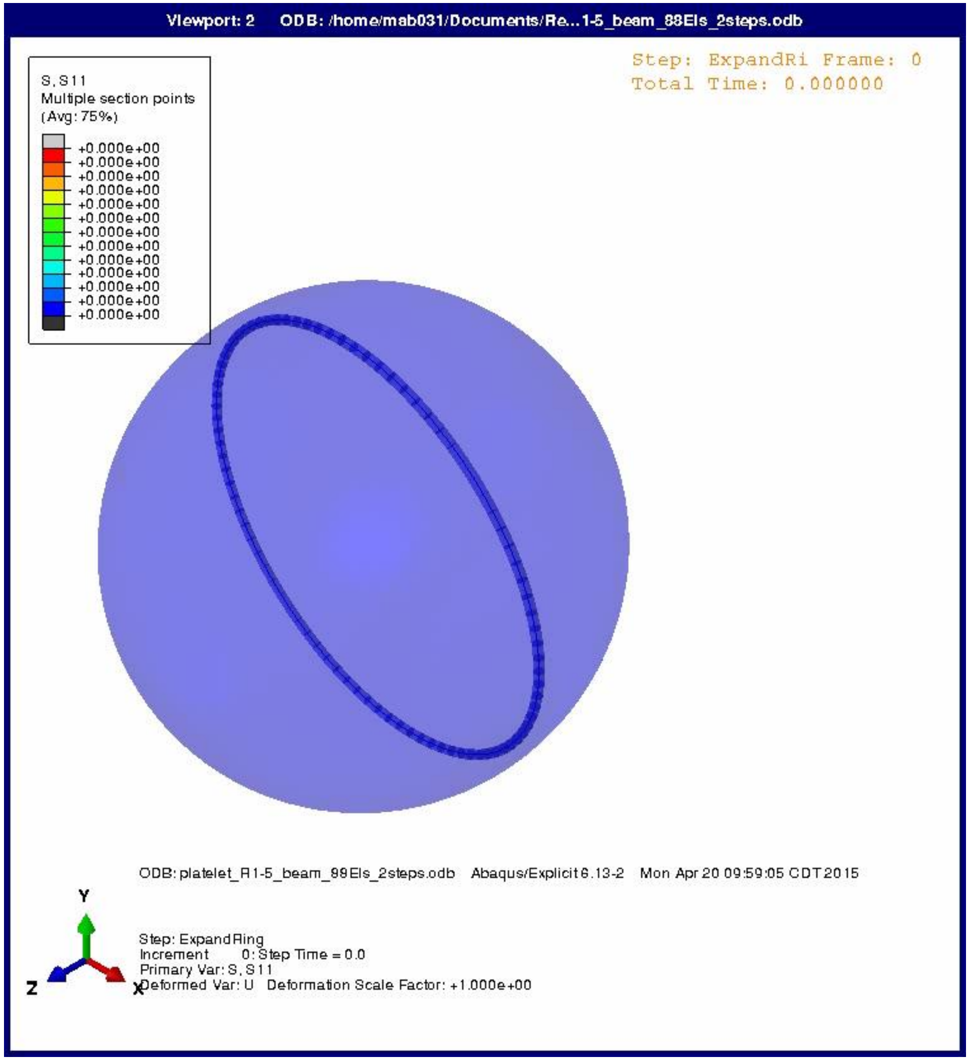
Barbell Precursors



Discoidal Precursors and platelets



Platelet Biogenesis



Simulation of activated platelet

Experiments