Accelerating Innovation in Healthcare and Medical Devices

Through Engineering Simulations

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The road to autonomy

Our core capabilities

CORE CAPABILITY
Reality Capture

CORE CAPABILITY
Positioning

SENSOR SOLUTIONS

data capture

AUTONOMOUS SOLUTIONS

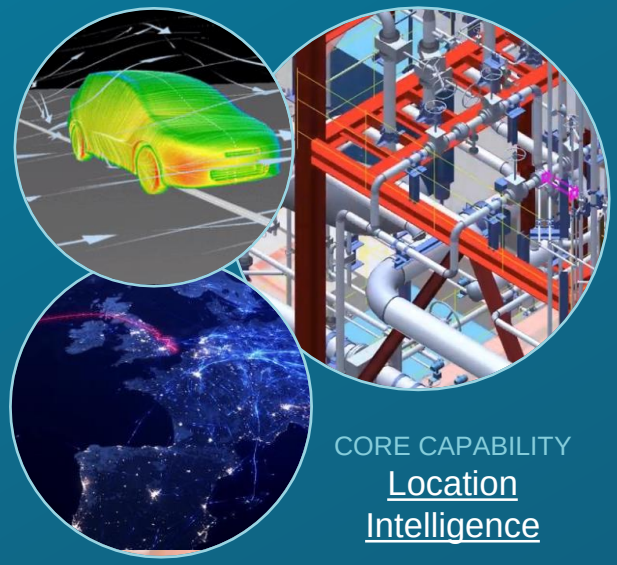
data leverage

CORE CAPABILITY
Autonomous Technologies

SOFTWARE SOLUTIONS

data intelligence

CORE CAPABILITY
Design and Simulation

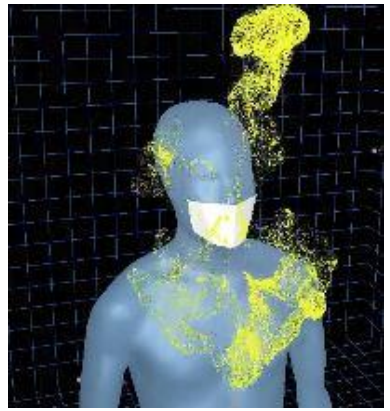


CORE CAPABILITY
Location Intelligence

HEXAGON

Contents

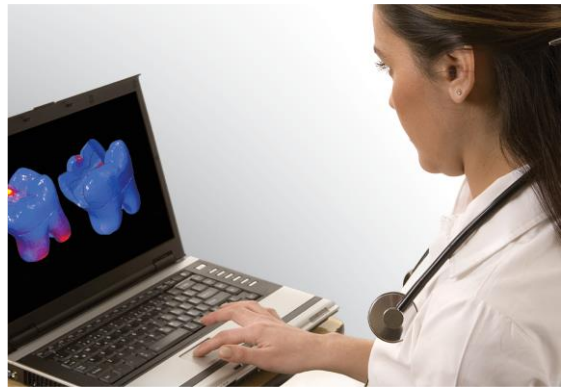
- ❑ Introduction to CAE Solutions in Healthcare
- ❑ Simulation Technology for Medical Outbreaks
- ❑ Engineering Simulations for Advanced Healthcare applications
- ❑ Key Takeaways

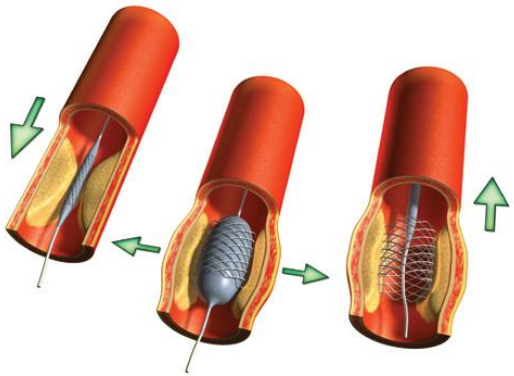


Factors Driving the Medical Device Industry

Critical Business / Product Test Issues

- Increasing product complexity and demands
  - A need to design innovative devices that are small and fail-safe so they don’t need replacement
- Prototype and test process are time consuming and expensive.
  - Being late to market can lead to major loss in market share and profits
- Build confidence in ever increasing Clinical Trials
- Increased risk inherent in new medical product development projects
  - Testing biocompatibility, performance, behavior of new materials is critical, but complicated
- Increased pressure to respond to rapidly changing surgeon needs and requirements for new implant designs
- Compliance to Quality System Regulations





Innovate, Design and Develop

Exoskeleton


Advanced Prosthetics


Advanced Drug Delivery


Surgical Robots

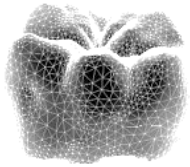

Smart Autonomous Beds

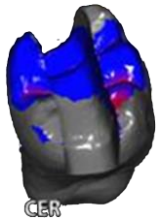

Advanced Digital Sensors

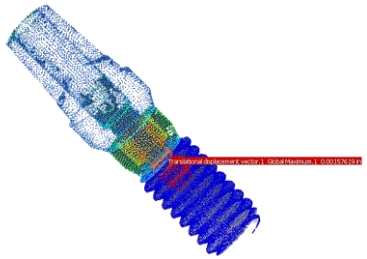
*Images Courtesy: Bertalan Mesko (2014). *The Guide to The Future of Medicine*: Webicina Kft

Healthcare CAE Simulations

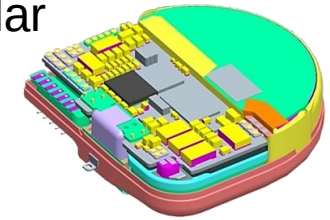
Dental

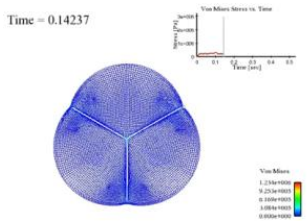




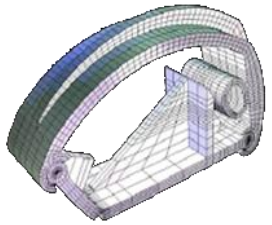


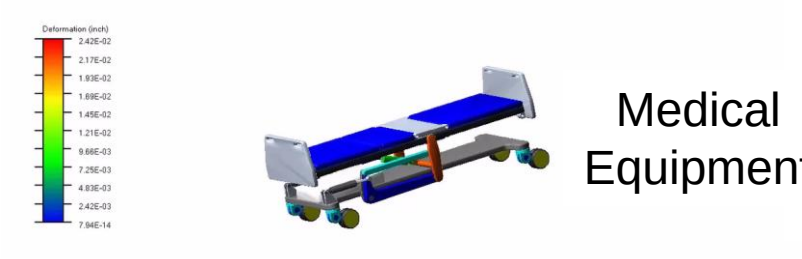
Cardio-Vascular





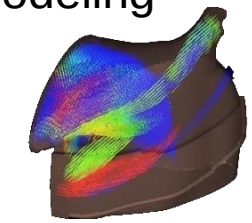
Infusion



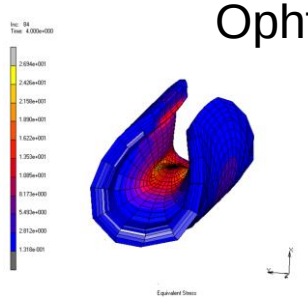


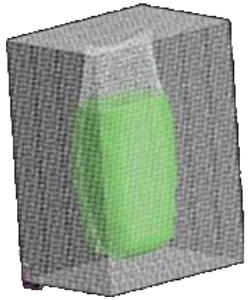
Medical Equipment

Muscle Modeling



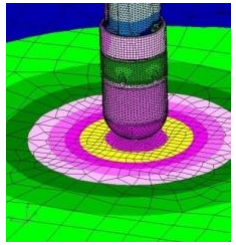
Ophthalmic



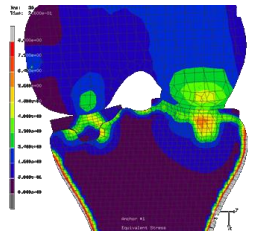


Medical Packaging

Surgery



Orthopedics



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Simulation Technology for Medical Outbreaks

Particle Dynamics

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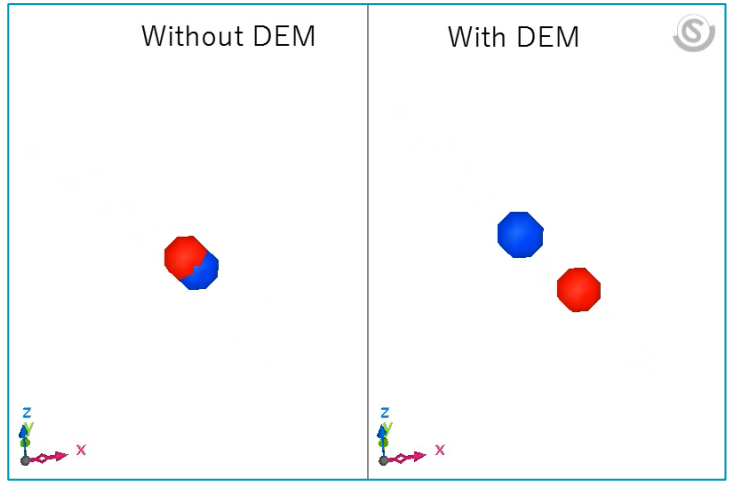
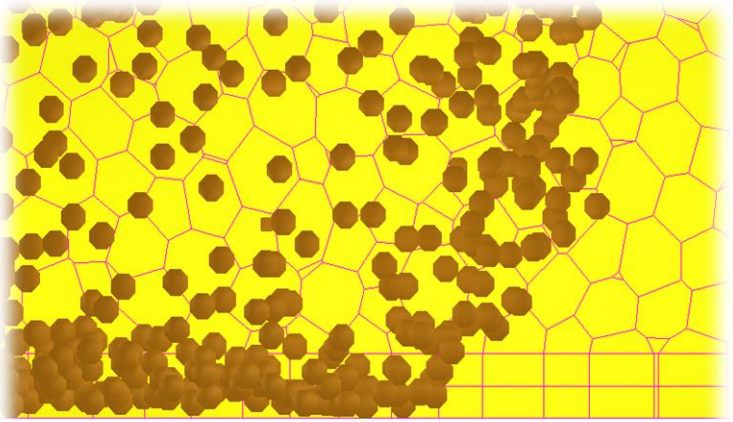
Introduction to Particle Dynamics

Complex Particle Dynamics



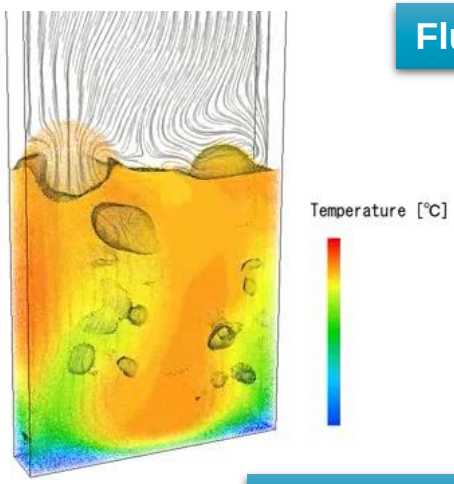
- Interaction between fluid and particles
- Contact forces between particles
- Volume of each particle also to be considered

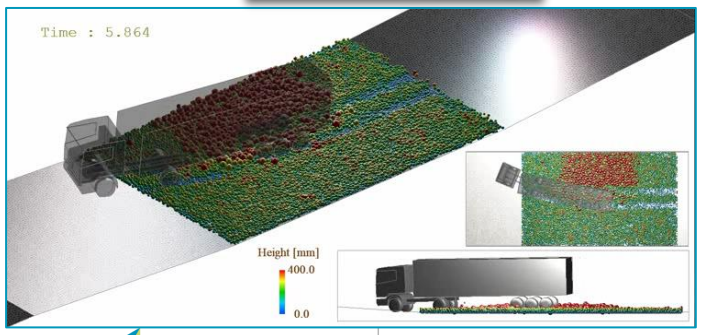
Large Mesh Size



- Particle size is assumed to be relatively small compared to CFD mesh size

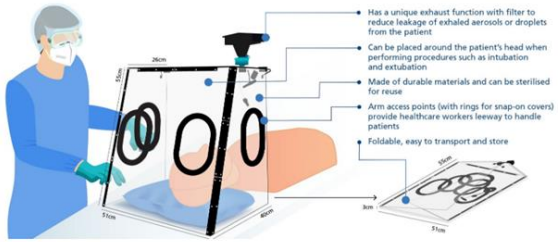
Complexity with Coupling





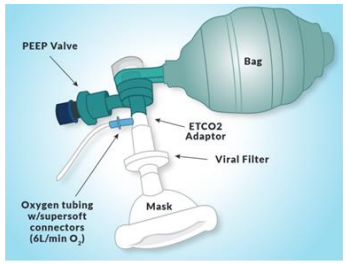
Mitigating Infection Transmission

Reduced Droplet Spread during Airway Manipulation



Credits: National University of Singapore

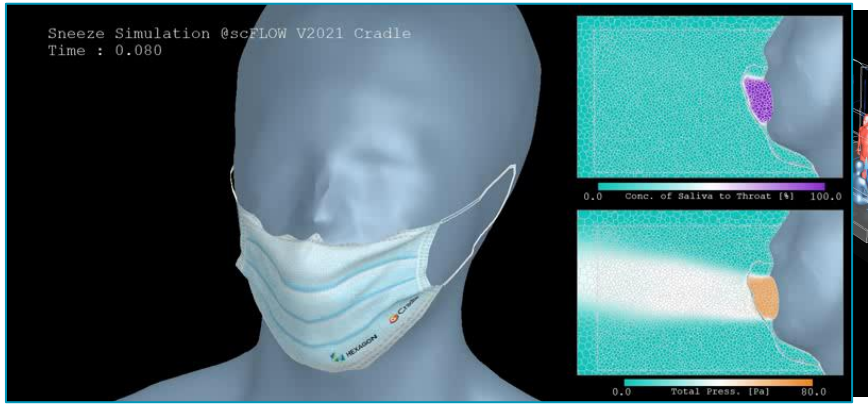
Spread Reducing Tent:
- Air flow pattern with breathing cycles
- Particulate dynamics & leakage study
- Study of exhaust function
- Intubation and Extubation processes
- Material study and 3D Printing

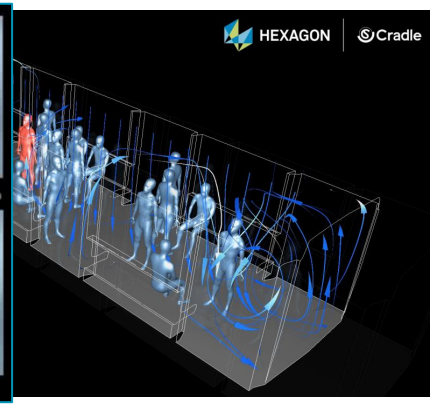


Credits: EMCrit

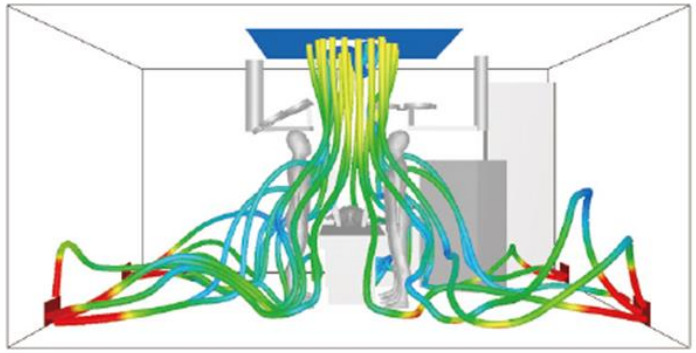
Modified Hudson Masks:
- Modified filter and valve attachments
- Specialised Airway Management
- Ingress and Egress slots for Extubation
- Materials study and 3D Printing

Distancing Effectiveness & Droplet Dynamics



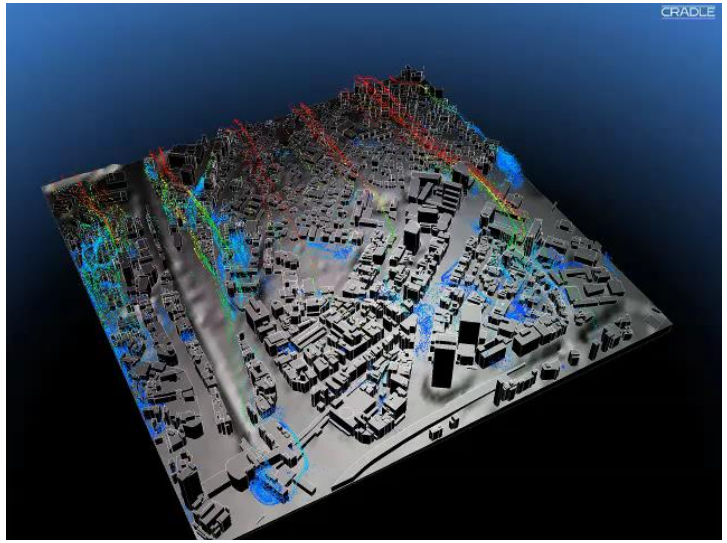


Containment Wards / ICU / OT



Key Areas:
- Effective Ventilation Configuration
- Reduce flow circulations
- Identify exhaust vent positions for effective evacuation

Large Area Disinfection

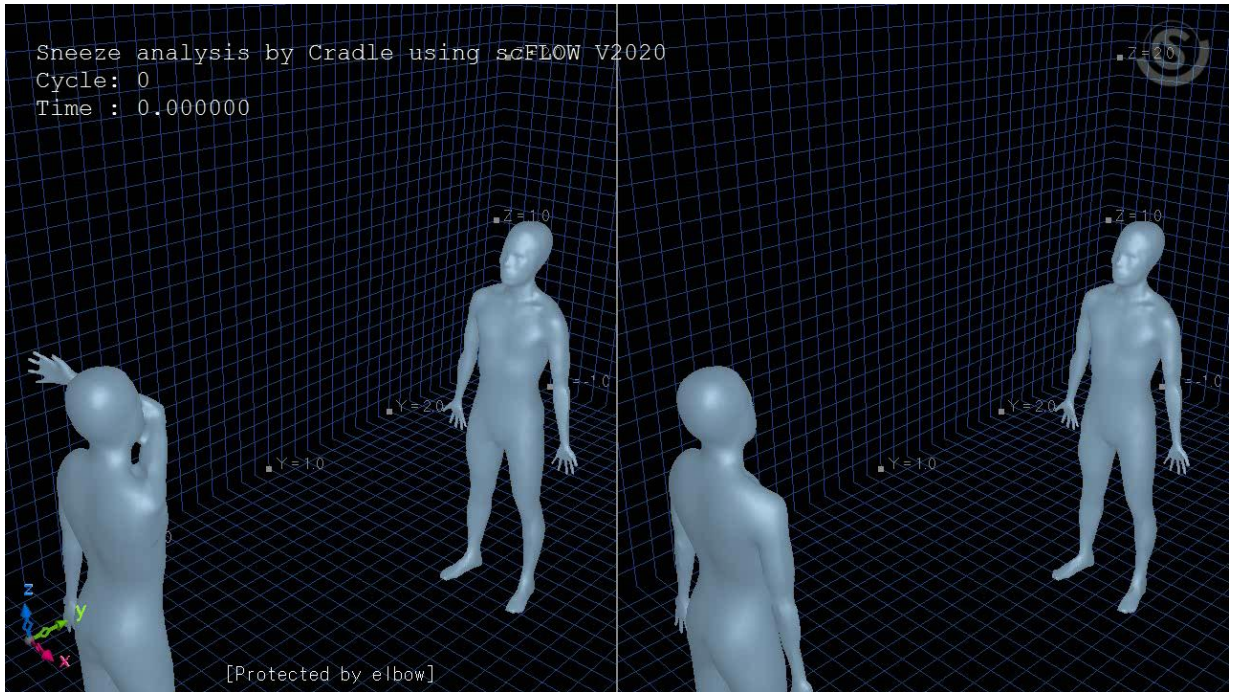


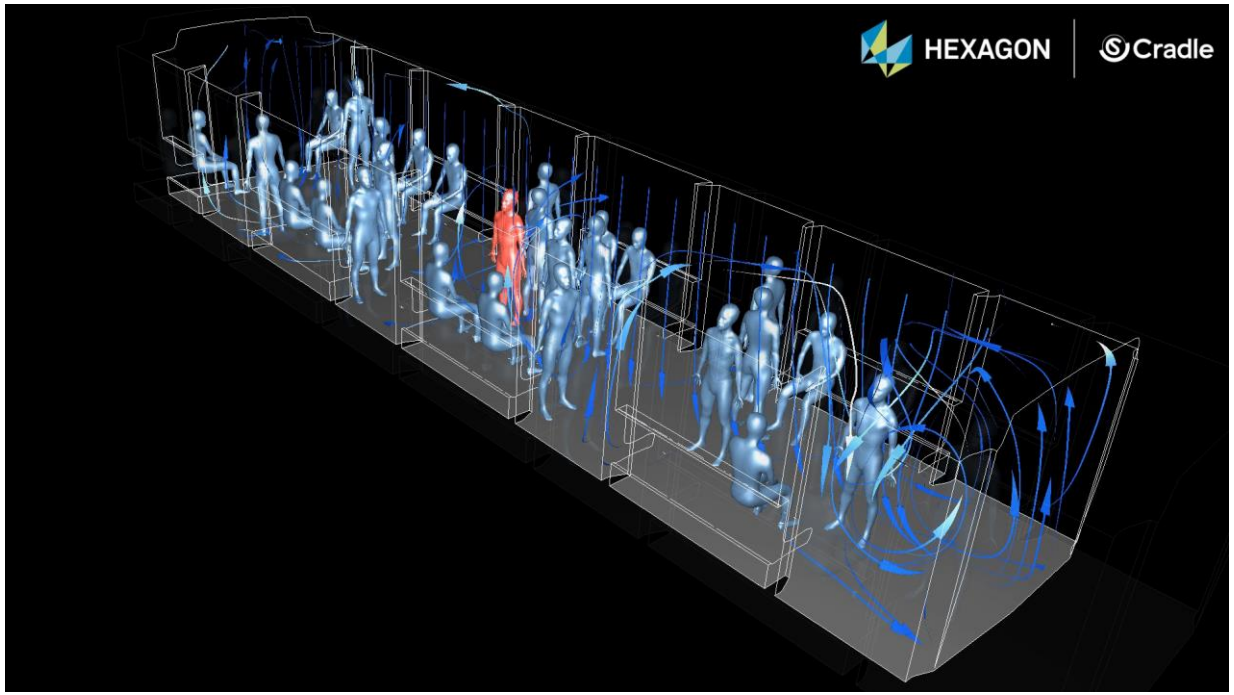
Key Impact:
- Infection Mitigation & Control
- Spray Effectiveness & Dispersion
- Flow Pattern and Disinfectant Spread
- Concentration through VOF

Phui S. Au Yong* and Xuanxuan Chen. (2020). Reducing droplet spread during airway manipulation: lessons from the COVID-19 pandemic in Singapore. *British Journal of Anaesthesia*. 125

Distancing Effectiveness – Droplet Dynamics

Cradle CFD simulations provide valuable insights on sneeze spreading & social distancing





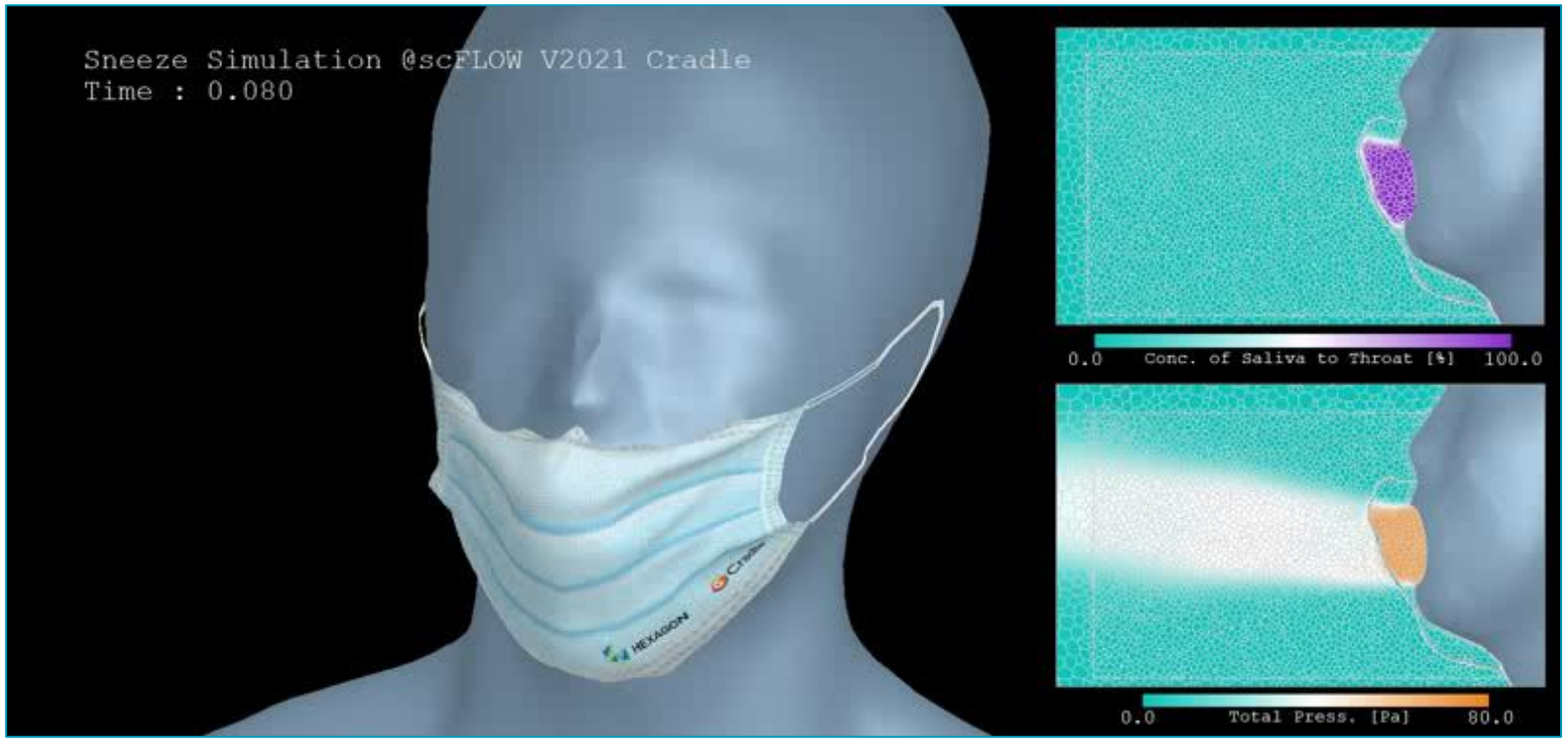
Hexagon Support for COVID Research: Licensing and Computational Support

https://hexagon.com/about/covid-19/simulations

Particle Dynamics – With CFD Coupling

Cloth model emulating a Mask

Mask Trapping Sneezing Droplets



Conditions

- Sneezing Max speed : 10 m/s
- DEM particle count : 4,753
- Particle Diameter : 2 mm (Uniform)
- Particle Density : 200 kg/m^3 (4 g at the whole Mask)
- Contact model : Walton-Braun
- Young's modulus : 1 kPa
- Static friction : 0.3
- Rolling friction : 0.3
- Restitution coeff. : 0.01
- CFD coupling : Used
- Mesh Count : 728,289

Calc.Spec.

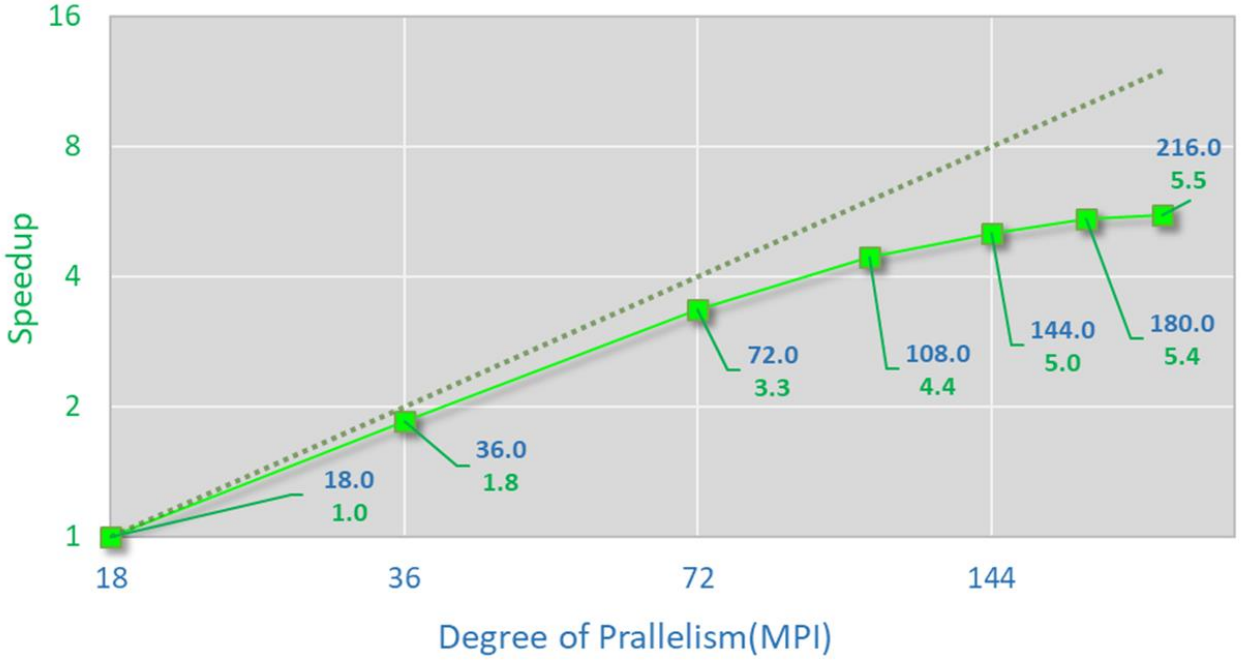
- Calc. Time : 6h : 36m : 29s @ rx2530
- MAX Memory(ALL) : approx. 38 GB
- Degree of parallelism : 144 MPI procs.
- Physical Time : 2 s
- CFD time step : 0.5 ms
- DEM time step :

the lesser of either 10 % of the critical Rayleigh time step, and 10 % of diameter divided by the velocity of particle (Avg. : approx. 0.1 ms)

Particle Dynamics - Scalability Study

*** Conditions**

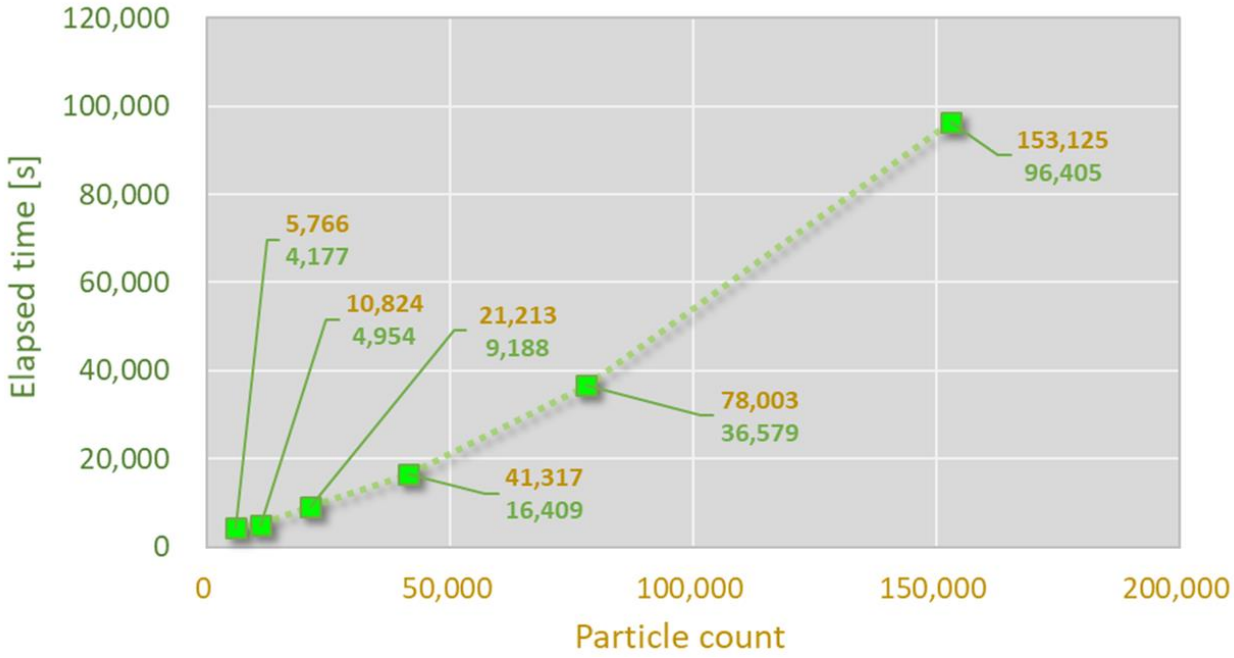
- DEM Particle count : 153,124
- Mesh Count : 28,513
- Contact Model : Walton-Braun
- Young's modulus : 1,000 Pa
- Diameter : 0.14 mm (uniform)
- Density : 2,650 kg/m^3



➡ With CFD skip mode, good efficiency achieved.

*** Conditions**

- Mesh Count : 28,513
- Contact Model : Walton-Braun
- Young's modulus : 1,000 Pa
- Diameter : 0.14 [mm] (uniform)
- Density : 2,650 [kg/m^3]

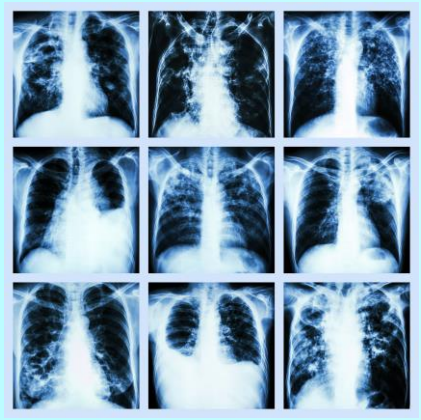


➡ The elapsed time is almost linear to the particle count.

Airway Manipulation & Drug Delivery

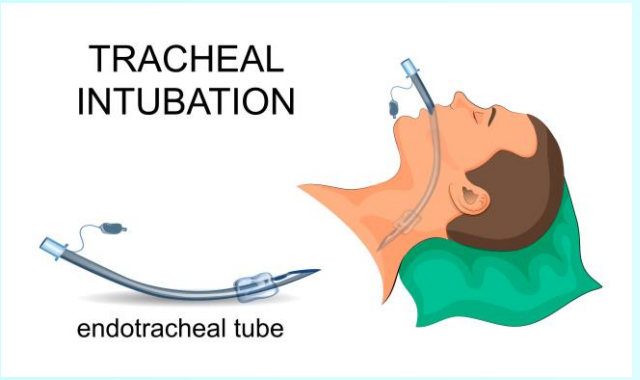
VOLUME GRAPHICS

3D Tomography Of Lungs



AI for Pneumonia Patterns specific to COVID 19

Endotracheal Tube



- Targeted Drug delivery simulation
- Advanced Medication through Aerosol

Technology Integrated Effective Drug Delivery

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Engineering Simulations for Advanced Healthcare Applications

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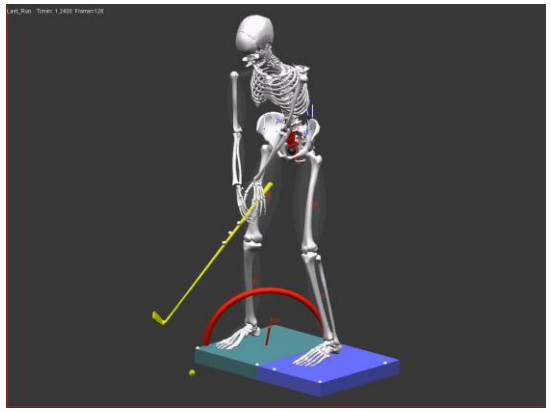
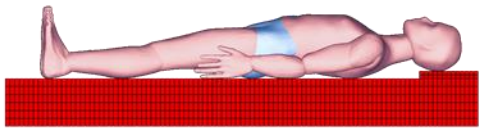
Design & Engineering: Multiphysics Simulations

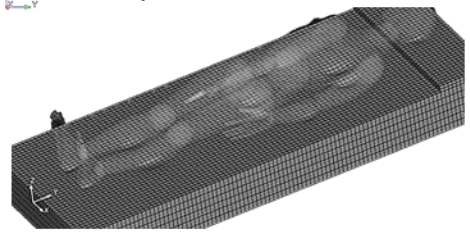


Initial Equilibrium from ADAMS

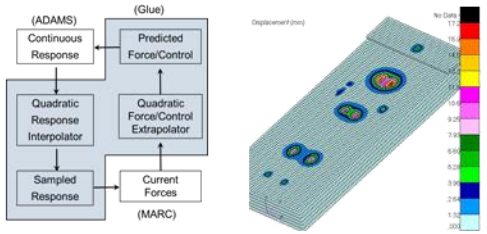
After connection to MARC

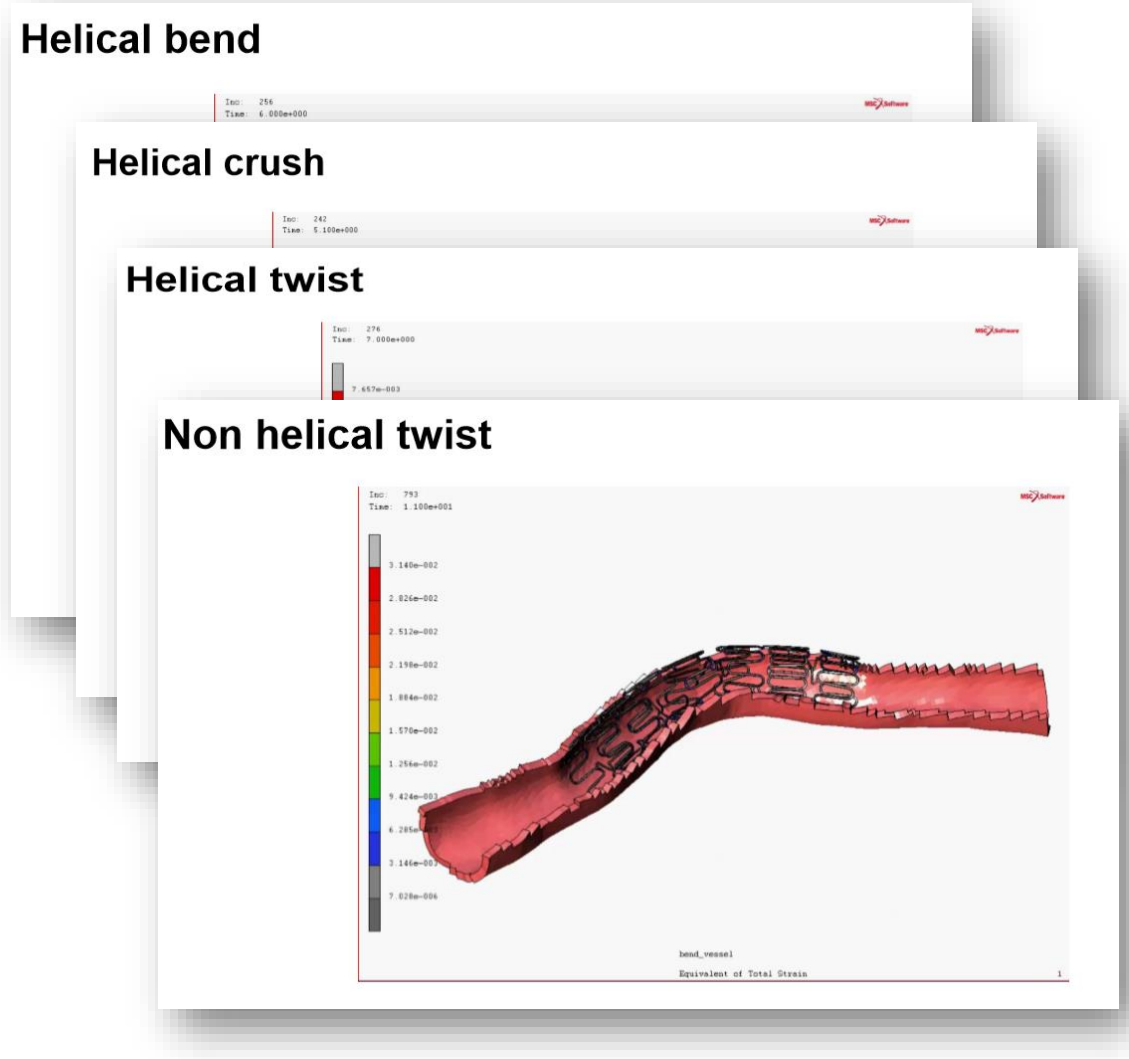


Final Equilibrium in MARC



Final Displacements in MARC





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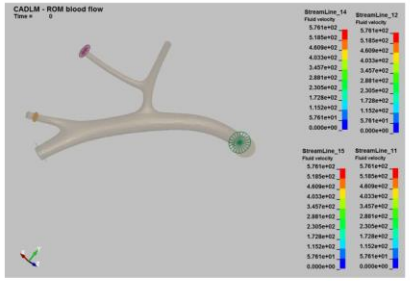
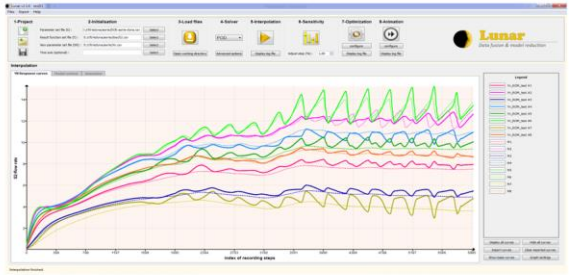
Design & Engineering: AI Based Medical Simulations

CFD - Blood flow model

ODYSSEE - Explore new industrial horizons
Optimal Decision Support System for Engineering and Expertise





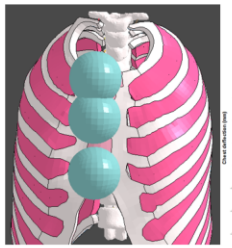
- Blood pressure injected in input surface => X1
- Blood pressure in one output surface => X2

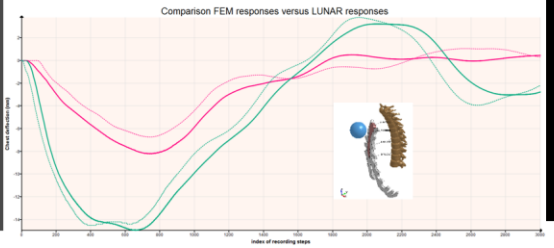
8 runs, 2 parameters

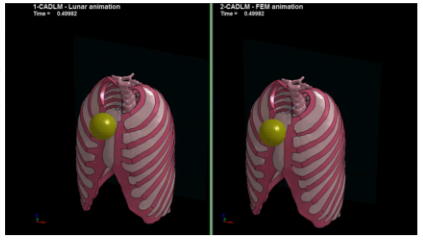
- FE = 2.5 hours
  LUNAR = 1 sec

- Flow rate measured at the input/output surfaces => Y

Thorax rubber ball impact







- Z Position => X1
- Speed => X2

9 runs, 2 parameters

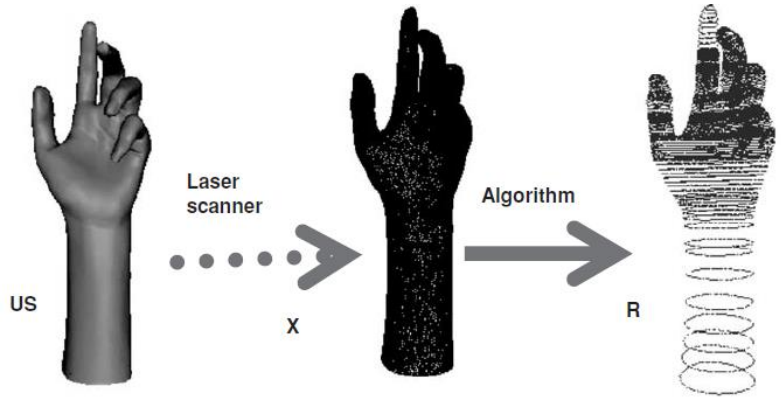
- FE = 47 minutes
  LUNAR = 1 minute

- Thorax compression => Y1

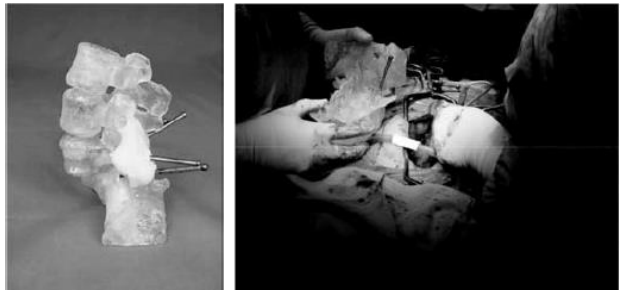
Advanced Manufacturing for Medical Applications

Surgical Planning through Biomodelling

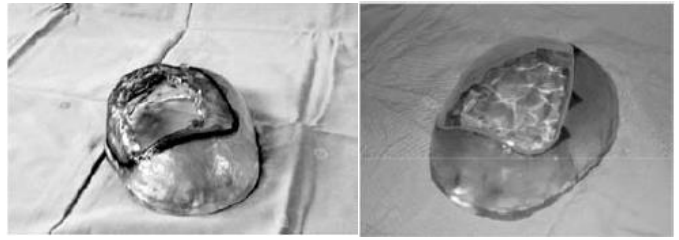
3D Scanning or CT Imaging



Generate 3D Render Data



Biomodel with stereotactic guide pins & sterilized biomodel being used intraoperatively



Biomodel with tumor invading skull & Biomodel with custom implant

Reconstruction of the mandible

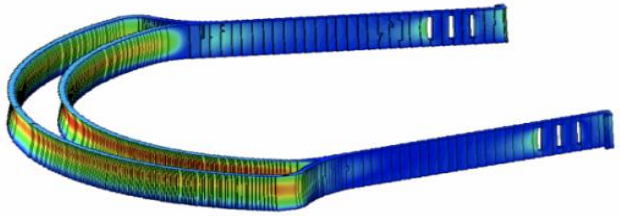
- Rapid digital manufacturing in Planning and Implementation of Complex medical treatments
- Surgical Planning, rehearsals and simulation of surgery
- Patient Specific anatomical features for custom treatment
- Accurate placement of Implants, creation of custom prosthetics
- Biomodelling for guided stereotaxy, vascular procedures, skull-based surgery, spinal surgery, orthopedic etc.

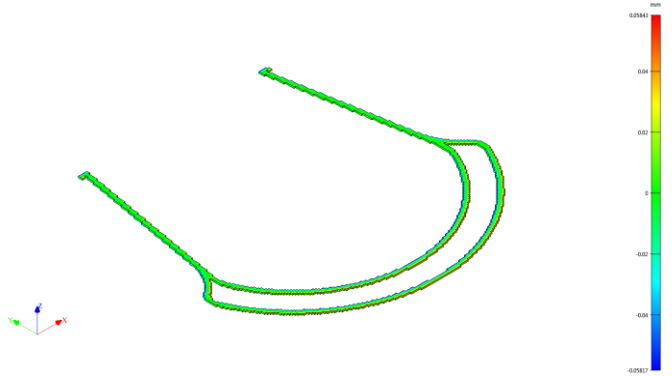
*Images Courtesy: Ian Gibson. *Advanced Manufacturing Technology for Medical Applications*. England: John Wiley & Sons, Ltd

3D Printed Polymer Face Mask Strap

Rapid response to the COVID-19 emergency in 2020

- In response to the Coronavirus crisis in March 2020, the Hexagon team in Belgium heard about a requirement for PPE, specifically face shield holders, in a nearby hospital.
- The team had access to a 3D printer and suitable material within the office.
- They first found an open CAD model that was available online and plugged it into the 3D printer and used the design to 3D print some face shield holders right at the Hexagon office.

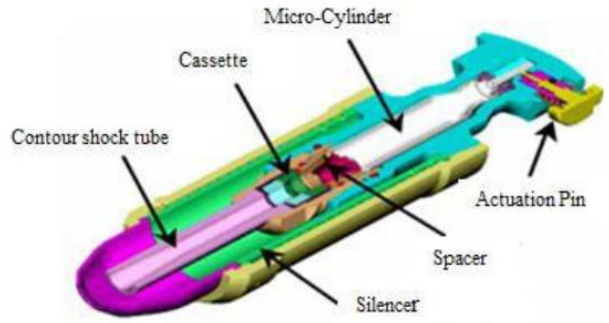


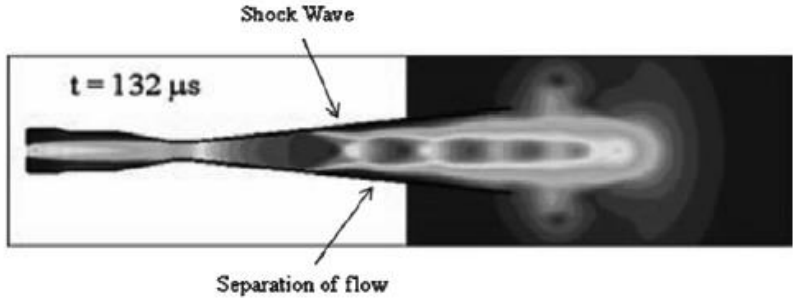


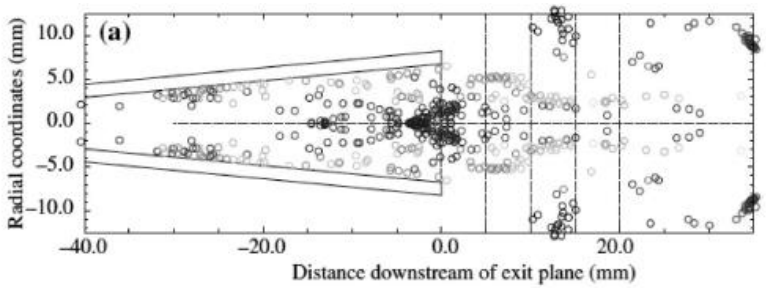
Advanced Needle Technology

Drug Delivery

Needle-Free Drug Delivery

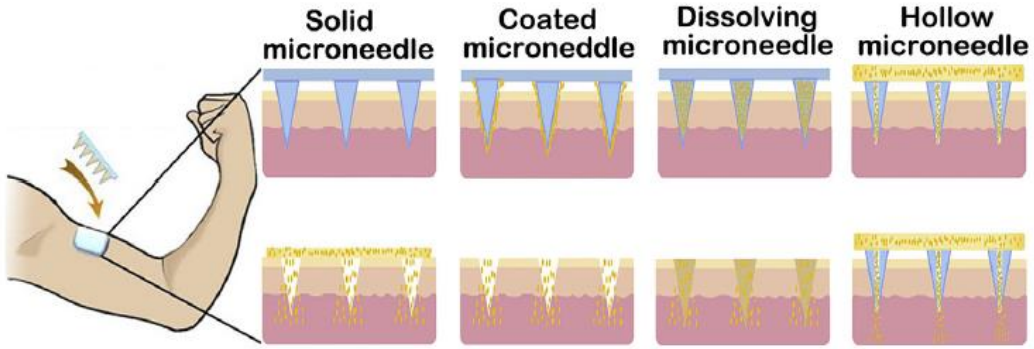




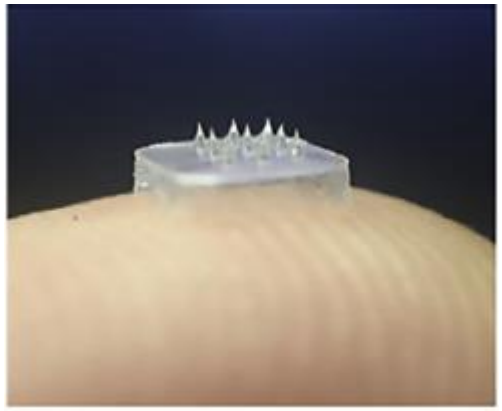


*Source: Experimental Study of Unsteady Flow in a Shock Tube for Needle-free drug delivery, Guang Zhang et. al
A computational study of drug particle delivery through a shock tube, M.A Ifthekhar Rasel et. al

Micro & Nano Needles



Drug Patch



Dermaroller

*Source: Recent advanced of microneedles for biomedical applications: drug delivery and beyond, Jian Yang et al.,

Muscle Modeling

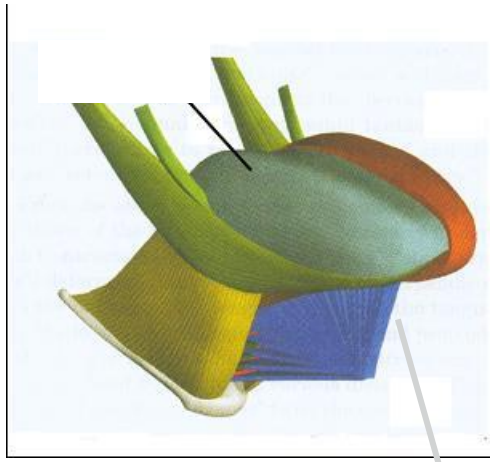
Tongue Modeling – Obstructive Sleep Apnea

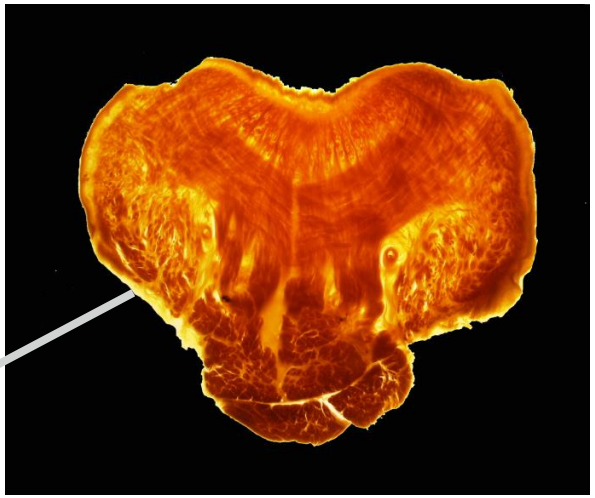
Anatomical drawings
(Takemoto, 2001)

MRI images

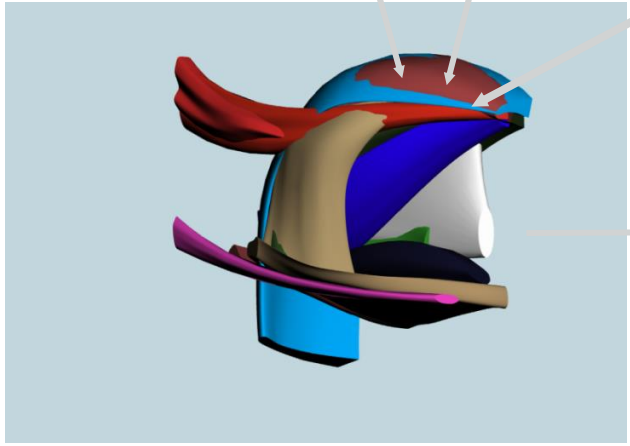
Visible Human Project

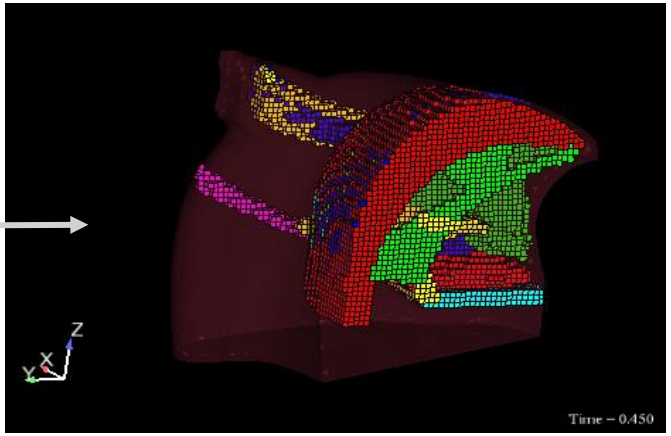
Input
Data





Our
Model





Hex.
Elements

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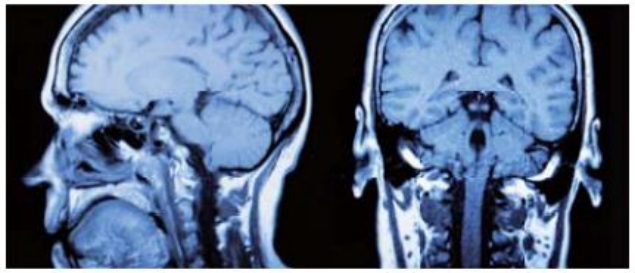
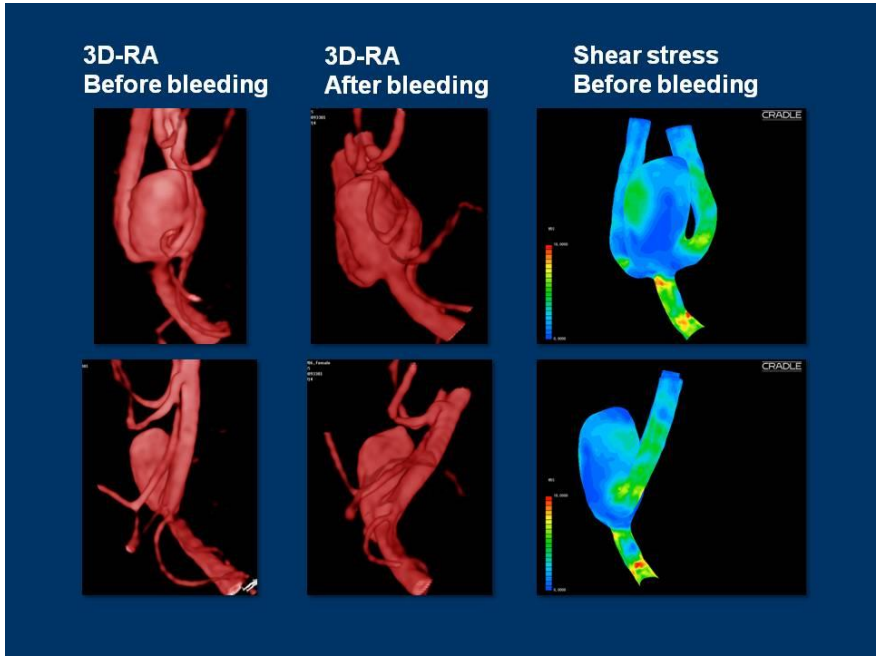
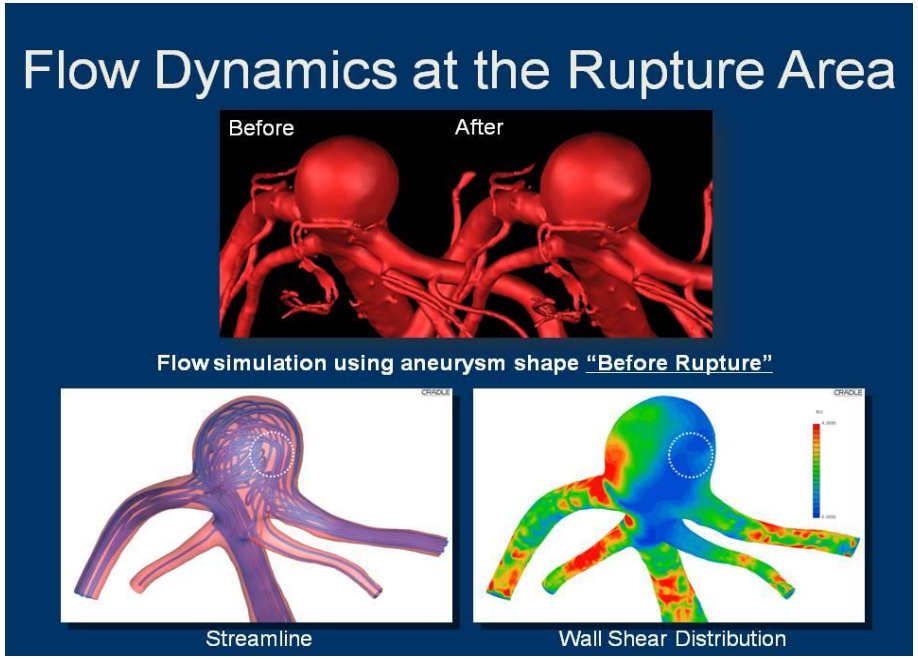
Surgical & Diagnostics

Hemodynamics





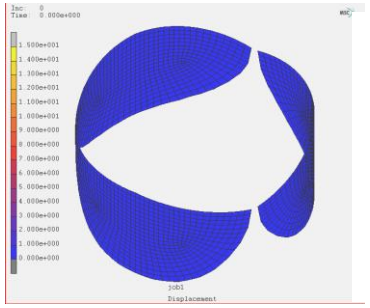


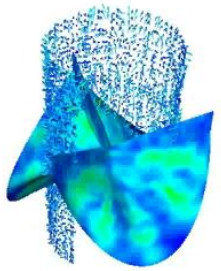
Low hemodynamic wall stress. High degree aneurysm growth. Angio-embrittlement

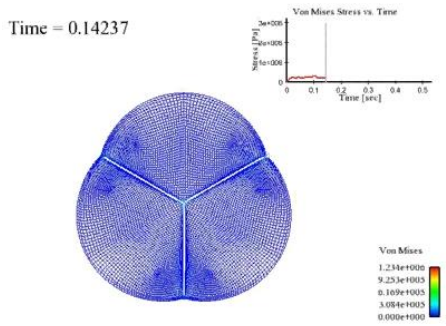
CV Mechanical Heart Valves

Application Description

A Heart Valve is a device used to replicate natural valves of the human heart when a malfunction occurs in any of the four heart valves







Design Criteria

- Biocompatibility
- Regurgitation
- pulsatile hemodynamics
- bluff body fluid mechanics
- Mechanical heart valve fatigue testing - 380 mil cycles

Simulation solution

- Structural analysis to determine minimum leaflet thickness; nonlinear orthotropic material
- Leaflet motion analysis
- Fluid-Structure Interaction
- Fatigue analysis
- Process Automation
- Management of design history file for regulatory compliance
- Fluid flow analysis

Solution Value:

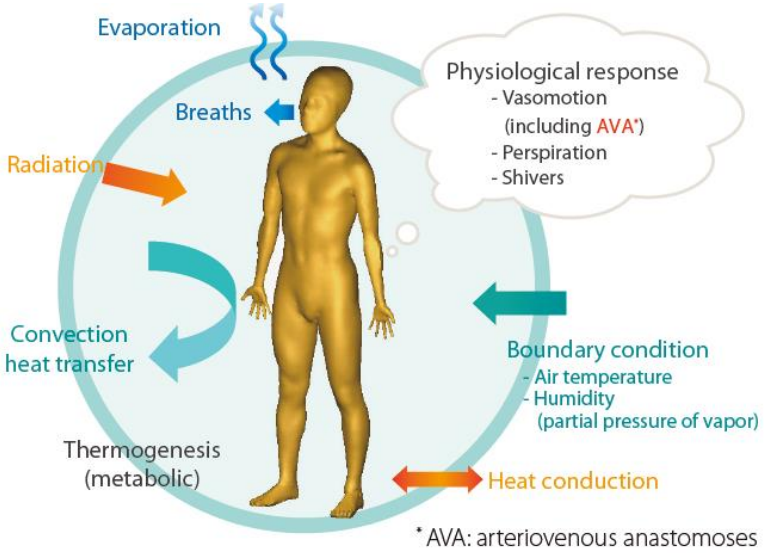
Reduce test costs, explore design options, valve performance with different materials

Hazard Mitigation with Human (JOS) Model

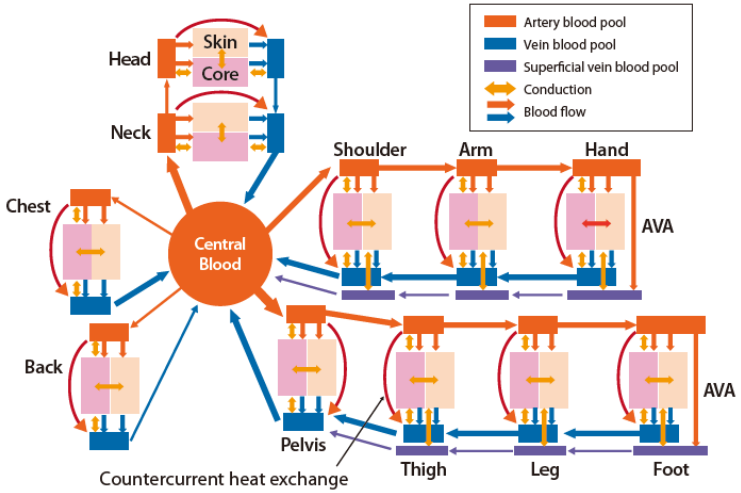
scFLOW

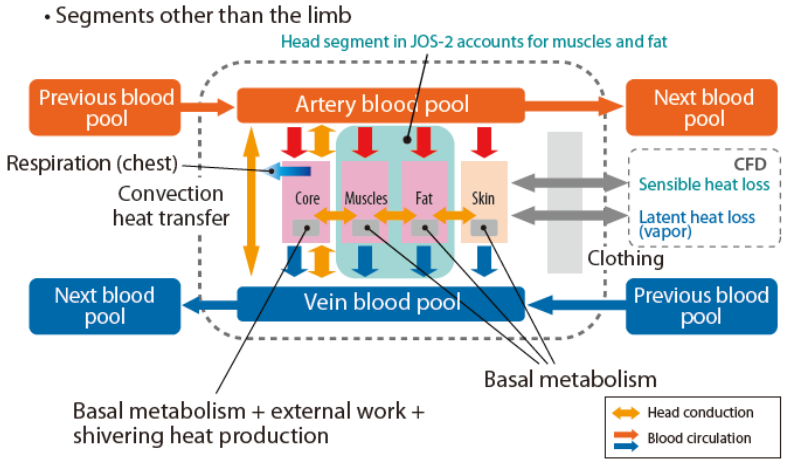
- JOS computes the temperature and quantity of perspiration of a human body
- JOS models a human body by dividing it into seventeen body segments. Each segment solves **heat balance equations**

Factors Considered in JOS

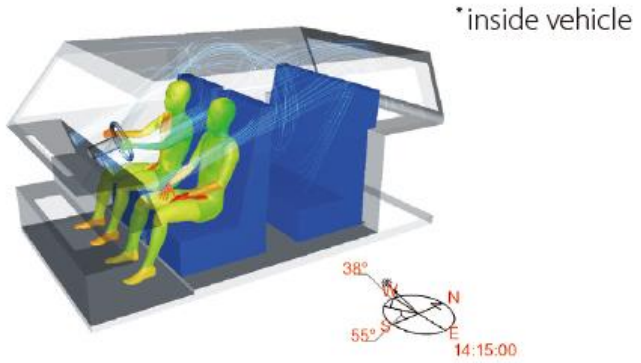


Heat Exchange within Body & Body Segment

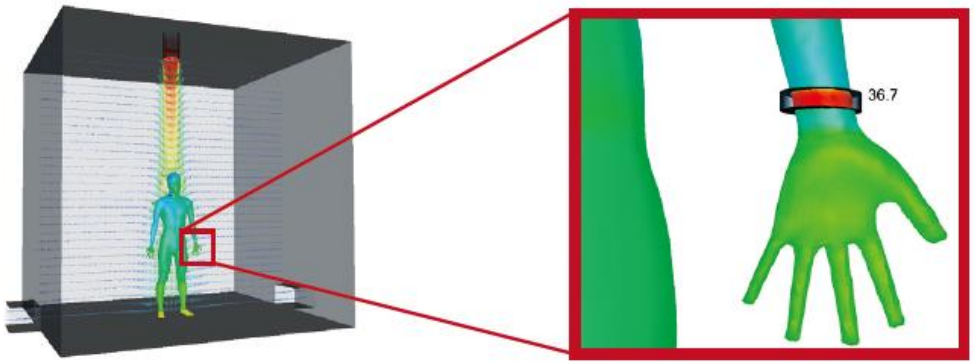




JOS APPLICATIONS



Human Comfort - Vehicle Interiors

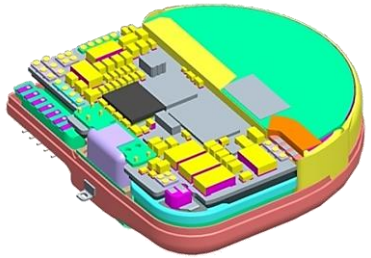


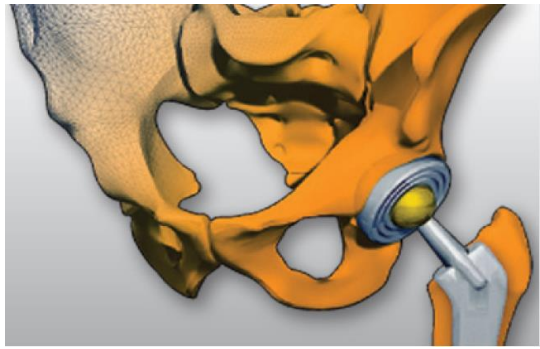
Human Body Temperature – With wearable device

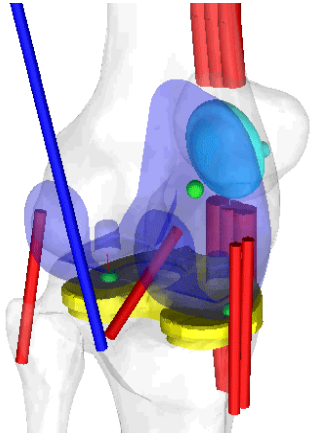
Key Takeaways

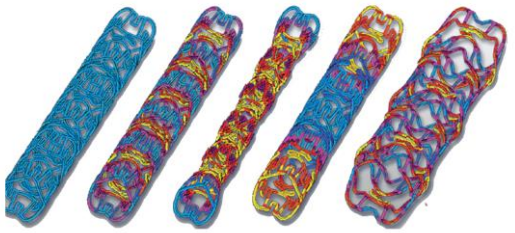
Importance of Engineering Simulations in Healthcare

- ❑ Reduce the need for physical prototypes and test costs by performing virtual tests
- ❑ Test product in representation to better plan clinical trials
- ❑ Predict new material behavior, durability, and performance through biomechanics simulations
- ❑ Explore design alternatives early in the design cycle
- ❑ Mitigate new product development risk by doing early virtual testing of new material behavior and device performance
- ❑ Help gain faster approval of regulatory bodies by managing virtual design history files









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