

Leveraging Computer Models and Simulation to make you live longer, healthier

Prith Banerjee, Ph.D.
Chief Technology Officer

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Changing the world through the power of simulation

50
YEARS OF
INNOVATION



Shatter Records



Unlock Possibilities



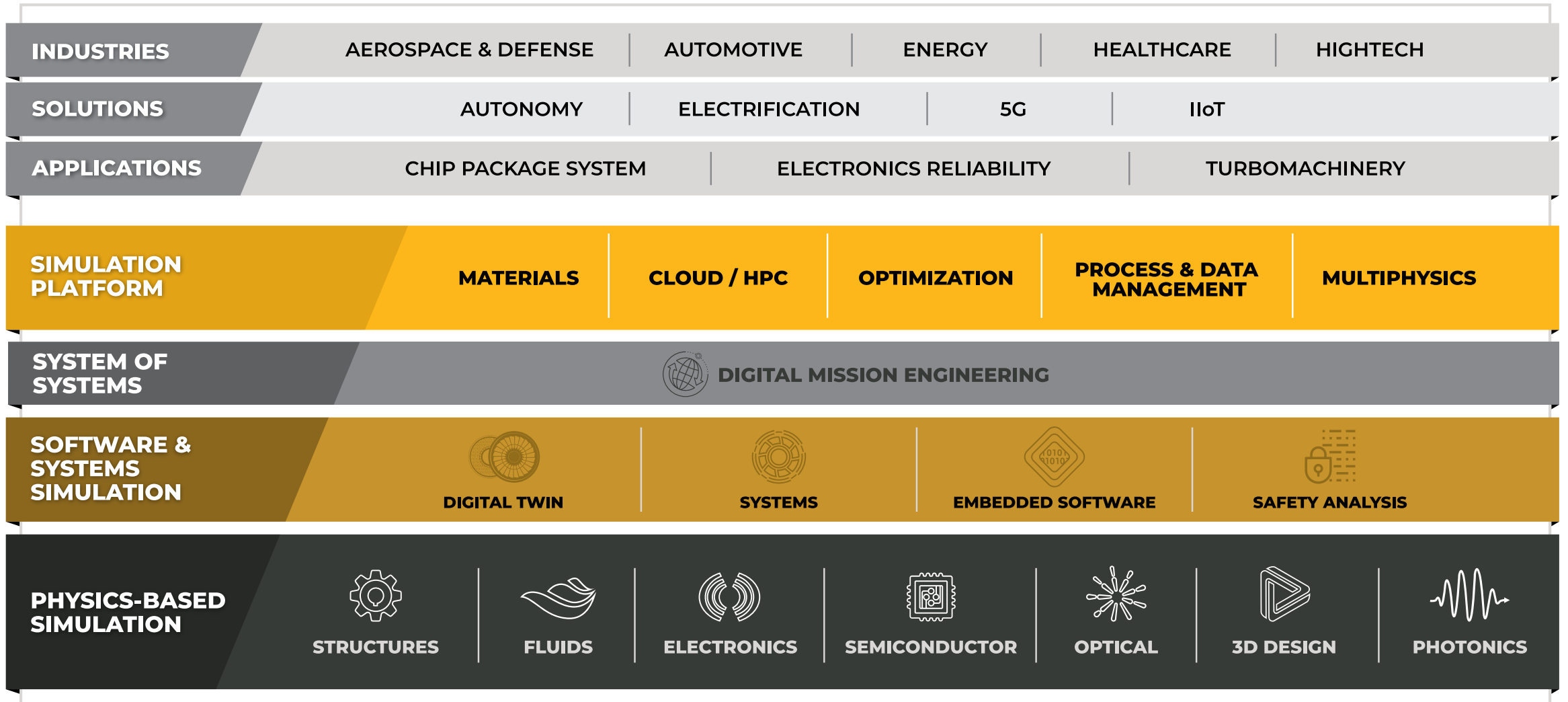
Make the Unmakeable



Save Lives

ANSYS

ANSYS Product Portfolio



ANSYS Long-Term Technology Strategy



NUMERICAL METHODS

- Accurate, fast, easy, robust
- Solver methods: direct, iterative
- Finite element, finite volume, IGA
- Implicit, explicit, hybrid, Bayesian



UI/UX AND VISUALIZATION

- Augmented Reality/Virtual Reality
- Ansys User Experience, Common UX, Common Components
- Reusable App Framework, MultiOS



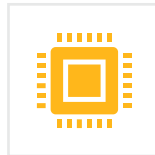
MODEL BASED SYSTEM ENGINEERING

- Collaborative System level modeling and 3D Sim
- Virtual Verification and Validation
- Lifecycle Trade Analysis & Optimization



MESHING / GEOMETRY

- Non- & Conformal Meshing
- Morphing, Immerse-Boundary
- Adaptive, Parallel Meshing



PLATFORMS/WORKFLOWS/DATA

- Multiphysics, Multi-domain, Multiscale
- Process Integration, & Optimization
- Data Management, Remoteable API



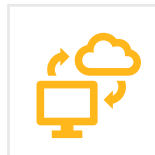
DIGITAL TWINS

- Data analytics/AI-ML
- Simulation-based, Hybrid
- DT for Design, Manufacturing, Operations



AI/MACHINE LEARNING

- Analysis Productivity
- Augmented Simulation
- Data Driven, Physics Informed, ML Based



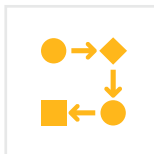
CLOUD

- Private, Public, Hybrid
- Cloud First, App Streaming, Solver/UI
- Lightweight web browser for solvers
- Ansys Cloud Studio, Ansys Cloud Direct



ICME, ADDITIVE, SUSTAINABILITY

- ICME & Multiscale Modeling
- Additive Manufacturing, Additive Science
- Sustainability, Life-cycle-analysis



HIGH PERFORMANCE COMPUTING

- Task based, Shared memory, message passing
- Fine grain (GPU)
- Exascale and quantum computing



DEVELOPER ECOSYSTEM, SOLUTIONS

- pyANSYS Framework
- Solutions: EV, AV, 5G, NVH, Healthcare
- 3rd Party App Development



HEALTHCARE VERTICAL

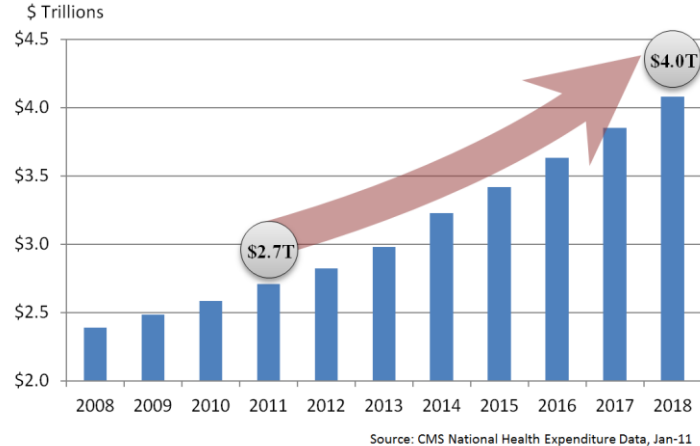
- Biopharma, Medical devices & equipment
- Virtual Organ Modeling, In-Silico Trials
- Digital twins of devices, organs, avatars
- Clinical, Nonclinical apps

Can we Leverage In Silico Methods to Live Longer, Healthier?

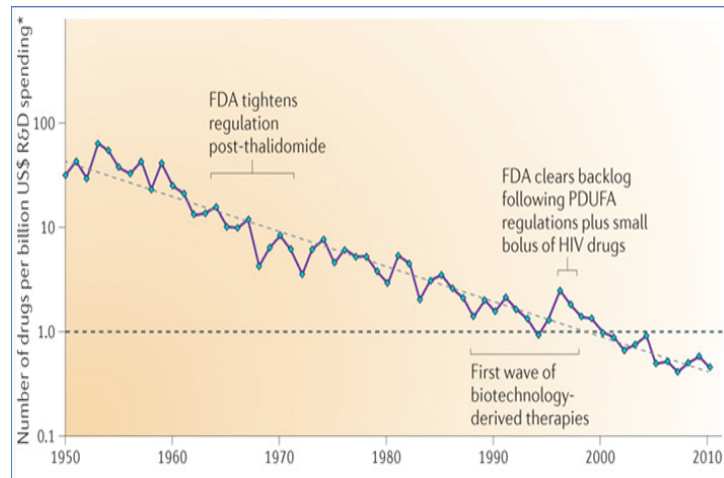
- Introduction
- **Need to digitalize healthcare**
- Adoption of in silico methods in healthcare
- Ansys Healthcare Roadmap
- Democratizing in silico methods with healthcare apps
- Digitalizing the regulatory approval process
- The Ansys Heart Project
- Joining forces to live longer, healthier

Healthcare Industry is reaching breaking point

Total U.S. Healthcare Expenditures



- Cost of healthcare is rapidly increasing and will worsen with an ageing population.
- It is estimated that the US alone wastes \$1TN/year due to lack of efficacy



- The cost to deliver a new drug to market using traditional trial based methods has increased significantly
- Bringing a new drug to market can cost up to \$2.5BN and take 15 years

Challenges Shaping the Healthcare Industry



Exploring New Vertical: Healthcare

- Total R&D Spend across all verticals is about **\$1 Trillion**; about 2% of the R&D spend in simulation (\$20 Billion)
- **Healthcare total spend is \$240 billion**; unlike other verticals, simulation is not used today in healthcare
- **Excessive time-to-market and high costs** takes 10-15 yrs to bring a new drug (\$2.5 B) and 4-7 yrs to bring a new medical device (\$100M)

Bio-Pharma



~\$182 B R&D SPEND (2019)

Drug Discovery

Computational Biology and Chemistry | Molecular and Materials Modeling

Drug Development

Solubility Predictions | Drug Safety | In-silico Trials | Virtual Human Modeling

Drug Manufacturing

Material Compaction | Mixing Tank | Bioreactor | Separation | Material Handling Molding and Forming | Packaging

Drug Delivery

Device Integrity | Fluid-Device and Device-Body Interaction | Drug Dispersion

Medical Devices and Hospital Equipment



~\$32 B R&D SPEND (2019)

Product Design

Materials | Multiphysics (Structures | Fluids | Electromagnetics | Lighting) | Functional Safety | Controls | Data Management

In-silico Trials

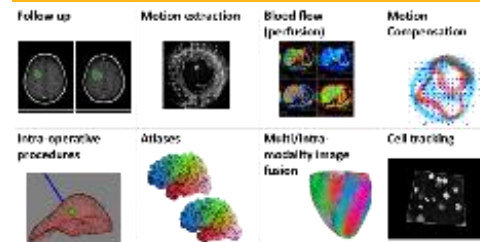
Regulatory Guidelines | Virtual Human Modeling | Patient-specific and Population-based Tests

Product Manufacturing

Additive Manufacturing | Packaging | Medical Tubing

Real World Evidence

Clinical Applications



~2.7 B IMAGING SCANS WORLDWIDE (2019)

Quantitative Imaging

Scheduling | Image Acquisition | Radiation Dose Exposure | Automated Triage | Data Fusion | Feature Quantification

Computer-aided Diagnosis

Image-based Modeling | Clinical Apps | Electrophysiology

Computer-aided Treatment

Surgery Planning

Digital Twins



~40 M CONNECTED HEALTHCARE DEVICES (2019)

Asset Twins

System Model Libraries | 3D Reduced Order Models | Data-based Models | IoMT Platform

Personal Digital Avatar

Virtual Human Models

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Simulation Solutions for the HealthCare Industry

Pharma & Biopharma

Upstream Process



Downstream Processing



Drug Delivery



Enabling Applications



Medical Equipment
& Supplies

Medical Imaging



Life Support



Disposable Supplies



Cardiac & cardiovascular



Musculoskeletal (MSK)



Respiratory



Neurology



Other Anatomy



Oncology

Medical Devices & Physiology

Heart Valve

Engineering Goals

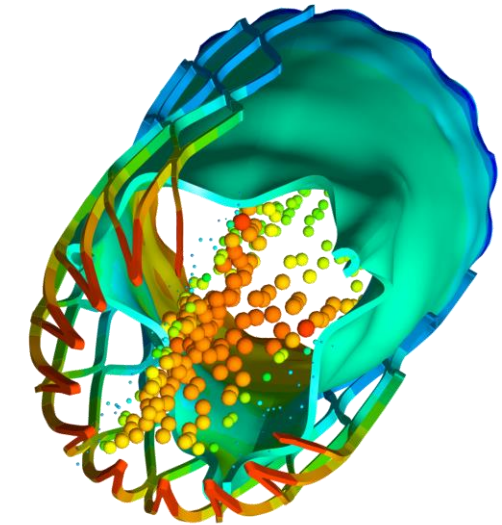
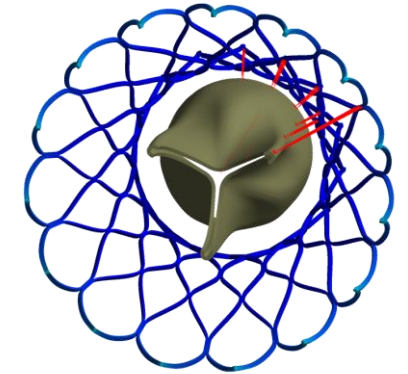
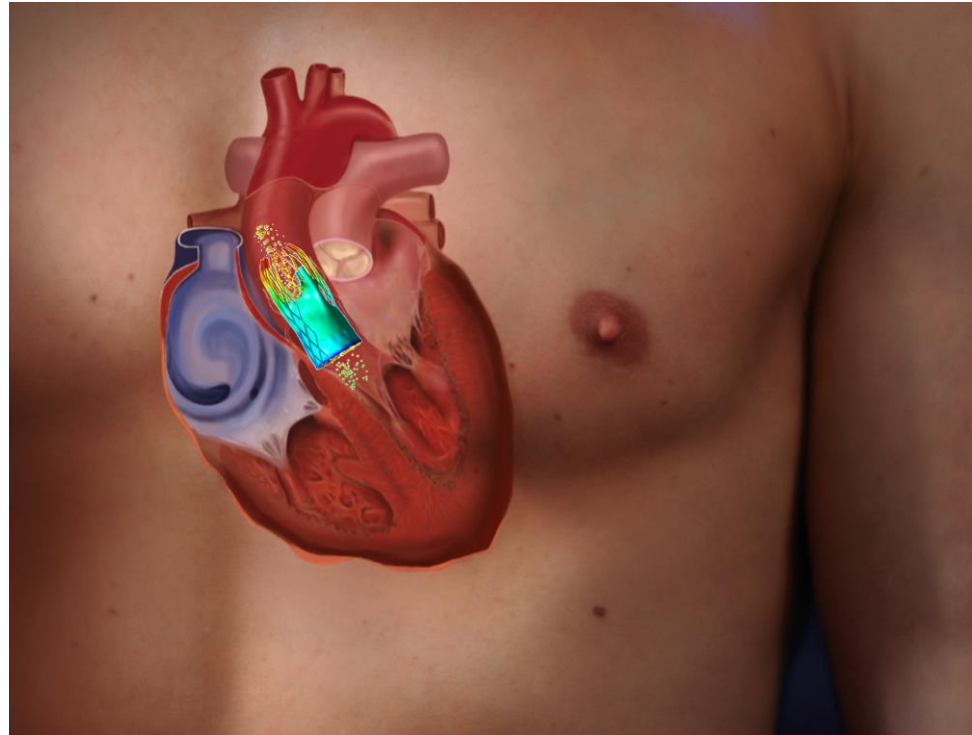
- **Replace** natural valve (calcified, leakage, etc.) by artificial valve
- **Optimize** valve design to minimize stress/strain and fatigue, leakage, deterioration of blood cell
- **Accelerate** regulatory approval
- Evaluate **patient-specific** delivery

Ansys Solutions

- **Fast Pre-processing:** Geometric wrapping for rapid valve & stent creation, design optimization capabilities
- **Accurate:** Nonlinear material models for valve, and hyperelastic for surrounding soft tissues
- **Robustness:** Contact detection

Benefits

- **Reduced** valve failure
- **Minimized** blood leakage
- **Reduced** the cost of physical testing by 10%



"Simulation reduces the cost of physical testing by about 10 percent"

Noureddine Frid
Cardiatis

MRI Safety

Engineering Goals

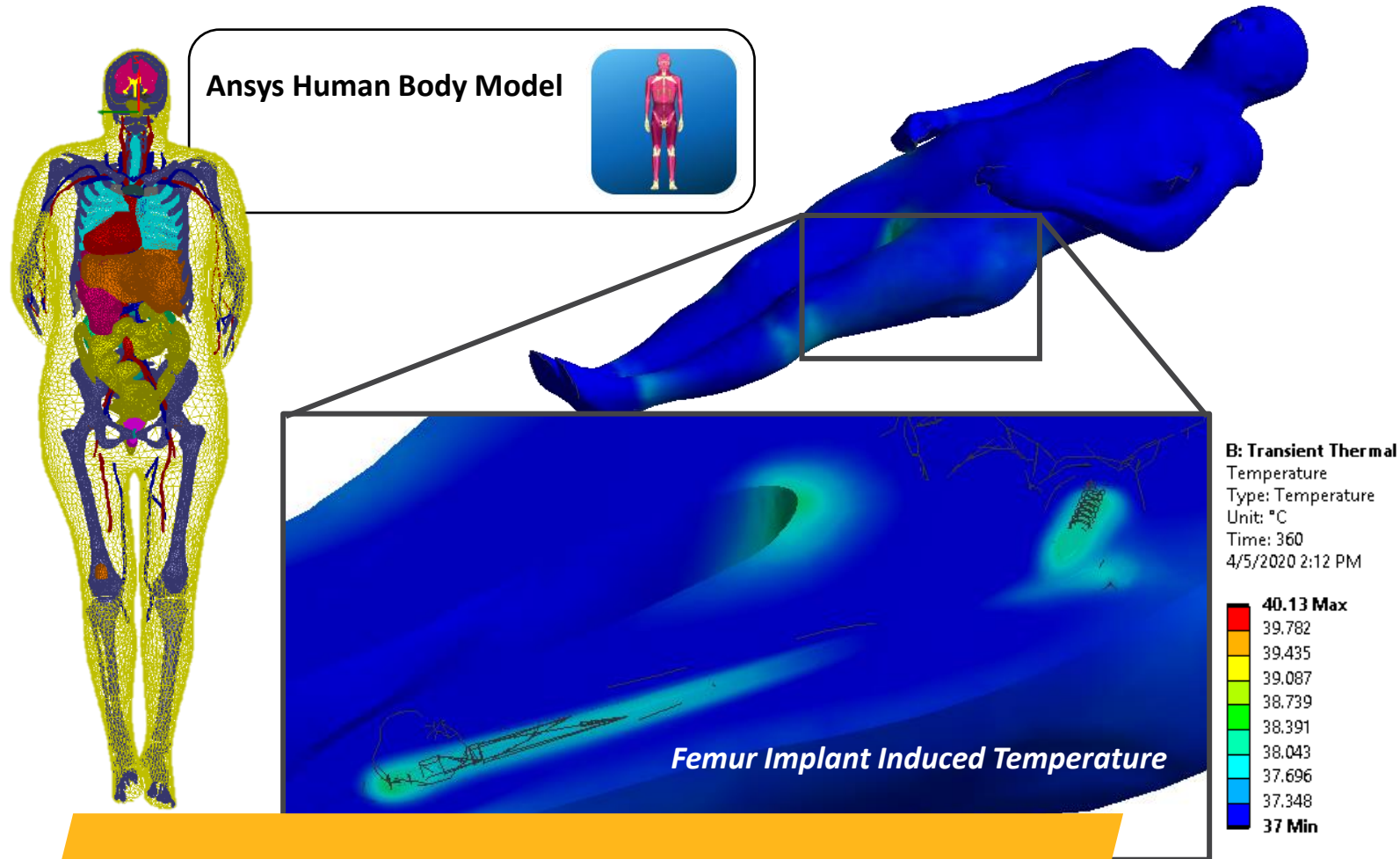
- Ensure **patient safety** during MRI scans
- Determine force and torque on implants during MRI
- Determine SAR and induced temperature rise near an implanted device during MRI
- Pass standard tests: ASTM F2052, F2213, F2182, ISO/TS 10974

Ansys Solution

- **Accuracy:** Coupled electrothermal simulation capability, electromagnetic field modeling, human body models
- **Speed:** Automated adaptive meshing, frequency domain analysis
- **Fidelity:** Bio-heat modelling

Benefits

- Model-based MRI safety evaluations are accepted by regulatory agencies
- Lower costs by **minimizing bench** testing
- **Reduce risk** through human body modeling



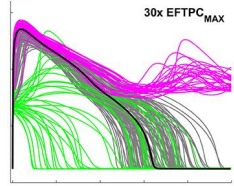
“The use of in silico computational modeling has provided a novel and efficient approach for assessing MR patient safety and improving information to clinicians.”

Dan Moreno

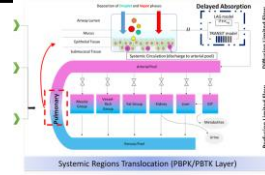
DePuy Synthes Companies / Johnson & Johnson

Pharma/Biopharma Drug Development & Manufacturing Process

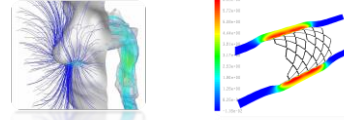
Drug / Vaccines



Cardiotoxicity



PB PK/PD in relation with drug delivery



Inhaler, Drug Eluting Stent, Insulin pump, Auto injector

Drug Discovery

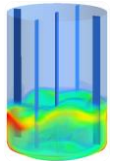
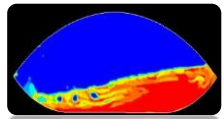
Drug Development

Drug Delivery

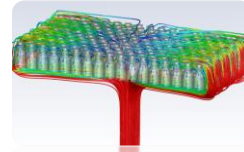
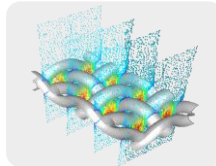
Drug Manufacturing

In-Silico Trial

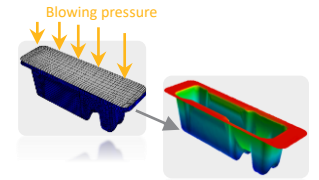
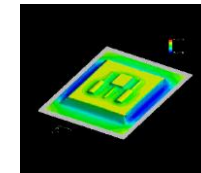
Drug Manufacturing



Seed Train, Mixer, Bioreactor, Crystallizer



Spray Drying, Filtration Chromatography, Lyophilization, Tablet Coating, Compression



Bottle filling, Blister Packing, Transportation

Upstream Process

Downstream Process

Packaging & Transport

Lab to Plant Scaleup & Design

Operations, Retrofitting, Troubleshooting, Inspection



Drug Delivery: The right dose for the right patient at the right time

Goals

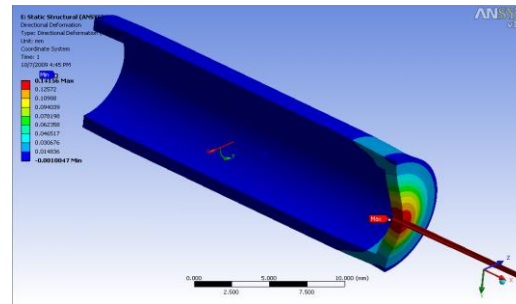
- Understanding the **interaction with the human body and tissues** (non uniform drug distribution pattern)
- Provide the **right dose, at the right location and at the right time**
- **Design trade offs** for combination products

Solution

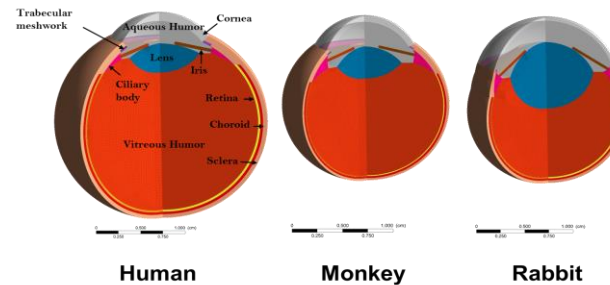
- Utilize idealized and/or **realistic anatomical models**
- **Multiphase and multiphysics** solutions
- **Open simulation architecture** for implementation of physiologic material properties and boundary conditions
- **Parametric Optimization**

Benefits

- Optimize **drug concentration profile**
- Reduce the **cost of animal testing and clinical trials**
- Optimize **delivery system design parameters**

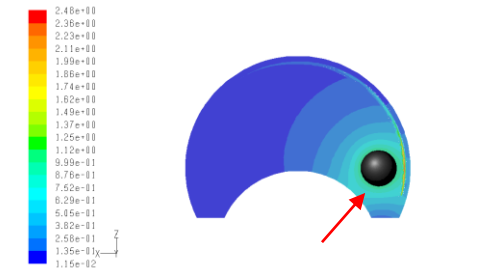


Injection in soft tissues

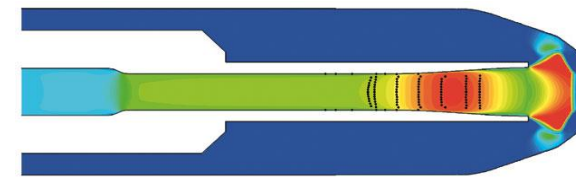


Human Monkey Rabbit

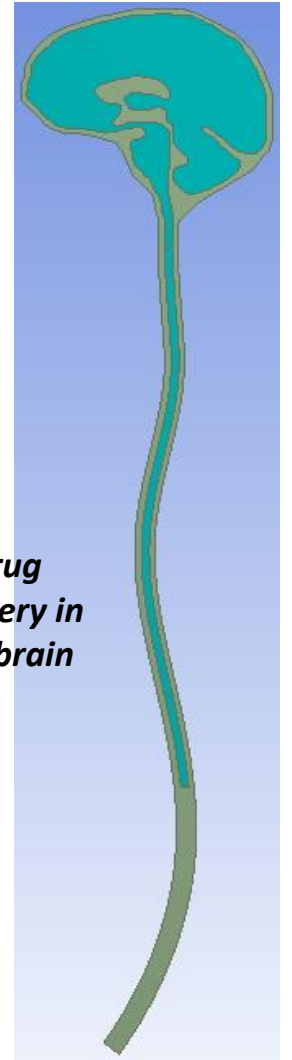
Idealized eye model repository



Device implanted in the eye



Needle-free delivery



Drug delivery in the brain

Spray Drying

Engineering Goals

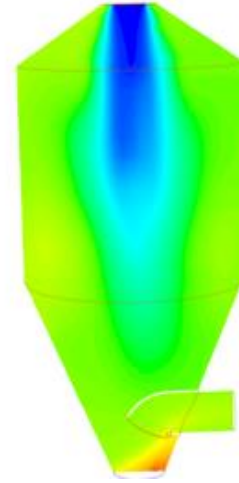
- Identify optimal nozzle design and operating conditions
- Manage droplet and **particle size distributions**
- Minimize **wall deposition**
- Prevent **particle overheating**

Ansys Solution

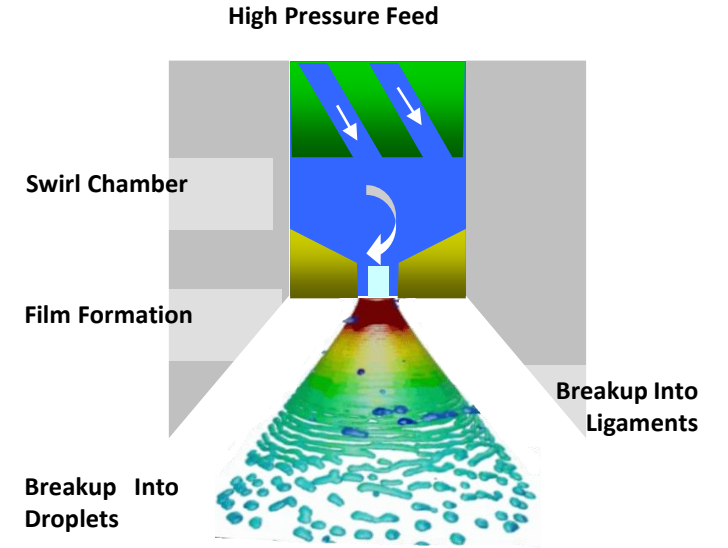
- **Robustness** of Multiphase models
- **Advanced Modeling** for Spray break up & evaporation models
- **High Performance Computing** for scalable up to 200,000 processors

Benefits

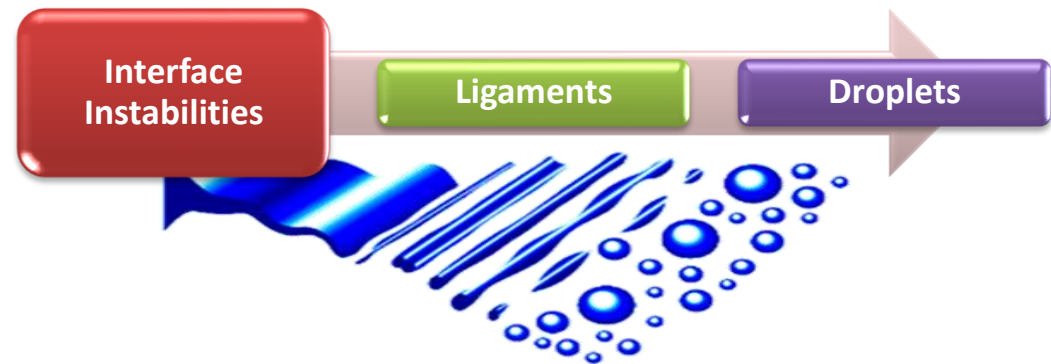
- Understand the impact of **nozzle design** on the **spray angle, particle residence time**
- **Optimized** spray dryer process design



Temperature Distribution



Primary jet break-up



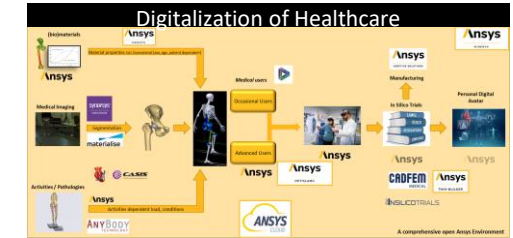
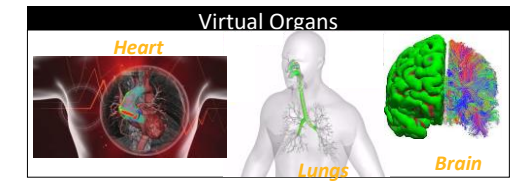
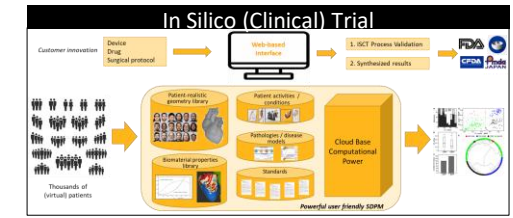
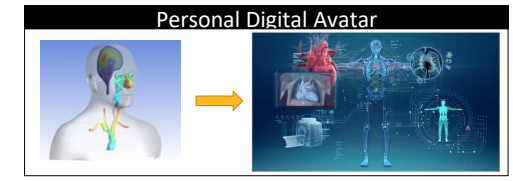
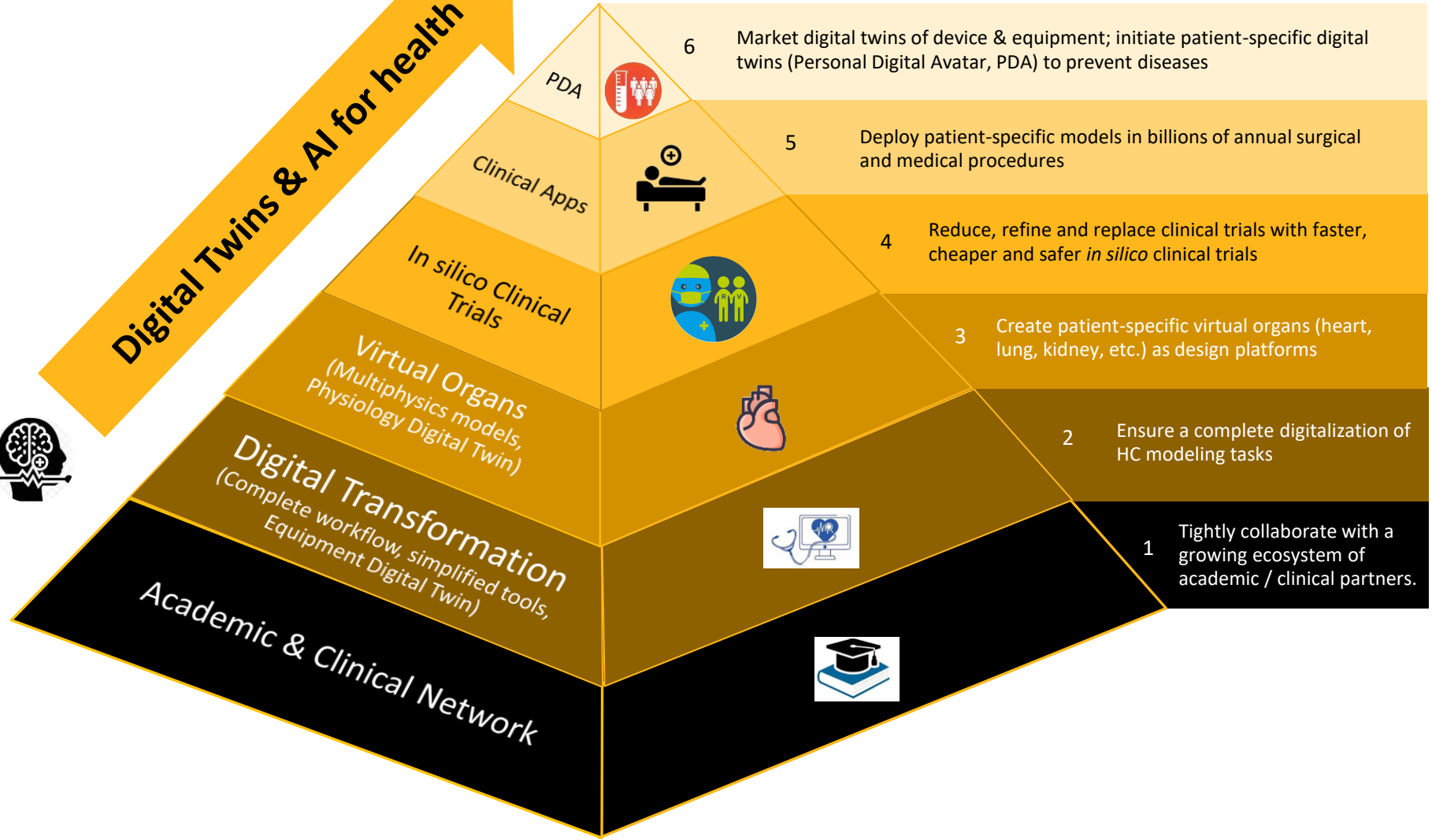
Robust multiphase modeling required to capture spray break up

Can we Leverage In Silico Methods to Live Longer, Healthier?

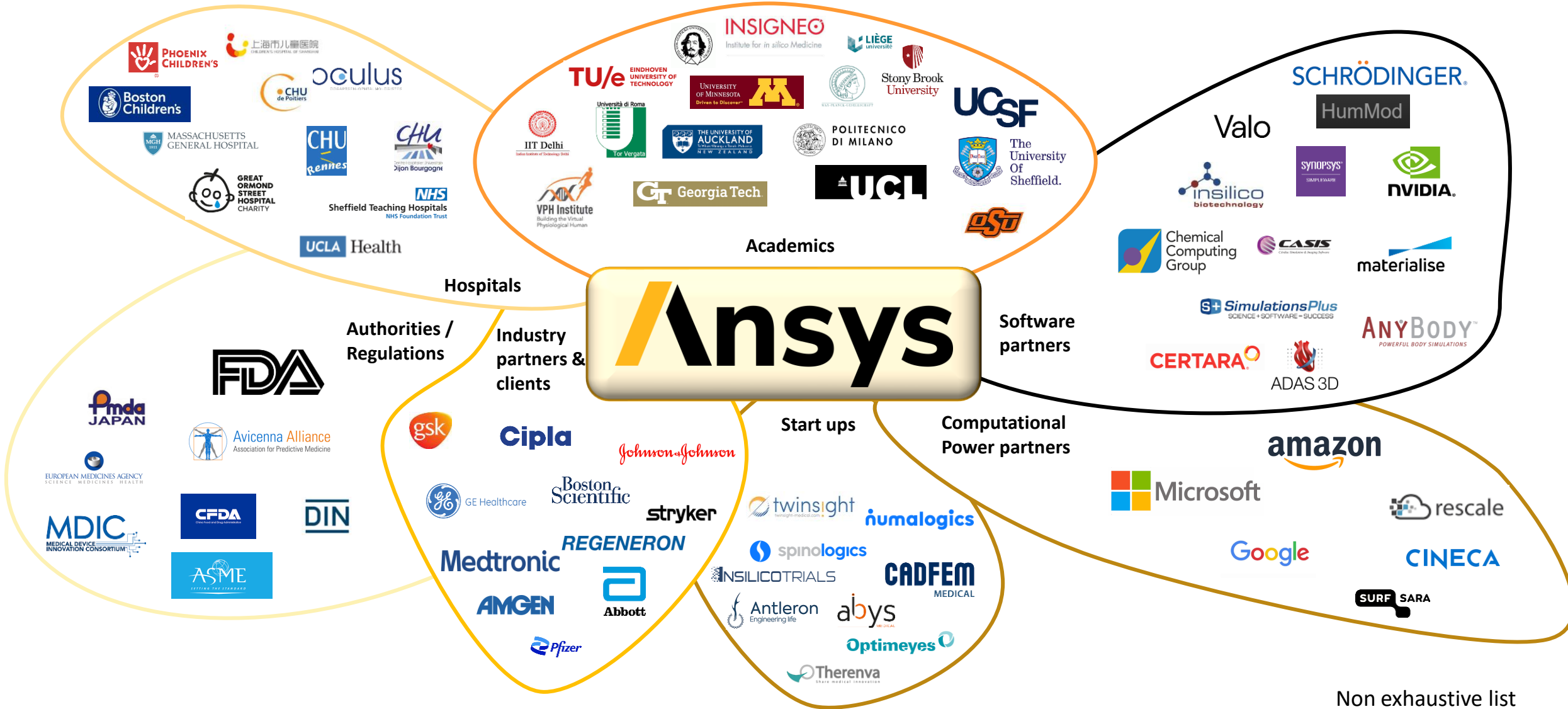
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Ansys Initiative in Healthcare

Digital Twins & AI for health



The Ansys Healthcare Ecosystem



Non exhaustive list

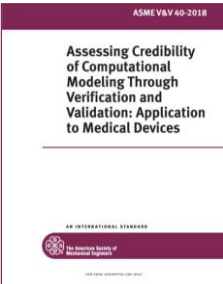
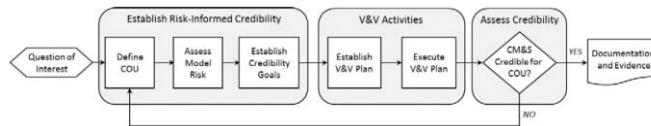


Driving the Digital Transformation

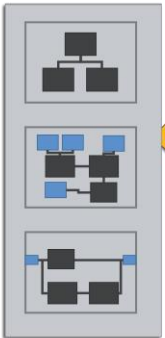
- To Overcome Product, Process and Organizational Complexities

Regulatory Compliance as a Business Process

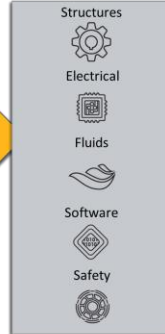
Verification & Validation Uncertainty Quantification Process



Systems Architecture Model

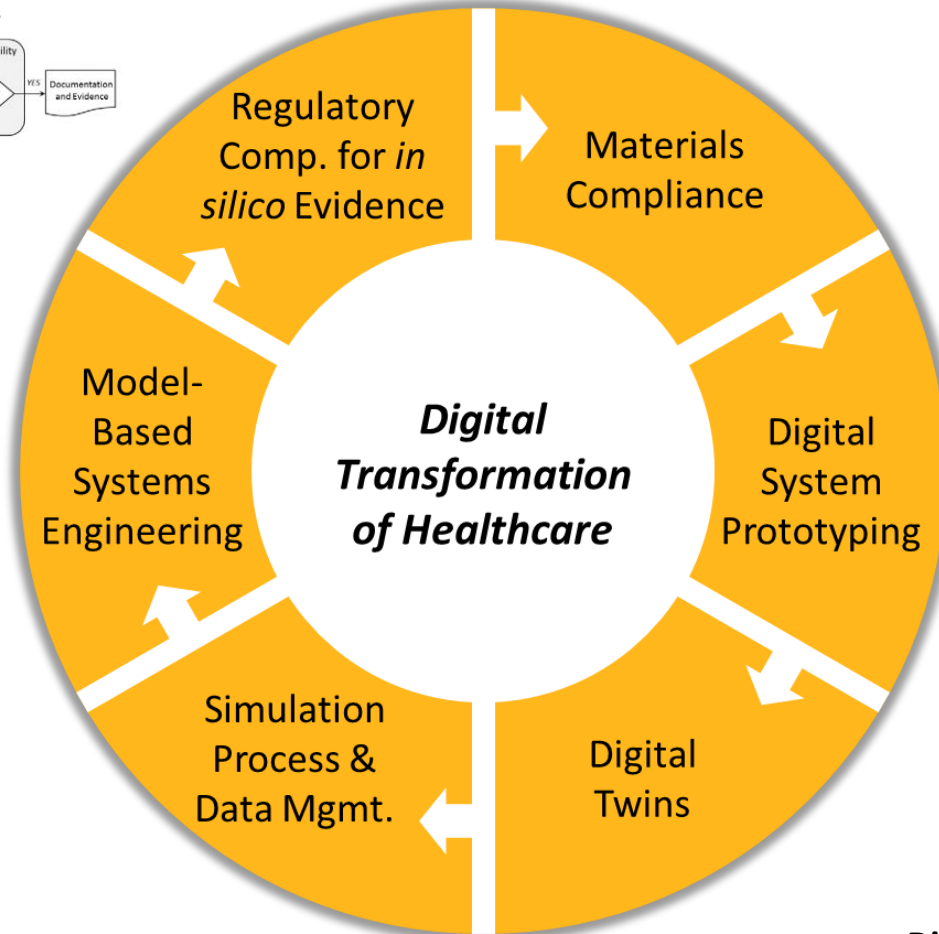


Analytical Models

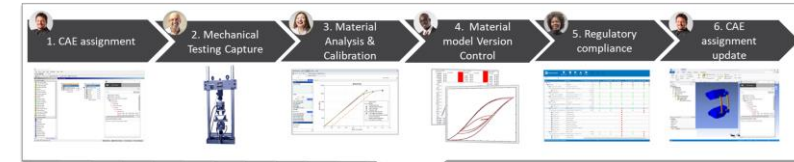


ModelCenter MBSE

Model-Based Systems Engineering



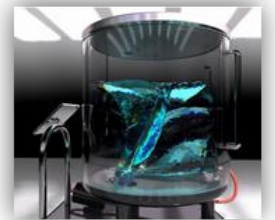
Materials Data as a Corporate Strategic Priority



Physical Twin



Digital Twin



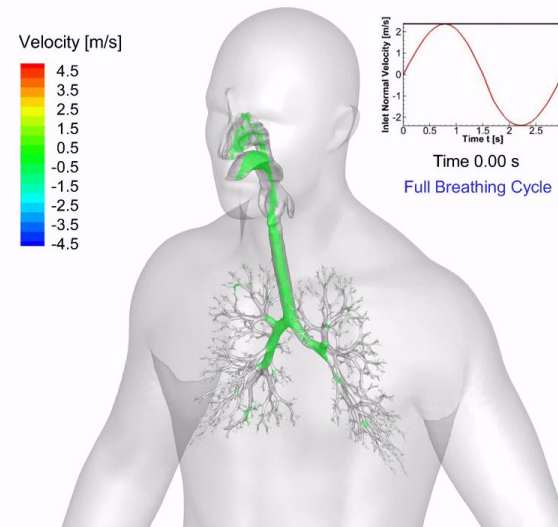
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Digital Twins of Products, Processes, and People



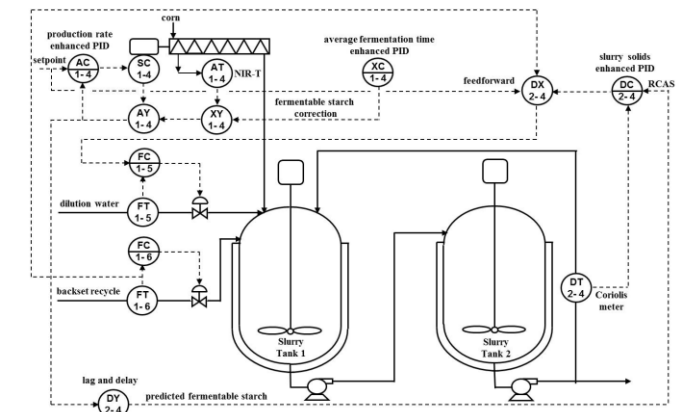
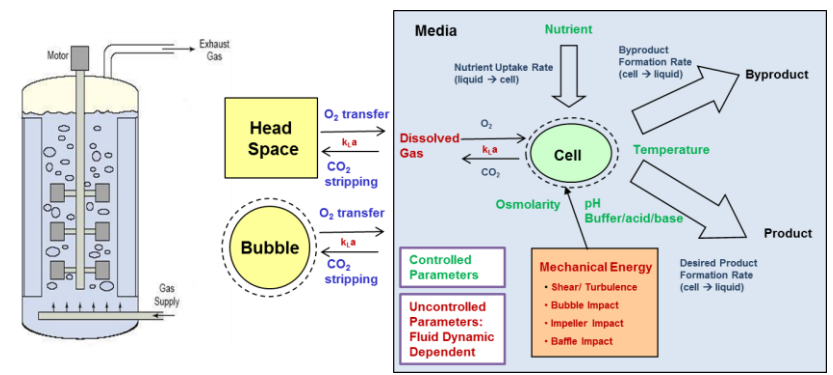
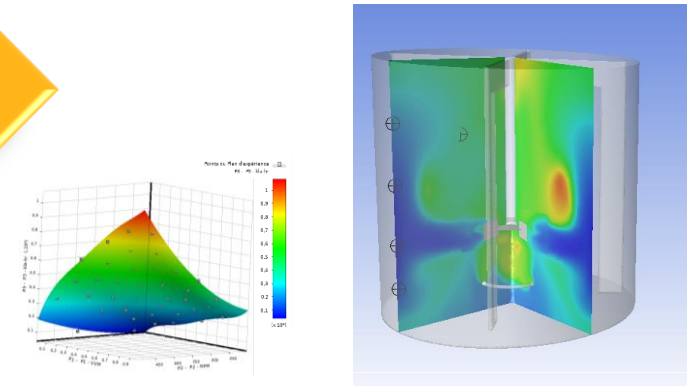
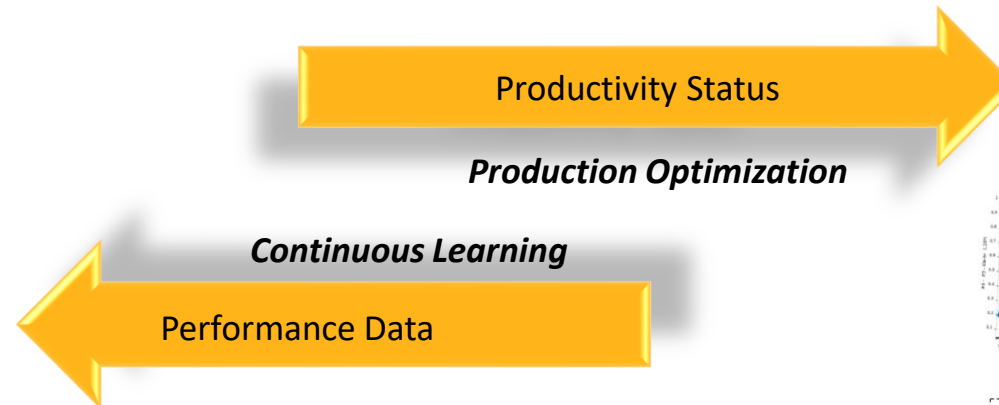
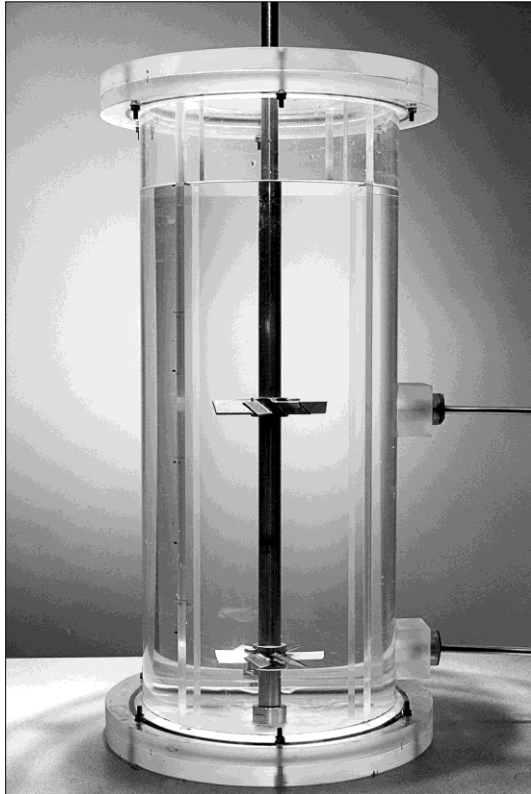
Virtual organs: a clinically validated patient specific model of organs as a platform to treat chronic diseases, delivery routes

- **High fidelity** simulation of patient specific organs.
- **General framework** to test medical devices in diseased organs in-silico.
- **All physics included** in a single compact package.
- High scalability to thousands of cores.
- **Flexible interface** connecting with Twin Builder for a more realistic simulation of the full system.
- **Strong interaction with industry and academia** provides realistic expectations and goals.



Bioreactor **Digital Twin** ensures an optimum productivity during the equipment lifecycle

To maintain a good level of productivity, the comfort of living entities is essential: continuously maintaining the right pH, temperature, Oxygen and nutrient level while evacuation CO₂ and waste can be controlled and automatically adjusted with a connected digital twin.



The Ultimate Goal: Human Digital Twin / **Personal Digital Avatar** will leverage simulation to prevent diseases, push back on death

Medical Device

Pacemaker, hip prosthesis, insulin pump, wearables, etc.



In Silico Clinical Trials



Computer Assisted Surgery



Clinical & Physiological
Computer Aided Diagnosis (CAD)
& Computer Aided Surgery (CAS)

Augmented Medical Imaging



Hospital Equipment & Supplies

MRI, X-Ray, smart bed, etc.

In Silico Clinical Trials



Pharma & BioPharma

Benefits:

1. Test different treatments
2. Customize implant / device
3. Adjust drug dose to patient
4. Prevent disease through continuous monitoring

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The Healthcare community expects various healthcare apps:

- Simplified and encapsulated workflow
 - Integration of 1 or several Ansys tools / solvers in a target customer environment
 - “Easier to use” for non-M&S experts
 - Deployable with simple customization
 - Common UI for consistency / branding

Industry

A specific and simplified interface built on top of our Ansys products to help **non experts simulation users** in medtec companies to use advanced modeling to design and optimize products or processes.

This is similar to many other industries; a typical example is the mixing template.

Regulatory

A specific interface built on top of our products (one or several) for **Regulatory Affairs Engineers** to reproduce a typical testing necessary to provide digital evidence for regulatory approval.

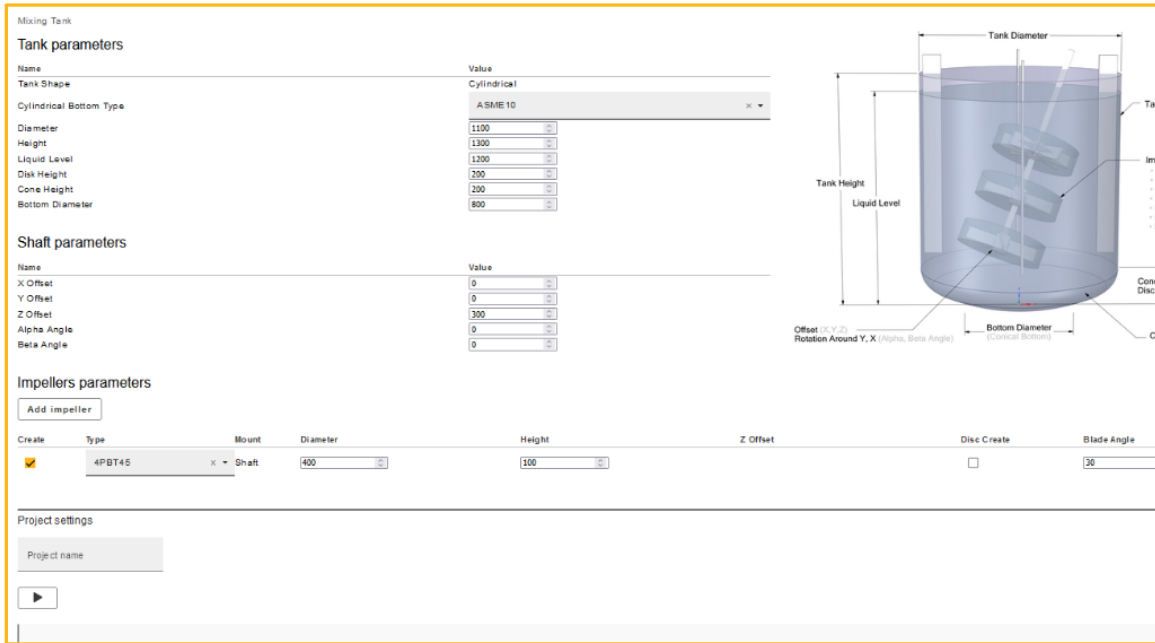
These testings are described in details into standards; therefore these applications are often an in silico version of an existing in vitro, occasionally in vivo test.

Clinical

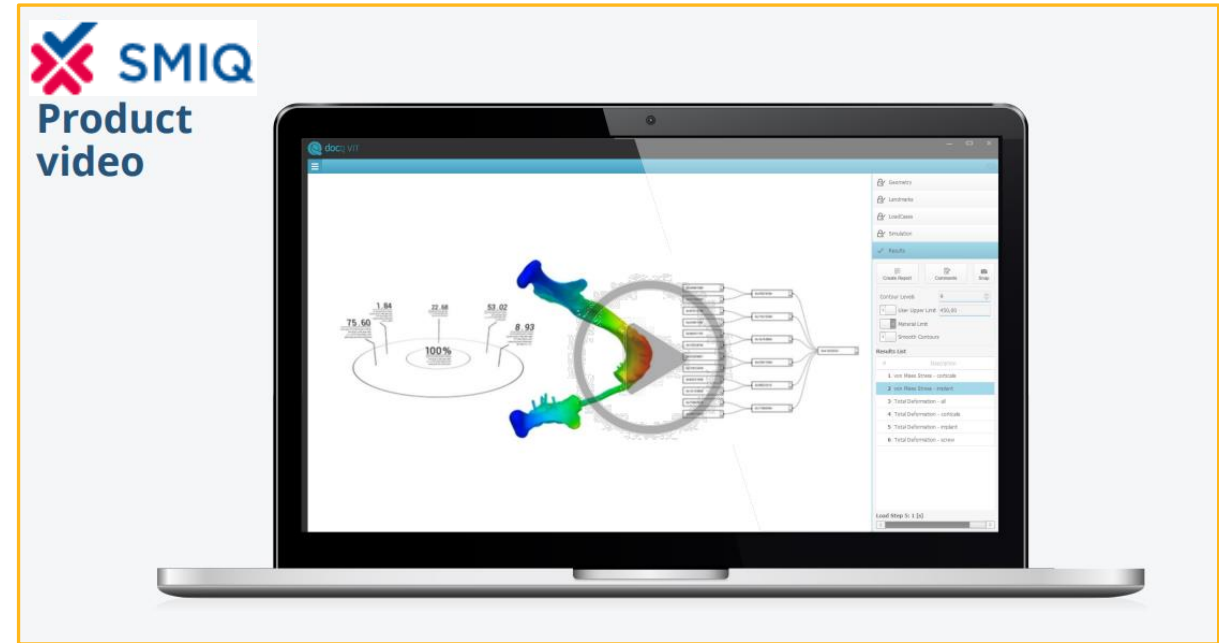
A specific and simplified interface built on top of our Ansys products to assist **clinicians or physicians** to plan their surgery or establish a diagnosis.

The patients are much closer to simulation. The applications could be developed by Ansys, startup / academic partners or our clients.

Creating Healthcare apps for traditional clients to delegate CM&S to non expert users



Mixing App Initiative



Medical Device App
SimQ Virtual Implant Testing

Democratizing In Silico Methods: Healthcare Apps!

Short Term Focus:

Stage 1
Ansys

1. Process Pharma Apps

- Upstream process,
- Downstream process,
- Packaging,
- Etc.

2. Med. Device Apps

- Cardiovascular,
- Orthopedic,
- Drug delivery, etc.

➤ Patient variability

Democratization of simulation for traditional clients

Stage 2
Ansys + partners

3. In silico / In vitro test

- Stent, valve
- Hip prosthesis, knee joint
- Autoinjector, etc.

4. In silico trials

- Stent, valve
- Hip prosthesis, knee joint
- Autoinjector, etc.

➤ Virtual / synthetic patients

Digitalization of the Regulatory Approval process

Stage 3
with partners

Personalization & Digitalization of healthcare:

5. Clinical Apps

- Surgery planning
- Diagnosis

6. Personal Digital Avatar

- Personalized Medicine
- Diagnosis

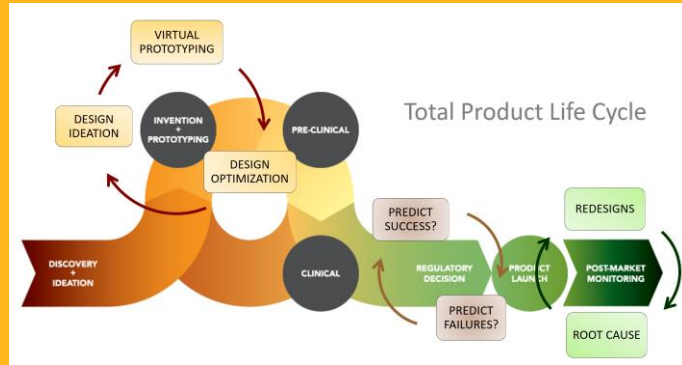
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Regulatory authorities are recognizing in silico methods as a reliable source of evidence

Prior to 2018

The Medical Device Development Pathway

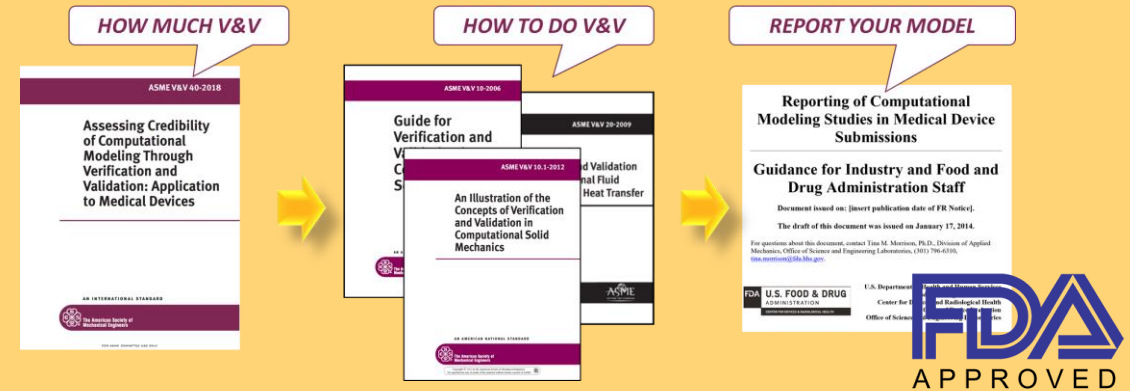


Supported by 3 Traditional Sources of Evidence

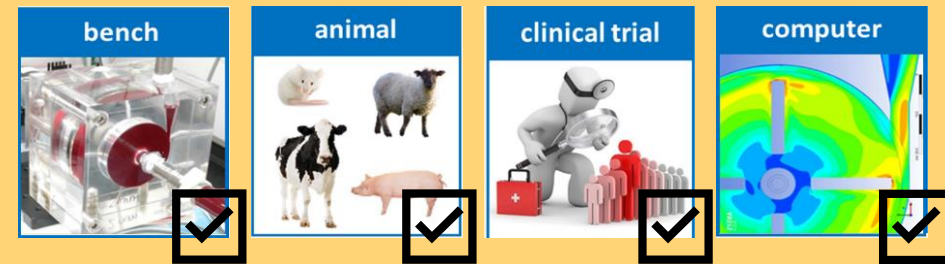


2018-present

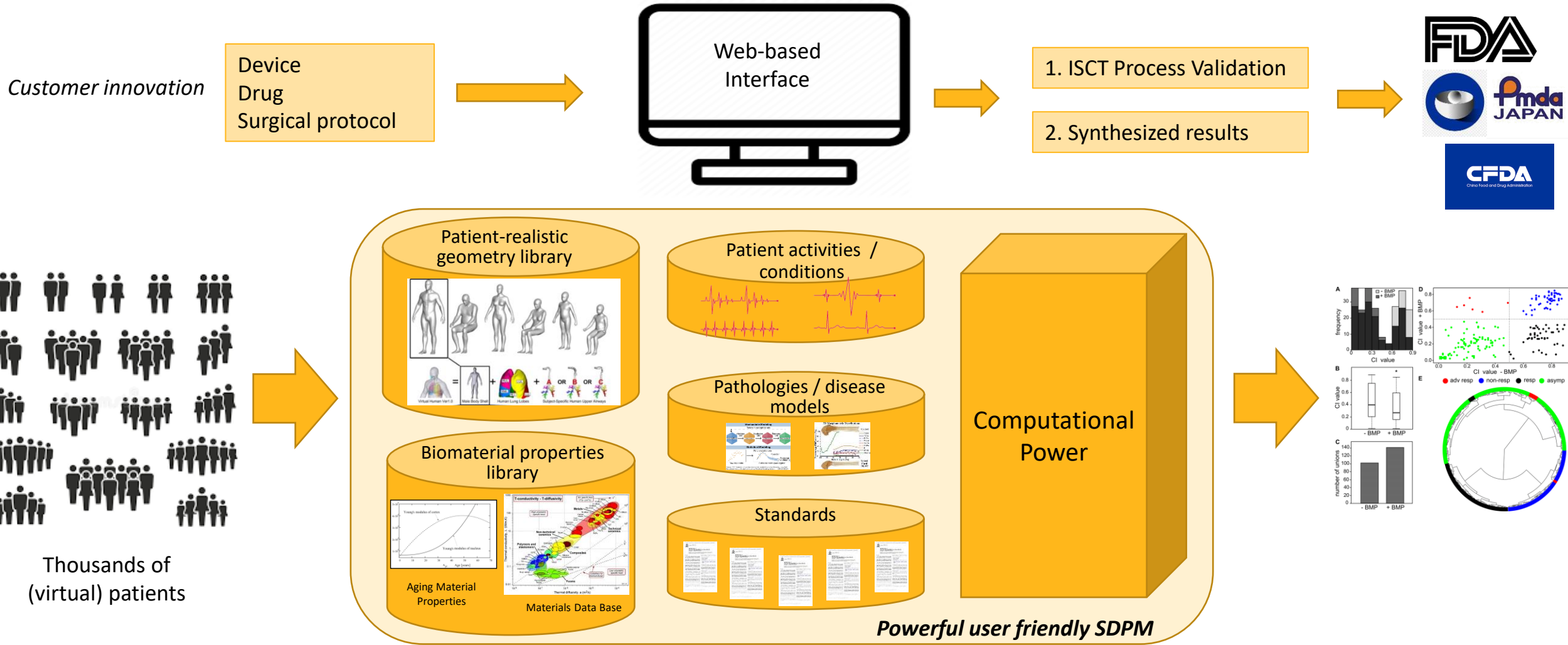
Regulatory Pathway for Computational Modeling



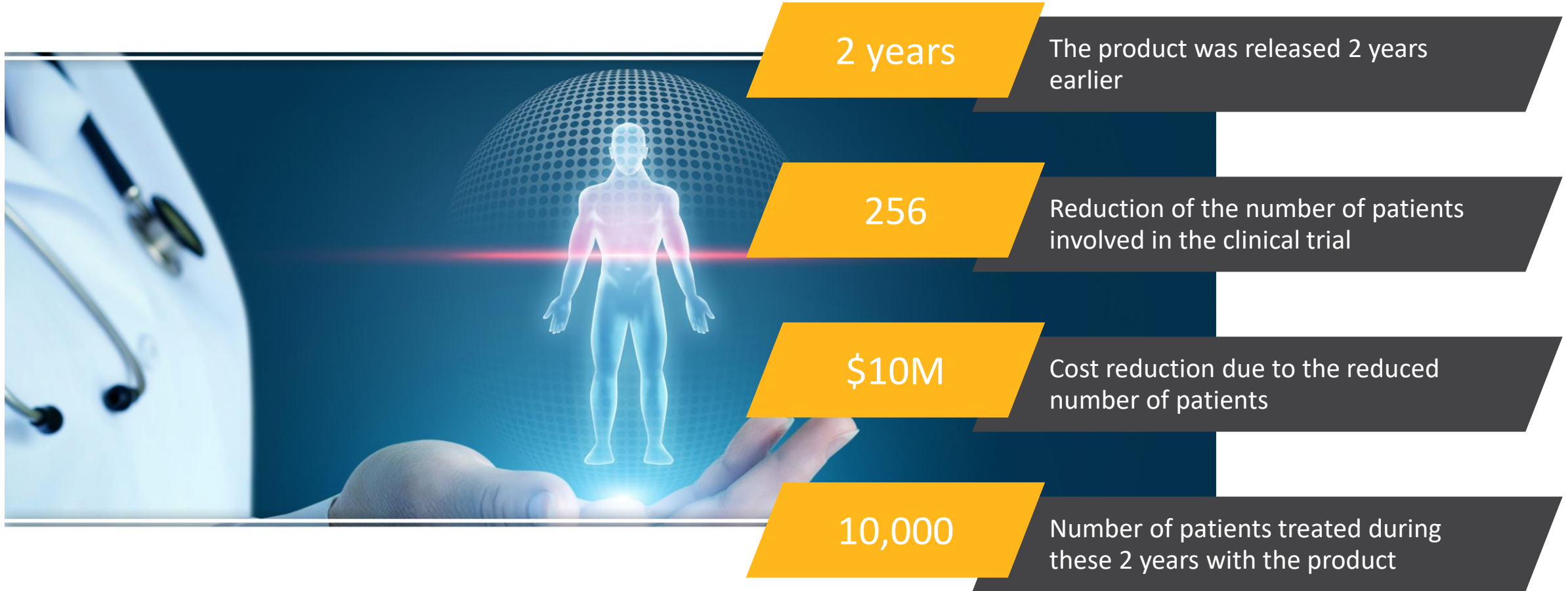
Enables Reviews Supported by Computer Models



There is a pressing need to deploy In Silico Trials in the healthcare industry



In Silico Clinical Trials help to bring treatment to patients faster while reducing cost to market



Reducing, Refining, Replacing (3Rs) Clinical trials by Computer Models

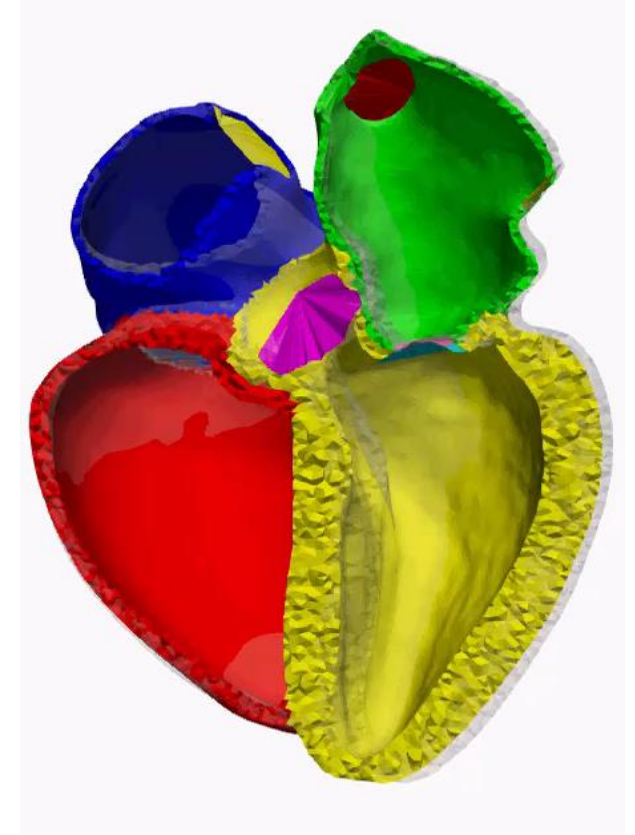
https://avicenna-alliance.com/files/user_upload/Conference_2018/materials/International_Avicenna_Alliance_Conference_Report_-_4_Sept._2018_final_.pdf

Can we Leverage In Silico Methods to Live Longer, Healthier?

- Introduction
- Need to digitalize healthcare
- Adoption of in silico methods in healthcare
- Ansys Healthcare Roadmap
- Democratizing in silico methods with healthcare apps
- Digitalizing the regulatory approval process
- **The Ansys Heart Project**
- Joining forces to live longer, healthier

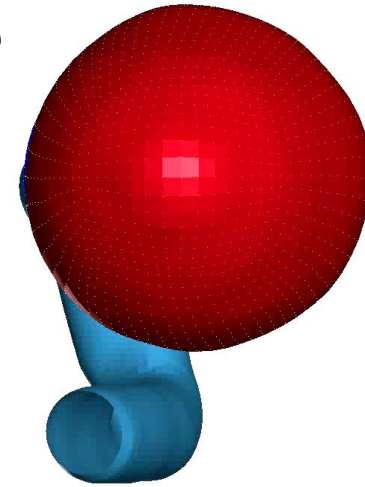
/ Ansys Heart Project

- Heart disease: number 1 killer.
- Focus of R&D team is in heart simulation
 - Automated easy-to-use robust workflows are essential
 - Will promote digitalization of the medical (device) industry
 - R&D effort is on
 - Physiologically accurate heart simulation
 - Development of automated Python workflows from medical imaging to simulation results
 - Two main applications
 - In-silico clinical trials
 - Embedded software with major MedTech partners

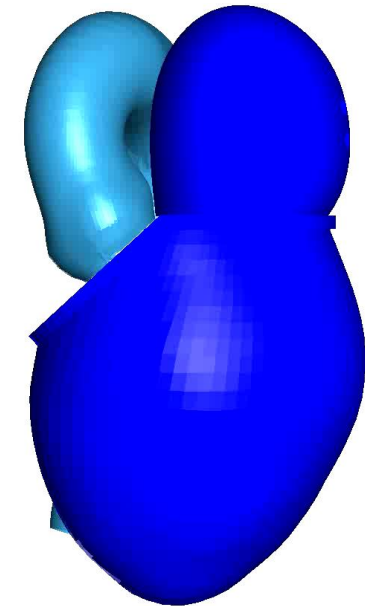


A complex multi-physics, multi-scale multi-time engineering challenge

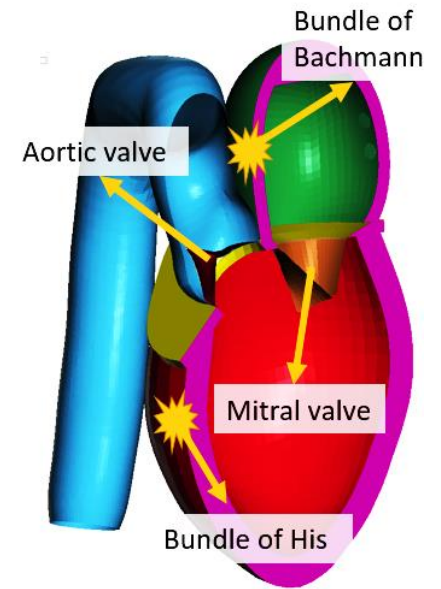
- Goal:
 - Developing a **clinically validated patient specific** model able to predict **instantaneously** the patient's heart behavior under **various scenarii**
- Status: fluid, structure, electrophysiologic model of the left heart
- Progress: Adding disease models and drug impact using Reduced Order Model (ROM)



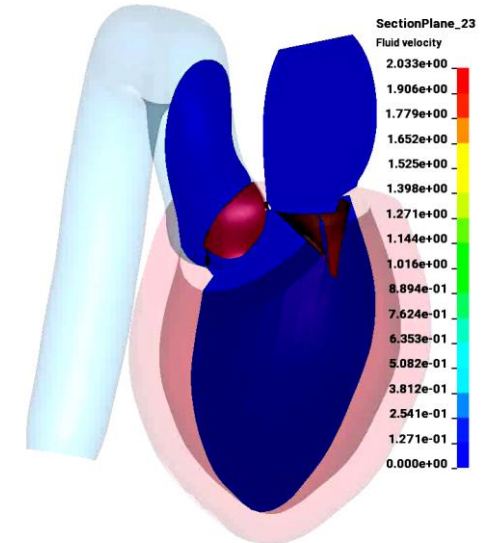
Helical motion during systole



Transmembrane potential

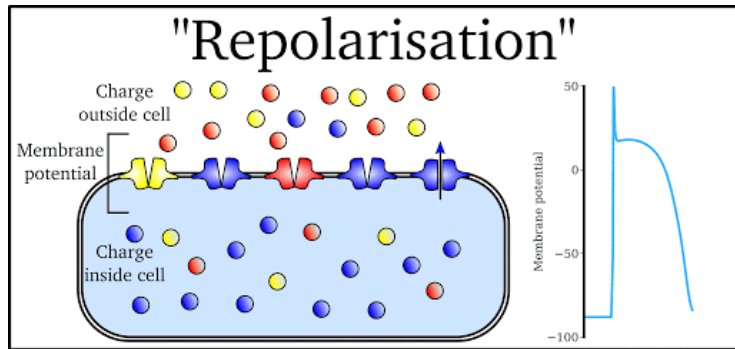


Valve dynamics and blood flow



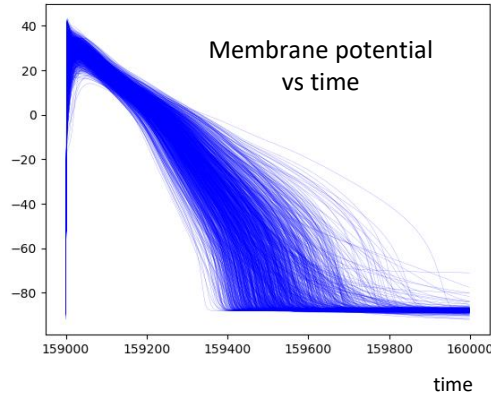
SectionPlane_23
Fluid velocity
2.033e+00
1.906e+00
1.779e+00
1.652e+00
1.525e+00
1.398e+00
1.271e+00
1.144e+00
1.016e+00
8.894e-01
7.624e-01
6.353e-01
5.082e-01
3.812e-01
2.541e-01
1.271e-01
0.000e+00

Application for Drug Discovery : Risk Assessments for Cardiotoxicity: Different drug concentration for different population models



The value of the electric potential V is essential for the cardiac risk assessment

Creating a virtual population of heart cells
(Ansys Twin Builder)



Modeling the drug effect

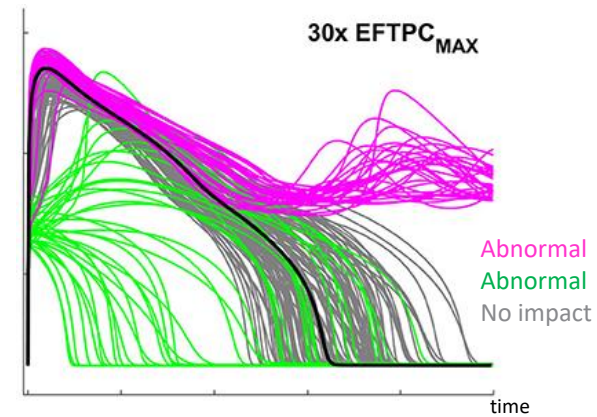
Pore Block models

Drugs models :

- **Pore-block model:** blockage to multiply to the corresponding g_{ion}

$$B_{ion} = \frac{1}{1 + \frac{[D]^h}{IC50}}$$

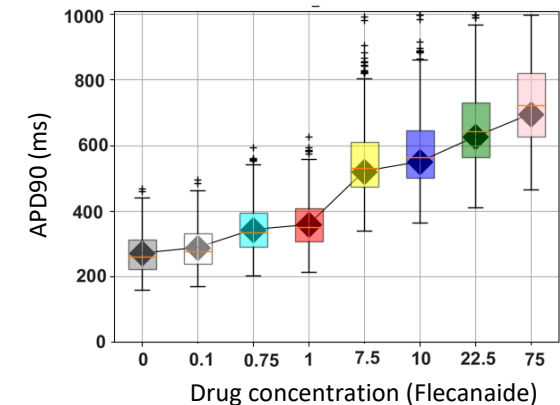
D: Drug concentration



Score assessing the risk of drug to induce abnormalities

$$TdP\ score = \frac{\sum_i(w_i * nRa_i)}{n_{mod} * \sum_i w_i}$$

0: no risk - 1: high risk

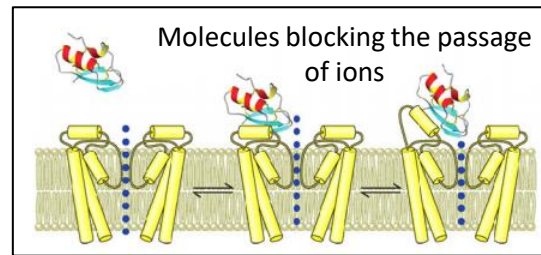


Modeling membrane potential:

$$\frac{dV}{dt} = -Cm * \sum I_{ion}$$

$$I_{ion} = g_{ion} * V$$

2 phenomena:



Ultimate Goal:

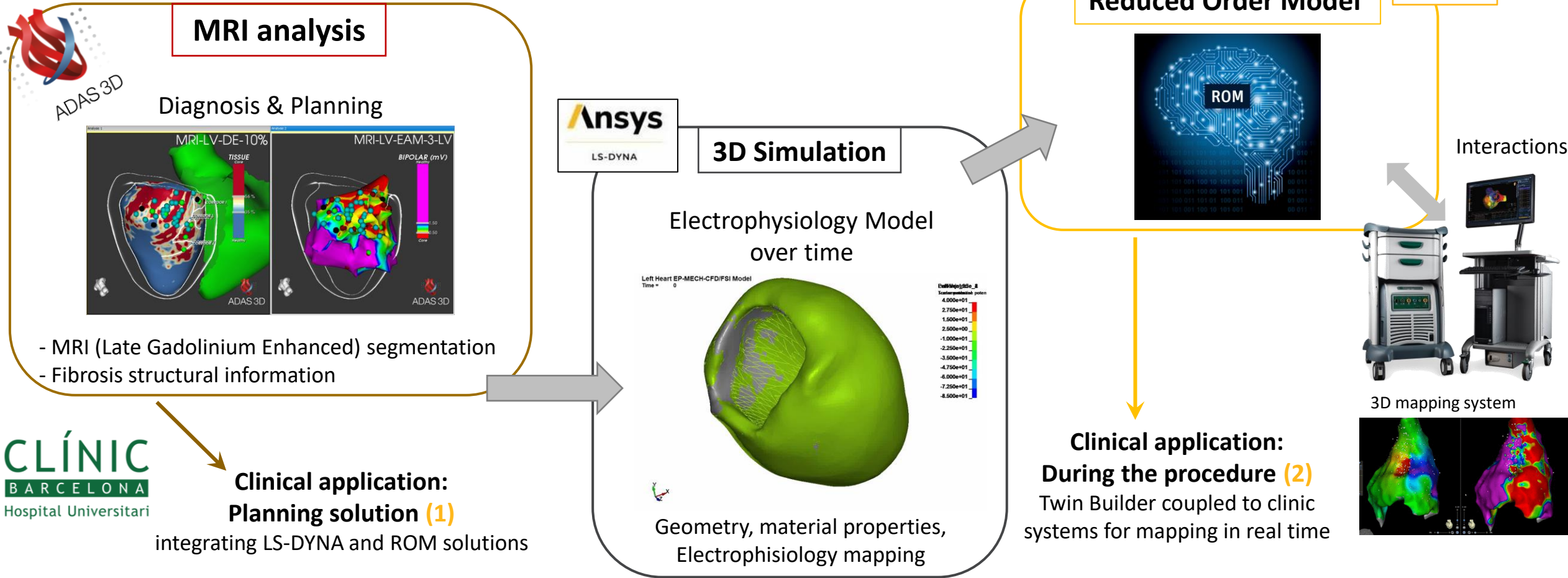
Predict pore block parameters for a new compound using machine learning, computational chemistry, and a database of experimental results

*Passini, E., Britton, O. J., Lu, H. R., Rohrbacher, J., Hermans, A. N., Gallacher, D. J., ... & Rodriguez, B. (2017). Human in silico drug trials demonstrate higher accuracy than animal models in predicting clinical pro-arrhythmic cardiotoxicity. *Frontiers in physiology*, 8, 668.

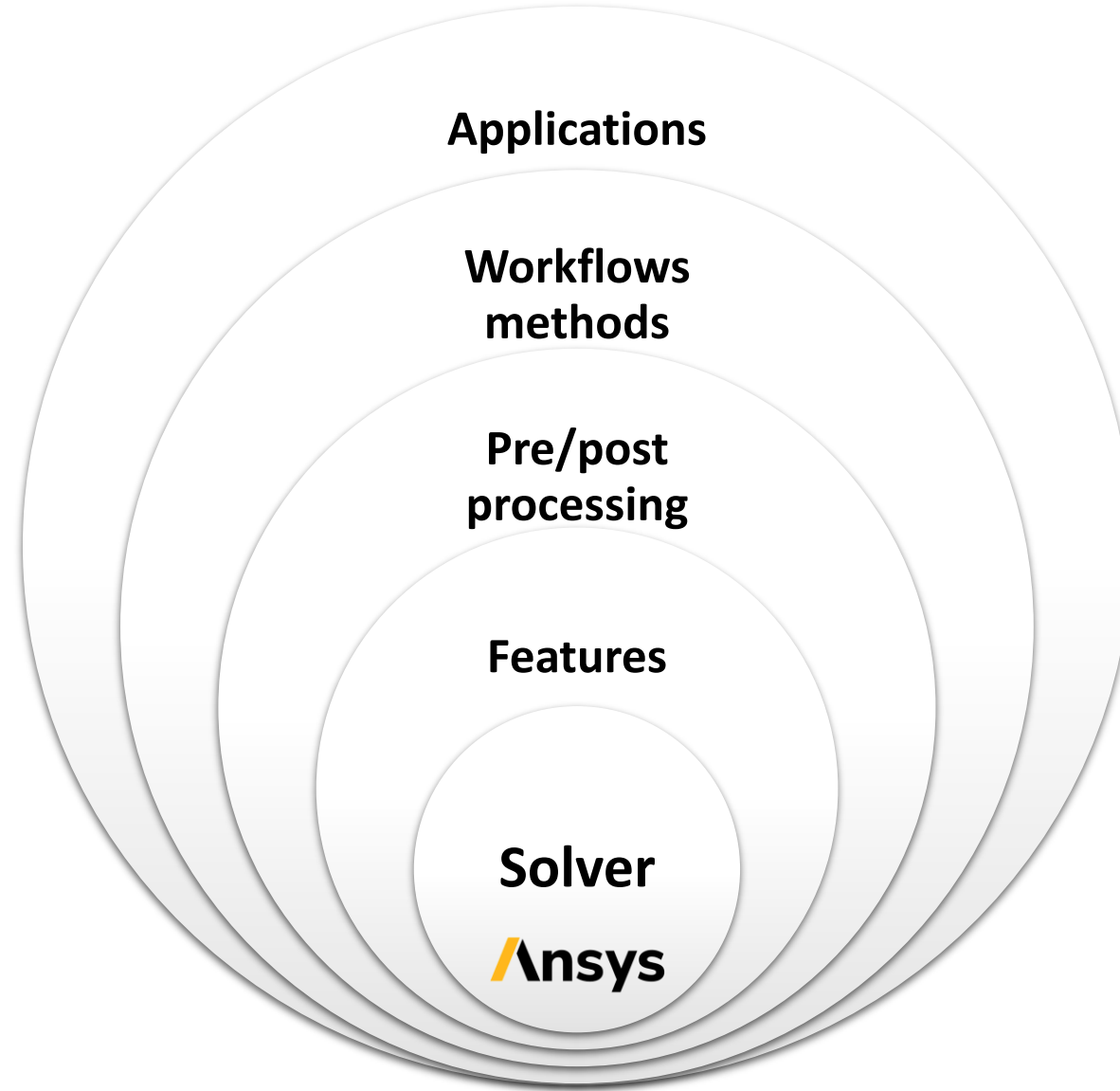
Possible applications for hospitals:

From medical imaging to planning treatment and guiding catheter ablation

- (1) Planning i) Arrhythmia risk prediction, ii) optimal ablation target
- (2) Real time calibration of cardiac Digital twin from partial EP measurements

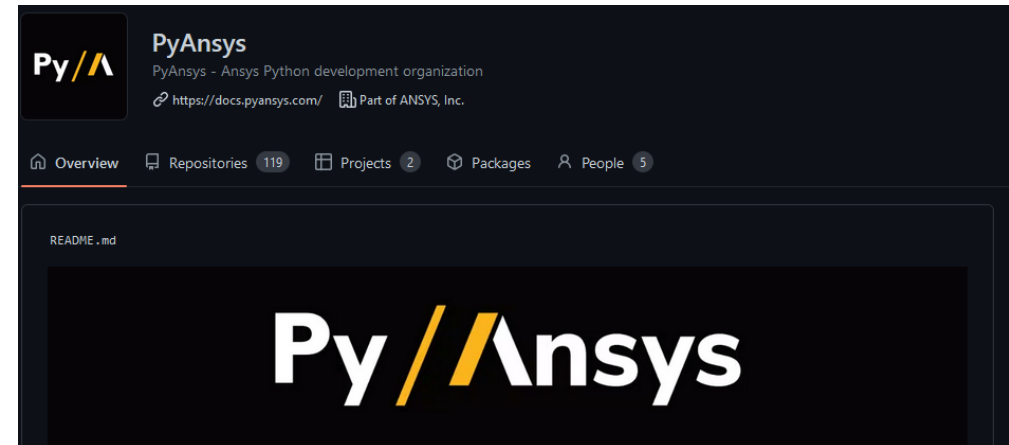


Heart modeling activities: **modeling layers**

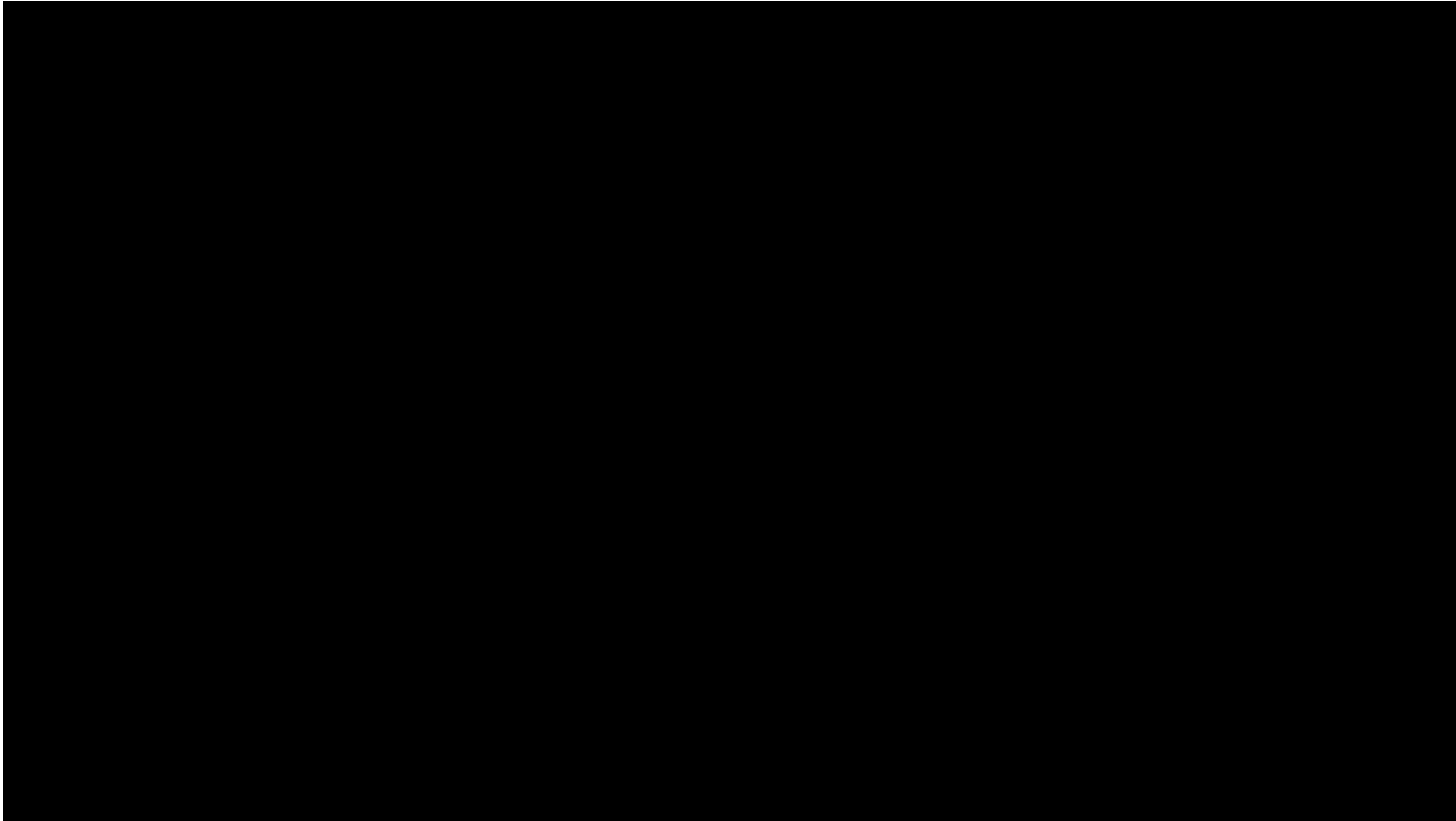


Python package development: motivation

- Effort for setting up simulation files
 - Substantial effort is needed to create and understand model input
 - Expert users only
- Data-availability
 - data to create heart models is not readily available to users
 - Use public databases
- Range of applications
 - Each requiring different levels of complexity
 - Geometry (left-ventricle, bi-ventricle, full heart, ...)
 - Physics (electrophysiology, mechanics, ...)
- To **facilitate adoption** of Ansys Solvers for heart simulations
- In line with PyAnsys initiative



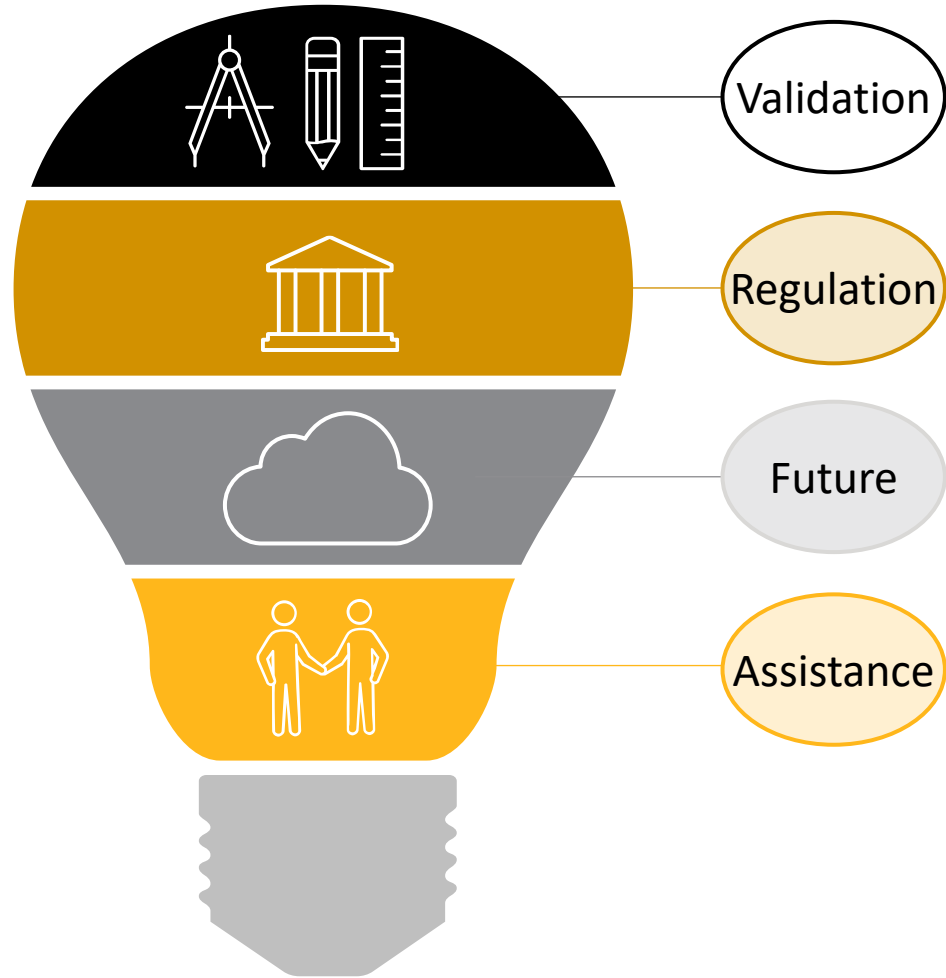
/ High-level structure of package



/ We Can Leverage In Silico Methods to Live Longer, Healthier!

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- The Ansys Heart Project
- **Joining forces to live longer, healthier**

Let's join forces to smoothly sail through this healthcare revolution



Computer models are widely used in healthcare; they are physically and clinically validated.

Regulators and policy makers are collaborating to encourage the pervasive adoption of in silico methods.

The Personal Digital Avatar is not a fantasy anymore but it is still a fantastic challenge.

Ansys will be working closely with you to help you succeed in this challenging journey.

Thank you for your time ...

So many things to say, so little time to discuss!

Let's stay connected

Prith Banerjee

Chief Technology Officer, ANSYS, Inc.

Prith.Banerjee@ansys.com

[in](https://www.linkedin.com/in/prith-banerjee/) : [in/prith-banerjee/](https://www.linkedin.com/in/prith-banerjee/)

[twitter](https://twitter.com/prithbanerjee) : [@prithbanerjee](https://twitter.com/prithbanerjee)



The Ansys logo is positioned on the left side of the slide. It features a yellow slanted bar to the left of the word "Ansys" in a bold, black, sans-serif font.

Ansys

