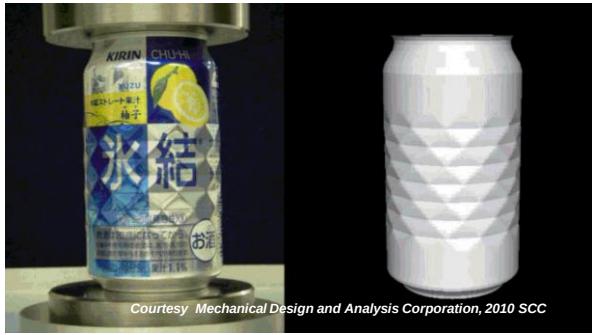
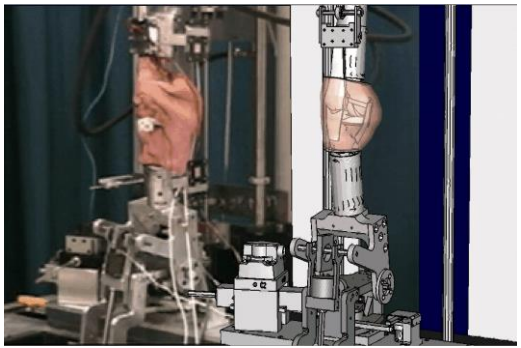
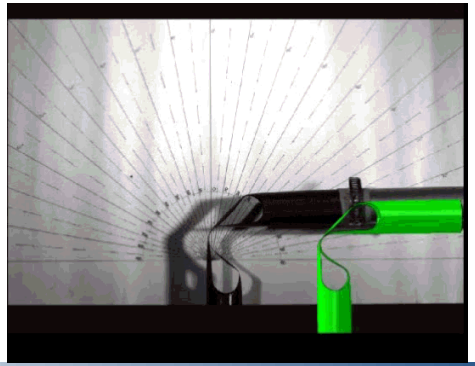
What is Realistic Simulation?

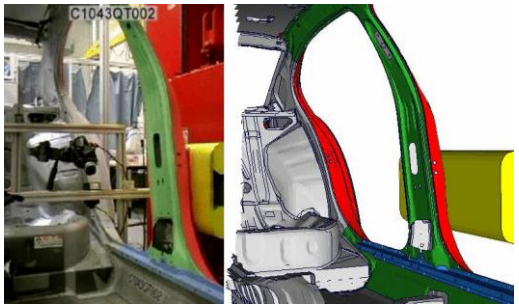
"Realistic Simulation" is a simulation that is physically realistic and "life like" in every way



Courtesy Mechanical Design and Analysis Corporation, 2010 SCC







Courtesy of BMW Group, 2010 SCC

What if doctors had access to the same incredible realistic simulation technology that others




have used for decades to virtually design, test, and validate products before they have been built…

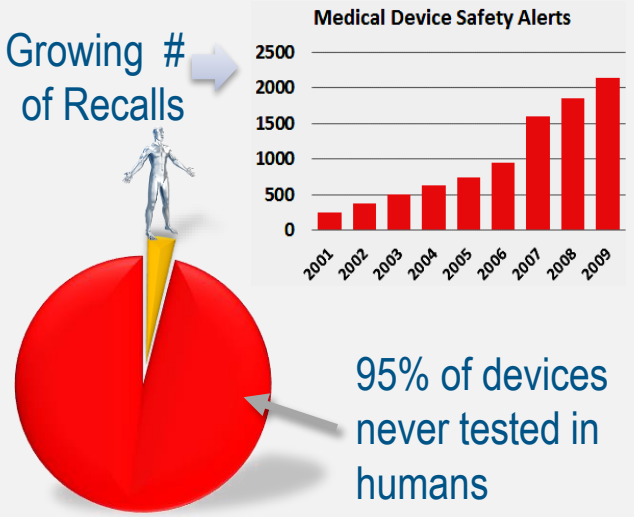

could they do this?

Why Simulate the Heart?

#1 Cause of Death

$445B = Cost of Cardiovascular Disease in US*

- Projected >$1 trillion by 2030
- **40%** **116 million people** will have some form of CVD



More then 2,000,000 CVD procedures WW per year

Heart Valve Procedure (2008, US)	Coronary Bypass (2008, US)	Cardiac Catheterization and Coronary Arteriography (2008, US)	Other Heart Procedure (2008, US)	Pacemaker / Cardioverter / Defibrillator Procedure (2008, US)
103K procedures	207K procedures	566K procedures	139K procedures	333K procedures
$162K per procedure	$117K per procedure	$34K per procedure	$99K per procedure	$82K per procedure

FDA cost to test all new devices in humans in > $3.2B

*American Heart Association

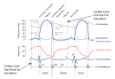
The Living Heart Project

Mission:

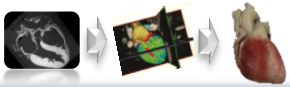
Advance the **development** of safe & effective cardiovascular products and treatments by **uniting** engineering, scientific, & biomedical experts to deliver validated models and **translate** simulation technology into improved patient care

Valuable insight into heart function and disease

Establish validated heart models to enable translation of research to practical tools and services.



Personalized clinical diagnostics, treatments & pre-surgical planning



Improved medical devices designs, speed approvals & lower cost

Project and Model Timeline

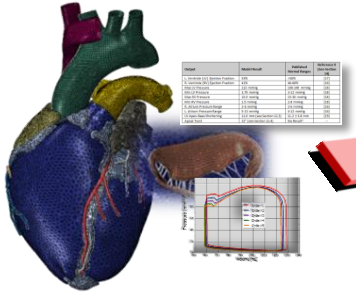
Human Heart CTE Model Proof of concept

- DS developed
- CTE activated
- Fung tissue model w/fiber
- Open loop blood flow

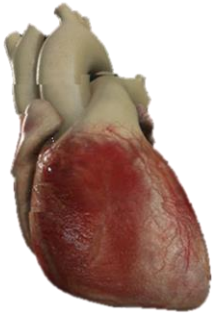
Electro-Mechanical Activation

- Crowdsourced development
- Holzapfel tissue model
- Monodomain electrical activation
- Closed loop blood flow

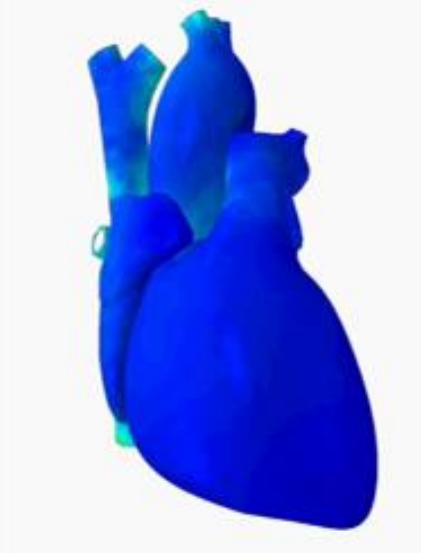
Electro-Mechanical Network Model

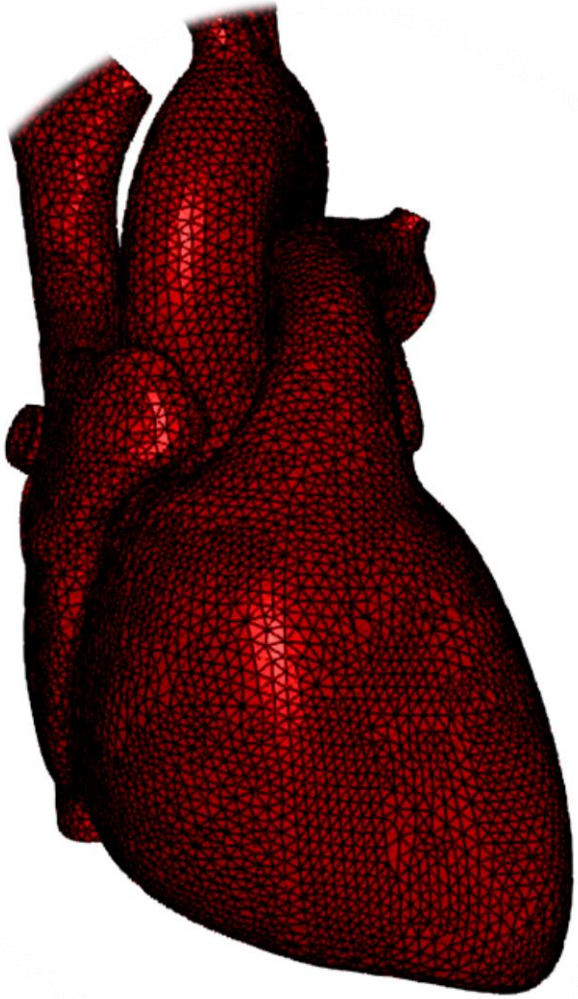


- Quantitative V&V
- Electrical network
- High fidelity geometry
- Enhanced blood flow

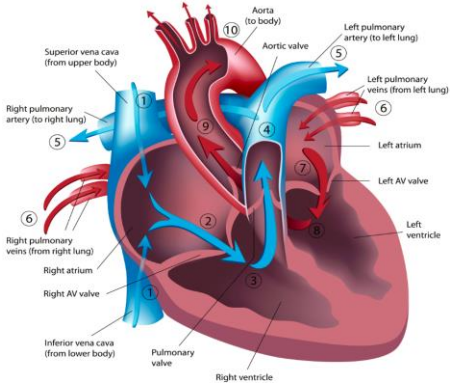


Application Based Rendering





Living Heart Model: Cardiac Physics

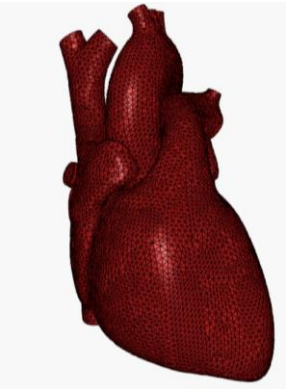


- **Fluid:** Pressure changes in heart chambers force blood through the heart and around the body
- **Structural:** Muscular contractions in heart muscle affect chamber volumes and pressures
- **Electrical:** Electrical stimuli cause muscle contractions

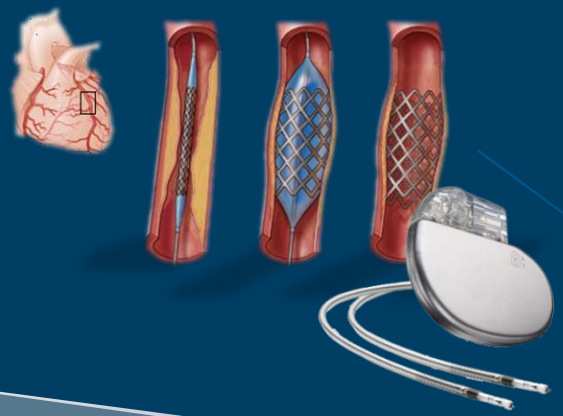
Included in Living Heart Model

- **Cellular/Ionic:** Ionic gradients (Na^+, K^+, Ca^{2+}) across cardiac muscle cells drive electrical impulses and generate force
- **Molecular:** Biochemical reactions and pathways that underpin behavior at higher scales

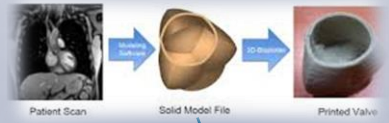
Can be explored with external tools



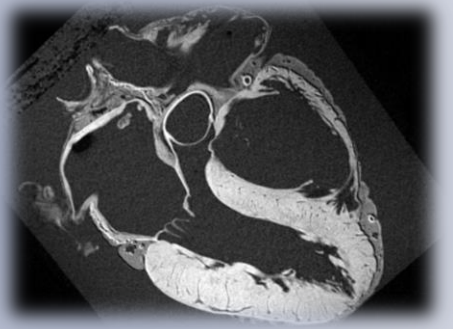
Medical Devices

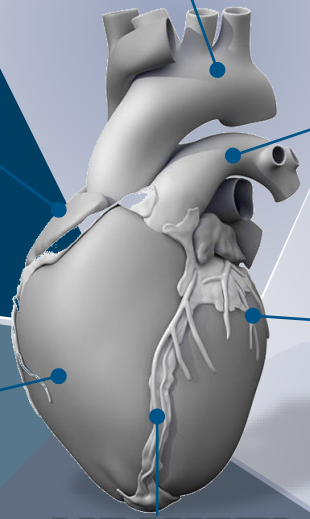


3DP printing

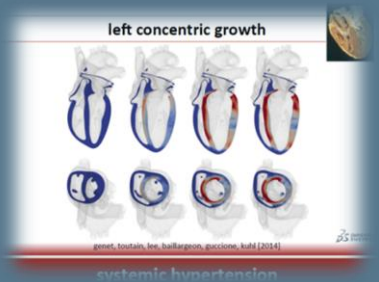


Medical Imaging Enhancement

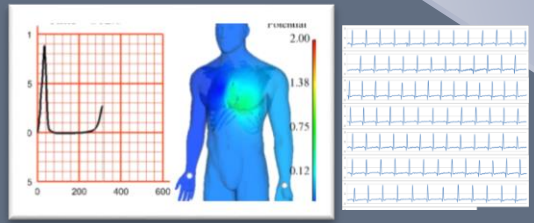




Heart Disease - diagnosis & treatments

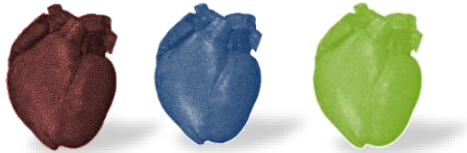


Data Analytics



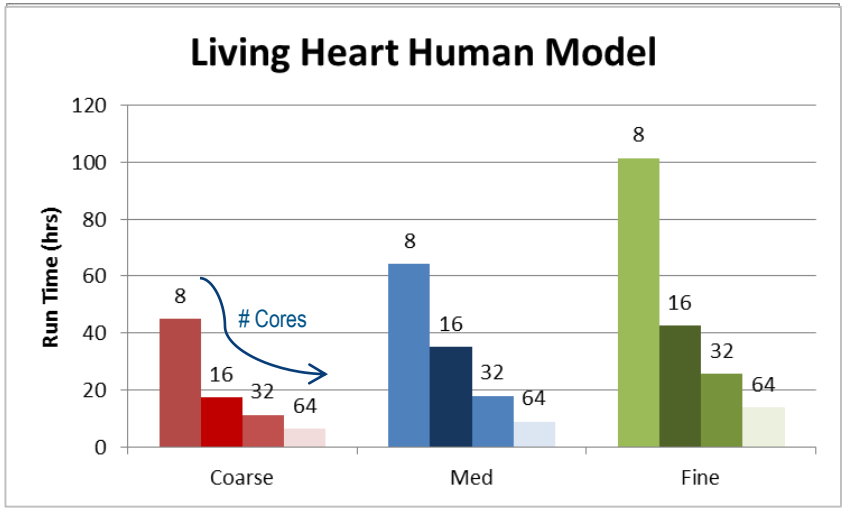
Drug safety and efficacy

Living Heart Model: Performance



Mechanical Simulation* (3 beat cycles)

Representation	Number of CPUs	Run Time [hrs.]
Coarse	8	45
	16	17
	32	11
	64	6
Medium	8	64
	16	35
	32	17
	64	8
Fine	8	101
	16	42
	32	25
	64	13



Hardware: Linux 64 cluster, containing Intel Xenon E5-2680 v2 (Ivy Bridge) chip sets, with a 10 Gb/s interconnect, each with 16 cores.

*Electrical simulation run times on 16 cores
Coarse:46 minutes, Medium: 64 minutes,
Fine: 105 minutes

Impact of Computer Simulation