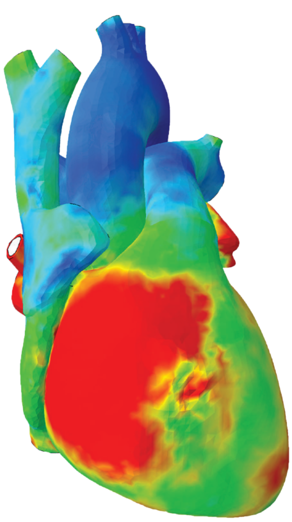
CASE STUDY

Advancing Heart Simulation to Save Lives

High-Performance Computing

Intel® Xeon® Processor E5-2600 v4 Product Family

With the Living Heart Project, Dassault Systèmes has brought together a multidisciplinary team of experts to collaborate on breakthrough technology for improved products and treatments for cardiovascular disease. The project's first output is the Living Heart Model (LHM), a realistic 3D computational model of the human heart. Team members Intel and MIT have worked with SIMULIA to advance the model, reduce compute time, and prepare the model to represent cardiovascular disease and explore treatment options or develop improved medical devices. In the future, further developments and clinical applications arising from the project may help clinicians decide on optimal treatment for individual patients.*



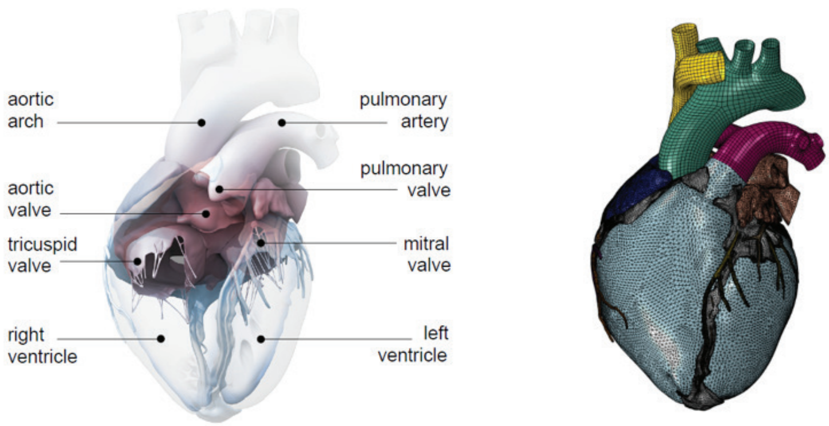
Computed stresses depicted on a 3D rendering of the Living Heart Model.

The Living Heart Project

Despite extensive research, cardiovascular disease remains the number one cause of death worldwide. Because knowledge about the cardiovascular system is spread widely across multiple domains of inquiry, it has been difficult to work with this body of knowledge as a whole. To address this challenge, the Living Heart Project has assembled a multidisciplinary team of experts from research, industry, clinical practice, and regulatory bodies, with the aim of providing a unifying framework to collect and synergize existing cardiovascular knowledge within a common technology platform. The project's first commercial output, the Living Heart Model (LHM), is an anatomically accurate electromechanical model of a complete adult human heart with dynamic behavior driven by physiological principles. By modifying model inputs and parameters, researchers can simulate cardiac diseases and devise effective treatments.

Intel, MIT, and the Living Heart Project: Dual-Resolution Approach

While the high-resolution LHM can capture heart behavior accurately, the underlying simulations involve high-density meshes and are computationally intensive, often requiring run times of hours or even days. In critical situations, this may be too slow, or simply impractical. For researchers, it hampers calibration of the complex LHM to represent specific heart disease states. To address this limitation, Dassault Systèmes has collaborated with team members MIT and Intel to develop a technique where a fast-running low-resolution heart model can be used to provide precise inputs to the longer-running high-resolution model. This dual-resolution approach dramatically reduces the total compute time required and allows easier calibration of the high-resolution model. Dr. Kumaran Kolandaivelu, Medical Director, IMES Clinical Research Center MIT, reports that using this approach, "time to achieve steady state response decreased from five beats to within a single beat, reducing computational resource time from 20 to four hours (on 24 cores)." The reduced run times are allowing rapid calibration of the model to study specific disease states.



Internal anatomy of the heart model (left) courtesy Zygote Media Group; Finite Element representation (right).

Development of the dual-resolution approach required large amounts of compute time on Intel's Endeavour cluster, a Top500 Supercomputing site with more than 12,000 cores. The use of Endeavour made hundreds of cores available for the many hours of time needed to complete LHM runs. Intel provided expertise in configuration of the cluster to complete the required runs efficiently and effectively.

"The Living Heart Project **extends the value of high-performance computing in the life sciences**, alongside research and therapies in areas such as genomics, pharmacology, and computational biology. Intel is committed to applying our computing innovation to **advance human knowledge** across scientific disciplines, and it's immensely satisfying when we see these efforts contribute to the greater human good."

– Ketan Paranjape | General Manager, Life Sciences and Analytics, Intel

Intel® Xeon® Processor E5 Family: A High-Performance Platform for SIMULIA

The SIMULIA suite of simulation software available on the **3D**EXPERIENCE* platform is used by the LHM to simulate the heart and major blood vessels. This model can accurately represent heart function, in terms of three-dimensional structure, electromechanics, and fluid dynamics.

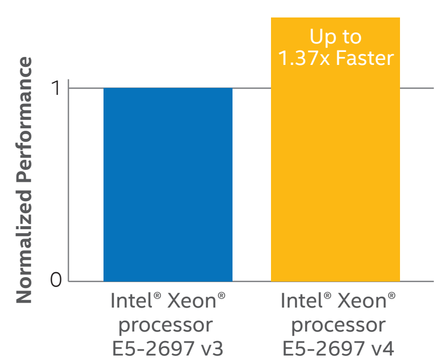
The Intel® Xeon® processor E5 family is the underlying compute engine powering the LHM. Intel has done extensive optimization work with SIMULIA on the underlying Abaqus* multiphysics simulation and finite element analysis software to achieve high levels of performance on Intel Xeon processors. Intel works to ensure scaling from desktop to cluster by focusing on the following areas:

- **Core-level optimization** ensures that individual software threads execute efficiently.
- **Node-level optimization** divides workloads effectively among execution cores.
- **Cluster-level optimization** tunes code to operate efficiently across multiple nodes.

The Intel® Xeon® processor E5-2600 v4 product family provides features and capabilities that dramatically improve compute performance for the Living Heart Project. These include support for DDR4 memory at speeds of up to 2400 MT/s, up to 55 MB of last-level cache, and up to 22 cores per socket. The solution also takes advantage of Intel® Advanced Vector Extensions 2.0, which doubles the number of floating-point operations per cycle compared to the first generation of the technology.

This architecture provides speedups on a variety of HPC and enterprise workloads, including Abaqus. The combination of the Intel Xeon processor E5-2600 v4 product family and SIMULIA Abaqus software has shown a speedup of approximately 1.37x compared to the previous generation of the hardware.[1] While the workload used to generate this particular result is not the LHM, it is one of the standard Abaqus benchmarks, and it illustrates the value of continuing hardware advances to this important work.

SIMULIA* Abaqus/Explicit* Performance Increase[1]



Increased performance with the Intel® Xeon® processor E5-2600 v4 product family.[1]

"Computational Engineering and Biology are two of the most compute-intensive domains bottlenecking businesses today. The **more than 35 percent performance improvements[1] we've seen with the Intel® Xeon® processor E5-2697 v4** can directly translate into better products and reduced time to market for our customers. Further, with the addition of **Intel® AVX2, we've seen an additional performance boost**.

In the future, performance improvements will be measured in number of lives saved."

– Steve Levine, PhD | Executive Director, The Living Heart Project

Computational models of the human heart enable robust 3D visualizations for use in clinical, educational, and research settings.

Clinical Applications of the Living Heart Project

Cardiac medicine has developed a host of interventions and other therapeutic approaches to respond to cardiovascular illness. However, complexity remains in determining what specific medical action to take for a given patient. The Living Heart Project seeks to help doctors make better decisions and to optimize patient outcomes.

The LHM is already being used to simulate heart disease and to study the effects of medical device implants under normal and extreme conditions. The project hopes to one day create a library of fully functioning disease models with genetic specificity for more improved diagnosis and targeted treatment planning. It can also be used in conjunction with other human body models to extend studies beyond the heart itself. The model will be enhanced by ongoing gains in compute capacity presented by Intel® architecture and the tighter integration of compute, memory, storage, fabric, and software offered by the Intel® Scalable System Framework. These improvements will reduce time to knowledge, coming closer to the ideal of real-time simulation.

Whereas non-surgical approaches available to cardiologists typically provide second-order, indirect evidence of the patient's condition, the Living Heart Project seeks to provide direct visualizations of the present state and future course of disease in an individual patient. These approaches are intended to be both less expensive and less invasive than surgical exploration.

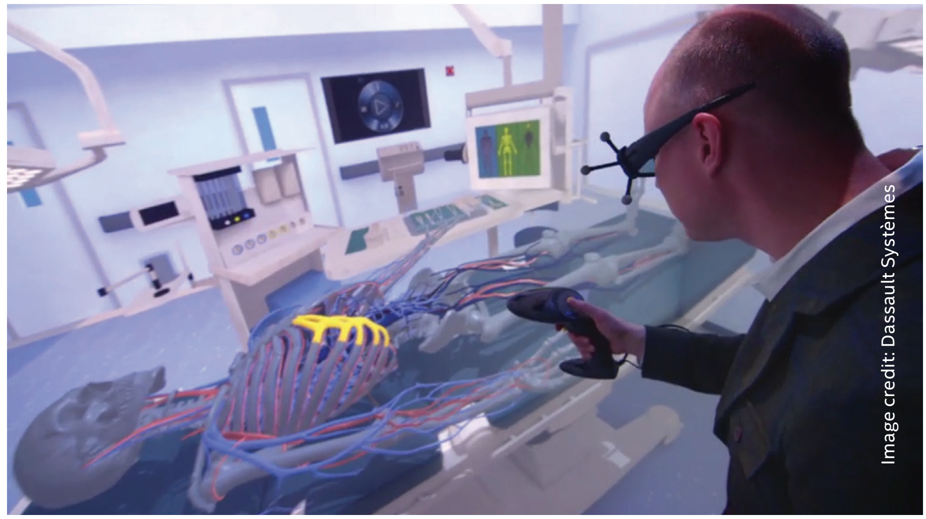
Dassault Systèmes has used its expertise in advanced visualization to develop immersive, interactive 3D virtual reality environments to demonstrate and interact with the LHM. One environment offers a representation of a patient's beating heart, which can be manipulated and studied. Another environment is a virtual operating room that visualizes an entire body. In the future, such virtual-reality tools will allow medical staff to investigate procedures on a simulated patient lying on the operating table, in real time.

Conclusion

The Living Heart Project is expanding the potential of cardiac medicine, with future-facing diagnostic and therapeutic capabilities. Continuing contributions from the project's many members serve to refine the model and increase its value. Ultimately, this work will save many lives.

Learn more about the Living Heart Project:
www.3ds.com/heart

Learn more about the Intel® Xeon® E5-2600 v4 product family:
www.intel.com/xeon



Virtual operating room, visualized using 3DEXCITE*.

[1] SIMULIA* Abaqus 2016.0: e5 benchmark (blast-loaded plate). Testing by Intel, 1/22/2016.
BASELINE: Intel® Xeon® processor E5-2697 v3 (35 M Cache, 2.60 GHz) Grantley-EP (Wellsburg), 128 GB total memory, 16 slots / 8 GB / 2133 MT/s / DDR4 RDIMM, Intel® Solid State Drive Data Center Family, turbo on, on Red Hat Enterprise Linux* 6.4 kernel 2.6.32-358, Request Number: 1979.
NEW: Intel® Xeon® processor E5-2697 v4 on Grantley-EP (Wellsburg), 64 GB total memory, 8 slots / 8 GB / 2400 MT/s / DDR4 RDIMM, Intel® Solid State Drive Data Center Family, turbo on, on Red Hat Enterprise Linux* 6.4 kernel 2.6.32-358, Request Number: 1979.

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