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► **To cite this version:**

Mark Potse. Modeling the heart cell by cell: the MICROCARD project. Cardiac Physiome meeting 2024, Sep 2024, Freiburg, Germany. hal-04713134

HAL Id: hal-04713134

<https://inria.hal.science/hal-04713134v1>

Submitted on 28 Sep 2024

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Modeling the heart cell by cell: the MICROCARD project

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Almost all cardiac arrhythmia are linked to fine-grained structural abnormalities in the cardiac tissue, but the numerical heart models that are used today cannot represent such abnormalities well because they work with elements that are far larger than a cell. The choice for such large elements has been well founded: computations with smaller elements or even individual cells were simply not feasible one or two decades ago. But the machines keep growing and with the arrival of exascale supercomputers (in the US in 2021 and in Europe in 2024) it becomes thinkable to simulate the electrophysiology of a whole heart, or a sizeable part of it, cell by cell.

The MICROCARD project was funded by the European Union (EU) to develop a cell-by-cell cardiac simulation code, as one of the flagship applications of the EU's new exascale supercomputers. This application comes with many mathematical and numerical challenges which we are tackling with a collaboration between computer scientists, biomedical engineers, mathematicians, and numerical scientists, working on the simulation software itself and on the construction of geometrical models ("meshes") of the myocardium with sub-cellular resolution.

Although neither the exascale machines nor our simulation software are ready to run at this time, the project has made much progress towards its goals, and many of its developments have also been made available in the widely-used OpenCARP simulation software. The recent decision to fund a second iteration of the MICROCARD project, which will run until 2027, gives us hope that we will see actual three-dimensional cell-by-cell simulations by next year.