Designing with Quantum-dot Cellular Automata (QCA):
A Revolutionary Technology for Ultra-dense Computers

Given the potential limitations facing CMOS, there has been an explosion of research into various nanoscale materials and properties. Most of this work has been done strictly with devices, with little attention given to circuits or architectures. At Notre Dame, we have taken a different route by considering the new system capabilities opened up by a new nanotechnology and how to leverage the past 40 years of design experience with silicon to achieve such capabilities. Working with the device physicists, we have influenced significantly the development of devices for one such nanotechnology, Quantum-dot Cellular Automata (QCA), to the point where we understand in detail the entire roadmap for bringing QCA into truly revolutionary systems much sooner than may be possible for other nanotechnologies.

QCA relies on arrays of basic cells, each of which has four quantum dots and two free electrons. By controlling tunneling between dots, a cell can take on two “polarizations” of electrons (one for a logical 0 and one for a 1). Multiple cells placed next to each other can transmit their polarization via Coulombic interaction. Besides “wire,” logic functions such as invertors and majority gates, can be constructed with potential densities of a few nanometers per device. Our explorations have developed schemes for clocking and increasing basic robustness from manufacturing defects, layout patterns that can maximize functional density, design tools for creating hierarchical designs, and complete systems that offer equivalent capabilities to conventional silicon designs, but orders of magnitude higher than the best that might be possible from end-of-the-road silicon.

Engineering Faculty: P. Kogge and C. Lent
Engineering Students: M. Niemier, S. Frost, T. Dysart, and A. Rodrigues
Funding Sources: SRC, NSF, and JPL