

Variability-Aware Software for Efficient Computing with Nanoscale Devices

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Project Summary

As semiconductor manufacturers build ever smaller components, circuits and chips at the nanoscale become less reliable and more expensive to produce – no longer behaving like precisely chiseled machines with tight tolerances. Modern computing is effectively ignorant of the variability in behavior of underlying system components from device to device, their wear-out over time, or the environment in which the computing system is placed. This makes them expensive, fragile and vulnerable to even the smallest changes in the environment or component failures.

We envision a computing world where system components – led by proactive software – routinely monitor, predict and adapt to the variability of manufactured systems. Changing the way software interacts with hardware offers the best hope for perpetuating the fundamental gains in computing performance at lower cost of the past 40 years. The *Variability Expedition* fundamentally rethinks the rigid, deterministic hardware-software interface, to propose a new class of computing machines that are not only adaptive but also highly energy efficient. These machines will be able to discover the nature and extent of variation in hardware, develop abstractions to capture these variations, and drive adaptations in the software stack from compilers, runtime to applications. The resulting computer systems will work and continue working while using components that vary in performance or grow less reliable over time and across technology generations. A fluid software-hardware interface will thus mitigate the variability of manufactured systems and make machines robust, reliable and responsive to the changing operating conditions.

The *Variability Expedition* marshals the resources of researchers at the California Institute for Telecommunications and Information Technology (Calit2) at UC San Diego and UC Irvine, as well as UCLA, University of Michigan, Stanford and University of Illinois at Urbana-Champaign. With expertise in process technology, architecture, and design tools on the hardware side, and in operating systems, compilers and languages on the software side, the team also has the system implementation and applications expertise needed to drive and evaluate the research as well as transition the research accomplishments into practice via application drivers in wireless sensing, software radio and mobile platforms.

A successful Expedition will dramatically change the computing landscape. By re-architecting software to work in a world where monitoring and adaptation are the norm, it will achieve more robust, efficient and affordable systems that are able to predict and withstand not only hardware

failures, but other kinds of software bugs or even attacks. The new paradigm will apply across the entire spectrum of embedded, mobile, desktop and server-class computing machines, yielding particular gains in sensor information processing, multimedia rendering, software radios, search, medical imaging and other important applications.

Transforming the relationship between hardware and software presents valuable opportunities to integrate research and education, and this Expedition will build on established collaborations with educator-partners in formal and informal arenas to promote interdisciplinary teaching, training, learning and research. The team has built strong industrial and community outreach ties to ensure success and reach out to high-school students through a combination of tutoring and summer school programs. The *Variability Expedition* will engage undergraduate and graduate students in software, hardware and systems research to promote the concepts around *physically-aware computing systems* that are in constant touch with their environment and produce behaviors that take into account their changing conditions.

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