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New Computing Devices and the Drive toward Nanometer-scale Manufacturing

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In recent decades, we have become used to the idea of exponentially compounding improvements in manufacturing precision. These improvements are driven in large part by the economic imperative to continuously shrink the devices of information technology, particularly the Complementary Metal Oxide Semiconductor (CMOS) field-effect transistor. However, CMOS technology is clearly approaching some important physical limits. Since roughly 2003, the inability to reduce supply voltages according to constant-field scaling rules, combined with economic constraints on areal power density and total power, has forced designers to limit clock frequencies even as devices have continued to shrink. New channel materials, new device structures, and novel circuits cannot fundamentally alter this new status quo. The device physics must change in a more fundamental way if we are to realize fast digital logic with very low power dissipation. The continued vitality of the information technology revolution and the continued push of manufacturing precision toward nanometer dimensions, will depend on it. Fortunately, there is no shortage of new digital switch concepts based on physical principles which avoid the fundamental voltage-scaling limit of the field-effect transistor. The Nanoelectronics Research Initiative (NRI) is a consortium of leading semiconductor companies established in 2005 to guide and fund fundamental research at U.S. universities with the goal of finding the "next switch" to replace the CMOS transistor for storing and manipulating digital information. The National Institute of Standards and Technology (NIST) and the National Science Foundation (NSF) have partnered with NRI to fund this research. To date, NRI has funded the exploration of many novel device concepts, and has guided research comparing the capabilities of these devices. Although no single device has yet emerged as a clear winner with the potential to eclipse the field-effect transistor, results are sufficiently promising that member companies have recently renewed their commitment to NRI. Based on the learning to date, a vision for the next five years of research has emerged.