Modern engineering relies heavily on abstraction and modularity to facilitate the design of complex yet robust, high-performance systems. A coder can initialize variables in any programming language without worrying where the physical entropy goes, and semiconductor companies can develop new components and trust that they will be adopted by circuit designers who have no time to learn about their inner workings. Virtualization and cloud services make even the notion of a computer abstract, and when we stream video to our phones over the internet, information is translated seamlessly among myriad signal formats and disparate physical media en route from a file server to our eyes and ears.

While abstractions generally facilitate hierarchical design, as well as innovation within isolated layers of the protocol stack, an unwillingness to abandon familiar “old” abstractions may severely hinder vertically-crosscutting paradigm shifts by fixing design elements that are unnatural for revolutionary new paradigms. If we cling to archaic abstractions inappropriately they may induce excessive apparent inefficiencies in our explorations of new architectures, and thus send us down the wrong roads in engineering research. A potential example of this unfortunate dynamic may be emerging in the context of quantum computing, in which the community’s current focus on qubits and error correcting codes may be severely misplaced since classical binary logic relies implicitly on the ideal amplifier abstraction, which we know is unphysical in the quantum regime. One *can* (if one insists) adopt a “logical qubit” abstraction in quantum architecture design, but this particular abstraction seems to be unnatural for the underlying hardware and thus very costly to enforce. This may be an underlying cause of the very high redundancy ratios (1000 physical qubits per logical qubit) that seem to be required for large-scale quantum computation with realistic low-level error rates.

A fixed set of inter-layer abstractions in a protocol stack defines an engineering paradigm that promotes efficient incremental refinement of systems and devices, but revolutionary co-design may require the invention of radical new abstractions. At present we lack any broad theory or methodology that addresses the need for such rethinking of an entire design frame (set of abstractions in a stack). Is there a robust, portable, and efficiently-enforceable abstraction for a unit of secure information? Can we formulate new protocol stacks that enable network applications to promptly predict the energy cost of distributed operations? When we discover new materials with unprecedented properties of a functional but unconventional nature, can we systematically analyze a range of signal formats, input-output behaviors, and associated composition (circuit) rules that devices based on them would support?

Cutting through protocols and abstractions lies at the heart of co-design and represents a fundamental new intellectual challenge for engineering. While pursuing timely case-studies in co-design, our Institute will scrutinize meta-issues related to the breaking of old abstractions and formulation of new ones. The lessons learned will seed the development of core methodology for co-design, helping to turn it into a new engineering science for the postmodern era.