Civil infrastructure systems, e.g. transportation networks, pipe networks, electrical grids, structures, and building environments, are typically managed and controlled with outdated, inefficient, and minimally automated legacy controllers. This is apparent from costly oil pipe-line leaks, electrical outages, bridge collapses, and power plant failures. The relatively recent advents of small inexpensive microcontrollers and low-power wireless networking technologies reveals opportunities for managing and improving the operational effectiveness of aging and new civil infrastructure systems. Academic research in this field is maturing, yet the field is in its nascent years of commercial viability, which focuses mainly on low data-rate sensing with centralized processing. Little focus has been on distributed wireless control systems for civil infrastructure, largely due to limitations of current hardware that has limited speed and scalability.

This dissertation follows the development and utilization of a new cyber-physical system architecture for controlling civil infrastructure. Cyber-side data, communication, and computation are connected with physics-side plant dynamics, disturbances, and actuation through the novel dual-core wireless controller node, the Martlet, designed here-in. Once realized, the Martlet enabled the latter half of this dissertation presenting a distributed model predictive controller for hybrid-dynamical systems motivated by hydronic cooling systems. Insight is provided on different nonlinear system models, cost functions, and agent-based control architectures, and their effectiveness when implemented on a network of Martlets. The goals of these control architectures are to achieve satisfactory plant performance compared to traditional centralized control, while leveraging the Martlet’s communication and computation capabilities to create a rapidly deployable ‘smart’ control system robust to cascading cyber-physical failures. These developments in wirelessly distributed control of complex systems are presented not only with the tested hydronic systems in mind, but to be extendable to improve the performance and reliability of a wide variety of controlled cyber-physical civil infrastructure systems.