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The Life-Changing Magic of Nonlinearity in Network Control

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The proper functioning and reliability of many man-made and natural systems is fundamentally tied to our ability to control them. Indeed, applications as diverse as ecosystem management, emergency response and cell reprogramming all, at their heart, require us to drive a system to—or keep it in—a desired state. This process is complicated by the nonlinear dynamics inherent to most real systems, which has traditionally been viewed as the principle obstacle to their control. In this talk, I will discuss two ways in which nonlinearity turns this view on its head, in fact representing an asset to the control of complex systems. First, I will show how nonlinearity in the form of multistability allows one to systematically design control interventions that can deliberately induce "reverse cascading failures", in which a network spontaneously evolves to a desirable (rather than a failed) state. Second, I will show that nonlinearity in the form of time-varying dynamics unexpectedly makes temporal networks easier to control than their static counterparts, with the former enjoying dramatic and simultaneous reductions in all costs of control. This is true despite the fact that temporality tends to fragment a network's structure, disrupting the paths that allow the directly-controlled or "driver" nodes to communicate with the rest of the network. Taken together, these studies shed new light on the crucial role of nonlinearity in network control, and provide support to the idea we can control nonlinearity, rather than letting nonlinearity control us.