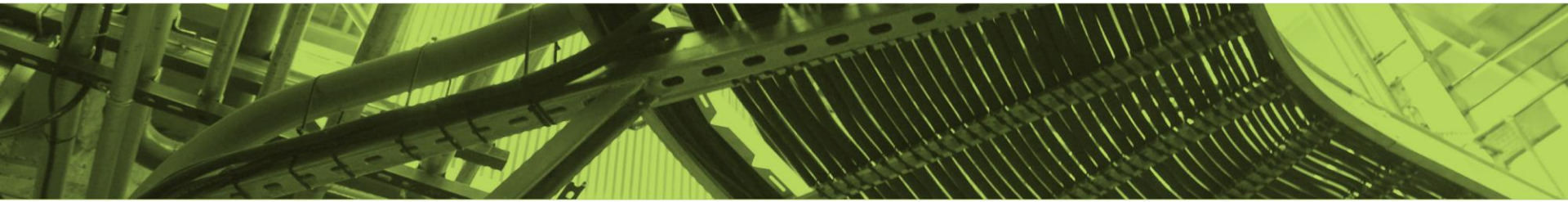
To Distribute or to Centralize: Architectures for Control of Power Systems



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Holger Kley | 22 May 2017

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Outline

- The Smart Grid Paradigm
- Architecture
- Hierarchical Control
- Distributable Control
- Industry Drivers
- A few examples

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Smart Grid

- More sensing/Better sensing
  - AMI
  - IEDs including PMUs
  - Inverter-based sources
  - Behind-the-meter devices
- More controllable resources: DER!
- Better communication
  - Fiber-based networks
  - Radio networks
  - Internet
- Greater computing power

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The Promise of Smart Grid

Rich data, distributed via modern communications, processed on powerful computers to control a rapidly growing portfolio or resources will lead to

- Improved power quality
- Improved load factor
- Improved reliability
- Decarbonization of supply

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Architecture

Software engineering concept. From Wikipedia's entry:

> "**Software architecture** refers to the high level structures of a software system [...] These structures are needed to reason about the software system. Each structure comprises software elements, relations among them, and properties of both elements and relations. [...] Software architecture is about making fundamental structural choices which are costly to change once implemented."

Modern controls are implemented in software, hence architecture for controls

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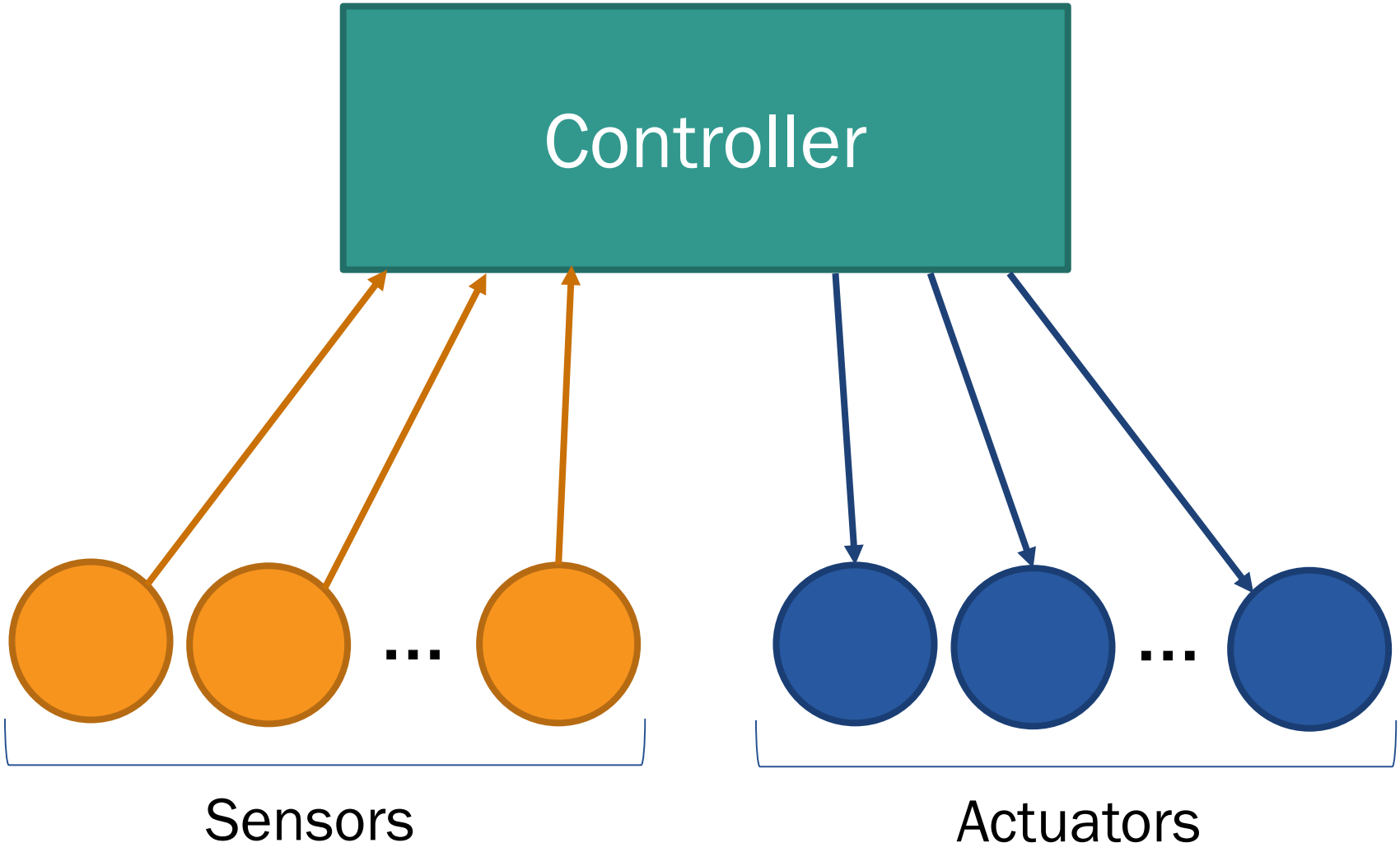
Central Control



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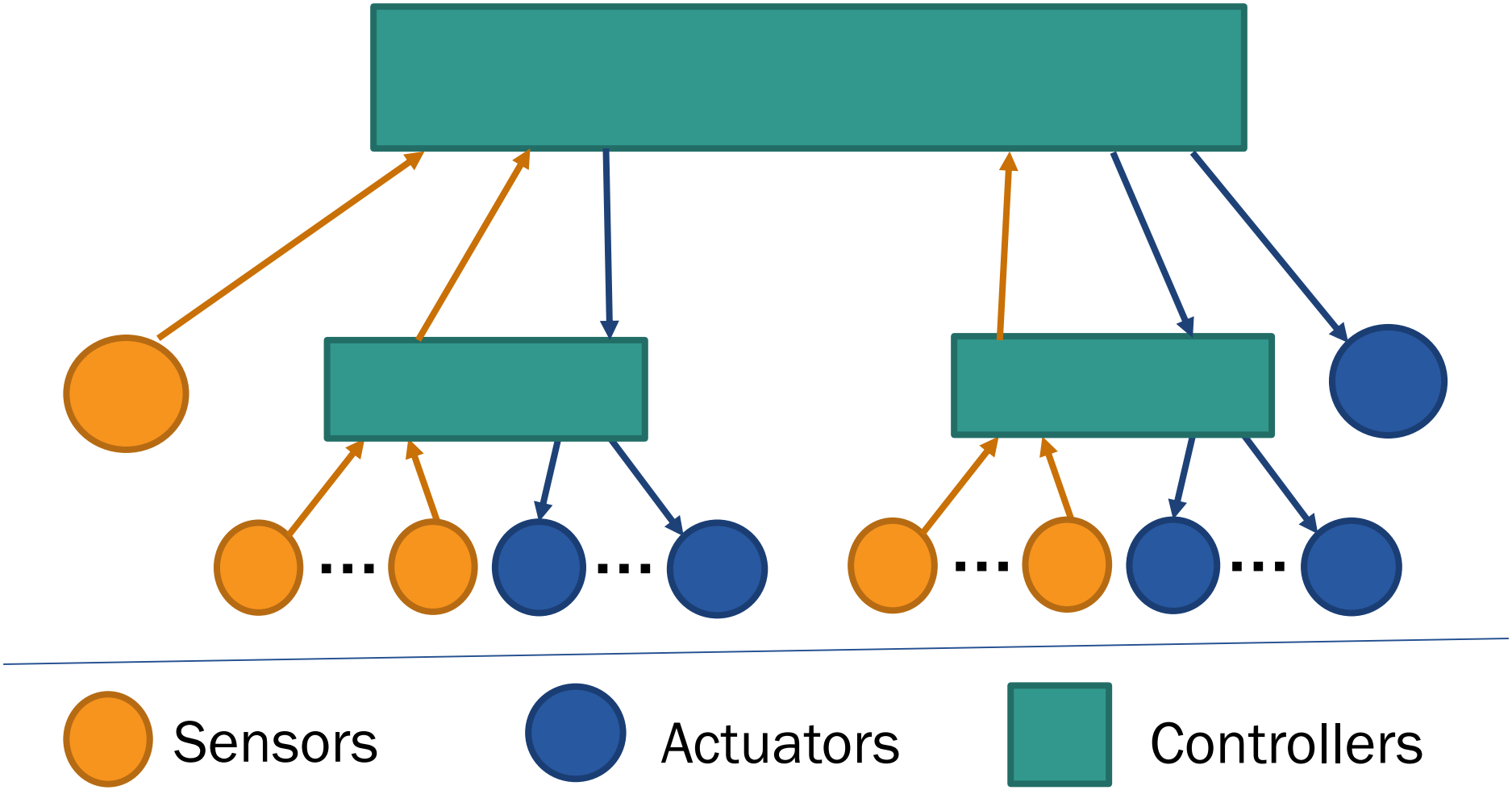
Hierarchical Control



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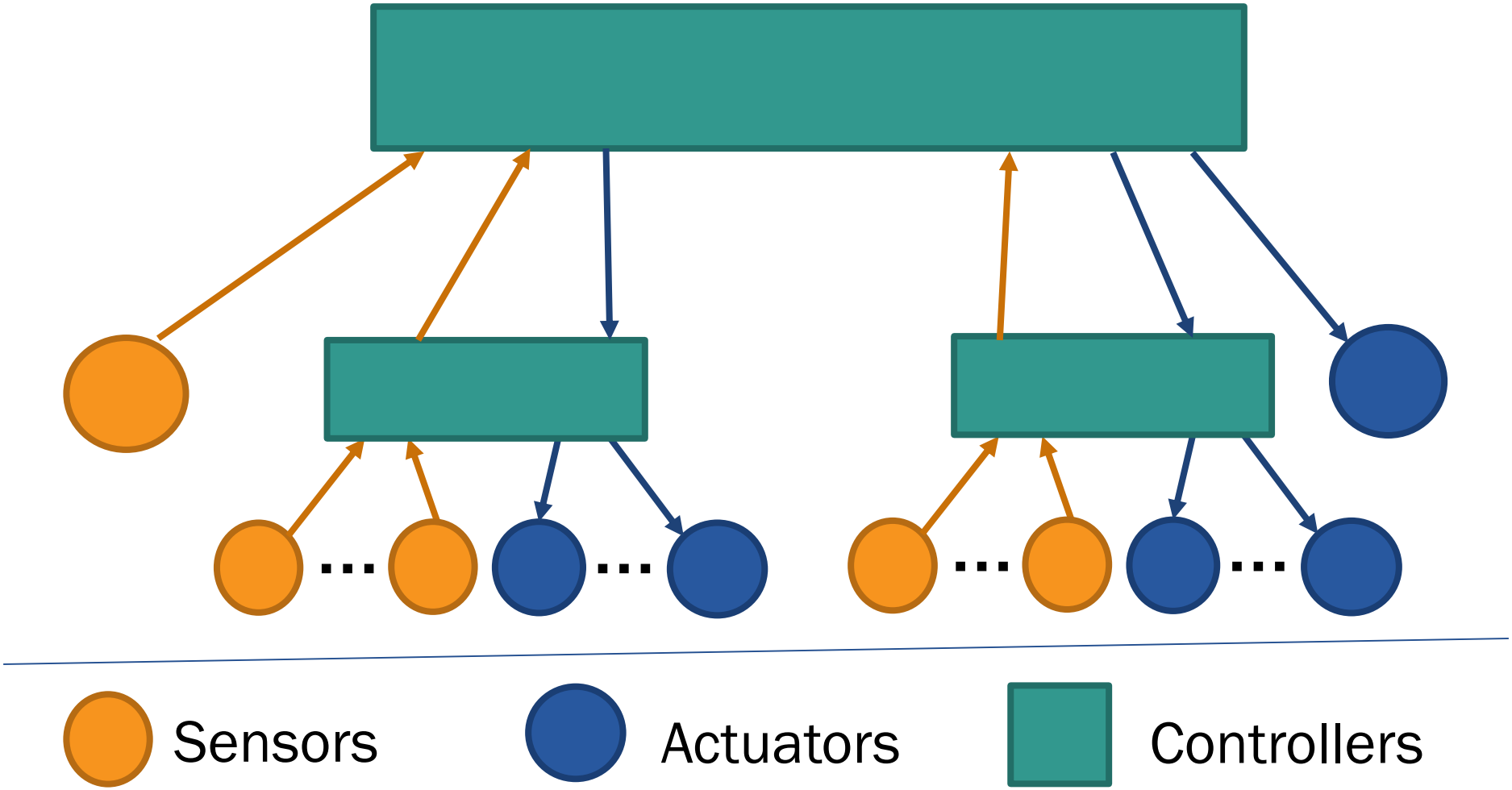
Is Hierarchical Control Central?



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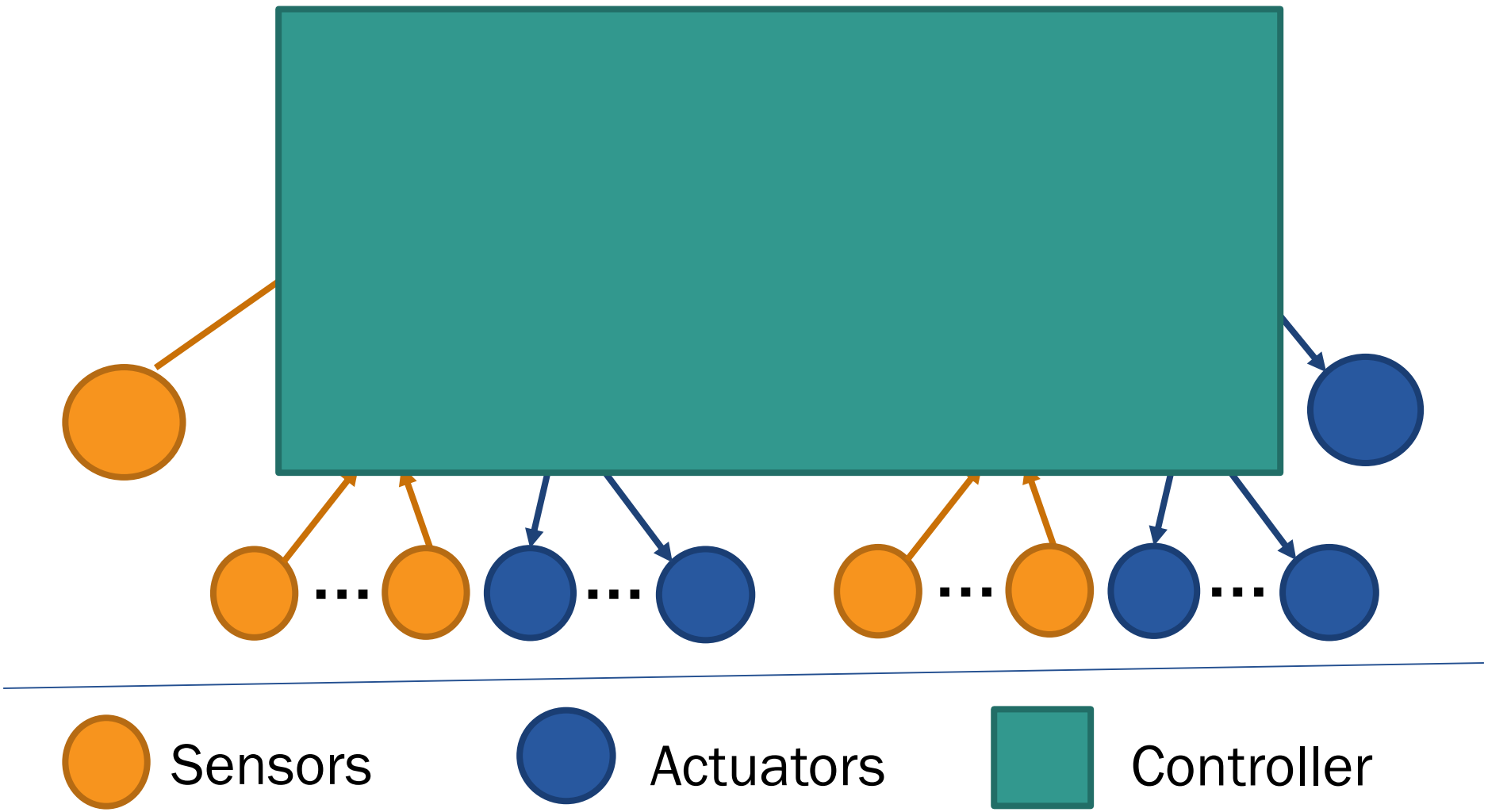

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The Reality of Smart Grid

- All data are not available everywhere -- or even at a central node -- at all times.
  - Communication bottlenecks
  - Communication failure
  - Data ownership may restrict access

- All available data are not processed instantly everywhere or at a central node
  - Problems of scale
  - Problems of complexity/non-linearity

- Commands may not be actuated at will
  - Bandwidth
  - Actuator ownership may restrict access

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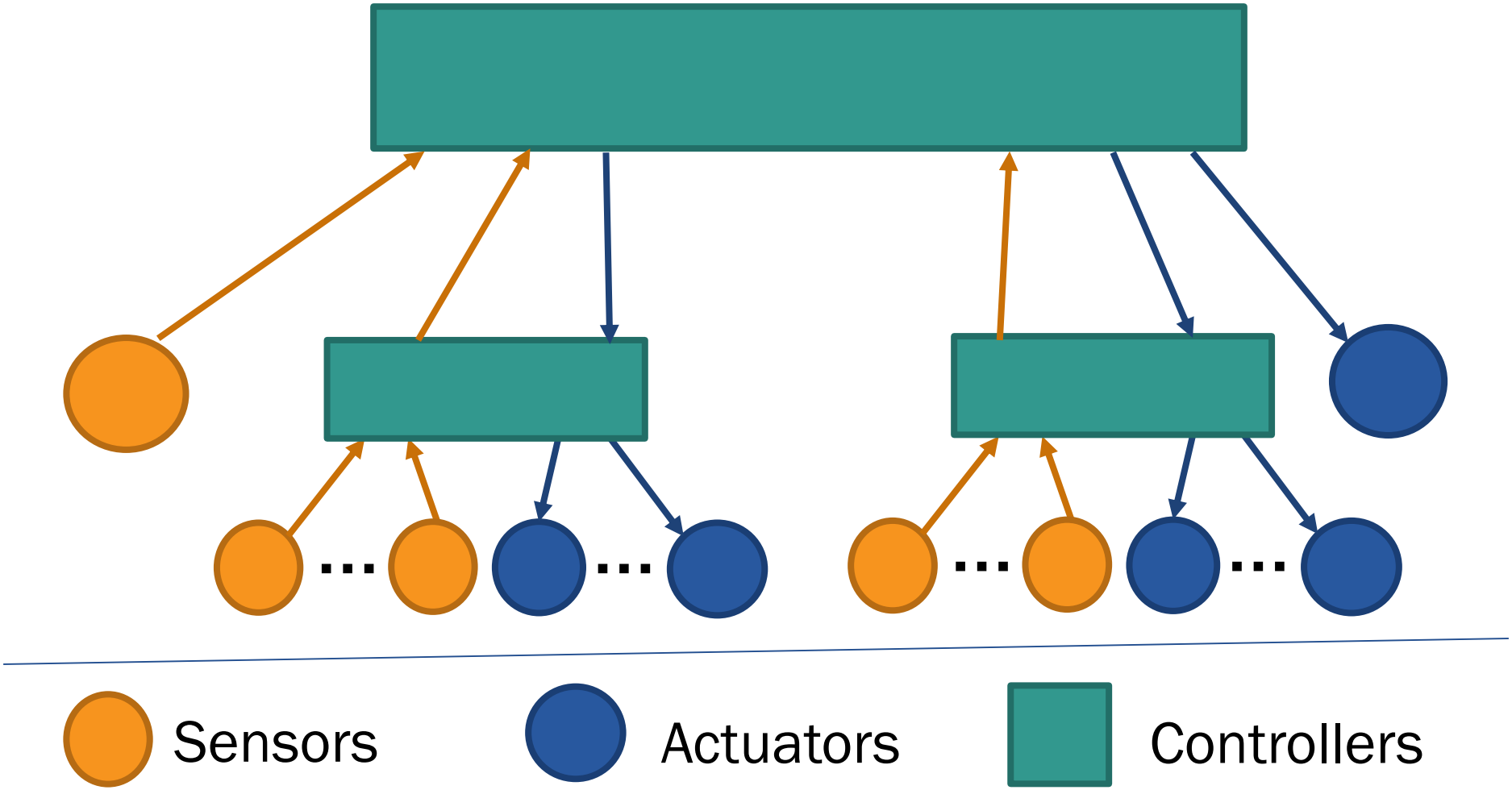
Distributing Hierarchical Control



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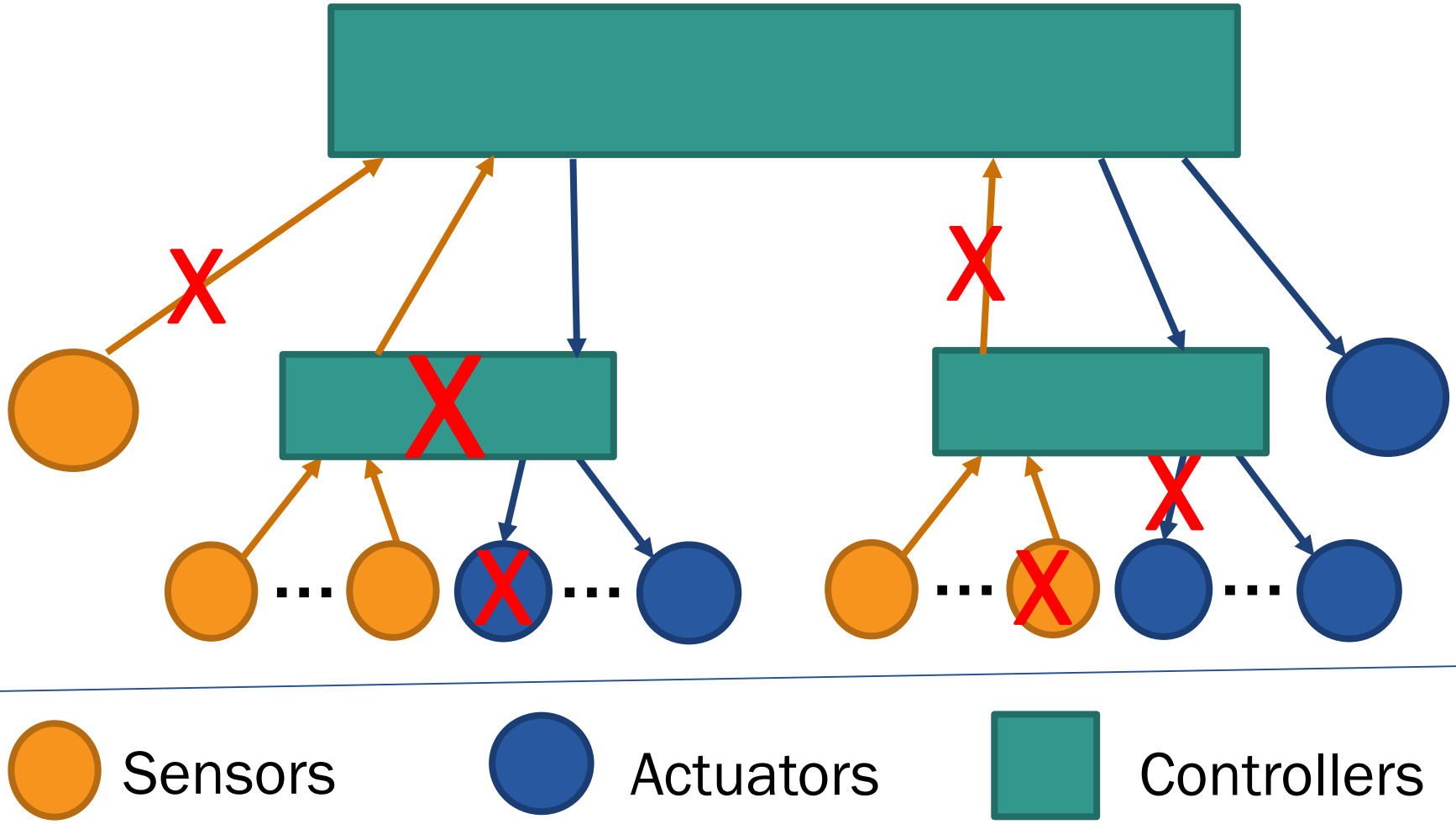
Distributing Hierarchical Control: Resiliency



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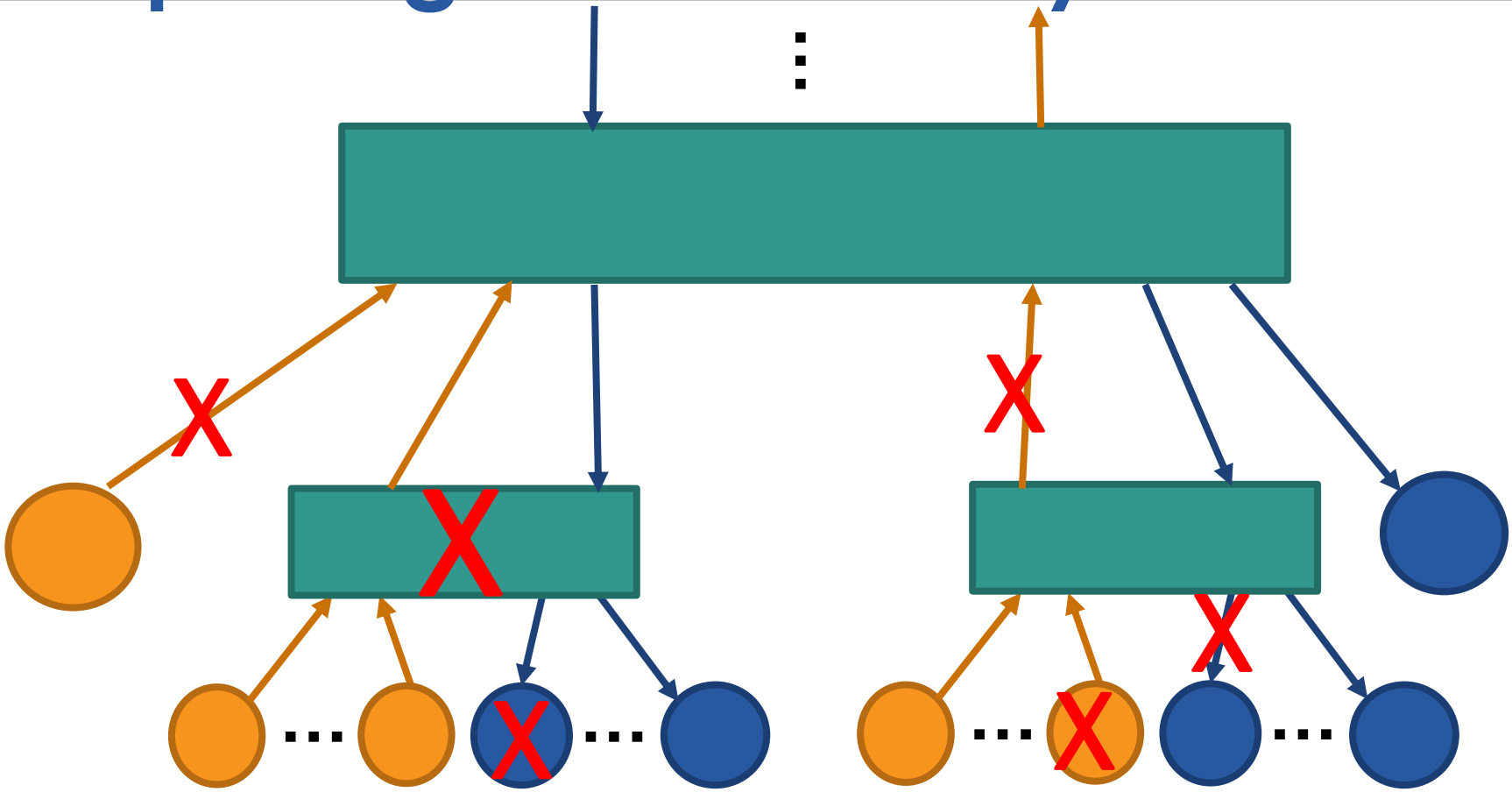
Distributing Hierarchical Control: Deepening the Hierarchy



Sensors Actuators Controllers

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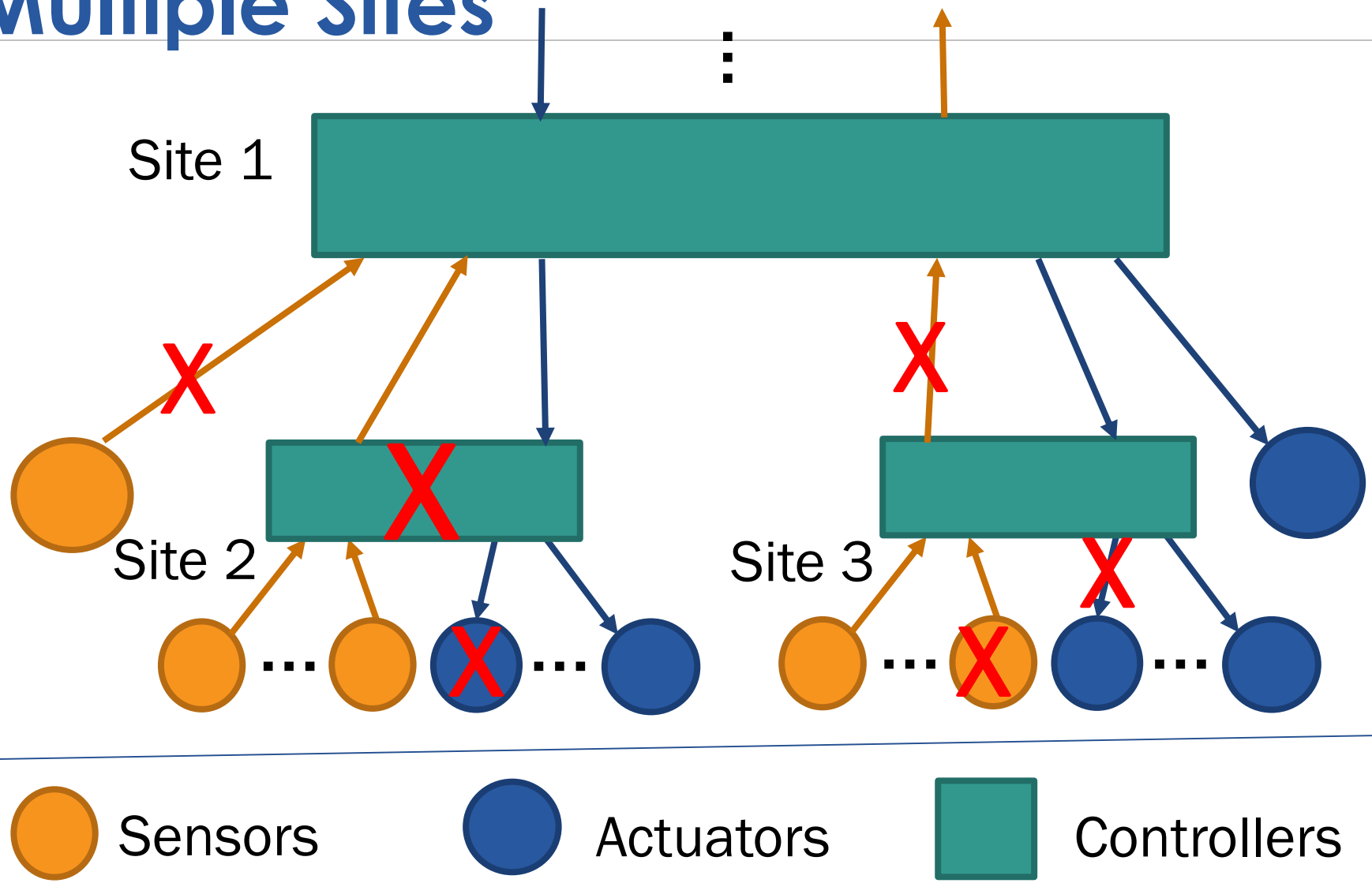
Distributing Hierarchical Control: Multiple Sites



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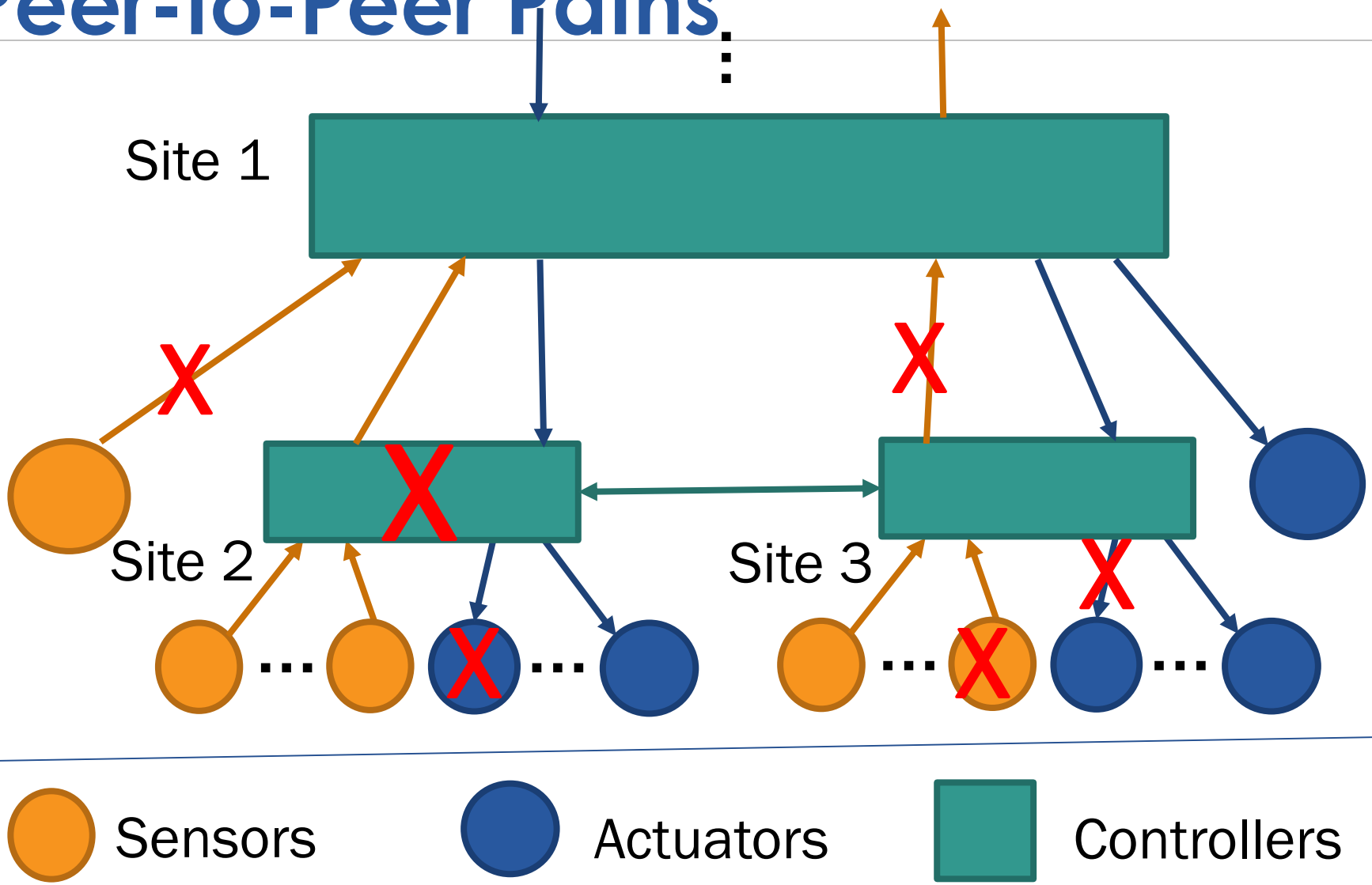
Distributing Hierarchical Control: Peer-to-Peer Paths



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Industry Perspective

Productize!

- Apply solutions widely
  - Multiple scales
  - Dynamic resource mix
  - Reduce custom engineering
  - Reusable components/modules

- Constrain solution costs
  - Limit hardware costs
  - Limit network costs
  - Reduce engineering services for deployment and maintenance

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Distributable Control

- Hierarchical controls that can be deployed to sites and devices
  - Work with “just enough” information
    - Incomplete models
  - Robust with regard to delayed or unavailable information
    - Embrace stochastic of data
  - Conscious of network latency and bandwidth requirements
  - Move away from setpoints
    - Stochastic control

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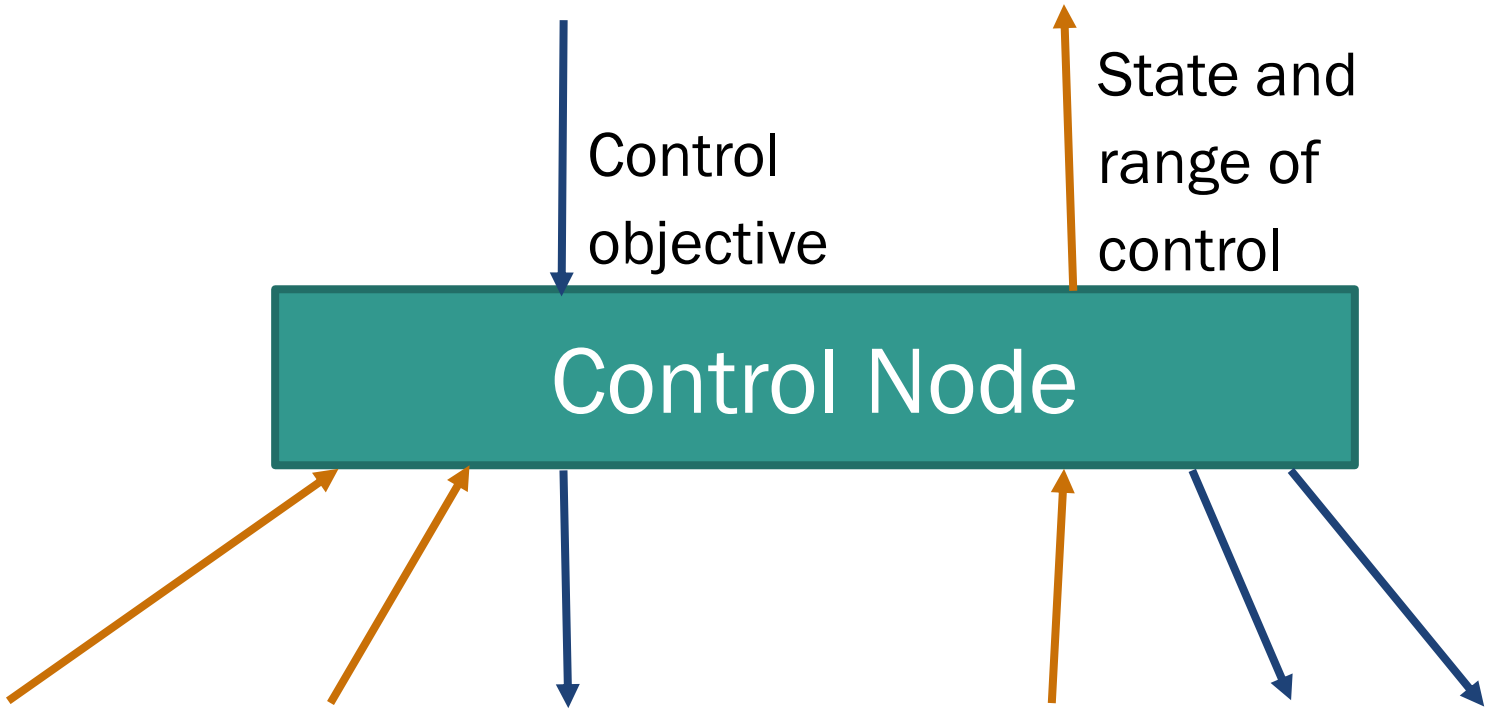
Nodal Model



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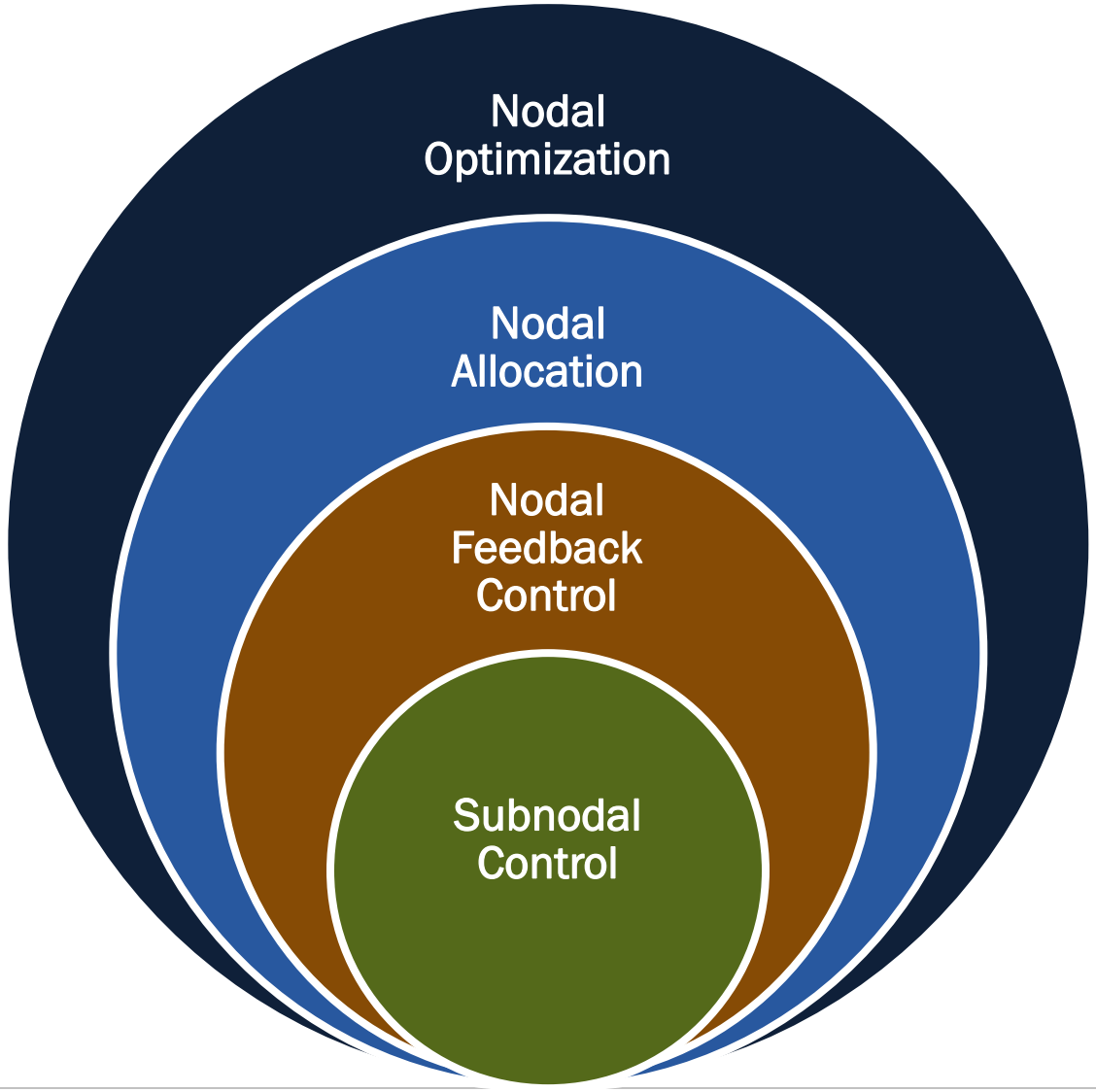
Nodal Control



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Examples

- Traditional frequency control
- Under-frequency load shedding/over-frequency generation shedding
  - Compute and distribute trigger levels and timers infrequently
  - Local frequency sensing for trigger/restoration
- Voltage and frequency stability during distribution island transition

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Thank You for Your Attention

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