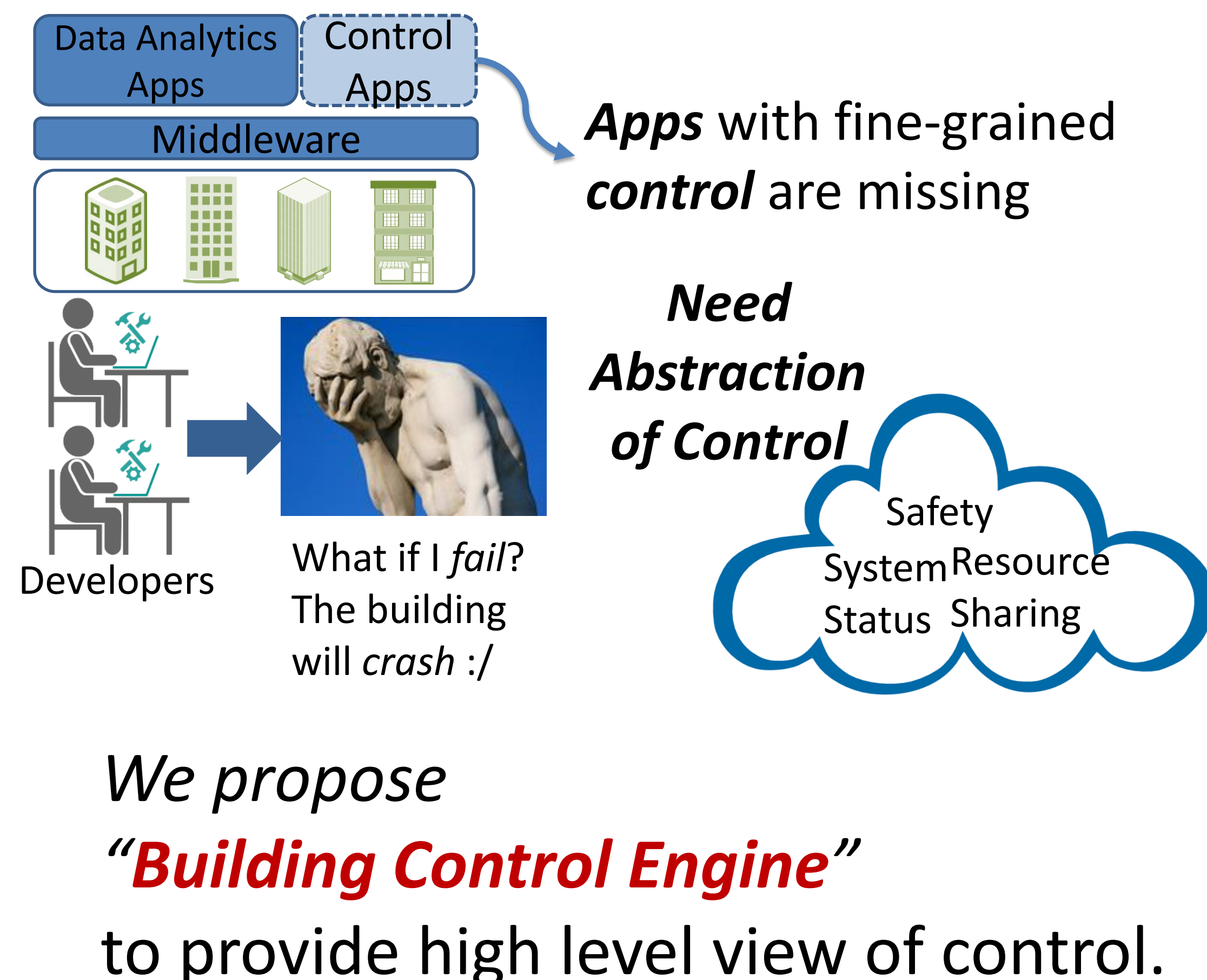


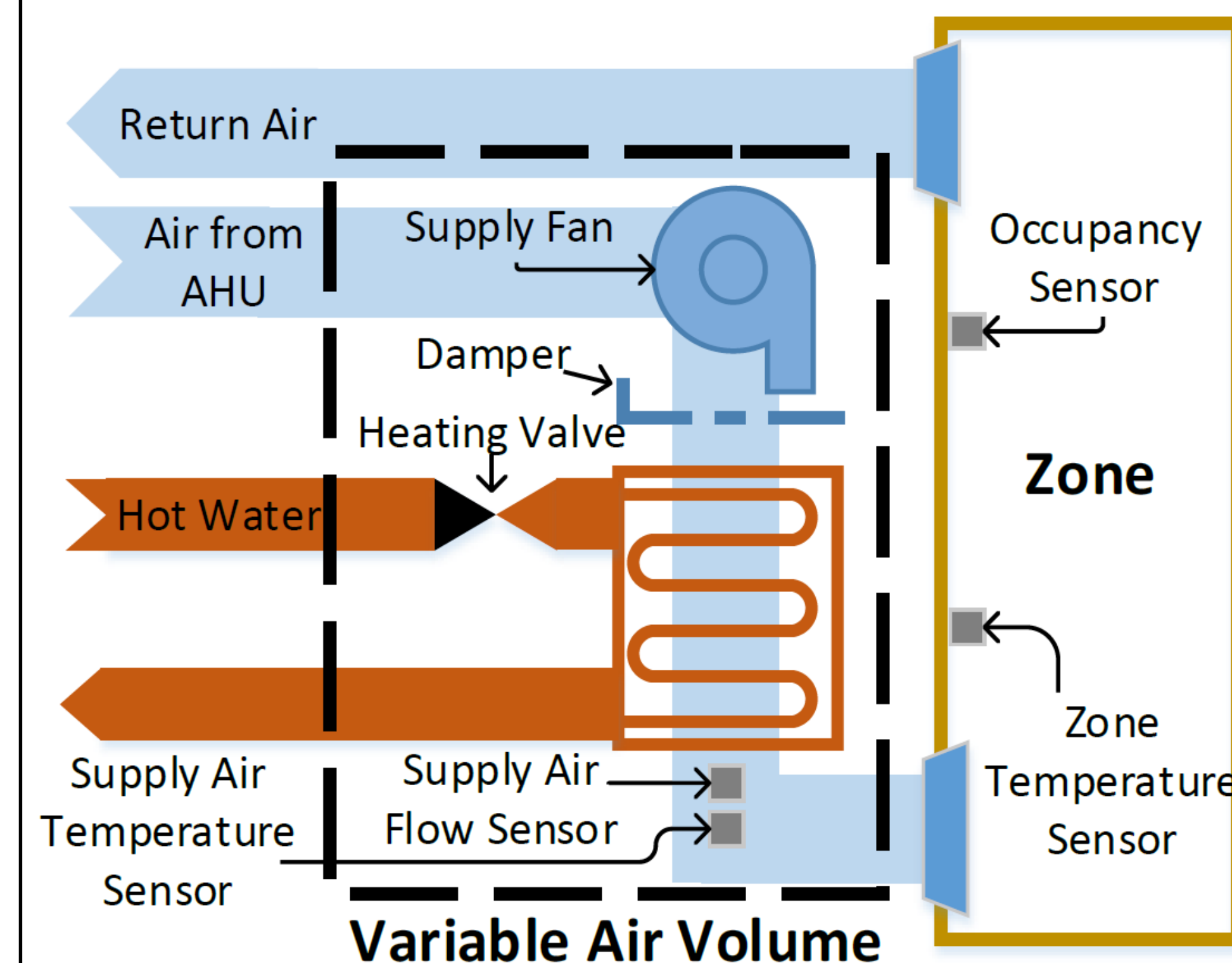
Controlling Actuation in Central HVAC Systems in Buildings

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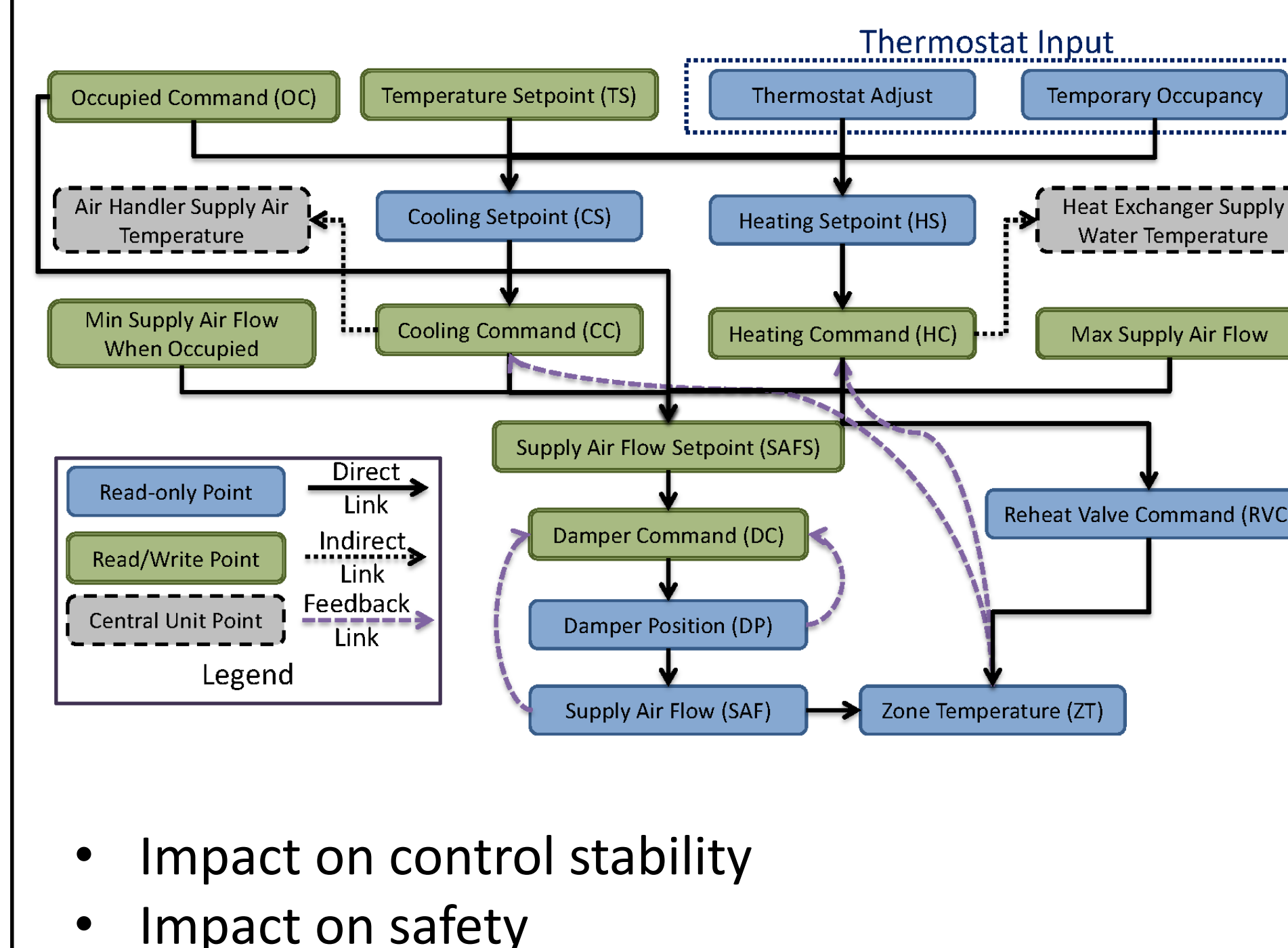
Need for Control Platform



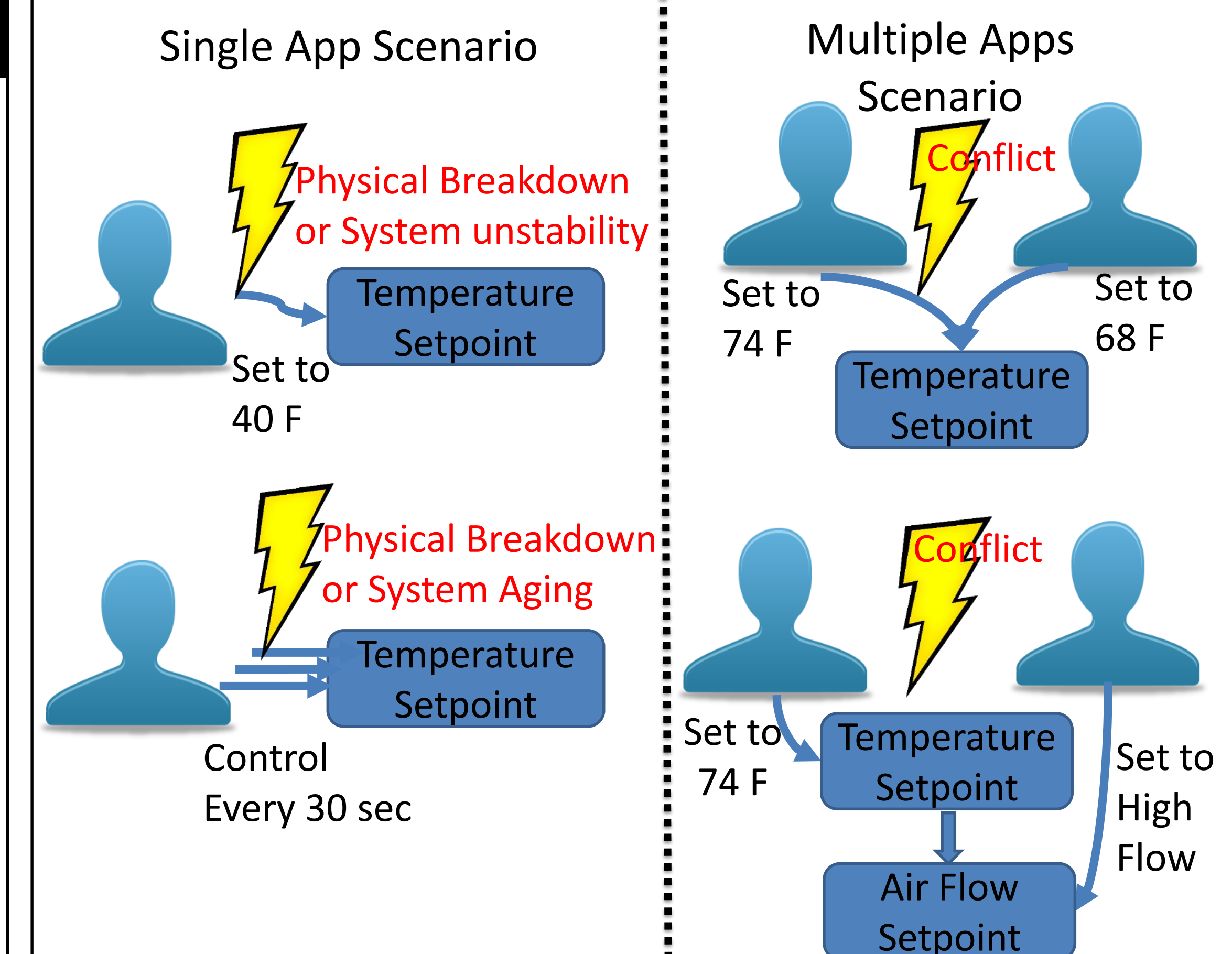
HVAC Background



Sensor/Actuator Dependency Graph



Challenging Scenarios



Building Control Engine (BCE)

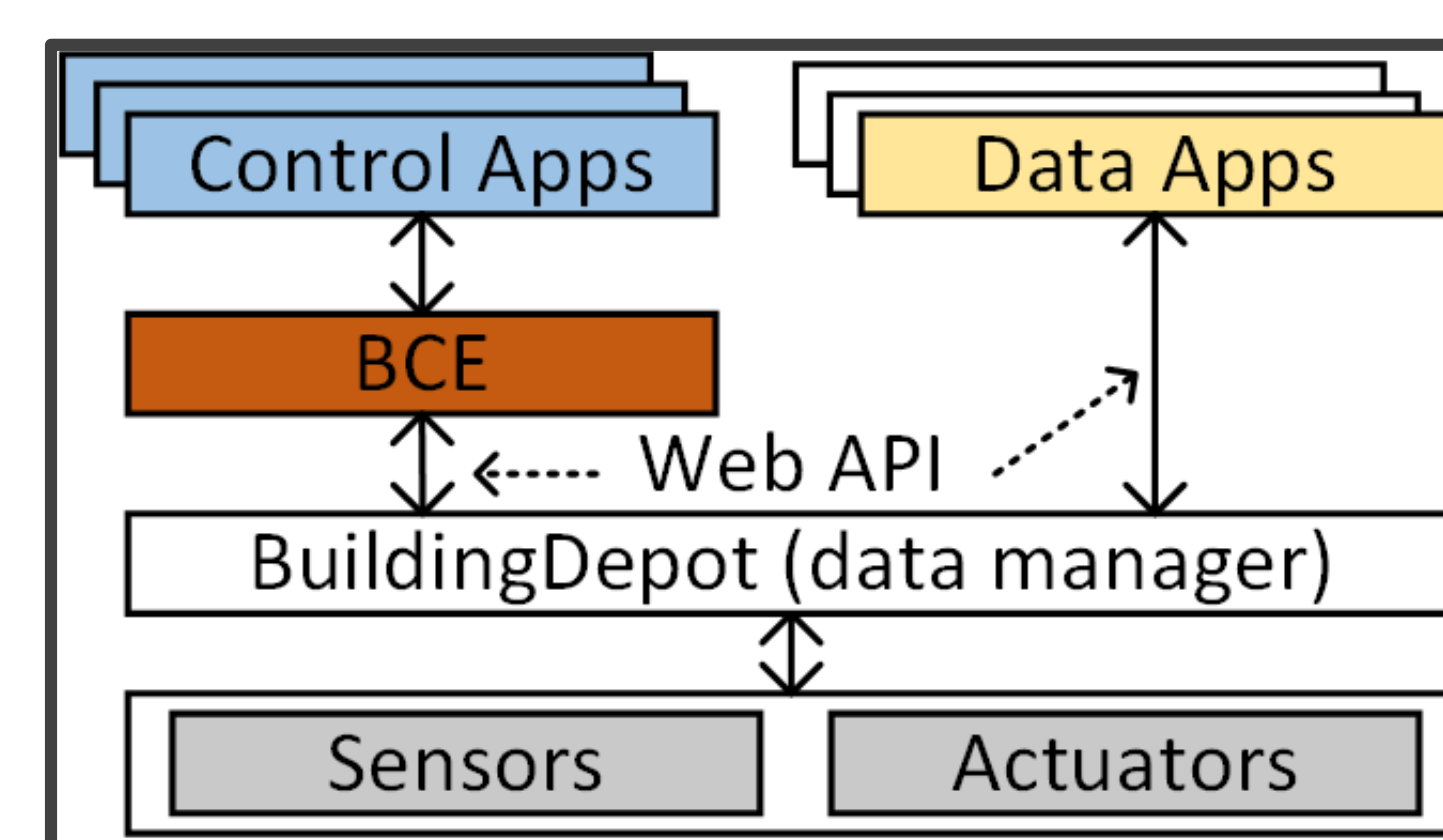
Design Goal

- 1. Provide a library as API**
- 2. Reject unsafe operation**
 - Should not exceed operating range. e.g., Temperature Setpoint to 40°F
 - Should not operate too frequently. e.g., Damper command change in every 30 seconds.
- 3. Status of operation per a sensor/actuator is stored/managed**
 - Points are dependent on others.
 - Need to track status of each resource, and its dependency information.
- 4. Logging entire history of control**
 - Logging history of all system status
 - Need for both data analysis and system management
- 4. Rollback**
 - In case of system down or user interrupt.

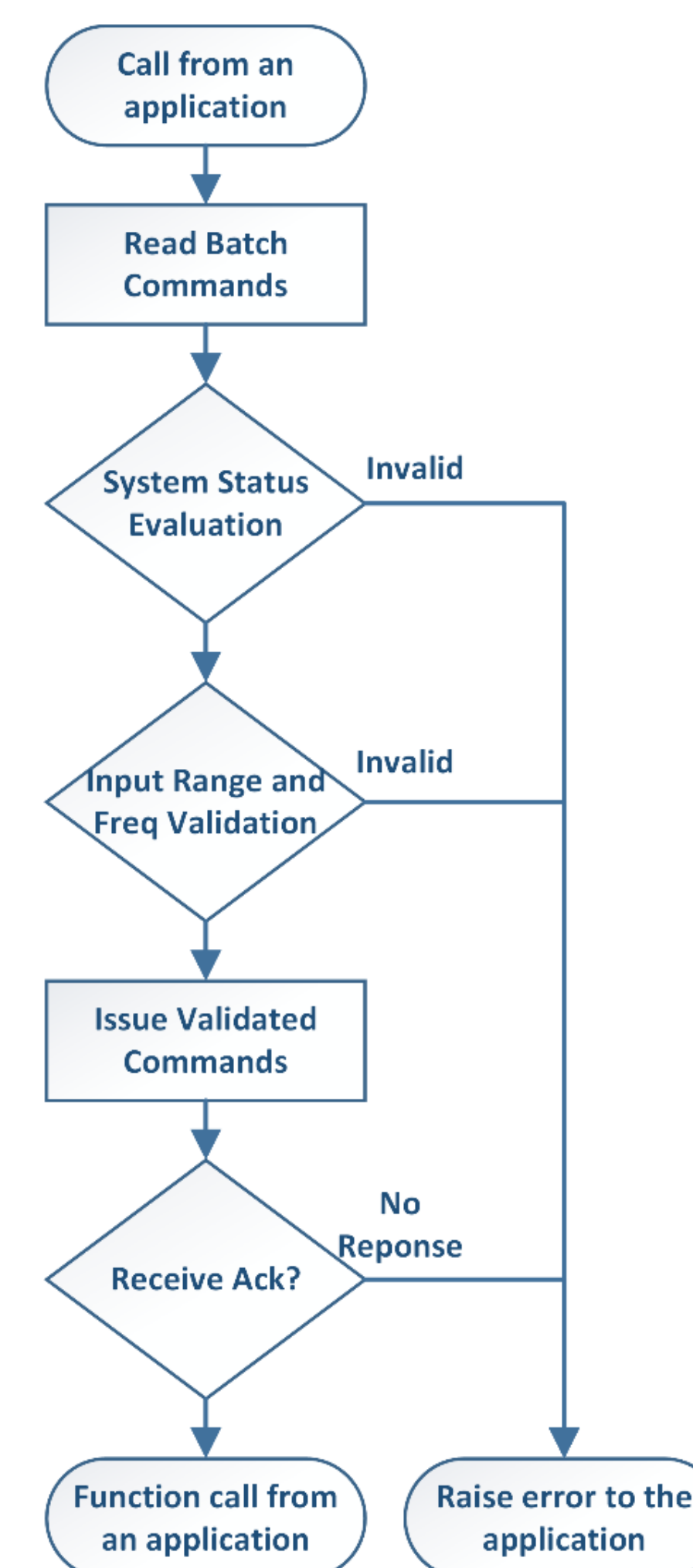
Unsafe operation

- Definition of unsafe operation
 - Exceeding normal operating range.
 - Too frequent operation.
- Each actuator has its own definition of unsafety.
- Each operation affects dependent points.

System Architecture



Validation Algorithm



Application Suggestion

- 1. System Diagnosis**
 - Active fault diagnosis
 - System estimation for security
- 2. System Identification**
 - Sensor/actuator colocation
 - Type identification
 - Finding control function
 - Finding dependency graph
- 3. Personalized Control**

Example Application: Sensor/Actuator Co-location

Problem: Co-location of sensor/actuators when location metadata is unavailable.
Assumption: Sensor and actuator types are known.
Hypothesis: Co-located points will be distinguishable if unique control signal is applied. The signal is unique in terms of *amplitude*, *frequency*, and *phase*.
Method: Use control to make information more observable.

Algorithm for Co-location

- Apply large pulses to a Temperature Setpoint
- Extract time-series features from each point over all zones
- Pick a point with most abnormal features

Result: 68 % recall with 98.6 % precision over 8 zones.

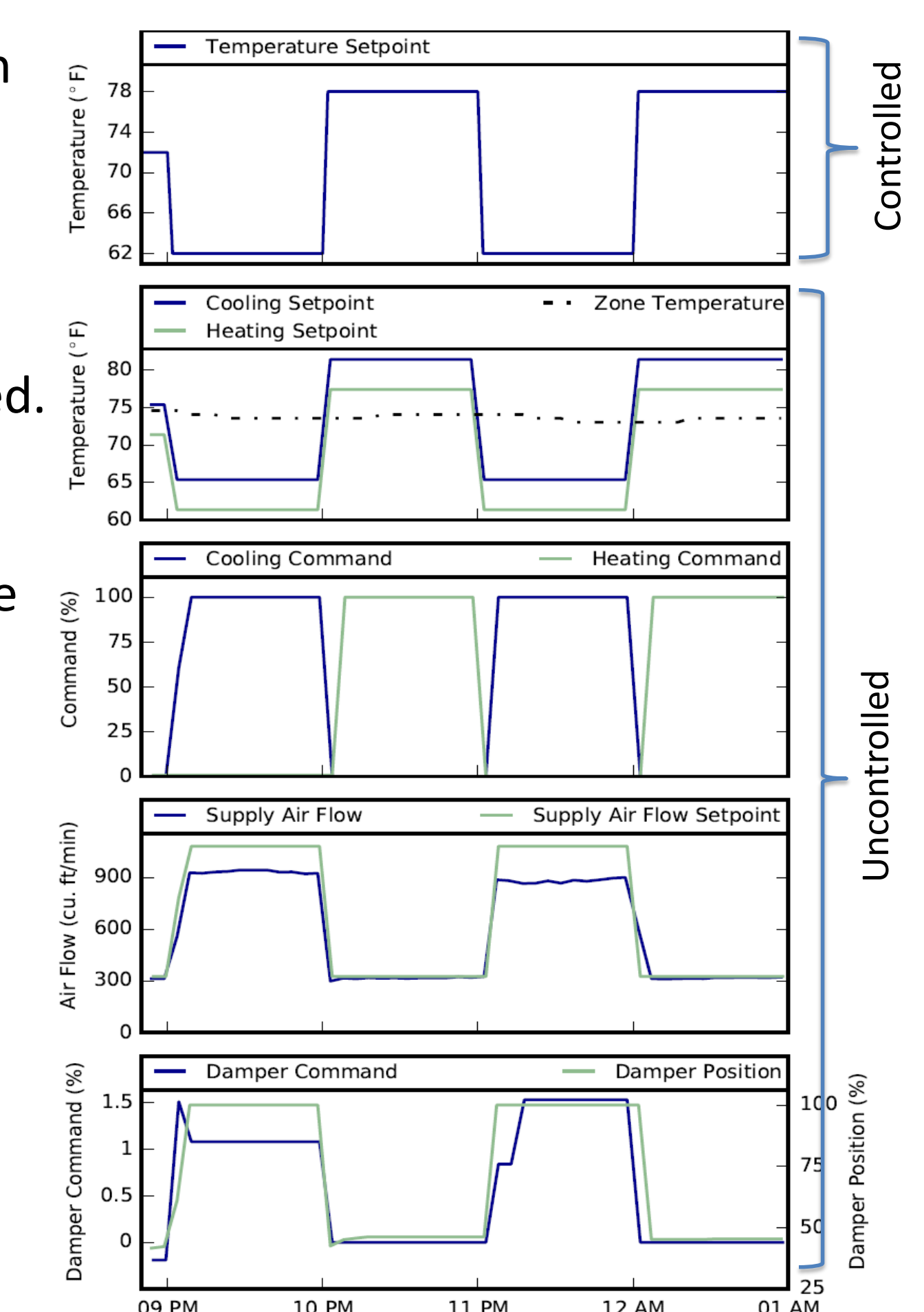


Fig. Example of control experiment for co-location