Solar Decathlon 2011 House HVAC System Design ENES489P Midterm Presentation 21 April 2011

"The Sink Group"
Bob Hayes
Will Seeber
Zhen Zhao
Zhen Kuang

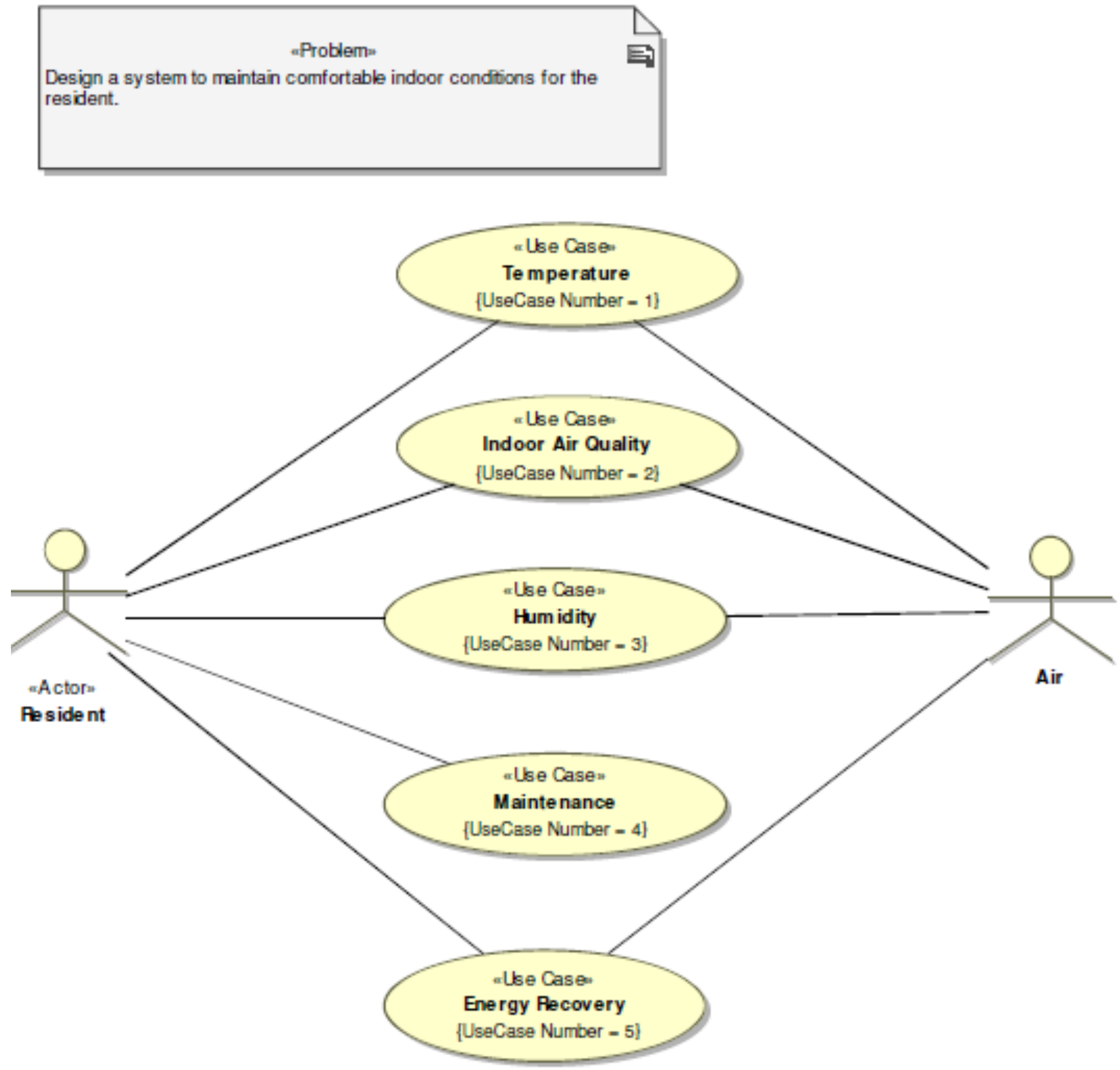
Problem Statement/ Objective:

The HVAC system in the 2011 Solar Decathlon house must maintain comfortable interior living conditions based on user input. HVAC is typically the largest electrical load in a residence and through modeling the system and the environment, we intend to highlight design trade-offs in pursuit of energy savings.

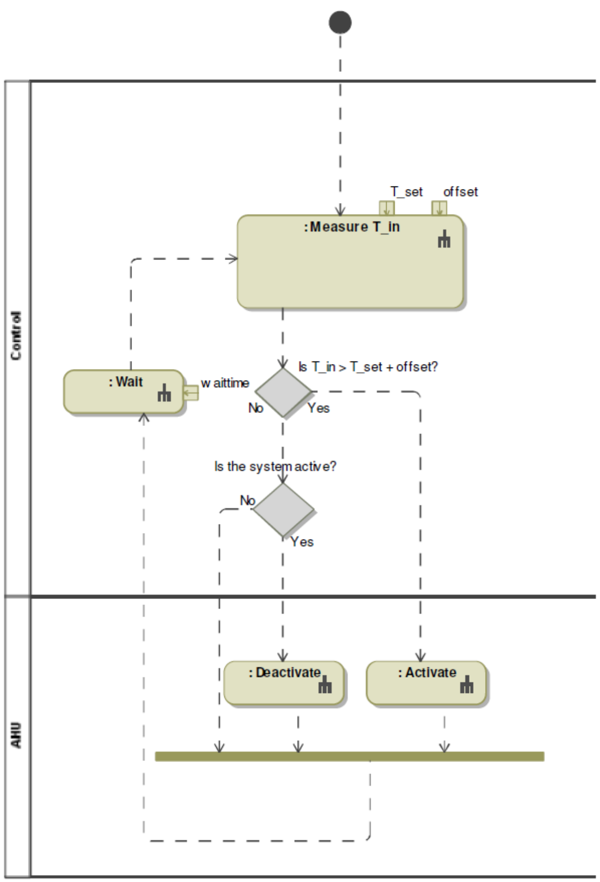
Model Solar Decathlon House HVAC system performance for various weather scenarios and equipment layouts

- Evaluate design choices and highlight key energy saving strategies based on model data
- Generate set of optimal component choices and settings for modeled load conditions

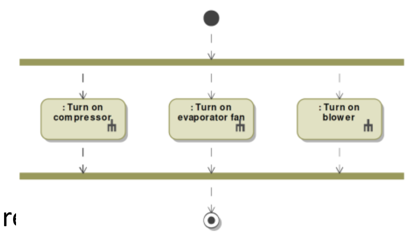
Use cases

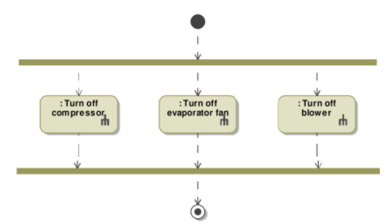

«Problem»
Design a system to maintain comfortable indoor conditions for the resident.
«Use Case»
Temperature
{UseCase Number = 1}
«Use Case»
Indoor Air Quality
{UseCase Number = 2}
«Use Case»
Humidity
{UseCase Number = 3}
«Use Case»
Maintenance
{UseCase Number = 4}
«Use Case»
Energy Recovery
{UseCase Number = 5}
«Actor»
Resident
Air

Indoor Air Temperature

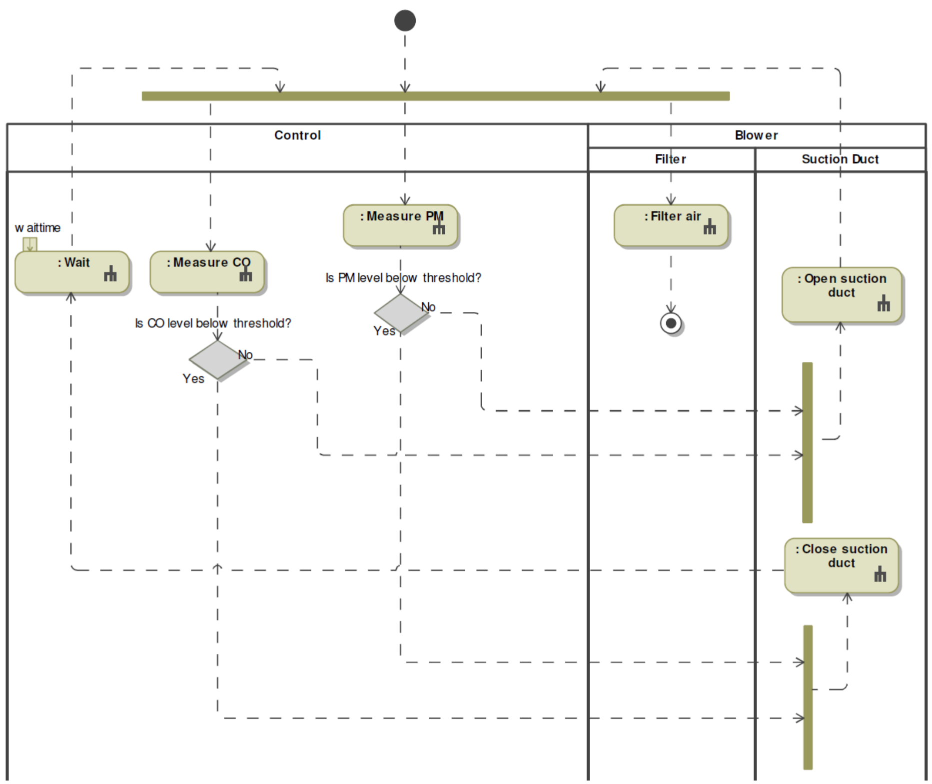


- **Use Case 1:** Indoor air temperature
- **Description:** User selects desired temperature and it is maintained by the HVAC subsystem
- **Primary Actors:** Resident, air
- **Pre-conditions:**
  a. The set temperature, T_set, is specified
  b. Wait time is specified
  c. Temp offset is specified
  d. HVAC system is off
  e. HVAC system has power
- **Flow of Events:**
  a. User sets control subsystem to desired temperature
  b. Control subsystem measures temperature
  c. Measured temperature is above/below desired temperature by a given threshold
  d. The control subsystem turns on the compressor subsystem
  e. The control subsystem turns on the evaporator fan
  f. The control subsystem turns on blower subsystem
  g. The measured temperature will approach the desired temperature
  h. The control subsystem turns off the compressor, evaporator fan, and blower subsystems
  i. Repeats from step b.
- **Post-condition:** Indoor air is within the set temperature threshold



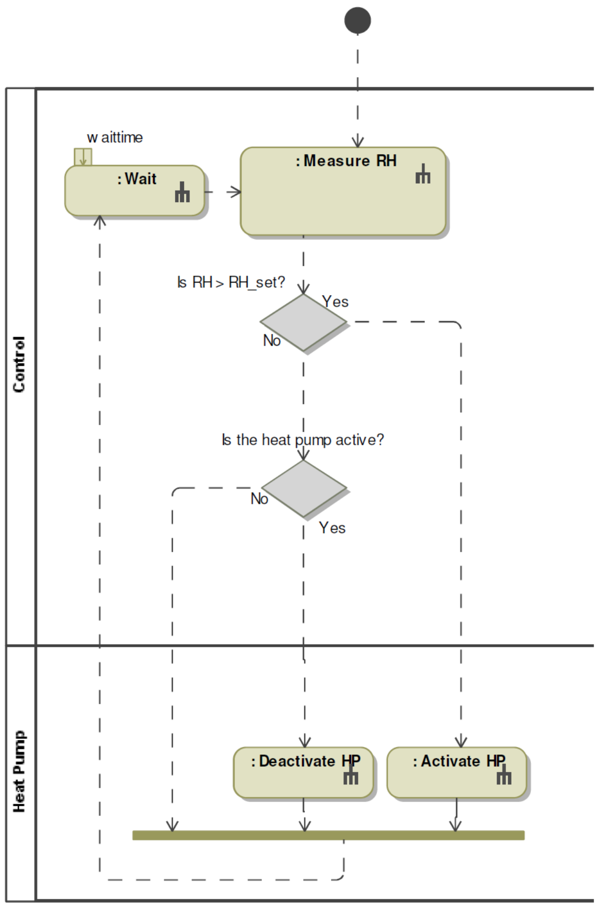


Indoor Air Quality



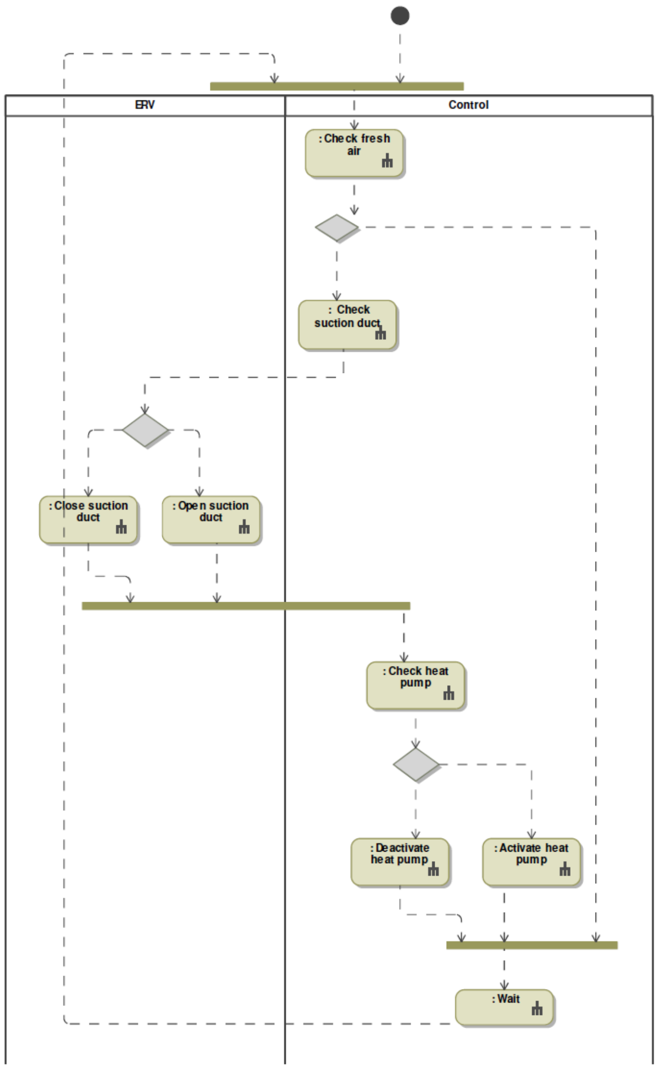
- **Use Case 2:** Indoor air quality
- **Description:** Air quality is maintained at a safe and healthy level
- **Primary Actors:** Resident, air
- **Pre-conditions:**
  - a. Threshold value for particulate matter (PM) specified
  - b. Threshold value for carbon monoxide (CO) specified
  - c. A filter is installed in the blower
  - d. The suction duct is closed
- **Flow of Events:**
  - a. Air traveling through the blower is filtered
  - b. CO level is measured
  - c. PM level is measured
  - d. The CO level is above the threshold,
  - e. The PM level is above the threshold
  - f. The suction duct will open
  - g. The CO level will approach the threshold
  - h. The PM level will approach the threshold
  - i. Repeats from step a.
- **Post-condition:** PM and CO levels are maintained at safe levels

Humidity



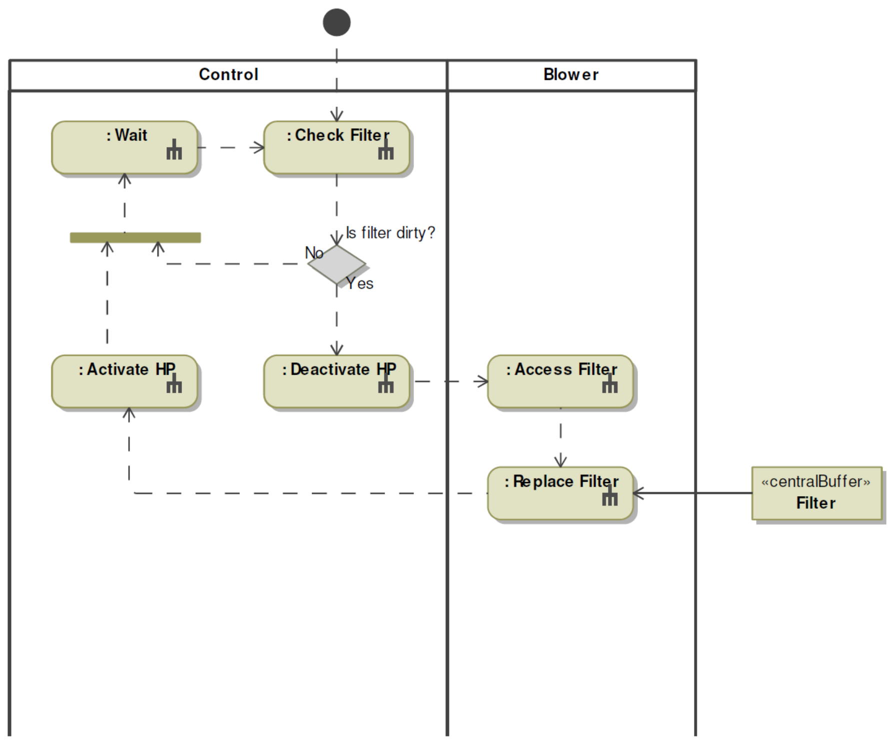
- **Use Case 3:** Humidity
- **Description:** Maintain relative humidity below a given maximum
- **Primary Actors:** Resident, air
- **Pre-conditions:**
  a. Humidistat is set to desired RH.
  b. HVAC system is off
  c. HVAC system is powered
- **Flow of Events:**
  a. Humidistat measures RH
  b. RH is greater than given maximum
  c. The control subsystem turns on the compressor subsystem
  d. The control subsystem turns on the evaporator fan
  e. The control subsystem turns on blower subsystem
  f. RH approaches threshold value
  g. The control system turns of the compressor, evaporator fan, and blower subsystems
  h. Repeats from a.
- **Post-condition:** RH is maintained below desired value

Energy Recovery



- **Use Case 4:** Energy is recovered from vented air
- **Description:** Heat is transferred from fresh air to vented air before it is cooled by the condenser.
- **Primary Actors:** Resident, air
- **Pre-conditions:**
  - HVAC system is operating
  - Fresh air is required by control subsystem
- **Flow of Events:**
  a. Suction duct is opened
  b. Outside air flows through air-to-air heat exchanger with inside air
  c. Cooled outside air enters blower
  d. Suction duct is closed
- **Post-condition:** Less energy is used to cool fresh air

Maintenance



- **Use Case 5:** Maintenance
- **Description:** Subsystems require maintenance to ensure reliable operation throughout life-cycle
- **Primary Actors:** user, technicians, all subsystems
- **Pre-conditions:**
  a. Dirty air filter
- **Flow of Events:**
  a. Heat pump is active
  b. Control system checks filter
  c. Filter is dirty
  d. Heat pump is deactivated
  e. User accesses filter
  f. User replaces filter
  g. Heat pump is activated
  h. Repeat from b.
- **Post-condition:** Air filter is clean and ready to use

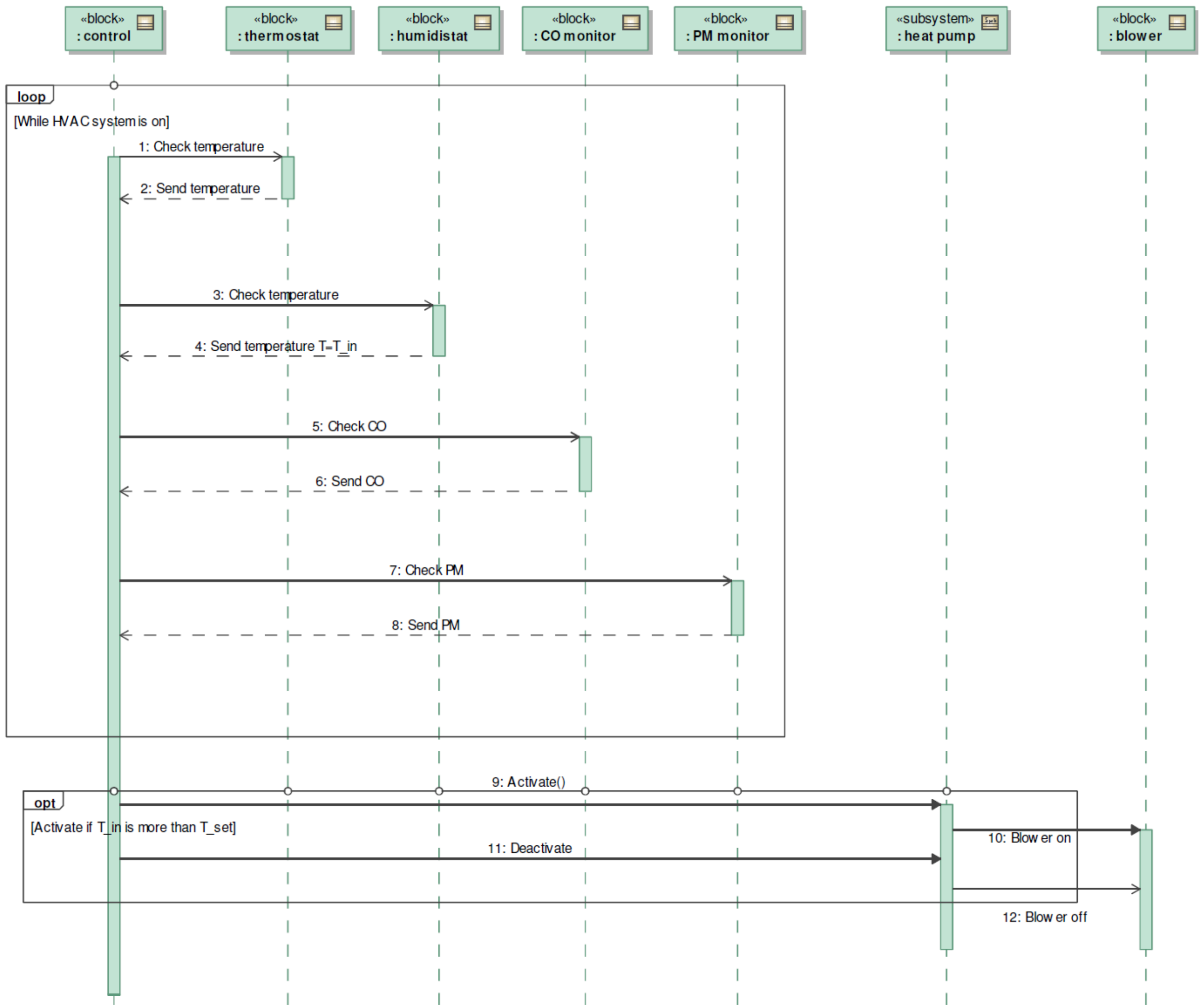
Goals and Scenarios

- **Goal A:** Maintain desired indoor temperature, relative humidity and air quality
  - Scenario 1.1: 95 degree summer day, high humidity, high ventilation
  - Scenario 1.2: 95 degree summer day, high humidity, low ventilation
  - Scenario 1.3: 95 degree summer day, high humidity, no ventilation
  - Scenario 1.4: 95 degree summer day, low humidity, high ventilation
  - Scenario 1.5: 95 degree summer day, low humidity, low ventilation
  - Scenario 1.6: 95 degree summer day, low humidity, no ventilation
  - Scenario 1.7: 80 degree summer day, high humidity, high ventilation
  - Scenario 1.8: 80 degree summer day, high humidity, low ventilation
  - Scenario 1.9: 80 degree summer day, high humidity, no ventilation
  - Scenario 1.10: 80 degree summer day low humidity, high ventilation
  - Scenario 1.11: 80 degree summer day, low humidity, low ventilation
  - Scenario 1.12: 80 degree summer day, low humidity, no ventilation
  - Scenario 1.13: 85 degree summer night, high humidity, high ventilation
  - Scenario 1.14: 85 degree summer night, high humidity, low ventilation
  - Scenario 1.15: 85 degree summer night, high humidity, no ventilation
  - Scenario 1.16: 85 degree summer night, low humidity, high ventilation
  - Scenario 1.17: 85 degree summer night low humidity, low ventilation
  - Scenario 1.18: 85 degree summer night, low humidity, no ventilation
  - Scenario 1.19: 80 degree summer night, high humidity, high ventilation
  - Scenario 1.20: 80 degree summer night, high humidity, low ventilation
  - Scenario 1.21: 80 degree summer night, high humidity, no ventilation
  - Scenario 1.22: 80 degree summer night, low humidity, high ventilation
  - Scenario 1.23: 80 degree summer night, low humidity, low ventilation
  - Scenario 1.24: 80 degree summer night, low humidity, no ventilation

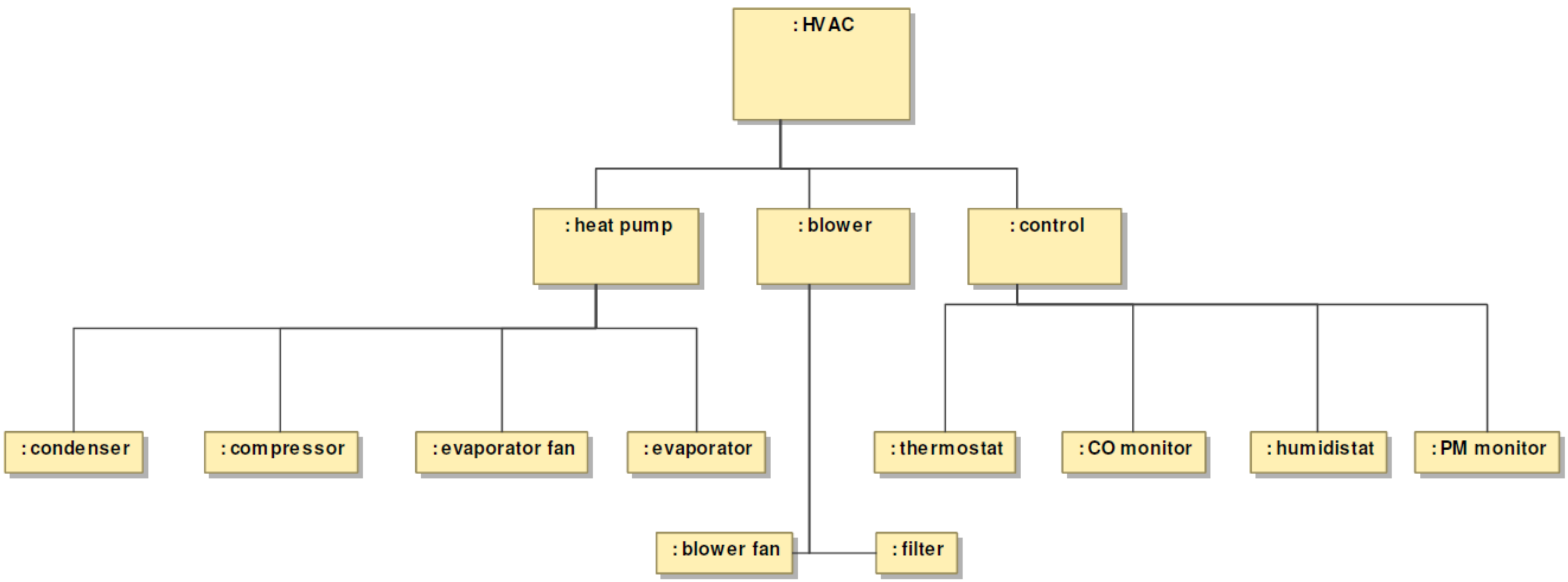
Goals and Scenarios (cont.)

- **Goal B:** Maintained desired indoor climate most energy efficiently
  - Scenario 2.1: Highest COP Dual Ductless Mini-Split System Inverter w/ ERV
  - Scenario 2.2: Highest COP Dual Ductless Mini-Split System Inverter w/o ERV
  - Scenario 2.3: Highest COP Dual Ductless Mini-Split System Non-Inverter w/ ERV
  - Scenario 2.4: Highest COP Dual Ductless Mini-Split System Non-Invert w/o ERV
  - Scenario 2.5: Highest COP Ducted Mini-Split System Inverter w/ ERV
  - Scenario 2.6: Highest COP Ducted Mini-Split System Inverter w/o ERV
  - Scenario 2.7: Highest COP Ducted Mini-Split System Non-Inverter w/ ERV
  - Scenario 2.8: Highest COP Ducted Mini-Split System Non-Inverter w/o ERV
  - Scenario 2.9: Highest COP Ducted Central System Inverter w/ ERV
  - Scenario 2.10: Highest COP Ducted Central System Inverter w/o ERV
  - Scenario 2.11: Highest COP Ducted Central System Non-Inverter w/ ERV
  - Scenario 2.12: Highest COP Ducted Central System Non-Inverter w/o ERV

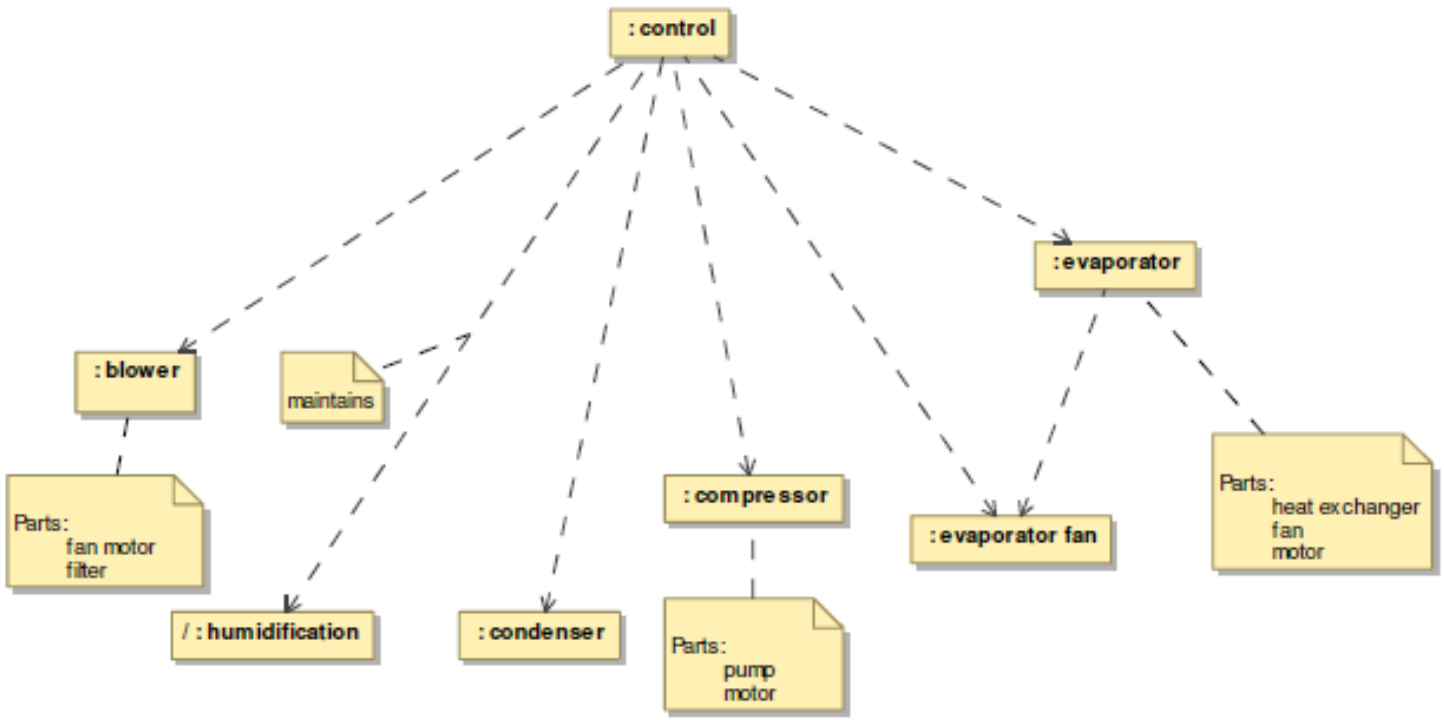
Sequence Diagram



Structure Diagram



Relationship Diagram



Preliminary Requirements

<u>Level 1</u>
R1.1Maintain comfortable indoor conditions
R1.2Energy efficient

<u>Level 2</u>
R2.1 Maintain specified indoor temperature (T_in)
R2.2 Maintain desired relative humidity (RH_in)
R2.3 Maintain desired indoor air quality

<u>Level 3</u>
Compressor
Co1 The compressor must be outdoors
Co2 The compressor unit must have at least 18000 BTU cooling capacity
Co3 The compressor SEER rating must exceed 15

Control System
Cs1 Indoor max temperature set point 24 degrees Celcius, min set point 22 degrees Celcius
Cs2 Must measure and control carbon dioxide
Cs3 Must measure and control particulate matter
Cs4 Must measure and control relative humidity

Air Quality
B1 ERV's benefits in air quality must exceed energy losses
B2 System must have forced ventilation or natural ventilation meeting or exceeding national standard 0.35 air changes per hour but no less than .5 liters per second per occupant
B3 Particulate level must not exceed national standard
B4 Carbon Monoxide level must not exceed national standard

Humidification
H1Humidification must meet or exceed national standard but be customizable by user within range

Indoor Units/ Ducting
U1There must be either two indoor units and/or ducts from the outdoor compressor unit or central unit
U2 Each unit must be at least 9000 BTU capacity with variable airflow customizable by user

References

- Indoor Air Quality http://epb.lbl.gov/publications/lbnl-54331.pdf
- Maintenance http://www.energystar.gov/index.cfm?c=heat_cool.pr_maintenance
- Watershed Team Maryland Project Manual
- Solar Decathlon Rules http://www.solardecathlon.gov/rules.html