Case Study: San Francisco Federal Building
Mark Levi
U.S. General Services Administration
• Upper Tower Perimeter: Active Natural Ventilation
• Upper Tower “Cabins”: UFAD
• Lower Tower: UFAD
• Annex: Conventional VAV
Special Challenges

- Controls Complexity
- Active Scrim System – Smoke Control Function
- Fire/smoke Dampers on BAS
- Lower Tower AHUs – Closets on Floors
- Heat Pumps for Upper Tower
- No Interior Reheat in Annex
Proactive Efforts

• Early BAS Programming
  ○ Not followed through by BAS contractor

• Natural Ventilation Simulation by LBNL
  ○ Value lost due to programmer turnover

• Comprehensive Review of Visio Diagrams
  ○ Stalled due to programmer turnover, non-response to comments

• Commissioning Program
  ○ Delayed functional testing
  ○ Long delay due to bad batch of controllers
  ○ FPTs after occupancy
Underlying Sources of Problems

- BAS Contractor Not Prepared for Complexity, Level of Effort
- BAS Contractor Programmer Turnover
- Product Defect in Firmware – Contractors Blamed Electrical, Months Wasted Finding Cause
- Product Substitutions – Scrim Actuators
- UFAD Leakage, Thermal Loss Through Slab
- Design Issues: Thermostat Locations, Slab Cooling, Air Circulation, AHU Noise, Etc.
- Finger-pointing by Parties
Example of Legal Waffling

- Designer RFI Response (Excerpt) to Scrim Panel Actuator Product Substitution

“[X] takes no exception to the substitution request…With the substitution, [X] will only continue to bear responsibility for the design intent of the sunshade control, but not the design of the wiring or other control design associated with the change in the hardware.”
Energy Performance (Btu/Gsf)

- SFFB Energy Model: 29,000 btu/gsf
- SFFB CY 2008: 47,000 btu/gsf
- Burton FB (1963) CY 2008: 57,000 btu/gsf
- FB 50 UNP (1933) FY 2006: 28,000 btu/gsf
Lessons

- Complexity + Field Installation Is Precarious
- Complexity Must Be Funded
- Never Mix Fire/Smoke Systems with BAS
- Has BAS Contractor Read the Specs?
- Programmer Stability Critical – BAS Programmer is a Key Person
- System Problems Can Run Out the Clock
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Case Study New San Francisco Federal Building

Jonathan Soper, P.E.
Principal
Enovity, Inc.
Enovity Project Role

- Commissioning Authority
  - Contracted during construction phase in April 2005
- Operations and Maintenance Contractor
  - Contracted at Building Occupancy in Feb 2007
Project Team

Building Owner
General Services Administration

Design Team
- Executive Architect: SmithGroup, Inc.
  - Design Architect: mOrphosis
  - Building Engineer: ARUP

Commissioning Authority
- Enovity, Inc.

Contractor
- General: Dick/Morganti
  - Mechanical: Marelich
  - Controls: Syserco

Construction Manager
- Hunt Construction
Current Project Status

- Building Occupied for Two Years
- Construction Phase Cx Complete
- Outstanding Punch List from Warranty Phase
  - Enovity to complete by Oct 2009
Building Architecture

- 650,000 sq.ft
- Tower
- Annex
- Child Care Center
- Conference Center
- Computer Wing
- Cafeteria
- Sky Garden
Summary of Building Systems

- **Chilled Water Plant**
  - 2 x 300-ton Carrier centrifugal chillers in basement
  - Primary variable flow CHW distribution system
  - 3 x Marley cooling towers on roof

- **Heating Hot Water Plant**
  - On San Francisco steam distribution system – steam to hot water heat exchangers
  - Primary variable flow HW distribution system

- **Alerton Envision BACnet DDC System**
• Air Distribution Systems
  ○ Traditional VAV overhead systems serves Annex, Child Care, Conference Center
  ○ Under floor VAV built up air handlers serves Tower floors 2 thru 5
  ○ Under floor CV heat pumps serves Tower ‘core’ zones on floors 6 thru 18

• Natural Ventilation System
  ○ Natural ventilation system serves Tower ‘perimeter’ zones on floors 6 thru 18
Natural Ventilation System – Morphosis Early Rendition
Natural Ventilation System – System Components

- Fixed Vertical Sunshade
- Blast Resistant Insulated Glass, w/ Low-E Coating, TYP
- Automated Upper Vent Window
- Manual Operated Window
- Automated Trickle Vent at Sill
- Exposed Concrete Slab and Ceiling
- Operable Perforated Stainless Steel Sunscreen
- Blast Resistant Insulated Glass, w/ Low-E Coating, TYP
- Automated Upper Vent Window
- Manual Operated Window
- Automated Trickle Vent at Sill
- Exposed Concrete Slab and Ceiling
Natural Ventilation System – Fin Tubes & Trickle Vents
UCSD - Computational Fluid Dynamics shows upward macro flow
Natural Ventilation System – Plan View
• Group windows together
• Closed, half-open or fully-opened positions
• 10 opening modes
• The windward and leeward sides are identified
• Temperatures, and external pressures measured
• Each half of each floor is independently controlled
• The system responds to these variables by changing the Mode value by ±1
## Natural Ventilation System – ‘Modes’ of Operation

### Table of Modes

<table>
<thead>
<tr>
<th>MDN</th>
<th>Windward Windows Position</th>
<th>Leeward Windows Position</th>
<th>ASTM</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Trickle Vents</td>
<td>Group 1</td>
<td>Group 2</td>
</tr>
<tr>
<td>Storm Modes</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mode 1</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Mode 2</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Heating &amp; Rain Modes</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mode 3</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Mode 4</td>
<td>1</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Mild Weather &amp; Cooling Modes</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mode 5</td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Mode 6</td>
<td>0</td>
<td>1</td>
<td>0.5</td>
</tr>
<tr>
<td>Mode 7</td>
<td>0</td>
<td>1</td>
<td>0.5</td>
</tr>
<tr>
<td>Mode 8</td>
<td>0</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Mode 9</td>
<td>0</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Mode 10</td>
<td>0</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

(0= Closed, 0.5= Intermediate position and 1= Open)
Summer 1% design = 78 °F db/62 °F wb;
Winter 99% design = 39°F

Bars show range of mean max/mean min
SF Outdoor Temperature Behavior

Natural ventilation comfort range superimposed on outdoor air graph

Need internal pickup of less than 7°F
• **Pre-functional Testing**
  - Point to point and sensor location checks
  - Sensor calibration checks critical
  - Over 650 window/ trickle vent actuators to verify open/closed and 50% position
  - Verify all window and trickle vent ‘modes’ are correct before functional testing can begin
• Functional Testing
  ○ Created ‘Commissioning Screen’ on the BAS
  ○ Variables for wind speed, DP, rain sensor, outside air, space and slab temperatures were over-ridden to artificially create the ten (10) ‘Modes’
  ○ Daytime Operation, Night Cooling, Morning Warm-up all were tested
  ○ One half-floor thoroughly tested first then programming downloaded to other floors
  ○ Five re-tests needed before system fully functional
Natural Ventilation System Actual Performance

6th Floor East Performance

- Sum of Window Mode Command (1-10)
- Sum of Tower OSA Temp (C)
- Sum of Wind speed (m/s)
- Sum of Slab Temp. (C)
- Sum of Avg Space Temp. NW (C)
- Sum of Avg Space Temp. SW (C)
- Sum of Delta P Across Floor (Pa)

Time of Day

00:00 01:00 02:00 03:00 04:00 05:00 06:00 07:00 08:00 09:00 10:00 11:00 12:00 13:00 14:00 15:00 16:00 17:00 18:00 19:00 20:00 21:00 22:00 23:00
18th Floor East Performance

- Sum of Window Mode Command (1-10)
- Sum of Tower OSA Temp (°C)
- Sum of Slab Temp. (°C)
- Sum of Avg Space Temp. NW (°C)
- Sum of Avg Space Temp. SW (°C)
- Sum of Delta P Across Floor (Pa)

Time of Day

OA, Space, Slab Temp (°C) & Wind Speed (m/s)
Under Floor Air Distribution—Summary

- Seven (7) VAV Air Handlers on Floors 2 thru 5
  - Reasonable design from a leakage standpoint
  - Complex air handler configuration
- Fifty (50) Constant Volume Heat Pumps on Floors 6 Thru 18
  - Not well detailed from a leakage standpoint
  - Many system challenges
Under Floor VAV Air Handler Details
Under Floor Heat Pump Details
Under Floor System Testing

- Rigorous Testing on 1 x VAV System and 1 x CV Heat Pump System
  - Independent test fan used to pressurize under floor plenum and measure leakage at different pressures
  - Category 1 is leakage to unconditioned space and category 2 is leakage to conditioned space
  - Very poor results initially (>40% Cat 1) initially and many leakage paths identified
  - Smoke test to identify leakage paths
  - Follow up tests and remediation work required post occupancy
Testing Technique
Leakage Paths CV Under Floor Heat Pump System
Leakage Paths VAV Under Floor System
### Results of Under Floor Testing

#### Initial Test - Category 1 Leakage Only

<table>
<thead>
<tr>
<th>Floor</th>
<th>Static Pressure (inches w.c.)</th>
<th>Leakage (cfm)</th>
<th>% Leakage (per Design Airflow)</th>
<th>Leakage per Area (cfm per sq. ft.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>VAV Vertical Air Handler</td>
<td>0.05</td>
<td>3,267</td>
<td>37%</td>
<td>0.39</td>
</tr>
<tr>
<td></td>
<td>0.07</td>
<td>3,982</td>
<td>45%</td>
<td>0.47</td>
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<tr>
<td></td>
<td>0.1</td>
<td>4,792</td>
<td>54%</td>
<td>0.57</td>
</tr>
<tr>
<td>CV Heat Pump</td>
<td>0.05</td>
<td>1,410</td>
<td>180%</td>
<td>0.67</td>
</tr>
<tr>
<td></td>
<td>0.07</td>
<td>1,757</td>
<td>224%</td>
<td>0.84</td>
</tr>
<tr>
<td></td>
<td>0.1</td>
<td>2,207</td>
<td>282%</td>
<td>1.05</td>
</tr>
</tbody>
</table>

#### Final Test - Category 1 & 2 Leakage

<table>
<thead>
<tr>
<th>Floor</th>
<th>Static Pressure (inches w.c.)</th>
<th>Leakage (cfm)</th>
<th>% Leakage (per Design Airflow)</th>
<th>Leakage per Area (cfm per sq. ft.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vertical VAV Air Handler</td>
<td>0.05</td>
<td>675</td>
<td>8%</td>
<td>0.08</td>
</tr>
<tr>
<td></td>
<td>0.07</td>
<td>925</td>
<td>10%</td>
<td>0.11</td>
</tr>
<tr>
<td></td>
<td>0.1</td>
<td>1,125</td>
<td>13%</td>
<td>0.13</td>
</tr>
<tr>
<td>CV Heat Pump</td>
<td>0.05</td>
<td>340</td>
<td>20%</td>
<td>0.18</td>
</tr>
<tr>
<td></td>
<td>0.07</td>
<td>410</td>
<td>27%</td>
<td>0.22</td>
</tr>
<tr>
<td></td>
<td>0.1</td>
<td>515</td>
<td>31%</td>
<td>0.28</td>
</tr>
</tbody>
</table>
• Leakage Testing Performed on All Remaining VAV & CV Systems
  ○ CV Heat pump systems - Cat 1&2 leakage rates generally between 15% & 35% @ 0.08”, two heat pumps as high as 45%
  ○ Heat pumps supply fans needed to be ramped up above design flows to overcome losses
  ○ More significant problem with heat pumps is high residence time of air and high supply air temperatures at diffusers
  ○ VAV Air Handler systems leakage rates between 13% & 25% @ 0.08”, again mostly Cat 2 – minimal comfort complaints.
Major Outstanding Issues

• Natural Ventilation System
  ○ Cross flow ventilation creates some cold complaints – even if space 70 deg.F ‘feels’ colder.

• Under Floor Systems
  ○ Insufficient cooling capacity in a few of the cabins – high residence time of air

• Other
  ○ Chiller over-sized for night time and weekend cooling loads
  ○ Several BAS discrepancies from warranty phase need to be corrected
  ○ Water side economizer for heat pumps not very effective
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