Commissioning The
San Francisco PUC
Headquarters

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May 16, 2013
Agenda

- Project Overview
- Commissioning of Major Systems
- Commissioning Challenges
- Lessons Learned
- Questions
Project Overview
San Francisco Public Utilities Commission

Who we are

- Water, Power and Wastewater Services
- Environmental stewardship as core values
- Municipal power provider to City Facilities
- Power from hydro, solar, cogeneration & wind
- City building energy efficiency and renewable retrofits
- Building Commissioning of City Buildings
- 54++ million square feet of civic real estate
- HQ building planned as a sustainability showcase
Building Features

Overview

- 13+ stories, 277,500 s.f.
- 32% less total energy use over baseline
- 7% of power from PV and Wind
- HVAC energy savings of 51% over baseline
- Living machine
- Rain water harvesting
- 60% less potable water use
- Datacenter, Childcare center & Café
- Unique seismic design
- LEED Platinum Certification anticipated

Awards

- AIA award - top ten green projects of 2013
- RealComm award - “2012 Smartest Building”
Building Features

Air Distribution

- Operable Windows
- Under Floor Air Distribution (UFAD)
  - Personal control over air flow
  - Cooling at body level
  - Ease of maintenance, space reconfiguration
  - Underfloor Terminals (UFTs)
  - ECM motors 70% efficiency
Maximized daylighting - 25 feet

Light shelves & exterior venetian blinds
  - Reduce heat gain, Increase daylighting

Interior roller shades prevent glare

Shades automated on South, East and West

T-5 Lighting, 0.6 W/s.f.

Dimmable ballasts & photocell s

LED Task Lighting, 0.2 W/s.f.

Occupancy and vacancy sensors
Building Features

Mechanical System

- Primary-secondary chilled water loops
- Plate & Frame HX for condenser economizer
- Dual compressor chillers
  - Magnetic levitating bearing
  - 500 Ton and 250 Ton`
  - IPLV=0.33 kW/ton
- Data Center CRAC - condenser water economizer
- Condensing boilers with 15:1 turndown
  - 3MMBtu & 1.5 MMBtu
  - 92% - 94% efficient
- Air Handling Units with fan walls
  - Cooling Coils: 8 rows, 10 fin per inch
  - Heating Coils: 1 row, 8 fin per inch
- Advanced Sequence of Operations and Resets
Building Features

*Integrated Building Management System*

- Bringing all systems under one supervisory platform
- Unifying databases and expanded reporting
- Automated Demand Response sequences
- Analytics for maintaining system operating efficiency
- 4’ x 58’ Media wall for public interaction and display

![Diagram of Building Features]

- **IBMS**
  - HVAC
  - Elevators
  - Lighting
  - Shades
  - Living Machine
  - Power Monitoring
Commissioning of Major Systems
Shade Controls

*System Overview*

**Exterior Venetian Blinds (EVBs)**
- Very few similar deployments in the U.S.
- Slat angle is automatically adjusted to prevent or limit solar penetration into space
- Goal is reduced cooling loads while maintaining outside views
Shade Controls

System Overview – Interior Shades

Interior Shades

- The sun’s position and angle is tracked based on the time and day of the year, building’s location and geometry
- Shades are commanded to maintain the solar penetration set point for the individual zones
- Brightness override feature prevents glare
- Radiometers on the roof detect clear or cloudy conditions
- Local touchscreens for occupant overrides
Shade Controls

Commissioning Approach

- Previews utilized to cross check commanded position against actual

- Testing clear / cloudy conditions

- Testing of Local / Master Overrides
  - Individual offices have local overrides for the shades
  - Each floor has a touchscreen station capable of overriding all individual zones on the floor

- Testing of Brightness Override Function

- Seasonal test of EVBs
Shade Controls

Changing Sun Position Across Various Seasons

- Test by changing the system time clock – simulate different months and time of day conditions
Shade Controls

Commissioning Issues & Lessons Learnt

- Learning and acceptance of the system by occupants
  - Floor captains
  - Developed training documentation for operators
- System is fairly new to the industry
  - Specifications need to allow for time to tune the system during post occupancy
  - System parameters need to be tuned in construction phase based on owner feedback and mock-up demonstrations
  - Sequence of operations need to be discussed during submittal reviews to ensure correct interpretation
- EVB operation – challenging to achieve stability
- Erratic behavior of shades
  - Repeated verification visits
  - Importance of recording the time of occurrence of the issues and differentiating occupant overrides from system malfunction
- Occupant override limits
Lighting Controls

System Overview

Open Offices
- Occupancy Sensor Controls
- Photocell Controls
- 30% ON, raised to 90% upon occupancy
- Time of day controls

Private Offices
- Four Button Controls – 50%, 70%, 90%, 100% and OFF
- Occupancy controls

Corridors and Elevator Lobbies
- Override switches and time of day controls
Lighting Controls

System Overview
Lighting Controls

**Commissioning Approach**

- Checked every space – high visibility to occupants
- Alongside testing, identified discrepancies in plans and installation
- Very good point to point testing by contractor (sample in subsequent slides)
- Impact of furniture color and placement on lighting - photocell calibrations needed to be done prior to furniture installation
- Measured relative dimming w.r.t switch function
Lighting Controls

Furniture Placement and Photocell Calibration Considerations

Foot Candle Level to be Maintained – 30 fc at work surface
# Contractor’s Checklist

<table>
<thead>
<tr>
<th>Area</th>
<th>Prerequisites</th>
<th>Remove Jumpers</th>
<th>Confirm Zone Programming - Flash Zones</th>
<th>Confirm Sensors</th>
<th>Setup Daylighting</th>
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<th>Set Up Shade Control</th>
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Lighting Controls

Commissioning Issues

- As-Built Sequences were documented as part of Commissioning Effort
- Labeling of the switches was missing
- Four button switch installed in place of 2 button switch – helped to carry the plans in hand while going through the spaces
- No switch in the lobby
- Discrepancies in space designation and associated controls
PV and Wind

System Overview

PV
- System Capacity - 165 kW STC
- PV Monitoring – A data acquisition system monitors the AC energy and power, wind speed, solar irradiance and PV panel temperature

Wind Turbines
- System Capacity
- Vertical axis design
- Pilot project demonstrating building integrated wind
- Data acquisition – Wireless modules can gather data but receiver needs to be in close proximity
PV and Wind Turbines

Commissioning Approach

- PV
  - The actual system output was verified against theoretically expected value based on measured irradiance conditions, cell temperature and number of modules
  - System performed better than expected!

- Wind
  - Performance Testing
    - Need to plan ahead for a day with wind conditions that would allow for testing
    - Need to ensure that they are properly balanced
    - Challenging to simulate conditions for capacity testing
    - Need factory documentation that the turbine has been tested under these conditions
    - Long term monitoring to ensure proper performance
HVAC

System Overview

- **Air Distribution**
  - Two main air handling units (SAF and RAF fan walls) serving floors 2 through 13
  - Additional AHUs (two) for serving basement and lobby
  - Under floor Air Distribution

- **Central Plant**
  - Two chillers, variable chilled water and condenser water pumps, Water Side Economizer
  - Two boilers, variable hot water pumps

- **IDF rooms**
  - Fan Coil Units serving IDF spaces

- **Window switches**
  - Disable UFTs when window is opened

- **Data Center**
  - CRAC units serve this space
  - Hot Aisle / Cold Aisle Containment
System Overview – Air Distribution

North Zone

South Zone

Operable Window Opened

AHU-1

AHU-2

Plenum Divider

UFTs

UFTs
**HVAC**

**Commissioning Approach**

- Verification of Contractor’s Documentation
- Performance Testing
  - Complex Sequences!
  - Commissioning involved a review of the programming logic with contractor during the functional testing
  - Interpreted some of the sequence text into logical flow diagrams to ensure that system responded per design intent

<table>
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<th>UFT Cooling Requests</th>
<th>Tmax</th>
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<tr>
<td>Internal Floor Temp</td>
<td>Tmin</td>
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<th>AHU SAT Set Point Value</th>
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<tr>
<td>Interior Floor Temp</td>
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HVAC

Sequence Interpretation

Single Chiller Mode: The demand is determined by the sum of BTU meter calculated load for each chiller. If the total demand is less that 75% (Adj.) of the rated chiller 2 load of 230 tons, Chiller 2 shall be the lead chiller. If the secondary load exceeds 85% (Adj.) of the rated 230 tons, switch the lead to Chiller 1. On any demand based switchover from either chiller, enable the new lead chiller for at least 5 (Adj.) minutes before the new lag chiller is disabled.

Dual Chiller Mode: If the demand in the secondary system as measured by pump speed and temperature differential in the secondary loops exceeds 85% of the Chiller 1 capacity of 460 tons, enable Chiller 1 and leave Chiller 2 enabled. If the total demand drops to less that 75% (Adj.) of the rated Chiller 1 load of 460 tons, disable Chiller 2. On any demand based switchover from either chiller, enable the new lead chiller for at least 5 (Adj.) minutes before the new lag chiller is disabled. Provide independent minimum on and off times for both chillers as set the minimum on at 30 minutes (Adj.) and the minimum off times at 10 minutes (Adj.)

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<th>If Secondary BTU Load</th>
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<td>Lead</td>
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<td>&gt; 195.5 Tons</td>
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<td>&lt; 172.5 tons</td>
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HVAC

Cx Issues (Highlights)

- Introduction of plenum divider in system design (peer review)
- Boiler – fail safe operation (BMS relay did not allow for local control)
- AHU fan tripping issue
- Pressure issue on upper floors
- Other Misc. Issues
  - Lack of condensate drain piping on some units
  - Leakage in the boiler flue stack
  - Loop tuning / controls issues
  - CHW differential pressure not monitored properly etc.
- High natural gas usage during construction
  - Found that the hot water valves were left full open at night – overrides were requested as part of test and balance but not released
AHU – Fan Tripping Issue

Initial Diagnosis of the Problem…

AHU-1

Fan Trips on High Static

Floor Dampers Close

AHU-2

Fan Trips on High Static

Floor Dampers Close
AHU – Fan Tripping Issue

5 Second Trends Revealed….

AHU-1

Fan Trips on High Static

Floor Dampers Closed

X

X

AHU-2

Fan Trips on High Static

Floor Dampers Closed

X

X
Building Pressurization Issue

Observations
- Upper floors experienced high negative pressure
- Alongside pressure issue, high noise experienced from the return grille (> NC 45)
- High winds in the elevator lobby
- High wind speed from core to stairwell area

Investigations
- Potential relation with the elevator shaft?
- Perhaps relief damper for the stairwell is not operating properly
- Building pressure sensors out of calibration or located incorrectly?
- RAF and Exhaust damper controls?
Parties Involved in Issue Resolution – Joint Site Inspection and Investigation

- Owner
- Design Team
- Design – Peer Reviewer
- General Contractor
- Mechanical Contractor
- Cx Agent
- TAB Contractor
- AHU Vendor
- Chief Building Engineer
- Fire Life Safety Contractor
- Owner
- Design Team
- Design – Peer Reviewer
- General Contractor
- Mechanical Contractor
- Cx Agent
- TAB Contractor
- AHU Vendor
- Chief Building Engineer
- Fire Life Safety Contractor
Goal is to have enhanced visibility on electrical usage and the capability to breakdown power consumption for HVAC, Lighting and Plug Loads

Main HVAC equipment is metered separately (by PMCS)

Plug loads can be calculated based on “Overall load - HVAC load”

Renewable energy generation is also monitored

Power is monitored at the distribution panel level; system also has breaker level usage monitoring for 120/208 volts circuits
Power Monitoring and Control System

Cx Issues

- Commissioning scope did not cover full system, only integration aspects with IBS

- CT sizing issues identified - CTs sized too high for monitoring the associated loads

- Back-up generator meter needed to be powered to push data out, when not powered, it provided an incorrect reading
Living Machine

System Overview
Commissioning Challenges
Several Interactive Systems

- Optimize BTU load
- Maximize Views
- Optimize Electric Load
- Maintain foot candle set point
- Maintain Space
- Comfort
- Optimize central plant load
Commissioning Challenges

- **Fast Tracked schedule and occupancy**
  - Needed to test the systems as and when contractor notified completion
  - Issue verification for the tested systems went hand in hand with new system testing
  - Weeknights and Weekends had to be utilized to achieve the completion of commissioning in the given timeline
  - Had to commission few systems with partial occupancy

- **Dealing with Recurrent and Intermittent Issues**
  - Multiple verification visits had to be performed for some issues with HVAC / Shades
  - Discussed strategy with owner and contractor to assure issue resolution
Commissioning Challenges (cont.)

- **System Balancing**
  - Many complex components in the HVAC system
  - Challenges with fan wall operation, comfort issues, pressure considerations and complicated control strategies with interactive effects
- **Large number of systems under scope**
  - Had to focus on multiple systems simultaneously - construction through occupancy
  - Tracking issues on each system and coordinating with various subs for commissioning
  - Tracked non-Cx issues during the commissioning meetings
Lessons Learned
Commissioning Lessons Learned

- Considerations need to be given to several aspects – operability, occupant comfort, aesthetics, energy consumption, stability and functionality.

- For complex, visible and highly optimized occupant comfort systems, education goes hand in hand with ensuring correct performance.

- Controls logic and integration meeting even more important for interactive systems such as shades, lighting etc.

- Submittal Reviews – Shop drawings as important as product data

- Zone Level Controls as important as main AHU controls
What Contributed to Project Success

- Strong Owner’s involvement in Design through Post Occupancy
- Involvement of Building Engineering Team - Chief Engineer on board several months before turnover
- Owner fostered project team cooperation
- GC’s Commissioning Coordinator’s leadership of subcontractors
- Comprehensive use of commissioning checklists as a sign off document
- Regular use of Issues List to keep track of project progress, issues, timeline, status, future enhancements etc.
- Regular Cx Meetings – Pivotal in driving issues to resolution and monitoring project progress
What Contributed to Project Success (Cont.)

- Clear vision of the project
- Strong Cx team
- Involving the Cx team early
- Careful design review of the project
- Owner’s involvement through design comments resolution
- Monitoring team cooperation at start of each phase not in middle
- Plan for systems equalization before completion of integration
- Bringing system vendors together early for controls integration
- Early occupant engagement
Acknowledgements

- Brook Mebrahtu, Department of Public Works
- Shelby Campbell, San Francisco Public Utilities Commission
- Mark Lawn, Able Engineering
- Kelly Galloway, KMD Architects
- Michael Rossetto, KMD Architects
- Dan Knickerbocker, Webcor Builders
- Phil Williams, Webcor Builders
- Matt Rossie, Webcor Builders
- Andrea Weisheimer, Webcor Builders
- Alex Brown, SJ Engineers
- Neil Joson, SJ Engineers
- Steve Taylor, Taylor Engineering
- Jim Sinopoli, Smart Buildings
- Andres Szmulewicz, Smart Buildings
- Gustav Deuss, GRD Energy
- Doug Chamberlin, EnerNOC
- Joshua Kuempel, EnerNOC
Q & A

Masoud Vafaei, Green Building Commissioning Program Manager, San Francisco Public Utilities Commission

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Doug Chamberlin, Director of Energy Services, Northwest Region, EnerNOC