AABC Commissioning Group

AIA Provider Number: 50111116

Commissioning in the Real World: A Case Study

Course Number: CXENERGY1508

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Siemens Industry

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Course Description

This presentation will explore how commissioning strategies meet real world challenges. Learn about the good, the bad and the ugly of a recent project at the HP headquarters building in Palo Alto, CA.

This project involved commissioning select equipment serving over 490,000 square feet of conditioned office space in an expedited timeframe of 5 weeks. The results were improved system performance and identification over 300,000 kWh/year and 20,000 Therms/year in potential energy savings from diagnosis and remediation of inaccurate sensors, mechanical failures, and controls issues.

Learning Objectives

At the end of the this course, participants will be able to:

1. Tailor common commissioning practices and strategies to meet real world challenges.
2. Understand how commissioning strategies can be used to enhance system performance and increase energy efficiency.
3. Learn to diagnose inaccurate sensors, mechanical failures and controls issues.
4. Understand the steps necessary to remedy building performance shortcomings stemming from faulty building sensors, mechanical systems and controls.

HP Building 20

Key Building Characteristics:

- Approximately *490,000 SF over 4 levels* (A, B, C and D).
- A *37,700 SF, annex was added in 2013*, the Executive Briefing Center and new front lobby for the Headquarter Building.
- Key Systems included: (23) Air Handling Units, (1) AC Unit, (3) Chillers, (2) Cooling Towers, and (4) Boilers.
- Primary Function is *office space and showcase for executive customers*.

HP Building 20

Source: Image taken from Google Earth, March 2015

Goals for the Existing Building Commissioning at B20

Project Goal

- Complete all assessment, investigation and implement approved corrective actions by *April 30, 2014*.
- Support the target of *reducing GHG emissions to 20 percent* below 2005 levels. (Energy use accounts for 98 percent of the greenhouse gas (GHG) emissions generated by operations at HP.)
- Identify *corrective actions and measures* through the project.
- Achieve a *simple payback of 2.5 years* for the overall project through energy improvement measures executed during the project.
- Review and document HVAC systems performance

Challenges:

Work Within the Customer's Expedited Timeline

Support Sustainability Target

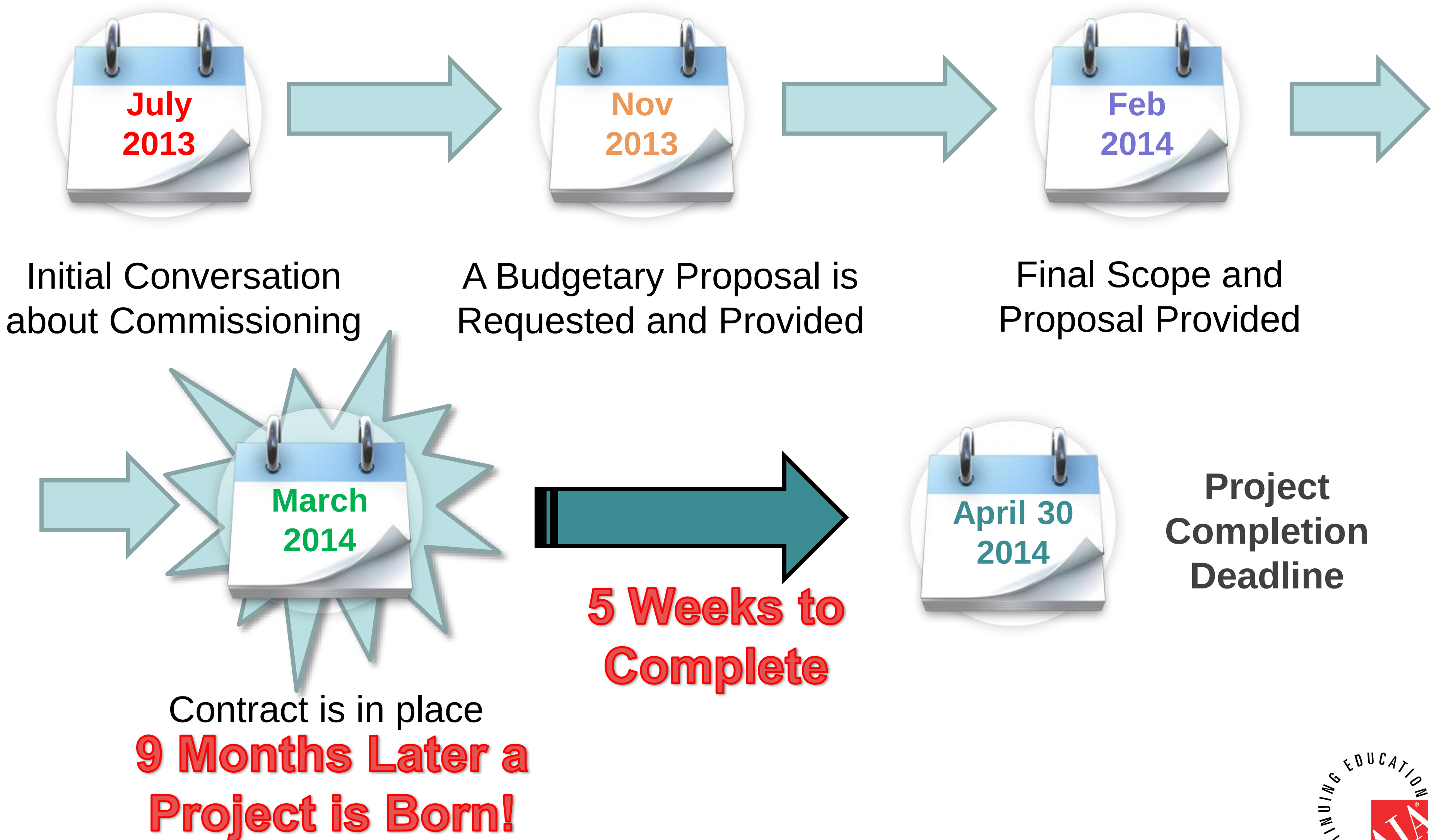
Find and Achieve Energy Savings

Document Performance

CONTINUING EDUCATION AIA

Challenge No. 1:
Time is not on our side

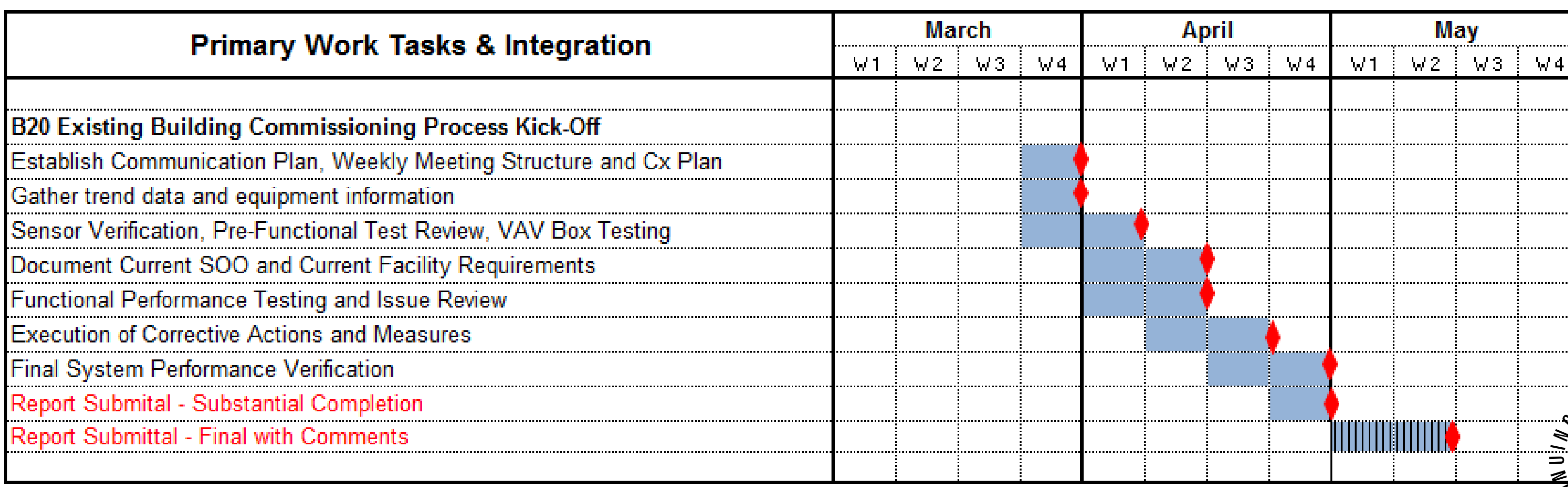
Project Development Timeline



Scope of Work for 5 Week Duration

- Verify (79) Critical HVAC Control Sensors
- Repair/Replace Faulty Sensors as found in Investigation
- Verify Current SOO's with Existing Controls Programming
- Confirm Current Facility Requirements
- Functionally Test Major HVAC Systems
- Investigate a Representative Sample (20%) of VAV boxes
- Recommend Corrective Actions and Measures for Found Issues
- Execute Approved Corrective Actions and Measures

HP Bldg 20 - Project Schedule

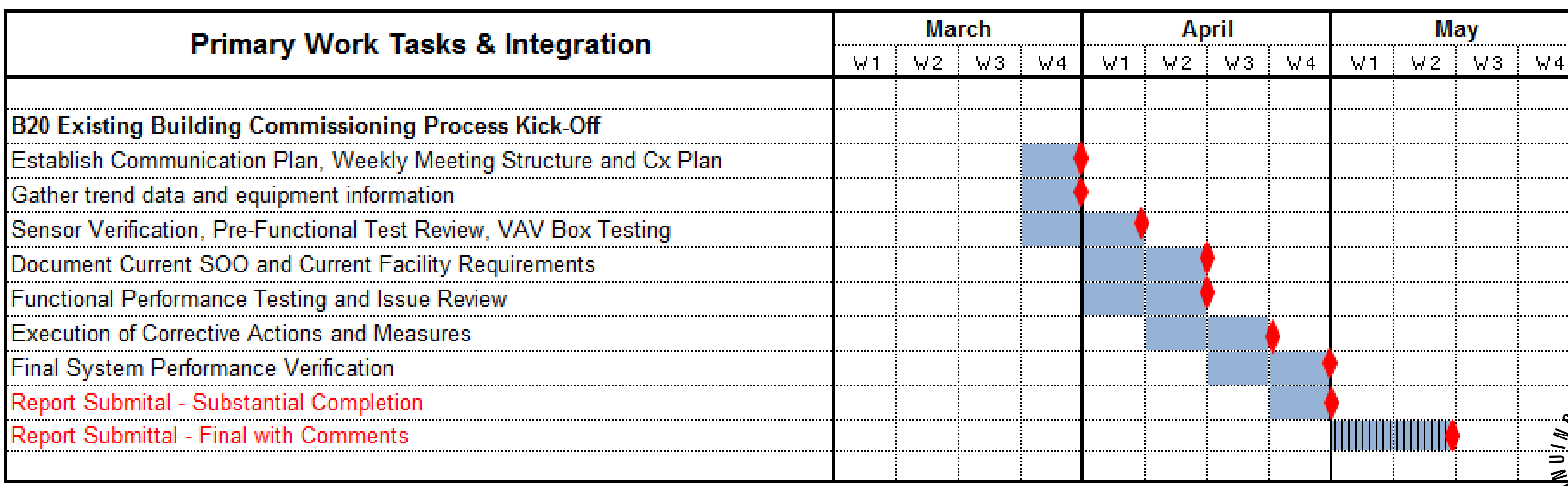


Plan the Process

Key Take Aways:

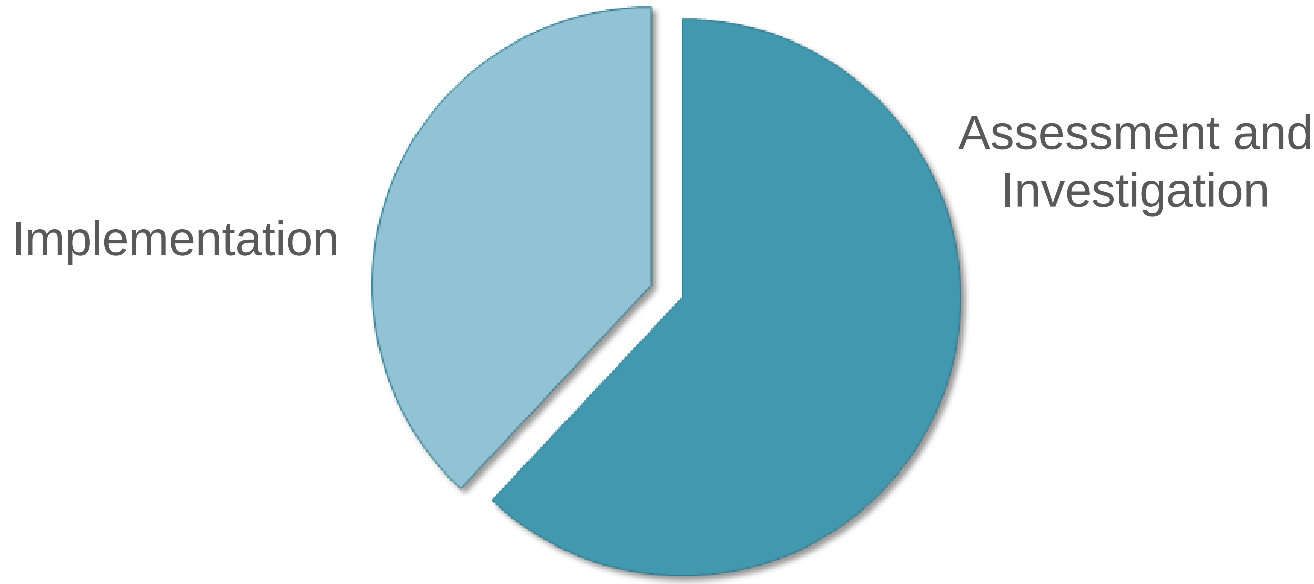
- Identify and address all resource needs
- Identify critical path tasks and potential risks
- Obtain early commitment of other involved parties
- Be clear and direct in communication
- Set up a workflow that has a bias to action
- Gather you data and information as early as possible

HP Bldg 20 - Project Schedule



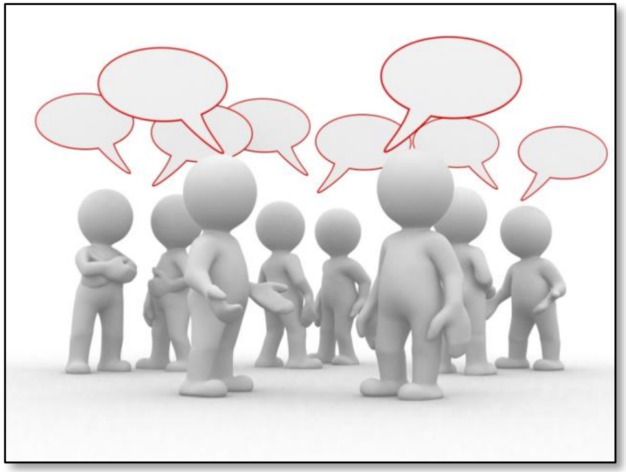
Project Budget Breakdown

- Approximately *62% of the project budget was allocated to the Commissioning Activities of Planning, Assessment, Investigation and Verification*.
- The remaining *38% was set aside for the implementation budget*, to perform low cost corrective actions and measures.
- Low cost corrective actions and measure included replacing faulty sensors, VAV box zone controllers, minor repair to mechanical devices (i.e. dampers and linkages).

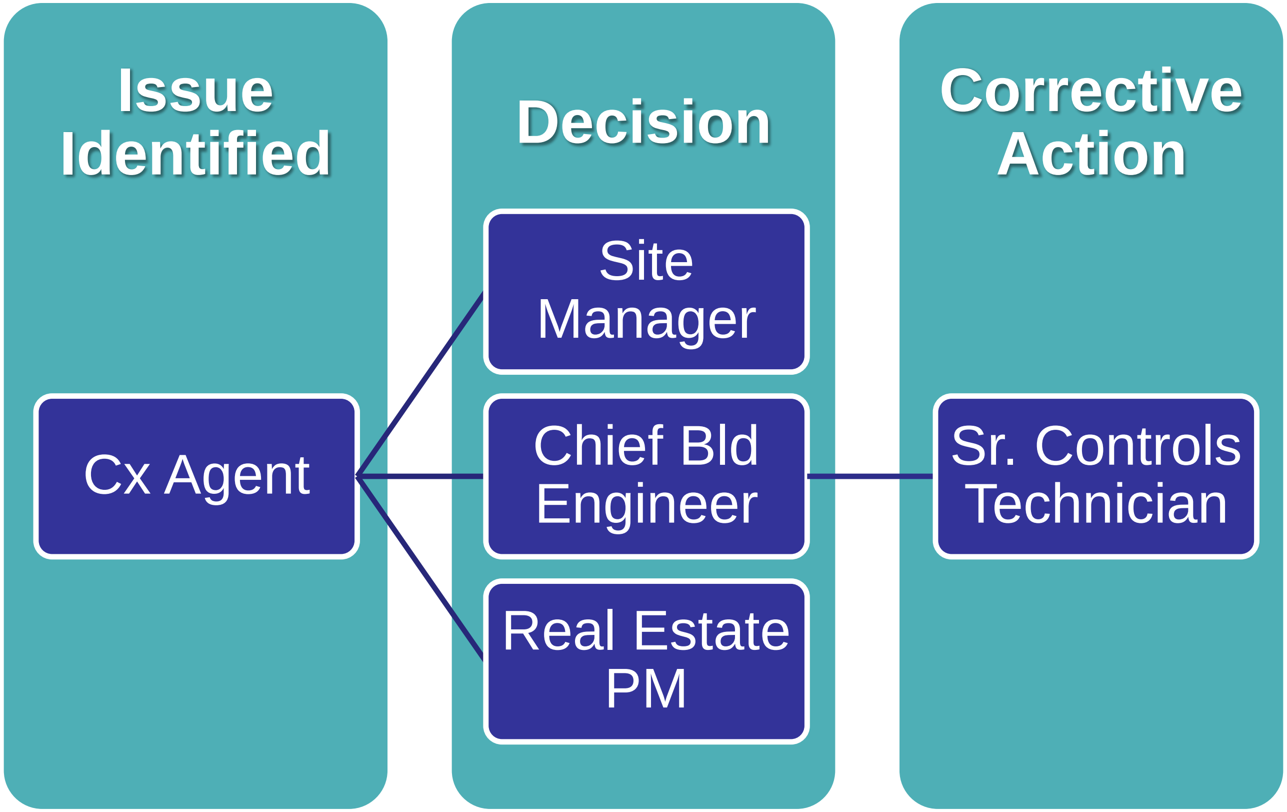


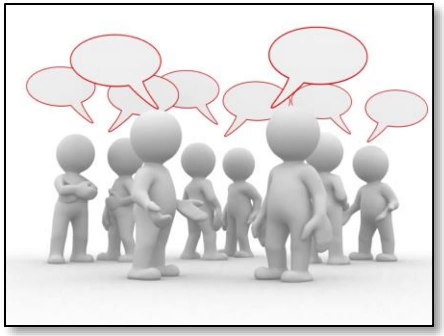
Communication and Collaboration

- Stipulated in the proposal that access would be readily available.
- Weekly Status Meetings were established with the focus of making decisions at the meetings.
- A communication document was created early on and roles/ responsibilities were discussed.
- Parties involved in the process:
  - Commissioning Agent
  - Site Manager
  - Chief Building Engineer
  - Corporate Real Estate Project Manager
  - Facility Management Company Representative
  - Corporate Sr. Mechanical Engineer
  - Sr. Controls Technician (dedicated for duration of project)
  - Calibration Services Team



Bias towards Action

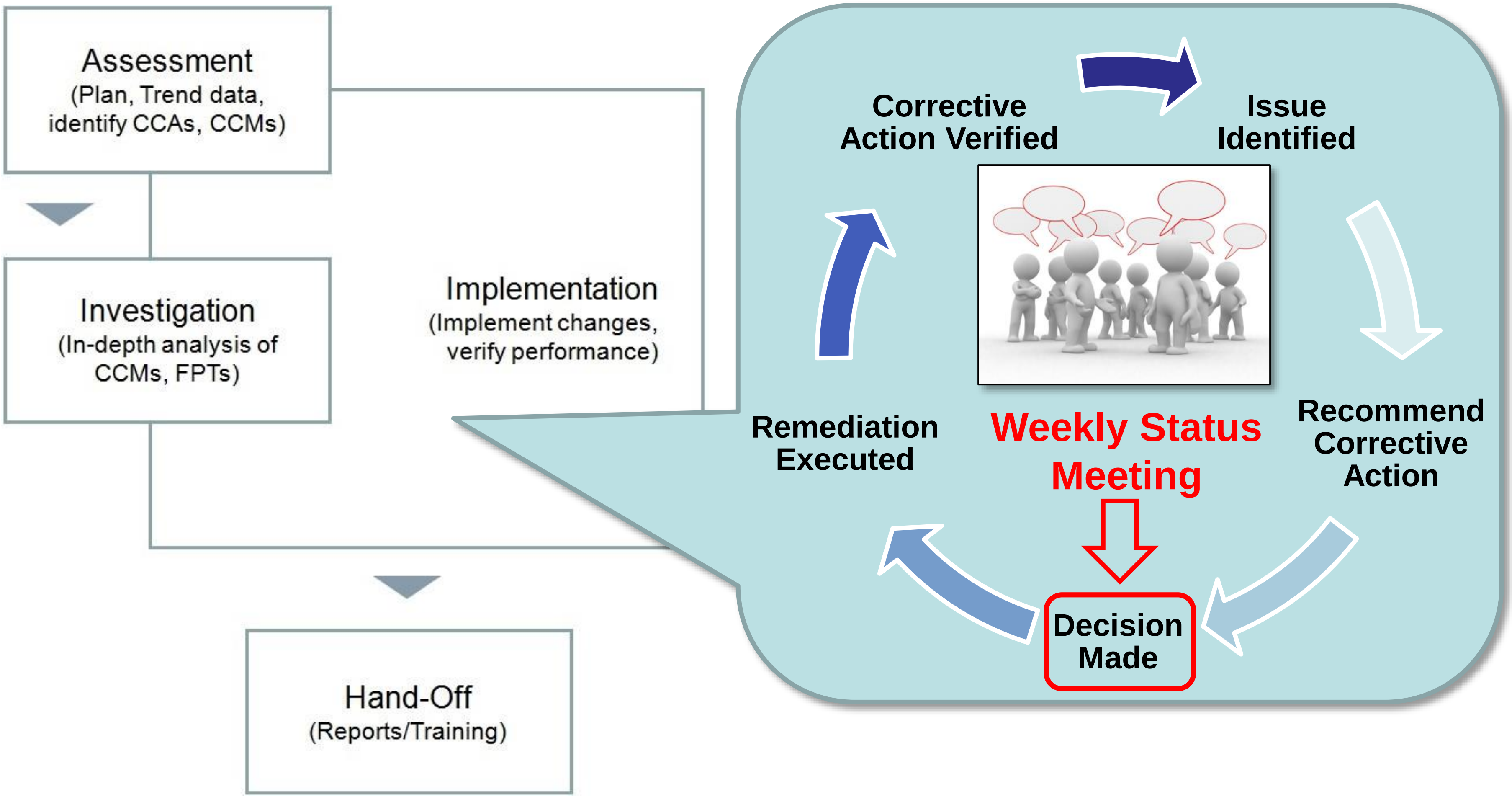




Project Team and Meeting Structure created to support a Fast Track Workflow

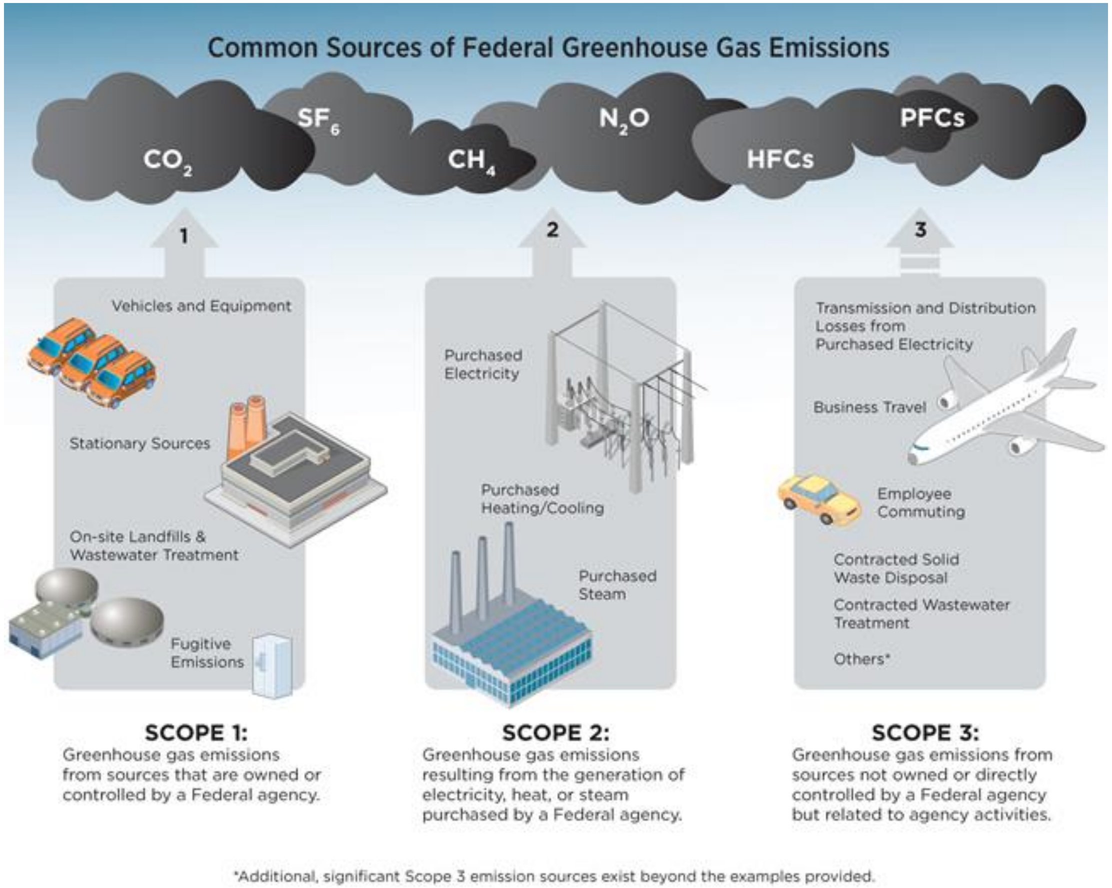
Informed Advisors:
Facility Management Company Representative
Corporate Sr. Mechanical Engineer

Fast Track Workflow



Challenge No. 2:

Reduce GHG Emissions through Energy Savings

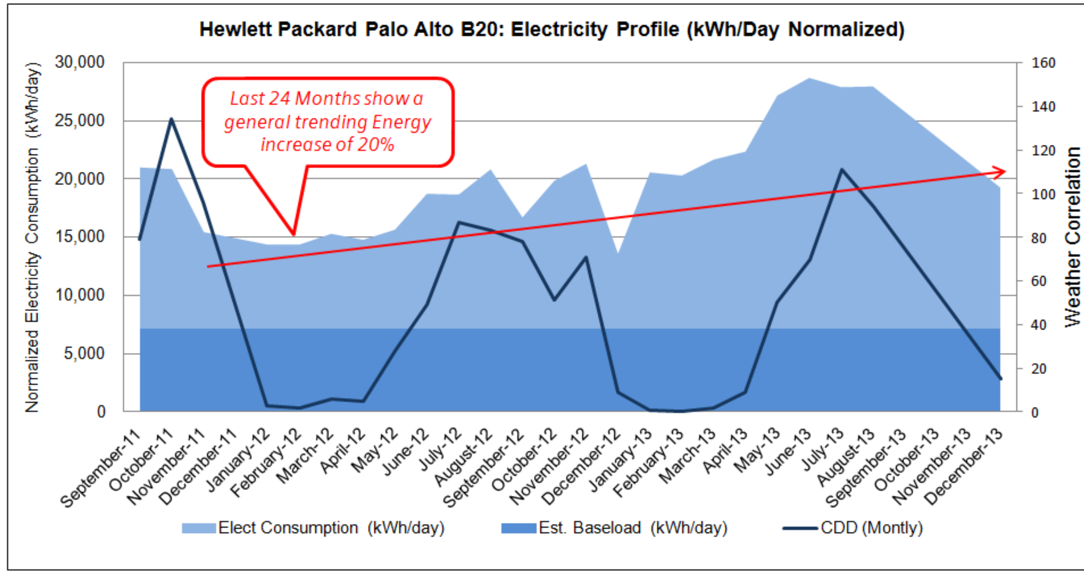


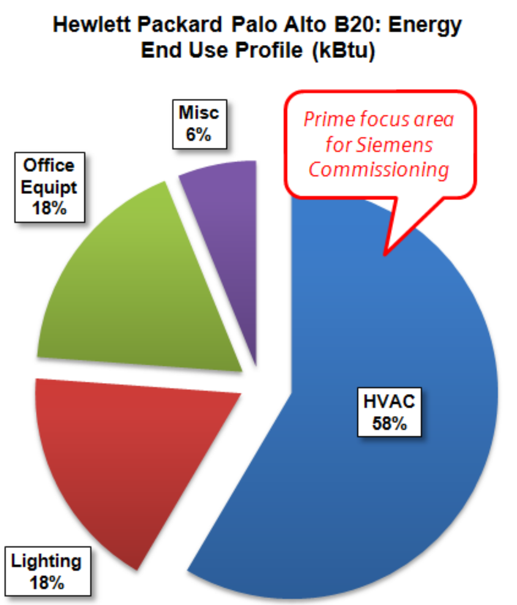
Energy Profile of Building 20

Building Energy Performance Scorecard

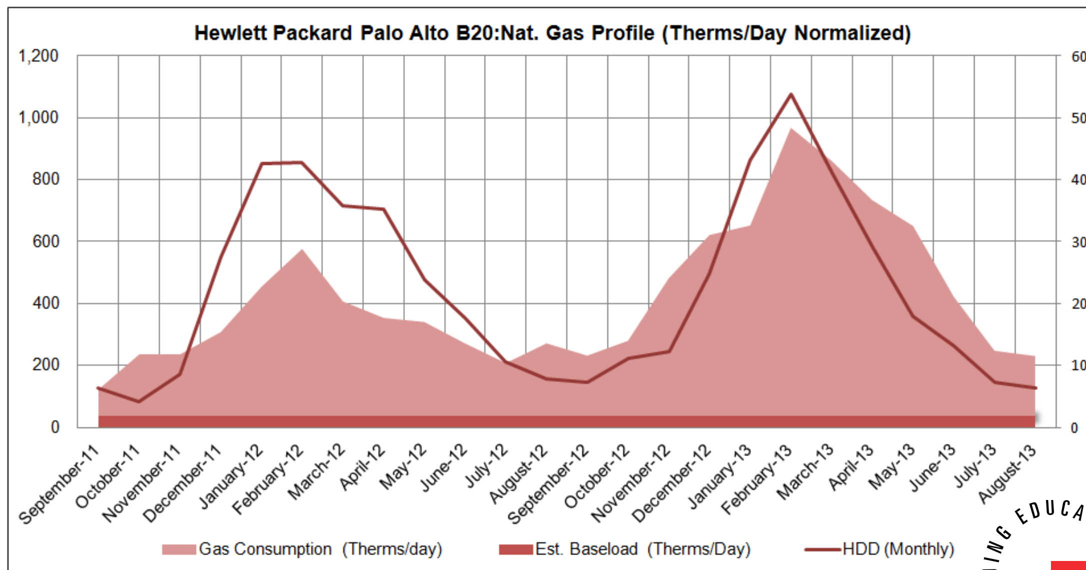
Your Energy Use Intensity	↑	70	kBtu/SF-Yr
Market Average EUI		81	kBtu/SF-Yr
Elect: Energy Rate	→	$0.100	$/kWh
Gas: Energy Rate	↓	$1.25	$/Therm
Elect: Peak to Base	↓	44%	Ratio
Gas: Peak to Base	↑	14%	Ratio
Elect: Weather Correlation	↓	0.191	R^2 Value
Gas: Weather Correlation	→	0.562	R^2 Value
Peak Electricity Month (kWh)		Jul-13	Month-Year
Peak Demand Month (kW)		Nov-12	Month-Year
Peak Gas Month (Gas)		Feb-13	Month-Year

Siemens Energy Services (Nor-Cal Area Team, MH 06/28/13)





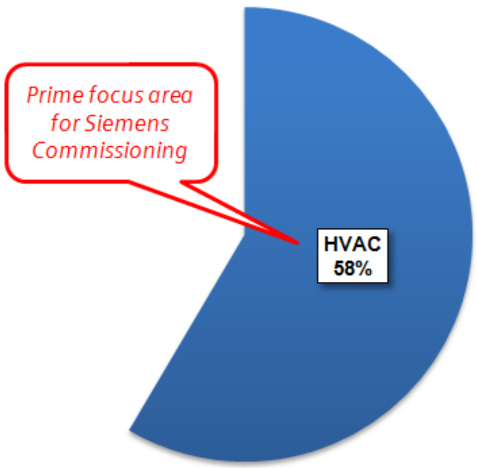
*Estimated from CEUS 2006 data



Focused Investigation

- Given the Fast Track nature of the project where do we start?
- What systems have the largest impact on energy consumption?
- What systems or areas are most prone to failure?
- What devices drive the systems?

Follow the Money… eh..Energy!



(23) Air Handling Units
(3) Chillers
(2) Cooling Towers
(4) Boilers

Outside Air Dampers
Critical Sensors

Sensors: Critical Point of Failure

- This outside air sensor, located in an alcove is the reference for (14) of the (23) air handling units in the building.
- This sensors was found to **6 degrees off** from the calibrate reference reading.

OAT Reference

Economizer Enable

Chiller Enable

Boiler Enable

AHU Pre-Heat Enable

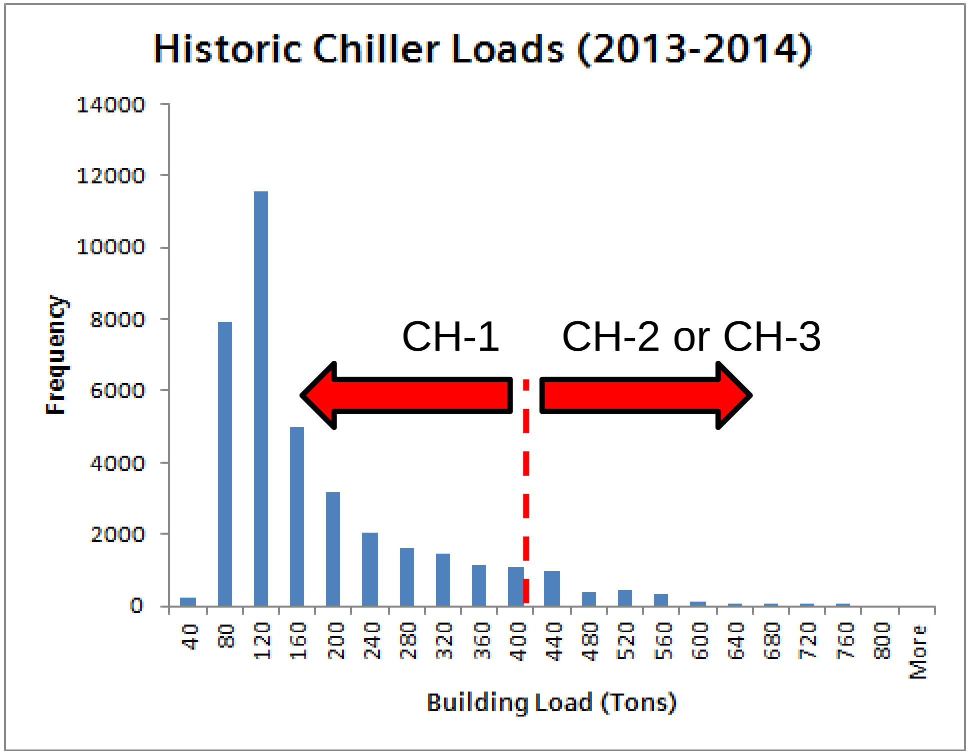
Sensors: (<u>Don't</u>) Trust but ***Verify***

- This was a new combination sensor was used in the annex area. (Installed in 2013)
- This sensors was found to **4 degrees off** from the calibrated reference reading.

Chiller Lead/Lag Staging

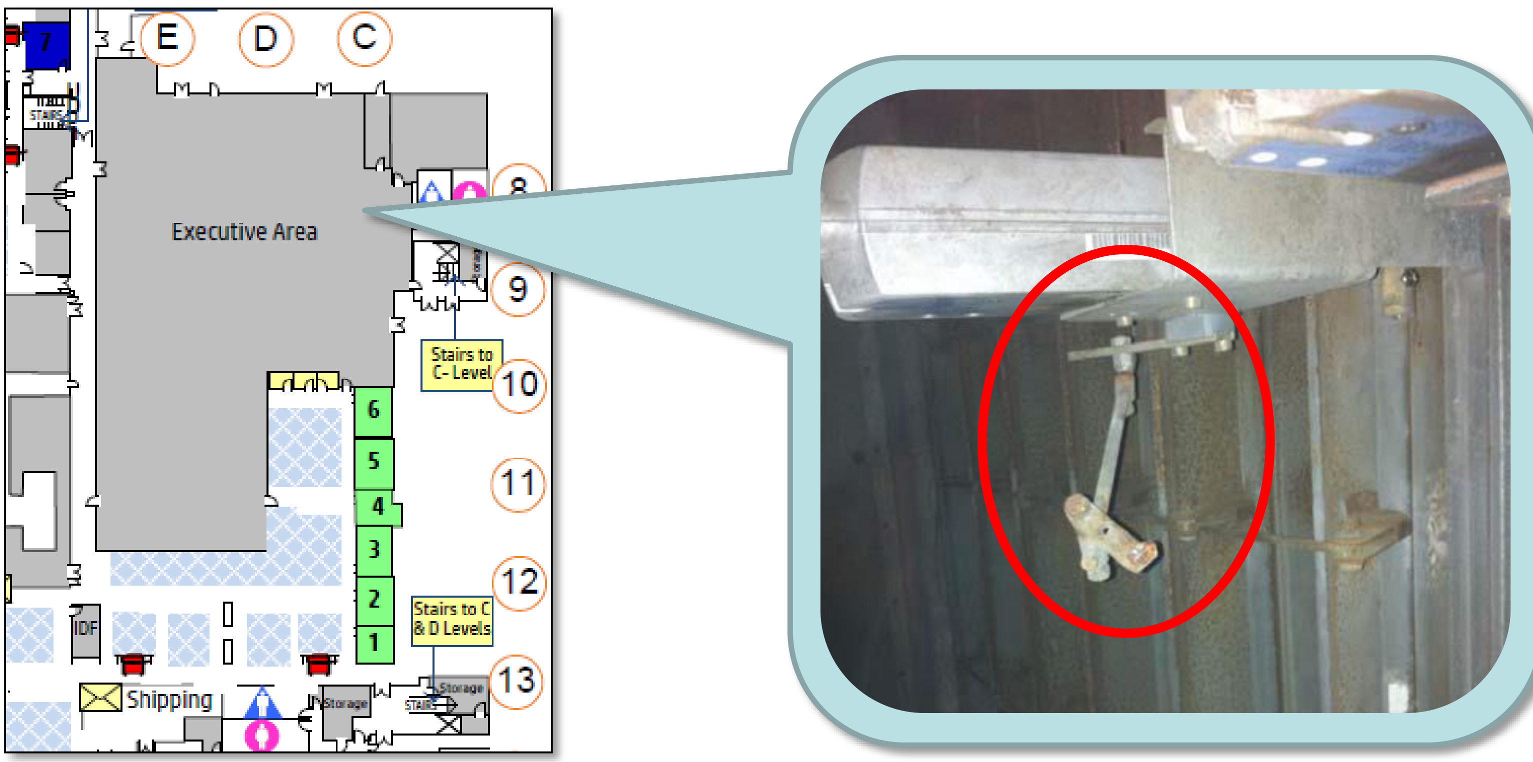
- The Building Chief commented that the CH-1 stays on when switching over to CH-2 or CH-3
- The Chiller Capacities: CH-1: 450-Ton, CH-2: 600-Ton, and CH-3: 800-Ton

Tons	*Frequency*
40	237
80	7920
120	11587
160	4985
200	3156
240	2033
280	1639
320	1476
360	1112
400	1060
440	996
480	392
520	440
560	309
600	94
640	45
680	8
720	4
760	3
800	0
More	0



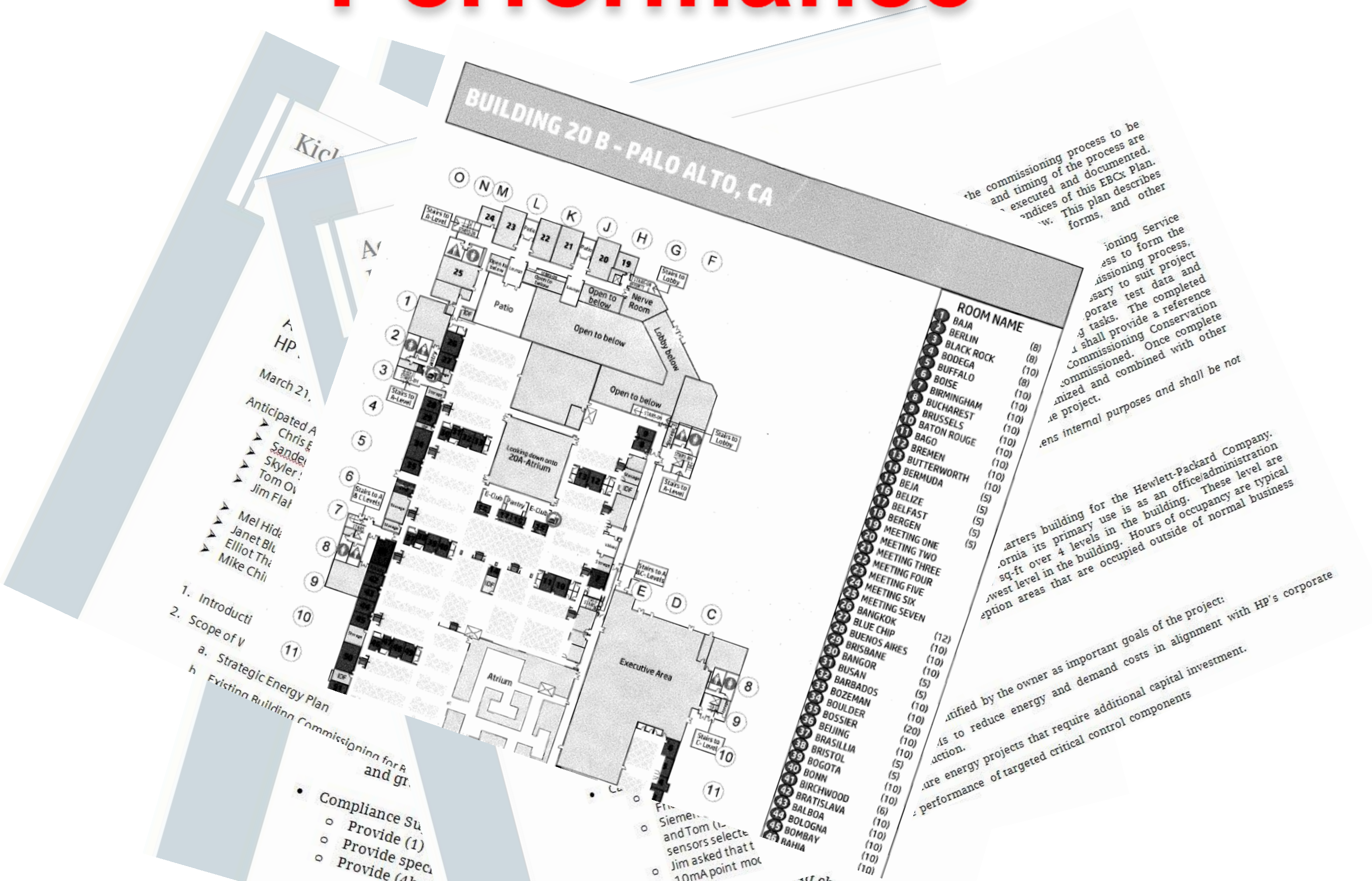
Broken Damper Linkage

- This broken linkage was on the air handling unit serving an executive area.
- First clue was inspecting the fan room and seeing the VFD at full speed.
- This area cannot be readily access and therefore this issue went undiscovered for a period of time.



Challenge No. 3:

Document System Performance



Key Documentation Tasks

- Utility Data Analysis (Performance Baseline)
- Current Facility Requirements (CFR)
- Current Sequence of Operations (SOO)
- Functional Performance Test (FPT) of Specific HVAC Equipment
- Issues Log
- Recommended Commissioning Corrective Action and Measures (CCA/CCM)

Assessment Phase
- Utility Data Analysis
- Current Facility Requirements

Investigation Phase
- Sequences of Operations
- Functional Perf. Tests

Cross-Phase Documents
- Issues Log
- CCA/CCM List

Determining Current Sequence of Operations

Turn This…

(Raw BAS Code)

```
00992   C
00994   C   -------SET UP THE NAME OF THE MECHANICAL SYSTEM-------
00996   C   REPLACE WITH MECHANICAL SYSTEM.
00998   C
01000   DEFINE(X,"B20.AHU-1.")
01005   DEFINE(Y,"HP.B20AnX.AHU-")
01094   "B20.PXCC01.BATTERY" = $BATT
01096   C   -------USER DEFINED LOCAL POINTS-------
01098   C
01100   LOCAL(MADRMP,COOLON,COLOFF,MADRCT,MADCTL,MATCTL,MAD,MOAD,ECONDB,SPFRMP,RNFRMP)
01110   LOCAL(RMTPG,RMTIG)
01120   LOCAL(BSPPG,BSPIG,BSP100,BSS100)
01130   LOCAL(OCFPG,OCFIG,OCF10,OCS10,MAM)
01140   "B20.AHU-1.SMOKE" = "B20.AHU-1.SSD"
01194   C
01196   C   -------RESET TIMERS / COUNTERS-------
01198   C
01200   SAMPLE(5) IF("%Y%1.SF.VFD:RUN.STOP CMD" .EQ. ON) THEN "$MADRMP" = "$MADRMP" + 5 ELSE SET(0.0,"$M
01210   SAMPLE(5) IF("%Y%1.SF.VFD:RUN.STOP CMD" .EQ. ON) THEN "$SPFRMP" = "$SPFRMP" + 5 ELSE SET(0.0,"$S
01220   SAMPLE(5) IF("%Y%1.RF.VFD:RUN.STOP CMD" .EQ. ON) THEN "$RNFRMP" = "$RNFRMP" + 5 ELSE SET(0.0,"$R
01244   C
01246   C         -------CALCULATE AIR VOLUME FROM VELOCITY PRESSURE AND DUCT AREA-------
01248   C
01250   "B20.AHU-1.OCF" = ("B20.AHU-1.OA.VP") * 4.37
01260   C
01270   C CALCULATE KW LOADING OF THE FANS
01280   "HP.B20AnX.AHU-1.SF.KW" = ("%Y%1.SF.VFD:CURRENT" * "%Y%1.SF.VFD:OUTPUT VOLT")/1000
01285   "HP.B20AnX.AHU-1.RF.KW" = ("%Y%1.RF.VFD:CURRENT" * "%Y%1.RF.VFD:OUTPUT VOLT")/1000
01290   C 35 x 18 / 144 4.37      2.91 x 1.5 4.37     was 25
01292   C   -------SETUP THE RANGES FOR THE CONTROL VALVES & DAMPERS-------
01294   C   REPLACE ???CLS AND ???OPN WITH THE MINIMUM
01296   C   AND MAXIMUM SIGNALS FOR THE DEVICES.
01298   C
01300   TABLE("B20.AHU-1.CCO","B20.AHU-1.CCV",0,0,100,100)
01310   TABLE("B20.AHU-1.HCO","B20.AHU-1.HCV",0,0,100,100)
01320   TABLE("B20.AHU-1.MAO","B20.AHU-1.MAD",0,0,100,100)
01330   TABLE("B20.AHU-1.SVO","%Y%1.SF.VFD:INPUT REF 1",0,0,100,80)
01340   TABLE("B20.AHU-1.RVO","%Y%1.RF.VFD:INPUT REF 1",0,0,100,100)
01390   C
01392   C
```

…Into This

Air Handling Unit Sequence of Operations

The following sequence of operations was proposed, reviewed and installed as part of the Siemens EBCx Pilot Project at B20. (as of 06/05/14)

This sequence applies to: **B20 EBC AHU-1**

Occupied Mode:
When system is in occupied mode, turn on the supply and return/exhaust fans.

Unoccupied Mode:
When the system is unoccupied mode the following shall occur. The supply and return/exhaust fans shall turn off, the mixed air damper shall open to 100%, the outside air damper shall close to 0%, and the cooling and heating controls valve shall close to 0%.

Economizer Mode:
Decision Logic:
System shall switch over to Economizer Mode if the outside air temperature drops below the return air temperature. When the outside air temperature rises above the return air temperature + 2°F then Economizer Mode shall be turned OFF.

Economizer Mode ON:
When in Economizer Mode, the mixed air damper shall modulate so that the mixed air temperature set point is maintained.

Economizer Mode OFF:
When Economizer Mode is OFF, the mixed air damper shall be commanded to minimum damper position.

Temperature Control:
Cooling Control Valve Logic:
As the supply air temperature loopout value varies between 55 and 100, the cooling control valve shall modulate between 0% and 100% open.

Heating Control Valve Logic:
As the supply air temperature loopout value varies between 45 and 0, the heating control valve shall modulate between 0% and 100% open.

Deadband:
When the supply air temperature looput value varies between 45 and 55, both the cooling and heating control valves shall be closed.

Logic Table:

SAT Loopout	CCV (% Open)	HCV (% Open)
100	100	0
55	0	0
45	0	0
0	0	100

Rinse and Repeat

- Even though there were (23) individual air handling units in the building there were *only (5) unique applications*.
- Therefore once the functional test form was optimized on one air handling unit it could be used on all others with the same application.

VAV AHU Performance Test
VAV AHU Performance Test
VAV AHU Performance Test

VAV AHU Performance Test

Equipment Tag	**AH-01 (Level A)**
Testing Date	04/17/14-04/18/14
Technician Name	Dunn Rosete
General Notes	

Task	Procedure	Results/Relevant Data
Calibration Notes	Verify sensors within calibration interval	
	Current Calibration/Verification Date:	Verified as of 03/28/2014
Trend Verification	Verify the associated system trends	
	Verify the following points have been trended:	

Description	Point Name	Description	Point Name
CCV	B20A.AH01.CCV	SAT STPT	B20A.AH01.SAT.STPT
CFM DIFF	B20A.AH01.CFM.DIFF	SA CFM	B20A.AH01.SCF
DSS	B20A.AH01.DSS	HW STPT	B20A.AH01.SHW.STPT
ECM	B20A.AH01.ECM	HW TEMP	B20A.AH01.SHW.TEMP
HCV	B20A.AH01.HCV	HWV	B20A.AH01.SHWV
MAD	B20A.AH01.MAD	SSP	B20A.AH01.SSP
MAT	B20A.AH01.MAT	SSP STPT	B20A.AH01.SSP.STPT
MAT STPT	B20A.AH01.MAT.STPT	SYS	B20A.AH01.SYS
MOAD	B20A.AH01.MOAD	RF FREQ	B20A_AH01.A1E.RF:FREQ OUTPUT
RAT	B20A.AH01.RAT	SF FREQ	B20A_AH01.A1E.SF:FREQ OUTPUT
RA CFM	B20A.AH01.RCF	OAT	B20A.AH01.VOAT
SAT	B20A.AH01.SAT		

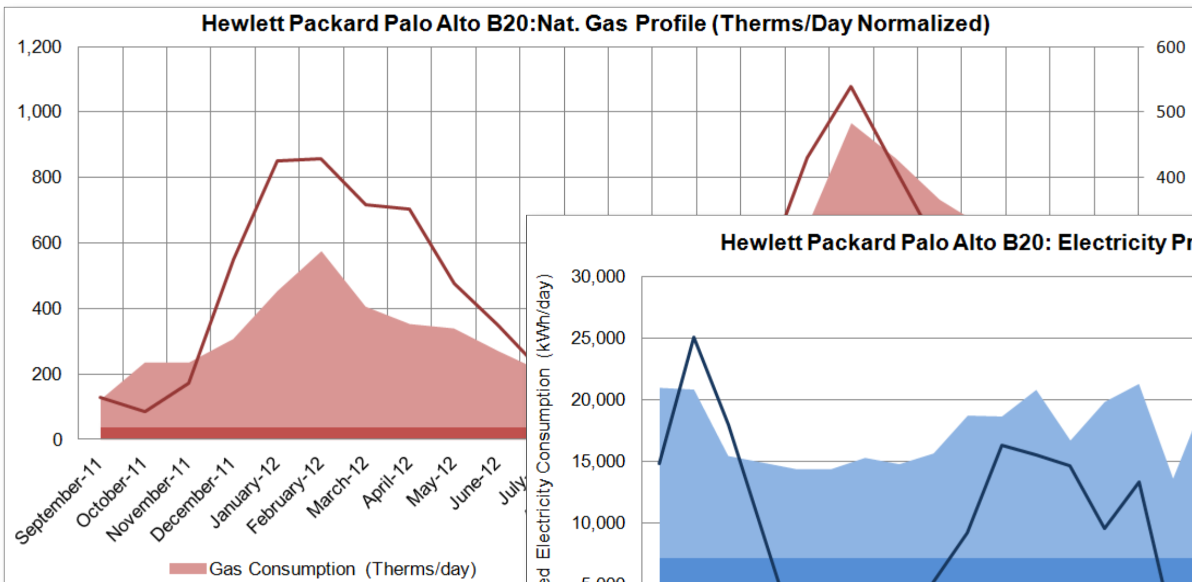
Task	Procedure	Results/Relevant Data
Schedule Confirmation	Verify the current operating schedule	
	1. Review the AHU STATUS point and confirm that the system schedules off	This unit is require to run continuously. Per discussion with the Building Engineer

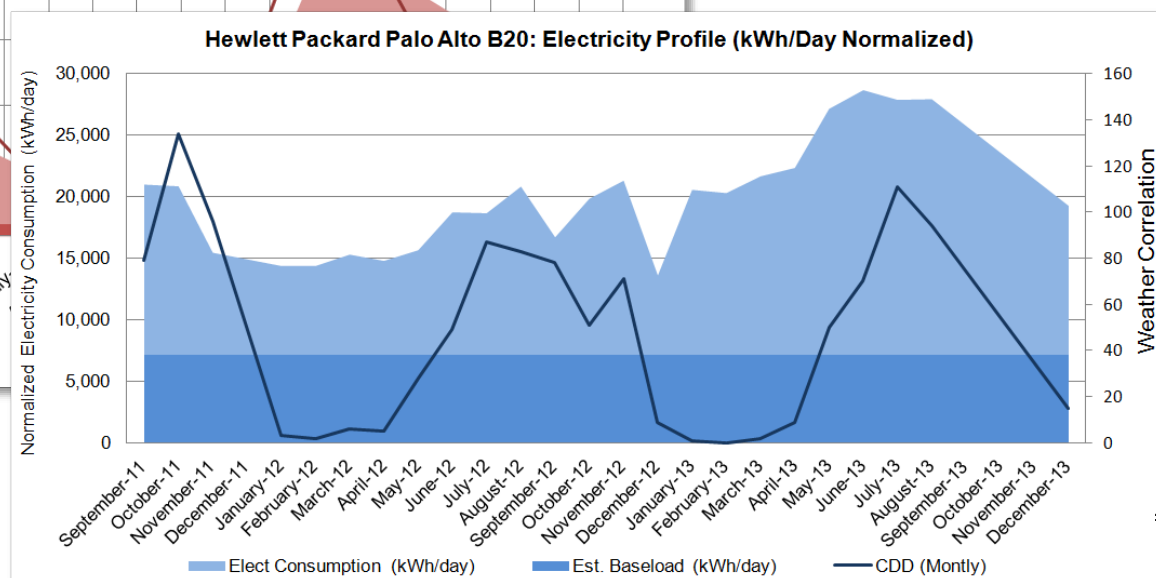
Challenge No. 4:
Utility Cost Savings (Achieve 2.5 Yr SPB)

Anticipated Energy Savings

Based on the building's energy profile and documented consumption over the last 24 months it was conservatively estimated that the corrective actions and measures would save…

420,000 kWh/yr and 11,000 Therms/yr which equates to approximately *$52,000/year.*

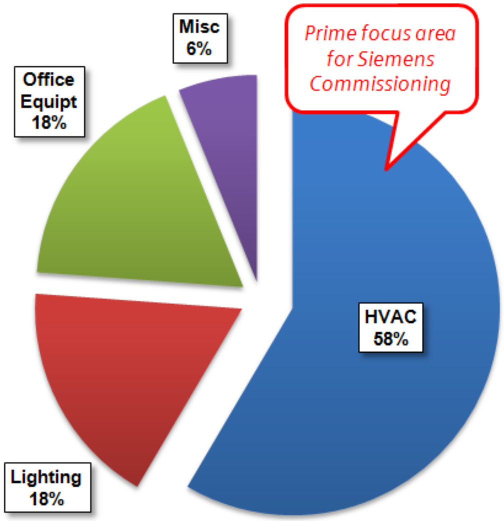




Sources of Savings

- Air Handling Unit Schedule Optimization
- Economizer Repairs
- Replacing Inaccurate, Mis-located or Faulty Sensors
- Chiller Staging Optimization
- Air Handling Unit Pre-Heat Lockout Adjustment
- After Hours Space Temperature Setback
- Supply Air Temperature Reset

Hewlett Packard Palo Alto B20: Energy End Use Profile (kBtu)



*Estimated from CEUS 2006 data

Energy Impacting Commissioning Corrective Actions/Measures

Energy Impacting CCA/CCMs:	Electricity Savings (kWh/yr)	Natural Gas Savings (Therms/yr)	Elect. Cost Savings ($/yr)	Nat. Gas Cost Savings (Therms/yr)	Energy Cost Savings ($/yr)
Schedule Optimization	59,659	7,510	$5,709.35	$7,833.33	$13,542.68
Supply Air Temperature Reset	75,244	3,585	$7,200.84	$3,738.78	$10,939.62
Chiller Staging Optimization	31,425		$3,007.37		$3,007.37
AH-05 (B Level) Economizer Repair	43,114		$4,126.02		$4,126.02
AH-04 (EBC) Economizer Repair	2,819		$269.82		$269.82
AH-12 (D Level) Economizer Repair	5,005	1,027	$479.02	$1,071.07	$1,550.09
After hours Schedule Setback	57,936	5,958	$5,544.47	$6,213.90	$11,758.38
OAT sensor repair (B20_OAT)	26,036	3,232	$2,491.65	$3,370.97	$5,862.62
OAT sensor repair (B20.AHU-1.OAT)	-73	97	-$6.97	$101.34	$94.37
Static Pressure Reset	30,728	1,783	$2,940.70	$1,860.02	$4,800.72
HW Pump Lockout Adjustment	4,594		$439.62		$439.62
Totals	336,488	23,192	$ 32,202	$ 24,189	$ 56,391

Results

- All items in the Scope of Work were able to be completed
- Year over Year energy consumption (As of Dec 2014) was reduced by over 940,000 kWh and 17,000 resulting in *over $96,000/yr in savings*
- (79) Sensors were verified, *(21) sensors were replaced*
- *(4) Failed VAV Box Controllers were replaced*
- *(2) Outside air damper linkages were repaired*
- *(1) Critical Outside Air Temperature Sensor was relocated*
- The following corrective/optimization measures or actions were taken:
  - AHU Schedule Optimization
  - Supply air temperature reset for select AHU's
  - After hours scheduled setback for select AHU's
  - Pre-heat lockout adjustment
  - Economizer controls were optimized for the AHU's
  - Chiller Staging was adjusted
- All systems reviewed (AHU's, CH's, CT's, and Boilers) had their Sequence of Operations documented.

Key Take Aways

- Firm *commitments up front* to the process and objective by all involved parties.
- Spending *extra time planning saves time in the long run*. On a fast track project you will probably not have time to make major planning adjustments.
- *Verify your sources* of information human, electronic or otherwise.
- Spend as much time as possible with the *Building Engineers*, their *knowledge is invaluable*.
- *Prep as much as possible offsite* because once you're on site it is easy to be led off course.

Questions?

This concludes The American Institute of Architects Continuing Education Systems Course

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