

Continuous Commissioning[®] Process

By

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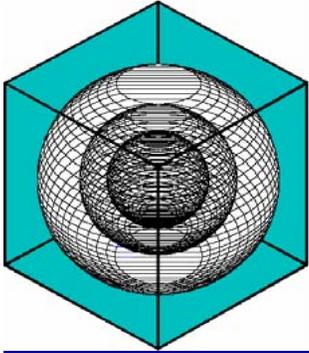
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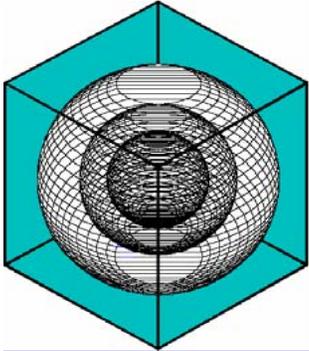
**Energy Systems Laboratory
Texas A&M University System
College Station, Texas**

**Presented at
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Orlando, Florida
August 2003**



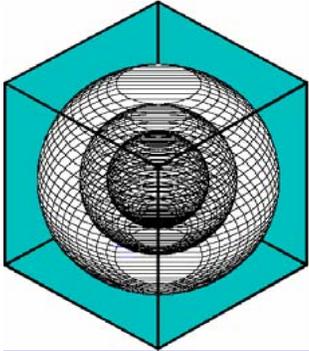
Continuous Commissioning[®] Process

- **Continuous Commissioning (CC[®]) is the process of optimizing building energy and plant energy systems to reduce energy consumption, improve comfort, and increase productivity**
- **Continuous Commissioning and CC are registered trademarks of the Texas Engineering Experiment Station (TEES), the Texas A&M University System, College Station, Texas**



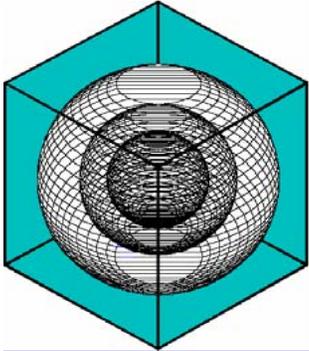
Outline of Presentation

- 1. Evolution of Continuous Commissioning Process**
- 2. Summary of Applications**
- 3. Energy Systems Laboratory Info**
- 4. CC Case Studies**
 - Terrell State Hospital**
 - Matheson Courthouse – Salt Lake City**
 - Prairie View A&M University**
- 5. CC Costs and Savings**
- 6. CC Assessment Process – 1st Steps**
- 7. Continuous Commissioning Guidebook for Federal Energy Managers**
- 8. Conclusions, Q&A**



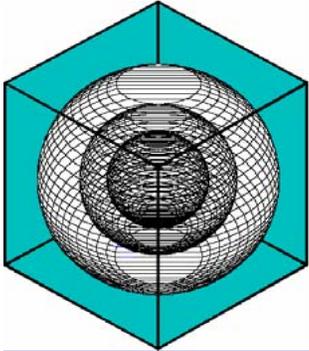
Evolution of Continuous Commissioning Process

- **LoanSTAR – Loans to Save Taxes and Resources (approved in 1988)**
- **\$98.6 Million Capital Retrofit Fund for Energy Efficiency Improvements**
- **DOE Demonstration Project (retrofits had to be metered and monitored for verification of energy savings)**
- **Texas A&M's Energy Systems Lab was selected as the M&V subcontractor**



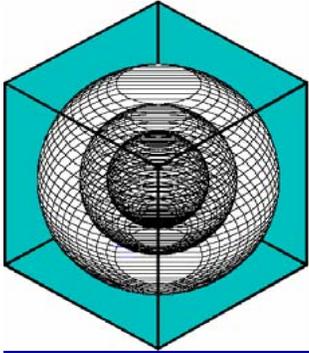
➤ **Evolution, cont'd**

- **Hourly data (electrical, NG, chilled water, steam, hot water, and some submetering) were coming into Energy Systems Lab**
- **Developed analysis methodologies to determine savings – IPMVP and ASHRAE 14P**
- **Had hourly data on hundreds of LoanSTAR buildings—Large, building energy consumption relational database**



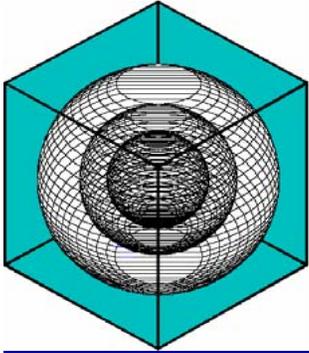
Evolution, cont'd.

- **Began analyzing the hourly data for operational improvements, i.e., systems which could have improved operation schedules or be shut off completely**
- **Called these O&M improvements (~1992)**
- **In 1993, we began the development of air-side models to analyze performance**



Evolution, cont'd.

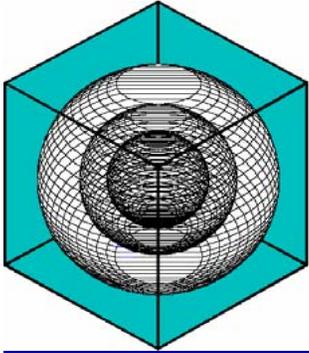
- **Started going into buildings to make operational improvements**
- **Commissioned the retrofitted buildings in LoanSTAR and made additional operational improvements**
- **Additional savings averaging 20% of utility bills were achieved (over and above the retrofit savings!)**



Summary of Applications of Continuous Commissioning

Can be applied to:

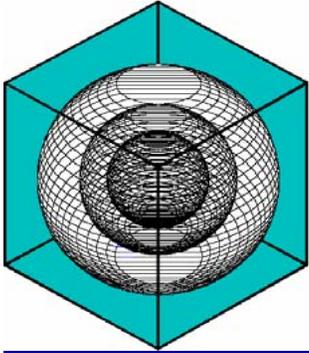
- **Buildings retrofitted for energy efficiency**
- **Existing buildings as a stand-alone process**
- **New (or nearly new) buildings as a stand-alone process**
- **Buildings/plants undergoing retrofits as an integral part of the retrofits, i.e., a CC Energy Conservation Measure**



Energy Systems Laboratory

A research laboratory specializing in:

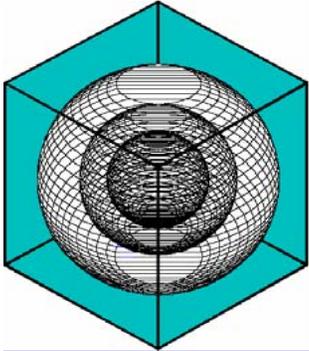
- **Energy management and conservation**
- **Building Continuous Commissioning**
- **Plant Continuous Commissioning**
- **Building metering and monitoring**
- **Energy savings analysis**
- **Electric utility deregulation**
- **Indoor air quality (mold, moisture, CO₂)**
- **Emissions calculations from energy efficiency**



Energy Systems Laboratory, cont'd.

Personnel

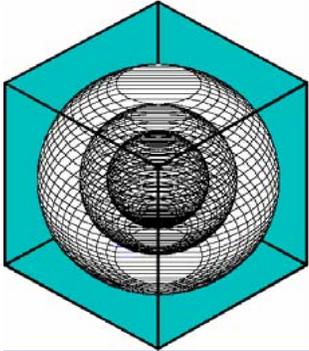
- 36 full-time staff
- 7 faculty
- 45 undergraduate and graduate students



Energy Systems Laboratory, cont'd.

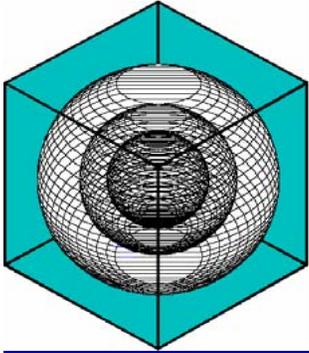
Facilities

- **Fan testing and certification facility**
- **Calibration laboratory (flow meters, electrical sensors, pressure, temperature, and humidity)**
- **Psychrometric chambers for air conditioning and heat pump testing and research**
- **Extensive computer facilities**
- **Thin-film photovoltaics test facility (in work)**



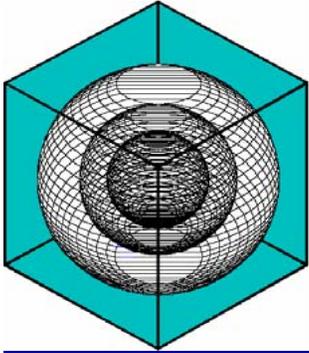
Continuous Commissioning Activities

- Presented 16 one- and two-day commissioning workshops
- Commissioned over 165 buildings, three central plants, three thermal storage facilities
- Currently conducting Continuous Commissioning services at Texas A&M University, TAMIU-Laredo, Prairie View A&M University, Alamo Community College District-San Antonio, and State of Utah buildings



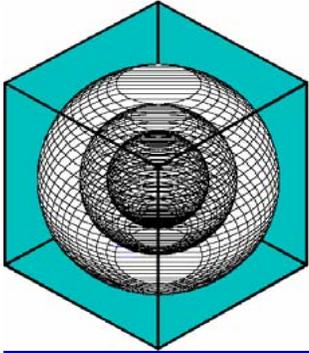
Continuous Commissioning Activities, cont'd.

- **Currently working on a licensing agreement to transfer the Continuous Commissioning process to private sector**
- **Several patents pending on CC process**

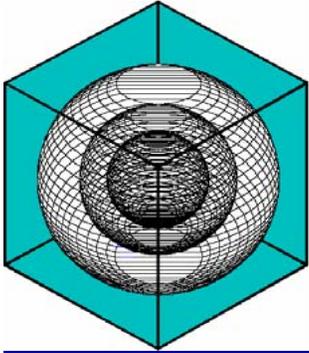


Case Studies

- 1. Terrell State Hospital (commissioned older, retrofitted facility)**
- 2. State of Utah – Matheson Courthouse (fairly new, modern building)**
- 3. Prairie View A&M University (includes CC as an ECM in a retrofit project)**

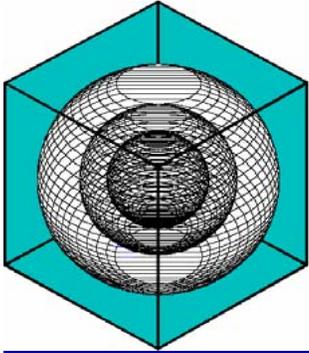


Continuous Commissioning of a Retrofit Project—Terrell State Hospital, Terrell, Texas



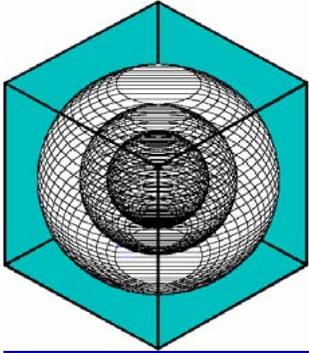
Facility Information

- **Building: 20 major buildings with a total floor area of 676,000 square feet**
- **Chiller system: 5 chiller plants connected to a 7000 ton-hr thermal storage system**
- **AHUs: 80**
- **Modern Control System**



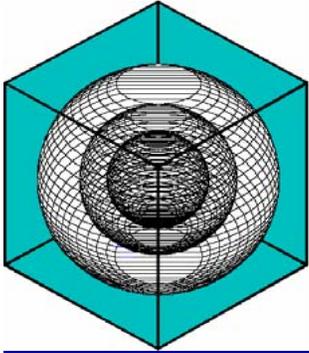
Special Issues

- **Old facility**
- **Operating staff is short of manpower**
- **Comfort problems exist in most of the buildings**
- **Thermal storage system operation is unstable**
- **Any modifications are subjected to pre-approval by operating staff**



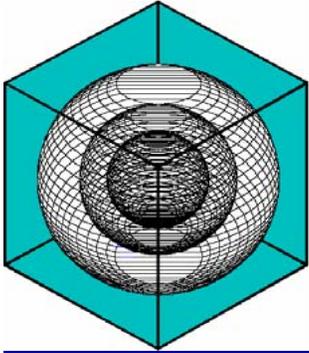
Retrofit Results:

- **Achieved only 55% of savings projected by design engineer**
- **Thermal storage system had to turn on a chiller during utility peak period**
- **Client could not repay loan from utility savings**
- **SECO asked ESL to investigate for possible commissioning opportunity**

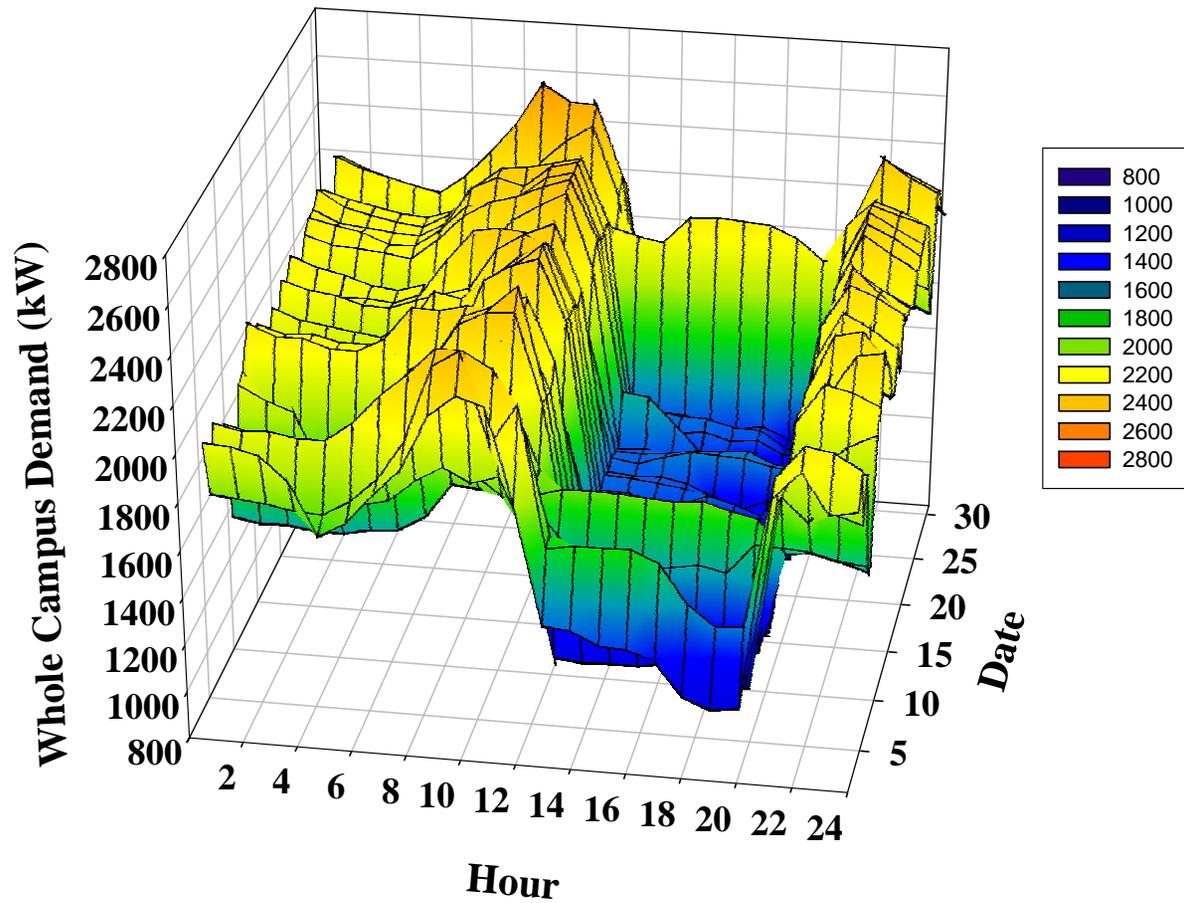


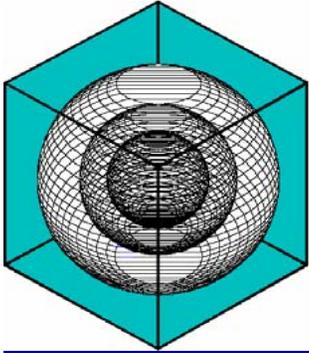
Findings:

- **Some controls hardware in place, but not connected**
- **Some controls hardware missing**
- **Lack of training of staff on new system**
- **No attempt to fix obvious HVAC problems within buildings**
- **Algorithms programmed into Controls System were not specific to facility**
- **Thermal storage charging/discharging not optimized**

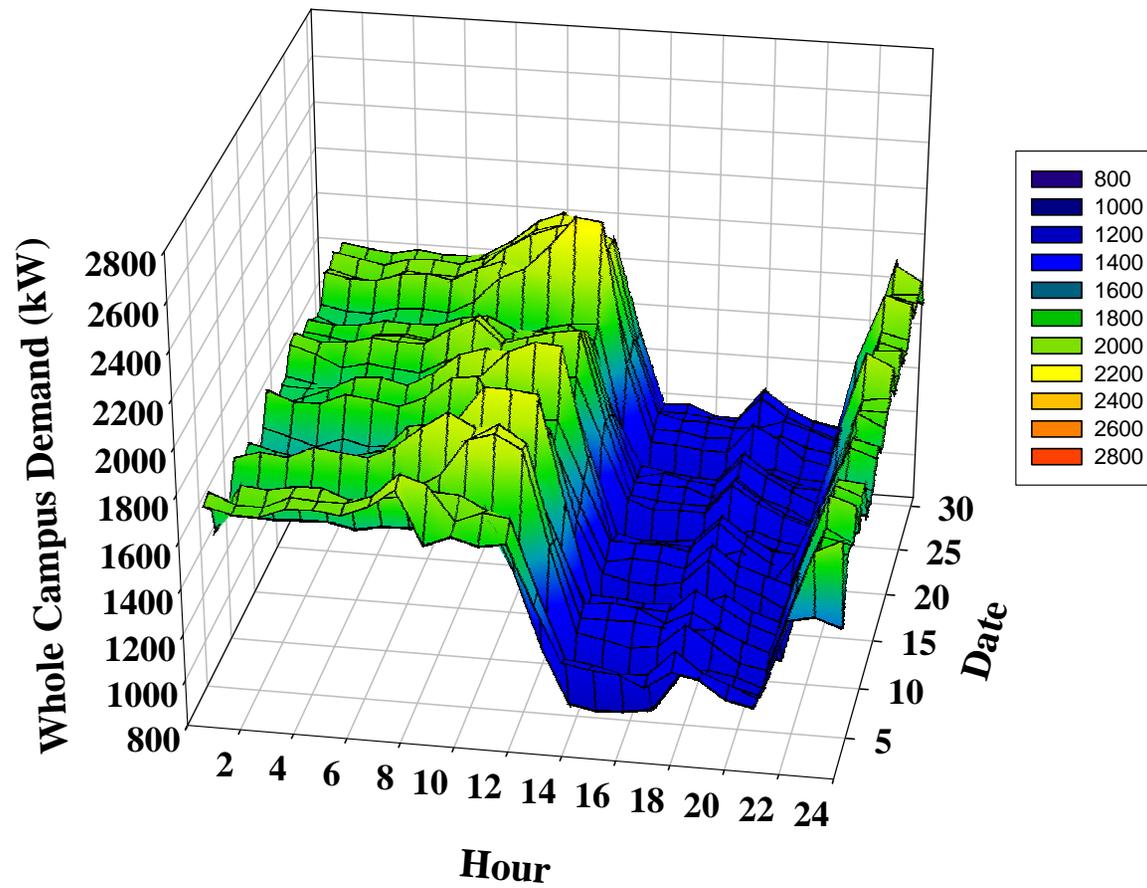


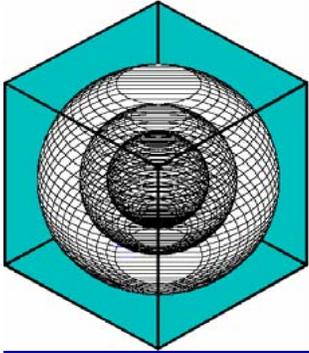
**Hourly Demand Profile for July 1997
(Prior to CCSM)**



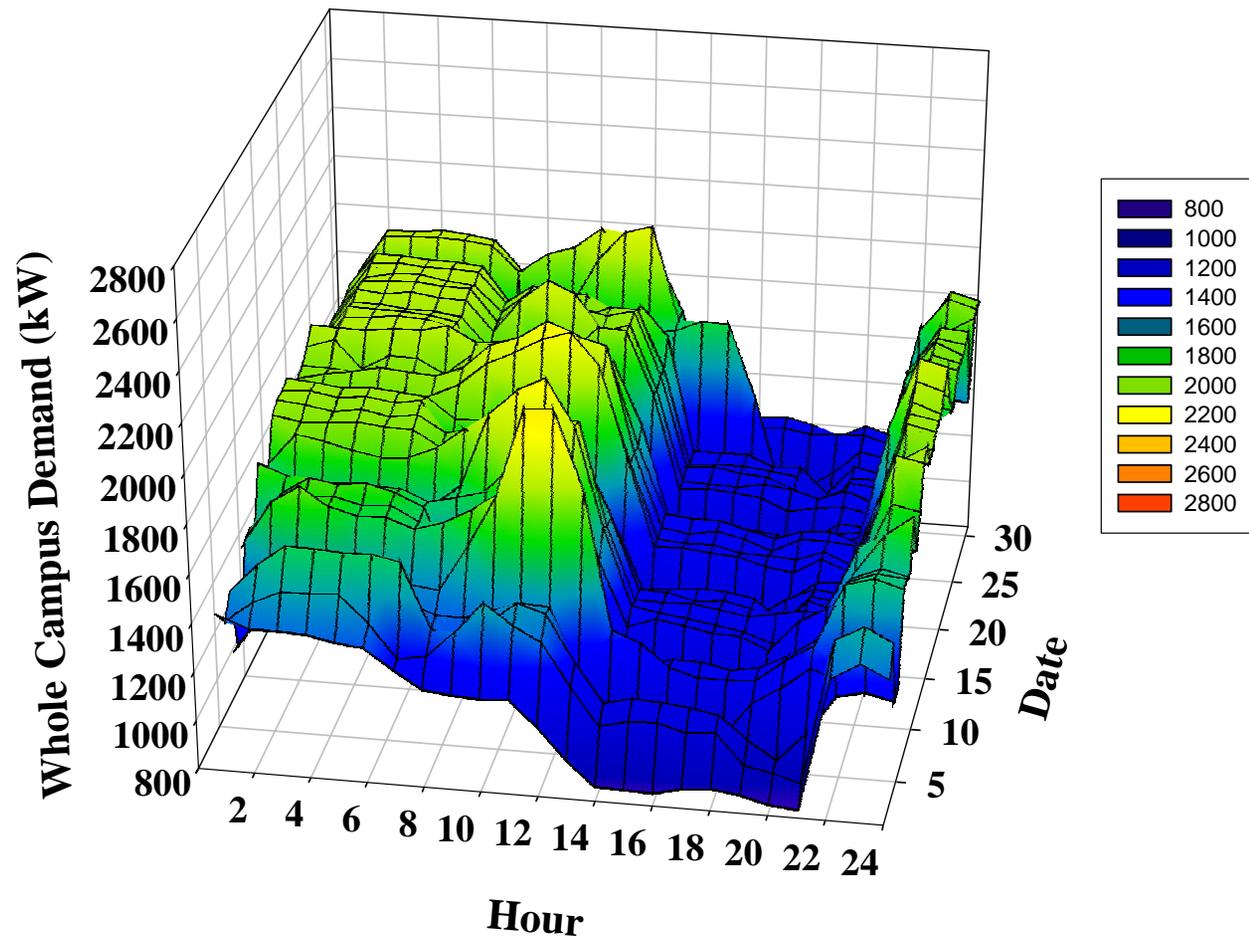


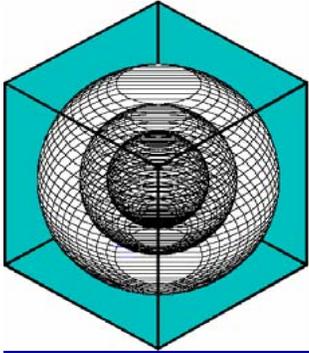
**Hourly Demand Profile for July 1999
(First Year After CCSM)**



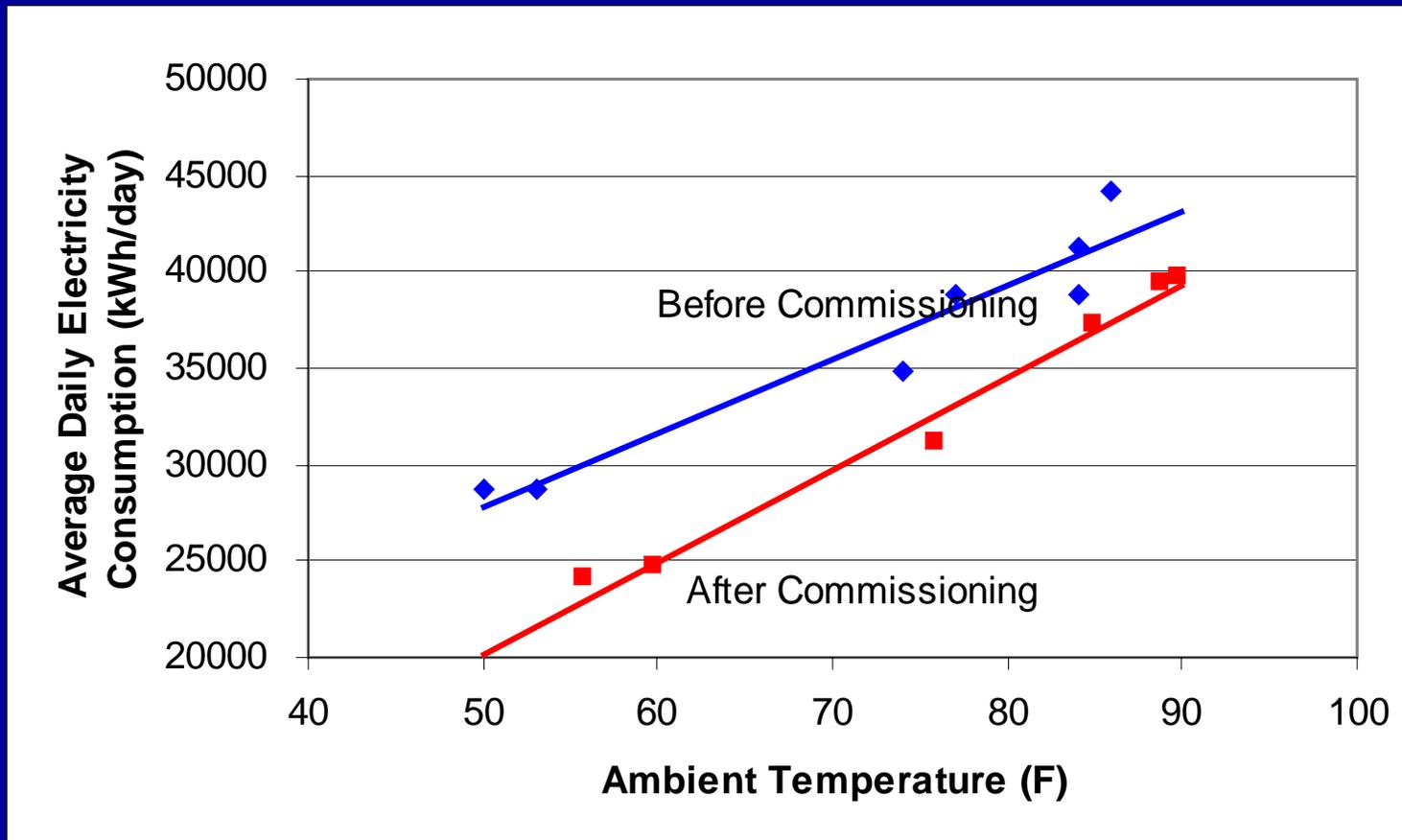


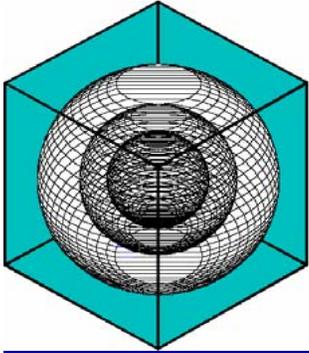
Hourly Demand Profile for July 2001 (Third Year After CCSM)





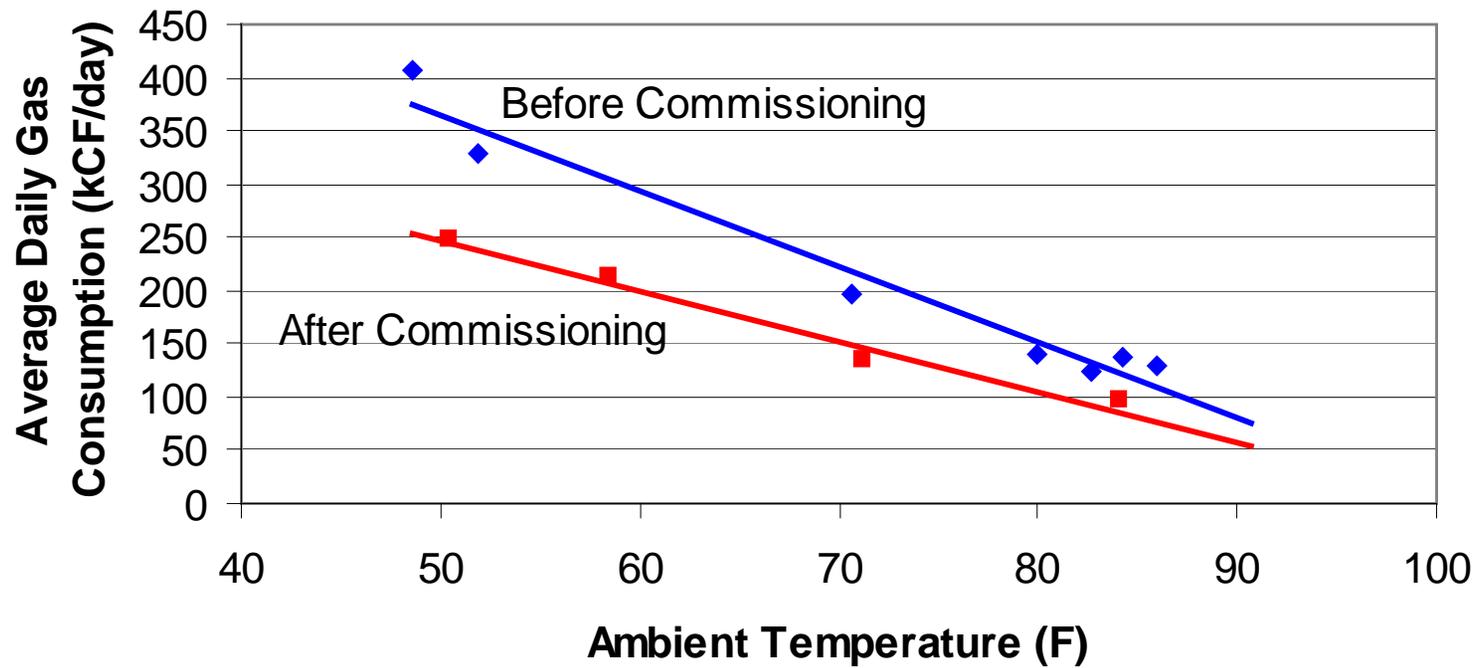
Comparison of Campus Electricity Consumption

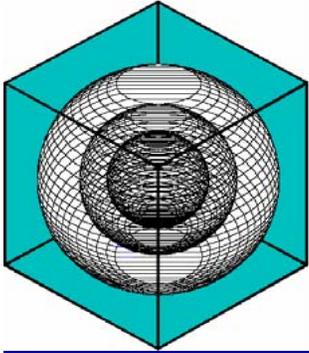




Comparison of Campus Gas Consumption

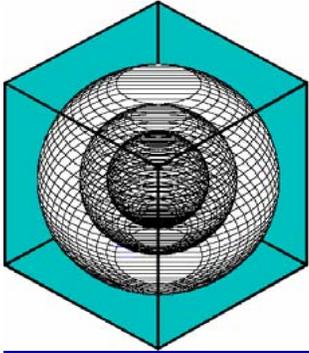
Comparison of Measured Gas Consumption



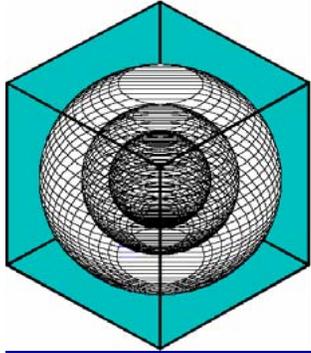


Post-Retrofit Commissioning Results

- **Brought savings to 95% level in 1st year**
- **Optimized control systems operation**
- **Optimized chilled water tank charging and operation**
- **Calibrated sensors and identified hardware problems, both for maintenance staff and controls vendor to fix**
- **Achieved additional savings in 2nd year of CC to bring total savings to about 105% of audit-estimated savings**

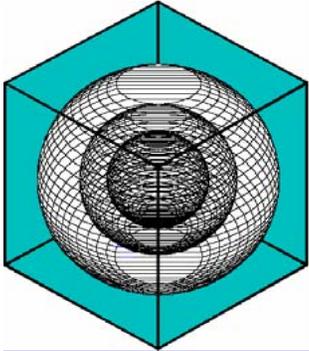


- **First year savings after CC (7/99 - 06/00):**
\$175,112
 - **\$34,096 for demand**
 - **\$88,832 for electricity**
 - **\$55,736 for gas**
- **Demand costs: \$7.63/kW-Mo**
- **Energy costs: \$0.037/kWh**
- **Gas costs: \$2.40/MMBtu**



Summary

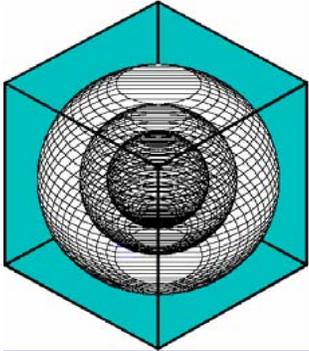
- **Comfort improved**
- **Thermal storage system performance improved**
- **Measured savings: \$175,000/yr in first year**



State of Utah – Matheson Courthouse

(CC of an existing, modern building)

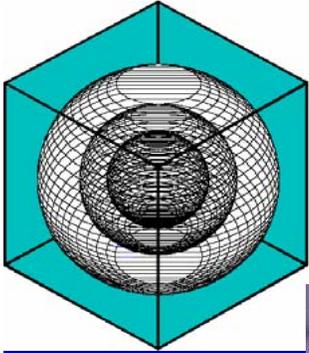
- **CC assessment conducted in February '01**
- **Contract completed in October '01**
- **CC started in January '02**
- **Bulk of CC completed in November '02, but process is ongoing**



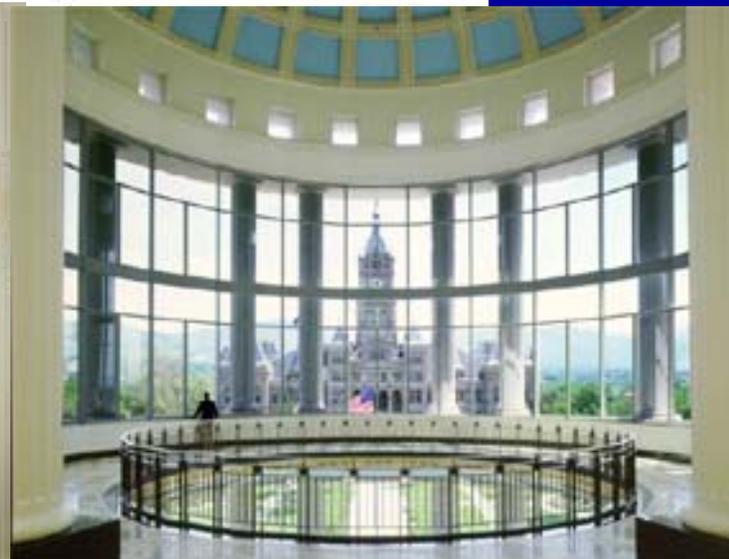
Matheson Courthouse Retro- Commissioning Progress Report to DFCM 8 May 2003

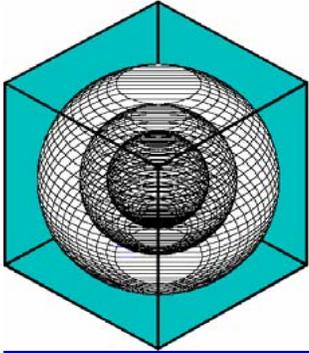
by: Dr. Dan Turner, Song Deng (ESL), Kevin Healy, Mike Butler (DFCM), Jim Hood (UEO)





Matheson Courthouse

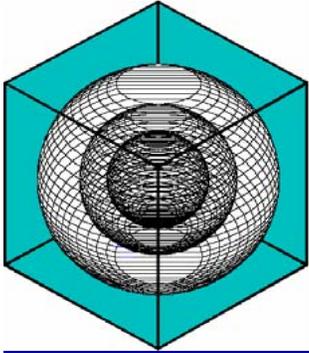




BUILDING DESCRIPTION

- **Matheson Courts Complex**
- **COVERED AREA : 420,000 ft²**
- **CONDITIONED AREA: 370,000 ft²**
- **37 courtrooms, offices, holding cells, 3 level underground parking**

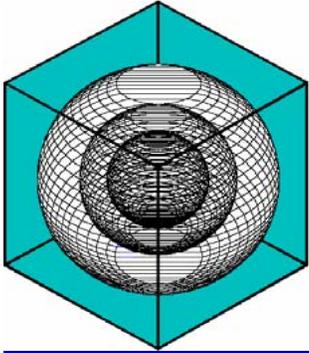




Matheson Courthouse

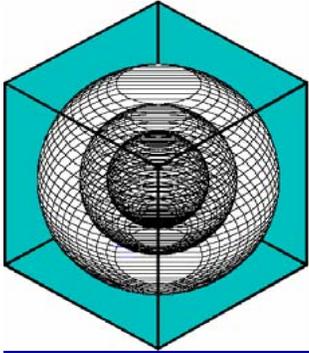
Installed HVAC Equipment

- **One (1) 400-ton and one (1) 770-ton chiller**
- **Six (6) single duct, VAV AHUs, with hot water terminal reheat**
- **Two (2) 500-hp hot water boilers**
- **Modern DDC building automation system**



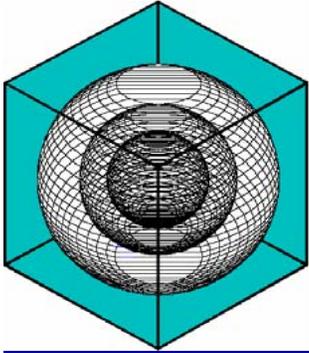
Matheson Courthouse – Energy Information

- **2001 utility bills were \$400,000 (\$300,000 for electricity, \$100,000 for gas)**
- **Energy Cost Index = \$1.08 per square foot per year, based on conditioned area**



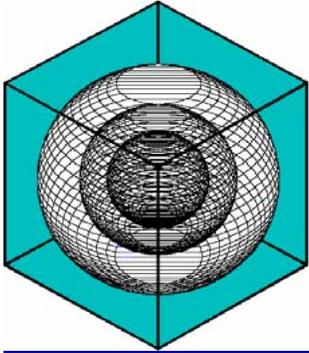
Matheson Courthouse – CC Team

- **Engineer from Utah Energy Office,
Department of Natural Resources**
- **Controls Specialist from Utah
Department of Facilities Construction
and Management**
- **Building Facilities Manager**
- **Two engineers from Energy Systems
Laboratory**



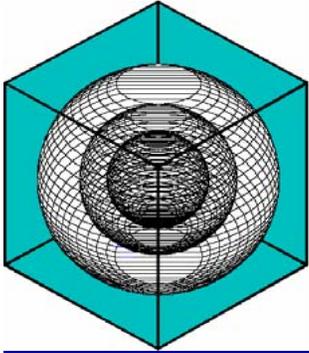
Matheson Courthouse – CC Findings (From CC Assessment and Detailed Investigations)

- **Several CO₂ sensors were bad, including one which had failed at a reading of 2000 ppm**
- **Several AHU temperature sensors were off and in need of replacement/recalibration**
- **About 70% of the VAV boxes were in need of recalibration or had broken flow stations or dampers**
- **Two boilers were operating on high fire**
- **Two pumps were normally operating when one pump could carry the load**



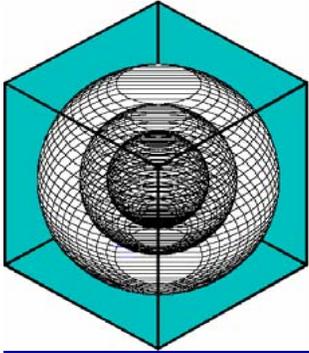
Matheson Courthouse – CC Findings, cont'd.

- **Glycol de-icing system was not programmed correctly**
- **Building start-up/shut-down sequence was not optimal**
- **A few maintenance problems (dampers out of adjustment, leaking valves) were identified**
- **Outside air temperature sensor was not reading correctly and RH sensor was giving false outputs**



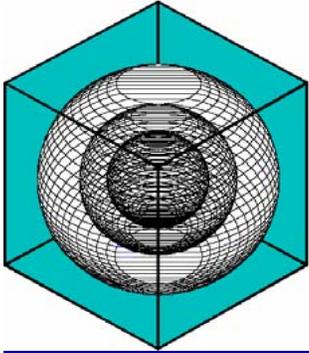
Matheson Courthouse – CC Findings, cont'd.

- **Chiller sequence was not optional**
- **Duct static pressure sensors were reading too high**
- **Building static pressure sensors were out of calibration**
- **Chilled water pressure sensor was not a ΔP sensor but a static pressure sensor**



CC Findings, cont'd.

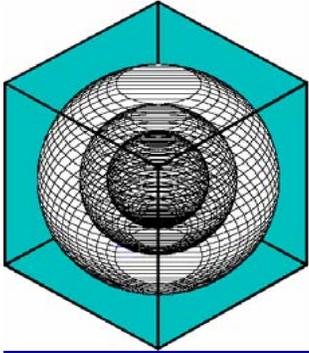
- **Insulation was missing around one of the AHUs, which allowed outside air to mix with building return air**
- **Exhaust air dampers would not close completely or sometimes failed to open**



Matheson Courthouse – CC Measures Implemented

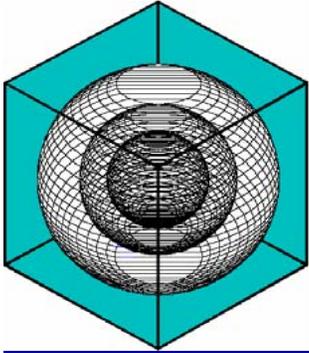
Sensor Issues

- 1. Replaced (2) CO₂ sensors and recalibrated the third**
- 2. Recalibrated temperature sensors**
- 3. Recalibrated duct static pressure sensors**
- 4. Recalibrated building static pressure sensors**
- 5. Replaced OA temperature and humidity sensor**
- 6. Recalibrated all 500 plus VAV boxes (done by TAB contractor)**
- 7. Recommended a ΔP sensor be installed for chilled water loop (to be implemented)**



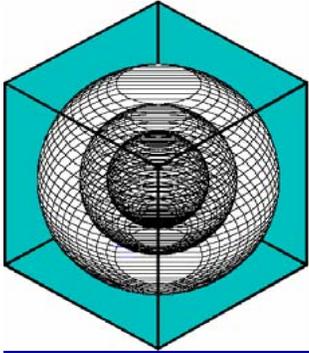
Matheson Courthouse – Operational Changes Implemented

- 1. On boilers, changed to one boiler operation, starting on low or medium fire**
- 2. Revised two-pump operation to one-pump operation on systems where one pump can carry the load**
- 3. Glycol loop operation had an error in programming which allowed the Glycol system to come on anytime RH was above 80%, regardless of temperature**



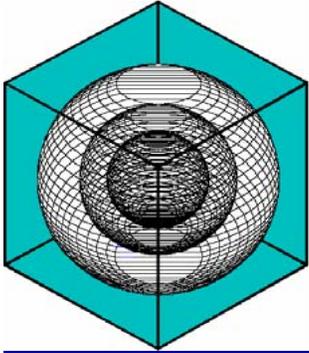
Matheson Courthouse – Operational Changes Implemented, cont'd.

- 4. Chiller start-up sequence in spring allowed all chillers, cooling towers, pumps to run, which created an electrical demand spike and start-up sequence was modified**
- 5. Programming logic allowed both chillers to run during changeover from small to large chiller, which was changed**
- 6. Early morning start-up of building was inefficient, which wasted a great deal of energy. A “semi-occupied” mode was created to optimize building start-up**



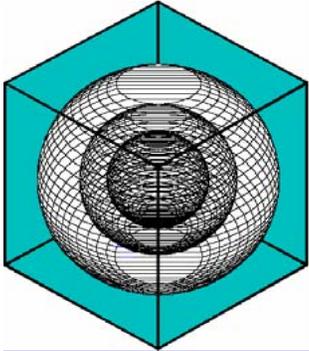
Matheson Courthouse – Maintenance Issues Implemented

- 1. Dampers were adjusted to close as completely as possible**
- 2. Two (2) leaking valves were repaired**
- 3. Insulation was added to one (1) AHU to seal off outside air**
- 4. Sticking isolation valve on small chiller was repaired**
- 5. Exhaust dampers were adjusted and programming logic was changed to ensure dampers were closed when exhaust fans were off**



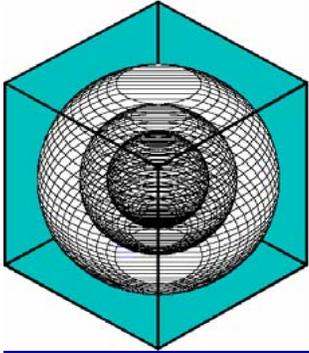
Matheson Courthouse – Optimization Measures Implemented

- 1. A cold deck temperature reset schedule was implemented for each AHU, based on outside air temperature**
- 2. Hot water temperature was lowered to 155-160°F (the lowest temperature the boiler controller could go). A recommendation was made to purchase a new controller which could be programmed to have a reset schedule with OAT**



Matheson Courthouse – Optimization Measures Implemented, cont'd.

- 3. Duct static pressures were reset according to OAT. Also a semi-occupied mode was established which also reset duct static pressure**
- 4. Airflow settings were changed on some VAV boxes, both for occupied and semi-occupied modes. During periods of low building occupancy, outside airflow was reduced.**
- 5. Pending – shut off both boilers in summer**



Matheson Courthouse – Results of Continuous Commissioning

Model savings, based on 2001 prices, weather normalized

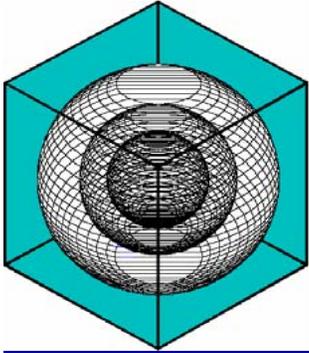
- **\$80,000 annual savings (60% gas, 40% electricity)**

Actual Savings for 2002

- **\$116,000 (both gas and electricity were somewhat cheaper than baseline prices)**

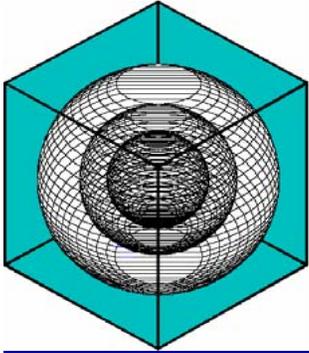
Actual ECI for 2002 = \$0.77 per square foot/year
(2001 ECI was \$1.08 per square foot/year)

Simple payback was 1.2 years, based on outside labor/contractors. Over 700 operating hours were eliminated by creating a new start-up sequence and shutdown sequence.

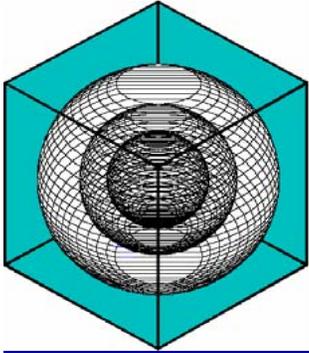


Matheson Courthouse - Conclusions

- **Continuous Commissioning at Matheson was a team success**
- **A second building commissioning effort is underway in Utah**
- **Energy office wants to expand initiative statewide with a team of Utah staff, private industry, and the ESL.**

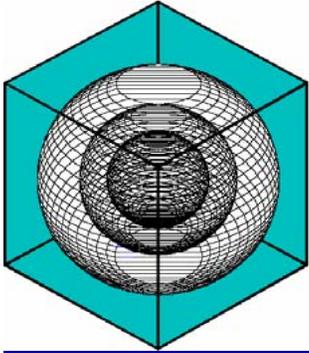


**Continuous Commissioning as an
ECM in an Energy Efficiency
Capital Retrofit Project – Prairie
View A&M University**



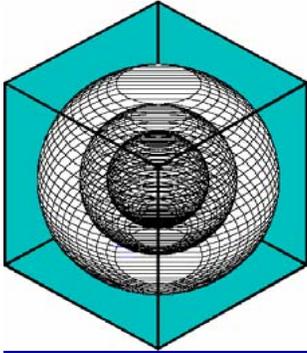
Prairie View A&M University Energy Project (LoanSTAR Project)

- **Engineering firm conducted investment grade audit for capital retrofits**
- **ESL concurrently conducted CC audits**
- **Modeled and simulated energy consumption of 16 major campus buildings as part of the CC audit (1st project in LoanSTAR program allowing CC as an ECM)**
- **Original intent was a \$5 million loan**



Prairie View A&M, cont'd.

- **When savings and ECMs were identified, project simple payback was under 8 years**
- **With a lower payback, customer wanted to get two new chillers and we were asked to revise project to include additional chillers and stay within a 10-year payback required by LoanSTAR**
- **Final project involved two loans totaling \$4.7M and \$1.7M each, with a combined payback of 9.4 years**

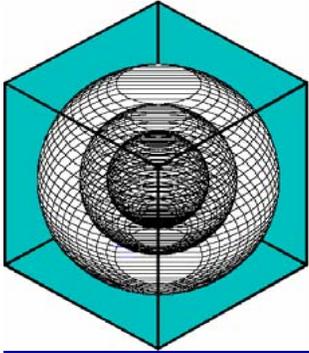


PVA&M ECMs

ECM	Simple Payback, yrs
Lighting retrofits	6.0
Replace two chillers	19.8
Repair steam system	7.2
Install motion sensors	7.3
Expand chilled water loop	8.4
Convert to primary/ secondary pumping	9.0
Replace DX systems	13.0
Upgrade DDC EMCS	13.7
Continuous Commissioning	3.0

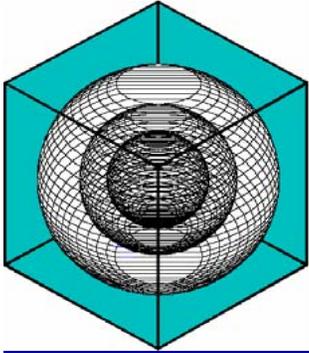
Project Cost = \$6,436,460

Simple Payback = 9.4 years



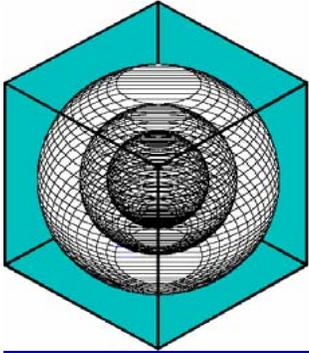
CC Measures at PVA&M University

- **Hot and cold deck temperature resets**
- **Elimination of unnecessary simultaneous heating and cooling**
- **Air and water balancing**
- **Duct static pressure resets**
- **Sensor calibration/repair**
- **Improved start/stop/warm-up/shutdown schedules**
- **Improved chiller and boiler plant operation**
- **Retrofit commissioning**



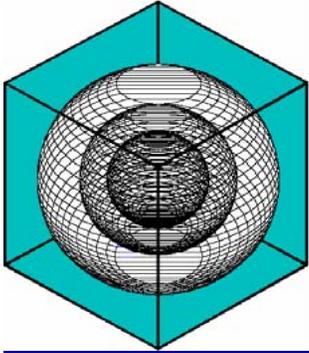
Project Status

- **LoanSTAR project is combined with major campus renovations in three phases**
- **Phase A (~9 buildings) includes lighting, EMCS, motion sensors, primary/secondary loop conversion is at 100% design phase**
- **Phase B is at 50% design phase**
- **Metering hardware has been installed or calibrated/verified in first 4 buildings to be commissioned**
- **CC has begun in first three major buildings**



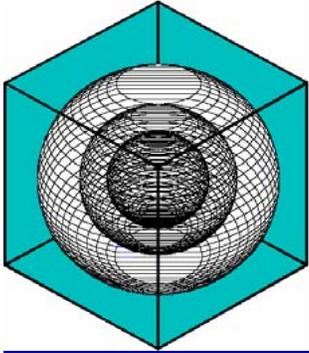
Project Summary

- **1st LoanSTAR project where CC is an ECM, along with other energy efficiency measures**
- **CC represents roughly 1/3 of project savings, with a payback of 3 years (including CC, metering installation, meter calibration, M&V, training, one year's CC follow-up, project administration)**
- **Energy projects are coupled with major campus renovation projects, which creates unexpected coordination problems**



PVA&M Project Challenges

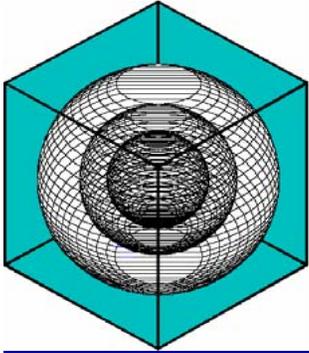
- **Energy projects are only part of major campus renovations**
- **Design firm is not the original engineering firm that performed the energy audits**
- **“Phased” approach requires ESL engineers to commission on a “piece meal” basis**
- **Much more coordination and planning is required, i.e., 25% review, 50% review, etc., and we expect even more coordination will be required during construction**



Conclusions

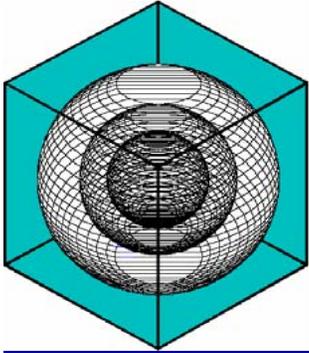
The CC process has been successfully applied

- **After buildings received energy retrofits**
- **To existing buildings with no retrofits**
- **To new (or nearly new) buildings**
- **As an ECM in major energy retrofit projects**



Conclusions, cont'd.

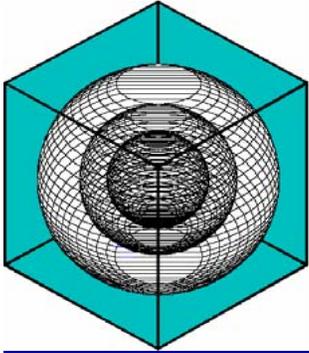
- **While CC savings results vary from building to building, overall average savings are 15-25%, regardless of the applications**
- **Using CC as an ECM in an energy conservation project is one of the fastest payback items, which allows longer payback items to be purchased**
- **By properly commissioning the retrofits, the owner gets a capital energy project that will meet the owner's requirements, as well as a project which saves energy**



Continuous Commissioning[®]

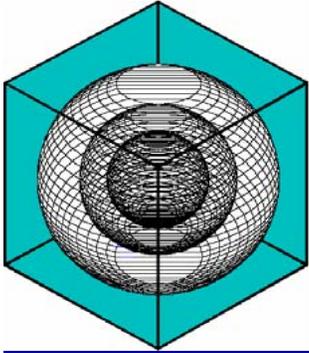
-Savings & Costs

Buildings	Savings (\$/kft²/yr)	Costs (hr/kft²)
Hospitals	\$430	4.74
Lab/Offices	\$1,260	3.68
Class/Offices	\$430	2.26
Offices	\$220	3.29
Schools	\$170	3.36
Average	\$540	3.59



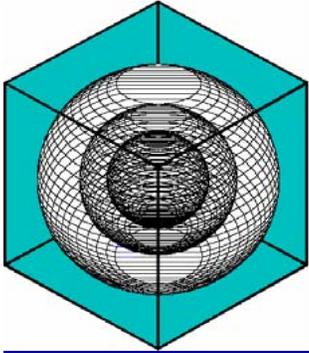
Metering & Reporting Costs Per Building

Approach	Metering	Reporting	Total
Utility Bill		\$15,000	\$15,000
Short Term Measured Data	\$5,000	\$5,000	\$10,000
Long Term With Existing Meters	\$4,000	\$3,500	\$7,500
Long Term With Dedicated Meters	\$17,000	\$3,500	\$20,500



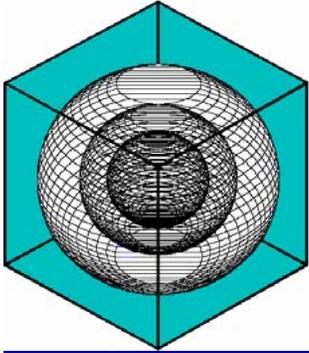
Big Picture of Continuous Commissioning Savings

- **Over 165 buildings commissioned since 1993**
- **Cumulative measured savings through August 2002 – about \$60 million**
 - **LoanSTAR - \$30 million**
 - **Texas A&M - \$22 million**
 - **Brooke Army Medical Center - \$1.5 million**
 - **Others - \$6.0 million**



Steps in the Continuous Commissioning[®] Process

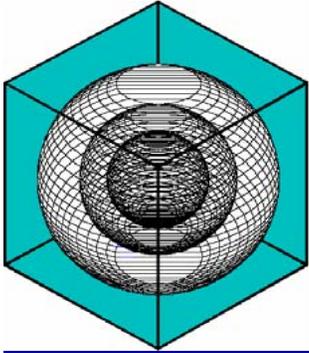
- **Initiate a commissioning assessment**
- **Usually 1-3 days on site, depending on the size and complexity of the building(s)**



For the Continuous Commissioning[®] Assessment

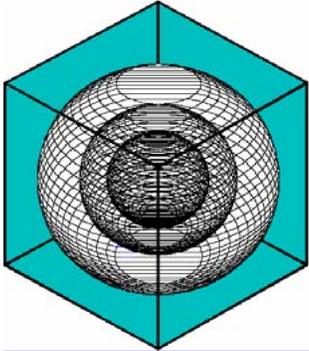
Prior to the Visit

- **Need mechanical systems drawings**
- **Controls schedules**
- **Chiller/boiler plant equipment sizes,
pump info**
- **Floor layout**
- **One year of utility data, if available (gas,
electric, any purchased utilities)**



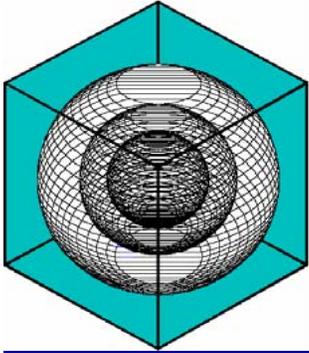
During the On-Site Assessment

- Need access to mechanical rooms**
- Need time on BAS to review control settings, schedules**
- Prefer to have a member of operations staff dedicated to us for the visit**
 - Should know where mechanical rooms are and have access to them**
 - Know locations of sensors**



During the Assessment, cont'd.

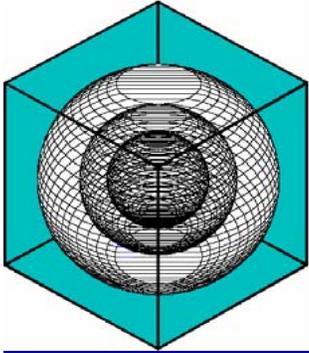
- **We will measure supply air, cold deck, hot deck (if applicable) CW temps, static pressure, cfm, OA, for major AHUs**
- **We will spot check space temps, RH, CO₂ levels within the building**
- **We will note any comfort problems, O&M issues, sensors out of calibration**
- **If requested by client, we will also identify potential capital retrofit measures**



Results of CC Assessment

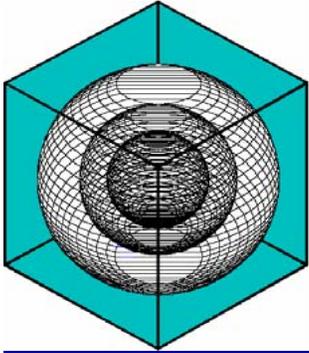
Provide an implementation report which will:

- **Identify potential CC measures**
- **Estimate savings from CC**
- **Estimate CC cost**
- **Discuss comfort issues and observed problems**
- **Identify any O&M or safety problems**
- **Recommend level of metering/submetering, if applicable**
- **Identify potential capital retrofit measures (optional)**



Continuous Commissioning Guidebook for Federal Energy Managers

- **Prepared by Liu, Claridge, Turner**
- **Delivered to FEMP/DOE in October 2002**
- **Should be available for distribution by FEMP soon**



**Continuous Commissioning Workshop
At Energy 2003 on Thursday**

Seats are still available

Questions on CC Process?