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Contract and Beyond GEMnet Status and Accomplishments: GSA's Energy and Maintenance Network

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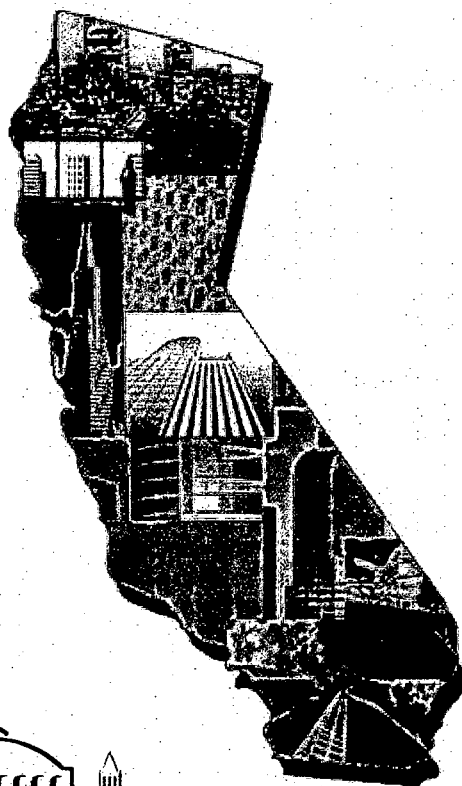
# HPCBS

## High Performance Commercial Building Systems

### **GEMnet Status and Accomplishments: GSA's Energy and Maintenance Network**

*Element 5  
Project 2.2  
Task 1b2*

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General Services Administration



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## Contract and Beyond GEMnet Status and Accomplishments: GSA's Energy and Maintenance Network

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May 2002

## **GEMnet Status and Accomplishments: GSA's Energy and Maintenance Network**

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### **Abstract**

The U.S. General Services Administration Pacific Rim Region (Region 9), manages over 20 million gross square feet of federally owned office space, plus additional leased office space, for the federal government in California, Nevada, Arizona, Hawaii and the Pacific territories. To assist in this real estate management the Pacific Rim Region is developing the GSA Energy and Maintenance Network, or GEMnet. GEMnet is a collection of information technology initiatives, including remote monitoring and control to reduce operational costs by improving energy efficiency, reducing peak demand, and optimizing maintenance in buildings. Ultimately the various systems use a common database platform. This paper describes the status and plans for GEMnet, focusing on how it compares with related monitoring and information technology currently used in nonresidential buildings. This paper will also report on recent activities within the GEMnet purview, demand-shedding and retro-commissioning. For example, two large GSA office buildings in the San Francisco Bay Area participated in the California Independent System Operator (ISO) demand relief program (DRP) during the summer of 2001, shedding nearly 1 MW when called upon. In conjunction with the fielding of GEMnet related programs, a series of retro-commissioning projects is being implemented, scoped to the needs of particular buildings. Details on the BAS retro-commissioning at one building is presented.

### **Introduction**

The U.S. Government's General Services Administration is the largest building manager in the world, owning and operating over 250 million ft<sup>2</sup> of building space in North America. The mission of GSA is to help federal agencies better serve the public by offering, at best value, superior workplaces, expert solutions, acquisition services and management policies. To expertly manage their buildings, GSA invests in high quality information systems, building maintenance management systems, and energy efficiency. Energy efficiency policy goals derived from Executive Order 13123 are considered along with cost effectiveness and asset improvement or preservation in making investment decisions (Clinton 1999).

This paper focuses on building information technology activities within GSA's Pacific Rim Region (also known as Region 9). The Pacific Rim Region is the largest geographic region of GSA, which includes the states of California, Nevada, Arizona, and Hawaii. Headquartered in San Francisco, California, this region includes about 20 million ft<sup>2</sup> of federally owned building space, most of which is office space, and manages additional space in leases.

The paper begins with an overview of the scope of GEMnet, followed by a more technical description of the technology platform, BAS protocols, and a description of the computerized maintenance management systems. We then present some characteristics and energy use data for the current GEMnet buildings. The final section reviews achievements with the Retro-Commissioning activities at one building, along with the demand-reduction results from summer, 2001.

## **GEMnet History and Overview**

GSA's Pacific Rim Region has had a history of innovation in building technologies. During the 1980s GSA noticed that the proprietary communications in direct digital control (DDC) systems stifled building automation system procurement. Competitively priced additions to DDC systems could not be procured, and additions were limited to only those products offered by the original system's manufacturer (Goldschmidt, 1998). To address this problem, ASHRAE led the industry's effort to develop an open communications protocol, known today as BACnet (ANSI/ASHRAE 1995). GSA led the building industry's use of BACnet with the largest full scale, multi-vendor BACnet project at the Philip Burton Building (also known as 450 Golden Gate Applebaum and Bushby, 1998). More recently, the Pacific Rim Region developed guide specifications defining networking, communications, and standards for new BAS projects.

The objective of the GEMnet system is to interface real-time applications such as BAS and lighting controls with a centralized maintenance management system (both for asset tracking and management, and to turn system needs into work orders); to data warehouse information derived from many systems and buildings in a consistent manner; to provide a framework for performance benchmarking, data analysis and building diagnostics; and to provide mechanisms for centralized support of field operations related to automation systems. The features are described as follows:

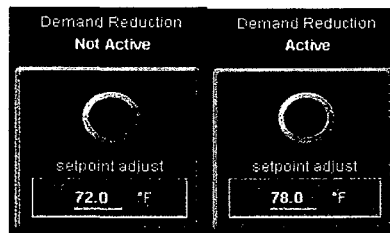
**Maintenance management.** The regional maintenance management program is one of the GEMnet applications. The use of a common database management system (SQL Server) and most of the other GEMnet applications, and design of interfaces between databases, permits maintenance work orders to be automatically created from system alarms, or from data trends indicative of a problem. This will prompt correction of equipment and system problems before an asset is degraded or tenants note a problem. Linking building real-time systems with static equipment inventories and work records in the maintenance management system will also create a more current and dynamic database of equipment assets, and permit the planning of maintenance and retrofits on a more scientific basis.

**Diagnostics.** GEMnet is designed to provide a platform for building system diagnostics capable of analyzing trends in equipment performance, diagnose problems and equipment/system deterioration and recommend remedies. The National Institute of Standards and Testing is developing Variable-Air-Volume box diagnostics. LBNL is performing on-going analysis of the BAS data, along with developing model-based diagnostic techniques for implementation in GEMnet. GEMnet also includes the use of PACRAT (Friedman and Piette, 2000).

**Remote programming and BAS optimization.** Depending upon the facility's BAS, there may be some ability to optimize the operations of individual facility systems – given the presence of a competent technician at the building to validate the strategy; in addition, efforts to install improved instrumentation and conduct optimization/retro-commissioning activities concurrently with GEMnet site installation are being made. Retro-commissioning efforts at the Dellums Federal Building in Oakland are further described below.

**BAS integration.** GEMnet provides a common front-end to BAS', which should reduce dependence on BAS vendors, permit GSA staff and maintenance contractors to train consistently on a single system, and permit resources to be used in a more focused manner.

**Specialized central control.** Although developed prior to the recent instability in Western power markets, GEMnet provides flexibility in response to rapidly developing programs, primarily through providing some ability to initiate demand response programs remotely. GEMnet will also help GSA in the future through improved data acquisition and management. While GEMnet is not intended to generally provide direct central control of distributed buildings, GEMnet does provide a platform for specialized functions, such as participation in demand-reduction and other programs being developed in light of the energy crisis in California and the western region of the U.S. **Figure 1** shows the demand response control interface. The left button shows the system in normal operation, when the demand-response is not active, with space temperatures set to 72 F. The right hand control shows the “active” mode, with space temperatures increased to 78 F. The centrally maintained BAS software incorporated in GEMnet may also be used, on a case-by-case basis, for use as the primary BAS application (this is being tested in a small building in Tucson now).



**Figure 1.** GEMnet demand response control interface.

## Technology Description

### *Building Automation Systems Overview*

GEMnet consists of an Information Technology (IT) infrastructure for integrated facility management. GEMnet offers a set of applications residing on a server using a common operating system and database engine. The initial applications will consist of a web-based monitoring and control program that offers two-way communication. GEMnet is one of the nation's first systems in which multiple BAS communicate via the Internet to a high speed Digital Subscriber Line (DSL) installed at each building. Within facilities where a BACnet compliant BAS is installed, a gateway-router module provides the communication link from the DSL to the BAS. Within facilities that are not BACnet compliant, communication will use bridging-gateway devices specifically programmed to translate the GEMnet-based protocol (BACnet) to the legacy BAS protocol. Additionally, a gateway-router module has been installed at each facility to achieve an appropriate level of supervisory control and data acquisition.

In practice, there is a degree of variability in how GEMnet relates to individual facilities; i.e., the degree of controllability as opposed to simple data acquisition. Reasons for this difference range from limitations of each to facility operator and management practices. In part, the intent of the project is to be cooperative with and adaptive to the requests of local Property Management Offices. The GEMnet regional infrastructure (software, database design, and server hosting) is being developed on a path parallel with necessary systems, controls, instrumentation, and programming upgrades at individual facilities.



As mentioned above, the GEMnet infrastructure is designed around an open protocol basis, utilizing the BACnet communications protocol and ODBC applications. The network is anticipated to be capable of incorporating other open communication protocols. Legacy proprietary systems will be incorporated through the use of gateway technologies. The open protocol structure should minimize difficulties communicating with entities such as local utilities and scheduling coordinators. The network is being developed with the objective of maintaining as much competition as possible among local vendors for future installation and support work.

GEMnet includes a data collection program that uses a BACnet protocol stack tool, which reads BACnet objects and stores the data in a central SQL Server database. The BACnet-Reader program resides on a computer located in the building connected to the same network as the building automation system and to the Internet. The software reads the data from the BACnet object at a frequency set in the database and depending on the settings either stores the reading or stores the reading and saves the reading to a trend log. The BACnet-Reader program stores the information collected locally, then at a predetermined time sends this data to the SQL Server via the Internet. If for any reason the SQL Server is not available to the BACnet-Reader program, the program stores the data locally until it can upload to the SQL Server. All data is time and date stamped.

Currently at 450 Golden Gate there are over 60,000 points on the BAS listed in the database. About one-quarter of those will be checked at regular intervals. The data collected and stored on the SQL Server can be viewed and downloaded by all users of this web site. Some of the issues in the management of these data include the ease of setting up a point, or multiple points for polling and the ability to use the data to cross-check against what the BAS is doing. It is also important to be able to store the data in a useful database format. Some BAS output data in problematic formats.

### *Computerized Maintenance Management Systems (CMMS)*

GEMnet is implementing a Computerized Maintenance Management System (CMMS) software program. The SQL database for the CMMS program is centrally located at the Regional Office in San Francisco. One function of the CMMS software is to maintain a schedule for preventive maintenance on building equipment. The schedule of inspections or maintenance is set forth by either the equipment manufacturer or by GSA. The CMMS program creates work orders based on the frequency and maintains a history of all work done on the equipment. Since most CMMS software tends to be intimidating to non-maintenance personal, GEMnet is implementing a web interface database that requires little training or understanding of building maintenance. In some cases the web interface improves the original CMMS program by adding customized functions not available in the CMMS program, and simplifying the entry screens for the CMMS program.

One such customized function is the Work Request page, where users, including tenants, may enter work requests. If the request is an environmental request (too hot, too cold) then the current temperature for the room or area that the request is for, is displayed on the screen and added to the work request. In this way it can be determined that the request is valid because the displayed temperature is outside of the normal settings. Since the current temperature is from the building automation system and is added to the work request, the building staff can see that at the

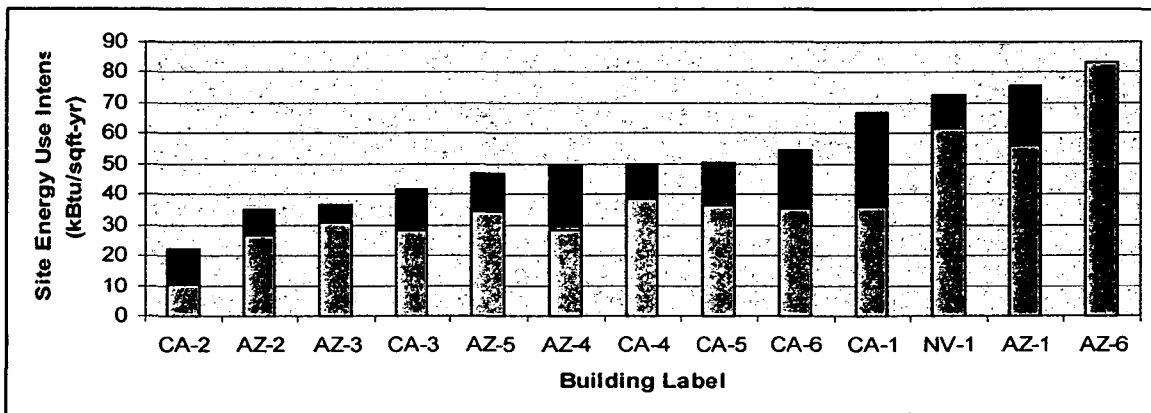
time of the request the temperature was indeed outside the range set for the area, even if the current temperature is within the range. This functionality requires that the building be BACnet compatible since the software that maintains building trend information reads BACnet objects.

We are currently working on a function to create CMMS work orders based on building automation system alarms. The interface will create work orders, email or page depending on the type of alarm and the settings in the alarm description. This function requires some type of attachment to the building's automation system software and since there are so many different types of software being used in the region, it may take some time to implement. Since all work orders are in a central database, reports can be produced to show how many work orders are done on a daily basis and of what type or nature.

Another innovation that GEMnet is developing is techniques to allow tenants to directly enter service call data. This effort will include a live tenant interface to inform tenants of activities that may affect HVAC or related services within the building (Federspiel 2001).

### GEMnet Buildings

Not only is GEMnet an IT infrastructure for building management, it is also a framework for organizing building performance data and projects. **Table 1** lists 13 of the GEMnet buildings for which the energy data were readily available. In the buildings listed in **Table 1**, a few are just being added to the GEMnet project. One such site is the Dellums building in Oakland, and the Reagan Courthouse. Two Sacramento buildings will also be added soon. The buildings vary by size and type, from 7000 to over 1 Million ft<sup>2</sup>. Both the gross and the net rentable floor area are shown for the sites where we were able to collect the net rentable areas. Floor area definitions are extremely important in energy use intensity (EUI) comparison. These EUIs help define the baseline for these buildings for quantifying future reductions related to GEMnet. **Figure 2** shows the annual energy use for 10 GEMnet buildings (final draft will include all 13). EUIs vary by nearly a factor of four, ranging from 22 to 83 kBtu/ft<sup>2</sup>-yr (site units). These buildings span a large number of climates and building operating schedules. Energy costs range from by a factor of four as well, with a low of \$0.54/ft<sup>2</sup>, and a high of \$2.06/ft<sup>2</sup>.



**Figure 2.** GEMnet building site energy-use intensities. Electricity is lower bar, gas the upper, except for building CA-3, which is purchased cooling and steam bar).

**Table 1. GEMnet Buildings, Current Energy Use and Energy Costs**

Building Name	City	Bldg Label	Gross Area (sqft)	R/G**	Elec kBTu/ sqft-yr	Gas kBTu/ sqft-yr	Total kBTu/ sqft-yr	Cost (\$/sqft-yr)
U.S. Border Patrol Sector HQ	Tucson	AZ-1	13,627		56	19	76	2.06
Walsh Courthouse	Tucson	AZ-2	82,360		27	8	34	1.01
Tucson Fed Building	Tucson	AZ-3	138,394	0.61	31	5	36	0.90
Phoenix Fed Bldg & Ct house	Phoenix	AZ-4	373,023		28	21	50	0.82
DeConcini Fed Bldg & Ct house	Tucson	AZ-5	413,000	0.86	34	12	47	1.07
O'Connor U.S. Ct house	Phoenix	AZ-6	519,981	0.77	83	0	83	1.48
Shea Federal Building	Santa Rosa	CA-1	80,108	0.61	36	31	67	1.69
NARA Federal Records Center	San Bruno	CA-2	238,269	0.85	10	12	22	0.52
Santa Ana Federal Building *	Santa Ana	CA-3	272,678	0.58	29	0	42	1.44
Reagan Fed Office & Ct Hse	Santa Ana	CA-4	517,360		39	11	50	1.47
Dellums Fed Office & Ct Hse	Oakland	CA-5	1,105,321		37	14	50	1.36
Burton Fed Office & Ct Hse	San Francisco	CA-6	1,424,042		35	19	54	1.39
L. George U.S. Courthouse	Las Vegas	NV-1	373,216	1	62	11	72	1.45

\* Also uses purchased chilled water and steam

\*\* Rentable/Gross ratio of floor areas

### *Retro-Commissioning at the Ron Dellums Oakland Federal Building*

Retro-commissioning is generally thought of as a set of procedures to ensure that a building is operating "as expected," or as it should to meet the current functional needs. In this section we discuss the Retro-Commissioning underway at the Ron Dellums Oakland Federal Building. The project has developed into a major BAS reprogramming effort. This section illustrates the complexity of BAS reprogramming, which is part of the GEMnet activities. The Direct Digital Control (DDC) BAS was installed in 1993. The HVAC Equipment consist of:

- 1250 Variable Air Volume Controllers (VAV's),
- 2 main tower air handlers consisting of a cold and hot deck, and return fans located on the fifth floor and upper penthouse of each tower serving each 18 story tower (2500 horsepower total),
- Separate air handlers and VAV controllers located in the ancillary 5 story courthouse and auditorium wings,
- Boiler with two 350 horsepower and one 80 horsepower boiler and pumps,
- Central plant consisting of a plate-and-frame heat exchanger, three 1000 ton and two 450 ton chillers, associated primary loop pumps and three secondary loop pumps with Variable Frequency Drives (VFDs) on the secondary loop.

Upon starting the Retro-commissioning process, the BAS Specialist with the GEMnet program reviewed LBNL Data on chiller performance and electricity use, operational observations and complaints from the building management, observed control routines in the programming, and noted system errors and fluctuations/anomalies. Upon reviewing these criteria, it became clear there were numerous discrepancies to address. Specifically, the most critical areas of need were:

- Lack of consistency in Zone VAV Programming (PI setpoints and Individual temperature and occupancy setpoints). Each VAV had to be addressed individually for its setpoints (1250 times!), and there were occupancy commands for each floor's VAV's to occupied or unoccupied control. Neither of these commands reflected a "shutdown" mode and would allow the box to open fully upon loss of air from the air handlers.
- Schedules on the air handlers, which would not reflect the occupancy states or needs of the field VAV's. The air handlers would stage, seemingly arbitrarily, various combinations of fans, causing an interruption in static pressure/airflow to the individual boxes, which was generating numerous hot/cold calls.
- Central plant staging was inconsistent, starting and stopping equipment under load to satisfy an erroneous "tons" value, whose calculation was directly affected by the stopping and starting of the chillers. Chillers would not respond to temperature setpoints issued by the BAS System, and chillers 4 and 5 had VFDs installed by a third party, whose operation was undocumented and unverifiable. Another anomaly was the continuous, non-selectable operation of secondary pump 6 as the lead pump.
- Boilers were operating with a local bypass valve set for 120 degrees, which was below the manufacturer's specifications of 170 F. This situation was requiring each large boiler to be re-tubed at the unacceptable interval of 2 years.

As the retro-commissioning commenced, the programming and setup of the BAS reflected an installation oriented toward meeting the design specification. Unfortunately, such specifications are not always up to date. The BAS had not benefited from sufficient maintenance support and service, and only major BAS failures have been addressed. The network hardware reflected the capabilities of the period of installation; while the product line had advanced significantly since that time. Many simple service issues, such as airflow measurement, controller "drift," setpoint adherence and controller performance, and network communications performance had not been updated. Meanwhile, tenant improvements and the addition of controllers added simply for short term HVAC fixes, often by vendors laboring with a limited controls knowledge, and modifications to the system addressing changes within the building served to degrade the overall system performance. Essentially, the original programming needed to be addressed, updated, or changed, and the condition of the system as a network needed to be addressed, to ensure optimum performance. Additionally, California experienced power issues, such as electrical shortages and blackouts, which the original programming of the system, with only comfort in mind, could not address.

### *VAV/Zone Control*

The VAV's had no programming reflecting global temperature setpoints, or occupancy. Each box had an ineffective set of factory default proportional/integral parameters, reflecting the manufacturer's climatic conditions at their headquarters in Wisconsin. Many boxes had parameters differing from that of their neighbors, thus it was possible to have one zone complaining of too cold, and its immediate neighbor complaining of too hot. To address these issues, and insure predictable performance at the zone level, all 1250 VAV boxes had their local routines standardized. All PI values were changed to reflect the box's purpose (differences such as cooling only, dual-duct heating, or cooling with reheat Coil) to optimize the capabilities and minimize potential flaws of each mode. The networking of the boxes was streamlined to allow

system operators to see the 2 most pertinent values related to the controller (zone temperature and airflow), with the capability of opening a secondary window to observe additional performance (cfm setpoints, occupied and unoccupied temperature setpoints, airflow, damper/valve command, occupancy status). The effect of this change was to allow the operator to scan a summary for discrepancies.

The temperature setpoints of the boxes were then established floor-by-floor. This change was implemented with a future ability to address need to shed power by changing 30+ boxes per floor with one command, versus 30 commands. The controllers were also configured for proper self-diagnostics, which had been virtually ignored prior to the start of retro-commissioning, an important step in controllers of this vintage. Floors also had a "shutdown" condition implemented, to allow startup of the building to occur against a "closed, but opening" damper. The prior arrangement was to shutdown in the "unoccupied" mode, which would allow the damper to open while seeking to be satisfied with lower setpoints. The flaw with starting from an open damper is that in a large system such as Oakland, a tremendous amount of fan energy is required to satisfy the controllers upon startup, requiring much fan staging within the air Handler and much time to achieve effective airflow in the spaces. The current Shutdown mode allows more flexibility for necessary shedding routines, and eliminates wasted energy in the after hours mode (allowing 1 after-hours floor to achieve its necessary HVAC vs. all floors). Future program modifications will include Optimal Start, where four VAV's per floor will be polled as to their zone temperatures in the early morning, and an "Early" start time will be subtracted from the scheduled occupy time to "pre-start" the fans at a time reflecting real time conditions, rather than schedules.

### *Air Handlers*

Prior to retro-commissioning, the air handler control program was using four stages; ranging from a single cold deck, hot deck and return fan to all fans running. The criterion for staging the fans was based upon VFD position of the master control loop for static pressure on the cold deck, without considering the static pressure vs. setpoint, number of floors occupied, or other pertinent information. The program has been rewritten to use only two running stages, and a third stage of "standby." The system awaits a floor VAV unoccupied or occupied status, and starts the fifth floor hot deck and return fans, plus the penthouse cold deck and return fans. When the number of floors occupied equals or exceeds the setpoint (currently set for 8 floors), the system starts the remaining fans. While this has been an extremely difficult situation to fine tune (and will need further tuning/testing), the result thus far has been more reliable air delivery than the previous program, resulting in fewer tenant complaints. The hot deck fans are now programmed with the option of disabling when outside air conditions warrant (currently set for 75 degrees), the hot deck discharge air setpoint is currently reset from the lowest value of the two return air sensors (from the penthouse and the fifth floor); the cold deck discharge air setpoint is reset from the highest value of the two sensors. Plans are to monitor the VAV positions (4 per floor) to determine if the cold deck discharge setpoint needs to be biased higher or lower than the calculated value from the return air calculations, this programming will be incorporated after the central plant programs. Further issues to be addressed in the fans also include airflow monitoring for return fan tracking (currently considered flawed by erroneous sensing), and possibly static pressure reset.

## *Boilers*

Hot deck fans in the tower, and reheat coils in the courthouse and auditorium VAV's provide heating in the building. The previous program awaited a signal that a fan was on, and started boilers accordingly; there was no disable capability to allow for times when an area without a need for heat was on, or when outside conditions did not warrant heating (mainly after hours operation). The previous program also maintained individual boiler bypass valves at the setpoint for the building hot water, which was reset by outside air conditions. This bypass program did not represent optimum running conditions for the equipment, and resulted in systematic tube fouling in the boilers, along with low temperature failures by the internal safeties on the equipment, creating operational nightmares for the building management. The new program looks at the operation of the building fans, allows a schedule to override operation (for after hours modes), verifies outside air conditions to determine which boiler to operate, schedules a new lead boiler if the current lead fails, operates the individual bypass valves at the manufacturer's recommended 170 degrees, while independently modulating the building bypass loop to keep the supply hot water at the setpoint of 160 degrees, stages the two large boilers as needed to maintain the setpoint, and allows the operators to regulate the equipment's response to the staging with time intervals.

## *Central Plant*

The central plant is currently (March 2002) under renovation. The previous programming/hardware interfacing was unable to control chilled water setpoints, used calculations for staging that were affected by the staging process itself (tons calculations that required CHW delta temperatures and flow, both of which were affected by the act of transitioning new equipment), and would cancel a call for an additional chiller immediately after starting the equipment, which would eventually require the newly started, then stopped chiller to be restarted within 20 minutes. Renovations at this point include installation of a plate and frame heat exchanger (which has been in operation since November, 2001), retrofitting the control panels on each chiller, installing a VFD on 1000 ton chiller three, and incorporating operation and control of the existing speeds drives into the UCP2 panels on chillers four and five. Programming and check out should be completed by mid-April, 2002.

## *Demand Reduction*

During Spring 2001, GSA modified the BAS to respond to the ISO's calls for electrical demand reduction. The modifications to the system at that time imposed a limit on the control loops for static pressure (to limit the consumption of the fans), stopped the hot deck fans, set lower static setpoints in the courthouse, and duty-cycled the auditorium fans. The effect of this was an immediate reduction in energy use, but at the expense (somewhat uncontrollably in some areas) of comfort and air quality. The changes now in place in the building programs will allow better control of the demand reduction in the future. Upon completion of the central plant program, a call for demand reduction will be implemented in the form of higher temperature and lower cfm setpoints at all VAV's, heating hot water system shutdown, operation of only the 1000 ton VFD chiller in the central plant, and shutdown of all hot deck fans in the complex. Further programming will include a "soft" return to normal upon canceling demand reduction restrictions

to avoid setting a new “peak” demand afterwards; this will be accomplished by ramping the central plant to accomplish the coldest possible chilled water, which will then be sent to the air handlers, to allow them to cool focusing on temperature rather than air volume.

### Energy and Demand Savings from GEMnet Buildings

As mentioned, GSA’s Pacific Rim Region participated in the California Independent System Operator’s (ISO) 2001 Summer Demand Reduction (DRP) program (Kinney et al, 2001). The demand reduction target was 1.2 MW, and the participating buildings were the Philip Burton Federal Building in San Francisco and the Ronald Dellums Federal Building in Oakland. Only one curtailment was called during the program duration, June 1 through September 30. According to the ISO, 65% of the 1.2 MW target, or 780 kW was shed on July 3, and GSA’s compensation was calculated accordingly. The baseline calculation used by the ISO does not take into account the effect of temperature variation on energy use in commercial buildings. LBNL estimated that under a linear regression baseline was used that accounted for temperature, that 120% of the demand reduction was achieved, or 1.5 MW. The demand reduction was assisted in part by low occupancy due to the July 4 holiday. **Figure 3** shows the actual electric load from July 3<sup>rd</sup>, along with two baseline scenarios.

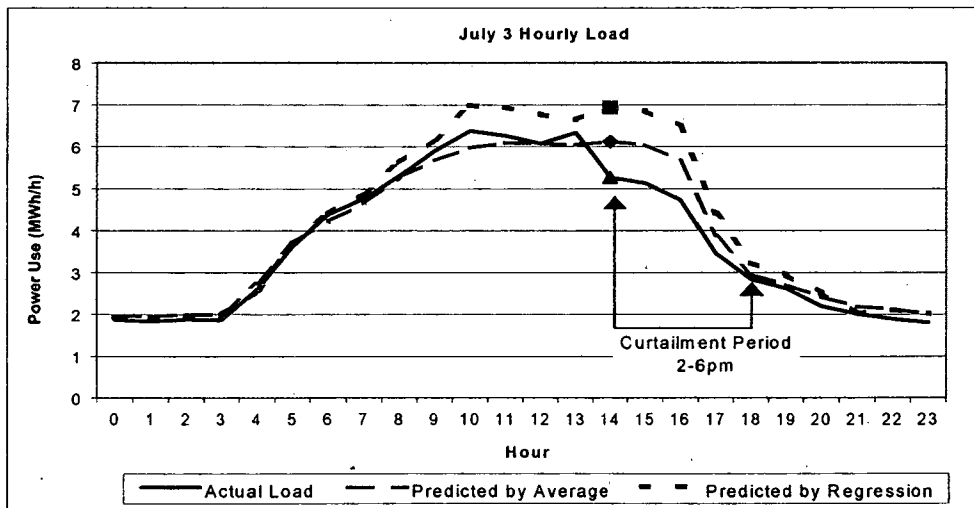


Figure 3. Combined load shape of two office buildings: baseline and curtailment results.

**Figure 4** shows the multi-year energy use data showing that the electricity use grew for four straight years, but was reduced in 2001 for the first time by about four percent. Greater savings are predicted for 2002. Similar savings will be documented in additional buildings as retro-commissioning, diagnostics, and BAS improvements proceed.

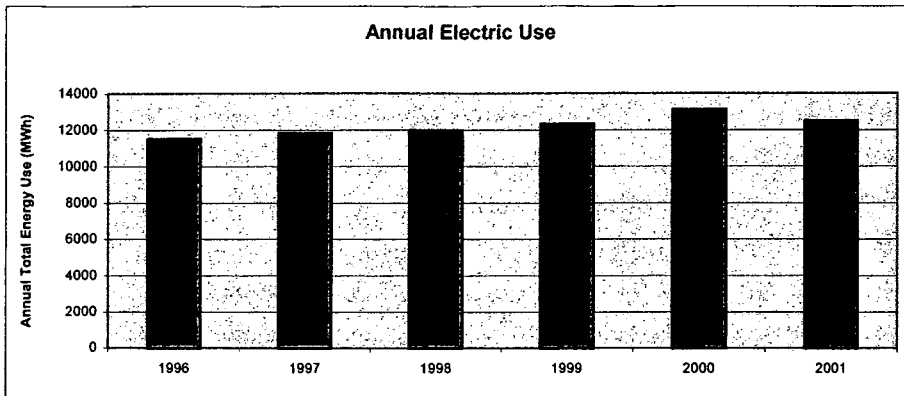


Figure 4. Multi-year electricity use of the Dellums Federal Building.

## Conclusions and Future Directions

This paper has described the objectives of, components in, and technology platforms for GSA's GEMnet system. This system represents a significant advancement in integrating building control, remote monitoring, diagnostics, load shedding, and maintenance management. Such systems put to use the advancements of information technology to reduce energy use while helping to manage other operating costs. This technology helped launch GSA's response to California's energy crisis, as shown in the demand shedding events in the San Francisco Bay Area. Similar strategies will be developed for additional buildings. GSA is also making significant investments in building retro-commissioning, tackling the difficult and complex tasks to rework building control systems.

The technology infrastructure being developed within GEMnet sets the foundation of more fully automated diagnostic systems. In the future, model based diagnostic systems can be linked directly to maintenance management systems. Such systems would, for example, help establish the link between good chiller efficiency (kW/ton) and condenser cleaning. Similarly, when filters are cleaned, corresponding pressure drops from BAS data should confirm changes in performance metrics.

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## References

California Independent System Operator. *Summer 2001 Demand Relief Program*. Informational publication available at [www.caiso.com/clientserv/load](http://www.caiso.com/clientserv/load).

ANSI/ASHRAE Standard 135-1995: BACnet-A Data Communication Protocol for Building Automation and Control Networks.



Applebaum, Martin A. and Bushby, Steven T. 1998. "BACnet's™ First Large-Scale Test," *ASHRAE Journal*, July 1998, pp. 23–30.

Goldschmidt, Ira. 1998. *The Development Of BACnet™*, <http://www.bacnet.org/>.

Federspiel, Cliff. 2001. "A Web-based Occupant Feedback User Interface," LBNL High Performance Commercial Buildings Systems Program, Element 5, Project 2, Task 2.2.1. [http://buildings.lbl.gov/cec/Year\\_01/Element\\_5/01\\_E5\\_P2\\_2\\_4.html](http://buildings.lbl.gov/cec/Year_01/Element_5/01_E5_P2_2_4.html).

Kinney, S., Piette, M.A., Gu, L., and Haves, P. *Demand Relief and Weather Sensitivity in Large California Office Buildings*. Proceedings of the International Conference on Enhanced Building Operations, Austin, TX, 2001.

Friedman, Hannah and Mary Ann Piette, 2001. *Comparative Guide to Emerging Diagnostic Tools for Large Commercial*. LBNL-48629. <http://eetd.lbl.gov/btp/pub/CDpub.html>.

Clinton, William. 1999. Executive Order 13123. *Greening the Government Through Efficient Energy Management*. U.S. White House.

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