



**The  
California  
State  
University**  
Office of the Chancellor

**Control Systems  
Procurement Guide**

## **Control Systems Procurement Guide**

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## 1.0 INTRODUCTION

CSU campuses currently use Energy Management & Control Systems (EMCS) to monitor and control mechanical and electrical systems such as central heating and cooling plants, HVAC air distribution systems and terminals units, lighting systems, etc. Most campuses find their EMCS are able to meet technical energy management and control needs, but they have not been satisfied with other aspects such as competitive pricing, maintenance, and service. Few campuses have found approaches that fully meet their needs.

Ideally, the EMCS should provide and maintain the following features:

1. Excellent comfort control
2. Low EMCS maintenance and operator training costs
3. Minimum energy usage and energy costs
4. Extensive energy and efficiency performance metering and monitoring
5. State-of-the-art fault diagnostics and alarming capabilities
6. High density trending capability for analysis of system performance
7. Competitive first costs both for the initial phase of construction and for future phases as the campus expands
8. Competitive costs for responsive post-construction contractor maintenance and support
9. Flexibility with respect to possible changes in control system vendor in the future in case systems or their contractors do not perform as desired

Many systems can meet the technical goals posed by items 1 to 6. The more difficult task is developing a procurement approach that is successful at delivering features 7 to 9. The purpose of this Guide is to discuss the various procurement options that have been used and to recommend the few that have been the most successful at delivering these features. Note that this Guide is limited to commercial control systems; it is not intended to address industrial controls such as programmable logic controllers (PLCs) used by some campuses, particularly for specialized applications such as cogeneration plants.

## 2.0 PROCUREMENT OPTIONS

The table below summarizes the most common EMCS procurement options. Most but not all options apply to both new campuses and expansions of existing EMCS for existing campuses. Recommendations for both the best option for both new and existing campuses are provided in Section 5.0.

**Table 1 - Procurement Options**

Approach	Description	Advantages	Disadvantages
1. Open bidding	Allow any qualified bidder to bid each project. Results in various manufacturers being installed in different buildings across the campus.	Usually lowest first costs  No legal issues	High maintenance costs. With the 7 to 12 vendors that may result from this approach, staff levels would have to increase several-fold over normal levels.  Training requirements would increase by 100% with each new system added to campus.  Poorly operating MEP systems due to insufficient training, familiarity  Higher-end energy control strategies would be difficult or too costly to implement since data between different systems cannot easily be shared.
2. Two vendors, pre-qualified	Pre-qualify and select two vendors and allow only those two to compete on campus projects.	Limited competitive bid  Maintaining two systems is manageable (although not as easy as one)  Good option for campuses currently with unsuccessful sole-source approach	Politics and legal issues involved in picking the two vendors (e.g. why not three? Why these two?)  Compatibility between systems required for higher-end control strategies that require inter-communication of data  Cost control for expansion of existing building systems still required – may necessitate unit pricing or open book pricing  Possible collusion among the bidders is possible over time.  One vendor may fail to perform, leaving only one preferred vendor and subsequent reduced competition.

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Approach	Description	Advantages	Disadvantages
3. Two vendors, low bid	Select the low bid for initial campus construction (or existing sole source vendor) then allow any vendor (perhaps limited to compatible vendors; see option 7) to bid new projects. The low bidder becomes the second allowed vendor for all future phases.	<p>Limited competitive bid for work after initial bids</p> <p>Maintaining two systems is manageable (although not as easy as one)</p> <p>Good option for campuses currently with unsuccessful sole-source approach</p>	<p>No prequalification required.</p> <p>Still a political/legal question, “why not three vendors?”, but the question, “why these two” is defused.</p> <p>Compatibility between systems required for higher-end control strategies that require inter-communication of data. This may limit acceptable second vendors, reducing competition.</p> <p>Cost control for expansion of existing building systems still required – may necessitate unit pricing or open book pricing</p> <p>Possible collusion among the bidders is possible over time.</p> <p>One vendor may fail to perform, leaving only one preferred vendor and subsequent reduced competition.</p>
4. Sole source with equipment price controls	Select initial vendor based on low bid for initial campus construction (or existing sole source vendor) then allow only this vendor for all future projects with price controls on equipment (e.g. GSA pricing) to ensure competitive equipment pricing. Pricing from vendor should be obtained prior to bid and stipulated in bid doc's.	Only one system reduces training and maintenance costs	<p>Parts from vendor amount to only about 15% of total costs. Total parts and equipment costs amount to only 30% to 50% of project costs. This approach does not ensure competitive pricing on application engineering, installation, and start-up and commissioning. A labor rate for these tasks is a good idea but not enough to limit these costs.</p> <p>Danger of “low balling” initial bid with higher pricing for future phases.</p>
5. Sole source vendor supplying only “parts and smarts”	Select initial vendor based on low bid for initial campus construction (or existing sole source vendor) then allow only this vendor for all future projects to provide only application engineering, parts, final terminations, and start-up and commissioning. Vendor would prepare drawings for all sensor and control wiring prior to bid. Conduit/wire and installation and sensor installation to be included in Division 15 or 16 as part of bid. Price controls on equipment (e.g. GSA pricing) and labor rates. Pricing from vendor should be obtained prior to bid and stipulated in bid doc's.	<p>Only one system reduces training and maintenance costs</p> <p>Competitive bid on wiring and conduit and sensor installation</p>	<p>Does not ensure competitive pricing on application engineering, start-up and commissioning, which amount to about 15% to 35% of project costs. A labor rate for these tasks is a good idea but not enough to limit these costs.</p> <p>Danger of “low balling” initial bid with higher pricing for future phases.</p>

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Approach	Description	Advantages	Disadvantages
6. Sole source with unit pricing	Select initial vendor based on low bid for initial campus construction (or existing sole source vendor) but also include unit pricing of typical applications, including costs for installation, engineering, and start-up and commissioning. Unit prices for future projects must be weighted so that low bid includes impact of future phases. Unit prices are regularly renegotiated and adjusted for inflation, etc.	<p>Only one system reduces training and maintenance costs</p> <p>Future buildings fairly priced as long as unit price systems cover a large majority of building applications.</p>	<p>High engineering cost required to define unit pricing items and their scope.</p> <p>Added bid effort may dissuade some contractors from bidding.</p> <p>Not all applications covered by unit pricing, possibly resulting in some price inflation on unusual applications.</p> <p>Prices will have to be updated after a few years to reflect inflation and technology changes, leaving open the possibility of future price inflation due to no competition.</p>
7. Open protocol systems	Limit bidding to systems using one of the two open protocols (BACnet or LonWorks). Select protocol based on low bid for initial campus construction (or existing sole source vendor provided they use open protocol) then allow only vendors using this protocol for all future projects.	<p>Low cost due to multiple bidders, although number of bidders is reduced after initial installation in order to ensure compatibility.</p> <p>Ensures that gateways to subsystems (e.g. chillers, lighting) will remain supported (unlike those to proprietary networks)</p>	<p>Eliminates vendors with proprietary networks</p> <p>True plug &amp; play ideal is not currently possible with either protocol. Gateways are generally required just like to proprietary networks.</p> <p>Does not eliminate the need to learn and use multiple set-up and application engineering programs for each vendor.</p> <p>Greater networking knowledge is required to successfully integrate multiple open protocol systems at a single location, particularly with LonWorks</p> <p>No single source of responsibility for inter-compatibility</p>
8. Vendor represented by multiple installing contractors	Limit bidding to control systems that are sold "over the counter" to various installing contractors, or to systems that have multiple contractors/dealers serving the same geographic territory, allowing the contractors to compete but limiting the controls hardware to a single vendor. Price controls on equipment (e.g. GSA pricing) to ensure competitive vendor equipment pricing.	<p>Only one system reduces training and maintenance costs</p> <p>Low cost due to multiple bidders, although number of bidders may be limited</p> <p>Flexibility in future for service and installation; if one contractor does not support the product well, others are available</p>	<p>Can limit vendors since only a few vendors have multiple contractors/dealers serving one territory</p> <p>Because of the remoteness of some campuses, there may not be many contractors representing these products, reducing, perhaps eliminating competition</p> <p>For "over the counter" products, quality of installing contractors varies since generally "anyone" can sell the product</p> <p>No single source of responsibility for inter-compatibility due to numerous installing contractors</p>

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Approach	Description	Advantages	Disadvantages
<p>9. Multiple vendors with third party integrator</p>	<p>Allow multiple vendors to bid each building (perhaps limited to open protocols) but use a common "single seat" front-end graphical user interface that can provide the same look-and-feel interface to all systems</p>	<p>Low cost due to multiple bidders</p>	<p>Limited third party integrators on market</p> <p>Integrator generally becomes sole source after first phase of construction</p> <p>Requires cooperation among various vendors and contractors</p> <p>No single source of responsibility for inter-compatibility due to numerous installing contractors</p> <p>Does not eliminate the need to learn and use multiple set-up and application engineering programs for each vendor.</p> <p>Higher-end energy control strategies would probably not be possible since data between different systems cannot easily be shared and front-end system mostly likely will not have the speed to serve as a gateway for transfer of data required for control loops.</p>
<p>10. Campus becomes dealer and installer</p>	<p>Vendors pre-qualified to those that would allow campus to become dealer. The controls would be bid among qualified vendors for the initial construction, then the campus would become a dealer of the selected system and self-perform controls design, start-up, and commissioning on all but very large projects. Conduit, wire, and sensor installation would be bid as part of Division 15 and 16 work.</p>	<p>Only one system reduces training and maintenance costs</p> <p>Lower installation cost since no mark-up and profit from outside firm</p> <p>In-house personnel are experts (not just trained) on system and thus can maintain it better, improving energy and comfort performance</p> <p>Small changes such as adding a zone or optimizing control programming can be more easily done (no outside POs and contracts to write)</p>	<p>Limits vendors in initial bid to those willing to allow campus to become a dealer.</p> <p>Exposure to inflated pricing on large projects since local non-campus vendor will be required (in-house staff will be most likely be too small)</p> <p>Requires commitment from campus to hire and retain high-end controls technicians and a department manager. If this does not happen, this option in effect becomes the sole-source approach.</p> <p>Overhead higher due to larger number of and management for in-house technicians. If managed well, however, this cost will be offset by reduced control system cost.</p> <p>If the in-house group does not perform on a project, they can be blamed for any delays or problems that arise, resulting in claims against campus.</p> <p>Lack of continuity if controls work is not continuous since not enough work to keep technicians employed</p> <p>Difficulty in accounting for in-house costs used for construction projects</p>

### 3.0 INTEROPERABILITY AND OPEN PROTOCOLS

Open protocols are those whose characteristics are published and may be used by anyone freely or by license. There are two major open protocol systems used in building EMCS: BACnet and LonWorks.

The BACnet protocol was developed using the ANSI consensus process through ASHRAE. BACnet was designed for building automation systems by EMCS manufacturers and users and is under continuous development by ASHRAE and worldwide user groups.

LonWorks and the LonTalk protocol were developed by a manufacturer (Echelon) through a private process and must be licensed. It is supported by an organization of manufacturers (the LonMark Consortium) who develop implementation standards and device certification. It was developed as a general information network protocol and has been applied to many industries in addition to building control.

The goal of open protocols is to provide interoperability among multiple vendors, much the way Microsoft Windows-based PC peripherals from various manufacturers can be installed and operated with minimal user configuration. Unfortunately, this “plug & play” ideal is not currently possible with either BACnet or LonWorks. Furthermore, even when different devices are able to coexist on a single network, each product will still have its own proprietary setup and application engineering software, and each will have its own unique maintenance requirements for which operators must be trained. Thus from a maintenance and operations standpoint, there is no advantage, and in fact there may be a distinct disadvantage, to mixing EMCS controllers from various manufacturers even if they were interoperable.

If a single EMCS manufacturer is used for the entire campus (some type of sole-source relationship), interoperability would seemingly not be an issue – the EMCS clearly could use either open or proprietary protocols.

So why consider limiting EMCS vendors to only those using open protocols? The primary advantage for a CSU campus is that it provides an “exit strategy;” it makes it much easier and less disruptive to migrate to another vendor or product line in the future. There are a number of plausible scenarios that could trigger this need, including: insolvency of the vendor, problems with either the supplier or local support, or acquisition of the vendor by another control company that discontinues support of legacy systems. In any of these cases, new projects could be completed with a new vendor/product line using the same open protocol while the existing systems are phased out over time. With an open protocol system, a single interface and, possibly, a common network could be used to access all of the controls throughout the transition period.

Another advantage of an open protocol is that third party software for user interface, trending, and alarming can be employed across all of the manufacturers’ systems. Open protocols also make it easier and less expensive to maintain gateways between the EMCS and subsystems (e.g. lighting and chiller controllers) as software on either side of the gateway is updated with new

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versions. (Proprietary EMCS protocols can require expensive custom reprogramming of gateways when software upgrades are made.)

Finally, companies that use open protocols tend to have a different overall business relationship with their users, a less “possessive” attitude; they earn future business by meeting customer needs, not by trapping customers with proprietary products.

### 3.1 LonWorks vs. BACnet

A brief comparison of LonWorks and BACnet is presented in Table 2<sup>1</sup>:

**Table 2 – LonWorks and BACnet Comparison**

	LonWorks	BACnet
<b>History</b>	1988-Released by the Echelon Corporation 1994-LonMark® Organization formed 1997-First LNS release 1999-ANSI/ESI standard	1987-ASHRAE committee formed 1995-ASHRAE 135 BACnet1995 released 2001-ASHRAE 135 BACnet 2001 released 2003-ASHRAE 135.1 BACnet Method of Test released 2004-ASHRAE 135 BACnet 2004 released 2004-Adoption as ISO/CEN standard
<b>Goals</b>	Vendor Independence Interoperability	Vendor Independence Interoperability
<b>Architecture</b>	A "bottom up" solution focused on the controller Open protocol Flat architecture	A "top down" solution focused on HMI integration Open standard Tiered architecture
<b>Certification</b>	LonMark Organization sets LonWorks standards and certification requirements Device certification LonMark Functional Profiles (LFP) Standard data types (SNVT and SCPT)	BacNet Testing Laboratories (BTL) test and verify manufacturer's selected use of BACnet BTL does not set BACnet standards Undergoing test qualification program, with testing open to BMA members only.
<b>Protocols</b>	LonTalk® Embedded into every Neuron® Chip Can be ported to any processor, from 8-bit microcontrollers to 32-bit microprocessors Every LonWorks device used LonTalk Supports various media - 1 protocol	Multiple protocols supported BACnet/IP, Ethernet, ARCNET, MS/TP, PTP, LonTalk All industry standard protocols Each with specific implementation and media requirements
<b>Controllers</b>	Neuron Chip processor Neuron C programming language I/O Channels Transceiver Hosted controller Controllers have "out of the box" commonality	Processor independent Programming language independent I/O Channels Final controller specification at manufacturer's discretion Controllers have nothing in common "out of the box"

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<sup>1</sup> This table is from a TAC white paper, “Open Systems: LonWorks Technology and BACnet Standard” by Frank Capuano. TAC is a LonMark member at the Sponsor level. Although this table is fairly complete, it represents a bias towards LonWorks due to its author's affiliation.

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**Table 2 – LonWorks and BACnet Comparison**

	LonWorks	BACnet
<b>Distribution</b>	<p>Direct from manufacturer as part of a complete solution</p> <p>Many companies produce solution independent LonWorks devices (lighting, sensors, drives, power metering, diagnostic, etc.)</p> <p>Independent distributors representing devices from multiple vendors.</p>	<p>Direct from manufacturer as part of a solution</p> <p>Very few companies produce solution independent BACnet devices (lighting controllers, diagnostic tools, gateways)</p> <p>No independent distribution</p>
<b>OSI</b>	<p>Data packet structure based on the 7-layer OSI reference model.</p> <p>LonTalk uses 7-layer data communication packets</p> <p>Using all 7 layers enables LonTalk to be used in control environments beyond building control</p>	<p>Data packet structure based on the 7-layer OSI reference model</p> <p>BACnet uses 4-layer data communication packets (collapsed architecture)</p> <p>Using only 4 layers limits the number of control environments to which BACnet can be applied</p>
<b>Topology</b>	<p>Flat architecture</p> <p>No gateways</p> <p>Change media, use same protocol</p> <p>Every device is a peer on the network</p> <p>Each device can communicate directly with the HMI using SNVT and SCPT data formats</p>	<p>Tiered architecture</p> <p>Gateway solution</p> <p>Native BACnet solution</p> <p>Change media, new protocol</p> <p>Controllers are grouped behind supervisory devices</p> <p>Typical implementation uses multiple protocols</p>

Both the LonWorks and BACnet Standards have advantages and disadvantages.

LonWorks primary advantages over BACnet include:

- 1) LonWorks typically results in a less expensive architecture at the device level, allowing the use of “smart” devices each addressable by the network. This lends itself particularly to lighting controls and zone-level HVAC controls. (A relatively new concept using BACnet for micro lighting control networks, Integrated Building Environmental Communications System – IBECS, is under development but not yet commercially available.)
- 2) There currently are a larger number of manufacturers developing LonWorks products, although the trend appears to be shifting towards BACnet (see below) for building-related systems. Both protocols have HVAC, lighting, security and life-safety control products. There are currently many more products available using LonWorks than BACnet in related industries such as audiovisual and elevator controls. In theory, these products can be tied to a single, massive network, potentially reducing installed costs. However, in practice separate networks are used due to the common industry practice of procuring each function from different contractors, and the predominant use of proprietary configuration tools and user interfaces by each vendor. Also, as discussed in Section 4.0, there is also little synergy to having a single network integrating EMCS, security, life safety and other functions.

- 3) LonWorks devices are currently closer to plug & play than BACnet, although both protocols are still a long way from achieving the interconnectivity found with modern PCs using Microsoft Windows. BACnet provides less seamless integration due to more variations in network transport protocols and more varied implementation possibilities of BACnet objects compared to LonMarked devices. With LonWorks, different vendors' VAV box controllers can usually be interconnected on a single LonWorks network, for instance. However, as noted above, there are disadvantages to doing so since each vendor's controller would require unique configuration and programming software and maintenance requirements.

BACnet advantages over LonWorks include:

- 1) BACnet has protocols for trending, alarms and scheduling while LonWorks does not. LonWorks based products use proprietary protocols for these functions and as such are not truly interoperable with other LonWorks systems.
- 2) LonWorks systems generally use a flat architecture where intelligence is widely distributed, at times resulting in controlled devices and controlled variables connected to separate controllers with the LonWorks network required to provide the necessary information transfer. Most control system designers recommend avoiding this architecture since network traffic speeds vary, or the network may be physically interrupted, which can lead to control loop instabilities or system failure. LonTalk is a non-deterministic transport protocol, which means there is no way to guarantee how long it will take for a message to get from one node to another under all circumstances. In practice, however, manufacturers of LonWorks products claim that the network is sufficiently robust to "work" using this architecture.
- 3) The BACnet protocol was developed with input from both users and manufacturers during its development through the ASHRAE/ANSI standards process. The LonWorks protocol and LonMark standards are proprietary and not open to public comment; only dues-paying members (virtually all of whom are manufacturers) can participate in their development. The BACnet standard, designed specifically for building control and with non-manufacturer input, does a better job of addressing facility owners' needs (such as defining standardized trending and alarm objects).
- 4) LonWorks allows a wide range of extensions for proprietary purposes. However, using these extensions is almost guaranteed to cause undesirable interactions between "uncoordinated implementations," and hence not allowed if the product is to have a LonMark label. So while LonWorks is easily extensible in theory, it is not safely extensible and, for LonMarked products, it may not be extended without the changes agreed to by the LonMark Consortium. BACnet is freely extensible, allowing manufacturers to more easily increase functionality. This is of course both an advantage and a disadvantage since it can reduce plug & play interoperability, as noted above.
- 5) BACnet is not hardware-specific and can run on virtually any network transport protocol, including TCP/IP and even LonTalk. LonWorks systems use a proprietary "Neuron<sup>®</sup> chip" and the LonTalk protocol with network speeds limited by LonTalk

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transceivers, typically a relatively slow 78 kbps. Faster transceivers are available but generally used only at the highest levels to minimize costs and only up to 1.25 Mbps using LonTalk. This may be a limiting factor in the massive point trending capability often desired for CSU campuses due to high network traffic. Ethernet speeds (>100 Mbps) available with BACnet/IP products are currently only possible with LonWorks using tunneling routers or servers, such as Echelon’s i.LON 1000 server/router or Tridium’s JACE. These are generally based on proprietary methods with little or no standardization or interoperability across vendors. This can limit the scalability of Lon networks because only Lon-based routers can be used, and Ethernet and other truly standard LANs cannot be employed using standardized internetworking technology.

- 6) Configuring LonWorks networks is relatively complex. Echelon encourages the use of its LonMaker Integration tool and the LNS Network Operating System, a generic platform for configuring LonWorks networks. Presumably because of the cost of licensing this software and/or to make it easier for installers to configure their systems, many vendors have developed their own proprietary configuration software. However, this can effectively make the system proprietary and no longer interoperable with other Lon systems.
- 7) BACnet appears to be “winning” among building related control system products, as shown in the table below. A significant indicator of the trend is the number of manufacturers who have developed “native” (top to bottom) BACnet product lines is ever increasing, including manufacturers currently with major market share in proprietary products and one manufacturer with a mature LonWorks product line. If the trend continues, interoperability among BACnet products will likely improve.

	Units (1000s)			Revenue (millions of \$US)		
	BACnet	LonWorks	BACnet Advantage	BACnet	LonWorks	BACnet Advantage
1998	145	44	+101	110.4	43.4	+67
2001	183 (26% increase)	58 (32% increase)	+125	231.4 (110% increase)	61.2 (41% increase)	+170.2
2008*	747 (308% increase)	90 (55% increase)	+657	648.1 (180% increase)	78.5 (28% increase)	+569.6

**Table 3** - Units sold and revenue for BACnet and LonWorks in the building automation systems industry, 1998-2008  
(Source: Frost & Sullivan, *North American Building Protocol Analysis*, 2001).

### 3.2 Open Protocol Recommendations

Limiting vendors to those using open protocols can limit competition, although the impact is ever decreasing as market pressures continue to push towards open protocols. Using open protocols may offer the advantages described above, but forcing this approach would be a poor course of action if it eliminated all or even most of the proven high performing EMCS vendors available. After all, it is the system's performance and dealer support that will play a more significant role in the success of the installation than what protocol is used.

Fortunately, market forces are such that proprietary protocols are all but gone; the last major holdouts using proprietary protocols now have or soon will have Lon and/or BACnet product lines. Hence, we recommend that campuses insist on using open protocols for new projects even if they have legacy systems that use proprietary protocols.

## 4.0 INTEGRATED SYSTEMS

It is possible to integrate the EMCS with other systems such as security, fire alarm, and life safety systems into a single system. This allows them to share points and information, such as:

- For buildings requiring smoke control (e.g. high rise buildings or atria), control points such as fan status and damper overrides can be shared between EMCS and fire/life safety controls, reducing sensor costs.
- Security data can be used for EMCS logic, such as starting HVAC systems or enabling lighting when a space is entered during off-hours using a security card-key.

But there are several disadvantages to integration:

- It limits the number of vendors since very few offer fully integrated systems. To use the EMCS for smoke control, the product must be UUKL listed, further limiting product options and possibly increasing controller costs. The reduced competition can (and usually does) offset the cost savings noted above resulting in increased overall costs.
- Fire/life safety systems must be fully tested and approved by local fire authorities before the building can be certified for occupied. EMCS are notorious for being late in completion – they are seldom fully commissioned and operational when the building opens. Integrating the two can therefore jeopardize occupying the building on time.
- Integrated systems are more prone to failure of critical components due to improper work done on less critical elements. For instance, with an integrated EMCS and security system it is possible for an HVAC maintenance worker to inadvertently bring down the security system network during routine EMCS work.
- Integrated systems are more prone to “hacking” and unauthorized penetration of security systems. Insurance carriers often restrict integration for this reason.
- Security, life safety, and energy management/maintenance are generally assigned to different departments on campus so there is little opportunity for labor savings (and more opportunity for unauthorized access) due to integration.

Generally the disadvantages of integrated systems outweigh the advantages. The one advantage of integration, sharing information, can be easily (and usually less expensively) accomplished using a gateway or hard-wired I/O points between the systems.

## 5.0 PROCUREMENT RECOMMENDATIONS

Based on interviews with UC and CSU campus engineering and energy managers, the ideal EMCS procurement approach will:

- Result in a single EMCS vendor for ease of maintenance and integration of all campus buildings.
- Provide cost control through long term competitive pricing as the campus expands.

The best approach to achieve these goals depends significantly on the status quo at the campus. Table 4 summarizes typical campus status quo and recommended approaches for each. However, these are guidelines only; conditions at each campus and the campus’ relationship with current vendors and dealers/contractors can change the desired procurement approach.

**Table 4 - Procurement Recommendations**

Current Campus EMCS Status Quo	Recommended Approach	
	No. (See Table 1)	Description
New Campus or EMCS	7+8	Limit vendors to “native” BACnet open protocol and to those that have multiple dealers willing to share the CSU territory. (May not be possible at all campuses.)
Existing sole-source vendor, satisfactory relationship	5+7	Sole source vendor should supply only “parts and smarts,” allowing conduit/wire and installation and sensor installation to be included in Division 15 and 16 as part of project bid. Price controls on vendor equipment (e.g. GSA pricing), purchased equipment (purchase price plus fixed markup), and labor rates. Vendor should be required to migrate to open protocol option if currently proprietary.
Existing sole-source vendor, unsatisfactory relationship	7+8	If other dealers of vendor product exist locally, insist that they be allowed to bid as well.
	or 3+7	or Open bidding to a second vendor that uses same protocol as existing vendor.
Existing multiple vendors	3+7	Migrate toward only two vendors that use the same open protocol, preferably “native” BACnet.

## Appendix A - Bibliography on BACnet and LonWorks

### Publications

ASHRAE Standard 135-2001 - BACnet® - A Data Communication Protocol for Building Automation and Control Networks

ASHRAE Guideline 13-2000 - Specifying Direct Digital Control Systems

Introduction to the LonWorks® System. Echelon. Available from the Echelon manual website (see below). Publication 078-0183-01A

### Websites

DDC Online <http://www.ddc-online.org>. This website was originally developed by compiled by Jay Santos of Facility Dynamics (<http://www.facilitydynamics.com/>) and the Iowa Energy Center (<http://www.energy.iastate.edu/>). It details the network architecture of a core group of controls manufacturers.

AutomatedBuildings <http://www.automatedbuildings.com/>. This site is an e-zine on building automation and controls. There are a wealth of articles on both LonWorks® and BACnet® on this site.

Echelon <http://www.echelon.com/Products/Core/default.htm>. This site has product information for Echelon and the neuron chip.

Echelon <http://www.echelon.com/Support/documentation/Manuals/>. This site has a number of guides for LonWorks® and LonMark®.

LonMark <http://www.lonmark.org>. LonMark is a manufacturing association similar to BMA.

LonMark certified products [http://www.lonmark.org/products/prod\\_list.cfm](http://www.lonmark.org/products/prod_list.cfm). This site lists products that bear the LonMark certification.

BACnet® <http://www.bacnet.org/>. This is the official website of ASHRAE's Standard 135 committee. This committee is responsible for the publication of the BACnet® standard. There is a wealth of resources on this site for BACnet® including links to many other BACnet® websites.

BACnet® Manufacturer's Association (BMA) <http://www.bacnetassociation.org/>. This is a manufacturing association similar to LonMark.

BACnet® Testing Laboratory (BTL) <http://www.bacnetassociation.org/btl/default.htm>. This is a testing laboratory that is developing and administering tests to certify device compliance with the BACnet® standard.

### Articles

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