CALIFORNIA INSTITUTE OF TECHNOLOGY

Laser Interferometer Gravitational Wave Observatory (LIGO) Project

To/Mail Code: Distribution
From/Mail Code: Albert Lazzarini, Dennis Coyne
Phone/FAX: 818-395-8444, 2034
Refer to: LIGO-E950106-00-E
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Subject: LIGO Requirements and Options for Facilities Monitoring and Control System (FMCS)

The Integration Meeting of Monday 18 December 1995 was dedicated to a discussion of LIGO options in the selection of the FMCS for the buildings. In attendance were Althouse, Barish, Bork Coles, Coyne, Fischer, Heefner, Lazzarini, Sanders, Savage, Shoemaker, Sibley, Stapfer, Vogt, Weiss and Young.

1. Background

The PDR FMCS baseline consisted of a top-end FMCS design incorporating a separate fiber-optic LAN allowing inter-building communication and centralized facilities control from the Facilities Control Room in the OSB. The single vendor quote (from Johnson Controls) used to cost the design was approximately $300K in excess of the amount originally budgeted by RMP for the 100% Conceptual Design. The cost included at the 100% Conceptual Design corresponded to a bottom-end, conventional all-pneumatic, autonomous and independent array of controls for each building at the site. In an effort to contain cost of the facilities, a review was conducted, with the help of RMP, to establish options for LIGO. See the attached memorandum, LIGO-C951295-00-O from RMP (Hermann) to LIGO (Lazzarini) for details on the cost options.

2. Requirements

The one requirement on facilities performance affected by the FMCS is temperature control within the LVEA/VEAs. This has been specified at +/- 3.5F by LIGO to Parsons. The LIGO thermal environment requirement is silent on allowed spatial temperature gradients. All options considered provide this level of control accuracy in the steady state.

3. Desired Features

LIGO has decided to consider options other than the low-end pneumatic one because there are other features of the FMCS which have been deemed desirable by LIGO. These include:

- The ability to log a record of the facilities state vector: which equipment is running; which is off; with a time stamp resolution on the order of ten seconds. This feature is deemed useful to provide the ability off-line to correlate GW signals and PEM vetoes with specific hardware states.
- The ability to remotely switch machinery on and off from the FCR. This feature is

deemed potentially most useful in the shakedown and debug phases of interferometer integration.

- The ability to achieve better than requested thermal stability (reflecting in part the decision to choose a thinner foundation thickness). This is somewhat offset in that the FMCS thermal control design (and LIGO requirement) is silent on spatial variation of temperature within the LVEA/VEAs. According to RMP, the temperature specification is the temporal variation at the measurement point only (i.e., at the thermostat). Up to 5 thermostats can be linked in to the DDC system for each thermal control zone (of which there are 5 in the LVEA) and they can be averaged by the FMCS controller. Presumably, it should be possible to introduce any algorithm LIGO defines to better improve the spatial distribution. Note that the extra 4 sensors are included in the costs quoted for Options 2 and 3 in the referenced RMP document (though this is expected to be a minor cost and within the uncertainty of the estimated costs).

- The potential to use the FMCS by the relatively small number of LIGO personnel at the observatory during the off-hours to aid them in running the facility. This includes: the ability to access data from the out-lying stations from the FCR; the ability to remotely switch equipment on and off; the ability to pan CCTV to scan a remote site.

- The potential to use the operations log of the facilities equipment to perform diagnostics and preventative/planned maintenance to maximize the availability of the facilities for scientific observations.

4. Conclusions from the 18 December Meeting at LIGO

The options referred to below are described in the RMP memorandum attached.

[1] The general consensus was not to have an independent FMCS fiber-optic LAN (Option 1). This decision was based on considering its cost and the small advantages it brings over other options.

[2] For option 4, the all-pneumatic option, the lack of capability for upgrade and the lack of capability to log facility states, both of which are inherent with this option were identified as disadvantages. The general consensus was that Option 4 does not meet LIGO long term operational desires.

[3] Either Options 2 or 3 appeared acceptable, but additional information was requested by the group. Systems Engineering agreed to look into the following: (i) what constituted “Smart Lighting” or computer-controlled breakers (Option 1); (ii) how CCTV is provided in association with the options; (iii) what the spatial thermal distribution is expected to be; and (iv) whether, for Options 2 and 3, it is possible to apportion the cost increment between better thermal control and increased state vector logging and control. These are discussed below.

5. Actions and Answers

The issues raised in 4. above were addressed in a meeting at RMP attended by Lazzarini, Coyne, Hermann, Atia and Ramsing on 19 December 1995.

[i] Smart Lighting constitutes computer-addressable circuit breakers to turn circuits (primarily lights) on and off remotely. Option 1 includes communication between such smart breakers and the FMCS: none of the other options do. However, it is still possible to provide for smart breakers which can be controlled by another computer (other than FMCS). The costs associated with this feature were stated as: $1k/breaker panel for the transceiver unit; $50/breaker itself. Communication with a processor is via a twisted pair included in the breaker panel wiring. The PDR design carries computer-controllable breaker panels for lighting, CDS, and VE racks throughout the facilities. This appears excessive.

[ii] The Facility DCCD states that there is to be a CCTV system with video display in the FCR at the corner station. If the FMCS option chosen did not integrate the remote facilities with fiber-optic communications, then the CCTV would have to go over ISDN or modem. In this event, the frame rate would suffer considerably (flicker or "snap-shot" updates). This may be acceptable for LIGO needs, since we are not likely to use the CCTV to watch dynamic processes/events (e.g. watching a pressure gauge). Parsons was requested to define the requirements for analog transmission of the CCTV. (Note that CCTV is a peripheral issue and does not directly bear upon a decision regarding the basic FMCS option.)

[iii] The thermal analysis performed by Parsons does not directly model the transient response of the building or the temperature control system, nor does it calculate the spatial temperature gradients (other than on the coarseness of the chosen zones). The conclusions from a considerable amount of discussion are that

> (1) local heating problems need to be handled locally (not by directing flow down to a component from 30 ft above) and
>
> (2) if LIGO anticipates significantly non-uniform spatial variation in heat dissipation, then this should be reflected in the spatial discretization and number of zones.

During the integration process, the heating loads may in fact be somewhat nonuniform within each zone; the implications of this non-uniformity is not yet known, but will be addressed now. When the complete system is fully operational, then the heating loads are fairly well distributed (but there are to date no quantitative assessments on the resulting spatial temperature gradients). <u>The finding that spatial thermal gradients are not addressed in the RMP PDR design may be of potentially significant interest to Detector. If greater information than is presently available is required, this should be noted immediately.</u>

[iv] It is not possible to ascribe the cost increment between better thermal control and increased state vector logging and control, since the system which permits better thermal control, through digital sensing and control, inherently has the capability to perform the logging.

6. Recommendations and Findings

[A] The finding that spatial thermal gradients are not addressed in the PDR design should be noted. See the preceding discussions.

[B] During the meeting with RMP it was recommended that one (1) breaker panel in each of the 4 separated station buildings should be outfitted with a transceiver and smart breakers for lighting circuits (2 per building) and controlling the wall receptacle circuits (4 per building). No such provision is recommended for the corner station. Incidentally the computer-addressable circuit breakers are the same form factor as the non-addressable breakers and could be retro-fitted at a later date if desired elsewhere. In addition, it is recommended to delete the provisions for computer-controllable circuit breakers for CDS and VE circuits in the LVEA/VEAs.

[C] At present, there are no established requirements for the features inherent in an integrated FMCS. Nonetheless, the discussions in our 18 December meeting indicated that a consensus exists that, if possible, it is prudent to invest now for capabilities that will be required later to allow for expanded FMCS operationality. How this expansion might look would be deferred to a later date when experience with running the facilities identify needs.

As described in the RMP attachment, Option 3 does not allow remote building-to-building data transfer and centralized environmental control. Lack of these features is what distinguishes it from Option 2. However, in the follow-up meeting at RMP, it was determined that it would be possible, at a later date, to introduce modem/analog telephone links from the FCR to all other site buildings. Such a relatively low bandwidth link could be used to perform data log transfers to a centralized collection point. In addition, because the FMCS control bandwidths are low, the modem link could also permit real-time control from the FCR. To do this a workstation and accompanying control software would be required. The lack of a fiber-optic LAN communication system for FMCS with Option 3 implies that the bandwidth would always be limited to modem or ISDN-based communications. This would limit the video update rates for CCTV to rates well below real time. Furthermore, the FMCS operationality would be subject to the availability of telephone service at all times.

Option 2 provides real-time control of the facilities environmental via Ethernet LAN interfaces which would be provided in each of the remote buildings at the site and a FMCS workstation in the FCR. These interfaces will allow FMCS to utilize the LIGO CDS-LAN infrastructure[1] to communicate signals to the corner station FCR from separate building at the site.

The $20k cost difference between Options 2 and 3 is in the FMCS workstation, localized control software, and Ethernet LAN interfaces in all remote buildings that is required with Option 2. This additional $20k will provide, from the beginning of operations, [i] higher bandwidth capability,

1. Per CDS's suggestion, Parsons was requested to define a network protocol (or a set of preferred protocols) for connecting the FMCS to the CDS fiber-optic bundle, most likely dictated by available vendor products; LIGO will then review and approve a protocol before a specification is issued. In this scenario, CDS will handle routing the data to the fiber-optic transceivers.

[ii] remote environmental control and [iii] data transfer.

The decision regarding FMCS is central to the approach taken by the HVAC design, and lack of a decision will delay progress on the HVAC final design at Parsons. The recommendation is to select Option 2. The additional cost above Option 3 is a reasonable investment for future expendability.

The $120k incremental cost for an integrated FMCS (the difference between the Option 2 quote and the Option 4 estimate) needs to be compared to anticipated operational and life-cycle cost savings. This is a difficult and fuzzy analysis, especially since LIGO does not have operational experience with the facilities. A CCB action recognizing the following FMCS features of Option 2 as LIGO needs is required:

1. Seamless expendability of the FMCS.
2. Multiple thermal sensors for the control of individual LVEA zones.
3. Ability to remotely turn on and off various facilities HVAC elements during shakedown investigations.
4. Ability to log machinery operating times, both for scientific cross-correlation with data and for maintenance scheduling.
5. Ability to power up or power down at least one breaker panel in the remote buildings at the site.
6. Ability to provide for fast video update rates for the CCTV systems.

AL:al

cc:

Althouse	Coyne	Matherney
Asiri	Jones	Shoemaker
Coles	Lindquist	Stapfer
Zucker	Whitcomb	Raab
Sanders	Barish	Sibley
Spero	Savage	
Vogt	Weiss	Chronological File
Young	Worden	Document Control Center

Attachment: C951295-00-O, RMP FMCS Options Memorandum