LASER INTERFEROMETER GRAVITATIONAL WAVE OBSERVATORY
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Advanced LIGO Guardian Progress and Remaining Tasks

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1 Introduction

This document describes the progress towards completion of the Advanced LIGO automation system, otherwise known as *Guardian*. The primary motivation here is to define the point at which completion of automation work under the Advanced LIGO Project work can be declared, with further work under the scope of aLIGO Operations. As of this writing, the Project→Operations transition is scheduled for December 2014.

The requirements for Advanced LIGO automation are outlined in [1], and an overview description and user manual for the aLIGO Guardian system is described in [2].

Section 2 describes the current development and deployment status. Section 3 describes the remaining tasks that should be completed under the aLIGO Project. Section 4 describes further enhancements and improvements to the automation system that could be completed under aLIGO Operations.

2 Progress

After an initial attempt at defining an automation environment for aLIGO [3] failed to take hold, management of the automation system was restructured in Q2 2013. At that point the Guardian system was completely re-engineered from the ground up, with a new structure, behavior, and interface.

The new Guardian system has already achieved many key milestones towards full automation of the aLIGO detectors:

Core Guardian engine developed The new Guardian automation engine was defined and developed during Q3-4 2013. A new reference implementation was prototyped and deployed at the Hanford Observatory during Q4 2013, and deployed at the Livingston Observatory in Q1 2014. Stable versions are now installed and operational at both facilities (LHO 12486).

Supervision infrastructure deployed The Guardian process supervision infrastructure, by which all Guardian automation processes are managed on dedicated machines, is in place at both observatory facilities (LHO 8711, LLO 10434).

Input mode cleaner (IMC) auto-locker The first subsystem to be automated under the new infrastructure was the H1 input mode cleaner auto-locker in Q4 2013 (LHO 8942). This was followed by the IMC at LLO in Q1 2014 (LLO 10448).

Suspension (SUS) subsystem All multi-stage suspension systems have been automated for both interferometers (LHO 9757, LLO 10436).

Seismic (SEI) subsystem The seismic subsystem is now fully automated. This includes coordinated automation of the external pre-isolation (HPI) and all internal isolation stages for both chamber types (HAM and BSC) (LHO 11904, LLO 12965).

Interferometer lock acquisition An initial automation procedure for full interferometer lock acquisition has been demonstrated at LLO (LLO 12874, LLO 12928).

3 Remaining Tasks

The following tasks are essential for the proper functioning of the automation system, or for proper documentation, and should therefore be completed as part of the aLIGO Project.

1. **Monitor settings in RTS** New features are being added to the Real Time System (RTS) for improved setting and tracking of system parameters/settings [4]. After the new features are in place, all subsystems should be configured to enable parameter monitoring and alarming on unexpected changes. Existing Guardian code should be modified to include notifications for settings alarms.
2. **Node state tracking** The DAQ system is only able to record numeric values into the LIGO frame data. Guardian node states are therefore mapped to numeric values that can be recorded. Down stream data consumers wishing to reconstruct the state of the automation system (e.g. detector characterization and data analysis pipelines) will need the ability to reconstruct the state of the system from the numeric representation. The state numeric representation either needs to be made (more) static, or the mapping needs to be published in such a way that it can be reconstructed for any point in time in the past (or both).
3. **Resolve "critical" bugzilla issues** The Guardian bugzilla is being used to track bugs/issues with the guardian core software. Any bugzilla issues currently labeled "critical" should be completed.
4. **Documentation** Complete/update guardian documentation, including the design overview [3] and the primary user manual [2].

4 Future enhancements

The following tasks describe potential enhancements to the RTS and Guardian core systems that could potentially improve the automation effort. These improvements are not necessarily required for initial automation control of the aLIGO instruments, and can therefore be deferred to aLIGO Operations. These are in addition to the continued maintenance of the code and infrastructure, as well as the development of other unanticipated features to support full IFO automation.

1. **Channel access performance improvements** Channel access for Guardian is handled by the custom "ezca" channel access library. Currently, channel write performance using this library is quite poor, with writes taking significantly longer that channel access write in other programs (such as burtwb). Some of this is due to the extra checks being performed by ezca to verify that writes have succeeded. Profiling is needed to determine if write performance can be improved.
2. **Improvements to node manager interface** The Guardian "manager" interface, by which one Guardian nodes communicates with and controls another Guardian node, is somewhat clunky. For instance, it is currently not possible:

- to know which nodes are attempting to control a particular node
- to restrict control of a node to an authorized set of other nodes
- for subordinates to acknowledge that commands from the manager have been acted upon by the subordinate

These limitations are largely due to limitations in EPICS as an inter-process communication medium, such as the inability to exchange data on multiple channels synchronously. We may be able to get away with not addressing these issues, with careful code management, or it may be possible to address these issues in the current EPICS framework. We could also consider a more sophisticated interface than EPICS for inter-node communication.

3. **Channel access tracking** There is currently no convenient way to determine which Guardian nodes are accessing which channels. This makes auditing channel access more difficult. Ideally we should be able to audit the system to determine that every channel is either monitored by the RTS monitoring system, or being controlled and monitored by a single Guardian node. One solution would be to require that Guardian modules declare which channels they intend to access in a easily accessible array.

4. **Tracking of suspension alignment biases** Suspension alignment biases represent a difficult middle ground for system setting tracking. They can not be stored as "static" parameters, either in the front ends or in the automation code, because their values change too frequently. There is also frequently the need to restore to past values at known times. We should develop a more unified way to track these alignments that allows easy restoration of stored values, without resorting to text files on disk.

5. **Reconcile differences between sites** Control and automation logic differences exist in some subsystems between the sites. The IMC locking procedure is the most notable. Ideally all differences could be relegated to parameters of the control rather than in the control logic. If this were true it would likely be possible to maintain identical automation code between the two sites. Reconciling differences between the sites will be time consuming. This will likely be relevant for other ISC systems as well, such as the global LSC and ASC automation codes.

6. **Enforced settings in RTS** Once monitoring of parameters in the RTS is enabled (see item 1. of section 3) it becomes fairly straightforward to enable locking of settings to their base value. Locking would provide greater assurance that parameter values are not changing, as well as added feedback to operators and automation code that certain parameters are intended to be held static. There has been resistance to the idea of channel locking as some worry that it would make the system less flexible (others, on the other hand, find it desired for just that reason). This feature should be revisited after experience has been gained with front end parameter monitoring system.

In addition to the improvements to the core software infrastructure listed above, the following subsystems will require further development of their automation "user code" (e.g. automation logic) under aLIGO operations:

Thermal compensation (TCS) subsystem The thermal compensation system has not yet been automated. While aLIGO will likely operate at relatively low power initially, some amount of thermal compensation will be required, and will therefore need to be folded in to the automation.

Initial alignment The full interferometer initial alignment procedure will need to be automated. A Guardian node to handle initial alignment has been created at LLO, but it is not yet fully functional and will need to be refined and improved.

Lock acquisition The full lock acquisition procedure is still under heavy development, and will likely undergo many changes during commissioning in the Operations phase.

Alignment sensing and control (ASC) Enabling of the alignment control loops still needs to be folded into the main lock acquisition procedure.

Respond to changing seismic environment We will likely need to change the configuration of the seismic systems in response to changes in the ambient seismic environment (e.g. storms, increased wind, earthquakes, trains, etc.). This is under development now, to be deployed during Operations as needed.

References

[1] J. Rollins, "Advanced LIGO Automation Requirements", LIGO-T1300884

[2] J. Rollins, "Advanced LIGO Guardian Overview and User Manual", LIGO-G1400016

[3] S. Waldman, M. Evans, "Advanced LIGO System Guardian", LIGO-T1000131

[4] R. Bork, "RCG V2.9 - Loading and Monitoring of BURT settings by front end controls computers", LIGO-G1400742