DEVELOPMENTS OF THE ‘CERBERUS’ LASER INTERLOCK AND HAZARD DISPLAY SYSTEM AND ASSOCIATED DESIGN TOOL

D. A. Pepler†, R. Bickerton, A. Tylee, STFC Rutherford Appleton Laboratory, Didcot, UK

Abstract

Following on from the successful implementation of ‘Cerberus’ a comprehensive laser interlock / control and hazard display system [1, 2] on the Vulcan High-Power Laser at the Central Laser Facility (CLF) [3], the last few years have seen the safety system become a CLF standard and its use extended to many different laser systems and laboratories within the department.

This paper will provide an overview of the system, its most recent enhancements and in particular the developments of a design tool and the potential for this system to be used in other fields.

INTRODUCTION

Vulcan is a large, complex and Petawatt class (10^{15} W) neodymium-doped glass laser system. It has a footprint of two Olympic-sized swimming pools with some 250 m of beamlines from its initial suite of optical pulse sources through to a target. The short timescale (10^{-12} to 10^{-9} s) laser pulses pass through many optical components that are situated in a number of rooms which can be kept isolated (and which are then effectively controlled autonomously) or coupled together with remotely-controlled and pneumatically driven shutters that link two or more rooms together. All entry and exit points, laser enclosures and sources and the interconnecting shutters are part of the interlock system. Any potential increase in the level of hazard (e.g. enabling a laser source) requires simultaneous human operator authorisation key action from all affected areas. Reducing the level of hazard, for example by closing a shutter, can be achieved at any time with a single touch. Unauthorised entry or detection of a fault condition will automatically shut the affected areas down rendering them safe by disabling all local hazards and closing any links to other areas.

SYSTEM DESCRIPTION

In Greek mythology Cerberus is generally depicted as a three-headed guard dog and the laser interlock and control system was partially given that name because of its guarding nature and its threefold constituent parts – a control Programmable Logic Controller (PLC), a safety PLC and a Hazard Information Display system.

The control PLC provides the operator with multi-page touchscreen display that allows for the indication and control of various items such as laser hazard, shutters and beam-stops.

The safety PLC conforms to the international standard IEC 61508 [4] at Safety Integrity Level 2 (SIL2) and provides the underlying safety by constantly monitoring the state of the system and either permits or denies a particular action to take place on the basis of the required and present level of authorisation.

Within each room of the laser facility the Hazard Information Display comprises of a local PC with a dual monitor. At a glance, the first monitor gives operators an overview of the safety state of the whole system and the second monitor shows the specific laser hazards present within the room. Screenshots from these are shown in Fig. 1 below.

The overview screen is located at a rooms central control point whereas the hazard display is also duplicated in multiple locations around the room. Both screens are also duplicated at the entry point with the laser hazard display having a clear green or red colouration to denote whether the system is safe (no laser hazards) or not. For Vulcan, laser hazards would commonly be continuous or pulsed invisible near-IR lasers operating at 1053 nm and which if present require special protective eyewear to be worn.

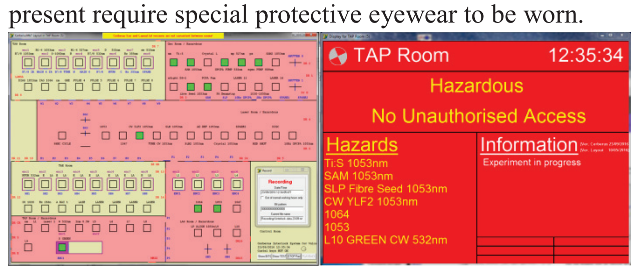

Figure 1: Images from the Hazard Information Displays showing left) the system overview screen, and right) the individual area’s laser hazard warning display.

Apart from the display function, the Cerberus application also has the ability to record all activity and changes within the interlock system in a text-based log file. This provides a way of checking for unexpected anomalies or out-of-normal-working-hours activity. This log can also be played back in real or enhanced time.

SYSTEM DEVELOPMENTS

Because all laser hazards are enabled through Cerberus controls and normally would turn the hazard display red demanding that goggles be worn, the inclusion of newer visible (532 nm) alignment lasers that are predominately eye-safe necessitated a separate indication. In the case where *only* eye-safe lasers are in use a new mode was implemented to complete the ‘traffic light’ warning notification. This is demonstrated in Fig. 2 where only a 532 nm laser is enabled and the hazard display is green apart from an orange band displaying the yellow / black flashing message ‘Hazardous at Focus’.

This approach was seen as visually clearer than having the whole screen orange so as to provide good discrimination between orange and red. If a non-eye-safe laser were to added then the display would revert to the standard red ‘Hazardous’ indication.

† dave.pepler@stfc.ac.uk

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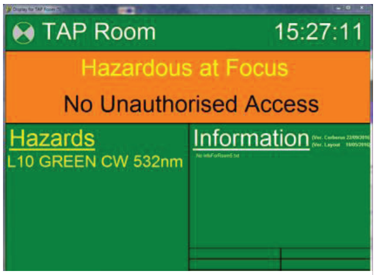

Figure 2: Laser hazard display with an eye-safe laser enabled.

In the original Cerberus application, the local PC's all individually built-up a picture of the system by interrogating every control PLC for itself. This was OK for small systems but as the number of rooms increase there's an exponential rise in ethernet traffic that can result in data collisions as multiple PC's attempt to extract data from the same PLC at the same time causing 'black-outs'. This issue was eliminated entirely by re-working the Cerberus code such that a PLC is only read by the local PC which then broadcasts out the data to the rest of the system via a single UDP packet. This allows for each local PC to be aware of the entire system with minimal effort and to easily update at 5 Hz. It also allows for a ready expansion of the system as well as for passive monitoring by other control systems associated with the operation of the Vulcan Laser.

The application has also been enhanced such that if a local PC 'dies' (which obviously means it is no longer broadcasting its PLC data) then within 1 s one of the other local PCs will take up the task of reading and broadcasting the PLC data instead and will do so in addition to its own. On recovery of the missing PC, it will revert to normal operation within 200 ms.

DESIGN TOOL DEVELOPMENT

A significant number of laser labs within the CLF are now using this application as standard and the differences that are seen in the individual laboratory scale, room connectivity, access points and internal hazards can all be accommodated through the use of a text based configuration file. Everything that is to visually appear on the overview screen or hazard displays (see Fig. 1) requires a record in the configuration file that details its category (e.g. room, door, enclosure, laser, shutter); its name; screen position, colour and controls. For example, a record for an eye-safe laser would look like the following:-

Laser 29 Title B1-6_527nm 250 35 11;
Laser 29 Position 270 80 300 110;
Laser 29 Beam 1100 70 1080 70;
Laser 29 InEnclosure 3;
Laser 29 OnBitPosition 3/1/12;
Laser 29 ComingOnBitPosition 3/12/12;
Laser 29 NoHazardInRoom 1 2 4 5 6;
Laser 29 EyeSafe;

These descriptions are used by the application to be informed as to where the relevant data comes from (room / word / bit) and where and how to draw the indicators on screen. These descriptors can be readily modified since they are in plain text but as the systems have grown more involved and complex creating a new configuration file from scratch can be a bit tedious.

In order to assist the rapid construction of new descriptor files there is a design tool being developed that is intended to allow a graphical approach to be taken which will allow an overview screen layout to be created far more quickly and accurately. It will allow any category object (such as a room, laser, door etc.) to be uniquely created and then simply dragged into the overview screen area and dropped into position. The associated record lines for an object will then be processed and where possible, automatically populated according to where an object is placed. For example, a door dropped onto room 3 would be declared to be InRoom 3. All data would be fully editable at any time as clicking on any object would allow it to be moved and its text record to be displayed and updated.

Figure 3 shows the development system with the bulk of the rooms populated with various objects and the entire Room 6 in the process of being relocated. It also shows the information panel open to the right of the main design area indicating the selected objects data – in this case the data for Room 6.

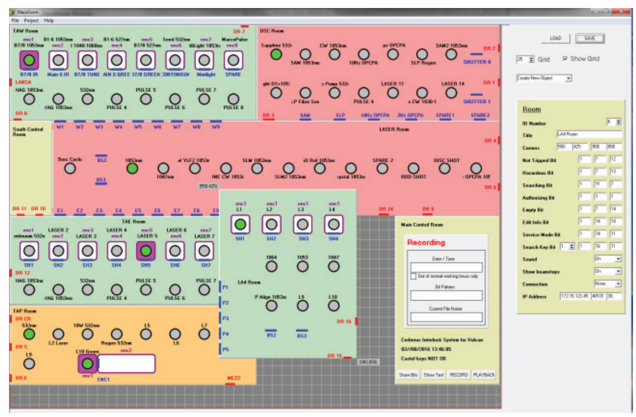

Figure 3: Design tool for the Cerberus overview screen.

CONCLUSION

Once in full production the editing tool will allow easy construction and modification of the system descriptor files. It also will have the potential to modify existing or introduce additional objects to the design suite which could be useful in translating the Cerberus interlock and hazard displays into other fields - for example, for radiation safety access systems.

REFERENCES

[1] CLF Annual Report 2004-05, "A new interlock system for the Vulcan laser", pp 241-242.

[2] CLF Annual Report 2006-07, "The Argus/Cerberus interlock system used throughout the CLF", pp 236-237.

[3] Central Laser Facility, `http://www.clf.stfc.ac.uk`

[4] "Functional safety of electrical/electronic/programmable electronic safety-related systems", IEC 61508 / BS EN 61508 (7 parts).

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