Automated image diagnostic system

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Vulcan imaging diagnostics have to date been based on 'frame-store' cameras. These systems were in need of upgrading as they were becoming increasingly unreliable after so many years of operation. These cameras also required manual arming and saving of images. The switch of technology from these obsolete 'frame-store' cameras to 'plug-and-play' USB cameras is at the crux of the development, with the principle advantages being reliability, cost, ease of installation and use, and the ability to arm cameras for pulses.

In addition, a diagnostic command broadcasting system was developed to enable all cameras within the laser to be armed, triggered and data saved automatically. This makes use of the Universal Datagram Protocol (UDP) communication over the lab network, as the standard method of broadcasting diagnostic commands is only available on the Vulcan internal network. This broadcasting system enables all cameras to receive information on the laser status, and to interpret the information dependent on the requirements of that particular diagnostic.

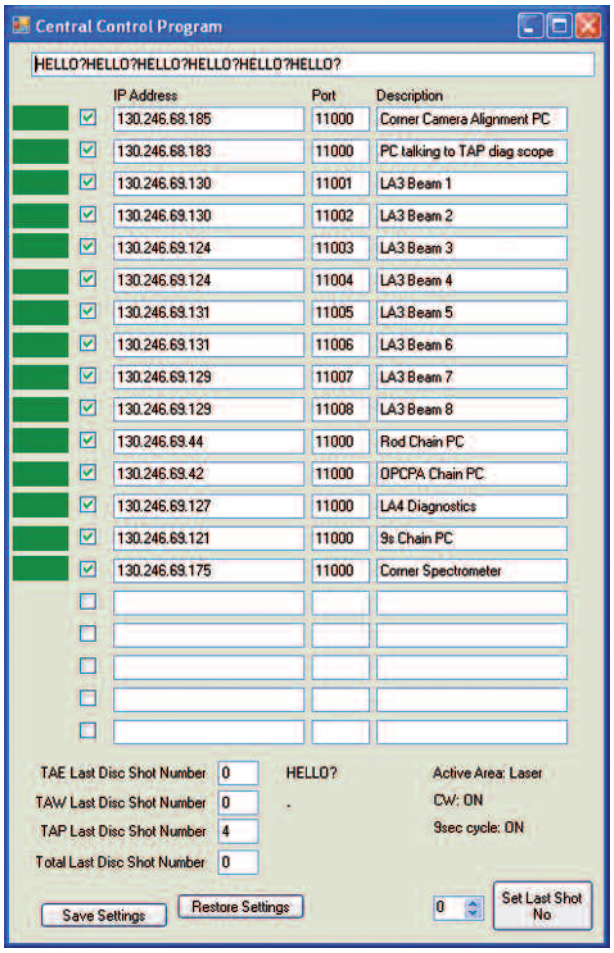

Figure 1. GUI for Central Control Program.

For each area within the system, different constraints and requirements are placed on the diagnostic cameras. As each camera system has a specific function, each associated program is expected to respond differently to diagnostic commands sent out by the Central Control system.

Due to the complexity of the laser system, the range of incident power on the CCD chips varies greatly with position within the laser system. This means that each camera system will require its own level of (constant or variable) filtering. These constraints therefore differentiated all the diagnostic cameras within Vulcan, giving each its own unique operating program.

Centralising Diagnostic Control

One of the main advantages of these diagnostic USB cameras (compared with the older obsolete cameras) is that they can be remotely armed to receive a trigger, or can be set to a live stream mode. 'Arming' in this context means setting the cameras to a mode that will receive a trigger and update the image, rather than update the image continuously. In this way, if communication can be established between a central diagnostic program and all the cameras in the system, all cameras can be easily armed at once, or told to enter a live stream mode.

The main computer control program in the Vulcan laser is called the 'ComHub', and it broadcasts laser information over serial connection, such as currently active target areas, shot mode, shot number etc. Any cameras that wish to receive this information are required to have a separate serial connection to the ComHub. This is highly impractical, limited primarily by the sheer number of cameras in the system and the lack of serial ports in the ComHub.

Therefore a method was required to broadcast the commands received from the ComHub to all the diagnostic cameras within the system. This would be the equivalent of the ComHub broadcasting commands to hardware, but the main difference being that it broadcasts on a different protocol, not an RS232 serial connection. A system was designed and developed to broadcast commands over the UDP to specified computers on the lab network, the GUI for which is shown below in Figure 1.

This program has many benefits:

- Only one serial connection to the ComHub is required.
- Can be used to communicate with any diagnostics, such as photodiodes, spectrometers and oscilloscopes.
- The broadcasting of UDP information is over Ethernet (i.e. the lab computer network), so no additional cables are required – all PCs controlling cameras are already on the network.

- There is no limit on the number of computers to send the information to, so there is significant room for expansion, allowing for further diagnostic expansion. This is significant, as it creates a flexible base, on which more diagnostics can be easily developed in the future.
- UDP is accessible in any programming language and so allows for communication between programs written by different people.

Figure 2 shows the schematic for this program, and how it allows for maximum expansion of diagnostics within the laser. In this manner when a shot is about to be fired, the Central Control program is able to arm all cameras, oscilloscopes and diodes for diagnostic purposes, as well as broadcast important information about target areas, shot number etc.

Although simple in its design, the Central Control program represents a large step forward in the upgrade and development of the Vulcan diagnostics, allowing for not just the replacement of obsolete cameras, but also the installation of new, useful diagnostics cameras, and the automated arming, capturing and saving of diagnostic data. The emphasis here is on 'automated', with very little user control required. Less time spent arming diagnostics for laser shots is appreciated in significantly reduce laser operation time, and in doing so maximising laser availability for the Target Areas.

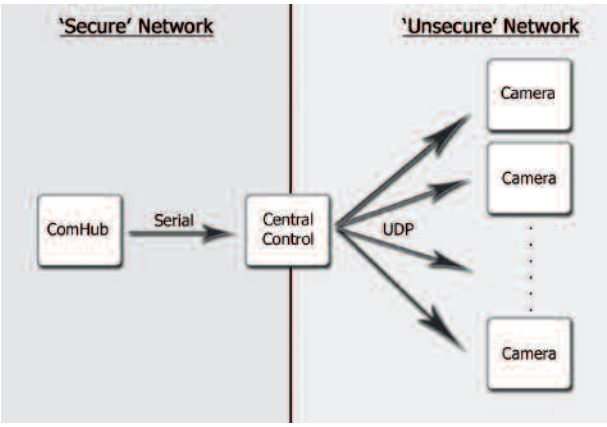

Figure 2. Broadcasting diagnostic commands over UDP.

Replacement of Laser Area Cameras

Older diagnostic systems within Vulcan were upgraded to make use of this broadcasting system and automated operation. The current Laser Area 3 cameras, although somewhat obsolete technology, give CW imaging to laser operators for diagnostic alignment purposes and so are essential to daily operation. These cameras, however, cannot be triggered and therefore give no additional diagnostics for laser shots. A camera system was developed that would act as both a CW alignment tool (ensuring the same functionality of the old system) and a shot diagnostic tool (introducing new functionality). Thus the requirements of this system were as follows:

- To replace the eight near field (NF) cameras and to introduce eight far field (FF) cameras.
- To enable the video feeds to be displayed in multiple locations throughout the laser area, as well as in the Main Control Room (MCR)
- For CW images to be displayed at all times, except on full energy shots.

In addition, the expansibility of the Central Control program is such that it is able to arm these cameras to capture an image of the beam on a disc amplifier shot, which is particularly useful for shot diagnostics.

This project required not just a significant investment in time but also a significant investment in capital, composed almost entirely of hardware costs, including 4 PCs, around 40 TFT screens, 16 cameras and the extensive hardware required to relay the video feeds to different areas.

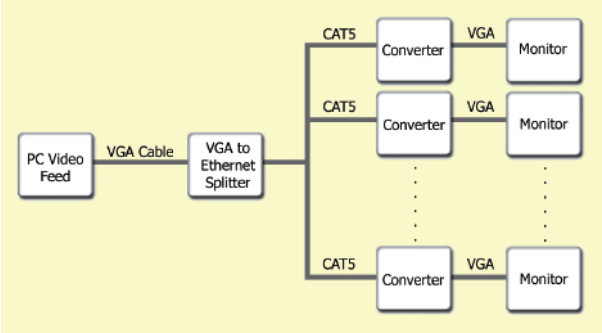

Figure 3. Schematic of video feed relaying.

Figure 3 shows the schematic of the system developed for video feed relaying, with CAT5 Ethernet cable being used to transmit the video data, as its maximum cable length of 100-150m is far greater than that of standard VGA cable (15m). Conversion of the VGA signal to CAT5 also allowed the video to be duplicated easily to multiple locations within Vulcan using this method. Figure 4 shows the GUI for this program.

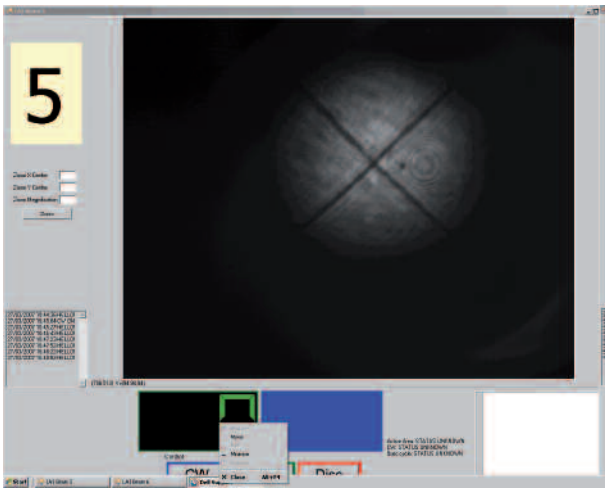

Figure 4. GUI for LA3 camera program.

In Laser Area 4, the near field, far field, interferometer and spectrometer cameras were upgraded and code was added for enhancement of contrast and brightness, shown in figure 5. Since the far-field reference is of particular importance when pointing up the Petawatt target area through the VSF pinhole, adjustable references were added to the near-field and far-field images; this diagnostic feed is relayed to several areas within the facility (Figure 5).

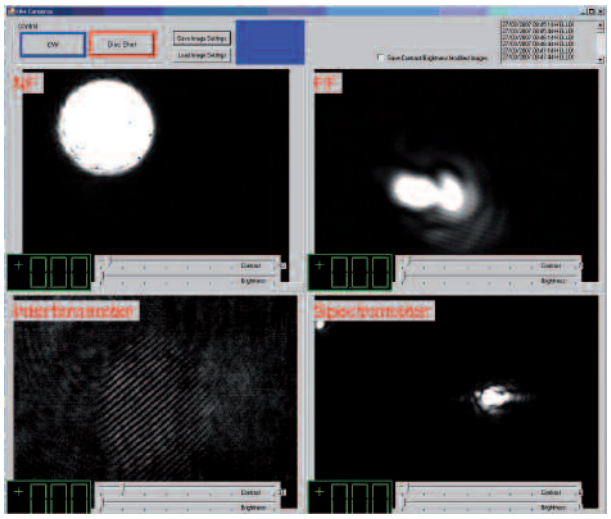

Figure 5. GUI for LA4 Diagnostic Cameras.

There are currently installed, or scheduled to be installed, over 40 USB cameras on the Vulcan laser system, each one linked to and controlled by the Central Control Program. Additional camera systems which are currently being installed include:

- OPCPA chain cameras. Another aide in diagnostic alignment, this will be primarily useful for alignment of the OPCPA before it reaches the rod amplifiers, and, as with all of the newly introduced diagnostic cameras, can capture diagnostic images on shots.
- Rod chain cameras.
- Pre-amp table cameras. Although the beam does not often have to be aligned through this table, it has a series of double passed rod amplifiers that make alignment particularly difficult, thereby allowing a camera system to reduce the alignment difficulty.