SWITCHING SOLUTION – UPGRADING A RUNNING SYSTEM

K. Tsubota, J. Johnson, J. Mader, W.M. Keck Observatory, Kamuela, HI 96743, USA

Abstract

The control system for the Keck telescopes is undergoing a major upgrade as described in MOCOAAB05[1]. This is called the Telescope Control System (TCS) Upgrade and is an upgrade on the existing system which is known as the Distributed Control System (DCS). One of the greatest challenges of the project will be faced during integration and commissioning. A key goal is to minimize downtime and maximize science throughput during the commissioning stage of the project. The team has sought solutions that will allow daytime testing and integration of TCS while providing a simple path to revert back to DCS for night time observing. After evaluating all the interfaces and the impacts of switching between the old and new systems, a number of different solutions were developed to achieve this goal. These include parallel operations, signal splitting, signal switching, modularization and software backwards compatibility.

OVERVIEW

All areas impacted by TCSU were identified and analysed and a set of solutions developed that support the ability to quickly and reliable switch back and forth between the old and new systems. From this analysis the following approaches were identified:

- Parallel Operations: allows us to work on the new system in parallel with the current system
- Signal splitting: simple tapping off of a signal, ideally suitable for monitoring, limit switching etc.
- Switching Signals: a physical box to route signals between old and new hardware
- Modular: functional and physical split of systems
- Software backwards compatibility: maintain existing interfaces and minimize impact to existing tools and GUIs

Takeaways from this safe and modular approach are:

- Eliminated "point of no return"
- Minimizes telescope down time
- Allows a subsystem by subsystem update
- Ability to move back and forth between current and new system
- Backwards compatible system
- Easily upgradable system

Currently the infrastructure is in place for all TCS subsystems which have their own controllers, upgraded versions of EPICS, a new timing system, IOC monitoring, CSS based alarming and archiving and newly implemented EPICS tools. The headquarters lab is close to being fully populated with the necessary hardware to perform headquarters integration and testing. On the summit there is a parallel elevation encoder in place and there is a new pointing subsystem running in parallel with the current operational control system.

The following sections describe in more details each of the solution options, its benefits, and how they were implemented..

SWITCHING SOLUTION OPTIONS

Parallel Solution

The parallel solution allows for implementation of the upgrade without impacting the existing system. This is the preferred approach but in practice there are limited opportunities to avail of parallelism. The most intense parallel solution implemented to date is the telescope elevation encoder. This was implemented without disturbing the existing operational system. It involved finding a suitable place to install the new optical encoder tape and read heads that did not interfere with the telescope movement and the existing encoder system. This also allows more time for daytime installation and testing since there is no need to daily "revert" back to operations. Currently daytime characteristics and performance tests are being run using the operational encoder as the base. At night data is gathered from old encoder systems for comparison and long term repeatability tests. The first night time on-sky parallel test occurred on Sept 12, 2013 and more night time tests are scheduled.

The new pointing software subsystem has also been experimentally deployed as a parallel solution. It currently uses a different EPICS channel name prefix than the operational system but it uses the actual operational inputs. These inputs are processed in parallel to DCS resulting in pointing demands to the telescope and rotators that are recorded for offline comparison and validation with the operational system. The outputs to the actual devices are currently disabled. Once the output demands are validated the upgraded pointing subsystem will be taken online by updating its EPICS channel name prefix to the same as the operational version and disabling the operational pointing subsystem.

Signal Splitting Solution

There are two subsystems that require signal splitting and signal switching: the telescope axes control (AXE) and the rotator control (ROT). The majority of the hardware for these subsystems exists within two large enclosures in each telescope's computer room. These enclosures are the servo amplifier assembly (SAA) for AXE and the auxiliary amplifier assembly (AAA) for ROT.

Approximately one third of the total signals can be simultaneously utilized by both systems. These include analogue and digital input signals. Examples of these are current monitoring, various faults, limits and various

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control switches and buttons and various status signals. AXE and ROT each have over 100 signals each that can be split between both the old DCS and new TCS hardware for simultaneous monitoring.

Even though signal splitting is less involved, it still requires careful cable construction and installation. The new equipment has to be housed within the enclosures and then carefully wired into the existing solution which may require some repositioning of the current hardware. Zuken E^3 wireworks has been used for all cable drawings as shown in Fig. 1.

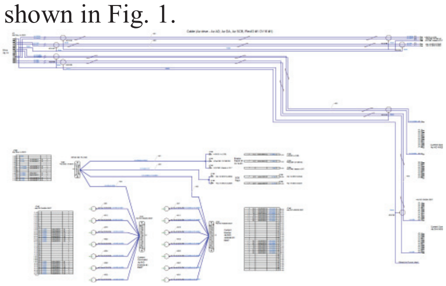

Figure 1: Signal Splitting cable example.

Signal Switching Solution

The switching solution provides the ability to switch over and back between DCS and TCS for testing. The solution will be implemented early as part of the "Summit Prep" tasks. Switching is provided by two switch boxes per telescope, one for AXE and one for ROT. The team opted for a simple relay solution that operates off a single control line that will switch all connected field I/O between DCS or TCS. Switching will not be a casual over and back operation and does require some downtime for each switchover. Power will be dropped from the SAA or AAA, the switch box will be switched to/from DCS/TCS and then power will be reapplied.

Figure 2 shows the constructed switch boxes before connection to the summit equipment. These boxes are temporarily mounted in the summit control room and are expected to remain in place for about a year after full system commissioning.

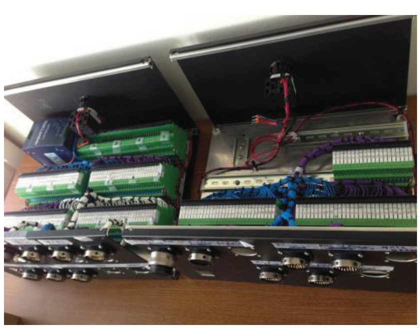

Figure 2: AXE and ROT switch box.

As mentioned earlier, switching signals is constrained to the minimum subset of control signals. In terms of implementation the old DCS will be wired first through the switch boxes and DCS will function as normal through this while TCS is tested and incrementally deployed. As AXE and ROT are deployed they will be wired to the switch box and then switching will take place as needed between DCS and TCS until the new subsystems are commissioned.

Switching control has been designed to ensure that a power glitch or power failure will not cause an unwanted toggle between DCS and TCS paths.

The SEC subsystem which is responsible for control and status of the secondary mirror also requires switching between the DCS and TCS during the testing phase. However SEC lent itself to a simpler solution. There is a small enclosure in the secondary top socket that houses the SEC driver controllers, amplifiers, logic and relays and these are hardwired to the field I/O. For TCS there will be a new enclosure with modern electronics replacing the obsolete controllers etc. This will be housed side by side with the existing box and the hardwired cables will be cut and have connectors applied so that they can be easily physically reconnected between the DCS and TCS enclosure. Figure 3 shows how this will be implemented. While ROT and AXE require hundreds of signals to be switched SEC requires very few and can be accomplished easily with three sets of cables for the motor, encoder and limit/switch signals, about 60 signals in total.

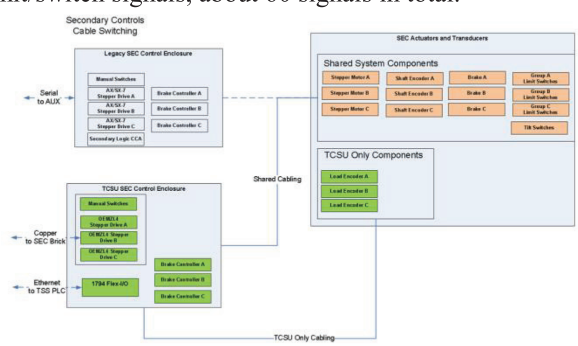

Figure 3: Example of SEC switching.

Modular Solution

Our current operational control software consists of two VME crates running VxWorks: TDC (Telescope Drive Control) and AUX (Auxiliary). TDC contains the pointing kernel (PNT) and telescope axis drive control (AXE). AUX contains the remaining subsystems: rotator control (ROT), secondary mirror control (SEC), and dome enclosure control (DOM). Each subsystem in the operational system is basically standalone and consists of an EPICS database, a set of initial configuration files, and a sequencer. This original design allows for easy extraction of a subsystem when the new replacement subsystem is deployed.

The new software control system maintains the existing subsystem division but separates each one into its own physical controller. Two control system VME crates have migrated to five Linux servers plus additional Linux servers for high capacity archiving, alarming, system monitoring and other supervisory functions. Subsystem controllers and new field I/O all share a common hardware implementation. While not all subsystems will need the full range of hardware, having a consistent common base allows for commonality of spare equipment between subsystems and telescopes.

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With this new software and hardware modular system, individual subsystems and servers can be tested and deployed in full, without affecting any other subsystem. Each subsystem can also be stopped, restarted or shutdown without affecting any other subsystem except for the loss of it's channel access interface. This allows for easy switching between DCS and TCS.

Backwards Compatible Software Solution

Maintaining backwards compatibility with the existing software control system was a key decision that enables quick and easy switching between systems. To help maintain backwards compatibility Keck chose to continue with the use of EPICS and to upgrade to a more current OSI version and migrate to newer more robust EPICS tools. In addition to EPICS the observatory uses Keck Transport Layer (KTL) for interfacing and operational tools. KTL allows mapping of "keywords" to EPICS process variables. By reusing EPICS KTL is 100% reusable and allows all operational tools and GUIs to continue working as long as TCSU maintains the existing set of keywords.

Continuing to use EPICS also allows the existing subsystem to subsystem channel access interfaces to be retained, and top level EPICS records to be directly reused, and allows the testing and release of software on a per subsystem basis. This minimizes the number of changes to the operational system and isolates troubleshooting.

IMPLEMENTATION

Status

The switch boxes have been constructed and cabling is currently being made. The solution is being tested at HQ and has yet to be installed on the summit. The K2 elevation encoder prototype has been installed and is undergoing testing. Good use of the modular and parallel approach has been utilised with PNT, BEAUTY, BEAST, user interfaces and more. In the lab, servers have been setup and configured and are being used to test the subsystem software. Hardware modules are also being configured and connected to the various subsystem controller and field I/O in the lab. Hardware interfaces and software tools have been successfully tested while implementing various subsystems in parallel.

Approach

With two separate telescopes to upgrade, there existed the option of releasing a subsystem on one telescope followed by a release on the other telescope. However it was decided to complete all subsystems on one to allow for troubleshooting while keeping the other telescope fully operational. This would also allow long term issues that may arise to be addressed in a more controlled manner.

The timeline per subsystem is development, unit and functional unit testing at headquarters, daytime testing, night time testing and finally commissioning and release. Once a subsystem has been implemented and thoroughly tested in the lab, it will be installed in the operational network and go through more daytime testing while integrated with DCS. As more and more subsystems are deployed and tested DCS will over time morph into TCS and eventually, perhaps after a year of successful operations, the switching boxes will be removed to form a permanent solution.

As integration begins the first tests will be a thorough checkout of the hardware switching solution and the interfaces to it. After this, control of the hardware by the new subsystems will be tested. The operational subsystem will then be disabled and replaced by the new subsystem. Over a number of weeks the new subsystem will be tested during the day and the solution switched back to the original implementation for night time observing. Once the daytime checkout has been fully successful night time engineering will begin until the subsystem is fully commissioned.

Work will be on a subsystem by subsystem basis starting with the pointing control subsystem, which has no hardware. The telescope interlock processing needs to be released before any of the other control systems since they all have a dependency on it. With this tested subsystem deployment will commence starting with the telescope drive control and secondary mirror subsystems. The last subsystems will be the dome and rotator subsystems.

Once a subsystem has passed commissioning, there will be a full formal handover to operations to allow the team to concentrate more fully on the next subsystem.

CONCLUSION

The night time on-sky parallel encoder prototype work showed success in implementing, aligning and calibrating the new encoder system with no telescope downtime and no impact to observing. A key goal for the project has been to avoid a "point of no return" where TCSU changes resulted in the inability to utilize DCS if needed. The encoder prototyping consisted of major mechanical changes with the addition of new electronics and software and proved successfully in meeting this goal. In other words, the original encoder system is still 100% intact with no changes and operating as normal.

The design and implementation is moving forward and there is confidence that it can be achieved on a subsystem by subsystem basis. With the switch boxes and signal splitting solutions the infrastructure will be in place to quickly and reliably switch between the DCS and TCS. The core upgrade of EPICS base and tools is working and have been utilized on both the running operational system and subsets of TCSU.

FUTURE WORK

In the coming months upgraded telescope pointing software will be integrated into the operational system. In the same timeframe the physical switch boxes and signal splitting solutions will be integrated followed by the

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interlock processing PLC. Once these are in place and tested, it should be straight forward to follow up with the remaining subsystems. Other near term tasks include the completion of the azimuth encoder prototype and, at that time, may also include closing the servo loop around the new encoder system. Since the secondary solution lends itself well to a parallel approach this will be the next deployment. The team will then continue the integration and commissioning for the remaining subsystems according to schedule.

ACKNOWLEDGMENT

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REFERENCES

[1] J. Johnson, K. Tsubota and J. Mader, “Keck Telescope Control System Upgrade Project Status,” MOCOAAB05, ICALEPCS 2013, to be published; www.JACoW.org.

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