Introduction of ITER CODAC relevant technologies on JET and MAST

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Abstract

The JET control and data acquisition system (CODAS) is an integrated system that provides all the pulse based and continuous data acquisition, real time and slow control and control room interfaces for JET. It has a long history, dating back to the beginning of JET in 1980. It utilises both commercially available hardware along with many in-house modules. The software has grown up and evolved largely independently of other developments in big science. Similarly, the data acquisition system on MAST has a long history of evolution from previous facilities at Culham (COMPASS). It utilises commercially available and in-house hardware (some shared with JET CODAS) and software that has developed largely independently of JET and other external developments. More recently, we have begun to adopt some ITER CODAC relevant technologies on both JET and MAST, in part, to also introduce some standardisation between the two facilities. This started with a pilot project to create a cubicle and environment monitoring system using commercial hardware and EPICS monitoring and HMI. We have since gone on to implement several camera and spectrometer filter controllers, several types of turbomolecular pump controller, and various radiation protection monitors in EPICS on JET. We are also implementing a central information display system for MAST that links the OPC interface on the machine control through to several display screens showing the machine state using EPICS. We have several MARTe based real time applications on JET and are now developing an application to provide real time processing of high-resolution Thomson scattering data using MARTe V2 (an ITER/F4E initiative to improve the robustness of this real-time framework). We are also considering upgrading the existing MARTe applications to this version. On JET we have also started to use another ITER CODAC technology – SDN to supplement the ATM based real time control network on JET. Initially, as a proof of principle, a real time plasma profile display was implemented. This system is now being extended to include several real time data sources which will feed their data back into the ATM network and on to the real time controllers. Looking forward, we anticipate extending the JET real time network with a purely ITER CODAC/SDN connected real time control system and provide a richer ITER CODAC interface to the JET CODAS to accommodate the possibility of ITER diagnostics testing and provide a real stress test for ITER archiving technologies.

Introduction

JET CODAS has a stable and reliable infrastructure that has been developed over very many years. The software has generally been developed in isolation from other similar big science control and data acquisition systems. Similarly the control and data acquisition systems on MAST have a long pedigree going back through previous generations of facilitates at Culham and again the software has been developed largely in isolation from JET and other external developments. However there are some significant gaps with slow controls and monitoring on MAST. There is a strong desire for common approach on JET and MAST and to gain experience with ITER CODAS technologies that we think can provide this common approach. We can only justify new developments if we don't already have a working and maintainable solution that can be repeated (step and repeat). Where new developments were required, we have been able to introduce EPICS based systems on JET and MAST. We have also started to extended JET real-time networks using ITER CODAC SDN.

EPICS Training at Culham

Active member of the local EPICS community
- Attend and host EPICS meetings

In-house EPICS training course based on the Cosylab and Tessella material:
- Self-study modules
  - EPICS and EPICS modules
  - CSS
- Hands on training
  - LEDs driven from a RaspberryPi
  - Motor controller (clock)
  - Camera.

EPICS on MAST

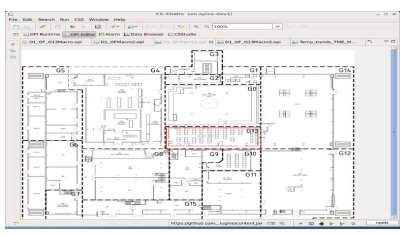
No standard slow monitoring and control infrastructure
- ➢ no EPICS

MAST Cubicle Environment Monitoring

Simple proof of principle application
Standard cots snmp environment monitor
- PAPOUCH TME temperature sensor
- TERACOM TCW 122B-CM
  - ➢ also provide contact for door monitoring

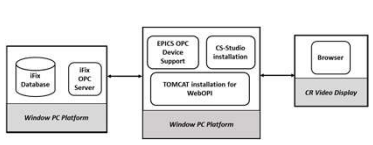
EPICS IOC already available
CSS HMI (BOY)
Logging (BEAUTY)
Alarms (BEAST)
Python script to regenerate EPICS database and BOY when sensors are added

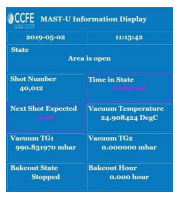




MAST Central Information Display

EPICS IOC implementing iFIX OPC connection to the control system OPC server (Windows/PC)
HMI implemented within Tomcat WebOPI (Windows/PC)
Web output proxied through MAST firewall giving read only access





An enabling development that opens up two possibilities
- Replacement of some or all of the iFIX systems with EPICS/CSS
- EPICS managed data acquisition systems

Other Developments MAST

Data acquisition for spectroscopic CCD cameras
MAST has 8 models of camera from 4 camera manufacturers
EPICS areaDetector extension being considered

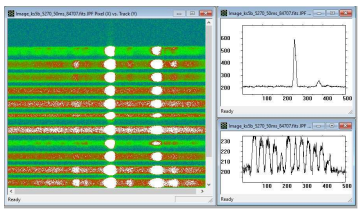


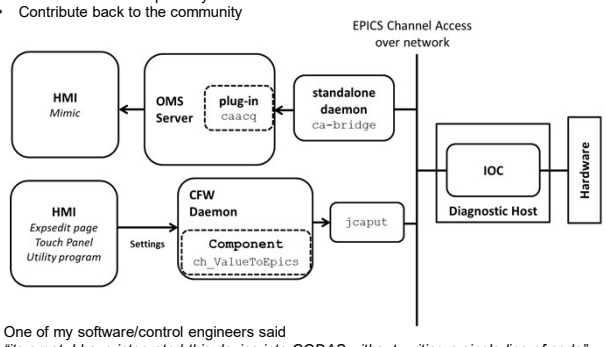
Image taken from KS5 on JET

EPICS on JET

JET CODAS has an extensive, integrated, well established slow control and monitoring infrastructure
- Point (150000), alarms (12000), trends (7000), logic and sequences, mimic (3000), control panels, role based security, read only access over the online firewall

So why change?
- Developed in isolation – like many systems at the time
- Developed a very long time ago for Norsk Data systems and ported to Oracle Solaris
- Difficult to migrate to new hardware/operating systems
- Becoming increasing difficult to support

Introduce EPICS
- And build a bridge
- Access to a vast body of well supported (open source) software
- Cross platform support (Windows and Linux)
- ITER compatible
- Introduce some compatibility with MAST
- Contribute back to the community

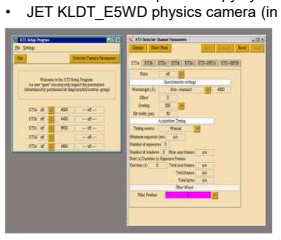


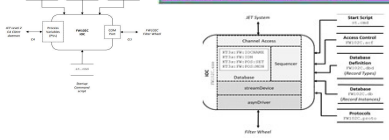
One of my software/control engineers said
"its great, I have integrated this device into CODAS without writing a single line of code"

Spectrometer Filter Wheel Controller

Thorlabs FW102C filter wheel
- high-precision, motor-driven, six-position filter wheel
- it has text-based command line interface (CLI) protocol

EPICS IOC streamDevice support module.
General purpose controller, suitable for managing an FW102C filter wheel in a variety of applications
Full integration with JET CODAS
Deployed to
- JET KT3 Diverter Spectroscopy system
- JET KLDT_E5WD physics camera (in development)





Radiation Protection Instrumentation

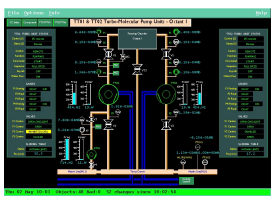
Premium Analyse Tritium Monitors
- EPICS Modbus/TCP-IP device
- Periodic polling
- Full integration with JET CODAS
- Trends recoded in JET CODAS

Hosted on a virtual Linux server
2 currently deployed but this is due to expand to 13
Full integration with JET CODAS

Turbomolecular Pump Control

PLC control to interlock with valves and gauges etc
Specific pump controller for detail monitoring and specialist controls.

Oerlikon LeyboldTurbo specific EPICS IOC
- Engineering data
  - Pump rotation speed,
  - Converter temperature
  - Motor current
  - Pump temperature
  - Circuit voltage
  - Error status
- On/off and reset controls
- USS (Universal Serial Specification Interface Protocol) communication protocol and the EPICS application has been developed using the EPICS asynDriver module. Implemented on Windows
- Integration with JET CODAS



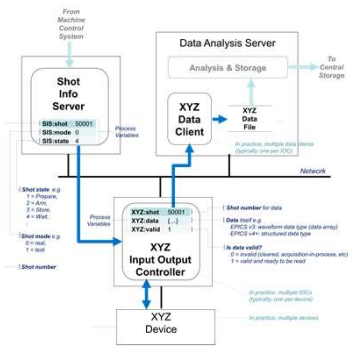

Agilent - Tritium compatible
- 2300 main turbomolecular pumps
  - Engineering data
  - Controls (only reset made accessible to the operators)
- 550 diagnostic turbomolecular pumps
  - Engineering data
  - No controls
- Serial interface using the EPICS streamDevice. asynDriver module handles the serial port. Implemented on Windows
- Integration with JET CODAS

Edwards STP-A2203 Series Turbomolecular Pump/SCU-1600 Control Unit.
- EPICS IOC controls
- Engineering data
  - pump rotation speed
  - motor current
  - motor temperature
- Controls
  - Set the rotation speed
  - On/off
- Serial interface using the EPICS streamDevice. AsynDriver module handles the serial port. Developed on Linux and then built and deployed to Windows
- Integration with JET CODAS

Conceptual data acquisition design for fusion facilities at Culham using EPICS

The use of EPICS for control is well-established. Its use for data-acquisition is less well developed. However, with the introduction of modules such as areaDetector (to capture video data) and the advent of structured data-types for process variables, EPICS becomes more functional in this regard.

The fusion experiments at the CCFE have a requirement to perform shot-based data-acquisition. The figure presents one possible high-level design for how this might be achieved using EPICS.

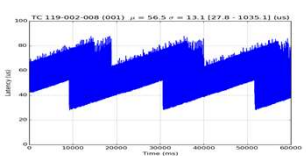


Extension of the JET real-time network

- Real-time control & Real-time protection
- Current system based on ATM technology
  - VXWorks/PowerPC, Windows/PC, Linux/PC
  - ATM cards difficult to source & some only work in one direction
- Technology refresh & more computational power
- ITER CODAC Ethernet/SDN

Network Technology Choice and Qualification

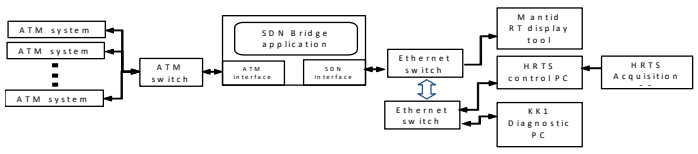
Intel Pro1000 nics and Gigabit switch with 10 Gigabit interconnects from Extreme
Switches nic and switch performance tests:
- Using same test techniques as for an ITER/F4E real time network qualification contract – udp multicast transmitter and receiver
- nic – nic
- nic – switch – nic
- nic – switch – switch – nic
- with and without an aggressor injecting additional high network traffic

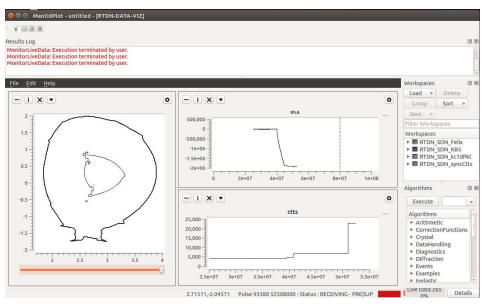


Typical performance
not seen with the ITER technology

JET architecture to ITER CODAS SDN

- JET real-time network/ATM – ITER CODAC Ethernet/SDN bridge
- MARTe application
- Initially unidirectional
  - Real-time Flux surface reconstruction and real-time display based on Mantid
- Extended to bidirectional
  - Loopback through the existing real time signal server
- Currently extending across 2 switches
  - Real time High Resolution Thomson scattering (HRTS) reconstruction (KE11), a MARTe V2 application
  - Real time ECE Michelson interferometer (KK1)





Future plans
- Enhanced real time controller
- Move local actuator managers onto Ethernet/SDN
- Release spares for real-time protection system

Future Developments and Possibilities

EPICS managed data acquisition
EPICS areaDetector extension for spectroscopy cameras
EPICS interface for Granville-Phillips Ion Trap Vacuum mass spectrometer
  Development complete but not yet deployed
  Of interest to ITET via the US DA
EPICS archiver
EPICS CSS based HMI's
ITER CODAC DAN – load test in a large real word application
ITER Real Time framework for JET RTCC2/PCS

Conclusion

We have started to introduce EPICS on both JET and MAST. On MAST, we have implemented a proof of principle application to monitor cubicles. We have also implemented a Central Information Display that opens the way for EPICS managed data acquisition systems.

On JET, we have built a bidirectional bridge between JET CODAS and EPICS and implemented EPICS interfaces for:
- a spectroscopy filter wheel controller
- several turbomolecular pump controllers
- Radiation Protection Instrumentation

Thereby providing some commonality between JET and MAST by utilising technologies to be used in ITER CODAC. We are looking forward to the possibility of developing EPICS managed data acquisition systems, possibly camera based spectroscopy.

On JET we have extended the ATM based real-time network using the ITER CODAC SDN over Ethernet. We consider the use of Gbit Ethernet sufficient for our application and have verified the performance of the selected products. Initially a new real-time boundary reconstruction display was implemented that used data stream from the data sourced on the traditional JET ATM based network, through the bridge and on via the new SND network. We are now completing the development of a real-time data reconstruction for High Resolution Thomson Scattering diagnostic (KE11) and ECE Michelson Interferometer diagnostic (KK1) that stream data onto the SND extension to the real-time network and back into the traditional ATM real-time network.

Looking forward to developing a new SND based real-time control system, based on ITER real-time framework for JET post 2020. We would also like to be able to develop an ITER CODAC like fast controller that uses EPICS, SDN and DAN.

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