Graphical Abstract

JET Plasma Control System Upgrade using MARTe2

A.V. Stephen

Highlights

JET Plasma Control System Upgrade using MARTe2

A.V. Stephen

- Research highlight 1
- Research highlight 2

JET Plasma Control System Upgrade using MARTe2

A.V. Stephen

Computing Division, United Kingdom Atomic Energy Authority, Culham Campus, Abingdon, OX14 3DB, Oxfordshire, United Kingdom

Abstract

JET real-time plasma control has been delivered with a heterogeneous collection of control systems linked by a dedicated low-jitter, low-latency network. To provide a high degree of flexibility in tuning plasma control algorithms to experimental requirements, the Real-Time Central Controller (RTCC) has been available since 1997. RTCC provides a sandboxed execution environment where experimental algorithms can be deployed with a rapid development workflow. New control laws can be developed by operators during the course of an experimental session. The potential impact of a defect in algorithms evolved without full lifecycle quality assurance can be bounded by clipping feedback control requests at the actuator managers. The likelihood of such defects is reduced in the first place by constraining the algorithms to be composed from reusable blocks and trusted real-time signals. Although this system operated successfully for a long time, limitations in compute capacity of the legacy hardware on which the application was deployed constrained algorithm development.

Motivated by the need to provide physics operators with a more performant system, an upgrade project was carried out to port the RTCC application to a modern high performance PC platform. The architecture selected was to use the MARTe2 framework. Development was able to reuse existing MARTe2 data sources to connect the application to the JET environment using the ITER SDN protocol. RTCC blocks were converted to MARTe2 functions. Python tooling was created to automatically convert previously deployed RTCC algorithms to MARTe2 configuration form.

This paper describes the techniques used to demonstrate system correctness prior to deployment in the JET operating environment. This was particularly important given that it was deployed around the time of the DT campaigns. It explains how the system was used to demonstrate some novel

control methods which delivered useful experiments in the final JET campaigns. It also outlines how the JET legacy data combined with this MARTe2 application can offer future value, even in the absence of the JET machine itself.

Keywords: real-time, control, MARTe2, JET, QA

1. Introduction

1.1. Background

Plasma Control Systems[1] are large and complex. There are variations in approach, but most fusion projects distinguish between the disciplines of algorithm design and real-time system implementation. The former abstracts higher level descriptions of the plasma control processes from the physics perspective. Thus dealing with magnetic, kinetic, MHD and error field control as well as wall conditioning, disruption and runaway electron control. Real-time system implementation must then map the control tasks into robust, resilient, deterministic control software. The implementation must deal with practical real-world constraints. These include signal processing to compute the required algorithm inputs, management of target control references throughout the shot, and provision of exceptional handling strategies to resolve off-normal conditions (whether in the plasma, or in the sensor and actuator subsystems).

This paper concentrates on the second challenge, of real-time plasma control system implementation.

1.2. Engineering Approaches

- Monolithic
- Distributed
- MBSE
- Custom Code
- Frameworks
- Integration Ecosystems

[1] PCS - Plasma Control System

1.3. JET PCS Architecture

The JET PCS architecture was[2] *distributed* and *heterogeneous*. The design choice to separate it into around 80 subsystems supported broad delegation of responsibility and promoted maximal separation of concerns. This proved to be beneficial as the project lifetime was repeatedly extended and as the machine configuration was significantly upgraded. The heterogenous hardware and software components selected for implementation were partly imposed by necessity as the project outlived successive generations of vendor supported technology and partly by differences in requirements for individual subsystems.

2. Materials and Methods

Overall coordination and configuration of these disparate systems was achieved through two unifying services.

2.1. Configuration Management

Most importantly, the *Level-1* configuration management subsystem provided a consistent and detailed model of each subsystem. Representing the attributes and modifiable options for each subsystem as rich parameters, the *Level-1* database, user interfaces, and codes provided a meta-programming system for the overall PCS. This configuration tooling was used to define all of the control settings to achieve a given experimental goal (parameter values, calibration, reference time series and inter-system dependencies). This system tuning was required to be completed before a JET discharge could begin.

2.2. Real-Time Data Network

The second unifying service was the real-time data network. This was a high performance, dedicated private network with low latency and low jitter communications between all of the PCS systems. The communications topology was point to multi-point. Implementation translated across three generations of networking equipment. The early version of the network ran over 100Mbps ethernet using UDP unicast. An upgrade in the mid 1990s

[2]JET is entering decommissioning, and although the PCS systems still exist, they are not longer operating.

introduced telecommunication standard equipment using ATM[3] switches in which the delivery of data was configured in the switch. In 2016, motivated by the increasing difficulty in obtaining ATM equipment, the ITER SDN ethernet multicast solution was adopted.

3. Theory and Calculation

3.1. Theory

The basis for the work.

3.2. Calculation

The practical development from the theory.

4. Results

5. Discussion

6. Conclusion

7. Glossary

Field specific terms.

8. Abbreviations

Check that non-standard abbrevs are defined in a footnote on page 1.

9. Acknowledgements

Individuals who helped (but were not co-authors).

[3]

10. Author Contributions

Using CRediT taxonomy.

Conceptualization

Data Curation

Formal analysis

Funding acquisition

Investigation

Methodology

Project administration

Resources

Software

Supervision

Validation

Visualization

Writing - draft

riting - review and editing

Funding
This work was supported by *ldots*

Appendix A. Example Appendix Section

Appendix text.
Example citation, See [1].

References

[1] Leslie Lamport, *LaTeX: a document preparation system*, Addison Wesley, Massachusetts, 2nd edition, 1994.