MARTe in fusion

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(JET, IST, RFX, COMPASS, FTU)

Outline

- MARTe: a bit of history
- MARTe in JET
- MARTe in fusion devices
- Summary

MARTe: a bit of history (1)

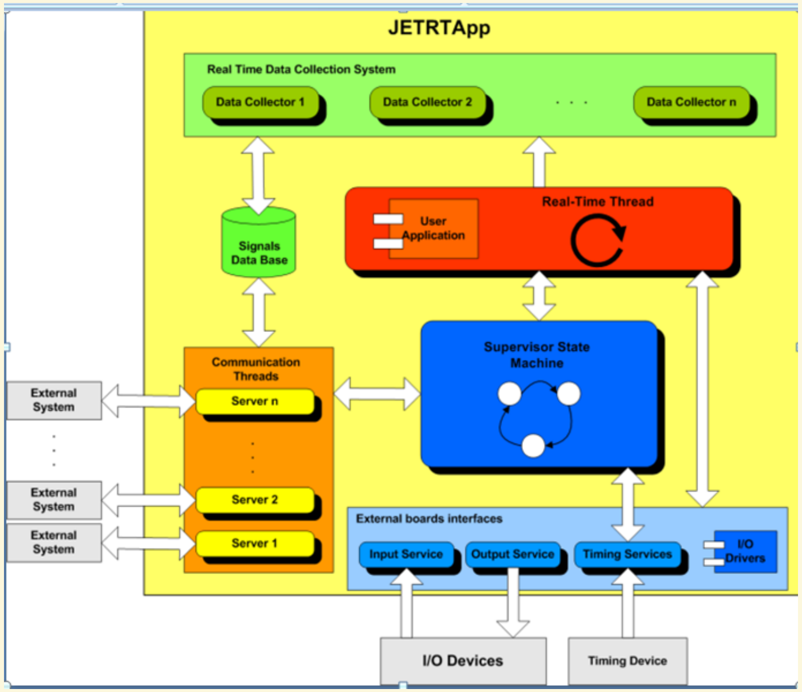
At the end of the 90s at JET only dedicated hardware/software solutions where used for magnetic control. SC was operating on VxWorks Power-PC and VS was deployed on 4 DSP.

Limitations:

- No flexibility
- no easy debugging and testing
- long commissioning time

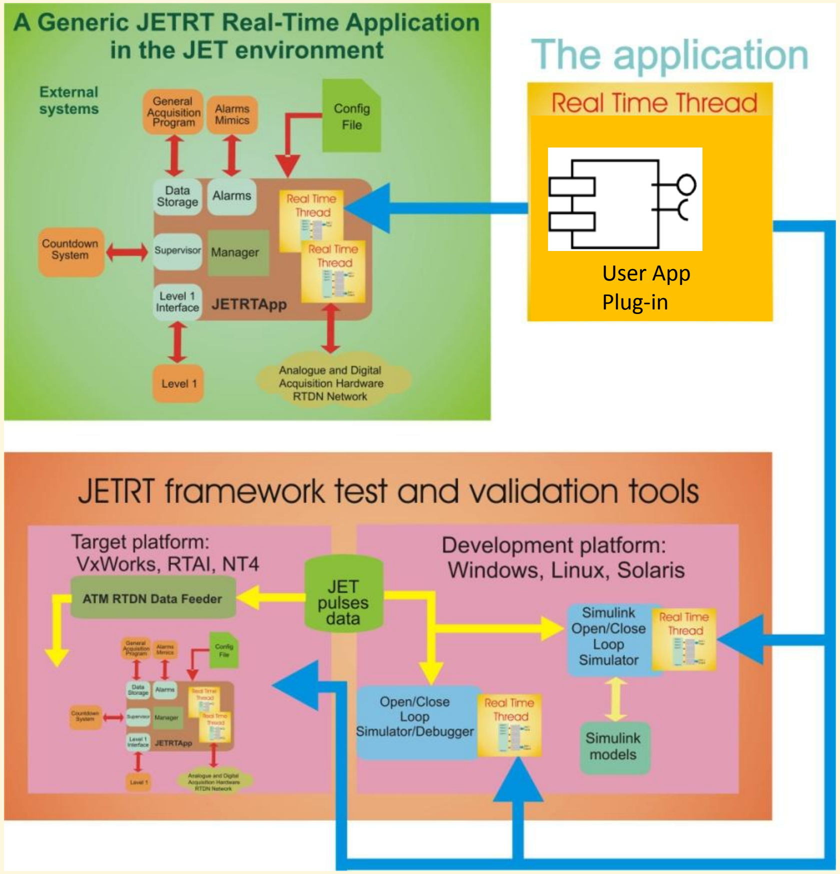
JETRT framework

- Based on a cross-platform library: **BaseLib**
- Clear separation between application and infrastructure software



MARTe: a bit of history (2)

- Application can abstract from the plant interfaces
- Increase code reusability
- Achieve standardization



- Perform offline validation against a plat model
- Perform real-time validation with hardware-in-the-loop
- Run the real-time system on the plant

XSC was performed offline on a Windows--based platform and then commissioned in only 3 days on a VxWorks system.

MARTe: a bit of history (3)

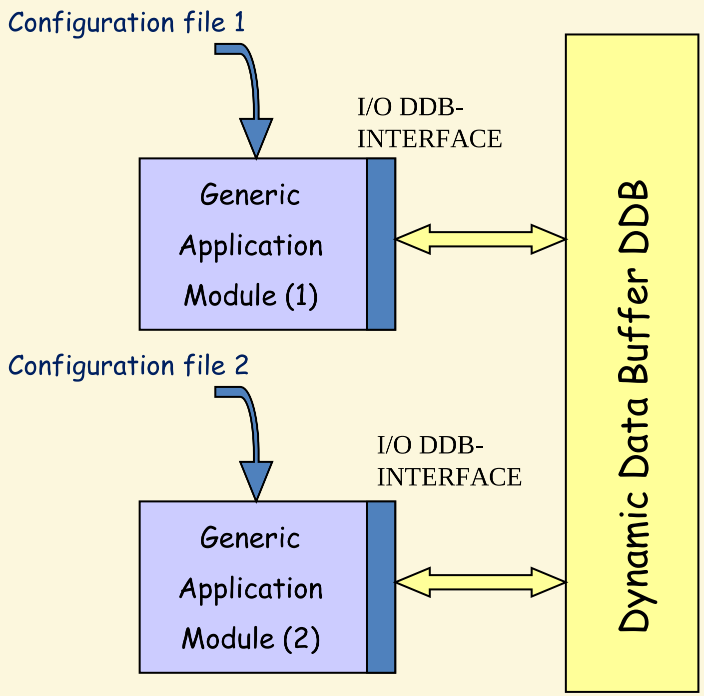
JETRT limitations:

- It didn't provide a real separation between the user application from the plant-interface software!
- Need to be recompiled entirely in case of changing in both interface side and/or application side!

First intermediate step:

Modularity -> Generic Application Modules (programmable and reusable)

Separation -> Dynamic Data Buffer (link between GAMs)

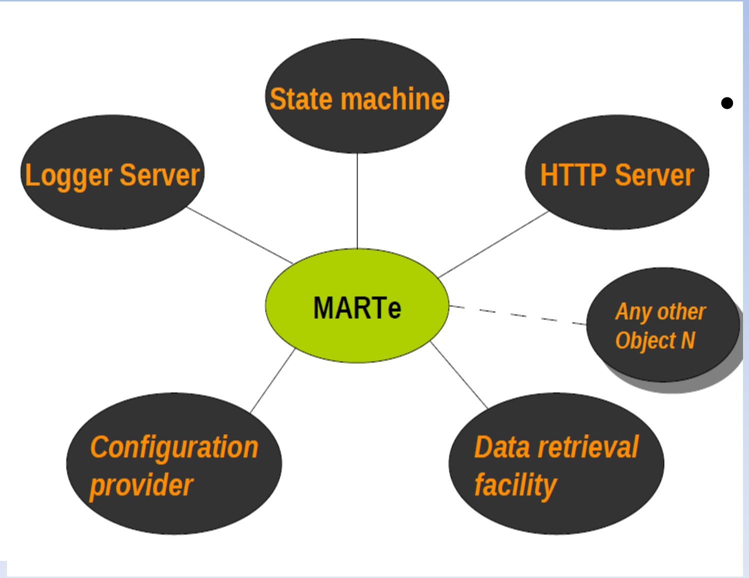


MARTe: a bit of history (4)

Final step: MARTe

- By using the features implemented in BaseLib2, MARTe deployed not only the real-time threads scheduling but also all the I/O activities.

- MARTe is as collection of real-time threads scheduled by an internal state machine.

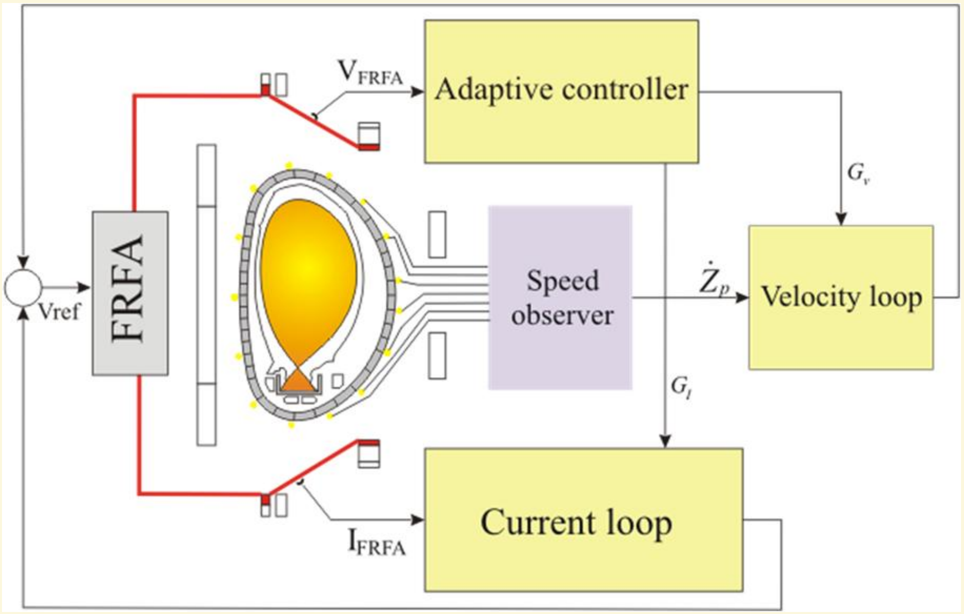


- Each real-time thread is totally configurable (applications and timing).
- Via e communication protocol, additional totally configurable modules loaded in MARTe cover all the I/O needs:
  - state machine for operation (e.g. JET pulse sequence);
  - I/O communications (e.g. CODAS or WEB interfacing);
  - additional (e.g. security or logger service).

MARTe at JET: VS

Vertical Stabilization System:

- Driven by the needs of the PCU Project it was the first MARTe framework based system running at JET
- It allows flexible use of the ERFA amplifier for vertical stability
- Entirely configurable via configuration files (or JET-Level1).



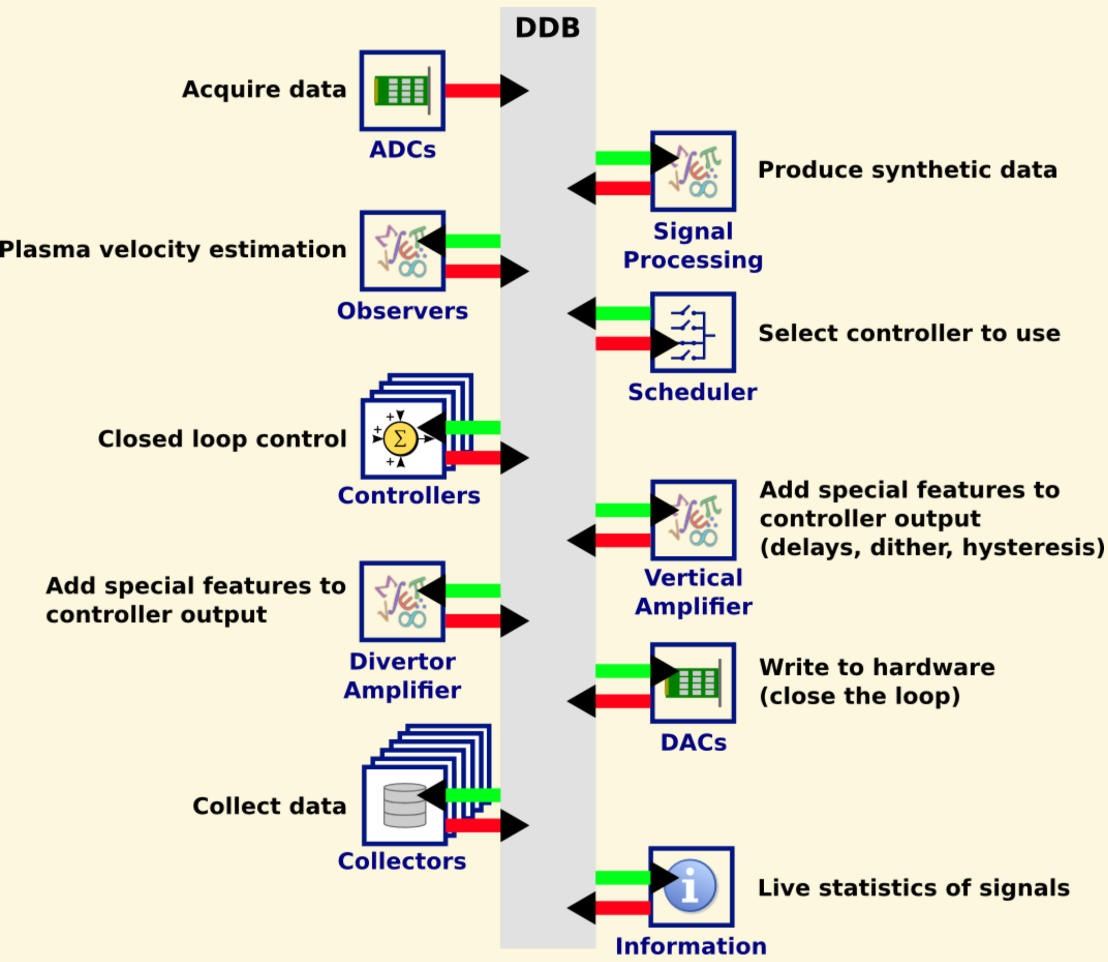
10 GAMs running at 50us with a very low latency

Vertical Stability chain of GAMs allows large flexibility in how to run the vertical system:

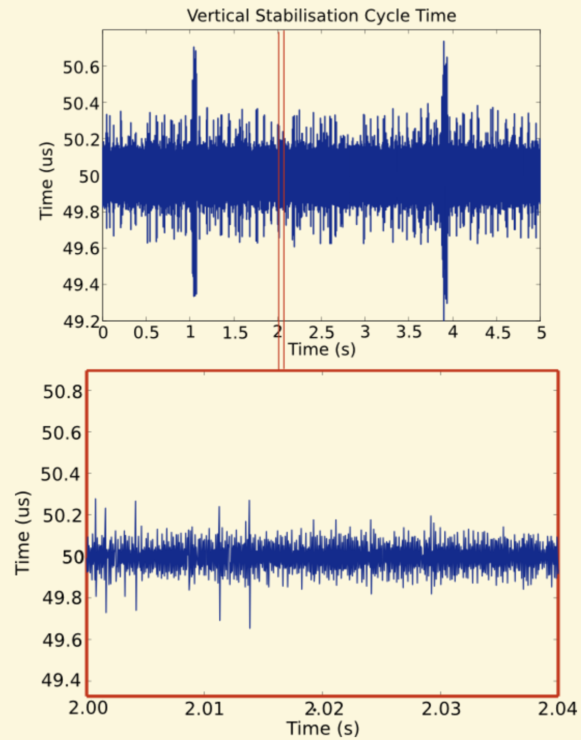
- easily change in velocity estimation module
- programmable artificial events (kicks) with VS or Divertor
- easy switch-on/off of modules

MARTe at JET: VS

GAM collection

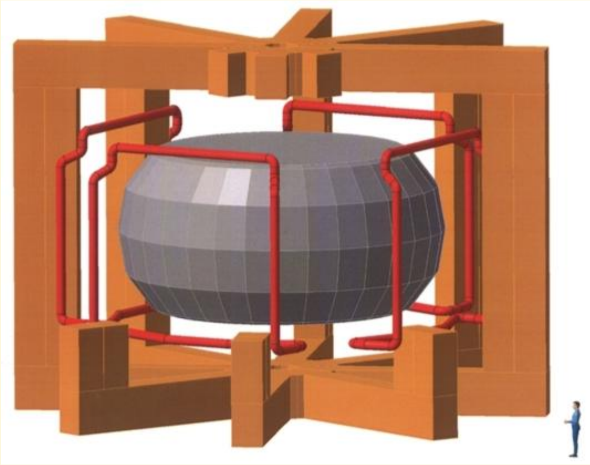


Architecture	ATCA/PCIe
Processor	Intel Core2 Quad
O.S.	RTAI
Input	198 18bits ADCs @2MHz
Output	5 DACs
Cycle time	50us



Error Field Correction Coils – EFCC:

- Devoleped for improving the capabilities of the EFCC system by using a more performance amplifier (with a more advance amplifier control algorithm)
- First MARTe system running on VxWorks platform

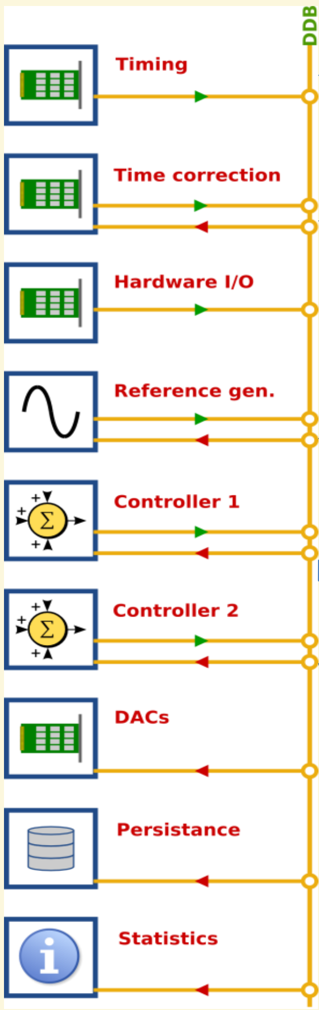


- The first version has run with a simple PID.
- Improved waveform generation GAM and editor.
- A particular approach has been used for the thread timing generator using the VxWorks internal timer and JET synchronization.
- The system has required a short commissioning.

(*) The integration of the new and advanced controller algorithm will require simply the modification of the MARTe cfg.

MARTe at JET: EFCC

GAM collection



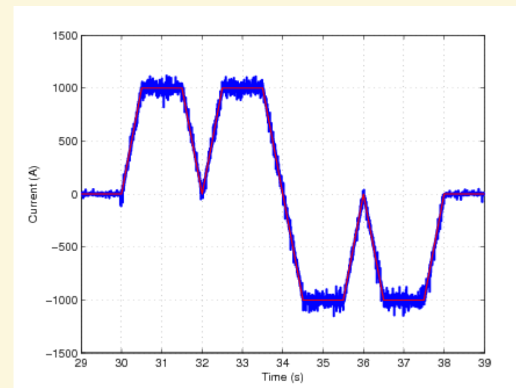
Internal timer

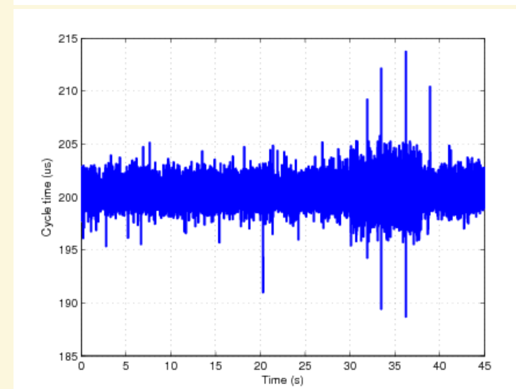
Absolute time correction on JET timing system

Advance waveform editor developed inside JET-Level 1 interface

Controller 1 and 2 can be enabled or disabled in the CFG based on the n=1 or n=2 amplifier configuration

Architecture	VME
Processor	MVME5100 Power PC
O.S.	VxWorks
Input	10 12bits ADCs @330khz
Output	2 DACs
Cycle time	200us





MARTe at JET

Many GAMs are presently available.
Combinations of them allow to build-up entire applications.

Module	
FELIX	plasma magnetic topology reconstruction (different plasma models can be implemented) - Used in Shape Control, WALLS, BetaLi, q-Profile RT.
WaveformGeneration	flexible and programmable waveforms generator - Used in VS, EFCC, auxiliary applications for power request.
Equation Solver	equation solver
I/O GAMs	reading and writing data from/to multiple sources/format (signal databases, text files, Matlab files, MDSplus, web,…) – Used online and/or offline
DisplayGAM	JAVA display GAM by using JScope tool.
StateSpaceModel	Allows running state space models
WebStatisticGAM	Allows checking the status of signals in the DDB

MARTe at JET

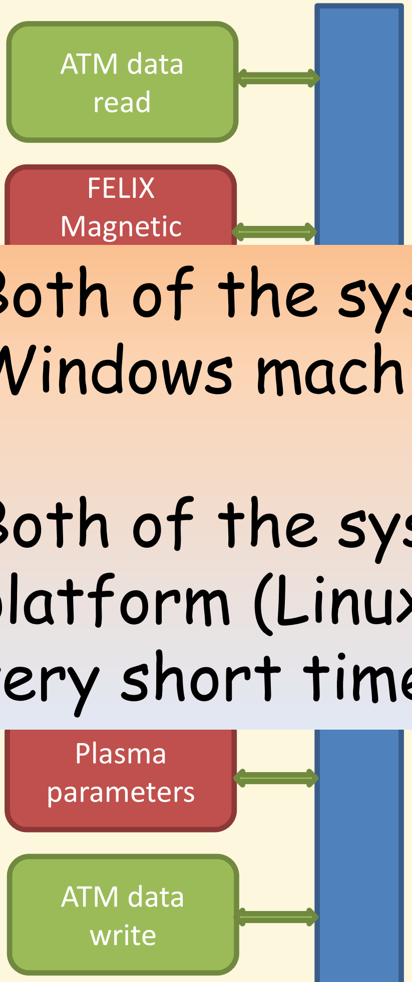
Dedicated applications have been developed as well with the same philosophy allowing reusability of some of their GAMs.

Applications	
BetaLi	plasma parameters calculation (5 GAMs)
WALLS	Plasma first wall and divertor protection system (4GAMs)
Disruption Prediction	Disruption prediction based on 3 different approaches (density limits, FFT, N2 algorithm) (3GAMs)
RTMX	Matlab Simulink to GAM
RTMX2	Generic application system (linked to all ATM packets can be used for creating any possible application starting from the available library of GAMs)

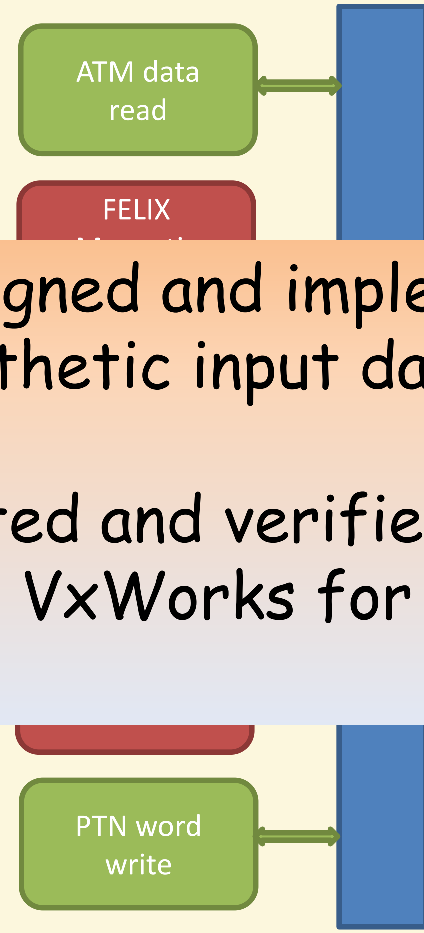
Some of the applications or combination of GAMs are used also offline for data analysis, pulse analysis (applications run on a different data input sample time), fault investigation.

MARTe at JET

BetaLi: Plasma parameters



WALLS: First-wall protection system



Protect against plasma positioning in weak area of

additional data to WALLS via ATM or adding to WALLS chain the BetaLi GAMs chain.

Both of the systems were designed and implemented on a Windows machine by using synthetic input data.

Both of the systems were ported and verified on different platform (Linux for BetaLi and VxWorks for WALLS) in a very short time.

MARTe at JET

Together with the GAMs and applications, already a large number of support libraries and drivers have been developed.

Applications	
I/O Drivers	Acquisition cards and output cards (e.g. ATCA and ATM).
Timer drivers	From external and internal devices.
Support libraries	Communication modules for different machines (e.g. CODAS JET)
Communications	Http, Java applet, Web service (in GAM version as well)
Data reading and storage	GAMs and libraries to read data from databases or files (e.g. PPF, JPF, MDSPlus, text files) and writing data to database or file (e.g. PPF, JPF, Matlab binary files)

JET RTPS - Real Time Protection System

- New protection system for the ITER like Wall
- Overrides references to the plasma, gas and additional heating actuators
  - Stop responses can be adapted to the phase discharge
    - 25 time windows x 10 stop types x N local manager configurations
  - Avoids reaching conditions where the protective hard stop actions would otherwise be triggered
- MARTe running on PowerPC using the latest version of VxWorks 6

MARTe at JET: recent developments

VTM – Vessel Thermal Map	WALLS2011
Primary first-wall protection system. • Checks the wall for temperature hotspots produced by IR camera. • Responds to the hotspots according to configurable logic.	It is a model-based protection for the first-wall. • Monitoring temperature, strike-point position, field-line angle inclination, deposited energy and power. • Raises alarms/warnings based on operational (configurable) thresholds

- MARTe on Linux O.S. with 3 cores (AMD Phenom II).
- Time synchronization for threads from RTPS-ATM packets each 2ms.
- Cycle time 10ms.

MARTe in fusion

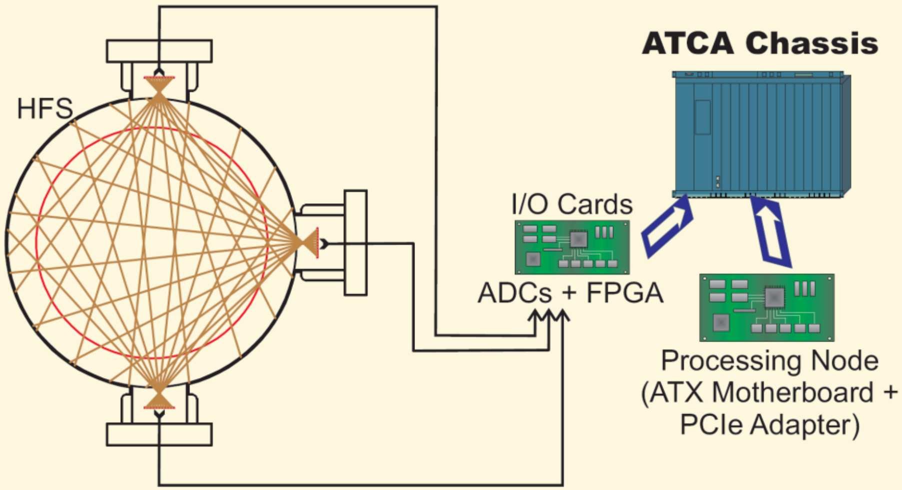
Many machines have adopted MARTe as real-time framework for their control systems.

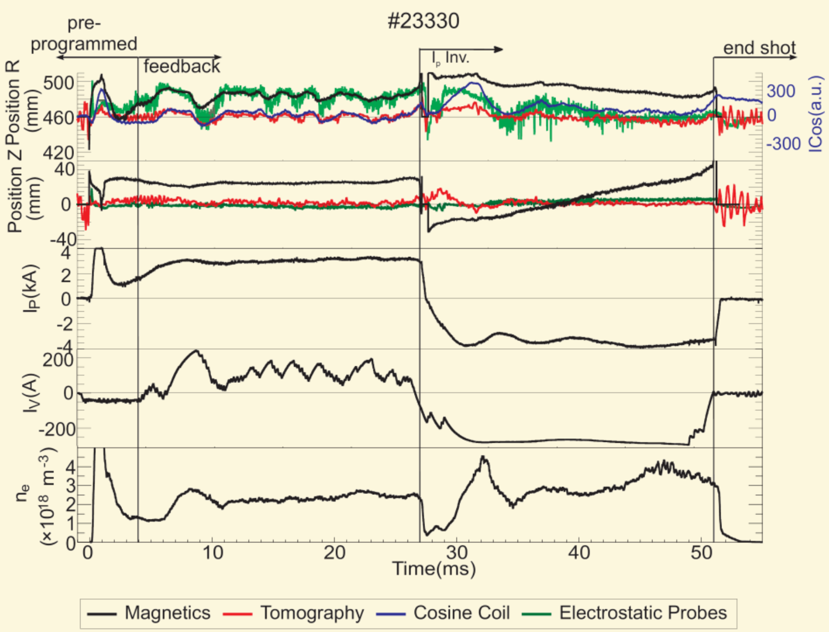
- ISTTOK - IST Lisbon, Portugal
- COMPASS - Prague, Czech Republic
- RFX - Consorzio RFX Padua, Italy
- FTU - ENEA Frascati, Italy

MARTe in fusion: ISTTOK

Real-time tomography from radiation emissivity for plasma position control.

Architecture	ATCA/PCIe
Processor	Intel Core2 Quad
O.S.	Linux
Input	30 18bits ADCs @2MHz
Output	2 RS-232
Cycle time	100us

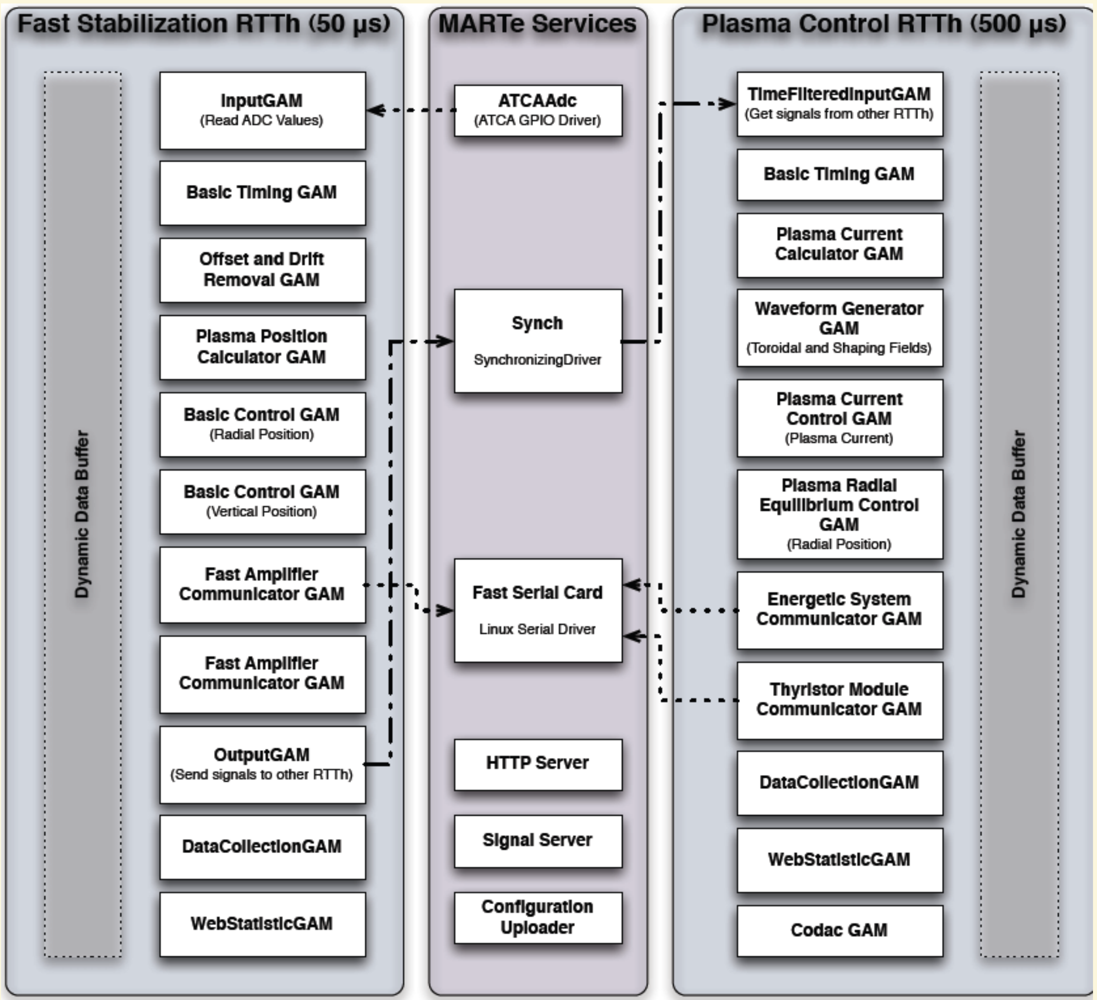




~5us acquisition
~40us tomography
~10us communication

MARTe in fusion: COMPASS

Plasma magnetic control system



Architecture	ATCA/PCIe
Processor	Intel Core2 Quad
O.S.	Linux
Input	12 18bits ADCs @2MHz
Output	5 RS-232
Cycle time	50-500us

Slow loop 500us:
GAMs execution time < 100us

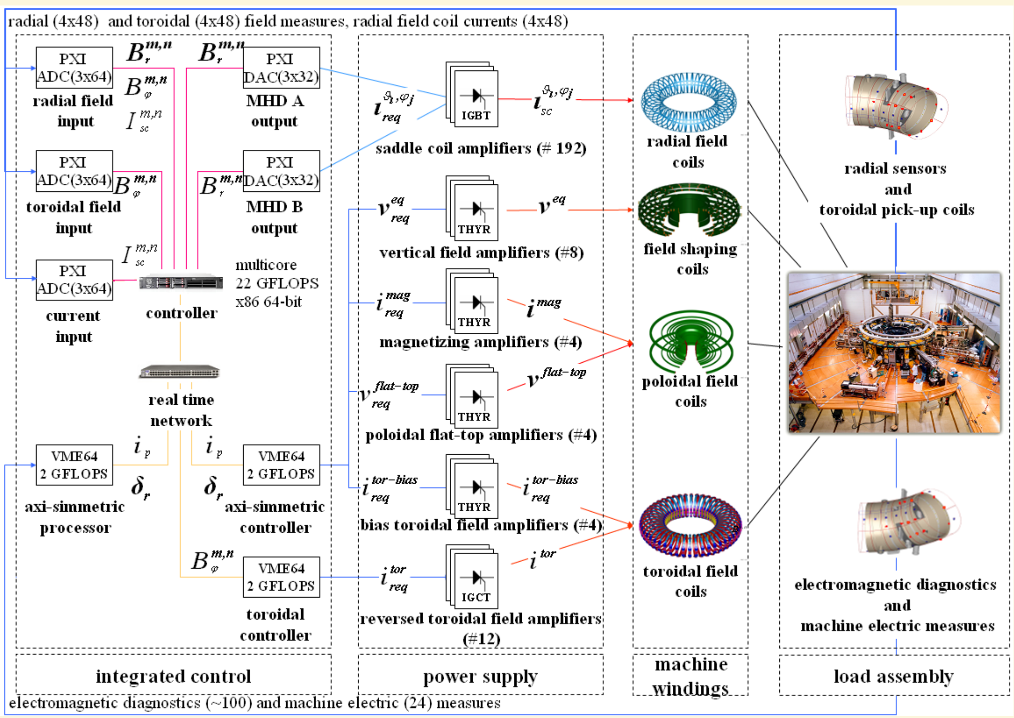
Fast loop 50us:
GAMs execution time < 30us

Slow loop provides data to the fast loop

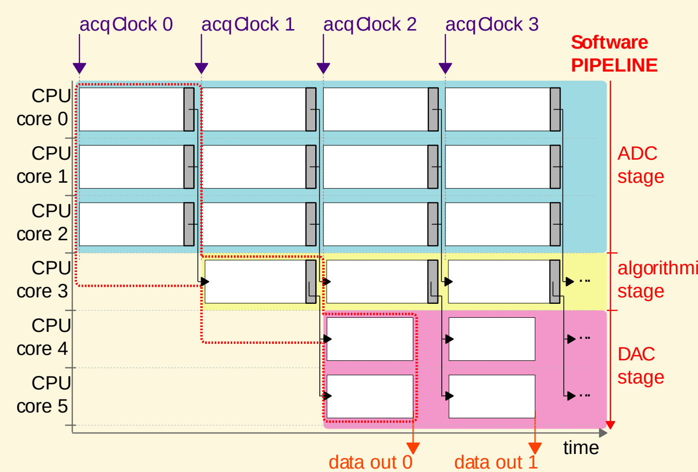
MARTe in fusion: RFX

RFX magnetic control system

Architecture	PXI
Processor	Intel Xenon E5500 6 cores
O.S.	Linux (PreemptRT)
Input	576 16bits ADCs@8-10kHz
Output	192 13bits DACs@8-10kHz
Cycle time	200-250us



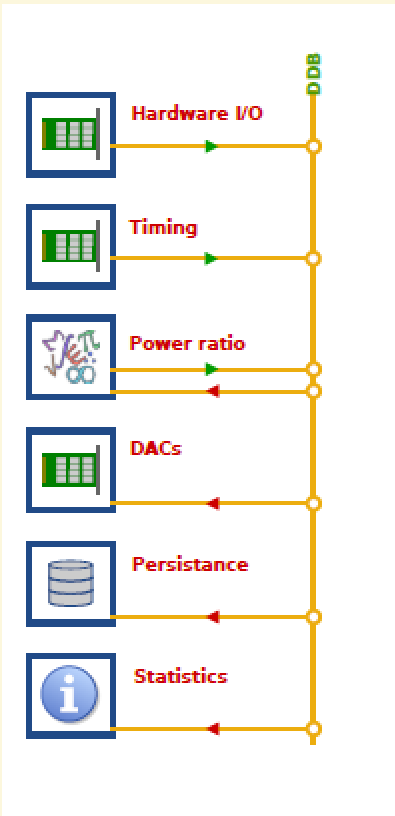
A THREE stage pipeline was developed in MARTe to achieve 8-10kHz acquisition clock while adopting multiplexed acquisition boards.



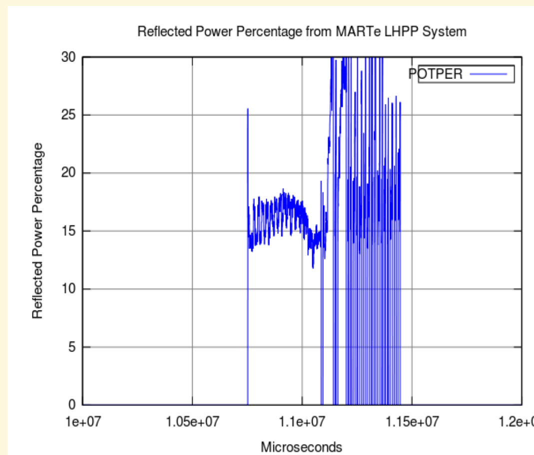
MARTe in fusion: FTU

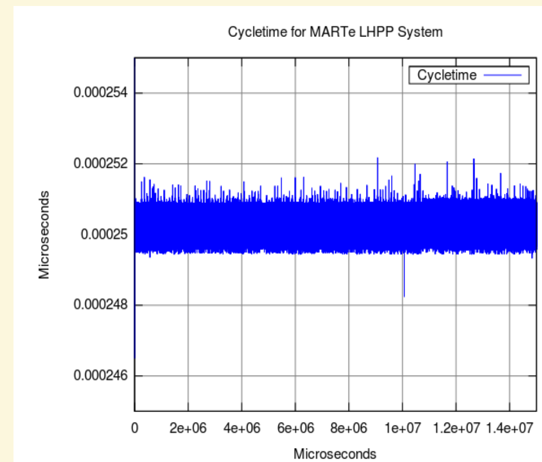
Lower Hybrid power ratio control

Architecture	VME
Processor	Intel Core2 Duo
O.S.	RTAI
Input	16 12bits ADCs @500kHz
Output	16 DACs
Cycle time	250us



Change plasma position to maximize coupling with LH source

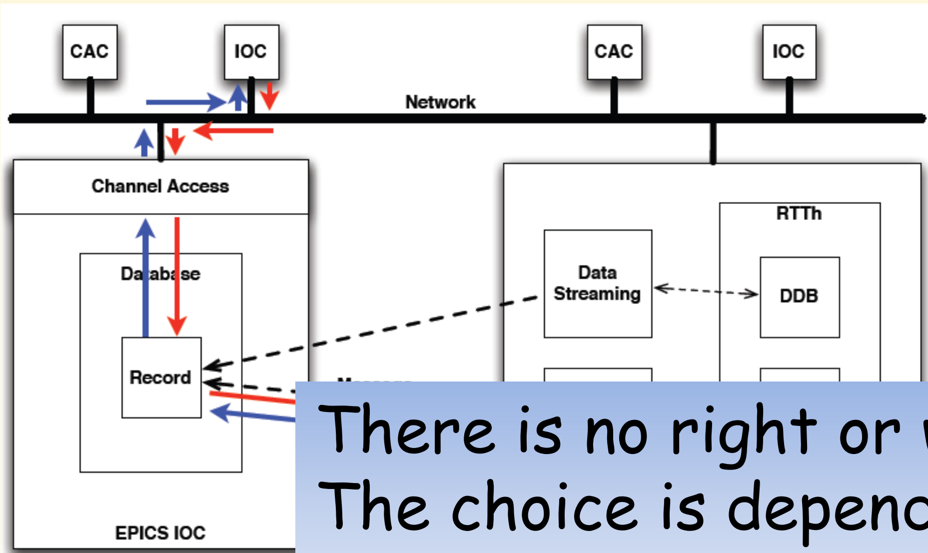




(*) The ODIN code for equilibrium reconstruction has been recently adapted for real-time and run under MARTe framework for replacing the magnetic control system in FTU.

MARTe in fusion: EPICS

MARTe ⟷ EPICS



Alternatives:

- I/O GAMs for communication between MARTe and EPICS.
  Atomic changes/monitoring in MARTe.

can access

ld be
ortable
CAS (pCAS) library and avoid all the unnecessary complication of IOCs.

There is no right or wrong approach. The choice is depending on the particular problem to be solved.

So far a traditi
implemented.
ConfigurationLibrary:

- remotely configure any MARTe object using a messaging mechanism.
- ConfigurationLibrary used in a EPICS IOC to configure a GAM

MARTe in fusion: MDSplus

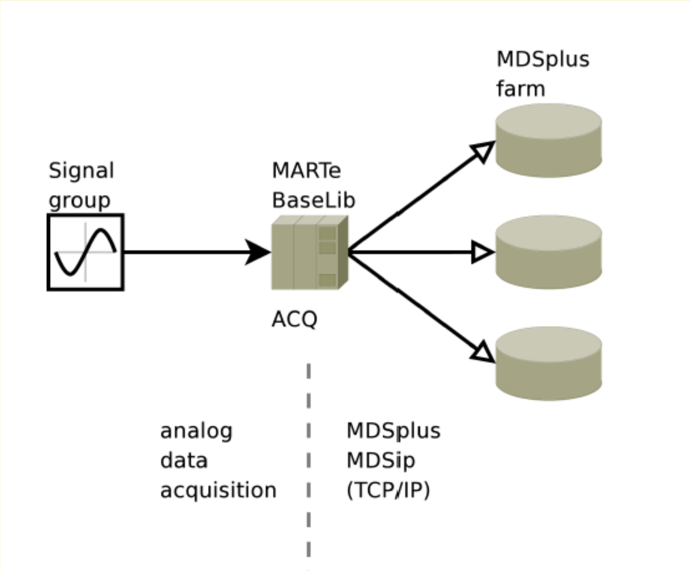
A software adaptor between MARTe and MDSplus has been developed supporting post-pulse data storage and continuous data acquisition via MDSplus segments interface.

GAM for data streaming from the real-time thread in MARTe to MDSplus
Appends new data block to the corresponding waveform stored in the pulse file.

GAM for data recording to MDSplus
Create a new waveform data.

GAM for data reading from MDSplus
Read data from MDSplus.

Under development MDSaction and MDSip for action driven by MDS plus and tcp/ip protocol MARTe/MDSplus



Summary (1)

- MARTe is an implementation of numerous concepts during the last 10 years of work mainly at JET.
- Underlying BaseLib2 is the supporting collection of libraries that make MARTe possible.

Summary (2)

- The net separation between I/O and application has been the driving concept.
- High modularity and separation allow fast debugging and testing, short commissioning time, high portability and adaptability.
- Programmability of single GAM allows to use the same algorithm in many application. High reusability.

Summary (3)

- Many systems with variegated requirements in JET(e.g. from 50us to 10ms cycle time) are supported by MARTe framework.
- Different machines in Europe have adopted MARTe as real-time framework for many of their real-time systems and applications.
- Updated version of MARTe with enlarged capabilities, applications design and implementation within GAM and interfaces with external tools (e.g. EPICS and MDSPlus) are continuously provided by the MARTe community.

Thank you for your attention

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Thanks to the MARTe team

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