First Applications of MARTe2/MDSplus/Simulink framework for real-time control applications.

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13th IAEA TM on Plasma Control Systems, Data Management and Remote Experiments in Fusion Research

Control System Framework

- Use Cases:
 - Plasma Operation
 - Verification / Hardware in the loop simulation
 - Run planning
- Must provide:
 - Code once / Run many
 - Easy to use platform for PCS algorithms
 - High-level automated translation simulation environment -> RTF run-time environment
 - Robust scalable operation Modular and Distributed
 - Recording of
 - Inputs
 - Outputs
 - Configuration/Calibration
 - Intermediate results
 - Synchronous Multi–rate computation
 - Asynchronous event–based activities

MARTe2

- Developed by F4E
- Cross platform real-time execution environment
- Code Quality / Testing MISRAC++:2008
- Based on MARTe used by existing Tokamaks (JET)
- XML description
 - Compute Modules GAMS
 - IO components IO GAMS
 - Connections between components

MARTe2/MDSplus

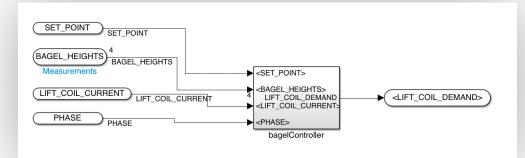
- Set of MDSplus 'devices' which describe MARTe2 objects and their connections.
- MARTe2 XML is generated as a 'method' of the supervisor device
- MARTe2 framework is started/stopped as 'methods' of supervisor device
- Generic devices
 - SDN communication
 - Simulink generated code
 - User python code
- Custom Devices
 - Any custom MARTe2 GAMs
- Simplifies/abstracts MARTe2 primitives

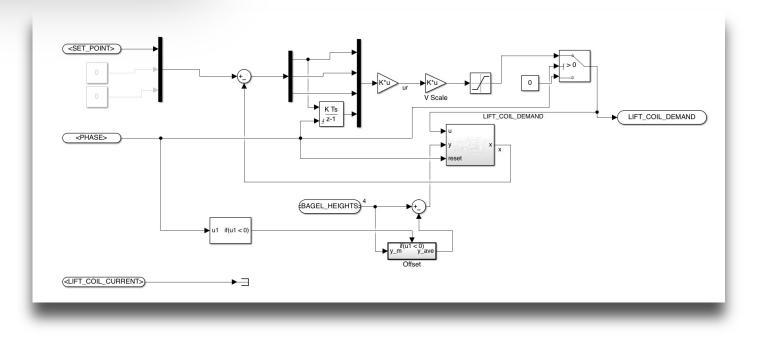
Need: Automatic generation of MDSplus trees from Simulink models

Simulink

- MathWorks commercial product
- Algorithms can be developed and tested off-line
 - Generated C++ code free from 'user coding mistakes'
- Used to drive Simulations for run planning and shot verification
 - Overall PCS structure described in Simulink
 - Hand coded modules need Simulink wrappers
- · Specialized communication blocks facilitate variety of use cases
 - MARTe2 real-time communication
 - MARTe2 SDN communication
 - Simulation
 - Simulink native
 - Simulink compiled modules
 - MARTe2 simulated operations

MARTe2/Simulink/MDSplus



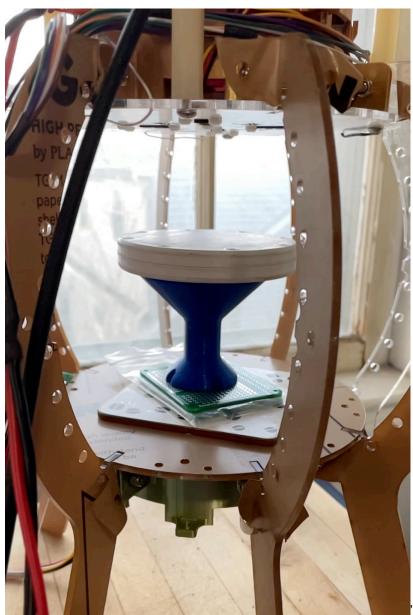


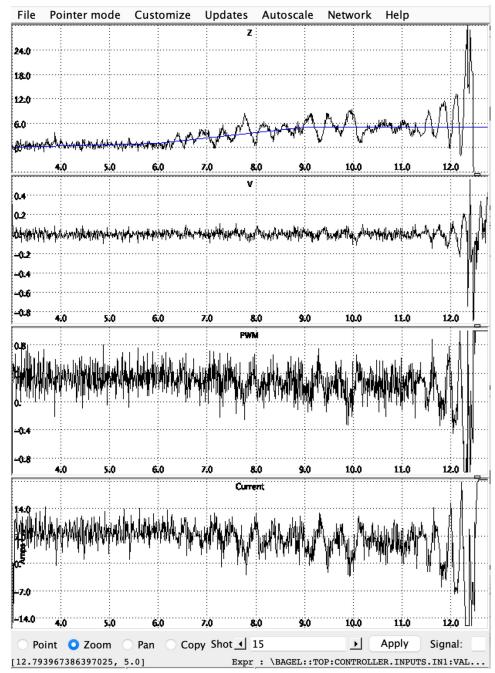
Control System Test Apparatus – levitated bagel

- Complete system demonstrating most aspects of the final system.
 - Distributed multi-rate real-time control
 - MARTe components managed through MDSplus
 - Controller switching (soft landing)
 - User interface for target specifications stored in MDSplus
 - Simulink control algorithms
 - System simulator
 - Real-time inputs from network
 - Real-time outputs to network
 - Outputs and intermediate results stored in MDSplus



Good News / Bad News





MARTe2/Simulink/MDSplus

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<u> (</u> TOP)				
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🗢 📘 CONTROLLER	Comment:	Check		
• 📕 INPUT				
• MARTE	Application Name: Bagel	Num. States: 1 Dispatch 🔤		
OUTPUT	State1 State2 State3 State4			
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Tree: BAGEL Shot: -1	Thread1 Thread2 Thread3 Threa	MARTe2 Simulink Generic device \BAGEL::TOP:CONTROLLER		
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	GAMs: [.⊰INPUT, .⊰CONTROLL	Simulink module: bagelController0 Write CPU Mask: 15 Fill fields Verbosity: 2 sources of the second		
	Ok	Input 1 Name: SET_POINT Type: float64 Dimension (0 for scalar, array otherwise): 0		
		Value::SET_POINT		
		Input 2		
		Name: BAGEL_HEIGHTS Type: float64 🔤 Dimension (0 for scalar, array otherwise): [4]		
		Value:: INPUT.OUTPUTS.OUT01: VALUE		
		Ok Apply Reset Cancel	11.	

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Fast Breakdown detection in ITER NBTF

- Required to stop feeding reference waveforms to power supply when a acceleration grid breakdown is detected
 - After a programmable time (~20ms), a new reference is generated so that the reference waveform 'reconnects' the original one
- Implemented in MARTe2-MDSplus as a set of devices:
 - A MARTe2 supervisor
 - A Digital input synchronizing the Thread at the input HW clock (1 kHz)
 - A GAM device implementing a programmable real-time state machine to model the desired behavior
 - A DAC device to output the reference waveforms
 - A Digital Out device to program the required triggers controlling power supplies
- System configuration, including reconnection waveforms stored in the experiment model and read in real-time

Calorimetric online computation at ITER NBTF

- Required to provide in real-time a set of elaborated calorimetric values to be displayed in control room and for online analysis
- 100ms cycle time, no HW synchronization, no HW devices
- ~300 Inputs collected via MDSplus streaming, ~100 outputs stored in the pulse file and streamed out for online visualization
- Software Synchronization via a DataSource device waiting for a MDSplus event.
- A Single MARTe2 Thread for collecting input data, calorimetric computation and output streaming

1	MARTe2 Supervisor \SPIDER::TOP	SPIDER_A.CALORIMETRY:MARTE2		
Trash	Comment:	Check		
	Application Name: Calorimetry	Num. States: 1 Dispatch 🔽		
	State1 State2 State3 State4			
jTraverser - Tree: SPIDER S	Name: Statel	Num Threads: 1		
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- 🗟 CODAS	Name: Thread1 CPU Mask:	15 Seg. Len (0 to disable): 0		
→ ♣ PLANTS • ▲ SPIDER A			:::TOP.SPIDER_A.CALORIMETRY:MARTE_CAL_ON * □ ×	
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A IN_SIGNALS	Stream Name: NB-SIGV-VSS:MPI32-PT	Value: TIMEBASE	Type: int32 🔻 Channel: CalTime	
AN SUMMARY	Stream Name: V_EGRaw	Signal 2		
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		- Signal 4		
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