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

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SPARC

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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

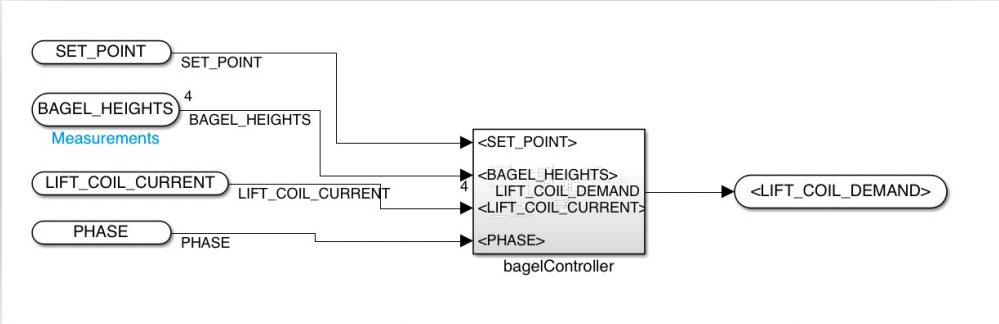
MARTe2/MDSplus

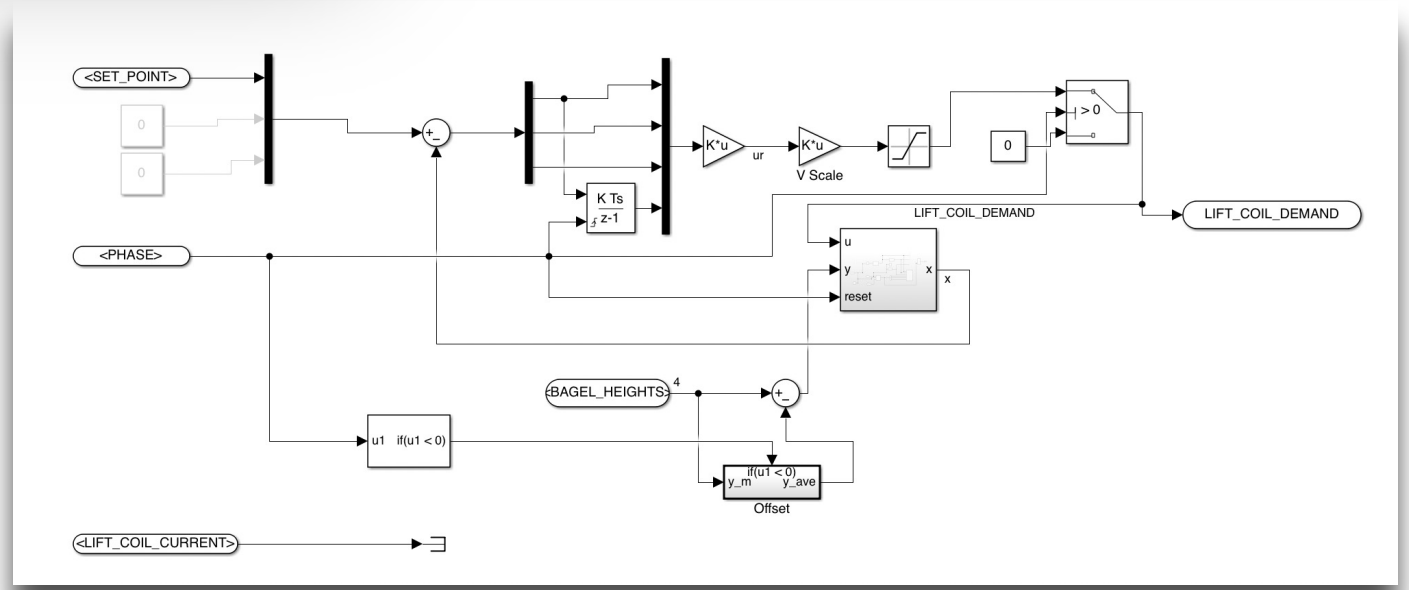
- Set of MDSplus ‘devices’ which describe MARTe2 objects and their connections.
- MARTe2 XML is generated as a ‘method’ of the supervisor device
- MARTe2 framework is started/stopped as ‘methods’ of supervisor device
- Generic devices
  - SDN communication
  - Simulink generated code
  - User python 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

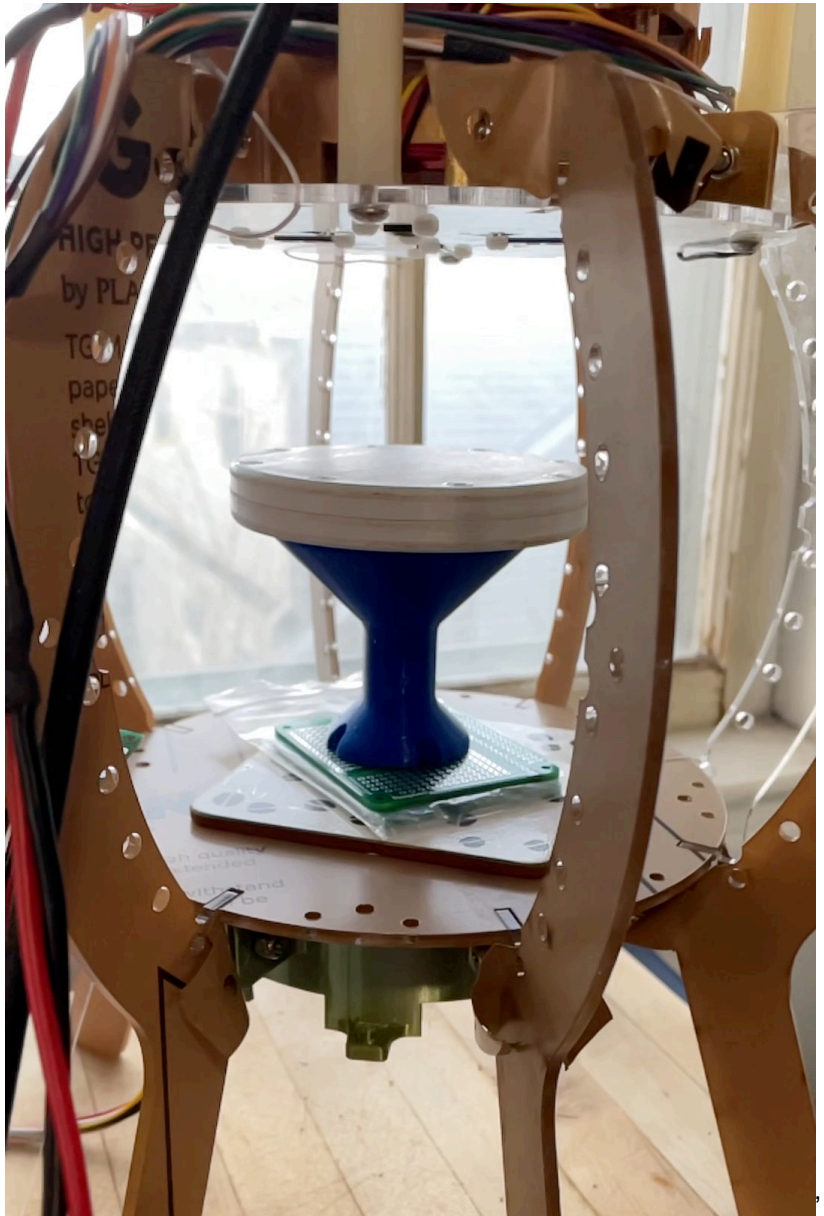


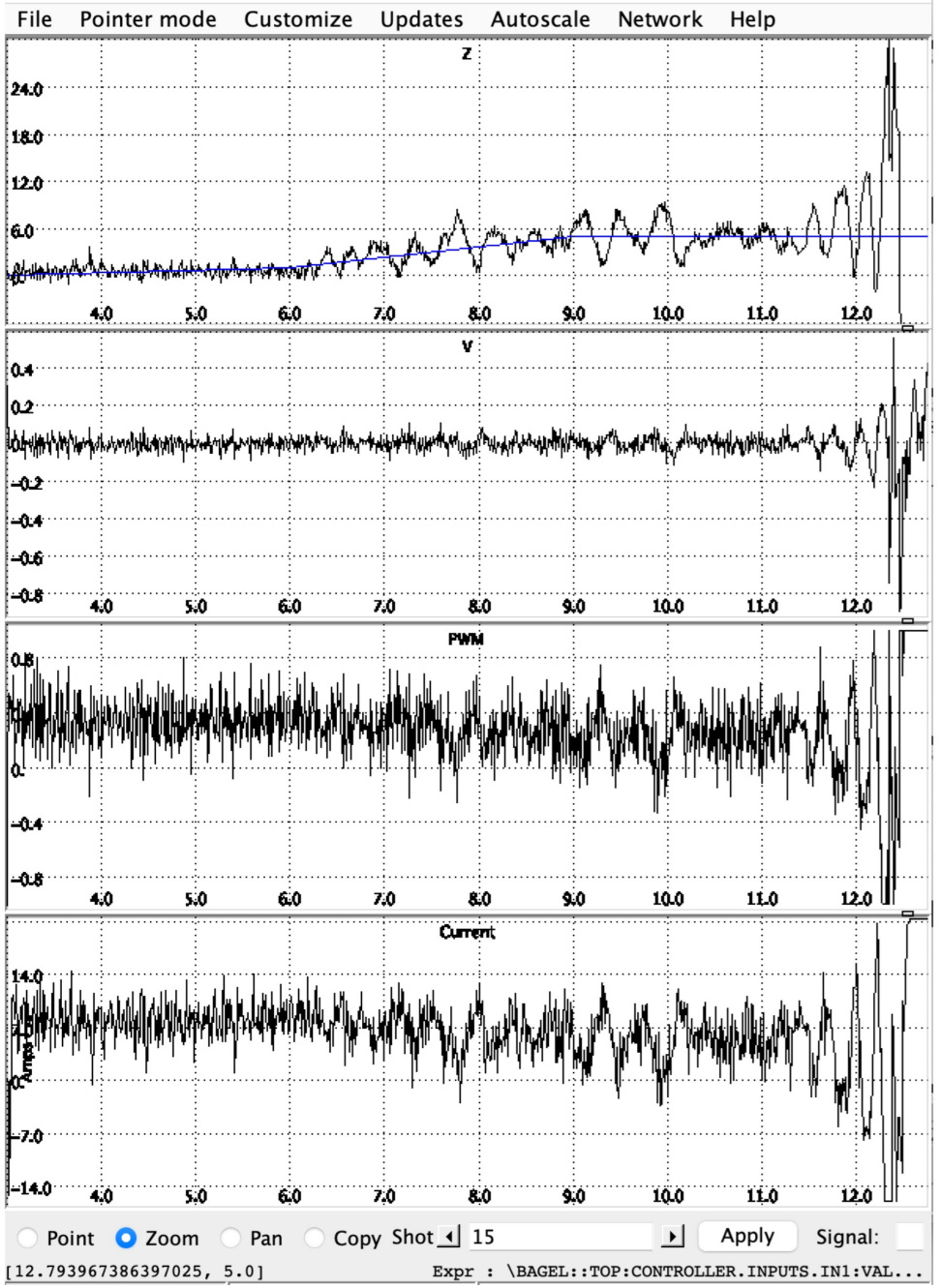


Control System Test Apparatus – levitated bagel

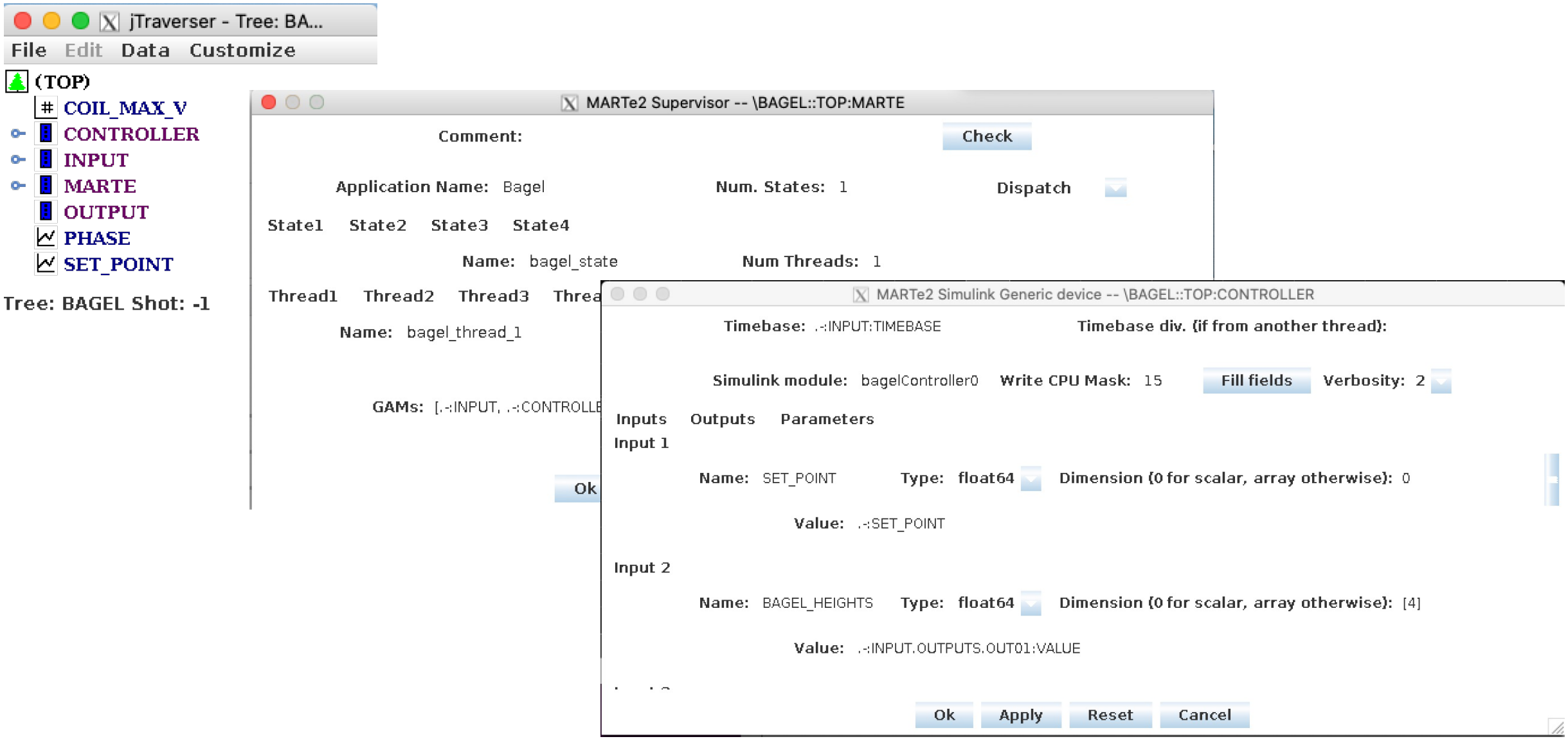
- Complete system demonstrating most aspects of the final system.
  - Distributed multi-rate real-time control
  - MARTe components managed through MDSplus
  - Controller switching (soft landing)
  - User interface for target specifications stored in MDSplus
  - Simulink control algorithms
  - System 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



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