The architecture and test-bed of the T-15MD tokamak plasma control system

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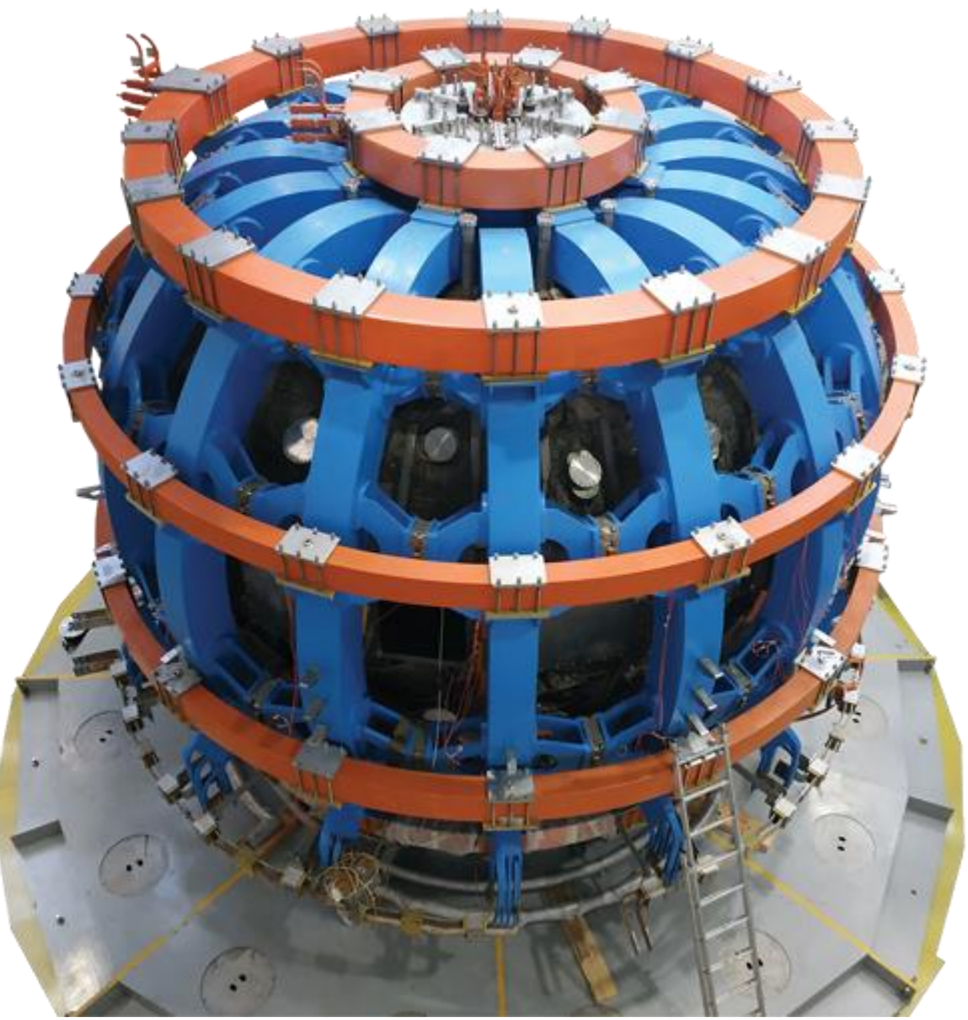
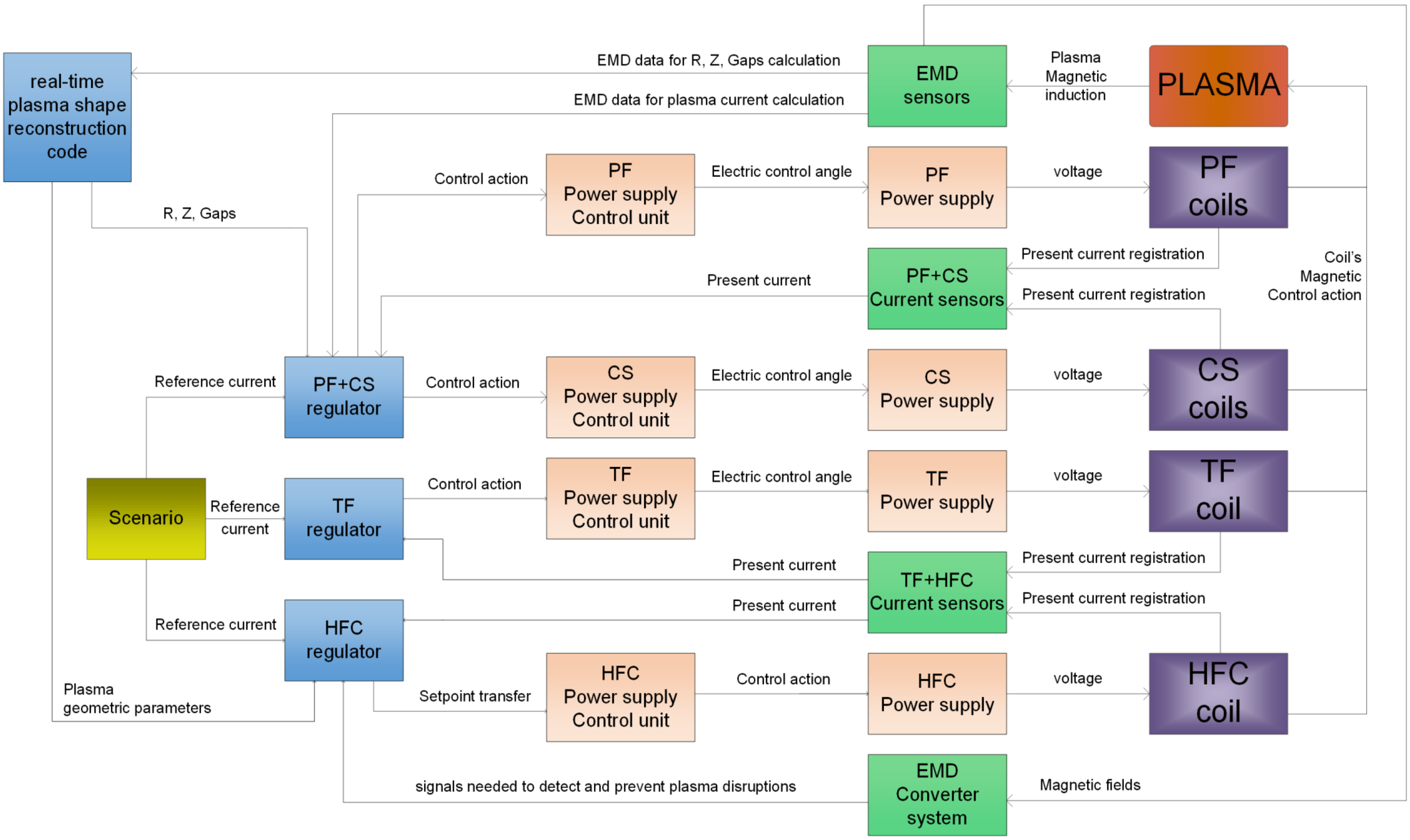
Tokamak T-15MD features

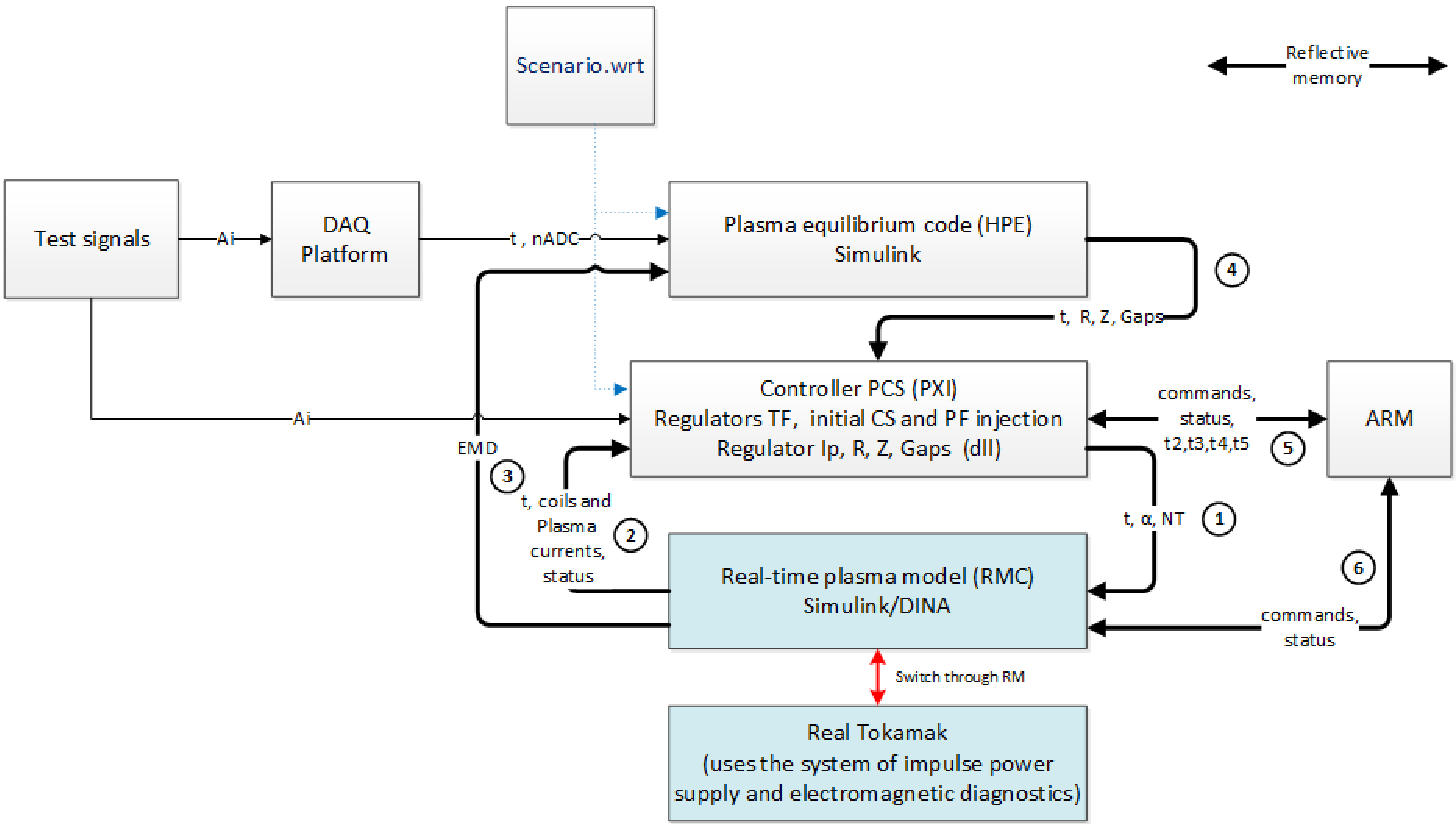


Plasma current Ip, MA	**2**
Aspect ratio A	**2.2**
Large radius of the torus R0, m	**1.48**
Small plasma radius a, m	**0.67**
Elongation of the section k95	**1.7-1.9**
Triangularity σ 95	**0.3-0.4**
Toroidal field on the plasma axis B_{T0}, T	**2.0**
Duration of the discharge plateau tplato, s	**10**
Duration of the plasma current plateau 2 MA, s	**≤ 1.5**
Plasma heating power P_{add}, MW	**≤ 20**
Plasma density n_e, 10^{20} m^{-3}	**≤ 1**
Greenwald limit for density n_e, G, 10^{20} m^{-3}	**1.4**
Total flow reserve cs, Wb	**6**

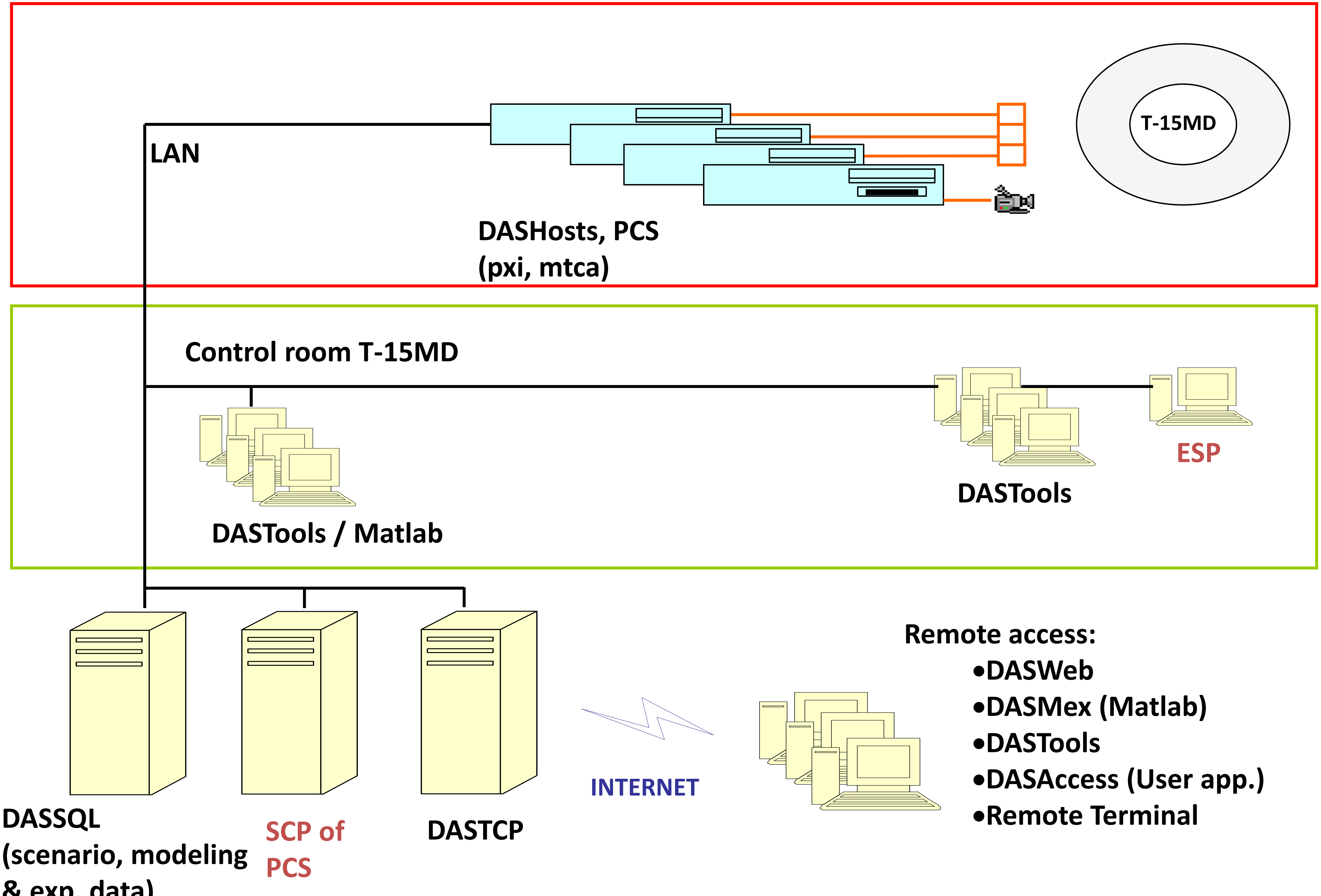
Complete electromagnetic plasma control system (PCS) diagram for tokamak



Electromagnetic PCS controller operational configuration (model/real)



Experimental Data Acquisition, Data Handling And Remote Access



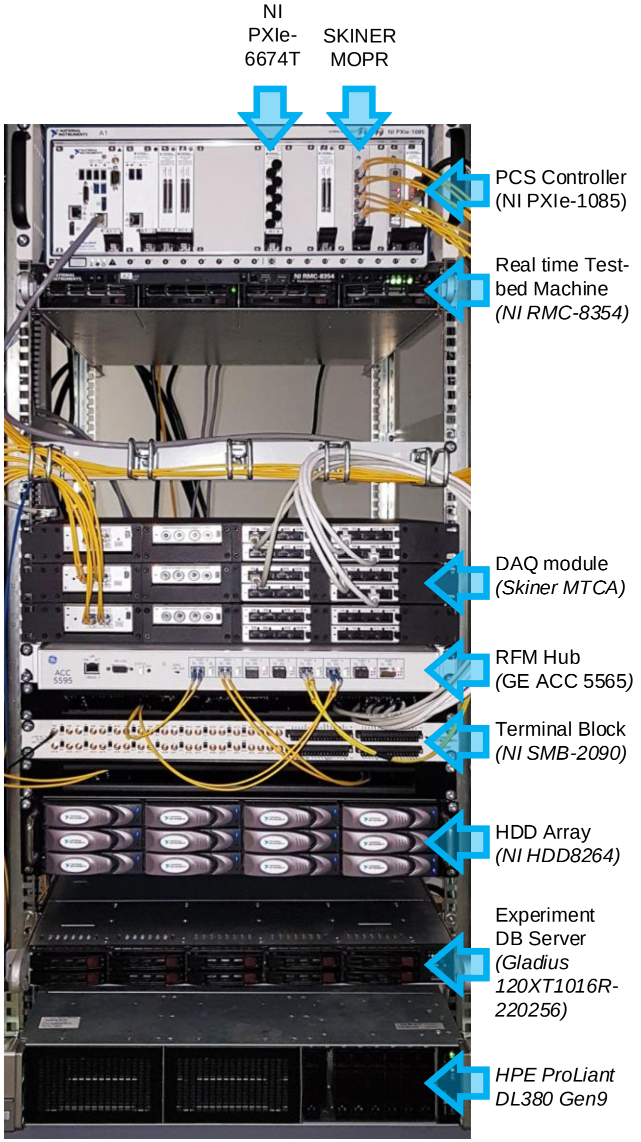
implementation of an electromagnetic PCS.

The achievements and advantages of PCS architecture:

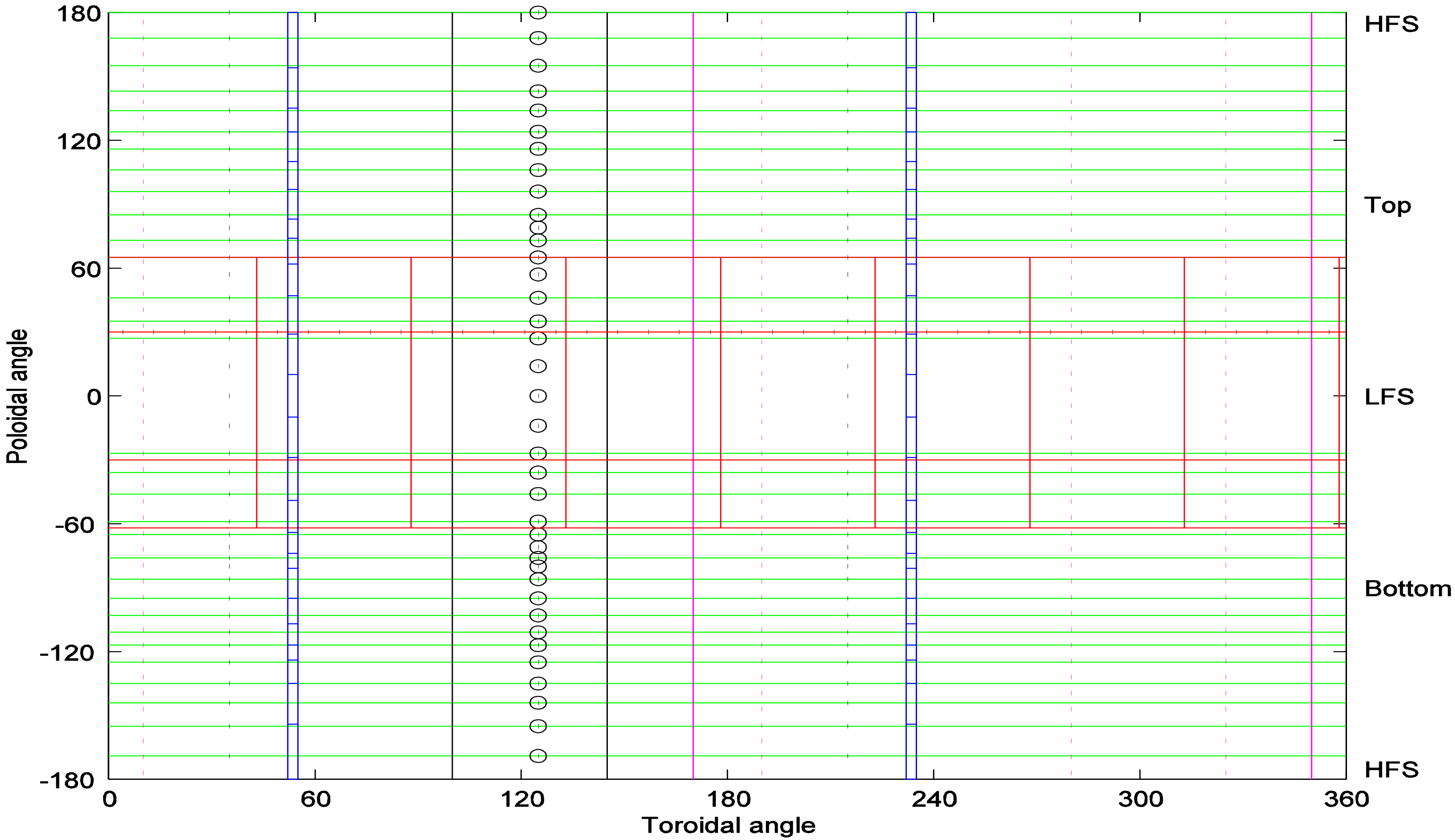
1) Development of regulators, codes, and models in the Simulink and DINA environment:
- Currently, Linux OS used with function ported from Simulink;

2) Adding the HFC PS control system after the T-15MD tokamak physical start-up will be performed as a simple upgrade without changing the hardware architecture and software.

3) The use of RFM network and the implemented decomposition of the hardware kit allow to quickly and cost-effectively switch from operational configuration to HIL test-bed and expanding PCS functionality.

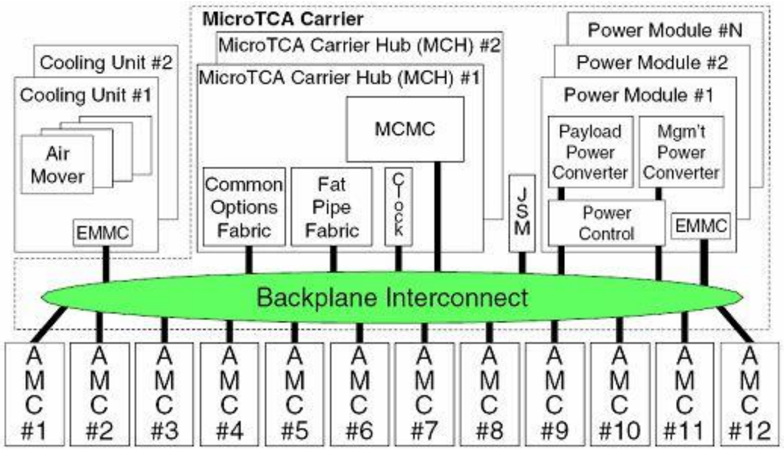


Electro magnetic diagnostics (EMD)



T-15MD vacuum vessel wall showing magnetic diagnostics location: tangential field probes (black points), normal field probes (black circles), pick-up coils (magenta points), poloidal flux loops (green solid lines), Rogovsky coils (black solid lines), diamagnetic loops (magenta solid lines), toroidal arrays of saddle loops (red solid lines), poloidal arrays of saddle coils (blue solid lines).

MicroTCA "Environment"



Main Targets:

- Price sensitive Crate System
- High digital Performance
- Modularity und Scalability
- High Availability with redundancy and remote Control
- Developement Communtity

MicroTCA is an open standard embedded computing specification

MCH (MicroTCA Carrier Hub)
- Data switch
- Highest Management instance

AdvancedMCs
- Application specific daughter cards

PM (Power Module)
- Voltage conversion
- Supply of the modules

CU (Cooling Unit)
- Intelligent fan cassette

Skiner MicroTCA DAQ Platform

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MTCA №: 0x1:
paket number = 64 time = 1 mksec
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MicroTCA based reference DAQ Platform is part of the ecosystem of MTCA products

Key Features:

-Six AMC Slots
-10G System Hub with PTPv2 Support
-LVDS 1G Backplane with Star Topology
-MCH based on complex FPGA-
    10G Interfaces
    Low Latency Data Processing

- IEEE1588v2 Precision Time -Protocol support, with nanosecond-accurate CLOCK System
-IPMI Management

Wide range of Application specific daughter cards:

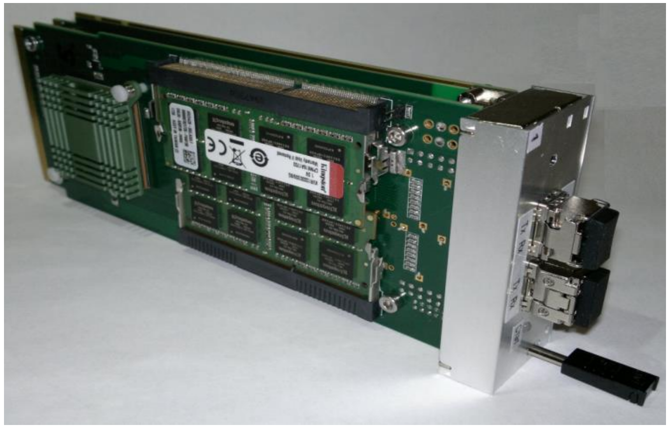
- SK-mTCA-ADC16 16 channel Isolated ADC AMC
- SK-mTCA-A8 8 channel ADC FPGA based AMC
- SK-mTCA-DAC2 Dual Channel Low noise DAC
- CPU Cards
- Networking Card
- FPGA Cards

Skiner MicroTCA Components for DAQ Systems

- SK-mTCA-ADC16 16 channel Isolated ADC AMC
- 16 16-Bit 5MSPS ADC
- Low noise
- Differential inputs and wide input common mode range
- Programmable gain/ attenuator per channel82dB SNR (Typ) at fIN = 2.2MHz
- –88dB THD (Typ) at fIN = 2.2MHz
- 28 nm On board Intel FPGA
- Isolated LVDS Links

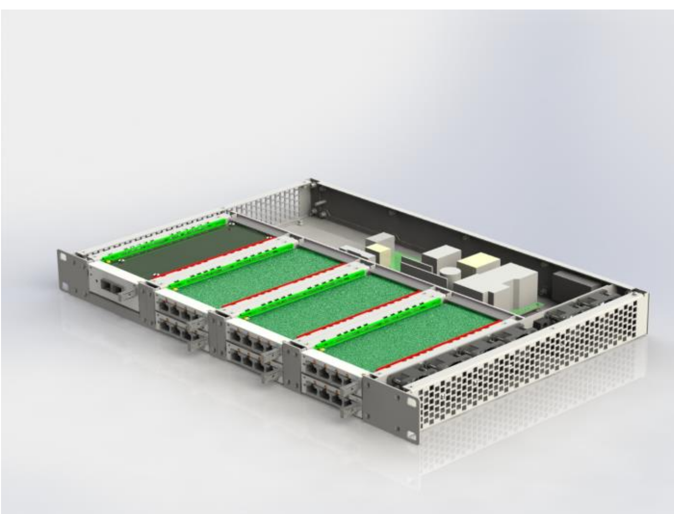
- SK-mTCA-DAC2 Dual Channel Low noise DAC
- Dual Low noise DAC 16-bit with reference bandwidth: 10MHz
- Low Noise: 12nV/√Hz
- Both current and voltage outputs
- On board Intel FPGA
- Isolated LVDS Links

Skiner MicroTCA Components for DAQ Systems



SK-MCH-C Cost Saving MCH based on Intel FPGA

- Dual-Port 10GbE with SFP+
- 28 nm FPGA with flexible transceivers up to 10.3125 Gbps
- 2 Slot DDR3 SODIMM. Up to 16GB DDR3 Memory.
- Switch Fabric Stat Topology
- Star Connection IPMB
- On board Intel MAX10 FPFA for configuration, monitoring and diagnostic.
- The SK-MCH-C provides programmable high-quality clock distribution/synthesis for FCLKA , TCLKA/TCLKB/TCLKC/TCLKD for



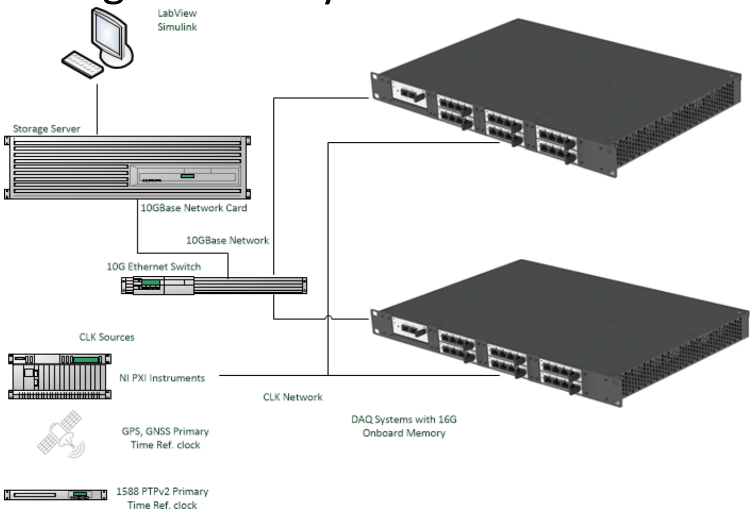
SK-1U-6-1 MicroTCA 1U 19” rack mount chassis platform, up to six single module mid-size AMC

- Built-in power supply
- Compact cost saving solution
- Right to left airflow
- Intelligent Cooling Units
- IPMI management,

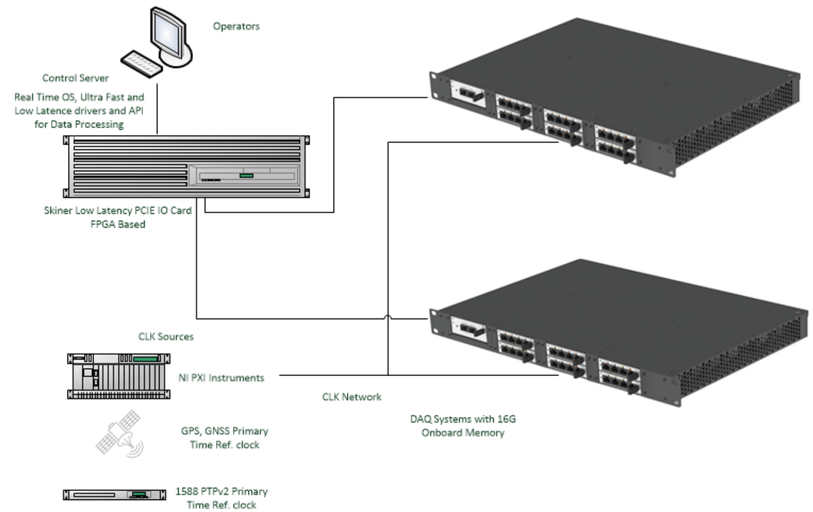
Skiner Products System Integration

Usage scenarios

Registration Systems



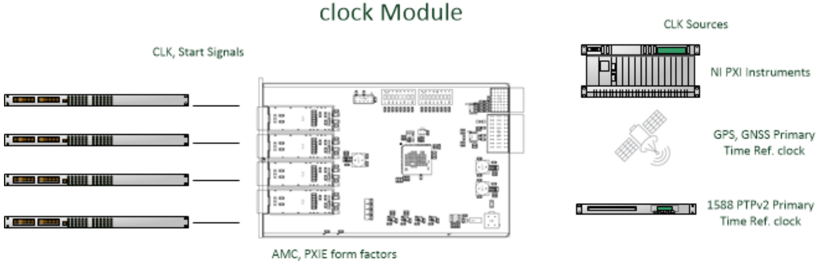
Control Systems

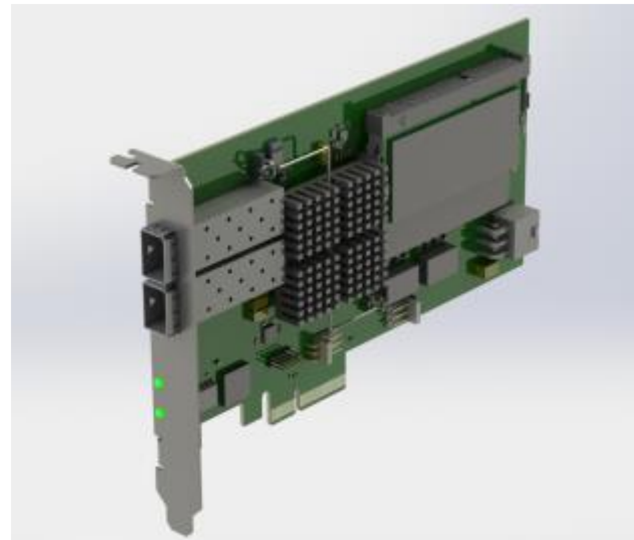


- Precision Time and Clock Synchronization with different sources (PPS, PTPv2 Sources, NI, Simulink Systems)
- Ultra Low Clock Difference between Channels, Chassis or External Sources for correlation measurements
- Ultra Low Latency Data transfer for real time control systems
- Integration with NI LabView, Mathworks Simulink Systems
- Complex FPGA Based cards allow preliminary data processing, onboard DSP.
- Galvanic isolation and Electromagnetic compatibility for use in harsh conditions

Skiner Components for System Integration

Skiner Time and clock Module





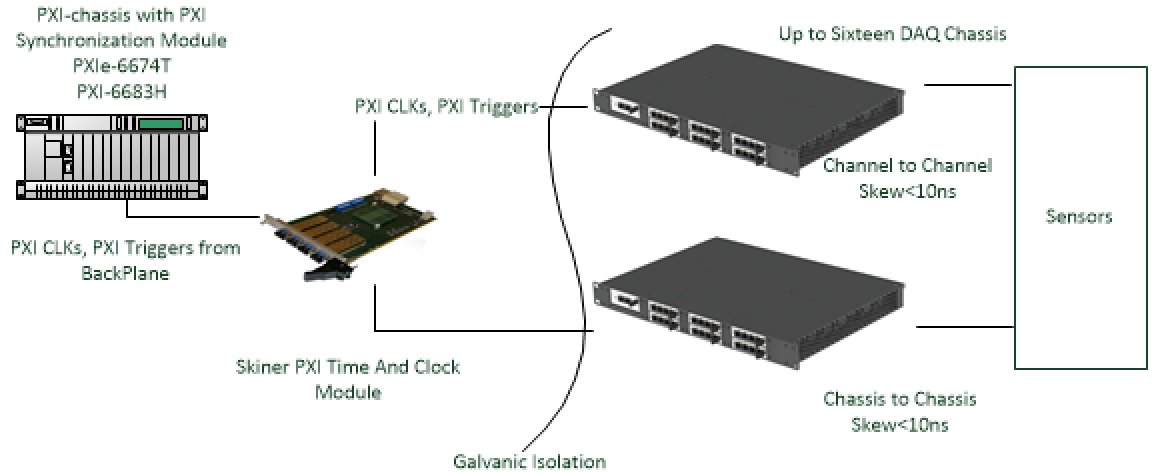
- Nanoseconds accurate Time and Clock Synchronization with different sources (PPS, PTPv2 Sources, NI, Simulink Systems)
- Nanoseconds accurate Time and Clock Synchronization between channels, chassis and external sources

Skiner Low Latency PCIE IO Card
- 10GBase – Optic Ethernet
- Onboard complex FPGA for preliminary processing and Fast SGDMA based data IO
- Onboard DDR3 Memory
- Simulink Integration
- RT Linux Drivers and API

Skiner Products Clock and Timer Synchronization

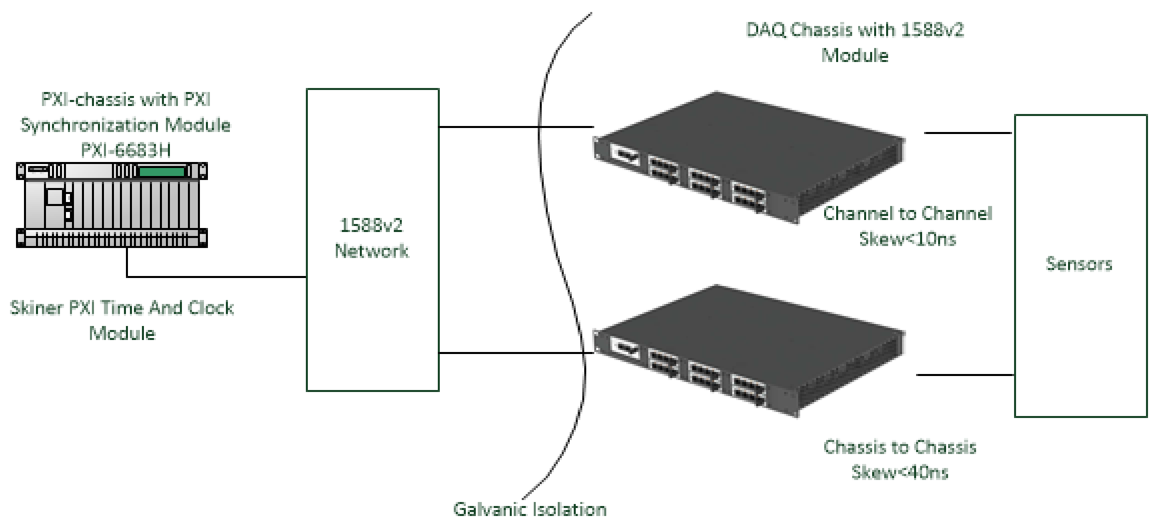
Clocks And Triggers from NI PXI

- Clocks and Triggers distribution from PXI Systems with nanoseconds skew between channels, chassis and external sources through dedicated optical network
- PXIe-6674T, PXIe-6683H as Clocks and Triggers Sources
- Up to Sixteen DAQ Chassis for one Skiner PXI Time and Clock Module



IEEE 1588v2 Synchronization

- IEEE 1588v2 PTP synchronized TXCO in DAQ Chassis
- Up to 40 ns Clock Accuracy from PXIe-6683H through a 1588 switch



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