Nominal Device Support (NDSv3) as a Software Framework for Diagnostics

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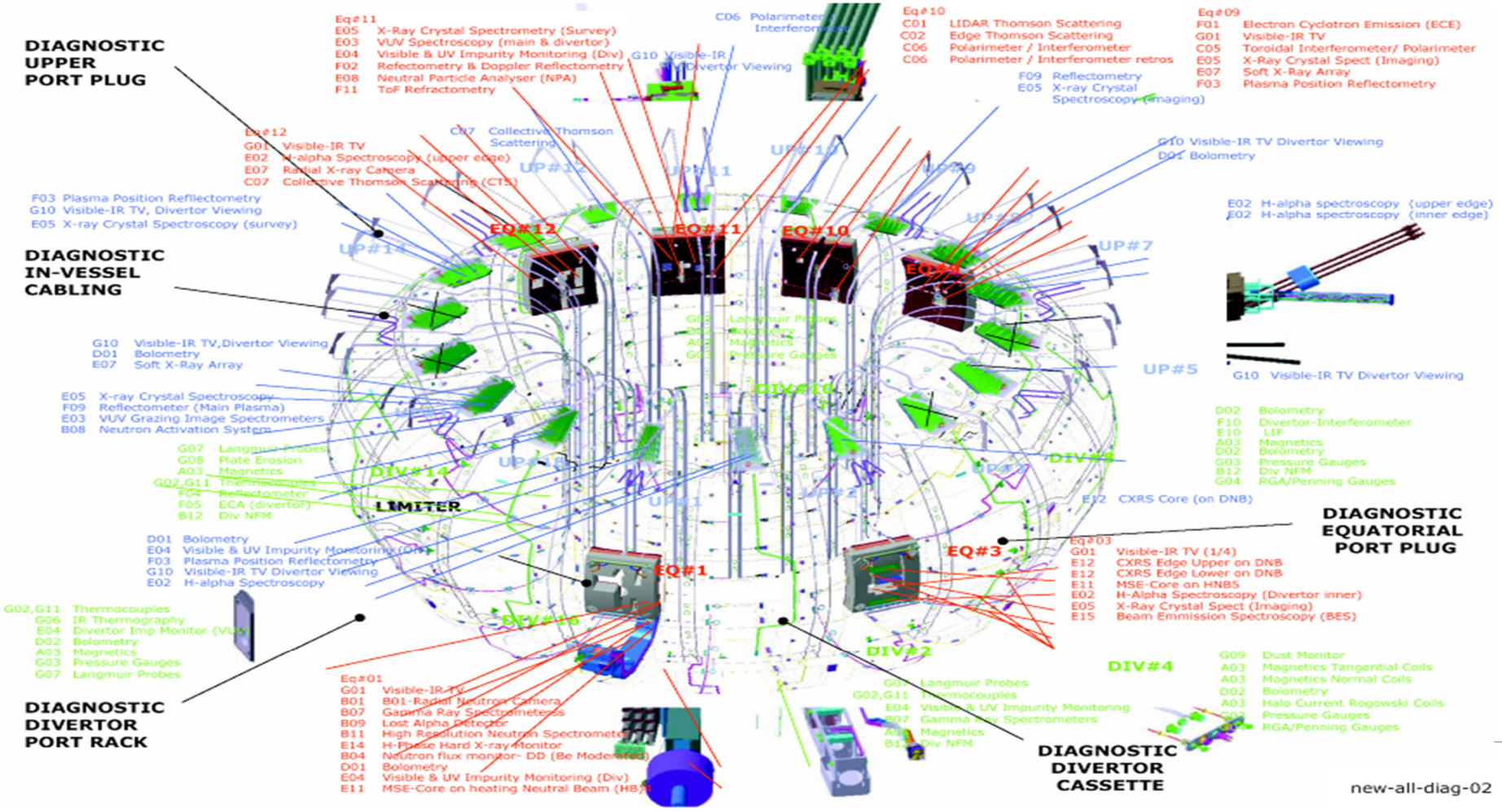
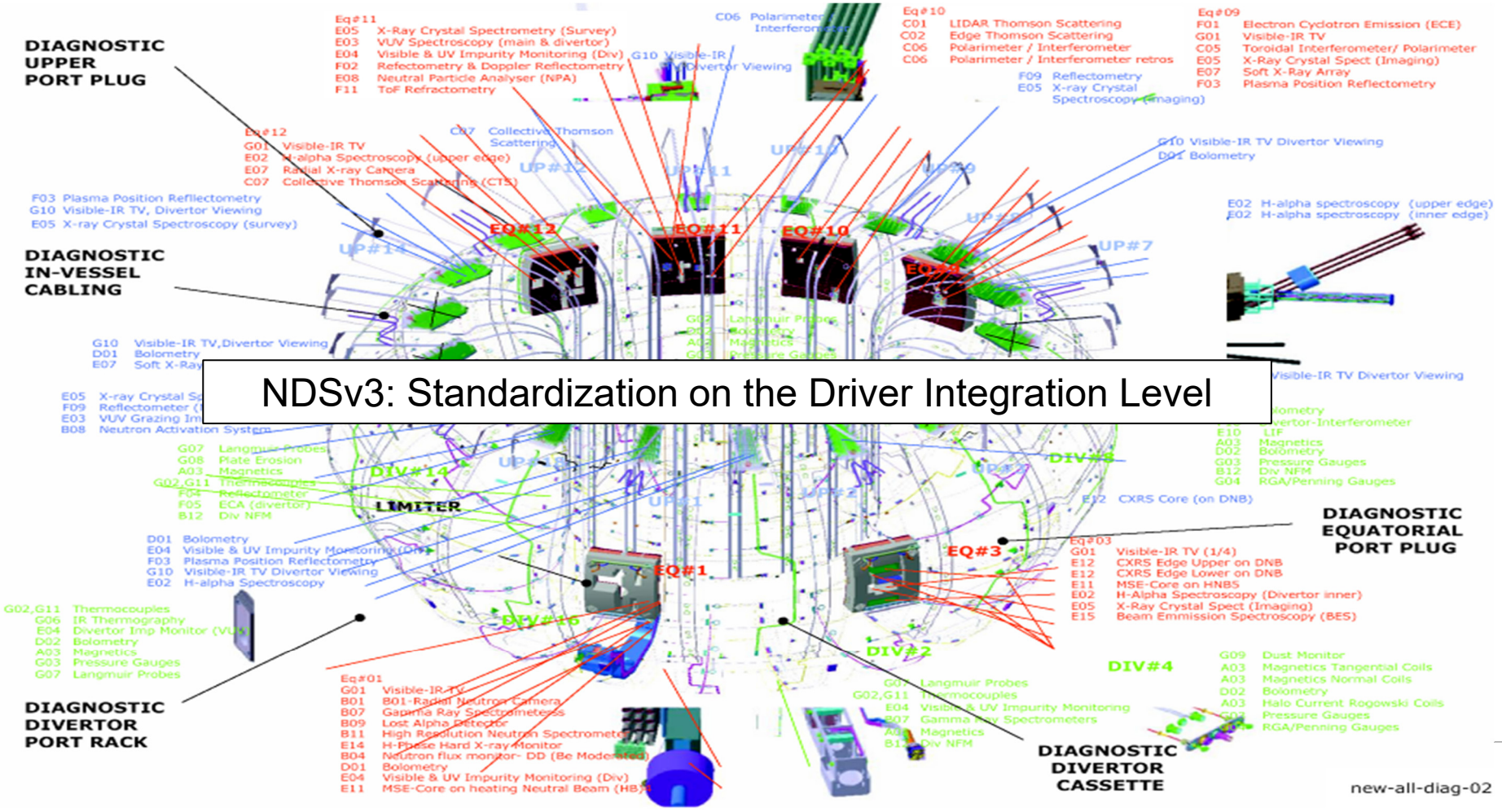
Motivation


DIAGNOSTIC UPPER PORT PLUG
Eq#11
E05 X-Ray Crystal Spectrometry (Survey)
E03 VUV Spectroscopy (main & divertor)
E04 Visible & UV Impurity Monitoring (Div)
F02 Refectometry & Doppler Reflectometry
E08 Neutral Particle Analyser (NPA)
F11 ToF Refractometry
C06 Polarimeter / Interferometer
G10 Visible-IR TV Divertor Viewing
Eq#10
C01 LIDAR Thomson Scattering
C02 Edge Thomson Scattering
C06 Polarimeter / Interferometer
C06 Polarimeter / Interferometer retros
F09 Reflectometry
E05 X-ray Crystal Spectroscopy (imaging)
Eq#09
F01 Electron Cyclotron Emission (ECE)
G01 Visible-IR TV
C05 Toroidal Interferometer/ Polarimeter
E05 X-Ray Crystal Spect (Imaging)
E07 Soft X-Ray Array
F03 Plasma Position Reflectometry
Eq#12
G01 Visible-IR TV
E02 H-alpha Spectroscopy (upper edge)
E07 Radial X-ray Camera
C07 Collective Thomson Scattering (CTS)
C07 Collective Thomson Scattering
G10 Visible-IR TV Divertor Viewing
D01 Bolometry
F03 Plasma Position Reflectometry
G10 Visible-IR TV, Divertor Viewing
E05 X-ray Crystal Spectroscopy (survey)
E02 H-alpha spectroscopy (upper edge)
E02 H-alpha spectroscopy (inner edge)
DIAGNOSTIC IN-VESSEL CABLING
EQ#12
EQ#11
EQ#10
UP#14
UP#13
UP#12
UP#11
UP#10
UP#9
UP#8
UP#7
UP#6
UP#5
UP#4
UP#3
UP#2
UP#1
G10 Visible-IR TV,Divertor Viewing
D01 Bolometry
E07 Soft X-Ray Array
G02 Langmuir Probes
G08 Plate Erosion
A03 Magnetics
G03 Pressure Gauges
G10 Visible-IR TV Divertor Viewing
E05 X-ray Crystal Spectroscopy
F09 Reflectometer (Main Plasma)
E03 VUV Grazing Image Spectrometers
B08 Neutron Activation System
DIV#10
D02 Bolometry
F10 Divertor-Interferometer
E10 LIF
A03 Magnetics
D02 Bolometry
G03 Pressure Gauges
B12 Div NFM
G04 RGA/Penning Gauges
G07 Langmuir Probes
G08 Plate Erosion
A03 Magnetics
G02,G11 Thermocouples
F04 Reflectometer
F05 ECA (divertor)
B12 Div NFM
DIV#14
LIMITER
DIV#9
E12 CXRS Core (on DNB)
DIAGNOSTIC EQUATORIAL PORT PLUG
D01 Bolometry
E04 Visible & UV Impurity Monitoring (Div)
F03 Plasma Position Reflectometry
G10 Visible-IR TV Divertor Viewing
E02 H-alpha Spectroscopy
EQ#1
EQ#3
Eq#03
G01 Visible-IR TV (1/4)
E12 CXRS Edge Upper on DNB
E12 CXRS Edge Lower on DNB
E11 MSE-Core on HNBS
E02 H-Alpha Spectroscopy (Divertor inner)
E05 X-Ray Crystal Spect (Imaging)
E15 Beam Emmission Spectroscopy (BES)
G02,G11 Thermocouples
G06 IR Thermography
E04 Divertor Imp Monitor (VUV)
D02 Bolometry
A03 Magnetics
G03 Pressure Gauges
G07 Langmuir Probes
DIV#16
DIV#2
DIV#4
G09 Dust Monitor
A03 Magnetics Tangential Coils
A03 Magnetics Normal Coils
D02 Bolometry
A03 Halo Current Rogowski Coils
G03 Pressure Gauges
G04 RGA/Penning Gauges
DIAGNOSTIC DIVERTOR PORT RACK
Eq#01
G01 Visible-IR-TV
B01 B01-Radial Neutron Camera
B07 Gamma Ray Spectrometers
B09 Lost Alpha Detector
B11 High Resolution Neutron Spectrometer
E14 H-Phase Hard X-ray Monitor
B04 Neutron flux monitor- DD (Be Moderated)
D01 Bolometry
E04 Visible & UV Impurity Monitoring (Div)
E11 MSE-Core on heating Neutral Beam (HB)
G07 Langmuir Probes
G02,G11 Thermocouples
E04 Visible & UV Impurity Monitoring
B07 Gamma Ray Spectrometers
A03 Magnetics
B12 Div NFM
DIAGNOSTIC DIVERTOR CASSETTE
new-all-diag-02

Motivation



NDSv3: Standardization on the Driver Integration Level

NDSv3 as a SW Framework for Diagnostics

- Nominal Device Support (NDS) Concept
- Main NDS Software Layers and Interfaces
- NDS Device Drivers for PXIe and MTCA Boards
- NDS Plugins for ITER Hi-Perf Networks and EPICS
- NDS System for Complex Setups
- Other NDS Solutions: NDS-IRIO-OpenCL
- Conclusions

NDS Basics

- Conceived by Cosylab, further developed by ITER partnering with UPM and GMV
- Goal: a driver development framework for ITER diagnostics measurement systems (focusing on DAQ and timing)
  - Small functional blocks (nodes) instantiated to build complex systems
  - Improved code reusability and testability
  - High software quality (automated tests and static code analysis)
  - Comprehensive user and developer documentation
- Allow development and operation using EPICS and other control systems

NDS Concepts

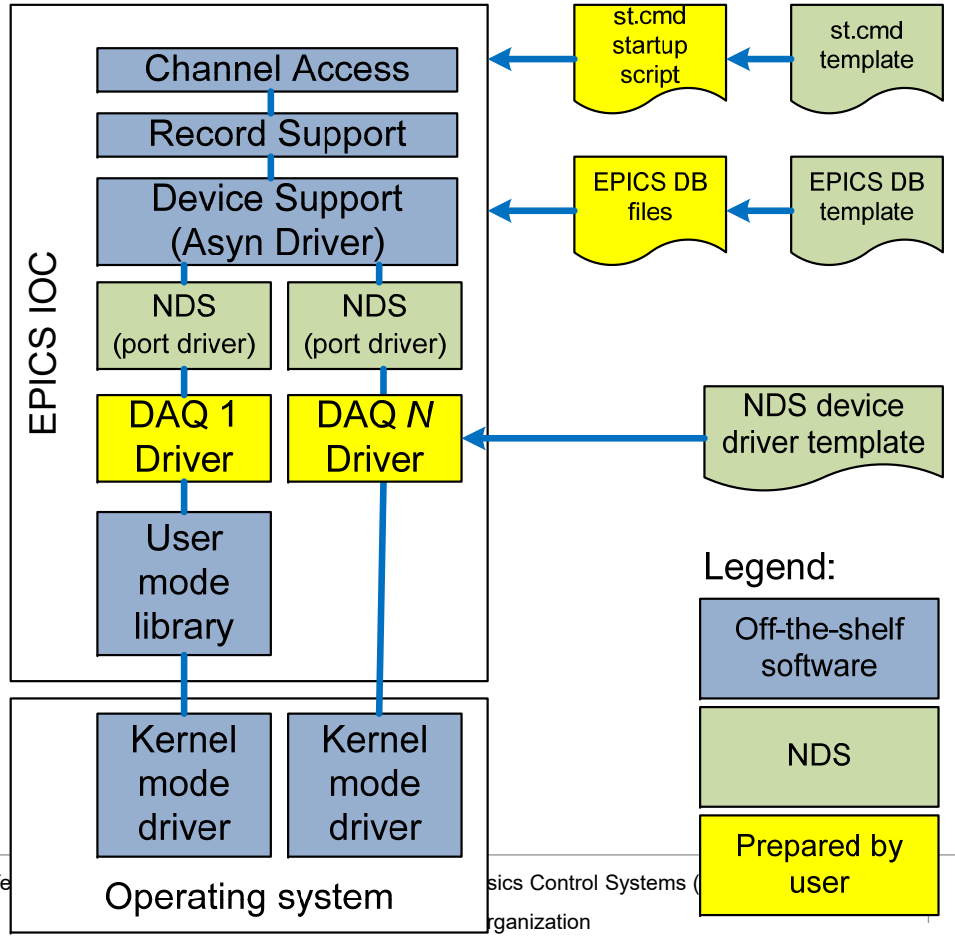
- C++ Library (device drivers as plugin libraries)
- Device drivers organized as hierarchy of nodes containing
  - Variables (NDS PVs) for communication
  - State machines
- Collection of standard nodes (base classes) covering
  - Analog input (DAQ), waveform generation, digital I/O
  - Timestamp and Future Time Event generation
  - Management of triggers and clocks
- Standard nodes w/ well-defined NDS PVs and functionality
- Adding a driver = new implementation of standard nodes

NDS Concepts

- "Control System" API allows running in different contexts
  - Inside a test fixture
  - Inside an EPICS IOC
  - Inside a Tango device server – *not tested*
  - Inside the ITER Real-Time-Framework (RTF) – *planned*

NDSv3 Device Inside an EPICS IOC

- EPICS Database is used for
  - Configuration
  - Control
  - Monitoring
- Specialized NDS nodes are used for
  - Device communication
  - Hi-perf archiving



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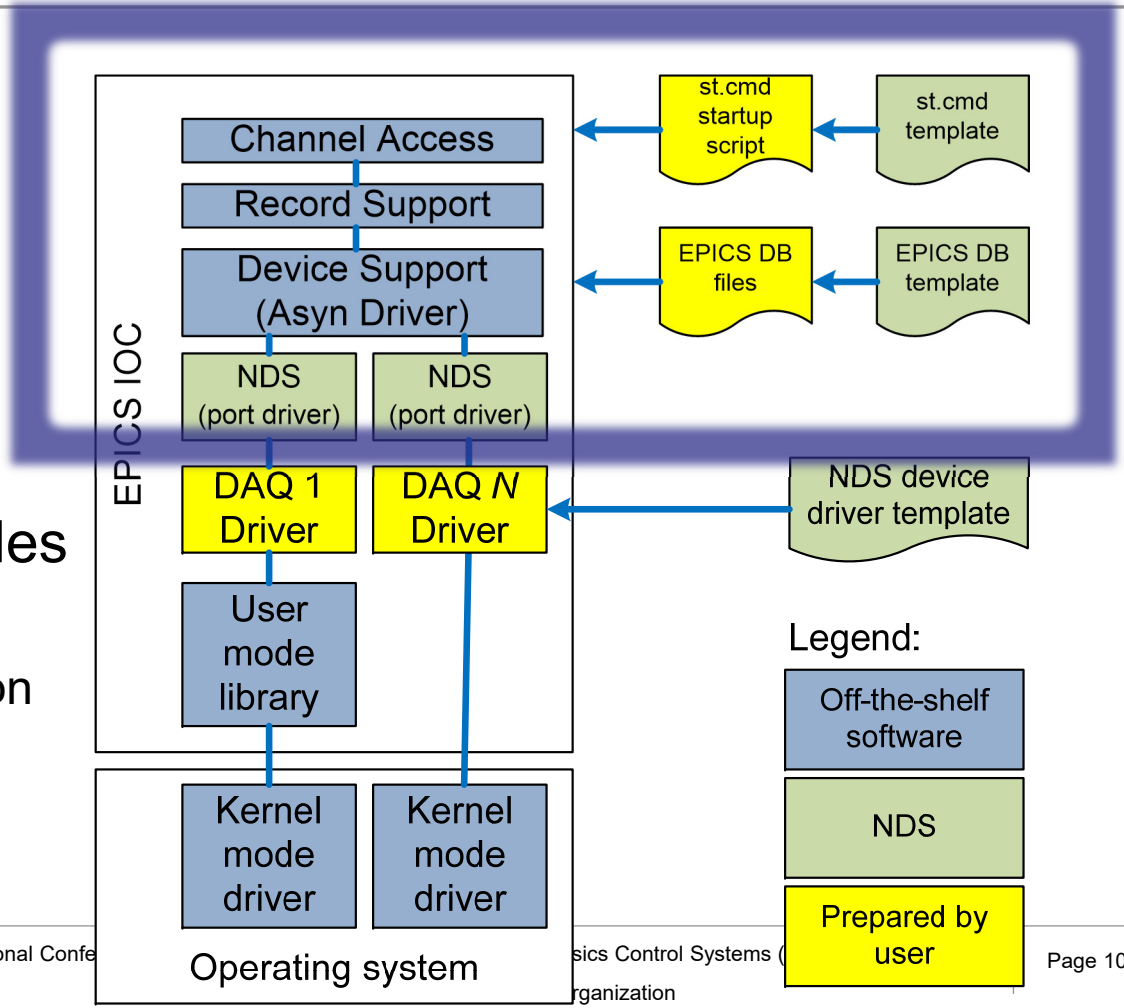
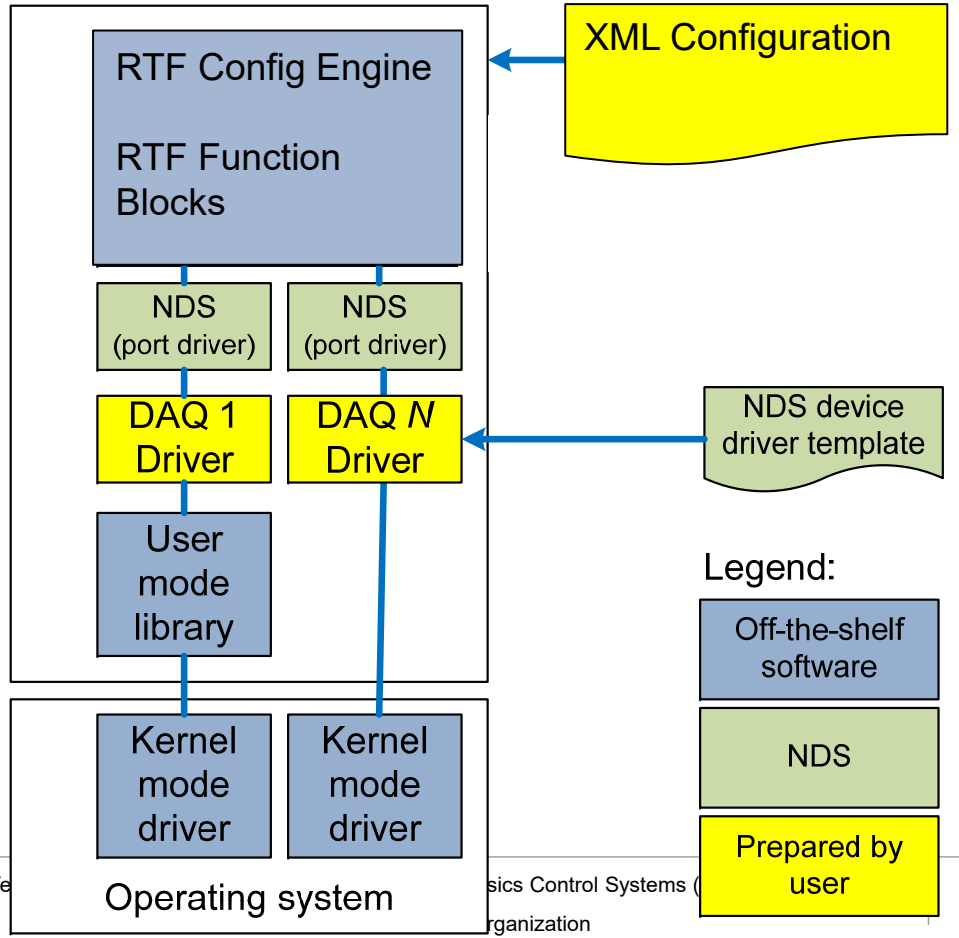


NDSv3 Device Inside a Real-Time-Framework Node

- RTF will be used for
  - Configuration
  - Control
  - Monitoring
- Specialized NDS nodes are used for
  - Device communication
  - Hi-perf archiving



NDS for PXIe Devices

- From the ITER hardware catalog
  - NI PXI6683H: timing (PTP) and triggering
  - NI X-Series (PXIe6363 and 6368): multi-functional DAQ
  - NI FlexRIO with NI5761 module

- Other developments (non-ITER)
  - Teledyne ADQ8/ADQ14 (UKAEA for JET/MAST)

NDS for MTCA Devices

- ITER supported
  - DMCS PTM1588: timing (PTP) and triggering
  - DMCS MFMC FMC Carrier: multi-functional DAQ

- Other developments
  - Teledyne ADQ8/ADQ14 (UKAEA for JET/MAST)
  - IOxOS IFC_1410 (ESS)
  - Struck SIS8300 (ESS)

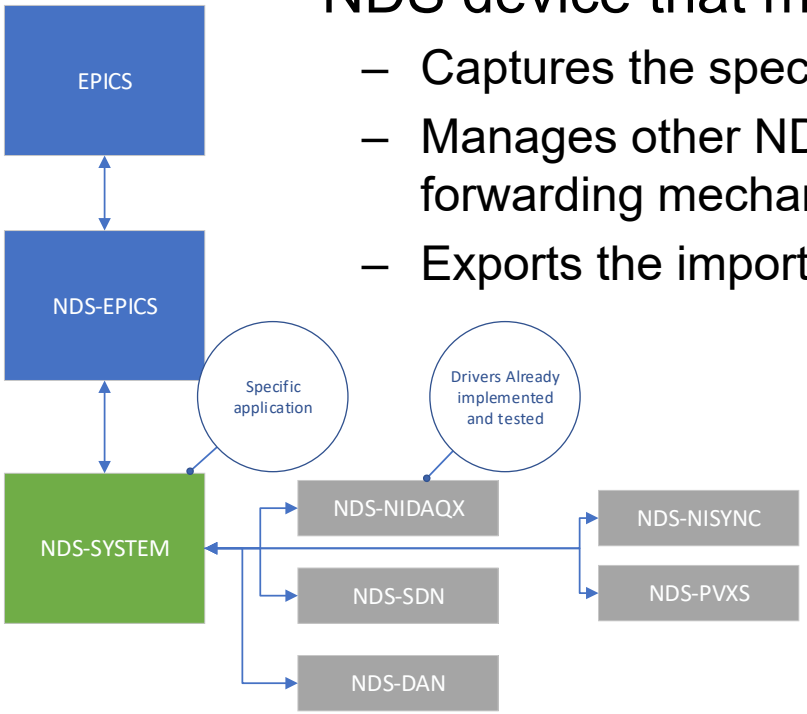
ADQ14DC–4C–MTCA

NDS Plugins: Communication

- NDS-SDN
  Publisher for ITER's real-time communication network
- NDS-DAN
  High-bandwidth stream to ITER's archiving system
- NDS-PVXS
  Integrating COTS devices using EPICS pvAccess
  - Supports read, write, monitor and RPC

NDS System: Complex Setups

- NDS device that manages other NDS devices
  - Captures the specifics of a complex ”measurement”
  - Manages other NDS devices through NDS PV value forwarding mechanisms and hierarchical state machines
  - Exports the important NDS PVs to the control system



Sample NDS System module features

- NDS-NISYNC: Timing and triggering, Backplane routing
- PXIe6368: DAQ, Waveform generation, digital IO
- PVXS: accessing data on external EPICS IOC
- SDN: combining acquired data, timestamp, external data in a published SDN topic
- Hierarchical state machine to control the system
- OPI panel to interact with the NDS-System
- Archiving to DAN (available Q4 2021)

NDSv3 for FPGA-Based Systems

- NDS IRIO-OpenCL: UPM in-house development

  Covers advanced DAQ/processing systems using SoCs and FPGAs

  – Generic NDSv3 driver to interface SoC/FPGA using OpenCL

  – Two platforms:

    - FPGA through PCIe on an INTEL host: Intel FPGA (OpenCL SDK)
    - SoC (ARM cpu + FPGA): XILINX (VITIS) and Intel FPGA (OpenCL SDK)

  – Integrates traditional DAQ applications and HW accelerators for processing

  – Adding machine learning

Conclusions

- NDSv3 for Diagnostics is in good shape
  - Drivers for basic functionalities for PXIe and MTCA
  - Communication nodes (Real-Time, Archiving, EPICS)
  - Sample application for a complex system
  - Good and comprehensive documentation, high software quality level
  - First users/applications outside of ITER (ESS, UKAEA)
- Thank you!
  - To Cosylab, who initially developed NDS
  - To the groups at UPM and GMV for their great work
  - For your attention