CODAC Core System Overview

CHD/CIT/CODAC
ITER Organization
IDM_D_97W6QN
Content

• Definition and scope
• RHEL
• EPICS
• SDD
• Development workflow
• PLC integration
• Fast Controller Support
• Support and distribution
Content

• Definition and scope
  • RHEL
  • EPICS
  • SDD
• Development workflow
• PLC integration
• Fast Controller Support
• Support and distribution
Before Integration: Mini-CODAC

- A local system directly connected to the plant-system I&C. Replaces the CODAC servers and acts as a CODAC Terminal.
- For the development and tests of the plant system I&C:
  - Provide local CODAC services
  - Can be configured with CODAC development tools
  - Provide local storage (database, files).
Plant System Host

- A standard system supplied by the ITER Organization that is a part of the plant system I&C.
- Implementing CODAC services and some plant system level supervision.
Plant System Slow Controller (PLC)

- **A SIMATIC S7 PLC**
- Programmed with STEP-7 engineering software from a Windows development system via a network connection to the controller.
- Exchanging data and commands with the Plant System Host through Ethernet.
Plant System Fast Controller

- A rack mounted computer compliant with IO specifications.
- Connected to the ITER networks
  - PON and TCN: always
  - SDN, DAN: if required
- Controlling plant system signals via I/O modules
The CODAC Core System

• The **CODAC Core System** is the CODAC software distribution for:
  – CODAC servers
  – CODAC terminals
  – Mini-CODAC
  – Plant System Host
  – Plant system fast controllers
• The distribution **includes** the Operating System
• It is the **software infrastructure** for all I&C computers with the exception of PLC and “COTS /intelligent device”
• 2 variants for each distribution:
  – Development, with development tools (SDD, Maven…)
  – Operation, without any development tool
CODAC Core System Architecture

Mini-CODAC

Control System Studio HMIs

Alarm server

Archive Server

PSH

PLC

PSH IOC

PLC IOC

IOC

PSH

CODAC Terminal
- Operator Interface (OPI)
- Alarm views
- Data plots

CODAC Server
- Alarm handling
- Archiving

PSH:
- I&C monitoring
- PLCs Gateway
- I&C coordination

Fast Controller

RT task

PCF IOC

I/O

TCN SDN DAN

Fast Controller:
- I/O interface
- TCN, SDN, DAN
- RT control
## CODAC Core System versions

<table>
<thead>
<tr>
<th>Infrastructure</th>
<th>2012</th>
<th>2013</th>
<th>2014</th>
<th>2015</th>
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<tr>
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<td><strong>6.0 6.1</strong></td>
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Ref: Core Systems Roadmap (2LTB5T)
Content

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The Operating System: Red Hat Enterprise Linux (RHEL)

- The selected operating system is **Red Hat Enterprise Linux** for the x86-64 architecture (**RHEL x86_64**)
  - Linux (open software)
  - With commercial support (**RHEL**)
  - For all computers (servers, PSH, fast controllers, terminals...)
- The version of the operating system will be upgraded at regular intervals throughout the lifetime of ITER (obsolescence mitigation).
  - RHEL 6.x (6.1, 6.3, 6.5) “now” (2012-2016)
    - Current is 6.5 (for CCS 5.0) that includes PTP support for PTP compliant hardware in fast controllers.
    - Support from supplier until 2020
  - RHEL 7 will be available soon
    - Important improvements for CODAC servers
    - Expected to be a significant change, not propagated immediately to controllers.
The MRG-R option

- A kernel option for enhanced control of the tasks execution to reduce latencies and **jitters**.
- When **determinism** is required, such as control processes for plasma control.
- Requires fine **tuning**
  - Tasks priorities
  - Tasks deployment on the CPU and cores.
  - Interrupts
- Fast controllers can be configured with this option
  - Special installation and **entitlement (!)**
  - Dedicated version of the I/O drivers.
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The infrastructure layer: EPICS

• The infrastructure layer is implemented with **EPICS** (Experimental Physics and Industrial Control System)

• EPICS is
  – an open-source control system toolkit
  – used in hundreds of large and small experimental physics projects world-wide: light sources, high energy physics, fusion (KSTAR, NSTX), telescopes
  – maintained and further developed by a world-wide community of users (including ITER)

• The same infrastructure for the CODAC servers and for the plant system controllers to ensure a uniform standard interface.
EPICS is

• **Channel Access (CA):** a fast, specialized and very robust Ethernet-based network protocol to exchange Process Variables.

• An **application framework** for building the applications for controllers and servers (records databases and state machines)

• Existing products for implementing the **CODAC services** (operator interface, alarms, opLogs…)

• Developed & maintained by its **user community**.

• **ITER** is an active member of this community
Control system architecture with EPICS

Channel Access Server (IOC)

Process Variables:
- CWS-PHTS-DLHT:VC1-FCVZ
- CWS-PHTS-DLHT:VC1-FCVY1
- CWS-PHTS-DLHT:VC1-FCVY2
- CWS-PHTS-DLHT:MT2-TT

Computer Interface

Flow Control Valve

Thermometer

Cooling water plant system
Channel Access in one slide

Who has a PV named “CWS-PHTS-DLHT:TTSPTARGET”?
I do.
What is its value?
25.5 degC
OK, it is now 30.5
Change its value to 30.5
Notify me when the value changes
It is now 20.5 degC
It is now 10.3 degC
It is now 9.2 degC
“connection request”
or “search request”
“get” or “caGet”
“put” or “caPut”
“set a monitor”
“put complete”
“post an event”
or “post a monitor”

Process Variables:
CWS-PHTS-DLHT:VC1-FCVZ
CWS-PHTS-DLHT:VC1-FCVY1
CWS-PHTS-DLHT:VC1-FCVY2
CWS-PHTS-DLHT:TTSPTARGET
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Self-Description Data
Motivation

• To prepare for the integration of the plant systems
  – Make sure the I&C are developed to be compliant with a common data schema
  – Integrate the I&C configuration during development

• To promote the application of CODAC standards
  – As Defined in Plant Control Design Handbook (PCDH)
  – Facilitate the development of standard I&C applications on standard control units (PLCs, fast controllers)
Self-Description Data Definition

- **The static configuration data** that describes a plant system I&C.
  - The plant system components’ **signals** that the I&C drive.
  - The implemented functions with the description of **variables and commands**
  - The description of the control units: **PLCs, fast controllers and PSH**.
  - The description of **cubicles and chassis**

- **Defined by the plant system I&C designers and developers**
  - Local tools: **SDD toolkit**
  - Central tools: **central database** and data exchange tools.

- **Used to configure CODAC**
  - Define the **interface** of the plant system I&C with CODAC (EPICS PVs, SDN data, DAN data…)
  - Configure the **CODAC services** (Alarms, Archives…)

• **SDD**
I&C Project
SDD Editor

[Image of the SDD Editor software interface.]

Function Editor:
- **Function Details**
  - **This section contains details of Function**
  - **Plant System &C Name**: TEST-S7
  - **Function Name**: TEST-S7- COMM

Description:
- **This section contains details of Variables**

<table>
<thead>
<tr>
<th>Variable Name</th>
<th>Description</th>
<th>Category</th>
<th>Deployment Target</th>
<th>Kind</th>
<th>Data Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>TEST-S7 COMM/A016-JZ-CRC</td>
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<td>state</td>
<td>45CTRL-PLC-0001</td>
<td>continuous int18</td>
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</tr>
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<td>signed word</td>
<td>state</td>
<td>45CTRL-PLC-0001</td>
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<td>45CTRL-PLC-0001</td>
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<td>TEST-S7 COMM/AIU16-JT-CRC</td>
<td>unsigned int16</td>
<td>state</td>
<td>45CTRL-PLC-0001</td>
<td>continuous uint16</td>
<td></td>
</tr>
<tr>
<td>TEST-S7 COMM/AIU32-JT-CRC</td>
<td>unsigned int32</td>
<td>state</td>
<td>45CTRL-PLC-0001</td>
<td>continuous uint32</td>
<td></td>
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<tr>
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<td>config</td>
<td>45CTRL-PLC-0001</td>
<td>continuous int16</td>
<td></td>
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<td>TEST-S7 COMM/AO32-JZ-CRC</td>
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<td>TEST-S7 COMM/AO48-JZ-CRC</td>
<td>Analog out char</td>
<td>config</td>
<td>45CTRL-PLC-0001</td>
<td>continuous int8</td>
<td></td>
</tr>
</tbody>
</table>
SDD web application
The SDD editor is an Eclipse RCP application integrated with the other development tools and operating on a local SDD database. It is the primary tool for:
- SDD data edition
- software development

The SDD web application is used from a web browser and can operate on remote SDD databases, including the SDD repository at IO. It is the primary tool for:
- Importing / exporting I&C projects from / to remote SDD databases
- Exchanging files between SDD databases and office computers
SDD Edition

- The SDD editor, alternatively the SDD web application allows to edit:
  - The list of signals interfaced by the plant system I&C
  - The list of functions and variables implemented by the plant system I&C
  - The list of control units (PSH, controllers) that belong to the plant system I&C
  - The communication between PSH and PLC
  - The configuration for alarms
  - The configuration for archiving
  - The configuration for OPIs
  - The configuration for the supported I/O boards
  - The cubicles that shall be monitored
  - The mapping of Common Operating State (COS) variables into plant-system specific ones (PSOS)
  - The SDN data produced or consumed by programs running on fast controllers
  - The DAN data produced by programs running on fast controllers
  - The location of cubicles and position of controllers and chassis in the cubicles
  - The association between EPICS variables and programs
  - … and more
Data Exchange

The SDD web application allows to:

- Deliver an I&C project to the IO SDD repository from a Mini-CODAC system
- Retrieve an I&C project from the IO SDD repository and load it into a Mini-CODAC system
- Import into a SDD database (mini-CODAC or central repository) data from an office computer (ex: variables list in Excel tables)
- Generate configuration files for Windows-based development tools (ex: Step-7)
SDD Translator
SDD Parser

• From the SDD data, the SDD translator generates:
  – EPICS configuration files (records, IOC files…)
  – PLC Configuration files (data definition)
  – Alarms configuration
  – Archiving configuration
  – Operator displays (display/control of the variables)

• The SDD parser parses EPICS configuration files (records definition) to update the SDD database

• Integrated with SDD editor and SDD web application
SDD sync

- Save/load plant system I&C projects from/to the local SDD database using XML files.
- Synchronize local databases on Mini-CODACs with IO central databases
  - Update shared definitions in local databases (ex: CBS)
  - **Validate** and **import** I&C definition in the central database
  - Export I&C definition to local databases.
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I&C project / Software unit

• For each I&C project:
  – One definition in SDD
  – One software unit
  – The software packages for installation on each target computer.
  – One SVN (*) unit

• For any software unit, standard commands, implemented with Apache Maven, are provided to
  – Compile all EPICS applications and C/C++ programs
  – Run / Stop the IOC processes
  – Package the files for deployment.

(*) SVN is the software revision control system used by IO
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Mini-CODAC / PSH / PLC communications

- **Mini-CODAC**
  - HMI
  - Alarms
  - Archives
  - Supervision

- **PSH**
  - PSH IOC

- **PLC**
  - PLC IOC
  - Communication
  - Processing
  - I/O

Additional variables and state machines (Common Operating State)

Get

Put

Monitor

Channel Access

EPICS

CODAC Core System Training – CODAC Core System Overview

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PLC Variables and Commands in SDD

![SDD Editor Interface]

This section contains details of Function

Plant System & C Name: TEST-S7

Function Name: TEST-S7-COMM

This section contains details of Variables

<table>
<thead>
<tr>
<th>Variable Name</th>
<th>Description</th>
<th>Category Type</th>
<th>Deployment Target</th>
<th>Kind Type</th>
<th>Data Type</th>
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<tr>
<td>TEST-S7-COMM.AI32-JT-CRC</td>
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<td>state</td>
<td>MyPLCForTest</td>
<td>continuous uint32</td>
<td></td>
</tr>
<tr>
<td>TEST-S7-COMM.AI16-JT-CRC</td>
<td>signed short word</td>
<td>state</td>
<td>MyPLCForTest</td>
<td>continuous int16</td>
<td></td>
</tr>
<tr>
<td>TEST-S7-COMM.AQ16-JZ-CRC</td>
<td>analog out unsigned int 16</td>
<td>config</td>
<td>MyPLCForTest</td>
<td>continuous uint16</td>
<td></td>
</tr>
<tr>
<td>TEST-S7-COMM.MB016-YT</td>
<td>State binary input record</td>
<td>config</td>
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<td>multistate uint16</td>
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<td>TEST-S7-COMM.AO32-JZ-CRC</td>
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<td>MyPLCForTest</td>
<td>continuous int32</td>
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<tr>
<td>TEST-S7-COMM.AO32-JZ-CRC</td>
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<td>TEST-S7-COMM.BI0-CY-CRC</td>
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<td>MyPLCForTest</td>
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</table>
# Variables and Commands in the PLC

## Variables and Commands List

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<th>Address</th>
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<th>Status value</th>
<th>Modify value</th>
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<td>DB200.DBX 62.0</td>
<td>&quot;TestDB&quot;.bad_header_fixed</td>
<td>BOOL</td>
<td>false</td>
<td>false</td>
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<tr>
<td>DB200.DBX 62.1</td>
<td>&quot;TestDB&quot;.bad_header_fixed</td>
<td>BOOL</td>
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<td>&quot;TestDB&quot;.bad_rate_0</td>
<td>BOOL</td>
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<tr>
<td>DB200.DBX 106.2</td>
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<td>BOOL</td>
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<td>DB200.DBX 106.3</td>
<td>&quot;TestDB&quot;.bad_rate_counter</td>
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<td>&quot;TestDB&quot;.change_states</td>
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<td>DB200.DBX 106.5</td>
<td>&quot;TestDB&quot;.clear_communication</td>
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<td>DB200.DBX 106.6</td>
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<td>BOOL</td>
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<td>DB1 01.DBW 0</td>
<td>&quot;CodacConfiguration&quot;.sample.TST.1_A0UC8_JZ_CRC</td>
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<td>0</td>
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<tr>
<td>DB1 01.DBW 2</td>
<td>&quot;CodacConfiguration&quot;.sample.TST.1_A0UC16_JZ_CRC</td>
<td>DEC</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>DB1 01.DBD 4</td>
<td>&quot;CodacConfiguration&quot;.sample.TST.1_A0UC32_JZ_CRC</td>
<td>DEC</td>
<td>L160</td>
<td>L160</td>
</tr>
<tr>
<td>DB1 01.DBB 8</td>
<td>&quot;CodacConfiguration&quot;.sample.TST.1_A0UC64_JZ_CRC</td>
<td>DEC</td>
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<td>0</td>
</tr>
<tr>
<td>DB1 01.DBA 10</td>
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<td>0</td>
<td>0</td>
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<tr>
<td>DB1 01.DBD 12</td>
<td>&quot;CodacConfiguration&quot;.sample.TST.1_A0UC64_JZ_CRC</td>
<td>DEC</td>
<td>L160</td>
<td>L160</td>
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<td>FLOATING_POINT</td>
<td>0.0</td>
<td>0.0</td>
</tr>
</tbody>
</table>

## Diagram Example

- [Image of PLC Variables and Commands Table]
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Fast Controllers Support

• EPICS includes a framework for building the fast controllers software

• The controller software is implemented by means of
  – EPICS IOC processes that are Channel Access servers.
  – If required, C/C++ programs for fast control

• The CODAC Core System distribution includes:
  – EPICS tools for building the controller software
  – The software components required for standardized I/O modules and for ITER time (TCN)
  – The SDN API for C++ programs
  – The DAN API for C/C++ programs
Mini-CODAC / Fast controller communications

Mini-CODAC

- HMI
- Alarms
- Archives
- Supervision

PCF

I/O
(EPICS Device Support)

Sequences, EPICS record database, I/O access.

FC IOC

FC Prog

SDN

DAN

EPICS

Channel Access

put

get

monitor

PLC
Standard Hardware Support

• CODAC Core System includes the software for ITER standard I/O boards
  – Linux driver
  – EPICS integration (EPICS device support)
  – SDD integration (configuration via SDD tools)
• Supported I/O boards:
  – N.I. PXI-6259: multi-function data acquisition
    • 16b analog input channels (16/32)
    • 16b analog output channels (4)
    • 16b digital input/output channels (48)
  – N.I. PXI-6528: Digital I/O
    • 24 optically isolated input channels
    • 24 solid-state relay output channels
  – N.I. PXIe-6368 (X-serie boards)
    • 16b 2MS/s analog input channels (16)
    • 16b 3.3 MS/s analog output channels (4)
  – N.I. PXIe FlexRIO and CompactRIO: Flexible I/O with FPGA.
Fast Controller edition

Fast controller

I/O Module

Signals

Deployed variables linked with signals
Content

• Definition and scope
• RHEL
• EPICS
• SDD
• Development workflow
• PLC integration
• Fast Controller Support
• Support and distribution
Version identifiers

CODAC Core System versions are identified with 3 numbers: 

major_number . minor_number . maintenance_number

- A new major number for a new OS version and/or other major changes in EPICS or in components.
- A new minor number for new features and/or new components
- The maintenance number distinguishes different levels of bug fixes

- Several minor versions belonging to the same major versions can be installed simultaneously on the same system.
- Maintenance releases replace each other. Only one maintenance release is installed per minor version.

<table>
<thead>
<tr>
<th>Version</th>
<th>Date</th>
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<tr>
<td>1.0.0</td>
<td>15-Feb-2010</td>
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<td>1.1.0</td>
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<td>2.0.1</td>
<td>06-May-2011</td>
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<td>2.1.0</td>
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<td>3.1.0</td>
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<td>4.0.0</td>
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<td>4.3.0</td>
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<td>5.0.0</td>
<td>20-Feb-2015</td>
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<td>4.3.1</td>
<td>30-Mar-2015</td>
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Changes management

- All changes are handled with an issue tracking system (Bugzilla)
  - Developers, testers and support team enter requests for enhancement or correction in one of the components.
  - Developers and testers update the status (assigned->resolved->verified)
- “bugs” are reviewed for assignment, progress and closure.
- Changes are tested individually or as part of the component tests.
- Corrections can be provided as patches

Changes implemented (“fixed bugs”)
In 2012-2015

<table>
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<tr>
<th>Version</th>
<th>Total</th>
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<tbody>
<tr>
<td>3.0.0 (2012-02-15)</td>
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<td>3.1.0 (2012-06-22)</td>
<td>303</td>
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<td>4.0.0 (2013-02-15)</td>
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<td>4.1.0 (2013-07-04)</td>
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<td>4.2.0 (2014-02-14)</td>
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<td>4.3.0 (2014-07-07)</td>
<td>268</td>
</tr>
<tr>
<td>5.0.0 (2015-02-20)</td>
<td>593</td>
</tr>
</tbody>
</table>
Distribution

- All versions provided by a dedicated service
  Red Hat Network Satellite Server
- Available to all registered organizations
  Any organisation which contributes to the development of ITER I&C systems such as ITER Domestic Agencies, institutes associated with them or industry under contract to ITER can be registered
CODAC Support

- Reachable by mail during IO hours: codac-support@iter.org
- First line support by small team (contract).
- Requests/answers monitored by IO ROs (expert support, verification)
- Whenever required, the requests are dispatched to appropriate experts

- Average: ~1 request a day. Peaks after new release.
- Assistance for installation is decreasing
- Assistance for software usage is increasing
Training

- **On-site: hands-on workshop in Cadarache**
  - 4 days with presentation and exercises
  - Regular trainers (contract)
  - Prepared and attended by IO ROs.
  - Systems in IO for exercises (inc. PLCs & fast controllers)
  - 13 sessions in 2012-2014
  - 2 planned for 2015 (May, Sept)

- **At DAs site.**
  - US (Mar-2014)
  - JA (Jul-2014)
  - CN (Sep-2014)
  - IN (May-2015)
  - KO (planned)

- **On-line training**
  - Video of presentations and demo
  - Modular

CODAC Core System Training Videos (PTZFLV)