Footprint in Fusion

Ongoing activity and key references



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Science, Infrastructures & Robotics

GTD is a **system and software engineering group** devoted to the design, development and integration of **large**, **complex** and/or **critical** Systems.

GTD Science, Infrastructures and Robotics is a company of the GTD Group.

gtd sir Science, Infrastructures & Robotics

GTD was founded in 1987, in Barcelona, with the mission to develop high quality control and information systems for the most demanding environments.

More than 400 engineers around the world

customers in 15 countries

+1500 hi-tech projects

Head offices:

- GTD Spain:
  Barcelona, Madrid, Cádiz
- GTD France:
  French Guiana, Toulouse, Cadarache
- GTD Germany
- GTD UK
- GTD Africa

GTD GROUP

Level 3 according to CMMI

Good practices in organization, development and project management.

CMMIDEV/3 SM

EXP 2018-03-04 / Appraisal #23859

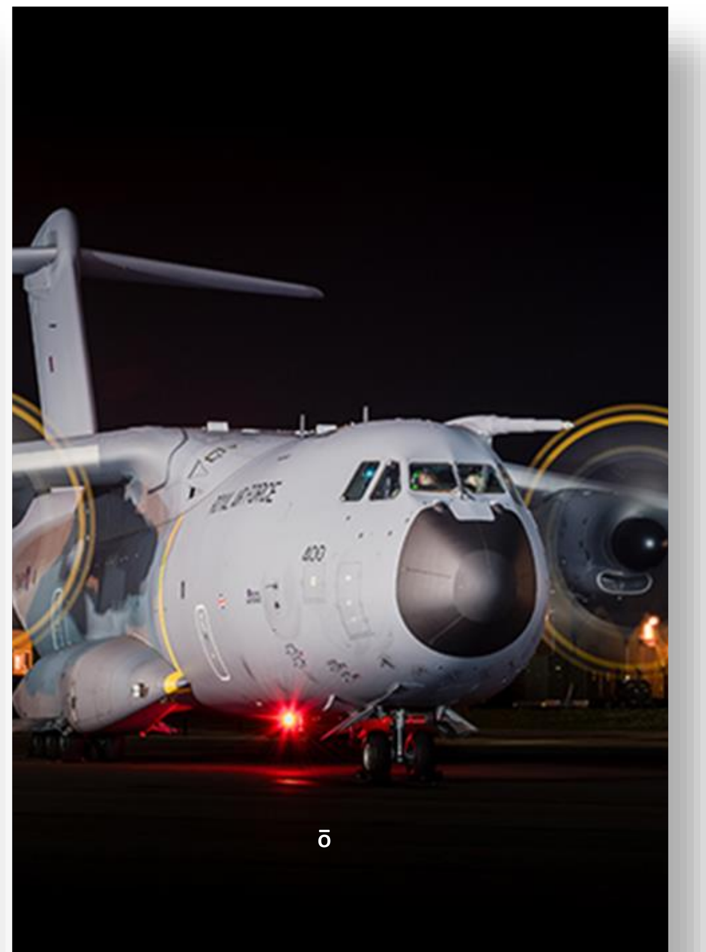
First Spanish engineering company to achieve quality certification ISO 9001

Activity Sectors – GTD Group

Activity Sectors of GTD SI&R

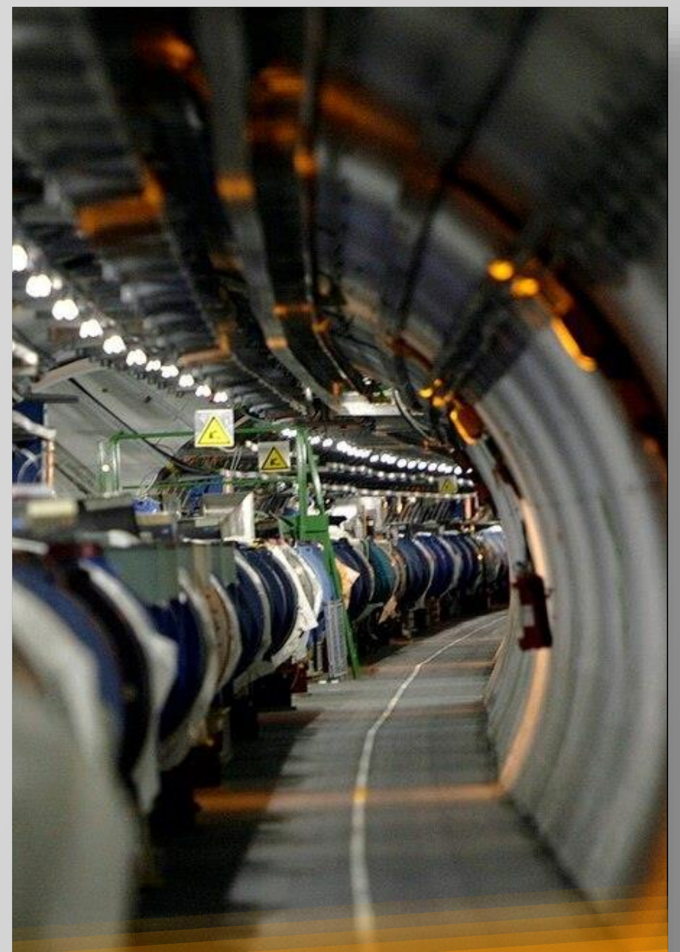
space

Space systems, with particular focus in commercial launchers, thus including ground-segment and onboard applications.



aeronautics

Onboard software, Validation and Verification, pilot aids: conflict detection & resolution.



big science

Command & Control and real-time distributed systems for Hi-Energy Physics and Nuclear Fusion laboratories.

infrastructures

Command & Control of intelligent, complex and large-scale energy and transport infrastructures.

robotics

Low-level, real-time, safety-critical software for robotics and remote-handling.

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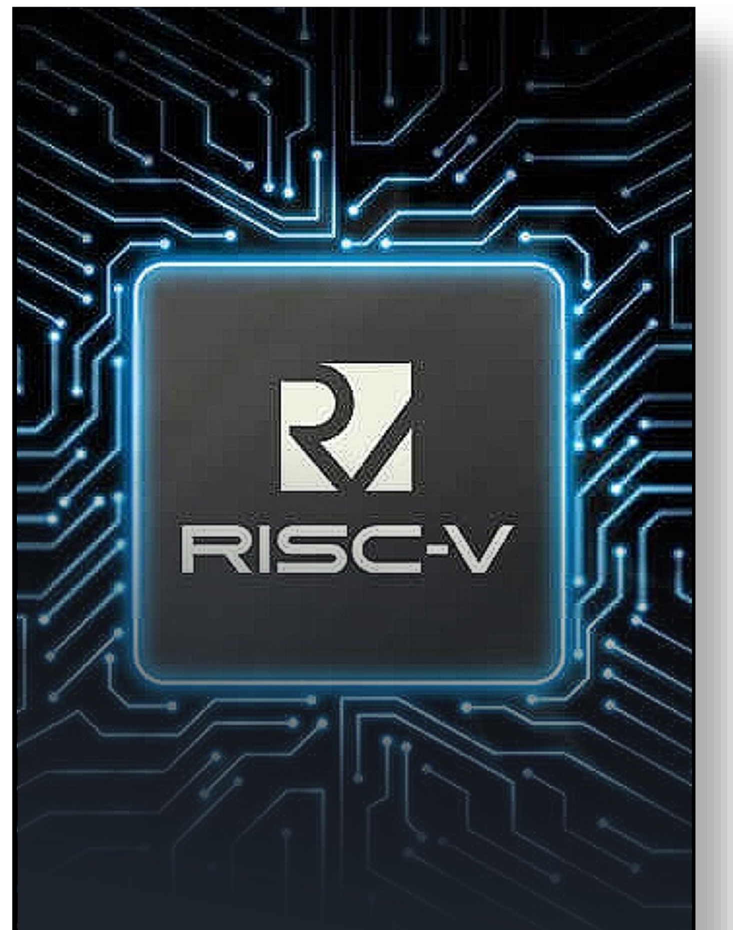
openchip



risc-V

Fabless semiconductor company for acceleration chips (<5nm under RISC-V) for HPC, AI/ML/DL.

LUXQUANTA

cybersecurity

Quantum Key Distribution (QKD / Quantum Cryptography) exploiting quantum mechanical properties to securely distribute shared keys.

Science, Infrastructures & Robotics

Knowledge Areas:

Hyper-Automation	Robotics	Edge Computing
Decision Support Data Analytics Supervision Control Room+IaaS Real Time Control Systems [ms] Industry 4.0 paradigms	Safety Critical (SIL2+Nuclear) Robotics Remote Handling – Human-Robot UI/UX Virtual and Augmented Reality	Real Time Control Systems [μs - ns] Embedded Electronics Embedded Safety FPGAs & RISC-V Bespoken Electronics

Foundation

Big Science

1987

1989

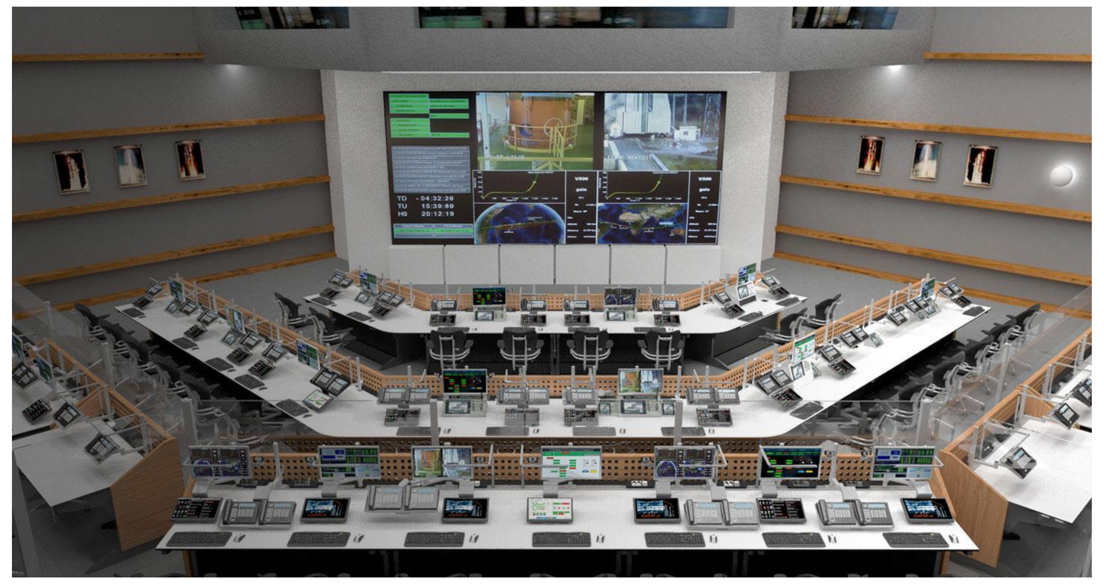
1st contract for SPACE

Ariane 4

1995

1st contract for BigScience

ESRF



Contract for Jupiter II Control Center

1997

CERN

1st company to implement an industrial control & interlock system for a CERN machine: the SPS

1999

NEUTRONS FOR SCIENCE

EPFL

CERN

GTD implemented the Cryogencics Control System for Large Hadron Collider (LHC). 1st implementation of UNICOS.

2000

Onboard SW for Ariane V

2001

Use of fuzzy logic, soft computing and AI techniques for mission control processes

AREVA

2003

Design of new CERN Control Room

2004

A400M

VEGA

2005

AI Decision Support Systems in Control Rooms

IBERDROLA

2009

Cooling Control ALBA synchrotron.

ALBA

SOYUZ

2012

GTD awarded the 1st I&C Engineering framework contract to work into the ITER Project, through F4E.

2014

Maintenance of the ALMA telescope common software

2015

GTD enters in Robotics with development of GENROBOT.

2016

Ariane 6 Control Bench Family

2017

2nd I&C Engineering Framework Contract

2018

Direct contract with ITER for maintenance of CODAC

2021

3rd I&C Engineering Framework Contract

Science, Infrastructures & Robotics

gtd sir

footprint in FUSION

The footprint of GTD SI&R in FUSION is highly rooted in our core expertise:

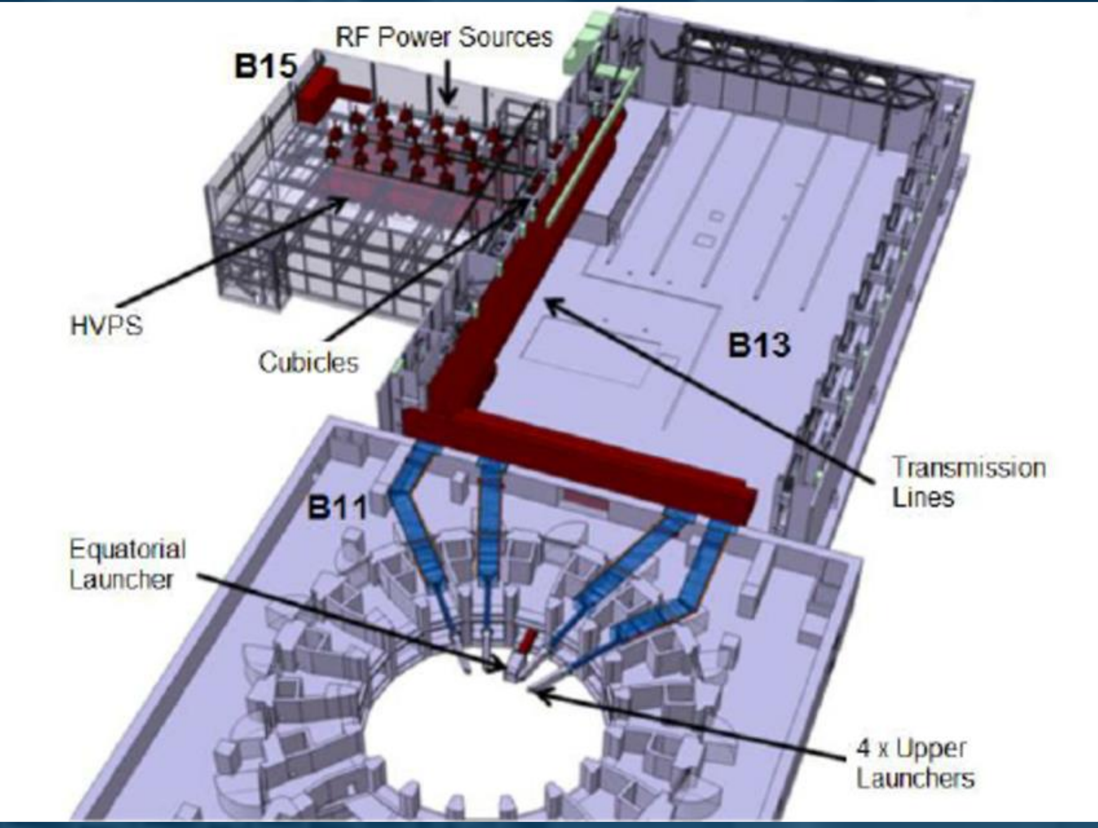
What we do:

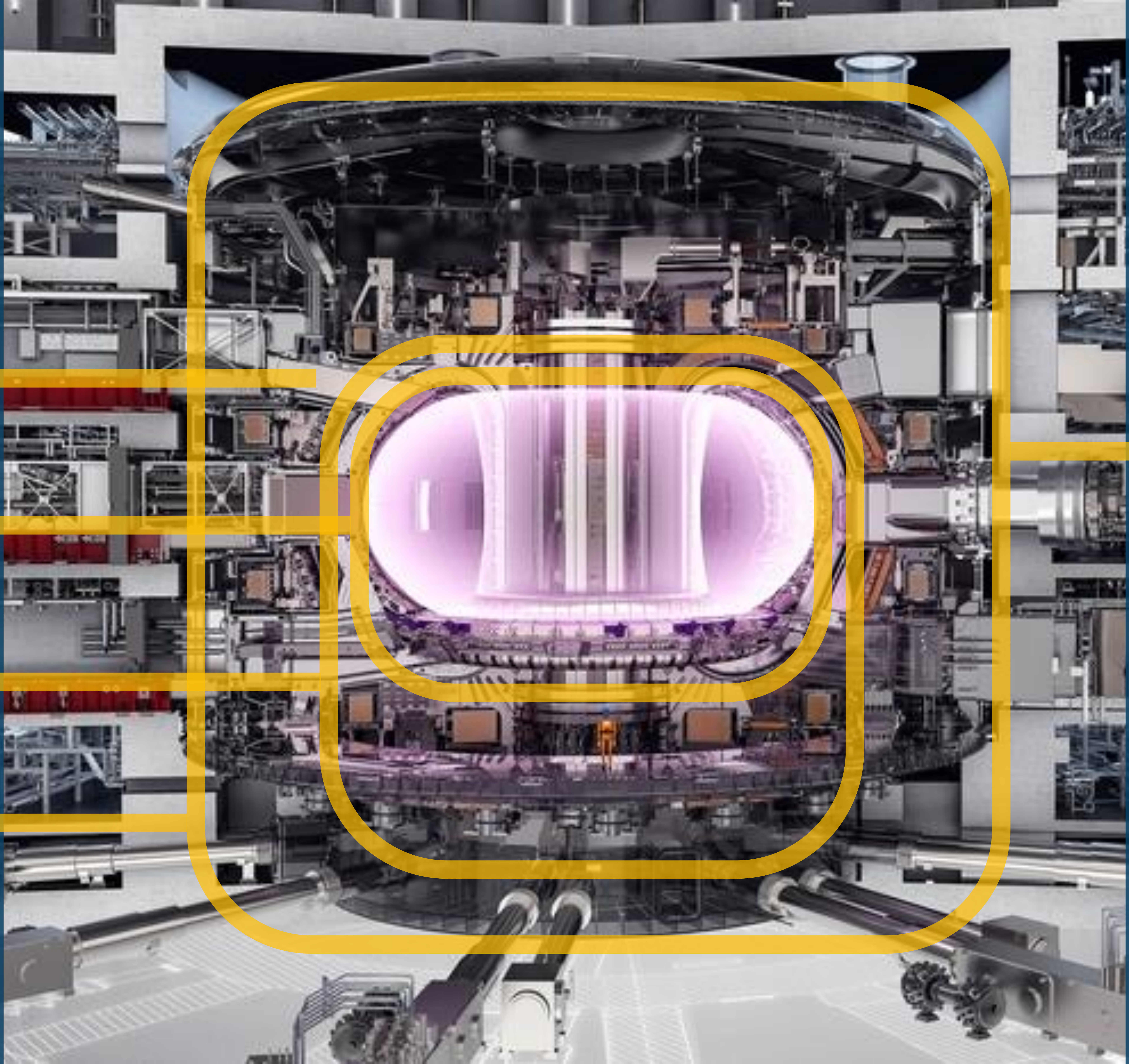
categories …		disciplines …
Large systems, complete I&C engineering lifecycle	✖	System Engineering
Diagnostics		Software Engineering
Safety Critical		I&C Conventional
Backbone Frameworks		Machine Protection
Bespoke Electronics		Occupational/Nuclear Safety
I&C and Engineering Support services (incl. on-site)		Bespoke Electronics
		Slow Control [ms]
		Fast Control [ns/μs]

How we do it:

- Project development
- Technology Development
- I&C Services: Integrations, Engineering Support, On-Site Support (also times&means)

GTD SI&R in fusion technology



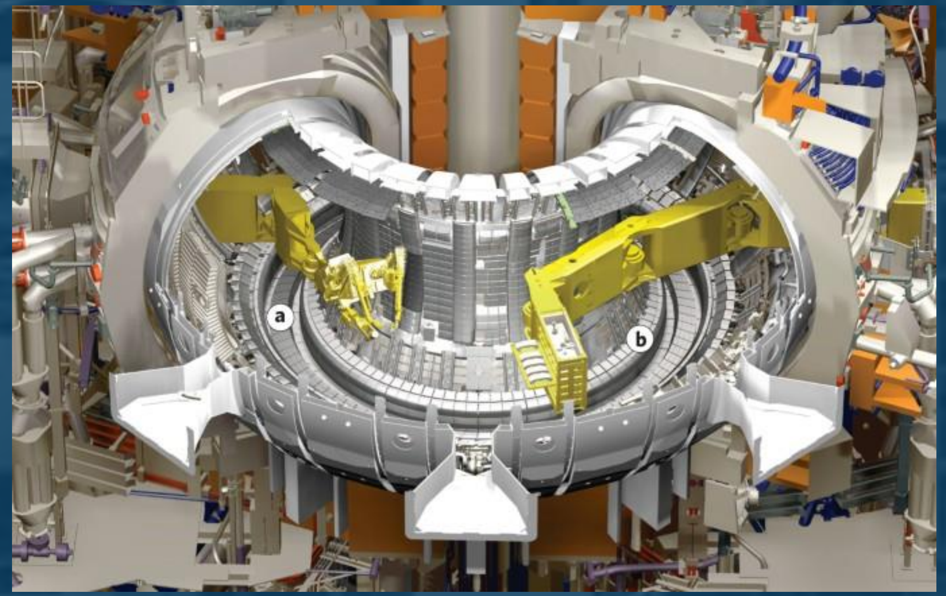


Electron Cyclotron Heating
Upper Launcher Subsystem

Disruption Mitigation System (DMS)
HCLL PbLi Loop
Magnetics Diagnostics

Front-End Cryogenic Distribution System (FECDS)
Torus & Cryostat Cryopumping System (TCCS)
Helium Leak Localization System

Tokamak Systems Monitoring



Remote Handling

Buildings integration into CODAC
Load Centers
Pulse Power Electrical Network
Steady State Electrical Network
Central Safety System
Fast Plant Controller
CODAC
Alarm Survey System

gtd sir

Along the last 10 years, GTD SI&R has been involved in the following fusion related systems:

categories	frameworks & projects	System Engineering	Software Engineering	I&C Conventional	Machine Protection	Occupational/ Nuclear Safety	Bespoke Electronics	Slow Control [ms]	Fast Control [ns/µs]	links →
Large systems, complete I&C engineering lifecycle	Cryogenic Distribution System: Torus & Cryostat Cryopumps	■		■	■	■		■		[Torus&Cryostat]
	Electron Cyclotron									
	ECT-Falcon Gyrotron Test Facility	■	■	■	■		■	■	■	[ECT-Falcon]
	Gyrotron Commissioning Components Control System	■	■	■	■		■		■	[GCC]
	EC Plant Control	■	■	■	■				■	[EC Plant]
	Upper Launcher Control System		■	■	■				■	[Upper Launcher]
Diagnostics	Magnetics Diagnostics System	■	■	■	■		■		■	[Magnetics]
	Tokamak Systems Monitor – Tokamak Simulator	■	■						■	[TSM]
Safety Critical	Alarm Survey System	■		■	■	■		■		[Alarm Survey]
	HCLL PbLi Loop	■		■	■	■		■		[HCLL PbLi Loop]
	LIPAc Machine Protection System	■	■		■				■	[LIPAc MPS]
	Disruption Mitigation System (DMS) Plant Interlock System		■		■				■	[DMS PIS]
Backbone Frameworks	Remote Handling Framework: GENROBOT	■	■	■	■	■			■	[GENROBOT]
	CODAC and CODAC Core System		■	■					■	[CODAC]
Bespoke Electronics	Generic Fast Plan Controller		■	■			■		■	[FAST PLANT]
	cRIO HotLink Modules		■	■			■		■	[cRIO]
I&C and Engineering Support services (incl. on-site)	Central Safety System (CSS), both Nuclear and Occupational Safety		■			■		■	■	[CENTRAL SAFETY]
	Electrical Network, Steady State and Pulse Power (SSEN & PPEN)		■	■				■		[ELECTRICAL NETWORK]
	Buildings (nuclear and non-nuclear) incl. Compressed Air, Demineralized Water, Nitrogen Systems, Helium Gas Distribution, Breathing Air system, HVAC, Heavy Nuclear Doors	■	■	■		■		■		[BUILDINGS]

key disciplines

Cryogenic Distribution System

Torus&Cryostat

category

Large systems, complete I&C engineering lifecycle

key disciplines

System Engineering | I&C Conventional | Machine Protection | Occupational/ Nuclear Safety | Slow Control [ms]

context

The Torus Cryopump (TCP) and Cryostat Cryopump (CCP), both of identical design, are cryogenic adsorption pumps which will maintain the pressure required in the ITER torus and cryostat respectively and pump residual gas from the torus during operation. The working principle of the pumps is based on the adsorption of exhaust gases by charcoal coated cryo-panels cooled to around 4.5 K. 6 TCPs and 2 CCPs will be installed in the port cells at level B1 of the Tokamak complex building No. 11.

project

Technical Specification for the Front-End Cryogenic Distribution System (FECDS) I&C Hw and Sw final design

reference

F4E -OFC-0811-09, 2019

description

This project concerned the Final Design of Instrumentation and Control (I&C) cubicles and cabinets, the related acquisition and control hardware (HW), and the control software (SW), for the ITER Front End Cryogenic Distribution System (FECDS).
The project covered the Final Design of the control SW and HW for 6 Torus Cold Valve Boxes (CVBs), 2 Cryostat CBVs, the Warm Regeneration Box and the FECDS Master Cubicle: a total of 11 floor standing cubicles (acquisition, conditioning and control electronics) and 32 wall-mounted enclosures (pilot valves, 16 conventional control + 16 nuclear safety).
GTD was responsible to provide the engineering services activities required to complete the FECDS I&C system lifecycle from the Preliminary Design stage to the Final Design. It covered:

- Design of FECDS I&C, for 8 CVBs (6xTorus, 2xCryostat), of two different types;
- Design of FECDS I&C for 1 Warm Regeneration Box;
- Design of FECDS I&C for 1 FECDS Master Cubicle (Plant Interlock);
- Final Design of the Conventional Control and Interlocks FECDS I&C HW:
  - Torus and Cryostat Cold Valve Box I&C;
  - Warm Regeneration Box I&C;
  - Master Cubicle - Plant Interlock System I&C;
  - I&C Test and Spare Part Equipment.
- Final Design of the Conventional Control and Interlocks FECDS SW: Software design for the CBVs, the Warm Regeneration Box and the PIS, comprising:
  - Analysis of operation software requirements;
  - Controllers software architecture,;
  - Data exchange protocols and architecture;
  - Operating states;
  - Integration in central CODAC;
  - Preliminary HMI proposals.
- Final Design of the Nuclear Safety FECDS I&C HW; and
- Nuclear safety I&C Test and Spare Part Equipment.

GTD SI&R also addressed the preliminary BOM and component qualification requirements, where ITER catalogues items (slow controllers, cubicles, cubicle configuration…) did not require qualification for the environmental conditions defined for Tokamak Gallery Corners.; however, the forced use of components not specified in ITER catalogues and several FECDS components installed close to PIC components were classified SC2, and required specific qualifications.

Back to INDEX

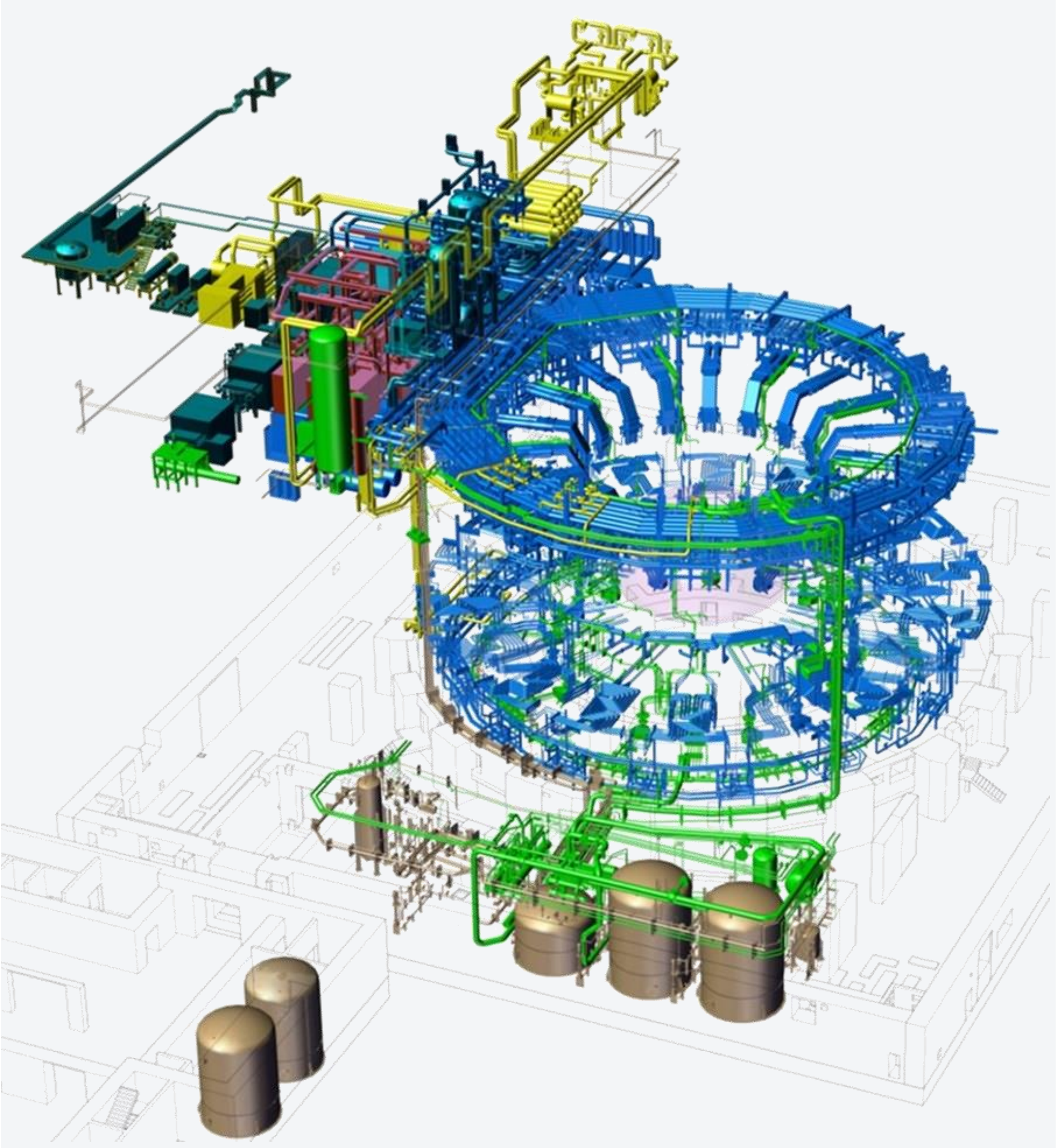
Cryogenic Distribution System

category

Large systems, complete I&C engineering lifecycle

key disciplines

System Engineering | I&C Conventional | Machine Protection | Occupational/ Nuclear Safety | Slow Control [ms]



Torus&Cryostat

project

Technical specification for TORUS and CRYOSTAT Cryopumping System (TCCS) ...

2/4

reference

F4E -OFC-0811-13, 2019

description

The project (complete title: "Technical specification for TORUS and CRYOSTAT Cryopumping System (TCCS) I&C integration with FECDS Final Design") addressed the consolidation of the ITER Torus and Cryostat Cryopumping System Instrumentation and Control (I&C) with the ITER Front End Cryogenic Distribution System (FECDS) I&C Final Design.

The scope of design activities included cubicles and cabinets, the required acquisition of the control hardware (HW), and the detailed design of the control software (SW) to address 6 Torus Cryopumping and 2 Cryostat Cyropumping Systems. GTD SI&R was responsible to provide the engineering services activities required to complete the TCCS I&C Final Design, consolidating the topics in common with FECDS I&C (control software, integrated architecture, diagrams and documentation) and proposing design optimization solutions (e.g. cubicles arrangement).

GTD SI&R further coordinated efforts in this contract with the parallel activities for FECDS I&C Final Design (OFC-0811-01-09. The project required compliance to lifecycle and processes defined by IEC 61513 for PIC/PIA, concerning I&C integration and manufacturing activities.

Torus&Cryostat

project

Front-End Cryogenic Distribution System (FECDS) I&C HW Qualification

3/4

reference

F4E -OFC-0811-14, 2019

description

The project concerned the qualification activities for the I&C hardware of the ITER Front End Cryogenic Distribution System (FECDS). The services covered preparation of the documentation required for the test campaigns, the acquisition of the EUTs, the execution of tests and preparation of tests reports.

The qualification covered:

- Environmental Qualification, to demonstrate compliance to the conditions where the specific component will be installed: Temperature and humidity; Radiation; Static Magnetic Field; Seismic; Fire; and Ageing.
- EMC Standards Qualification, to demonstrate compliance to ITER required standards and test methods.

The Qualification Activities did also address the following topics:

- Materials, regarding RoHS, Halogen Free, etc;
- Component CE marking; and
- Functional Qualification, to demonstrate the suitability of the component to perform the required function (performance, interfaces, etc.).

In addition, concerning PIC components, it was also in the scope of the project to demonstrate abidance to lifecycle and processes requirements defined by IEC 61513 and ITER SCS-N Overall Qualification Plan. For I&C components where the compliance to qualification criteria cannot be demonstrated by analysis, GTD prepared and executed the corresponding Qualification Tests.

Torus&Cryostat

project

FECD-TCCS I&C MRR and First-of-a-Kind Manufacturing

4/4

reference

F4E -OFC-0989-91, 2021

description

This project concerns the completion of the design of the Front End Cryogenic Distribution System (FECDS) and Torus and Cryostat Cryopumping System I&C, from Final Design to Manufacturing Readiness Review and As-Built documentation. It also includes the manufacturing, test and delivery of a First-of-a-Kind system, as well as the process control, protection and HMI software:

- Finalization of the I&C design for FECDS and TCCS, from the current Final Design stage to Manufacturing Readiness and As-Built documentation;
- Manufacturing and test of the First-of-a-Kind system, compliant to the requirements and as per design documentation; and
- Development and test of the process control, interlocks, HMI and interface software.

The activities to be covered in the project were grouped in 4 subtasks:

- I&C Manufacturing Readiness Review;
- I&C SW implementation;
- I&C first-of-a-kind HW manufacturing; and
- I&C test and as-built documentation.

Back to INDEX

ECT-FALCON

category

Large systems, complete I&C engineering lifecycle

key disciplines

- System Engineering
- Software Engineering
- I&C Conventional
- I&C Machine Protection
- Bespoke Electronics
- Slow Control [ms]
- Fast Control [ns/μs]

context

The Swiss Plasma Center (SPC) Gyrotron test stand facility in Lausanne was modified to host and operate the ECT-Falcon millimeter wave components test facility. The test facility (ECT FALCON) has got the mission to
test the microwave components for the ITER EC Upper Launcher, where the RF power was produced by a 1 MW continuous operation Gyrotron provided by the Russian supplier Gycom Ltd and procured by F4E.
The ECT-Falcon facility coexists with the EU Gyrotrons test stand: the two Gyrotrons are connected to the same High Voltage Power Supply and Water Cooling manifold (as the ECT-Falcon facility), although they have different auxiliary power supplies and vacuum pumps. Similarly the two Gyrotrons share the control and protection system hardware.
Since the functions implemented were different, it was necessary to design a reliable way to switch between two different control and protection logics while keeping compliance with the applicable safety standards.

project

Control and protection systems for ECT-FALCON

reference

F4E -OFC-0361-11, 2014

description

The project consisted in the implementation of the control and protection systems of ECT-FALCON.
The required architecture comprises both slow and fast controllers for the control and protection systems; the whole system was integrated into an EPICS based supervisory platform.
The departing conditions were particularly challenging in terms of missing detailed specifications. Because of the tight schedule and in order to cope with requirements that needed to be identified and finalized in parallel with the software development effort, an AGILE project lifecycle approach has been successfully merged with the demanding requirements of the applicable safety standards.

project

Implementation of the fast protection system for ECT-FALCON ...

reference

F4E -OFC-0361-16, 2014

description

The activity covered by this project (full title: "Implementation of the fast protection system for ECT-FALCON and the European Gyrotron test stand") was the actual implementation of the fast protection system of the European Gyrotron test stand facility and of ECT-FALCON.
The development of this activity has served as a verification of the preliminary design solution to be adopted for the fast protection system of the ITER EU Gyrotron controller.
The fast protection system has designed with reaction times of few μs to shut down the high voltage in case of fault in the Gyrotrons or external components. The finally delivered solution achieved the performance of 2 μs maximum response time implementing a configurable logic solver function.
Other functionalities included in the scope of the project were:

- Event acquisition and time stamping;
- Communication to PLC;
- FPGA safe configuration;
- Interface with the ECT-FALCON arc detection system via fiber optic and digital IO;
- Interface to HVPS via fiber optic to send a shutdown request;
- Interface to HVPS via fiber optic to receive analogue measurements (via a custom developed Compact RIO board); and
- Customization of the logics to the ECT-FALCON needs.

project

Instrumentation and Control for ECT-FALCON

reference

F4E -OFC-0361-18, 2016

description

The project addressed an extension to the instrumentation and control systems of ECT-FALCON.
It consisted in:

- Falcon Instrumentation and Control;
- The implementation of the fast real-time networking and data acquisition; and
- The implementation of the final analogue optical transmitter.

← Back to INDEX

Gyrotron Commissioning Components

category

Large systems, complete I&C engineering lifecycle

key disciplines

System Engineering	Software Engineering	I&C Conventional
I&C Machine Protection	Bespoke Electronics	Fast Control [ns/μs]

context

The Gyrotron Commission Components control system is intended to support operators in testing different gyrotrons combined with different power supply configurations (typically: a pair of gyrotrons. a power supply set - shared by the two gyrotrons, a cooling water system - powered by a chiller, a pair of vacuum pumps, a power monitor - RF monitor, a pair of dummy loads and sections of transmission lines, to connect the gyrotrons to the power monitor and to the dummy load.
The ultimate purpose of the GCC control system is supporting the operation of the system where the configuration of each test shall be organized following the concepts of experiments, sessions and campaigns. Consequently for a given test on a specific set of gyrotrons and power supplies, the GCC control system shall constrain actions that can be initiated by the user, set boundaries to parameters that can be adjusted by the user, initialize all the parameters available to the configurator, enable / disable the interlocks and alarms in consistency with the GCC configuration and the specific test to be performed.

GCC

project

1/2

Gyrotron Commissioning Components (GCC) Control System Design preparation

reference

F4E -OFC-0811-04, 2018

description

The activity covered by these project is related to the preparation of the presentation by F4E to the EC Control System stakeholders the final design of the GCC Control System.
During the meeting the use cases, the functional analysis and the final design of the control system were discussed.
The actual scope of the project was:

- Consolidation of the use cases;
- Consolidation of the requirements;
- Performing the functional analysis;
- Designing the detailed control system architecture;
- Definition of the interfaces; and
- Preparation of the documentation for the technical meeting.

The technical meeting was successfully held at the ECT FALCON site, in Lausanne.

GCC

project

2/2

Implementation of FAT Tools and Gyrotron Commissioning Components Control System

reference

F4E -OFC-0811-15, 2019

description

The purpose of this project was the design and implementation of the FAT Tools and the GCC Control System, based on the control systems already implemented for the ECT Falcon facility.
The activities covered:

- Development of the Fast Logic Solver protection system (2 μs). Therefore, the existing prototype implemented for ECT-FALCON were adapted to the specific electron cyclotron control system needs.
- Finalized the solution of the Fast Logic Solver for machine protection;
- Performed the needed unit tests of the final version of the Fast Logic Solver;
- Implementation of the final version of the full documentation set;
- Provide the effort to develop, integrate and test the fast logic solver final solution;
- Development of the FAT tools, which were a number of components to simulate the behaviour of the ECPC and verify that the interfaces which each SCU and towards the ECPC were correct.
- Development of the GCC control system, which refers to the ITER Gyrotron Commissioning Components (GCC), and consist of a set of temporary components devoted to the SAT of gyrotrons.

Back to INDEX

Electron Cyclotron Plant Controller

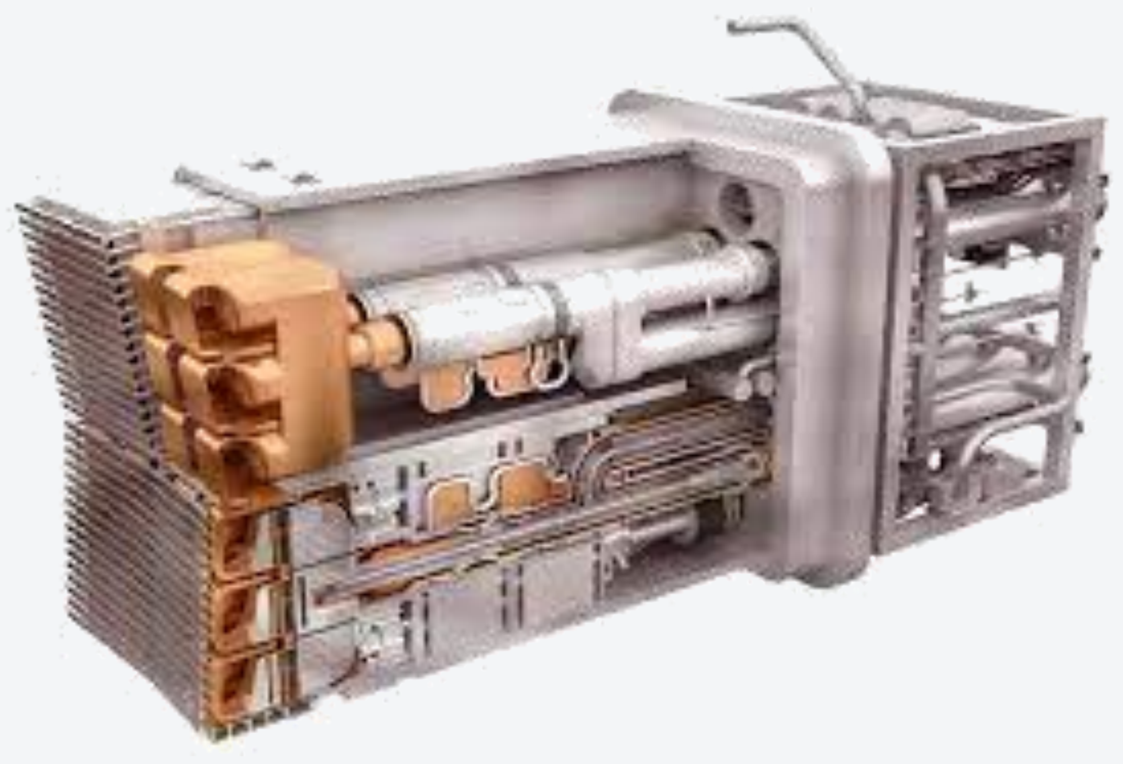
category

Large systems, complete I&C engineering lifecycle

key disciplines

- System Engineering
- Software Engineering
- I&C Conventional
- I&C Machine Protection
- Fast Control [ns/μs]

context



EC Plant

project 1/3

EC Plant Control Preliminary Design - Stage 1

reference

F4E -OFC-0811-01, 2017

description

The activity covered by this project is related to the completion of the instrumentation and control systems of ECT FALCON to serve as a basis for the EC Plant Control preliminary design.
The project was materialized - exceptionally - in terms of "time and means", in order to align with time constraints in the finalization of the EC Plant Control preliminary design.

EC Plant

project 2/3

EC Plant Control Preliminary Design - Stage 2

reference

F4E -OFC-0811-08, 2018

description

The activity covered by this project was related to the implementation of the instrumentation and control systems of ECT FALCON and to the testing of Control System solutions to be used in the GCCPC.
Both fast and slow controller need to be adapted to test the different architecture of the control system needed for the GCC, where control system procured by Ampegon, RFDA and JADA will be integrated together. Scope:

— Provision and integration of the hardware required for the adaptation of the FALCON facility to be able to test the solutions designed for the ITER EC Plant Controller.
— Software design and implementation for the PLC and EPICS/CCS, which due to lack of maturity of the requirements started by collecting and consolidating the applicable requirements (user stories, technical requirements, interfaces definition, ...).
— Software development resulted in the need to adapt the PLC architecture, the PLC software and the EPICS interface to be compliant with the GCC-PC.
— The interface of the fast controller to the ITER standard tools: SDN, DAN, TCN, was also implemented. As well as the interface of the fast controller to the remote IOs envisaged in the GCC-PC: the NI CompactRIO and NI PXI modules. Installation, testing, integration and SAT were conducted in the ECT FALCON site in Lausanne.

EC Plant

project 3/3

Conceptual Design and Prototyping of the EC Plant Controller

reference

F4E -OMF-0989-07, 2021

description

The project consisted in the conceptual design and prototyping of the EC Plant Controller. The ITER EC plant control system architecture foresees a Plant Controller (ECPC) interfaced to a series of local controllers called Subsystem Control Units (SCUs) for the main subsystems of the plant. The scope of the project was the review and consolidation of the requirements of the EC Plant Controller and the preparation of a conceptual design. The general I&C architecture included a slow controller, a fast controller and a fast protection controller. Addressed interfaces were:

— Central Interlock System;
— CODAC;
— Plasma Control System;
— Two Gyrotron Subsystem Control Units (SCU) where each SCU is responsible for the control of a pair of gyrotrons;
— Transmission line SCU;
— Upper Launcher SCU;
— Two HVPS power supplies SCUs;
— Cooling water system; and
— Vacuum system.

Back to INDEX

Upper Launcher Control System

category

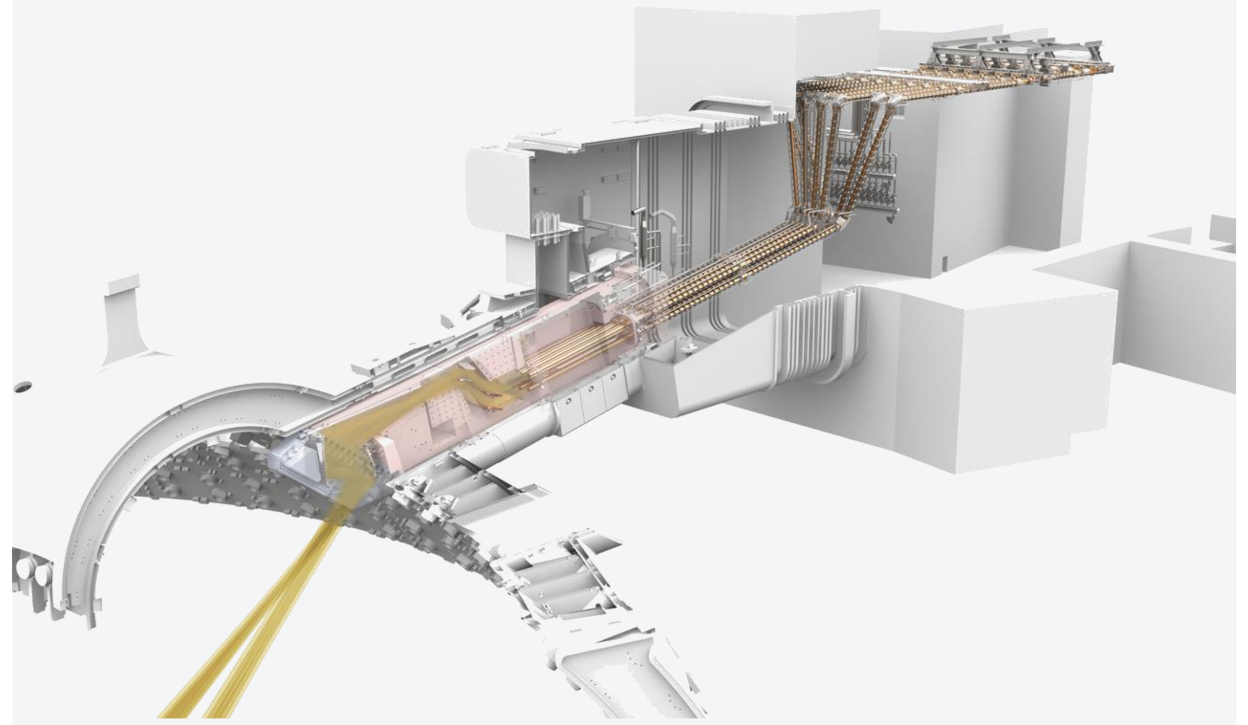
Large systems, complete I&C engineering lifecycle

keywords

Software Engineering | I&C Conventional | Machine Protection | Fast Control [ns/μs]

context

The ITER electron cyclotron (EC) upper port antenna (or launcher) shall drive current locally to stabilize the neoclassical tearing modes (NTMs) (depositing ECCD inside of the island that forms on rational magnetic flux surfaces) and control the sawtooth instability (deposit ECCD).
The launcher should be capable of steering the focused beam deposition location to the resonant flux surface.



Upper Launcher

project

Conceptual design of the Upper Launcher Subsystem Control Unit

eeference

F4E -OFC-0989-04, 2021

project description

The activities covered in this project are related to the design and implementation of the Electron Cyclotron Plant at ITER.
The scope comprises:

— Revision/consolidation of requirements and conceptual design of the Upper Launcher Subsystem Control Unit:
The ITER EC plant control system architecture foresees a Plant Controller (ECPC) interfaced to a series of local controllers called Subsystem Control Units (SCUs) for the main subsystems of the plant. The objective was the review and consolidation of the requirements of the Upper Launcher SCUs and the development of a conceptual design.

— Optimization of interfaces between the EC Plant Controller and the Subsystems Control Units. The EC Plant Controller and the gyrotron SCUs have both physical and functional interfaces.

- The physical interfaces consists of:
  - Optical Profinet interface;
  - Optical fast real-time network (EC-SDN); and
  - Optical digital inputs/outputs.
- The functional interfaces shall be:
  - To receive state change requests and to communicate the current gyrotron status;
  - To receive external trip request and fault resets;
  - To communicate internal faults;
  - To receive real-time power requests, modulation information and any other information required to remotely operate the gyrotron; and
  - To implement the required real-time references via the direct interface with the HVPS SCU.

←Back to INDEX

Magnetics Diagnostics System

category

Complex Diagnostics System

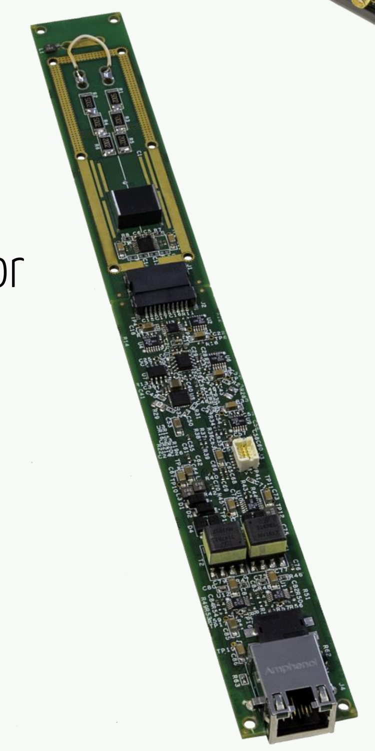
key disciplines

System Engineering	Software Engineering	I&C Conventional
Machine Protection	Bespoke Electronics	Fast Control [ns/µs]

context

FPGA Main Board (by GTD SI&R), which provides the interface of the integrators to the CODAC and CIS networks:

Magnetics integrator based on the chopper concept:



project

Requirements consolidation, preparation and planning of the magnetics diagnostic plant system design

reference

F4E -OFC-0361-01, 2013

description

The project consisted in developing a precise and detailed understanding of the magnetics diagnostic project requirements, as well as the setup of all the engineering tools that allow the complete traceability of all the design choices to the source ITER requirements. These tools were required to be fully compatible with the F4E requirement management model.
Once input requirements were consolidated, GTD was in the position to develop a complete implementation plan covering all the activities required to reach the preliminary design review (PDR) with the correct level of maturity. In particular, it enabled GTD to identify any high-risk requirements that would benefit from verification strategies based on requirement analysis techniques (e.g. prototyping, COTS survey and assessment, RAM models and model-based simulation).
The underlying objective of the work was to prepare all the necessary background for the magnetics plant system design activities, including:

- Setup and configuration of the requirements and design management tools: IBM Rational DOORS® and Sparx Systems Enterprise Architect®;
- Populating the requirements management tools with input documents;
- Detailed analysis and consolidation of the magnetics diagnostic plant system requirements;
- Generation of a formal requirements baseline module for the plant system design; and
- Detailed estimation of the resources and activities required to reach the preliminary design review with the design at the appropriate level of detail.

project

Preliminary design of the magnetics diagnostic plant system controller hardware and software

reference

F4E -OFC-0361-08, 2015

description

The project consisted in all the activities required to hold a Preliminary Design review of the Magnetics Plant System Controller, hardware and software, including the demonstration of the magnetic integrator concept.
The main objectives of the work were the development of an R&D activity that fully demonstrates the magnetics integrator based on the chopper concept and the development of the plant system controller hardware and software up to preliminary design review.
Given the deep interface between the plant system controller hardware and the magnetics integrator component, this project included two major activities:

- Preparing the plant system controller hardware and software preliminary design, including the production of all the necessary design documentation:
  - The management of all the magnetics diagnostic electronics and software requirements, using the database developed in the scope of the two previous task orders;
  - The update and maintenance of the functional analysis and system model developed in the scope of the previous task order;
  - The development of all the design documentation;
  - Supporting F4E in the preparation of the design review by preparing and presenting all the required material; and
  - Supporting F4E in the resolution of all the design review chits
- Developing further R&D on the integrator chopper concept, aiming at resolving all the open questions and chits from the preliminary design review.

Moreover, and following from the uncertainties in the physical interface definition between the magnetics diagnostic and the central interlock, the prototyping activity in the project was intended to further demonstrate a CPU-less connection between the sensor and the central interlock network, on a GbE based network.

Back to INDEX

Magnetics Diagnostics System

category

Complex Diagnostics System

key disciplines

System Engineering	Software Engineering	I&C Conventional
Machine Protection	Bespoke Electronics	Fast Control [ns/μs]

Magnetics

project

3/4

Final design of the magnetics diagnostic plant system controller and bespoke hardware

reference

F4E -OFC-0811-05, 2018

description

The main objectives of the project were to develop and document the final design of both the plant system controller and of the bespoke electronics. These designs should be supported by prototyping activities that aimed at lowering any risks related to manufacturing and to requirement compliance. Consequently, the main activities of the project were:

- The management of all the magnetics diagnostic electronics and software requirements, using the database developed in the scope of the previous projects;
- The update and maintenance of the functional analysis and system model;
- The development of all the design documentation, including the cubicle design;
- The design, development and testing of a test rig that demonstrates all the relevant CODAC and CIS interfaces against the identified requirements; and
- The support to F4E in the preparation of the design review and resolution of raised chits.

Regarding the bespoke electronics final design, the scope of this activity was to develop all the bespoke electronics up to final design, taking into account the chits raised during the preliminary conceptual design:

- Final design, development and testing of the bespoke data acquisition front-end (Integrator and ADC);
- Final design, development and testing of the bespoke FPGA Main board (which provides the interface of the magnetics to the CODAC and CIS networks);
- Design, development and testing of a test rig to (1) demonstrate the bespoke electronics against the project requirements; (2) demonstrate correct interface with the plant system controller; and (3) to automate the Factory Acceptance Testing of the electronics; and
- The exhaustive completion of the design documentation.

Magnetics

project

4/4

Magnetics Diagnostic Plant Controller Integration

reference

F4E -OFC-0989-01, 2020

description

This project consisted in all the activities required to integrate the magnetics plant controller hardware and software.
GTD proposed and implemented a robust QA infrastructure that allows the continuous integration of all the developed components (including the scientific software). For software, irrespective of their type, all components were required to be continuously tested in three stages:

- In standalone mode, where the software is (unit) tested without any dependencies on the hardware specific environment;
- Using a mockup server, where the software is expected to demonstrate that it fulfils all the functions taking into account all the relevant computer interfaces (e.g. network bandwidth, memory and CPU availability), but excluding any interfaces to the sensors;
- With integrated tests, where the software shows that it correctly meets all the expectations taking into account all the components and interfaces.

Since the ultimate objective of the work was to implement and integrate all the magnetics diagnostic I&C and scientific software. GTD scope of work comprised:

- Development, testing and integration (including FAT) of all the I&C software;
- Integration (including FAT) of all the scientific software;
- Implementation and testing all the diagnostic Man Machine Interfaces (for I&C and scientific software);
- Implementation of the system FAT; and
- Development of all the associated project documentation.

Back to INDEX

Tokamak Monitoring

category

Complex Diagnostics System

key disciplines

System Engineering | Software Engineering | Fast Control [ns/μs]

context

As any complex modern device, each main system of ITER tokamak is provided with operational instrumentation (OI): a range of discrete sensors of different types to monitor the components' state during normal machine operation and various off-normal events including plasma disruptions, vertical displacement events (VDEs), and others. Although OI sensors are spatially distributed as extensively as reasonably possible, they definitively cannot collect measurements from all areas of interest of the entire system. This means some areas of interest will not be directly surveilled. The TSM system will use available discrete sensor data to reconstruct information not directly available from the sensors and to provide, in a time scale of about one minute or less, a global picture of ITER tokamak behaviour during the operation. This shall allow to verify and calibrate various numerical simulation models and to later on employ them for calculation of the engineering states of all non-surveilled areas.

The output of TSM will give the ITER machine operators an integrated overview of the tokamak condition and transients to aid them in decision making and adjusting the operational plan as necessary.

TSM

project

Development of ITER Tokamak Systems Monitoring (framework)

reference

IO/19/CFT/70000439/LLJ, 2020 - in partnership with ESTEYCO

description

This 4+2 years multiannual framework covers the development of ITER Tokamak Systems Monitoring system (TSM system).
The project addresses the development of TSM reconstruction algorithms and their implementation as practical TSM software for seven main tokamak systems with five groups of the engineering disciplines:

- Thermo-hydraulics,
- Electromagnetic and Dynamic responses,
- Net interface loads including impact loads,
- Accumulated fatigue and structural damages and
- Unintended thermal and electrical contacts, for each system.

Complementing all these groups, a "Tokamak Simulator" activity combines algorithms and software developed to define and optimise user interfaces to the Tokamak Operator.

In terms of GTD, the activity mainly focus in the "implementation as a practical TSM software" objective and all its derivates. Therefore, GTD has to improve algorithms coding and to build an algorithm software infrastructure/platform to support coordinated execution of the algorithms plus the collection of results, in connection with the CODAC environment.
The project addresses 3 consecutive major reviews of TSM algorithms (CDR, PDR, FDR) and 6 formal Software Releases (from #1 to #6).

←Back to INDEX

Alarm Survey System

category

Safety Critical

key disciplines

- System Engineering
- I&C Conventional
- Machine Protection
- Occupational/ Nuclear Safety
- Slow Control [ms]

Alarm Survey

project

Programming and Integration of the ITER's Contractor's Area 2 (CA2) Alarm Survey System

reference

F4E -OFC-0361-02, 2013

description

The CA2 is part of the infrastructures provided by Fusion for Energy (F4E) to the ITER Organization (IO) site contractors. The Alarm Survey System is one of the services of the CA2.
The ITER Building B07 houses the CA2 Alarm Survey System Control Cubicle. The Control Cubicle contains the components in charge of gathering the data produced in the CA2 buildings (downstream) and to route them to the CODAC Environment (upstream).
The Control Cubicle includes:

- A Industrial Ethernet network switch;
- A S7 400 PLC (main slow controller);
- A S7 1200 PLC to control the cubicle Health Monitoring System;
- A Plant System Host (PSH) for the interface between the Programmable Logic Controller (PLC) and the mini-CODAC; and
- A mini-CODAC machine.

The CA2 buildings Fire Protection & Detection Systems was also interfaced with the Alarm Survey System.
Additionally, the electrical power distribution variables and the status of the transformers in the pre-fabricated Load Centre (PRLC1) have been included in the monitoring scope of the Alarm Survey System.

Alarm Survey

project

Implementation of FAT Tools and Gyrotron Commissioning Components Control System

reference

F4E -OFC-0361-14, 2016

description

The scope of this project included the design, programming and testing of the upgrade of the existent alarm survey system.
This upgrade further prepared the system for the extension of its responsibilities in the frame of the worksite of ITER. Moreover, the extension also addressed the facilities: CA1, CA2, B55/PF Coil manufacturing bulding, TB04, TB05 and TB06; and it included the specific development of a new control logic.

Back to INDEX

HCLL PbLi Loop

category

Safety Critical

key disciplines

- System Engineering
- I&C Conventional
- Machine Protection
- Occupational/ Nuclear Safety
- Slow Control [ms]

context

The Breeding Blanket (BB) is a component of a power plant fusion reactor of basic importance as it accomplishes the functions of tritium breeding and nuclear to thermal power conversion. For concept validation, Test Blanket Modules (TBM) will be installed in different ITER VV Ports and tested along the whole ITER lifetime. The Helium-Cooled Lithium-Lead (HCLL) TBM, which will be installed in the ITER Equatorial Port #16, is one of the two BB systems proposed by the European Union.

The PbLi loop is one of the main sub-systems of HCLL-Test Blanket System. Its main functions are:

- To provide and maintain Pb-16Li alloy to operating conditions suitable for HCLL-TBM correct operation;
- To move tritium from TBM to promote external tritium extraction;
- To provide confinement of Pb-Li and radioactive products;
- To contribute in ensuring safety provisions implementation for HCLL-TBS.

The I&C system for the PbLi loop includes all the sensors, actuators and controllers required to fulfil its functional requirements. This I&C system is segregated in three tiers:

- Conventional Control tier, that provides loop control and operations management functions;
- Interlocks tier, that provided investment protection functions; and
- Safety tier, sub-divided in two main systems: Occupational Safety and Nuclear Safety.

project

Preliminary Design of the I&C system for the HCLL PbLi loop

reference

F4E -OFC-0361-10, 2016

description

The objective of the project was to provide engineering support to bring the I&C system of the HCLL-PbLi loop from the Conceptual Design maturity to a Preliminary Design maturity, requiring (among other activities):

- Review, formalization and consolidation of functions:
  - Conventional control
  - Interlocks
  - Nuclear safety
  - Occupational safety
- Identification and classification (3IL1/2/3) of PbLi loop Interlock functions,- Evaluation of function gaps and needs for second level – supporting functions e.g. diagnostics I&C for preventive maintenance and early detection of failures (vibration monitoring, additional sensors, etc.),
- Development of a Control Breakdown structure;
- Assessment of the proposed list of instruments (sensors and actuators) in CDR and consistency with the functions to be implemented,
- Proposing a PbLi I&C system architecture considering the three tiers (control-interlocks-safety), consistent with the required functionalities and environmental constrains (radiation, magnetic field)
- Allocation of I&C components to functions and CBS (sensors, actuators, controllers),
- Definition of I&C components technical requirements (per type/component) with relation their I&C function:
  - Criticality: 3IL1/2/3, SIC-PIC 1/2/SR (class 1/2 and category A/B/C)
  - Redundancy,
  - Special requirements e.g. environmental: radiation, EMC, magnetic field. Applicability of standards and qualification requirements.
- Development of the set of I&C documents required according to the applicable standards and ITER requirements; in particular, according to IEC-61511 and IEC-61513, including the Compliance Matrix of the quality assurance plan and the requirements established in IEC-61513 for system planning of the nuclear safety I&C.

Back to INDEX

LIPAc MPS

category

Safety Critical

key disciplines

System Engineering | Software Engineering | Machine Protection | Fast Control [ns/μs]

context

The International Fusion Materials Irradiation Facility (IFMIF) is an accelerator-based, deuteron-lithium neutron source. Its goal is to produce high energy neutrons with the intensity and irradiation volume expected in future nuclear fusion reactors such as DEMO.
The IFMIF Engineering Validation and Engineering Design Activities (IFMIF/EVEDA) Project started in 2007, under the framework of the Broader Approach (BA) Agreement between EURATOM and Japan, with the objective of proving the feasibility of the Intermediate IFMIF Engineering Design issued in 2013.
The challenging requirements and characteristics of the systems forming the IFMIF project makes necessary the construction of the Linear IFMIF Prototype Accelerator (LIPAc), which is currently being commissioned at the Rokkasho BA site in Japan. Its target is to continuous wave operation of a high current deuteron beam like the one envisaged in IFMIF. The majority of the LIPAc components are supplied in-kind by European institutes of the national governments that have committed themselves as voluntary contributors of the projects defined in the Broader Approach Agreement.
Fusion for Energy (F4E) is the Implementing Agency for the European contributions to IFMIF/EVEDA.

project

LIPAc Machine Protection System

reference

F4E -OFC-0989-08, 2022

description

The project covers the design, procurement, installation and commissioning of the LIPAC Machine Protection System (MPS) upgrade.
The LIPAc Machine Protection System is part of the LIPAc Control System in charge of receiving information from the different accelerator components and ordering the necessary commands following a well-established interlock logic. In LIPAc, this was implemented using hardwired logic that receives the interlock signals (events) from the Local Control System (LCS) of each accelerator subsystem involved in the machine protection. The status of the hardwired channels are read by the actuators that perform the required interlock action when required.
The existing solution had some major drawbacks such as:

- Little or no flexibility at all on the protection logic;
- Small changes usually come with complex reconfiguration works (often involving hardware modifications) and extensive testing and validation;
- The operation of the system is limited to just monitoring and resetting.
- The current solution presents an important obsolescence issue since most of its parts are not available anymore.

As a design policy for the upgrade:

- Fastest possible response to an interlock situation:
  - System reaction time, from detection to action, shall be the highest priority design parameter in order to minimize any potential damage to the accelerator equipment during beam operation with a large beam current or in any other operation modes; and
  - The MPS must trigger the stop of the accelerator in less than 10 μs when an interlock signal is received.
- Robustness and security:
  - It shall be inspired by the IEC-61508 standard on functional safety.
  - System robustness based on the system architecture;
  - Material robustness based on equipment and devices;
  - Signal transaction robustness based on signal integrity and noise immunity;
  - The signal acquisition units at each LCS shall be designed so that their input interface (from each LCS) can accommodate the already existing signals to and from each LCS;
  - The LCS interface of each acquisition unit shall be homogenized and designed future-proof for future accelerators/systems, where the same interface could be used without changes as the default MPS interface 'as is'; and
  - Resistance to cyber-attacks.
- Flexibility and operability in a secure way:
  - Easy configurability of the interlock thresholds or interlock logic;
  - Addition of new signals made easy; and
  - Secure configuration management.

Back to INDEX

DMS PIS

category

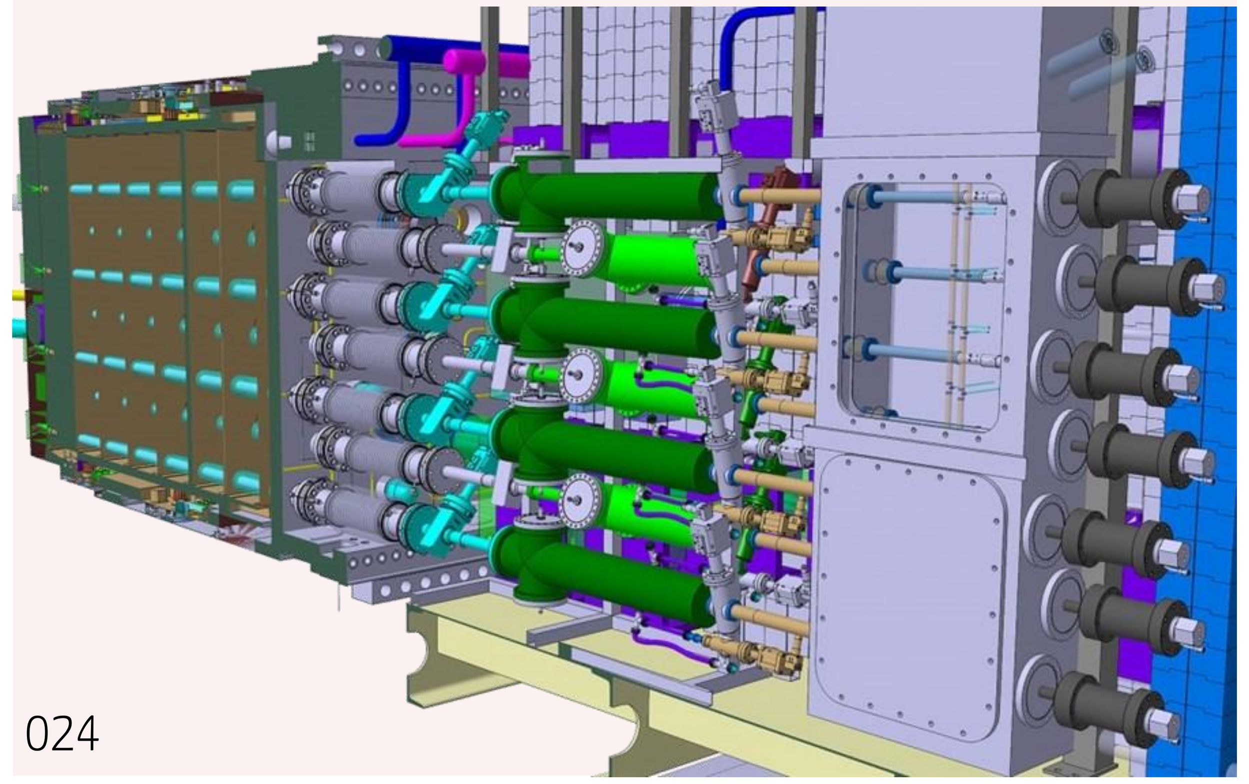
Safety Critical

key disciplines

Software Engineering | Machine Protection | Fast Control [ns/µs]

context

The purpose of the ITER Disruption Mitigation System (DMS) is to provide machine protection in order to reduce the detrimental effects of plasma disruptions and to ensure the appropriate lifetime of all affected ITER components.
It utilises cryogenic hydrogen and neon pellets which are generated inside the injectors which are located in the ISS. These pellets are pneumatically propelled in the time frame of milliseconds towards the plasma and just before entering the plasma are shattered into small fragments to enter the plasma and to reduce damage to the plasma facing components and other structures inside the ITER tokamak.



DMS PIS

project

Disruption Mitigation System (DMS) Plant Interlock System (PIS) development

reference

IO/23/CT/4300002807

description

The project covers the support to the completion of the design, prototyping, coding, and integration to be performed for the Disruption Mitigation System (DMS) Plant Interlock System (PIS).
The Plant Interlock System (PIS) of the DMS is the control system in charge of the critical functions related to the investment protection. It interfaces directly the main indicators and actuators of the DMS Plant, and is in permanent communication with the upper layer of the protection systems, the Central Interlock System (CIS) and the Advanced Protection System (APS). Functionally, it is also interfaced with the Plasma Control System (PCS).

The Advanced Protection System calculates in real time, based on plasma and other tokamak parameters, the injector triggering sequence, and communicates it to the PIS where it is updated and stored. The PIS also monitors the status of the DMS injectors during a pulse, and communicates its status back to the APS as a parameter to evaluate both the sequence and the need to stop the ongoing pulse. Finally, the CIS centralizes all requests of the DMS trigger (which may come from CIS internally, following the execution of other protection functions, or from any of the APS modules) to issue a unique DMS trigger request to the PIS which implements the injector firing sequence based on the sequence previously stored.

In its design and conception, the DMS PIS follows a similar architecture to that of the CIS Fast Architecture, composed of a set of two cRIO chassis NI9159 based on Virtex FPGAs which communicate internally through Manchester coding to exchange internal diagnosis, and externally to CIS. During tokamak operation, the requirements of the system imply the use of components capable of performing control-cycles in the micro-seconds range to meet function input-response requirements.
It is designed following the principles of the IEC-61508 standard on functional safety.
GTD shall:

- Strictly implement the IO procedures,
- Develop instructions and use templates.

←Back to INDEX

GEBROBOT

category

Backbone Frameworks

key disciplines

System Engineering	Software Engineering	I&C Conventional
I&C Machine Protection	Occupational/ Nuclear Safety	Fast Control [ns/µs]

context

About 14 different types of one-of-a-kind robotics and tele-operated devices are foreseen across F4E Remote Handling (RH) packages. These RH devices are considered as Safety Relevant and must reach a high level of quality and conventional safety. GENROBOT has been developed into a certifiable SIL-2 \ Cat. B generic robotics software controller for Remote Handling devices. It has been designed to facilitate quick integration and development of Remote Handling\Robotics applications. GENROBOT characteristics:

- GENROBOT incorporates a set of robotics motion control capabilities for manipulator arms and a command and monitoring HMI;
- GENROBOT is integrated into the ITER Remote Handling Control System (RHCS) architecture through interfaces to: RHCS networks (the Control, the Real-Time Network and the Diagnostic Networks), High Level Control System (HLCS), ...
- GENROBOT includes a validated library of drivers for I/O boards, EtherCat motion control bus and other components of the IO standard parts catalogue;
- GENROBOT is configurable, portable on computer & I/O boards and electro-mechanical platforms.
- GENROBOT is made available with software Quality Assurance and Configuration Management procedures and tools; and
- GENROBOT has been developed and is compliant with both (1) the NPP safety standards IEC 61513, IEC 62138 for category B software; and (2) the safety industrial standard IEC61508 for SIL-2 class software.

GENROBOT

project

Development Plan for the GENROBOT Project

reference

F4E -OFC-0361-05, 2013

description

The project covered the definition phase of the GENROBOT system, which was defined to become a generic robotics controller integrated in the Remote Handling Plant System. The main objective of the project was to properly plan GENROBOT 's activities, resources, organization, and costs considering a lifecycle compliant with applicable standards and with a number of project's requirements, assumptions and constraints.

GENROBOT

project

Phase 1 of the GENROBOT project development and validation

reference

F4E -OFC-0361-09, 2015

description

The project implemented the first phase of the development, verification and validation of the GENROBOT. It was the natural follow up of F4E-OFC-361-05, in 2013.

GENROBOT

project

Phase 2 of the GENROBOT project development and validation

reference

F4E -OFC-0361-19, 2016

description

Phase addressed the development, verification, integration and validation of the final set of application-related components of the GENROBOT software framework, in particular the Interpolator component (INT) and the Custom component (CUS).
Phase 2 also included the interface with the Remote Diagnostics System.

Back to INDEX

GEBROBOT

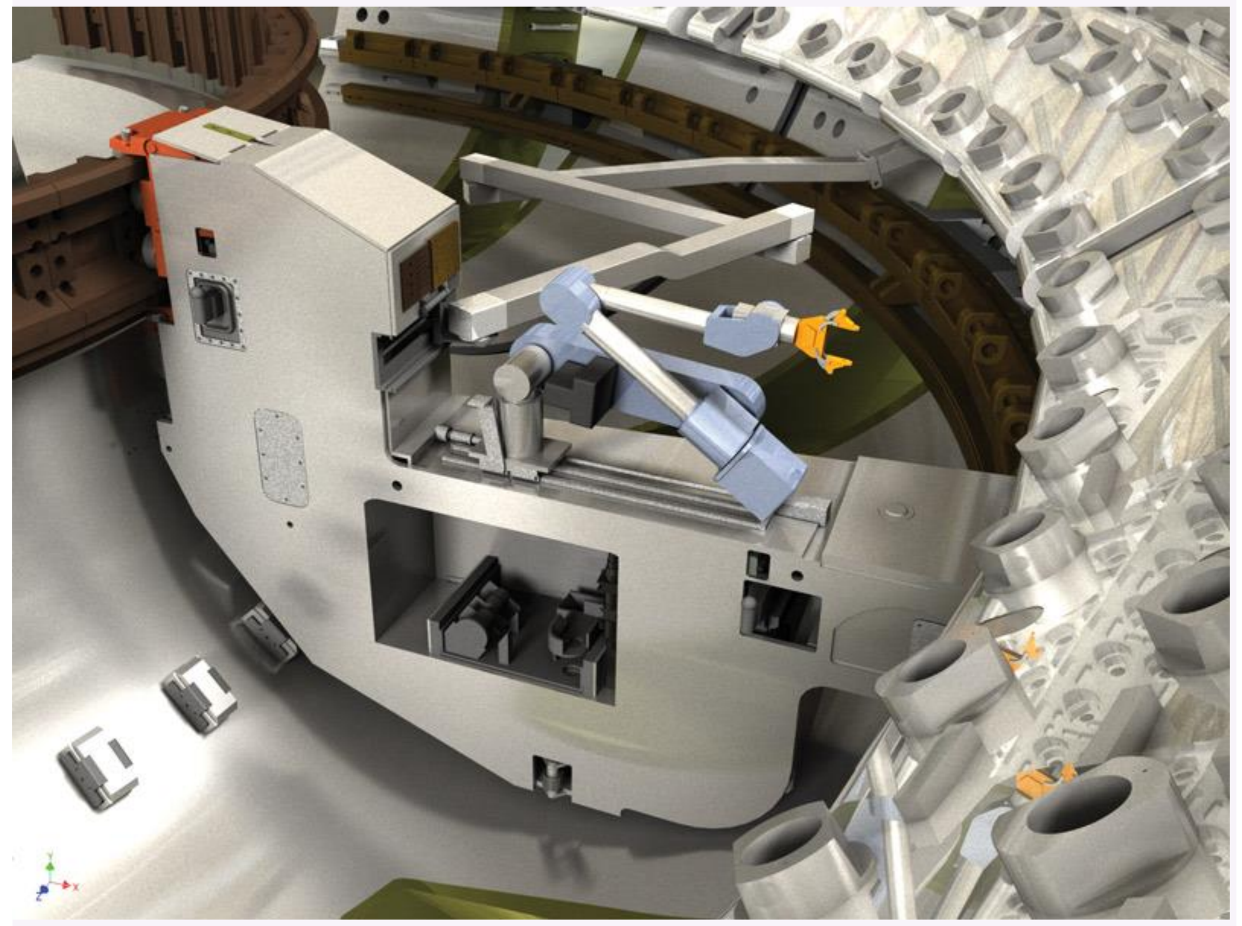
category

Backbone Frameworks

key disciplines

System Engineering	Software Engineering	I&C Conventional
I&C Machine Protection	Occupational/ Nuclear Safety	Fast Control [ns/μs]

context



GENROBOT

project

Test Bench Validation for GENROBOT

reference

F4E -OFC-0811-02, 2017

description

The project addressed a complete GENROBOT validation to make it ready for integration in RH equipment. Therefore, it was structured in several complementary activities:

- The development and testing of an electrical motor-based Test Bench for GENROBOT emulating interfaces to RH cubicle and field devices and sensors;
- Integration of GENROBOT to the Test Bench by developing a set of drivers (for CANOpen DS402 standard for motion control and EtherCAT I/O and servodrives), installing and configuring GENROBOT on the Test Bench; and
- Validation of GENROBOT on the Test Bench designing and running a set of configurations and test cases.

GENROBOT

project

Preparation of GENROBOT integration at DTP2

reference

F4E -OFC-0811-10, 2018

description

The project aimed at achieving:

- Functional Improvements, Source Code optimization and Issues Resolution;
- Project Documentation Development and Update-Testing & Integration activities; and
- Technical support activities.

More specifically, this project was a further consolidation step of the GENROBOT project to make it ready for integration in RH equipment and at DTP2 (VTT, Finland).

GENROBOT

project

Development and Validation of the RH Command and Control Application

reference

F4E -OMF-0811-16, 2019

description

This project aimed at developing and validating the primary operator interface toR emote Handling controllers, named the 'Command and Control' (C&C) application. The C&C has become a configurable operator interface to command and monitor RH equipment devices and tools. The C&C provides a GUI design compliant to ITER HMI requirements and is specially adapted to the 'man-in-the-loop' concept of RH operations. The C&C uses the GRI communication interface and is natively interfaced to the GENROBOT controller.
The development and validation of the C&C application was based in an incremental strategy.

← Back to INDEX

GEBROBOT

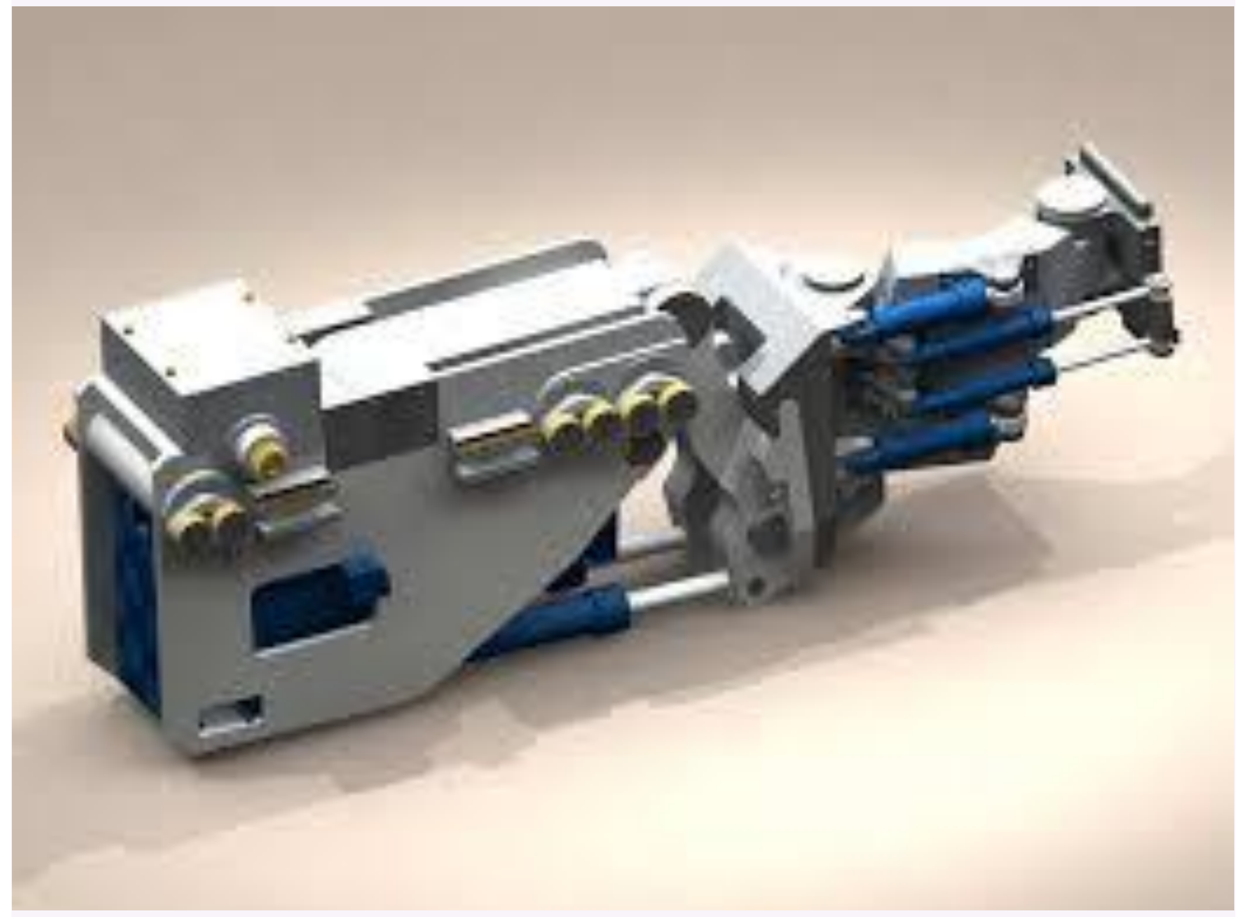
category

Backbone Frameworks

key disciplines

System Engineering	Software Engineering	I&C Conventional
I&C Machine Protection	Occupational/ Nuclear Safety	Fast Control [ns/μs]

context



GENROBOT

project

GENROBOT Consolidation

reference

F4E -OFC-0989-03, 2020

description

The main objective of the project was addressed at the consolidation of GENROBOT:

- Functional consolidation activities
- Test Plan for the final validation of GENROBOT through C&C
- Performance testing of the LLC
- EDD and user manual consolidation

Other activities were:

- GENROBOT platform update for obsolescence management, focus on software infrastructure upgrade, including porting some GENROBOT components to VxWorks 7.x 32 bits, the compilation of GENROBOT on 64 bits using the GNU compiler or the compilation of GENROBOT with the WindRiver certified DIAB compiler (in 64 bits) and studying the future portability of GENROBOT on a multi-core architecture.
- GENROBOT (pre)certification and audit - the subject of the certification should be the complete system (i.e.: the remote handling device and the GENROBOT software bundled together), yet GENROBOT was extensively reviewed and subjected to an external audit for certifiability.
- New integration of GENROBOT; including the integration with the VTT Remote Diagnostic Application; the interface to the VR4Robot platform; and the integration with the Master Arm.

GENROBOT

project

Operations Management System (OMS)

reference

F4E -OFC-0989-06, 2021

description

The project focused on the design and implementation of the entire Operations ManagementSystem (OMS) for ITER Remote Handling (RH); more specifically: its GUIs and its underlying database.
It also included the site integration at ITER (including interfaces top other HLCS) and the corresponding SAT.
Note that in order to ensure that RH operations are carried out safely and efficiently and to minimize mistakes or omissions by the operators, all RH tasks are planned at a detailed level. The final result of the RH task planning are well structured and documented RH tasks, which are stored and can be picked up and executed in future (potentially by RH operators who might not be involved in the task creation, but who are trained in the use of the RH equipment).
The OMS is further on required to formalise and record all RH task planning, as well as allow for controlled execution of pre-planned RH tasks.

←Back to INDEX

CODAC

category

Backbone Frameworks

key disciplines

Software Engineering | I&C Conventional | Fast Control [ns/μs]

context

CODAC - Control, Data Access, and Communication:

- Networking to communicate information between all plant systems and CODAC;
- Monitoring the ITER plant and displaying the status to operator stations;
- Acquiring, archiving and providing access to all engineering and scientific data concerning the operation of ITER for the duration of the project and beyond;
- Methods for specifying and verifying the parameters used during ITER operation, including during plasma pulses both on-site and remotely;
- Providing, distributing and monitoring a project-wide time reference;
- Providing, distributing and recording audio and video information inside the plant; and
- Operating ITER in terms of Global Operating States, which are linked to the Operation.

CODAC

project

CODAC Services Development and Maintenance

reference

IO/17/CT/6000000235, 2017

description

GTD was awarded a framework contract for the development and maintenance of the CODAC.
The activity included:

- Design of "applications", by capturing the user and technical requirements for the CODAC application, specify the operation and API/interface, and defining the behaviours and rules that the application must provide. Develop, test and document the CODAC application following the community and ITER best practices.
- Design of "core" modules: Capture the common component requirements for the core module, wrap and extend the underlying 3rd party platform and framework that are provided as part of the configuration so that these can be changed with minimal impact on the community of developers, isolate those elements of the module that the user is most likely to enhance or extend to reflect more specific project requirements. Develop, test and document the core module following the community and ITER best practices.
- Maintenance: Integrate continuous updates and upgrades from the community such as CS-Studio monthly releases. Customise the products to ITER environment. Adapt them to new major or minor versions of underlying components. Provide data and software migration to a new platform procedure. Provide build, packaging, configuration and backup procedures and scripts. Detect, support, analyse and fix bugs. Prevent problems by refactoring the products to make them more robust, flexible and extensible.- Release preparation: Prepare, build, test, document, coordinate and deliver major, minor, patch or snapshot release for ITER users according to requirements and plan. Audit the quality. Benchmark the performances. Produce test reports. Produce the release notes.
- Technical support: Support CODAC services users, develop templates and standard resources, prepare integration procedures and tools, develop CODAC operator interface according to requirements and plan.

CODAC

project

CODAC Core System Software Maintenance

reference

IO/21/CT/6000000350, 2021

description

This framework covers the supply of software maintenance services for the CODAC Core System distribution, through the construction and commissioning phases of the ITER project for the period of 2021-2026. The scope of the services includes:

- Preventive maintenance: Identify unknown defects and fix those selected;
- Corrective maintenance: Diagnose an issue, resolve it and verify the resolution;
- Perfective maintenance: Specify, implement and test/verify improvements; and
- Adaptive maintenance: Adapt code to changes in dependency software, e.g. operating system and drivers.

QA and the improvement of testability is an important aspect across all parts of this work, focusing on the improvement of scripted/automated software testing (unit tests as well as integrated testing). In this sense, software maintenance duties include but are not limited to the following tasks:

- Reviewing and assisting with updating if required the software technical specifications, in particular the Software Requirements Specification (SRS);
- Reviewing and updating if required the design document, in particular the Software Architecture and Design Description (SADD), with the impact of design changes;
- Detailing the changes or new features, implementing them and maintaining the status of the implementation in the issue tracking system;
- Updating the tests and the test plan;
- Executing the test procedures for the component;
- Updating the user documentation, in particular the Software User Manual;
- Updating the material for user support, such as online documentation, change logs, and knowledge database entries;
- Updating the material for training (e.g., review presentations and update exercises).

Back to INDEX

FAST PLANT CONTROLLERS

category

Bespoke Electronics

key disciplines

Sofyware Engineering | I&C Conventional | Bespoke Electronics | Fast Control [ns/μs]

context

F4E is responsible for the development of many ITER plant systems, covering a wide range of scope, which spans from more industrial systems (e.g. cryogenics) towards more scientific and fusion specific plants (e.g. additional heating and diagnostics). The integration strategy between these systems I&C and the central CODAC systems is prescribed by the Plant Control Design Handbook. One of the main actors in the integration process is the Plant System Controller, which bridges the plant specific data acquisition system with the central I&C networks. The plant system controller is further categorized in slow and fast: the former is expected to be used when the function can be implemented using COTS industrial components - typically PLCs; while the latter is tailored to fast control loops (> 100 Hz).While for slow controllers the project strategy was already sufficiently clear to enable the design, development and integration of a plant system I&C in ITER, for fast systems there were still several open questions to be addressed. In particular there were no clear and concise requirements on the hardware interface protocols and there was no existing software solution for the implementation of complex real-time software algorithms.

FAST PLANT

project

Advanced conceptual design of the plant system controller hardware and software architecture

reference

F4E-OFC-361-04, 2014

description

The advanced conceptual design of the plant system controller hardware and software architecture was implemented by GTD.
At the end of this project, a design review involving all the main stakeholders (ITER, F4E, GTD and external experts) has concluded that:

- The requirements for the system were properly documented but were not fully defined and should be better clarified before proceeding with the actual design;
- The interfaces for the proposed design were defined but were not fully specified. In particular the physical interface between the diagnostic and central interlock system should be better defined and prototyped during the next design activity; and
- The viability of the design was demonstrated against the F4E understanding of the requirements at the time of the design review.

FAST PLANT

project

Fast Plant Controller Prototype

reference

F4E-OFC-361-06, 2015

description

Assessment of plant controller hardware:

- To explore ITER selected data acquisition technologies while keeping in mind the F4E plant system requirements and prospective use cases;
- To investigate ITER existing solution of real-time and timing networks, while expanding the scope towards 1 GbE solutions; and
- To investigate ITER existing or market available solutions for very fast (1μs or above) solutions for logic/decision controllers. This includes both simple logic in/logic out solvers and hybrid analogic/digital solvers.

Development of a plant system fast controller prototype:
The prototype demonstrated the orchestration between all the components involved in the configuration, execution and monitoring of plant system real-time control processes. In particular it has allowed to assess the required levels of reliability and performance for plant systems, including:

- The prototyping, assessment and improvement of the real-time framework selected by F4E in order to meet the ITER requirements in terms of software quality assurance: the MARTe framework;
- Definition and setup of an appropriate Quality Assurance process for the upgrading and development of new framework components;
- Implementation and deployment of a software configuration management system to be used by the framework developers;
- Contribution to the development of new framework features and components;
- Development of specifications, design and user documentation of the framework and its architecture;
- Development of specifications, design and test documentation; and
- Formal testing and validation of the developments of reference.

←Back to INDEX

cRIO Hotlink Modules

category

Bespoke Electronics

key disciplines

Software Engineering | I&C Conventional | Bespoke Electronics | Fast Control [ns/μs]

context

The ITER EC Control System will be used in a noisy environment from the EMC point of view. Moreover, many of the necessary measurements, which need to be transmitted to the control cubicles, are taken in the high voltage area. To overcome these problems, whenever possible, the communication is performed by using optical links. The CRIO-HotLink-TX (transmitter) and CRIO-HotLink-RX (receiver) modules, are respectively a high speed analogue to optical converter and a high speed optical to analogue converter.
A typical application of the modules is to implement a high speed digital interface with the High Voltage Power Supplies for Gyrotrons at ITER. Another application of the module is to interface millimeter-wave radio frequency detectors with the Gyrotron control system, providing a high speed analogue link by means of an optical fiber. Both the transmitter and the receiver have three interfaces: analogue interface, optical serial interface and digital parallel interface.

— The analogue interface provides 2 differential input and 2 single ended output channels.
— The digital parallel interface is an 8 bit parallel bus compatible with the National Instrument Compact RIO Chassis.
— The optical interface allows transmitting and receiving of 200 Mbit digital data encoded using 8b/10b protocol. The modules can be configured for full speed 5 Msps single channel transmission or 2.5 Msps double channel transmission.

cRIO

project

HotLink transceiver modules

reference

F4E-OFC-0811-07, 2018

description

The activity covered by these project is related to the final design, procurement, testing and qualification of optical receiver and transmitter modules, previously designed.
The functions of the Transmitters are:

- Acquiring analogue signals via two differential 14-bit ADCs at 5 MSPS;
- Control the one or two-channel operation:
  - In the one-channel operation, only the ADC1 is sent to the FO transmitter and the CompactRIO backplane at a data rate of 5 MPSP;
  - In the two-channel operation, both ADC inputs are sent to the FO transmitter and the CompactRIO backplane at a data rate of 2.5 MSPS each.
- Control the normal or test mode; in test mode, a sawtooth signal generated in the module internal FPGA is sent to the backplane and to the fibre optic transmitter;
- Send the acquired analogue signals via the fibre optic transmitter; and
- Send the acquired analogue signals to the CompactRIO FPGA via the backplane.

The functions of the Receiver are:

- Receive the optical bitstream via the optical receivers;
- Decode the received signals;
- Drive the DACs to expose the analogue signals as outputs;
- Send the received signals to the CompactRIO FPGA in the backplane;

For both the Transmitter and the Receiver boards, the project addressed:

- Final design, including complete documentation;
- Modules Manufacturing (components acquisition, PCBs assembling, Hardware testing);
- Design, implementation and testing the firmware for above described functionality; and
- EMC testing for CE marking on the produced boards

cRIO

project

CRIO HotLink Manufacturing

reference

F4E-OFC-0811-17, 2019

description

Within the task order (TO) TO-07 of the framework F4E-OFC-361 the design of the modules has been documented and a batch of 20 transmitter modules and receiver modules produced and tested. On this basis, the activity in this project consisted in:

- Update the designs of HotLink modules and prepare for manufacturing; indeed the designs needed to be updated in order to accommodate new requirement regarding the possibility to enable or disable the analogue input circuit of the module. It was also checked for any potential supply RoHS or REACH issues;
- Manufacture the HotLink modules;
- CE marking of the HotLink modules; and
- Investigate new version of module using SFP with or without HotLink2.

←Back to INDEX

CENTRAL SAFETY SYSTEM

category

Engineering Services, incl. on-site support

key disciplines

Software Engineering	Occupational/ Nuclear Safety	Slow Control [ms]
Fast Control [ns/μs]		

CENTRAL SAFETY

project

Nuclear I&C Engineering Services

reference

F4E-OFC-620, 2015-2019 (in partnership Wood PLC)

description

The framework concerned the supply of services in the field of Instrumentation and Control System Engineering aiming to support F4E with the preparation of technical specifications, the follow-up of contracts and the acceptance of systems. The support addressed mainly the design of nuclear safety I&C systems.

CENTRAL SAFETY

project

Central Safety Systems: Lot 1 - System Engineering Services

reference

F4E -OFC-0811-10, 2018

description

The project aimed at achieving:

- Functional Improvements, Source Code optimization and Issues Resolution;
- Project Documentation Development and Update-Testing & Integration activities; and
- Technical support activities.

More specifically, this project was a further consolidation step of the GENROBOT project to make it ready for integration in RH equipment and at DTP2 (VTT, Finland).

CENTRAL SAFETY

project

Central Safety Systems: Lot 3 - Prototypes and dev. services

reference

F4E -OFC-0811-16, 2019

description

IO may request support to realize prototypes or mock-ups of nuclear or occupational safety systems, temporary CSS-N and/or CSS-OS subsystems and participate in the acceptance testing and integration of PSS-N and/or PSS-OS.

Services:

- Specification, selection of Hw and Sw components and detailed design of prototypes, mock-ups and/or temporary subsystems.
- Specification, design and development of testing tools to support acceptance and integration tests of ITER safety systems and components (both hardware and software).
- Development of software for safety PLCs and SCADA for prototypes, mock-ups and/or temporary subsystems.
- Mounting, integration and testing of prototypes, mock-ups and/or temporary subsystems.
- Participation in acceptance testing of PSS-N and/or PSS-OS.
- Definition of integration procedures for PSS-N and/or PSS-OS.
- Participation in the integration of PSS-N and/or PSS-OS.
- Technical assessment of hardware and software products and elaboration of proposals for its possible use in ITER safety systems.
- Draft Human Machine Interface (HMI) diagrams for the specification of the CSS-N and/or CSS-OS mimics.

Back to INDEX

ELECTRICAL NETWORK

category

Engineering Services, incl. on-site support

key disciplines

Software Engineering | I&C Conventional | Slow Control [ms]

context

ELECTRICAL NETWORK

project

Design and implementation of the Mini CODAC Development for SSEN

reference

F4E-OFC-0811-03, 2017

description

The scope of this project (full title: Design and implementation of the Mini CODAC Development for the ITER Steady State Electrical Network (SSEN)) focused in the development of the mini CODAC OPI's and communication of first part of SSEN HV (UTIL-HV), SSEN MV (UTIL-MV only for MV03) as well as the first part of SSEN-LV (UTIL-LV2), which were installed in the second quarter of 2018.

The pieces of equipment concerned were:

- 400 kV substation
- B36 22 kV Substation
- MV03 Load Centre (UTIL-MV)
- LC11 including low voltage
- LC06 including low voltage

For all these components, the project consisted in:

- The design of Mini-Codac HMI for the Electrical distribution System (SSEN) according to applicable requirements for HV part and the LV parts (LC11&06);
- The implementation of archiving and alarm handling for available signals;
- The development of a SIEMENS WinCC OA software that shall act as a gateway between IEDs and CODAC, by means of an OPC-UA server;-
- The programing of PLC controllers and the interface development of the OPC-UA server to PSH; and-
- The Full Mini-CODAC commissioning (verification of the visualized data and commands integrated in each synoptic).

ELECTRICAL NETWORK

project

Design and implementation of the Mini CODAC Development for PPEN

reference

F4E-OFC-0811-12, 2019

description

Following the successful experience with the SSEN (Steady State Electrical Network), F4E awarded GTD the design and implementation of the Mini Codac Pulse Power Electrical (PPEN).
It covered the full design, implementation and commissioning.
The Mini-Codac system was developed to offer comprehensive view of the different equipment from the electrical distribution systems. The scope of the project was limited to the development of the mini CODAC OPI's and communication of first part of PPEN HV (UTIL-HV) as well as the additional load centers connected to the 22kV SSEN network:

- 400kV substation;
- 66kV kV Substation;
- 22 kV Substation;
- Additional load centres:
  - MV02, MV01
  - LC03, LC05, LC10, LC14

ELECTRICAL NETWORK

project

Load Centers

reference

ENGIE Contracted, 2019

description

The project addressed the design and supply of the I&C for the load centers.
It covered:

- The Design, Manufacturing and Supply of the I&C cubicle of Load Center 05;
- The Design, Manufacturing and supply of the I&C cubicle of Load Center 14; and
- The Design, programming and Test & Commissioning of the control system of the LV-1 group of load Centers.

The LV-1 group include the LC04, LC05, LC10, LC13, LC14 and all the SDB's fed by these load centers.
The system was tested and commissioned on ITER site.

Back to INDEX

I&C SERVICES

category

Engineering Services, incl. on-site support

key disciplines

- System Engineering
- Software Engineering
- I&C Conventional
- Occupational Safety
- Slow Control [ms]

context

EU Cryoplant
The ITER cryogenic plant system provides cooling at 4 K, 50 K and 80 K to the 'users' (i.e. superconducting magnets, thermal shields and cryopumps of the ITER machine). It is made of four main components:

- LHe plant: Supplies cooling power at 4 K and 50 K,
- LN2 plant: Provides the cooling power for pre-cooling the LHe plants and cooling the 80 K loops,
- Cryodistribution: Provides the piping and ancillaries for the transportation of cryo-coolant to the users, and
- Master Controller: Coordinates the operations of the three systems described above.

The delivery of these components are managed by three parties of the ITER project (ITER Organization - IO, Indian Domestic Agency – INDA, European Domestic Agency – F4E), and implemented by four different suppliers - with possible chain of sub-contractors involved in the I&C SW development. In order to mitigate the risks due to the development of heterogeneous applications amongst the different suppliers, a specific ITER cryogenics PLC and HMI software framework has been developed. This framework is made of a number of software objects that implements standard functionalities and interfaces in PLC, with a matching HMI representation (super-symbol and faceplate).

BUILDINGS

project

Integration of buildings into ITER CODAC central system

reference

F4E-OFC-0361-07, 2014

description

The project was intended for the integration of the Building Management Systems (BMS) and various liquid and gas distribution systems, covering final design, manufacturing and commissioning phases. In particular, the project addressed the TB04, which covers the following ITER buildings:

- Nuclear Buildings B11, B14, B74
- Non Nuclear Building: B13, B15, B61, B17, B51, B52, B53, B71, B75
- Additionally, the Liquid and Gas distribution and generation system for ITER site (PBS65) was also addressed by the project, including control and monitoring from CODAC. In particular:
- Compressed Air System
- Demineralized water system
- Nitrogen systems
- Breathing Air System; and
- Helium Gas Distribution.

BUILDINGS

project

Mini CODAC Development for B61, B13-17, B32, B33, B36, B38 and PBS65 services.

reference

F4E-OFC-0811-06, 2018

description

The scope of this Task Order included:

- Design of Mini-Codac HMI for all the equipment's associated with the BMS of the building B61, B13-17, B32, B33, B36, and B38 as well as all the liquid and gas production systems in Building 61
- the Mini Codac system contained a comprehensive view of the different building equipment (HVAC, electrical distribution, Fire detection, etc.);
- Interface development of the PSH – BMS;- Interface Development of the PSH – Liquid and gas controllers;-
- Full Mini CODAC commissioning (verification of the visualised data and commands integrated in each synoptic).

BUILDINGS

project

I&C Execution Design of the B74, Heavy Nuclear Doors and Cryoplant Integration

reference

F4E-OMF-0989-09, 2022

description

This project refers to the following activities:

- Design of I&C systems in building B74, Tokamak Complex: HVAC, Utilities (Potable and Demineralized water, Industrial and Sanitary Drainage, Gaseous Nitrogen, Liquid leak detection system, Helium and Compressed Air) and Low voltage.
- Development of Tokamak complex BMS.
- Development of Tokamak Complex Plant Safety System for Occupational Safety, providing adequate mitigation for anoxia and monitoring breathable air supply, verified and validated as per IEC 61511.
- Development of Tokamak Complex Building Plant (Occupational) Safety System –as per IEC 61511.
- Development of the conventional control of the Heavy, Nuclear Doors of the Tokamak Complex, including integration into CODAC.

Additional on-site engineering services:

- Engineering support for CODAC integration, follow-up of I&C installation on site, SAT activities and commissioning
- I&C support to F4E I&C activities in the Cryoplant.

Back to INDEX

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Footprint in Fusion

Ongoing activity and key references



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