

CMS ECAL Sub-Project Specification**Sub-Project Name: Detector Control System (DCS)****Version: 1.0****Approval:**

	name	signature	date
Sub-Project Manager	G. Dissertori		
ECAL Project Manager	P. Bloch		

1.0 Scope

The scope of this project is the design, development, prototyping, testing, production and operation of the ECAL Detector Control System (DCS), traditionally known as “slow control system”. This system comprises the monitoring of the (hardware) status of the detector and of various kinds of environmental parameters, as well as the detector safety system which will generate alarms and hardwired interlocks in case of situations which could lead to damaging the detector hardware. The subdetectors concerned are ECAL Barrel, ECAL Endcaps and the Preshower.

In terms of hardware this project is responsible for all environmental sensors which are read out independently from the “standard” data acquisition chain, where data are transferred to some upper level readout system via optical links. That means, this project is not responsible for the readout of temperature sensors implemented in the capsules, of temperature sensors implemented in the VFE, FE and LVR PCBs (via the DCU), and of the reading of APD dark currents. It is also not responsible for the setup, control and monitoring of the front and very front end electronics. Nevertheless, an interface will be implemented between the DCS and DAQ software systems in order to transfer the relevant data to and from DCS, as well as to and from central databases such as the Run Conditions Database.

We understand that sensors relevant for the cooling system such as flow meters will be tested and installed by the cooling group. However, the readout of these sensors and the connection to the safety system (using Programmable Logic Controllers, PLCs) will be handled by the DCS group.

The DCS project is also not responsible for the setup of the laser monitoring system, as well as the High and Low Voltage Systems. However, the final operation of these systems (such as raising and lowering voltages, preparation of the laser system) should be handled from one (or more) central DCS stations.

Note that the main emphasis in this document will be given to the ECAL Barrel. For the Endcap a system as similar as possible will be envisaged. For the Preshower (SE) this document concentrates on temperature monitoring (cooling and heating screens).

2.0 Requirements

In this section details on the requirements on the system will be given.

Functions:

ECAL EB + EE:

- a) Precision temperature monitoring of the crystal cooling system (Temperature at the input, output, thermal screen and grid) in order to control the required temperature stability of the crystals and the APDs. Feedback to the cooling system is given.
- a) Temperature monitoring of the environment inside a module and generating of soft-and hardware alarms in case of critical readings (i.e. generating an interlock signal to be sent to the low and high voltage systems). This is called safety system (or also Temperature Safety System, TSS).
- a) Monitoring of flow/pressure meters in the cooling system and generating soft-and hardware alarms (see b)

- a) Monitoring of the humidity level in ECAL. Generating software alarms in case of critical readings.
- a) Monitoring of strain gauges. Relevant ONLY during installation, and not an integration issue since they will be mounted outside of supermodules (reference : Michel Lebeau)
- a) Monitoring of radiation sensors: Note that these sensors are not discussed further in this document, since a CMS-wide project is undertaken in order to find specifications. In addition, most likely these will not be installed inside a supermodule.

SE:

- a) Monitoring of the temperature sensors on the heating screens and of the related feedback system.
- a) Monitoring of temperature sensors on the cooling circuit and generating soft-and hardware alarms in case of critical readings.
- a) Monitoring of the humidity level.

Overall:

- a) setup of the software system for monitoring (logging and displaying) data from the environmental sensors given above, as well as from environmental data read out via the 'DAQ' chain (from DCUs).
- a) setup of the software/hardware which drives the system and generates/handles alarms.
- a) setup of the software system for the operation and monitoring of the detector status (high and low voltage, laser monitoring system)
- a) Reliable logging, storage and archiving of the data.
- a) Overall requirements for the software system are maximum stability and user friendliness.

Performance**ECAL EB+EE:**

- a) According to the cooling specifications, a temperature stability of $\pm 0.05^\circ$ (grid, thermal screen) is expected to be achieved. Therefore the sensors for the precision temperature monitoring system should be read with a relative precision of at least 0.01° (for the absolute precision 0.1° should be sufficient). In order to meet these stringent requirements, particular measures have to be taken in view of the length (120m) of the signal cable. All sensor readings should be updated about every few minutes.
- a) For the safety temperature sensors a precision of 1° is sufficient. Reading update: every 30 seconds.
- a) Precision required for the flowmeters to be defined by the cooling group. Reading update: every 10 seconds.
- a) Humidity sensors: The specifications are not final yet, and various types of sensors are currently under investigation. The required precision has an extremely strong impact on the sensor price. Requiring a precision of 5-10% should lead to a reasonable sensor cost.
- a) The requirements on strain gauges will be delivered at a later stage by the engineering group (according to M. Lebeau).

SE:

- a) The regulation system facing the EE has to insure a temperature stability of 0.5° . (Bloch et al., CMS NOTE 2000/064). Precision required for the sensors on the heating screen: 0.1° .
- a) For the safety temperature sensors a precision of 1° is sufficient. Reading update: every 30 seconds.
- a) Humidity : see point d) above.

Interfaces - the interfaces to other subsystems

The DCS project has interfaces to practically all other ECAL subprojects.

Integration: There is the obvious interface to the mechanics and electronics integration project, concerning exact location of sensors and related electronics (PCBs with multiplexers and transducers), their mounting and cable routing.

Upper-Level-Readout/DAQ: Communication has to be established via a software interface between the DCS and DAQ systems.

HV/LV/Laser: (Software-) Operation and monitoring of these systems. Interlock to the HV/LV systems from the safety subsystem.

Cooling: Reading of dedicated sensors (flow/pressure meters), and implementation of interlocks.

CMS DSS: the global CMS safety system will monitor the ECAL PLCs which are responsible for taking action in case of critical sensor reading and sending signals (interlocks). The global DSS takes action in case of no response of the ECAL PLCs. In addition a very small number of dedicated environmental sensors could be monitored directly by the global DSS. This has to be defined together with the DSS group.

Tracker: for certain environmental sensors (such as humidity sensors) a combined effort is undertaken to identify and test them. Experience in DCS issues can be obtained also from other subdetectors such as HCAL.

Mechanical

There are strong (space and cost) constraints on the allowed number of long signal cables. Therefore considerable multiplexing has to be implemented very close to the sensors.

Operating environment

All environmental sensors as well as additional electronics close to them (PCBs with multiplexers and transducers) have to be radiation hard and insensitive to the magnetic field.

3.0 System Description

A detailed description of the subsystems

- *Precision temperature monitoring*
- *Humidity sensors*
- *Temperature Safety system*

are given in the attached documents.

Regarding the TSS the following observations are necessary: A safety system should be fully independent from any other data acquisition and monitoring system, and it should be highly reliable (which also means that it should have the lowest possible fake alarm rate) without influence on the main electronics. Together with financial limitations this puts stringent constraints on the number of sensors and their positions. It is requested to monitor the temperature of every VFE, FE and LVR board in order to avoid a potential damage by overheating. This can be achieved by placing a DCU on every board. The data will be transferred from the DAQ to DCS and software alarms can be generated when the system is running (the DCU is running as soon as the system is powered up). As independent safety system we propose to put two sensors (redundancy) per module in order to monitor the air/environmental temperature. Thus in the costing given below we concentrate on solution 3' of the more detailed description in the TSS proposal.

Regarding the flow/pressure meters a combined effort together with the Tracker and other CMS DCS groups has started in order to start a collaboration with the cooling group.

A detailed description of the subsystems regarding the SE can be found in CMS NOTE 2000/064 and in the CMS ECAL Preshower and Endcap Engineering Design review.

The DCS software system will be fully based on the commercial SCADA system PVSS II, which is recommended by the Joint Controls Project (JCOP) at CERN, and which is also used on a CMS-wide basis.

4.0 Deliverables

In section 'Costs' (6.3) an item list can be found for some of the DCS subprojects.

5.0 Prototype and Production Quality Plan

Note that for the moment only a rough planning can be given.

5.1 Manufacturing plan

Practically all items (hardware and software) will be obtained from industry, from the shelf (sensors, cables, multimeters, PLCs, PCs). Critical items, mainly the PLCs, are currently scrutinized by the JCOP project (DSS subproject), and only recommended models will be ordered from industry.

What needs to be developed and produced on purpose are the T-MUX boards (see attached specification for the Precision Temperature Monitoring system). For this reason a collaboration with the LHC-ACR group has been initiated and as a result of this joint effort we may expect a manufacturing plan in the very near future.

5.2 Test plan

First tests of a temperature safety system and a precision temperature monitoring system have been performed during the M0' test beam period in summer 2002, and notes with descriptions of the test results should appear in fall 2002.

A next step for testing these two systems, as well as the integration of humidity sensors, is the construction of Module 0. Here the main purpose is to study all possible integration issues for cooling, electronics and DCS parts. The temperature safety system should be operational, other sensors might be simply replaced by mockups in order to test the positioning and cabling of sensors.

Regarding the precision temperature monitoring, a test setup is foreseen to be built during fall 2002 in order to study if the required high precision can be maintained with the proposed scheme (Keithley multimeter) over a signal cable length of about 120m. Furthermore, it is planned to analyse the maximum channel switching time which is achievable within the precision constraints.

After a successful development of a T-MUX board, the first prototype of this electronic system will undergo irradiation tests, foreseen for end of 2002.

Possible candidates for humidity sensors are currently being tested in collaboration with the Tracker DCS group (radiation hardness). Specifications are expected to be ready before end of 2002.

The development of the DCS software system will start in fall 2002, and intensive testing of a prototype system is foreseen to be performed in parallel with the setup and calibration of SM0.

It is foreseen to set up a database system (accessible via WEB), similar to an electronic logbook, where all test results should be logged, archived and easily accessible.

5.3 Installation plan

A detailed planning of the DCS integration will be elaborated in coordination with the electronics integration group. The installation procedure should include:

Part 1 – SM production

- testing/calibration of sensor assemblies (sensor probe + cable)
- installation of sensor assemblies in the detector (EB SM or EE Dee)
- testing that all installed sensors are OK

Part 2 – Installation in CMS

- laying down cables outside ECAL (probably a centralized activity)
- mounting connectors on the cables outside of the detector
- testing/calibration of the off-detector electronics (eg. T-MUX boards)
- installation of the off-detector electronics
- installation of the electronics and computers in the counting room
- connecting everything, powering on and final testing/commissioning

It is essential that items under Part 1 are synchronized with the ECAL EB/EE production schedule, i.e., they have to be performed during the SM/Dee assembly phase. Note that this item list will actually be split into two since temperature sensors on the thermal screen (or superbasket) have to be installed during the mechanical assembly stage, whereas sensors on the grid and pipes are more likely to be mounted during the electronics installation phase. Items under Part 2 are to be synchronized with the overall CMS assembly schedule.

5.4 Maintenance plan

Almost all hardware components will be designed in such a way to remain fully operational during the CMS lifetime. Redundancy for critical items goes into this direction. Repairing of on-detector elements (inside ECAL) is not envisaged, apart from exceptional detector openings.

Concerning the environmental sensors, periodical recalibrations will be necessary. In order to facilitate this task, we envisage to install additional sensors (of exactly the same type as the sensors in ECAL) outside CMS in the cavern. These are easily replaceable (once/year) and can be used to monitor any change in the sensor characteristics.

The T-MUX board will consist of replaceable components, which can be replaced every few years.

Systems such as the Keithley multimeter or the PLCs are off the detector, thus easily maintainable. Support from the manufactures (Keithley, Siemens) is anticipated.

The DCS software system will be heavily based on PVSS, for which maintenance and regular updates are expected to be delivered by the supplying firm. Nevertheless, such upgrades will not go without a certain main power investment by the DCS group. The maintenance of the software interface to the DAQ system is expected to be covered by the DAQ group.

Again, all actions in terms of maintenance or upgrades should be logged in the database mentioned under 5.2.

6.0 Project Management

6.1 Personnel

- 1) Günther Dissertori, ETH Zürich: Project Leader
- 2) Alison Lister, ETH Zürich: setup of software framework (PVSS) , started PhD in October 2002.
- 3) Serguei Zelepoukine, IHEP Protvino: Deputy Project Leader. Precision temperature sensors and humidity sensors.
- 4) Andrei Sidorov, IHEP Protvino: Electronics engineer. Development of a T-MUX system.
- 5) Serguei Gordeev, IHEP Protvino: Electronics engineer. Development of a T-MUX system.
- 6) Petar Adzic, VINCA Belgrade: Leader of the Belgrade group
- 7) Jovan Puzovic, VINCA Belgrade: Detector Safety System
- 8) Predrag Milenovic, VINCA Belgrade: Detector Safety System

6.2 Project plan

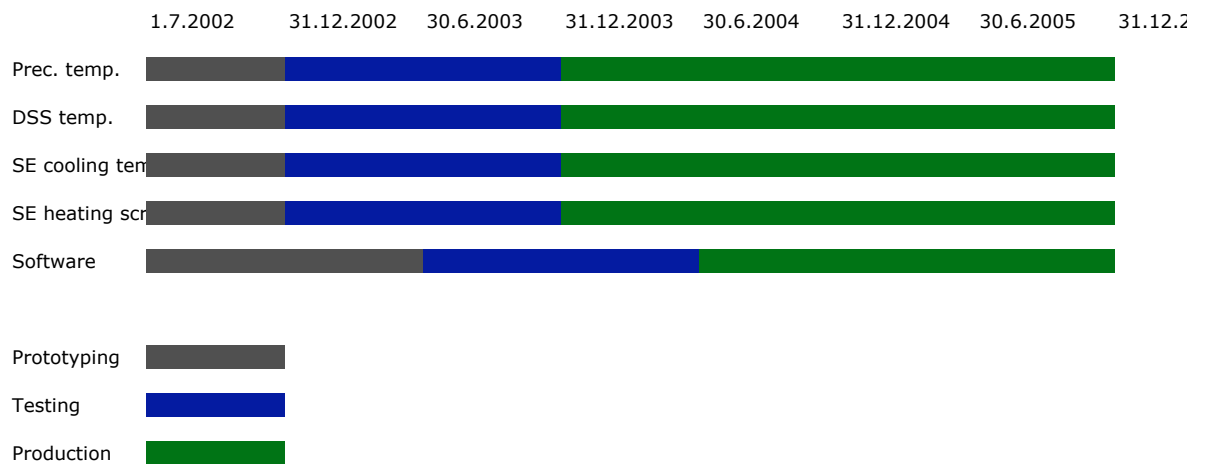
A very rough planning is given here. A more detailed planning for each of the subprojects shall be elaborated in fall 2002. The installation plan outlined in section 5.3 will define the major milestones, such as

- sensor probes / cables / SM patch panel connectors are ready for installation (i.e., ordered, delivered, assembled and tested/calibrated)
- electronics (T-MUX etc.) is produced and tested/calibrated, ready for installation
- cables outside of the detector are prepared (cables installed, connectors mounted and all components tested)
- power supply cabling is prepared and tested
- counting room electronics and computers are ready for installation (delivered, configured and tested)
- software applications are completed and tested
- system commissioning started

Below a preliminary scheduling proposal is given for those subprojects where major components are already well specified. This is not the case for the humidity sensors, the flow/pressure meters and the radiation sensors.

Planning (Time scales)

Item	Prototyping		Testing		Production	
	From	to	From	to	From	to
1 Prec. Temp.	1.7.2002	31.12.2002	1.1.2003	30.6.2003	1.7.2003	31.12.2005
2 DSS Temp	1.7.2002	31.12.2002	1.1.2003	30.6.2003	1.7.2003	31.12.2005
3 SE cooling ten	1.7.2002	31.12.2002	1.1.2003	30.6.2003	1.7.2003	31.12.2005
4 SE heating scr	1.7.2002	31.12.2002	1.1.2003	30.6.2003	1.7.2003	31.12.2005
5 Software	1.10.2002	30.6.2002	1.7.2003	30.6.2004	1.7.2004	31.12.2005



Man power requirements

Item	FTE	available	add. needed
ECAL prec. ter	3	3	0
ECAL DSS	3	3	0
SE cool. temp.	2	0	2
SE heat. scree	2	0	2
Software (PVS	6	3	3
TOTAL	16	9	7

6.3 Costs

The following remarks are important:

- i. The given cost estimates are very preliminary.
- ii. In particular, cost estimates are not yet available for the humidity sensors (since the sensor type is not specified yet), for the strain gauges (not specified yet, see remark under 2.0,e) and the flow/pressure meters (specifications expected to become available by the beginning of 2003).
- iii. In order to get an estimate also for EE, it is assumed that an EE quadrant is equipped with the same number of sensors as an EB supermodule.

6.3.1 Precision Temperature Monitoring

Cost estimates for the ECAL precision temperature monitoring app.

Option b : Two sensors per point (redundancy)

No. SM (EB)	36
No Quadrants (EE)	8
No. sensors per SM (or Quadrant)	10
Total No. sensors EB+EE	440
No. aux. (external) sensors -- installed	20
No. aux. spare sensors (periodic replacement, 2 yrs)	100
Total No. sensors - installed	460
Total No. sensors: installed + spare	560
No. T-MUX module channels (min)	12
No. T-MUX modules per SM (or Quadrant)	1
Total No. T-MUX modules -- installed	44
No. T-MUX modules -- spare	6
Total No. T-MUX modules (installed + spare)	50
Replaceable parts of T-MUX module (analog MUX)	132
No. T-MUX assemblies	4
(Each assembly includes a distrib.module and 10-16 T-MUX modules)	

Item description	Cost (CHF)	
	Per unit	Total
Sensor assembly (sensor + probe)	8	4480
Signal cable "sensor – patch panel", 1x STP, 3 m	3	1380
Patch panel (transition connector), 1 per SM, (1 CHF/pin)	20	880
Cable "patch panel – T-MUX", STP, 40m (5 CHF/m)	200	8800
T-MUX module (installed + spare)	200	10000
Replaceable parts of T-MUX module (analog MUX) -- spare	30	2640
Control distribution module, 12-16 outputs -- incl. 2 spare units	100	600
Control distribution cable, 12x STP, 120 m (5 CHF/m)	600	600
Control distribution cable, 12x STP, 40 m (5 CHF/m)	200	600
Power supply, 1 per T-MUX assembly	100	600
Power cable, 1 per T-MUX assembly, 120 m (3 CHF/m)	360	1440
Signal cable "T-MUX assembly – K-2750", 12x STP, 120 m (5 CHF/m)	600	2400
Keithley 2750	10000	10000
Digital I/O card, buffered transmitter module	500	500
Keithley 2750 spare	10000	10000
Digital I/O card, buffered transmitter module spare	500	500
PC (hardware only)	2000	2000
	Total:	57420
Including safety factor of 30%	Total:	74646
	Rounded	75000

6.3.2 Temperature Safety System

Preliminary specifications and cost estimates for ECAL Temperature Safety System (TSS)

I) 2 sensor points per module (T-MUXs, NTC, Twins)

1 T-MUX per SM	(36 SMs)x(2 twins)x(4 sensor points x 2 sensor wires) = 36x16 wires to T-MUX rack (average length 13m inside EB + 30m to T-MUX racks outside CMS)
1 T-MUX per quadrant	(8 quadrants)x(2 twins)x(4 sens. points x 2 sensor wires) = 8x16 wires to T-MUX rack (average length 12m inside EE + 30m to T-MUX racks outside CMS)
36 T-MUXs per EB	(36signals + 8 control bits + 2xaGND + 4xPow) = 50 wires (average length 130m from T-MUX racks to Control Room)
8 T-MUXs per EE	(8signals + same as EB bits) = 8 wires (average length 130m from T-MUX racks to Control Room)

TABLE 1	M	SM	HB	B	Quadrant	EE	Rack	Sum	Cost/unit of distrib.	Total
Sensors	2	8	144	288	2	8	x	296	CHF 8	CHF 2'368
Ref. Sensors	x	1	18	36	2	8	x	44	CHF 16	CHF 704
Conectors	x	2	36	72	1	4	76	152	CHF 7	CHF 1'034
T-MUXs	x	1	18	36	1	4	40	40	CHF 200	CHF 8'000
Cables inside SM	x	16 avrg. 3m	x	x	x	x	x			
Cables inside quadr.	x	x	x	x	16 avrg. 2m	x	x			
Cables from SM	x	x	16 avrg. 30m	x	x	x	x			
Cables from quadrant	x	x	x	x	x	16 avrg. 30m	x			
Cables from T-MUX rack	x	x	x	x	x	x	58 avrg. 130m			
All cables (m)		1728	11520	23040	256	5120	7540	37684	CHF 0.2	CHF 6'129
										CHF 18'234

PCB (hardware interface to PLC)	CHF 300
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PLC System: 2 DO modules 5 AI modules 1 CPU module 1 PS + 1 IT module 1 Rack + Independent Pow. Supply Spare modules	Total Cost CHF 15'000
PC system (hardware only)	CHF 2'000

Total (Hardware) Costs Estimates	CHF 36'000
Total (Hardware) Costs Estimates including 10% spares and 30% safety factor	CHF 52'000

6.3.3 Preshower: Temperature safety system and Cooling screen

Sensors for Preshower

Note: here only those sensors are discussed which have to be installed and read out independently from the rest of the DAQ (FEC, CCU, etc)

Sensor description :

Name	Type	Function	Readout	Cost/Unit [CHF]
A	PT100 or Betatherm (Thermistors)	Heating screen (4 wire)	PLC	8
B	as A	Cooling (2 sensors / Tpoint)	as A	8

Number of Sensors

Name	per HScreen	per Cscreen	per Cscreen	SE mod	Total	Cost [CHF]
A	24			48	96	768
B		12	24	48	96	768
					192	
Cost Sensors						1536

Estimate for cooling monitoring (DSS)

MUX factor	16	Total number of TMUX	6
Number of TMUX / SE mod	3	Total chan # inside	96
Number of channels inside SE mod	48	Total chan # outside	6
Number pf channels outside	3		
Number of 1xSTP cables inside one SE mod	48	Total # of 1x STP cables insid	96
Number of 12xSTP cables outside SE mod (note : *3: to include LV+ctrl)	1	Total # of 12x STP cables ou	2
Number of Siem DO mod	1		
Number of Siem AI mod	2		
Number of Siem CPU mod	1		
Number of Siem IT	1		
Number of Siem PS	1		
Price of such a PLC system [CHF]	6750		
Number of power supplies	1		
Number of PC systems	1		

Estimate for heating feedback system

MUX factor	16	Total number of TMUX	6
Number of TMUX / SE mod	3	Total chan # inside	96
Number of channels inside SE mod	48	Total chan # outside	6
Number pf channels outside	3		
Number of 1xSTP cables inside one SE mod	96	Total # of 1x STP cables insid	192
Number of 12xSTP cables outside SE mod (note : *3: to include LV+ctrl)	1	Total # of 12x STP cables ou	2
Number of Siem DO mod	1		
Number of Siem AI mod	2		
Number of Siem CPU mod	1		
Number of Siem IT	1		
Number of Siem PS	1		
Price of such a PLC system [CHF]	6750		
Number of power supplies	1		
Number of PC systems	1		

Item	Total
1 Cooling system	
1.1 sensors (+mechanics)	768
1.2 cabling inside (+connector)	672
1.3 cabling outside (+connector)	1296
1.4 TMUX boards	1200
1.5 PLC system	6750
1.6 PLC system spare	6750
1.7 power supplies	1000
1.8 PC systems	2000
	20436
2 heating screens	
2.1 sensors (+mechanics)	768
2.2 cabling inside (+connector)	1344
2.3 cabling outside (+connector)	1296
2.4 TMUX boards	1200
2.5 PLC system	6750
2.6 PLC system spare	6750
2.7 power supplies	1000
2.8 PC systems	2000
	21108
Total (including 10% spares + 30% safety factor)	59408

6.4 Risk Management

- In comparison to the VFE electronics project the DCS project can be considered to be low-risk.
- Regarding the system development the main risk is considered to be the successful prototyping of a radiation hard T-MUX board. In an attempt to minimize this risk, two technicians from Protvino as additional resources have been dedicated to this task. They are working in close collaboration with the LHC-ACR group.
- During operation, the main risk will be the loss of a sensors and/or the readout chain (and thus of the monitoring) dedicated to the safety system. This can be mitigated by a redundancy of the components in the system.
- At the moment the SCADA system (PVSS) is not considered to be fully stable when running on a Windows-based operating system. Linux-PCs should allow for a reduction in the risk of a breakdown of the software system. In any case, we rely on the thorough testing and evaluation of PVSS by the JCOP project.

6.5 Design Reviews

Design reviews will be indicated as milestones on the detailed planning, which is to be elaborated for each individual subproject.

6.6 Project Monitoring

It is planned to introduce a monthly progress reporting to the ECAL project manager. Further progress reports will be given at the meetings of the CMS DCS group.