Title: **PLM EMC Control and Verification Plan**

DRD No.:

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1	22.4.02	All	First formal issue	
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1 Introduction

This Control Plan defines the EMC design and qualification program with its management tools and control methods to be used by ASED in order to ensure overall EMC of the payload module of HERSCHEL equipped with the instruments FPUs of HIFI, PACS and SPIRE, inclusive the cryostat control electronic.
The approach to manage and to demonstrate the compatibility is presented.
This document is not applicable to equipment of lower level sub-contracts, who may, however, review and confirm/correct/comment the assumptions made on their equipment (e.g. w.r.t. grounding and frequency plannings).
For the HERSCHEL customer this document demonstrates the high level of reliability in EMC control as well as the correct understanding of the requirements imposed on the hardware under control and responsibility of ASED. This document shall be used as input to the satellite level EMC Control Plan.
The EMC design and qualification program is based on the HERSCHEL H/W organisation tree, fig. 1-1, which reflects the understanding of both, test H/W levels and ASED responsibility (for design and test). It shall not be compared with the HERSCHEL H/W tree that is defined for other objectives.

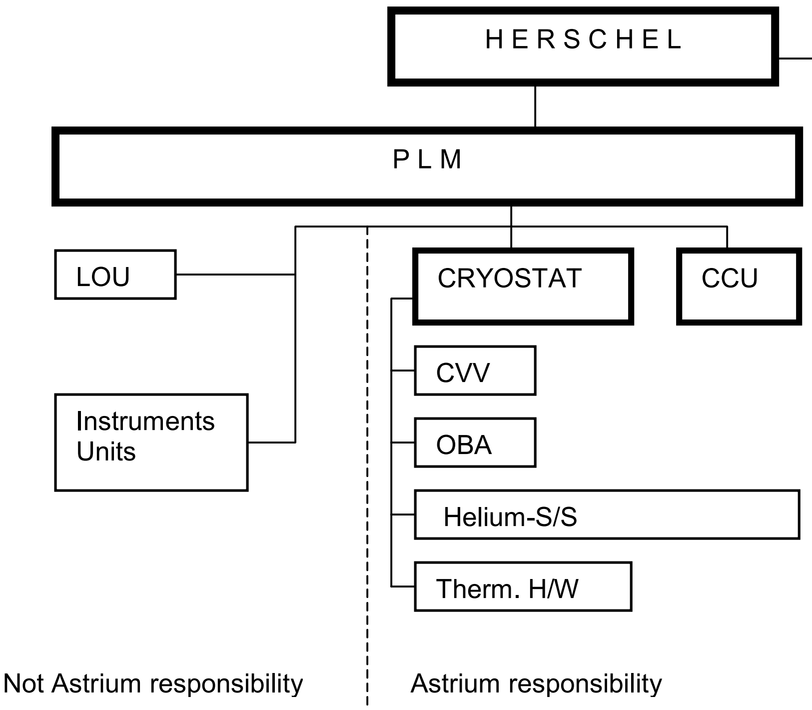

Fig 1-1: HERSCHEL PLM Hardware Organisation

2 Documents

2.1 Applicable documents

[AD1]	HERSCHEL EMC/ESD Control Plan	H-P-1-ASPI-PL-0038
[AD2]	HERSCHEL EMC Specification	H-P-1-ASPI-SP-0037
[AD3]	HERSCHEL GDIR	H-P-1-ASPI-SP-0027

2.2 Reference Documents

[RD1]	HERSCHEL Grounding Scheme	HP-2-ASED-DW-0001
[RD2]	Herschel/Planck EMC Analysis	HP-1-ASPI-AN-0202
[RD3]	Analysis on Feasibility of the CTA Internal RS Test Option	HP-2-ASED-AN-0001
[RD4]	EMC Test Plan	HP-2-ASED-PL-0037

3 EMC Management

3.1 Approach

The challenge of HERSCHEL is to realise a high performance mission with further aspects to be traded-off. This objective will be met by:
1. Effective specification with a good balance between specification margin and risk
2. Re-use of design and hardware already being used for ISO, a quite similar satellite which has performed its mission successfully.
3. Close co-operation with the HERSCHEL project and all of its subcontractors to provide for transparency of the objectives and identify areas of inconsistencies before they lead to harm for the HERSCHEL satellite project.

The figure below shows in general terms how the "EMC Management" will be performed. It clarifies also the evidence of the applicable documentations for HERSCHEL PLM w.r.t. EMC.

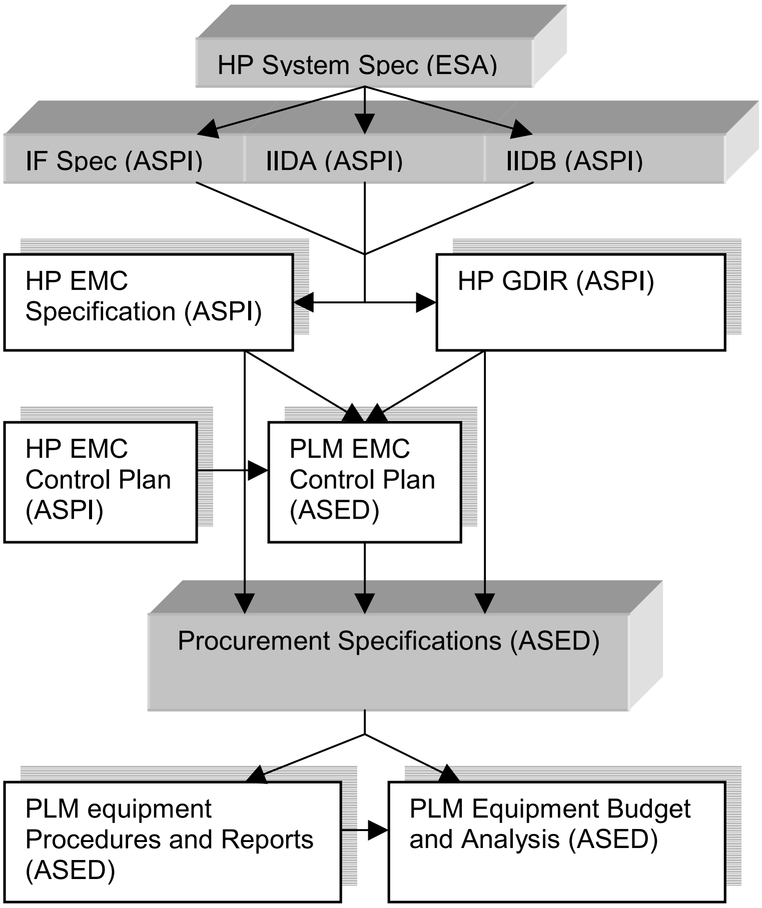

Fig. 3.1-1: EMC Management

The EMC design shall be reviewed periodically and in any case of change of any assumptions on which the design is based on (e.g. grounding concept, frequency planning). Critical areas in design, once addressed, shall be analysed asap. Therefore, first analysis models shall be kept simple and worst case, and standard EMC rules shall be considered (ref. [RD2] for a general example to calculate in 1st step a sensor link susceptibility). If the critical area w.r.t. EMC is confirmed by the simple model analysis result, it shall be decided either to go to design corrections or to re-analysis with a more precise model.
The simplicity of the analysis will result in an increase of visibility on critical areas and to the possibility to trade-off design corrections against each other quickly.

3.2 Responsibilities

ASED is responsible for the adequate design and the performance of all equipment subcontracted by ASED.
Although being formally not responsible for the payload instrument, ASED will support the Prime contractor by review of the EMC design of the payload instruments because the electromagnetic emission/susceptibility measured on PLM level will be a result of the instruments FPUs and their interactions inside the cryostat.

3.3 EMC Design

3.3.1 General

EMC design is based on the grounding concept meanwhile usual and well justified in the space businesses: The Distributed Single Point Grounding Concept (DSPG). The quality of the DSPG concept will determine the EMC performance of the equipments, instrument and HERSCHEL. Good quality means in general:

- All bonding have to made low resistive and low inductive, considering thermal constraints,
- digital interfaces have to be differential with optimised balanced signals,
- analogue TM/TC and non-differential interfaces must use lines isolated from ground.

Following the equipments/instruments specification will consequently lead to a design being adequate for EMC. Design risks will be reduced by reviews on the electrical design in the frame of the periodically performed progress meetings and reviews on HERSCHEL equipments and instruments (ref. §3.1).
Any EMC analysis necessary will be based on the grounding concept and the frequency plan. Both should be reviewed by each instrument team and confirmed, commented or corrected respectively.

3.3.2 Frequency Plan

The satellite frequency plan is the basis for analysis of the electromagnetic behaviour of the PLM. In this chapter the frequencies of the CCU are listed. The table shall be used as input for the satellite frequency planning done by ASPI.

Designation	Frequency		Comment	Level	Source
CCU DC/DC CV, freee running	100	kHz	+/- 10%		CCU Design Description, HP-2-PANT-DD-0003
Oscillator	16	MHz	D.C.: 33...67%		CCU Design Description, HP-2-PANT-DD-0003
MIL 1553 Interface clk	1	MHz			CCU Design Description, HP-2-PANT-DD-0003
AD conversion out	400	kHz			CCU Design Description, HP-2-PANT-DD-0003
DC/DC converter internal sync signal	100	kHz			CCU Design Description, HP-2-PANT-DD-0003

Table 3.3.2-1: CCU Frequencies (Input to HERSCHEL PLM Frequency Plan)

3.3.3 Grounding Diagram

The proposed grounding concept is shown in the scheme [RD1]. It comprises a DSPG system for minimisation of pick-up noise as well as minimisation of emission. In general the principle is based on the use of single ended or differential driver interfaces in combination with differential receivers or opto coupled interfaces. As a feature derived from ISO, there is no dedicated ground connection for the cryostat foreseen, i.e.: Grounding of the croystat can be accomplished by outer cryoharness overall shield and coaxial outer conductors only (last done for ISO).

3.4 EMC Verification

The objective of the HERSCHEL PLM /equipment verification program is the demonstration of HERSCHEL auto-compatibility (i.e. propper functioning in fully assembled configuration incl. compliance to the EMC specification, ref. [AD2]).

3.4.1 Methods

One can distinguish 3 different verification methods used to demonstrate EMC:

1. *Review of Design (ROD)*
This verification method comprises the visual examination of hardware related diagrams and drawings, descriptive files or hardware itself w.r.t. finishes, surface properties, dimensions etc.
2. *Analysis and Similarity Study (A/S)*
These verification methods may be used instead of or in combination with test data.
Similarity studies may be used when equipment or parts of equipment are similar or identical w.r.t. design and manufacturing to another product which has previously been qualified against similar requirements. Comparing test results, the test set-ups (especially harness characteristics and routing) shall be analysed.
3. *Test (T)*
Testing is the most preferred verification method for EMC requirements and will provide the most reliable information on the EMC performance.

3.4.2 Test Items

The following configurations are considered as suitable for EMC testing:

HERSCHEL PLM

- Cryostat (EQM: modified ISO QM cryostat)
- HIFI FPU with LOU
- PACS FPU
- SPIRE FPU
- SPIRE JFETs (Photometer and Spectrometer)
- Optical Bench Assembly
- PLM Thermal H/W (e.g. MLI)

Cryostat Control Unit (CCU)

- Unit level without MLI.

Solar Array

- Sunshade with OSR on front side and MLI on rear side
- Sunshield with Solar Cells on front side and MLI on rear side.
- Support structure (Struts, covered with MLI).

Instrument Warm Units

- HIFI Warm Units
- PACS Warm Units
- SPIRE Warm Units

4 HERSCHEL EMC Qualification Planning

4.1 Baseline Planning

In order to verify the proper instrument operation in the environment EMC tests can be performed on every relevant model of PLM, i.e.:

- the EQM Integrated Module consisting of a refurbished ISO cryostat including CQM FPUs and AVMs,
- the PFM Integrated Module which will be fully flight representative, and
- the satellite level

Tests on **EQM Integrated Module** can be performed for an early identification of any EMI emission and susceptibility. The modified ISO QM cryostat will be used including the focal plane units CQM operating at representative temperatures to have the detectors at representative sensitivity. The SIH cryo and the warm harness and its routing will be electrically flight representative. The optical windows to the HHLOU will be open to feed in the LO signals. The cryostat cover will be equipped with a miror surface which can be actively cooled in order to simulate the appropriate optical background to put the instruments to the sensitivity required for susceptibility test.
The instrument warm units will be integrated in a SVM dummy and interconnected with a representative harness.

The **PFM Integrated Module** shall be used for final acceptance w.r.t. EMC. It is fully representative except that the SVM equipment are not located in the SVM but on an external plate and w.r.t. the harness routing between the cryostat and the euipment of the service module.

The **PFM HERSCHEL S/C** is the most representative level as the SVM avionics equipment is complete and connected to the electronic equipment inside the CVV and on the CVV. EMC tests will be performed on this level in order to confirm the compatibility with the Launcher EMC requirements and to confirm the EMC performance of the spacecraft. It is important to note that although the satellite level tests will be performed by ASED, for the test definition and evaluation is subject of prime contractor responsibility.

It follows a table showing operational and structural representativity and objectives of the different test models w.r.t. EMC qualification.

	Configuration:
EQM Integrated Module	• ISO modified QM Cryostat • ~~Flight~~ Optical Bench Assembly • CQM FPUs/Outer CVV electronic (LOU ~~and BOL~~A) and CVV instrumentation • CVV inner cryo harness, el. representative • CVV SIH outer cryo-harness, representative • Equipped with specifically equipped cryostat cover • Avionics Modules: Instrument warm units integrated in a SVM dummy and interconnected with representative harness. ~~(no SVM)~~ • No telescope, no sunshield/sunshade
PFM Integrated Module	• Full flight configuration except: - CVV cover closed - No Telescope - No sunshield/sunshade
PFM Herschel S/C	• Full flight configuration except: - CVV cover closed
	Facility
EQM Integrated Module	• Cleanroom 100000 • Reference RF/IR sources (if needed)
PFM Integrated Module	• Cleanroom 100000 • Reference RF/IR sources (if needed)
PFM Herschel S/C	• Cleanr./Anech. Chamber (for RE) • Reference RF/IR sources (tbd/tbc)
	EMC Tests
EQM Integrated Module	• Radiated Susceptibility (RS) Refer to [RD4]
PFM Integrated Module	• Conducted Emission (CE) Refer to [RD4]
PFM Herschel S/C	• Conducted and Radiated Emission (CE and RE) Radiated Susceptibility (RS) Refer to [RD4]

Fig.4.1-1: EMC Tests and Configurations

5 Verification Matrix

It follows a first draft of the EMC verification matrix with reference to the requirements in the EMC specification [AD2]. The matrix addresses the particular requirement and propose a suitable verification method.
Please note that a not filled-in verification method means that the related requirement and its verification is not under ASED responsibility.

EMC Verification Matrix:

§		Key Words	EQM		PFM		
			PLM		S/C	PLM	
3.1.1	EMCSYS-000	S/C requirement, general			R		
3.1.2	EMCSYS-020	EGSE and MGSE to be designed to meet EMC with S/C			R		
3.1.3.1	EMCSYS-030	Radiation from Launch Vehicle			R		
3.2.1	EMCSYS-040	6 dB CE/CS margin on S/C level to be demonstrated			A		
3.2.2.1.1	EMCSYS050	RE E-field Narrowband in VEB plane in Launch Mode			T		
3.2.2.1.1	EMCSYS-052	RE E-field Narrowband at UHF and C-band in Launch Mode			T		
3.2.2.1.1	EMCSYS-055	Test once with Power supply, once with batterie			R		
3.2.2.1.2	EMCSYS-60	RE E-field Narrowband in Operational Mode at at 3 points around the cryostat from 14 kHz - 18 GHz			T		
3.2.2.2.1	EMCSYS-070	S/C RS E-field 14 kHz - 18 GHz			R		
3.2.2.2.2	EMCSYS-075	S/C RS H-field, 30 Hz - 66 kHz			R		
3.2.2.2.3	EMCSYS-080	S/C RS test with from three directions, tbd S/C configurations			R		
3.2.2.3	EMCSYS-90	CE measurements for not or marginal tested lines			R		
3.2.2.3	EMCSYS-92	CE Common and Differential Mode and noise tests on power lines between PCDU and instruments			T		
3.2.2.3	EMCSYS-094	Analysis to be run in case of limits exceeding. Approach in agreement with ESA			A		
3.2.2.3	EMCSYS-096	CE on TBD linkes between the SVM and PIM			T		
3.2.2.3	EMCSYS-098	Voltage ripple between SVM and PLM structure			T		
3.2.3.1	EMCSVM-000	The followong SVM tests in First and Planck configuration					
3.2.3.1.1	EMCSVM-005	SVM CE					
	EMCSVM-010	SVM CE					
	EMCSVM-020	SVM CE					
	EMCSVM-030	SVM CE					
3.2.3.1.2	EMCSVM-040	SVM CS					
3.2.3.2.1	EMCPLM-000	CE Common Mode Current on primary power lines between PLM and SVM				T	
	EMCPLM-010	CE Common and Differential mode on pre-amps and detector power lines (secondary power)					
3.2.3.2.2	EMCPLM-020	PLM CS on primary power lines (28 V)	R				
3.2.3.2.3	EMCPLM-030	RS **or** CS simulating RS test	T				
3.2.3.2.3	EMCPLM-035	CS simulating RS test per MIL 461E				R	
	EMCPLM-040	CS simulating RS in accordance to MIL 461E					
3.2.4.1	EMCEQ-000	General test requirements	R		R	R	
	EMCEQ-010	General test requirements	R		R	R	

§		Key Words	EQM		PFM		
			PLM		S/C	PLM	
	EMCEQ-020	General test requirements	R		R	R	
	EMCEQ-030	General test requirements	R		R	R	
	EMCEQ-040	General test requirements	R		R	R	
	EMCEQ-045	General test requirements	R		R	R	
3.2.4.2	EMCEQ-050	EMC qualification on flight equivalent units	R		R	R	
3.2.4.3	EMCEQ-060	EMC test documentation	R		R	R	
3.2.4.4	EMCEQ-070	Bandwidths	R		R	R	
	EMCEQ-070	Video filtering to be set to the greatest value	R		R	R	
3.2.4.5		All levels given in rms	R		R	R	
3.2.4.6.1.1.1	EMCEQ-100	RE-E-field general					
	EMCEQ110	RE TC notch					
3.2.4.6.1.1.2	EMCEQ-120	RE-E-field test methods					
3.2.4.6.1.1.2	EMCEQ-130	RE-E-field test methods					
3.2.4.6.1.1.2	EMCEQ-135	RE-E-field test methods					
3.2.4.6.1.1.2	EMCEQ-140	RE-E-field test methods					
3.2.4.6.1.2.1	EMCEQ-150	RE H-field, DC					
3.2.4.6.1.2.1	EMCEQ-160	RE H-field, DC					
3.2.4.6.1.2.1	EMCEQ-170	RE H-field, DC					
3.2.4.6.1.2.2	EMCEQ-180	RE H-field, narrowband					
3.2.4.6.2.1	EMCEQ-200	RS E-field	T		T		
3.2.4.6.2.1	EMCEQ-210	RS E-field	R		R		
3.2.4.6.2.1	EMCEQ-220	RS E-field	R		R		
3.2.4.6.2.1	EMCEQ-230	RS E-field	R		R		
3.2.4.6.2.1	EMCEQ-240	RS E-field	R		R		
3.2.4.6.2.2	EMCEQ-250	RS H-field AC	T		T		
3.2.4.6.2.2	EMCEQ-260	RS H-field AC	R		R		
3.2.4.6.2.2	EMCEQ-270	RS H-field AC	R		R		
3.2.4.6.2.2	EMCEQ-280	RS H-field, DC					
3.2.4.7	EMCEQ-300	ESD					
3.2.4.7	EMCEQ-310	ESD Test conditions	R				
3.2.4.7	EMCEQ-320	ESD Test conditions	R				
3.2.4.7	EMCEQ-330	ESD Test conditions	R				
3.2.4.7	EMCEQ-340	ESD Test conditions	R				
3.2.8.8.1.1	EMCPCDU-000	PCDU CE BB					
3.2.4.8.1.2	EMCPCDU-010	PCDU CE single transient event					
3.2.4.8.1.2	EMCPCDU-020	PCDU CE single transient event					
3.2.4.8.1.	EMCPCDU-	PCDU CE single transient event					

§		Key Words	EQM		PFM		
			PLM		S/C	PLM	
2	030						
3.2.4.8.1.2	EMCPCDU-040	PCDU CE single transient event					
3.2.4.8.1.2	EMCPCDU-050	PCDU CE single transient event					
3.2.4.8.1.2	EMCPCDU-060	PCDU CE single transient event					
3.2.4.8.1.3	EMCPCDU-070	PCDU CE single transient event					
3.2.4.8.1.4	EMCPCDU-080	PCDU CE NB					
3.2.4.8.1.5	EMCPCDU-090	PCDU CE test conditions					
3.2.4.8.2.1	EMCEQ-400	Equipment BB CE diff. mode					
3.2.4.8.2.1	EMCEQ-410	Equipment BB CE diff. mode					
3.2.4.8.2.2a	EMCEQ-420	Equipment CE narrowband					
3.2.4.8.2.2b	EMCEQ-430	Equipment CE narrowband test conditions (e.g. LISN)					
	EMCEQ-440	Equipment CE narrowband test conditions (e.g. LISN)					
	EMCEQ-450	Equipment CE narrowband test conditions (e.g. LISN)					
	EMCEQ-460	Equipment CE narrowband test conditions (e.g. LISN)					
3.2.4.8.2.3	EMCEQ-470	Equipment inrush current					
3.2.4.8.2.3	EMCEQ-475	Equipment inrush current					
3.2.4.8.2.3	EMCEQ-480	Equipment inrush current					
3.2.4.8.2.3	EMCEQ-585	Equipment inrush current					
3.2.4.8.2.3	EMCEQ-490	Equipment inrush current					
3.2.4.8.3	EMCPCDU-100	PCDU CS					
3.2.4.8.3	EMCPCDU-110	PCDU CS					
3.2.4.8.3	EMCPCDU120	PCDU CS					
3.2.4.8.3	EMCPCDU-130	PCDU CS					
3.2.4.8.3	EMCPCDU-140	PCDU CS					
3.2.4.8.4	EMCEQ-500	CS DM Contineous	T				
3.2.4.8.4	EMCEQ-510	Equipment and PLM CS	R				
3.2.4.8.4	EMCEQ-520	CS CM Contineous					
3.2.4.8.4	EMCEQ-530	Equipment and PLM CS	R				
3.2.4.8.4	EMCEQ-535	Equipment and PLM CS	R				
3.2.4.8.4	EMCEQ-540	Equipment and PLM CS	R				
3.2.4.8.4	EMCEQ-545	Equipment and PLM CS	R				
3.2.4.8.4	EMCEQ-550	CS DM Transient					
3.2.4.8.4	EMCEQ-560	CS DM Transient					
3.2.4.8.4	EMCEQ-565	Equipment and PLM CS	R				
3.2.4.8.4	EMCEQ-570	CS CM Transient					
3.2.4.8.4	EMCEQ-580	Equipment and PLM CS	R				
3.2.4.8.4	EMCEQ-585	Equipment and PLM CS	R				

§		Key Words	EQM		PFM		
			PLM		S/C	PLM	
3.2.4.8.4	EMCEQ-587	Equipment and PLM CS	R				
3.2.4.9.1	EMCEQ-600	General	R				
3.2.4.9.2	EMCEQ-610	CE Requirements on Signal Lines					
3.2.4.9.2	EMCEQ-620	CE Requirements on Signal Lines					
3.2.4.9.2	EMCEQ-630	CE Requirements on Signal Lines					
3.2.4.9.3	EMCEQ-640	CS Requirements on Signal Lines					
3.2.4.9.3	EMCEQ-650	CS Requirements on Signal Lines					
3.2.4.9.3	EMCEQ-660	CS Requirements on Signal Lines					
3.2.4.9.3	EMCEQ-670	CS Requirements on Signal Lines					
3.2.4.9.3	EMCEQ-680	CS Requirements on Signal Lines					
3.2.4.9.4	EMCEQ-690	CS/CE on MIL Bus					
4.	EMCSYS-100	S/C Testing Conditions			R		
4.	EMCSYS-110	S/C Testing Conditions			R		
4.	EMCSYS-120	S/C Testing Conditions			R		
5.	EMCPLM-100	Module Testing Conditions	R			R	
6.	EMCEQ-700	Equipment, S/S Test Cond.					
6.	EMCEQ-705	Equipment, S/S Test Cond.					
6.	EMCEQ-710	Equipment, S/S Test Cond.					
6.	EMCEQ-715	Equipment, S/S Test Cond.					
6.	EMCEQ-720	Equipment, S/S Test Cond.					
6.	EMCEQ-730	Equipment, S/S Test Cond.					
6.	EMCEQ-740	Equipment, S/S Test Cond.					
6.	EMCEQ-745	Equipment, S/S Test Cond.					
6.	EMCEQ-745	Equipment, S/S Test Cond.					
6.	EMCEQ-750	Equipment, S/S Test Cond.					
6.	EMCEQ-755	Equipment, S/S Test Cond.					
6.	EMCEQ-760	Equipment, S/S Test Cond.					
6.	EMCEQ-765	Equipment, S/S Test Cond.					
6.	EMCEQ-770	Equipment, S/S Test Cond.					
6.	EMCEQ-775	Equipment, S/S Test Cond.					
6.	EMCEQ-780	Equipment, S/S Test Cond.					
6.	EMCEQ-785	Equipment, S/S Test Cond.					
6.	EMCEQ-790	Equipment, S/S Test Cond.					
6.	EMCEQ-795	Equipment, S/S Test Cond.					
6.	EMCEQ-800	Equipment, S/S Test Cond.					
6.	EMCEQ-805	Equipment, S/S Test Cond.					
6.	EMCEQ-810	Equipment, S/S Test Cond.					
6.	EMCEQ-815	Equipment, S/S Test Cond.					
6.	EMCEQ-820	Equipment, S/S Test Cond.					
6.	EMCEQ-825	Equipment, S/S Test Cond.					
6.	EMCEQ-830	Equipment, S/S Test Cond.					
6.	EMCEQ-835	Equipment, S/S Test Cond.					
6.	EMCEQ-840	Equipment, S/S Test Cond.					
6.	EMCEQ-845	Equipment, S/S Test Cond.					
6.	EMCEQ-847	Equipment, S/S Test Cond.					
6.	EMCEQ-850	Equipment, S/S Test Cond.					
6.	EMCEQ-855	Equipment, S/S Test Cond.					
6.	EMCEQ-857	Equipment, S/S Test Cond.					
6.	EMCEQ-860	Equipment, S/S Test Cond.					

Legend:
A: Verification per Analysis
R: Verification per Review of Document
T: Verification per Test

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	Muhl Eckhard	OTN/EN 64		BOC Edwards	BOCE
	Pastorino Michel	ASPI Resid.		EADS CASA ESPACIO	CASA
	Peitzker Helmut	ED 65		Eurocopter	ECDE
	Peltz Heinz-Willi	SM 33		HTS AG Zürich	HTSZ
	Peters, Gerhard	ED 531		Linde	LIND
	Pietroboni Karin	ED 65		Patria New Technologies Oy	PANT
	Puttlitz Joachim	OTN/EN 64		Phoenix, Volkmarsen	PHOE
	Raupp Helmut	SM 33		Rembe, Brilon	REMB
	Rebholz Reinhold	ED 541		SENER Ingenieria SA	SEN
	Reuß Friedhelm	ED 62			