FLORIS Calibration Unit

Contamination and Cleanliness Control Plan

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Change Record

Modification	Page	Iss.	Rev.	Date
First Issue	all	1	0	28.04.2017
Update for URR		2	0	24.01.2018
Added witness samples definition AIV flow and preliminary version of use of witness samples	13-14			
Justification of calculation rationale for the breakdown presented	15			
Details updated for ISO5 cleanroom	20			
Precision regarding machining steps in uncontrolled environment Precisions regarding vacuum facilities	21			
Alternative method definition for PAC measurement	21			
General level of cleanliness before priming gluing painting detailed	22			
Cleaning method verification detailed	23-24			
Container cleaning detailed	24			
Container cleanliness analysis frequency left free for customer as it is after delivery	25			
Updated for PDR and according to URR Rids	all	3	0	06.07.2018
Updated with latest AIV flow, tests and their consequences.	all	4	0	23.01.2019

Contents

1 Introduction

1.1 Project Overview

The Earth Explorer - Fluorescence Explorer (FLEX) mission will map vegetation fluorescence to quantify photosynthetic activity.

The conversion of atmospheric carbon dioxide and sunlight into energy-rich carbohydrates through photosynthesis is one of the most fundamental processes on Earth – and one on which we all depend.

Information from FLEX will improve our understanding of the way carbon moves between plants and the atmosphere and how photosynthesis affects the carbon and water cycles.

In addition, information from FLEX will lead to better insight into plant health and stress. This is of particular relevance since the growing global population is placing increasing demands on the production of food and animal feed. At the moment, photosynthetic activity cannot be measured from space, but FLEX's novel sensor will observe this faint glow.

The FLEX satellite will orbit in tandem with one of the Copernicus Sentinel-3 satellites, taking advantage of its optical and thermal sensors to provide an integrated package of measurements.

Mission objectives can therefore summarized as follows:

- To assess the quality of fluorescence-derived photosynthesis data against classical optically-based methods (i.e. from fraction of absorbed photosynthetically active radiation times Light Use Efficiency).
- To address in more detail temporal and spatial scaling issues (from towers to satellite footprints).
- To identify and characterize the effects of different types of stress on fluorescence and photosynthesis (especially drought and freezing air temperatures).
- To indicate potential applications of the novel fluorescence observations.

Mission orbit:

- Orbit: Sun-synchronous
- Measurement altitude: 815 km

The FLEX Space Segment consists of a single satellite carrying the FLuORescence Imaging Spectrometer (FLORIS) push-broom instrument. This high-resolution imaging spectrometer will acquire data in the 500– 780 nm spectral range, with a sampling of 0.1 nm in the oxygen bands (759–769 nm and 686–697 nm) and 0.5–2.0 nm in the red edge, chlorophyll absorption and Photochemical Reflectance Index bands.

The monthly global maps will have an on-ground spatial resolution of 300 × 300 m2 with a swath width of 150 km.

1.2 Scope of the Document

This Cleanliness and Contamination Control Plan (C&CCP) is based on the normative ECSS Cleanliness and Contamination Control document ECSS-Q-ST-70-01C. This document defines the contamination control plan for the design, manufacturing, assembly, integration and test of space flight hardware and GSE's interfaces with flight hardware to fulfil the cleanliness requirements and achieve compliance with specifications. This Cleanliness and Contamination Control Plan ends at delivery of the hardware to the Customer in its clean room. It doesn't cover the higher level testing.

Allowable contamination requirements will be presented along with the planned methods for limiting contamination throughout all phases. Plans for analyses, laboratory investigations, clean-room and hardware monitoring will also be addressed.

There are two types of contaminations treated within this document:

- Particulate Contamination
- Molecular Contamination

Remark: The different cleaning methods addressed in this C&CCP are gathered and detailed in a dedicated document called Cleaning Procedure, see ALM-TEC-0062.

Non-flight models will be kept in a visibly clean cleanliness level.

2 Applicable and Reference Documents

2.1 Applicable Documents

Ref.	Title	Reference	Iss.
AD 105	Cover Letter	FLX-LET-FNM-INS-0003	3
AD 106	Special Condition of Tender	FLX-OF-FNM-INS-0001	4
AD 100	Contract for FLEX Unit/sub-system	Draft Contract	
AD 101	Generic Statement of Work for FLEX Unit/sub-system	FLX-SOW-FNM-INS-0001	2
AD 102	Specific Statement of Work	FLX-SOW-FNM-INS-0005	2
AD 103	Floris Calibration Unit User Requirement Specification	FLX-RS-FNM-INS-0006	5
AD 201	FLORIS Radiation Environment RS	FLX-RS-FNM-INS-0016	4
AD 202	FLEX FEMM Requirements Specification	FLX-RS-FNM-INS-0023	1
AD 203	FLEX GMM &TMM Requirements Specification	FLX-RS-FNM-INS-0024	1
AD 204	FLEX CAD Model Requirements Specification	FLX-RS-FNM-INS-0025	1
AD 205	FLEX Cleanliness Requirements for Sub-contractors	FLX-RS-FNM-INS-0028	3
AD 206	FLEX Instrument General Design Interface Requirements	FLX-RS-FNM-INS-0029	3
AD 208	FLEX PA Requirements for Subcontractors	FLX-RS-FNM-INS-0021	2
AD 209	FLEX PA SW Requirements for Subcontractors	FLX-RS-FNM-INS-0022	1
AD 210	FLEX Configuration Control and Documentation Management Plan	FLX-PL-FNM-INS-0001	3
AD 211	FLEX List of Acronyms and Abbreviations	FLX-LI-FNM-INS-0003	2

2.2 Reference Documents

Ref.	Title	Reference	Iss.	Date
[RD01]	FLORIS Calibration Unit Almatech Proposal	17-10S-225	1.0	15.06.2017
[RD02]	Leonardo Clarification Letter	FLX-LET-FNM-INS-0009	--	18.10.2017
[RD03]	Floris CU Negotiation Meeting #1 between Leonardo and Almatech	FLX-MIN-FNM-INS-0041		15.11.2017

2.3 Acronyms and Abbreviations

The abbreviations and acronyms used in this document are in accordance with [AD 211].

3 Terms and Definitions

3.1 Molecular Contamination (MOC)

Airborne or surface contamination (vapour, gas, liquid or solid) without observable dimensions (i.e. with dimensions at molecular level). Molecular contamination is characterised by:

- Chemical species
- Weight per unit area.

Molecular contamination degrades optics by causing transmission loss and change in spectral transmittance.

3.2 Outgassing

The evolution of gaseous species from a material, usually in a vacuum. This can also be termed "Thermal Vacuum Stability".

3.3 Offgassing

The evolution of gaseous products from a liquid or a solid material into an atmosphere.

3.4 Particulate Contamination (PAC)

Airborne or surface contamination due to particles is defined as contamination by solid contaminants (e.g. dust, chips, and fibres) having measurable dimensions, and is characterized by:

- Particle size distribution
- Number of particles greater than a specified size per unit area.

Particulate contamination degrades optics by causing obscuration, scattering and could result in rough operation and jamming of mechanical components.

3.5 Visibly Clean

The absence of surface contamination when examined with a specific light source, a specific angle of incidence and viewing distance using normal or magnified vision as defined in ECSS-Q-ST-70-50C.

Different visibly clean levels are defined in [AD 205] from "visibly clean" to "visibly clean, highly sensitive + ultraviolet light".

4 Cleanliness requirements

4.1 Cleanliness Requirements

Maximum level of contamination is defined in specifications

Deviation from the rules shall be notified and approved on a case by case basis.

Full Cleanliness requirements can be found in [AD 103], §5.4.2.2 and [AD 205] §5. Hereafter are listed some of these requirements:

Manufacturing environment: FLO-GEN-CLE-REQ-018 of [AD 205]
"At subsystem level, all AIT operations shall be carried out under controlled environmental conditions (ISO 5 cleanroom) in order to comply with cleanliness provisions pertinent to the instrument or subsystem. In this case, provisions as per [FLO-GEN-CLE-REQ-026] shall be described in the CCCP and systematically applied."

Cleanliness level of non-optical surfaces: FLO-CU-URD-REQ-1050 of [AD 103]:
"As minimum, at delivery to Instrument Prime Contractor, for all the non-optically effective surfaces (low sensitive items), cleanliness levels shall comply with Visibly Clean High Sensitivity, VCHS, and MOC level< $1.5*10^{-7}$ g/cm²"

PAC contamination: FLO-CU-URD-REQ-1060 of [AD 103]
"at delivery to Instrument Prime Contractor the diffuser and black target cleanliness (PAC) level shall be less than 40 ppm, while the baffles one shall be less than 100 ppm."

MOC Contamination: FLO-CU-URD-REQ-1070 of [AD 103]
"at delivery to Instrument Prime Contractor the diffuser cleanliness (MOC) level shall be less than $2.0 * 10^{-8}$ g/cm2 (TBC) and the black target shall be less than $1.5 * 10^{-7}$ g/cm2 molecular contamination levels."

Bake-Out Monitoring:
FLO-GEN-CLE-REQ-007 of [AD 205]
Non-metallic materials shall be considered potential sources of contamination and shall be then manufactured / procured against allowable upper temperature requirement in vacuum, so that an extensive bake-out process can be applied before their integration on the FM hardware. Bake-out shall be carried out by monitoring in real time the outgassing rate by mean of the TQCM, according to [FLO-GEN-CLE-REQ-008]. For those subsystems where consolidated heritage is present, the application of a baking time duration / temperature criteria instead of TQCM steady state achievement can be accepted (see annex 1 for list of exceptions).

FLO-GEN-CLE-REQ-008 of [AD 205]
"With respect to [FLO-GEN-CLE-REQ-007], when the bake-out is carried out using a TQCM, vacuum bake-out shall be carried out until outgassing rate (monitored in real-time by means of the TQCM) reaches a significantly reduced and almost steady state, i.e. until the rate of frequency change has reduced to values is lower than 1% per hour, according to below equation: $| f''(t) / f'(t) | \leq 0.01\ h^{-1}$"

4.2 Contamination budgets

The budget, allowed and accumulated during the different AIT phases (described in section 6), shall be evaluated and consolidated with in-situ measurements on witness plates with comparable surface properties.

Witness samples are either square parts made of the same materials as the hardware or PFO (particulate contamination) plus ZnSe (molecular contamination) samples. Same cleaning process is applied to the samples and the hardware.

These witness samples are accompanying the hardware during all AIT phases. During these phases they are placed as close as possible to the hardware but not under in order to avoid any "protection" from the hardware.

The number of witness samples is defined in the AIV plan. A preliminary version of the use of these witness samples is described in the AIT flow in **Figure 1**.

Figure 1 represents the witness samples allocated to the baffles. Witness samples allocated to Sun diffuser are presented in Sun Diffuser AIT flow in **Figure 2**.

Black target will be baked-out as a normal piece part as displayed in **Figure 1** however it will be kept stored and be integrated at the same stage as the Sun Diffuser. Just before integration it will be particulate cleaned using the rinsing method presented in paragraph 6.3.

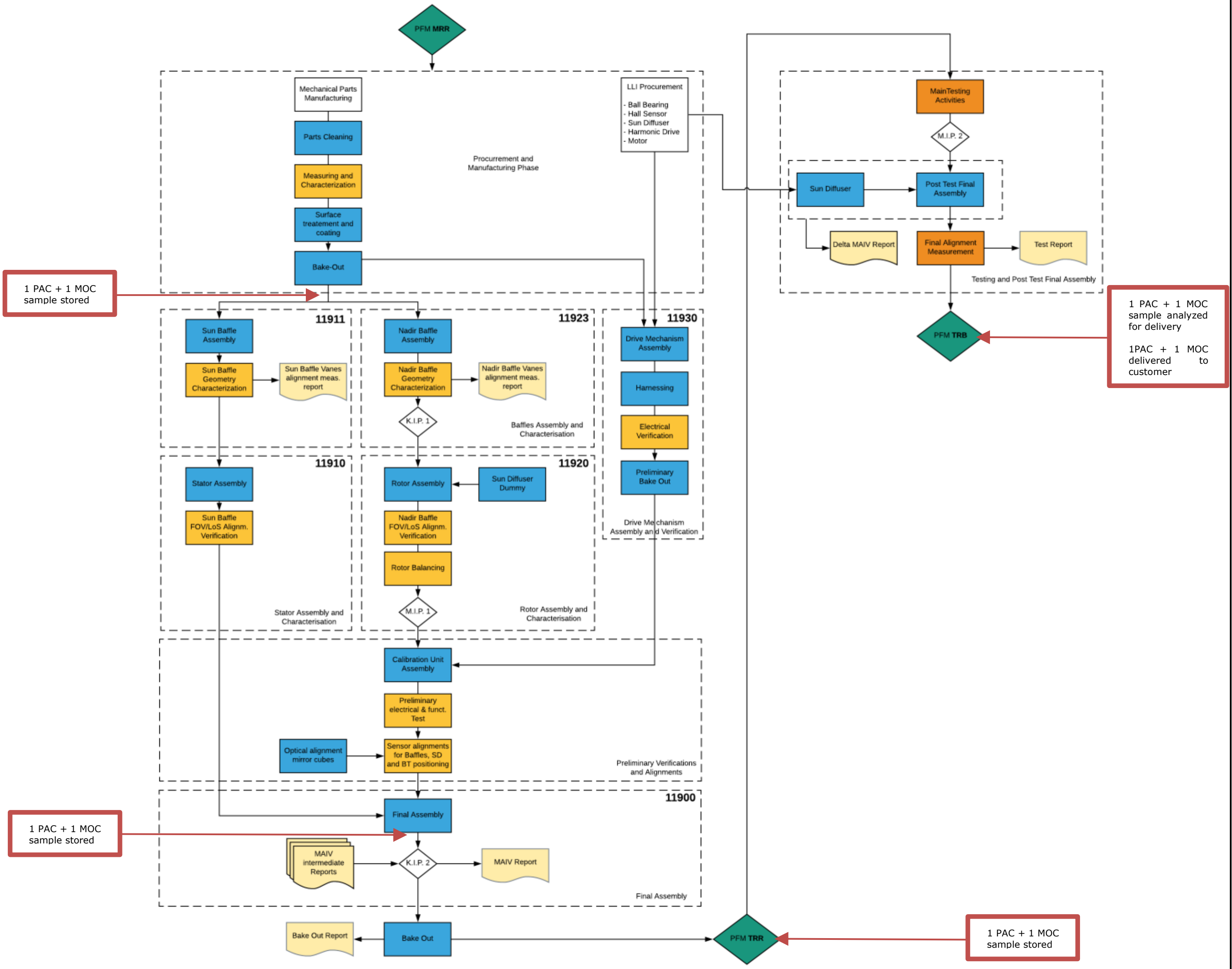

Figure 1: PFM witness samples use in the AIV Flow

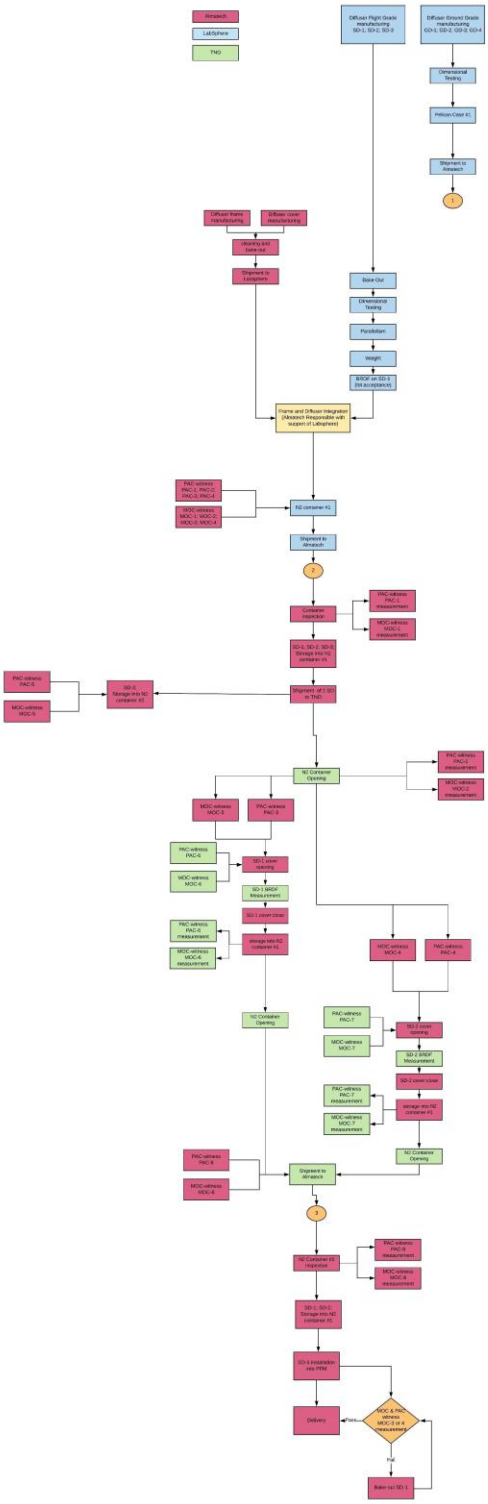

Figure 2: PFM Sun diffuser witness samples use in the AIV Flow

An accumulated contamination breakdown based on the operational sequences and phases is listed in Table 2 and is described hereafter.

The overall particulate contamination accumulated by the hardware during its AIT is allocated to each phases in Table 2. This table takes into consideration the baffles that are more critical in terms of particulate contamination than the rest of the parts (sun diffuser and black target are covered by Table 3). Almatech previously tested its cleaning method particulate contamination, the result was found to be at less than 10 ppm. To be on the safe side, an initial contamination of 10 ppm has been considered.

Based on well-established data for PAC per 24h (see Table 5-5 of ECSS-Q-ST-70-01C reported in Table 1) breakdowns were established and are presented in Table 2 and Table 3. However, based on Almatech experience, it is assumed that the effective PAC per working day in clean room is half of those for 24h. Indeed, during night, hardware are packed or boxed, avoiding any particulate contamination.

Working in ISO 5 cleanroom would not be sufficient with regards to the AIT time needed and gathered in Table 2. Almatech owns a laminar flow hood that is inside the cleanroom. This hood has been tested and proven to have a particle fallout of 2 ppm per 15 days 24/7 exposition as presented in ALM-TEC-0045. All activities that will be performed at Almatech will be done in this hood in order to reduce the PAC to a minimum.

The molecular contamination is given to be 50 ng.cm^{-2} per week of work in cleanroom by ECSS-Q-ST-70-01C. This value gives a contamination per hour of 2.976.10^{-10}g.cm^{-2}, considering that Almatech is working on the hardware during 7 hours per day, the molecular contamination is assumed to be 2.08 ng/cm^{2}/day in ISO Class 5 as during night, hardware are packed or boxed, avoiding any additional contamination.

It is further assumed that each purging of the container with N2 of purity class Alphagaz 2 99.9999% induces a MOC increase of 6.33E-10 g/cm2 (impurities susceptible to add pollution being hydrocarbons in a concentration of 16g/mole, and in comparison to a molar volume of ideal gas, this represents 0.087mg/m3 of gas that represents 6.33.10^{-10}g.cm^{-2}) and a PAC increase of 2 ppm. These values are assumed according to ECSS standard ECSS-Q-ST-70-01C.

MOC breakdown for both the Calibration Unit and the Sun Diffuser are above the requirements. If levels are higher than expected, an additional bakeout will be performed to reduce the molecular contamination level.

ISO class	PFO (mm^2/m^2/24 h)
5	2,0
6	10
7	52
8	275
NOTE	The data contained in this table are based on several measurements performed in different cleanrooms. They are represented by this approximate law: PFO = 0,069 $10^{(0,72M-2.16)}$ where M is the ISO class (e.g. ISO class 5)

Table 1 : Correlation airborne and PFO for cleanrooms

Contamination breakdown during CU AIT phases: PFM

Project phase	Duration (days)	CR Class	PAC	PAC cumulative	MOC	MOC cumulative	Facility
Cleaning		ISO 5	10.00	10.00	4.00E-08	4.00E-08	Almatech / Acktar
Transport	1	Purged	2.00	12.00	6.33E-10	4.06E-08	Container
Assembly	22	ISO 5	44.00	56.00	1.57E-07	1.98E-07	Almatech
Transport	1	Purged	2.00	58.00	6.33E-10	1.98E-07	Container
Handling	0.5	ISO 5	1.00	59.00	3.57E-09	2.02E-07	Intespace (Fr)
Bake Out	4	Vacuum chamber	0.00	59.00	4.00E-08	4.00E-08	Intespace (Fr)
Handling	0.5	ISO 5	1.00	60.00	3.57E-09	4.36E-08	Intespace (Fr)
Transport	1	Purged	2.00	62.00	6.33E-10	4.42E-08	Container
Electrical and initial functional test	3	ISO 5	6.00	68.00	2.14E-08	6.56E-08	Almatech
Mass, CoG, MOI	2	ISO 5	4.00	72.00	1.43E-08	7.99E-08	Almatech
Transport	1	Purged	2.00	74.00	6.33E-10	8.06E-08	Container
Handling	0.5	ISO 5	1.00	75.00	3.57E-09	8.41E-08	Ube
Optical Alignment tests	4	ISO 5	8.00	83.00	2.86E-08	1.13E-07	UBe
Handling	0.5	ISO 5	1.00	84.00	3.57E-09	1.16E-07	Ube
Functional & Performance Tests	3	ISO 5	6.00	90.00	2.14E-08	1.38E-07	UBe
Handling	0.5	ISO 5	1.00	91.00	3.57E-09	1.41E-07	Ube
Vibration Tests	5	ISO 5	10.00	101.00	3.57E-08	1.77E-07	UBe
Handling	0.5	ISO 5	1.00	102.00	3.57E-09	1.81E-07	Ube
Reduced Functional Tests	2.5	ISO 5	5.00	107.00	1.79E-08	1.98E-07	UBe
Handling	0.5	ISO 5	1.00	108.00	3.57E-09	2.02E-07	UBe
Thermal Vacuum Tests	8	Vacuum chamber	0.00	108.00	4.00E-08	4.00E-08	UBe
Handling	0.5	ISO 5	1.00	109.00	3.57E-09	4.36E-08	Ube
Transport	1	Purged	2.00	111.00	6.33E-10	4.42E-08	Container
EMC Tests	5	ISO 5	10.00	121.00	3.57E-08	7.99E-08	ESTEC
Transport	1	Purged	2.00	123.00	6.33E-10	8.06E-08	Container
Functional & Performance Tests	2	ISO 5	4.00	127.00	1.43E-08	9.48E-08	UBe
Optical Alignment & Characterisation	4	ISO 5	8.00	135.00	2.86E-08	1.23E-07	UBe
Transport	1	Purged	2.00	137.00	6.33E-10	1.24E-07	Container
PFM Sun Diffuser & Black Target integration	2	ISO 5	4.00	141.00	1.43E-08	1.38E-07	Almatech
Transport	1	Purged	2.00	143.00	6.33E-10	1.39E-07	Container
PFM Sun Diffuser Characterisation	2	ISO 5	4.00	147.00	1.43E-08	1.53E-07	TNO
Transport	1	Purged	2.00	149.00	6.33E-10	1.54E-07	Container
Delivery	2	ISO 5	2.00	151.00	1.43E-08	1.68E-07	Leonardo
Sum	**83.5**			**151.00**		**1.68E-07**	
Requirement FLX-RS-FNM-INS-0006 Rev. 3				**100**		**1.50E-07**	**g/cm2**
Percentage of the budget				**151.00%**		**112.11%**	

Table 2 : Accumulated contamination breakdown for FLORIS Calibration Unit PFM Model.

The total breakdown PAC and MOC are above the requirements. In this expectation, initial molecular and particulate contamination after cleaning shall be stringent (10 ppm and 40 ng/cm^2).

Contamination breakdown during CU AIT phases: PFM

Project phase	Duration (days)	CR Class	PAC	PAC cumulative	MOC	MOC cumulative	Facility
Delivery from LabSphere		ISO 5	0.00	0.00	0.00E+00	0.00E+00	LabSphere
Frame mounting	1	ISO 5	2.00	2.00	7.14E-09	7.14E-09	Almatech
Transport	1	Purged	2.00	4.00	6.33E-10	7.78E-09	Container
PFM Sun Diffuser Characterisation	30	ISO 5	60.00	64.00	2.14E-07	2.22E-07	TNO
Transport & Storage	365	Purged	2.00	66.00	6.33E-10	2.23E-07	Container
PFM Sun Diffuser & Black Target integration	2	ISO 5	4.00	70.00	1.43E-08	2.37E-07	Almatech
Transport	1	Purged	2.00	72.00	6.33E-10	2.38E-07	Container
Delivery	2	ISO 5	4.00	76.00	1.43E-08	2.52E-07	Leonardo
Sum	**400**			**76.00**		**2.52E-07**	
Requirement FLX-RS-FNM-INS-0006 Rev. 3				**40**		**2.00E-08**	**g/cm2**
Percentage of the budget				**190.00%**		**1259.50%**	

Table 3 : Accumulated contamination breakdown for FLORIS Calibration Unit PFM Model Sun Diffuser and Black Target.

Black target has the same PAC requirement as the sun diffuser while it has the same requirements as the rest of hardware for MOC. By exposing the Sun Diffuser to the environment, even if integrated at latest stage as possible, the budget is exceeded. A Bakeout will have to be envisaged at latest stage as possible to reduce the molecular contamination. Sun Diffuser inspection will be performed by Almatech at supplier premises as described in paragraph 6.3 of this document.

In addition and in order to reduce the amount of contamination, the hardware will be covered as much as possible during downtimes as described in §6.1.2.

A purging inlet is available on the housing as required by the specification. However, purging only would not be sufficient to maintain the Sun Diffuser cleanliness level during on ground testing of the hardware as the purging flow would be in front of the Sun Diffuser only when in launch position. Sun Diffuser would be exposed to normal clean room environment when in other positions.

4.3 Selection of materials and processes

Contamination prevention is a basic design driver and shall be considered throughout the development process.

To assure the most effective cleanliness control, the designer shall take the following points into account:

- The use of materials which induce release of particles is avoided.
- Consideration is given to cleanability as a design feature of parts, i.e. the possibility of accidental contamination is taken into account.
- The choice of manufacturing techniques and processes is governed by considerations concerning compatibility with desired cleanliness levels, unless the part can readily be cleaned afterwards.
- If possible, items like plates will be stored vertically to reduce particulate contamination.
- The use of permanent shields, temporary covers or clean tents/hoods for contamination protection during critical manufacturing, AIT, launch preparation, launch and in-orbit phases is taken into account.

Outgassing requirements are met by all subsystems and/or components through proper selection of materials and appropriate vacuum bake-out of parts, components, and subsystems.

In order to control contamination and protect sensitive surfaces, the use of minimal contaminating materials is considered. Manufacturing materials are low outgassing, non-shedding and non-flaking.

Efforts are made to select low outgassing materials (RML of <1.0% & CVCM of ≤0.1% by weight as per requirement "FLO-CU-URD-REQ-1240" of [AD 103]) for all applications. For questionable materials, or materials where data does not exist, it may be necessary to test outgassing characteristics. For materials exceeding the specified outgassing requirements an RFD is to be raised against requirement here above.

Outgassing data will be recorded in the DML, in conformance with ECSS-Q-ST-70-01C.

4.4 Mitigation and corrective actions

The coordination of instrument wide cleanliness and contamination control is recommended.

Vacuum bake-out should be envisaged in order to remove volatile contaminants. If selected, the bake-out task shall be reflected in the relevant AIT plans. Such bake Out shall be monitored with a TQCM (According to requirements "FLO-GEN-CLE-REQ-007" and "FLO-GEN-CLE-REQ-008" of [AD 205]).

Current foreseen bake-outs are the followings:

Items	Temperature	Minimum Duration
Sun Diffuser	Defined by Labsphere	Defined by Labsphere
Black Target	80°C 0/+3°C (TBC)	72h
Calibration unit without Sun Diffuser and Black Target	80°C 0/+3°C (TBC)	72h

After cleaning steps (See ALM-TEC-0062), PAC and MOC levels can be verified at external suppliers' facility by the analysis of witness samples using the following methods:
MOC: Detection of organic contamination of surfaces by infrared spectroscopy, according to ECSS-Q-ST-70-05C using rinsing method on the witness sample defined in §4.2.
PAC: Rinsing method according to ECSS-Q-ST-70-50C on samples defined in §4.2 flowing on a 0.5µm gold coated membrane filter using filtered IPA. Filter is then analysed using SEM inspection process, particles are counted and coverage ratio is calculated against sample surface giving the particulate contamination in ppm. This method allow to detect values of 0.01ppm for Almatech standard size samples (50x50mm).

5 Environments and Facilities

The overall Cleanliness and Contamination Control Program is based on the sensitivities and performance goals of the hardware.

All design, fabrication, assembly, integration, testing, packaging, transportation and integration must be performed in a manner which will minimize the probability of contamination.

5.1 MAIT areas

During MAIT phases, an active contamination monitoring program shall be in effect, by means of visual inspections, and/or witness plates.

MAIT shall take place in an ISO class 5 clean room environment or better. While out of the clean room, the flight hardware can be stored inside a vessel purged with ultra clean (Alphagas 2 99.9999%) nitrogen.

Almatech clean room is certified to ISO standard class 5 against ISO 14644 standard.

Cleanliness control is performed externally for both MOC and PAC contamination.

5.2 Area and Facilities Verification

Area verification is performed by external experts.

5.3 Internal Procedures for Training and Rules

Almatech personnel using the clean MAIT areas are fully qualified and experienced personnel with experience of clean room activities in the framework of space flight equipment assembly.

6 MAIT activities

6.1 Contamination prediction

6.1.1 Cleanliness Prediction Splitting

A general list of MAIT phases is shown below:

- Part manufacture
- Cleaning and assembly
- Integration
- Test
- Transport

6.1.2 Contamination phase list

The phases of the production that may be susceptible to contamination are shown in this section.

6.1.2.1 Manufacturing and Assembly Phases

In general, machining will take place in uncontrolled environments (> Class 8). Cleaning procedures are applied after delivery to Almatech.

This phase is followed by cleaning of all parts according to specific cleaning procedures defined in ALM-TEC-0062. The contamination after cleaning during storage is very small as all parts are either bagged within sealed, cleaned and contaminant free packaging or stored in purged storage and transport containers.

Assembly of individual parts shall take place in an ISO 5 or better class clean room. During all manufacturing and assembly phases, contamination control measures shall be applied. Surfaces shall be kept clean, and if any debris is generated during the manufacturing process, it shall be cleaned.

The assembly of the HW shall take place in an ISO 5 or better class clean room. Regular monitoring of the clean room will be accomplished to ensure that it corresponds to the ISO 5 or better requirements.

During downtimes when hardware is not actively being worked on, or for weekends and other non-operational times, flight hardware will be kept covered with an approved clean room certified, anti-static bagging material or stored in its purged transport and storage container. Bagging materials, drapes contamination and electrostatic discharge (ESD) approved materials can be used where necessary.

The MOC effective contamination of the hardware will be monitored with representative witness samples.

PAC contamination for optical parts will be monitored with representative witness samples. PAC contamination for all the other parts will be kept to a visibly clean highly sensitive items with UV light inspection level.

6.1.2.2 Test Phase

The Hardware may be subject to a number of testing operations. Generally, contamination requirements during the testing phases are identical to those during the integration phase.

The test and handling facilities and devices shall be cleaned by non-contaminating processes. Before and after tests the hardware shall be checked for molecular and particulate contamination using methods described in §6.2.1. The cleanliness class of test areas shall be the same, or better, than those for integration areas. If tests must be done in a non-certified environment or in a clean room which is classed lower than the required ISO 5 class, provisions must be made to protect the hardware against contamination.

Vacuum testing (e.g. bakeouts) facilities cleanliness shall be tested during a pre-test as described in ECSS-Q-ST-70-01C. A bakeout procedure will be established and sent to customer for approval to detail specific project specific conditions.

The effective contamination of the hardware will be monitored with representative witness samples.

6.2 Contamination Control

6.2.1 Contamination Monitoring Methods and Tools

The effective contamination level, accumulated during all MAIT phases, shall be evaluated and assessed with measurements on PFO and ZnSe windows or on representative witness samples. The witness sample shall present comparable surface properties as the reference component and have undergone the same cleaning procedure and exposure to contaminant history than the hardware. The witness plates shall be manufactured with the hardware and shall be made from identical material. There is an exception for the Sun Diffuser representative samples that have to be made of Metallic material as the Spectralon cannot be tested.

The following tests methods are used and will be carried out at the defined splitting time points:

- Particulate Contamination (PAC) will be kept to a visibly clean highly sensitive and UV lamp inspection level. Characteristics of this cleanliness are given in [AD 205] FLO-GEN-CLE-REQ-023
- Particulate Contamination (PAC) of optical surfaces will be measured either:
  - By using a PFO meter.
  - Or by particles counting under a scanning electron microscope (SEM) coupled to an energy dispersive X-ray spectroscope (EDX). All particles larger than 0.5 μm will be identified and the surface they cover will be calculated by image processing. The total surface covered by particles is then calculated by summing the particle area over the witness sample area. This method is an alternative method as per requirement FLO-GEN-CLE-REQ-021 to be approved by customer.

- Molecular Contamination (MOC) will be measured by Fourier transform infra-red (FTIR) spectrophotometry. The analysis is carried out according to ECSS-Q-ST-70-05C
  - Either on the liquid used to rinse the sample surface. Detection of hydrocarbons, ester and silicon species is possible with a sensitivity of 20 ng/cm^2.
  - Or on the ZnSe windows.

The results of these analysis will be documented in cleanliness reports.

Sensitivity of 20ng/cm^2 is not compatible with Sun Diffuser MOC requirements of 20ng/cm^2. Sun Diffuser supplier is able to guarantee the level of contamination so can cover their parts.

6.2.2 Subsystem Manufacturing and Assembly Phases Contamination Control

The hardware shall be maintained at a visibly clean level throughout the manufacturing process. Trained personnel will perform inspections. In addition, cleaning will be performed after manufacturing according to detailed cleaning procedures as listed in ECSS-Q-ST-70-01C. During manufacturing of the individual parts and sub-assemblies, the following actions will be carried out to minimize the contamination.

- During manufacturing operations such as machining, welding and soldering, contaminants shall be cleaned off of the hardware by wiping and/or vacuum cleaning. Lubricants and cutting oils shall be cleaned off as soon as possible after the manufacturing operation using appropriate solvents. For optical surfaces, specific lubricant will be used to ensure an easy removal and cleaning.
- Prior to priming, gluing or coating, surfaces shall be visibly free of particulate or molecular deposits and cleaned with dedicated procedure to remove most of the contaminants. Bake-out at higher temperature may be required.
- Upon the completion of a manufacturing operation, the parts will be subjected to a detailed cleaning procedure involving solvent washes and particulate removal as described in ALM-TEC-0062, yielding a visibly clean sensitive product. The manufactured parts will then be bagged to neglect contamination effects.
- Specific attention will be paid to remove glue, particles and contaminant from holes. Wiping should be in one direction only and each pass should be with a clean area on a wipe or using a new wipe for each pass. In some instances wipes will be ineffective and swabs moistened with alcohol may be used. Cleaning will continue until all surfaces are visibly clean upon inspection.
- Part with helicoils will be first cleaned after machining and before helicoil mounting. In a second phase, the helicoil will be mounted in a clean room, close to a vacuum cleaner.
- All boxes shall be inspected by Quality Assurance prior to closure for their cleanliness with respect to particle contamination. It is assumed no further particle contamination occurs after closure of box. If this cannot be confirmed a corresponding analysis shall be created.

The following list highlights the planned contamination control procedures to be implemented during assembly activities in the ISO 5 class clean room facilities:

- Personnel working in the clean room will wear appropriate clean room clothing, shoe coverings, mask and gloves.
- Oils, greases and other similar agents, which may be contamination hazards, will not be used during assembly without the permission of the PA manager.
- Rivets, bolts, nuts and so forth must be cleaned to remove any type of contamination such as lubricants and machining oils. Areas which become inaccessible for cleaning must be cleaned and inspected prior to that time, and be bagged following that time.
- All integration GSE, testing equipment, etc. will meet the visibly clean level. Surfaces, which will enter in contact with the flight hardware, must meet the flight hardware cleanliness requirements.

The effective contamination of the hardware will be monitored with representative witness samples for MOC of all parts and PAC of optical parts and with white and UV light inspection for PAC of remaining parts.

6.3 Cleaning and decontamination methods and tools

Cleaning procedures will be chosen such that the required cleanliness levels are achieved. These procedures, including the specification of the applicable solvents, their grades and their suppliers are described in a separate document, see ALM-TEC-0062.

The cleaning solvents have to be compatible with the material and surface properties of the item to be cleaned.

During assembly, mating surfaces will be cleaned prior to attachment. All interior volumes will be cleaned thoroughly prior to final assembly. IPA may be used as a solvent. All GSE will be kept visibly clean during assembly. Cables, harnesses, etc. will be cleaned before attachment to flight hardware, and if necessary baked-out.

Where bake-out of components is required, the hardware shall be put in a vacuum or atmosphere controlled chamber at bake-out temperature for at least 72 hours while the contaminants deposits are collected into a cold sampling plate and measured by a Quartz Crystal Microbalance (QCM). The duration of the test shall be such as to achieve effective cleanliness requirements, listed in §4.1 of this document, based on QCM measurements.

Non-optical surfaces will be cleaned to a visibly clean with UV light inspection level and baked-out to the maximum temperature of the limiting part to reduce the molecular contamination to the required level.

Nadir baffle & Black target will be black anodized. Almatech have several cleaning processes including one (Type B of project procedure SPICE-ALM-PR-4301 issue 4.0) that consists in multiple rinsing with high purity IPA above a filter and counting of particles for each rinsing. This method was analysed (for SPICE project for which report 1295/22C issue 2 that is not public has been established) and gave results down to 10ppm by rinsing method and particle counting. A bakeout will be applied after cleaning at maximum survivable temperature of the parts in order to reduce molecular contamination to the required level.

Sun Diffuser will be procured according to cleanliness requirements. Sun diffuser will be procured cleaned and covered by Labsphere. Sun diffuser shall always be handled by its metallic frame and no contact shall be made on the Spectralon. If any contact shall be made on Spectralon, cotton lint free gloves shall be used above the standard gloves.

Sun Diffuser and Black Target will be covered whenever possible in order avoid to contaminate these items.

Other optical parts than Sun Diffuser and Black Target, when installed into the hardware will be kept covered with protective caps as much as possible to reduce their exposure to contamination.

6.4 Packaging, storage and transportation

6.4.1 Transportation of critical items

The transport of the hardware will be done within a double box. The innermost box will be at ISO 5 class cleanliness. This is the same as the assembly clean area. The hardware will be placed in the inner box within the ISO 5 class clean assembly area (flow cabinet).

The container will be cleaned using ALM-TEC-0035 procedure before use and will reach a visibly clean high sensitivity level.

Container hardware interface plate and screws will be cleaned with ALM-TEC-0062 as PFM hardware and baked-out in the same conditions as PFM parts to reach the cleanliness levels required in FLO-CU-URD-REQ-1050 and FLO-CU-URD-REQ-1070.

The container will accommodate representative reference contamination witness samples that will serve to monitor the molecular and particulate contamination. The frequency of the sample analyses as well as the analyses themselves is under the responsibility of the Authority that decided shipment / storage.

Manufactured parts that are transported to Almatech will be double bagged. Cleanliness inspections are made at delivery.

6.4.1.1 Containers and packaging tools

As mentioned, the hardware will be transported in a purged double box. The double box has an inner container and an outer container. The inner container will accommodate the hardware with a suitable interface mounted upon a suspension buffer. A sealed shield will be mounted over the hardware and will form the inner box. The inner box is manufactured using cleanable material and will be at ISO 5 class level.

This inner box is then mounted within the outer box for transportation.

6.4.1.2 Storage Methods

For any long storage the hardware should stay inside its Storage and Transport Container (STC) in purged condition.

During downtimes when hardware is not actively being worked on, or for weekends and other non-operational times, flight hardware will be kept covered with an approved clean room certified, anti-static bagging material or stored in its purged transport and storage container. Bagging materials and drapes should be contamination and electrostatic discharge (ESD) approved where necessary.

6.4.1.3 Handling methods

The hardware is mounted inside the transport container inner box within the ISO 5 class MAIT area.

6.4.1.4 Monitoring and cleaning

Monitoring of the container cleanliness is performed by having witness plates attached inside the transportation box. These plates are in the same environment as the hardware. These samples are the hardware samples defined in §4.2 and frequency of analysis is defined in this flow. After delivery of the hardware the frequency of analysis is left to customer.

6.5 Responsibilities

Cleanliness control until delivery of the hardware is under the responsibility of the Almatech product assurance department.

Cleanliness procedures in subsequent phases are under the customer's responsibility.

Monitoring of the clean areas will be performed regularly during integration activities, at least by visual inspection with white light illumination.

All personnel working in clean areas have received training on the purpose and practice of clean area operations. Only those qualified personnel are authorized for area access.

7 Forms

In case of any non-conformance, an NCR shall be raised, and treated according to ECSS-Q-ST-10-09C.

7.1 Definition of Documentation

7.1.1 PAC and MOC Measurement Report

The MOC and optical parts PAC reports are provided by external controlled suppliers.

The non-optical parts PAC final inspection before delivery will be documented with pictures in the cleanliness report.

7.1.2 Cleanliness Declaration of Conformity

The required cleanliness of the equipment / instrument is certified by a Cleanliness Certificate of Conformity which shall be part of the ADP.