**TITLE**

EXOMARS
CLEANLINESS AND CONTAMINATION
CONTROL REQUIREMENTS

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<tr>
<td>P. PARODI</td>
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<td>C. LOBASCIO</td>
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1. INTRODUCTION

1.1 Scope

This specification establishes cleanliness and contamination requirements for Exomars Composite S/C and is applicable to development and design, production and test, storage and shipment, pre-launch activities down to equipment and material level. For requirements of standard parts, materials, and processes (PMP) refer to the ExoMars Product Assurance Requirements [NR 04]. This document establishes the requirements of performance and verification for contamination control of ExoMars hardware, ground processing facilities as applicable. This issue reflects the ExoMars Phase B/C/D baseline.

1.2 Applicability

This specification is applicable to the ExoMars Space Segment, for all levels from parts level up to Flight Configuration level, including ground processing and flight operations, and to Ground Support Equipment (GSE) and facilities.
2. ACRONYMS

A
ABCL  As Built Configuration List
ABS  Airbags System
AD  Applicable Document
ADP  Acceptance Data Package
ADR  Architecture Design Review (Software)
AFT  Abbreviated Functional Test
AIT  Assembly Integration and Tests
AIV  Assembly, Integration and Verification
AME  Absolute Measurement Error
AOCS  Attitude and Orbit Control System
APD  Absolute Pointing Drift
APE  Absolute Pointing Error
APT  Abbreviated Performance Test
AR  Acceptance Review
AR5-ECA  Ariane 5 Etage Cryogenique A
ARES  Atmospheric Relaxation and Electric field
ASW  Application Software
ATM  Atmospheric Software
AVM  Avionics Verification Model
AVS  Avionics (CTU, RU, LA)

B
BCR  Baseline Consolidation Review
BEE  Best Engineering Estimation
BSL  Baseline
BOL  Beginning of Life
BS  Backshield
BSH  Back-shell
BSS  Backshell Structure

C
CAB  Change Appeal Board
CADM  Configuration and Data Management
CADMO  Configuration and Data Management Organisation
CAM  Collision Avoidance Manoeuvre
CCB  Configuration Control Board
CCD  Charge Coupled Device
CCN  Contract Change Notice
CDMU  Central Data Management Unit
CDR  Critical Design Review
CF  Cold Finger
CFI  Customer Furnished Item
CI  Configuration Item
CIDL  Configuration Item Data List
CIS  Configuration Inspection
CLUPI  Close UP Imager
CM  Carrier Module
CM-DM, BSH-FS  Separation Mechanisms
CMO  Configuration Management Office
CMP  Configuration Management Plan
CoG  Center of Gravity
CP  Change Proposal
CR  Change Request
CRB  Change Review Board
CSA  Configuration Status Accounting
CSC  Configuration Software Component
CSG  Centre Spatiale Guyanais

Error! Reference source not found.
CSU  Configuration software Unit
CVCM  Collected Volatile Condensable Mass

D
DB  Design Baseline
DCN  Document Change Notice
DCR  Document Change Record
DDL  Document Delivery List
DD&V  Design, Development and Verification
DDVP  Design, Development and Verification Plan
DDOR  Delta Differential One-way Ranging
DDQ  Design Development Qualification
DH  Data Handling
DHS  Data Handling System
DIBS  Drill-Integrated package for Borehole Sciences
DIL  Deliverable Item List
DM  Descent Module
DMC  Descent Module Composite
DOF  Degree(s) of Freedom
DP  Data Package
DRD  Document Requirement Description
DRL  Document Requirement List
DSL  Documentation Status List
DSN  Deep Space Network
DSPG  Distribute Single Point Grounding

E
EB  Engineering Board
EC  Experiment Cycle
ECOS  ESA Costing Software

Error! Reference source not found.
FOV  Field of View
FRR  Flight Readiness Review
FS   Front Shield
FTP  File Transfer Protocol
FUMO Functional Model

G
GC   Gas Chromatograph
GDSS Geophysical and Environment Payload
GEP  Geophysical and Environmental Package
GMM Geometrical Mathematical Model
GNC Guidance, Navigation and Control
GOC GEP Operation Centre
GPR Ground Penetrating Radar
GS  Ground Segment
GSE Ground Support Equipment

H
HEO Highly Elliptic Orbit
HF   High Frequency
HGA High Gain Antenna
HKTM Housekeeping Telemetry
HP3 Heat Flow and Physical Properties Package
HRC High Resolution Camera
HRN Harness
HV   High Voltage
HW   Hardware

I
ICD Interface Control Document
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<tr>
<td>ICS</td>
<td>Integrated Control System documents</td>
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<td>ICU</td>
<td>Instrument Control Unit</td>
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<td>ID</td>
<td>Informative Document</td>
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<tr>
<td>ILS</td>
<td>Instrument Line of Sight</td>
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<td>IMA</td>
<td>Instrument Multilateral Agreement</td>
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<td>IMU</td>
<td>Inertial Measurement Unit</td>
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<td>IOCR</td>
<td>In-Orbit Check-out Review</td>
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<td>IR</td>
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<td>Ionising Radiation Sensor</td>
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<td>IRev</td>
<td>Implementation Review</td>
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<td>Interface Thermal Mathematical Model</td>
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<td>J</td>
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<td>Jet Propulsion Laboratory</td>
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<tr>
<td>LA</td>
<td>Lander</td>
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<tr>
<td>LaRa</td>
<td>Lander-Radio science instrument</td>
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<tr>
<td>LCL</td>
<td>Latching Current Limiter</td>
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<td>LEOP</td>
<td>Launch and Early Orbital Phase</td>
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<td>LGA</td>
<td>Low Gain Antenna</td>
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<tr>
<td>LH</td>
<td>Laser Head</td>
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<td>LIBS</td>
<td>Laser Induced Breakdown Spectroscopy</td>
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<td>Landing Platform</td>
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<td>LV</td>
<td>Launch Vehicle</td>
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<td>LVA</td>
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<td>LVDS</td>
<td>Low Voltage Differential Signal</td>
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<td>MA_MISS</td>
<td>Mars Multispectral Imager for Subsurface</td>
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<td>MCD</td>
<td>MARS Climate Data Base</td>
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<tr>
<td>MCM</td>
<td>Mid Course Manoeuvre</td>
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<tr>
<td>MD</td>
<td>Mechanical Dummy</td>
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<tr>
<td>MEDUSA</td>
<td>Martian Environment Dust Systematic Analyser</td>
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<tr>
<td>MEOP</td>
<td>Maximum Expected Operating Pressure</td>
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<td>MERR</td>
<td>Mars Entry Readiness Review</td>
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<tr>
<td>MGA</td>
<td>Medium Gain Antenna</td>
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<td>MGSE</td>
<td>Mechanical Ground Support Equipment</td>
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<td>MIMA</td>
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<td>MIMOS-II</td>
<td>Miniaturised Mossbauer Spectrometer</td>
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<td>MLI</td>
<td>Multi Layer Insulation</td>
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<td>ML2SP</td>
<td>Mars Long Lived Surface Package</td>
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<td>MOCC</td>
<td>Mission Operation and Control Center</td>
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<td>MOD</td>
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<tr>
<td>MoI</td>
<td>Moment of Inertia</td>
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<td>MOMA</td>
<td>Mars Organic Molecule Analiser</td>
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<td>MOU</td>
<td>Memorandum of Understanding</td>
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<td>MOXI</td>
<td>Mars OXidant Instrument</td>
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<td>MPPT</td>
<td>Maximum Power Point Tracker</td>
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<td>MRO</td>
<td>Mars Reconnaissance Orbiter</td>
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<tr>
<td>MS</td>
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<td>MSMO</td>
<td>Mars Surface Magnetic Observatory</td>
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<td>MSRD</td>
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MTO  MARS Telecommunication Orbiter

N
NA  Not Applicable
NCR  Non Conformance Report
ND  Normative Document
[NR]  Normative Reference
NRO  NASA Relay Orbiter

O
OBDH  On-Board Data Handling
OBSW  Onboard Software
OGSE  Optical Ground Support Equipment
OH  Optical Head
OM  Orbiter Module
OTS  Off the Shelf

P
PA  Product Assurance
PanCam  Panoramic Camera
PAS  Parachute System
PCDU  Power Conditioning & Distribution Unit
PCR  Payload Confirmation Review
PDM  Product Data Management
PDR  Preliminary Design Review
PFM  Proto-Flight Model
PL  Payload
PMO  Program Management Office
PMP  Parts, Materials and Processes
PP  Planetary Protection

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<td>PPL</td>
<td>Pasteur Payload</td>
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<td>PSE</td>
<td>Payload Support Equipment</td>
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<td>PT</td>
<td>Product Tree</td>
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<td>PWR</td>
<td>Power (PCDU, BAT)</td>
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<td>QA</td>
<td>Quality Assurance</td>
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<td>QM</td>
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<td>QR</td>
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<tr>
<td>RCS</td>
<td>Reaction Control System</td>
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<td>RCT</td>
<td>Reaction Control Thruster</td>
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<td>RD</td>
<td>Reference Document</td>
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<td>RDA</td>
<td>Radar Doppler Altimeter</td>
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<td>RF</td>
<td>Radio Frequency</td>
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<td>RFD</td>
<td>Request For Deviation</td>
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<td>Request for Quotation</td>
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<td>Radio Frequency System</td>
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<td>Request For Waiver</td>
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<td>RMS</td>
<td>Root Mean Square</td>
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<td>ROCC</td>
<td>Rover Operations Control Centre</td>
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<tr>
<td>ROM</td>
<td>Rough Order of Magnitude</td>
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<tr>
<td>RU BSH</td>
<td>Remote Unit</td>
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<tr>
<td>RV</td>
<td>Rover Vehicle</td>
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**S**

SA  Solar Array  
SADA  Solar Array Drive Assy  
SADM  Solar Array Deployment Mechanism  
SAL  Sterility Assurance Level  
S/C  Spacecraft  
SCC  Space Components Coordination  
SCF  Software Configuration File  
SCN  Software Change Notice  
SES  Support and Egress System  
SEU  Single Event Upset  
SMR  Surface Mission Review  
S/N  Serial Number  
SOCC  Science Operation and Control Centre  
SOW  Statement of Work  
SPDS  Sample Preparation and Distribution System  
SPR  Software Problem Report  
SRR  System Requirements Review  
S/S  Subsystem  
STM  Structural & Thermal Model  
STP  System interface Temperature reference Point  
STR  Star Tracker  
SVT  System Verification Test  
S/W  Software  
SWT  Science Working Team

**T**

TAA  Technical Assistance Agreement  
TAD  Top Assembly Drawing  
TAS  Thales Alenia Space

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<td>Trajectory Correction Manoeuvre</td>
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<td>Thermal Mathematical Model</td>
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<td>TOA</td>
<td>Target Orbit Manoeuvre</td>
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<td>TPS</td>
<td>Thermal Protection System</td>
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<tr>
<td>TRL</td>
<td>Technology Readiness Level</td>
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<td>TRP</td>
<td>Thermal Reference Point</td>
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<tr>
<td>TRRRB</td>
<td>Test Readiness Review Board</td>
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<tr>
<td>TS</td>
<td>Tapping Station</td>
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<td>TT&amp;C</td>
<td>Telecommand, Telemetry and Control</td>
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<td>UFOV</td>
<td>Unobstructed Field Of View</td>
</tr>
<tr>
<td>UHF</td>
<td>Ultra-High Frequency</td>
</tr>
<tr>
<td>UOAF</td>
<td>Unit Optical Alignment Frame</td>
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<tr>
<td>UVIS</td>
<td>UV Spectrometer</td>
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**V**

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<td>Verification Control Document</td>
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3. APPLICABLE & REFERENCE DOCUMENTS

3.1 Applicable Documents

The following documents form a part of this specification to the extent defined in this specification. In case of conflict, this specification shall be considered superseding. All documents are considered in their latest issue.

3.1.1 ESA Normative Documents

SOW
General

[NR 01] ExoMars Mission and System Requirements Document
EXM-MS-RS-ESA-00001

[NR 02] ExoMars Rover Requirements Document
EXM-RM-RS-ESA-00001

[NR 03] ExoMars Management Requirements Document
EXM-MS-RS-ESA-00012

[NR 04] ExoMars Product Assurance Requirements
EXM-MS-RS-ESA-00002

[NR 05] ExoMars Assembly, Integration and Verification Requirements
EXM-MS-RS-ESA-00006

[NR 06] ExoMars Scientific Payload Requirements Document
EXM-PL-RS-ESA-00001

[NR 07] ExoMars Planetary Protection Requirements
EXM-MS-RS-ESA-00005

[NR 08] ExoMars Mission Analysis Guidelines
EXM-MS-TN-ESA-00001

[NR 09] ExoMars Operation Interface Requirements Document
EXM-GS-IRD-ESA-00002

[NR 10] Space to Ground Interface Requirements Document
EXM-GS-IRD-ESA-00001

[NR 11] Pasteur Payload Experiment Interface Requirements Document
EXM-PL-IRD-ESA-00001

[NR 12] Geophysical and Environmental Package Interface Req’s
EXM-PL-IRD-ESA-00002

[NR 13] Customer Furnished Items List
EXM-MS-LI-ESA-00001

[NR 14] Document Requirements List
EXM-MS-RS-ESA-00009
[NR 036] ECSS-E20-08A : Photovoltaic assemblies and components
[NR 037] Tailoring of ECSS E30 Part1A Mechanical– Thermal Control for ExoMars
EXM-MS-RS-ESA-00025
[NR 038] ECSS E30 Part3A Mechanical – Mechanisms
[NR 039] Tailoring of ECSS E30 Part5.1 Mechanical – Liquid and electric propulsion
[NR 040] Tailoring of ECSS E30 Part6A Pyrotechnics - Mechanisms
[NR 041] ECSS E30 Part 7A Mechanical Part
[NR 042] ECSS E30 Part 8A Materials
[NR 043] ECSS-E-30-01A : Fracture control
[NR 044] ECSS-E30-11A Modal Survey Assessment
[NR 045] Tailoring of ECSS E32 A – Structural General Requirements for ExoMars
EXM-MS-RS-ESA-00020
[NR 046] Tailoring of the ECSS-E-32-02 : Structural Design and Verification of Pressurized Hardware
EXM-MS-RS-ESA-00022
EXM-MS-RS-ESA-00023
EXM-MS-RS-ESA-00024
[NR 050] Tailoring of ECSS E40 part 1B and 2B Software DRDs for EXOMARS
EXM-MS-RS-ESA-00027
[NR 051] Tailoring of the ECSS E50 Part 1A Communications – Part 1: Principles and requirements for ExoMars
EXM-MS-RS-ESA-00026
[NR 052] ECSS E50 Part 2A: Document requirements definition (DRDs)
[NR 053] Tailoring of the ECSS-E-50-02A Ranging and Doppler tracking for ExoMars
EXM-MS-RS-ESA-00016
EXM-MS-RS-ESA-00017
[NR 055] ECSS E-50-12A SpaceWire - Links, nodes, routers and networks
[NR 056] On-Board Interfaces MIL 1553-B-Notice
[NR 057] ECSS E60A Control Engineering
[NR 058] ECSS E-60-02: Star Sensor Standard
WP-15 February 1993
CCSDS
[NR 060] CCSDS 131.0-B-1 TM Synchronization and Channel Coding.
[NR 062] CCSDS 133.0-B-1 Space Packet Protocol.
[NR 063] CCSDS 231.0-B-1 TC Synchronization and Channel Coding.
[NR 064] CCSDS 231.0-B-1 Cor. 1 Technical Corrigendum 1 to CCSDS 231.0-B-1.
[NR 068] CCSDS 211.2-B-1. Proximity-1 Space Link Protocol — Coding and Synchronization Sublayer.

LAUNCHERS


ROVER SPECIFICATION

[NR 074] ExoMars Model Surface Science Scenario Requirements
EXM-RV-RS-ESA- 00002

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3.1.2 TAS-I Documents

SPACECRAFT COMPOSITE

[NR 0100] EXOMARS spacecraft composite requirement specification
EXM-MS-SYS-AI-0001

[NR 0101] EXOMARS Mechanical and Thermal General Design and Interface Requirements
EXM-MS-SSR-AI-0003

[NR 0102] EXOMARS Electrical General Design and Interface Requirements
EXM-MS-SSR-AI-0001

[NR 0103] EXOMARS Software Support Requirements
EXM-MS-SRR-AI-0006

[NR 0104] EXOMARS EMC and Power Quality Requirements
EXM-MS-SSR-AI-0002

[NR 0105] EXOMARS Environment and Test Requirements
EXM-MS-SSR-AI-0004

[NR 0106] EXOMARS Cleanliness and Contamination Control Requirements
EXM-MS-SSR-AI-0005

[NR 0107] Product Assurance Plan
EXM-MS-PLN-AI-0010

[NR 0108] DM to CM IRD - EXM-MS-IRD-AI-0006

[NR 0109] DM to OM IRD - EXM-MS-IRD-AI-0007

[NR 0110] ExoMars Inter-Elements Communication IRD
EXM-MS-IRD-AI-0010

[NR 0111] RM to DM IRD - EXM-MS-IRD-AI-0005

[NR 0112] PA requirements for Subcontractors
EXM-MS-RQM-AI-0004

[NR 0113] EGSE General requirement specification
EXM-MS-RQM-AI-0006

[NR 0114] MGSE General requirement specification
EXM-MS-RQM-AI-TBW

CARRIER MODULE COMPOSITE SPECIFICATION

[NR0200]
DESCENT MODULE REQUIREMENT SPECIFICATION

NR[0300] DM EDL Trajectory Data Base (ETDB)
NR[0301] DM Aero Dynamic Data Base (AEDB)
NR[0302] DM Aero Thermodynamic Data Base (ATDB)
NR[0303] Requirements specification for Reduced TMM/GMM of DM elements
        EXM DM-SPE-AI-0001
NR[0304] .
NR[0305] .
NR[0306] .
NR[0307] .
NR[0308] .
NR[0309] .
NR[0310] DM Thermo-Mechanical ICD
NR[0311] DM Electrical ICD
NR[0312] DM-Landing Platform ICD
NR[0313] DM-EDLS ICD
NR[0314] .
NR[0315] .
NR[0316] .
NR[0317] .
NR[0318] .
NR[0319] .
NR[0321] DM EDLS Requirements specification - EXM-DM-SSS-AI-0016

ROVER MODULE REQUIREMENT SPECIFICATION

3.2 REFERENCE DOCUMENTS

The following documents as referenced herein shall be considered as non-contractual in nature. Their reference is to support the clarification, explanation and/or definition to a specific set of requirements for better understanding.

[RD 01]  FED--STD-209E - Airborne particulate cleanliness classes in clean rooms and clean zones


4. PLANETARY PROTECTION ASPECTS

Bio-burden and organic contamination are strictly related to ExoMars mission success. Planetary Protection issues must be pursued with all possible strength from the initial stage of the programme. Relicts of extinct micro-organisms as well as any organic molecule have crucial impacts on mission scientific objectives and the philosophy of build it "dirty" because it can be sterilised later is unacceptable for this mission and payload.

Planetary protection measures that apply to ExoMars project - from early design phase - are aimed at:

- Protecting Mars environment from terrestrial biological contamination
- Preserving Mars sample properties to avoid false results

For preventing false positive risks (due to forward contamination) the distinction must be made between missions dedicated to direct and to indirect exobiology, because they lead to different requirements.

- Direct exobiology is the search for active forms of life. It requires sterilisation to kill any terrestrial micro-organisms on hardware in contact with samples, because they are able to bring confusion in the biological experimentation results.
- Indirect exobiology is the search for organic compound or molecules linked to past or present life. For this purpose, sterilisation is not enough, because the organic matter stays on place with other kind of organic contaminants. The problem here is that such contamination may be analysed as extraterrestrial compound.

ExoMars includes both direct and indirect exobiology. Thus, all ExoMars parts, in particular those which can transfer organic and biological contamination to extraterrestrial samples (by direct contact or through cross contamination), shall comply with both sterility assurance level requirement and organic cleanliness requirement.

[MS-CL-0001]
All ExoMars modules shall fulfil the Planetary Protection requirements. The ExoMars Planetary Protection requirements as per [NR 03] shall apply. Molecular contamination, particulate contamination and bio-burden have to be considered in conjunction.

*
The following contaminants are of concern for ExoMars mission (TBC):

- **Aromatic hydrocarbons** (e.g. benzene, toluene, higher molecular weight aromatics, Polycyclic aromatic hydrocarbons)
- **S, N, O heterocyclic aromatics** (e.g. furan, pyridine, pyramadine, benzothiopene)
- **Carboxylic acids and their salts** (e.g. alkyl and aromatic acids, fatty acids)
- **Non aromatic hydrocarbons** (e.g. alkanes, alkenes, atmospheric methane)
- **Nitrogen containing compounds** (e.g. Amino acids, amines, amides, purines, pyrmidines, porphyrins)
- **Alcohols**
- **Carbonyl compounds** (e.g. esters, ketones, aldehydes)
- **Sulfonic, phosphonic acids** (e.g. methanesulfonic acid)
- **Lipids and derivatives**
- **Sugars and derivatives**
- **Proteins**
- **Nucleic acids, nucleotides** (e.g. DNA fragments)
5. CONTAMINATION ENVIRONMENT

5.1 General

[MS-CL-0003]
ExoMars Spacecraft Composite and its equipment design shall be such that it fulfils all applicable functional performance requirements, if the contamination environment is in accordance with this specification.

5.2 Ground Environment

[MS-CL-0004]
ExoMars Carrier shall be assembled and maintained in ISO 8 level clean room as per ISO 14644-1 (Clean rooms and Associated Controlled Environments – part 1: Classification of air Cleanliness) or better, with appropriate controls and procedures as per ISO 14644-2 (Clean rooms and Associated Controlled Environments – part 2: Specification for testing and monitoring to prove continued compliance with ISO 14644-1).

[MS-CL-0005]
ExoMars DMC shall be assembled and maintained in ISO 8 level clean room as per ISO 14644-1 or better, with appropriate controls and procedures as per ISO 14644-2.

Note:
Taking into account Planetary Protection needs, it has already been proposed DMC assembly to take place in ISO 7 level grade B clean room, with an ISO 5 area containing and ISO 3 glow-box for AIT on sensitive equipment as SPDS, Drill, Analytical Laboratory (TBC).

End of Note

5.3 Launch and Ascent Environment

[MS-CL-0006]
ExoMars S/C and its equipment shall withstand and operate as required when exposed to the following (cumulative) contamination environment during launch campaign launch and ascent phases:

- Molecular deposition over:
  - Launch preparations: < 2 mg/m²/week
  - Launcher outgassing during flight: < 2 mg/m²
  - Launcher thruster plume: < 2 mg/m²
Particulate contamination:
  - ISO 8 level clean room conditions during launch campaign before encapsulation
    - particle fallout: **275 ppm/day** (as per ECSS-Q-70-01A – Cleanliness and Contamination Control)
  - ISO 7 level clean room conditions encapsulated under fairing until launch
    - particle fallout: **52 ppm/day** (as per ECSS-Q-70-01A)

Note:
ECSS-Q-70-01A correlation between particles in air and particles fall-out is referred to [RD 01] clean room classification, and it is been extended to equivalent clean room classes in ISO standard.
End of Note

6. CLEANLINESS PERFORMANCE

6.1 List of Contamination Sensitive Items

Contamination sensitive items, in the frame of ExoMars project, are those items that, if affected by contamination:

1. Can show reduction of performances
   This is a ‘classical’ effect of contamination in space mission. Preliminary list of this kind of contamination sensitive items is included here below:
   - Thermal control surfaces (MLI, Radiators)
   - Solar arrays
   - Optical surfaces for UV, visible and IR sensors

2. Can show unacceptable ‘false positive’ results in the search for organic compounds
   Pasteur Payload Analytical Laboratory instruments which are in direct search of organic compounds belong to this list. Their need is that organic contaminants of terrestrial origin placed on the sample acquisition, distribution and analysis chain surfaces or in close proximity do not contaminate the samples in such a way to exceed the Instruments’ detection limit and reveal ‘false positive’ results.

In this sense all surfaces that come in contact or in close proximity with the samples (namely, the entire sample acquisition, distribution and analysis chain and surfaces in direct view) can be considered contamination sensitive as well.

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[MS-CL-0007]
ExoMars shall provide contamination protection and monitoring for contamination sensitive items. Sensitive items and specific constraints shall be identified by Subcontractors at all contractual levels and Payload Investigators, and they shall provide following information:

1 - Location: Module where the sensitive item is contained
2 - Subsystem including the sensitive item
3 – Sensitive item
4 - Type of sensitivity (molecular, particulate, or both)
5 – Max. allowable level of contamination before unacceptable degradation of performances (EOL needs)
6 - Operating temperature
7 - Reference: As an example, the payload or subcontractor’s cleanliness & contamination plan
8 - Monitoring: How the contamination is controlled during assembly
9 – Protection

Pasteur Payload Analytical laboratory instruments shall provide relevant detection limits.

**Note:**
For info, preliminary contamination EOL needs for items listed in bullet 1 are contained in the table below (values taken from literature or previous programs experience).

<table>
<thead>
<tr>
<th>EOL Cleanliness Level Needs</th>
<th>Molecular ([g/cm^2])</th>
<th>Particulate ([ppm])</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thermal Control Surfaces</td>
<td>(1 \cdot 10^{-5})</td>
<td>5000</td>
</tr>
<tr>
<td>Solar Arrays</td>
<td>(2 \cdot 10^{-6})</td>
<td>1300</td>
</tr>
<tr>
<td>Star Trackers optical surfaces</td>
<td>(1 \cdot 10^{-6})</td>
<td>300</td>
</tr>
<tr>
<td>IR sensor optical surfaces</td>
<td>(5 \cdot 10^{-6})</td>
<td>50</td>
</tr>
<tr>
<td>UV sensor optical surfaces</td>
<td>(4 \cdot 10^{-7})</td>
<td>TBD</td>
</tr>
</tbody>
</table>

**End of Note**

\* 

**6.1.1 Protection of Sensitive Parts**

[MS-CL-0008]
Contamination sensitive equipment shall be protected by covers, protection caps or equivalent devices as shield or structures. Covers shall have the same cleanliness level, or better, than the equipment to be protected.

\*
6.1.2 Purging

[MS-CL-0009]
Whenever possible, optical equipment shall be closed and purged with nitrogen or synthetic air, to eliminate outgassing products and prevent particulate contamination.

* [MS-CL-0010]
Contractors of equipment or instruments needing purging activities shall specify:
- Form of purging (continuous or periodic);
- Duration of periodic purging;
- Phases in which purging is mandatory;
- Individual purge rates;
- Purity grade of purging fluid;
- Exact position of purging I/F (to be agreed with ESA Project Office and Prime Contractor) and shall guarantee accessibility to purging I/F after integration on spacecraft in case purging is needed until launch.

6.2 Chemical Releases

6.2.1 Carrier Chemical Releases

[MS-CL-0011]
ExoMars Carrier subsystems/items shall limit outgassing during the space phase, such that relevant molecular deposition onto Carrier external surfaces does not exceed \(9 \times 10^{-8} \text{ g/cm}^2\) (TBC), and relevant molecular deposition over optical surfaces dose not exceed \(2 \times 10^{-8} \text{ g/cm}^2\) (TBC).

Note:
10% of total molecular deposition has been allocated on thrusters plume impingement/backflow effects (TBC).
Once EOL needs of Star Trackers will be provided by Subcontractor, final apportionment for space phase will be calculated.
End of Note

* [MS-CL-0012]
Carrier Subcontractor shall provide description of non-metallic materials for system level verification of this requirement.
The requested information is the following:
• **Commercial identification**  
  Trade name and number, correct and standard designation  
  If no trade name exists, then the manufacturer's name plus number are entered.

• **Composition**  
  Chemical composition of the material

• **Use and location**  
  Indicates in what subsystems, box or item the material is used and whether it acts as a structural element, thermal control, electrical insulation etc. as relevant.

• **Cure**  
  Description of thermal cure parameters, if any

• **Temperature**  
  Nominal operating temperature [°C] - average and maximum

• **Size**  
  Surface area [cm²] or mass [g] and the indication if the identified non-metallic material is sealed or not

• **Thermal vacuum stability (TVS) values** from identified reference:  
  o TML  
  o RML  
  o CVCM

• **Condensable outgassing rates**

Condensable outgassing rates from dynamic outgassing tests such as ESA VBQC-test or ASTM E1559 shall be provided (at material/item operative temperatures). According to [NR 021] guidelines, as a minimum it shall be done if the used material covers an area larger than 1000 cm².

* [MS-CL-0013]
  The characteristics of the thrusters and their accommodation on the spacecraft shall minimise contamination on Carrier external surfaces due to plume impingement/back-flow so that deposition on Carrier sensitive surfaces does not exceed $1 \cdot 10^{-7}$ g/cm² (TBC).  
  Thruster nozzles in line of sight to sensitive surfaces shall be shielded.

*
6.2.2 DMC Chemical Releases

[MS-CL-0014]
ExoMars DMC subsystems/materials shall limit outgassing during mission (especially entry phase and planet phase), such that relevant molecular deposition onto sensitive surfaces shall not exceed TBD.

[MS-CL-0015]
DMC Subcontractors and Payload Investigators shall provide description of non-metallic materials for system level verification of this requirement.
The requested information is the following:

- **Commercial identification**
  Trade name and number, correct and standard designation
  If no trade name exists, then the manufacturer's name plus number are entered.

- **Composition**
  Chemical composition of the material

- **Use and location**
  Indicates in what subsystems, box or item the material is used and whether it acts as a structural element, thermal control, electrical insulation etc. as relevant.

- **Cure**
  Description of thermal cure parameters, if any

- **Temperature**
  Nominal operating temperature [ºC] - average and maximum

- **Size**
  Surface area [cm²] or mass [g] and the indication if the identified non-metallic material is sealed or not

- **Thermal vacuum stability (TVS) values** from identified reference:
  - TML
  - RML
  - CVCM

- **Condensable outgassing rates**

- **Outgassed products and relevant quantities**

Condensable outgassing rates from dynamic outgassing tests such as ESA VBQC-test or [RD 02] standard shall be provided (at material/item operative temperatures). According to [NR 021] guidelines, as a minimum it shall be done if the used material covers an area larger than 1000 cm².

Relevant condensable outgassing rate at operating temperatures shall be provided taking into account all the processes the item is going to undergo before being delivered to Prime (e.g. DHMR).
Information on outgassed products and relevant quantities shall be provided for all materials.
The ExoMars Descent and Landing systems shall minimise the contamination of the Rover with rocket exhaust containing organic compounds, so that deposition over Rover surfaces and GEP, PPL is TBD.

Subcontractor shall provide following information:
- Thruster nozzle geometry
- Operational parameters (such as mass flow, composition of gaseous jet, combustion chamber temperature and pressure, fuel ratio)

The ExoMars landing system design shall minimise the contamination of the landing site with rocket exhaust containing organic compounds so that deposition is TBD.

All by-products of the ExoMars landing system shall be analytically characterized and reported, including any trace substances or impurities present, at ppb level.

6.3 Particulate Releases

ExoMars Mechanisms and hardware deployments shall not generate particulate debris or molecular contaminants that will adversely impact adjacent external surfaces or other external contamination sensitive surfaces.

6.4 Contamination Monitoring

Cleanliness of contamination sensitive items shall be monitored during on-ground phases by using detectors and/or optical surfaces to detect both molecular and particulate contaminants.
7. CLEANLINESS DESIGN

7.1 General

[MS-CL-0022] ExoMars shall comply with the contamination control requirements of ECSS-Q-70-01A, but taking into account bio-contamination needs as per [NR 07].

7.2 Cleanability, Sterilization and Assays

[MS-CL-0023] To avoid degradation of materials and improve treatment efficiency, materials selection and flight configuration equipment/structures/utilities design shall take into account compatibility and suitability with cleaning, sterilisation and assays. Contextually efficiency of cleaning and sterilisation/assays shall be taken into account – e.g. every time bio-burden reduction methods are applied to subsystems/items, it shall be verified if they affect allocated cleanliness levels. If so, items/subsystem shall be cleaned again.

7.2.1 Ultra-cleaning

[MS-CL-0024] All parts of the Sample Acquisition System (SAS) and Sample Preparation and Distribution System (SPDS), and in general all instruments surfaces (both internal and external) that are designed to contact martial soil samples or in direct view with them shall be compatible with ultra-cleaning processes.

Note: Ultra-cleaning processes shall be in accordance with ESA standard TBD (in preparation).

End of Note

7.3 Materials and Processes

7.3.1 Outgassing

[MS-CL-0025] The control of material outgassing shall be performed by:

- initial screening of materials for their outgassing properties (TML, RML, CVCM) with acceptance criteria of RML < 1% and CVCM < 0.1% (as defined in ECSS-Q-70-02A, Thermal Vacuum Outgassing Test for the Screening of Space Materials – see Note)
- submittal of declared materials and processes list

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• for DMC (including Rover, GEP, PPL), avoiding materials whose outgassing products include compounds pertaining to the families listed in [MS-CL-0002]
• In general, adoption of silicone-free materials, every time viable alternatives exist
• provision of condensable outgassing rates vs. temperature for system level evaluations (see MS-CL-0012 and MS-CL-0015)
• selection of appropriate countermeasures such as vacuum bake-out

Note:
Outgassing parameters as per ECSS-Q-70-02A or [RD 03] standard have to be considered at material operative temperatures, if they are greater than 125 °C.
End of Note

* [MS-CL-0026]
Bake-out will be mandatory:
• When RML or CVCM are out of requirement
• When deposition limits on contamination sensitive items exceed as defined in [MS-CL-0011] and [MS-CL-0014] are exceeded.

7.3.2 Particulate

[MS-CL-0027]
The control of external particulate contamination shall be performed by:
• selection of non-flaky, non-dusty, non-shatterable materials,
• identification of moving parts or mechanisms and protection from the release of particles
• observing the specified cleanliness requirements

7.4 Packaging

[MS-CL-0028]
Clean items will be protected from contamination by preservation, packaging or storage techniques prior to further handling, transportation, assembly and integration. ECSS-Q-70-01A, and [NR 03], will be followed.
In addition to chapter 6.5 in ECSS-Q-70-01A, the condensation of moisture or contaminants on cold surfaces during test or transportation shall be prevented.

7.4.1 General

[MS-CL-0029]
Packaging material shall maintain the cleanliness level of the hardware to be protected.

7.4.1.1 Packaging of Organic Contamination Highly Sensitive Items

[MS-CL-0030]
Organic Contamination highly sensitive items shall be sealed and pressurized after cleaning to protect against recontamination.

7.4.2 Impermeability

[MS-CL-0031]
Packaging material shall be impermeable in order to protect hardware from contamination caused by penetrating contaminants.

7.4.3 Visual Inspection

[MS-CL-0032]
Packaging materials selected for cleaned items shall possess qualities allowing for visual inspection and identification of the cleaned item (i.e. transparent material).

7.4.4 Cleanliness

[MS-CL-0033]
Packaging materials selected for cleaned items shall be verified to have a cleanliness level compatible with the cleanliness level required for the item.

7.4.5 Particle Sloughing

[MS-CL-0034]
Packaging materials selected for cleaned items shall be resistant to particle sloughing such that it is compatible with the required cleanliness levels.

7.4.6 Anti-static Properties

[MS-CL-0035]
Packaging materials selected for cleaned items shall possess anti-static properties compatible with the item. Care has to be taken that the antistatic materials does not shed particles.
8. CLEANLINESS LEVELS

8.1 Flight Hardware

8.1.1 Cleanliness Level during Ground Operations

[MS-CL-0036]
All flight hardware shall be normally maintained, as a minimum, in a "Visually Clean" status as defined in chapter 9 of this document.

8.1.2 Cleanliness Level at Delivery

[MS-CL-0037]
The cleanliness level of ExoMars Composite and its hardware at delivery shall be verified to be
- Carrier: 500A (TBC)
- Descent Module Composite (including Rover, excluding SPDS, Drill, PPL): 300 A (TBC)
as defined in ECSS-Q-70-01A, Tables 1 and 3, unless more stringent levels are needed for performance of specific items.

8.1.2.1 Cleanliness Level of Items in Contact with the Samples

[MS-CL-0038]
The surfaces of SPDS, Drill, PPL Analytical Laboratory and in general surfaces in direct contact or view with Mars samples shall be clean (i.e. free from non-volatile residues and particulate material of terrestrial origin) at a verifiable level equal or better than:
- 1 ng/cm² (A/1000 according to ECSS-Q-70-1A – TBC) for molecular contamination
- TBD for particulate

Note:
This requirement has to be intended until the end of operations on Mars. According to [NR 03], the maximum amount of terrestrial contamination transferred to the organic instruments per gram of sample can be considered on the order of nano-gram TOC until further clarifications. The appropriate cleanliness level for all parts that come in direct or indirect contact with the samples to meet this requirements needs to be better assessed.

End of Note
8.2 Connectors

[MS-CL-0039]
Connectors of flight equipment or being connected to flight equipment shall have the cleanliness level "Visually Clean Plus Microscope" (as defined in chapter 9 of this document) if no higher levels are assigned by the design, unless more stringent levels are needed for the performance of specific items.

8.3 Identification on Drawings

[MS-CL-0040]
The assigned flight equipment cleanliness levels, cleaning procedures, packaging procedures, protection caps, etc. shall be called up in all the corresponding drawings.

8.4 Cleanliness of Ground Hardware

[MS-CL-0041]
All deliverable non-flight hardware, including engineering models, qualification models, and GSE shall be "Visually Clean", as defined in chapter 9 of this document.

8.5 Cleanliness of GSE Interfaces

[MS-CL-0042]
GSE interfaces being connected to Flight Hardware shall have the same cleanliness level of the corresponding flight hardware.

8.6 Fluids

[MS-CL-0043]
Operating, testing and purging fluid (liquid and gases) cleanliness levels shall be defined and verified in due consideration of the flight hardware cleanliness levels. The levels shall be called up on the corresponding drawings and cleaning procedures.

8.7 National Laws

[MS-CL-0044]
The on-ground contamination levels shall conform to the relevant national laws concerning allowable contamination levels, occupational and environmental regulations.
8.8 Cleaning Methods and Processes

8.8.1 Methods

[MS-CL-0045]
Required Cleaning Methods shall use consolidated and Prime accepted methods.

8.8.2 Cleaning Processes/Procedures

[MS-CL-0046]
Required Cleaning Processes shall use consolidated and Prime accepted processes and procedures.

9. FACILITY REQUIREMENTS

9.1 Cleanliness Levels of Facilities

[MS-CL-0047]
Clean rooms and clean workstations required for product processing shall be classified in accordance with ISO 14644-1 and shall be compatible with the required cleanliness level of the product.

9.2 Test Environment

[MS-CL-0048]
The required test environment, defined in [NR 0105] shall be compatible with the required cleanliness level of the tested product.

9.3 Storage

[MS-CL-0049]
Storage provisions shall be made, including protection and storage directives, to prevent the product from deterioration and re-contamination during storage periods in facilities. The protection and the container shall have the same order of cleanliness, or better, that its equipments.
9.4 Shipping and Transport

[MS-CL-0050]
Shipping and transport (also internal) shall be such that no contamination, humidity, corrosion and other environmental influences could lead to hardware deterioration and/or re-contamination.

* 

9.5 Launch Site

[MS-CL-0051]
Usage of cleaned containers, handling equipment and the observation of cleanliness requirements at interfaces shall be implemented and shall be reflected in the procedures.

* 

10. GLOSSARY

10.1 Definition of Terms

Clean Room
Enclosed area, designed, equipped, maintained and controlled in such a way that the degree of contamination of a product can be controlled

Clean Workstation
A clean workstation is a workbench or similar work area characterized by having its own filtered air or gas supply.

Cleanliness Level
An established maximum of allowable contaminants based on size, distribution or quantity on a given area or in a specific volume.

Contaminant
Any unwanted matter which could be detrimental to the required operation, reliability, or performance of a part, component, subsystem, or system.

Critical and/or Significant Surface
A surface which requires precision cleaning.

Fibre
A particle whose length-to-width ratio is in excess of 10 to 1 (minimum length of 100 micrometers)

Fluid
A liquid or gaseous material

Flush
A rinsing of a part, component, subsystem, or system using a liquid as a rinsing medium.

Landed System
System (lander, landing probe, penetrators, separable items, etc.) designed to land or to crash on extraterrestrial body.

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Organic compound, material or molecule
Compound, material or molecule including carbon, oxygen, hydrogen and/or nitrogen, which are the four reference atoms related to life.

Organic contamination
Contamination by organic compound, material or molecule, including living entities

NVR (Non-Volatile Residue)
Soluble (or suspended) material and insoluble particulate matter remaining after controlled evaporation of a filtered volatile liquid, usually measured in milligrams. Filtration is normally through a 0.45 or 0.8 micrometer membrane filter prior to evaporation.

Particle
Matter with observable length, width and thickness usually measured in micrometers. This definition includes fibres.

Particle Counters
Automatic electronic devices designed to electronically separate, size and count individual particles.

Particulate Matter
Matter with observable length, width, and thickness, as contrasted to non-particulate film matter without definite dimension.

Visually Clean
Visually clean to the normal unaided eye (except corrected vision) when examined under oblique white light (50 to 150 foot candles or 540 to 1600 lux) and from a distance of 30 to 60 cm.

Visually Clean
Visually clean to the normal unaided eye (except corrected vision) when examined under oblique white light (50 to 150 foot candles or 540 to 1600 lux) and from a distance of 30 to 60 cm.

Visually Clean Plus Ultraviolet
Visually clean (as defined above) and inspected with the aid of an ultraviolet (black) light of 2500 - 3800 Angstrom wavelength.

Visually Clean Plus Microscope
Visually clean when examined through a stereoscopic microscope with 8 to 10 times magnification and under oblique white light (50 to 150 foot candles or 540 to 1600 lux) at least.