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Standard Practice for Preparation of Aerospace Contamination Control Plans[1]

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1. Scope

1.1 This practice is intended to assist in the preparation of formal plans for contamination control, especially of aerospace critical surfaces. Requirements may be established at the systems level, either by the customer or the systems integrator, or at the subsystem level. Subsystem requirements may be imposed by the responsible subsystem supplier or they may be flowed down from the systems organization (4.7). The extent of detail and level of cleanliness required can vary with the particular application and type of hardware being built, but all aspects of contamination control must be included in a final plan. Therefore, each of the following elements must be considered for inclusion in a contamination control plan (CCP):

1.1.1 *Cleanliness requirements* for deliverable hardware addressing particulate, molecular, or biological contaminants or combination thereof. Specify contamination limits and any budget allocations.

1.1.2 *Implementation plans* to achieve, verify, and maintain the specified cleanliness requirements. Specify material and process controls, cleaning techniques, verification tests, protection and prevention plans, transportation controls, and corrective action for discrepancies.

1.1.3 *Environmental controls* including clean facilities to be used, facility maintenance, and monitoring schedule.

1.1.4 *Personnel and operational controls* including operating procedures, restrictions, training, motivation, and organizational responsibilities including the organization or individual for implementation and verification of the CCP.

1.2 The values stated in SI units are to be regarded as standard. No other units of measurement are included in this standard.

1.3 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

E595 Test Method for Total Mass Loss and Collected Volatile Condensable Materials from Outgassing in a Vacuum Environment

E1216 Practice for Sampling for Particulate Contamination by Tape Lift

E1235 Test Method for Gravimetric Determination of Nonvolatile Residue (NVR) in Environmentally Controlled Areas for Spacecraft

E1549 Specification for ESD Controlled Garments Required in Cleanrooms and Controlled Environments for Spacecraft for Non-Hazardous and Hazardous Operations

E1559 Test Method for Contamination Outgassing Characteristics of Spacecraft Materials

E2042 Practice for Cleaning and Maintaining Controlled Areas and Clean Rooms

E2217 Practice for Design and Construction of Aerospace Cleanrooms and Contamination Controlled Areas

F50 Practice for Continuous Sizing and Counting of Airborne Particles in Dust-Controlled Areas and Clean Rooms Using Instruments Capable of Detecting Single Sub-Micrometre and Larger Particles

F303 Practices for Sampling for Particles in Aerospace Fluids and Components

F312 Test Methods for Microscopical Sizing and Counting Particles from Aerospace Fluids on Membrane Filters

2.2 *Government Standards:*

FED-STD-209E Airborne Particulate Cleanliness Classes in Cleanrooms and Clean Zones[3,4]

USAF Tech Order 00-25-203 Contamination Control of Aerospace Facilities, U.S. Air Force[3]

[1] This practice is under the jurisdiction of ASTM Committee E21 on Space Simulation and Applications of Space Technology and is the direct responsibility of Subcommittee E21.05 on Contamination.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] Available from Standardization Documents Order Desk, Bldg. 4 Section D, 700 Robbins Ave., Philadelphia, PA 19111-5094, Attn: NPODS.

[4] FED-STD-209 has been superceded by ISO 14644-1 and -2. It may continue to be used if mutually agreed to by customer and supplier.

2.3 *International Standards:*[5]

ISO 14644-1 Cleanrooms and Associated Controlled Environments, Classification of Air Cleanliness

ISO 14644-2 Cleanrooms and Associated Controlled Environments—Specifications for testing and monitoring to prove continued compliance with ISO 14644-1

ISO 15388 Space Systems—Contamination and Cleanliness Control

2.4 *IEST Standards:*[6]

IEST-STD-CC1246D Product Cleanliness Levels and Contamination Control Program

NOTE 1—The Institute of Environmental Sciences has several Recommended Practices which may also be useful in the preparation of a CCP.

3. Terminology

3.1 *Definitions:*

3.1.1 *bidirectional reflectance distribution function (BRDF)*—the scattering properties of light reflected off surfaces, expressed as the ratio of differential outputs of radiance divided by differential inputs of radiance. Surface contaminants scatter the incident radiation in all directions and with variable intensities; BRDF is a method to quantify the spatial distribution of the scattered energy.

3.1.2 *biological contamination*—living material such as algae, bacteria, fungus, and so forth, which is capable of reproducing, thus being an increasing contaminant source.

3.1.3 *budget allocation*—the itemized summary of contamination accumulation for a given critical hardware item distributed over all phases from manufacture through end of performance lifetime.

3.1.4 *cleanroom*—an environmentally conditioned area where temperature, humidity, and airborne contaminants are controlled by design and operation. High Efficiency Particulate Air (HEPA) filters or better are usually required to achieve the air cleanliness level. Air particulate cleanliness is classified in accordance with ISO 14644-1.

3.1.4.1 *as-built cleanroom*—a cleanroom that is complete and ready for operation, with all services connected and functional, but without equipment or operating personnel in the cleanroom.

3.1.4.2 *at-rest cleanroom*—a cleanroom that is complete and ready for operation, with all services connected and functional, and with equipment installed and operable, as specified but without operating personnel in the cleanroom.

3.1.4.3 *operational cleanroom*—a cleanroom in normal operation, with all services functioning and with equipment and personnel, if applicable, present and performing their normal work functions in the cleanroom.

NOTE 2—For batch operations, specific conditions and requirements should be noted for monitoring and control.

3.1.5 *clean zone*—a defined space in which the concentration of airborne particles is controlled to meet a specified airborne particulate cleanliness class.

3.1.6 *controlled area*—an area which does not require a high degree of temperature and humidity control but a semi-clean atmosphere is desired. Air conditioning is standard commercial design except that filtration is rated to 80-85 % for 1.0 micrometer (µm) and larger particles to control airborne contaminants. These areas shall not exceed the airborne particle concentration of Class 8.5 (FED-STD-209E Class 300, 000) at 0.5 µm and Class 8 (Class 100,000) at 5.0 µm per ISO 14644-1 (FED-STD-209E). Reference USAF Tech Order 00-25-203.

3.1.7 *facility*—the total real property required to accomplish the environmental control and operation of cleanrooms, clean zones, and controlled areas as well as administrative and personnel support.

NOTE 3—This includes the cleanroom proper, air locks, change rooms, parts cleaning, storage, HVAC equipment, offices, and so forth.

3.1.8 *HVAC*—Heating, Ventilating, and Air Conditioning.

3.1.9 *image analysis*—the measurement of size, shape, number, position, orientation, brightness, and other parameters of small objects using the combination of an autofocusing microscope, an imaging sensor, and a dedicated computer system. Can be used to perform particle counts or measure particle dimensions automatically, with far greater accuracy than manual techniques.

3.1.10 *molecular contamination*—nonparticulate matter in the form of droplets or thin films which adversely affects component or system performance.

3.1.11 *nonvolatile residue (NVR)*—soluble material remaining after evaporation of a filtered volatile fluid or precipitate from a gas phase, usually reported in milligrams per unit area (or volume).

3.1.12 *particulate contamination*—small discrete mass of solid matter, usually measured in micrometers (µm), which adversely affects component or system performance.

3.1.13 *precision cleaning*—cleaning of hardware surfaces by approved engineering methods to meet specific cleanliness criteria.

3.1.14 *visibly clean*—absence of particulate or molecular contaminants when viewed from a specified distance with normal (or corrected to normal) vision with a specified illumination level.

4. Contents of CCP

4.1 *General Items and Information:*

4.1.1 All CCPs shall include an introduction or scope specifying the contamination-sensitive component(s) or system(s) being addressed, a list of applicable documents, and a list of definitions including any acronyms and abbreviations used in the document.

4.1.2 The level of detail required and the nature and extent of controls needed depends upon a number of factors. The

[5] Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036, http://www.ansi.org.

[6] Available from Institute of Environmental Sciences and Technology (IEST), Arlington Place One, 2340 S. Arlington Heights Rd., Suite 100, Arlington Heights, IL 60005-4516, http://www.iest.org.

systems organization or systems integrator has a better overview of contamination limitations, sensitivity of specific components and hardware, and total mission requirements than sub-tier suppliers. Contamination limits for total systems are the primary responsibility of the systems organization. Final contamination limits at delivery of the integrated system and at end of life should be established by agreement between the purchaser and systems supplier. Each supplier is responsible for defining and controlling the contamination level of the particular hardware being supplied, with the approval of the systems organization, in addition to requirements levied by the systems integrator.

4.1.3 The buyer and seller should agree on the contents and implementation of the CCP before any parts are processed beyond the first cleaning or inspection point. Suppliers of subsystems and components should prepare Contamination Control Plans so that the functional requirements of the hardware are protected. If a subsystem is particularly sensitive to contamination, there must be adequate controls and compliance with system contamination requirements. Examples of sensitive subsystems include optical or non-optical sensors, gyros, thermal control systems, liquid propellant systems, and cryogenic devices.

4.1.4 Some subsystems are relatively insensitive to contamination. These should be identified and justifications given for limited contamination control efforts. Even if a particular subsystem or hardware is not sensitive to contamination it must not be a source of contamination for other, more sensitive or critical hardware. Also it is important that system performance or contamination allowables not be degraded by contaminants emanating from contamination tolerant hardware.

4.2 *Cleanliness Requirements:*

4.2.1 Cleanliness requirements must be specified for deliverable components or systems addressing particulate, molecular, or biological contaminants, or combination thereof. Primary responsibility for contamination control remains with the hardware or subsystem supplier. Levels of control and allowable types and quantities of contaminants shall be as agreed by the supplier and systems organization when applicable. Specify contamination limits and the point in time when the requirement must be verified (for example, IEST-STD-CC1246D Level XXX after manufacture, or X.XX % area coverage at delivery to integration contractor). Define any budget allocations if different cleanliness levels are to be verified at different time intervals. Also identify whether the requirement is critical to the hardware performance or is necessary to protect other critical hardware.

4.2.2 Define how the cleanliness requirements will be imposed in operation; identify the relevant documents such as drawings, process documents, inspection procedures, test plans, manufacturing flow diagrams, acceptance plans, and so forth.

4.3 *Implementation Plan:*

4.3.1 *Attainment of Cleanliness Requirements*—Describe the means for achieving the specified cleanliness requirements. This focuses on (*1*) selection of low outgassing, low shedding, and low particle generating raw materials, (*2*) design features to protect against contamination such as filters, cold traps, baffles, debris shields, and so forth, (*3*) cleaning and processing techniques that will effectively remove contaminants from surfaces, and (*4*) facilities to be used for various operations such as cleanrooms of a specified class or controlled areas. Where pre-launch or post-launch cleaning operations are planned, these shall be described here also. These elements may be contained in separate documents, but shall all be responsive to the requirements and cross-referenced in the CCP. ISO 15388 also contains recommendations on contamination control requirements and guidelines for establishing contamination control plans.

4.3.2 *Verification of Cleanliness Requirements*—Identify the techniques planned to verify compliance with the cleanliness requirements, including particulate, molecular, or biological contaminants, or combination thereof. Rationale for use of witness samples versus direct examination or solvent extraction techniques should be included. Specify method of direct sampling, such as tape-lift per Practice E1216, spray flush per Practices F303, and so forth, and specify method of testing, such as microscope counts per Test Methods F312, outgassing per Test Method E595, Test Method E1559 to evaluate outgassing materials characteristics and properties, black or white light visual examination, BRDF, and so forth. Specify methodology for obtaining representative samples and method of analysis for witness samples such as reflectance of mirrors, image analysis, direct quantitative measurement, black or white light visual examination, BRDF, and so forth. State the frequency of sampling, whether sampling is directly on the hardware or via witness samples, and the justification for the sampling plan. Define the calibration of equipment used for cleanliness verification tests.

4.3.3 *Materials Control*—Describe the process for control and disposition of discrepant materials. Identify the documents which contain approved materials and those which have been approved by waiver.

4.3.4 *Maintaining Cleanliness Requirements*—The CCP must address the environmental controls and protection and prevention plans which will be imposed to maintain the hardware cleanliness requirements. This includes test environments such as acoustic and thermal vacuum chambers, cleanrooms, shipping containers, and so forth, as well as assembly areas and storage areas. See 4.4 for more details on cleanroom controls.

4.3.4.1 Product protection and packaging must consider storage of work in process to protect it when not being worked on during off-hours/evenings/weekends, in case of emergencies/power failure/natural disaster, or when potentially contaminating operations occur. Preparation for shipment or transfer out of the cleanroom should be addressed including type of container, type of packaging, cleaning before packaging, protective measures, identification of hardware, and verification of cleanliness. Materials and processes are critical to provide effective protection; approved packaging shall be identified and shall not compromise the cleanliness requirements of the critical hardware. The use of inspection seals and controls plus notation of any precautions or special handling on the packaging shall be described.