



European Cooperation for
Space Standardization



ECSS Q-70 Training Course

Cleanliness and Contamination Control

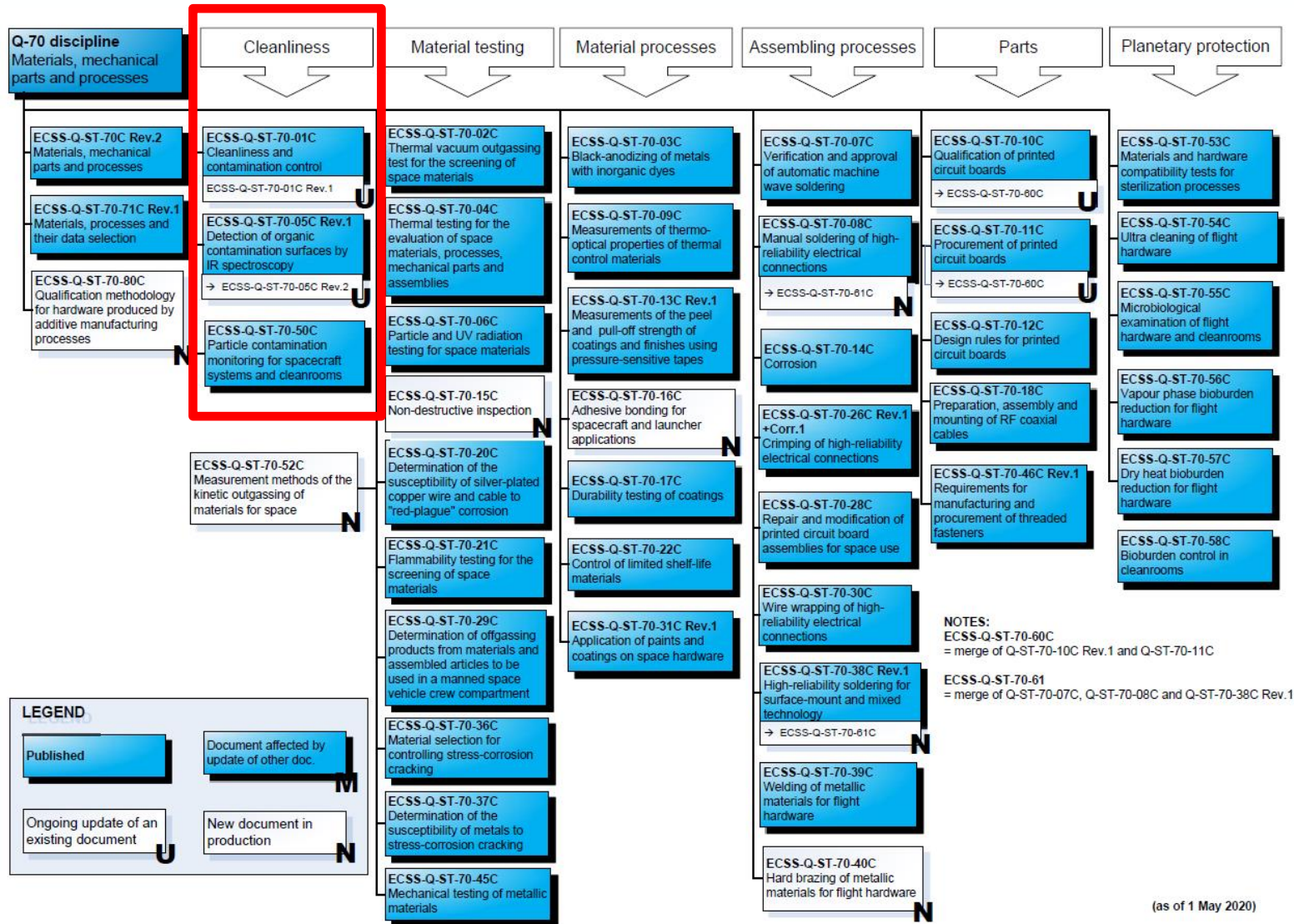
Julien Eck

05/10/2023

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→ THE EUROPEAN SPACE AGENCY



Cleanliness & contamination control

General overview standard

ECSS-Q-ST-70-01C

Currently under revision –
watch out for the public
review !

The specific standards for cleanliness & contamination monitoring methods:

Molecular organic contamination (MOC)

ECSS-Q-ST-70-05C



Currently under revision –
public review completed

Particulate contamination monitoring (PAC)

ECSS-Q-ST-70-50C

Correlating standards:

Outgassing, screening test (material suitability)

ECSS-Q-ST-70-02C

Outgassing, dynamic test (lifetime prediction)

ECSS-Q-TM-70-52A

=> Source tracing of contaminants

Thermo-optical properties

ECSS-Q-ST-70-09C

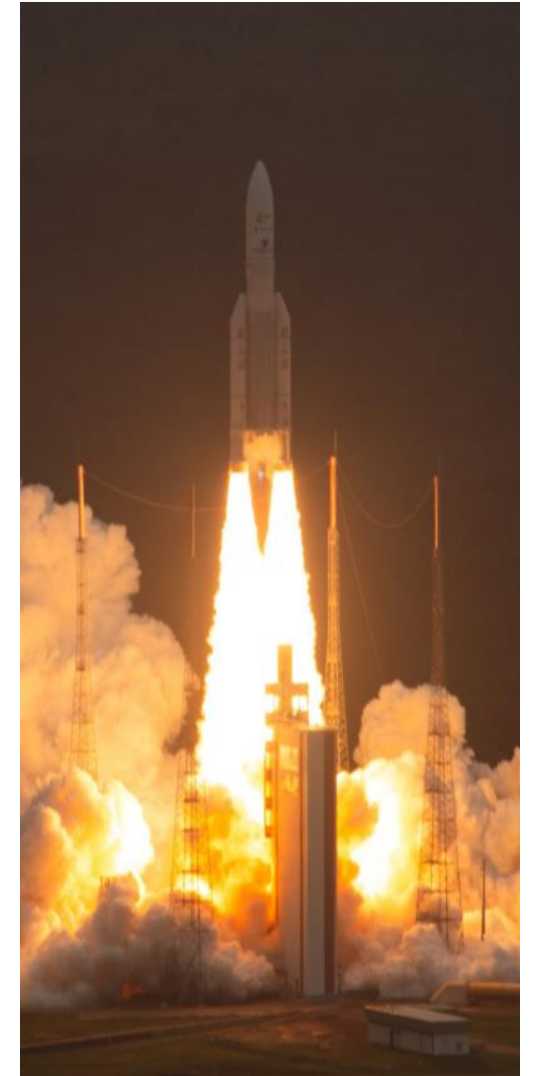
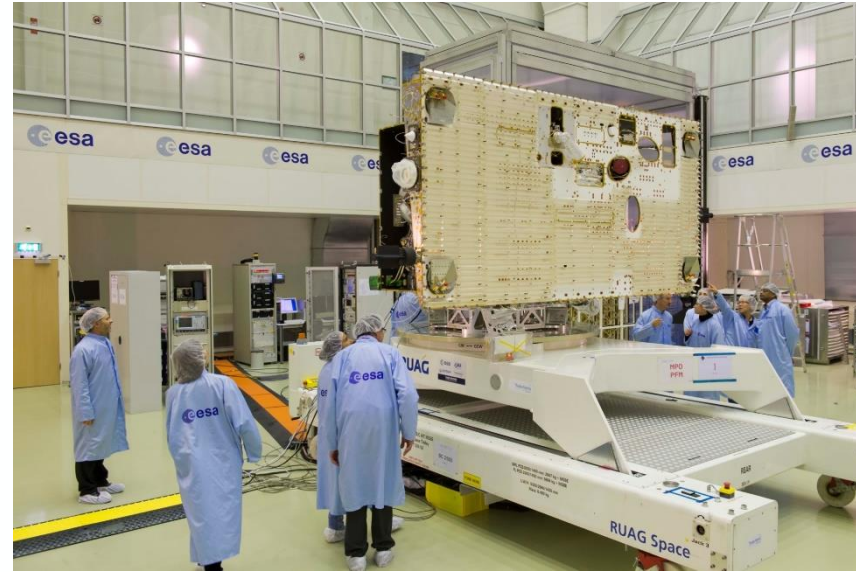
=> Effects of contaminants on optical & thermal control surfaces

- **ISO: 14644-1:** Classification of air cleanliness.
- **ISO: 14644-2:** Specifications for testing and monitoring to prove continued compliance with ISO 14644-1.
- **ISO: 14644-3:** Test methods.
- **ISO: 14644-4:** Design, construction and start-up.
- **ISO: 14644-5:** Operations.
- **ISO: 14644-6:** Vocabulary (*Status withdrawn*).
- **ISO: 14644-7:** Separative devices (clean air hoods, gloveboxes, isolators and mini-environments).
- **ISO: 14644-8:** Classification of air cleanliness by chemical concentration (ACC).
- **ISO: 14644-9:** Classification of surface cleanliness by particle concentration.
- **ISO: 14644-10:** Classification of surface cleanliness by chemical concentration.
- **ISO: 14644-12:** Specifications for monitoring air cleanliness by nanoscale particle concentration.

- The purpose of this standard is to define:
 - The selection of critical items, the definition of cleanliness requirements to satisfy the mission performance requirements and control the levels to be met by personnel, items, facilities and operations of space projects.
 - The management, including organization, reviews and audits, acceptance status and documentation control.
- Covers design, development, production, testing, operation of space products, launch and mission.
- Also guidelines given for identification of possible failures and malfunctions due to contamination and guidelines for achieving and maintaining the required cleanliness levels during ground activities, launch and mission.

The scope covers :

- Contamination control programme
- Specifications
- Design, AIT, pre-launch/mission
- Monitoring and testing techniques
- Cleanrooms
- Cleaning techniques
- Vacuum facilities and other ground activities

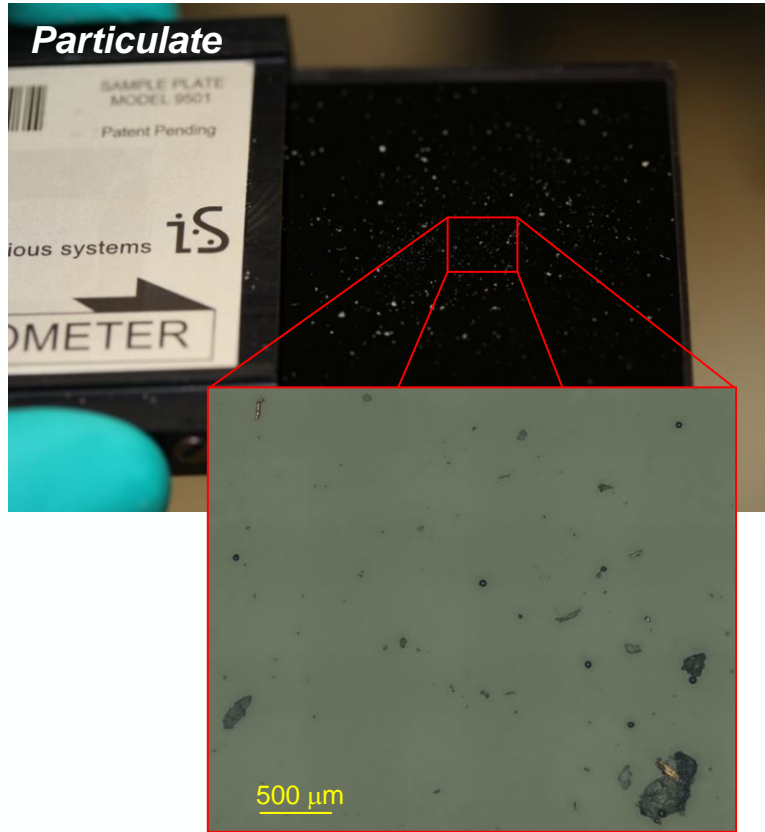


Contaminant

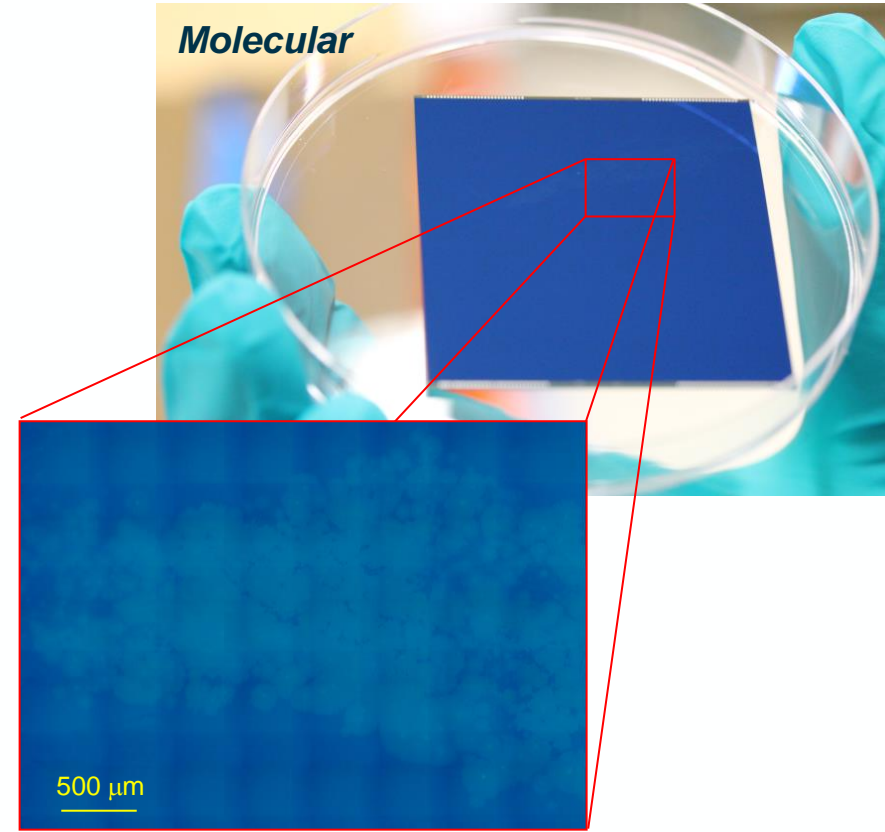
Cleanliness and Contamination Control

w/ Planetary Protection & Life Science

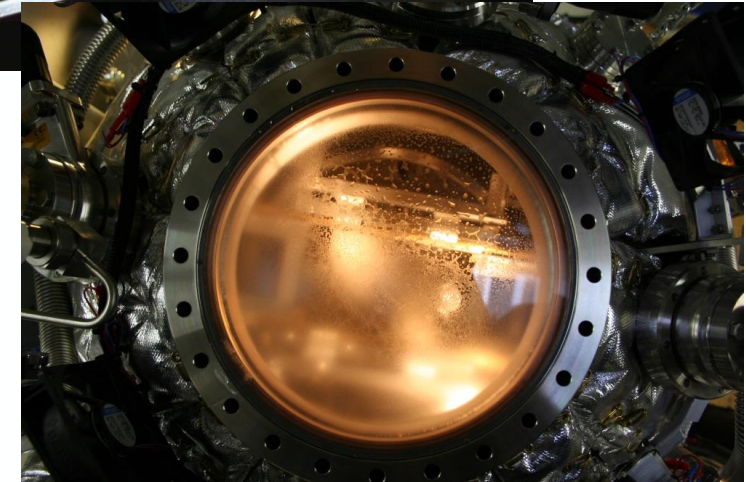
Any unwanted **molecular or particulate matter** (including **microbiological matter**) on the surface or in the environment of interest, that can affect or degrade the relevant performance or life time (from ECSS-Q-ST-70-01 [1])



Particulate contamination refers to the deposition of visible - μm sized -conglomerations of matter



Molecular contamination refers to the cumulative build-up of individual molecules of foreign matter



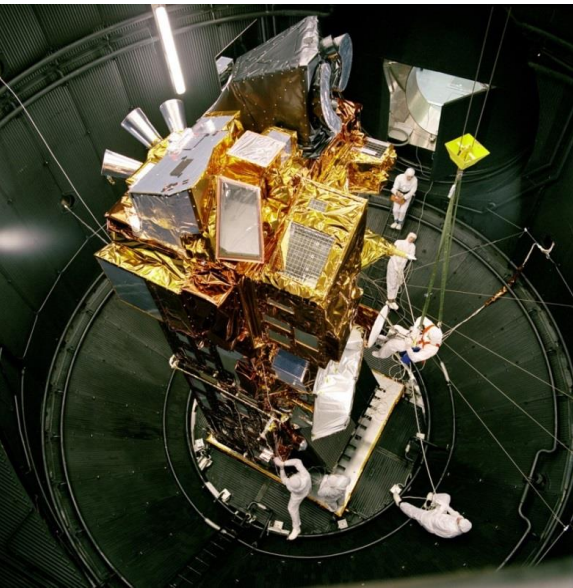
Airborne contamination refers to:

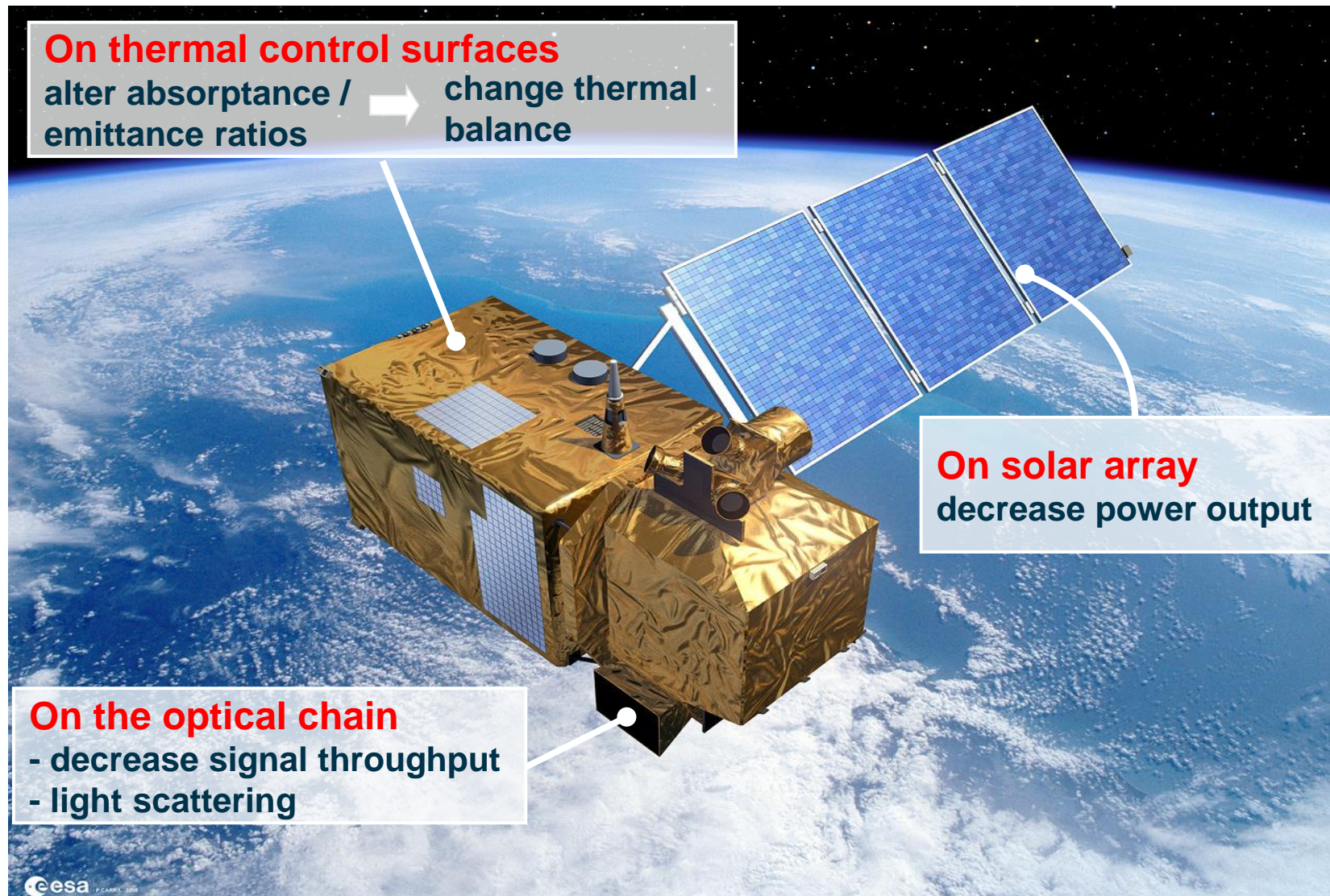
- particle suspended in air
- the presence in the atmosphere of chemical substances in the gaseous or vapour state

Surface contamination refers to:

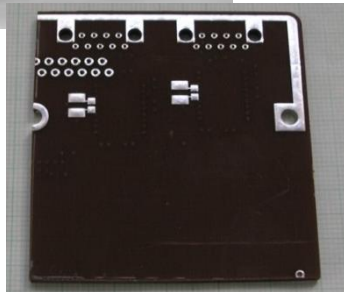
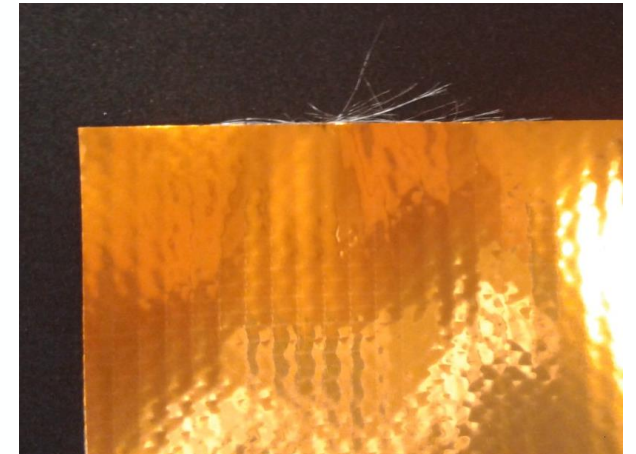
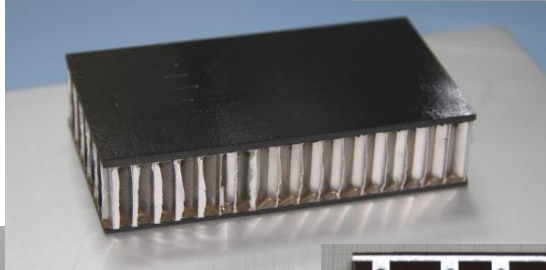
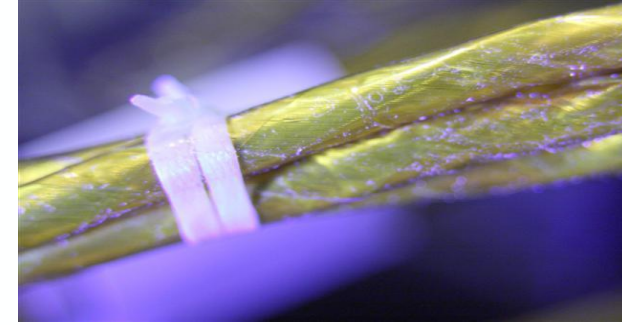
- accumulated deposit of particulate matter on a surface
- presence of chemical substances in the sorbed state

ECSS-Q-ST-70-01C: When Can Contamination Happen?





ECSS-Q-ST-70-01C: Typical Contamination Sources

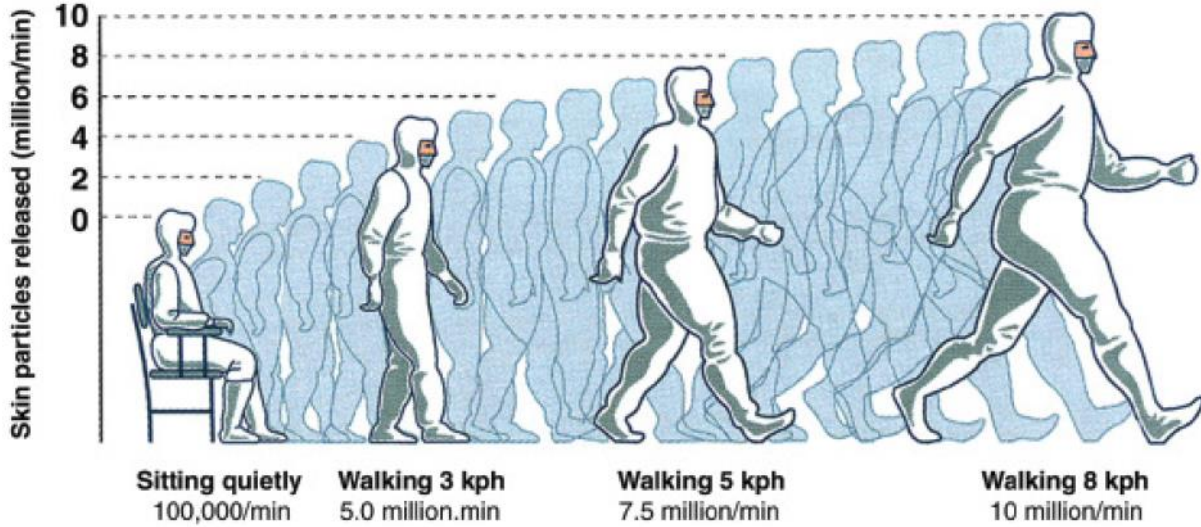


Materials may:

- Be sources of Offgassing and Outgassing (all Titanium is impossible!)
- Be or become brittle (when exposed to detrimental environments)
- Become a contamination source if processed incorrectly

ECSS-Q-ST-70-01C: Typical Contamination Sources

Humans, environment and 'dirty' processes (some examples)



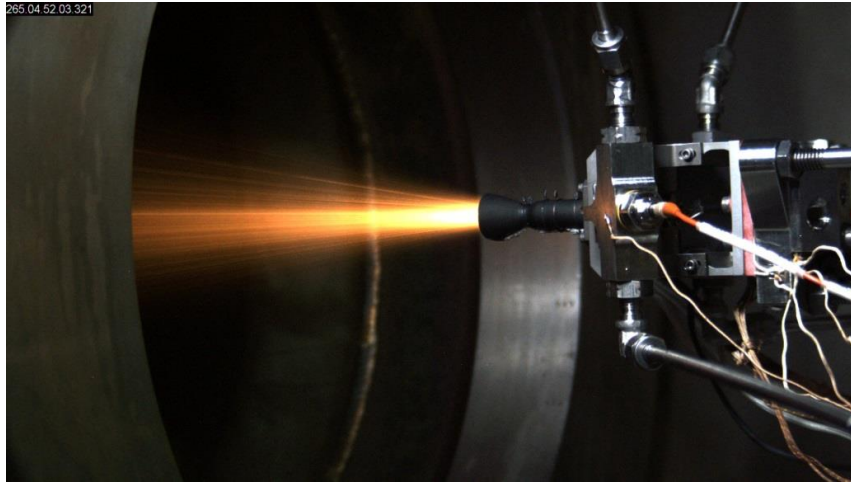
Contaminant Type	Size (μm)
Human hair	70-100
Human skin flakes	0.4-10
Pollen	5-100
Mold	2-20
Smoke	0.01-1
Bacteria	0.25-10

Image credit Gerard Aalbers



ECSS-Q-ST-70-01C: Typical Contamination Sources

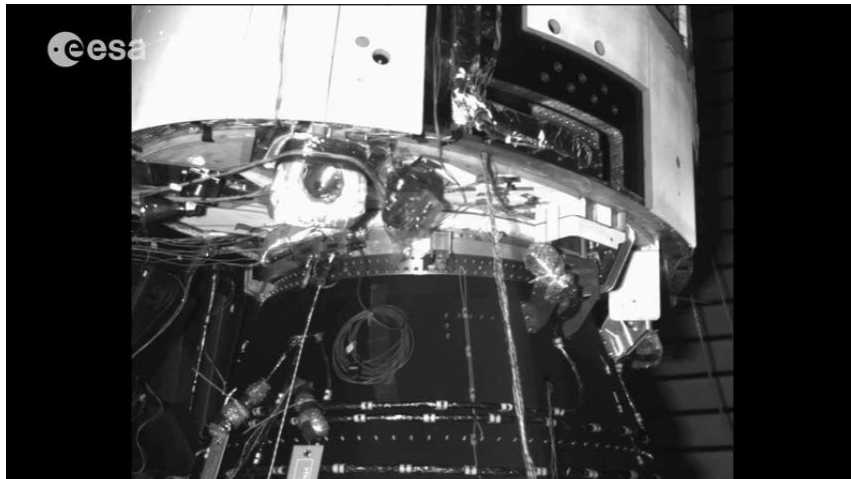
Propulsion systems



Mechanisms



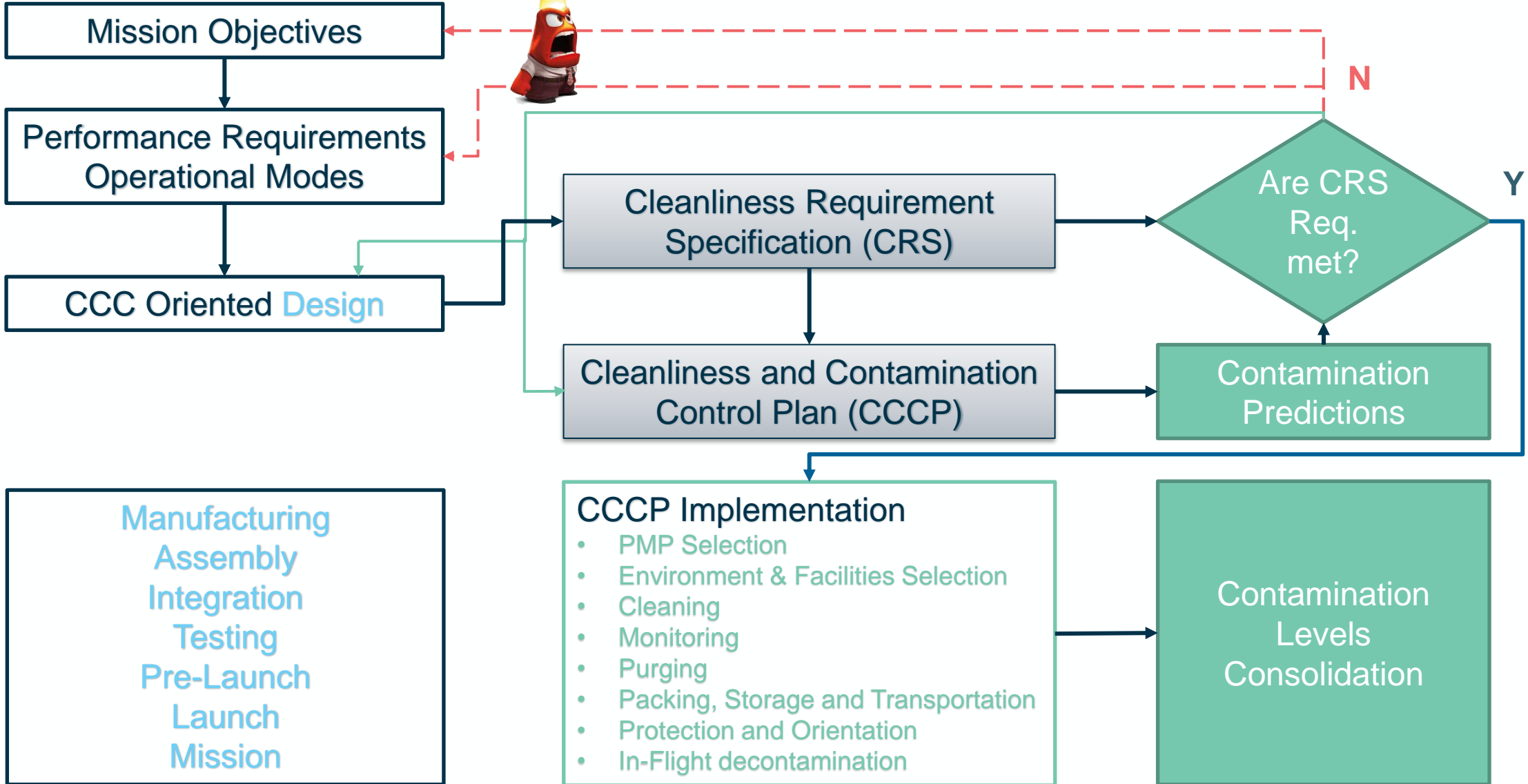
Separations



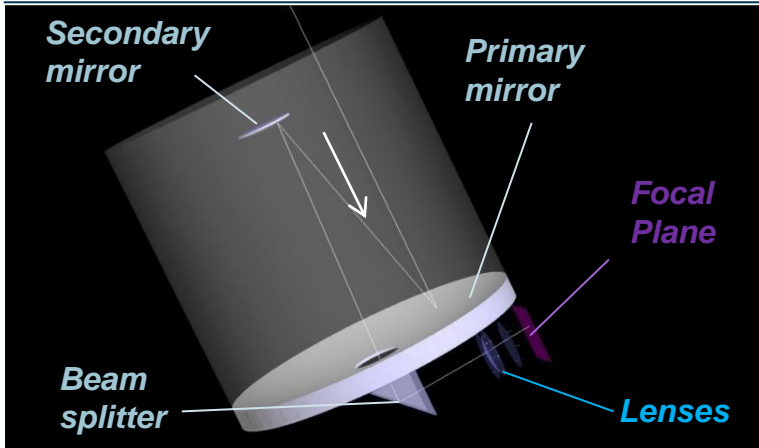
ECSS-Q-ST-70-01C: Definition of CCC Policies



Project Phases

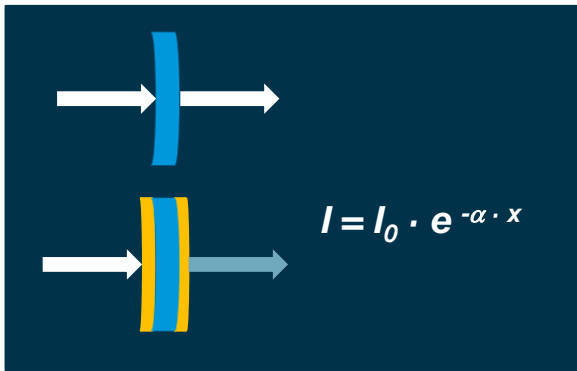


ECSS-Q-ST-70-01C: Molecular Contamination (Ex.)

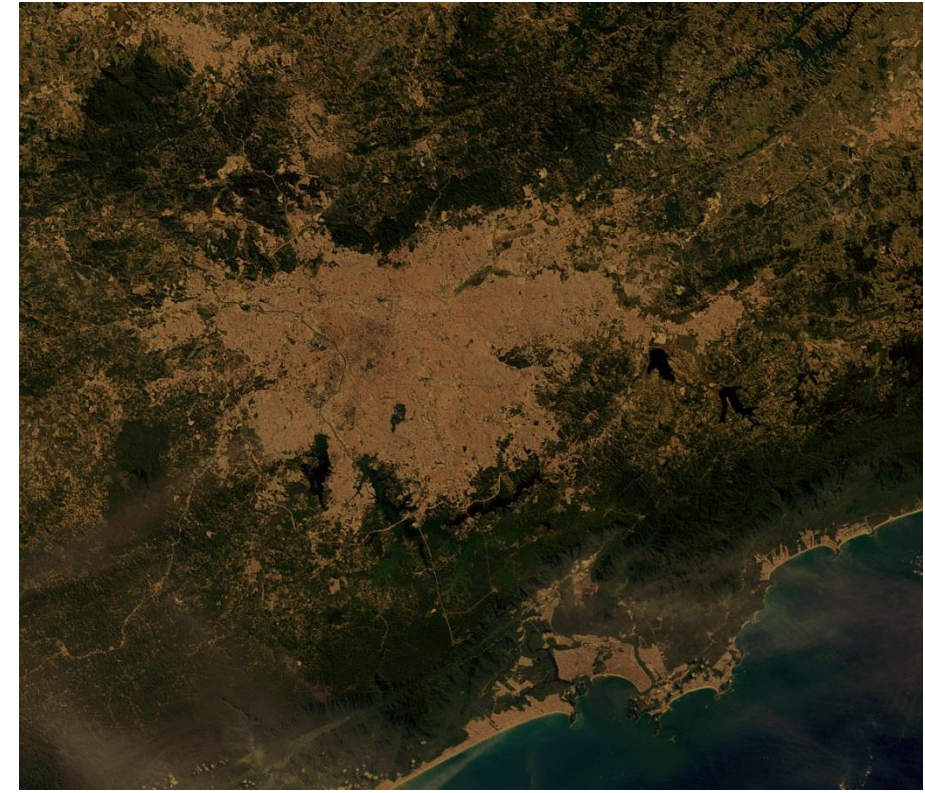
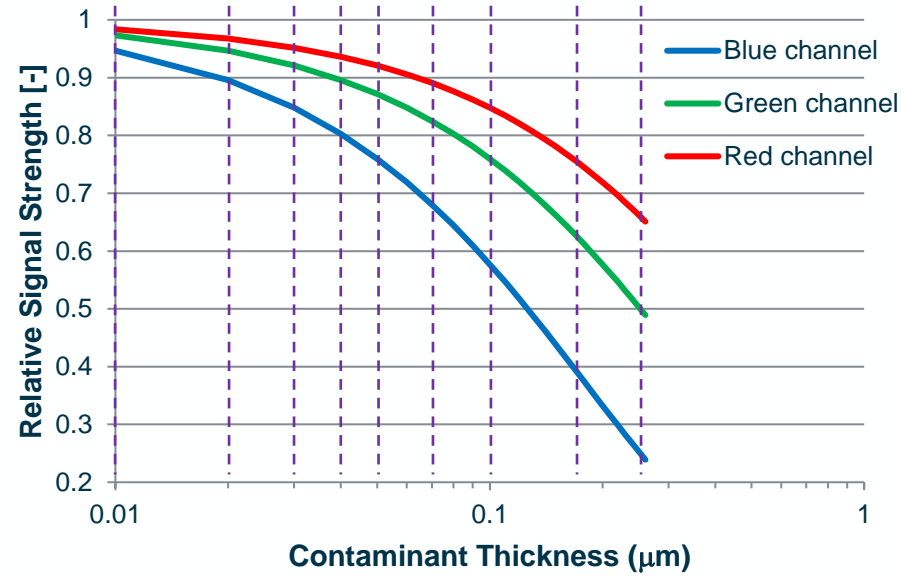


Example of a visible sensor, composed of:

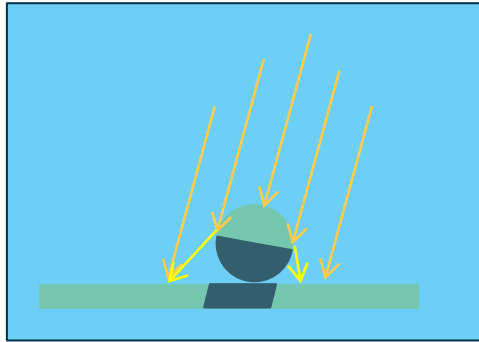
- 2 reflective mirrors
- a beam splitter
- 2 transmissive lenses
- a focal plane



Level A Level B Level C Level D Level E Level F Level G Level H Level I Level J*
ISO-15000-1:2000 ISO-15000-2:2000 ISO-15000-3:2000 ISO-15000-4:2000 ISO-15000-5:2000 ISO-15000-6:2000 ISO-15000-7:2000 ISO-15000-8:2000 ISO-15000-9:2000 ISO-15000-10:2000

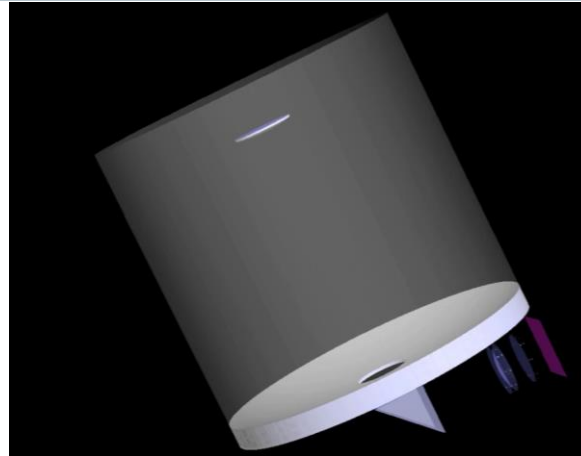


*as per IEST-STD-CC1246E and ISO 14644-10

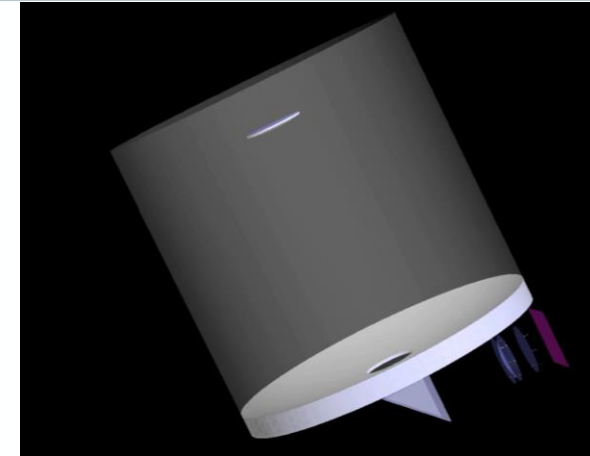


Particles may:

- Absorb
- Scatter



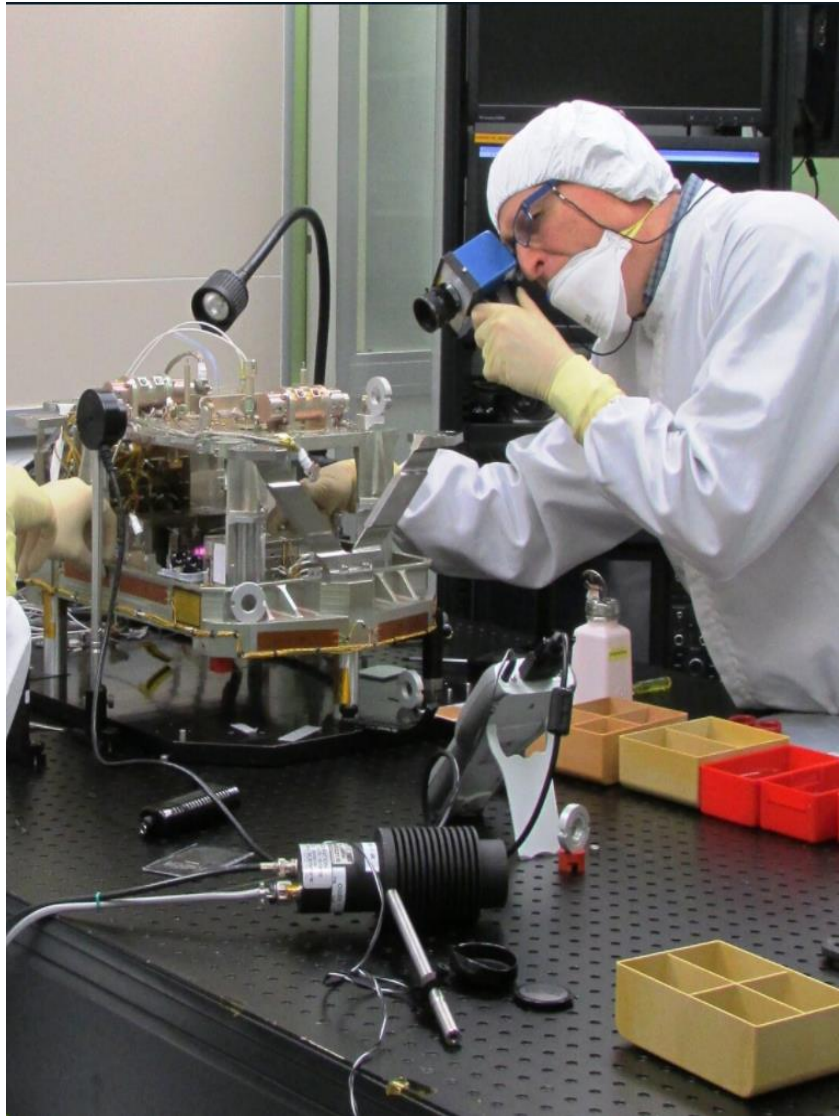
Theoretical model



Contaminated by Level 400



ECSS-Q-ST-70-01C: Inspection and cleaning





Inspection and cleaning

The cleanliness verification shall make use of recognized methods for the determination or the monitoring of the contamination levels

Depending on the type of contamination (molecular or particle) and the target application, the monitoring technique needs to be adapted.

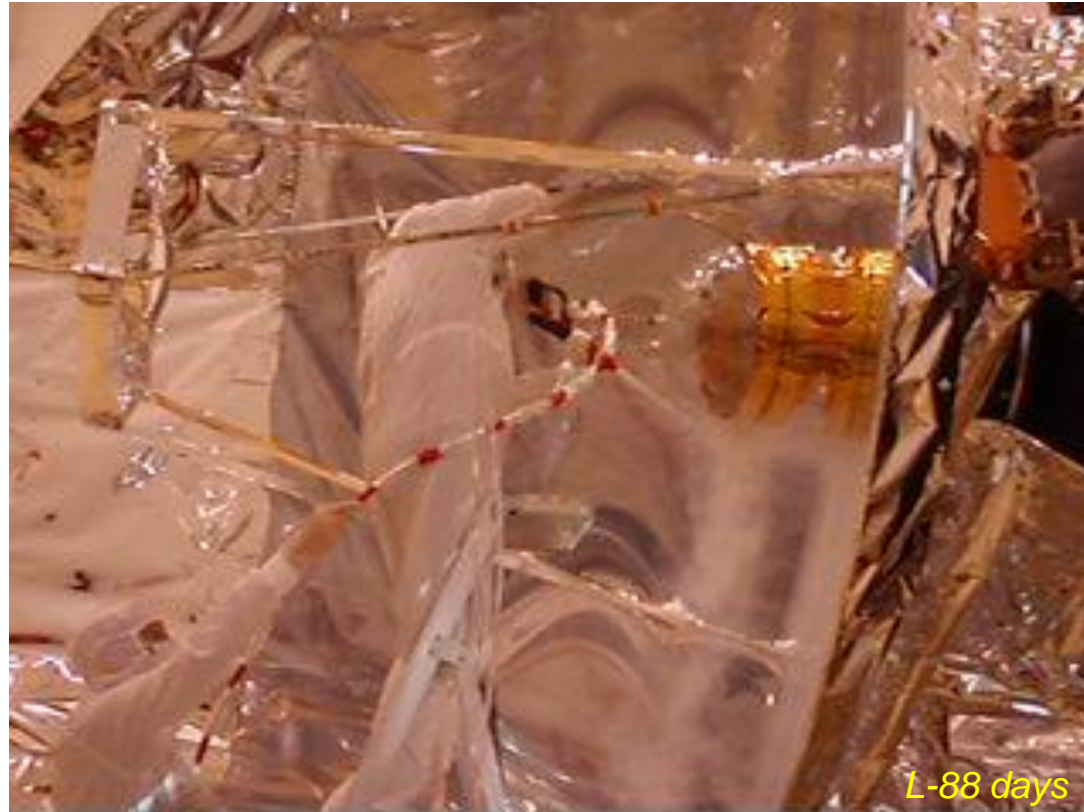
Molecular Contamination

- FTIR – Fourier-Transform Infra-Red Spectrometer
- GC/MS (Gas Chromatography / Mass Spectrometry)
- QCM (Quartz crystal microbalance)
- RGA (Residual gas analysis)
- ...

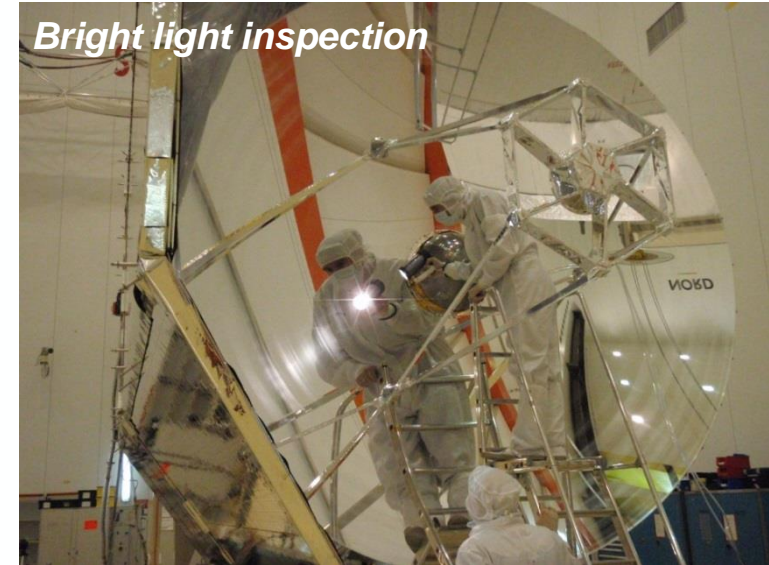
Particle Contamination

- Particle fallout measurement (PFO)
- Microscope counting measurements
- Liquid Particle counter
- ...

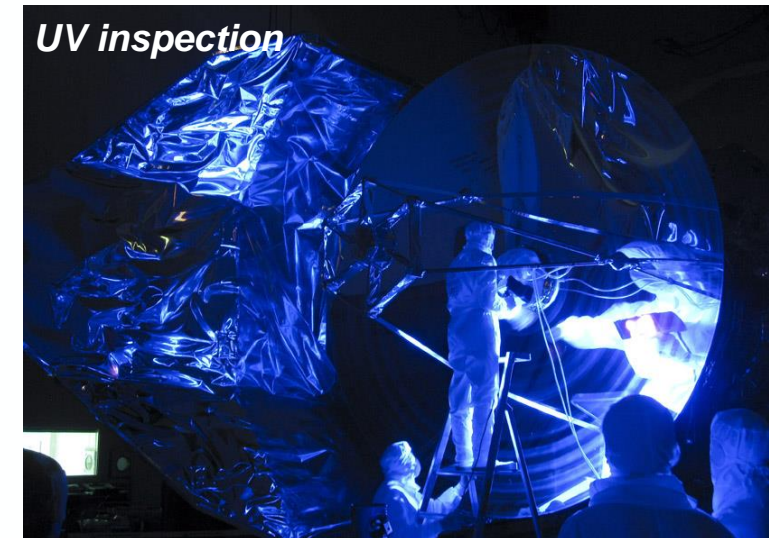
CO₂ cleaning of the Herschel primary mirror



Bright light inspection



UV inspection



Some possible cleaning methods:

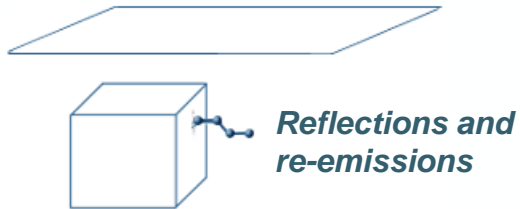
- Vacuum cleaning
- Wet and dry wiping
- Gas jet cleaning
- Tapes and films trapping
- Vapour and ultrasonic cleaning
- Plasma cleaning
- Bakeout
- UV-ozone cleaning

✓ Every cleaning process shall be defined, validated and verified

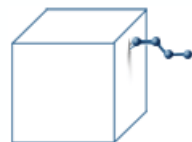
ECSS-Q-ST-70-01C: In-flight modelling (1/2)

- COMOVA – existing as stand-alone application, as well as integrated in the ESABASE2 suite (which is free of charge for Class C contracts: Students, Universities, Space Agencies)
- SYSTEMA/Outgassing – Airbus DS proprietary SW
- FCMT – on-going development under ESA contract (no distribution policy yet defined)

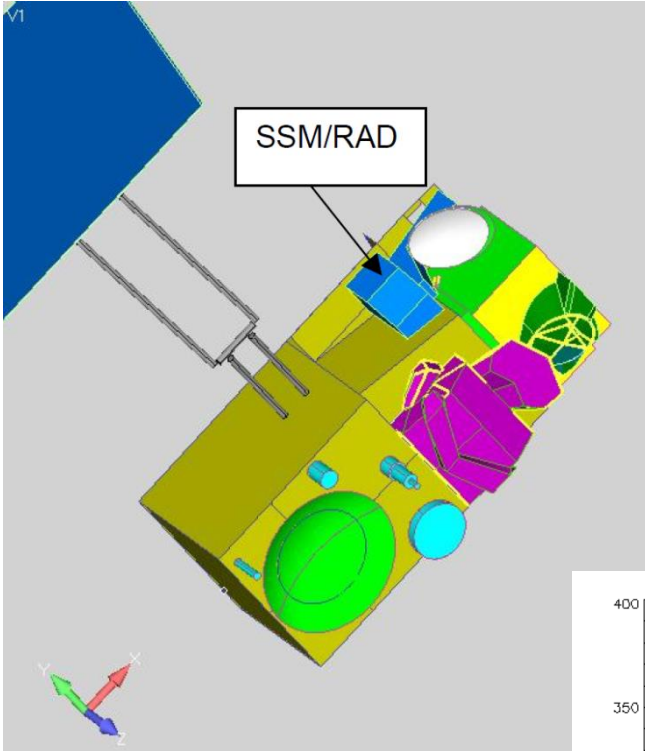
Emission and direct view



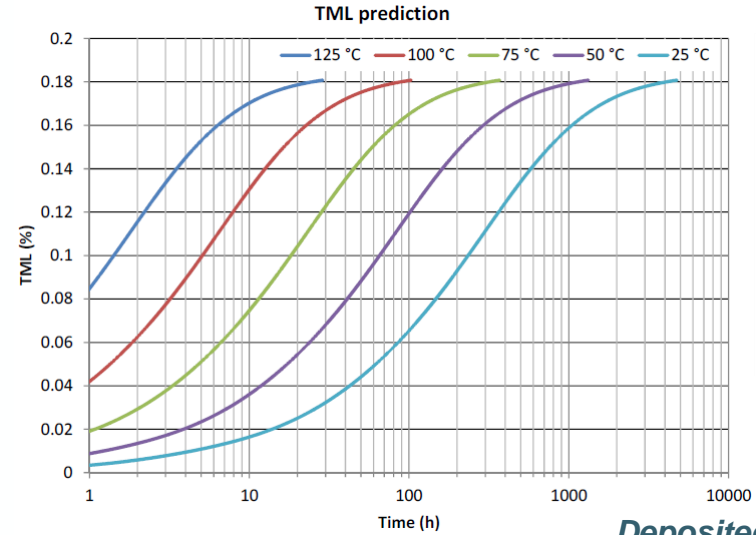
Collisions



Geometrical model

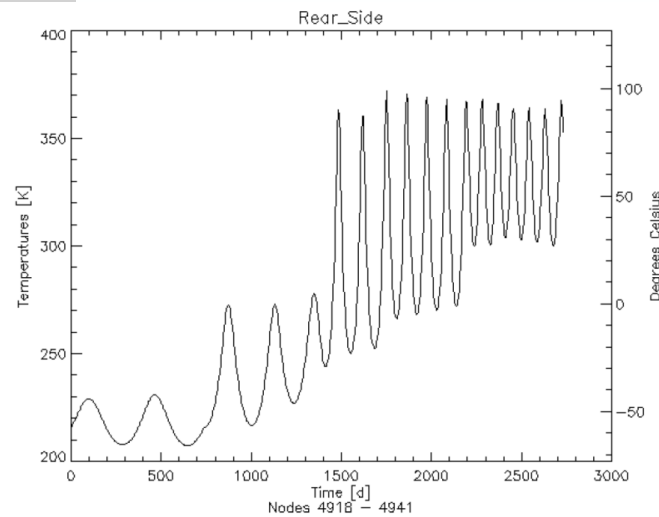


Outgassing prop.

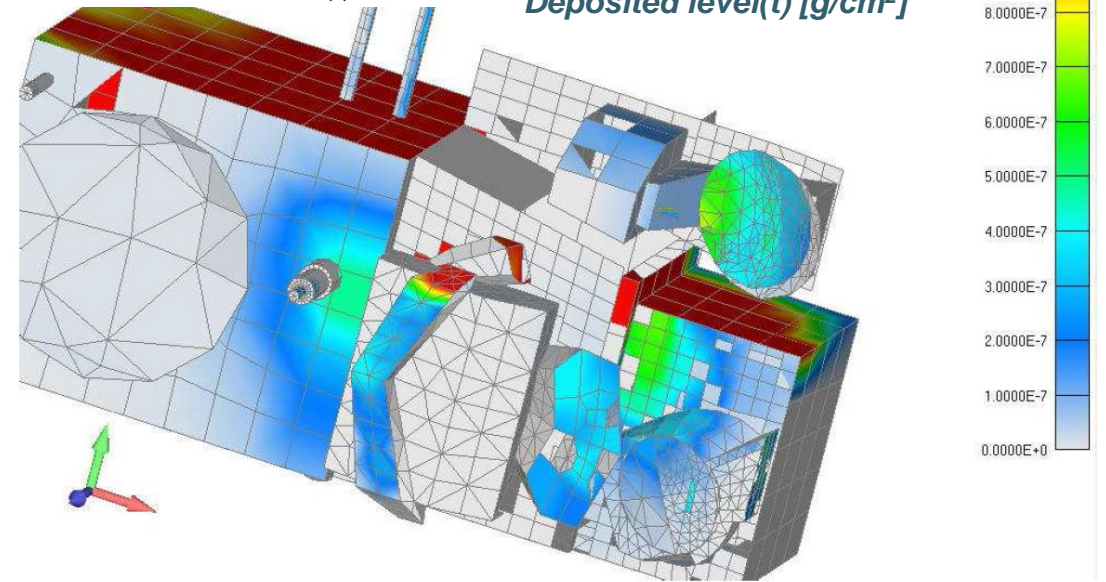


$\tau_{0,i}$ (h)	$W_{0,i}$ (%)
0.5	0.00037
2.353	0.00547
11.08	0.00200
31.10	0.01418
87.35	0.01653
245.3	0.07269
689.0	0.05744
1934	0.00863
5434	0.00729

Temperature profiles



Deposited level(t) [g/cm²]

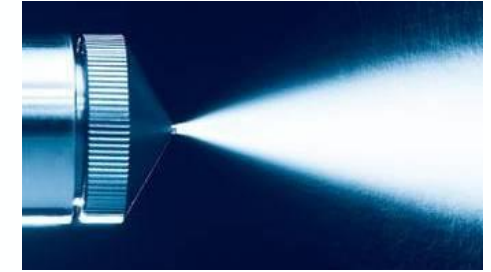


Design and operational measures

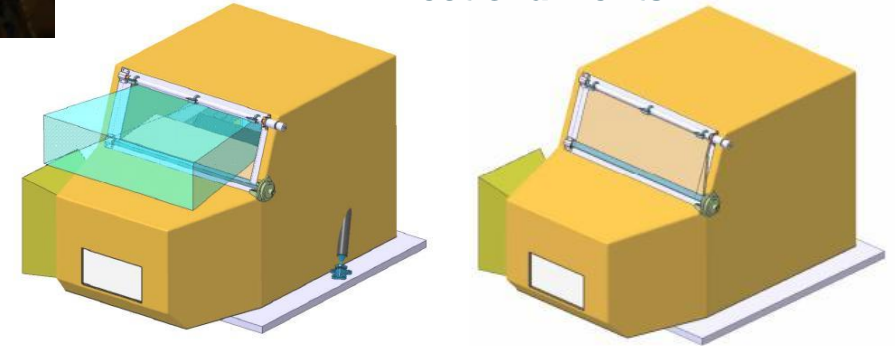
- Can be effective **on-ground** as well as **in-flight**
- Can be **preventive** or **corrective**
 - minimise the view factors wrt contaminant sources
 - minimise the exposure time to contaminating environment



Baffles



Directional vents



Protective shutters

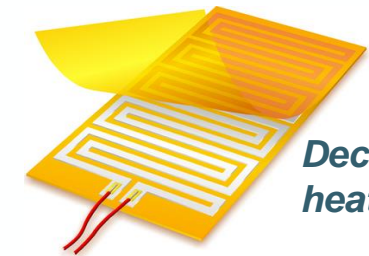
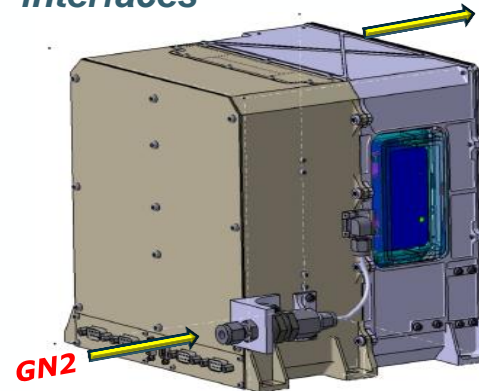


Orientation



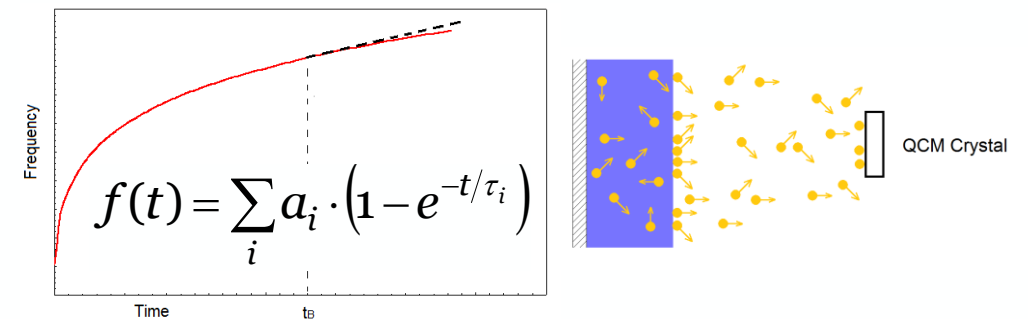
Protective covers

Purging interfaces



Decontamination heaters

- Activity of increasing the temperature of hardware to accelerate its outgassing rates with the intent of reducing the content of molecular contaminants within the hardware
 - The bake-out is done in order to **reduce the risk of cross-contamination** between spacecraft components during the flight.
-
- Bake-out shall be performed as per ECSS-Q-ST-70-01C standard
 - Monitoring and data analysis shall follow requirements from TEC-QT/2014/344 technical note
 - From practical point of view, under certain conditions, may be combined with Dry heat bioburden reduction (ECSS-Q-ST-70-57C)



Cleanliness & contamination control

General overview standard

ECSS-Q-ST-70-01C

The specific standards for cleanliness & contamination monitoring methods:

Molecular organic contamination (MOC)

ECSS-Q-ST-70-05C

Particulate contamination monitoring (PAC)

ECSS-Q-ST-70-50C

Correlating standards:

Outgassing, screening test (material suitability)

ECSS-Q-ST-70-02C

Outgassing, dynamic test (life time prediction)

ECSS-Q-TM-70-52A

=> Source tracing of contaminants

Thermo-optical properties

ECSS-Q-ST-70-09C

=> Effects of contaminants on optical & thermal control surfaces

TAKE-HOME REQUIREMENTS

- The supplier shall define and document cleanliness requirements in a cleanliness requirement specification (CRS), in conformance with the DRD in Annex A.
- The level of sensitivity to contamination shall be one of the drivers in the initial design.
- External contamination control during mission shall be done through preventive actions, specific design provisions and operations.
- Particulate and molecular contamination shall be monitored during all the on ground phases.
- When contamination predictions exceed the allocated contamination budget, a bakeout shall be performed

Common topics for discussion :

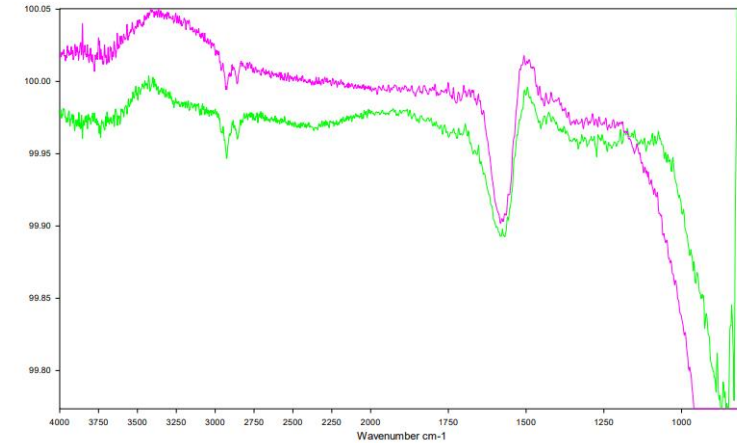
- Bake-out duration
- Nitrogen vs vacuum
- Cleaning methods (especially optical surfaces)
- Excessive contamination in vacuum chamber (undeclared materials)
- Cleanliness requirements specification vs plan
- Handling of sensitive hardware
- Silicones



- Defines test requirements for detecting organic contamination on surfaces using direct and indirect methods with the aid of infrared spectroscopy.
- Can be used to detect organic substances from a variety of sources e.g. Volatile condensable products of materials out-gassing under vacuum, Back-streaming products from pumping systems, Handling residues (e.g. human grease), Residues of cleaning agents, Non-filtered external pollution, Creep of certain substances (e.g. silicones).
- Applies to controlling and detecting organic contamination on all manned and unmanned spacecraft, launchers, payloads, experiments, terrestrial vacuum test facilities, and cleanrooms.
- Informative annexes are included to give more detailed testing guidelines e.g. Calibration of infrared equipment, Training of operators. Use of molecular witness plates, Collecting molecular contamination

- Infrared qualitative analysis is carried out by functional group identification
- The four main group are hydrocarbons, esters, methyl silicones, and phenyl silicones
- Infrared quantitative analysis of levels of contaminants is based on the Lambert-Beer's law and requires calibration.

FTIR Spectra:



#034 sp (180°C, 87h)	Transmission CaF2	Apollo 7 002.0	VERTEX 70v
#109 sp (180°C, 87h)	Transmission CaF2	Apollo 7 002.1	VERTEX 70v

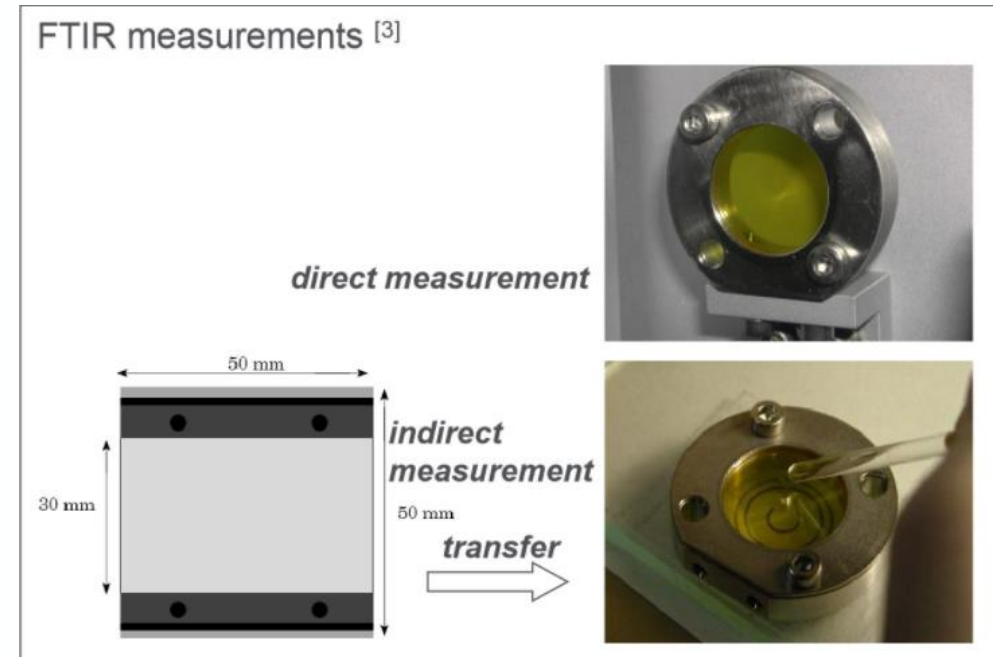
Figure 1, FTIR spectra of moc witness #034 & #109

Table 5-1: Standard materials used for the IR analysis

Standard ^a	Chemical nature	Characteristic peaks (cm ⁻¹)
Paraffin oil ^b	Long chain aliphatic hydrocarbon	2920
Bis(2-ethylhexyl) phthalate (DOP) ^c	Aromatic ester	1735
Poly(dimethylsiloxane)	Methyl silicone	1260, 805
Poly(methylphenylsiloxane)	Methyl phenyl silicone	1260, 1120, 805



- Direct methods : IR-transparent windows used as witness plates (e.g. CaF₂, ZnSe, Ge) are placed in situ, for example, inside a vacuum facility, cleanroom or spacecraft. Contamination of the windows is then analysed (without further treatment) using an IR spectrophotometer.
- Indirect methods : The contaminants on the surface to be tested are collected by means of a concentration technique, for example by washing or wiping a larger surface. Such a surface can also be a witness plate, which is removed after exposure and treated in the same way. The resultant contaminated liquid or tissue is then processed, and finally extracted contamination is deposited on an IR-transparent window for measurement



G. Papendrecht (ESA)

TAKE-HOME REQUIREMENTS

- The spectrometer shall have the following specification:
 1. Spectral range: At least, 4 000 cm^{-1} – 600 cm^{-1} (2,5 μm - 16,7 μm).
 2. Resolution: 4 cm^{-1} .
 3. Absorbance of 0,0001 as detection limit for transmission methods.
- Plates of infrared-transparent material shall be available.
 - Typical materials are NaCl, MgF₂, CaF₂, ZnSe, or Ge.
- Contamination levels shall be expressed in terms of the contribution of the following four main group equivalents: hydrocarbons, esters, methyl silicones, and phenyl silicones
- Equipment shall be calibrated for obtaining quantitative information.

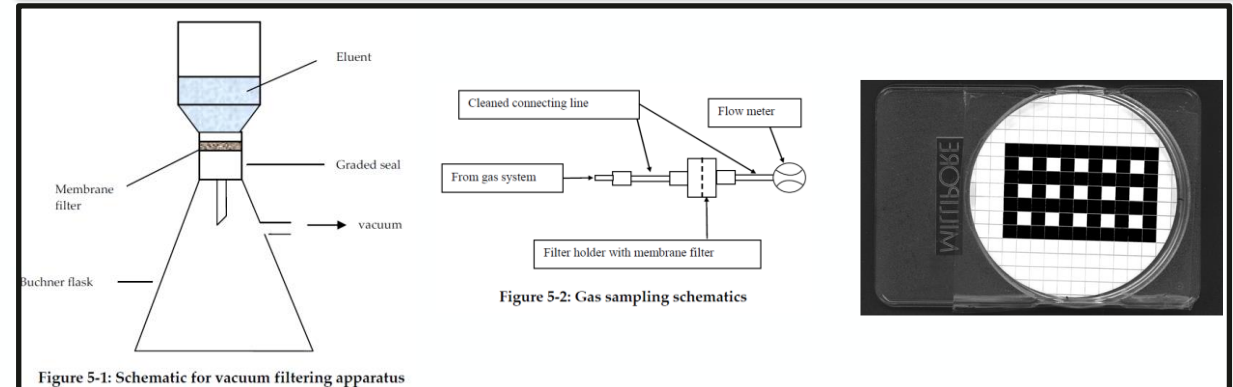
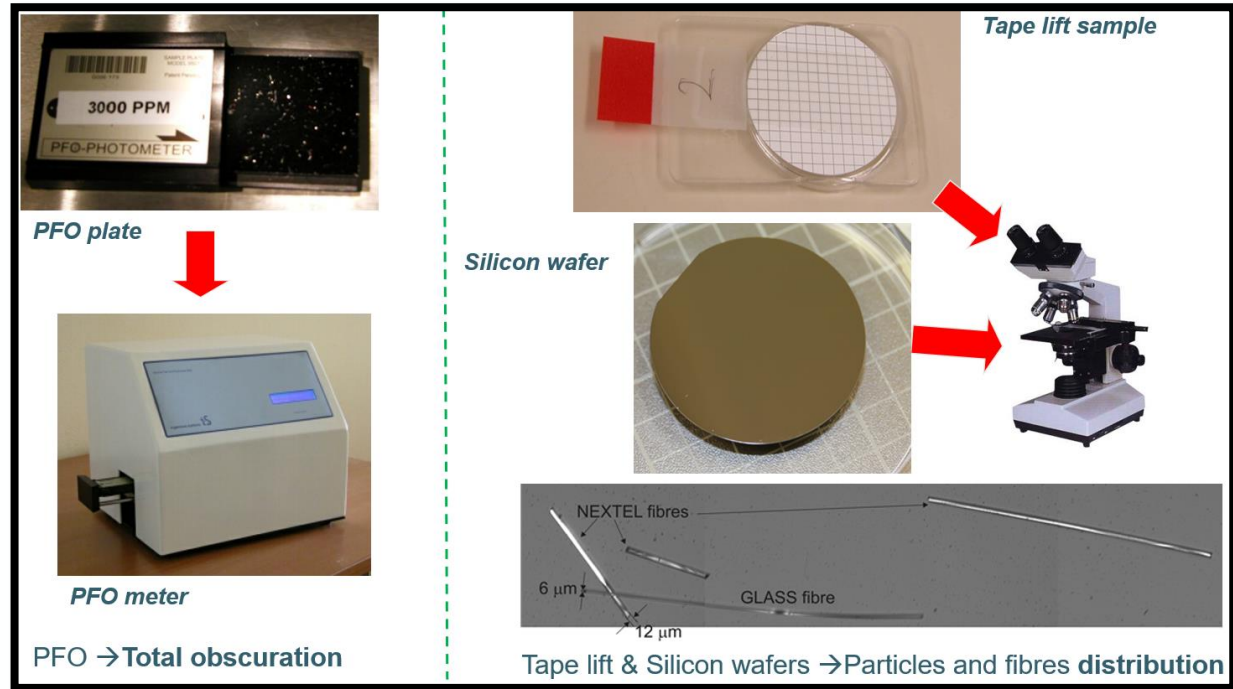
- Defines the requirements and guidelines for the measurement of particulate contamination on the surfaces of spacecraft systems and those of the cleanrooms or other cleanliness controlled areas in which they reside.
- This standard also defines the methods to be used for the visual inspection of spacecraft system hardware for particulate contamination.
- Applies to controlling and detecting particle contamination on all manned and unmanned spacecraft, launchers, payloads, experiments, terrestrial vacuum test facilities, and cleanrooms.
- The measurement of airborne particulate contamination is not covered in this standard and ISO 14644 “Cleanrooms and associated controlled environments” is applicable in this case
- This standard does not cover particulate contamination monitoring for spacecraft propulsion hardware which is covered in ECSS-E-ST-35-06.

- Visibly clean: absence of surface contamination when examined with a specific light source, angle of incidence and viewing distance using normal or magnified vision

Cleanliness Level	Inspection Distance (cm)	Light Intensity (Lx)	Light Spectra
Visibly Clean Standard (VC)	150 to 300	540	White Light
Visibly Clean Sensitive (VCS)	60 to 120	540	White Light
Visibly Clean Highly Sensitive (VCHS)	15 to 45	1080	White Light
VCHS+UV	15 to 45	1080	White Light + UV

- Visual inspection depends on many factors such as operator, lighting conditions, inspection angle and the optical properties of the item being inspected.
- **Qualitative Inspection CANNOT BE USED to confirm quantitative cleanliness levels**

- Particles sampling from surfaces:
 - Tape-Lift Method
 - Direct deposition on silicon wafers
 - Rinsing (direct or indirect)
- Volume sampling:
 - Particles sampling from filtered liquid samples
 - Particles sampling from filtered gas samples
 - Particles sampling with automatic counters
- Particles counting with microscope
- Particle fallout measurement (PFO)



TAKE-HOME REQUIREMENTS

- Difference between Qualitative and Quantitative Methods/Requirements shall be made
 - Visibly Clean
 - Obscuration Factor
 - Particle Size Distribution

- The inspection/sampling method shall be defined depending on
 - The hardware configuration and accessibility
 - The expected outcomes

- Qualitative Inspection **CANNOT BE USED** to confirm quantitative cleanliness levels

THANK YOU FOR YOUR ATTENTION

