European Cooperation for Space Standardization

ECSS Q-70 Training Course

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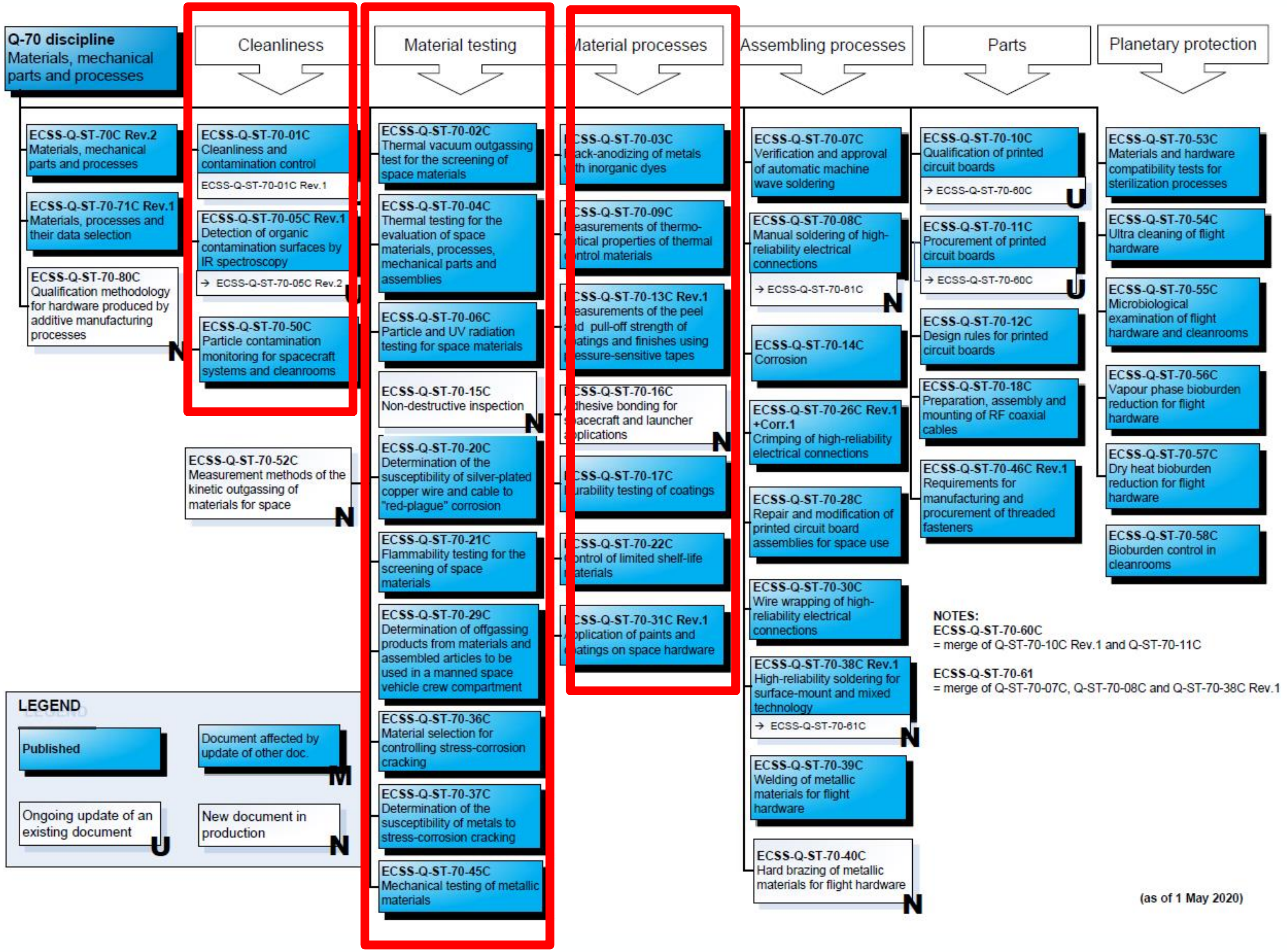
ESA-TECQEE-HO-2022-000559

15/02/2022

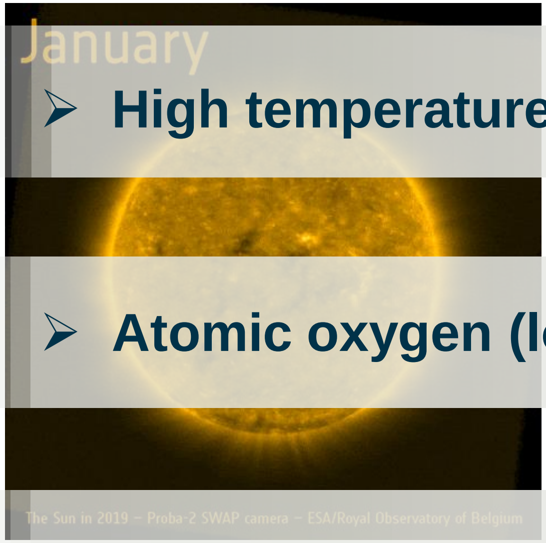
ECSS Q-70 Branch

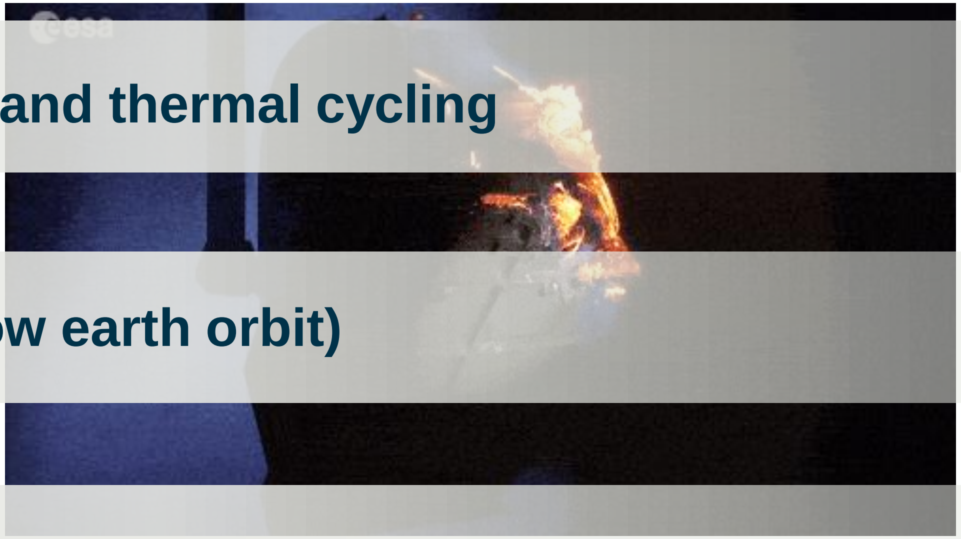
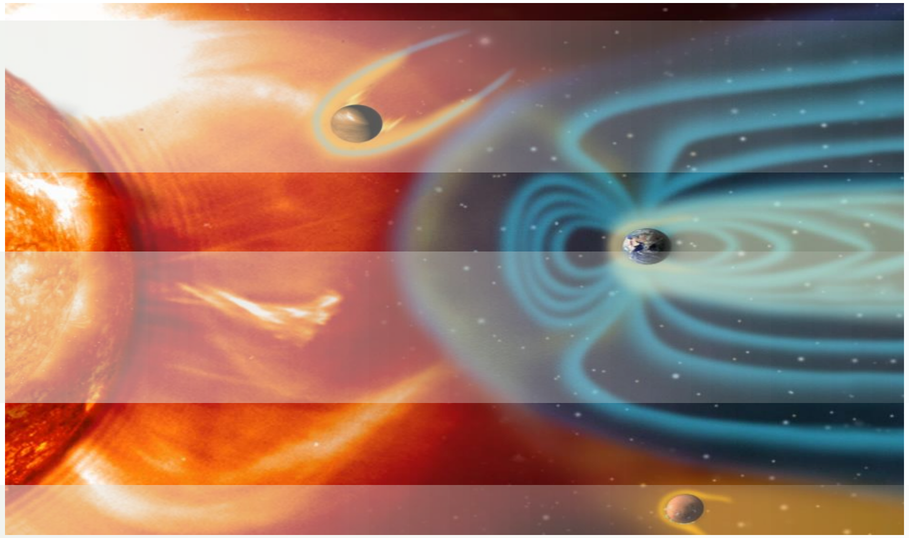
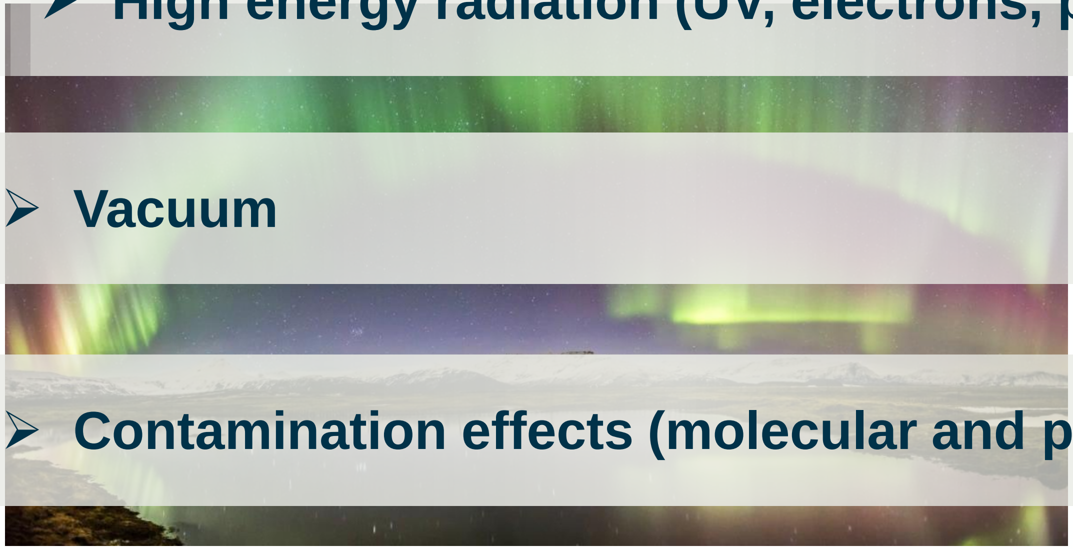
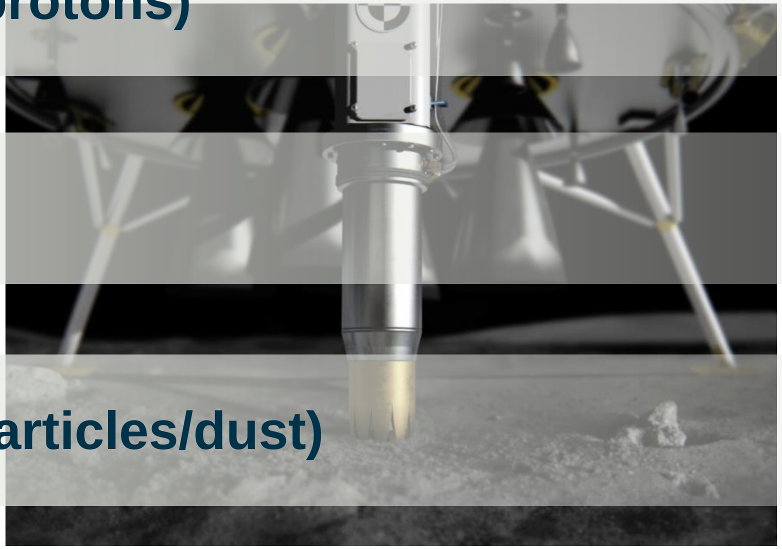
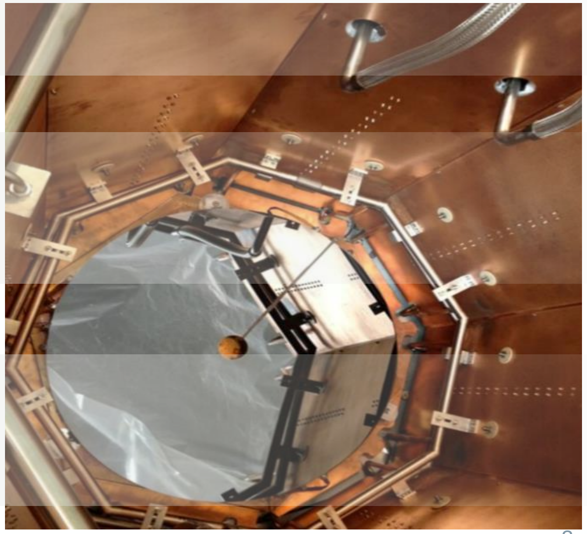


- Today : Environments and materials testing
- Tomorrow : Adhesive bonding and cleanliness

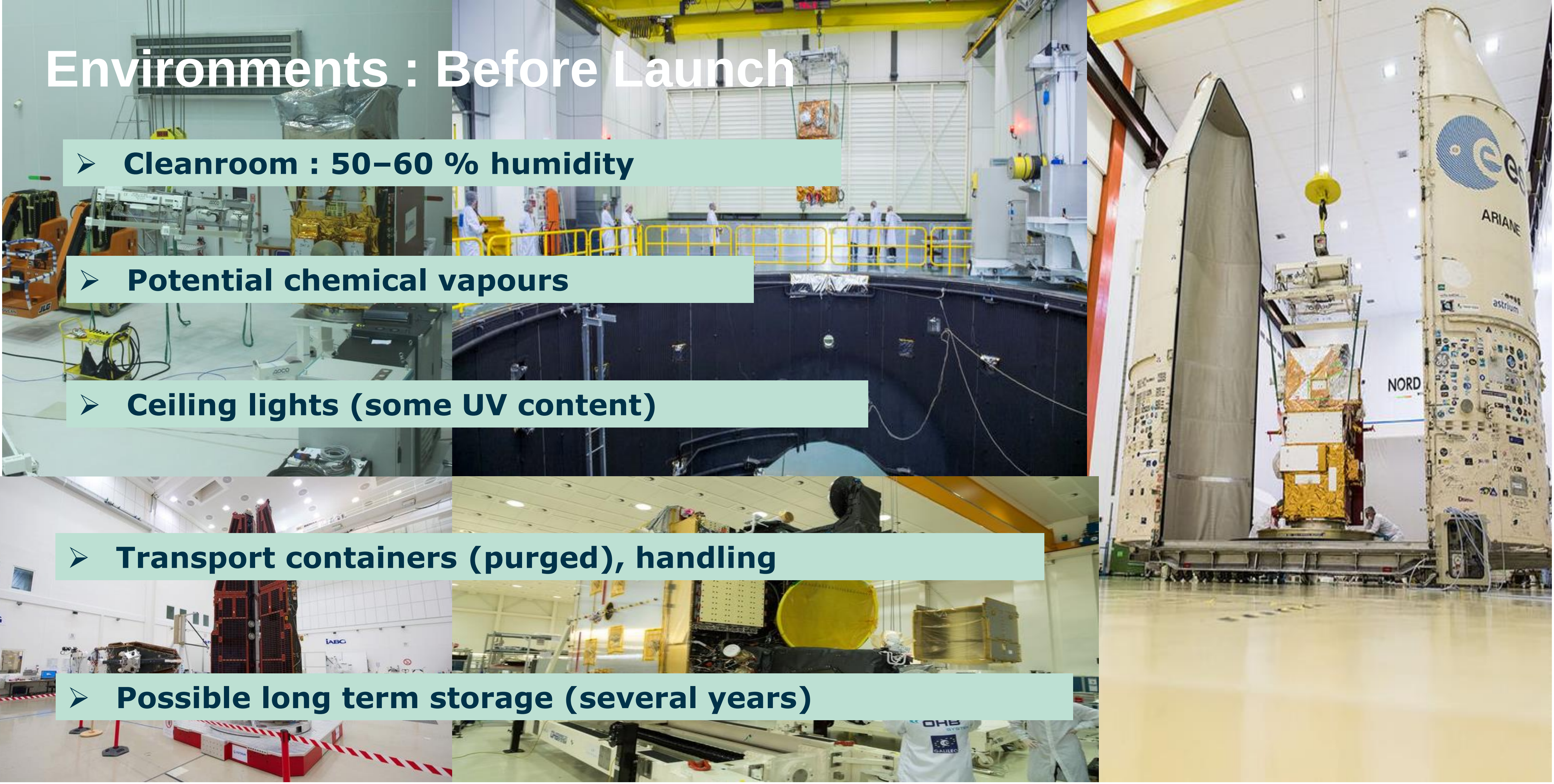
Harsh space environments

- High temperature and thermal cycling
- Atomic oxygen (low earth orbit)
- High energy radiation (UV, electrons, protons)
- Vacuum
- Contamination effects (molecular and particles/dust)



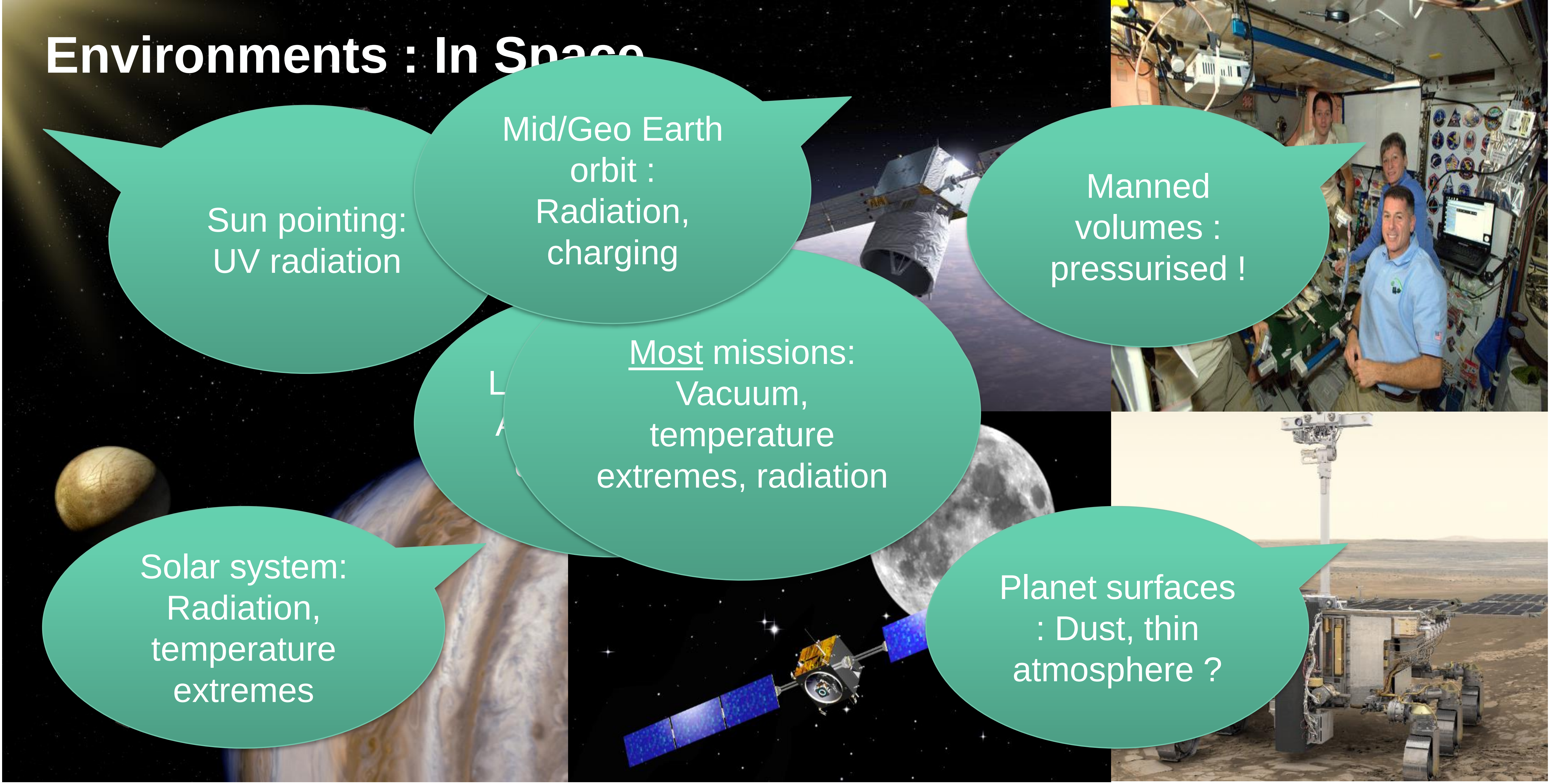






Environments : Before Launch



- Cleanroom : 50–60 % humidity
- Potential chemical vapours
- Ceiling lights (some UV content)
- Transport containers (purged), handling
- Possible long term storage (several years)

Environments : In Space



Materials Selection Requirements

esa

Definition

Black thermal control paint for satellites presenting good thermo-optical properties.

Aspect: mat black

AFNOR NFT 36005 classification: Family I Class 6a.

Purpose: developed by CNES, PU1 coating may find applications in the following fields: space industries, Vacuum technologies......

Satellite references: SPOT 2 - SPOT 4 - TELECOM 2 - ... - HELIOS - SCARAB - TURKSAT - INTELSAT VII - D... SYRACUSE 3B -THEOS - GALAXY 17 - ARABSAT 4 - ... SPIRALE - AEOLUS - ALADIN - ROCSAT 2 - SKYNET 5 - CHINASAT - AMOS 3 - GOSAT - CIEL 2.

Properties

Test carried out	CNES qualification
Moisture test Thermal cycling under vacuum Outgassing Surface potential ATOX	88/CT/DRT/TVE/TH n°411
Spectral measurements @ cryogenic temperature	NT-100/CT/AE/MTE/TH
Thermal cycling after accelerated curing	NT-99-016/DTS/AE/MTE/TH

PU...

... Low outgassing black ...

- **Functionality**
- **Reliability**
- **Survivability**

Coating characteristics (1/2)

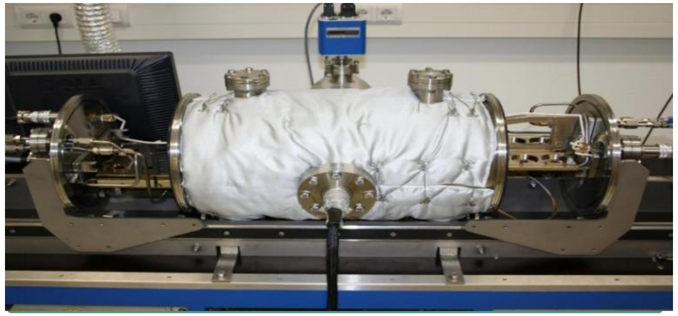
Polymer matrix	Polyurethane
Density	1.12 ± 0.05
Solids content	64 % ± 3 %
IR Emittance	$\varepsilon_{N,IR}$ = 0.88 ± 0.04 ε_C = 0.89
Outgassing	in compliance with ESA standard: ECSS-Q-70-02A
Standard thickness	50 µm to 60 µm dry 1 mist coat + 1 to 2 crossed coats
Theoretical Consumption	145 g/m² of product @ 55 µm 1.4 g dry / m² per dry µm

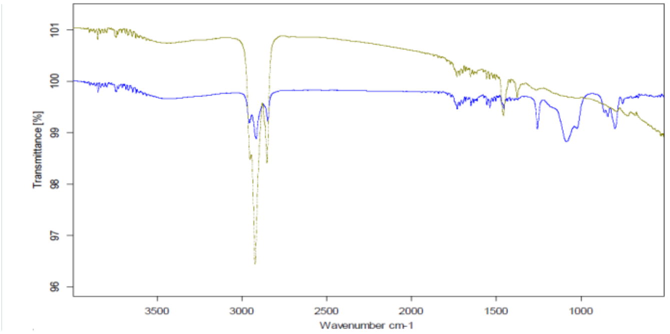
Coating characteristics (2/2)

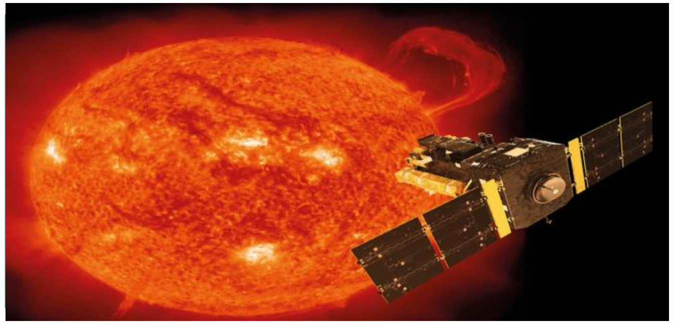
Base / hardener weight ratio	75 / 25
Thinner	20 % to 30 % of PU1 thinner
Filtration	80 µm nylon filter
Viscosity	40s to 55s AFNOR Cup 2.5 33s to 53s ISO Cup 3
Induction time	15 min to 20 min @ 20°C
Pot life	2 h @ 20°C
Applying conditions	18°C ≤ T° ≤ 25°C 30 % < RH < 80 %
Covering time	Let dry between coats until you get a mat aspect
Drying conditions	18°C ≤ T° ≤ 25°C 30 % < RH < 80 % 8 days drying before any control test (adhesion, thickness, etc.) 4 weeks drying before any ageing test.

Typical space grade paint

Materials testing







ECSS-Q-ST-70-02C : Outgassing

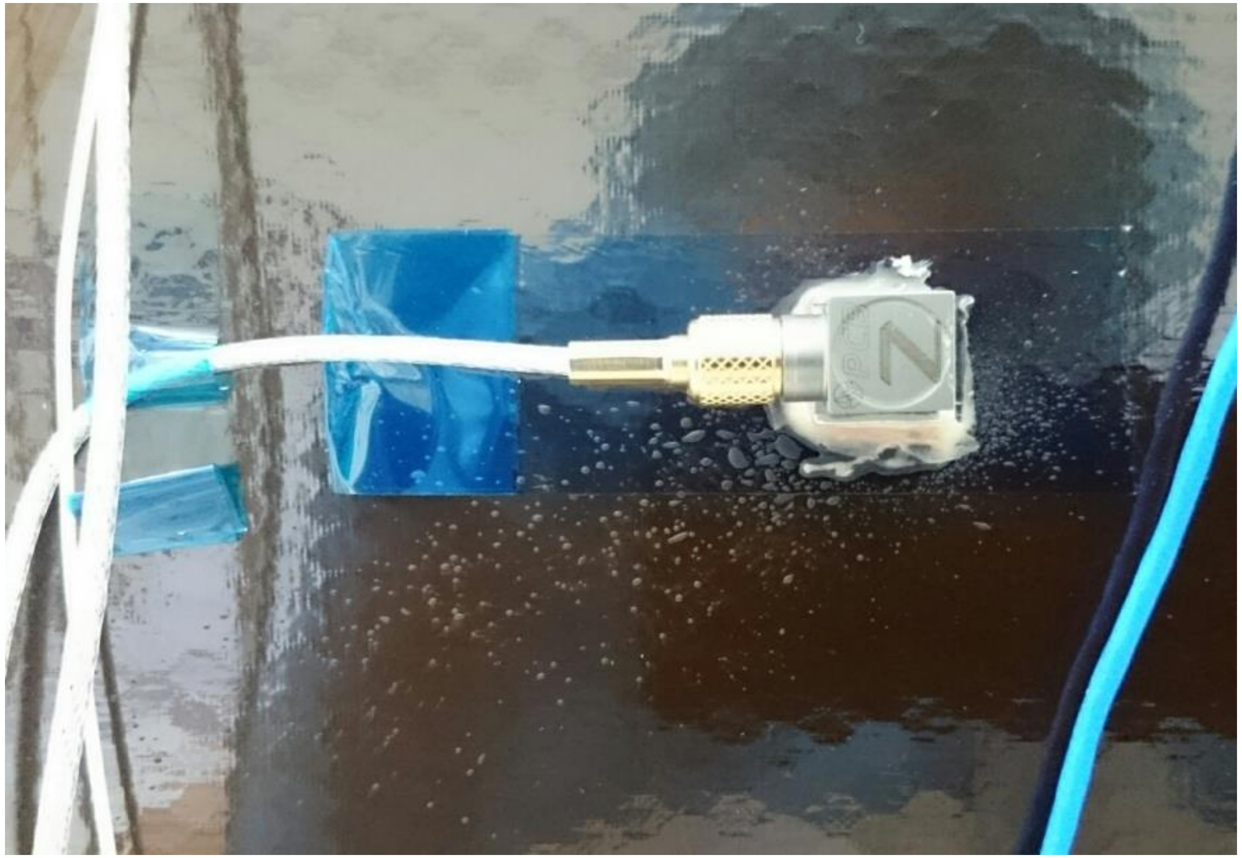
- Thermal vacuum test to determine the outgassing screening properties of materials proposed for use in the fabrication of spacecraft and associated equipment, for vacuum facilities used for flight hardware tests and for certain launcher hardware

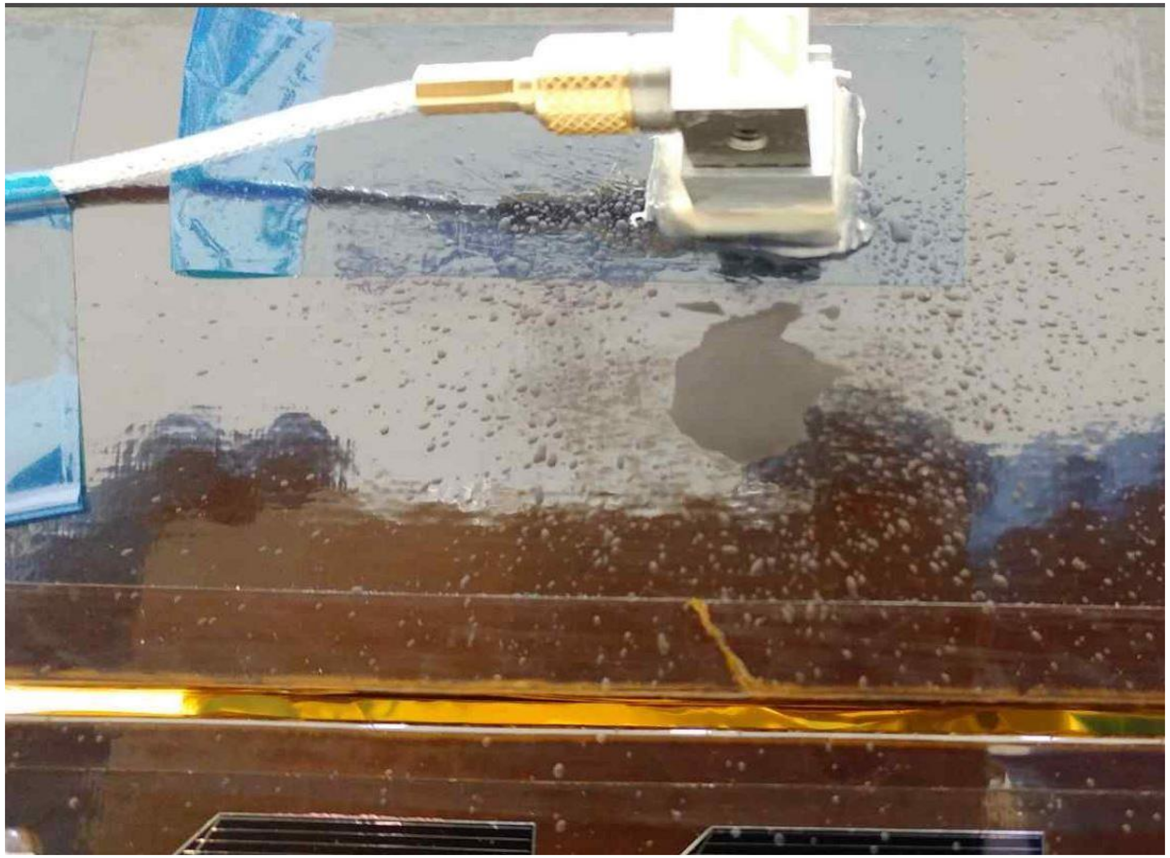
- Applicable for all unmanned spacecraft, launchers, payloads, experiments. The test is also valid for external hardware of inhabited space systems and for hardware to be used in terrestrial vacuum test facilities

- Outgassing and condensation acceptance criteria for a material depend upon the application and location of the material and can be more severe than the standard requirements (e.g. for optical instruments)

This is a screening test only and it cannot be used to predict the "contamination potential" of the material over the mission duration

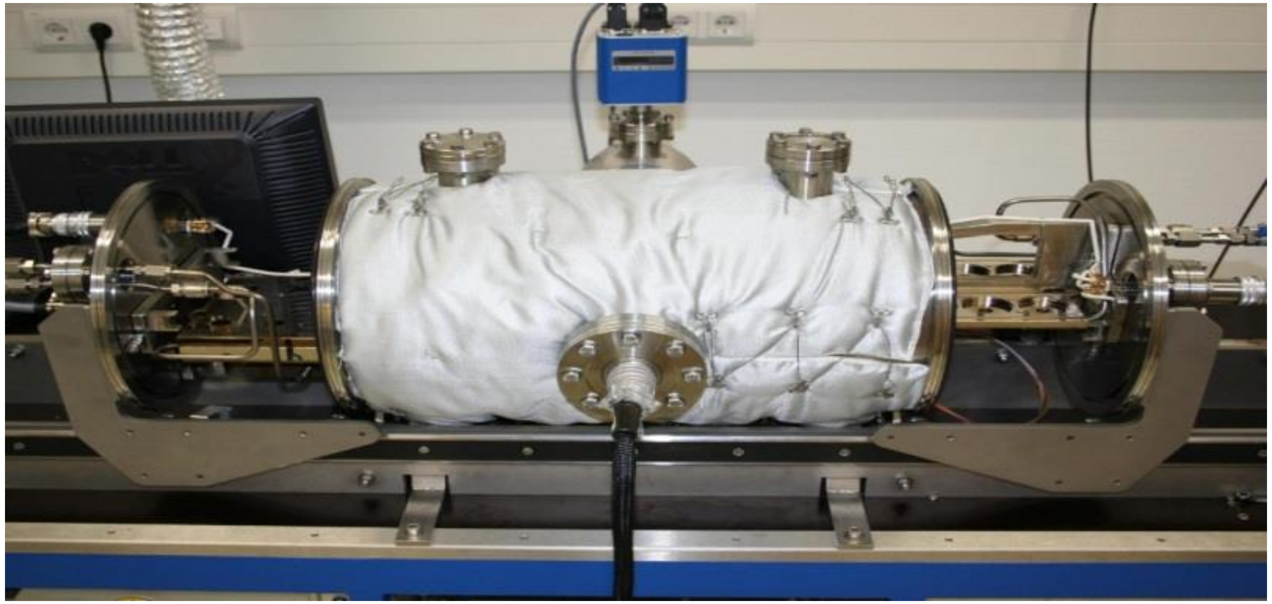
ECSS-Q-ST-70-02C : Outgassing

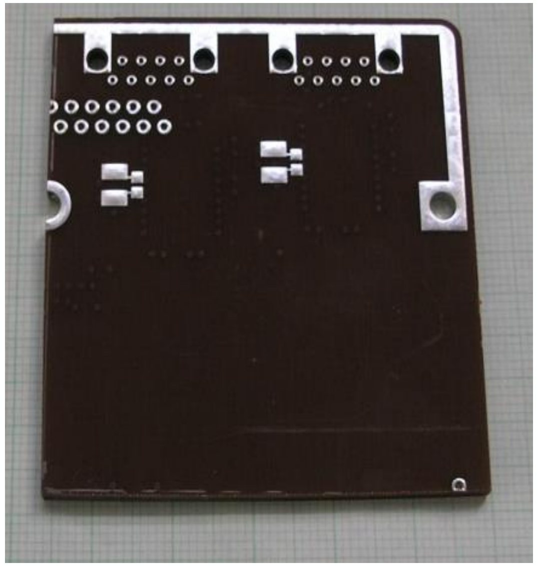


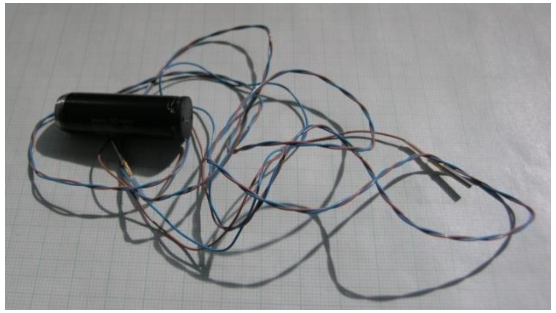


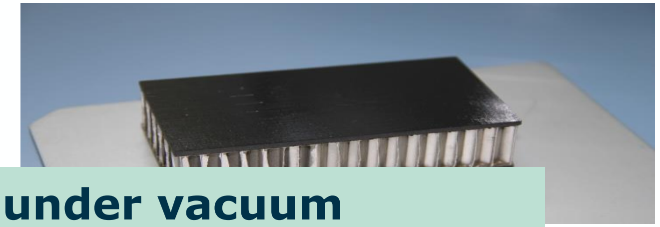
Contamination on surface of satellite after vacuum test due to outgassing of adhesive underneath accelerometer

ECSS-Q-ST-70-02C : Outgassing









To measure precisely the mass loss of materials under vacuum

ECSS-Q-ST-70-02C : Outgassing

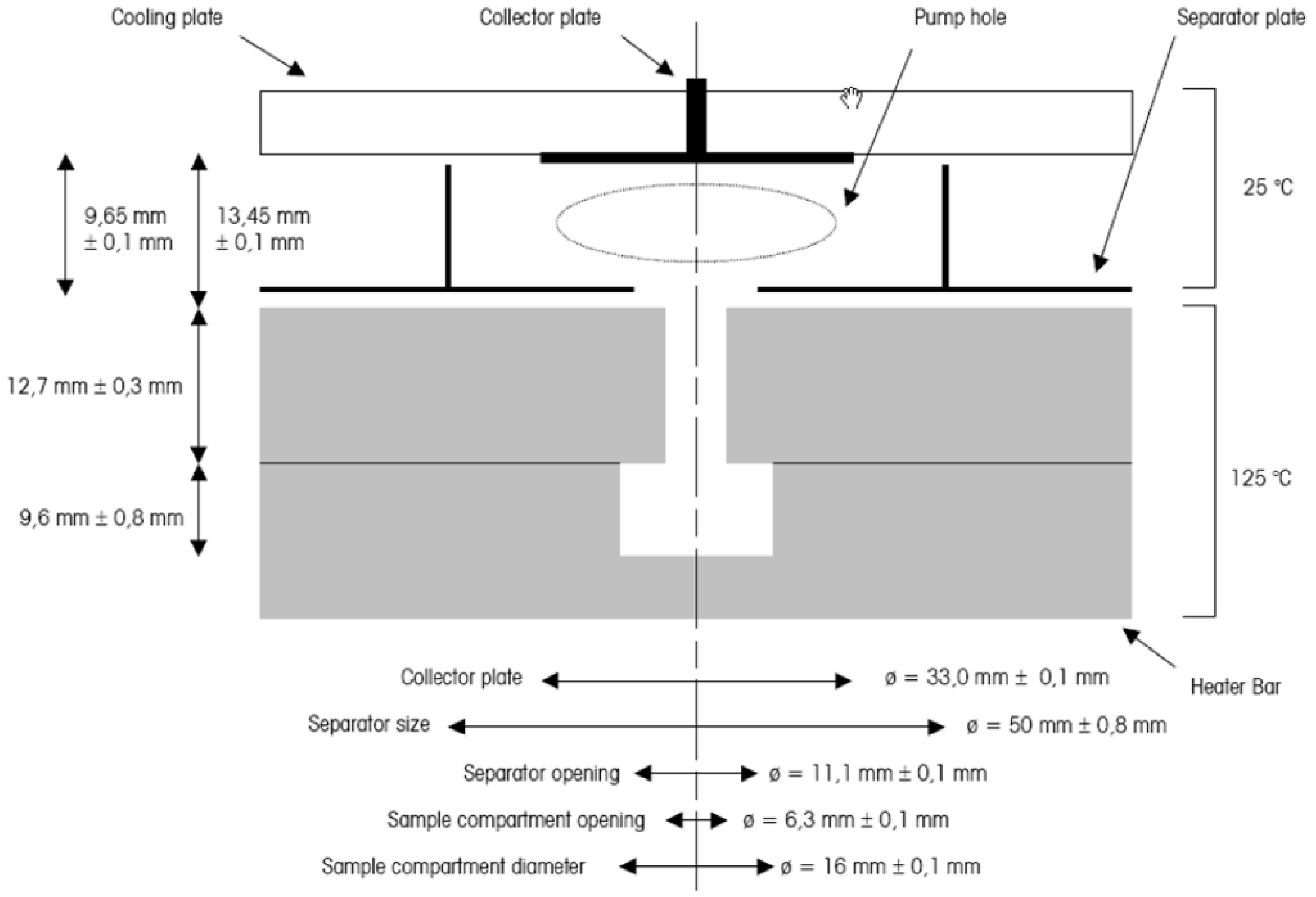


Figure 5-1: Micro-VCM equipment

ECSS-Q-ST-70-02C : Outgassing

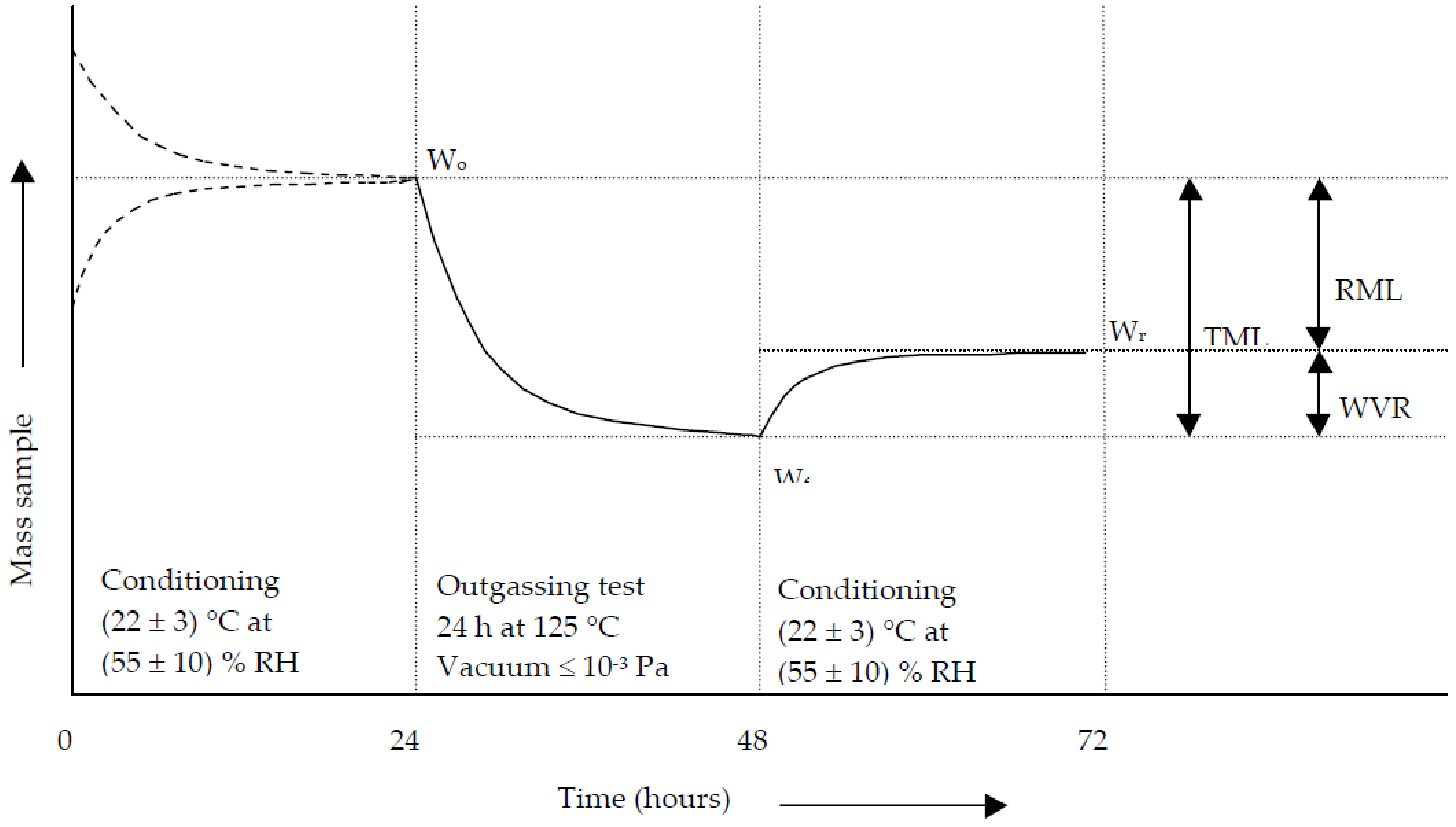


Figure 4-3: Parameters for sample

ECSS-Q-ST-70-02C : Outgassing

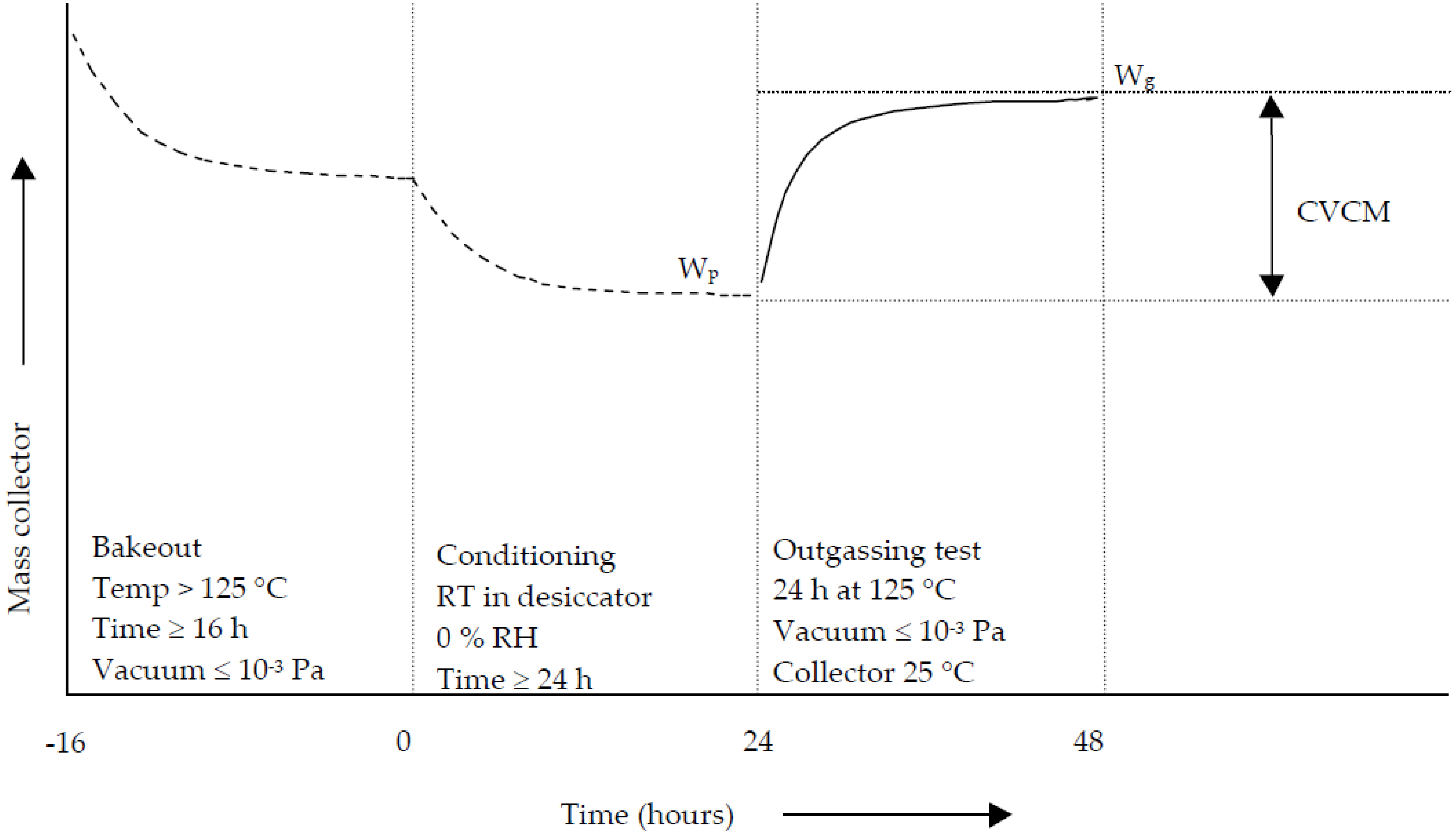


Figure 4-4: Parameters for collector plate

ECSS-Q-ST-70-02C : Outgassing

Item no.	Commercial identification or standard designation	Chemical nature ISO-1043	Product type	Procurement information manufacturer/ supplier procurement spec .	Summary of process parameters	Use and location	User code contractor project	TML %	RML %	WVR %	CVCM %	Test reference no.	IR-data results	Observations
1	Honeycomb	EP/Al	honeycomb	Casa	Spec Ca-423-95A	structure	Meris-C3							
2	Aeroglaze Z306 + Pyrolac P123	PUR/EP	paint black/ primer yellow	Lord/Akzo	Cure 24 at RT + 6 d at 65 °C	optical equipment	XMM	1,55	0,47	1,08	0,00	E 448	None	
3	Aeroglaze Z306 + Pyrolac P123	PUR/EP	paint black/ primer yellow	Lord/Akzo	Cure 24 at RT + 6 d at 65 °C	battery PF3/a12	Mipas-A5							
4	Eccosil-4952	SI	potting	Emerson & Cuming	Cure 7 d at RT + 24h at 45 °C	connector	EURECA-Columbus							
5	Araldite AV100/ HV100	EP	adhesive	Ciba Geigy	Cure 4 h at 60 °C	insert	ISO-SS-Fok							
6	Electrodag 501	Fluoro Carbon	paint-cond. black	Acheson	as received		SOHO							
7	Solithane 113	PUR	potting	Thiokol	as received		Silex							

Figure C-1: Example of filled in Micro-VCM datasheet

ECSS-Q-ST-70-02C : Outgassing

Material	Typical TML
PVC plastic	20-30 %
Superglue	15%
Marking ink	10%
Conformal coating	1-2%
CFRP	<1%
Silicone	0.1%
Kapton	0.1%
Metals	<0.01%

- Screen materials (outgassing test)
- Bake-out materials (reduce outgassing potential)
- Reduce view factors, use baffles
- Use heaters for cold surfaces
- Apply protective coatings
- Test before you fly !

ECSS-Q-ST-70-02C : Outgassing

TAKE-HOME REQUIREMENTS

- For those materials that are subjected, during the mission, to temperature above 125 °C for short period of time (in the order of hours) or above 50 °C for an extended period of time (in the order of weeks or above), dedicated tests shall be performed at conditions representative of the real application (i.e. higher temperature tests).
- Modelling of the outgassing phenomenon shall be based on dynamic test results only and not on screening results obtained from this Standard.
- The customer shall make the limits defined in clause 5.5.3.1 more stringent if the materials concerned are used in critical areas.
- In case the material outgassing is higher than the general requirements in 5.5.3.1, corrective actions shall be taken.

ECSS-Q-ST-70-02C : Outgassing

Common topics for discussion :

-Materials slightly exceed the outgassing requirements e.g TML = 1.1 %

-Outgassing data greater than 10 years old

-Outgassing data not available at all (e.g. for materials inside commercial unit)

-Data source for outgassing values not quoted in the DML

ECSS-Q-ST-70-04C : Thermal vacuum

- Establishes the requirements for the specification, the procedures, the execution and the reporting of a thermal cycling test under vacuum for the evaluation of materials, processes, mechanical parts and assemblies intended for use in the fabrication of spacecraft and associated equipment

- Determine the ability of theses articles to withstand changes of ambient temperature under vacuum

- Typical materials or assemblies that can be evaluated by means of this test method are adhesives, bonded joints, coatings (paint, thermal and protective), insulating materials, metallic bonded joints, metallic samples, finished by plating or chemical conversion, metallized plastic films, organic or non-organic bonding, plated surfaces, potting compounds, reinforced structural laminates, sealants….

- But not limited to the above !

ECSS-Q-ST-70-04C : Thermal vacuum

External items | Internal electronics | External items

-200	-150	-100	-50	-20	0ºC	20	50	100	150	>200

ECSS-Q-ST-70-04C : Thermal vacuum

Initial inspection of samples at (22 ± 3) °C, RH (55 ± 10) % within six hours prior to the commencement of thermal cycling, see D.3a.
Sample mounted on sample holder within thermal vacuum chamber, see D.3b and 5.2.2.2.
Chamber evacuated to 1×10^{-5} Pa at (22 ± 3) °C, see D.3c and D.3d.
Chamber cycled between +(100 ± 5) °C and -(100 ± 5) °C for 100 cycles unless otherwise stated, see D.3e and D.3f.
Final inspection of samples at (22 ± 3) °C, RH (55 ± 10) % within six hours after completion of thermal cycling, see D.3g.

This is a commonly used test sequence for thermal testing. However, it should be noted that this table appears in the informative annex of the standard and therefore does not contain requirements

ECSS-Q-ST-70-04C : Thermal vacuum

Pay attention to :

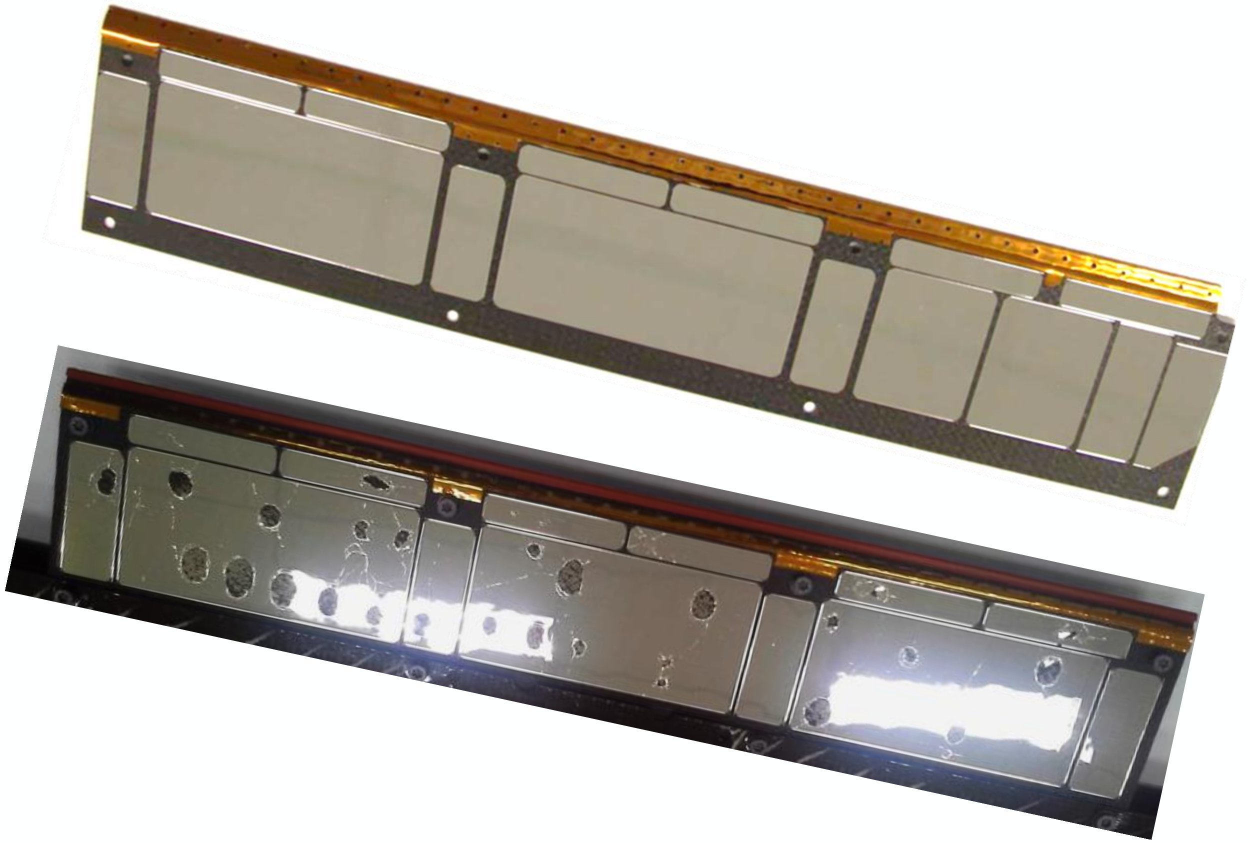
- Vacuum chamber bake-out
- Contamination control (especially for optical components)
- High outgassing materials
- Thermal coupling (conductive/radiative)
- Heating rates and temperature limits

Typical small scale thermal vacuum facility for materials testing (ESA)

ECSS-Q-ST-70-04C : Thermal vacuum

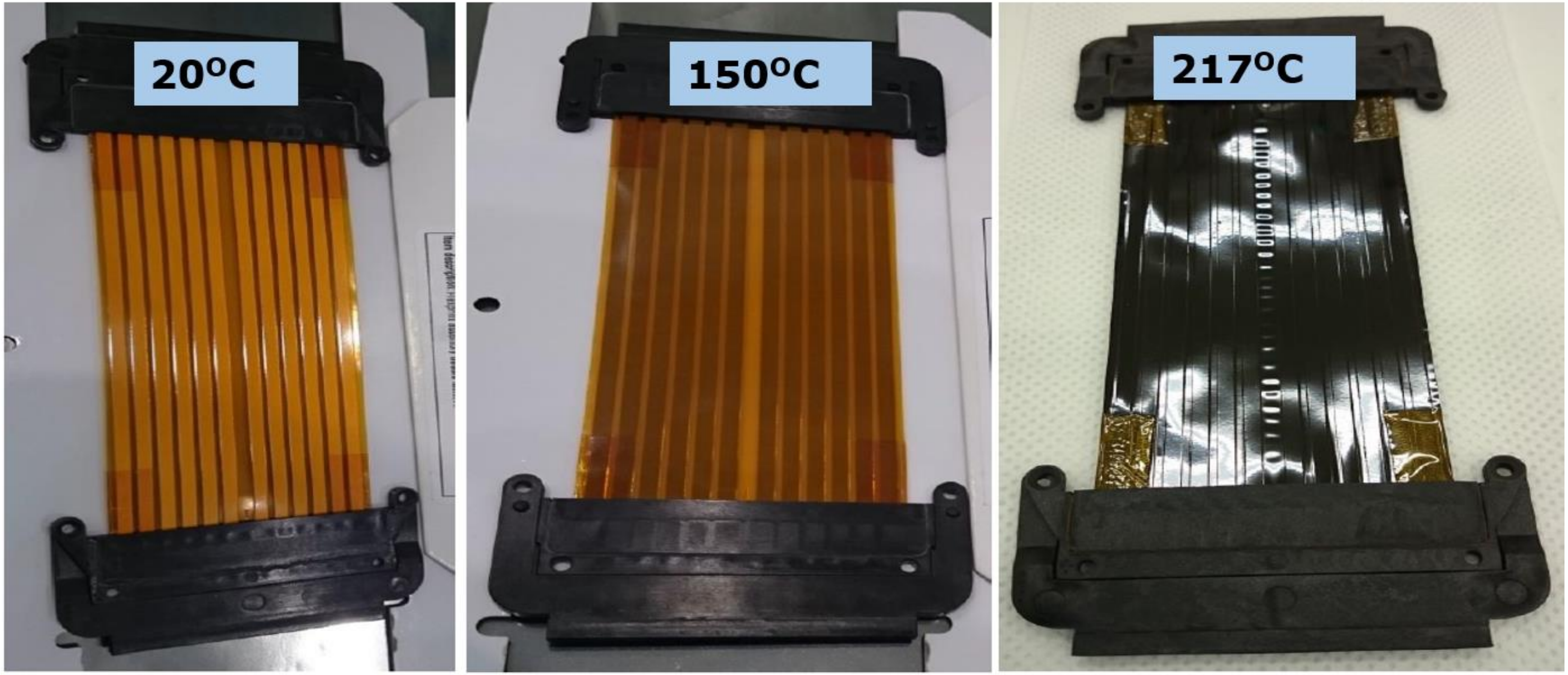
Possible effects include :

- cracking or fracture of materials or assemblies due to sudden dimensional changes by expansion
- contraction or pressure
- short circuiting of electrical wiring
- overheating of materials or assemblies due to change in convection and conductive heat transfer characteristics



Fracture of glass solar reflectors during thermal vacuum cycling

ECSS-Q-ST-70-04C : Thermal vacuum



Materials degradation after thermal vacuum cycling

ECSS-Q-ST-70-04C : Thermal vacuum

TAKE-HOME REQUIREMENTS

- During thermal testing, the temperature of the sample (test item) shall be measured.
- In case of optical or thermo-optical properties measurements, contamination effects on the sample shall be controlled.
- During and upon completion of the test sequence the sample shall be investigated for signs of cracking, fracture, overheating and significant electrical degradation.

And remember that test temperatures, vacuum level and number of cycles are not specified as requirements in the standard, but rather they depend on the specific mission conditions

ECSS-Q-ST-70-04C : Thermal vacuum

Common topics for discussion :

-How many thermal cycles do we need to perform ?

-Can we do the thermal cycling using inert atmosphere instead of vacuum ?

-Can we split the thermal cycles into low temperature / ambient and ambient / high temperature ?

-Do we need to perform materials level thermal cycling or can we rely on the unit level qualification ?

ECSS-Q-ST-70-06C : Particle and UV radiation

- Defines the procedures for electromagnetic radiation and charged particles testing of spacecraft materials.

These materials include for instance thermal control materials, windows, coatings, and structural materials.

- Includes simulation of the environment and the properties to be verified. Excludes electronic components.

- Typical properties to be verified are :

• optical (transmission, absorption of windows)

• thermo-optical (spectral and solar absorptance, infrared emissivity)

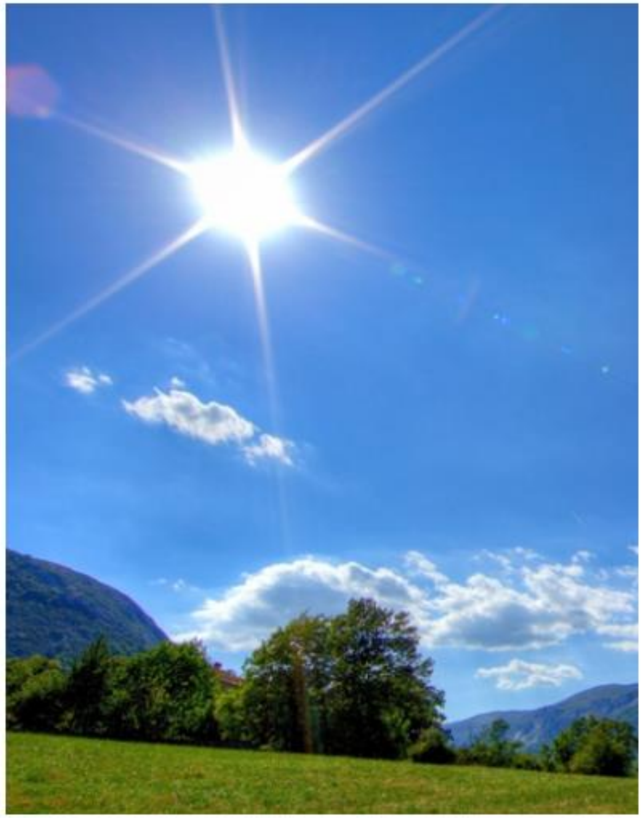
• electrical properties (e.g. conductivity, charging)

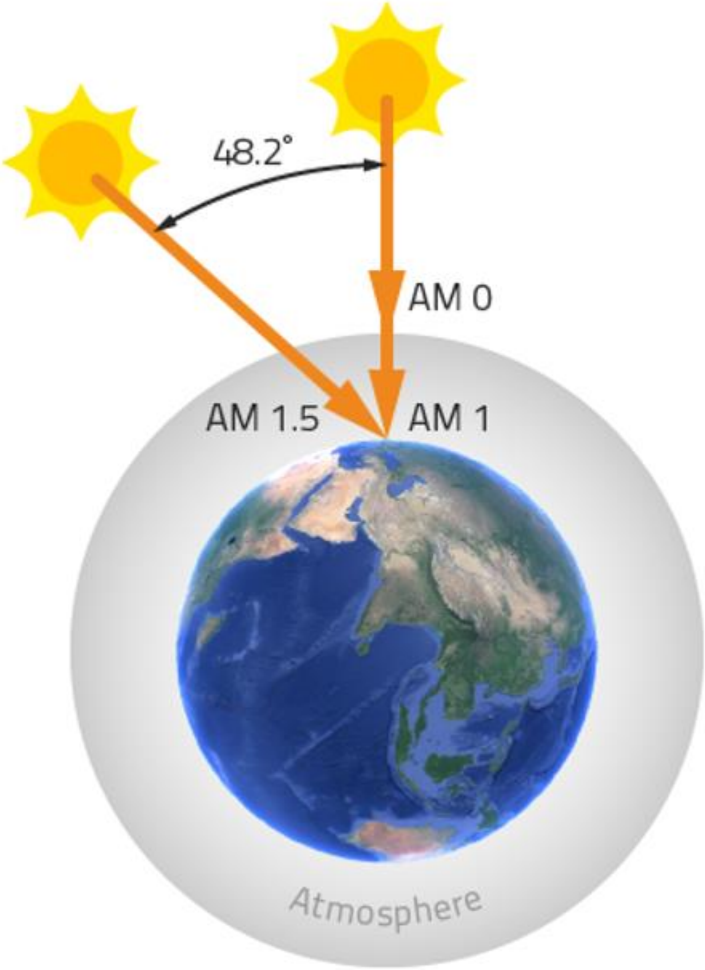
- Generally the materials are exposed on the outside of the spacecraft

- Radiation can be ionising (e.g. high energy particles and VUV) or non-ionising (e.g. UV)

ECSS-Q-ST-70-06C : Particle and UV radiation

AM1





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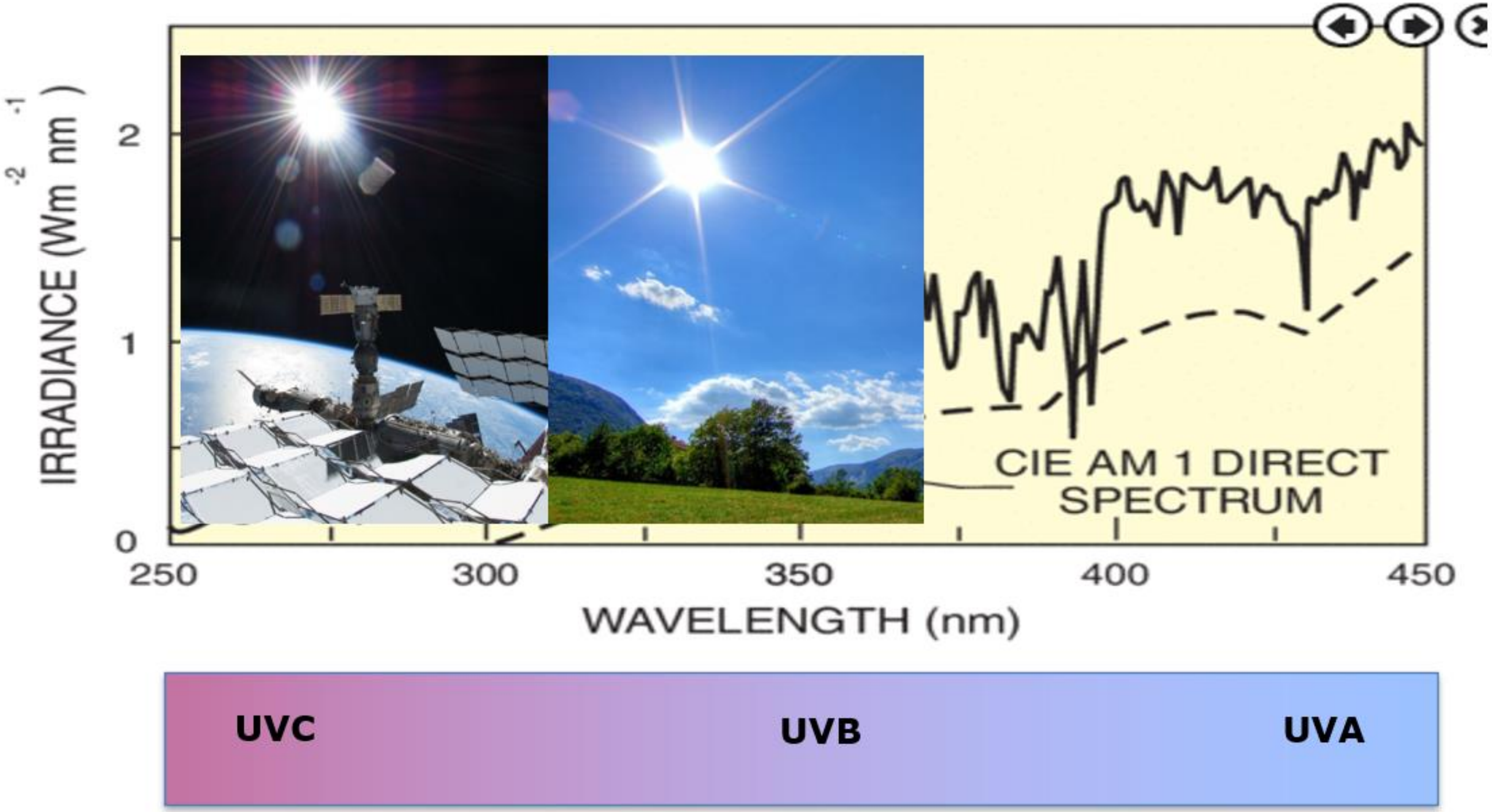
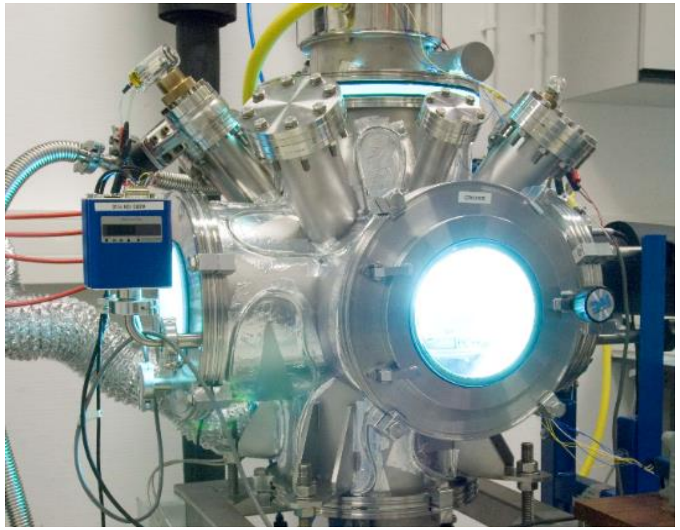
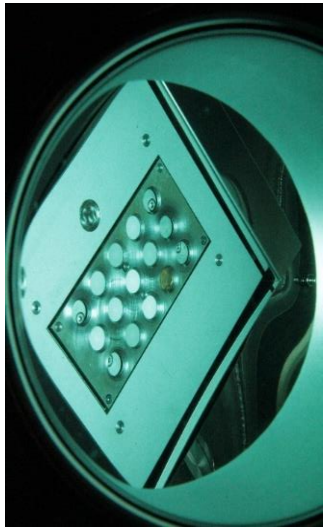
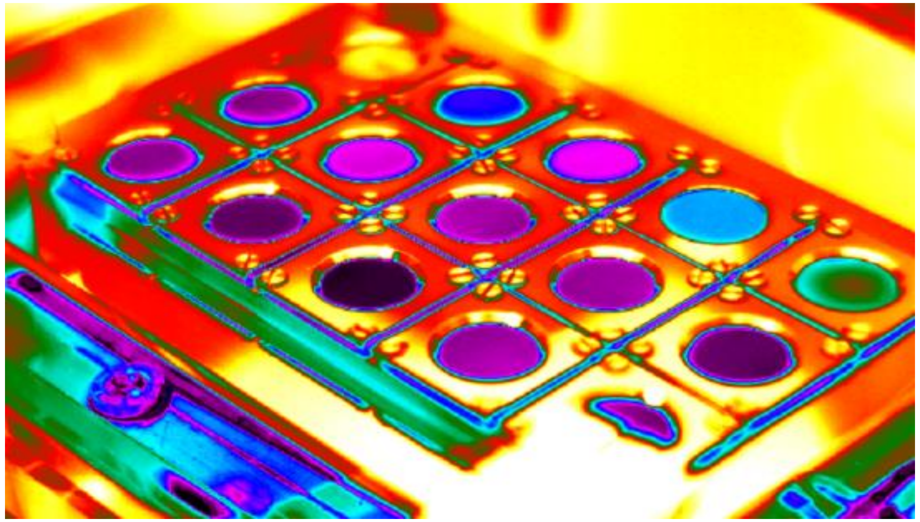
ECSS-Q-ST-70-06C : Particle and UV radiation

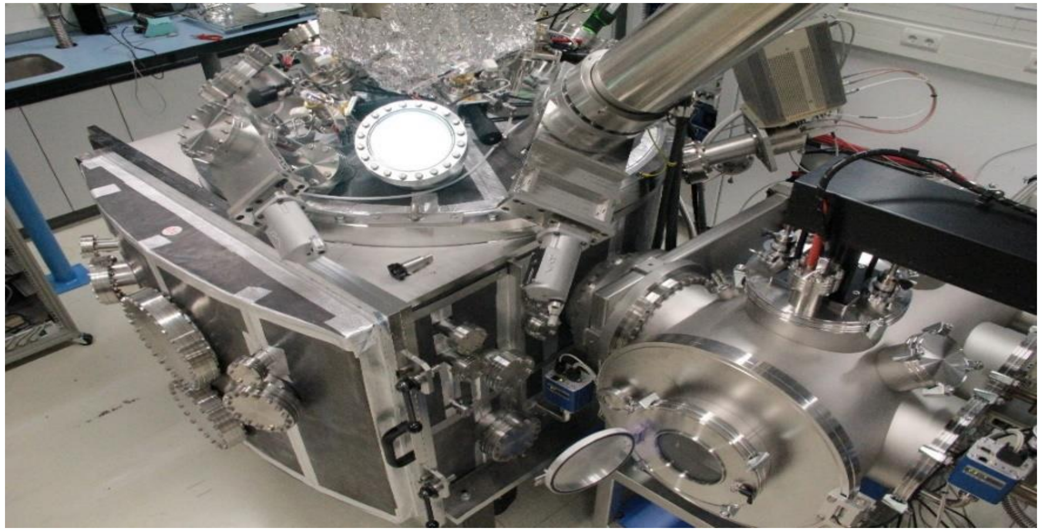


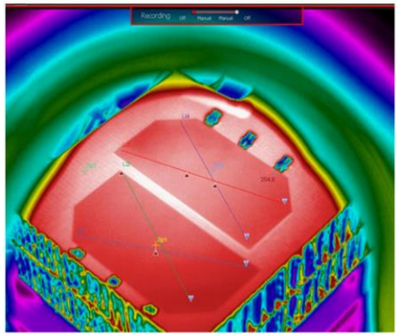
ECSS-Q-ST-70-06C : Particle and UV radiation

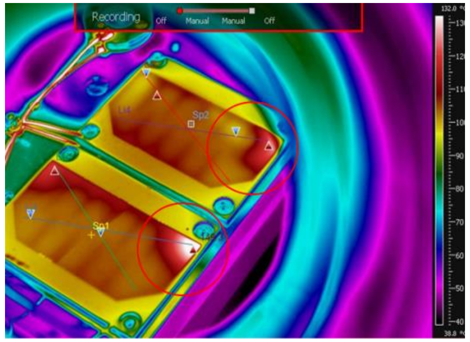






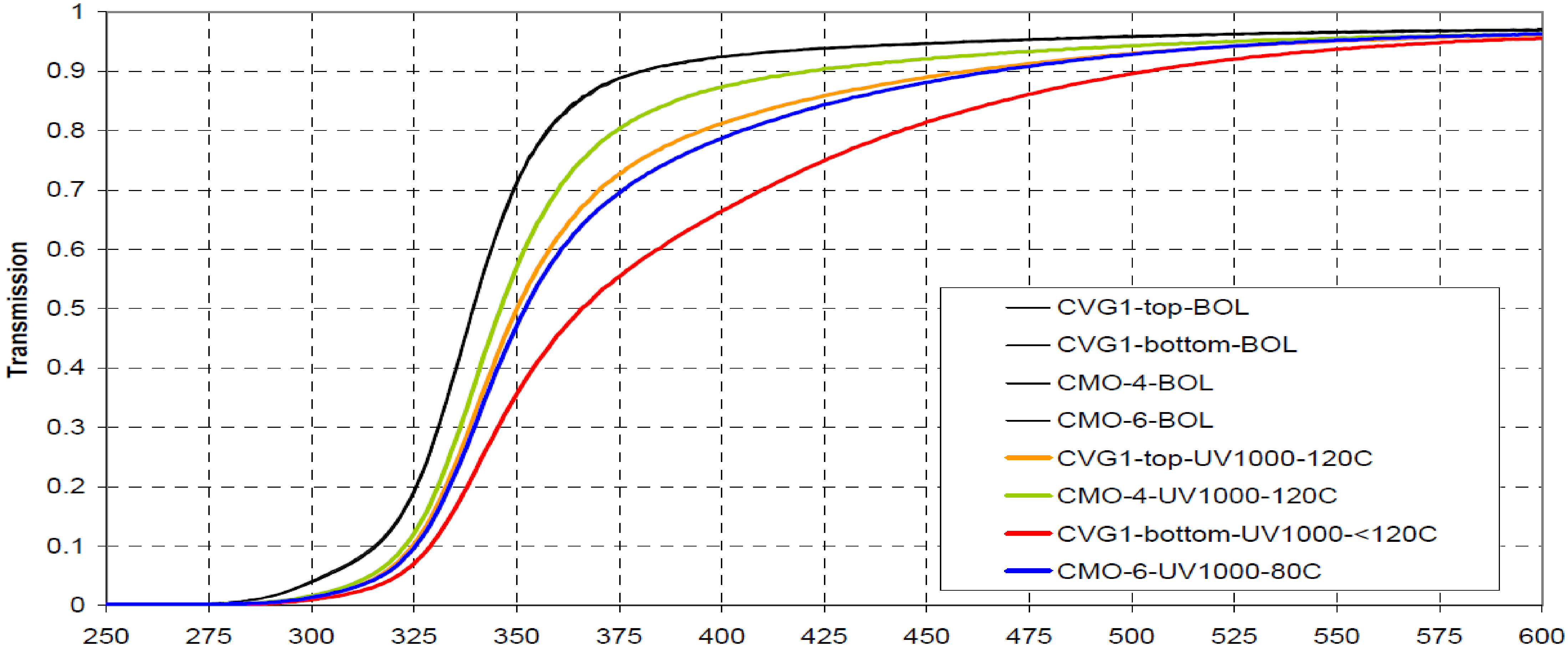






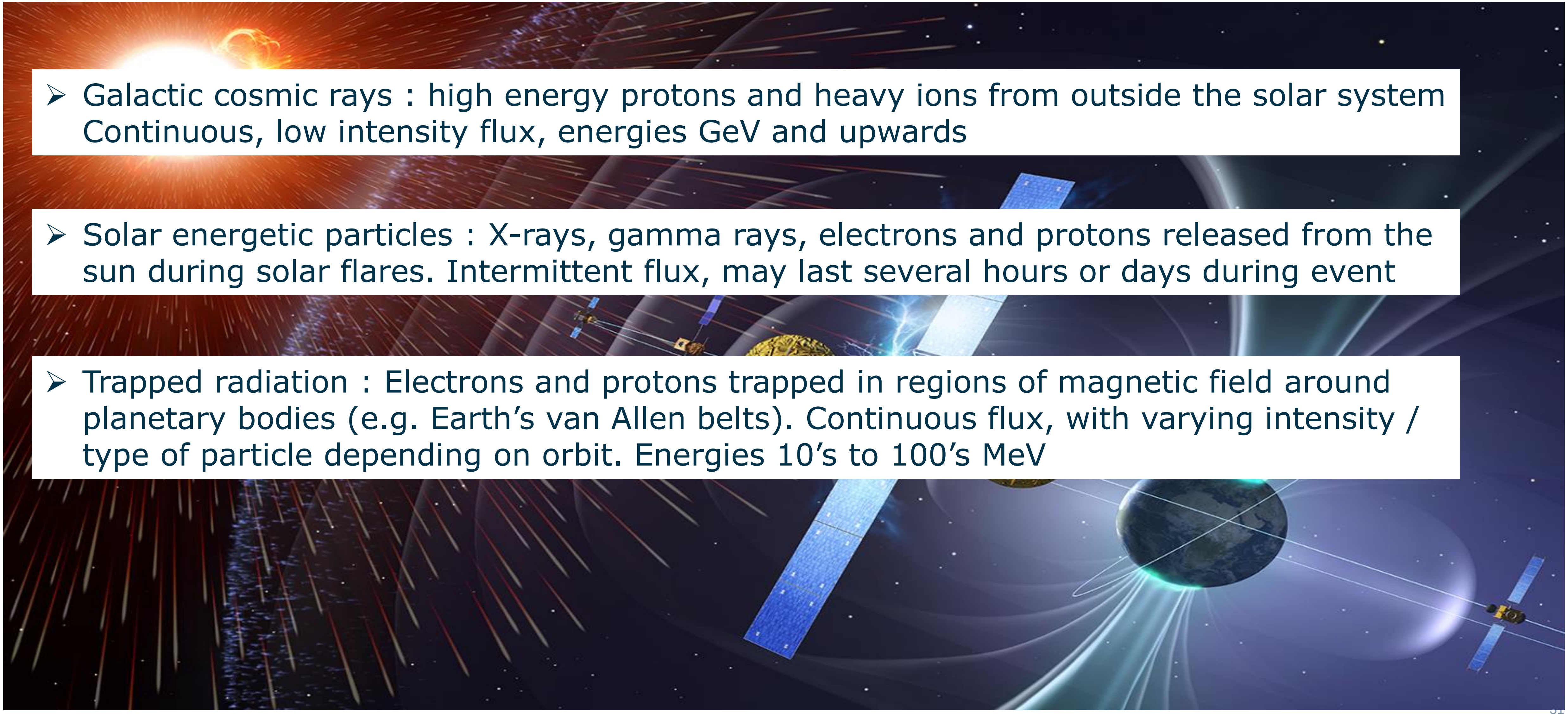
Typical small scale UV simulation facilities for materials testing (ESA)

ECSS-Q-ST-70-06C : Particle and UV radiation



Reduction in transmission of solar cell cover glass adhesive after UV exposure

ECSS-Q-ST-70-06C : Particle and UV radiation



- Galactic cosmic rays : high energy protons and heavy ions from outside the solar system
  Continuous, low intensity flux, energies GeV and upwards

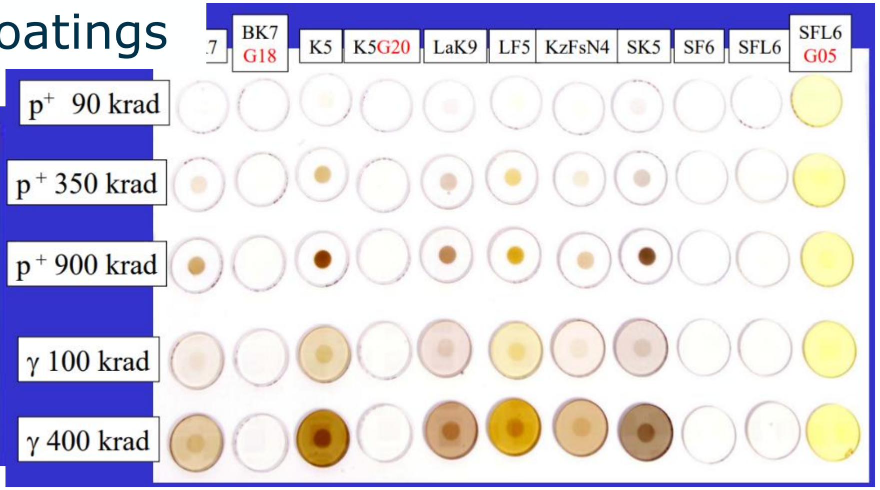
- Solar energetic particles : X-rays, gamma rays, electrons and protons released from the sun during solar flares. Intermittent flux, may last several hours or days during event

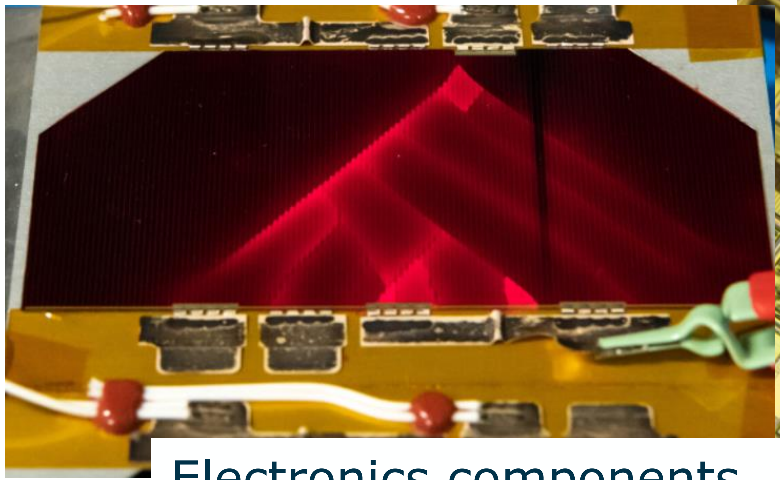
- Trapped radiation : Electrons and protons trapped in regions of magnetic field around planetary bodies (e.g. Earth’s van Allen belts). Continuous flux, with varying intensity / type of particle depending on orbit. Energies 10’s to 100’s MeV

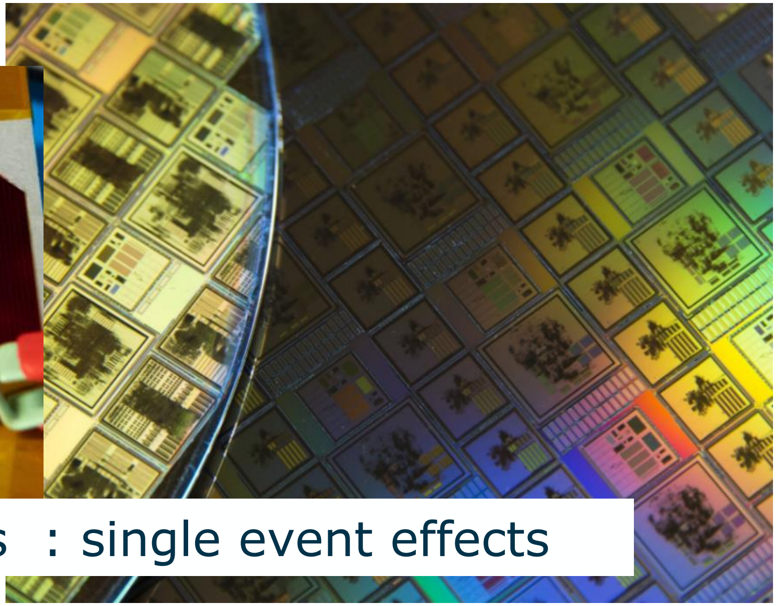
ECSS-Q-ST-70-06C : Particle and UV radiation

Embrittlement of polymers

Degradation of optical glass and coatings



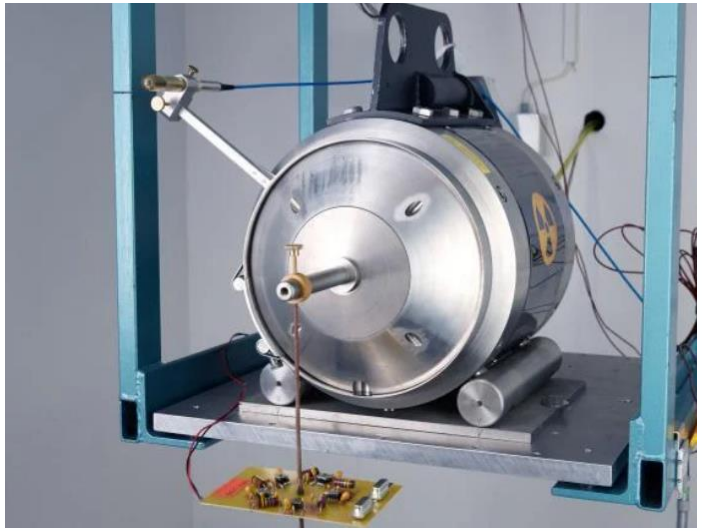




Electronics components : single event effects

Human health – shielding

ECSS-Q-ST-70-06C : Particle and UV radiation

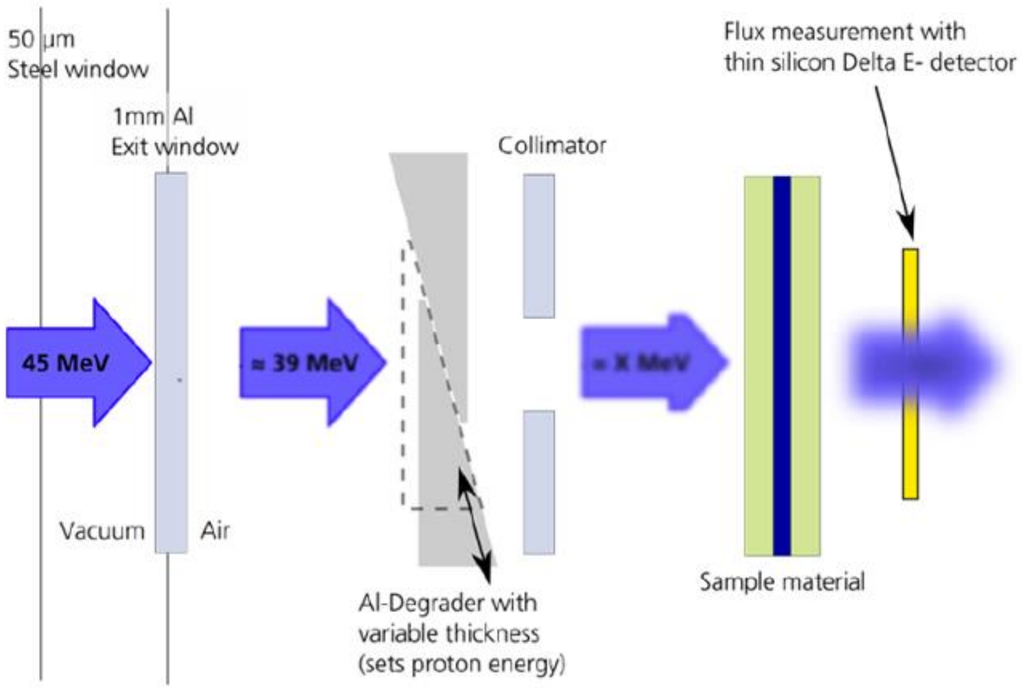


Typical Co60 source

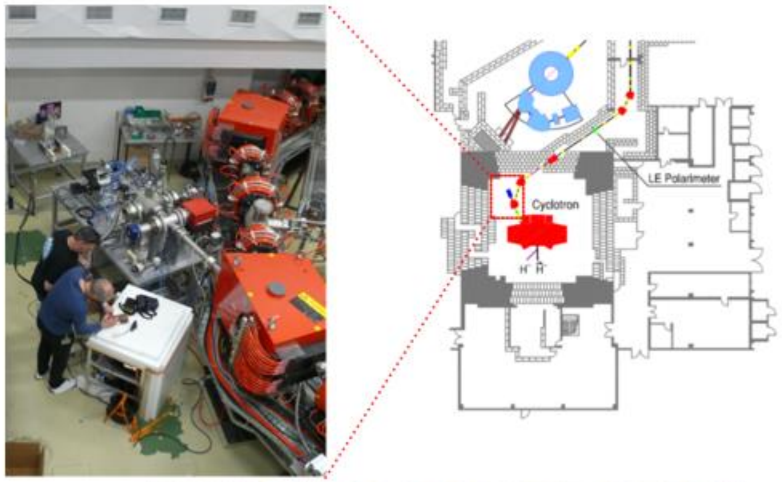
- *Co-60 decays to Ni-60 via beta-decay with a half-life of 5.3 years*
- *excited Ni-60 nuclei decay to their ground state by emission of energetic gamma radiation with energies of 1.172 MeV and 1.332 MeV*

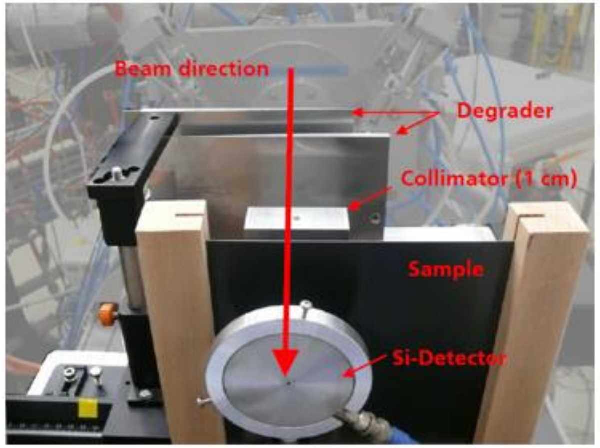
ECSS-Q-ST-70-06C : Particle and UV radiation

Sample Proton Shielding Test Setup at JULIC



45 MeV protons degraded to variable energies by aluminium degrader wedge with variable thickness





ESA GSTP project, Tiedemann et al, HPS Germany

ECSS-Q-ST-70-06C : Particle and UV radiation

TAKE-HOME REQUIREMENTS

- The customer shall identify (in the request for radiation test), the materials properties to be investigated.
- The value of maximum dose rate (or an energy flux on a material surface) shall be determined both by the allowable temperature increase of a sample and the admissible acceleration factor.
- In case of optical or thermo-optical properties measurements, contamination effects on the sample shall be controlled.
- Radiation tests shall be conducted under vacuum conditions (equal or less than 10^{-3} Pa).
  - NOTE Tests in air, inert gas or primary vacuum can be performed if it is demonstrated that this has no effect on the property to be investigated.

ECSS-Q-ST-70-06C : Particle and UV radiation

Common topics for discussion :

-Using gamma rays for radiation testing of optical coatings

-Overheating of samples during UV test

-Spectrum of UV lamp source

-Duration of UV test and acceleration factor

ECSS-Q-ST-70-09C : Thermo-optical properties

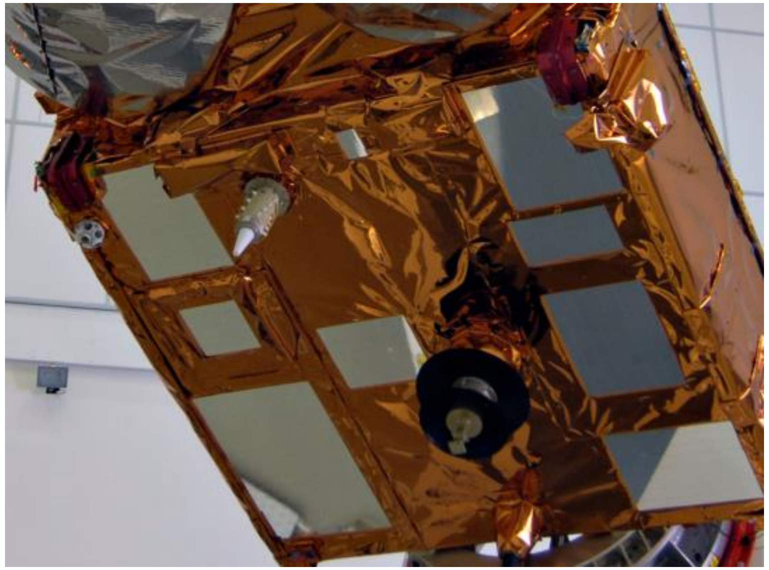
- Describes the methodology, instruments, equipment and samples, used to calculate the thermo-optical properties of thermal-control materials

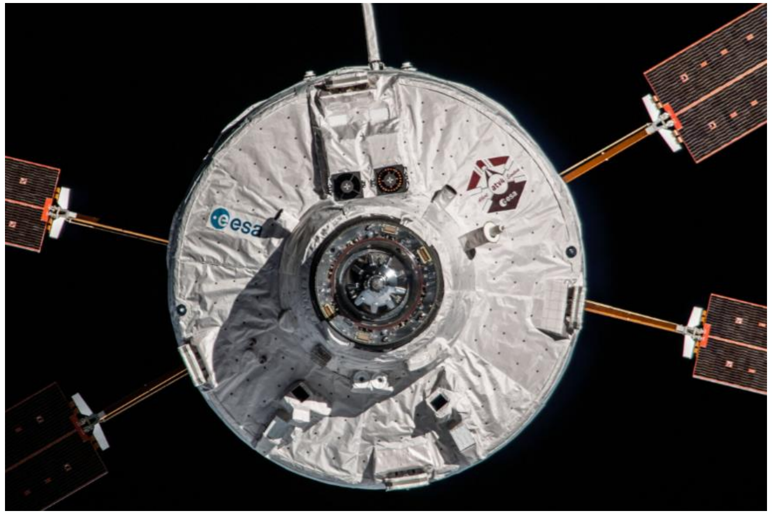
- Includes Solar absorptance using spectrometer, comparative/portable test method, Infrared emittance using thermal test method, IR spectrometer (εh) and portable equipment (εn)

- Standard has been written in connection with instruments and equipment available at major tests houses (ONERA, INTESPACE and ESTEC); however, any supplier is encouraged to built up his own instrument or equipment provided the accuracy of the results is equivalent to the one specified in the standard

- It should be noted that the *test methods* are *informative*

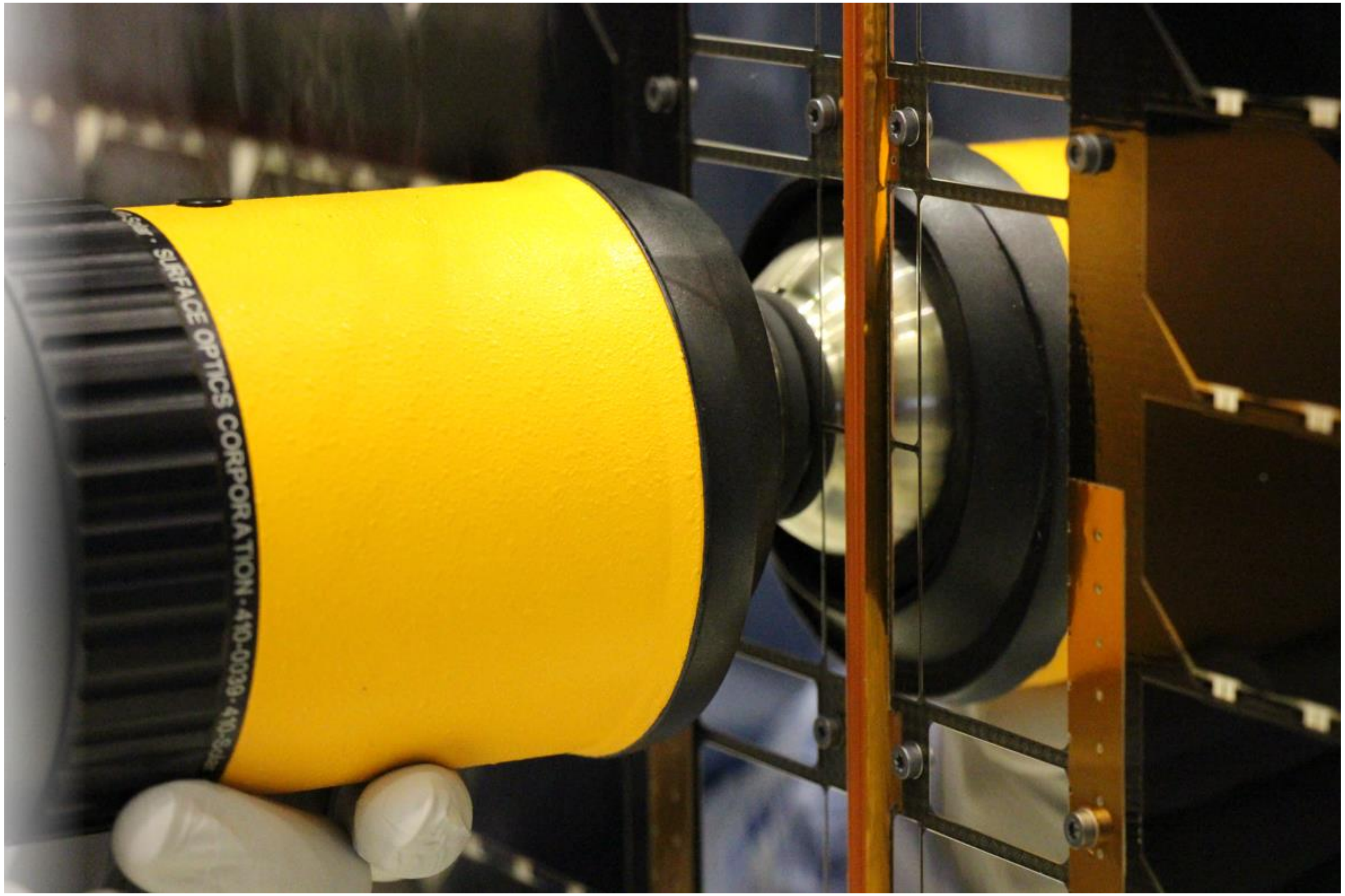
ECSS-Q-ST-70-09C : Thermo-optical properties





Common thermal control materials

ECSS-Q-ST-70-09C : Thermo-optical properties



Portable solar absorptance measurement on a solar array wing (ESA)

ECSS-Q-ST-70-09C : Thermo-optical properties

Typical bench-top spectrophotometer for measurement of solar absorptance

C.2.5 Calculation of absorptance

The spectrum is taken between 250 nm and 2 500 nm, and covers 96 % of the total energy.

$$\alpha_s = 1 - R_s$$

$$R_S = \frac{\int_{\lambda_1}^{\lambda_2} R(\lambda) S(\lambda) d\lambda}{\int_{\lambda_1}^{\lambda_2} S(\lambda) d\lambda}$$

where:

$R(\lambda)$ is the spectral reflectance after 100 % reference correction;

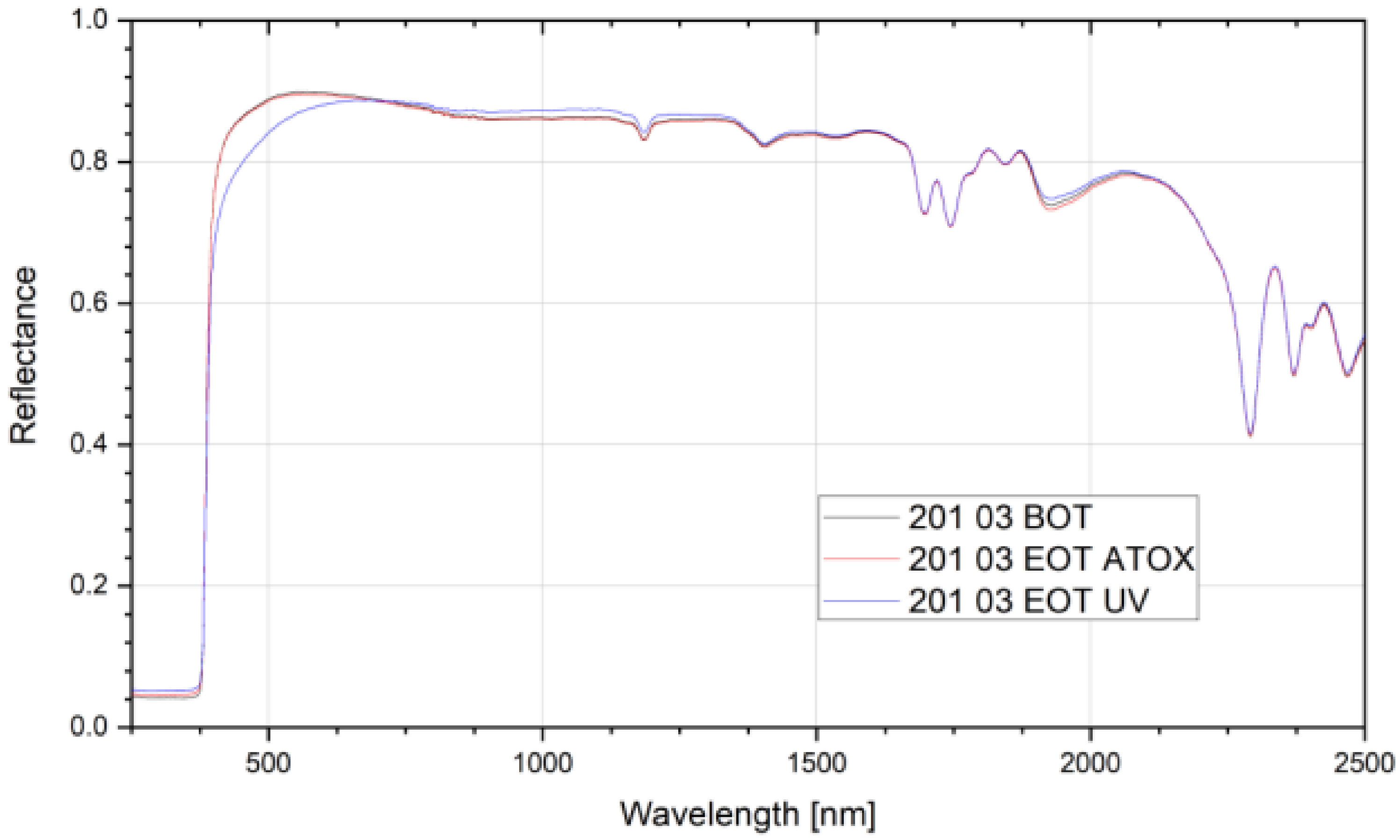
$S(\lambda)$ is the spectral solar irradiance (see ASTM E 490);

$d\lambda$ is typically 1 nm;

λ_1 is 0,25 µm;

λ_2 is 2,5 µm.

ECSS-Q-ST-70-09C : Thermo-optical properties

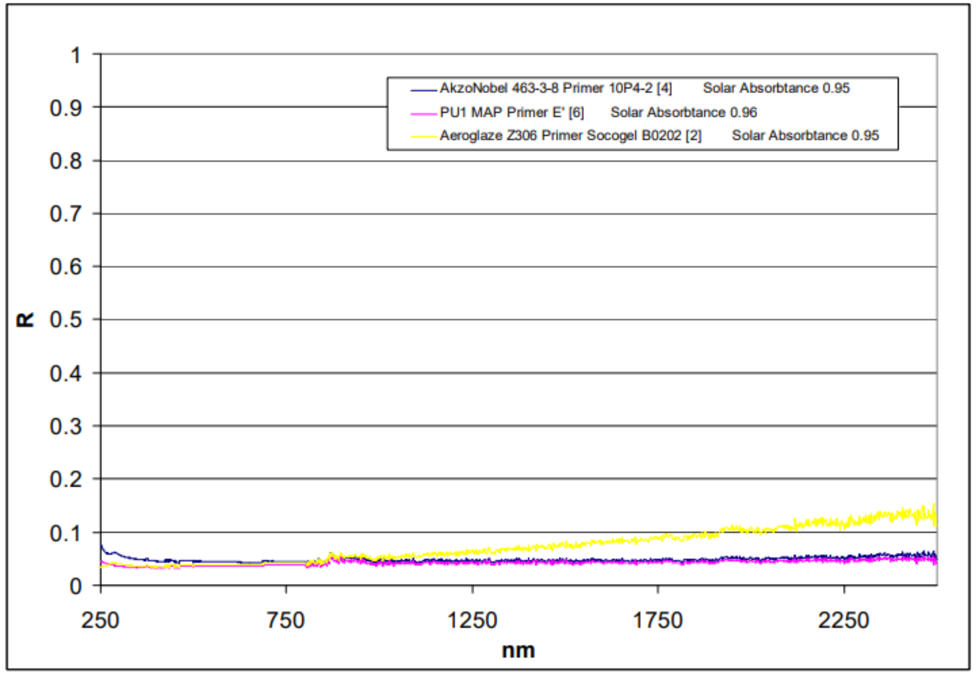


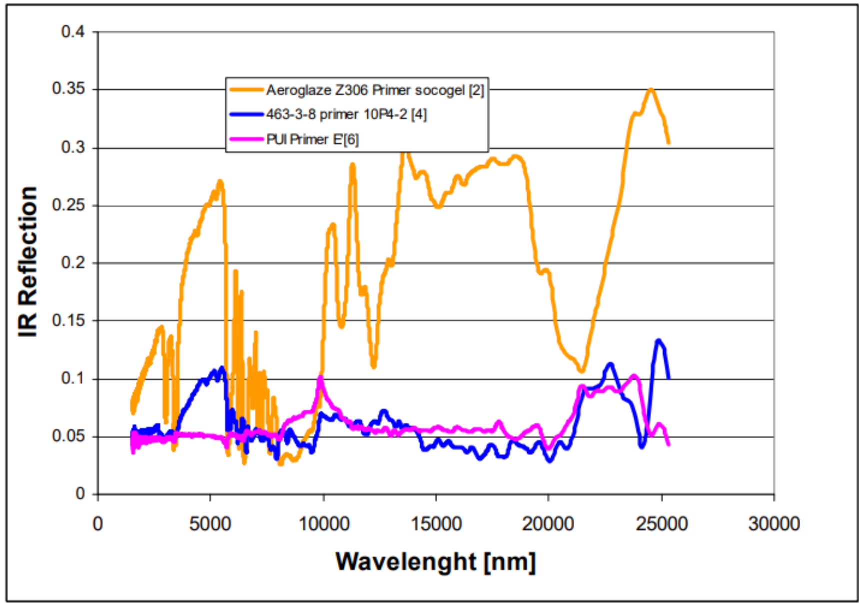
Typical reflectance spectrum used to calculate solar absorptance

ECSS-Q-ST-70-09C : Thermo-optical properties

Black Paint	*Primer*	α_s	ε_N	α/ε
Aeroglaze Z306	Socogel B0202	0.95	0.78-0.80	**1.19-1.22**
AkzoNobel 463-3-8	10P4-2	0.95	0.87-0.88	**1.08-1.09**
PU1 (MAP)	E’	0.96	0.87-0.88	**1.09-1.10**

Black Paint	*Primer*	*at room temperature*	ε_{IR} *at 150°C*
Aeroglaze Z306	Socogel B0202	0.82	0.84
AkzoNobel 463-3-8	10P4-2	0.94	0.94
PU1 (MAP)	E’	0.94	0.94





Typical measurements of solar absorptance and IR emittance

ECSS-Q-ST-70-09C : Thermo-optical properties

TAKE-HOME REQUIREMENTS

- The supplier shall prepare the material samples according to the process specification or manufacturer's data

- The supplier shall select the test methods depending on the type and size of the samples

- The supplier shall calibrate any measuring equipment to traceable reference standards

(such as reference mirrors or diffuse reflectance standards)

- The customer's product assurance department shall audit the system after it has been built or purchased.

NOTE The audit is necessary before the system can be accepted for running qualification or quality control tests on materials for use in customer projects.

ECSS-Q-ST-70-09C : Thermo-optical properties

Common topics for discussion :

-Air / vacuum testing

-Low temperature thermal emittance

-How to measure non-uniform / partially transparent samples

ECSS-Q-ST-70-13C : Tape peel strength

- Details a test in which pressure-sensitive tapes are used to assess the suitability of, for example, coatings, paints, films and other thin materials, proposed for use on spacecraft and associated equipment.

- Applicable for materials such as organic coating, e.g. varnishes, paints and plastic films, metallic finishes on, for example, printed circuit boards, second-surface, mirrors, thermal radiators, plastic films, adhesive layers composite thin films, small assemblies, e.g. solar cells having attached glass covers.

- This test method requires a “*power-driven machine capable of maintaining a specified constant rate of loading and able to be used for both tensile and compressive testing*”

- An alternative, simpler test method is also described in ECSS-Q-ST-70-17C for testing coatings and paints

ECSS-Q-ST-70-13C : Tape peel strength

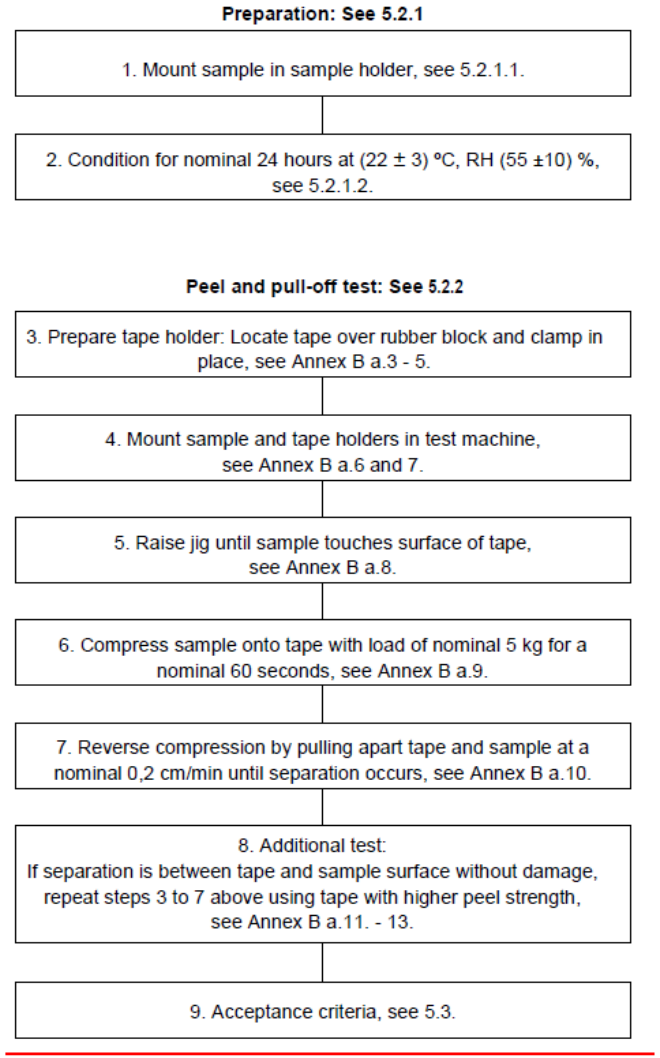


Figure 4-1 Test procedure flow diagram

5.1.4.2 Testing machine

a. The supplier shall employ a power-driven machine capable of maintaining a specified constant rate of loading and able to be used for both tensile and compressive testing.

b. The machine shall have a fixed or essentially stationary member supporting a load cell and the tape holder.

c. A movable member shall carry the sample holder.

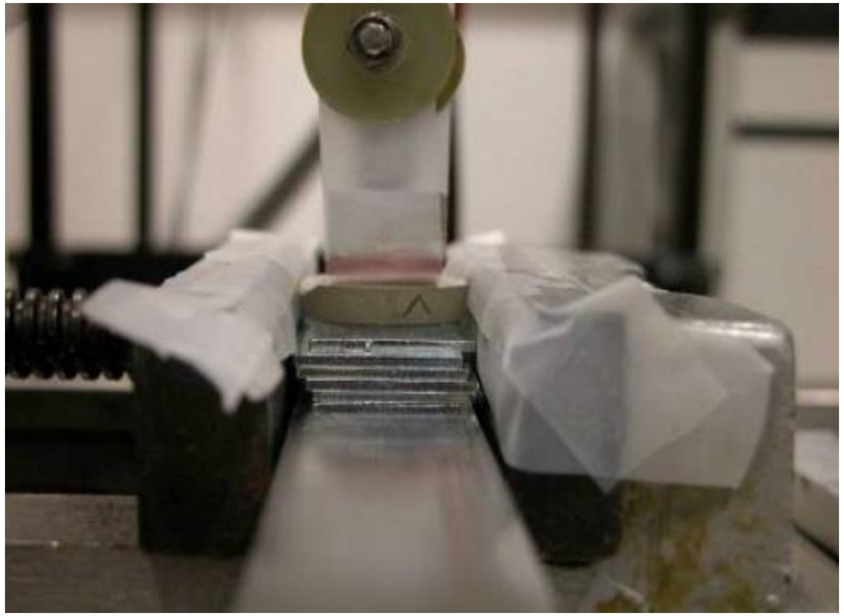
d. The applied compressive and tensile loads, as measured and recorded, shall be accurate within 1 percent of the load.

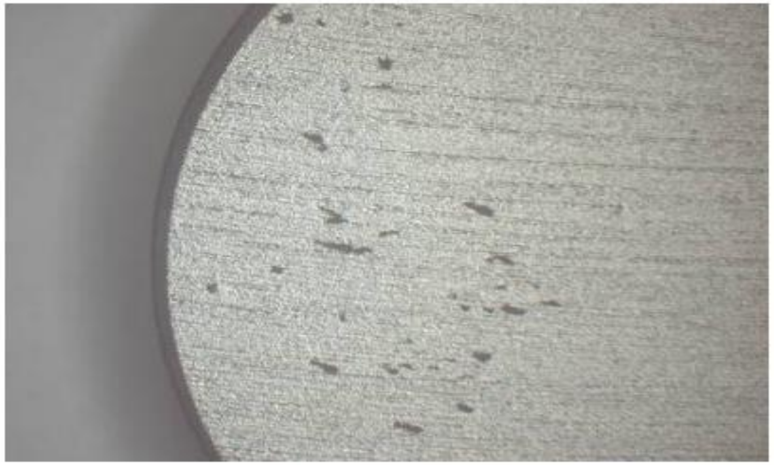
e. The rate of travel of the sample holder shall be at a nominal rate of 0,2 cm/min.

5.1.4.5 Peel adhesion tape

a. The supplier shall employ a range of pressure-sensitive tapes for the tests with peel adhesion strengths of 220, 330, 440 and 670 g/cm, all with a tolerance of ± 10 %.

ECSS-Q-ST-70-13C : Tape peel strength





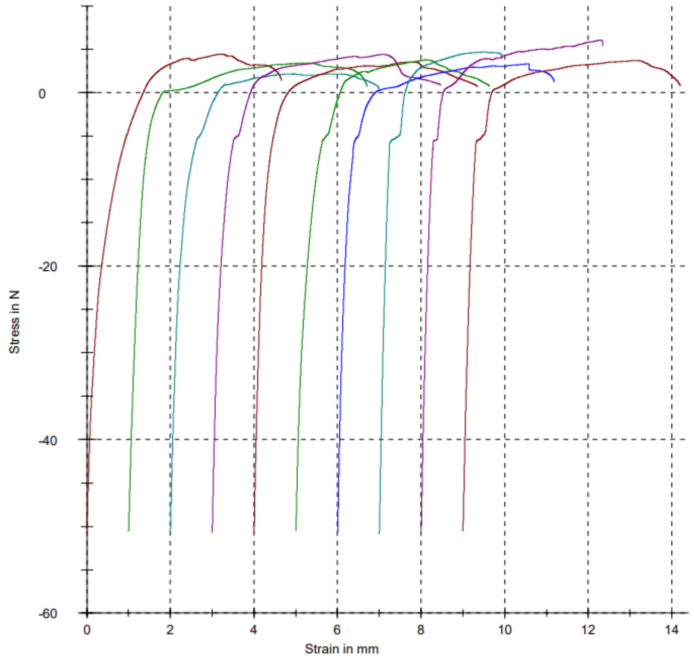


Figure 6: Force-displacement curves for tape tests P1[LHS curve] through P10{RHS curve]

Tape test on optical sample acc. ECSS-Q-ST-70-13C

ECSS-Q-ST-70-13C : Tape peel strength

TAKE-HOME REQUIREMENTS

- The width of the test sample surface face shall be at least equal to the width of the tape used in the test procedure
- The supplier shall employ a power-driven machine capable of maintaining a specified constant rate of loading and able to be used for both tensile and compressive testing
- The sample holder shall be firmly located beneath the tape holder on the movable member of the testing machine.
- The supplier shall take a photographic record of the tested samples at appropriate level of magnification NOTE Typical topographical features are recorded at ×2, ×20, ×50, ×100, ×250, ×500 or ×1000 magnifications.

ECSS-Q-ST-70-05C : IR spectroscopy

- 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.

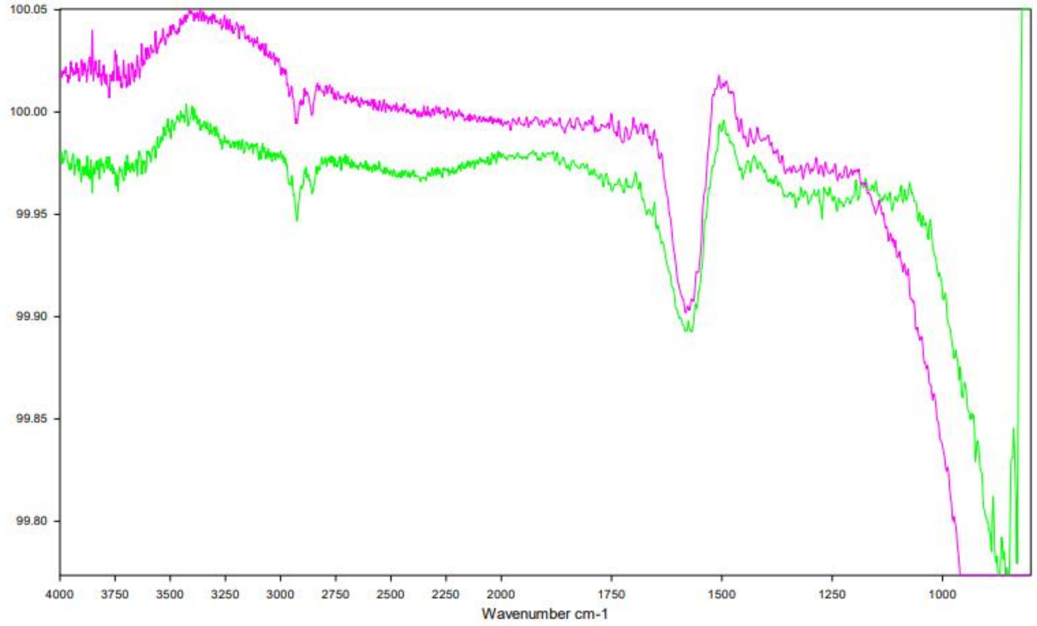
- Informative annexes are included to give more detailed testing guidelines e.g. Calibration of infrared equipment, Training of operators. Use of molecular witness plates, Collecting molecular contamination

ECSS-Q-ST-70-05C : IR spectroscopy

- Infrared qualitative analysis is carried out by functional group identification

- Infrared quantitative analysis of levels of contaminants is based on the Lambert-Beer's law and requires calibration.

FTIR Spectra:



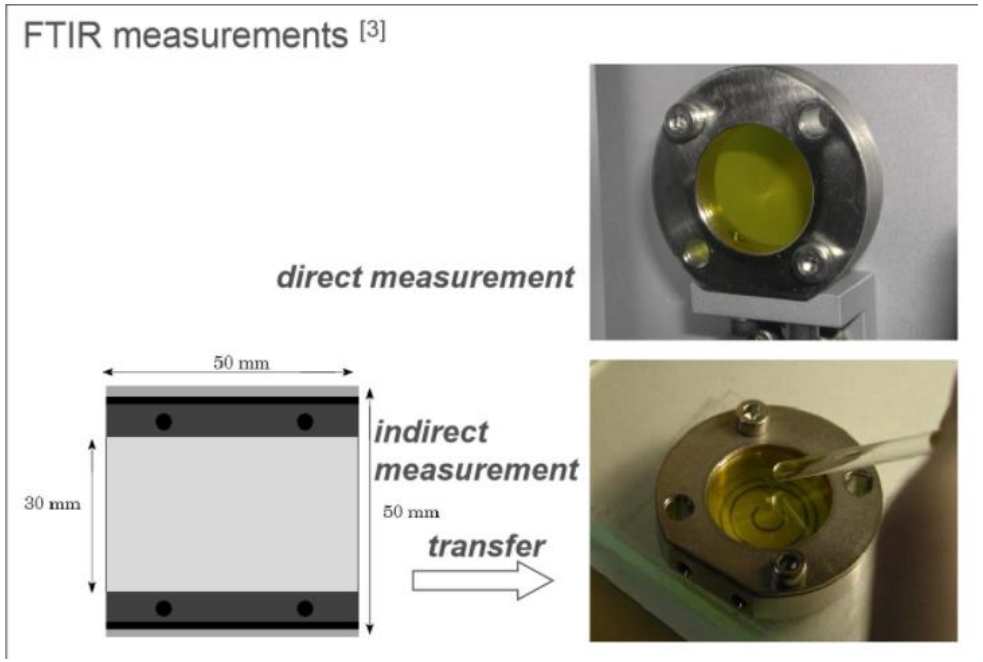
#034 top (180°C, 87h)	Transmission CaF2	Apollo 7 002.0	VERTEX 70v
#109 top (180°C, 87h)	Transmission CaF2	Apollo 7 002.1	VERTEX 70v

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

ECSS-Q-ST-70-05C : IR spectroscopy

- 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 an IR-transparent or a reflective window containing the



G. Papendrecht (ESA)

ECSS-Q-ST-70-05C : IR spectroscopy

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.

NOTE 1 Typical materials are NaCl, MgF_2, CaF_2, ZnSe, or Ge.

- A blank analysis shall be performed in conformance with 5.2.3.3f and 5.2.3.3g until a background level of less than 5 × 10-7 g for any tissue size is obtained (for indirect method)

- Equipment shall be calibrated for obtaining quantitative information.

ECSS-Q-ST-70-29C : Offgassing

- Defines a test procedure for the determination of the trace contaminants release by non-metallic materials under a set of closely controlled conditions. The test procedure covers both individual materials and assembled articles.

- Applicable for the closed environment of a manned spacecraft where contaminants within the atmosphere are potentially dangerous with respect to toxicity and its consequences for the safety of the crew.

- Describes a test to provide data for aid in the evaluation of the suitability of assembled articles and materials for use in a space vehicle crew compartment. The data obtained are in respect of the nature and quantity of organic and inorganic volatile contaminants evolved when subjected to the crew compartment environment.

ECSS-Q-ST-70-29C : Offgassing

- Basic facility for the performance of the tests included a sealed test chamber (oven), a sampling capability and the analytical equipment.
- The sampling equipment shall consist of either (1) direct atmosphere sampling using containers of accurately known volume for subsequent direct gas analysis, or (2) Dynamic atmosphere sampling performed by passing a known volume of the test atmosphere through an enrichment device.
- Analysis is performed using a gas chromatograph with at least one flame ionization detector, a temperature programming facility, the necessary data recording equipment and a capillary GC column

Compound	Reference Compound	Offgassing mg/oven	PSC mg/m3	SMAC mg/m3	T-value
Isobutylene	1-Butene	6.23E-03	6.23E-05	1144.45	5.45E-08
Fluorotrimethylsilane	Toluene	2.30E-03	2.30E-05	0.5	4.60E-05
Ethanol	Ethanol	1.28E-02	1.28E-04	2000	6.41E-08
Acetone	Acetone	7.92E-02	7.92E-04	52	1.52E-05
Isopropyl Alcohol	Isopropanol	2.77E-02	2.77E-04	150	1.84E-06
Silicon tetrafluoride	Toluene	5.43E-03	5.43E-05	0.1	5.43E-04
Hexamethyldisiloxane	Toluene	4.14E-03	4.14E-05	96.6	4.29E-07
Carbonic acid, ethyl methyl ester	Butyl acetate	5.31E-03	5.31E-05	0.1	5.31E-04
Toluene	Toluene	1.72E-03	1.72E-05	15	1.14E-06
Carbonic acid, diethyl ester	Butyl acetate	4.94E-02	4.94E-04	0.1	4.94E-03
Hexamethylcyclotrisiloxane	Toluene	6.60E-03	6.60E-05	90	7.34E-07
Octamethylcyclotetrasiloxane	Toluene	1.36E-02	1.36E-04	280	4.85E-07
Decamethylcyclopentasiloxane	Toluene	3.61E-03	3.61E-05	100	3.61E-07

Typical offgassing test results

ECSS-Q-ST-70-17C : Coating durability

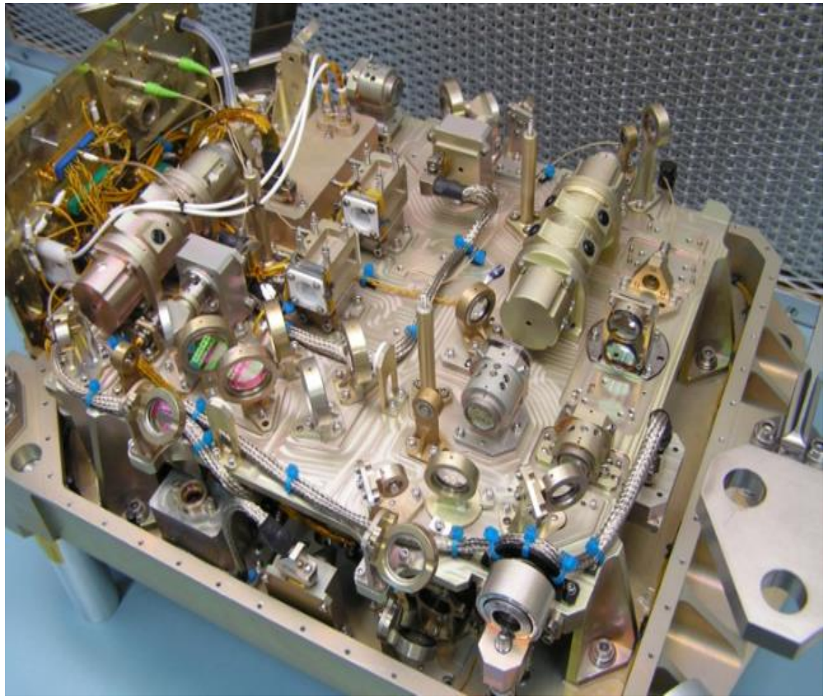
- Specifies requirements for the durability testing of coatings most commonly used for space applications, i.e.:

Thin film optical coatings, Thermo-optical and thermal control coatings (the majority are paints, metallic deposits and coatings for stray light reduction), Metallic coatings for other applications (RF, electrical, corrosion protection)

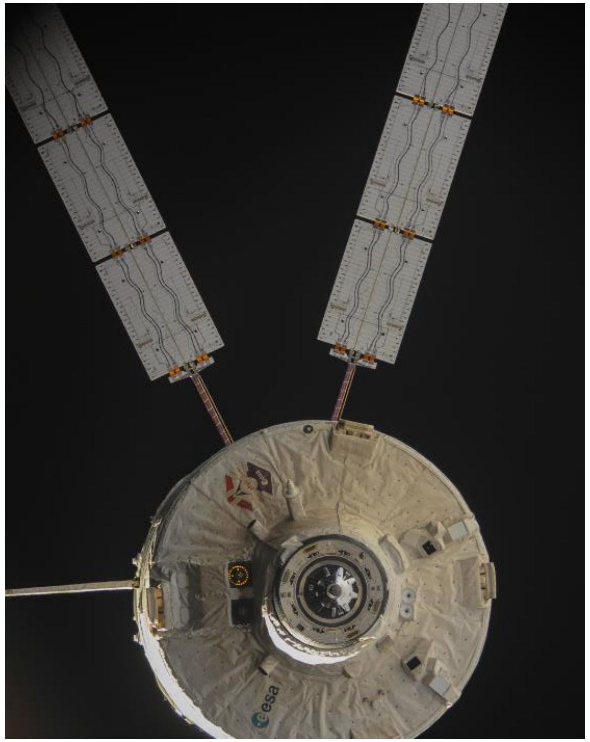
- Specifies the types of test to be performed for each class of coating, covering the different phases of a space project (evaluation, qualification and acceptance)

- Not applicable for Solar cell cover glass coatings or Surface treatments and conformal coatings applied on EEE parts

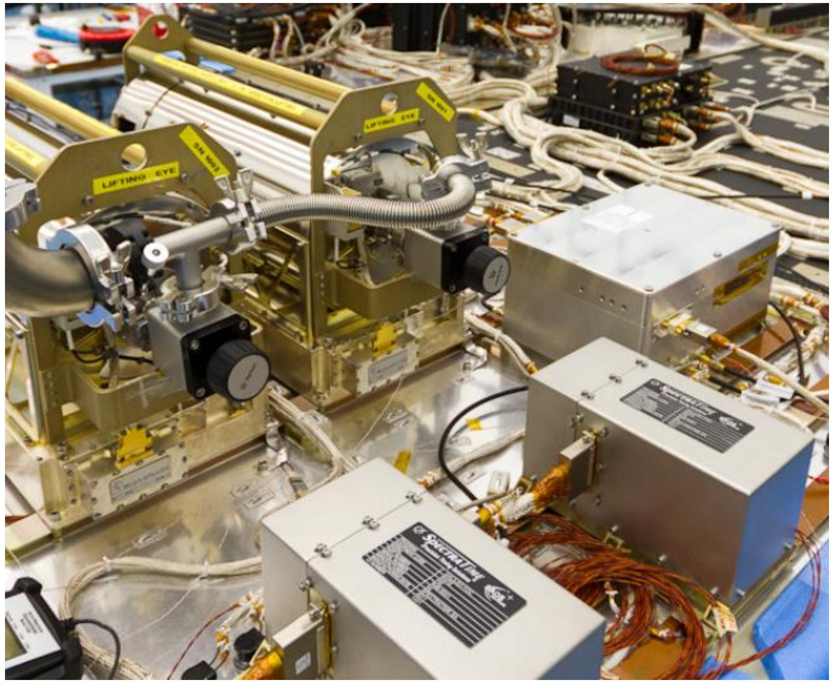
ECSS-Q-ST-70-17C : Coating durability



Optical thin film coatings

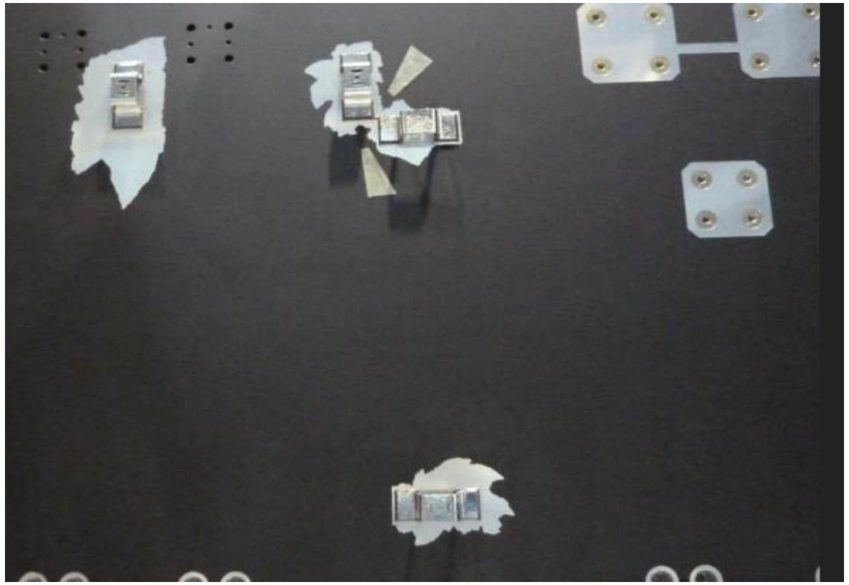


Thermo-optical coatings

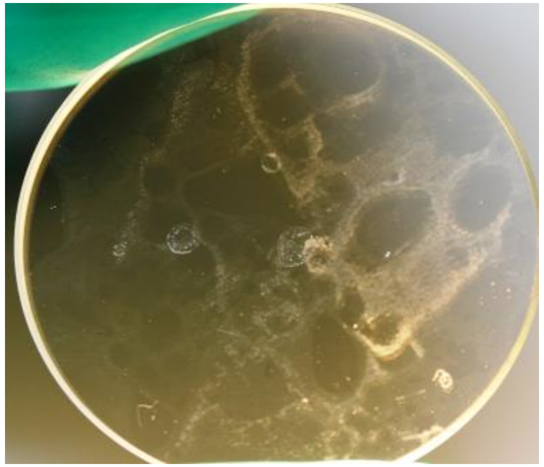


Other metallic coatings

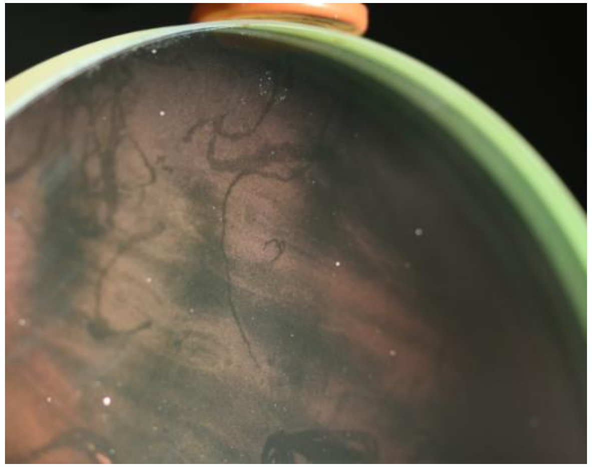
ECSS-Q-ST-70-17C : Coating durability



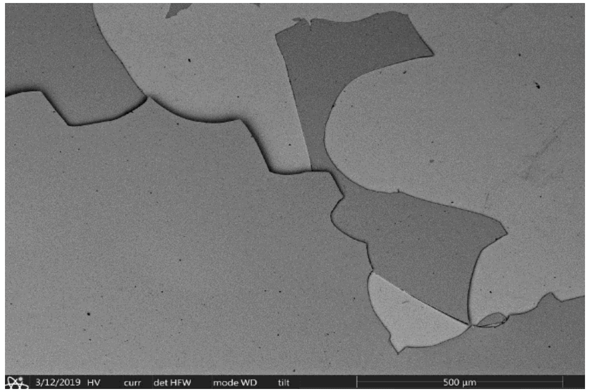
Paint delamination

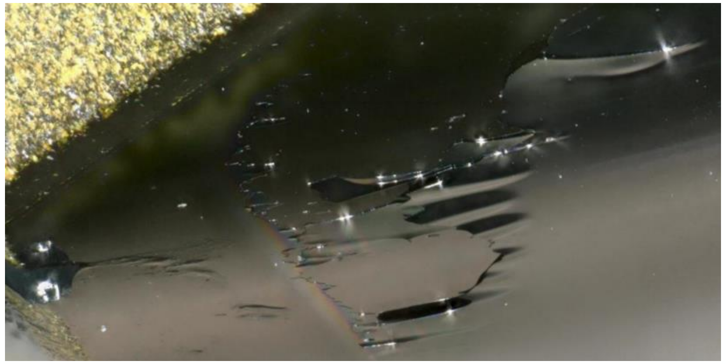


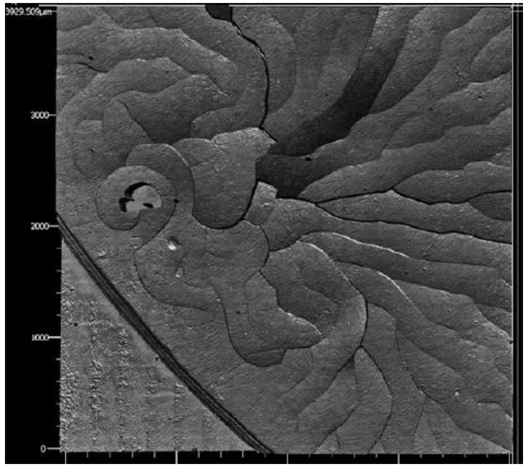
Humidity effects



Contamination



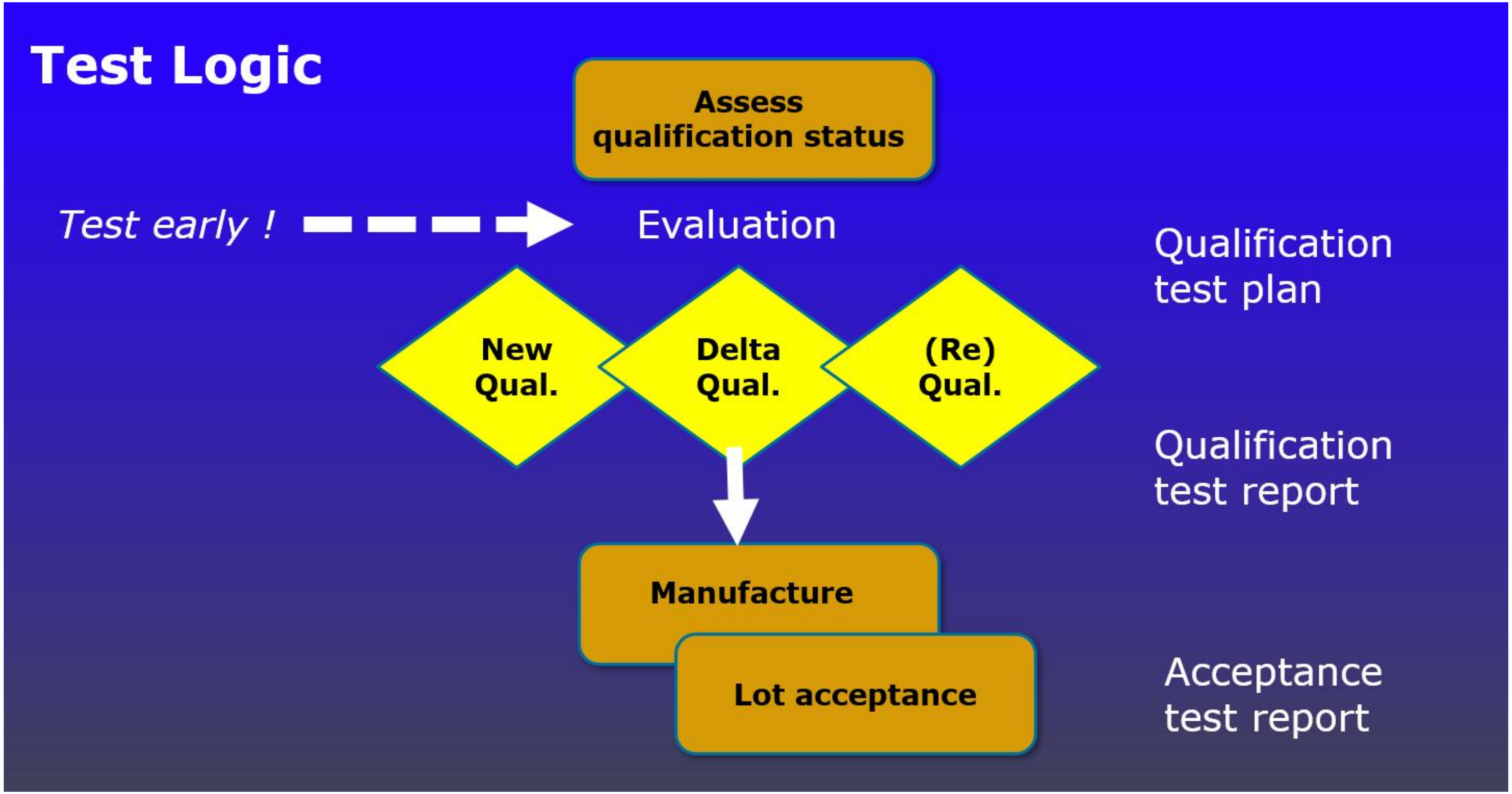




Delamination

Typical coating problems

ECSS-Q-ST-70-17C : Coating durability

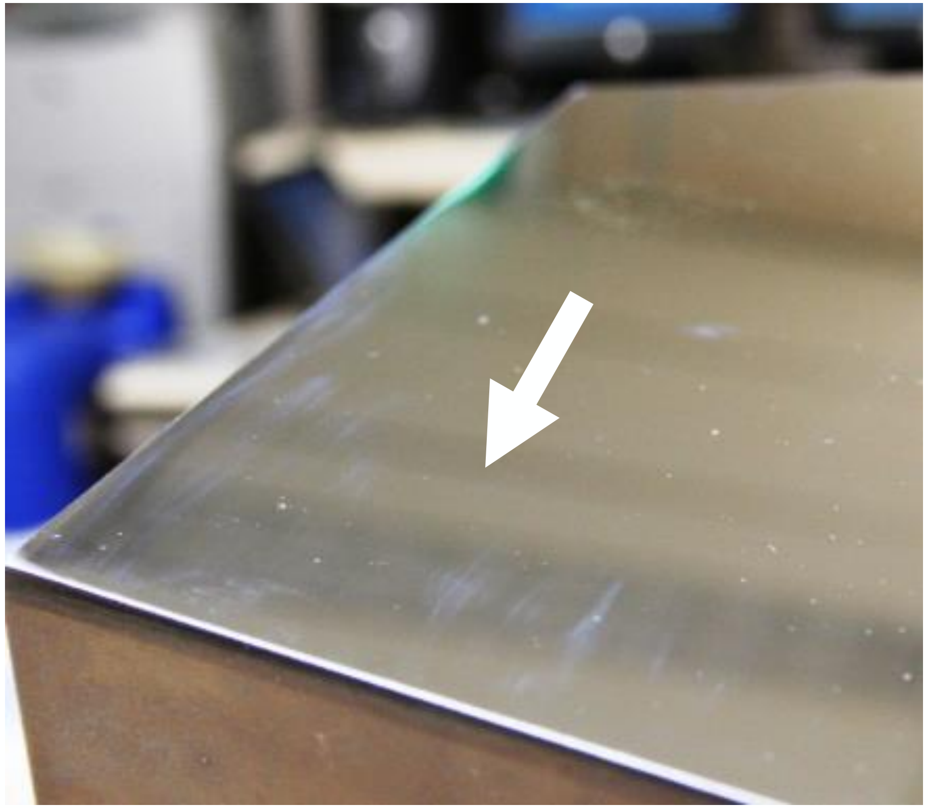


ECSS-Q-ST-70-17C : Coating durability

Table 5-1:Test matrix for qualification of optical coatings

Test	Method description	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Sample 6
Performance		1, 5	1, 3	1, 3	1, 5	1, 5	1
Adhesion	Clause 6.2	6	4	4	6	6	
Cleanability	Clause 6.5	2					
Moderate abrasion	Clause 6.6	3					
Humidity	Clause 6.3	4			2	2	
Thermal vacuum and cycling	Clause 6.4		2		3	3	
Particle and UV Radiation	Clause 6.7			2	4	4	
Additional tests	in accordance with requirement 5.2i						

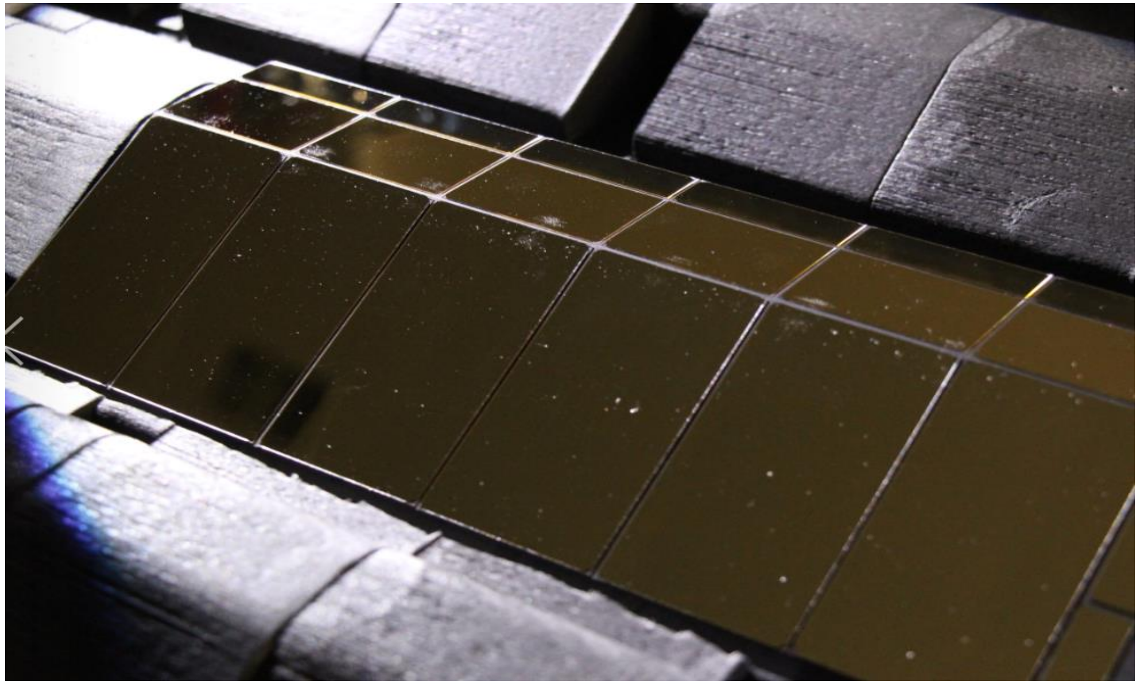
ECSS-Q-ST-70-17C : Coating durability



Controlled illumination conditions are critical for visual inspection of optical coatings

ECSS-Q-ST-70-17C : Coating durability

Standard room lighting



Dark room, single light source

Controlled illumination conditions are critical for visual inspection of optical coatings

ECSS-Q-ST-70-17C : Coating durability

TAKE-HOME REQUIREMENTS

- A minimum of 25 thermal cycles shall be performed, with at least the first five cycles performed under vacuum.
- Samples shall be cleaned and inspected before and after each test step to verify that the defects are in conformance with the coating specification.
- In the context of this standard, the humidity test is a quality control test to check mechanical resistance, and stress in the coating
- The adhesion test shall be selected according to the coating and substrate thickness.

For recurrent production, the customer can organize a regular material and process review (e.g. every 3 years) to confirm that no modification of the process or process application has been implemented or if implemented, that the changes have no impact on the qualification status.

ECSS-Q-ST-70-17C : Coating durability

Common topics for discussion :

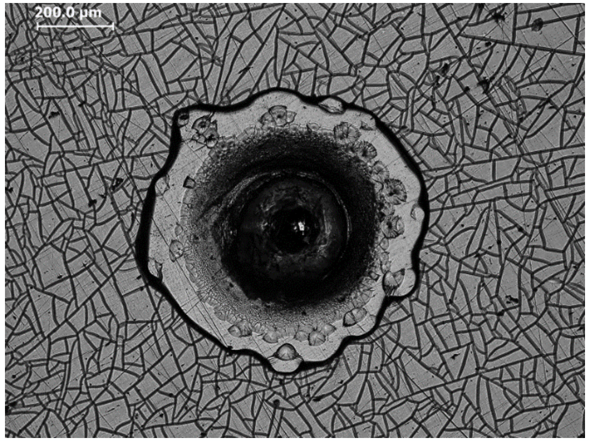
-How many samples to test

-Can we rely on heritage data for the radiation test

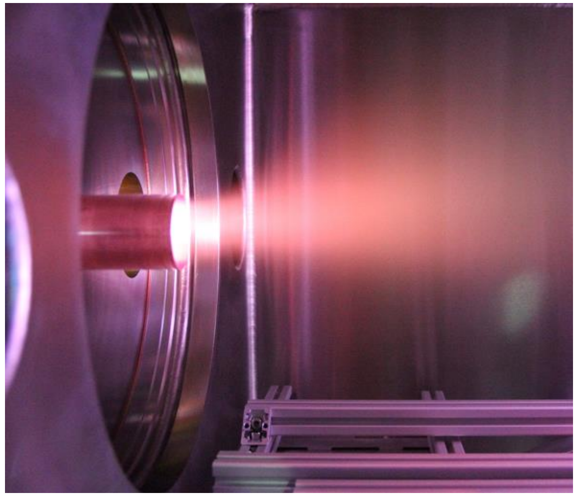
-Why do we need to perform a humidity test if the samples will always be kept in a purged system / in the cleanroom ?

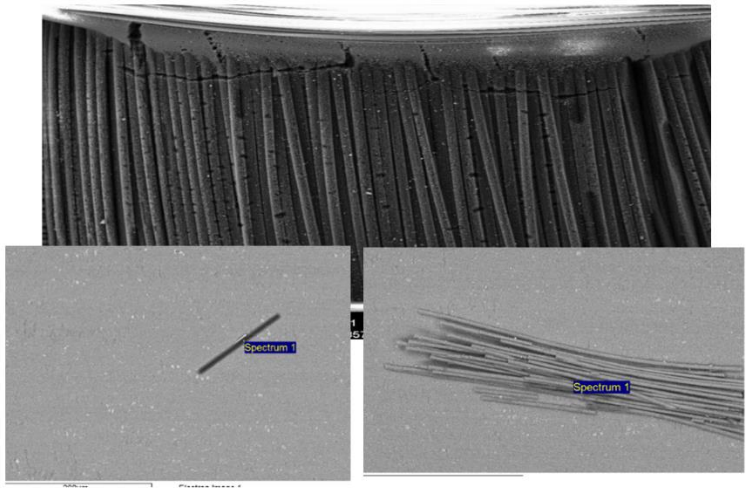
- Should we perform a tape test on flight hardware ?

Some other topics, not (yet) standardized



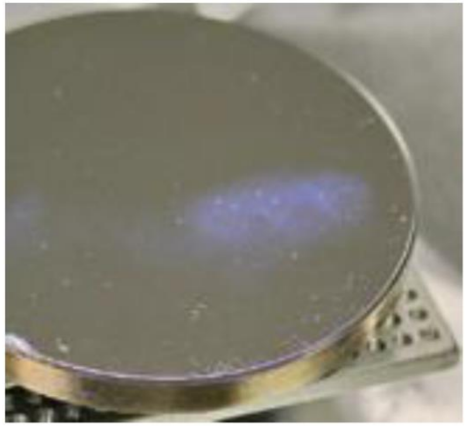
Space debris impacts

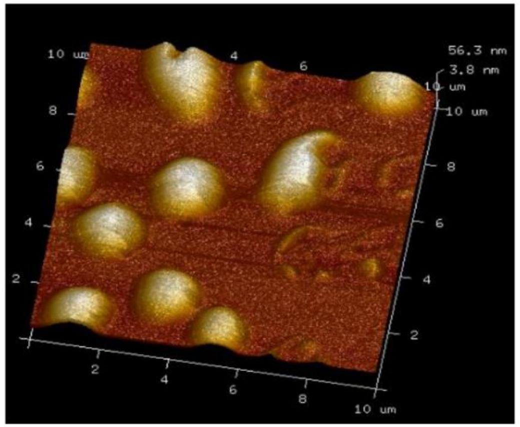




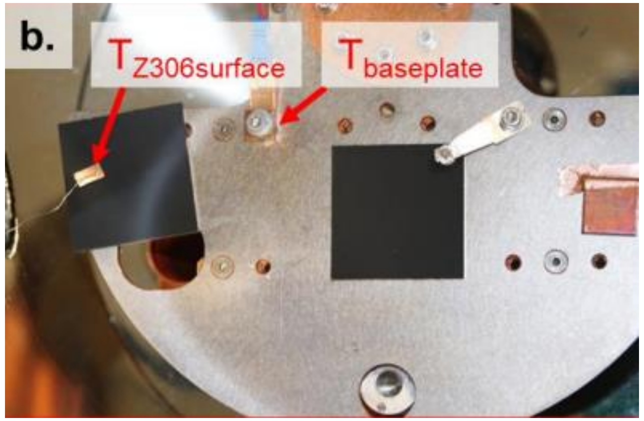
Atomic oxygen testing

Sun illumination testing





Radiation testing of coatings



ESD testing

Under development : ESA Dust Handbook

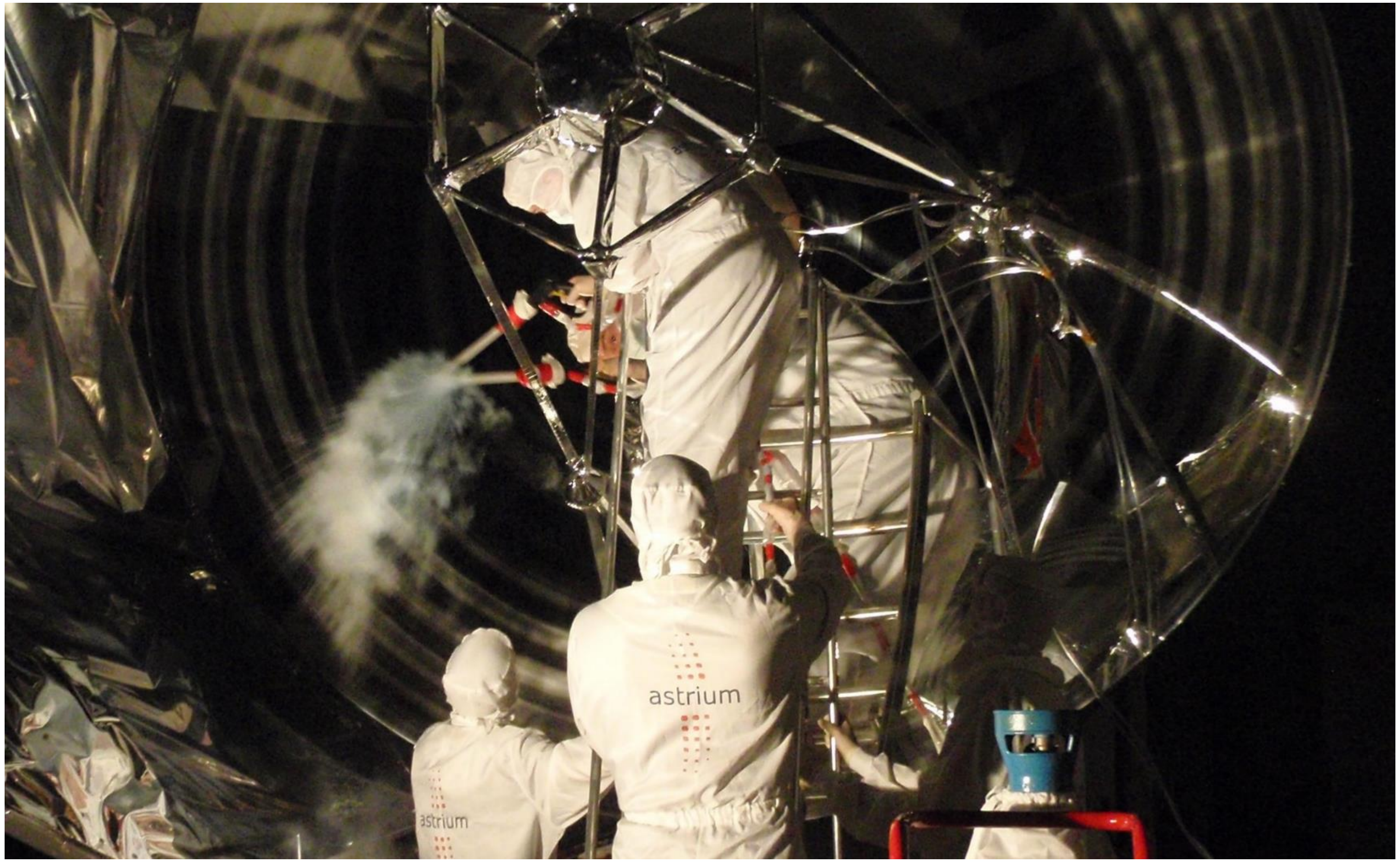
- The aim is to develop a handbook which will provide the European space community with background information, advice and guidelines on how to deal with the challenges related to dust contamination originating primarily from the surface of the Moon and Mars

- Will meet the needs of on-going and future Science and Exploration projects (Lunar and Martian landers, Lunar Gateway) and associated technology development activities

- Will utilize lessons learnt from previous projects, published literature and historical documentation from the Apollo era

“One of the most aggravating, restricting facets of lunar surface exploration is the dust and its adherence to everything no matter what kind of material, whether it be skin, suit material, metal, no matter what it be and it’s restrictive friction-like action to everything it gets on” : Eugene Cernan, commander of Apollo 17

For tomorrow….




ECSS-Q-ST-70-01C
15 November 2008

EUROPEAN COOPERATION
ECSS
FOR SPACE STANDARDIZATION

Space product assurance

Cleanliness and contamination control

ECSS Secretariat
ESA-ESTEC
Requirements & Standards Division
Noordwijk, The Netherlands

ECSS standards : Cleanliness and Contamination

Cleanliness & contamination control	
General overview standard	ECSS-Q-ST-70-01C

Currently under major revision – watch out for the public review !

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	

Associated ISO standards

- **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.

ECSS-Q-ST-70-01C : Cleanliness and Contamination

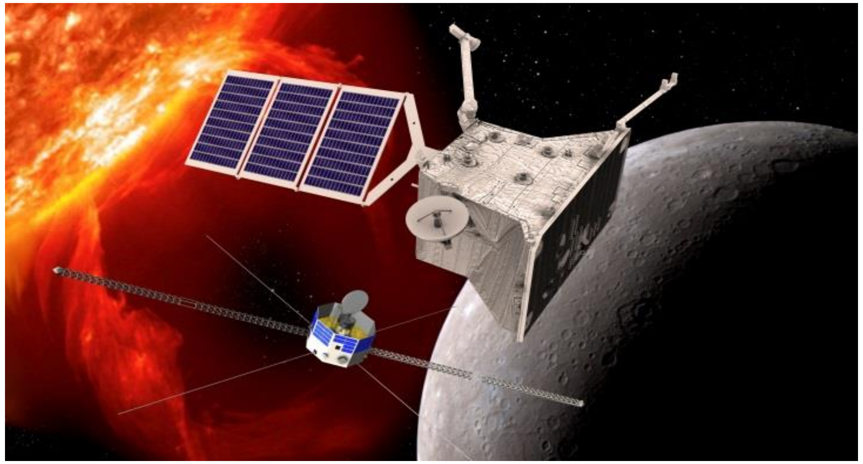
- The purpose of this standard is to define:
    - The selection of critical items, the definition of cleanliness requirements to satisfy the mission performance requirements and control the levels to be met by personnel, items, facilities and operations of space projects.
    - The management, including 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.

ECSS-Q-ST-70-01C : Cleanliness and Contamination

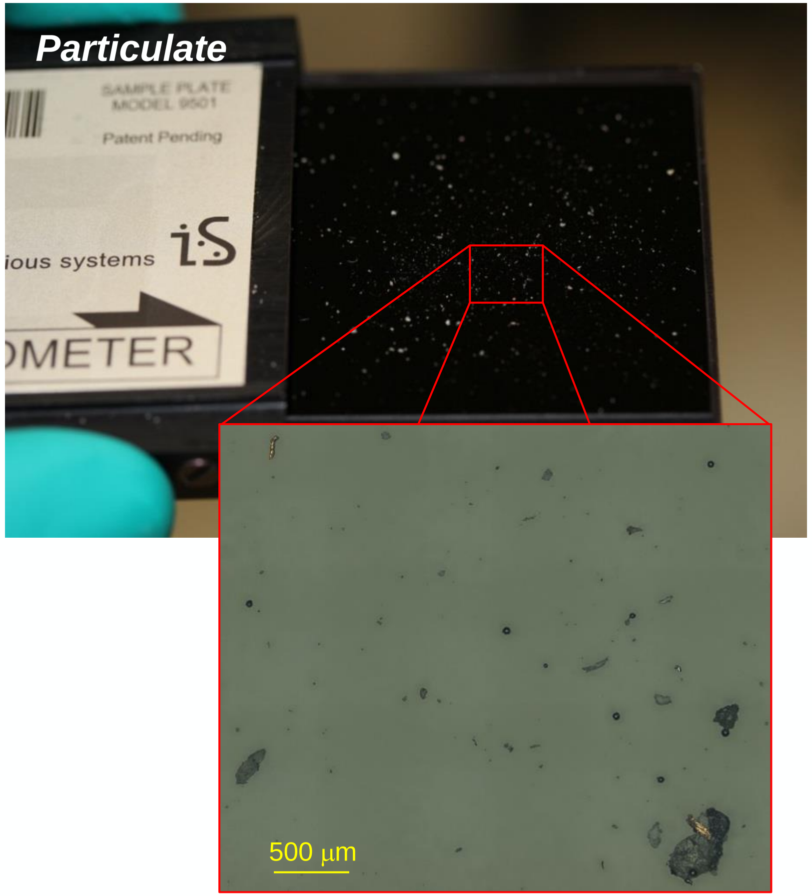
The scope covers :

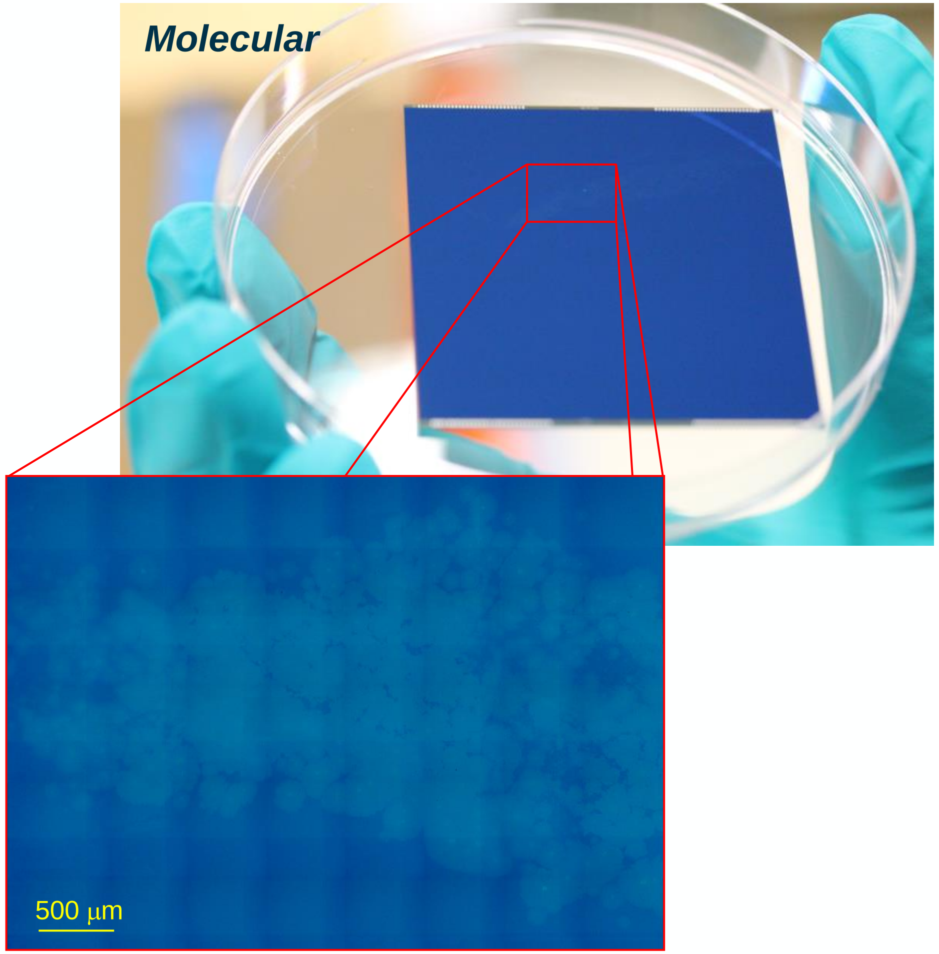
- Contamination control programme
- Specifications
- Design, AIT, pre-launch/mission
- Monitoring and testing techniques
- Cleanrooms
- Cleaning techniques
- Vacuum facilities and other ground activities



ECSS-Q-ST-70-01C : Cleanliness and Contamination

Types of contamination



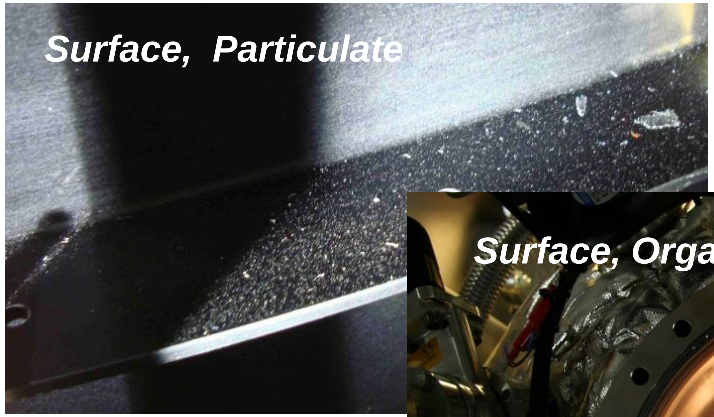


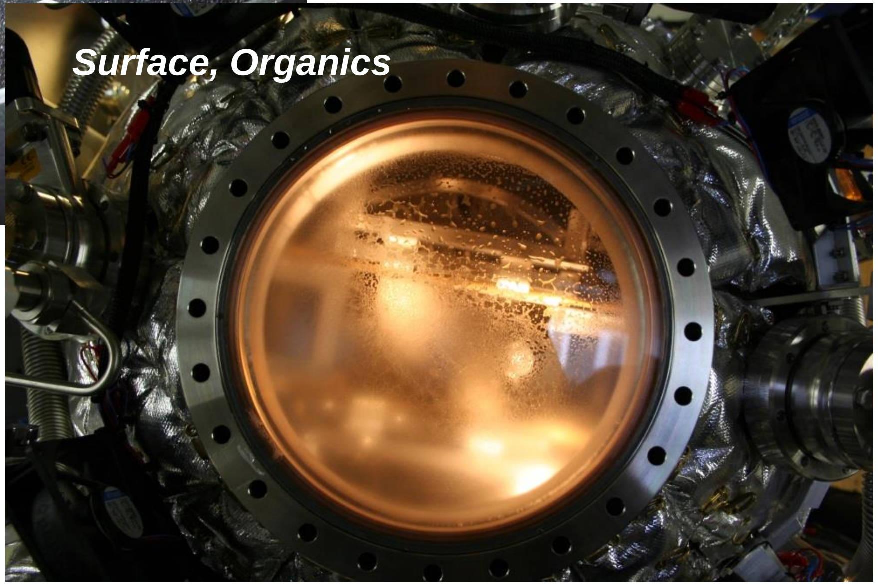
Particulate contamination refers to the deposition of visible - µm sized -conglomerations of matter

Molecular contamination refers to the cumulative buildup of individual molecules of foreign matter

ECSS-Q-ST-70-01C : Cleanliness and Contamination

Types of contamination





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:

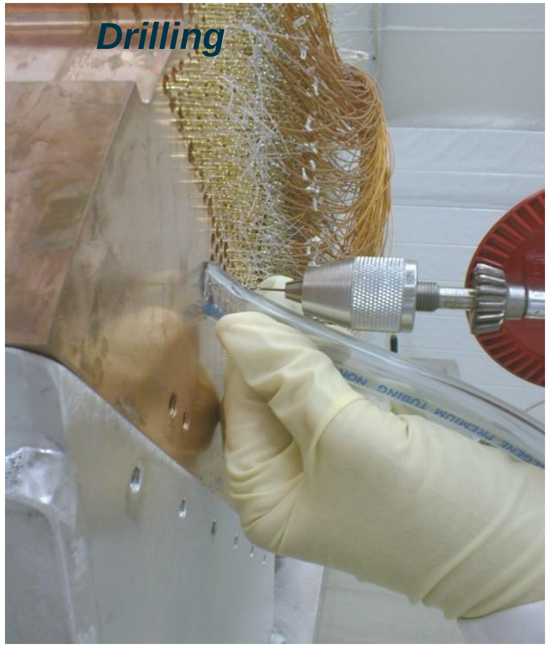
- accumulated deposit of particulate matter on a surface
- presence of chemical substances in the sorbed state

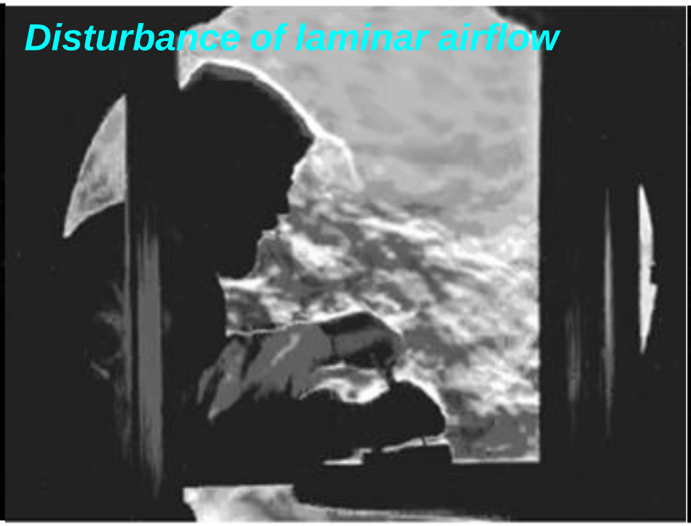
ECSS-Q-ST-70-01C : Cleanliness and Contamination

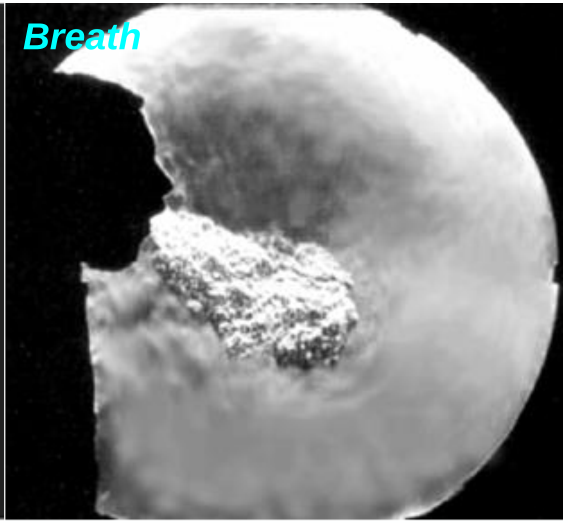
Contamination sources

- Humans, sneeze, breath, contact, clothing, skin, hair, bacteria,
- Machining, particles, cooling fluid,
- Working activities, soldering, integration, cleaning
- Vacuum testing, outgassing
- Vibration/shock testing,
- Thrusters, pyro-bolts/valves, wire cutters

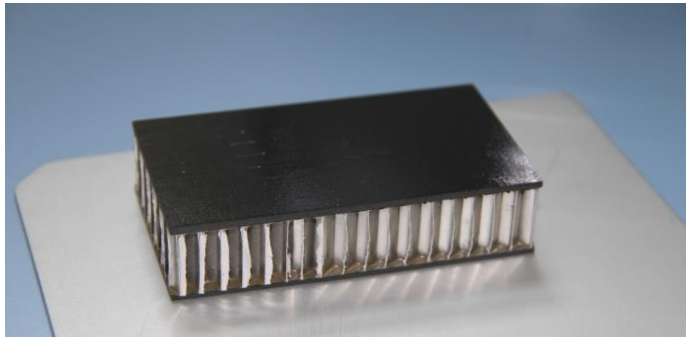
Gluing

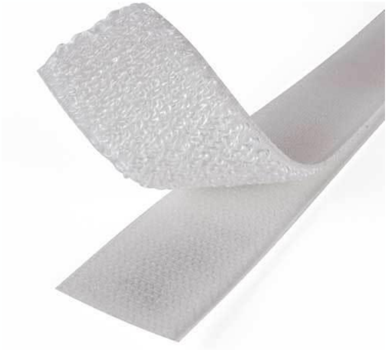
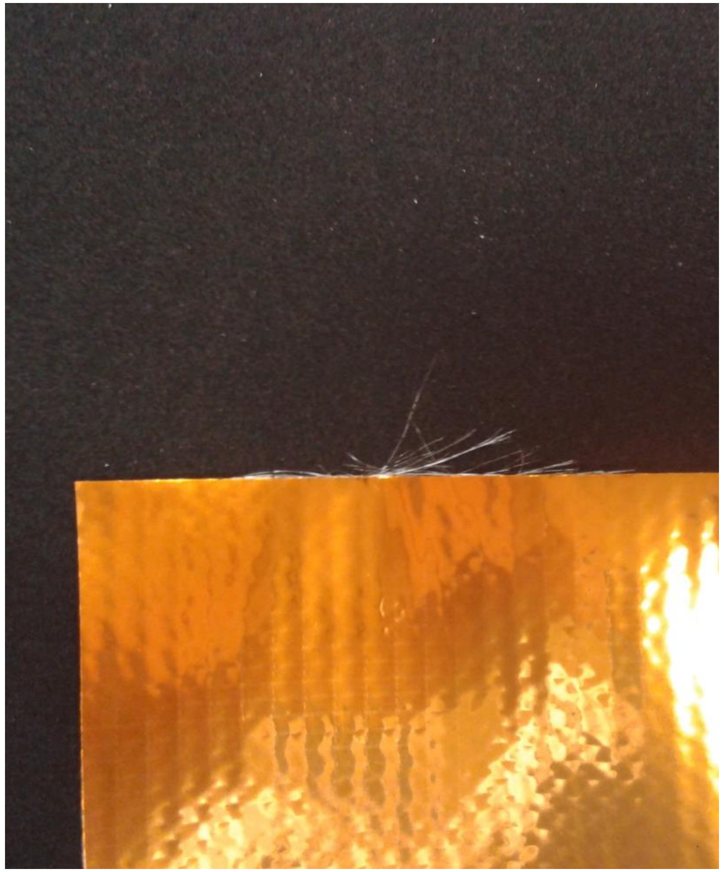
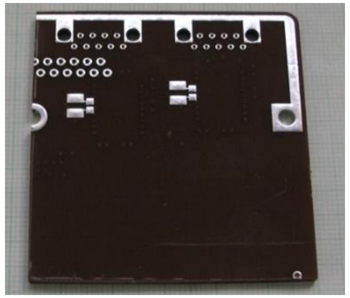






ECSS-Q-ST-70-01C : Cleanliness and Contamination



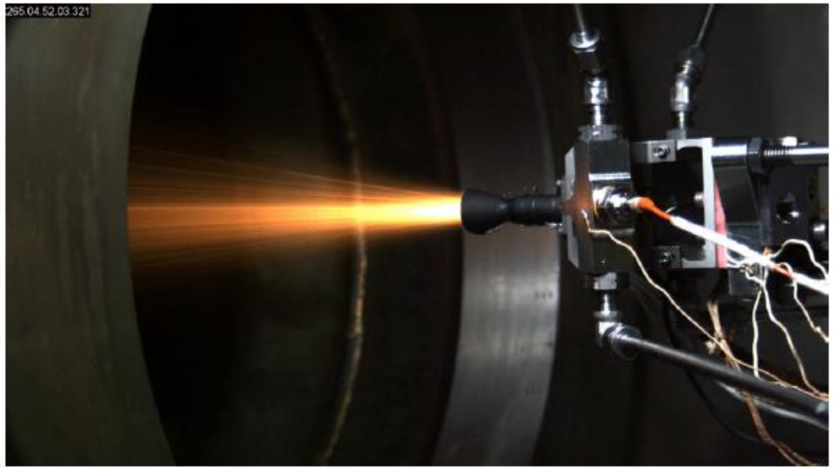




Materials may become:
- sources of offgassing and outgassing
- brittle (when exposed to detrimental environments)
- a contamination source if processed incorrectly

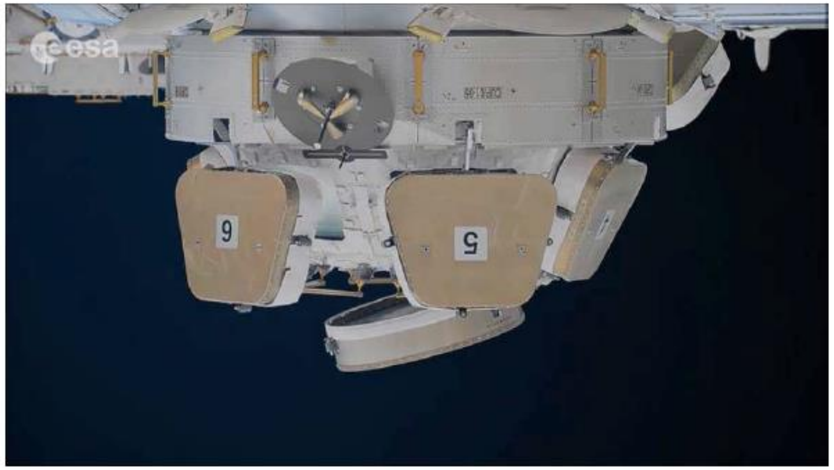
Contamination sources

ECSS-Q-ST-70-01C : Cleanliness and Contamination

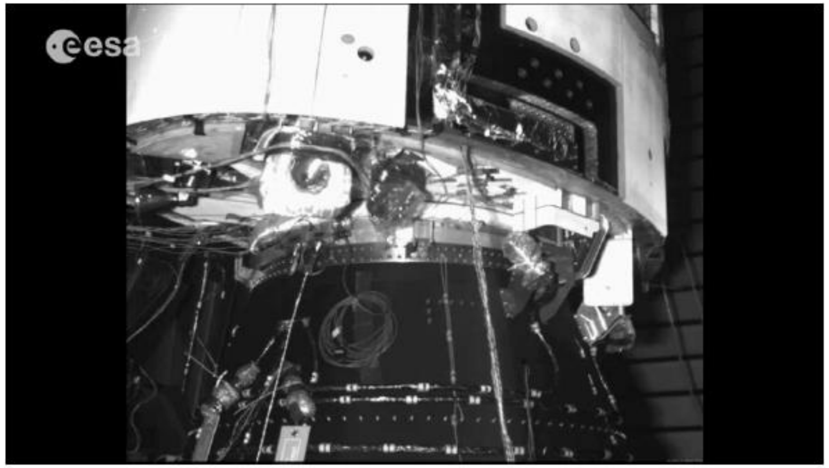
Propulsion systems

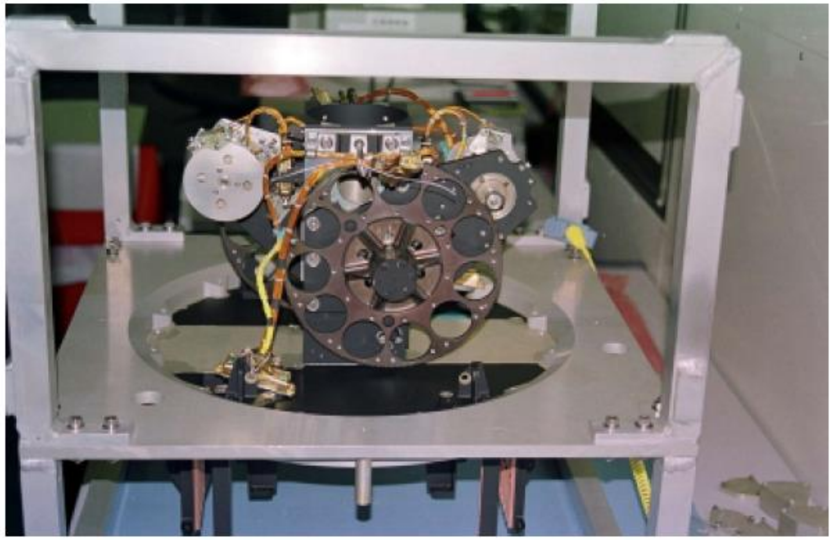


Mechanisms



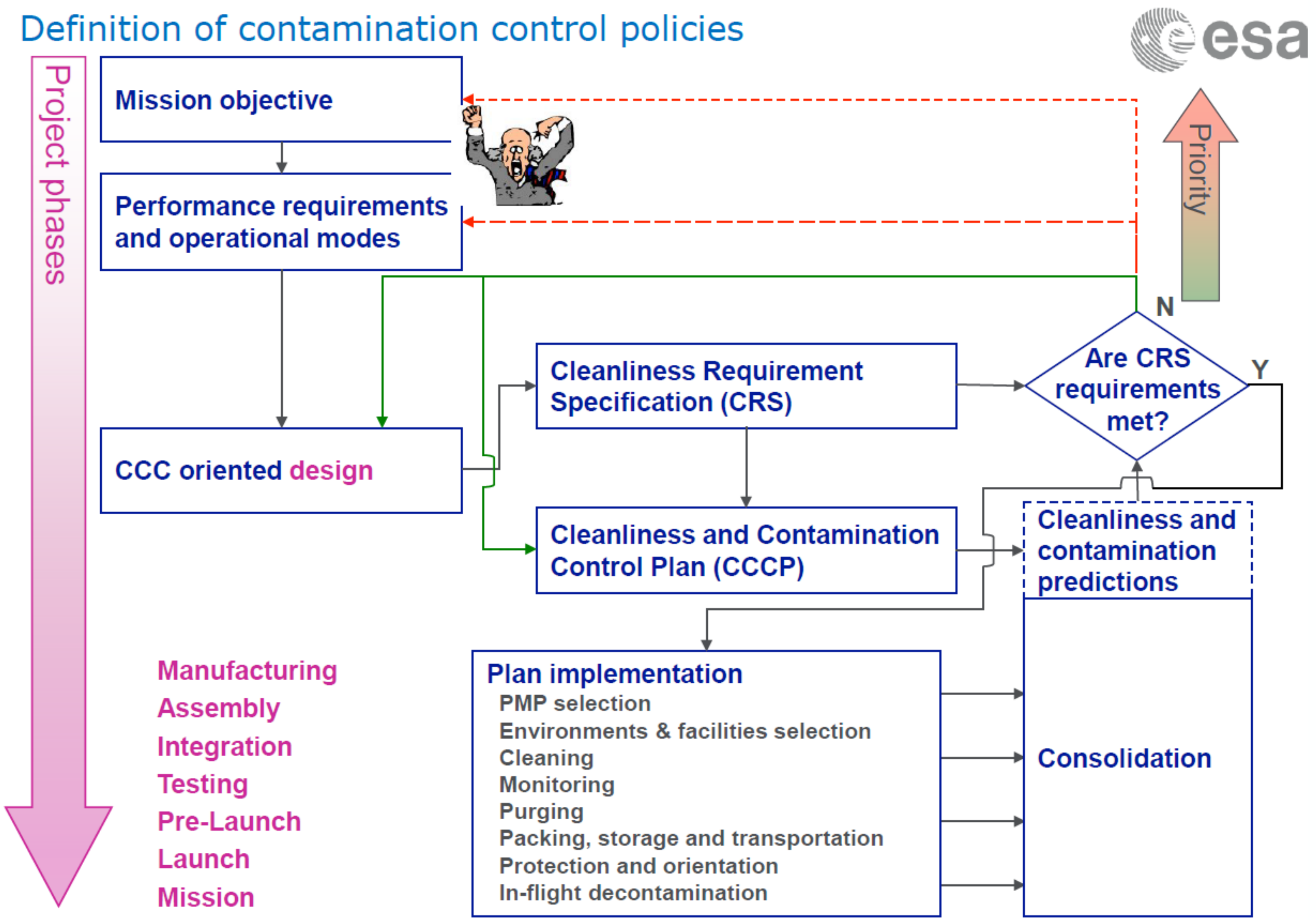
Separations





Contamination sources

ECSS-Q-ST-70-01C : Cleanliness and Contamination



ECSS-Q-ST-70-01C : Cleanliness and Contamination

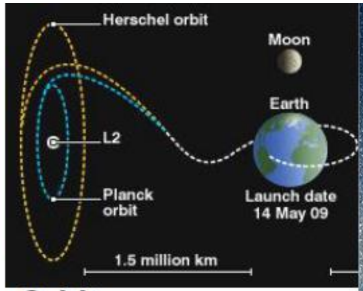
Mission objective

↓

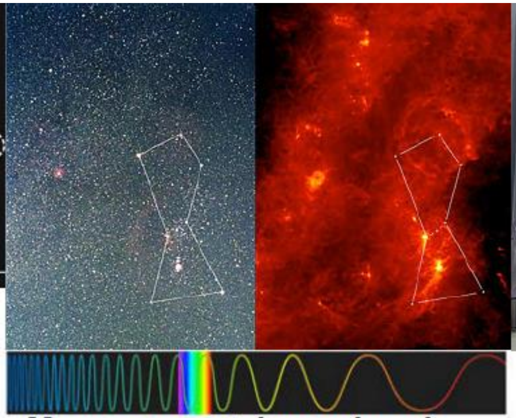
Performance requirements

↓ Performance-loss analyses, for each identified sensitivity*

Cleanliness requirements



Orbit



Measurements' wavebands

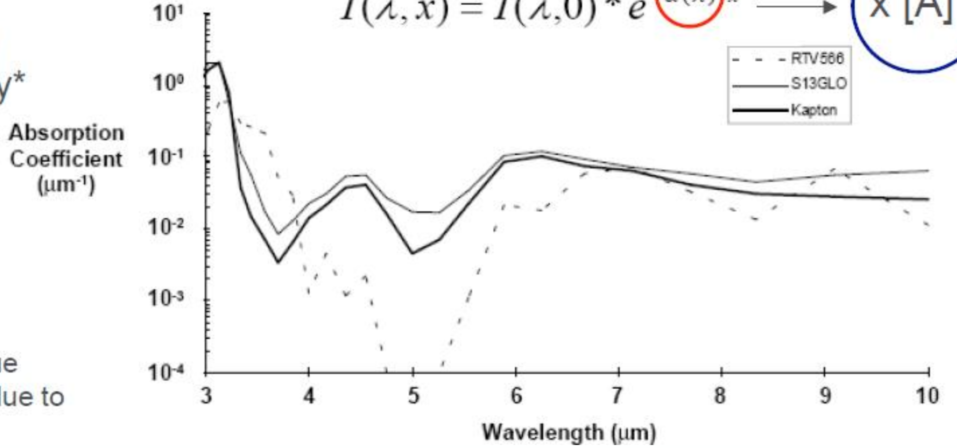
Kind of optic

Maximum tolerated performance loss $1-\frac{I}{I_0}$ [%]

Lambert-Beers law

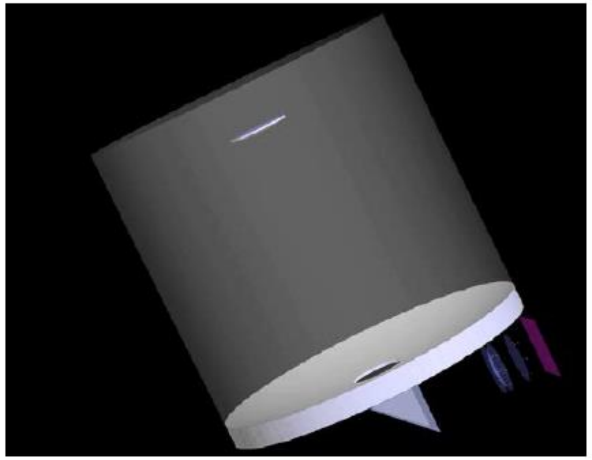
$$I(\lambda,x) = I(\lambda,0) * e^{-\alpha(\lambda)*x} \longrightarrow x\ [Å]$$

?

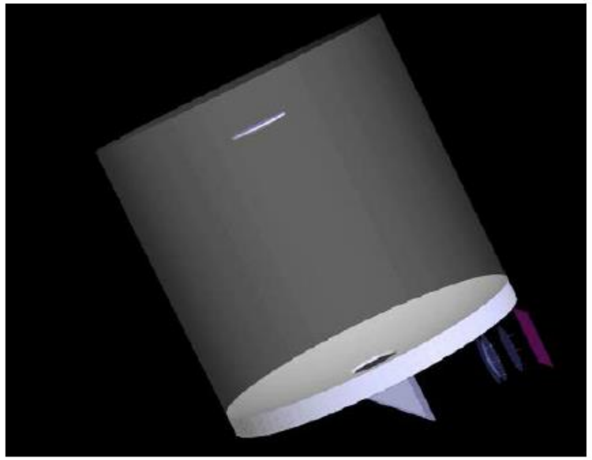


* This for instance can be transmission loss due deposited molecular layers or light scattering due to deposited particles

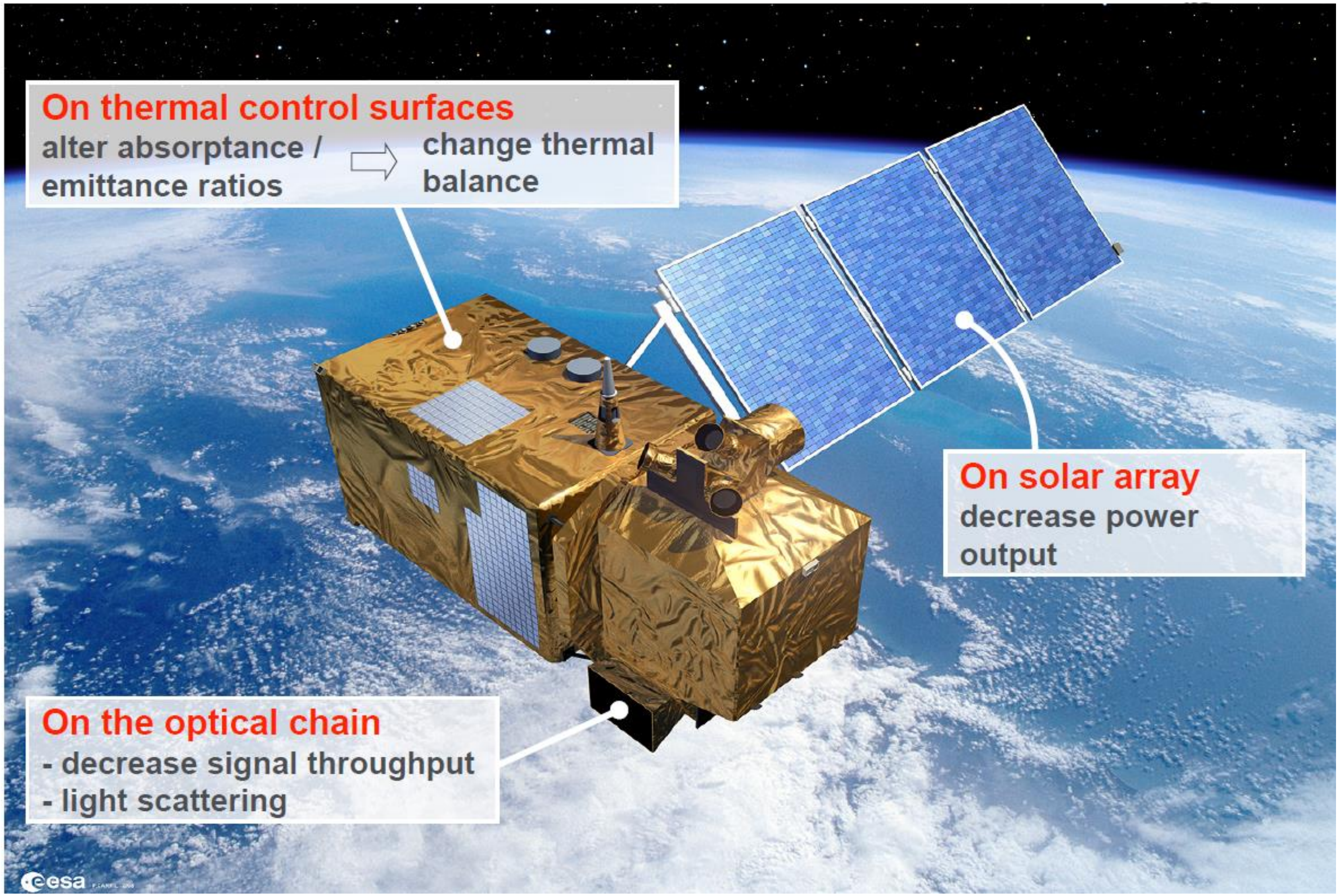
Theoretical model



Contaminated by Level 500

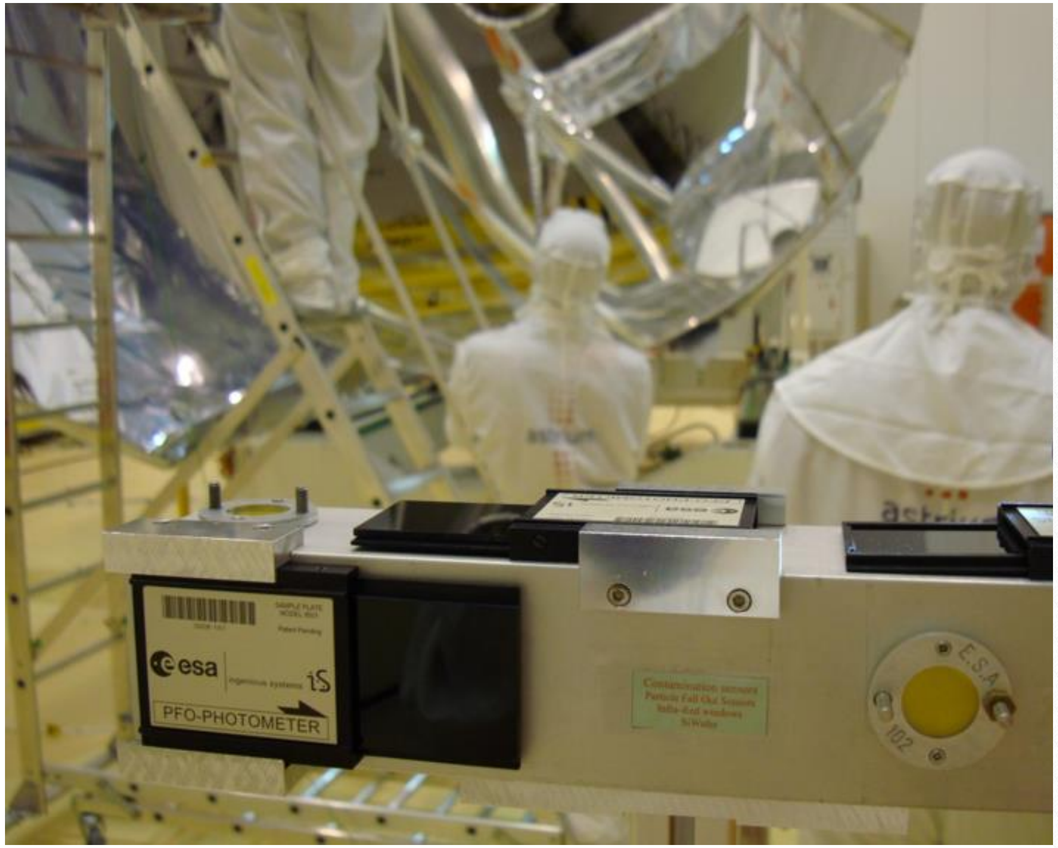


ECSS-Q-ST-70-01C : Cleanliness and Contamination



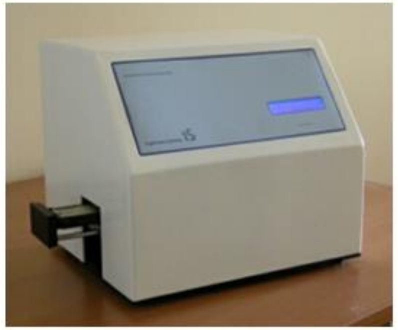
Contamination effects

ECSS-Q-ST-70-01C : Cleanliness and Contamination



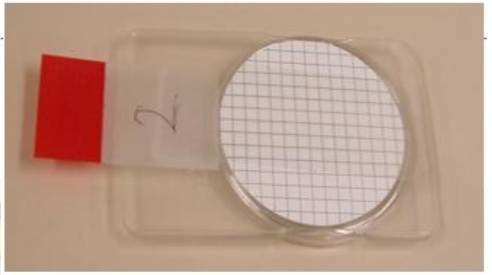
Methods typically defined in ECSS-Q-ST-70-50C [5]

PFO plate

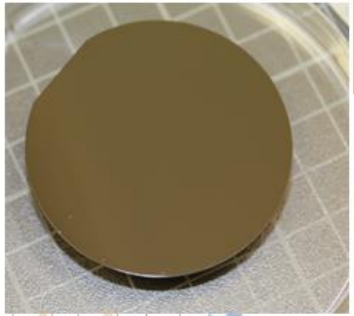


PFO meter

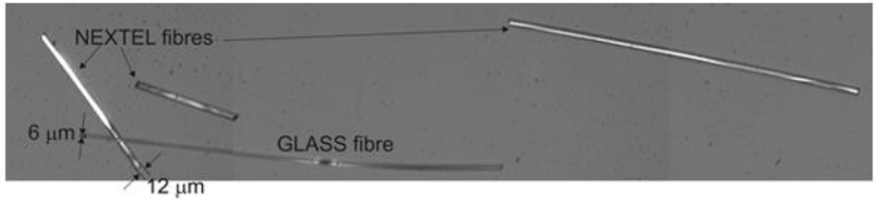
PFO →**Total obscuration**



Tape lift sample



Silicon wafer

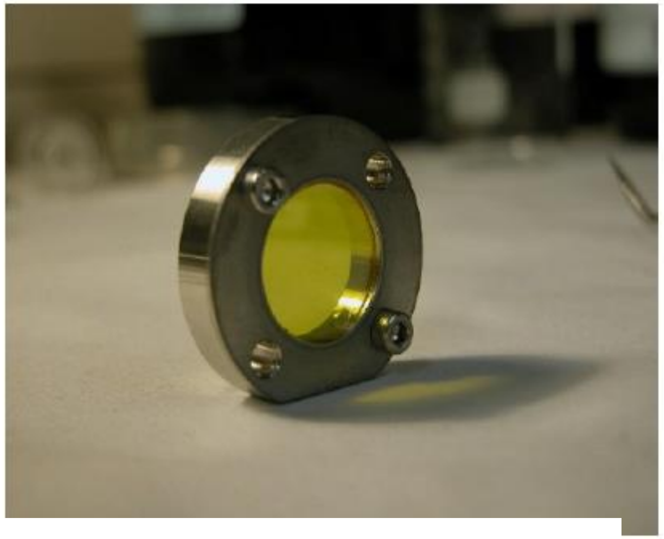


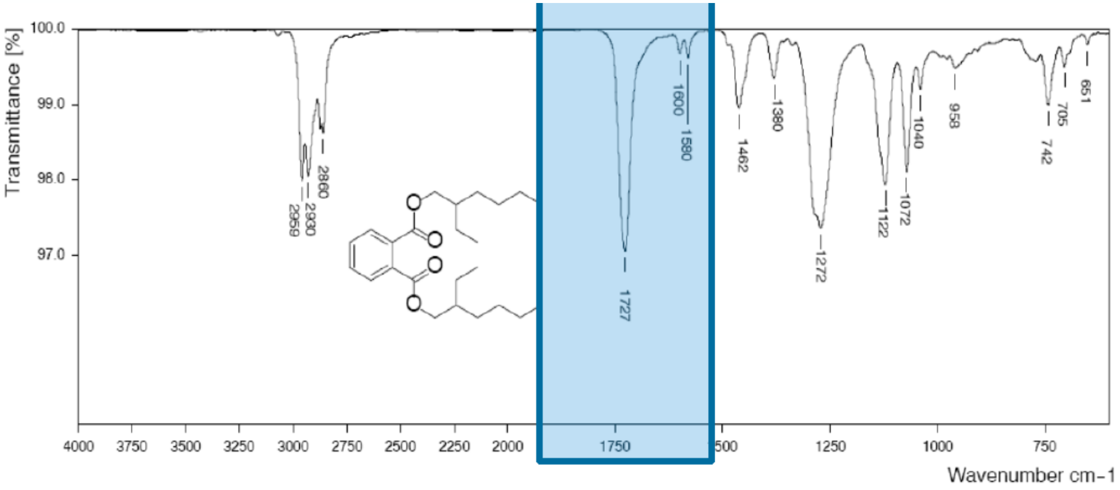
Tape lift & silicon wafers → Particle & fibre **distribution**

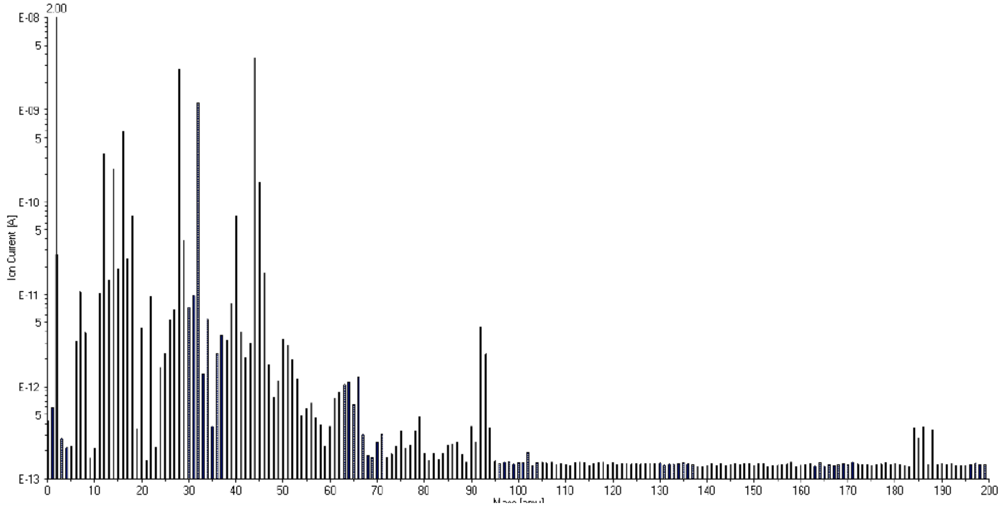
Monitoring – particulate

ECSS-Q-ST-70-01C : Cleanliness and Contamination

- FTIR – witness plates
- GC/MS (gas chromatography)
- Quartz crystal microbalance (QCM)
- Residual gas analysis (RGA)

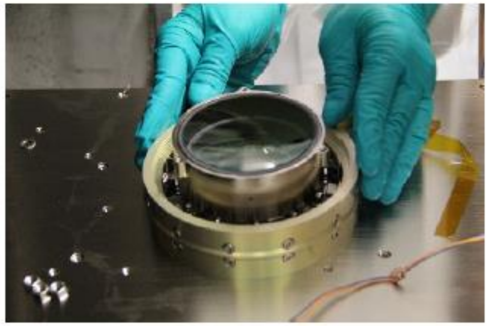


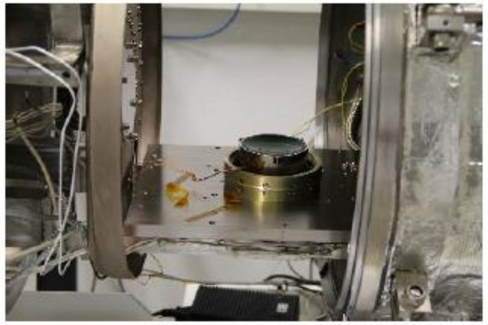


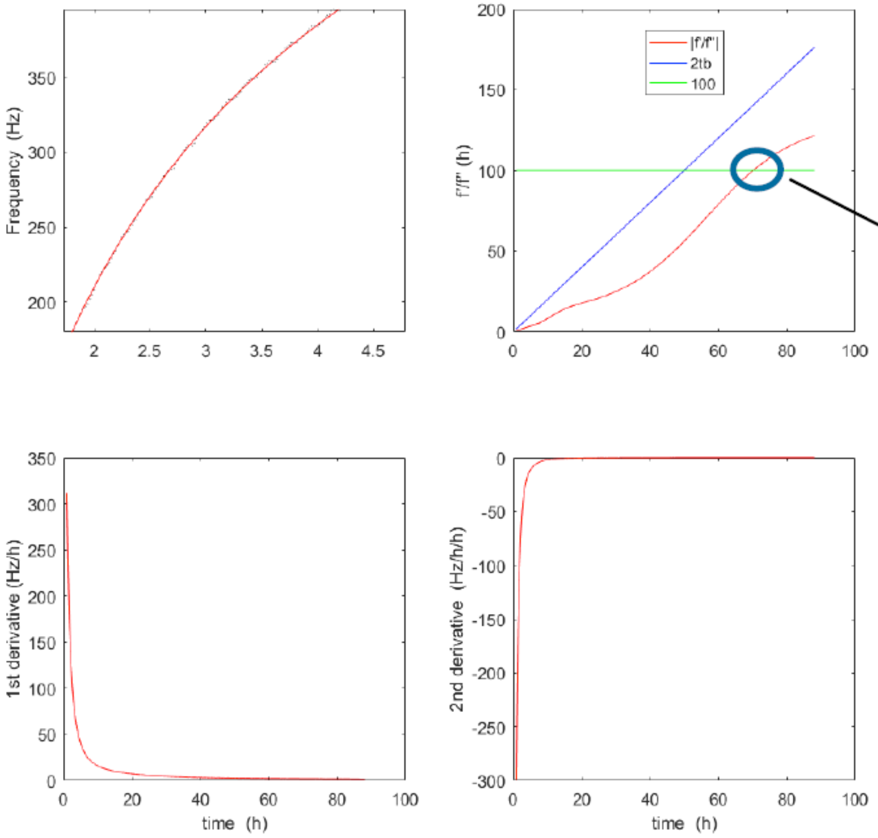


Monitoring - molecular

ECSS-Q-ST-70-01C : Cleanliness and Contamination



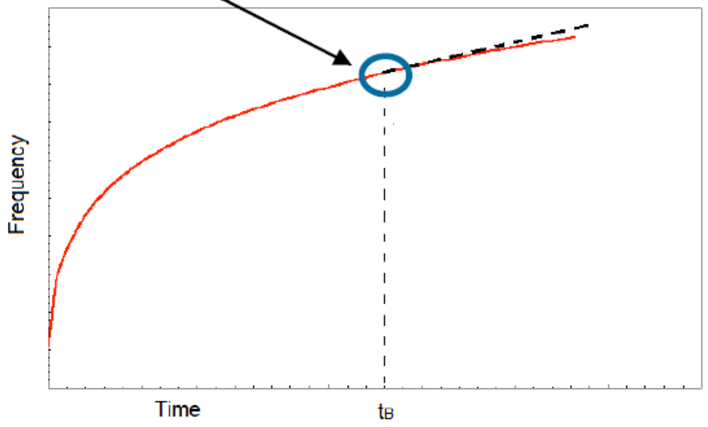




Deviation of linearity $\zeta' < 1\%/h$

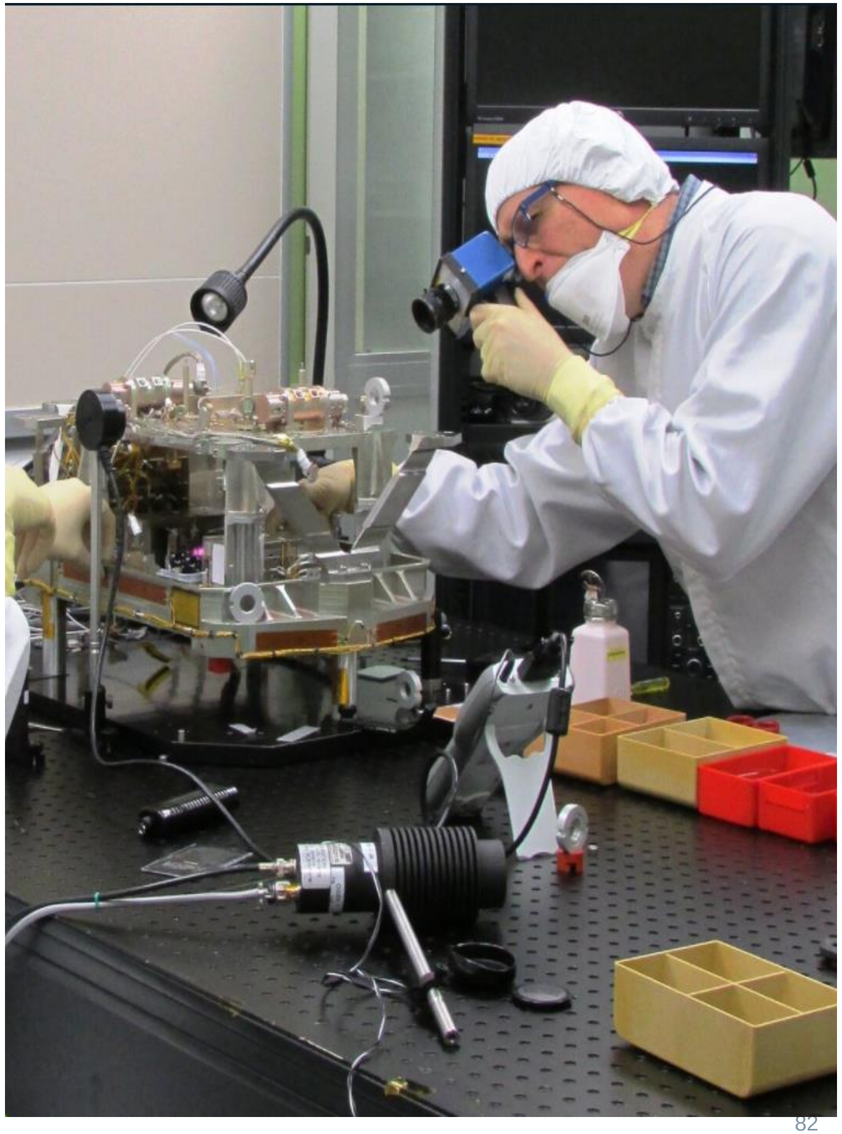
- Equivalent to $\tau_{app} > 100$ h
- Minimum bake-out time of 48 h required

(only residence times ~< 2*bake-out time can be reliably fitted)



Bake-out

ECSS-Q-ST-70-01C : Cleanliness and Contamination

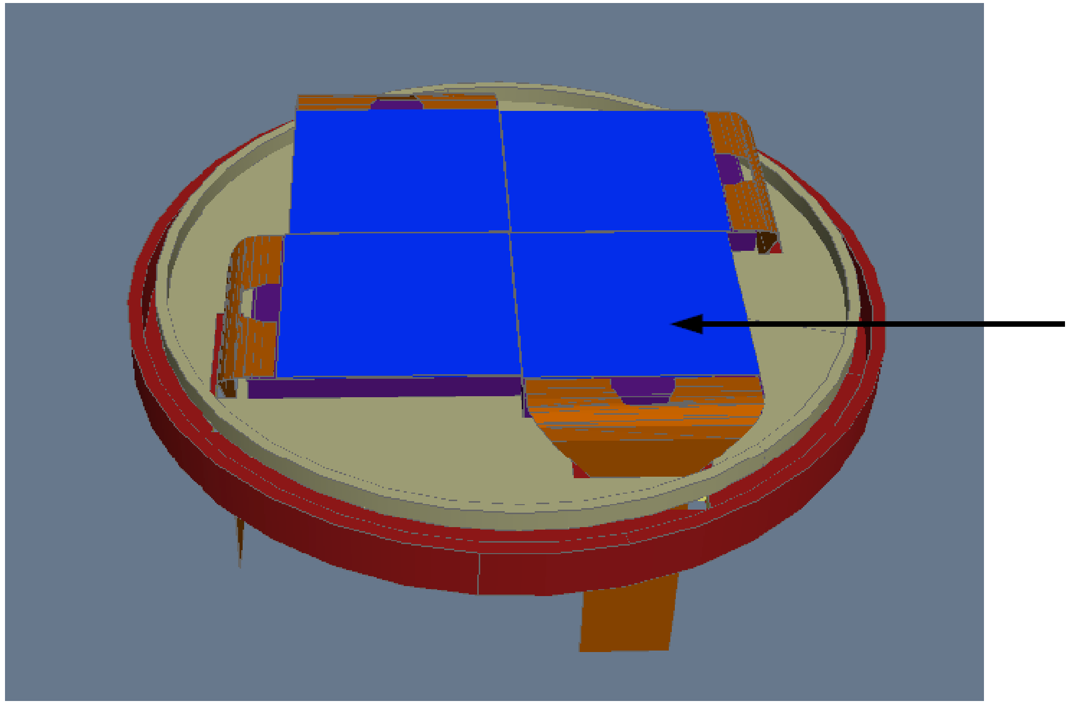


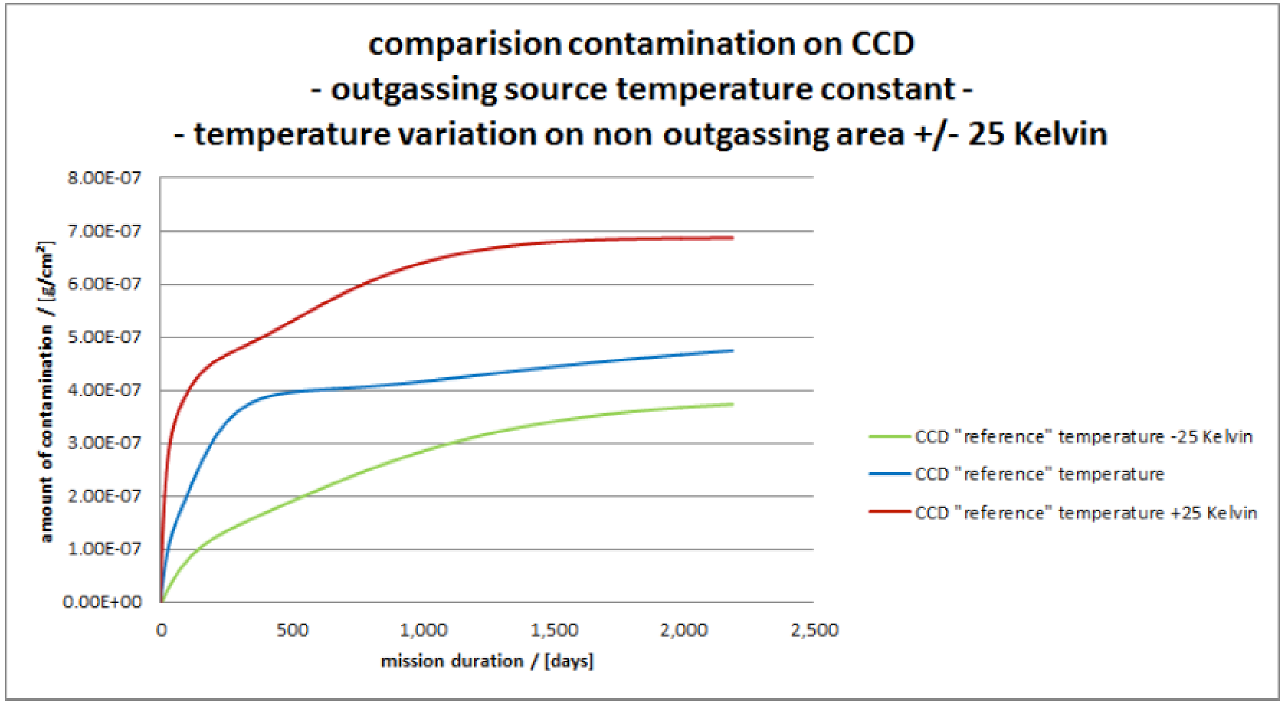
Inspection and cleaning

ECSS-Q-ST-70-01C : Cleanliness and Contamination

Inspection and cleaning

ECSS-Q-ST-70-01C : Cleanliness and Contamination





In-orbit simulation

ECSS-Q-ST-70-01C : Cleanliness and Contamination

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

ECSS-Q-ST-70-01C : Cleanliness and Contamination

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

Questions ?

THANK YOU FOR YOUR ATTENTION

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ECSS European Cooperation for Space Standardization