Venting path efficiency

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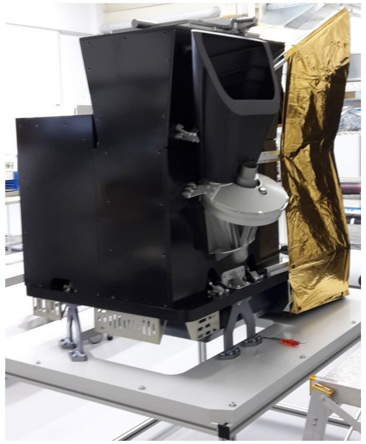
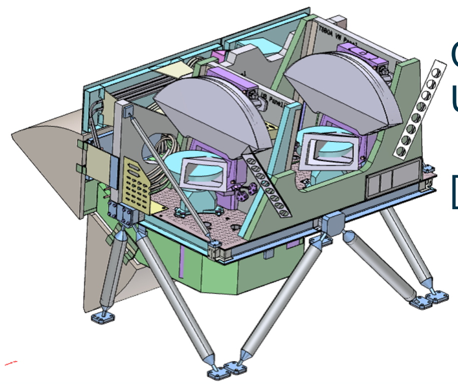
Background

esa

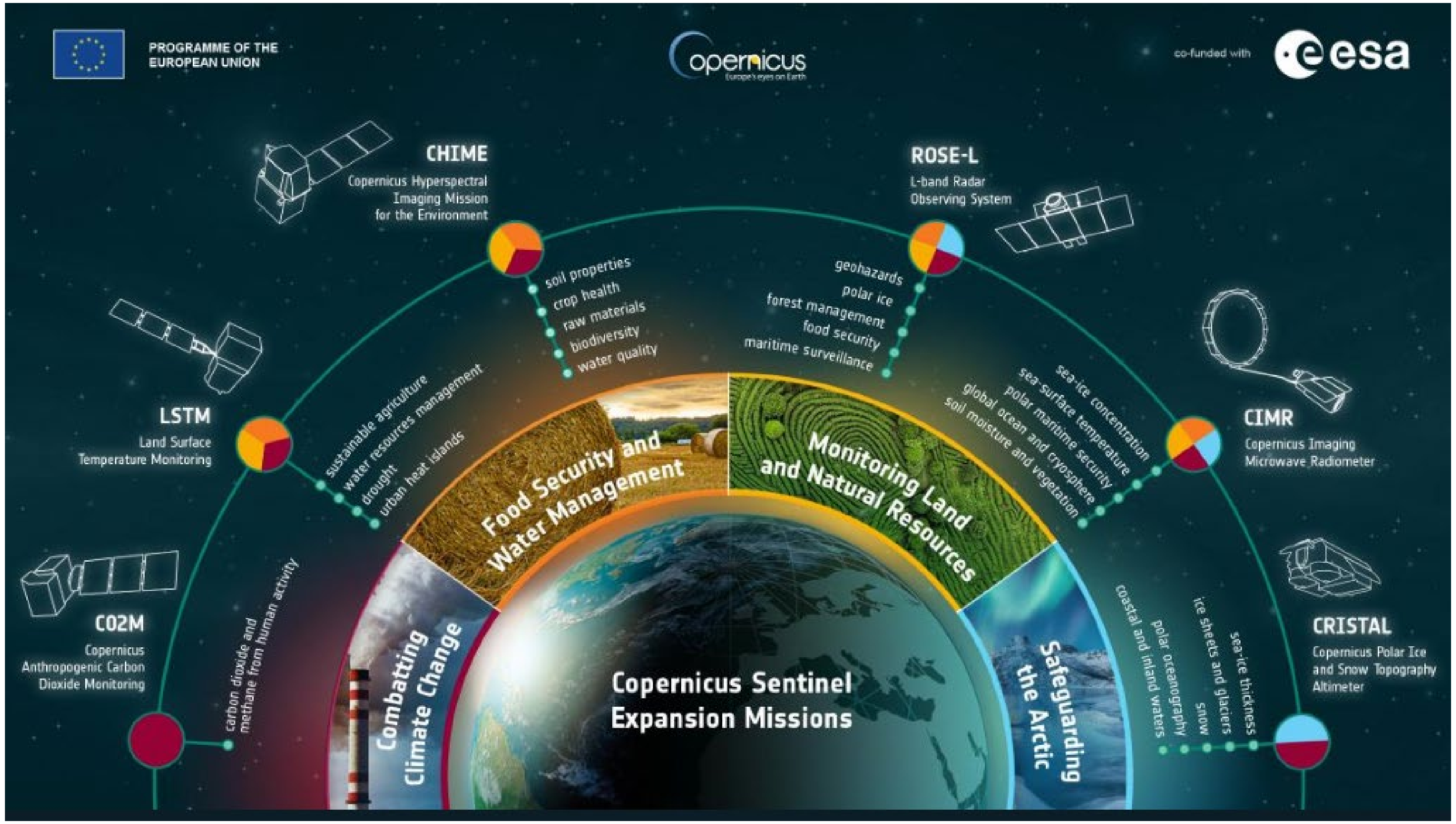
Instruments sensitive to contamination



Copernicus Sentinel 4 - UVN:
Mock-up of the Optical Module (OIM) unit
[image credit: ESA]



Copernicus Sentinel 5 - UVNS
 Instrument
[image credit: ESA]



[image credit: ESA]

→ **Stringent Cleanliness Requirements**

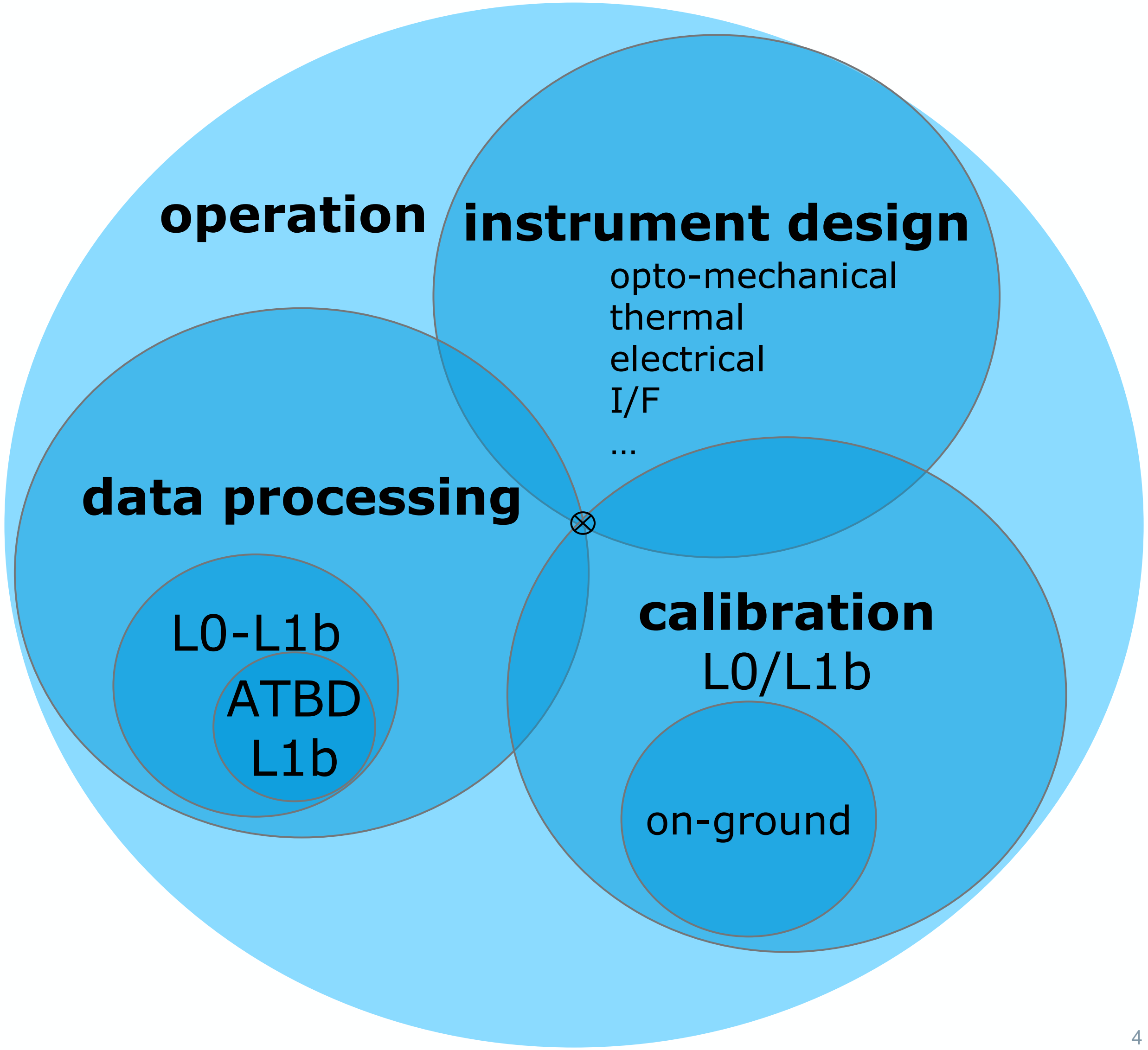
On-ground mitigations

- Careful selection of materials and processes
- Monitored bake-out at highest allowable temperature and at lowest sub-unit level
- Cleaning as far as possible and decontamination in accordance with molecular and particulate monitoring
- Contamination prevention at all levels including:
  - Design, e.g. covers, cold traps (not to be the detectors!)
  - Assembly, integration and testing (AIT)
  - Handling
  - Purging
  - Operation, e.g. regular degradation monitoring measurements

Is it enough to guarantee performances?

System approach ‘Blue Bubble’

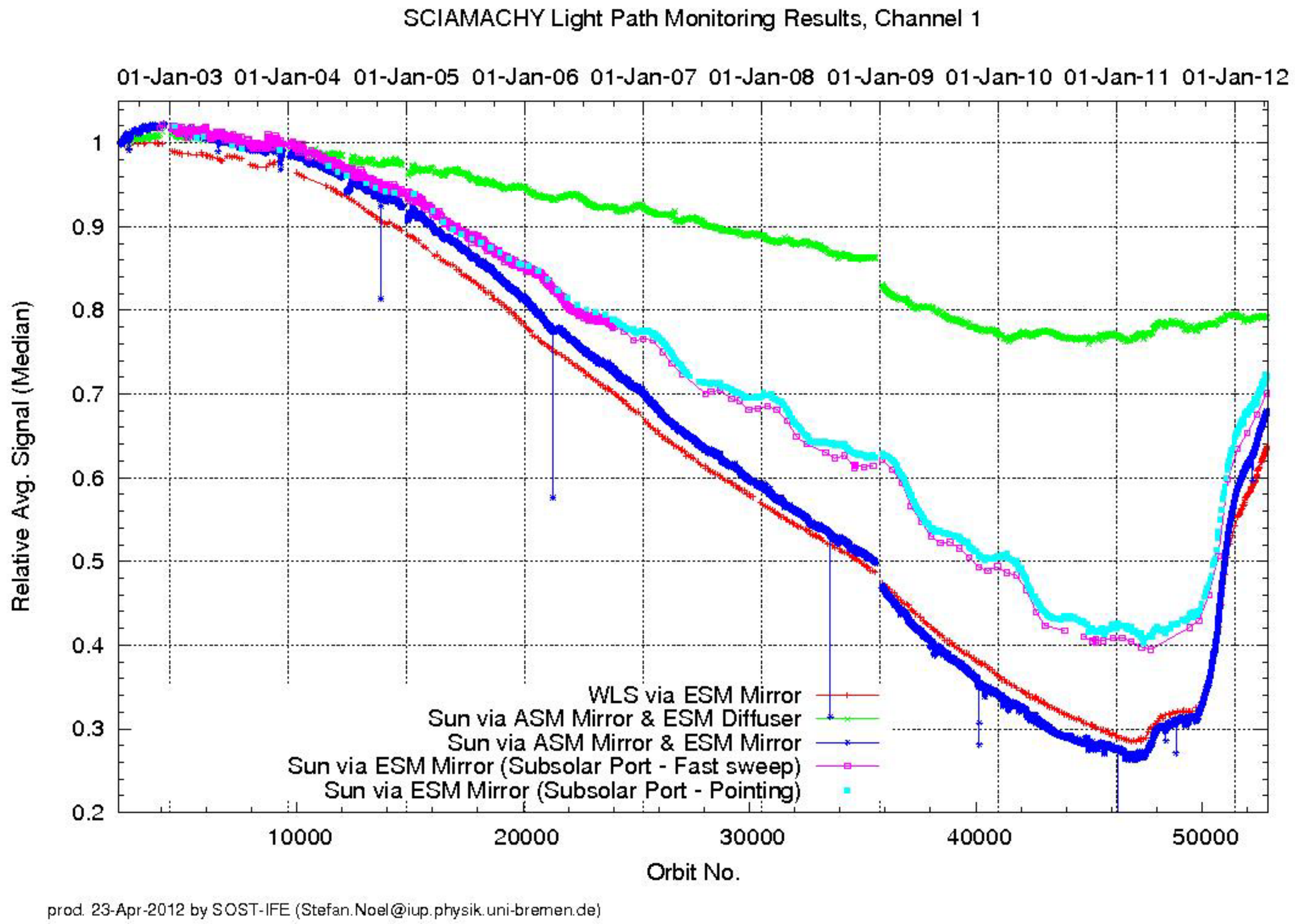
- Design
- Operation
- Calibration
- What can(not) be corrected?!
- Monitoring
- **PREVENTION**



ATBD – algorithm theoretical basis document

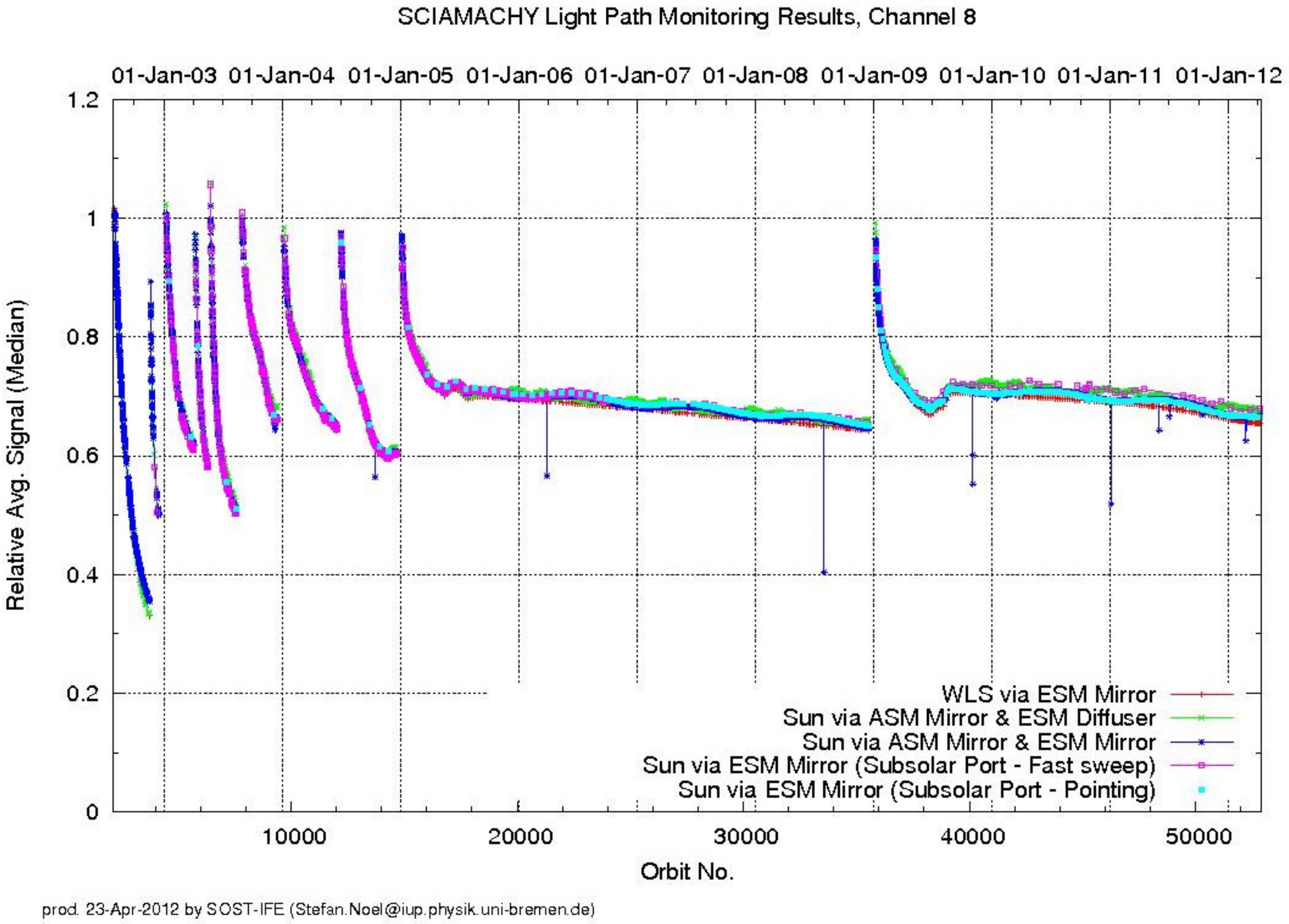
In-orbit observed degradation (including contamination)

SCIAMACHY channel 1 (214-334 nm)



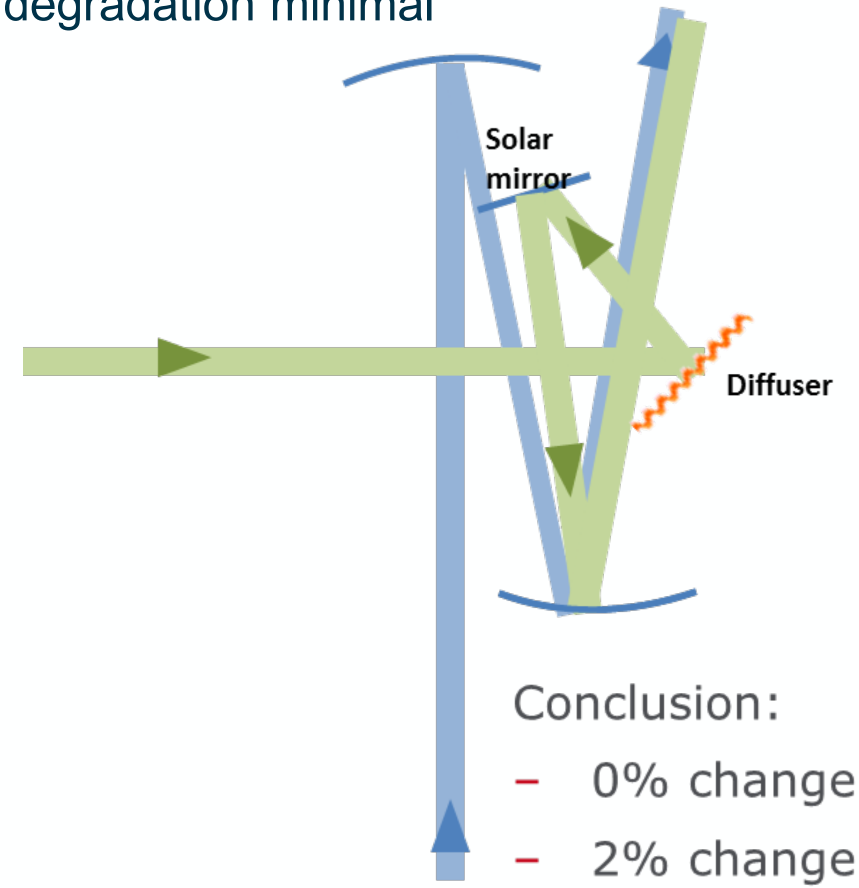
In-orbit observed degradation - ice

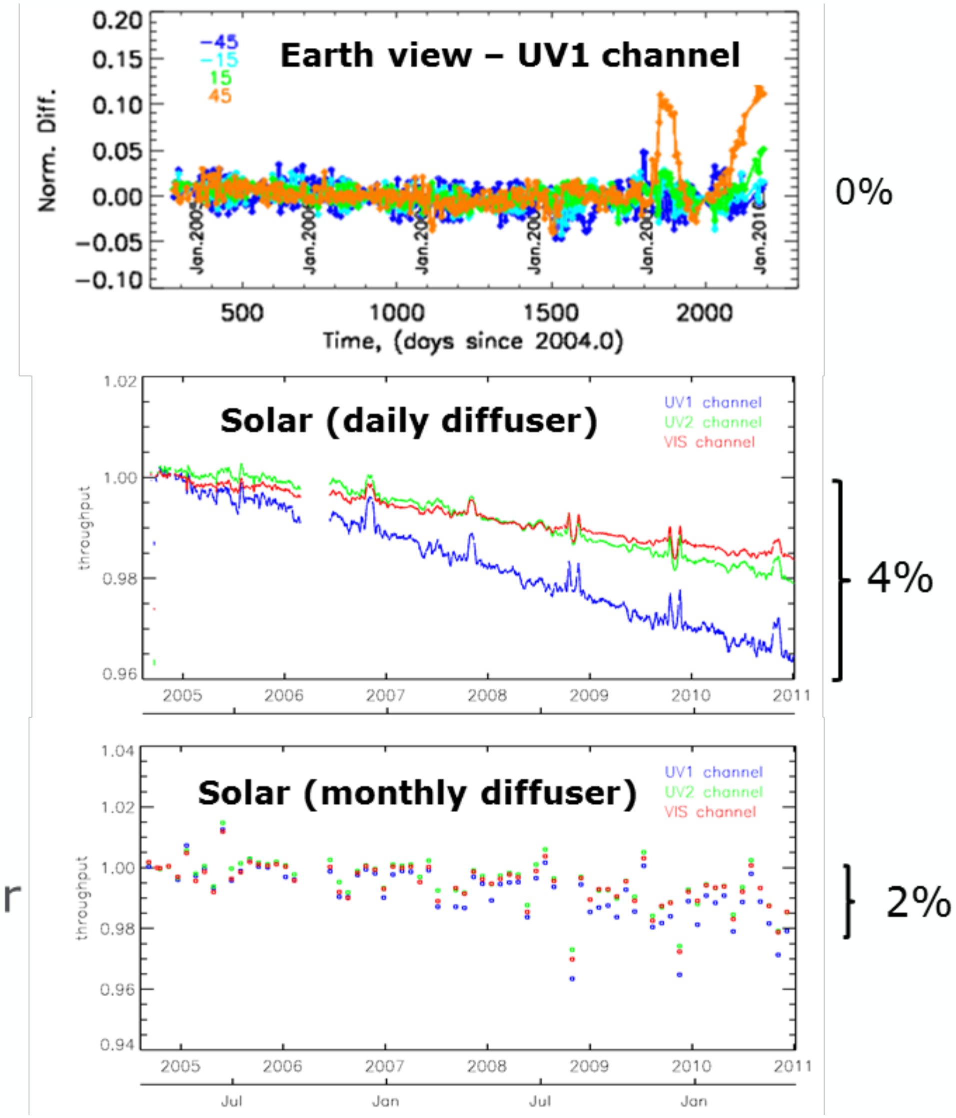
Sciamachy light paths 2259-2386 nm



In-orbit observed degradation (including contamination)

OMI degradation minimal





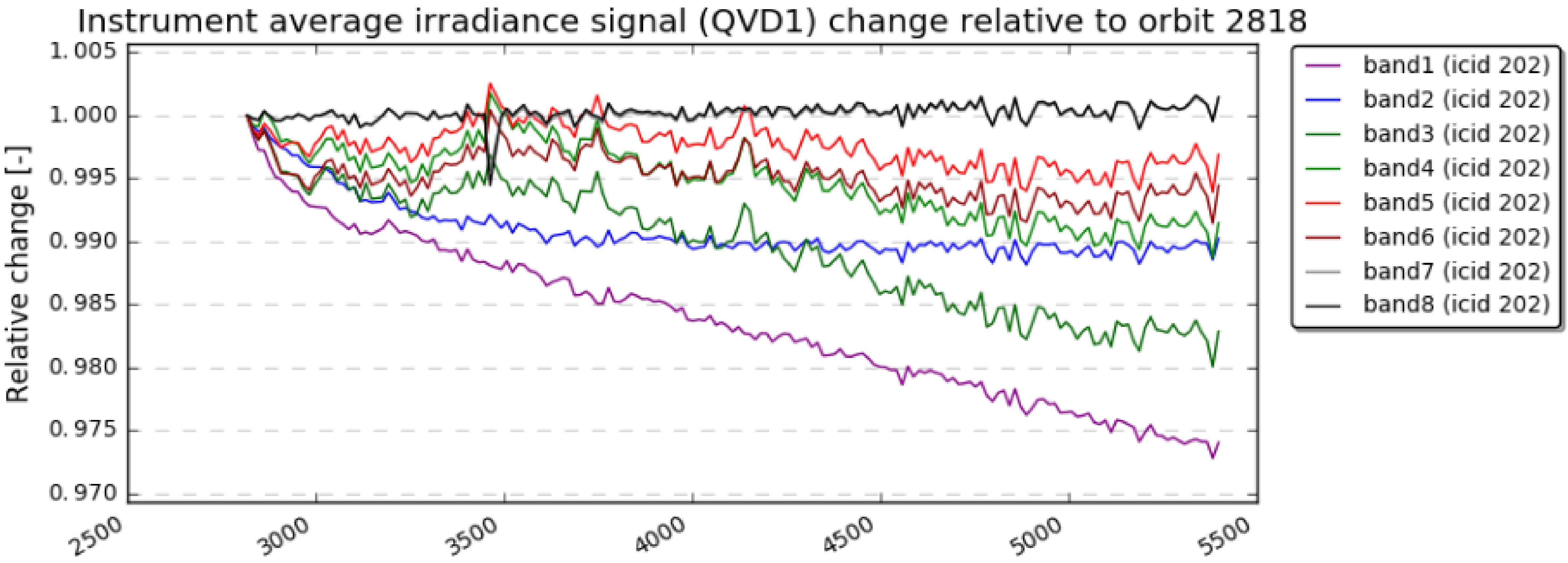
Conclusion:

- 0% change in Earth optics
- 2% change in daily diffuser
- 2% change in solar mirror

> OMI project

In-orbit observed degradation due to contamination

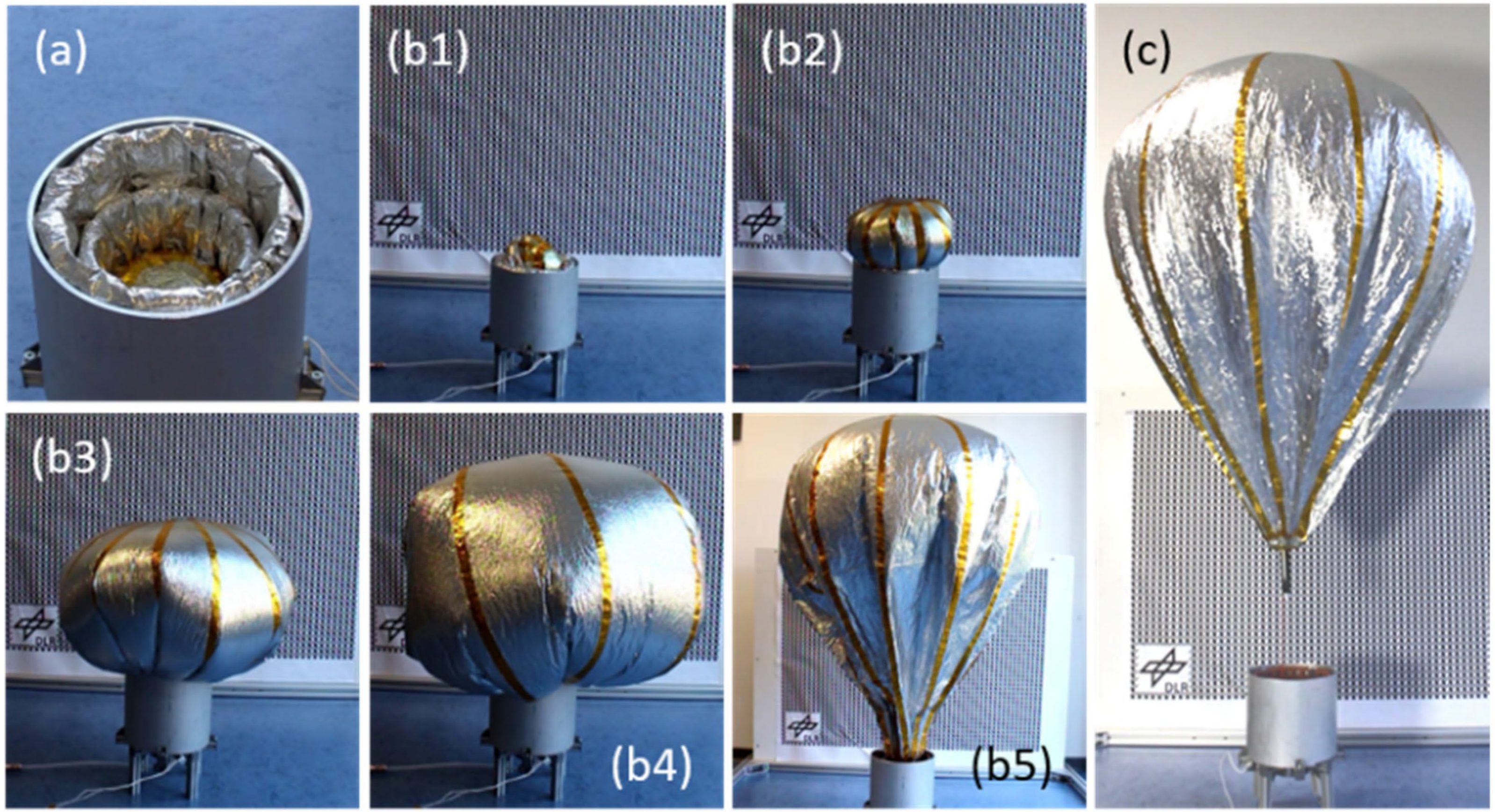
TropOMI irradiance signal degradation



> TropOMI project (KNMI).

Venting holes

Ensure that sufficient venting possibilities are implemented in the MLI to prevent that it ‘**balloon**’ during rapid **depressurisation** during launch (e.g. HIRDLS/Aura, ATV).



> https://doi.org/10.3390/aerospace9030136

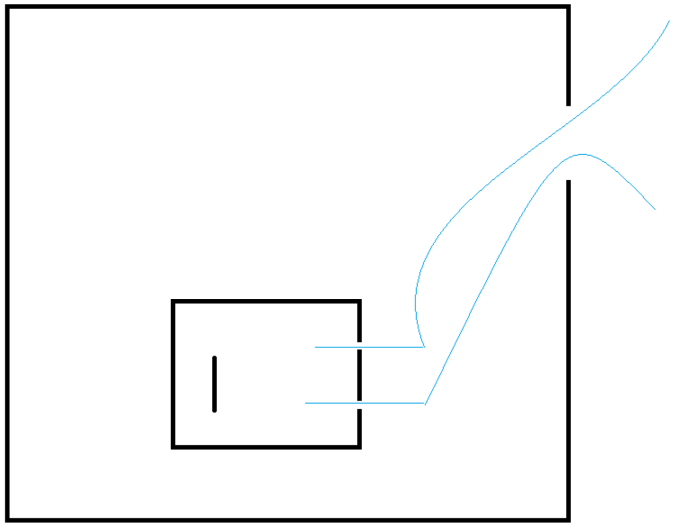
Venting out

The venting out in an instrument / spacecraft happen in three steps:

1) The first step is the venting after launch which begins after around 30 seconds.

2) The second venting regime is a transition regime were the venting driven by pressure differences is moving into the free molecular flow regime

3) The last venting step is the venting of outgassing of molecules in orbit from material of the S/C



→ The venting to openings from one cavity to another in orbit can be described by the **effusion model**

Modelling of venting in orbit (effusion)

The efficiency of the venting paths under vacuum conditions (or also sometimes called contaminant communication paths) can be modelled in two different ways:

1) By numerical calculation
   → With the numerical calculation the effusive flow rate gives the number of particles, which are streaming out of a cavity per unit time based on the molecules which are within the volume of the cavity under consideration of the mass of the molecules and the temperature

2) By the in-orbit simulation which is based on a Monte-Carlo ray-trace technic
   → The in-orbit simulation calculates the mass flow out of a cavity per unit under consideration of material depended outgassing properties (measured by representative material testing) under consideration of thickness, temperature, surface orientation and average residual time of the molecules after impinging a surface

Effusion vs. in-orbit simulation

While the effusion calculation is based on an amount of gas in a cavity without considering additional effect like molecule to surface interaction, the in-orbit simulation is based only on a pure mathematical model without e.g. considering effects like increasing of reevaporating in dependency of the contamination layer thickness.

Due to the limitation of both technics to predict the behavior of outgassing under vacuum conditions **it is essential to verify the models by testing.**

On ground verifications

How to verify effusion calculation and in orbit simulation?

The verification of both technics can be implemented in the later stages of the AIT flow, during the performance tests of the instruments.

By implementing **decontamination modes** within the performance testing and comparing the calculating / simulated changes of the performances during the tests with the measured performances, the accuracy of the models can be verified.

This is the only way to verify the accuracy of the models and the venting efficiency **based on the real hardware design on ground**!

→ This is essential, as the outcome of both technics can have an impact onto the required decontamination modes in orbit and therefore also onto the qualification of the hardware (additional temperature cycles) and also on the required instrument availability during mission.

Venting path and purging

While venting path efficiency is important mainly to remove molecular contamination during mission, the venting paths during on ground activities are important when purging is required to reduce the molecular and particle contamination during the AIT activities.

What to consider for the venting path design when purging is needed:

- The inlet and outlet of purging shall always be selected under consideration of possible turbulences which can accumulate particles.
- The purging design should when ever possible the supported by a CFD (fluid dynamic simulation) to optimize the design and the flow rate
- The purge flow shall never be guided over a possible contamination source (e.g. adhesives) and afterwards streaming over a contamination sensitive area.

How to verify purge design / venting path efficiency?

Beside the modeling technics, the purge / vent design efficiency can be **verified by testing** using a dedicated mock-up and measuring under ambient conditions time depended the humidity level inside mock-up at the contamination representative area. In a first approximation the humidity level can be assumed to be representative also for molecular contamination.

This test does also allow to understand how long it takes until the environment conditions inside and outside the instrument are equal.
In addition the information can be used to optimize the allowable purging outage time, which is normally based on an estimation.

Beside the humidity level measurements, dedicated molecular and particle witness samples can placed closed to the humidity sensor and close to the outer side of the mock-up.

After the test, the samples can be analyzed to verify the purging efficiency against molecular and particle contamination.

Conclusion

Satellites sensitive to contamination require mitigations to meet EoL requirements

→ Venting efficiency is important to guarantee high level of cleanliness

→ analysis is not enough but dedicated tests are required