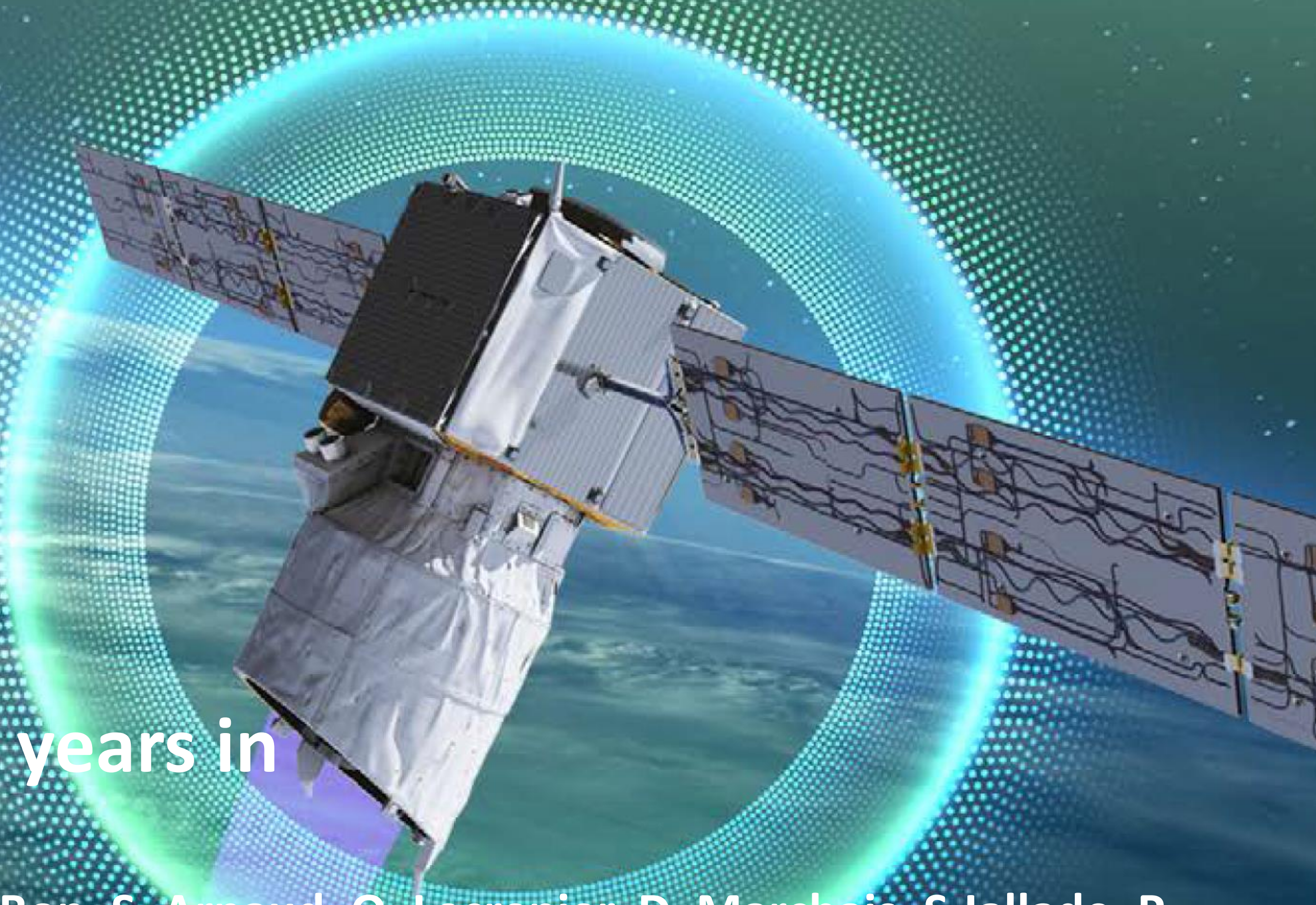
DEFENCE AND SPACE

AEOLUS
3rd ANNIVERSARY
CONFERENCE
28.03–01.04 2022
TAORMINA, ITALY

Aeolus Platform & Instrument 3 years in Space



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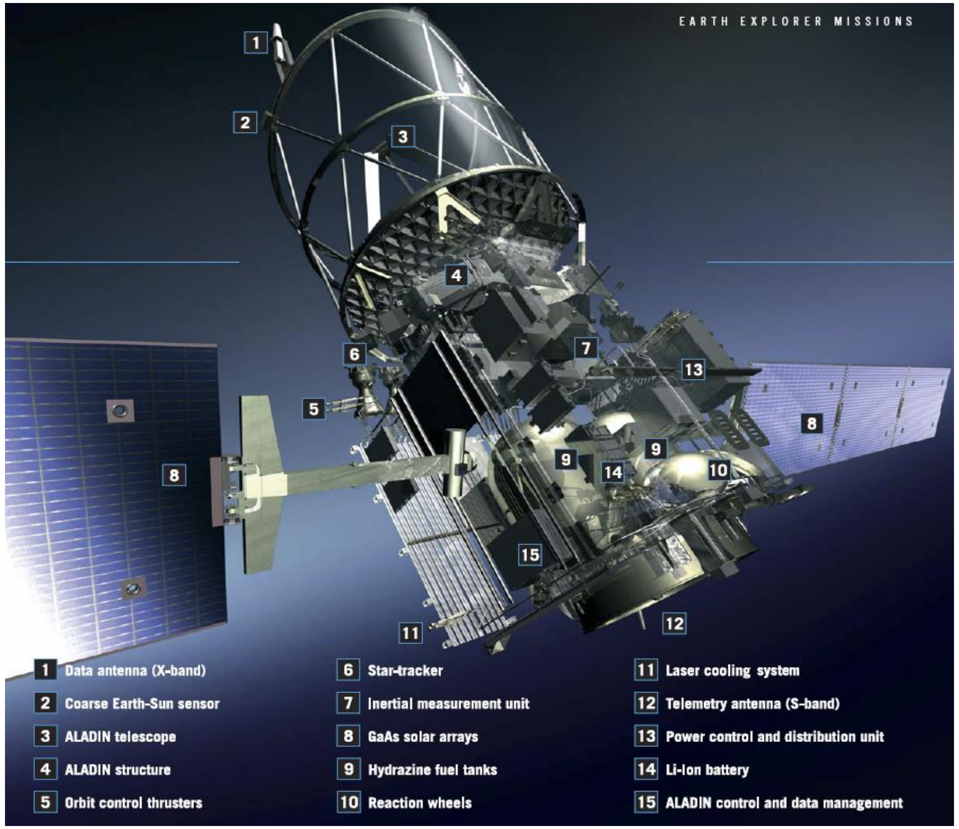
V. DeSanctis (b)
(a) : Airbus Defence and Space , (b) : Leonardo

AEOLUS Platform Description (1/2)

- Aeolus was successfully launched into a Sun-synchronous 320 km dawn-dusk near-polar orbit by **a Vega launcher in 23rd August 2018**.

The three years mission life time has been achieved successfully and extended for one more year

- The Aeolus platform - a box structure to which Aladin is mounted - supplies all of the resources required by the instrument (1400 kg including 500 kg for instrument)
- The **Command and Data Management Unit (CDMU)**, at the core of the spacecraft, runs either the nominal application or, in extremis, the Safe Mode software. This constantly controls the platform performance and executes uploaded operations.
- Power is provided by **two static solar array wings**, rotated by 45 deg after deployment, with an 84 Ah (BoL) Li-ion battery operating at 44 to 50.4 V.



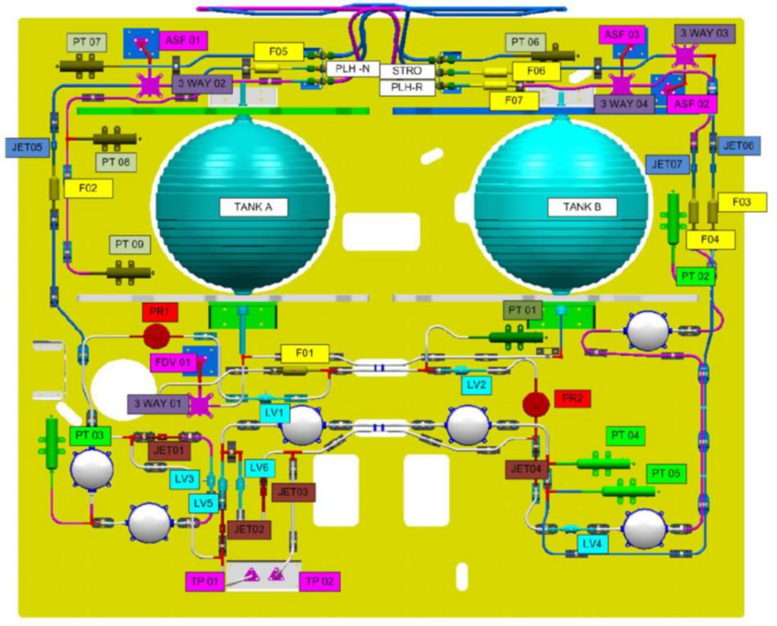
Courtesy ESA

- The AOCS is a bespoke **gyro-stellar design** to deliver both accurate pointing and safety requirements:
  - ALADIN **requires fine pointing** for normal operations, with **a steering law guidance profile to cancel the Earth and satellite apparent velocity**
  - **The telescope needs to be protected from for sun intrusion.**

AEOLUS Platform Description (2/2)

- The Communication Subsystem consists of:
  - S-Band Subsystem (SBS) - **Reception and demodulation** of up-link telecommands (TC), modulation and transmission of downlink housekeeping (HK), plus ranging capabilities.
  - X-Band Subsystem (XBS) - **Modulation and transmission** of downlink (science data) signals.

- In-Situ Cleaning System (ICS), located in the platform, **supplies oxygen to ensure that the Laser Induced Contamination** (LIC) of the optics is reduced to acceptable levels:
  - The hybrid mechanical/electrical pressure regulated gas feed system provides **low pressure oxygen to the Power Laser Head (PLH) and Sealed Transmit/Receive Optics (STRO).**



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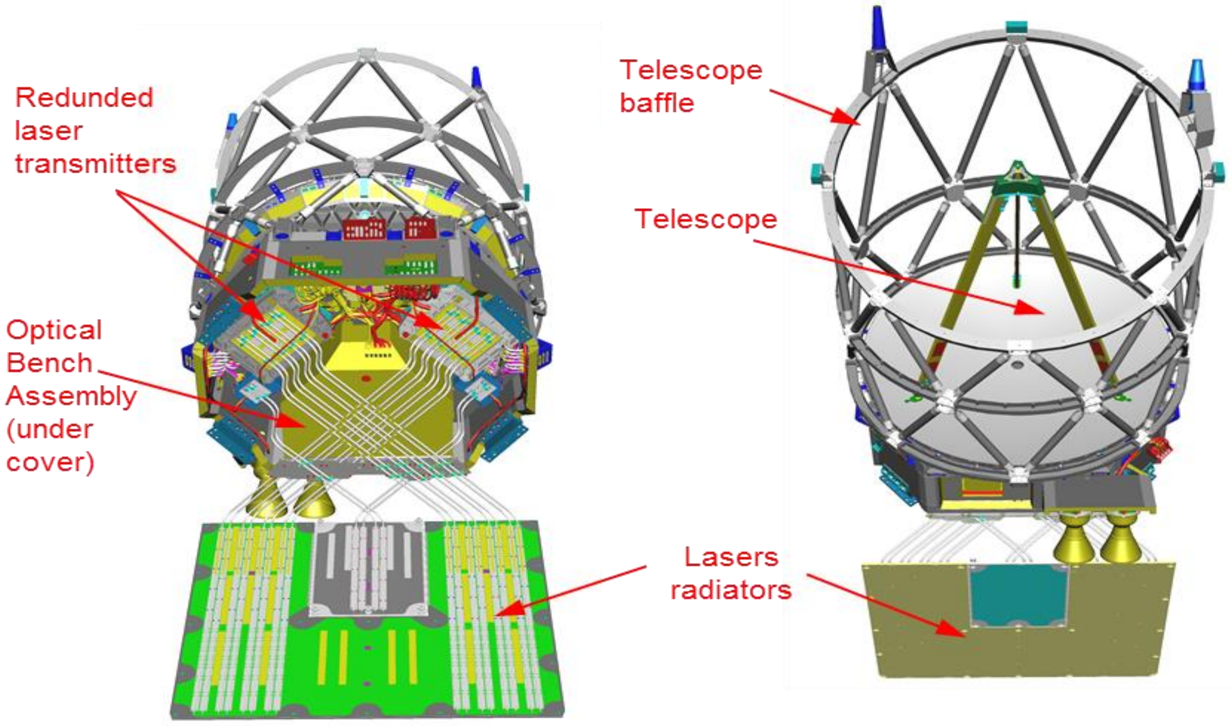
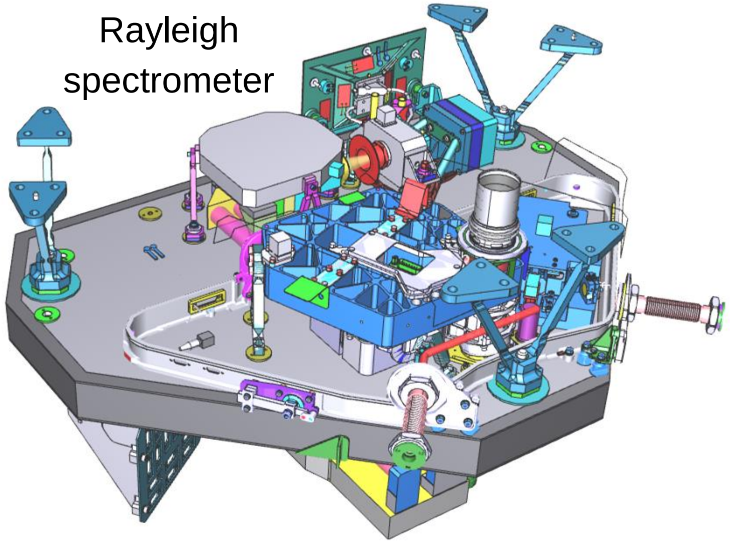
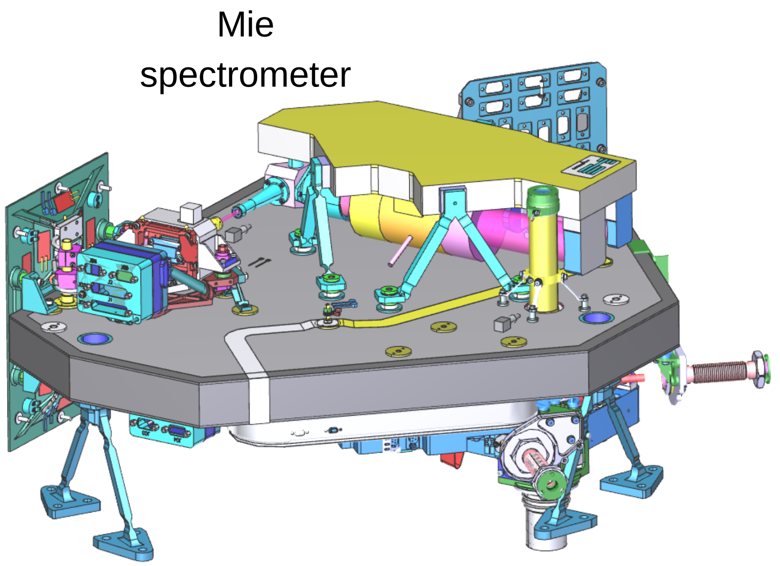
Aladin Instrument Description



- The instrument is based on a **monostatic optical architecture** : the same Telescope is used in emission and reception
- The Laser sources are used **in cold redundancy** (**Laser energy ~70 mJ/ 50 Hz**)
- The cooling of the laser heat dissipation is done using a **radiator with heat pipes** for heat transport.
- The Telescope us a full **SiC structure** with a primary **mirror 1.5 m diameter**.
- The receiver is based on **direct detection** using two spectrometers tailored to Mie and Rayleigh spectra.
- Instrument power consumption is **840W** in average





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AIRBUS support to AEOLUS - overview

- AIRBUS is involved in several support activities:
  - ➢ **Periodic** Telemetry (TM) **monitoring** for both Platform and instrument
  - ➢ **Periodic** instrument **performance** monitoring
  - ➢ **On demand support** for specific topics involving dedicated field of **expertise**
  - ➢ Support for **Special Operations** and investigations
  - ➢ Dedicated **analysis** and/or **investigations**
  - ➢ Definition and **validation of S/W patchs**

Specific support
- 30 specific instr. requests over 2019-2021
  - Hot pixel
  - M1 temperature control
  - Laser cooling sys tuning
  - Orbit lowering
  - Reentry strategy definition…

High interest performance report
- Every 6 months
- Rayleigh, Mie internal reference beam charateristics
- …..

HK Telemetry report
- Light 3 month reports
- Extensive 6 month reports

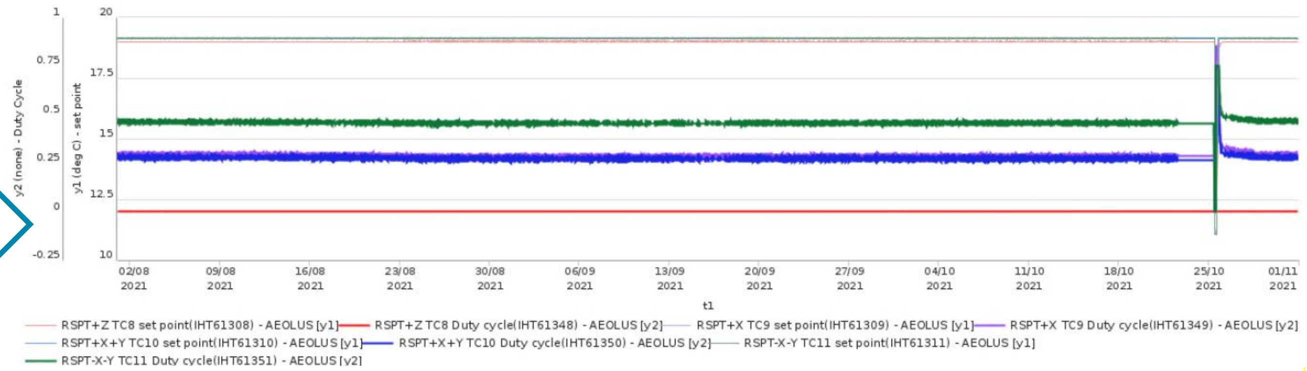
Fields of expertise
- Instrument
- AOCS
- Operations
- Thermal
- Mechanical
- AIT record

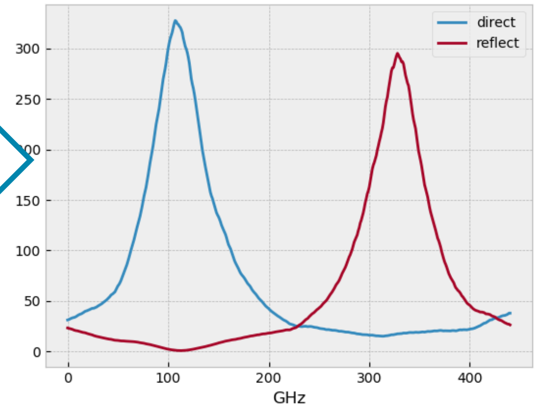
AIRBUS support

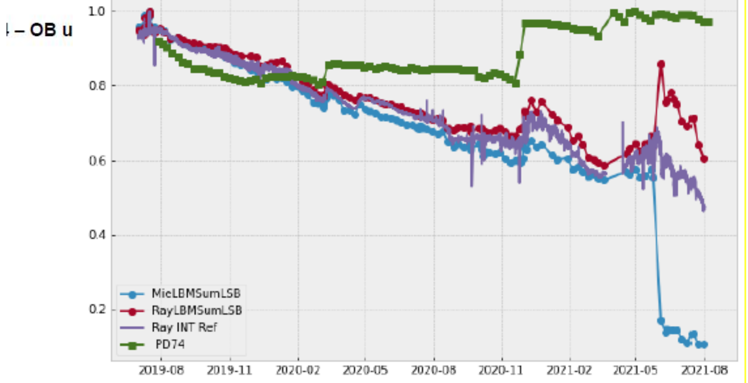
In orbit routine monitoring

- Long Term Performance Analysis of platform subsystems
- Periodic **updates of on-board parameters**:
  - Thruster parmeters (as fuel depletes)
  - Guidance and control parameters
  - Rate Measurement Unit calibration
- 3/6 month Instrument HouseKeeping report
  - Trend analysis (CP temperature jumps)
  - Anomaly indentification
  - Trend monitoring with alarms (Peltier temperature drift)
  - Inputs for specific 6 month laser report
- 6 month instrument performance reports
  - Focused on instrument high interest performances
  - Inputs for performances improvements

Item ID	Location & parameter	Nominal values	Previous values[1]	Current values (min / max) [2]	Deviation & trend	Anomaly	Comment
9	Struts mean Z Gradient	4.5 +/- 1°C	3.0 / 4.8°C	3.2 / 4.7°C	~ stable	No	Gradient value involving 6 temp (IHT614xx). See Graph_2 in appendix. Successive peaks (Δ gradient of +0.9°C and -5.5°C) on 25/10/21 linked to ALADIN switched down to Survival mode (22/10/21 at ~14h00).
	Optical Bench						
10	OB mean Temp	16 +/- 0.5°C	16.7 / 17.0°C	16.9 / 17.1°C	~ stable	No	Mean value of 8 temp (IHT614xx). See Graph_3 in appendix. Drop (ΔT of -12°C) on 25/10/21 linked to ALADIN switched down to Survival mode (22/10/21 at ~14h00).
11	OB X Gradient	0.4 +/- 0.2°C	0.33 / 0.38°C	0.37 / 0.41°C	~ stable	No	Gradient value involving 8 temp (IHT614xx). See Graph_2 in appendix. Successive peaks (Δ gradient of +0.16°C and -0.6°C) on 25/10/21 linked to ALADIN switched down to Survival mode (22/10/21 at ~14h00).



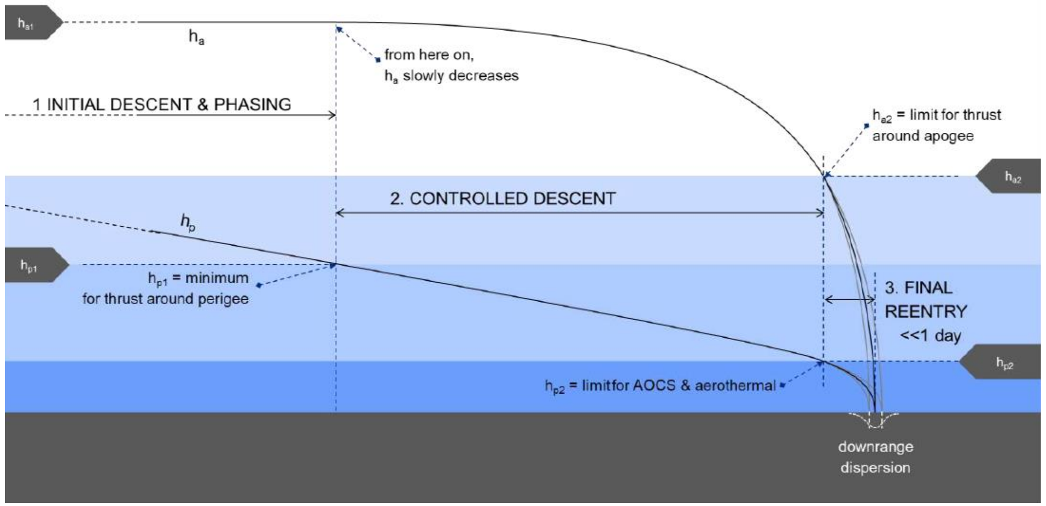




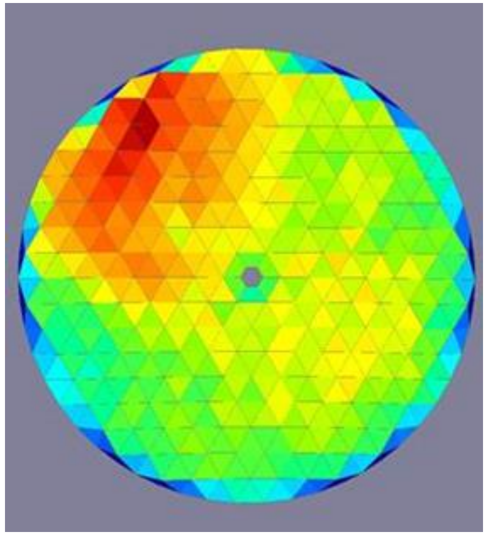
Instrument /Satellite Specific support

- **30** specific support activities (**14 for Platform and 16 for instrument**) covering various topics such as (the list is not exhaustive)
  - **Laser energy increase** (sensitivity tests with definition of best operating point with users
  - Support to Anomaly investigation (receive path signal loss, STRO pressure loss …)
  - **Hot pixels investigation involving E2V manufacturer**
  - **Telescope M1 mirror thermal control optimisation including thermal model correlation**
  - Orbit decrease impact and feasibility (Sat + Instrument)
  - **Assisted reentry** (Satellite deorbiting)
  - …

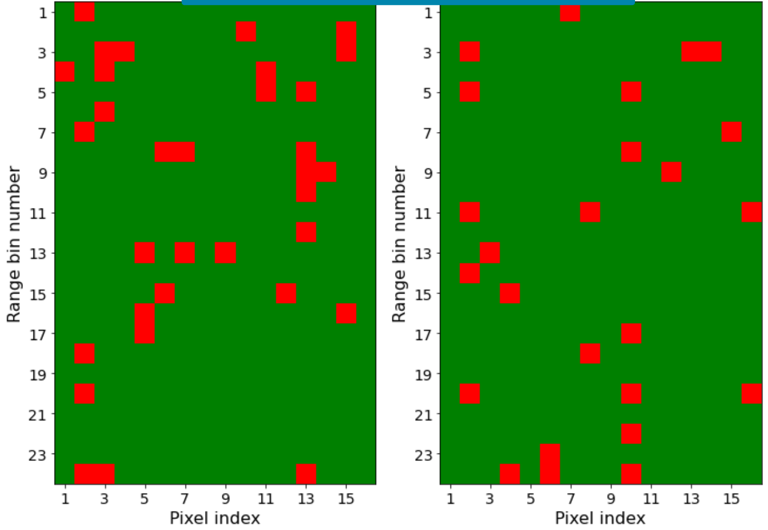
Assisted re-entry study



Telescope thermal control



CCD Hot pixels investigation support



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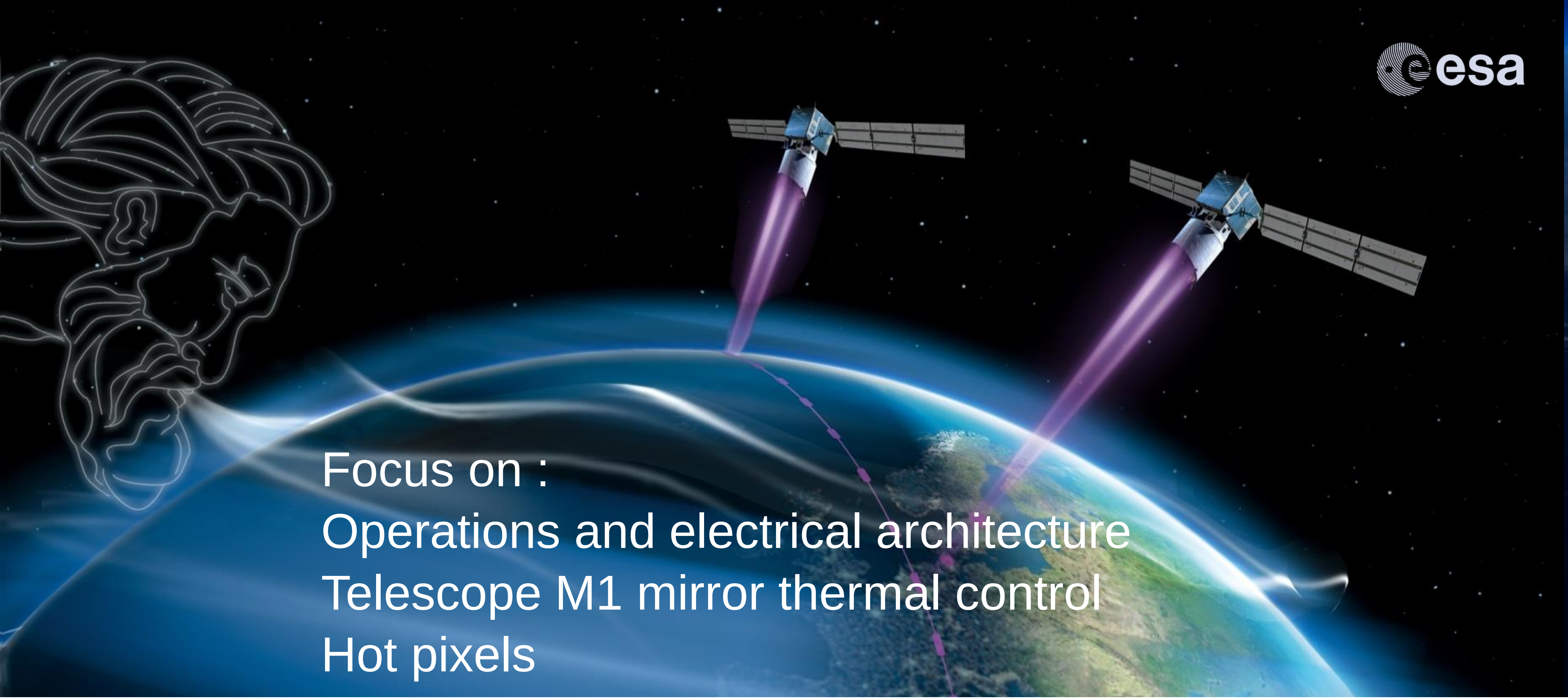

Focus on :

Operations and electrical architecture

Telescope M1 mirror thermal control

Hot pixels

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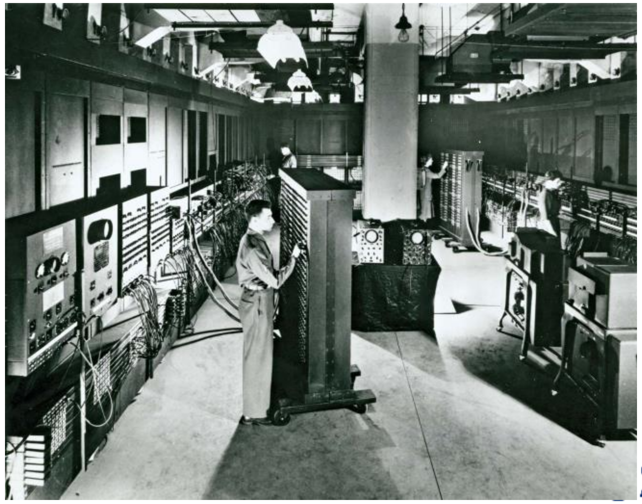
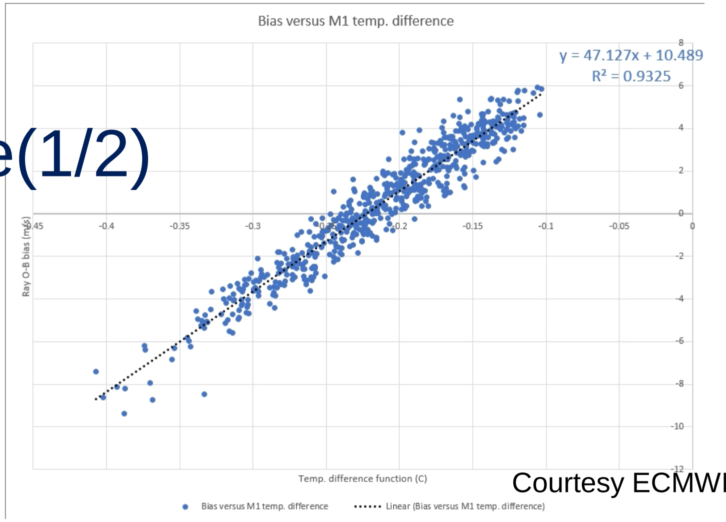
In orbit operations and electrical architecture

- ALADIN is the **first European instrument including a high power laser flight on a low orbit altitude** with limited visibility for commandability :
  - On board autonomy and adequate protection
- A **large number of special operations** were carried out over the 3+ years in orbit operations for performances improvement or sensitivity analysis : all these ops were carried out with success with efficient and good colaboration with ESA and ESOC
- **No electronics failure (neither nominal nor redundant) have been reported** up to now only transcient outage due to environment. All nominal electronic equipment being used.
- This is a **key achievement** knowing that all ALADIN electronics :
  - Have been designed around year 2000
  - Have been delivered around year 2005 for flight models
  - Have been actually used in orbit since 2018
  - Have exceeded their in orbit lifetime.



Telescope M1 Thermal control investigations and upgrade(1/2)

- Motivation is linked to the **orbital bias observed by ECMWF** (M. Rennie et al) **correlated to the M1 temperature radial gradient** evolution.



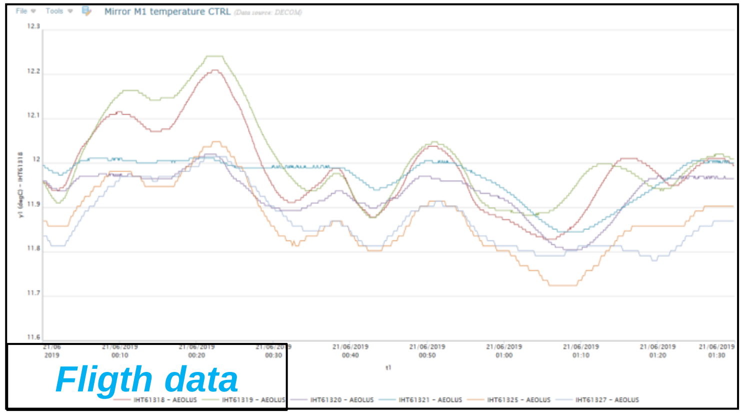
Courtesy ECMWF

Flight thermal model improvement

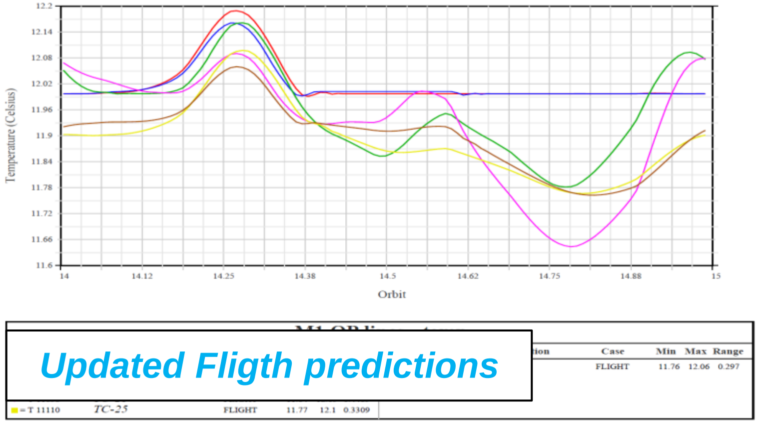
- Upgrade of thermal control law (sensor digitalization)
- Improved external fluxes representativity (albedo and IR maps)

M1 thermal control limitations

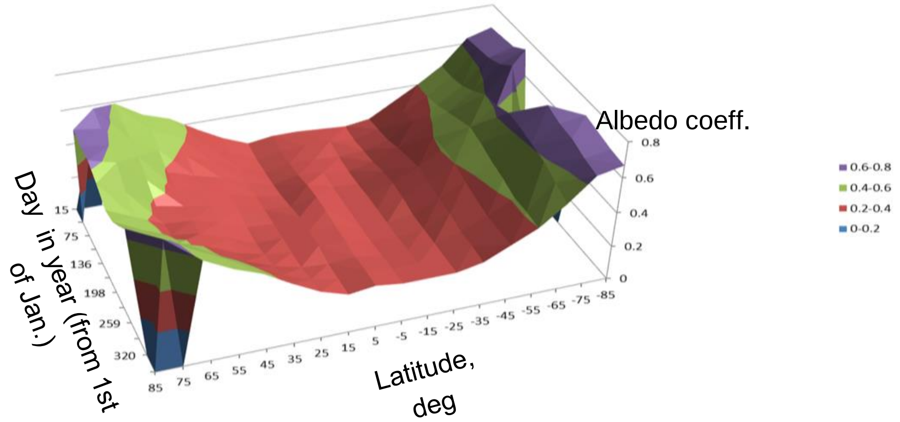
- Controler performances (Single In Single Out)
- Hardware : lack of heat power to compensate external fluxes orbital variations

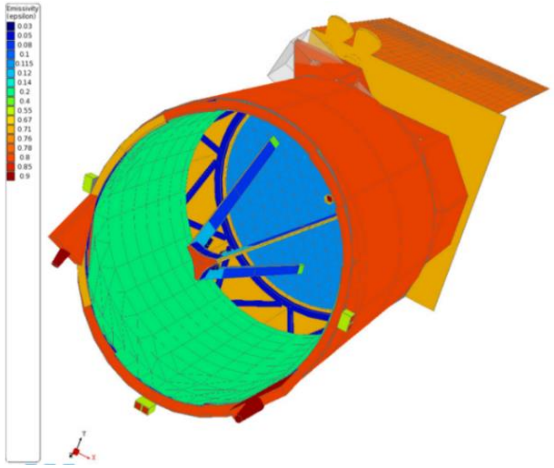


Fligth data



Updated Fligth predictions





Telescope M1 Thermal control investigations and upgrade(2/2)

In a second step , a specific **M1 thermal control law parameters tuning** has been proposed by Airbus in order to reduce the orbital thermal gradient.

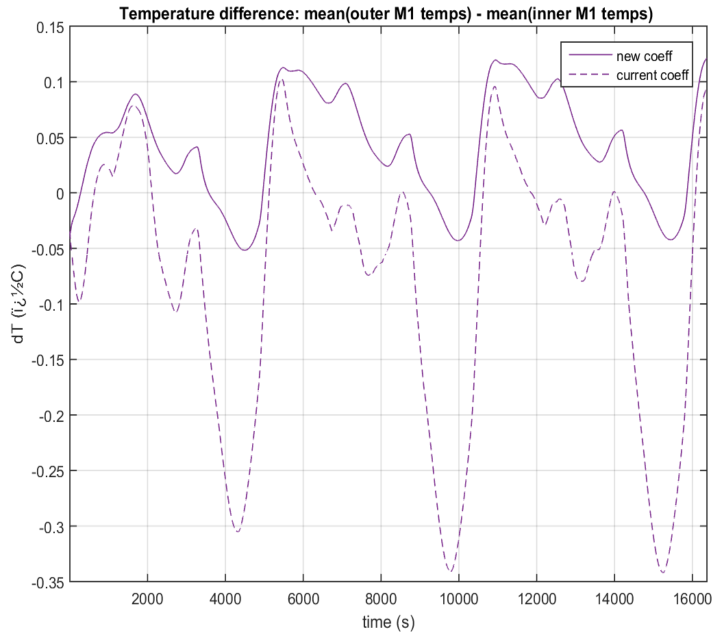
Thermal parameter tuning :

- Use of tools and process from flight analysis and AOCS team
- 3 technics used to work around controller limitations

Thermal control parameter validation with updated thermal model

In flight test done 6/7 July 2020

- **satisfactory results in terms of M1 thermal behaviour**
- Receive signal orbital variability increase (limited TMs observability, ..)

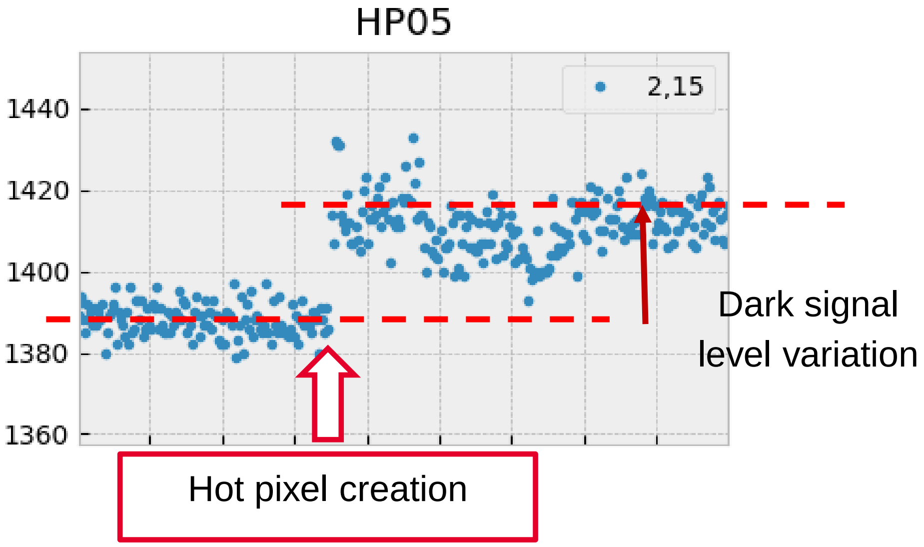


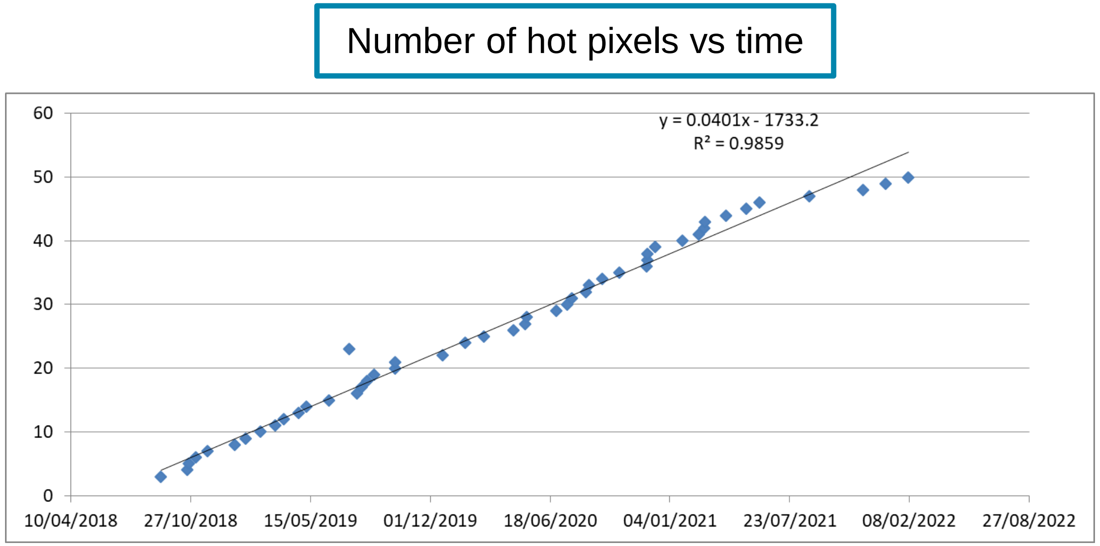
These inflight investigations performed have lead to a lot of lesson learns and key improvements for future missions:

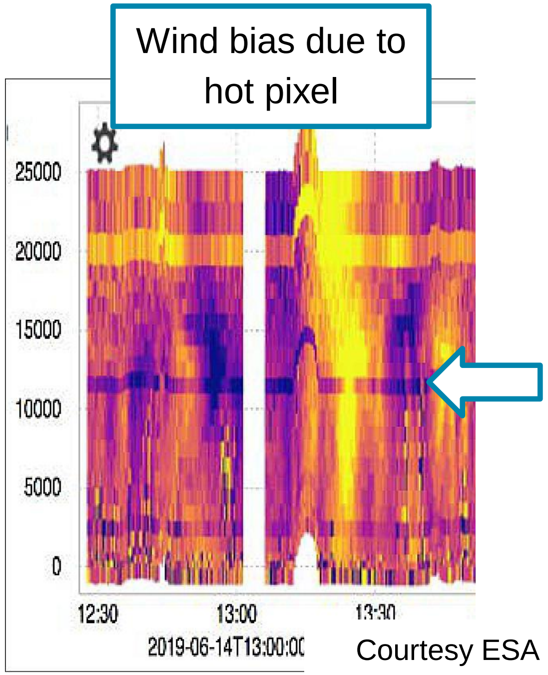
- ❑ **Thermal design improvement** (M1 External fluxes variations influence decrease, M1 design insensitive to thermal gradients..)
- ❑ **Thermal control law improvement,** in parallel an R&T study ESA RFP/3-17336/21/NL/KML/va: *Advanced Control Methods for Space Thermal Management Applications* , is on going with Aeolus flight results as typical study case and improvement objectives for AFO

Hot pixels (1/3)

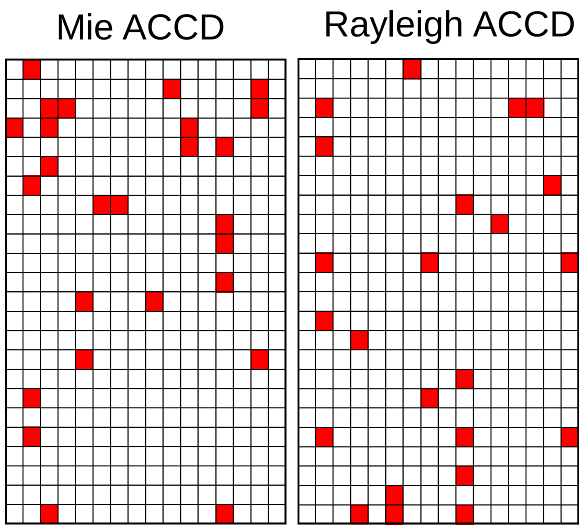
- Hot pixel (HP) characteristics
  - They are characterized by a **sudden and permanent increase of dark signal** in an increasing number of pixel, on both CCD.
  - The anomaly has been highlighted as a **bias in in L2 wind products**
  - Generally a common phenomenon related to **radiation,** but on Aladin
    - specific to only a **selective area**, characterized by a specific design,
    - **Unstable dark current** on some pixels after event trigger,
    - Requires **frequent calibration** : 4 times a day currently.







Courtesy ESA



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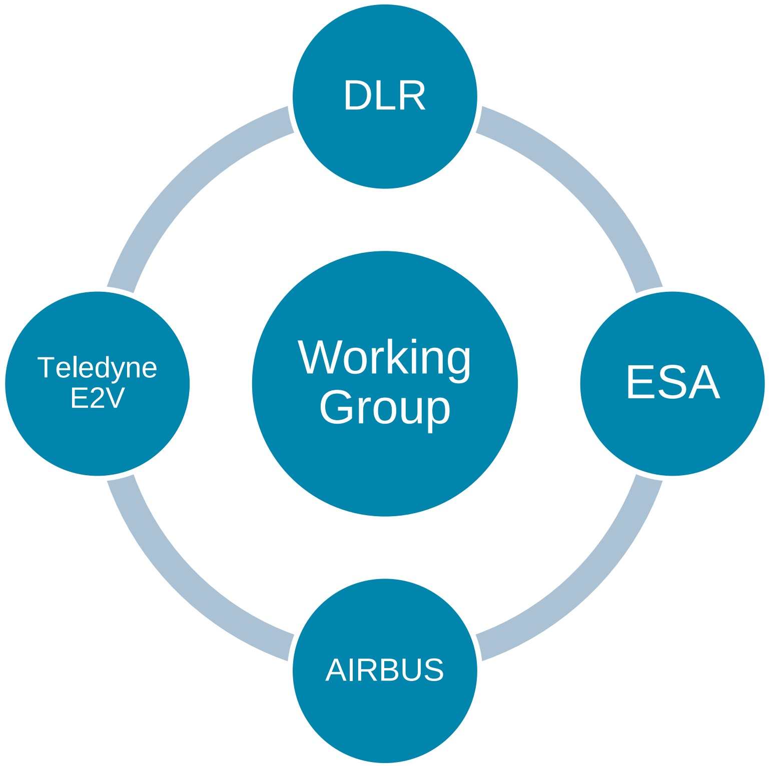
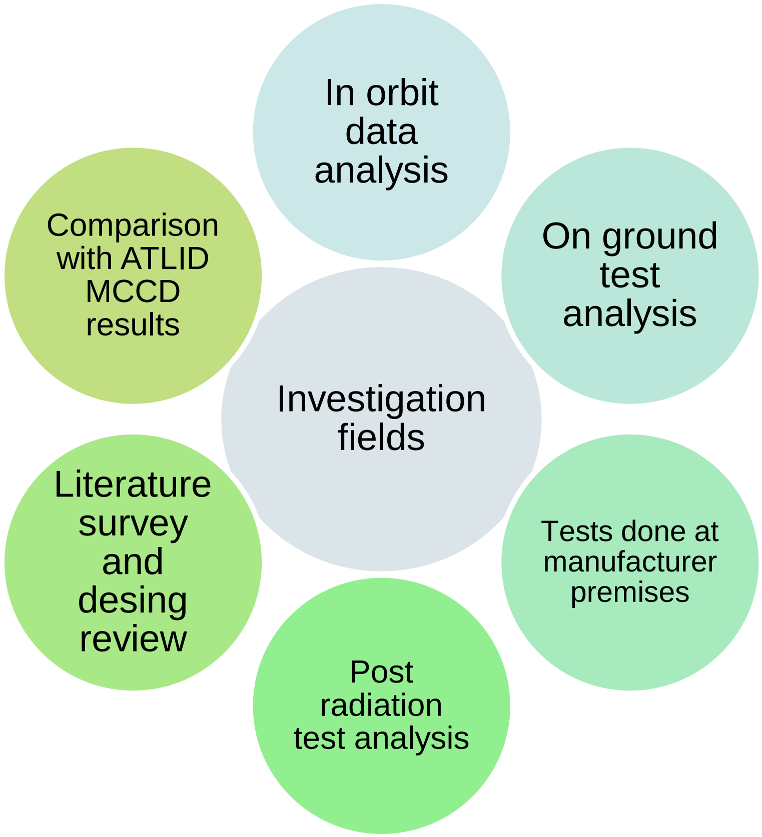
Hot pixels (2/3)

- Investigations were led within **a working group comprising ESA, DLR, AIRBUS and Teledyne E2V (**ACCD manufacturer).
- Several fields were investigated both **in flight and on ground test results**
- So far the investigation results points to a side effect associated to **Clock Induced Charges effect in silicon** (CIC)
  - Attached to accumulation area pixels design
  - Revealed by **specific operating mode**





Hot pixels (3/3)

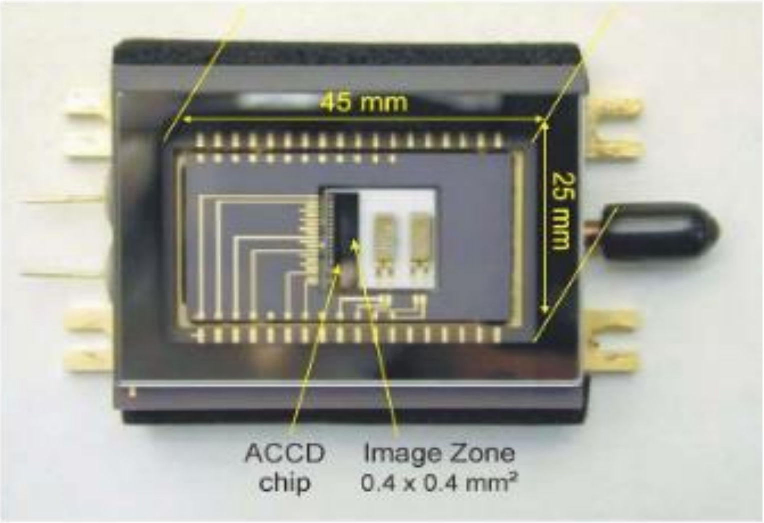
- Current **mitigation actions** for ongoing Aeolus demonstrator
  - DUDE = acquisitions in darkness 4 times a day for characterization
  - Recovery by **on-ground processing workaround**
  - Demonstrate performance recovery on Aladin

- Aeolus Follow-On perspective
  - Identification of **detector design workaround**

  ➔ Detector silicon design architecture
  - Identification of **operational workaround**

  ➔ Live dark current monitoring

In flight Mitigation	Mitigation for future missions(Aeolus FO)
Acquisition in darkness (DUDE)	Lower operating temperature
Processing modification	CCD Design and clocking modifications
	Real time dark image acquisition



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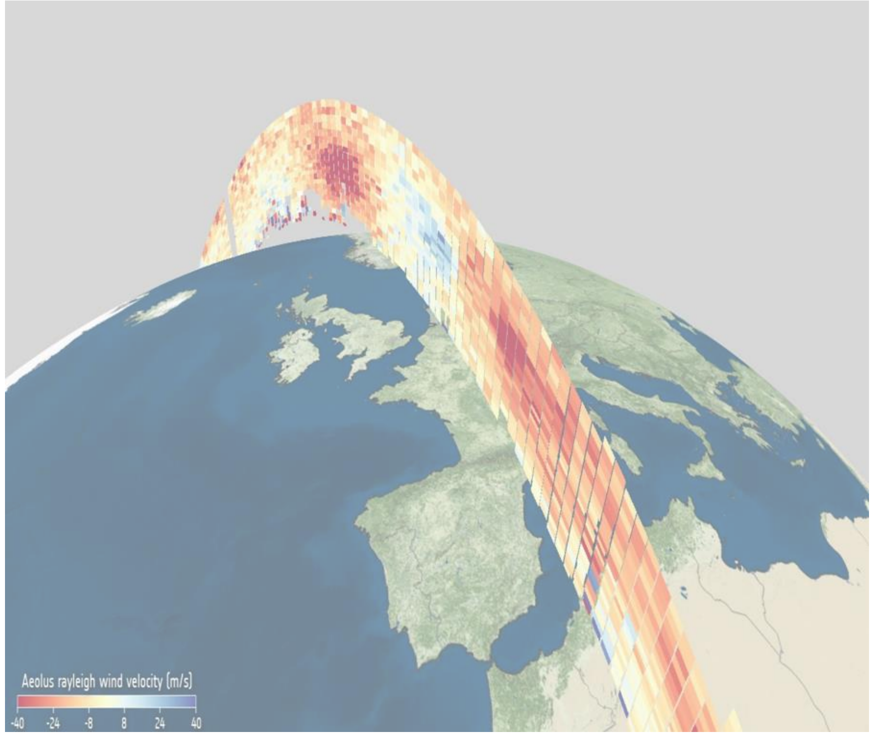
Summary and outlook



- AEOLUS has been **operated successfully for more than three years**
- **AIRBUS Customer Service** is involved in both **routine monitoring** as well as **specific support activities**.
  - AIRBUS contributes with **key expertise on platform and instrument design**, comparison with models and on ground test data and **support to specific operations**
- A very **fruitful collaboration** between ESA, ESOC, ESRIN, DLR, DISC and industry allows to turn the AEOLUS mission into **a real success :**
  - Demonstrated **positive impact on weather forecast models**
  - In **flight follow up is a key asset** to support such complex instrument for **a new family of remote sensing instruments**
  - Developed as a demonstrator, wind data from AEOLUS is **used for weather forecast since January 2020.**
  - Design lifetime of **3 years was achieved on January 2022** with no failure reported -> allowing **lifetime extension by at least one year**

- **AEOLUS is opening the way of a new family of remote sensing instruments**