Aeolus First Light – First Glimpse

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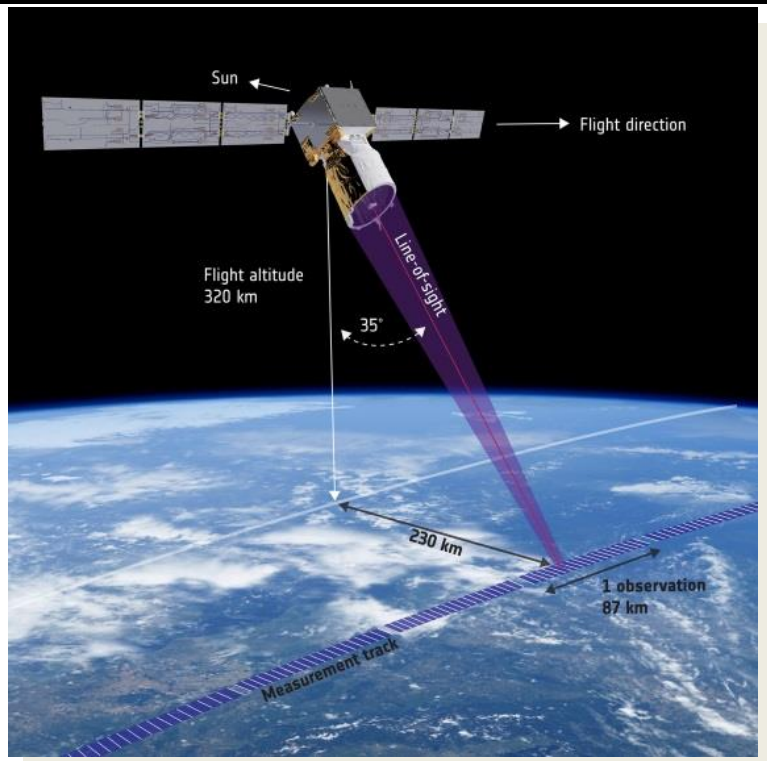
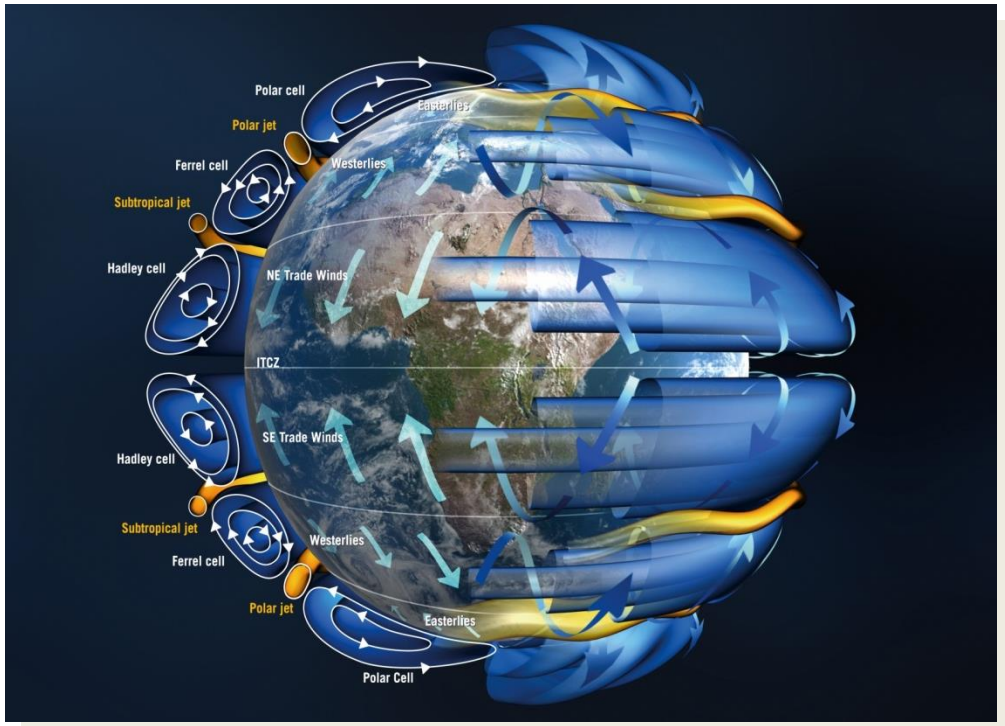
What is the Aeolus satellite for?





- **Direct detection UV Doppler wind Lidar operating at 355 nm and 50 Hz PRF, with dual receivers.**
- **Mie receiver to determine winds from aerosol & cloud backscatter.**
- **Rayleigh receiver to determine winds from molecular backscatter.**
- **The line-of-sight is pointing 35° from Nadir to obtain horizontal backscatter component**
- **The line-of-sight is pointing orthogonal to the ground track velocity vector to remove contribution from the satellite velocity.**

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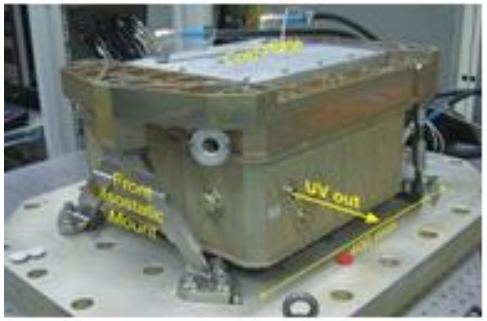
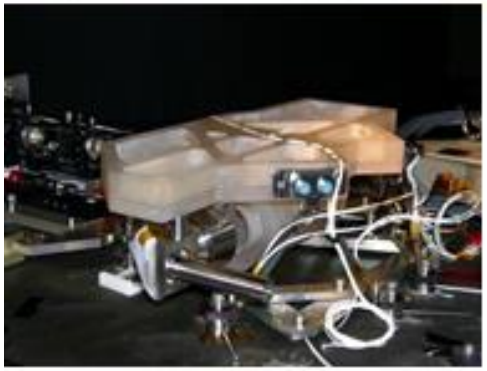
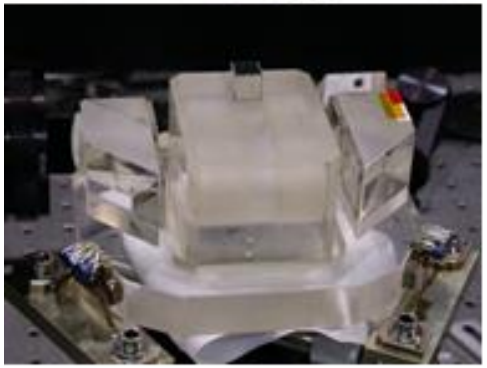
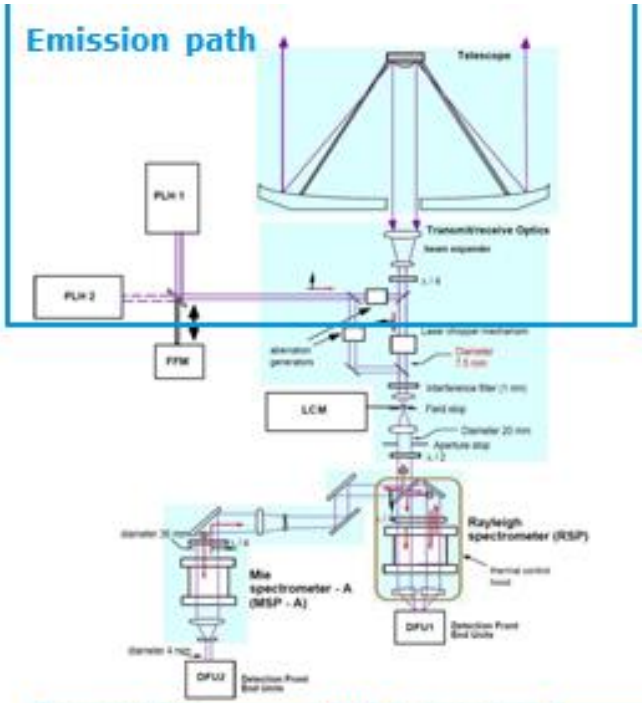
What is the Aladin instrument?

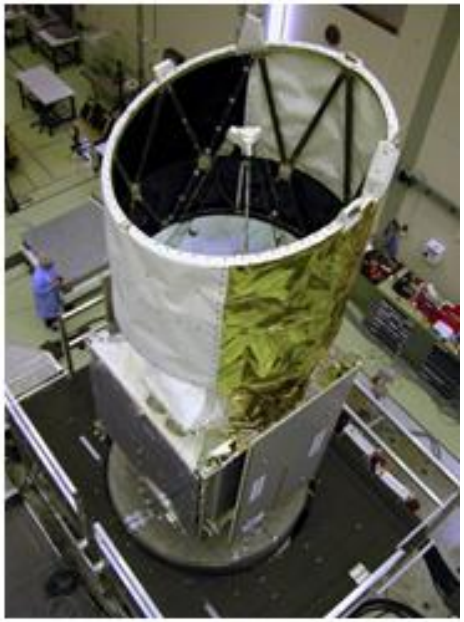








Laser type	Diode pumped Nd:YAG operating in 50-100Pa O_2
PRF	50Hz
Wavelength	355nm
Energy	100mJ
Peak fluence	1.1Jcm^{-2}
Pulse width	20ns
Lifetime	3 years (5Gshots)



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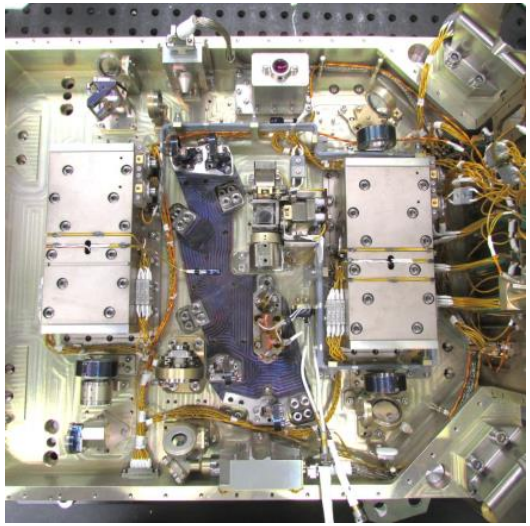
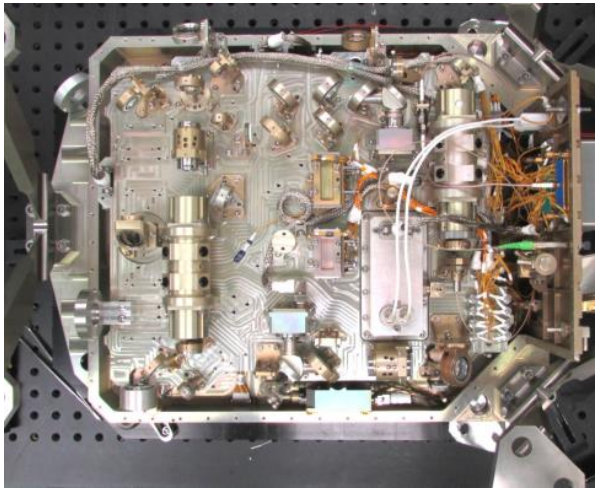
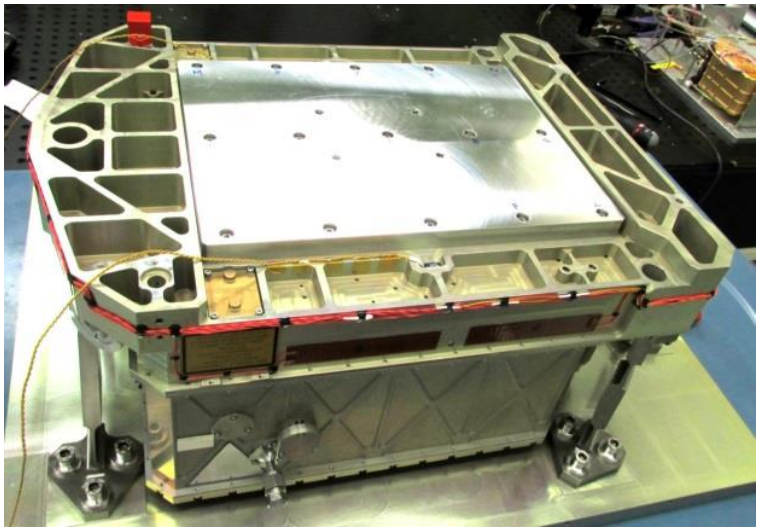
The Aladin laser transmitter



Upper optical bench



Lower optical bench



Parameter	Value
Dimensions	(582x422x215)mm
Volume	30L
Mass	30Kg
Power consumption	300W
Wavelength	354.8nm
Pulsewidth	20ns (FWHM)
Pulse repitition frequency	50.5Hz
Energy (IR)	280mJ
Energy (UV)	80mJ
Harmonic section conversion efficiency	28%
Peak fluence (UV)	$1Jcm^{-2}$
Wall plug efficiency (UV)	1%

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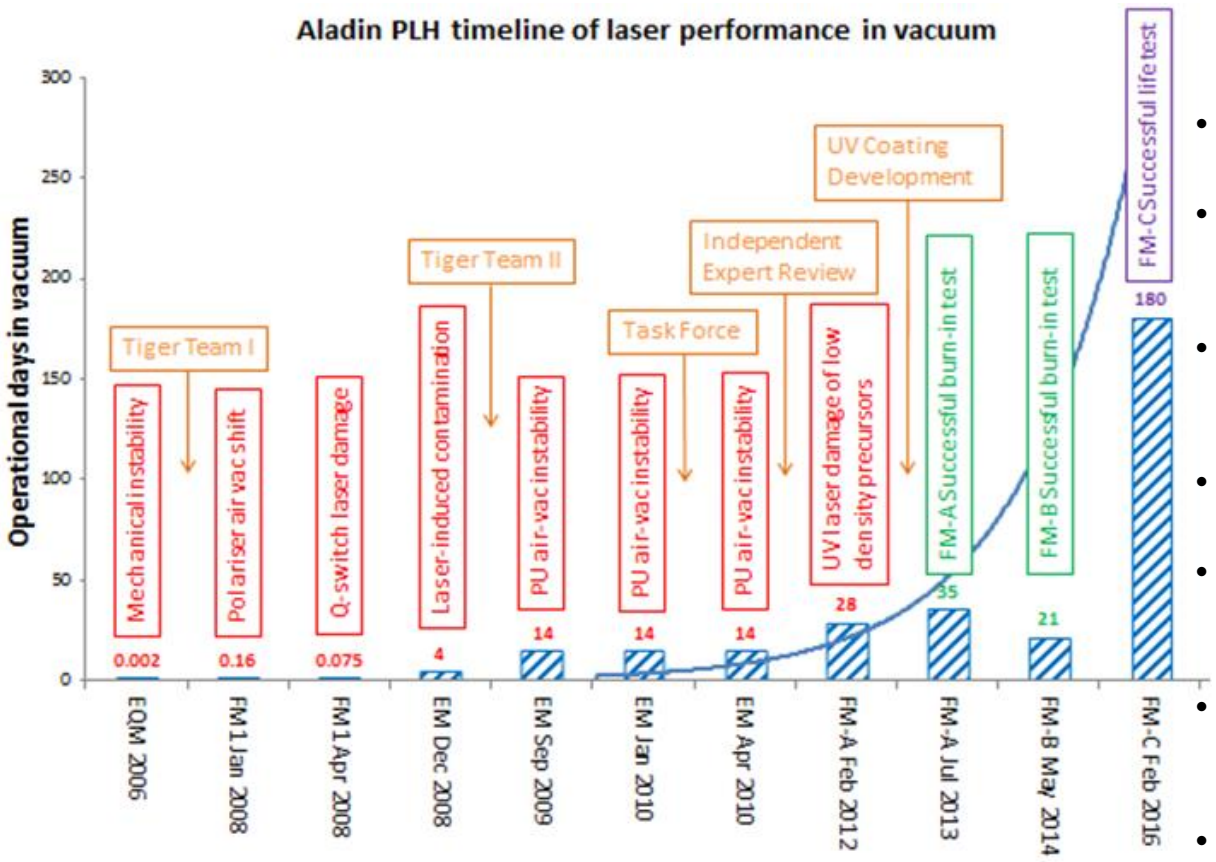
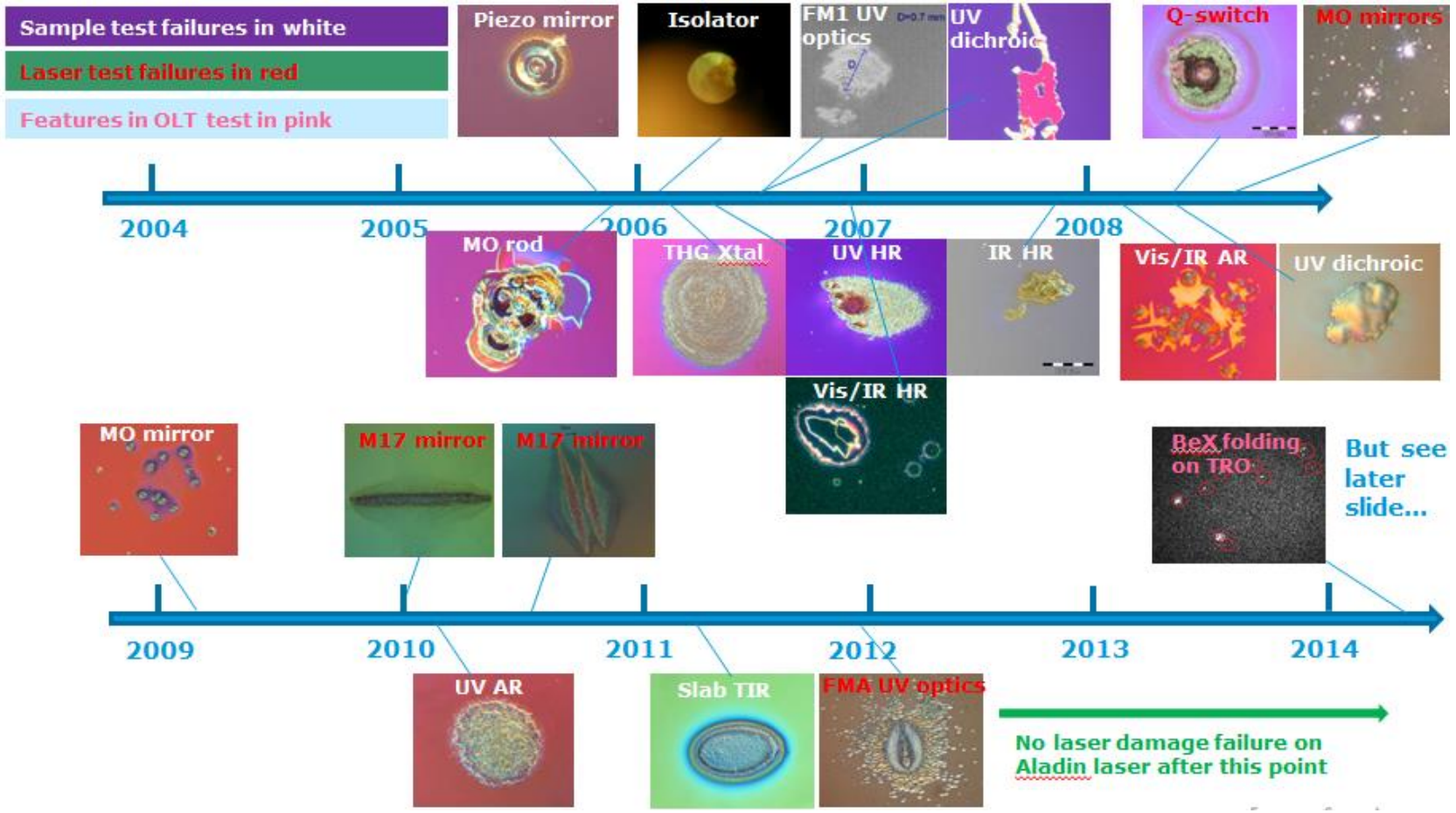
The Aladin lasers' long and winding road in vacuum (2006-2016)



Graph showing the evolution of the "lifetime" of the Aladin laser transmitter in vacuum from 2006 to 2016. It has been very painful!!! (Leonardo)

- **In 2005 Leonardo had produced a laser transmitter with 150mJ output (albeit in air and in "burst mode"**
- **EQM failed after a few minutes in 2006 due to optics misalignment in the MO**
- **FM-1 failed in Jan 2008 after a few hours due to the air-vac shift of the polariser (porous coating) in the MO**
- **FM-1 failed again after a few hours Apr 2008 due to laser damage of the Q-switch**
- **FM-1 failed yet again in Dec 2008 due to LIC reducing the energy by 50% in 6hrs**
- **There were 3 failures of the EM in 2009/2010 due to the settling of the PU interfaces misaligning the MO**
- **The FM-A failed in 2012 due to the evolution of laser damage after 50Mshots**
- **Finally "burn-in" tests were performed on the FM-A (2013) and FM-B (2014) and we had a successful 6 month test of the FM-C (2016)**

Laser damage through the ages



Timeline of laser damage events through the development of the Aladin laser and emission path optics

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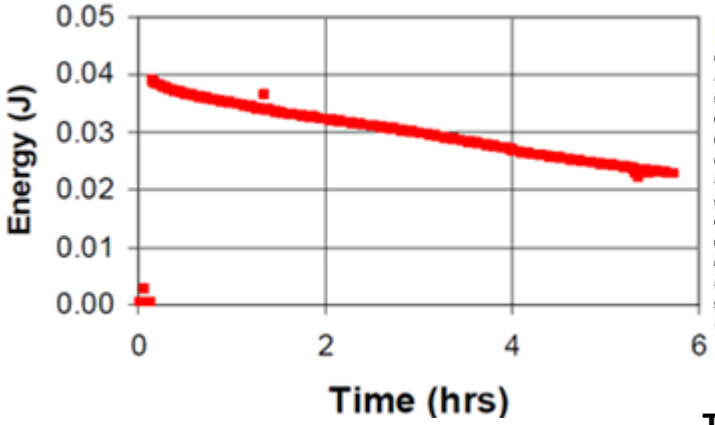
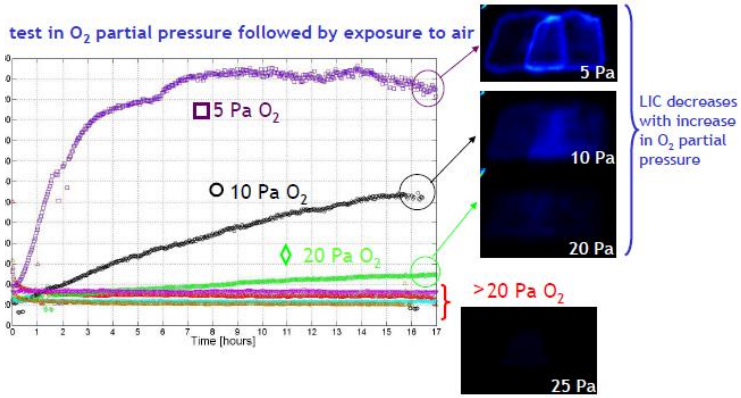
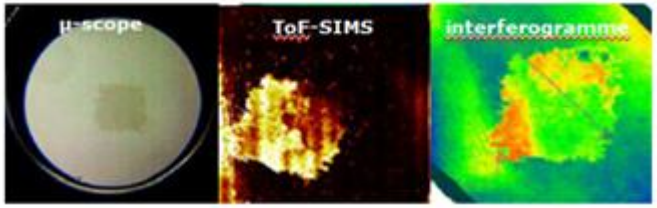
The curse of laser-induced Contamination (2008) and the evolution of the in-situ cleaning system (2010)



Energy of the FM-1 laser in 2008 vacuum test showing 50% drop in the energy in a few hours (Leonardo)



Test using different pressures of O_2 to check what levels would be needed to prevent LIC (TEC-MME, ESA)



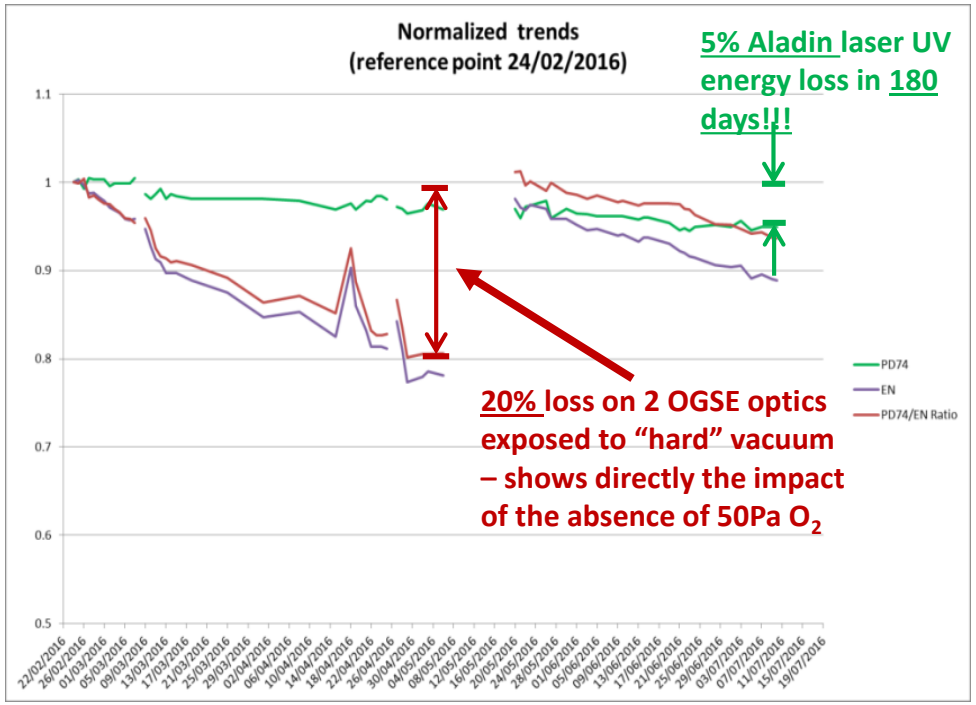
Analysis showing that the degradation of energy was due to LIC in the UV section (Aystorm/TEC-MMO)

The In-Situ Cleaning System (ICS) developed to provide O_2 to the UV high emission path optics and prevent LIC (Airbus)

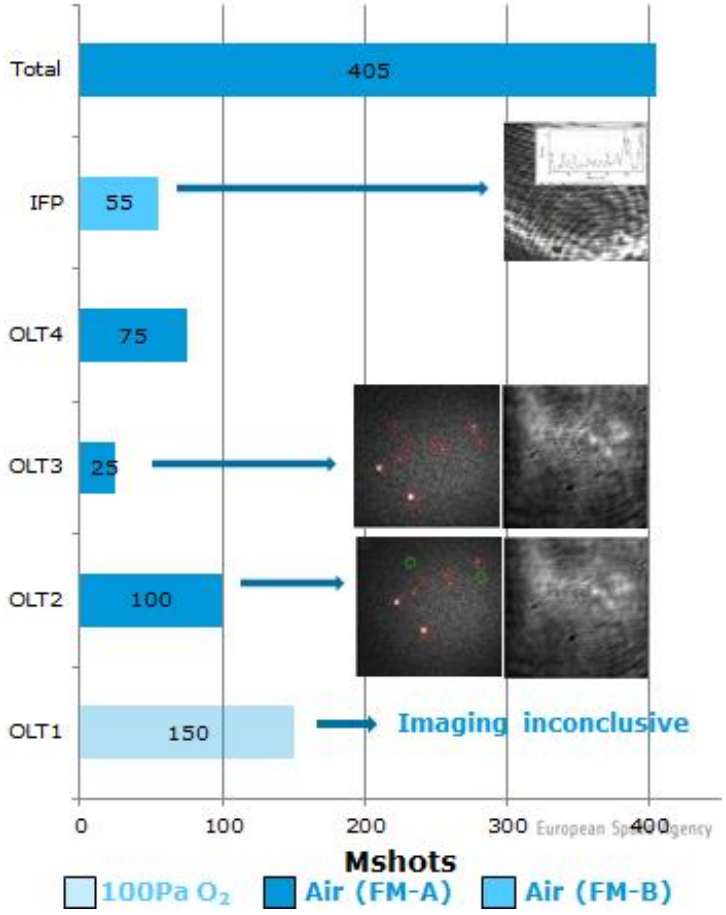
The ICS integrated on the Aeolus satellite

F.E. Hovis et. al. Contamination damage in 1µ pulsed lasers, Proc. SPIE, Vol. 2714 (1996)

Endurance testing at subsystem and system level



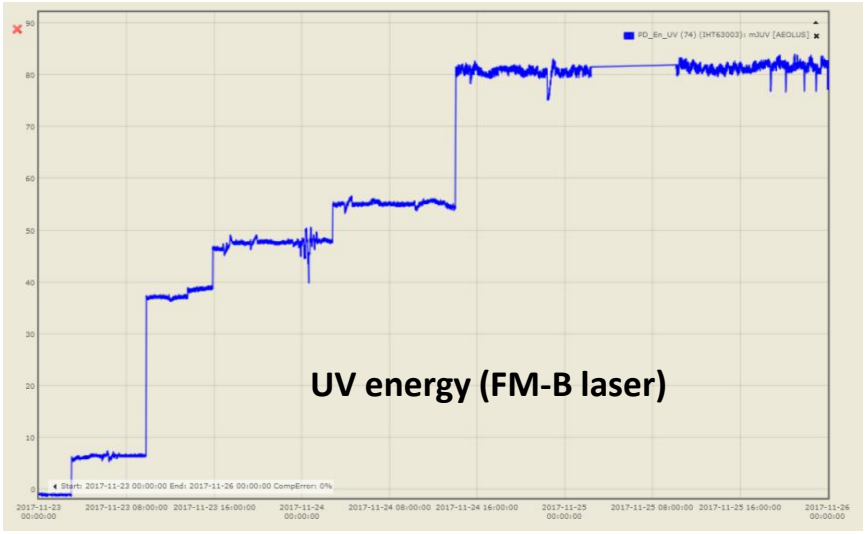
The energy evolution during the Aladin flight spare laser vacuum endurance test with 50Pa O_2 (6 months/800Mshots)

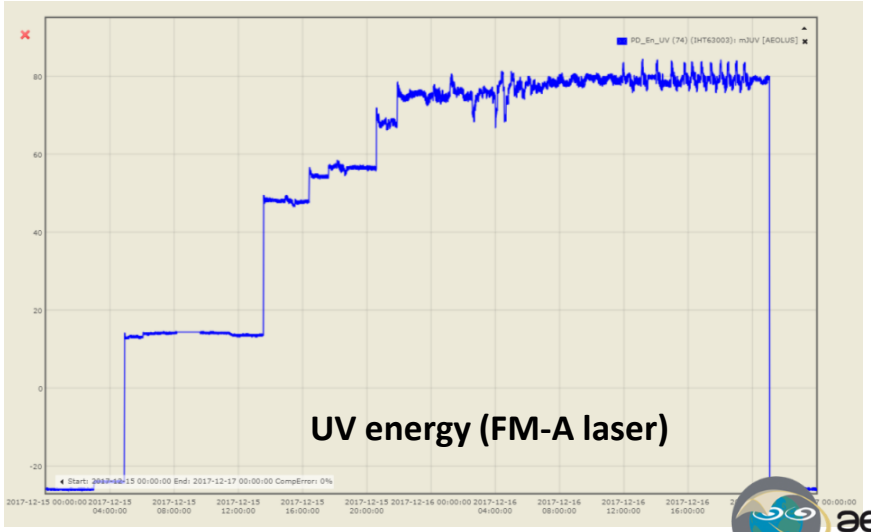


Endurance testing of the rest of the emission path optics in vacuum and in air (Airbus Defence & Space Toulouse)

Note: Lasers tested for total of 1.5Gshots, Emission path for 400Mshots (Leonardo and Airbus Defense & Space) and 1.2Gshots at sample level on ground (TEC-MME ESA)

Satellite level testing
TVAC campaign (Nov/Dec 2017)





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The launch on August 22nd 2018

Roll back of Vega VV12 with Aeolus on the launch pad

Launch of Aeolus from the Guiana Space Centre on August 22nd

Note: we were due to launch on August 21st but the launch was delayed due to high altitude winds!

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Did we do a good job in the end?
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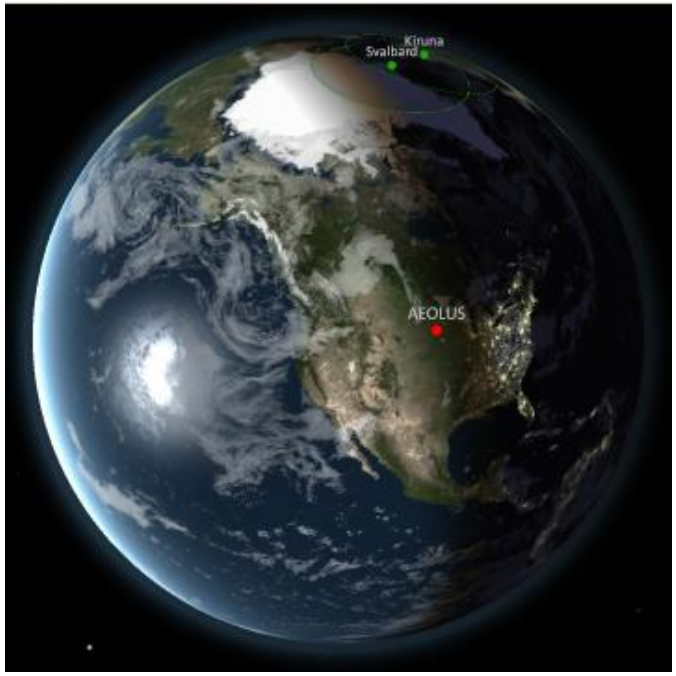

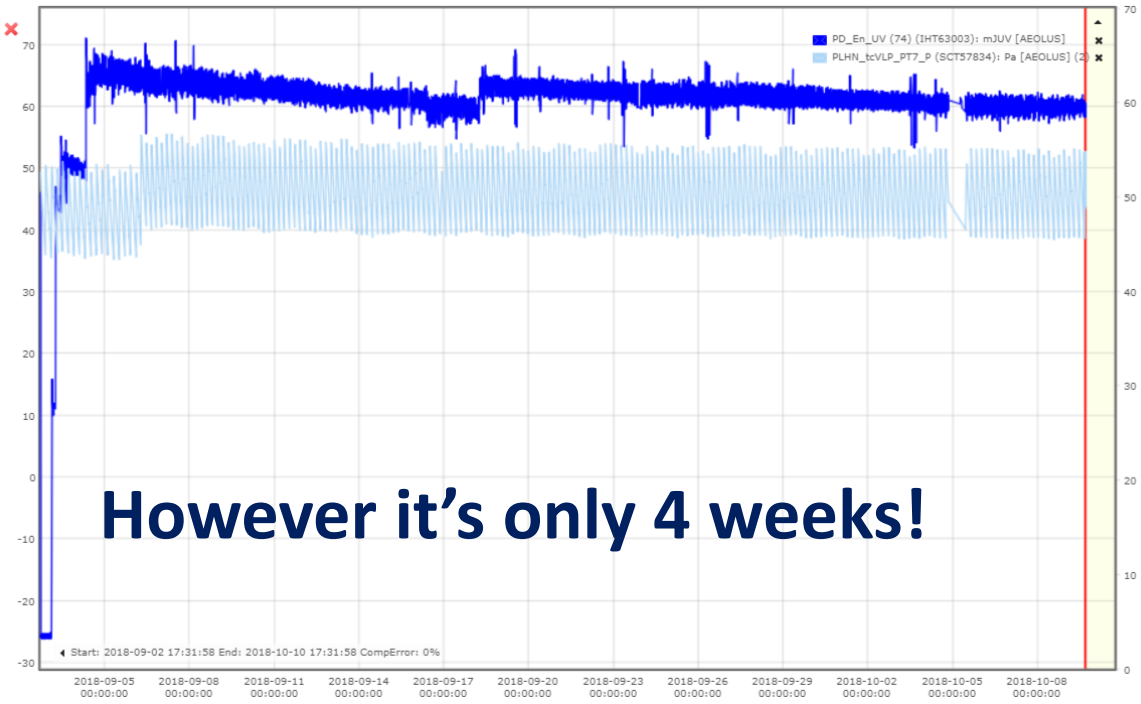

In-orbit results for UV energy (dark blue) and O_2 pressure (light blue)

- **The Aladin FM-A UV energy started around 70mJ and has "settled" around 60mJ over the last month**
- **This is 10-15mJ lower than the performance in TVAC**
- **The ICS is working well in both the laser and emission path cavities**

Did we do a good job in the end?
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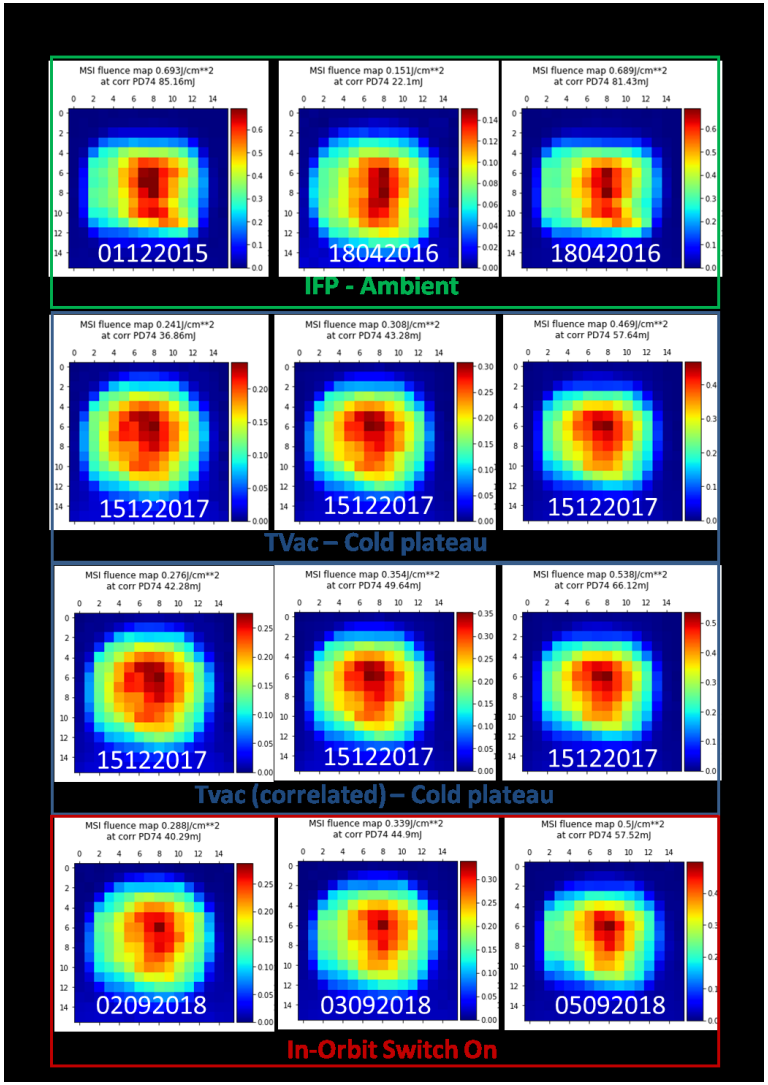

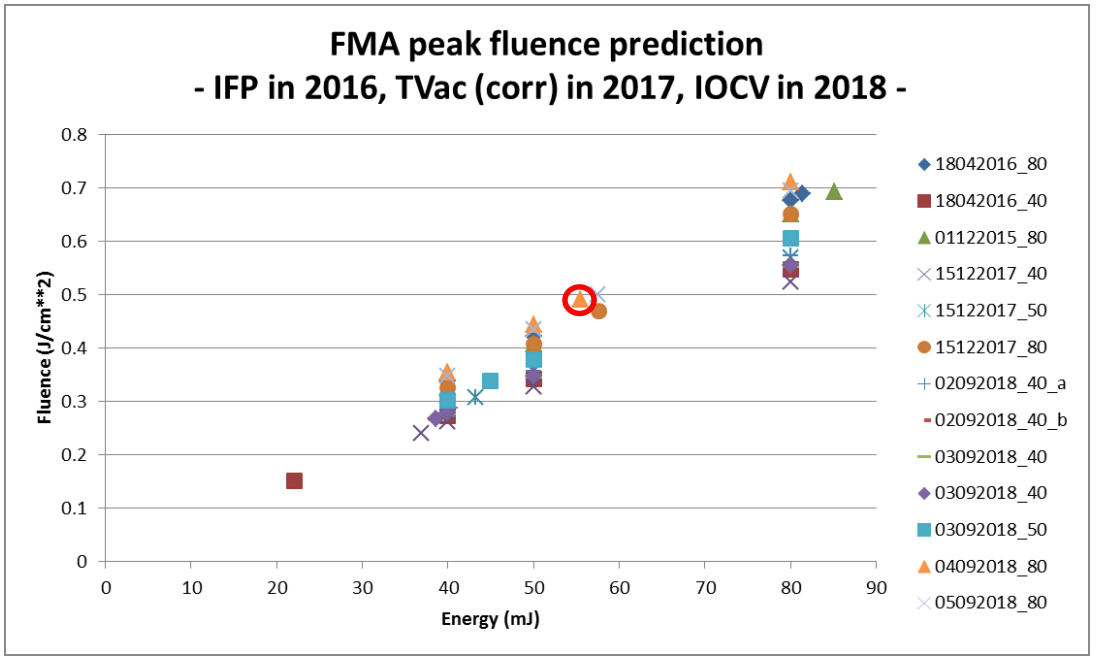

The calculated fluence of the FM-A laser obtained from the low resolution imaging mode of the Mie spectrometer (above) and a collection of near field profiles obtained from the same imaging mode comparing the beams from Instrument Full Performance test, TVAC test and in-orbit.

The comparison of the near field profiles shows that they are similar between TVAC and In-orbit.

Did we do a good job in the end?
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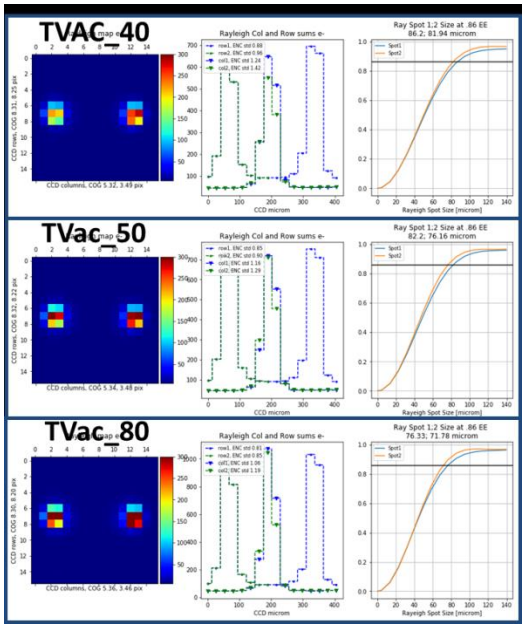

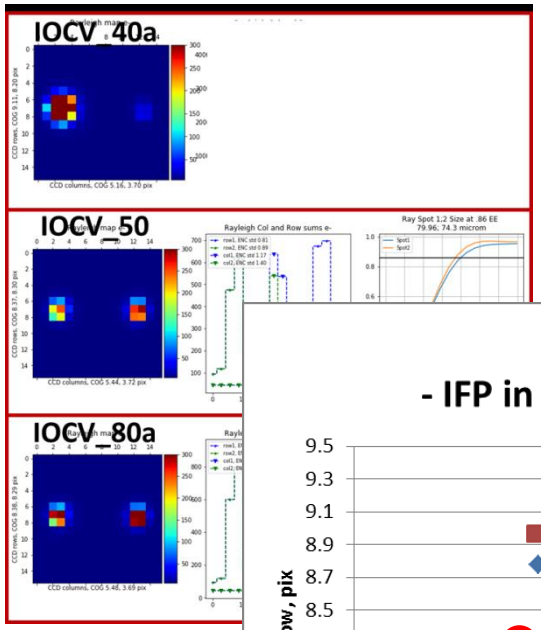

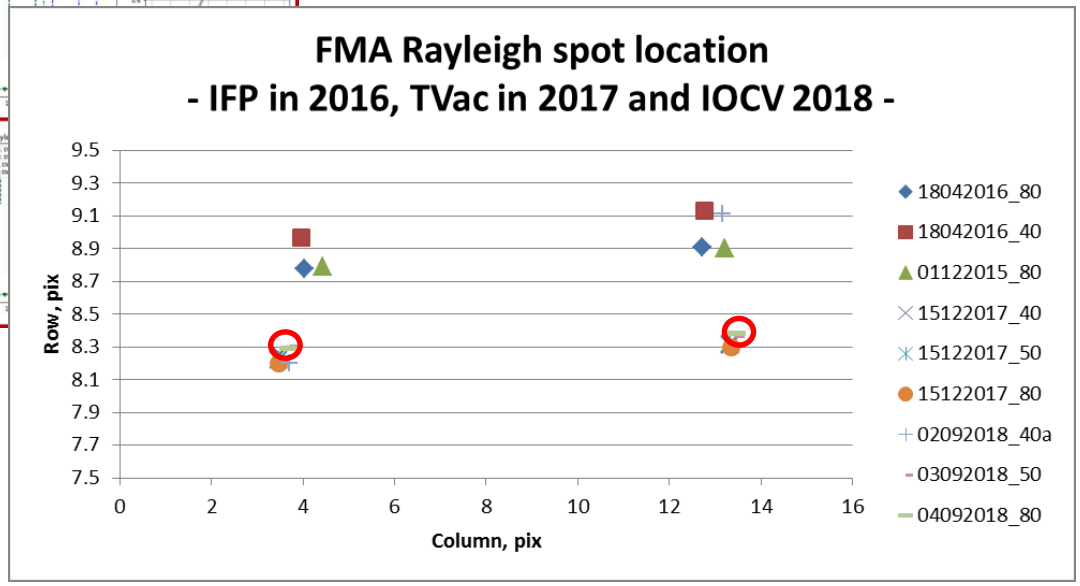

In-orbit Rayleigh spots obtained in imaging mode (above left) and the centroids compared to those obtained in the instrument full performance test and TVAC (above right). After the motion of the spots between IFP and TVAC, the centroids have remained stable indicating that there is no significant change in the Line of Sight.

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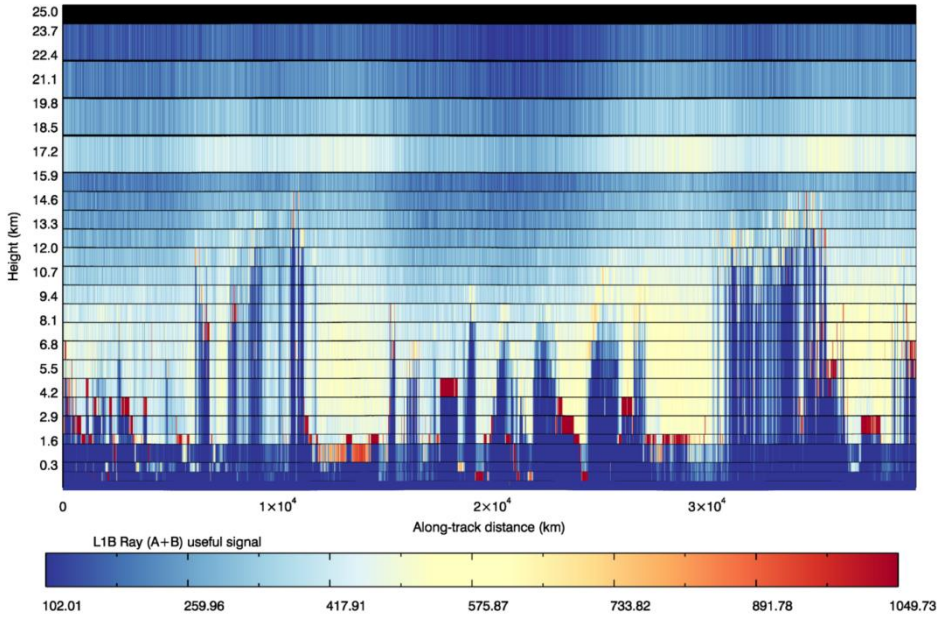
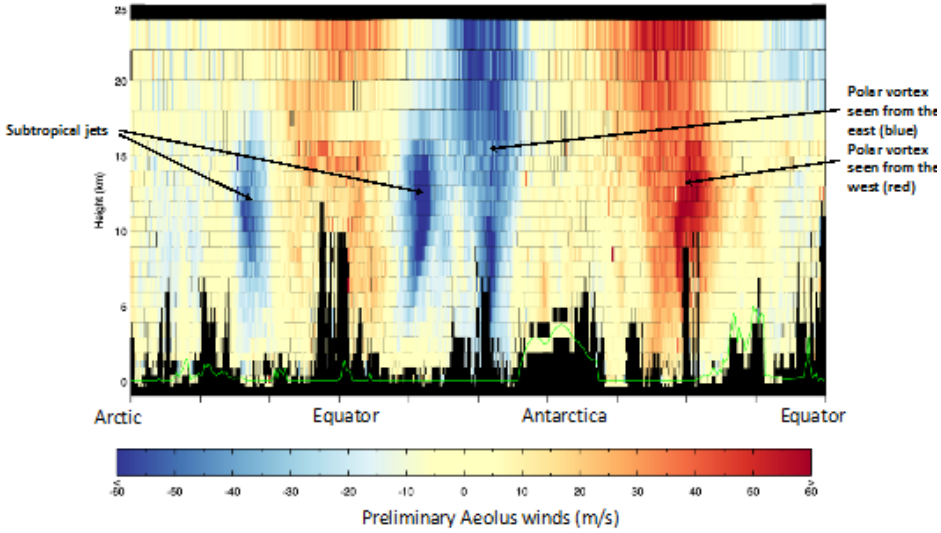
And what about the winds? Aeolus First Glimpse



First light



First winds (courtesy ECMWF)

- Although these results are very promising it is too early to make any conclusions on the impact of the wind data sets yet..
- We need some months of calibration and validation to conclude

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What can we conclude thus far?

- Putting the Aladin instrument into space has proved to be quite challenging but due largely to the resilience, skills and dedication of the various team members over the last 15 years we can say that:
- The nominal laser transmitter has been successfully switched on and the energy is quite stable over the last month in orbit with no signs of LIC or LID.
- The beam profile of the laser measured via the calibration path of the instrument has shown that there has been no significant change in the near field from the TVAC test showing that the instrument has survived the launch with little impact.
- The centroids of the Rayleigh spots have remained stable between TVAC and in-orbit indicating that the laser emission path is still well aligned.
- The instrument is working well and both Mie and Rayleigh spectrometers are successfully measuring global wind returns generating profiles which is a world first. We are measuring the “invisible ocean”.
- We will have to wait and see what the impact of these profiles will be on the NWP models which will take many months of calibration and validation activities which are starting very soon.
- **So far, so good!!**

And who is to blame for all of this?

Laser damage testing:
DLR (Stuttgart), ESA D-TEC labs (Netherlands), Laser Laboratorium (Gottingen), Laser Zentrum (Hannover)

Lifetime testing:
Leonardo (Italy), Airbus Defence & Space (Toulouse), ESA (Netherlands), Laser laboratorium (Gottingen)

Materials analysis:
Aystorm (Stoke), ESA D-TEC labs (Netherlands)

Laser-induced contamination testing and development of the laser cleaning in oxygen:
ESA D-TEC labs (Netherlands), DLR (Stuttgart), Aystorm (Stoke), Airbus Defence & Space (Toulouse)

Coating development/manufacture:
Laseroptik, Layertec , Tafelmeyer, DLR (all Germany), Aystorm (UK), D-TEC labs (Netherlands)

In-situ cleaning system and associated hardware development:
Airbus Defence & Space (Stevenage, Toulouse), Leonardo (Rome and Florence)

General guidance and development strategy (Laser Risk Reduction Working Group):
Laser Zentrum (Hannover), Laser Laboratorium (Gottingen), DLR (Stuttgart), CEA (Grenoble), Institute Fresnel (Marseilles), Aystorm (Stoke), ONERA (Toulouse)
Boulder Laser Damage Conference for many insights and interesting ideas

Post-launch activities:
Airbus Defence&Space, Leonardo, ESA teams

General support over the years:
EOP Directorate ESA, Member states, Mission Advisory Group, Meteorologist, D-TEC ESA

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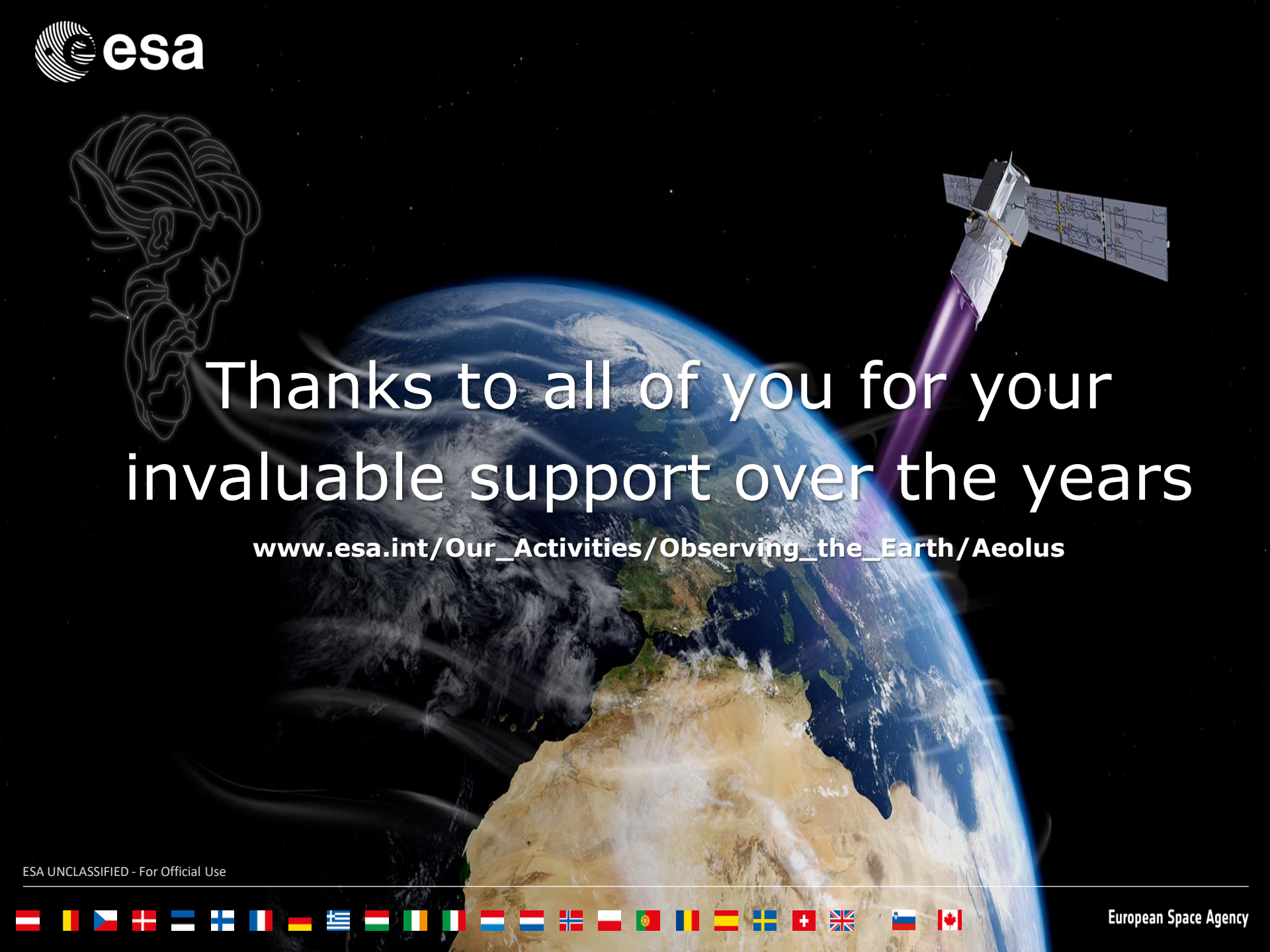

Thanks to all of you for your invaluable support over the years

www.esa.int/Our_Activities/Observing_the_Earth/Aeolus