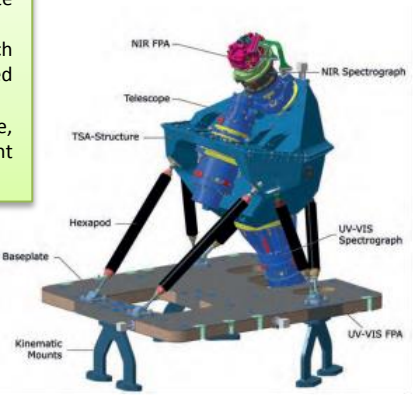
Sentinel-4 – A Geostationary Imaging UVN Spectrometer for Air Quality Monitoring
Integration and Alignment of the Instrument Proto Flight Model

Pierangelo Marenaci[a] (pierangelo.marenaci@airbus.com), Luis Esteras Otal[a] (luis.esteras.otal@airbus.com), Ellart Meijer[a] (ellart.meijer@airbus.com), Jean-Francois Pittet[a] (jean-francois.pittet@airbus.com), Stefan Riedl[a] (stefan.riedl@airbus.com), Sai Shilpa Suram[a] (sai_shilpa.suram.external@airbus.com), Christoph Ehrhart[a] (christoph.ehrhart@airbus.com), Grégory Bazalgette Courrèges-Lacoste[b] (gregory.bazalgette@esa.int), Gerard Bulsa[b] (Gerard.Bulsa@esa.int), Arnaud Pasquet[b] (arnaud.pasquet@esa.int), Giorgio Bagnasco[b] (giorgio.bagnasco@esa.int)

[a]Airbus Defence and Space GmbH, Taufkirchen, Germany. [b]European Space Agency ESTEC, Noordwijk, Netherlands

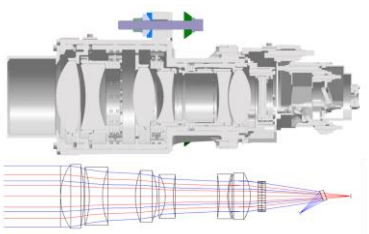
Introduction

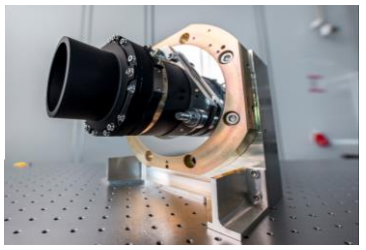
Sentinel-4 is an imaging UVN (UV-VIS-NIR) spectrometer, developed by Airbus Defence and Space GmbH under ESA contract in the frame of the joint EU/ESA COPERNICUS program. The mission objective is the operational monitoring of trace gas concentrations for atmospheric chemistry and climate over Europe. Sentinel-4 will provide accurate measurements of key atmospheric constituents such as ozone, nitrogen dioxide, sulfur dioxide, methane, and aerosol properties.
The instrument is a hyperspectral imager. It is composed of two imaging spectrometers covering the spectral ranges of 305 – 500 nm and 750 – 775 nm and a telescope which projects an image of the Earth onto the slits of the spectrometers. The instrument will be placed in a geostationary orbit, and a 3D spectral-spatial data-cube will be acquired thanks to the mirror scanning in East-West direction.
The Telescope Spectrograph Assembly (TSA) represents the core of the optical system inside the Optical Instrument Module (OIM). It is composed of one common Telescope, two Spectrographs and two Focal Plane Assemblies integrated and aligned into a three-dimensional supporting structure. The TSA is later integrated into the main instrument structure which already includes the Scan Mirror Unit, Calibration Assembly and Front Baffle; thus completing the full optical chain.

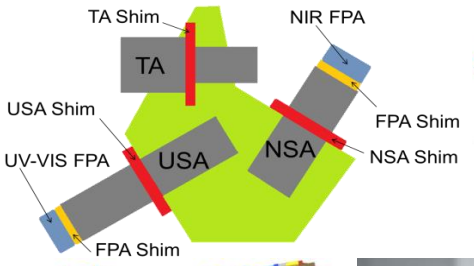


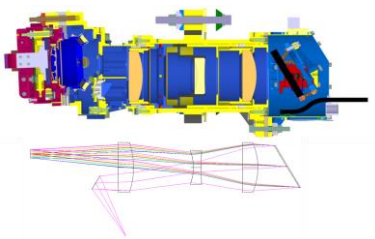
Alignment strategy

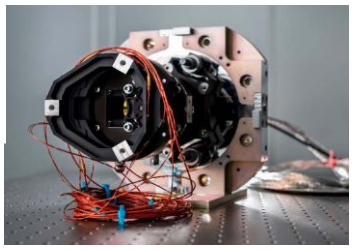
The Telescope Spectrograph Assembly (TSA) consists of three Combined Optical Assemblies (COA) and two Focal Plane Assemblies (FPA) mounted on a three dimensional aluminum structure. In total there are five interfaces that need to be aligned in six degrees of freedom by means of alignment shims. At each interface three degrees of freedom (thickness and tip/tilt angle) are defined by the thickness and wedge of the relative shim that is manufactured with a typical accuracy of 5 µm. The remaining three degrees of freedom (lateral displacement and clocking angle) are adjusted with the same level of accuracy within the range defined by the oversize of the bolts holes.
One of the challenges of the TSA alignment is that the dioptric lens design of telescope and spectrometers in laboratory conditions behaves differently than in operating conditions in vacuum. The reason is the variable refractive index of air, dependent on environmental parameters like pressure, temperature and humidity. The main effect can be described by a geometrical shift in the position of object and image planes, but also a change of other optical parameters such as focal length and magnification. All optical measurements in air require therefore a compensation of the air-to-vacuum shift and the alignment status needs to be verified in vacuum. A specific Optical Ground Support Equipment (OGSE) was developed for the TSA alignment and provides all the necessary capabilities.

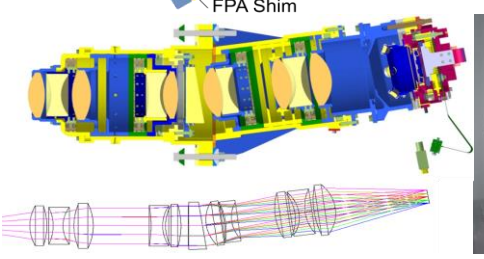


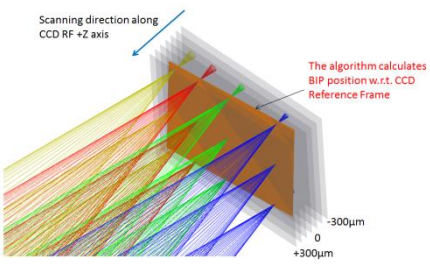


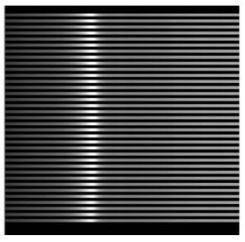


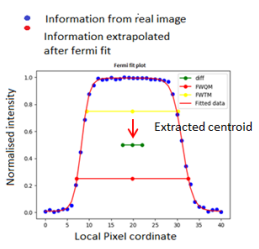


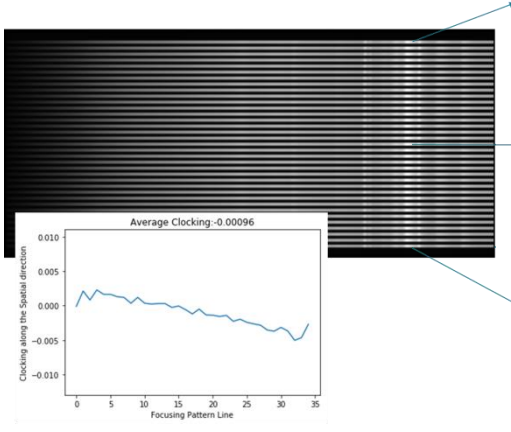


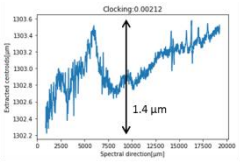


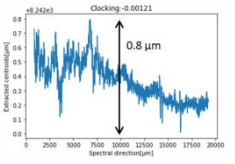


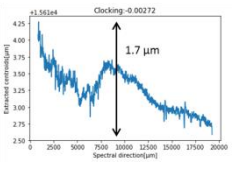


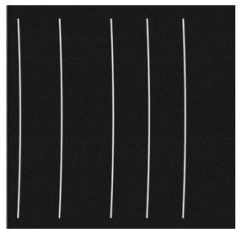












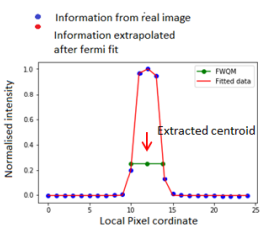


Image processing algorithm

Several test images with a combination of different light sources and targets are produced by the OGSE.
A dedicated image processing algorithm is developed and used to calculate several parameters from the images acquired during the different alignment phases: geometrical (best focus position, centroid coordinates, clocking angles) and optical performance (enslitted energy in spatial and spectral direction, distortion).
Objective of the algorithm is to calculate the input parameters necessary to define the delta-alignment steps and to finally judge the performance achieved by the system in the current alignment status.
Through-focus scans are performed either with the AIT-OGSE CCD or directly with the FPA detector mounted on a specifically developed alignment tool. During the test in the TVAC chamber the FPA detector position is fixed but the scan is performed moving the COL object target along the optical axis.

Test results and current status

The TSA alignment is successfully completed in one step without the need of alignment iterations after verification in vacuum. All the optical performance parameters are measured in operating conditions and are compliant to the alignment target values, with the exception of a marginal deviation measured for the inter-band co-registration.
The TSA PFM has been moved to the next facility for the integration inside the Optical Instrument Module which is already started and will be completed in Q1 2021. The final instrument performance verification is planned for the second half of the year during the calibration and characterization campaign at the RAL facilities, in the UK.