ALTIUS EARTH WATCH ELEMENT: PROJECT IMPLEMENTATION AND STATUS

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ABSTRACT

Altius (Atmospheric Limb Tracker for Investigation of the Upcoming Stratosphere) is a limb sounder mission for the monitoring of the distribution and evolution of stratospheric ozone at high vertical resolution in support of operational services and long term trend monitoring.

The Altius mission will provide detailed stratospheric ozone profiles information at high vertical resolution, which adds valuable information to total column ozone used for data assimilation systems by operational centres based on nadir sounders.

The Altius data will also be of high importance for the atmospheric modelling community, for use as input to climate models and their validation. It will reduce a gap in high-resolution limb observation data. It has the potential to contribute to the GCOS (Global Climate Observing System) ozone profile ECV (Essential Climate Variable). Off-line Altius products are relevant for the validation of the Copernicus Atmosphere Monitoring Service (CAMS) model. Other secondary products, such as Aerosols extinction, will be provided as well for scientific interests. The geophysical validation of the different Altius products will provide also valuable scientific opportunities.

The Altius mission is under implementation by ESA within its Earth Watch Programme, with participation of Belgium, Canada, Luxembourg and Romania. Based on the innovative Proba-Next (P200) platform, developed by QinetiQ Space in Belgium, the Altius satellite embarks an optical instrument made of three independent channels (VIS, UV and NIR) to observe the Earth limb through a field of view of 100 km x 100 km, measuring scattered Sun light (bright limb) and atmospheric attenuation (Solar and stellar occultation mode) in order to retrieve ozone and other atmospheric species. The Altius instrument's three hyperspectral channels are based respectively on Acousto-Optic Tuneable Filters (AOTFs) in the Visible (440-675nm) and NIR (600-1020nm) range, and a cascade of Fabry Perot Interferometers (FPI) in the UV (250-355nm). The use of tuneable active spectral filter shall allow the Altius instrument to perform observations with a spectral resolution ranging between 1nm and 10nm in an extremely versatile operational concept.

This paper will present the Altius mission main objectives and constituting elements (platform, instrument, PDGS), focusing on the innovations and new technologies flying on-board the satellite platform and instrument, and the current project development status and plans.

1 INTRODUCTION

1.1 Mission Background and Objectives

The ozone layer is a natural layer of gas in the upper atmosphere. Stratospheric ozone acts as sunscreen, absorbing much of the ultraviolet radiation in sunlight before it reaches Earth's surface - hence playing a vital role in protecting life on our planet.

In the 1970's, scientists discovered that the ozone layer was being depleted, particularly above the South Pole, resulting in what is known as the ozone hole. To address the destruction of the ozone layer, in 1987, the international community established the Montreal Protocol on ozone-depleting substances.

The global consumption of ozone-depleting substances has since reduced by about 98%, and the ozone layer is showing signs of recovering. However, it is imperative that concentrations of stratospheric ozone are monitored continually, to not only assess the recovery process, but also for atmospheric modelling and for practical applications, including weather forecasting.

While ozone depletion is not a major cause of climate change, the two are nevertheless linked. Firstly, ozone absorbs Solar ultraviolet radiation, which heats the stratosphere. Secondly, it absorbs infrared radiation emitted by Earth's surface, effectively trapping heat in the troposphere. Therefore, how ozone effects the atmosphere depends on its concentrations at different altitudes.

Satellites are the only way of measuring recovery and change in a consistent and systematic manner. Most ozone-measuring satellites, such as the Copernicus Sentinel-5P mission, provide a value for the amount of ozone in a column of air from the ground (or just above the ground) to the top of the atmosphere. In conjunction, profiles, which show concentrations at different altitudes, are also needed to gain the full picture. Since the end of ESA's Envisat mission, there are only a few instruments in orbit that provide profiles of ozone, and some of these missions will end in the next few years.

The Altius (Atmospheric Limb Tracker for Investigation of the Upcoming Stratosphere) mission fills this important gap in the continuation of "limb" measurements for atmospheric science, by monitoring the distribution and evolution of stratospheric ozone at high vertical resolution. This will be achieved by an innovative limb sounder flying on a small spacecraft in a Sun-synchronous orbit. The payload consists of three optical channels in the UV, VIS and NIR spectra which can provide 2D images of Earth's limb at specific wavelengths.

The Altius mission objectives are split into:

- primary objectives, to observe the global distribution of stratospheric ozone at high vertical resolution in support of operational services in near-real time and to contribute to stratospheric ozone long term monitoring targeting ozone monitoring,
- secondary objectives, addressing mesospheric ozone, other atmospheric constituents, temperature and ozone tomography, for scientific studies related to ozone chemistry, climate change and atmospheric dynamics.

1.2 Mission Requirements

The Altius mission requirements are also divided into primary mission requirements (PRI) and secondary mission requirements (SEC). The secondary mission requirements should be achievable with the same input data as provided for the primary mission requirements (at Level 1). The development of these data products is of high scientific interest but they will be treated as complimentary mission extensions and will not be the drivers of the mission design.

For the primary mission requirements, all the uncertainty values are based on the identified user needs presented in [3] and summarised in Table 1 below:

The first requirement is the generation of product containing vertical concentration profiles of stratospheric ozone (between 15 and 45 km altitude) on a global scale with a 3-day near repeat cycle and full latitude coverage every 200 km along the orbit. This Level 2 data product shall be available within 3 hours after sensing and be made available to Numerical Weather Prediction Centres.

The second is to generate products to contribute to ozone profiles climatologies with high accuracy

(3% goal, 10% threshold) vertical concentration profiles of stratospheric ozone (between 20 and 45 km altitude) on a global scale with a 3-day near repeat cycle and full latitude coverage every 200 km along the orbit. This level 2 data product shall be available within 4 weeks after sensing.

The third requirement is to generate profile data in ozone hole conditions, to contribute to determining spatial gradients across and along the polar night vortex, to efficiently detect screening by polar stratospheric clouds (PSC) and correlated effects.

Component	O_3	O_3	O_3
Altitude range [km]	15-45	20-45	15-45
Target vertical/across-track resolution [km]	0.5 / 50	0.5 / 50	1 / 20
Threshold vertical/across-track resolution [km]	1 / 100	1 / 100	2 /100
Along-track sampling [km]	200	200	NA
Target uncertainty [%]	5	3	10
Threshold uncertainty [%]	20	10	30
Target absolute uncertainty [ppbv]	50	50	50
Threshold absolute uncertainty [ppbv]	100	100	100
Coverage	Global	Global	Polar
Data latency	< 3 hrs	4 weeks	4 weeks

Table 1: Altius Primary Mission Requirements

1.3 Mission Design

The Altius mission, using an approach previously developed in the frame of the ESA Proba missions, has been conceived from the beginning as an end-to-end mission, involving all mission elements in the evaluation of design options, starting from the early project's development phases. Figure 1 below shows the various elements of the Altius mission and their interactions.

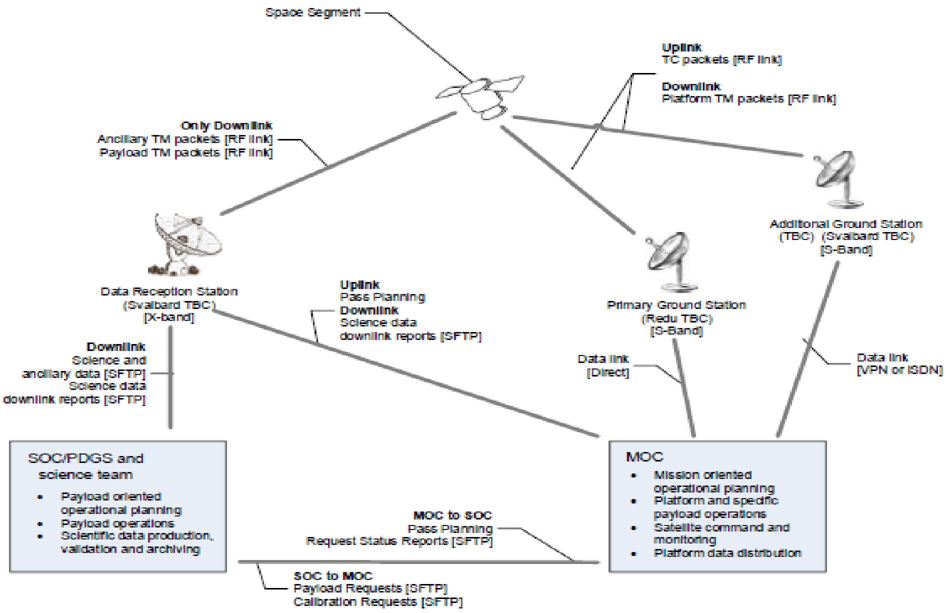

Figure 1: Altius Mission Elements

Space Segment

The Altius space segment, developed under Prime contractorship of QinetiQ Space nv (QS) (B), is composed of the Proba-Next platform and the Altius Instrument.

Altius foreseen operational orbit is a 668 km circular polar quasi Sun-synchronous frozen orbit, with a LTDN of 10:30 AM at launch time. The orbital parameters at injection have been optimized to limit the LTDN variation, due to orbital plane's drift, within 30 minutes, during the 5 years (extended) mission's lifetime, with a minimal need for orbit maintenance.

Ground Segment

Located at the ESA Redu Ground Station at ESEC, in Belgium, the Mission Control Centre (MCC), developed by Spacebel (B) under the responsibility of QS, is in charge of the satellite commanding and control through two S-Band communication links per day.

Thanks to the extremely high level of automation implemented in the MCC's functionalities, most of the passes can be realised unmanned, allowing to require station manning for the monitoring of the satellite only during normal office hours, while at the same time maintaining a level of availability required by the operational nature of the Altius mission.

Beside the MCC, the Ground Segment is composed of the Redu Proba antennas' system, complemented, during the Launch and Early Operations Phase (LEOP) and the early part of the system commissioning, by antennas in Kourou and at Northern latitudes, for contact opportunities' increase.

The Altius instrument data will be downlinked, in X-Band, through a network of Data Retrieval Stations' (DRS) antennas located at high Northern latitudes, at a pace of more than 14 contacts per day (to maximise the amount of data that can be processed and transmitted to the Users' community within three hours after imaging). The downloaded data, in excess of 40 GBytes each day, are then automatically transmitted over a normal Internet link to the Payload Data Processing System, located at B.USOC in Uccle (Belgium) where the mission's Payload Data Ground Segment (PDGS) is located, for further processing.

Payload Data Ground Segment

Upon reception of the downlinked Altius Instrument data, the Payload Data Ground Segment (PDGS), developed under Prime contractorship of Spacebel (B), is in charge of de-commuting and processing them, up to the final product (from Level 0 up to Level 2), and located, together with the data distribution and archiving facilities, as well as the Mission Performance Centre (MPC), permanently checking the distributed product, at B.USOC, in Uccle, Belgium.

To support the data products' quality, regular calibration campaigns are programmed in the PDGS, for autonomous on-board execution. This process is initiated by the PDGS' operator through the Scientific Mission Planning tool, allowing to schedule both calibration campaigns and instrument imaging as well as to change the Altius instrument's settings. The Scientific Mission Planning tool automatically transmits any new request to the MCC. In turn, the MCC generates autonomously a new schedule of activities to be uplinked on-board the satellite at the next ground pass.

Launch and LEOP

The Altius spacecraft will be launched from the Guyana Space Centre (CSG) in Kourou, as a co-passenger on-board a Vega-C multi-payload flight planned in mid-2025, and directly injected into its operational orbit.

After separation from the launcher, the spacecraft will be automatically powered on, enter safe mode, and start de-tumbling, reducing the separation angular rate. The solar arrays will be deployed, a nominal attitude acquired providing a stable power and thermal environment, and the propulsion system made ready for operations.

After conclusion of the LEOP, envisaged to last no longer than 48 hours, the functional and performance commissioning of the entire system (platform, instrument and ground segment) will be completed, followed by payload calibration and full PDGS commissioning, prior to start of Altius nominal operations.

2 THE PROBA-NEXT PLATFORM

The Altius spacecraft platform is based on the Proba-Next (P200) general purpose platform, developed and qualified by QinetiQ Space nv (QS) in the frame of the ESA GSTP Programme, tailored to the specific needs of the Altius instrument and mission profile.

Based on the heritage and lessons learnt from Proba-1, Proba-2 and Proba-V, the Proba-Next (P200) platform has inherited many (hardware and software) technological choices of its predecessors, however improving a number of elements, to further increase platform's and system's flexibility to match requirements of different, and more demanding, missions scenarios, to ensure compatibility with different launchers and payload typologies, and to augment resources available on-board to embarked payloads.

2.1 Structure and Propulsion

The Proba-Next general purpose platform's body and structure is designed to maximise the separation between platform module and embarked payloads, in terms of mechanical interfaces and structural and thermal de-coupling between the two elements. This with the goal to minimise mission tailoring engineering needs and maximise separation of development and verification activities of the two elements, including minimising integration complexity between platform and embarked payloads.

In terms of volume, mechanical environment and interfaces, the Proba-Next spacecraft is designed to be compatible, between other launch options, with a dual launch configuration inside a Vega-C/Vespa+R carrying system, as well as various multi-payload configurations available for the Vega-C SSMS option, ensuring compatibility with virtually all launch options foreseen for secondary payloads on the Vega-C launcher.

Remaining very compact in stowed configuration (fitting, in some configurations, within a 800x800x1200 mm^3 volume, including the payload module) while allowing a maximum power generation in excess of 600 W (depending on the efficiency of the selected solar cells/PVA), the Proba-Next's main platform module is based on a load bearing frame structure, shaping a rectangular volume, built on aluminium honeycomb panels, accommodating all bus units inside the bus structure and foldable, to allow high accessibility to all units during all phases of the satellite's integration.
The main platform body is complemented by two deployable Carbon Fibre Re-enforced Polymer (CFRP) honeycomb solar panels wings with, in the Altius mission application, two panels per wing.

The bottom board, interfacing with the launcher, carrying the launch loads to the main body of the satellite, and incorporating all the propulsion system's elements, is, similarly to all its predecessors, in milled aluminium alloy.

The hydrazine-based blow-down propulsion system is based on four Nammo MHT-1 1 Newton thrusters, capable of delivering dV in excess of 80 m/s, sufficient for the Altius mission's debris mitigation (end-of-life disposal/de-orbiting) requirements and the mission's extended lifetime's orbit maintenance and collision-avoidance needs.

The Proba-Next platform's dry mass, depending on the mission configuration, can be as low as 150 kg, and support payloads up the 100+ kg range. In the Altius mission configuration, the total wet satellite mass is ~275 kg, including an instrument mass of ~70 kg.

2.2 Avionics

The Proba-Next avionics system and bus are built around the third generation Advanced Data and Power Management System (ADPMS3), developed and manufactured in line with the applicable ECSS standards, in the frame of the ESA GSTP Programme, in parallel to Proba-Next by QinetiQ Space nv (QS), and currently undergoing its final stages of qualification.

The fully redundant ADPMS3 set of avionics is constituted by the on-board computer (OBC), the power conditioning and distribution unit (PCDU), the remote terminal unit (RTU) and the mass memory unit (MMU - developed by Deltatec as QS Subcontractor) of the Proba-Next platform, and is based on a fully modular and expandable avionics system architecture, to be compatible with a wide variety of mission scenarios' and payloads' needs.

The ADPMS3 OBC is based on the LEON3 dual-core processor and supports both analogue and digital I/O I/F (UART/RS422, MIL-1553, SpaceWire, JTAG) to peripherals and units, and PPS inputs and outputs for overall precise time management and distribution.

The OBC design and redundant architecture, coupled with the adopted OBSW implementation, allow an autonomous and complete system re-initialisation and nominal operational mission continuation, with no interruption or need of ground contact, also after major detected anomalies potentially requiring a system reboot.

The PCDU, at the core of the spacecraft's power management system, is scalable and capable of managing continuous power in excess of 600 W as, for example, in the Altius configuration.
Its design (as well as that of the satellite's power system) is fully compliant with the applicable ECSS end-of-life passivation guidelines and regulations, and providing protected and fault-tolerant power distribution to all platform equipment and payloads and battery protections, capitalising on architecture and detailed design features proven effective, on ground and in flight, in the previous ADPMS and Proba satellites.

The fully redundant (modular) RTU, also relying on architecture and detailed design features inherited from the previous ADPMS and Proba satellites, is dedicated to the interfacing and the detailed management of the propulsion system and all its constituents (pressure transducers, latch valves, flow control valves, catalytic beds heaters, etc.. The RTU is also used for interfacing with the spacecraft's magnetotorquers and satellite's deployables' hold-on and release mechanisms, as well as of the satellite's thermal control system's heaters.

The redundant MMU, with a storage size of 512Gbits on each lane, is used for storage and forwarding to the X-Band Payload Data Transmission (PDT) system of scientific and housekeeping data generated by payloads, instruments and units directly connected to the MMU through SpaceWire high speed (100 Mbps) links. In addition, the MMU is used for storage and forwarding to the X-Band PDT system of housekeeping data generated by the platform or by embarked payloads not directly connected to the unit's SpaceWire I/Fs, and is serving as commanding/monitoring interface and for dissemination of clock synchronisation pulse (PPS) to connected payloads, instruments and units.

The rest of the satellite avionics, fully redundant at unit level, is composed of:

- A set of redundant EWC-40 GNSS receivers, delivered by Syrlinks (France),
- An internally (cold) redundant star tracker fitted with three (hot redundant) optical heads (integrating micro inertial measurement units – when needed for mission agility needs), from

DTU (Denmark),

- Three internally redundant magnetotorquers, organised in an orthogonal configuration, manufactured by Zarm (Germany),
- Two 3-axes magnetometers (in cold redundancy) from DTU (Denmark),
- Four (including one redundant) reaction wheels, in a tetrahedral arrangement, supplied by MSCI (Canada),
- Two EWC-29 S-Band transceivers, with hot redundant receivers (via NSO lines from the PCDU) and cold redundant transmitters, from Syrlinks (France),
- Two (cold redundant) EWC-28 X-Band transmitters with variable output power set point, developed with Syrlinks (France).

2.3 On-Board Software

The ADPMS3 LEON3 processor is running the on-board software (OBSW), developed by Spacebel (B) around the RTEMS V15 real time operating system. The platform and system management elements of the OBSW are largely exploiting the previous Proba's OBSW developments and re-using several services already available from the Proba-V and Proba-3 OBSW developments, as well as largely re-using units' managers, for common units. On the other hand, mission specific modules, like for example the software mission manager and the instrument manager, are being specifically developed and tuned for the Altius mission application.

The Proba-Next OBSW is fully in line with the ESA Packet Utilisation Standard (PUS), and is being designed and implemented to provide the system with a very high level of on-board autonomy. It is capable of handling the routine mission (nominal observations and calibrations, including all related manoeuvres) completely on-board, only interacting with the ground segment for the downlink of science data and for the acquisition of new on-board activities' schedules. Besides this, a large quantity of possible on-board anomalies can be handled without ground intervention, due to integrated Failure Detection, Isolation and Recovery (FDIR) capabilities, allowing system automatic reconfigurations, to ensure continuity of scientific data acquisitions, as long as a minimum set of required units is available.

The OBSW is fully re-configurable and can be partially or completely patched and uploaded in flight, with virtually no interruption of nominal operations.

The System Modes have been simplified to the maximum extent (Figure 2). The satellite being in most of the time in Nominal Observation Mode except when calibrations of the Altius instrument are required, for which the satellite enters Calibration Mode. While in system Nominal Observation Mode, however, the platform and the instrument are autonomously handled by the OBSW, on the basis of inputs generated by the AOCS SW (integrated in the OBSW and developed by NGC - Canada), to optimise on-board resources and performances handling, with autonomous toggling between bright limb observations, Solar observations (when the Sun is visible through the atmosphere) and stellar observations (to observe, when in eclipse, stellar rises, sets or transitions through the atmosphere), and interleaving Sun pointing attitudes to maximise power generation when no instrument imaging is requested and with autonomous powering on and off of AOCS units when not needed, for power demand reduction.

Calibration Mode will be used to handle the calibration requests sent from ground, requested for instrument calibration purposes, or for scientific or demonstration purposes scenarios. The satellite will be commanded from Observation Mode and will go back to this same mode after finishing the calibration request.

The different calibration scenarios will require, next to the nominal satellite's pointings, also Earth target pointing, Nadir pointing, and Full Sun, full Moon or dark sky imaging profiles. In addition, the satellite's platform and payload are capable of supporting a "tomography mode", where the payload images the air mass already imaged on the previous orbit under a different viewing angle. This requires a side-looking mode with an azimuth profile to reorient the satellite to the air mass during the bright limb.

For each calibration request, a specific platform and instrument scenario is applicable. The platform scenarios will provide the correct pointing (fixed or dynamic) to perform the calibration request, while the instrument scenarios will provide the correct observations with the correct instrument's channels and settings.

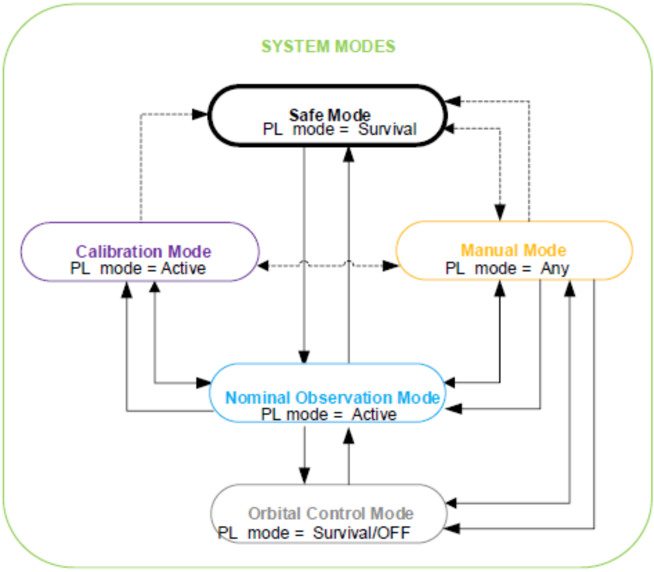

Figure 2: Altius System Mode Transition Diagram/Altius System and Instrument Modes

2.4 Attitude Determination and Control Accuracies

The stringent requirements specified for the Altius spacecraft, derived from the mission scientific needs and instrument imaging requirements, and requested to be applicable for each imaging session and for all observation geometries and diverse pointing profiles, and listed in Table 2 below:

	Parameter	Requirement [mrad]	Timescale [s]	Comments
APE	RY	2	N/A	Absolute angular distance between the actual pointing and the target value on the specified timescale.
	RX	2		
	RZ	2.5		
AKE	RY	0.1	N/A	Absolute error on the estimation of the pointing on the specified timescale.
	RX	1		
	RZ	2.5		
RPE	RY	0.1	1	Difference between the actual pointing error and the MPE on the specified timescale.
	RX	1		
	RZ	2.5		
RKE	RY	0.1	1	Difference between the instantaneous error on pointing estimation and MKE on the specified timescale.
	RX	1		
	RZ	2.5		
RPE	RY	0.1	10	Difference between the actual pointing error and the MPE on the specified timescale.
	RX	1		
	RZ	0.25		
RKE	RY	0.1	10	Difference between the instantaneous error on pointing estimation and MKE on the specified timescale.
	RX	1		
	RZ	0.25		

Table 2: Altius Space Segment Pointing Requirements

directly transformed into different sets of critical pointing performance to be satisfied by the platform while imaging in the different AOCS Modes (e.g. Limb, Sun, Inertial, Orbital, Earth Target, Stellar Occultation, etc.), the most stringent of which, needed for limb looking and stellar occultations, are listed below:

- Attitude Knowledge Error (AKE): 5 arcsec (95% confidence level)
- Absolute Performance Error (APE): 25 arcsec (95% confidence level)
- Relative Performance Error (RPE): 3 arcsec over 1 s (95% confidence level)

and, as also proven in the frame of the previous Proba's missions experiences, considered to be within the reach of the platform AOCS achievable performances.

In addition to very accurate guidance and pointing performances during all imaging scenarios and profiles, the Altius AOCS subsystem is also required to provide sufficient agility to enable 5 to 10 stellar occultation acquisitions during each eclipse.

3 THE ALTIUS INSTRUMENT

The Altius Instrument is integrated on top of the Proba-Next platform. The payload is composed of the UV and VIS/NIR optical benches, which contain all optical elements and three Channel Control Units (CCU's), placed next to the bench, which contain most of the Instrument electronics and control system. The Altius payload general layout onto the platform is shown in Figure 3.

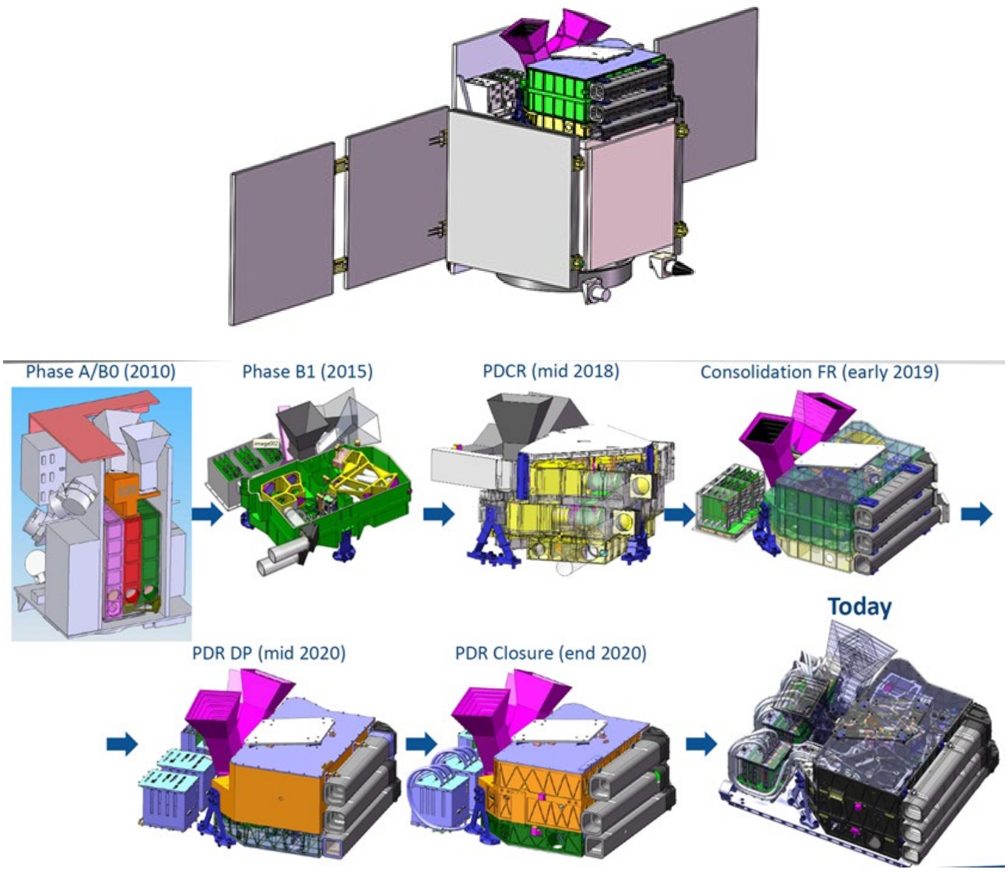

Figure 3. (top) Illustration of the Altius Instrument on top of the Proba-Next Platform; (bottom) Altius Instrument design evolution to today

The Altius Instrument integrates three independent hyperspectral channels observing the limb respectively in the UV (250-355nm), the Visible (440-675nm) and the NIR (600-1020nm) spectral range. In order to fit to tight volume constrains, the optical benches are developed based on a modular and compact concept. Each bench containing an optical channel, they are stacked on top of each other and co-aligned while can be seen as individual units with their own independent control electronics.

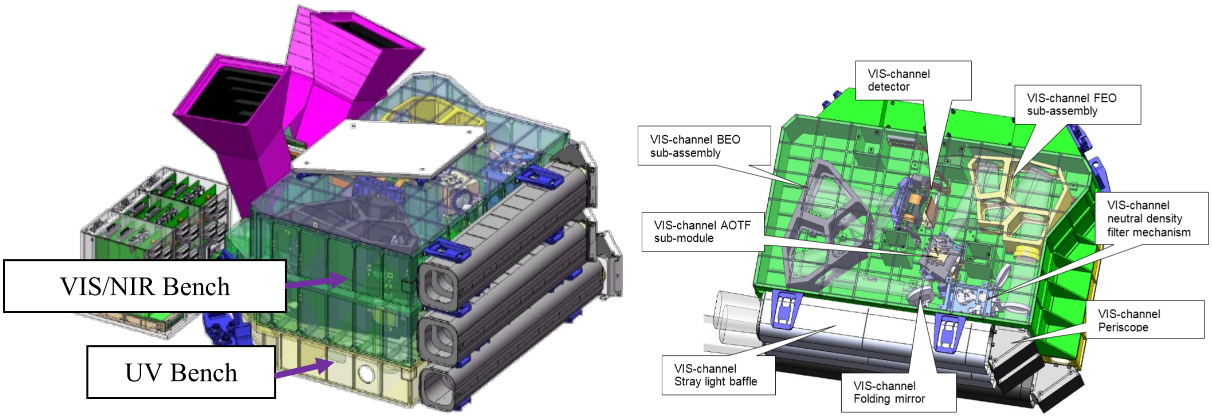

Figure 4. (left) Altius optical benches; (right) internal VIS channel layout

Each channel is based on a reflective optical design and contains the following main optical elements:

- A front baffle to protect the Instrument from out of field stray light;
- A front periscope mirror which is allowing fine co-alignment of the different Instrument Lines Of Sight (LOS's);
- A Front End Optics (FEO) Module that collects the light and passes it to the spectral filter;
- A tunable spectral filter which enables to select the required wavelength band (AOTF in the VIS and NIR, Fabry Perot Interferometer in the UV);
- A Back End Optics (BEO) Module that forms an image of the selected spectral band in the observed scene onto the detector;
- The Focal Plane Assembly, which consists of the detector and its proximity electronics (i.e. ADC and serializers).

The optical design is conceived such that each channel complies with the requirements summarized in Table 1 together with very challenging SNR requirements. In addition, to cope with the large dynamic range between limb, stellar and solar occultation, it was necessary to foresee in each channel the possibility to match the radiometry of the sun scene to the high sensitivity of the Instrument required for the limb preventing saturation effects. This is done in each channel, by means of a mechanism which is integrating a neutral density filter positioned every orbit prior to solar occultations and removed at the end of the sun observation.

Table 3. Key requirements applicable to the Altius Instrument

Parameter	**Value**
Observation modes	Occultation modes (Stellar and solar) Bright limb mode
Observation type	Direct 2D hyperspectral imaging

Spectral range channels UV VIS NIR	 250 - 355 nm 440 - 675 nm 600 - 1020 nm
Spectral resolution UV VIS NIR	 2.5 - 10 nm (varying with wavelength) Better than 10 nm Better than 10 nm
FOV1 for UV Stellar Occultation (low light levels)	6.3 mrad at least
FOV2 for UV Bright Limb (high light levels)	34 mrad (1.95°)
FOV3 for VIS/NIR channel (low/high light levels)	35 mrad (2.00°)
Volume of the optical bench (approximately)	< 410 x 580 x 320 mm³

Altius UV Channel Concept

The layout of the UV channel optical design is shown schematically in Figure 5. The UV channel has two apertures, used respectively for Bright Limb (BL)/Solar Occultation (SoO) and Stellar Occultation (StO).

The entrance pupil of the bright limb channel is located in the middle of the Fabry-Pérot assembly. In the stellar occultation mode, a flip mirror is moved in the optical path to switch between the BL and StO line of sights. For StO measurements, it is important that the aperture is as large as possible to maximize the signal on the detector. A larger aperture is realized by means of magnifying optics at the cost of a smaller FOV. The magnification of the optics is the ratio between the stellar occultation aperture and the Fabry-Pérot filter aperture.

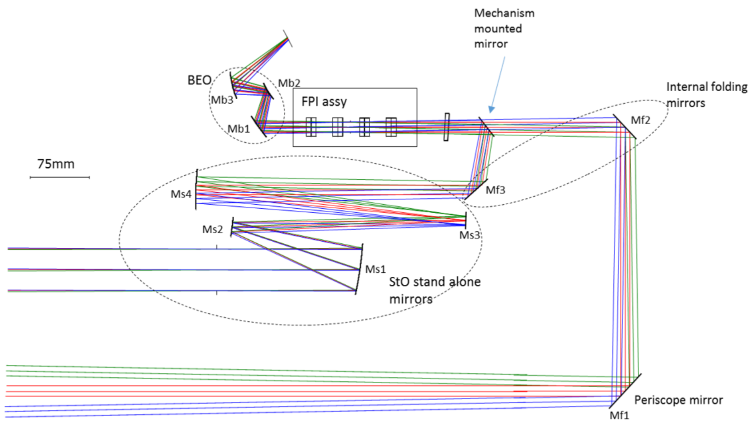

Figure 5. Altius optical UV channel layout

The signal detection is realized through a CIS115 CMOS sensor developed by Teledyne-E2V in the frame of the JANUS project (on board the ESA JUICE Mission) for which anti reflection coating has been adapted for the UV range for the Altius.

The spectral selection is based on a stack of four Fabry Pérot interferometers used as spectral filter and an objective that images the light from the bright limb aperture on the detector. The aperture of a Fabry-Pérot filter determines the aperture of the BL path. The Fabry Pérot air gaps are tuned such that selected interference orders overlaps only for one selected central wavelength, which is getting transmitted, as shown in Figure 6.

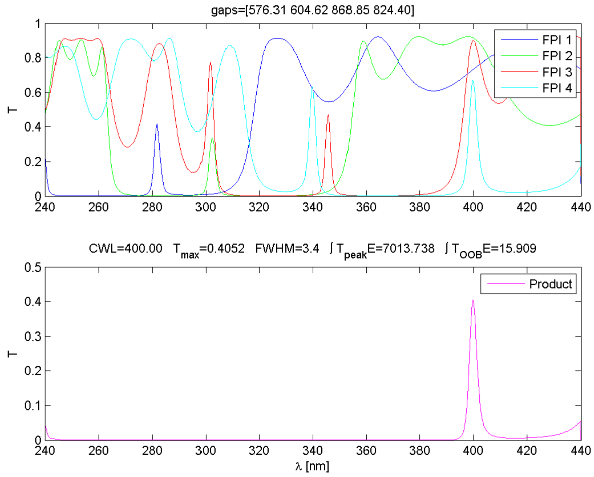

Figure 6. Principle of the FPI stack spectral selection

Figure 7: EQM of the 4 Fabry-Perot Interferometer of the UV Chanel spectral filter

Altius VIS and NIR Channels Concept

In the VIS and NIR channels, the optical design is based on the use of an Acousto-Optic Tuneable Filter (AOTF). Such filter rely on the diffraction effect created in the bulk of a TeO_2 crystal by an acoustic wave. The selected diffracted wavelength is defined by the phase matching conditions with the corresponding acoustic wave frequency travelling within the AOTF.

The AOTF is used in combination with wire grid polarizers which are selecting the appropriate polarization and order of diffraction. The Front End Optics assembly is telecentric and forms an image 5 mm behind the exit surface of the AOTF to reduce the influence of the acoustic wave on the homogeneity of the image. The Back End Optics relay the image onto the detector and match the image size with the size of the Focal Plane Assembly.

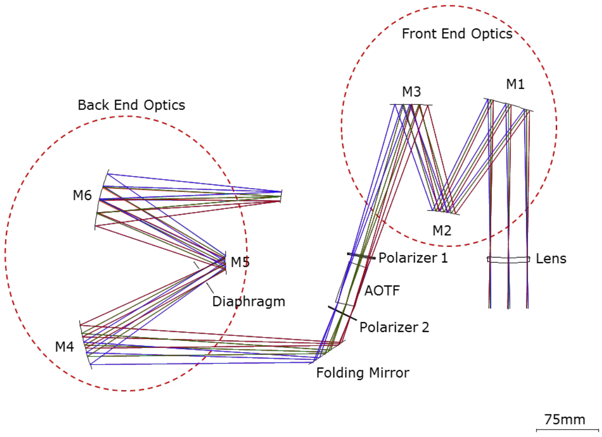

Figure 8. Altius optical VIS channel layout

The signal detection is in the VIS and NIR channel also realized by means of a CIS115 CMOS sensor.

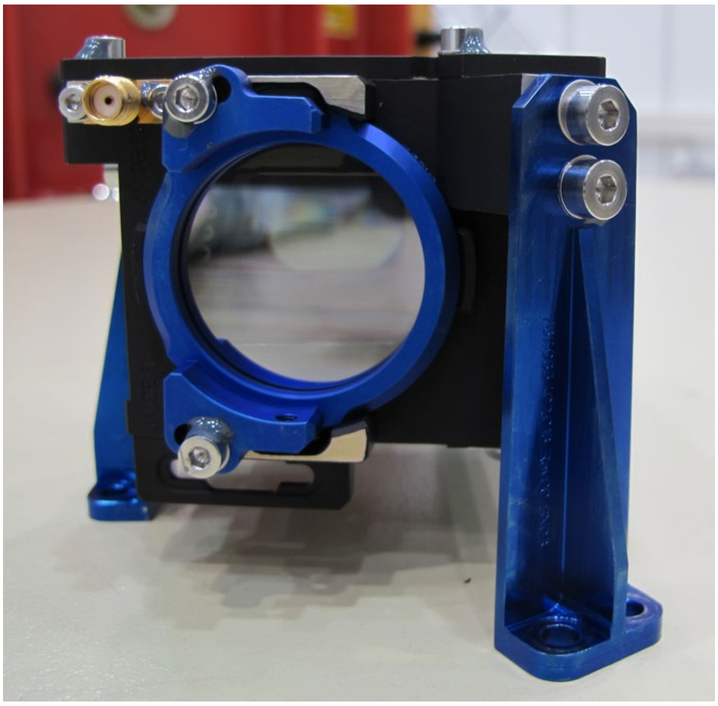

Figure 9: EM of the VIS Channel AOTF Assembly (with polarizer)

4 PDGS

The Payload Data Ground Segment (PDGS) will be located at the Belgian User Support and Operations Centre (B.USOC) in Uccle (Belgium). The PDGS infrastructure and software is developed by Spacebel with the collaboration of the Belgium Institute of Space Aeronomy (BISA) and the Canadian University of Saskatchewan. The PDGS is responsible generating scientific imaging planning requests for the payload, for processing the science and ancillary data, generate L1 and L2 products, updating the calibration database, and managing all the relevant scientific data and products, including dissemination and archiving.

The PDGS will comprise, among others, the following elements:

- An interface to the Data Retrieval Stations for the reception of raw telemetry data,
- A Level 0 to Level 1B/1C Processing Facility (based on a prototype developed by QS)

performing routine processing tasks for Altius, atmospheric and calibration measurements, including corrections such as stray light removal, as well as basic product quality control,
- A Level 2 Processing Facility, hosting the various processors for the generation of Altius geophysical data products, as well as basic product quality control,
- An interface for the delivery of S/X-Band station availability and station use data to the FOS,
- An interface for the reception of specific housekeeping telemetry (S-Band) by the FOS (in case such parameters are not already included in the X-Band TM),
- An interface for the reception of externally provided auxiliary data,
- A pick-up point for the delivery of Level 1 and Level 2 data products to Expert Users and the public,
- An Archiving Facility, for short- and medium-term archiving of all generated data products,
- The routine part of the Mission Performance Centre (MPC) to perform routine quality control,
- An interface to the MPC,
- An interface to the ESA Data Access infrastructure, to support user service and product dissemination tasks,
- A Reprocessing Facility.

PDGS operations include, among others:
- Payload Operations Planning and Request,
- Data Management Centre Service operations,
- Processing and Archiving Centres Service Operations,
- Mission Performance Centre Service Operations,
- Infrastructure Management Service Operations,
- Ground Segment Security Operations Management,
- Coherent User Services End to End Monitoring & Control and System Management,
- User Services including:
    - On-line registration functionality, providing access to Altius data,
    - On-line registration for accessing restricted Altius data,
        - Logging and reporting on data access,
        - User Help Desk functions,
        - Data catalogues, coherent data description,
        - Single sign-on for all datasets,
        - Advertisement of Core and Collaborative Ground Segment services (including product list).

5 PROJECT STATUS AND FUTURE PLAN

The ESA Earth Watch Altius mission is currently into Phase C of its development aiming a Critical Design Review by end 2022.

The platform development is progressing and can capitalise on a successful Proba-Next (P200) satellite STM campaign run already in 2019. Production and verification of the fight platform elements, units and subsystems are well underway and completion of platform integration and verification is currently envisaged by end 2023.

The Altius Instrument is completing the STM manufacturing with an environmental campaign to be completed late this summer. The critical optical subsystems QMs are under testing. The PFM instrument delivery is currently scheduled by Q3 2024 aiming a launch by Q3 2025 on board a

Vega-C launcher as co-passenger of the ESA Earth Explorer mission Flex.

6 REFERENCES

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