ALTIUS Earth Watch Element: Project Implementation and Status

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ESA/ESTEC

22/11/2021

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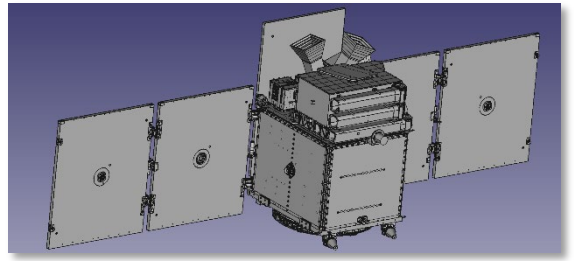
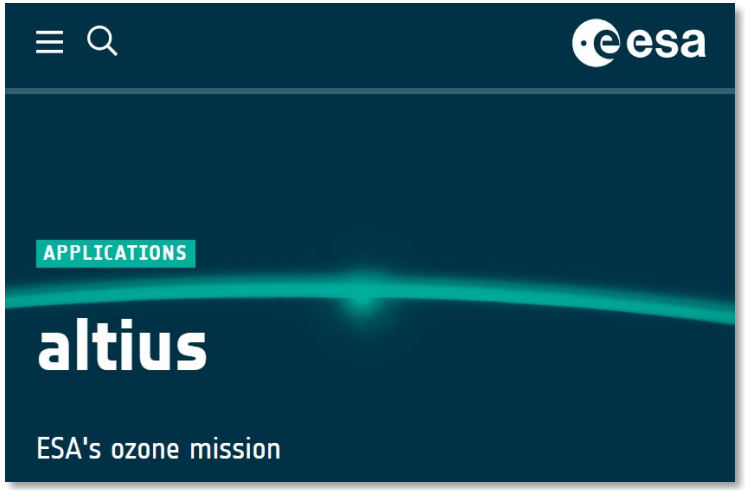




https://www.esa.int/Applications/Observing_the_Earth/Altius

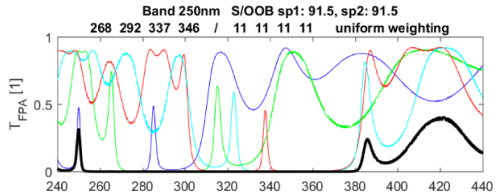
What is ALTIUS

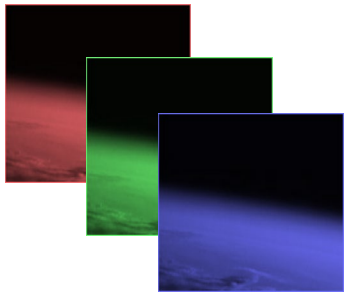
- Limb sounder mission for the monitoring of the distribution and evolution of stratospheric ozone at high vertical resolution
- Support of operational services and long term trend monitoring
- Other, secondary products, also possible pending retrieval performance
- Concept developed by the team of D. Fussen at BISA

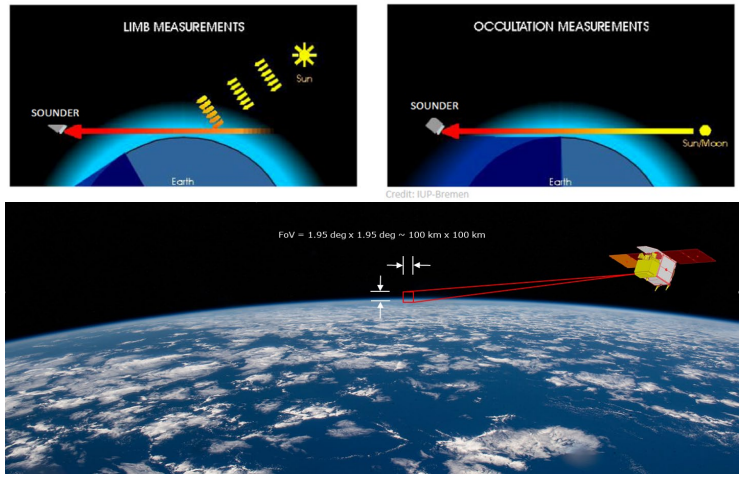
  => See the presentation following this one
- Implemented by the ESA as part of the **Earth Watch Programme**
- Presented at ATMOS 2018 http://atmos2018.esa.int/files/2_ALTIUS%20Daniel%20Navarro.pdf

Observation concept: Limb sounder

- Monochromatic 2-D snapshots taken by three separated cameras:
  - UV, VIS, and NIR
- Snapshot wavelength tunable (FPI and AOTF)
- Observations contain several snapshots at different wavelengths
  - Bright Limb
  - Occultation: Sun, bright stars and planets
- FoV ~ 100 x 100 km at tangent point
- Several imaging modes for spectral, radiometric and pointing calibration
- Agile platform supporting these observations modes







Goals and Users

- Only few missions providing limb measurements, several might terminate within the next few years => ALTIUS will fill therefore an upcoming data gap
- Stratospheric ozone profiles, complementary to total ozone column measurements (GOME-2, Sentinel-5P) used for operational data assimilation
- High importance for the atmospheric chemistry modelling community, for use as input to climate models and their validation
- ALTIUS data will extend the existing GCOS ozone profile ECV as produced with the ESA CCI ozone project

Mission Requirements

- MRD (ALT-RS-ESA-MI-0075) endorsed by MAG
  - Primary Products, stratospheric zone, operational and scientific

Primary mission requirements	ALT-MRD- PRI-010	ALT-MRD- PRI-020	ALT-MRD- PRI-030
Component	Ozone	Ozone	Ozone
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

  - Secondary products as scientific goals: other components and magnitudes
    - Aerosols, NO2, H2O, BrO, OClO etc…

Key System Requirements

- Spectral range and resolution

Optical Channel	Mandatory spectral range	FWHM	Observation Mode
UV	250- 280 nm	< 10 nm	Occultation
	280-290 nm	< 5 nm	Limb, Occultation
	290 - 310 nm	< 3 nm	Limb, Occultation
	310 – 355 nm	< 2.5 nm	Limb, Occultation
VIS	440 - 675 nm	< 75 cm^{-1} (= 1.2 nm @ 400nm)	Limb, Occultation
NIR	600 – 1020 nm	< 75 cm^{-1} (= 6.5 nm @ 940nm)	Limb, Occultation

- Signal to Noise ratio

Limb scattering geometry

Tangent Altitude (km)	Wavelength (nm)										
	250	300	350	450	500	550	600	650	700	800	1020
5	*1*	*55*	*1120*	*5660*	*3940*	*2210*	*1400*	*1170*	*908*	*831*	***2030***
10	*1*	*55*	*1130*	*4790*	**3290**	**1800**	**1090**	**913**	*707*	*631*	***1480***
15	*1*	*56*	*1130*	**4060**	**2760**	**1470**	**850**	**711**	*551*	*479*	***1080***
20	*1*	*58*	*1100*	**3430**	**2310**	**1200**	**662**	**554**	*429*	*365*	***791***
25	*1*	*59*	*971*	**2910**	**1940**	**978**	**516**	**431**	*334*	*278*	***579***
30	*2*	*61*	**765**	**2460**	**1630**	**801**	**402**	**336**	*260*	*212*	***425***
35	*2*	**64**	**568**	**2080**	**1370**	**657**	**313**	**262**	*203*	*162*	***312***
40	*2*	**67**	**407**	**1760**	**1150**	**540**	**244**	**204**	*158*	*124*	*230*
45	*2*	**73**	**291**	*1490*	**968**	**445**	**190**	**159**	*123*	*95*	*169*
50	*2*	**78**	**208**	*1260*	**814**	**366**	**148**	**124**	*96*	*73*	*125*
55	*2*	**65**	**147**	*1070*	**685**	**302**	**115**	**96**	*75*	*56*	*92*
60	*2*	**44**	**99**	*904*	**577**	**250**	**90**	**75**	*58*	*43*	*68*
65	*3*	**26**	**62**	*765*	*486*	*207*	*70*	*58*	*45*	*33*	*51*
70	*2*	*14*	*36*	*648*	*410*	*172*	*54*	*45*	*35*	*25*	*38*
75	*1*	*7*	*18*	*548*	*345*	*142*	*42*	*35*	*27*	*20*	*28*
80	*0*	*3*	*9*	*464*	*291*	*118*	*33*	*28*	*21*	*15*	*21*
85	*0*	*1*	*4*	*393*	*246*	*99*	*26*	*22*	*17*	*12*	*16*
90	*0*	*0*	*1*	*332*	*207*	*82*	*20*	*17*	*13*	*9*	*12*

- Stray light to signal ratio

Limb scattering geometry

Tangent Altitude (km)	Wavelength (nm)										
	250	300	350	450	500	550	600	650	700	800	1020
5	*2.273*	*0.055*	*0.003*	*0.001*	*0.001*	*0.002*	*0.002*	*0.003*	*0.003*	*0.004*	**0.002**
10	*2.222*	*0.054*	*0.003*	*0.001*	**0.001**	**0.002**	**0.003**	**0.003**	*0.004*	*0.005*	**0.002**
15	*2.174*	*0.053*	*0.003*	**0.001**	**0.001**	**0.002**	**0.004**	**0.004**	*0.005*	*0.006*	**0.003**
20	*2.128*	*0.052*	*0.003*	**0.001**	**0.001**	**0.002**	**0.005**	**0.005**	*0.007*	*0.008*	**0.004**
25	*2.055*	*0.051*	*0.003*	**0.001**	**0.002**	**0.003**	**0.006**	**0.007**	*0.009*	*0.011*	**0.005**
30	*2.000*	*0.049*	**0.004**	**0.001**	**0.002**	**0.004**	**0.008**	**0.009**	*0.011*	*0.014*	**0.007**
35	*1.923*	**0.047**	**0.005**	**0.002**	**0.002**	**0.005**	**0.010**	**0.011**	*0.015*	*0.019*	**0.010**
40	*1.841*	**0.045**	**0.008**	**0.002**	**0.003**	**0.006**	**0.012**	**0.015**	*0.019*	*0.024*	*0.013*
45	*1.754*	**0.041**	**0.010**	*0.002*	**0.003**	**0.007**	**0.016**	**0.019**	*0.024*	*0.032*	*0.018*
50	*1.649*	**0.039**	**0.014**	*0.002*	**0.004**	**0.008**	**0.020**	**0.024**	*0.031*	*0.041*	*0.024*
55	*1.523*	**0.047**	**0.020**	*0.003*	**0.005**	**0.010**	**0.026**	**0.031**	*0.040*	*0.054*	*0.032*
60	*1.288*	**0.068**	**0.030**	*0.003*	**0.005**	**0.012**	**0.034**	**0.040**	*0.052*	*0.070*	*0.044*
65	*1.200*	**0.115**	**0.048**	*0.004*	*0.006*	*0.014*	*0.043*	*0.051*	*0.066*	*0.091*	*0.059*
70	*1.705*	*0.213*	*0.085*	*0.005*	*0.007*	*0.017*	*0.055*	*0.066*	*0.085*	*0.118*	*0.080*
75	*1.705*	*0.437*	*0.164*	*0.005*	*0.009*	*0.021*	*0.071*	*0.085*	*0.110*	*0.153*	*0.107*
80	*1.705*	*0.974*	*0.352*	*0.007*	*0.010*	*0.026*	*0.091*	*0.109*	*0.140*	*0.199*	*0.143*
85	*1.705*	*2.381*	*0.845*	*0.008*	*0.012*	*0.031*	*0.117*	*0.140*	*0.181*	*0.259*	*0.192*
90	*1.705*	*2.381*	*0.845*	*0.009*	*0.014*	*0.037*	*0.150*	*0.180*	*0.231*	*0.334*	*0.257*

Only values in bold apply, values in italics are for reference.

Design evolutions (1/2)

- Instrument configuration modified due to
  - (1) Technical and programmatic trade off on original SWIR Channel has led to adoption 600-1020nm NIR Channel based on similar design as VIS (Optics and detector)
  - (2) trade-off of spectral range versus improved resolution (for NO_2 retrieval)
  - (3) Trade-off of spectral range versus spectral leak rejection
- Current design
  - ensures stratospheric O3 retrieval in bright limb, stellar and solar occultation
  - should be capable to observe aerosol extinction, NO2, and others…

BEFORE (2018)

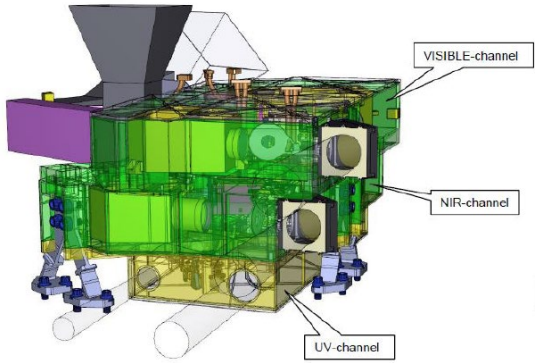
UV	250-400 nm
VIS	400-800 nm
SWIR	800-1800 nm

AFTER (2021)

UV	250-355 nm	(3)
VIS	440-675	(2)(3)
NIR	600-1020	(1)(3)

Design evolutions (2/2)

BEFORE



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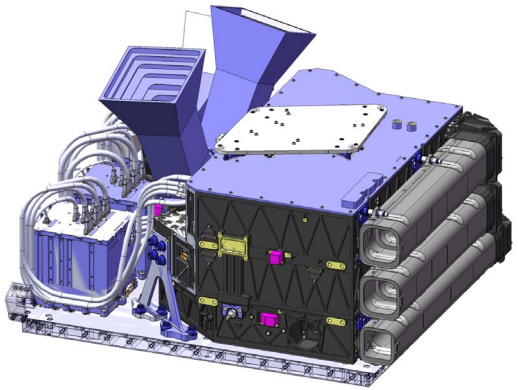


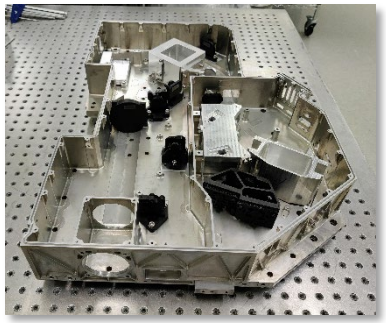
- Addition of long baffles => reduction of far out-of-filed stray light
- Increase of UV stellar occultation aperture => improve SNR
- Use of state-of-the art reflective coatings
  - => Improve SNR (VIS and NIR): Proba-V evolution
  - => Improve out-of-band rejection (UV) from NIR region: cold coating
- Tuning of FPI Bragg-mirrors coating (UV)
  - => improve SNR/out-of-band rejection
- Band-pass filters:
  - => Improve out-of-band rejection (UV) from NIR region
  - ⇒ Additional filter to limit zero-order effects in NIR (AOTF)
- Additional field stop to limit zero-order effects (VIS/NIR AOTF's)

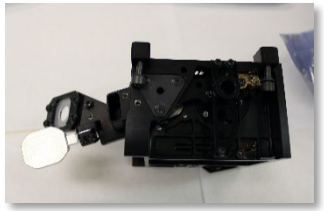
Project Status - Overview

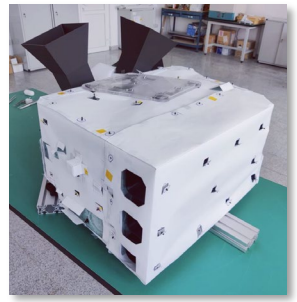
- System (Platform + Instrument + CAL) phase B2CD
  - Kicked-off in January ‘20
  - Successful PDR in October ’20
  - CDR in September ’22
  - FAR expected January ‘24
- Payload Data Ground Segment (+ E2E + VAL) phase B2CD
  - Kicked-off in Dec ’20
  - Successful PDR in July ‘21
  - Successful E2E PDR in Sep ‘21
  - CDR in Q3 ‘22
- Launcher procurement on-going => Launch May 2025

Project Status - Instrument

- Phase C on-going with CDR expected in July ’22
- Optical sub-assemblies: coatings qualified, structural models under test
- Fabry-Perot interferometers engineering model manufacturing
- Electronics detail design, parts manufacturing on going
- Optical benches structural models finished
- Mechanism drivers prototypes tested, engineering models dev on going
- AOTF crystal manufacturing on-going
- Baffles structural models on-going, MLI mock-up finished

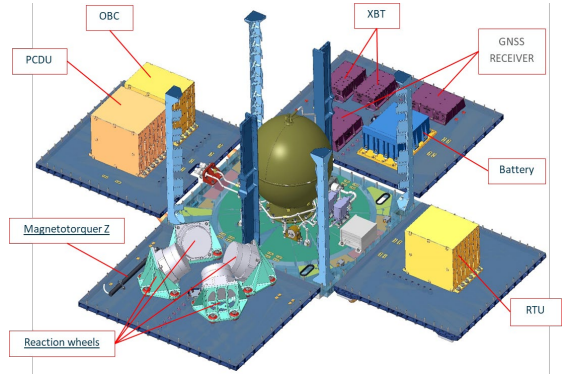


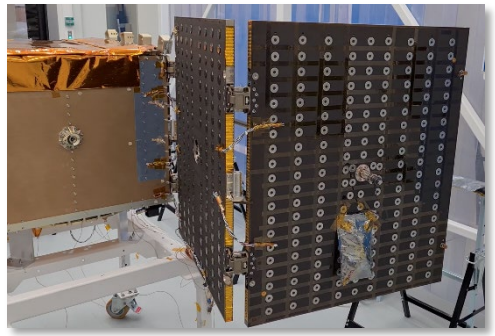


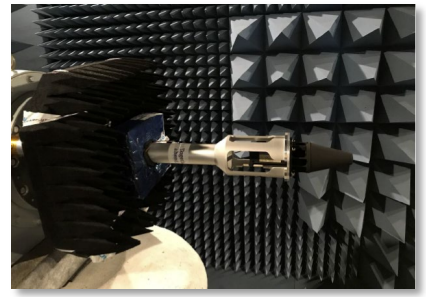


Project Status - Platform

- Subsystems undergoing phase C activities, engineering models being built and tested.
- STM already qualified
- Thrusters have been qualified
- Avionics engineering model testing on-going
- Battery CDR beginning ’21
- Panel manufacturing to start soon
- Some off-the-shelf items already provided as flight models







Project Status – Ground Segment

- PDGS + E2E Simulator + VAL
  - PDR passed
  - E2E passed:
    - E2E SW requirements, design, and validation plans
    - L2 ATBD's for NRT O3 and other byproducts.
    - Algorithm validation plans.
    - Geophysical validation approach
- FOS
  - CDR passed
- Ground Stations
  - RF coordination, submission to ITU May '22

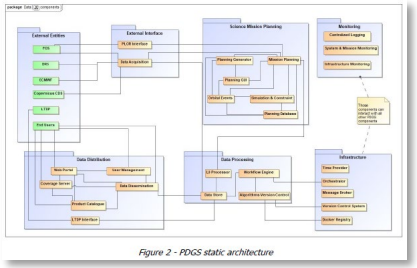
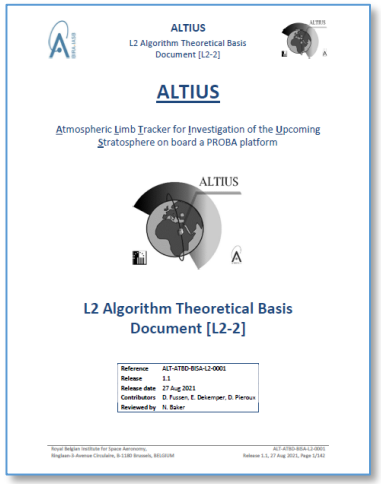
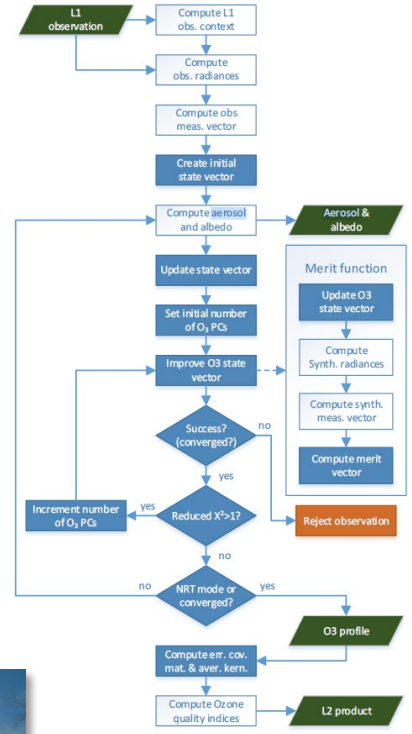


Figure 2 - PDGS static architecture





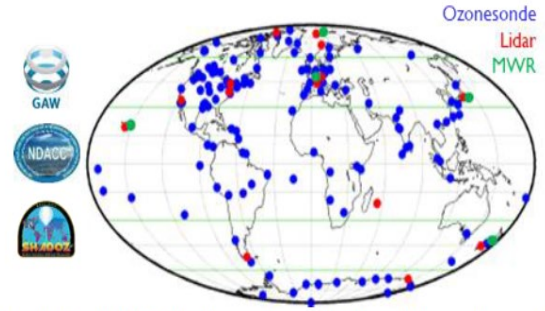
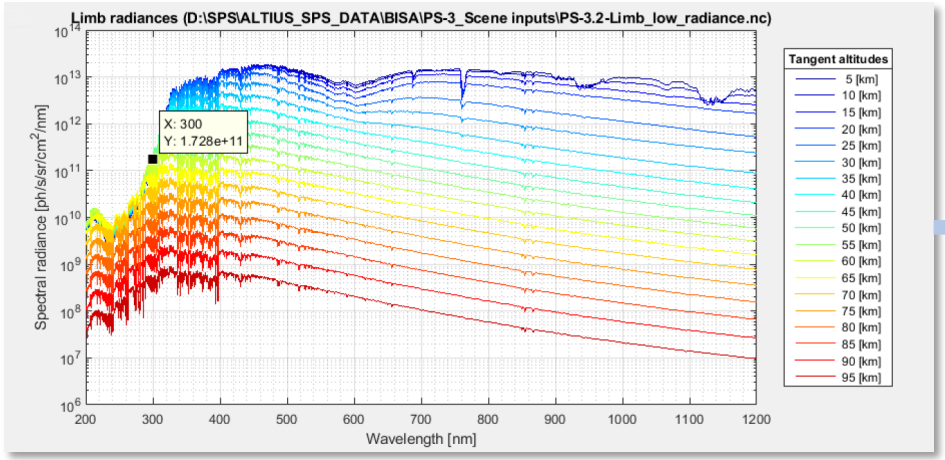


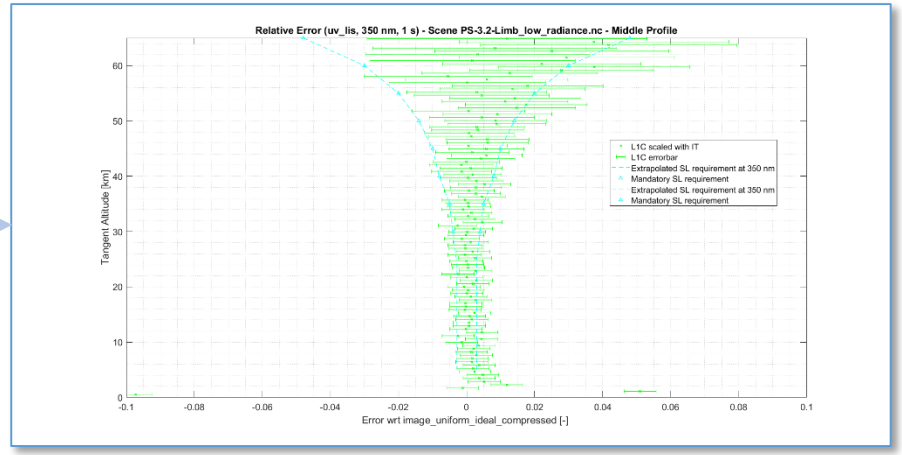
Figure 1 – Geographical distribution of ozonesonde, stratospheric lidar and microwave radiometer stations having contributed ozone profile data to WMO's Global Atmosphere Watch (GAW) through the GO3OS, NDACC, NOAA/ESRL, and SHADOZ monitoring programmes.

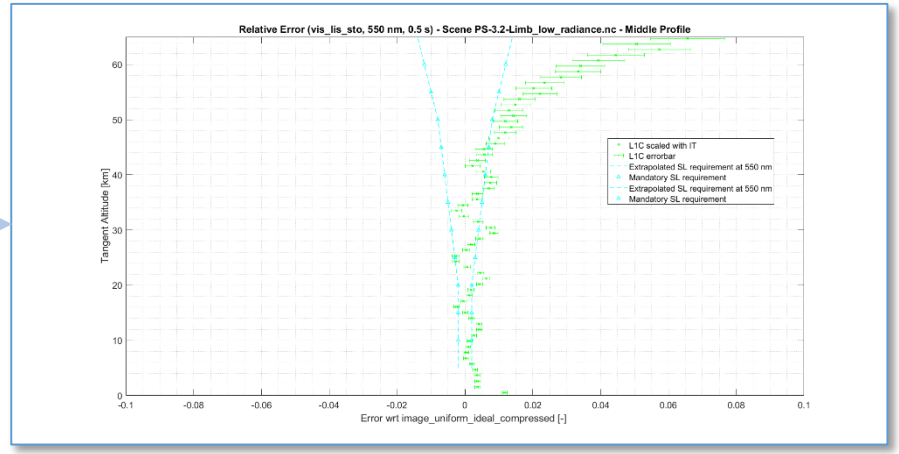
Project Status – Preliminary Performance

- System Performance Simulator (SPS) + synthetic calibration data
- L1c (Radiometrically corrected, georeferenced, stray light removed)
- Low radiance scene



SPS

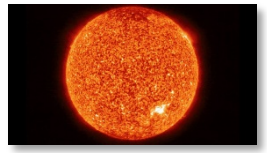


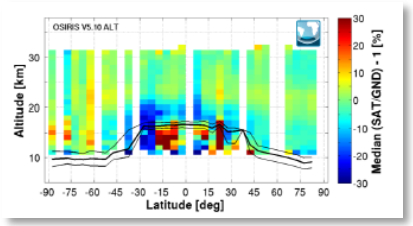


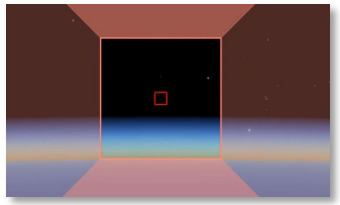
- Stray light requirement as reference for the L1c error (L1c – ideal_signal)/ideal_signal

Launch and Operations

- Launch expected in May 2025 with Vega-C
- Operations run from ESA Redu  Processing from B.USOC 
- Phase E1, about 6 months
  - LEOP and Satellite commissioning
  - System (Instrument, satellite, L1 processing) Calibration and Verification
  - Mission Geophysical Validation
    - Cross-validation, ground measurements; A.O.



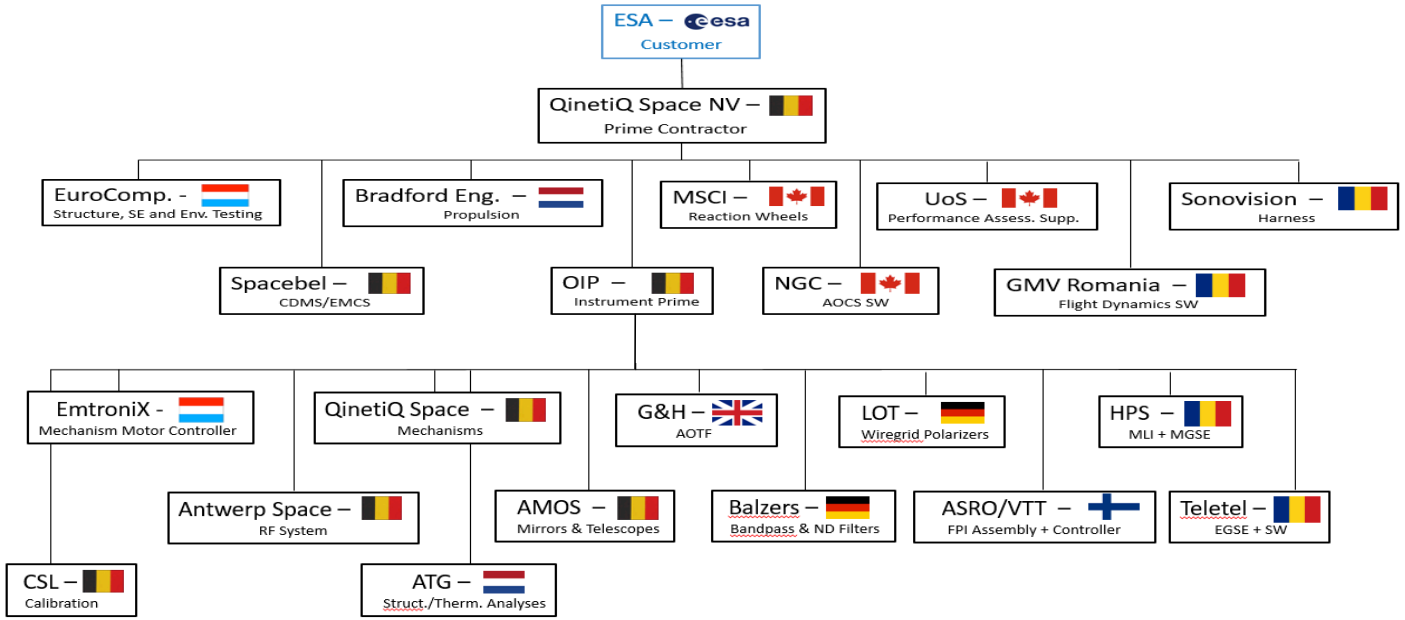


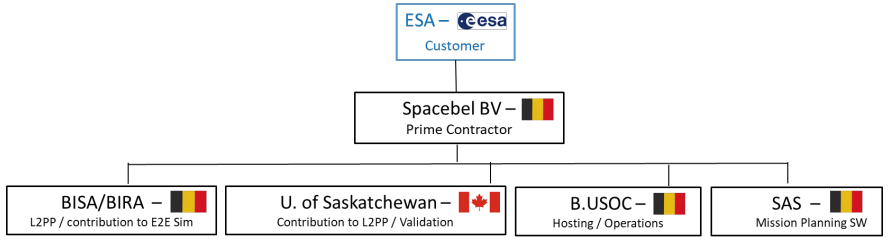


- Phase E2, about 3 years (extendable to 5 years)
  - 80% operational products: O3 NRT, O3 consolidated, and by-products
  - 20% secondary products and repeat CALVAL

Acknowledgments

To our Industrial and Institutional Partners





Questions…?