# Status of GMES Sentinel 5

2nd Post-EPS User Consultation Workshop

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## Presentation Outline

- The GMES atmospheric chemistry missions objectives
- Sentinel 5 observation requirements
- Overview of instrument concepts
- Technology developments
- Programmatics

## GMES Sentinels 4 and 5 primary objectives

- The GMES Atmosphere Service will provide coherent information on atmospheric variables in support of European policies and for the benefit of European citizens. Services are proposed to cover:
  1. Air quality
  2. Climate change/forcing
  3. Stratospheric ozone and solar radiation

- The primary objectives of Sentinel 4 and 5 are:
  - **High temporal and spatial resolution** measurements of tropospheric composition, including Planetary Boundary Layer (PBL), for *air quality applications*
  - **High spatial resolution and high precision monitoring** of tropospheric climate gases ($CH_4$, $CO_2$ and precursor CO) and aerosols with sensitivity to PBL concentrations for *climate protocol monitoring*



## Implementation of Sentinels 4&5 on EUMETSAT platforms

According to current ESA-EUMETSAT working assumptions on GMES and following recommendations expressed by the GMES Atmospheric Service Implementation Group (GAS-IG), the Sentinels 4 and 5 missions will be accommodated as additional payloads on EUMETSAT platforms:

- Sentinel 4 (GEO component) will consist of
  - A UVN spectrometer embarked on the MTG-S platform;
  - TIR data from the IR sounder onboard the same platform; and
  - Imagery data from the imager on-board MTG-I.

- Sentinel 5 (LEO component) will consist of
  - A UVNS spectrometer embarked on the Post-EPS platforms;
  - TIR data from the Post-EPS IR sounder; and
  - Imagery data from the imager on-board Post-EPS.

# Sentinel 5 geometric requirements

**Global Daily Coverage**

The Sentinel 5 flight segment shall allow a global daily coverage of the Earth atmosphere.

**Spatial Sampling Distance (SSD)**

| | |
|---|---|
| UV-1 | 15 km (G) / 50 km (T) |
| UV-2, VIS, NIR, SWIR | 5 km (G) / 15 km (T) |

**Geolocation knowledge** < 0.1 SSD (G) / 0.2 SSD (T)

**Inter-band spatial co-registration** < 0.01 SSD (G) / 0.05 SSD (T)

**Observation Zenith Angle (OZA)** < 66º

**Sun Zenith Angle (SZA)** < 92º (requirements to be met up to 80º)



# Sentinel 5 spectral and radiometric requirements

| Band ID | Spectral bands [nm] | Spectral Resolution [nm] | Spectral Sampling Ratio | SSD [km] | SNR @ Lref_TR | SNR @ Lref_HL | SNR @ Lsun | Priority |
|---|---|---|---|---|---|---|---|---|
| UV-1 | 270-300 | 1.0 | 3 | 15 (G), 50 (T) | 100 | 100 | 1000 (270 nm) 3000 (208nm) | 1 |
| UV-2a | 300-308 | 0.5 | 3 | 5 (G), 15 (T) | 100 | 100 | | 1 |
| UV-2b | 308-400 | 0.5 | 3 | 5 (G), 15 (T) | 1000 | 1000 | 3000 | 1 |
| VIS-1 | 400-405 | 0.5 | 3 | 5 (G), 15 (T) | 1000 | 400 | 3000 | 2 |
| VIS-2 | 405-500 | 0.5 | 3 | 5 (G), 15 (T) | 1050 | 450 | 4500 | 1 |
| VIS-3 | 590-640 / 610-680 / 710-750 | 0.4 | 3 | 5 (G), 15 (T) | 700 | 700 | 2000 | 2 |
| NIR | 750-775 | 0.05 (G), 0.4 (T) | 3 | 5 (G), 15 (T) | 200/1000 | 200/1000 | 1500 | 1 |
| SWIR-1 | 1593-1672 | 0.25 | 3 | 5 (G), 15 (T) | 190 | | 1000 | 2 |
| SWIR-2(*) | 1940-2030 | 0.25 | 6 (G), 2 (T) | 5 (G), 15 (T) | 100 | | 1500 | 3 |
| SWIR-3 | 2305-2385 | 0.25 | 6 (G), 2 (T) | 5 (G), 15 (T) | 90 | | 1500 | 1 |

- The CAMELOT study provided scientific support to the consolidation of the requirements. EUMETSAT also involved.
- Concepts trade-off were based on the priorities: SR, OZA, SSD and SNR
- In yellow the bands implemented in the Sentinel 5 Precursor mission

*) SWIR-2 band was not implemented because of priority 3

# Sentinel 5

# Instrument concepts



## Sentinel 5: General characteristics

- Two instruments concepts (A and B) have been studied by industry in the frame of the Sentinel 4 and 5 phase 0 studies
- Instruments are compatible with the Post-EPS orbit at LTAN of 9:30
- Global daily coverage from the Post-EPS altitude of 817 km
- Wide swath (~2657 km) pushbroom spectrometer concept
- Field of view: 108° ACT and < 4° ALT
- 6 grating spectrometers: 4 UVN, 2 SWIR
- Detector technology: CCD for UVN, CMOS for SWIR
- Separate telescopes for UVN and SWIR
- Passive cooling concepts
- Irradiance measurement in anti-flight direction to reduce diffusers contamination
- The instrument is expected to be always kept ON for temperature stability
- Data rate acquired during ~70% of the orbit (including 15% for calibration)
- Instruments aperture of ~3 mm
- Both instrument concepts are an evolution of the Sentinel 5 Precursor concept

# Sentinel 5: General performance (1/2)

- Performance presented are applicable to both concepts unless explicitly stated

| | | | | |
|---|---|---|---|---|
| **Spatial sampling distance (Level 0 data)** | 15 km (UV1)<br>5 km (UV2/VIS/NIR/SWIR) | | | |
| **Spectral bands** | ***Band ID*** | ***Spectral range (nm)*** | ***Spectral resolution (nm)*** | ***Spectral sampling Ratio [1]*** |
| | UV-1 | 270-300 | 1 | 3.5 |
| | UV-2 | 300-350 | 0.5 | 3.5 |
| | VIS-1&2 | 350-500 | 0.5 | 3.5 |
| | VIS-3&NIR | 710-775 | 0.4 | 3.8 |
| | SWIR-1 | 1593-1672 | 0.25 | 3.1 |
| | SWIR-3 | 2305-2385 | 0.25 | 3.1 |
| **Interband spatial co-registration [2]** | Concept (single/double telescope) dependent | | | |
| **Sensitivity to polarisation [3]** | < 0.5% in VNIR | | < 5% in SWIR | |
| **Radiometric accuracy** | Compliance TBC (needs further analysis) | | | |

[1] Concept B has a sampling ratio of 3.2 in UVN

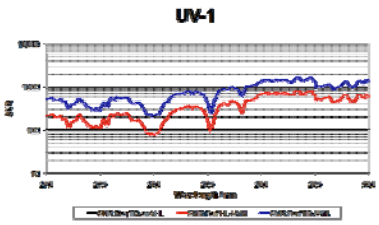
[2] The inter-channel spatial co-registration is achieved in both concepts

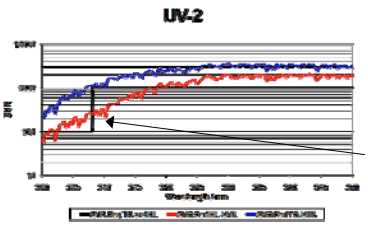
[3] Polarisation compliance is dependent on the position of the scrambler:

- In concept A scrambler is at intermediate pupil => specs are not met
- In concept B scrambler is at entrance pupil => specs are met

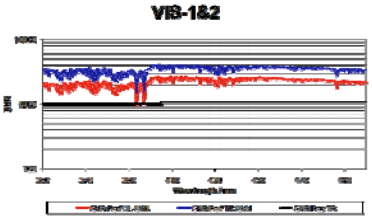


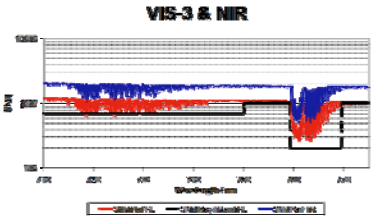
# Sentinel 5: General performance (2/2)




SNR performance is within specifications, except a non compliance for a limited spectral range in the UV2 band at high latitude (HL)




Regarding SWIR bands, SNR compliance is achieved with some margins

SNR estimate based on 3x3 on-ground spatially binned pixels

# Sentinel 5: Calibration and Detectors

## Calibration

- The instrument is expected to operate with 100% duty cycle on the bright side of the orbit
- Once per day (TBC) this is interrupted for ~1 min at the North pole to observe the sun via the dedicated sun diffuser (solar irradiance measurement)
- At the dark side of the orbit, the instrument will regularly perform the following instrument calibrations:
  - Detector dark current measurements (every orbit)
  - LED and White Light Source (WLS) measurements (once a week TBC)

## Detectors

- Both industrial teams are confident about the availability of both (UVN/SWIR) detectors in time for a launch in 2019

| | CCD for UVN | CMOS (MCT) for SWIR |
|---|---|---|
| **Pixel pitch** | 13 / 15 µm | 20 / 30 µm |
| **Format** | 1.25 x 1.2 k / 1 k x 1 k | 1 k x1 k / 1000 x 768 |
| **Temperature** | 210 K in UV<br>250 K in NIR | 200 K in SWIR-1<br>160 K in SWIR-3 |
| **Notes** | CMOS was discarded after trade-off | Baseline derived from existing Sofradir Saturn |

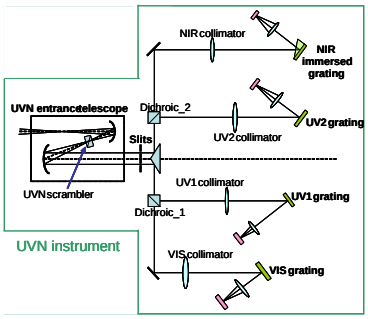


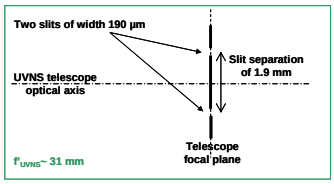
# Sentinel 5

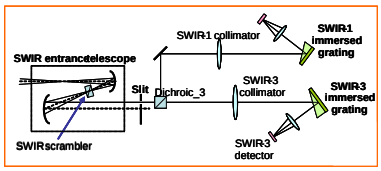
# Concept A

# Sentinel 5: Optical layout

- UVN/SWIR aperture 3.1 mm
- Two slits in-field separated at UVN telescope focal plane (=> ALT FoV ~0.5°) (=>8 s of temporal corr.)
- Two dichroics allow to separate the UVN bands before spectrometers
- One dichroic allow to separate the SWIR bands
- Immersed gratings used for NIR, SWIR-1 and SWIR-3



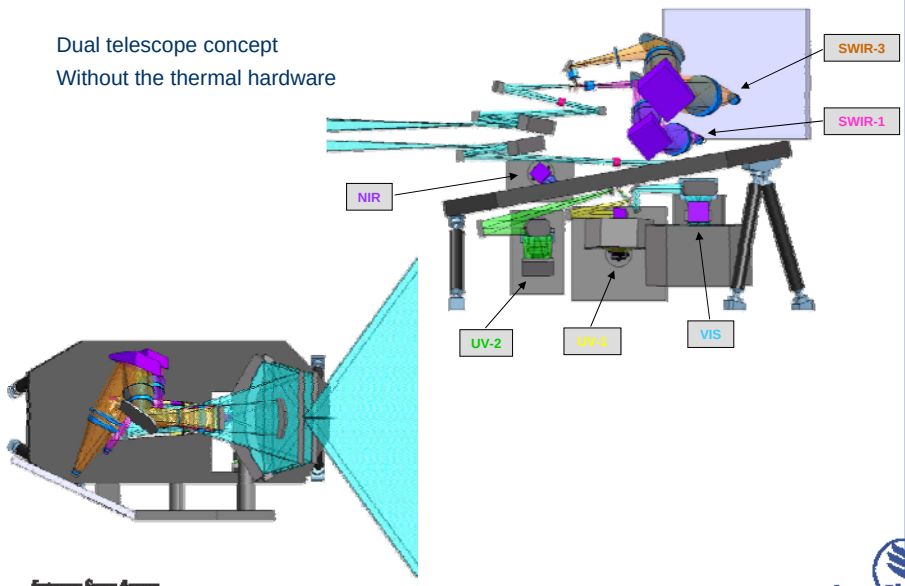





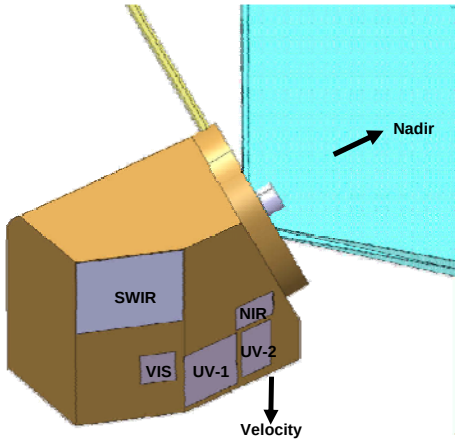

# Sentinel 5: Mechanical implementation (1/2)

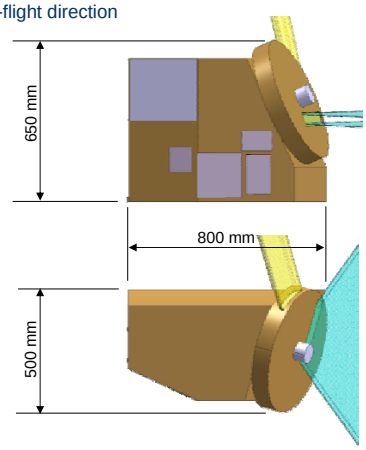
Dual telescope concept
Without the thermal hardware



# Sentinel 5: Mechanical implementation (2/2)

- Sun irradiance measurement direction is 37.5° w.r.t. anti-flight direction
- Accommodation of all radiators on the anti-sun face

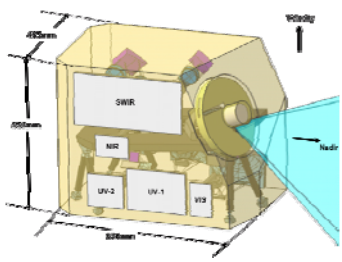


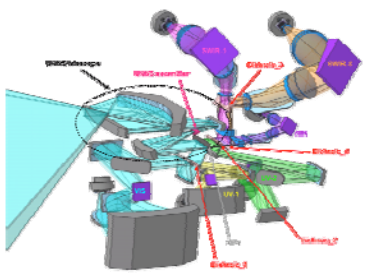






# Sentinel 5: Single/Dual telescope trade-off

- The evolution analysed consists in suppressing one telescope, and thus in implementing all the UVNS bands with a single telescope



| | Single telescope | Dual telescope |
|---|---|---|
| Mass (*) | + | - |
| Volume | + | - |
| Spatial co-registration | + | - |
| Polarisation sensitivity | - | + |
| Calibration | - | + |

*) The mass savings compared to dual telescope concept are ~10 kg

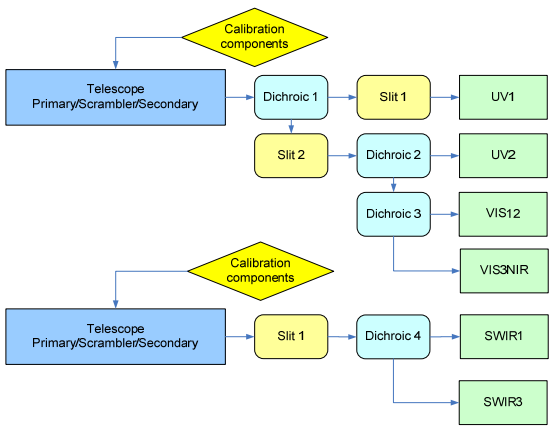
# Sentinel 5

# Concept B

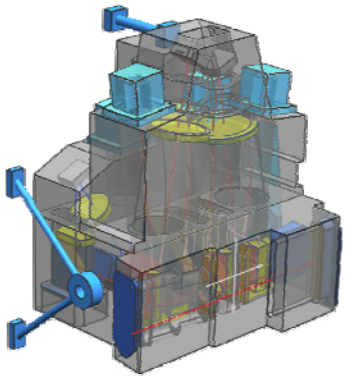


## Sentinel 5: Optical layout

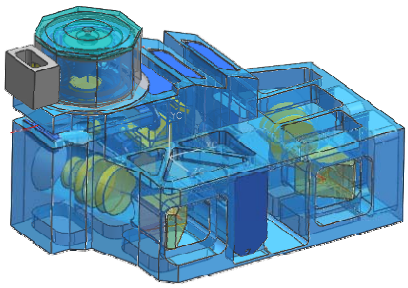
- UVN aperture 3.6 mm / SWIR aperture 2.1 mm
- Three dichroics allow to separate the UVN bands before the UVN spectrometers
- One dichroic allows to separate the SWIR bands
- Immersed gratings used for SWIR-1 and SWIR-3



# Sentinel 5: Mechanical implementation (1/2)



UVN module

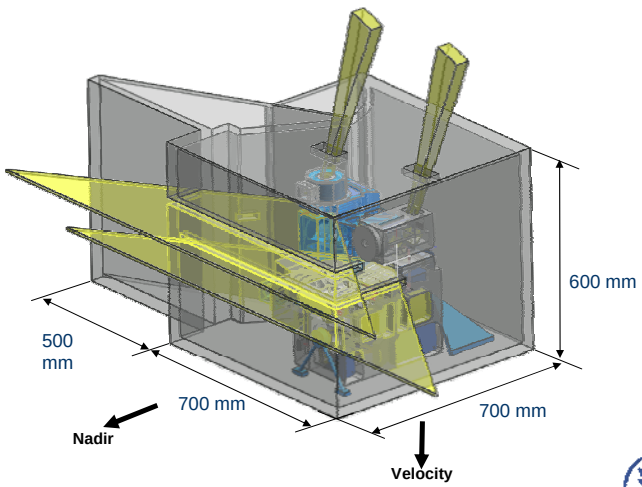


SWIR module



# Sentinel 5: Mechanical implementation (2/2)

- Sun irradiance measurement direction is 37.5° w.r.t. anti-velocity direction
- Accommodation of all radiators on the anti-sun face



## Sentinel 5: Concepts summary

- The baseline is the dual telescope concept

| | Concept A | Concept B |
|---|---|---|
| Payload mass (*) | 181 kg | 152 kg |
| • Optical unit mass | 160 kg | 128 kg |
| • Electronic unit mass | 21 kg | 24 kg |
| Payload dimensions | | |
| • Optical unit | 800 x 500 x 650 $mm^3$ | 700 x 600 x 700 $mm^3$ |
| • Electronic Unit | 23 $dm^3$ | 75 $dm^3$ |
| Power budget (*) | 96 W | 190 W |
| Data rate (**) | 23 Mbps | 21.6 Mbps |
| Data volume per orbit (***) | 96 Gbits | 90 Gbits |

*) Mass and Power budgets include 20% margin

**) Data rate corresponding to a native SSD of 5 x 5 $km^2$

***) Data volume => a 15% overhead is estimated for calibration



## Sentinel 5: Technology developments

- The **NIR immersed grating technology**, in order to achieve high dispersion (goal: 0.05 nm spectral resolution) with reasonable grating sizes
- **SWIR immersed grating technology** for both SWIR-1 & 3 spectrometers to reach high grating efficiency with reasonable grating sizes
- **SWIR MCT detector development**: optimize the ROIC, hybridation and packaging of the detector to the Sentinel 5 needs
- **Calibration diffuser technology** and manufacturing process to minimize the spectral features effect
- Specific reflective **coatings** for UVN telescope and UV-1, UV-2 and VIS spectrometers
- **Polarization scrambler** device to achieve the required depolarization efficiency
- Specific **dichroics** optimizations in transmission and reflection
- Technological survey on high speed 14 bit ADC

Technology development actions to cover this are initiated or under preparation

## Sentinel 5: Programmatic status summary

- Sentinel 5 to be embarked on Post-EPS with launch date ~2019, requires observations in all bands, from UV to TIR => Synergy with Post-EPS IRS is essential: high priority of atmospheric composition requirements needs to be kept in Post-EPS
- Instrument design concepts from Sentinel 5 Phase 0 studies has been fed into Post-EPS Phase 0 studies
- System level aspects (accommodation, envelope, end-to-end data flow,..) are addressed in the frame of the on-going Post-EPS phase 0 system studies
- Sentinel 5 Phase A to take place in 2010, in parallel with Post-EPS phase A
- GMES Space Component (GSC) Segment 2 includes phase B1 and complementary pre-developments
- Phase B2/C/D are for CMIN-2011, synchronized with Post-EPS phase B/C/D



## Thank you

# Backup Slides



## Sentinel 5: Concepts Summary

### Concept A

| Spectrometer bands | UV-1 | UV-2a, UV-2b | VIS-12 | VIS-3, NIR | SWIR 1 | SWIR 3 |
|---|---|---|---|---|---|---|
| Wavelength range (nm) | 270 - 300 | 300 - 350 | 350 - 500 | 710 - 775 | 1593 - 1672 | 2305 - 2385 |
| Spectral resolution (nm) | 1.0 | 0.5 | 0.5 | 0.4 | 0.25 | 0.25 |
| Spectral sampling ratio | 3.5 | 3.5 | 3.5 | 3.8 | 3.1 | 3.1 |
| Native SSD ALT x ACT (km) | 45 x 5 | 5 x 5 | | | | |
| Integration time (s) | 6.82 | 0.76 | | | | |
| SSD binning ALT x ACT | 1 x 9 | 3 x 3 | | | | |
| Product SSD ALT x ACT (km) | 45 x 45 | 15 x 15 | | | | |

### Concept B

| Spectrometer bands | UV-1 | UV-2a, UV-2b | VIS-12 | VIS-3, NIR | SWIR 1 | SWIR 3 |
|---|---|---|---|---|---|---|
| Wavelength range (nm) | 270 - 300 | 300 - 350 | 400 - 500 | 710 - 775 | 1593 - 1672 | 2305 - 2385 |
| Spectral resolution (nm) | 1.0 | 0.5 | 0.5 | 0.4 | 0.25 | 0.25 |
| Spectral sampling ratio | 3.2 | 3.2 | 3.2 | 3.2 | 3.0 | 2.0 |
| Native SSD ALT x ACT (km) | 15 x 5 | 5 x 5 | | | | |
| Integration time (s) | 2.27 | 0.76 | | | | |
| SSD binning ALT x ACT | 3 x 3 | 3 x 3 | | | | |
| Product SSD ALT x ACT (km) | 45 x 15 | 15 x 15 | | | | |