**Unitary Test Reports**

**Earth Observation Data Processing**

|  |  |  |  |
| --- | --- | --- | --- |
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# Introduction

This document provides the Unitary Test Reports for each of the algorithms specified in [EODP\_ATBD] and whose test is specified in [EODP\_SPE].

# References

## Applicable Documents

Table ‑: Applicable Documents

| **Ref.** | **Code** | **Title** | **Issue** |
| --- | --- | --- | --- |
| [EODP\_ATBD] | - | EODP Algorithm Theoretical Baseline Document | 1.0 |
| [EODP\_SPE] | - | EODP Unitary Test Specifications | 1.0 |

## Reference Documents

Table ‑: Reference Documents

| **Ref.** | **Code** | **Title** | **Issue** |
| --- | --- | --- | --- |
|  |  |  |  |

## Acronyms

Table ‑: Acronyms

| **Acronym** | **Description** |
| --- | --- |
| AD | Applicable Document |
| FYI | For Your Information |
| ISS | International Space Station |
| RD | Reference Document |
| TN | Technical Note |

# EODP-TS-GEO-0001. DEM

The goal of this test is to run the Geometry Module (GM) and to acquaint oneself with the EOCFIs. The Geometry Module is delivered as a functional code, no implementation is needed. In this test the GM shall be run with a DEM, and the goal is to obtain the profile of the altitudes.

## Pass/fail Criteria

The PASS/FAIL criteria defined for the Geometry Module contains the following test with a summarized justification of how they were obtained.

### State Vector in ECEF

* **Criteria**: What is the first and last state vector in ECEF; how many state vectors there are. Verify that the number of samples is coherent with the duration of the acquisition and the sampling time.

To identify the initial and final state vectors and calculate the total count of state vectors, you should examine the "*real\_orbit.xml*" file within the designated GM output folder. It can be verified the number of samples, acquisition duration, and sampling time (available in "gm\_local\_conf.xml") by performing the following calculations:

* To determine the acquisition duration, multiply the sampling time by the number of samples.
* To find the sampling time, divide the number of samples by the acquisition duration.

### Sun-synchronous Orbit

* **Criteria**: What is the Sun-synchronous orbit (defined in the Orbit Scenario File in the auxiliary folder).

The parameters governing the sun-synchronous orbit are specified within the auxiliary folder, “*osf\_sentinel2a.xml*”. The essential parameters to be verified include the repeat cycle, cycle length, ANX longitude, MLST, and MLST drift. These specific parameters define the sun-synchronous orbit.

### Quaternions in ECEF

* **Criteria**: What is the first and last quaternion in ECEF.

To ascertain the initial and final quaternions, it's essential to inspect the "*real\_attitude.xml*" file situated within the chosen GM output directory.

### Geolocation Matrices

* **Criteria**: What is the size of the geolocation matrices (lat, lon, alt).

The dimensions of the geolocation matrices can be found in the "*geolocation.nc*" file within the designated GM output folder. To access the projection images containing altitude, latitude, and longitude, open this file using Panoply. Finally, ensure you examine the file dimensions, specifically the variables "*n\_lines*" and "n\_columns."

### Acquisition Country

* **Criteria**: Over which country is the acquisition passing; what DEM file do you need to use.

After importing the geolocation file into Panoply, it is possible to observe the country through which the acquisition transpires. Following this, the DEM file can be procured by conducting a search within the ESA GETASSE repository. It is crucial to emphasize that the correct DEM file must be determined by referencing the South-West corner of the image's covered area.

### Altitude Plots

* **Criteria**: Plot the altitudes (in Panoply). Verify that the altitudes are not zeros (the simulation is correctly using the DEM).

After updating the relevant DEM file, altitudes can be plotted using Panoply. To verify the accuracy of the data, a comparison can be conducted between the data array obtained from Panoply and a thorough check to ensure that there are no zero values.

## Summary: PASS/FAIL

This exercise is a **PASS**.

## Test Results

This section contains the results, plots and descriptions that supports the pass/fail criteria.

### State Vector in ECEF

A screenshot of a computer code

Description automatically generated

Figure 3‑1: Initial State Vector in ECEF.

A screenshot of a computer code

Description automatically generated

Figure 3‑2: Final State Vector in ECEF.



Figure 3‑3: Total Number of State Vectors.

Considering the configuration parameters specified in the [EODP\_SPE] for both the total propagation time (20 seconds) and the sampling time (0.00672 seconds, it is readily ascertainable that the total count of samples aligns with these defined values.

In accordance with this configuration, if one were to divide the total propagation time or acquisition duration by the number of samples, it should yield the sampling time as the result. Thus:

Conversely, when the sampling time is multiplied by the number of samples, it should yield the total propagation time as the outcome.

### Sun-synchronous Orbit

A screenshot of a computer code

Description automatically generated

Figure 3‑4: Sun-Synchronous Orbit Parameters.

### Quaternions in ECEF

A number and date on a white background

Description automatically generated

Figure 3‑5: First Quaternion in ECEF.

A number and numbers on a white background

Description automatically generated

Figure 3‑6: Last Quaternion in ECEF.

### Geolocation Matrices

The number of lines and columns is obtained from Panoply. Therefore, the geolocation matrices (latitude, longitude and altitude) dimensions are **2976 x 1000**.

A white screen with black text

Description automatically generated

Figure 3‑7: Geolocation Matrices Dimensions.

### Acquisition Country

In Figure 3‑8, a depiction of the acquisition path in terms of latitude is presented alongside the corresponding geographical coordinates, including latitude and longitude (in this case, approximate values of 30.8°N and 3.55°E, respectively), displayed in Google Earth.

Upon examining Figure 3‑8, it is evident that the country encompassing the acquisition path is Algeria.

A map of the world

Description automatically generated

1. Google Earth Location

|  |  |
| --- | --- |
| A map of the world  Description automatically generated | A map of the world  Description automatically generated |
| 1. Panoply Location, Latitude Plot | 1. Panoply Location, Latitude Plot |

Figure 3‑8: Location of Data Acquisition Country.

To accurately select the appropriate Digital Elevation Model (DEM) file from the ESA GETASSE repository, one must focus on the South-West corner of the imaged area. As mentioned earlier, an estimated midpoint of the acquisition path is situated at approximately 30.8°N and 3.55°E. Consequently, the corresponding South-West corner coordinates are approximately 30.0°N and 0.0°E, considering that the set of Digital Elevation Model tiles covers an area spanning 15 degrees of longitude by 15 degrees of latitude. The requisite DEM file in this case is "***30N000E.GETASSE30***."

### Altitude Plots

After updating the DEM file, altitude data can be visualized and plotted using Panoply, as demonstrated in Figure 3‑9. A straightforward method to confirm the presence of non-zero values within the altitude array is to examine this figure. The minimum value for altitude, which is 335.1 meters, serves as the reference point on the color bar. In the event of encountering a zero value, it would correspond to the lower limit of the color scale.

A blue and yellow chart with red and yellow flames

Description automatically generated with medium confidence

Figure 3‑9: Altitude Plot.

# EODP-TS-ISM-0001. OPTICAL Stage

The goal of this test is to run the ISM Module and to check the optical stage: the spectral integration of

the ISRF filter, the conversion of radiances to irradiances and the spatial filter (MTF).

## Pass/fail Criteria

The PASS/FAIL criteria defined for the ISM Module contains the following test with a summarized justification of how they were obtained.

### Instrument Spectral Response TOA

* **Criteria**: Check for all bands that the differences with respect to the output TOA (ism\_toa\_isrf) are <0.01% for

at least 3-sigma of the points.

To ascertain that the disparities between the ISRF obtained, in comparison to the reference values located in the “*EODP-TS-ISM”* folder, remain below the threshold of 0.01%, a script named "*Test\_ISM\_Optical\_Stage.py*" has been developed. This script facilitates the calculation of deviations between the obtained outputs and reference outputs by performing a straightforward subtraction operation and subsequently displaying the resultant values.

### Optical Stage TOA

* **Criteria**: Check for all bands that the differences with respect to the output TOA (ism\_toa\_optical) are <0.01%

for at least 3-sigma of the points.

To ascertain that the disparities after the optical stage obtained, in comparison to the reference values located in the “*EODP-TS-ISM”* folder, remain below the threshold of 0.01%, a script named "*Test\_ISM\_Optical\_Stage.py*" has been developed. This script facilitates the calculation of deviations between the obtained outputs and reference outputs by performing a straightforward subtraction operation and subsequently displaying the resultant values.

### Radiance to Irradiance Conversion Factor

* **Criteria**: What is the radiance to irradiance conversion factor for each band. What are the units of the TOA at

this stage.

The conversion factor can be derived by the equation which facilitates the transformation of radiances into irradiances. The equation is expressed as follows:

Where

is the irradiance expressed per ground area

is the optical transmittance

is the radiance of the ground

is the telescope pupil diameter

is the focal length in meters

Consequently, the conversion factor is defined as:

The units of TOA measurements at this stage are expressed in radiances as [mW/sr · m²]. Following the conversion process, these TOA units are transformed into irradiances, denoted as [mW/m²].

### System MTF Plots

* **Criteria**: Plot for all bands the System MTF across and along track (for the central pixels). Report the MTF at

the Nyquist frequency. Explain whether this is a decent or mediocre value and why.

The MTF implementation can be found within the "*mtf.py*" file situated in the "*ism*" folder.

### Border Effect Cause

* **Criteria**: Explain the cause of the border effect introduced by the spatial filter (MTF) and what would be an

appropriate solution (if any). How many pixel lines does it affect (roughly).

Explanation included in section [4.3.5]

### TOA Plots

* **Criteria**: Plot the TOA for all bands after the optical stage (with Panoply).

Following the completion of MTF and the optical stage module implementation, the TOA plots after the optical stage will be displayed using Panoply.

## Summary: PASS/FAIL

This exercise is a **PASS**.

## Test Results

### Instrument Spectral Response TOA









Figure 4‑1: ISRF TOA Difference Check.

### Optical Stage TOA









Figure 4‑2: Optical Stage TOA Difference Check.

### Radiance to Irradiance Conversion Factor

### System MTF Plots

A graph of lines and colors

Description automatically generated with medium confidence

Figure 4‑3: System MTF slice ACT for VNIR-0 (for the central pixels of ALT).

A diagram of lines and colors

Description automatically generated with medium confidence

Figure 4‑4: System MTF slice ACT for VNIR-1 (for the central pixels of ALT).

A diagram of a diagram

Description automatically generated with medium confidence

Figure 4‑5: System MTF slice ACT for VNIR-2 (for the central pixels of ALT).

A graph of a number of lines

Description automatically generated with medium confidence

Figure 4‑6: System MTF slice ACT for VNIR-3 (for the central pixels of ALT).

A graph of lines and colors

Description automatically generated with medium confidence

Figure 4‑7: System MTF slice ALT for VNIR-0 (for the central pixels of ACT).

A graph of different colored lines

Description automatically generated

Figure 4‑8: System MTF slice ALT for VNIR-1 (for the central pixels of ACT).

A diagram of a graph

Description automatically generated with medium confidence

Figure 4‑9: System MTF slice ALT for VNIR-2 (for the central pixels of ACT).

A diagram of a system

Description automatically generated

Figure 4‑10: System MTF slice ALT for VNIR-3 (for the central pixels of ACT).

Table 5‑1: System MTF Values at Nyquist Frequency.

|  |  |  |
| --- | --- | --- |
|  | **System MTF ACT Values** | **System MTF ALT Values** |
| **VNIR-0** | 0.357 | 0.356 |
| **VNIR-1** | 0.408 | 0.406 |
| **VNIR-2** | 0.441 | 0.438 |
| **VNIR-3** | 0.449 | 0.447 |

### Border Effect Cause

Border effects manifest during the application of image processing. Image processing involves the utilization of neighbouring input pixels, and as a consequence, the output values become undefined in the vicinity of the image borders.

Typically, border effects become pronounced following convolution operations, as is the case with the MTF application. When convolutions are performed on signals with finite lengths, border distortions become evident. Figure 4-5 serves as an illustrative example of these border effects, observable at the initial and final sections of the curve.

A graph with a red line

Description automatically generated

Figure 4‑11: Central ACT position of “ism\_toa\_optical\_VNIR-0”.

Addressing border or edge defects entails various steps, such as:

Creating a margin around the image, where "fake" pixels are simulated in both the ACT and ALT directions. These are subsequently removed after the spatial filtering process. To perform convolution with the Point Spread Function (PSF), it suffices to have a margin equivalent to half the kernel size. For multiplication with the MTF, a larger margin, typically spanning 2 to 3 pixels, is preferable. This approach aims to rectify border effects introduced during convolution by accounting for the erroneous pixels and eliminating them post-spatial filtering.

Employing spatial oversampling on the input TOA data, thereby increasing the sampling rate to mitigate edge effects. Following the application of spatial filtering, the image is subsequently down sampled to its native resolution. This step complements the previous one by providing higher pixel resolution.

Numerous methods from existing literature can be utilized to mitigate border effects, including zero-padding, symmetrization, smooth padding, and periodic padding

### TOA Plots

A chart of a color spectrum

Description automatically generated with medium confidence

Figure 4‑12: Plot ism\_toa\_optical\_VNIR-0.

A chart of a temperature

Description automatically generated with medium confidence

Figure 4‑13: Plot ism\_toa\_optical\_VNIR-1.

A diagram of a number of colors

Description automatically generated

Figure 4‑14: Plot ism\_toa\_optical\_VNIR-2.

A chart of a number of colors

Description automatically generated with medium confidence

Figure 4‑15: Plot ism\_toa\_optical\_VNIR-3.

# EODP-TS-ISM-0002. DETECTION and VIDEO CONVERSION

The goal of this test is to run the ISM Module and to check the detection and the video conversion unit

(VCU) stage. The detection stage has the irradiance to photon conversion and three effects in the chain:

❑ Photon Response Non-Uniformity (PRNU)

❑ Dark Signal (DS)

❑ Simulation of bad and dead pixels

## Pass/fail Criteria

The PASS/FAIL criteria defined for the detection and video conversion of the ISM Module contains the following test with a summarized justification of how they were obtained.

### Video and Control Unit TOA

* **Criteria**: Check for all bands that the differences with respect to the output TOA (ism\_toa\_) are <0.01% for at

least 3-sigma of the points.

In this section, simulations for the detection and video processing stages has been conducted. It is imperative to ensure that the disparities in the acquired TOA data, specifically after the video processing stage, exhibit minimal variation when compared to the reference output provided. To facilitate this comparison, a script named "*Test\_ISM\_Detect\_Vid\_Conversion.py*" has been developed to perform the subtraction and evaluate the discrepancies.

### Conversion Factors

* **Criteria**: What is the irradiance to photons, photons to electrons, electrons to Volts, and volts to Digital numbers conversion factor for all bands. What are the units of the TOA at each stage.

The formulas to obtain these conversion factors are summarized below:

* Irradiances to photons:

Where,

;

is the detector element area in

is the integration time in seconds

is the Planck constant in

id the central wavelength for channel in meters

is the speed of light in vacuum in

Thus, the conversion factor is given by:

The units of TOA measurements at this stage are expressed in irradiances as [mW/m²]. Following the conversion process, these TOA units are transformed into irradiances, denoted as [].

* Photons to electrons:

Where

is the quantum efficiency in

Thus, the conversion factor is:

The units of TOA measurements at this stage are []. Following the conversion process, these TOA units are [].

* Electrons to Volts:

Where

is the Output Conversion Factor

is the system gain

Thus, the conversion factor is given by:

The units of TOA measurements at this stage are []. Following the conversion process, these TOA units are [].

* Volts to Digital Numbers:

The units of TOA measurements at this stage are []. Following the conversion process, these TOA units are converted to digital numbers.

### Image ‘Stripes’

* **Criteria**: Explain why there are ‘stripes’ in the image, and why they are in the ALT direction.

Explanation given in section [5.3.3].

### Saturated Pixels

* **Criteria**: For all bands, check whether there are any saturated pixels. Quantify the percentage of saturated

pixels per band.

To determine the presence of saturation in all spectral bands, TOA plots after the execution of the detection and video processing stages will be presented, with a focus on the central ALT position. These plots serve to assess the quantity of saturated pixels, if any.

### TOA Plots

* **Criteria**: Plot the TOA for all bands after the detection and the VCU stages (with Panoply).

Following the completion of detection and video conversion stages, the TOA plots will be displayed using Panoply in section [5.3.5].

## Summary: PASS/FAIL

This exercise is a **PASS**.

## Test Results

### Video and Control Unit TOA









Figure 5‑1: Video and Control TOA Difference Check.

### Conversion Factors

Table 5‑1: Conversion Factors Values for all Bands

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | **Irradiance to Photons** | **Photons to Electrons** | **Electrons to Volts** | **Volts to Digital Numbers** |
| **VNIR-0** | 14918705.378 | 0.8 | 3.024E-6 | 4762.0 |
| **VNIR-1** | 20246814.441 | 0.8 | 3.024E-6 | 4762.0 |
| **VNIR-2** | 26336081.943 | 0.8 | 3.024E-6 | 4762.0 |
| **VNIR-3** | 28771788.943 | 0.8 | 3.024E-6 | 4762.0 |

### Image ‘Stripes’

The presence of stripes, as exemplified in Figure 5‑2, results from a combination of various factors, such as:

* Photo Response Non-Uniformity (PRNU): This effect arises due to slight variations in how each pixel responds to incoming radiation. Consequently, for a given input irradiance, the read-out values of individual pixels exhibit variations.
* Bad/Dead Pixels: Within the Charge-Coupled Device (CCD), certain pixels may either fail to function entirely (referred to as "dead" pixels) or provide inaccurate readout values (referred to as "bad" pixels). In both scenarios, the readout values are diminished, leading to the appearance of stripes in the image.

A chart of a number of columns

Description automatically generated with medium confidence

Figure 5‑2: Plot of the final TOA in DN.

### Saturated Pixels









Figure 5‑2: Percentage of Saturated Pixels per Band.

### TOA Plots

A chart of a number of colors

Description automatically generated with medium confidence

Figure 4‑15: Plot ism\_toa\_VNIR-0.

A chart of a number of colors

Description automatically generated with medium confidence

Figure 4‑15: Plot ism\_toa\_VNIR-1.

A graph of a number of columns

Description automatically generated with medium confidence

Figure 4‑15: Plot ism\_toa\_VNIR-2.

A red and blue chart

Description automatically generated

Figure 4‑15: Plot ism\_toa\_VNIR-3.

# EODP-TS-L1B-0001. EQUALIZATION AND RESTORATION

## Pass/fail Criteria

*In this section justify point by point each of the pass/fail criteria defined in [EODP\_SPE].*

## Summary: PASS/FAIL

This exercise is a PASS.

*(If all the pass fail criteria are met)*

## Test Results

*Plots, results, description, anything that supports the pass/fail criteria*

# EODP-TS-L1C-0001. MGRS

## Pass/fail Criteria

*In this section justify point by point each of the pass/fail criteria defined in [EODP\_SPE].*

## Summary: PASS/FAIL

This exercise is a PASS.

*(If all the pass fail criteria are met)*

## Test Results

*Plots, results, description, anything that supports the pass/fail criteria*

# EODP-TS-E2E-0001. TLS.

## Pass/fail Criteria

*In this section justify point by point each of the pass/fail criteria defined in [EODP\_SPE].*

## Summary: PASS/FAIL

This exercise is a PASS.

*(If all the pass fail criteria are met)*

## Test Results

*Plots, results, description, anything that supports the pass/fail criteria*

# Summary of test results

This table summarizes the results of the execution:

*Fill in with the results (PASS/FAIL) of the tests above.*

Table 9‑1: Summary of test execution reports

|  |  |  |
| --- | --- | --- |
| **Test ID** | **PASS/FAIL** | **Comments** |
| EODP-TS-GEO-0001 | PASS |  |
| EODP-TS-ISM-0001 | PASS |  |
| EODP-TS-ISM-0002 | PASS |  |
| EODP-TS-L1B-0001 | PASS |  |
| EODP-TS-L1C-0001 | PASS |  |
| EODP-TS-E2E-0001 | PASS |  |

# Section

This section has example of titles levels:

## Subsection

Example Text.

### Subsection

Example Text.

#### Subsection

Example Text.

##### Subsection

Example Text.

* Indent
* Indent
* Indent



Figure 10‑1: ISS low-res (weak).

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