Technical Note on Quality Assessment for NEMO-HD Video

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AMENDMENT RECORD SHEET

The Amendment Record Sheet below records the history and issue status of this document.

ISSUE	DATE	REASON
0.1	22/10/2021	First draft version for review.
0.2	12/04/2022	Updated after feedback received from Space-SI
1.0	21/04/2022	First issue

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1. INTRODUCTION

The primary objective of Next-generation Earth Monitoring and Observation – High Definition (NEMO–**HD**) microsatellites is to explore a new Earth Observation (**EO**) concept which combines optical video and still imagery for interactive real-time and low latency remote sensing services. [RD.1].

These assessments are performed in accordance with the assessment guidelines, detailed in [RD.2], that constitute the European Space Agency (**ESA**) Earthnet Data Assessment Pilot (**EDAP**) Project's *EO Mission Data Quality Assessment Framework*. An important representation of the latter framework, constructed by the National Physical Laboratory (**NPL**), is what is known as the *maturity matrix*. It is a diagrammatic summary of the following:

- ***Documentation Review****: the EDAP Optical team reviews materials (e.g., data and documentation) provided by the data provider or operator, some of which may not be publicly available, or even the scientific community (e.g., published papers). The results are detailed in Section 3 (covering the first four columns of the maturity matrix).*

- ***Data Quality Assessments:*** *the EDAP Optical team performs the data quality assessments (i.e., validation assessments), independently of any validation assessments performed by the data provider and / or operator. The results are detailed in Section 4 (covering the last column, 'Validation', of the maturity matrix).*

The above assessments are performed by the EDAP Optical team using the appropriate in-house and open-source ad-hoc scripts/tools.

It is important to note the purpose of the EDAP EO Mission Data Quality Assessment Framework is to ensure that the delivered commercial mission data is fit for purpose and that all decisions regarding the inclusion of the commercial mission as an ESA third party mission can be made fairly and with confidence.

1.1 Reference Documents

The following is a list of documents with a direct bearing on the content of this report. Where referenced in the text, these are identified as RD.n, where 'n' is the number in the list below:

[RD.1] NEMO-HD Product User Manual, draft, 31 August 2021.

[RD.2] EDAP Mission Quality Assessment Guidelines, Issue 1.2, 19 July 2019.

1.2 Glossary

The following acronyms and abbreviations have been used in this report:

EDAP	Earthnet Data Assessment Pilot
EO	Earth Observation
ESA	European Space Agency
HR- HD	High Resolution - High Definition

LR- HD	Low Resolution - High Definition
NEMO–HD	Next-generation Earth Monitoring and Observation – High Definition
NPL	National Physical Laboratory
PUM	Product User Manual
RD	Reference Document
SNR	Signal-to-Noise Ratio
Space-SI	Slovenian Centre of Excellence for Space Sciences and Technologies

2. EXECUTIVE SUMMARY

This technical note details the results of the (preliminary) mission data quality assessments performed on a sample of NEMO-HD video products provided by the Slovenian Centre of Excellence for Space Sciences and Technologies (Space-**SI**), the mission operator. A companion technical note describes the NEMO-HD imagery, covering the standard assessments (including geometric calibration, radiometric calibration, and image quality).

Table 2-1 Mission – NEMO-HD Video: Assessment Area Results

Assessment Area	Results
Visual Inspections	The visual inspection shows that over the ocean the data becomes noisier due to the lower signal to noise ratio, which is not unexpected. The filenames are limited but there is metadata to specify where the video data was captured; Latitude and Longitude information in the XML file.
Object Detection and Tracking	The conclusion is that video data can be used to detect and track objects, a common application of EO video data, reasonably well. However, it is important that the data provider ensures detailed documentation is provided to support users with this type of application.

3. EDAP QUALITY ASSESSMENT

3.1 EDAP Maturity Matrix

Table 3-1 NEMO-HD Quality Evaluation Matrix

Product Details	Product Generation	Ancillary Information	Uncertainty Characterisation	Validation
Product Information (Intermediate; Information Not Public)	Sensor Calibration & Characterisation Pre-Flight (Not Assessable)	Product Flags (Not Assessable)	Uncertainty Characterisation Method (Not Assessable)	Reference Data Representativeness (Not Assessable)
Availability & Accessibility (Not Assessable; Information Not Public)	Sensor Calibration & Characterisation Post-Launch (Not Assessable)	Additional Information (Not Assessable)	Uncertainty Sources Included (Not Assessable)	Reference Data Quality (Not Assessable)
Product Format (Intermediate; Information Not Public)			Uncertainty Values Provided (Not Assessable)	Validation Method (Not Assessable)
User Documentation (Not Assessable; Information Not Public)			Geolocation Uncertainty (Not Assessable)	Validation Results (Not Assessable)

Key
Not Assessed
Not Assessable
Basic
Intermediate
Good
Excellent
🔒 Information Not Public

3.1.1 Product Information

Product Details	
Product Name	*NEMO-HD Video*
Sensor Name	*NEMO-HD*
Sensor Type	*The primary instrument provides still imagery (panchromatic and multispectral channels / bands) and HR-HD optical video channel and the secondary instrument provides LR-HD optical video channel.*
Mission Type	*Single microsatellite*
Mission Orbit	*517 km, Sun-synchronous Orbit, 10:30 LTDN*
Product Version Number	*Unknown*
Product ID	*Named*
Product Processing Level	*Unknown*
Measured Quantity Name	*DN*
Measured Quantity Units	*N/A*
Stated Measurement Quality	*Unknown*
Spatial Resolution (GSD @ nadir)	*One video channel is 2.8 m GSD (5 km swath), and the second is 40 m GSD (75 km swath).*
Spatial Coverage	*Global*
Temporal Resolution	*6 – 13 days (depends on latitude)*
Temporal Coverage	*Operating since 03 September 2020, with an expected life of 3-5 years*
Point of Contact	*SPACE-SI Aškerčeva 12 SI-1000 Ljubljana Slovenija Tel: +386 40 866 945 Email: info@space.si*
Product locator (DOI/URL)	*Not available*
Conditions for access and use	*Commercial mission*
Limitations on public access	*Commercial mission*
Product Abstract	*Not available*

Availability & Accessibility	
*Grade: Not Assessable Justification: The draft Product User Manual (**PUM**) states that the video data will be available on the SPACE-SI web page.*	
Compliant with FAIR principles	*The product information does not meet some of the FAIR principles*

Data Management Plan	*None.*
Availability Status	*The products for this mission are made available upon request only.*

Product Format, Metadata & Flags	
Grade: Intermediate *Justification: MP4 is a standard format for video data, and metadata is provided in accompanying XML file (as supplied for the still imagery) with the centre location and solar/viewing geometry. The filename is not explained in the documentation; it is possible to infer some aspects, but other elements are unclear so more detailed documentation would support usage.*	
Product File Format	*MP4 for video data*
Metadata Conventions	*XML metadata file*
Analysis Ready Data?	*N/A*

User Documentation		
Grade: Intermediate *Justification: There is information on the video data capture in the PUM, but this is more limited than is available for the imagery product. However, Section 4.3 does include a post-launch analysis of the data.*		
Document	*Reference*	*QA4ECV Compliant*
Product Guide	*NEMO - PUM v1.0 - 20220311.pdf*	*N/A*
Sensor Data Sheet	*There is a product sheet for the imagery, but not video data*	*N/A*

Limited cells are valid for the Maturity Matrix as the video data procured is not radiometrically or geometrically calibrated. Therefore, this assessment focuses on the product details, including documentation and product format.

4. DETAILED NEMO-HD VIDEO QUALITY ASSESSMENT

4.1 Goal

Three NEMO-HD video products were procured for assessment, see Table 4-1.

The first two products are videos of busy airports located in Frankfurt (Germany) and New York (USA), with limited scanning across the location equating to approximately 13 to 14 seconds duration (i.e., although there is a movement of the frame being observed, it is limited). Therefore, we have developed a Jupyter notebook to track the movement of aircraft to demonstrate the applicability of the video dataset for object tracking.

The third video product is named "Obala", and the video is scanning a much larger area with a more varied environment, including both the land and sea along the Slovenian coast. The accompanying metadata (XML) files provide information such as the acquisition date, mode, centre Latitude/Longitude co-ordination, solar and viewing geometry. It is not possible to understand the reason for this video because it does not contain apparent moving objects so, instead of attempting to track objects, only the general quality of the video will be assessed.

Table 4-1: NEMO-HD Video Products

Product	Site	Product Name	No. of frames
1	Frankfurt, focused on airport	NHDHFrankfurtTT_1D.mp4	340
2	New York, focused on airport	NHDHNewYorkTT_1D.mp4	347
3	Obala, panning across the land and sea in Slovenia between Koper and Piran	NHDHObala1_1D.mp4	584
4	Lefkas, panning across the land and sea in the Greek Ionian Islands	NHDLLefkas_1D.mp4	583

4.2 Visual Assessment

Figure 4-1 shows stills from the three videos for the products listed in Table 4-1. The video dimensions are 1080 by 1920 pixels for all three products, and the data was extracted as a 3-band RGB array. For Frankfurt and New York, there is a single frame, while for Obala and Lefkas two examples are chosen as that video pans over an area of the sea with a much lower Signal-to-Noise Ratio (**SNR**). The entire sea scene shows that although the SNR is suitable for terrestrial applications, the data becomes noisier over the ocean. Also, for the Lefkas video there appear to 'spots' of contamination.

There are two channels [RD.1]:

- High Resolution - High Definition (HR-**HD**) channel, where the video is provided by the primary instrument
- Low Resolution - High Definition (LR-**HD**) channel, where the video is provided alongside still imagery from the secondary instrument.

Both channels are captured at 25 frames per second, encode the raw stream with an H.264 codec, and the resulting video is streamed to the ground in real-time or save it for later transmission [RD.1]. Three of the video examples are from the HR-HD channel and the fourth (Lefkas).

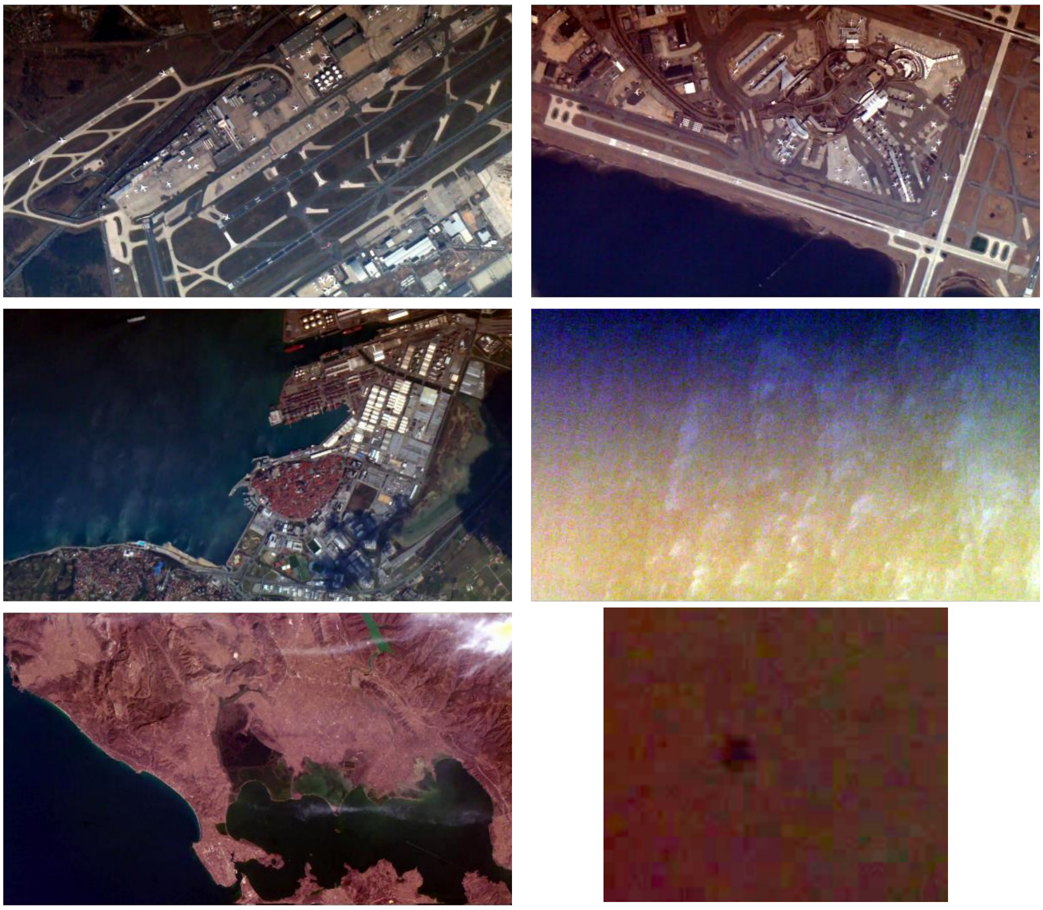

Figure 4-1: Shows extracted frames (from top to bottom and left to right): Frankfurt and New York on the top row, Obala and then Obala entirely over the sea on the middle row, then Lefkas examples on the bottom row with a zoomed in area highlighting one of the 'spots' that appear to be contamination as they exist throughout the video.

4.3 Object Detection and Tracking Assessment

The OpenCV open-source library includes computer vision, machine learning, and image processing modules that were utilised to detect and track objects. The code was written in Python, within a Jupyter Notebook, where the following steps were undertaken:

- Extract the first frame, and then find corner points within it.
- Use optical flow, in this case, the Lucas-Kanade Algorithm provided by OpenCV - cv2.calcOpticalFlowPyrLK(), to track the location of all the corner points for each successive frame.
- Plot colour tracks to show the movement of each corner point.

Figure 4-2 shows the identified corner points for the first frame of the Frankfurt and New York products. The frames are shown in black and white, so the blue circle identified corner points are visible. A significant number of corner points identified for both frames are aircraft, but other (stationary) features such as features on the buildings are also detected. When the videos are viewed, it is also possible to see moving vehicles in the Frankfurt image, but these were not identified as corner points; a section of which is enclosed in a red box.

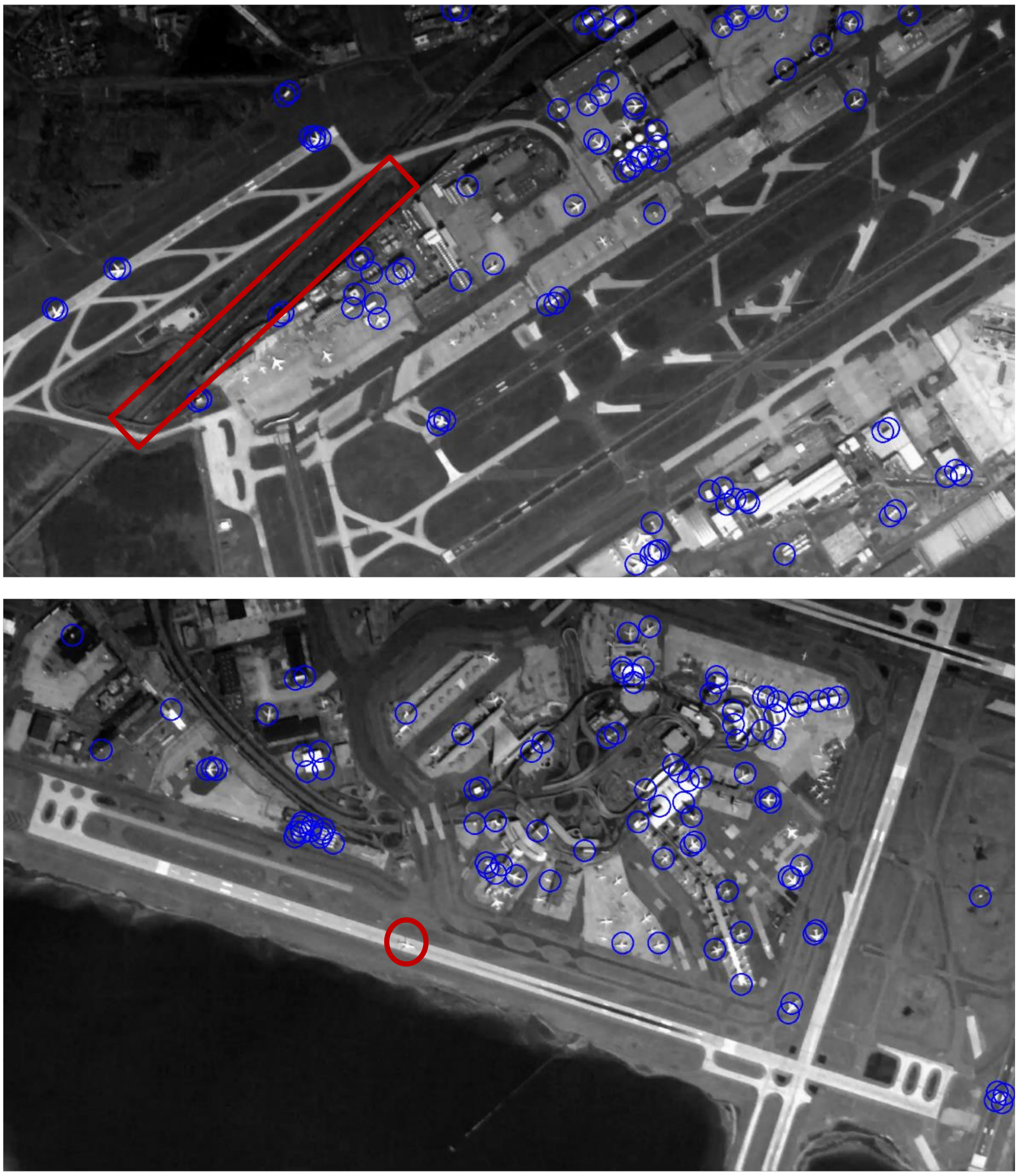

Figure 4-2: Identified tracking features for Frankfurt (top) and New York (bottom) surrounded by blue circles. For Frankfurt, an area of the road with moving vehicles is shown using a red box. For New York, a fast-moving plan (red circle) was not detected with the current settings.

The default Lucas-Kanade Algorithm options for these examples were used and so results could probably be improved through non-default tuning, but this was not the aim of this assessment.

Figure 4-3 shows the tracks (with different random colours) for the detected and tracked objects. The zoomed-in area for Frankfurt shows the aircraft that was moving along the runway and its tracks. This track shows both the movement of the aircraft and any shift in the central location of the video (i.e., where the video is physically pointing at).

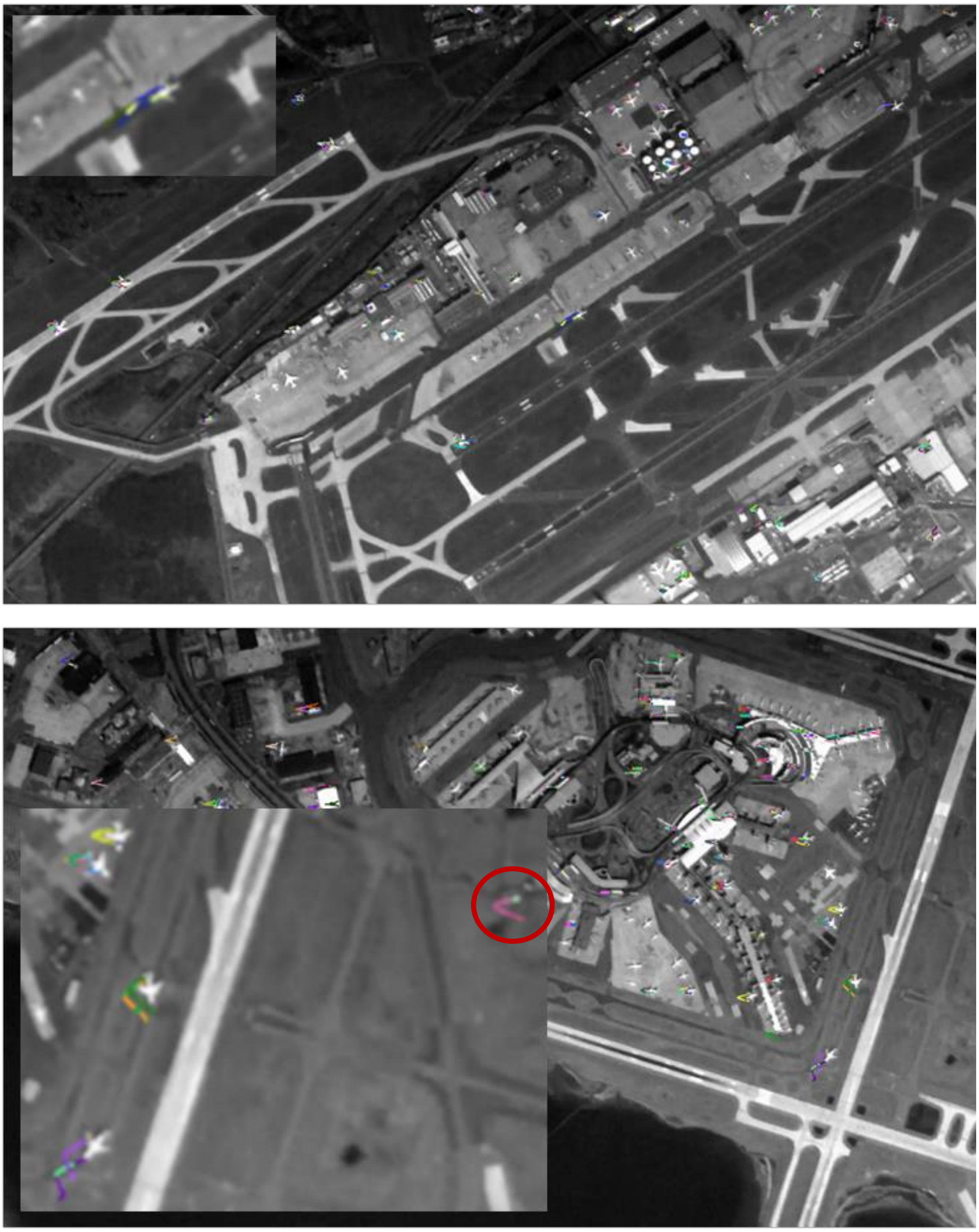

Figure 4-3: Plane tracking for Frankfurt (top) and New York (bottom). For New York, the zoomed in area shows the tracks in more detail for some of the objects.

The zoomed-in area for New York shows some of the tracks in further detail, and the point on the right (surrounded by the red circle) is stationary, so the capture process includes the movement of the sensor. The two aircraft at the top have similar tracks to the fixed point, so they are also likely to be stationary, while the tracks for the two aircraft lower down in the zoomed-in area are different, indicating they were moving. Unfortunately, the aircraft that moved the most (enclosed by a red circle in Figure 4-2) was not detected in the first frame, so it was not tracked. Therefore, further work is needed to optimise the implementation.

5. CONCLUSION

The conclusion is NEMO-HD video data can be used to detect and track objects, a common application of EO video data, reasonably well. The videos have been provided within product metadata, which is useful but limited. Therefore, it is important that the data provider ensures detailed documentation is also provided in order to support users with this type of application (or any other application of the video data).

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