Technical Note on Quality Assessment for Jilin-1 GF03B

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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	21 01 2022	First draft for ESA review
1.0	23 06 2022	First issue

1. EXECUTIVE SUMMARY

The Jilin-1 constellation of Earth Observation (**EO**) satellites, operated by **Chang Guang Satellite Technology Company** (China), consists of the optical **Jilin-1 "Daily Vision" GF03A** (prototype, launched 2019) and **B** (cluster of 6 satellites, launched 2020) satellites. Jilin-1 GF03 provides the user community with Very High Resolution (**VHR**) multispectral (**MS**) and panchromatic (**PAN**) still imagery of the Earth's surface.

The results of the preliminary data quality assessments, performed on the orthorectified bundle of Jilin-1 GF03B products (only) that were procured from the data provider, **Head Aerospace,** between April and September 2021, are summarised in Table 1-1.

Table 1-1: Jilin-1 GF03B: Assessment Area Results

Assessment Area	Results
GF03B 01 / 02 / 03 / 04 / 05 / 06 Ground Sampling Distance / Pixel Size @ Nadir: Panchromatic: 0.98 m Multispectral: 3.92 m.	
Geometric Calibration Quality	**1. Absolute Geolocation Accuracy** The results of this assessment indicate the absolute geolocation accuracy of the panchromatic imagery is (average) 3.3 m RMSE and 4.4 m CE90. Therefore, the minimum performance requirement specified by the operator as 8.0 m CE90 [RD-3] has been met. The results of this assessment indicate the absolute geolocation accuracy of the multispectral imagery is (average) 8.4 m RMSE and 12.8 m CE90. It is assumed, however, the aforementioned performance requirement is not applicable to multispectral imagery. **2. Temporal Geolocation Accuracy** The temporal geolocation accuracy could not be assessed for this sensor due to the very small sample of suitable products procured. Note a minimum performance requirement has not been specified by the operator for this metric. **3. Band Co-registration Accuracy** The results of this assessment indicate the band co-registration accuracies of the multispectral band pairs (blue-green, green-red and red-near-infrared) is < 0.83 multispectral pixels CE90 (i.e. accuracy is sub-pixel), but the multispectral-panchromatic bands are not and this may be because further corrections are to be performed if the data is to be pansharpened (pansharpened products available).

	Note no minimum performance requirement has been specified by the operator.
Radiometric Calibration Quality	**1. Absolute Radiometric Accuracy** The results of this assessment indicate the data is poorly calibrated (absolute radiometric accuracy < 30 %) and the reason(s) for this is not clear at this time. However, as this result appears to be prevalent with the other assessed Jilin-1 missions that have been calibrated by the operator in the same way, it could be due to the calibration method used. It is recommended that the operator re-assess the latter. Note a minimum performance requirement has not been specified by the operator for this metric. **2. Temporal Radiometric Accuracy** The temporal radiometric accuracy could not be assessed for this sensor due to the very small sample of suitable products procured. Note a minimum performance requirement has not been specified by the operator for this metric.
Image Quality	**1. Modulation Transfer Function** This assessment could not be performed as the tool could not precisely detect / define the edges provided by the acquisitions of two artificial modulation transfer function targets (i.e. blurring is evident, poor sharpness indicates degradation of image quality) and this may be because the modulation transfer function compensation correction had not been applied during processing, as indicated in the product metadata. Note a minimum performance requirement has not been specified by the operator for this metric. **2. Signal-to-Noise Ratio** The results of this assessment, performed using acquisitions of La Crau (France), indicate the signal-to-noise ratio is reasonable and consistent (stable). This assessment could not be performed using acquisitions of a more suitable site, such as Libya-4 (a well-known pseudo-invariant calibration site), these could not be procured. Note a minimum performance requirement has not been specified by the operator for this metric. **Image Interpretability**

	The results of this assessment indicate the multispectral and panchromatic imagery of this sensor is of a quality that allows objects or features of interest, which correspond to its interpretability category, to be delineated. However, this can be improved with the reduction of blurring (and is especially evident when the multispectral imagery is compared to reference imagery from Pléiades). Note a minimum performance requirement has not been specified by the operator for this metric.
Visual Inspections	The results of the visual inspections indicate there are no anomalies or artefacts, except for the blurring noted previously, present in the multispectral and panchromatic imagery procured.

2. INTRODUCTION

This technical note details the results of the preliminary data quality assessments (geometric calibration, radiometric calibration and image quality) performed on a sample of orthorectified bundle products generated for the optical Earth Observation (**EO**) **Jilin-1 GF03B** mission (a relatively new addition to Head Aerospace's EO portfolio of commercial optical missions).

The aforementioned data quality assessments are performed in accordance with the assessment guidelines, detailed in [RD-1, 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**, U.K), 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. ancillary / auxiliary data and documentation) provided by the mission provider (i.e. data provider and / 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, see Table 3-1).*

- ***Data Quality Assessments:*** *the EDAP optical team performs data quality assessments (i.e. validation assessments), independently of those performed by the mission provider. The results are detailed in Section 4 (covering the last column of the maturity matrix, see Table 3-1).*

The above data quality assessments are performed by the project's 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 the delivered commercial mission data (products) 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.

2.1 Reference Documents

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

RD-1. EDAP Best Practice Guidelines, EDAP.REP.001, v1.2, September 2019.

RD-2. Earth Observation Mission Quality Assessment Framework – Optical Guidelines, EDAP.REP.002, v2.0, December 2020.

RD-3. Head Aerospace – Daily Vision (JL-1 GF03B) Data Sheet, v1.0, 2020.

RD-4. Chang Guang Satellite Technology Co Ltd., Jilin-1 Imagery Product Guide, v1.1, April 2021.

RD-5. Wilkinson, M.D., Dumontier, M., Aalbersberg, I.J., Appleton, G., Axton, M., et al. 2016. The FAIR Guiding Principles for scientific data management and stewardship. Scientific Data 3, 160018. (doi:10.1038/sdata.2016.18)

RD-6. Head Aerospace – Introduction to the Jilin-1 Satellites and Products, v0.1 (Draft), May 2020.

RD-7. Chang Guang Satellite Technology Co Ltd., Jilin-1 Radiometric Calibration, v1.0.

RD-8. M. Cournet, A. Giros, L. Dumas, J.M. Delvit., D. Greslou, F. Languille, G. Blanchet, S. May, and J. Michel (2016). 2D Sub-Pixel Disparity Measurement Using QPEC / Medicis, Int. Arch. Photogramm. Remote Sens. Spatial Inf. Sci., XLI-B1, 291-298, doi: 10.5194/isprs-archives-XLI-B1-291-2016.

RD-9. Zanoni, “IKONOS Signal-to-Noise Ratio Estimation”, March 25-27, 2002, JACIE Workshop, 2002 https://ntrs.nasa.gov/search.jsp?R=20040004380

RD-10. National Image Interpretability Rating Scales, https://fas.org/irp/imint/niirs.htm

RD-11. SPOT Image Quality Performances, CNES C443-NT-0-296-CN, https://www.intelligence-airbusds.com/files/pmedia/public/r438_9_spot_quality_performances_2013.pdf

RD-12. Blanc, P., Wald, L. 2009, A review of earth-viewing methods for in-flight assessment of modulation transfer function and noise of optical spacebourne sensors, https://www.researchgate.net/publication/259157057_A_review_of_earth-viewing_methods_for_in-flight_assessment_of_modulation_transfer_function_and_noise_of_optical_space-borne_sensors

RD-13. Sentinel-2 MPC L1C Data Quality Report, S2-PDGS-MPC-DQR, Issue 71, 03/01/2022. https://sentinel.esa.int/documents/247904/685211/Sentinel-2_L1C_Data_Quality_Report

RD-14. Department of the Interior U.S. Geological Survey, Landsat 8 (L8) Data Users Handbook, LSDS-1574, Version 5.0, https://prd-wret.s3-us-west-2.amazonaws.com/assets/palladium/production/atoms/files/LSDS-1574_L8_Data_Users_Handbook-v5.0.pdf

2.2 Glossary

The following acronyms and abbreviations have been used in this Report.

CEOS	Committee for Earth Observing Satellites
DGPS	Differential Global Positioning System
EDAP	Earthnet Data Assessment Pilot
EO	Earth Observation
ESA	European Space Agency

ESF	Edge Spread Function
FAIR	Findable, Accessible, Interoperable and Reusable
GCP	Ground Control Points
IVOS	Infrared and Visible Optical Sensors
MS	Multispectral
MTF	Modulation Transfer Function
NIIRS	National Imagery Interpretability Rating Scale
NPL	National Physical Laboratory
PAN	Panchromatic
PHR	Pleaides High-Resolution
PICS	Pseudo-invariant Calibration Site
PSF	Point Spread Function
SNR	Signal-to-Noise Ratio
VHR	Very High Resolution
WGCV	Working Group for Calibration and Validation

3. EDAP QUALITY ASSESSMENT

3.1 EDAP Maturity Matrix

Table 3-1: Maturity Matrix for Jilin-1 GF03B

Product Information	Product Generation	Ancillary Information	Uncertainty Characterisation	Validation
Product Details	Sensor Calibration & Characterisation Pre-Flight 🔒	Product Flags	Uncertainty Characterisation Method	Reference Data Representativeness
Product Availability & Accessibility	Sensor Calibration & Characterisation Post-Launch 🔒	Ancillary Data	Uncertainty Sources Included 🔒	Reference Data Quality
Product Format 🔒	Additional Processing 🔒		Uncertainty Values Provided 🔒	Validation Method
User Documentation			Geolocation Uncertainty 🔒	Validation Results
Metrological Traceability Documentation				

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

3.1.1 Product Information

<table>
<tr><th colspan="2">Product Details</th></tr>
<tr><td colspan="2">Grade: Intermediate
Justification: As there is some required and recommended information (included in product metadata, documentation, etc.) missing, the status of this section of the maturity matrix has been graded as "Intermediate".</td></tr>
<tr><td>Product Name</td><td>GF03B Bundle Standard Orthorectified</td></tr>
<tr><td>Sensor Name</td><td>GF03B ("Daily Vision") 01 / 02 / 03 / 04 /05 / 06</td></tr>
<tr><td>Sensor Type</td><td>Pushbroom, Optical (Multispectral and Panchromatic)</td></tr>
<tr><td>Mission Type</td><td>JL1GF03B1,2,3,4,5,6 (constellation of six micro-satellites)</td></tr>
<tr><td>Mission Orbit</td><td>GF03B: Sun-synchronous (535 km altitude, Descending Node Local 09:20)</td></tr>
<tr><td>Product Version Number</td><td>-</td></tr>
<tr><td>Product ID</td><td>JL1GF03B04_PMS_20210405172946_200046263_103_0001_001_L3A

Satellite Name and number (JL1GF03B0x: 1 - 6), Detector Name (PMS), Imaging Time (YYYYMMDDHHMMSS (Beijing Local)), Mission Planning Number, Segment Number, Scene Number, Production Times, Product Level.</td></tr>
<tr><td>Product Processing Level</td><td>The products used for these assessments are those generated by Level 1 and Level 3A product processing levels (definition taken from [RD-4]).

<table>
<tr><td colspan="2">L1</td><td>Based on L0 product, sensor and radiometric correction products, this level product includes RCP files.</td></tr>
<tr><td rowspan="3">L3</td><td>A</td><td>Based on L1 products, orthorectified products with its correspondent projection information.</td></tr>
<tr><td>B</td><td>Based on L3A products, it is reflective pre-orthorectified product with atmospheric correction.</td></tr>
<tr><td>C</td><td>Based on L3A product, it provides fusion product combining a high-resolution panchromatic image (PAN) with a low-resolution multispectral image (MS).</td></tr>
<tr><td colspan="2">L5</td><td>Mosaiced image are orthorectified and color balanced products. Image framing is performed according to image GSD.</td></tr>
</table></td></tr>
<tr><td>Measured Quantity Name</td><td>Digital Numbers (DN) (16-bit) / Spectral Radiance</td></tr>
<tr><td>Measured Quantity Units</td><td>DN / W.sr^{-1}.m^{-2}.μm^{-1}</td></tr>
<tr><td>Stated Measurement Quality</td><td>Radiometric Quality: Not specified.
Geometric Quality: CE90 < 8.0 m (assumed @ Nadir and panchromatic only)</td></tr>
<tr><td>Spatial Resolution</td><td>GF03B - Very High Resolution
Multispectral: 3.92 m GSD @ Nadir
Panchromatic: 0.98 m GSD @ Nadir
Full Swath Width @ Nadir: 17.0 km</td></tr>
<tr><td>Spatial Coverage</td><td>Near-global (Orbital Inclination 45°)</td></tr>
</table>

Temporal Resolution	*Revisit < 0.5 Days (GF03A and GF03B)*
Temporal Coverage	*Mission lifetime not known / provided*
Point of Contact	*contact@head-aerospace.fr*
Product locator (DOI/URL)	-
Conditions for access and use	*contact@head-aerospace.fr*
Limitations on public access	*The sensor products are made available upon request (orders / tasks are placed with the data provider's imagery support team: contact@head-aerospace.fr) or through their online catalogue (https://headfinder.head-aerospace.eu/pub).*
Product Abstract	*The standard license for imagery, adapted on a case-by-case basis (i.e. depending upon the needs of the user), is delivered to the customer by the Head Aerospace sales team (contact e-mail address provided above).*

Availability & Accessibility	
Grade: Intermediate *Justification: The products and their content are compliant with many of the Findable, Accessible, Interoperable and Reusable (**FAIR**) Data Principles [RD-5] for scientific data management and stewardship. The data is available to users, at cost, through an easy-to-access commercial license.*	
Compliant with FAIR Principles	*The products and their content are compliant, and where applicable, with many of the FAIR Data Principles for scientific data management and stewardship. It is recommended, however, the data be released with a clear and accessible data usage licence (as this is not available to users at all).*
Data Management Plan	*This is not shared by the data provider.*
Availability Status	*As mentioned previously, the products are made available upon request (orders / tasks are placed with the data provider's imagery support team: contact@head-aerospace.fr) or through their online catalogue (https://headfinder.head-aerospace.eu/pub).*

Product Format
Grade: Intermediate *Justification: The product format and content, in which standard file formats and naming conventions are generally used, is only partially described in [RD-3]; product metadata file format and content is not fully described and product quality metadata file format and content, with valuable / useful data, is not described at all (this includes units and how the values for quality parameters are calculated / determined).* *It is recommended that existing documentation be updated in order to ensure the format and contents of all products are described fully, where applicable, for full understanding of the product. It is also recommended, for ease of use by the user that timestamps (in product name and metadata) are not given in Beijing Local Time but in UTC.* *The data is not considered as analysis ready data (e.g. Committee for Earth Observing Satellites (**CEOS**) Analysis Ready Data, https://ceos.org/ard/).*

Product File Format	*The product format ensures the following imagery and metadata files, adopting standard file formats (i.e., includes:* *•Product Image (.TIF)* *•Product Image Metadata (.XML)* *•Product Image Quality Metadata (.XML)* *•Product Browse Image Icon (.JPG)* *•Product Browse Image Icon Thumbnail (.JPG)* *The product format applies to the main product type procured for these assessments (i.e. L3A) but deviations to this product format exist for products of a different type (i.e. L1).*
Metadata Conventions	*Not implemented as optional (e.g. Geographic Information – Metadata ISO).*
Analysis Ready Data?	*No (N/A)*

User Documentation		
Grade: Basic *Justification: The product user guides, provided upon request to the data provider, contains high-level information only (e.g. basic description of sensor, product type and processing level, and spectral information and instructions that allows users to convert data from digital numbers to top-of-atmosphere reflectance). The product user guide or any other available documentation does not include algorithm theoretical basis document-type information. Therefore, the status of this section of the maturity matrix has been graded as "Basic".*		
Document	*Reference*	*QA4ECV Compliant*
Product User Guide (Chang Guang)	*[RD-4]*	*No*
Product User Guide (Head Aerospace)	*[RD-6]*	*No*
Data Sheet	*[RD-3]*	*No*
Algorithm Theoretical Basis Document	*Documentation not made available.*	*N/A*

Metrological Traceability Documentation	
Grade: Not assessable.	
Document Reference	*-*
Traceability Chain / Uncertainty Tree Diagram Available	*Document not made available.*

3.1.2 Product Generation

Sensor Calibration and Characterisation – Pre-Launch
Grade: Basic *Justification: There is very basic information (i.e. stated values and not methodology used) provided on pre-launch radiometric calibration and characterisation, using the radiometric and spectral calibration test platform of Chang Guang Satellite Technology, only. As there is no information on pre-launch spectral or spatial calibration and characterisation activities, this section of the maturity matrix has been graded as 'Basic'.*

Summary	*This document provides high-level information on the radiometric calibration of all sensors within the Jilin-1 constellation. However, the document is not made available to users.*
References	*[RD-7] Documentation not made available to users.*

Sensor Calibration and Characterisation – Post-Launch	
Grade: Basic *Justification: There is very basic information (i.e. stated values and not the methodology used) provided on post-launch radiometric calibration and characterisation, using primarily cross-calibration methods, only. As there is no information on post-launch spectral or spatial calibration and characterisation activities, this section of the maturity matrix has been graded as 'Basic'.*	
Summary	*This document provides high-level information on the radiometric calibration of all sensors within the Jilin-1 constellation. However, the document is not made available to users.*
References	*[RD-7] Documentation not made available to users.*

Additional Processing	
Grade: Basic *Justification: There is no documentation on the processing steps carried out for orthorectification, apart from the brief mention of the NASA Shuttle Radar Topographic Mission 90 m spatial resolution at equator (STRM90 Digital Elevation Model), and so this section of the maturity matrix has been graded as 'Basic'.*	
Summary	*Orthorectification*
Reference	-

3.1.3 Ancillary Data

Ancillary Data	
Grade: Basic *Justification: Justification: The key ancillary data required to define measurement data does not include, importantly, the following:* • *The viewing angle of the acquisition; the operator has advised that the roll angle can be used as the viewing angle, however, this is not strictly true as the viewing angle needs to take into account the pitch angle (the latter is only true when the pitch angle equals zero).* • *The uncertainties associated with measurement data (where applicable).* *Therefore, this section of the maturity matrix has been graded as 'Basic'.*	
Description	*The product-specific ancillary data (e.g. viewing and solar geometry angles, longitude, latitude, altitude), used to define measurements, can be found in product metadata and general ancillary data (e.g. in-band solar irradiance) can be found in the accompanying documentation (e.g. product guide, other documentation requested from the data provider). However, uncertainties have not been quantified, where applicable, for or as ancillary data.*
Reference	-

Product Flags

Grade: Not Assessable *Justification: These products do not contain flags, in their conventional form, and so this section of the maturity matrix has been graded as 'Not Assessable'.*	
Description	*The products do not contain flags in the conventional form (e.g. bit settings per-pixel) but they do contain quality information which can be used as flags (e.g. per product cloud content, product quality grade, etc.).*
Reference	-

3.1.4 Uncertainty Characterisation

Uncertainty Characterisation Method	
Grade: Not Assessable *Justification: The methods used to characterise the uncertainties associated with geometric and radiometric calibration quality are not included in the documentation made available to users, and so this section of the maturity matrix has been graded as 'Not Assessable'.*	
Description	*(see above)*
Reference	-

Uncertainty Sources Included	
Grade: Basic *Justification: There is only information / documentation concerning the sources of uncertainty related to the pre-launch radiometric calibration and characterisation of the sensor (the aforementioned radiometric calibration of Jilin-1 sensor document shared only with the EDAP team). Therefore, this section of the maturity matrix has been graded as 'Basic'.*	
Description	*(see above)*
Reference	-

Uncertainty Values Provided	
Grade: Basic *Justification: The documentation provides single uncertainty values that are used to characterise geometric performance per product and for the whole mission only but as it is not known how these uncertainty values are determined (quantified) and where they are directly applicable (i.e. at nadir (assumed here) or full range viewing angles), this section of the maturity matrix has been graded as 'Basic'.* *It is recommended the operator provides uncertainty values used to characterise the radiometric performance (e.g. absolute radiometric accuracy) for the whole mission also.*	
Description	*(see above)*
Reference	-

Geolocation Uncertainty
Grade: Intermediate

Justification: A single geolocation uncertainty (i.e. geolocation accuracy) value, typically described as a circular error associated to a 90 % confidence level, is provided for the whole mission and a single geolocation uncertainty value is provided per product (found in the quality metadata file as <GeoPrecision> but this is an assumption as the product guide does not provide any detail on this parameter) and so this section of the maturity matrix has been graded as 'Intermediate'. Note the calculation of the latter is not known.	
Description	*The geolocation uncertainty associated with orthorectified data for this mission is < 8 m (applicable to full range of viewing angles?) with ground control or < 100 m without ground control.*
Reference	*[RD-3]*

3.1.5 Validation

It is important to note this section, relating to the 'Validation' column of the maturity matrix, is based on the results of the data quality assessments performed by the EDAP Optical team **only** (i.e. **independently** of any data quality assessments performed by the data provider and / or operator).

Reference Data Representativeness	
Grade: Basic *Justification: The representativeness of the set of reference data, which refers to the extent (e.g. dynamic range, seasonal variation, geographical variation) to which reference measurements reflect the satellite measurements that they are being used to validate, is good (i.e. suitable) but the variety of reference data used (e.g. 'gold standard' reference mission sensor data, in-situ data) is relatively small, compared to what is available to the community, and so this section of the maturity matrix has been graded as 'Basic'.* *(Note, in general, increasing representativeness requires that a variety of different reference datasets, to cover different observation conditions, be used.)*	
Summary	*(See above)*
References	-

Reference Data Quality and Suitability	
Grade: Intermediate *Justification: The reference data quality and suitability used by EDAP comes with a single uncertainty value for the entire sensor mission, and so this section of the maturity matrix has been graded as 'Intermediate'*	
Summary	*The data used as a reference for some of the radiometric calibration quality assessments include in-situ reference data from the well-established and documented RadCalNet.* *The data used as a reference for the geometric calibration quality assessments include orthorectified panchromatic imagery from SPOT-5, which is validated by CNES as 2.5 m RMSE absolute accuracy, and ground control points derived during a field survey with an absolute accuracy as 0.1 m RMSE.* *The data used as a reference for the image quality assessments include orthorectified multispectral imagery from Pléiades.*

References	*[RD-9], [RD-11]*

Validation Method	
Grade: Intermediate *Justification: The validation methods used, despite being well-documented and used by the scientific community, produce simple uncertainty values (e.g. from a statistical distribution of results), and so this section of the maturity matrix has been graded as 'Intermediate'.*	
Summary	*The validation methods used to assess image quality, geometric calibration and radiometric calibration quality are all well-documented and used by the scientific community.*
References	*[RD-9], [RD-4]*

Validation Results	
Grade: Intermediate *Justification: The validation results, from validation assessment performed independently of those performed by the operator, show good agreement between satellite sensor and reference measurements (and within uncertainties), with the exception for the validation results of radiometric calibration quality, and so this section of the maturity matrix has been graded as 'Intermediate'.*	
Summary	*The validation results of all assessments are summarised in Section 1.*
References	*See Section 4 and 5.*

4. DETAILED JILIN-1 GF03B QUALITY ASSESSMENTS

4.1 Objectives

The objective of this work are to assess all core aspects of sensor data quality (geometric calibration, radiometric calibration, image quality) against sensor and product requirements or specifications, using the sample of sensor products provided.

4.2 Geometric Calibration Quality

This section describes the assessment of geometric calibration quality, implemented by the processing chain, of sensor products in terms of **absolute geolocation accuracy**, **temporal geolocation accuracy** and **band co-registration accuracy**. Table 4-1 shows the names of the products used in these assessments.

Table 4-1: Products used for Geometric Calibration Quality Assessments

Product Number	Product Name (JL1GF03Bx) *L3A	Roll Angle / Viewing Angle (°)
1	03_PMS_20210228172525_200042708_104_0001_001	-2.83
2	04_PMS_20210405172946_200046263_103_0001_001	8.23
3	01_PMS_20210401173100_200045867_103_0001_001	7.73

4.2.1 Absolute Geolocation Accuracy

4.2.1.1 Description and Method I (Panchromatic)

The absolute geolocation (planimetric) accuracy of orthorectified panchromatic imagery is assessed using a method that directly determines the difference between the ‘absolute’ (actual) and apparent location of a set of ground control points (**GCPs**), defined by the Differential Global Positioning System (**DGPS**)[1] during a field survey, in the image.

This assessment was performed on the following product(s):

La Crau (France)

Product 2, 3

The orthorectified imagery included in these three products has been used to determine the absolute geolocation accuracy of a *relatively low and homogenous topography*. Note the topography of La Crau does not exceed 190 m above the ellipsoid.

[1]This field survey was conducted by ESA for contribution to the Japan Aerospace Exploration Agency’s Advanced Land Observing Satellite (JAXA ALOS) optical calibration / validation activities. The accuracy of the GCPs defined by DGPS is within 0.1 m.

The orthorectified imagery required to determine the absolute planimetric geolocation accuracy of *relatively high and inhomogeneous topography* has, unfortunately, not been procured due to tasking priorities by the operator.

The minimum requirement for the absolute geolocation accuracy of this sensor has been specified as < 8.0 m CE90 [RD-3] (no off-nadir angle range specified, therefore at nadir assumed). Note it is common for the absolute geolocation accuracy to be described as a circular error at a specified percentile (i.e., CE90 means that a minimum of 90 % of the points measured have an error that is less than the stated CE90 value).

4.2.1.2 Results I

The results of this assessment are detailed in Table 4-2; the absolute geolocation accuracy of the panchromatic imagery is slightly degraded by the precision (standard deviation, random error contribution) but still meets the specified aforementioned minimum performance requirement.

Table 4-2: Panchromatic Imagery: Absolute Geolocation Accuracy Assessment

Parameter	Product 2	Product 3
GCP Sample #	12	13
Mean Easting Error (m)	-0.40	1.07
Mean Northing Error (m)	-0.21	0.17
Easting Error Standard Deviation (m)	2.69	2.49
Northing Error Standard Deviation (m)	1.70	2.04
Easting Root Mean Square Error (m)	2.71	2.71
Northing Root Mean Square Error (m)	1.71	2.04
Root Mean Square Error (m)	3.21	3.40
CE90 (m)	**3.66**	**5.04**

For more reliable results, assessments of multiple products from each satellite in the constellation of six satellites are needed (only two products, from two different satellites in this constellation were assessed here).

4.2.1.3 Description and Method II (Multispectral)

The absolute planimetric geolocation accuracy of the sensor's multispectral imagery cannot be assessed using the same method adopted for the panchromatic imagery due to a lower spatial resolution (i.e. control points cannot be accurately identified). Therefore, the method used instead is one that involves the use of an image-matching tool (based on a zero mean normalised cross-correlation algorithm, validated sub-pixel / 0.2 m accuracy), provided by the CNES MEDICIS / QPEC tool [RD-8], between the sensor's multispectral imagery and (actual) multispectral imagery from a similar sensor that has been validated for use as reference.

It is important to note, the accuracy of this tool is limited by the contrast available in the input image.

This assessment was performed on the following product(s):

Salon-de-Provence (France)

Product 1

Reference Product <SPOT-5>

The reference imagery used for this assessment was from SPOT-5. It was delivered by CNES as free from systematic errors and as free from non-systematic errors (i.e. due to terrain relief), and the absolute accuracy validated to be within 2.5 m (RMSE) [RD-11]; the main contributor to this slightly degraded accuracy was not the precision but actually the bias, which appeared to be systematic, of about 1.5 m. This information is of importance when using this reference imagery.

The assessment was performed using post-processed red-band imagery from the sensor (e.g. rescaled from 16 bit to 8 bit to match reference SPOT-5 imagery) and post-processed reference SPOT-5 imagery (resampled down from 2.5 to 3.97 m to match the pixel size of Jilin-1 GF3B).

4.2.1.4 Results II

The results of this assessment are detailed in Table 4-3 and Figure 4-1; the absolute geolocation accuracy, determined by performing image matching at a 95% confidence level, is relatively very good. However, the true confidence / reliability of the result is reduced by the fact that the number of matched pixels is low (most likely due to the loss of radiometric information, especially when the range is particularly small, when rescaling from 16-bit to 8-bit).

Note image matching is performed at a specified confidence level (e.g. if the confidence level is specified as 95 % then the image matching results (i.e. geolocation accuracy) will be based on pixels that have been matched with 95% confidence / certainty).

This result does not meet the aforementioned performance requirement, but it is most likely that this particular requirement is not applicable to multispectral imagery (mission provider to clarify this in user documentation).

Table 4-3: Multispectral Imagery: Absolute Geolocation Accuracy (Image Matching Confidence Level 95%).

Parameter	Product 1
Total valid pixels	3215
Number of matched pixels	142
Mean Easting Error (m)	-3.4
Mean Northing Error (m)	3.9
Easting Error Standard Deviation (m)	5.7
Northing Error Standard Deviation (m)	3.4

Parameter	Product 1
Easting Root Mean Square Error (m)	6.7
Northing Root Mean Square Error (m)	5.1
Root Mean Square Error (m)	8.4
CE90 (m)	**12.8**

JL1GF03B06_PMS_20201215121706_200035736_103_0002_00_GF03BvsSPOT_C=0.95

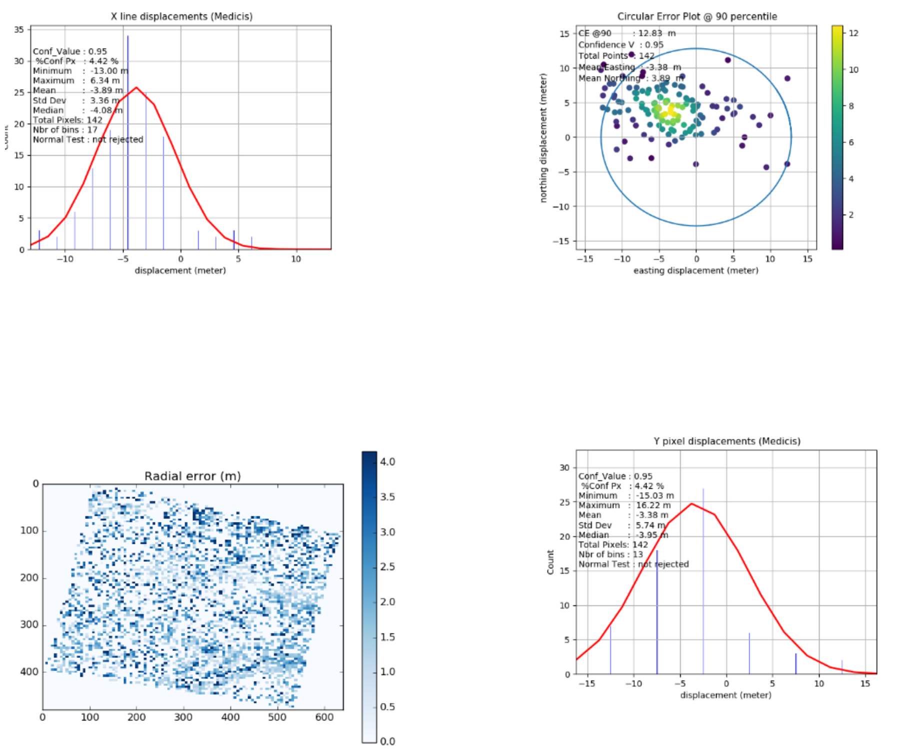


Figure 4-1: Product 0 image matching results with SPOT-5 at Confidence Level 95%.

For a more reliable / accurate result, a larger sample of products should be assessed.

4.2.2 Temporal Geolocation Accuracy

This assessment could not be performed as a true and meaningful time series could not be constructed from the data procured; the most suitable site had three acquisitions from two different satellites, and the two acquisitions from the same satellite were sensed only twelve days apart.

4.2.3 Band Co-registration Accuracy

4.2.3.1 Description and Method

The band co-registration accuracies have been assessed using the aforementioned image matching tool, where it was applied to the imagery of each pair of adjacent or consecutive bands (e.g. blue **(band 1)** and green **(band 2)**, green and red **(band 3)**, red and near-infrared **(band 4)**, near-infrared and panchromatic **(band 5)**, and panchromatic and blue);

for any pixel location in the image space, a displacement, D, in both line (y) / pixel (x) directions is computed.

This assessment was performed on the following product(s):

Product 0

Note there is no minimum performance requirement has been specified by the operator for band co-registration accuracy.

4.2.3.2 Results

The result of the band co-registration accuracy for the multispectral bands is given in Table 4-4.

Table 4-4: Band Co-registration Accuracy (MS only Image Matching CL@99%) Results.

Parameter	Band 1	Band 2	Band 3	Band 4
	Band 2	Band 3	Band 4	Band 1
Total valid pixels	7757	7775	3276	2787
Number of matched pixels	1041	941	58	262
Mean Easting Error (px)	0.1650	0.4832	0.1390	-0.8259
Mean Northing Error (px)	0.0647	-0.0190	-0.0606	0.2590
Easting Error Standard Deviation (px)	0.1808	0.2584	0.2175	0.7297
Northing Error Standard Deviation (px)	0.1348	0.2593	0.2502	0.7853
Easting Root Mean Square Error (px)	0.2448	0.5479	0.2582	1.1021
Northing Root Mean Square Error (px)	0.1495	0.2600	0.2574	0.8269
RMSE (px / m)	0.2868	0.6065	0.3646	1.3778
CE90 (px / m)	0.43/1.71	0.83/3.27	0.54/2.13	1.97/7.74

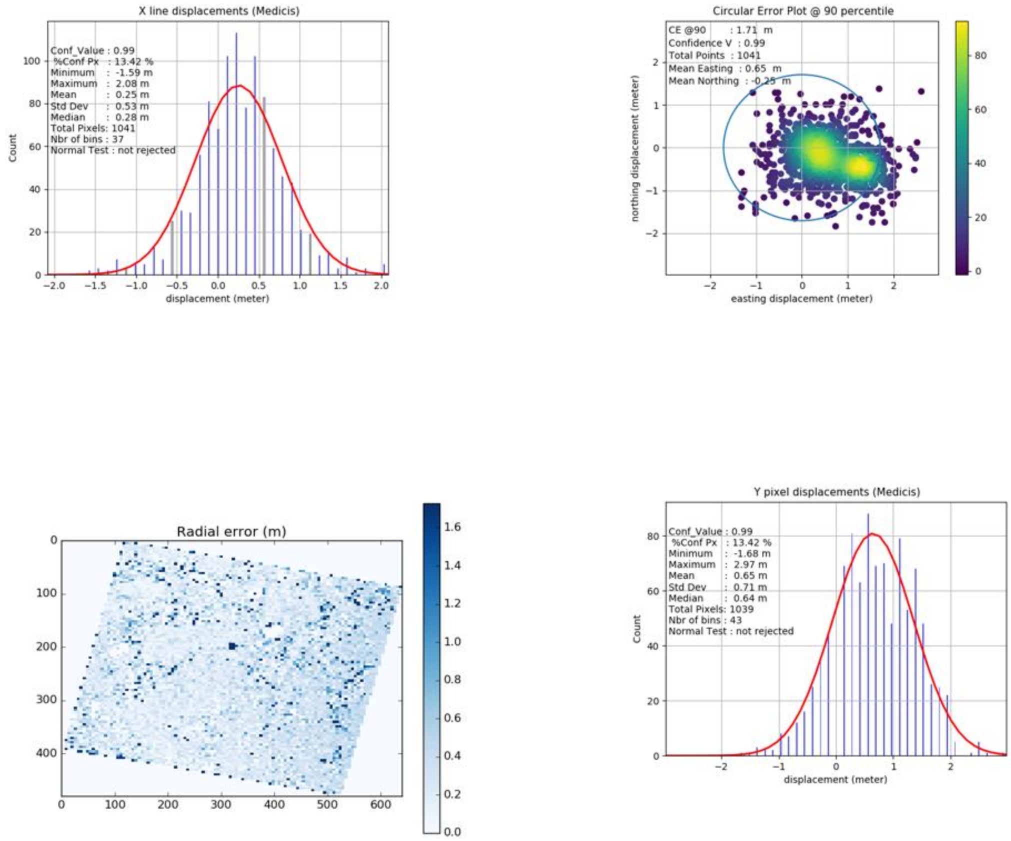


Figure 4-2 Product 3 Band Co-Registration Accuracy Result: Blue vs Green.

The result of the band co-registration accuracy of the multispectral-panchromatic bands is given in Table 4-5.

Table 4-5 Band Co-registration Accuracy (MS-PAN Image Matching CL@95%) Results

Parameter	Band 4	Band 5
	Band 5	Band 1
Total valid pixels	2153	7187
Number of matched pixels	115	834
Mean Easting Error (px)	-2.1609	-3.5273
Mean Northing Error (px)	-0.8047	-0.4927
Easting Error Standard Deviation (px)	1.9815	0.4615
Northing Error Standard Deviation (px)	-0.7817	0.9691
Easting Root Mean Square Error (px)	2.9318	3.5573
Northing Root Mean Square Error (px)	1.1218	1.0871
RMSE (px / m)	3.1391	3.7198
CE90 (px / m)	6.06/19.82	4.36/17.28

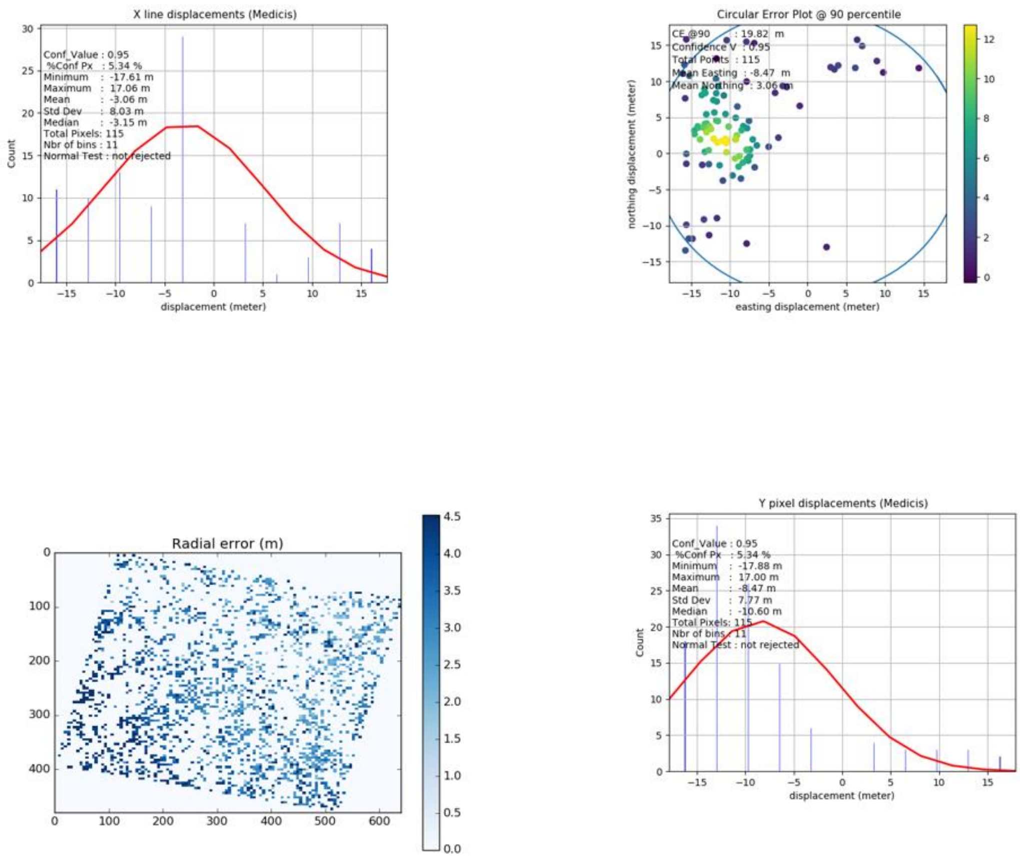


Figure 4-3: Product 0 Band Co-Registration Accuracy Result: NIR vs PAN.

The results indicate the multispectral bands are relatively well co-registered (i.e., accuracy is sub-pixel), but the multispectral-panchromatic bands are not and this may be because further corrections are to be applied if the data is to be pansharpened (either by the user or the data provider).

In addition to the above, the error budget is computed (in this case, only multispectral bands), and it is based on the rule that per pixel displacement errors are transitive across all band pairs. By summing the displacement for all band pairs (e.g. (B, G), (G, R), (R, N)), the result is in the same order of displacement for the twin (B, N), as shown in the equation below.

$$D_{B,N} \cong D_{B,G} + D_{G,R} + D_{R,N}$$

Where $D_{B,N}$ stands for displacement between the blue band and the NIR band (calculated for the easting and northing direction).

By comparing this estimate $(D_{B,N})$ against the true value $(D_{N,B})$ obtained with image-matching, the error budget of the method is computed (i.e., error budget = $D_{B,N}$ + $D_{N,B}$ or $D_{N,B}$ -$D_{B,N}$). The results indicate the error budget in the easting direction is 0.0387 MS pixels, which is much smaller than that in the northing direction that is 0.2441 MS pixels.

4.3 Radiometric Calibration Quality

This section describes the assessment of radiometric calibration quality of sensor products, in terms of **absolute** and **temporal radiometric calibration accuracy**. Table 4-6 shows the names of the products used in these assessments.

Table 4-6: Products used for Radiometric Calibration Quality Assessments

Product Number	Product Name (JL1GF03Bx) *L3A	Roll Angle / Viewing Angle (°)
3	01_PMS_20210401173100_200045867_103_0001_001	7.73
4	04_PMS_20210511155831_200049555_104_0002_001	-9.16

The radiometric calibration, or correction, of sensor data sees to the successful conversion of raw data (i.e. digital numbers) to spectral radiance or reflectance, using coefficients (e.g. physical bias, physical gain, solar spectral irradiance constants) derived pre-flight in laboratory conditions. This is important as it improves the interpretability and quality of the sensor data (and is particularly important when comparing multiple sensor datasets over a period of time, which is commonly performed by the scientific community).

The digital number (DN) to spectral radiance (L) conversion of sensor data, per band (b) is enabled by the following:

$$L_b = (DN_b * GAIN_b) + BIAS_b$$

The spectral radiance (L_b) to top-of-atmosphere reflectance (ρ_b), per band (b) is enabled by the following:

$$\rho_b = \frac{\pi * L_b * d^2}{E_{0b} * Sin(\theta_s)}$$

Where:

E_{0b} is solar spectral irradiance at the sensor for band b (units: $Wm^{-2}\mu m^{-1}$).
θ_s is solar elevation angle at the time / location of acquisition (units: degrees).
d^2 is Sun-Earth distance at the time of acquisition (units: astronomical units).

Note conversion formulae and coefficients mentioned above can be found in the product user guide, the product metadata and online.

4.3.1 Absolute Radiometric Calibration Accuracy

4.3.1.1 Description and Method

The method used to determine the absolute radiometric calibration accuracy of the sensor's bands is based on comparing the top-of-atmosphere (**TOA**) reflectance values derived from the sensors acquisitions of the chosen RadCalNet calibration sites with the TOA reflectance values derived from the RadCalNet calibration sites themselves (i.e., reference TOA reflectance values).

The RadCalNet calibration sites, operated by the CEOS Working Group for Calibration and Validation (**WGCV**) Infrared and Visible Optical Sensors (**IVOS**), provides the scientific community with the following:

- TOA reflectance values, derived from both in-situ surface and atmosphere measurements (e.g., surface pressure, columnar water vapour, columnar ozone, aerosol optical depth, etc.) that are **SI-traceable**, at:
    - 30-minute intervals between 09:00 and 15:00 local standard time (cloud-free data only), and 10 nm spectral sample intervals between 400 nm and 1000 nm.

Note the RadCalNet TOA reflectance values are representative of nadir viewing observations only, so comparison to sensor top-of-atmosphere reflectance values should be done with caution - when the sensor viewing zenith angle deviates significantly from nadir, both atmospheric and surface non-Lambertian behaviour can lead to significant deviations from at-nadir simulated signal. The correction for the latter (i.e., off-nadir viewing angle effects), as well as illumination (solar) angle effects, can be done using bi-directional reflectance modelling.

The product(s) used to assess the absolute radiometric calibration accuracy, by temporal and spectral simulation (according to the modelled relative spectral response as the original was not provided, see Figure 4-4 and Figure 4-5), with RadCalNet data, are the following:

La Crau (France)

Product 3

Gobabeb (Namibia)

Product 4

These products provide acquisitions of the chosen RadCalNet calibration sites, La Crau (see Table 4-7) and Gobabeb (see Table 4-8).

Table 4-7: RadCalNet La Crau Calibration Site Description

Parameter	Description
Geographic Location	Latitude: 43.558889, Longitude: 4.864167, Altitude: 20 m
Characteristics	The RadCalNet top-of-atmosphere reflectance spectra are representative of a disk of 30 m radius.

Table 4-8: RadCalNet Gobabeb Calibration Site Description

Parameter	Description
Geographic Location	Latitude: -23.6002, Longitude: 15.1196, Altitude: 510 m
Characteristics	The RadCalNet top-of-atmosphere reflectance spectra are representative of a disk of 30 m radius.

Table 4-9 Spectral Calibration Results from Chang Guang (Product Guide) [RD-4] GF03B01 (for La Crau)

Spectral Band	50% Response Wavelength		Center Wavelength (nm)	Spectral Width (nm)
	Rising Edge (nm)	Falling Edge (nm)		
PAN	507.95	695.28	601.61	156.19
B1	470.65	510.77	490.71	36.84
B2	520.42	576.90	548.66	40.47
B3	640.08	698.33	669.21	52.65
B4	764.33	869.88	817.11	96.69

Table 4-10 Spectral Calibration Results from Chang Guang (Product Guide) [RD-4] GF03B04 (for Gobabeb)

Spectral Band	50% Response Wavelength		Center Wavelength (nm)	Spectral Width (nm)
	Rising Edge (nm)	Falling Edge (nm)		
PAN	509.65	695.87	602.76	155.82
B1	468.52	512.66	490.59	38.17
B2	511.89	575.60	543.74	45.04
B3	638.46	696.67	667.57	54.10
B4	764.15	873.61	818.88	96.21

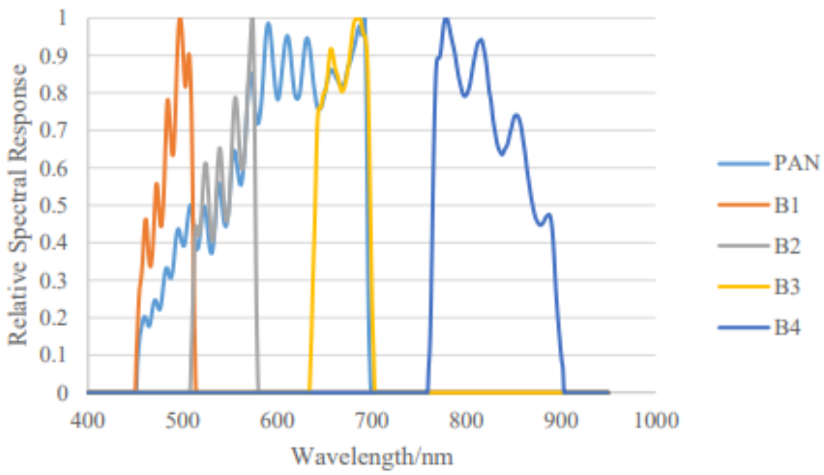


Figure 4-4 The relative spectral response for GF03B01.

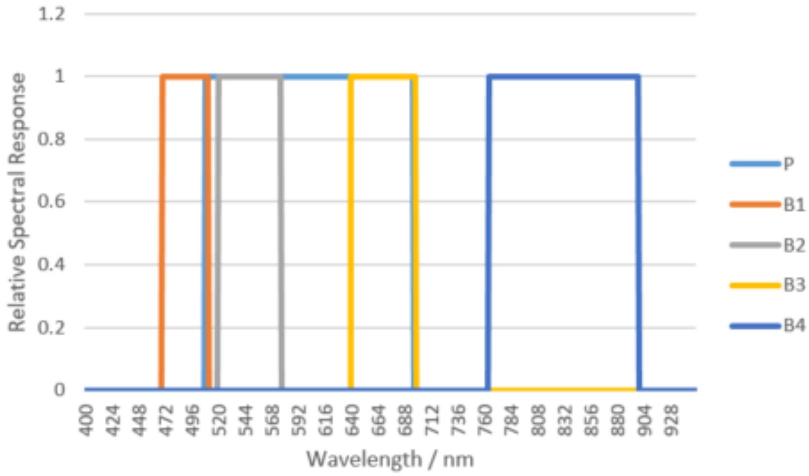


Figure 4-5 The coarsely modelled relative spectral response for GF03B01 (given the details in Table 4-9).

(Note, the assumption made here is that the coarsely modelled relative spectral response for GF03B01 will be the same for GF03B04.)

The determined absolute radiometric calibration accuracy cannot be evaluated against a minimum performance requirement as it has not been specified by the operator. Instead, this will be evaluated against what is generally considered very good, based on similar "gold standard" sensors such as Sentinel-2 and Landsat 8, which is approximately < 5 % for all bands [RD-13, RD-14].

4.3.1.2 Results

The results of this assessment are detailed in Table 4-12 - Table 4-13.

Table 4-11: Jilin-1 GF03B Sensor Observation Conditions (Solar and Viewing Geometries)

Product	Roll Angle / Sensor Viewing Angle (°)	Sensor Azimuth Angle (°)	Solar Elevation Angle (°)	Solar Azimuth Angle (°)	Water Vapour (g/cm)	AOD ()
3	7.730	280.581	41.245	133.197	0.210	0.187
4	-9.160	96.980	30.030	50.096	2.010	0.018

Table 4-12: La Crau: GF03B and Simulated GF03B (RadCalNet) TOA Reflectances

		ρ TOA Reflectance				
Product	**Origin**	**Blue**	**Green**	**Red**	**NIR**	**PAN**
3	Sensor	0.1028907	0.1008694	0.1024444	0.1835076	0.1000910
	RadCalNet	0.1285033	0.1246921	0.1352334	0.2485569	0.1279648
	Difference (%)	19.93	19.11	24.25	26.17	23.10

Table 4-13: Gobabeb: GF03B and Simulated GF03B (RadCalNet) TOA Reflectances

		ρ TOA Reflectance				
Product	**Origin**	**Blue**	**Green**	**Red**	**NIR**	**PAN**
4	Sensor	0.1743268	0.1946026	0.2743772	0.3021630	0.2344670
	RadCalNet	0.1983756	0.2239770	0.3080761	0.3302690	0.2635907
	Difference (%)	12.12	13.11	10.94	8.51	11.05

The difference, expressed as a percentage, between GF03B TOA reflectances ($\boldsymbol{\rho_b}\ work$) and simulated GF03B TOA reflectances ($\boldsymbol{\rho_b}\ simulated$) is calculated as follows:

$$\rho_b = ((\boldsymbol{\rho\_b}\ simulated - \boldsymbol{\rho\_b}\ work)/(\boldsymbol{\rho\_b}\ simulated)) * 100$$

The result of this assessment suggests the data is poorly calibrated as the absolute radiometric accuracy is generally low and unstable. The cause(s) of the latter is not yet clear, especially seeing as the products assessed have viewing and solar geometries (and atmospheric conditions) within normal or ideal limits, but it may be due to the radiometric calibration method used by the operator [2]– all satellites in the Jilin-1 constellation are cross-calibrated with MODIS (MODIS BOA reflectances propagated to TOA reflectances, using the 6SV radiative transfer model, for acquisitions over China and Africa only which may not be suitable for global acquisitions either). Therefore, it is recommended that the operator re-assess their calibration method.

4.3.2 Temporal Radiometric Accuracy

This assessment could not be performed as the products for the most suitable site, Pseudo-invariant Calibration Site (**PICS**) Libya-4, could not be procured.

4.4 Image Quality

This section describes the assessment of product image quality on the supplied sensor products in terms of **Signal-to-Noise Ratio** (**SNR**), **Modulation Transfer Function** (**MTF**) and **Image Interpretability**. Table 4-14 shows the names of the products used in these assessments.

Table 4-14 Products used for Image Quality Assessments

Product Number	Product Name (JL1GF03Bx)*L3A	Roll Angle / Viewing Angle (°)
2	04_PMS_20210405172946_200046263_103_0001_001	8.23
3	01_PMS_20210401173100_200045867_103_0001_001	7.73
5	06_PMS_20201215121706_200035736_103_0002_001	3.50
6	03_PMS_20210228172525_200042708_104_0001_001	-2.83

[2] *When the relative difference between cross-calibration gain coefficients and ground calibration gain coefficients is greater than 10%, the cross-calibration coefficients will replace the ground calibration coefficient [RD-7].*

7	05_PMS_20210622101957_200053467_102_0002_001_L1	**-7.58**

4.4.1 Signal-to-Noise Ratio

4.4.1.1 Description and Method

The SNR is used to quantify the performance of a sensor in response to a particular exposure; it quantifies the ratio of the sensor's output signal to the noise present in the output signal and can be expressed by the following:

$$SNR = \frac{\mu}{\sigma}$$

Where μ is the mean signal and σ is the standard deviation of the signal.

Ideally, this assessment is performed using a more suitable calibration site, usually PICS Libya-4. However, there were no products procured for this site as mentioned previously, and so a region of clear fields near La Crau was used instead. This approximate site is shown in Figure 4-6.

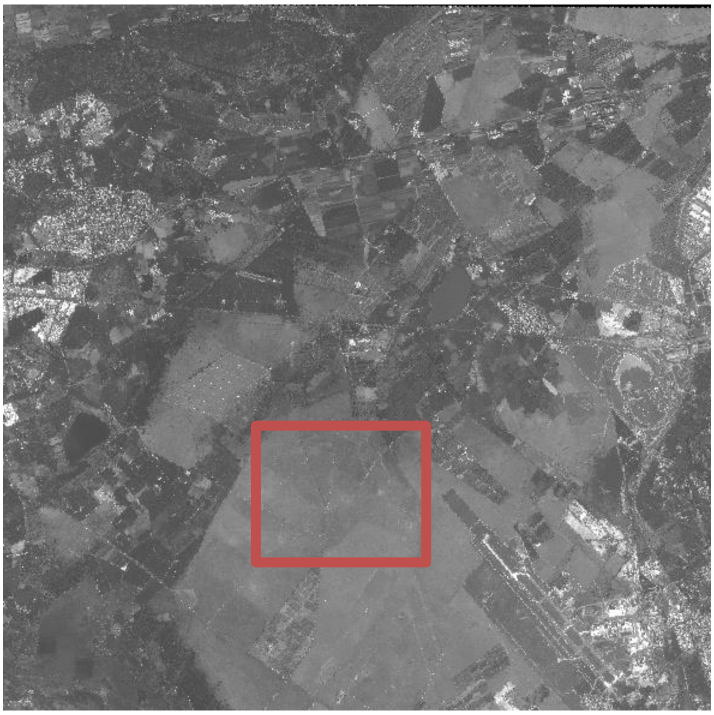


Figure 4-6 The orange box displays the clear-field area that was analysed for SNR (image from Product 3).

The following products were used:

La Crau (France)

Products 2, 3

The method proposed for this assessment allows for the estimation of (spatial) SNR, based on the aforementioned equation and the following assumption:

- The mean signal is defined as the spatial average of a group of pixels observing a spatially varying scene and the noise is defined as the standard deviation of this signal for the same group of pixels.

The method, modified since it was initially proposed in [RD-9], is performed for each spectral band, whose imagery has been converted from digital numbers to radiance, in the following way:

1. Compute the local statistics of a small (3 x 3 pixels) sliding window applied to the imagery being assessed. Select only the “best” small windows for the following steps.
    a. The selection of small windows ensures that increased site uniformity is generally maintained (if not, where spatially high frequencies exist (e.g. sharp transitions seen as dune summits), dedicated image processing is applied in order to detect this and filter).

2. Compute the statistical distribution (histogram), between the **minimum** and **maximum radiance**, of the selected “best” small windows (statistics of 3 x 3 pixel windows) – the signal is defined as the peak (i.e. mean radiance) of this statistical distribution and the noise is defined as the standard deviation of this statistical distribution about the mean.

3. Estimate SNR(s).

The estimated SNR, including that from quantisation, for each band will be evaluated against the expected performance specified in Table 4-15.

Note no minimum requirement has been specified by the operator.

4.4.1.2 Results

The results of this assessment are detailed in Table 4-15 and the outputs, for Product 3 as an example, are shown in Figure 4-7 to Figure 4-10.

Table 4-15: Calculated SNR values over clear fields region in La Crau, France.

	Product 2		Product 3	
Band	**Mean Radiance $W.m^{-2}.str^{-1}$**	**Calculated SNR**	**Mean Radiance $W.m^{-2}.str^{-1}$**	**Calculated SNR**
Blue	43.58	138.16	42.50	138.75
Green	40.30	105.0	40.32	94.56
Red	35.87	64.58	32.17	63.97
NIR	47.82	106.91	44.77	69.54
PAN	37.86	59.66	39.05	61.88

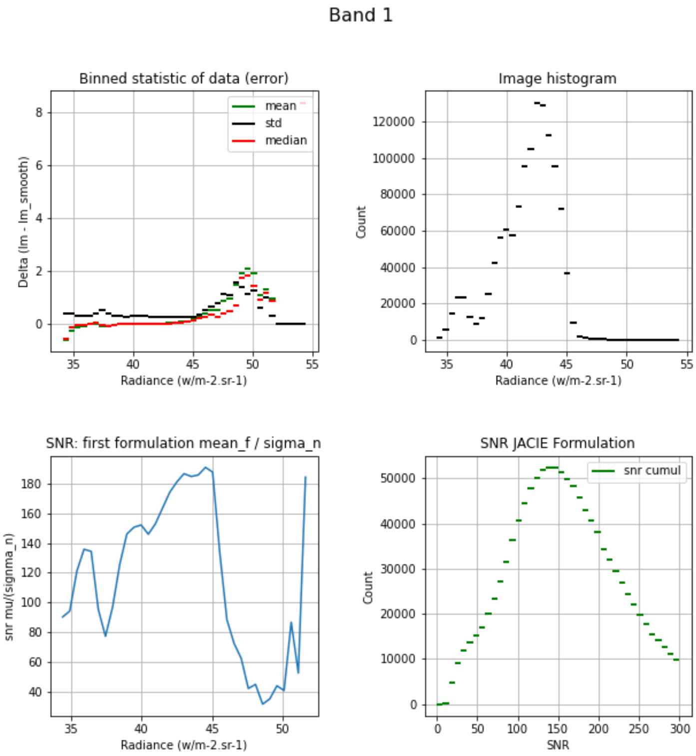


Figure 4-7 Statistical plots generated during SNR calculation for Product 3 band 1.

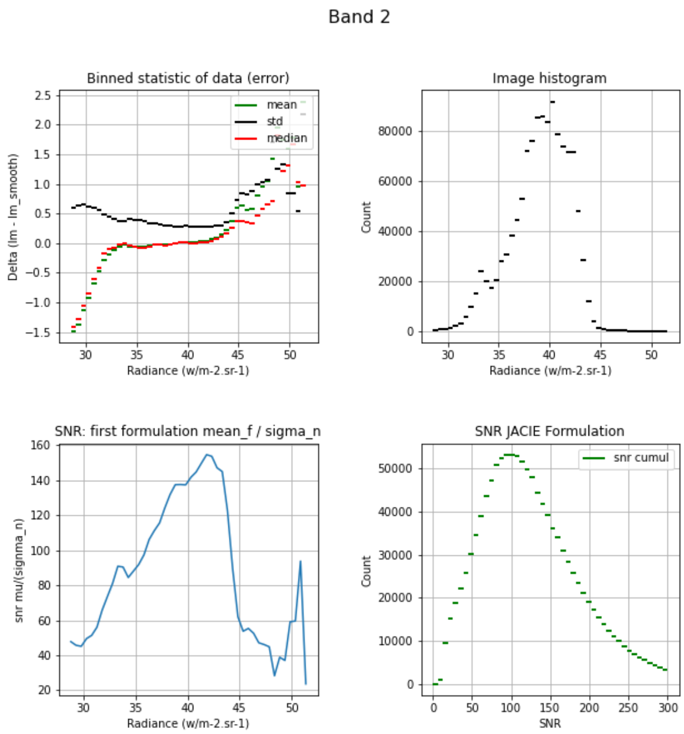


Figure 4-8 Statistical plots generated during SNR calculation for Product 3 band 2.

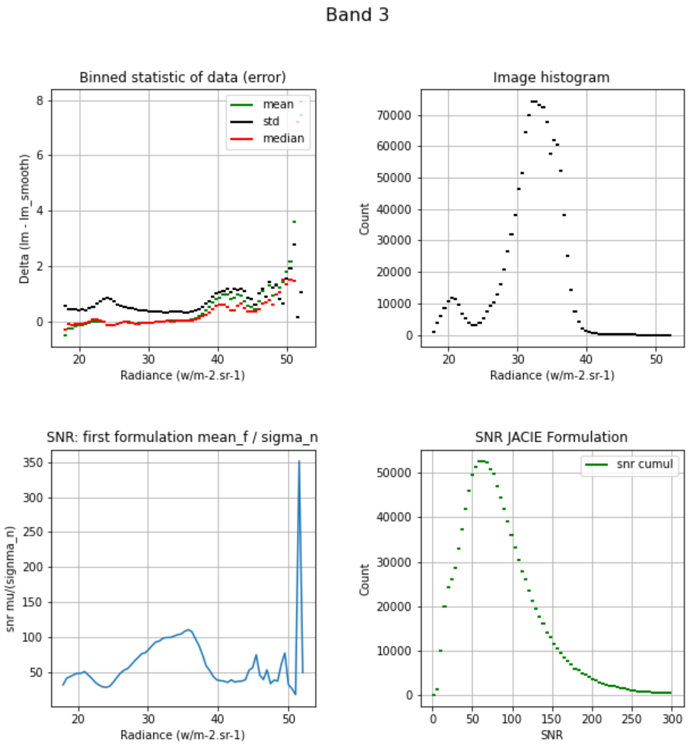


Figure 4-9 Statistical plots generated during SNR calculation for Product 3 band 3.

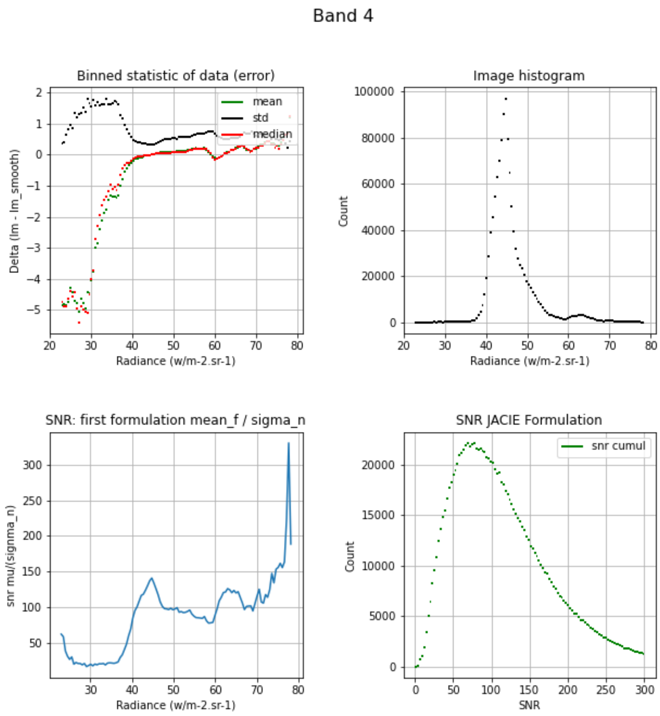


Figure 4-10 Statistical plots generated during SNR calculation for Product 3 band 4.

The results indicate above satisfactory and stable SNR values for all multispectral and panchromatic bands. Note no minimum performance requirement for SNR has been specified by the mission provider.

4.4.2 Modulation Transfer Function

4.4.2.1 Description and Method

The modulation transfer function importantly describes the response of the imaging sensor as a function of spatial frequency, and so is strongly related to concepts such as sharpness, contrast and spatial resolution. Therefore, it is considered as an important image quality metric.

(It is important that this image quality metric be monitored post-launch or in orbit, not just pre-launch, in order to ensure that launch vibrations, transitions from air to vacuum, or changes in thermal state, have not degraded the sharpness of the optical imagery.)

The product(s) used for this assessment include:

Shadnagar (India)

Product 5 (L1, Panchromatic band only)

Salon-de-Provence (France)

Product 6 (L1, Panchromatic band only)

Baotou (China)

Product 7 (L1, Panchromatic band only)

The metadata of these particular products indicate MTF compensation has not been applied (i.e. if it had been applied, we would expect the results to show an improved MTF).

Note these are basic Level 1 products (operator definition given in Section 3.1.1, L0 products are generally not made available externally / publicly) as products generated by higher processing levels commonly include resampling kernels which introduces a smoothing effect and therefore degrades the true MTF.

This assessment has been performed using an open-source tool, validated against third party software, made publicly available at https://github.com/JorgeGIlG/MTF_Estimator. The tool, accompanied by detailed documentation that includes information on the algorithm (Slanted-Edge methodology based) used, works in the following way:

1. Select a band and create a shapefile that defines the target edge to be used:
    a. The target edge must be straight and sharp (a man-made target is more likely to have these features) and defined by uniform high and low reflectance surfaces.
    b. The target edge must be vertical (i.e. the angle is important). This is an important requirement related to how the algorithm works - if an along track or across-track assessment is needed then the image can be rotated accordingly.
2. Run the tool
    a. The data in each transect (each image row), defined by the shapefile, is smoothed and then differentiated in order to obtain a coarse estimation of the pixel position of the target edge. The latter estimation is then used to set the

initial conditions of the optimisation technique which is used to fit a sigmoid function to the data (as shown in Figure 4-11).

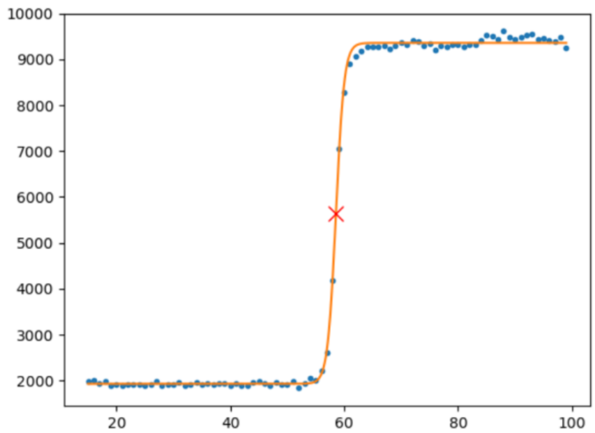


Figure 4-11 The sigmoid function (-) is fitted to the data (•) in a transect. The point of inflexion (x) shows the estimated sub-pixel edge position. X axis is pixels, y axis is digital numbers

b. The estimated sub-pixel position data for all transects is subjected to linear regression in order to ensure the target edge is straight as assumed (any outliers are removed during this process) and the target edge angle estimated.
c. The estimated sub-pixel edge position is used to shift each transect to a common origin, hence creating a supersampled virtual edge which is modelled as a spline and thus a representation of the Edge Spread Function (**ESF**).
d. The Point Spread Function (**PSF**) is obtained by fitting the spline shape to a Gaussian function (Line Spread Function) using Levenberg-Marquardt optimisation.
    i. The PSF defines the apparent shape of a point target as it appears in the resulting image: it is therefore directly related to the sharpness of images provided by the sensor / imaging system [RD-12].
e. The MTF is then estimated from the modulus of the Fourier transform of the PSF.
    i. The MTF informs on the contrast of the different spatial frequency components of the observed image.

4.4.2.2 Results

This assessment could not be performed as the image quality is degraded; the aforementioned tool could not precisely detect / define the edges, using the three artificial targets presented in Figure 4-12, Figure 4-13 or Figure 4-14. The edges of the artificial target appear to be significantly blurred (i.e., poor sharpness).

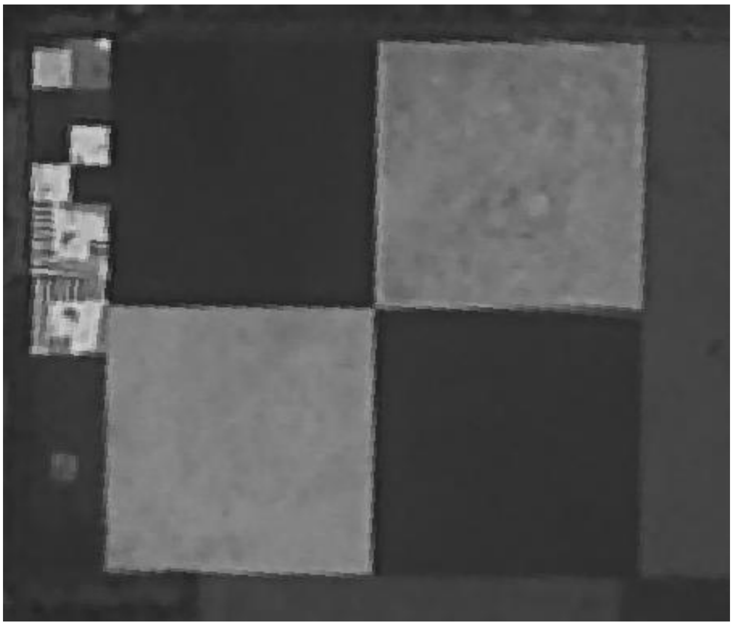


Figure 4-12 The artificial target in Shadnagar, India. The size of this target is 140 m x 140 m and is deemed suitable for the estimation of MTF of very high to some medium resolution optical sensors [https://calval.cr.usgs.gov/apps/shadnagar].

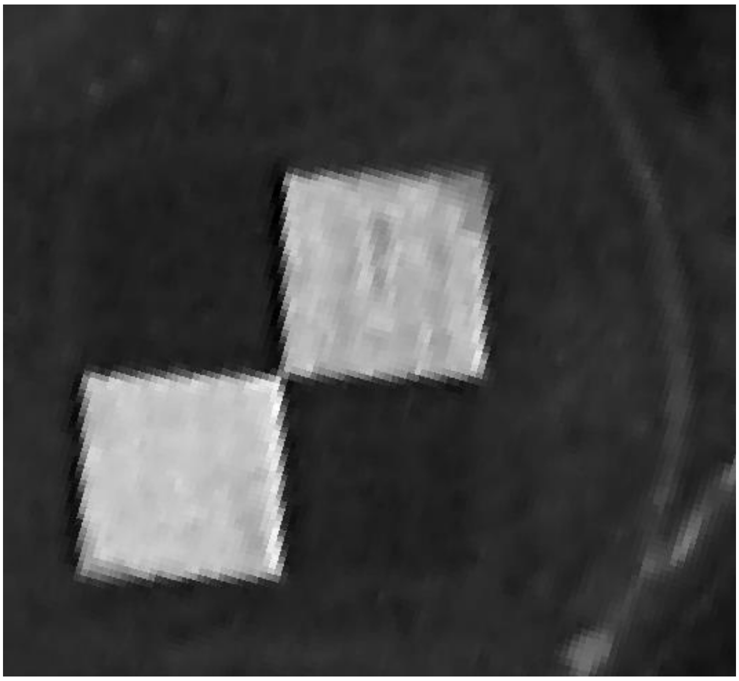


Figure 4-13 The artificial MTF target in Salon-de-Provence, France. The size of this target is 60 m x 60 m and is deemed suitable for the estimation of MTF of very high to some medium resolution optical sensors [https://calval.cr.usgs.gov/apps/salon-de-provence].

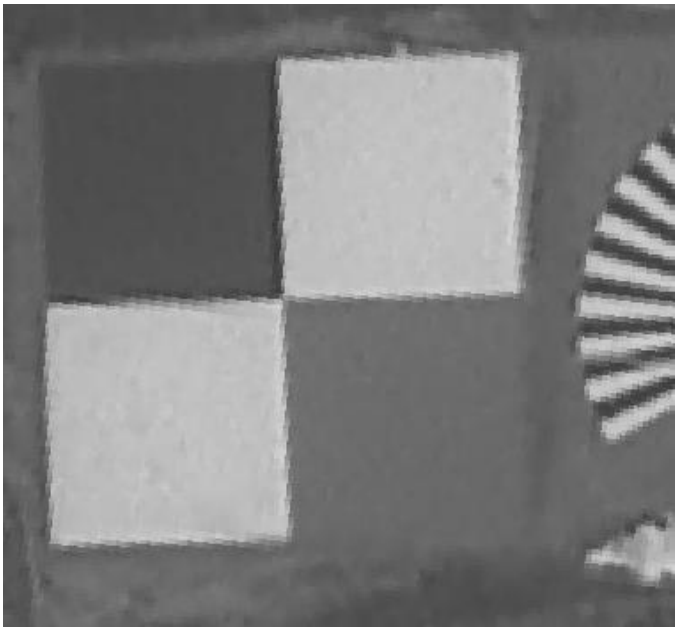


Figure 4-14 The artificial MTF target in Baotou, China. The size of this target is 48 m x 48 m and is deemed suitable for the estimation of MTF of very high to high resolution optical sensors (i.e. < 5.0 m) [https://calval.cr.usgs.gov/apps/baotou].

4.4.3 Image Interpretability

4.4.3.1 Description and Method

The image interpretability of optical sensor imagery is an important aspect of image quality (originating from the actual sensor or image processing), especially in terms of their practical use or application. This is commonly assessed, subjectively, using a well-defined procedure that is based on the successful interpretation of points (objects or features) according to the National Imagery Interpretability Rating Scale[3] (**NIIRS**) category in which the sensor belongs [RD-10]. This well-defined procedure also importantly allows for the cross-comparison of image quality from similar sensors.

The points of interest (**POI**) used for this assessment are defined in Table 4-16. The latter are deemed suitable for **NIIRS Category 3 (2.5 – 4.5 m)** and **NIIRS Category 5 (0.75 – 1.2 m GSD)** [RD-10] imagery.

Table 4-16: POI in Salon-de-Provence.

wkgt_geom (UTM 31)	Id	Description
Point (671090.3105554151115939 4830278.58671295549720526)	1	Modulation Transfer Function target
Point (671364.24309313111007214 4833044.0252351425588131)	2	Motor way / sharp transition (45° NE)
Point (668580.81736886233557016 4828965.45189037173986435)	3	Forest

[3] *https://fas.org/irp/imint/niirs.htm*

wkgt_geom (UTM 31)	Id	Description
Point (670056.62237295764498413 4828905.08180973120033741)	4	Roundabout / parking lot
Point (669985.90922565956134349 4832120.72269264236092567)	5	Elevated tree
Point (669956.03863696497865021 4832655.53592716064304113)	6	Motor way / roundabout
Point (670564.24590074480511248 4833363.40447467099875212)	7	The dam
Point (669836.88448120269458741 4832528.00618595350533724)	8	Big building (shadow)
Point (670518.95015854423400015 4829513.56928175128996372)	9	Landing track - 34
Point (670249.72702971810940653 4831735.03129190206527711)	10	Floor painting

The product(s) used for this assessment are the following:

Salon-de-Provence (France)

Product 6

The method used to assess image interpretability consists of the visual inspection of suitably sized clips of the sensor's imagery, for all bands, centred on the objects or features of interest listed in Table 4-16. If the latter can be successfully detected, at the very least, then image interpretability is considered as good.

Note comparisons are made with clips from a 'gold standard' reference mission (e.g. Pléiades High-Resolution (**PHR**) imagery, following downsampling of the spatial resolution (pixel size) to match the spatial resolution (pixel size) of GF03B, also.

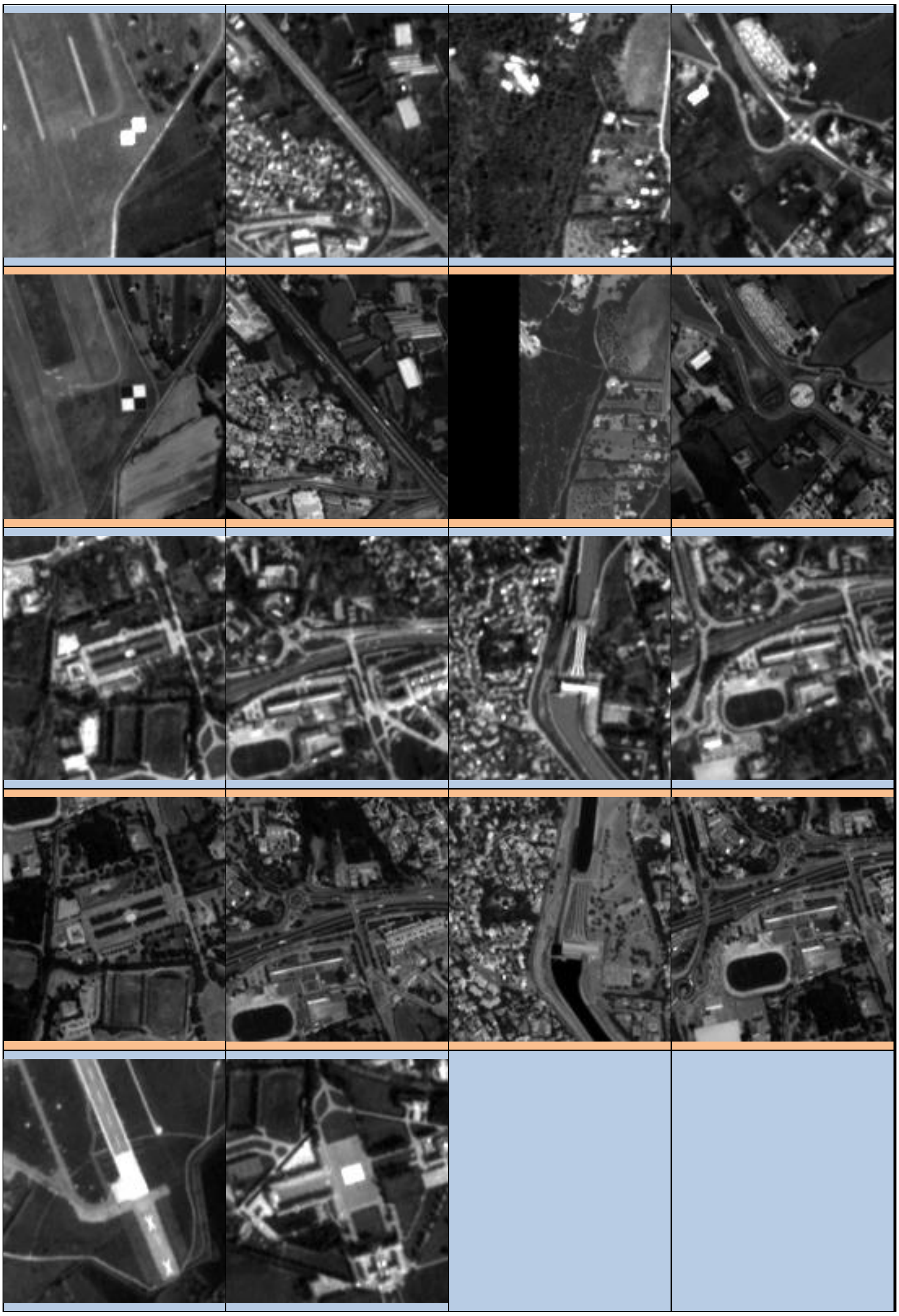
4.4.3.2 Results

The primary results generally indicate the objects or features of interest can be delineated in the multispectral and panchromatic imagery, as shown in the figures below, but this can be significantly improved upon with the reduction of blurring (evident and supported by the preliminary assessment detailed in Section 4.4.2).

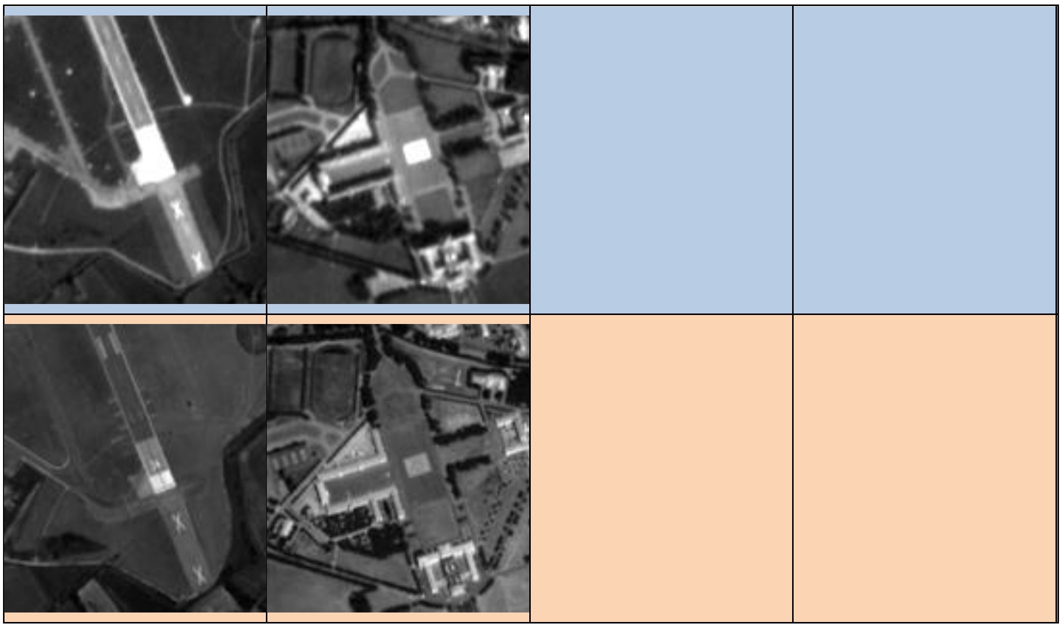
Note this assessment takes into account that the contrast is different between the imagery from the two sensors, which is expected as the two sensors have different spectral characteristics, and so is considered as only a minor disadvantage to using this particular method.

(There are some parts of the imagery that appear to be saturated but this is due to the viewing of the imagery quicklooks (subjected to histogram stretching after rescaled to 8-bit) only. The digital numbers have been checked and confirm the latter.)

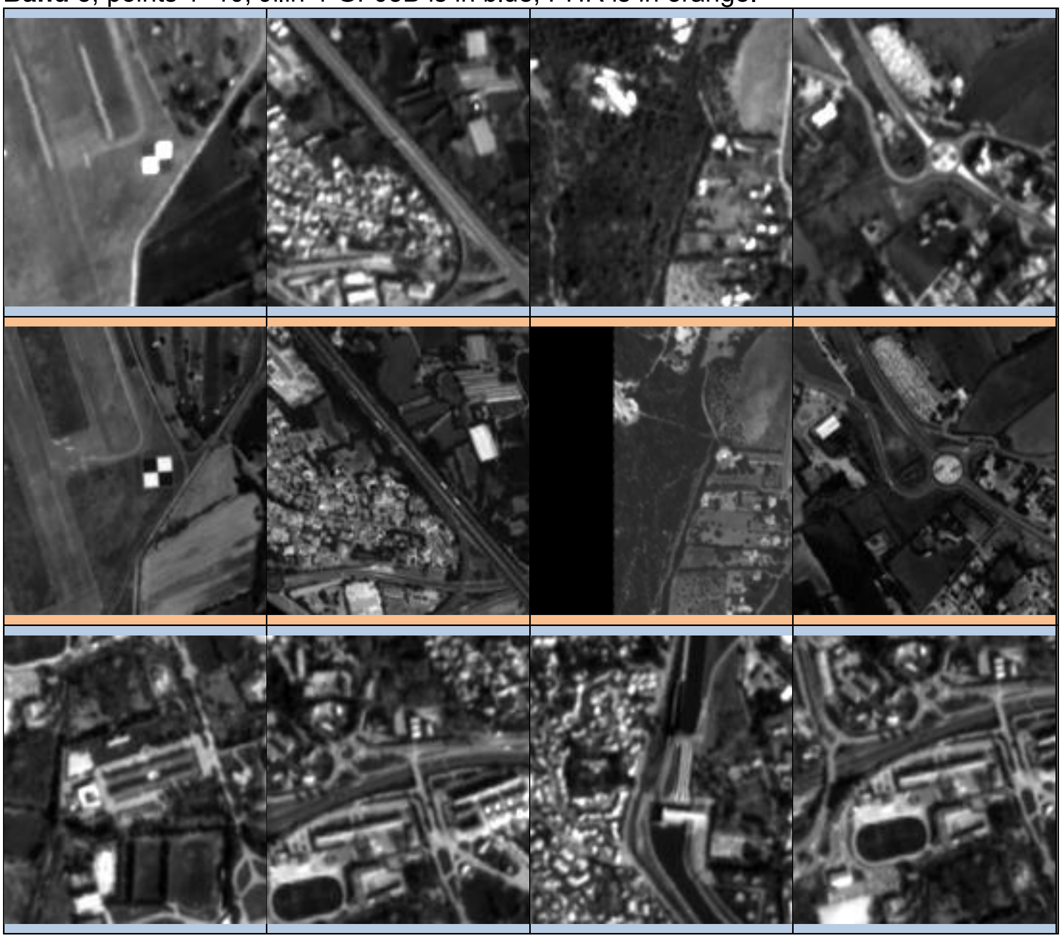
Band 1, points 1–10, Jilin-1 GF03B is in blue, PHR is in orange.

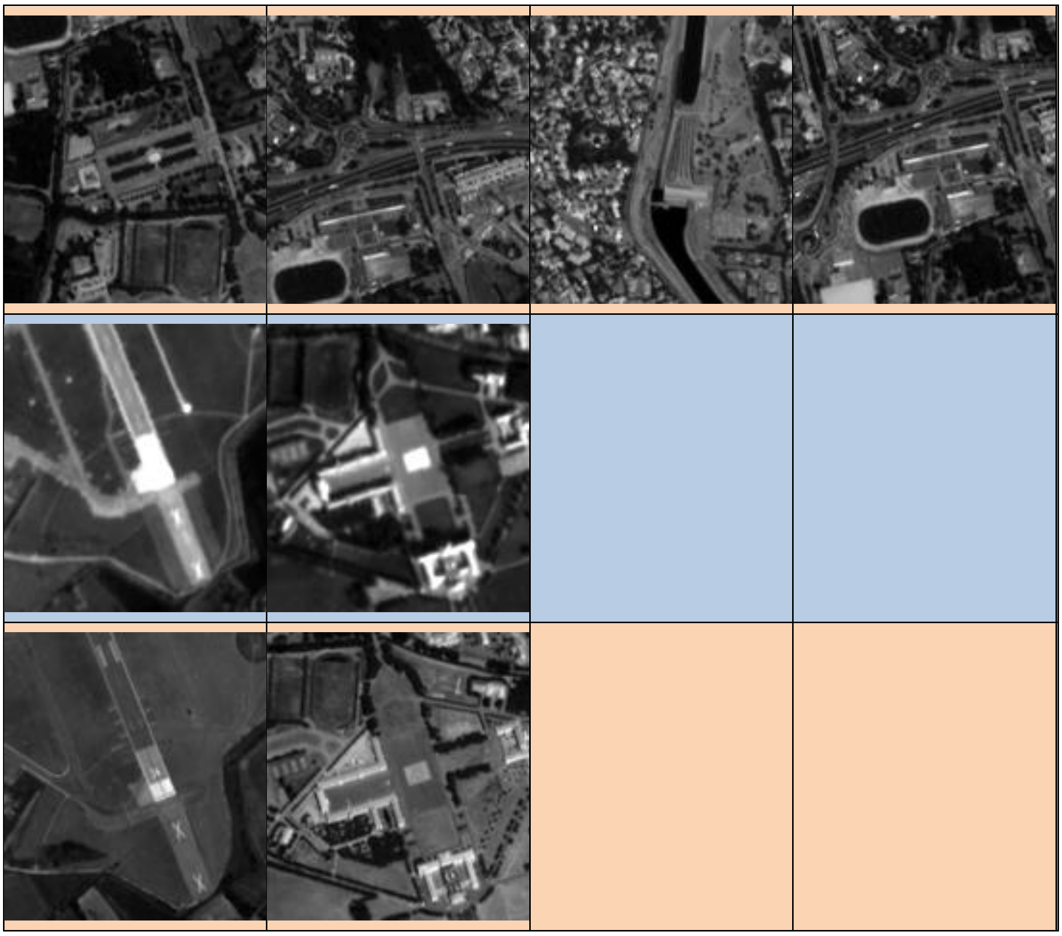


Band 2, points 1–10, Jilin-1 GF03B is in blue, PHR is in orange.

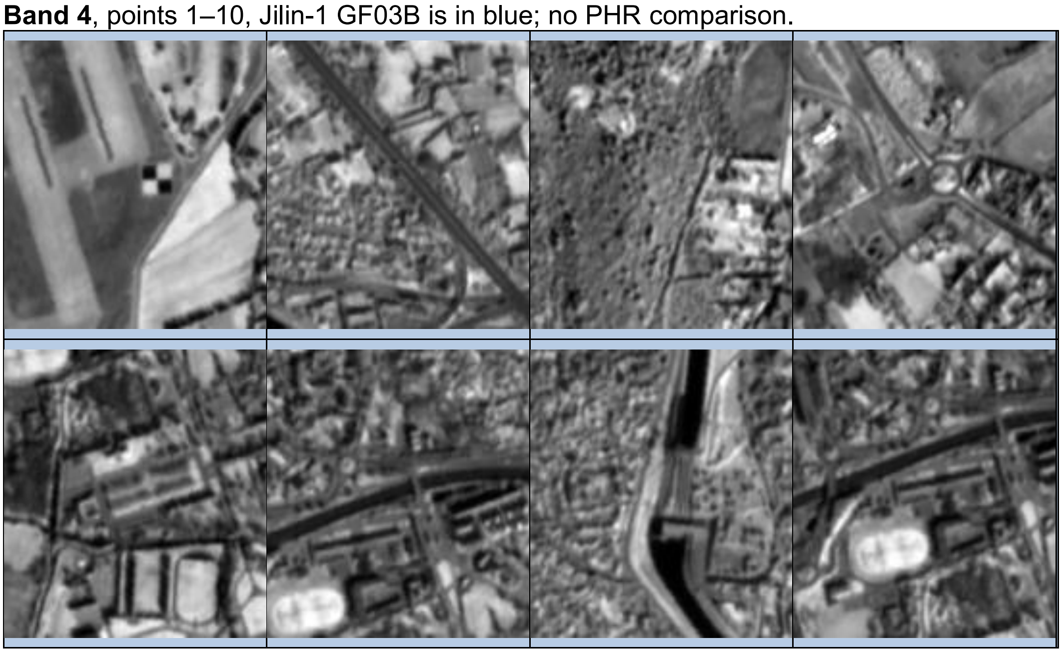


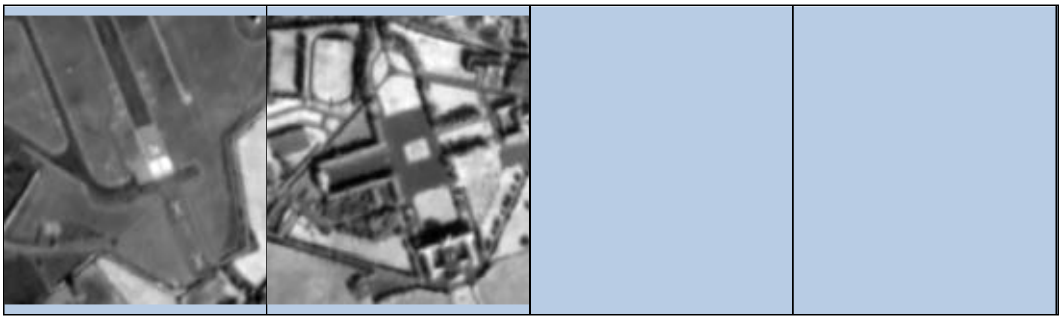
Band 3, points 1–10, Jilin-1 GF03B is in blue, PHR is in orange.



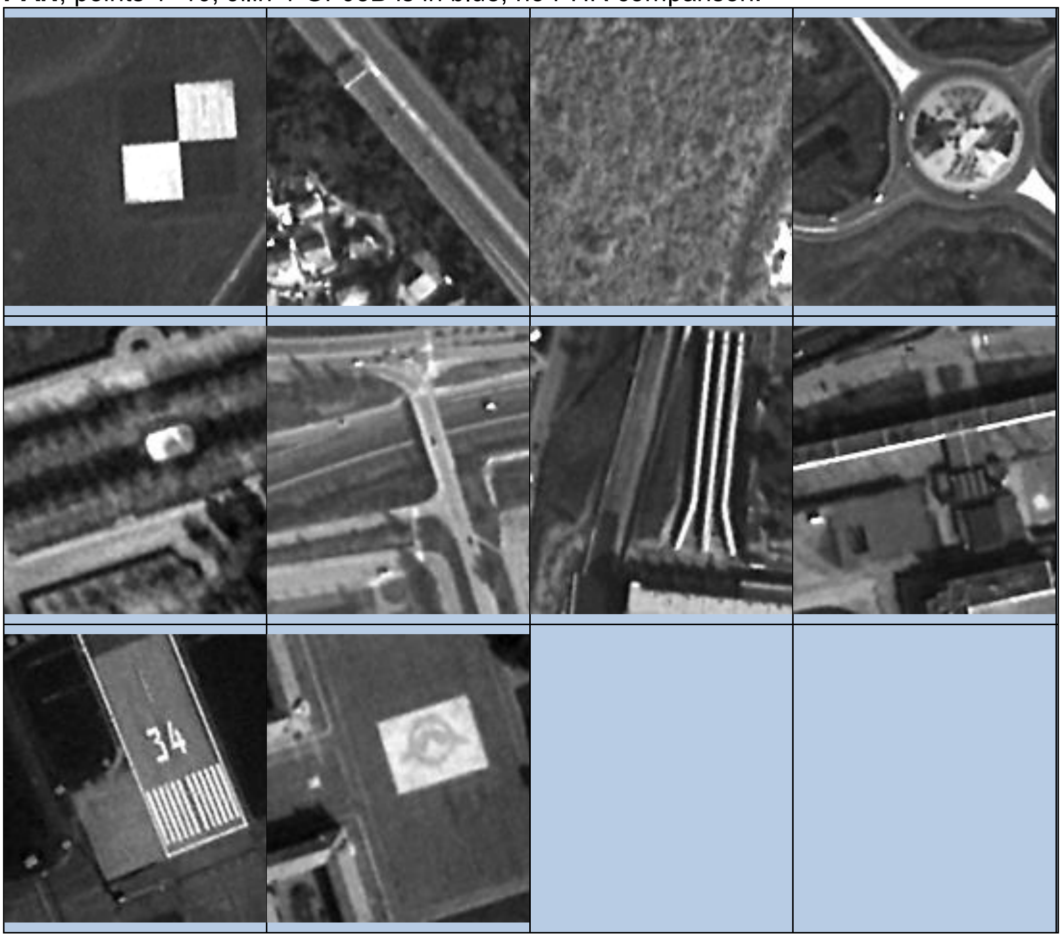


Band 4, points 1–10, Jilin-1 GF03B is in blue; no PHR comparison.





PAN, points 1–10, Jilin-1 GF03B is in blue; no PHR comparison.



4.5 Visual Inspections

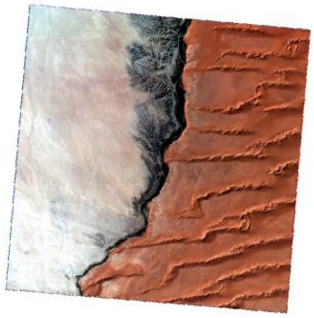
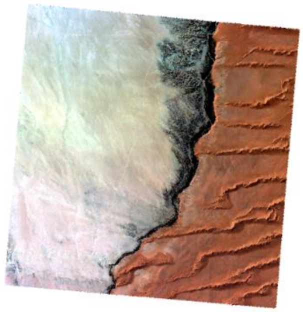
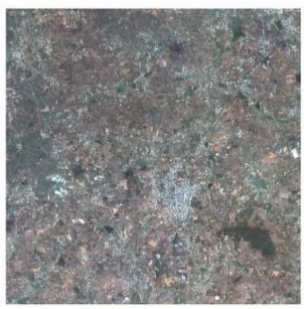
4.5.1 Description and Method

General visual inspections were performed on the multispectral and panchromatic imagery included in all products procured, despite not all being used in the previous assessments, in order to ensure there were no anomalies or artefacts present. The results are detailed in Section 4.5.2.

Note the visual inspections of the product imagery also include inspections of their histograms (e.g. support detection of anomalies or artefacts in the imagery, including saturation) and product metadata (the inspection and extraction of relevant metadata, for example the product quality grade and cloud score, for supporting information despite them not being fully described in the documentation (e.g. how is the product quality grade determined?)).

4.5.2 Results

Product	Visual Inspection Results	
1	Baotou (China) **Product Name**: JL1GF03B05_PMS_20210622101957_200053467_102_0002_001_L3A **Product Quality Grade**: A **Cloud Score**: 4 (%) **Comment**: The imagery does not appear to contain any anomalies or artefacts (including the mountainous areas, in the bottom left-hand corner of the image). The cloud score also appears to be estimated accurately also. (This product could not be used for the absolute radiometric calibration accuracy assessment as there was no RadCalNet data available for the date of this acquisition).	
2	La Crau (France) **Product Name**: JL1GF03B04_PMS_20210405172946_200046263_103_0001_001_L3A **Product Quality Grade**: A **Cloud Score**: 0 (%) **Comment**: The product imagery does not appear to contain any anomalies or artefacts.	
3	La Crau (France) **Product Name**: JL1GF03B01_PMS_20210401173100_200045867_103_0001_001_L3A **Products Quality Grade**: A **Cloud Score**: 0 (%) **Comment**: The product imagery does not appear to contain any anomalies or artefacts.	

4	Gobabeb (Namibia) **Product Name**: JL1GF03B04_PMS_20210511155831_20004955 5_104_0002_001_L3A **Products Quality Grade**: A **Cloud Score**: 24 (%) **Comment**: The product imagery does not appear to contain any anomalies or artefacts. The cloud score appears to be overestimated	
5	Gobabeb (Namibia) **Product Name**: JL1GF03B03_PMS_20210509155901_20004930 5_105_0001_001_L3A **Products Quality Grade**: A **Cloud Score**: 55 (%) **Comment**: The imagery does not appear to contain any anomalies or artefacts. The cloud score may be overestimated as the very light-coloured surface geology, composed of calcisols and gypsisols, of this area is predominant in this acquisition and might be mistaken for cloud in the calculation of the cloud score. (It is important to mention that this desert, which is known as a unique coastal fog desert, experiences morning fog (caused by cold currents in the Atlantic cooling the air just above the water, and then the winds blowing the cooled air inland and over the hot desert) on a near daily basis but then if this were the case then you would expect to see it cover the orange coloured Namib Sand Sea also.	
6	Shadnagar (India) **Product Name**: JL1GF03B06_PMS_20201215121706_20003573 6_103_0002_001_L1 **Products Quality Grade**: A **Cloud Score**: 0 (%) **Comment**: The product imagery does not appear to contain any anomalies or artefacts.	
7	Baotou (China) **Product Name**: JL1GF03B06_PMS_20210528102249_20000512 37_103_0001_001_L3A (although found in a	

	folder with a different name (JL1GF03B06_PMS_20210517101938_200050065_101_0003_001_L3A)) **Products Quality Grade**: A **Cloud Score**: 0 **Comment**: The product imagery does not appear to contain any anomalies or artefacts.	
8	Salon-de-Provence (France) **Product Name**: JL1GF03B03_PMS_20210228172525_200042708_104_0001_001_L3A **Product Quality Grade**: A **Cloud Score**: 0 **Comment**: The product imagery does not appear to contain any anomalies or artefacts.	
9	Wellington (South Africa) **Product Name:** JL1GF03B03_PMS_20210603154302_200051806_104_0001_001_L3A **Product Quality Grade**: A **Cloud Score**: 0 **Comment**: The product imagery does not appear to contain any anomalies or artefacts.	
10	Wellington (South Africa) **Product Name:** JL1GF03B01_PMS_20210705154347_200054624_106_0001_001_L3A **Product Quality Grade**: A **Cloud Score**: 0 **Comment**: The product imagery does not appear to contain any anomalies or artefacts.	

11	Wellington (South Africa) **Product Name:** JL1GF03B01_PMS_20210717153745_200055846_105_0001_001_L3A **Product Quality Grade**: A **Cloud Score**: 0 **Comment**: The product imagery does not appear to contain any anomalies or artefacts.	

5. CONCLUSIONS

This technical note details the preliminary data quality assessments (including geometric calibration, radiometric calibration and image quality) performed on a very small sample of **orthorectified Jilin-1 GF03B bundle products**. The results of the aforementioned data quality assessments generally indicate the **performance of the sensor and the processing implemented is relatively good**. It is, however, recommended that the mission provider address, at the very least, the following:

- The provision of more accurate product metadata (e.g. viewing angle).
- The provision of more detailed documentation (e.g., the product and quality metadata are a definite asset to the product but, unfortunately, the contents are not adequately described in the user guide and so not all of it can be used reliably or in the correct context).
- The provision of all minimum performance requirements so that it is clear to users what level of quality, especially geometrically and radiometrically, can be guaranteed or expected.
- The method used for radiometric calibration should be re-assessed by the operator, for the reasons described in relevant section of this technical note.

Please note the very small sample of products assessed here are from different satellites in the GF03B constellation so no comment can be made on items such as general stability (temporal assessments) or consistency across all satellites.

APPENDIX A JILIN-1 GF03B MISSION

The main source of information regarding the Jilin-1 GF03B mission was taken from [RD-4], which is fairly comprehensive.

Parameters

Table 3.37 The Parameters of Jilin-1GF03A/B

<table>
<tr><th>Attribute</th><th colspan="2">Value</th></tr>
<tr><td>Imaging mode</td><td colspan="2">Pushbroom imaging</td></tr>
<tr><td>GSD (at nadir)</td><td colspan="2">Panchromatic 1.06 m, Multispectral 4.24 m (Jilin-1GF03A)
Panchromatic 1 m, Multispectral 4 m (Jilin-1GF03B)</td></tr>
<tr><td>Spectral bands</td><td colspan="2">Panchromatic P: 450-700 nm
Blue B1: 450-510 nm
Green B2: 510-580 nm
Red B3: 630-690 nm
Near infrared B4: 770-890 nm</td></tr>
<tr><td>Dynamic range</td><td colspan="2">12 bits</td></tr>
<tr><td>Swath width</td><td colspan="2">> 17km</td></tr>
<tr><td>Standard scene size (at nadir)</td><td colspan="2">18.5 km × 18.5 km (Jilin-1GF03A)
17.5 km × 17.5 km (Jilin-1GF03B)</td></tr>
<tr><td rowspan="2">Orbit</td><td>Jilin-1GF03A</td><td>Type: Inclined circular
Altitude: 572 km</td></tr>
<tr><td>Jilin-1GF03B</td><td>Type: Sun-synchronous
Altitude: 535 km
Local time at descending node: 9:20 am</td></tr>
</table>

Figure 5-1: Jilin-1 GF03B specifications, taken from [RD-4].

[END OF DOCUMENT]