



agriculture, land reform
& rural development

Department:
Agriculture, Land Reform and Rural Development
REPUBLIC OF SOUTH AFRICA

Chief Directorate:
National Geo –spatial Information

Standard for the Acquisition of Digital Aerial Imagery

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SECTION A
Preliminary Informative Elements

A 1 Document Control

Version and Amendment Schedule

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| v1 | 14 December 2010 | Sissiel Kay |
| v2 | 18 December 2013 | Sissiel Kay |
| v3 | 19 December 2016 | Michelle Poole |
| v4 | 26 November 2018 | Michelle Poole |
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Approval and Control Schedule

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| v1 | Derek Clarke | Chief Director | | 14 December 2010 | <i>Master Copy</i> |
| v2 | Derek Clarke | Chief Director | | 18 December 2013 | <i>Master Copy</i> |
| v3 | Derek Clarke | Chief Director | | 19 December 2016 | <i>Master Copy</i> |
| v4 | Derek Clarke | Chief Director | | 26 November 2018 | <i>Master Copy</i> |
| v5 | Aslam Parker | Acting Chief Director | | 08 December 2020 | <i>Master Copy</i> |
| v6 | Aslam Parker | Director – for CD: NGI |  | 25 August 2021 | <i>Master Copy</i> |

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A 3 Foreword

This standard covers technical requirements for the acquisition of digital aerial imagery as mandated by the Land Survey Act, 8 of 1997, that may be used for *inter alia* photogrammetric compilation of elevation and topographic data.,

This standard, in conjunction with the “Standard for the Acquisition of Film Based Aerial Photography”, supersedes Mapping Instruction 15, Specification for Aerial Photography, of 1985.

Acknowledgement

This standard was reviewed and amended by the following members of the Standards Committee:

| | |
|-----------|-----------------------------|
| B Semoli | (Convenor) |
| A. Parker | (Invited Technical Advisor) |
| E. Kinsey | |
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| R Duesimi | |
| S Patel | |
| S Dlamini | |
| S. Aimes | (Quality Assurance) |
| M Poole | (Quality Assurance Manager) |

A 4 Terms and Definitions

[Refer to Glossary](#)

A 5 Symbols and Abbreviations

[Refer to Glossary](#)

A 6 Introduction

A 6.1 General

The Standard for the Acquisition of Digital Aerial Imagery serves as a collective of all the specifications required for the acquisition of digital aerial imagery as required by the CD: NGI and its status is mandatory.

Name of the Standard

The standard described in this document shall be known as the Standard for the Acquisition of Digital Aerial Imagery.

The shortened name, Acquisition of Digital Aerial Imagery Standard, may be used.

A 6.2 Purpose

The objective of this document is to outline the requirements and acceptable quality levels of all imagery, to be met by the CD: NGI and its contractors in the acquisition of digital imagery, and in support of the aerial imagery and mapping programmes of the CD: NGI.

A 6.3 Audience

The primary audience of this document are contractors tasked with acquiring digital imagery, including digital aerial photography and the processing thereof to ortho-rectified imagery. The secondary audience of this document is the staff of the CD: NGI who are involved in the aerial photography and the production of ortho-rectified imagery.

A 6.4 Applicability

This document is applicable to all role players, activities and processes involved in the acquisition of digital panchromatic, infra-red, colour infra-red (false colour) and normal colour aerial imagery and subsequent products.

A 6.5 Scope and Exclusions

This document outlines the requirements for the acquisition of digital aerial imagery.

A 6.6 Assumptions

It is assumed that the provisions of this document will be the primary source of requirements for the acquisition of digital aerial imagery.

A 6.7 Normative References, other standards and related documents

- The document Recommended Practice for the Structure and Drafting of Standards and Related documents is used to guide the format and structure of this document.

A 6.8 Maintenance Authority

Maintenance of the Standard for the Acquisition of Digital Aerial Imagery is the responsibility of the Division: Quality Assurance of the CD: NGI. Changes to this Standard will be instructed by the Chief Director as improvements or amendments become necessary, or as required. Any request for amendments to this Standard may be submitted by any institution, body or individual to the Chief Director for consideration. All such requests and any other comments on the Standard must be addressed to:

Chief Director: National Geo-spatial Information
Private Bag X10
Mowbray
7705

and be referenced as: Amendment – Standard for the Acquisition of Digital Aerial Imagery.

The Division: Quality Assurance shall maintain the provisions and structure of this document through amendment and revision activities.

A 6.9 Roles and Responsibilities

The roles and responsibilities of the main role players as it pertains to the use of this document are stated below.

A 6.9.1 Quality Assurance Division

- To maintain the provisions of this document.
- Keeping track of all amendments to this document.
- Providing assistance and guidance to the Standards Development Committees and the CD: NGI Management in interpreting the provisions of this document.
- Provisionally approving a proposed revision of this standard with respect to its structure and format.
- Ensuring that the use and purpose of this document is communicated effectively.

A 6.9.2 Standards Development Committee – Acquisition of Digital Aerial Imagery

- To draft specifications to the provisions of this document.
- To make recommendations on the update and amendment of the provisions of this document.
- Refer to the relevant section in the Terms of Reference of the Standards Development Committee for more details in this regard.

A 6.9.3 Manager: Management Support, and the Geomatics Manager: Quality Assurance

- Evaluate proposed amendments and revisions of this Standard.
- Provisionally approving proposed amendments to this Standard.
- Refer to the relevant section in the Terms of Reference pertaining to the Deputy Manager: Management Support, and the Geomatics Manager: Quality Assurance for more details in this regard.

A 6.9.4 CD: NGI Senior Management

- To approve, amendment and revise this Standard.

A 6.9.5 Contractors

- To acquire digital aerial imagery according to the provisions of this Standard.

SECTION B
Normative Elements

B 1 Acquisition of Aerial Imagery Using Digital Sensor Systems

B 1.1 Scoping

- (a) Acquisition of the digital aerial imagery shall be from airborne platforms capable of meeting the minimum specified criteria.

B 2 Sensor System Requirements

- (a) Only digital sensor systems which meet the requirements of these specifications, and as determined by appropriate sensor system documentation, certification and sample imagery submitted shall be used to acquire the digital aerial imagery.

B 2.1 Digital Sensor System

- (a) The primary sensor must be constructed from a single robust frame to ensure geometrical integrity against pressure, temperature and operational vibration and turbidity over time.
- (b) Only large format digital photogrammetric cameras will be utilised for the acquisition of aerial images.
- (c) Camera heads to be true nadir, oblique cameras producing virtual imagery requiring up sampling do not conform.
- (d) Separate camera channels per multispectral bands (PAN, Red, Green, Blue and NIR) must be provided for.
- (e) The PAN (panchromatic) channel, which is mandatory at full resolution, may be acquired via a cluster of camera heads stitched together without any up scaling or down scaling in forming the full resolution.
- (f) Multispectral bands (Red, Green, Blue and NIR) may be acquired at a resolution that is not less than 1/3 of the full panchromatic resolution, however, the panchromatic band at full resolution is required for pansharpening, and cluster camera heads as specified in B2.1 (e) above conform.
- (g) Separate Charged Couple Device (CCD) or Complementary-symmetry Metal-Oxide Semiconductor (CMOS) channels conform.
- (h) Single CMOS channels for multispectral acquisition using Bayer Pattern filtering/resampling will not be accepted.
- (i) A calibration certificate detailing the camera specifications and the geometric and radiometric performance, must be archived within the Integrated Topographical Information System (ITIS) archive system for each camera utilised in the acquisition of aerial imagery.
- (j) Calibration certificate, as specified in B2.1 (i), must conform to the naming convention as detailed in the (ITIS) Standard.

B 2.2 Sensor Lens Protection

- (a) The digital sensor lenses must be protected for take-off and landing of the aircraft.

B 2.3 Digital Sensor Shutter

- (a) The sensor shutter shall ensure that light is transmitted simultaneously to all parts of the format when it is opened.
- (b) The sensor shutter shall be of such a design that the operation of the shutter does not create disturbing vibrations.

B 2.4 Lens Distortion

- (a) The average of the radial distortion measured on four diagonals from lens axis to edge of field of view in the focal plane and based on the focal length shall not exceed 0,010 mm for wide-angle lenses.

- (b) The asymmetry of radial distortion measured on four diagonals from lens axis to edge of field of view shall be such that the largest absolute difference between measured radial distortion and the average radial distortion shall not exceed 0.005 mm.
- (c) For all cameras the maximum tangential distortion measured in the focal plane shall not exceed 0,005 mm.

B 2.5 Footprint Coverage

- (a) The digital sensor system shall be a large format system that provides imagery at a spatial resolution and flying height suitable for the CD: NGI operational purposes.

B 2.6 Capture of Multi-Spectral Imagery

- (a) The digital sensor system shall be able to simultaneously capture panchromatic and at least four multi-spectral bands, namely red, green, blue, (RGB) and near infrared (NIR).
- (b) There shall be minimal spectral overlap of multispectral bands.

B 2.7 Stereo Coverage

- (a) The digital sensor system shall be capable of acquiring consecutive image frames as determined by the relevant flight planning software, with a fore and aft overlap ranging between 45 and 90 percent in a single pass.

B 2.8 Integration with GNSS/INS Systems

- (a) The digital sensor system shall operate and be supplied with an integrated Global Navigation Satellite System (GNSS) and Inertial Navigation System (INS), which shall enable the gathering of *a priori* information about the exterior position and orientation of the imagery to assist with the aerial triangulation process and minimise ground control requirements.
- (b) The GNSS antenna shall be approved by the International GNSS Service (IGS) and be suitable for geodetic quality carrier-phase multi-channel reception for at least GPS and GLONASS and installed in accordance with the Civil Aviation Authority (CAA) airframe modification requirements. Antenna should be located as close as possible to the digital imaging sensor, and in a location to provide optimal GNSS signal quality and continuous reception in an appropriate, unobstructed location on the aircraft.
- (c) The electrical phase centre of the GNSS antenna and the INS system shall be co-ordinated and surveyed to the image centre of the sensor by a geomatics practitioner, registered with the South African Geomatics Council (SAGC).
- (d) IMU to GNSS Antenna Lever Arm survey results shall be provided and presented as follows:

X=-0.000, Y=0.000, Z=0.000 m (X-right, Y-fwd, Z-up), these are not literal values, only for illustration purposes, unit = meters.
- (e) The offset parameter, paragraph 2.8 (d), must be included in the mandatory GNSS/INS file together with registration details of the geomatics practitioner, as per paragraph 2.8 (c), for any test area and all program flight acquisition missions as defined by CD: NGI. **Annexure A** details the file format requirements of the GNSS/INS file.

B 2.9 Boresight Calibration

- (a) A Boresight Calibration shall be performed to determine the three misalignment angles and the spatial offset between the orientation of the IMU and the orientation of the airborne sensor. These angles and offsets reflect the mechanical misalignment between the IMU co-ordinate system and the co-ordinate of the airborne sensor.
- (b) A small, well controlled test area shall be flown. An even number of strips shall be flown, with a minimum of 4 strips flown in opposite directions. Each strip should consist of a minimum of 10 exposures (of which there shall be 2 in fly and 2 outfly exposures that fall fully outside the test

area). A forward overlap shall be within a range of 55% and 65% and a side lap of between 30% and 40% is required. If the operational test area, as presented in paragraph B 2.17, meets these requirements then it may be used for the computation of the boresight calibration.

- (c) The entire area shall be stereoscopically covered within the usable portions of the images.
- (d) The test area shall have a minimum of five surveyed Photo Ground Control (PGC) points, one in each of the four corners of the block and one in the centre of the block.
- (e) The test area shall be aerial triangulated, survey controlled as per paragraph 2.9 (d), with the resultant RMS values being within the allowable limits as specified by the camera manufacturer.
- (f) A boresight calibration shall be performed at any stage when the camera or IMU system has been disturbed in the aircraft.
- (g) The following records shall be submitted to the CD: NGI for approval in respect to the boresight calibration:
 - i) Boresight misalignment angles
 - ii) Aerial triangulation results
 - iii) Spatial offsets between the IMU and the airborne sensor
 - iv) Details of the control used for the aerial triangulation
 - v) A flight plan of the calibration site
- (h) The boresight misalignment angles shall be provided and presented as follows:
 - a) Body to Sensor Rotations:

XRot=0.000, YRot=0.000, ZRot=0.000 degrees (Rotate IMU into Vehicle Frame)
Units =degrees
 - b) Spatial offsets between the IMU and the airborne sensor shall be provided and presented as follows:

IMU to Secondary Sensor Lever Arms: (off set between IMU and airborne sensor)

X=-0.000, Y=0.000, Z=-0.000 m (X-right, Y-fwd., Z-up, IMU->SENSOR)
Units = Meters
- (i) The boresight misalignment angles and Spatial offsets between the IMU and the airborne sensor as presented in paragraph 2.9 (h) (a) and (h)(b) respectively, must be included in the mandatory GNSS/INS file together with registration details of the geomatics practitioner, as per paragraph 2.8 (c), for any test area and all program flight acquisition missions as defined by CD: NGI. **Annexure A** details the file format requirements of the GNSS/INS file.

B 2.10 Inertial Measurement Unit (IMU)

- (a) The IMU shall be attached closely and rigidly to the imaging focal plane and the gyro-stabilised mount shall receive its orientation information from this same built-in IMU. The system shall relieve the operator from drift setting. Drift reference for the sensor mount shall be provided by the orientation system.
- (b) The accuracy of the IMU positional data over time shall be quantified in any proposal for work, along with the acceptable flying time, between any activities required to maintain the accuracy of the IMU's positional data.
- (c) The flying time shall be such that data capture rates are not materially affected, with at least 20 minutes flying time between any activities required to maintain the IMU's accuracy.

B 2.11 Spatial Resolution

- (a) The digital sensor system shall produce high spatial resolution colour (RGB) and panchromatic digital imagery, and shall be capable of capturing a minimum GSD of 5 cm.

B 2.12 Radiometric Resolution

- (a) The digital sensor system shall have the ability to capture imagery with a minimum 12-bit radiometric resolution for each spectral band (Panchromatic, RGB and Near Infrared).

B 2.13 Radiometric Consistency

- (a) The individual digital images captured shall be processed per project area where radiometric consistency, across the project area, is required.
- (b) Dodging of the imagery and colour balancing shall be done only on specific written instruction by the Chief Director.
- (c) The radiometric accuracy shall be maintained over time to provide for a comparison of images from different epochs.

B 2.14 Geometric Accuracy

- (a) The geometric accuracy of the calibrated apparent pixel co-ordinates shall be to within 25% of the pixel size of the sensor, for each format of imagery and each lens system. True rectangularity of objects shall be maintained to within 25% of the pixel size of the sensor.
- (b) The accuracy of the focal length of the digital sensor system shall be less than or equal to 1 micron.
- (c) The maximum forward motion compensation permitted in the image plane shall not exceed 0,2% of the maximum number of pixel lines on the image, as calculated in the direction of flight.

B 2.15 Calibration of Proposed Digital Sensor Systems

- (a) The digital sensor system shall be radiometrically and geometrically calibrated by a competent testing organisation. Proof of such calibration shall be provided to the CD: NGI prior to any work being undertaken. Such calibration shall further be to a tolerance that meets the requirements of this standard.
- (b) Digital sensor systems shall be evaluated to determine if they meet the bid specifications, based on current technical descriptions and samples. The Chief Director shall, in his/her sole discretion, approve the use of a sensor or request the non-usage of any sensor when deficiencies in imagery attributable to the sensor are found to exist.
- (c) The digital sensor system shall be calibrated and tested in accordance with the manufacturers' specifications and guidelines.
- (d) The calibrated certificate shall include the following information:
 - i) The calibrated focal length (principal distance) of the lens, as mounted in the camera, with a standard error not exceeding 0.001mm.
 - ii) The radial lens distortion along plate diagonal from the lens axis to the edge of the field of view at intervals not exceeding 10mm with a standard error not exceeding 0.005mm.
 - iii) The average radial lens distortion, from the lens axis to the edge of the field of view, at intervals not exceeding 10mm.
 - iv) The location of the principal point of autocollimator or the point of symmetry with respect to the fiducial centre with a standard error not exceeding 0.005mm.

- (e) It shall be certified that the camera lens cone and lens have not been disassembled nor adversely disturbed since calibration. Should any part of the camera that affects the calibration be disassembled or disturbed then a new calibration shall be made before further use.

B 2.17 Operational Test

- (a) Prior to the commencement of imagery acquisition for the CD: NGI, and at any stage when the camera or IMU system has been disturbed in the aircraft, imagery of a CD: NGI approved test area shall be acquired for the purposes of an operational test. The Operational Test shall be undertaken after a successful Boresight Calibration has been completed.
- (b) The test area shall be flown at a ground sample distance at optimal of 0.25m of the GSD of CDNGI acquisition program, or as specified by the CD: NGI, with the same aircraft/sensor/peripheral equipment combination as will be used in the image acquisition programme of the CD: NGI.
- (c) This imagery shall consist of at least two adjacent strips, with each strip consisting of a minimum of six images with a forward overlap of between 55% and 65% and a sidelap of between 20% and 30%.
- (d) The entire area shall be stereoscopically covered within the usable portions of the images.
- (e) Ground control points (GCP) shall be used as supplied by the CD: NGI. The expected error, at a confidence level of 2σ , in the individual easting and northing components, after aerial triangulation, shall not exceed $\pm 0.068\text{m}$, to a maximum permissible error of $\pm 0.10\text{m}$.
- (f) The expected error, at a confidence level of 2σ , in the height, after aerial triangulation, shall not exceed $\pm 0.12\text{m}$, to a maximum permissible error of $\pm 0.30\text{m}$.
- (g) The following records in respect of the test area shall be provided:
 - i) Plan of the test area
 - ii) Co-ordinates, height and description of each GCP
 - iii) Enlargements on which the GCP are clearly marked at a scale such as to allow their easy identification
 - iv) All information as stipulated in paragraph B7.
- (h) Should the results obtained from the imagery of the test area not be consistent with the sensor calibration data supplied nor suitable for photogrammetric or photo interpretation purposes, the Chief Director may prohibit the use of that sensor.

B 3 Digital Imagery Acquisition

B 3.1 Coverage

- (a) The entire area shall be stereoscopically covered within the usable portions of the images.
- (b) In addition to (a), imagery coverage shall extend by at least 25% of the image size, across the direction of flight, over the edge of the area, parallel to the flight line.

B 3.2 Ground Sample Distance (GSD)

- (a) The nominal GSD shall be stipulated in the documentation of a specific contract.
- (b) The nominal GSD, shall not vary by more than 10% from that specified in B 3.2 (a)

- (c) The deviation from the limit specified in B 3.2 (b) shall be permitted. In areas of extreme variation in terrain relief, provided that the lowest GSD shall not exceed 10%, as specified in B 3.2 (a).
- (d) The panchromatic and multispectral bands shall be collected at the specified GSD.
- (e) For multispectral imagery, colour interpretation or pan sharpening shall be permitted to achieve the specified requirements.

B 3.3 Image Quality

- (a) New imagery shall be quality-controlled to ensure acceptable image quality, correct colour representation, tonal values and definition of ground detail. Only imagery meeting the requirements of the quality check shall be accepted.
- (b) In general, the imagery shall be a true reflection of the terrain at the time of exposure.
- (c) All imagery shall be spectrally consistent across the whole project and be of a good quality.
- (d) Small amounts of artefacts shall be acceptable if they are insignificant, i.e. they do not obscure objects or features. However, these should be only evident in localised areas. Any images with artefacts that obscure objects/features shall be rejected.
- (e) The image shall be free from clouds and cloud shadows, fire, smoke, haze, light streaks, shadows, excessive snow and other blemishes.
- (f) High, thin clouds shall be permitted above the flying altitude, with the proviso that it does not result in a mottling of the ground detail or a discernible reduction in the light levels and/or ground object shadows.
- (g) Contrast shall be consistent across the project area.
- (h) There shall be no image smearing, blurring or ghosting even where this is localised.
- (i) Colour bleeding shall not be detrimental to the image appearance.
- (j) There shall be sufficient shadow and highlight detail to facilitate accurate image interpretation.
- (k) There shall be no missing pixels in both the imagery and overviews.

B 3.4 Flying Height

- (a) Flying heights of the east-west strips shall be determined, based on the ground height of the terrain.
- (b) Flying heights of the cross-strips, including coastal, border, dam and other water body strips, shall be a mean of the heights of the east-west strips, which they intersect.
- (c) Flying height shall be maintained in accordance with the mission planning and the requirements stipulated in B 3.2 (b).
- (d) The departure from the predetermined flying height shall not exceed 10% of flying height above mean terrain, as specified in B 3.4 (c).
- (e) No deviation from the limit specified in B 3.4 (d) shall be permitted without the prior written permission from the Chief Director.

B 3.5 Flight Lines

- (a) All flight lines shall be approved by the Chief Director, prior to the commencement of flying.
- (b) Strips shall be designated as follows:

| Designation | Description |
|-------------|-------------------------|
| EW | East - West |
| WE | West - East |
| SN | South - North |
| NS | North - South |
| NWSE | North West – South East |
| SENW | South East – North West |
| NESW | North East – South West |
| SWNE | South West – North East |

- (c) Strips shall be classified as follows:

- i) Block strips, these strips are flown EW or WE
- ii) Tie Cross strips, these strips are flown SN or NS
- iii) Feature Cross strips, these strips are flown NW-SE, SE-NW, NE-SW, SW-NE

- (d) Block strips define the area of Interest required to be flown, coverage.
- (e) Tie Cross strips, tie the aerial triangulation block together.
- (f)
- (g) Feature Cross strips are required for curvilinear boundaries (water bodies), coastal areas and border strips.
- (h) Strip numbering must start from the northern boundary of the flight block. Strips will be numbered consecutively and starting as 01.
- (i) Image numbering must start from the northern boundary of the flight block, EW or WE strip. Numbering shall start in the direction of flight in strip 01 and shall be numbered consecutively starting as 0001.
- (j) Any flight strips that are interrupted for any reason must be completely re-flown. Explanation: Flight strips cannot be interrupted. A flight strip must be completed in one attempt.
- (k) For all standard jobs, tie strips shall be flown such that they traverse the start and end of the east-west strips.
- (l) Separate tie cross strips must be flown for each individual job. Two adjacent jobs cannot share the same tie cross strip.
- (m) Feature Cross strips, including coastal, border, dam and other water body strips, shall be flown such that all the requirements of the applicable aerial triangulation adjustment software, with GNSS/IMU assisted air-stations, are met.
- (n) All cross strips in the mountainous areas, shall be flown at the similar time of a day as the block strips (east-west as prescribed), which they intersect in order to facilitate aerial triangulation adjustment to prevent tie points falling in shadow areas
- (o) The maximum deviation of any flight strip, from the planned flight line, shall, not exceed 5% of the image size across flight direction to ensure that flight lines are straight and parallel.
- (p) If images are rejected within a strip, or there is a break in the strip's continuity, the entire strip shall be re-flown at a similar time of day to the adjoining strips. All the requirements of B 3.5 (e) must be complied with.

- (q) The first two and last two images of each strip shall be completely outside the area being flown.
- (r) Where the coastline, or a water body, forms a boundary for the area being imaged, additional strips shall be flown parallel to the coastline or water body such that the centre points fall well inland, and these strips must be suitable for aerial triangulation and permit stereoscopic viewing.
- (s) Images with more than 25% of their area covered by sea and large water bodies shall not be accepted.
- (t) Where the border of the Republic of South Africa forms a boundary of the area being imaged, additional strips shall be flown.
- (u) All the strips of an entire job shall be flown within one month of commencement of the job, unless prior written permission is obtained from the Chief Director.

B 3.6 Sidelap

- (a) Adjacent images of the east-west strips shall have an average sidelap of 25% of the image size across the flight direction and shall be within a range of 15% and 40%.
- (b) Sidelap shall compensate for extreme terrain variations.
- (c) Areas of extreme terrain relief where the specified sidelap cannot be maintained shall be covered by short auxiliary strips, flown between the main flight lines and parallel to them.
- (d) In the instance of short auxiliary strips having been flown between the main strips, additional cross strips shall be flown, to meet the requirements of the bundle adjustment software.

B 3.7 Forward Overlap

- (a) Forward overlap shall average 60% of the mean image size in the flight direction and shall not be less than 55%.
- (b) In addition to (a) forward overlap shall compensate for extreme terrain variations.

B 3.8 Crab

- (a) While collecting digital aerial imagery, the camera shall be compensated for the crabbing of the aircraft, with a resultant error not exceeding ± 5 degrees, as measured from the average line of flight, and the differential between any two successive exposures shall not exceed ± 5 degrees.

B 3.9 Tilt

- (a) Care shall be taken to keep the tilt of the camera to a minimum. Under no circumstances shall tilt exceed ± 5 degrees for any image frame, as well as the relative difference in tilt between consecutive frames.
- (b) The average tilt of images for the project area shall not exceed ± 1 degree.

B 3.10 Course Correction

- (a) Corrections to the aircraft's course between successive images shall not exceed 3 degrees.

B 3.11 Time of Day Considerations

- (a) The solar altitude shall be at least 30 degrees in average terrain and 40 degrees in very mountainous terrain or as specified by Chief Director
- (b) For particular cases it may be necessary to place an upper limit on the solar altitude. Such requirements shall be specified by the Chief Director.
- (c) The Chief Director shall accept imagery acquired during the time intervals, before or after local noon as accessed from the South African Astronomical Observatory website at https://www.sunearthtools.com/dp/tools/pos_sun.php or <https://www.esrl.noaa.gov/gmd/grad/solcalc/>
- (d) The threshold for flying times shall be specified by the Chief Director per job. The precautions shall be taken to minimise the effect of hot spots on the uniformity of the illumination.

B 3.12 GNSS and IMU Data Collection

- (a) All imagery shall be flown with integrated GNSS and IMU. The ground and airborne GNSS data shall be collected, processed and submitted to the CD: NGI, along with the IMU data files and final processed trajectory files.
- (b) The GNSS receiver shall collect data for at least 30 minutes prior to capturing imagery to improve ambiguity resolution during GNSS post-processing.
- (c) The GNSS PDOP and VDOP shall be <3 during acquisition of the imagery.
- (d) The aircraft shall not bank excessively such that loss of lock on the GNSS signal required for continuous kinematic solution occurs at any stage during the image acquisition process. If loss of lock occurs during image acquisition, the current strip shall be aborted and sufficient GNSS data shall be acquired prior to further image acquisition to enable re-initialization of the baselines to the TrigNet base station network.
- (e) Carrier-phase airborne multi-channel kinematic GNSS for at least GPS and GLONASS shall be acquired and used along with IMU measurements in processing trajectories. The proprietary/raw GNSS data shall be stored.
- (f) The IMU shall be capable of determining the absolute orientation (roll, pitch and yaw) and shall be proven to meet or exceed a post-processed accuracy in roll and pitch of 20" of arc and a post-processed accuracy in heading of 30" of arc.
- (g) Any failure of the IMU to accurately record orientation data shall be sufficient grounds for rejection of the affected strips.

B 4 Post-Acquisition Position and Orientation Processing and Accuracies

B 4.1 GNSS solution processing

- (a) The positions of the GNSS air-stations shall be determined relative to the latest ITRF realisation of TrigNet and the South African Land Levelling datum for the horizontal and vertical components respectively.
- (b) The GNSS antennae offset, in dy , dx and dHt , relative to the camera principal point position, shall be applied entirely, on all three components, in the differential correction process.

- (c) The ellipsoidal heights of the air stations, obtained after differential correction, shall be converted to orthometric heights, using the latest geoid model (currently SAGEOID2010).
- (d) All GNSS observation data, including event data shall be supplied in Receiver Independent Exchange (RINEX) format. See [ftp://igsceb.jpl.nasa.gov/igsceb/data /format/rinex2.txt](ftp://igsceb.jpl.nasa.gov/igsceb/data/format/rinex2.txt) for documentation describing the format.
- (e) A space delimited flat ASCII file, containing the information, as shown in Annexure A, shall also be supplied. The file naming convention shall be:

Job no_GNSS_INS_DATA.txt

- (f) The data of the differentially corrected GNSS observed co-ordinates and IMU data, captured per image centre, shall be supplied in ASCII format and reported in the following order:
 - i) Strip number (in sequence). These strip numbers shall coincide with those shown on the flight plans.
 - ii) Image number (shall be unique per job) starting at 0001.
 - iii) Time stamp (seconds of week)
 - iv) Easting, in international metres (Transverse Mercator projection)
 - v) Northing, in international metres (Transverse Mercator projection)
 - vi) H_{tmsl} (orthometric height – international metres).
 - vii) Orientation parameters (omega, phi, kappa,).
 - viii) Date and time of exposure (yyyy/mm/dd, HH:mm:ss)
 - ix) Standard deviation for position (separately for every component of position)
 - x) Standard deviation for orientation (separately for every component of orientation)

B 4.2 GNSS Accuracies Required

- (a) The air-station co-ordinates shall be referenced to the same longitude of origin (Lo.), per job as identified by the CD: NGI.
- (b) The air-station co-ordinates shall have absolute accuracies of better than or equal to 0.3 metres.
- (c) The air-station co-ordinates shall have a relative accuracy, i.e., Standard Deviation between consecutive air stations, of better than or equal to 0.1 metres.

B 5 Image Pre-processing

B 5.1 General

- (a) Image processing software shall be used to produce output images from the raw image data that is stored on the in-flight data storage system during imagery acquisition. This processing phase is used to radiometrically and geometrically process the images.
- (b) Processed, 8-bit, colour (RGB) and/or panchromatic and/or CIR imagery shall be supplied, radiometrically and geometrically corrected and compressed in accordance with paragraph B5.2, B5.3 and B5.4 respectively, that is capable of being immediately absorbed into the current photogrammetric workflow at the CD: NGI.

B 5.2 Radiometric Processing

- (a) The imagery shall be radiometrically corrected to compensate for any adverse effects of temperature, aperture or other radiometric factors.

B 5.3 Geometric Processing

- (a) The intermediate, radiometrically corrected images, shall be geometrically corrected for lens distortion and lens tilt in accordance with this standard.

B 5.4 Image Compression

- (a) Images shall be supplied in TIFF format
- (b) The TIFF images shall be compressed with a JPEG compression of Q=3 with tiles and a full set of overviews, as prescribed.

B 5.5 Image Orientation

- a) The resultant images must conform to the following requirements:
- b) Image orientation must at all times correspond to the IMU data as recorded during the image acquisition process.
- c) The image orientation shall be:
 - i) North-up for West-East flight direction;
 - ii) South up for East-West flight direction;
 - iii) West up for South-North flight direction;
 - iv) East up for North-South flight direction;
 - v) In the case of border or dam strips, these are to be treated the same as tie strips and oriented as per the above dependent on the direction of flight.
- d) Image orientation must facilitate the use of a single camera file setup for further photogrammetric processing.

B 5.6 Image Naming Convention

- (a) For all jobs flown the syntax of the image name shall be as follows for the RGB, CIR and Pan image respectively:
 - i) Quarter degree square_calendar year flown_job number_strip number_photo number_RGB,
e.g. 2727A_2010_22_01_0493_RGB
 - ii) Quarter degree square_calendar year flown_job number_strip number_photo number_CIR,
e.g. 2727A_2010_22_01_0493_CIR
 - iii) Quarter degree square_calendar year flown_job number_strip number_photo number_PAN,
e.g. 2727A_2010_22_01_0493_PAN

B 6 Flight Plan Data

B 6.1 Flight plan Index

- (a) The flight plans shall be supplied in digital .pdf format, with all detail clearly legible.

B 7 Submission to the CD: NGI

B 7.1 Delivery note

- (a) Delivery note containing the following information
- (i) To be compiled in A4 portrait format
 - (ii) Company letterhead
 - (iii) Company business address and contact details
 - (iv) Page Number
 - (v) Date of delivery note
 - (vi) Job Number
 - (vii) Bid reference
 - (viii) Job area name
 - (ix) Date of awarding of bid,
 - (x) Date range of imagery,
 - (xi) Date of delivery.
 - (xii) Executive Summary
 - General description of job,
 - Overview of reports
 - Data attached,
 - Equipment used – (Aircraft, Camera, IMU, Base stations, etc.
 - (xiii) Noteworthy issues:
 - Problems that were experienced, and how were they solved.
 - General comment on weather and terrain.
 - (xiv) Deliverables:
 - List of digital media supplied, manufacturer, storage capacity, serial numbers and reference numbers
 - List the Reports submitted,
 - List the Data files submitted,
 - Folder structure breakdown of the job as on the media submitted.
 - (xv) Authorised signature of company representative.

B 7.2 Survey Report

- (a) A detailed report on the airborne positioning and orientation reporting shall be submitted in digital format, as follows:
- (i) To be compiled in A4 portrait format
 - (ii) Company letterhead
 - (iii) Company business address and contact details
 - (iv) Page Number
 - (v) Report heading
 - (vi) Date of report
 - (vii) Job Number
 - (viii) Bid reference
 - (ix) Executive summary: Report on the following:
 - Provide an overview of the project and the final processed data sets.

- List the datasets in table form with the columns: Dataset ID, Date of Acquisition, Projects covered by the dataset, and Description/Flight Line(s) identification.
- (x) Positioning: Report on the following:
- Methods and equipment used,
 - Antenna offset,
 - TrigNet base station names and published (ITRF) geographical coordinates used,
 - Computation of air-station coordinates,
 - Range of positional accuracies achieved shall be reported,
 - Exposure frequency due to terrain compensation,
 - Provide schematics indicating the trajectory.
- (xi) General: Report on the following:
- Description of the datasets,
 - Date of imagery of each strip flown,
 - Strips rejected and reflight,
 - Dates and times of sessions,
 - The processing and
 - The results.
- (xii) Noteworthy issues: Provide an insight into any issues / problems that were experienced during processing, and how they were solved. Note any rejected data and comment on the quality of the data.
- (xiii) Final results: Provide the exterior orientation file with the exterior orientation parameters.
- (xiv) Authorised signature of company representative.

B 7.3 Imagery Post Processing Report

- (a) A detailed report on the processing of the imagery from raw (binary) imagery to calibrated imagery shall be submitted in digital and hard copy format containing the following information:
- (i) To be compiled in A4 portrait format
 - (ii) Company letterhead
 - (iii) Company business address and contact details
 - (iv) Page Number
 - (v) Report heading
 - (vi) Date of report
 - (vii) Job Number
 - (viii) Bid reference
 - (ix) Date of processing
 - (x) Executive summary
 - (xi) Radiometric: Provide an overview of the radiometric processing undertaken.
 - (xii) Geometric: Provide an overview of the geometric processing undertaken.
 - (xiii) Pan Sharpening: Provide an overview of the transformation used.
 - (xiv) Output Options: Provide an overview of the following output options for both the RGB and CIR deliverables:

- Image format
- Bit depth
- Compression algorithm
- Q factor
- Tile size
- Overviews (count)

(xv) Noteworthy issues: Provide an insight into any issues / problems that were experienced during processing, and how they were solved.

(xvi) Authorised signature of company representative.

B 7.4 Operations Report

A comprehensive operations report shall be submitted with delivery of the job, and shall contain the following information:

- (i) To be compiled in A4 portrait format
- (ii) Company letterhead
- (iii) Company business address and contact details
- (iv) Page Number
- (v) Date of report
- (vi) Job Number
- (vii) Bid reference
- (viii) Required Ground Sample Distance of job (GSD)
- (ix) Equipment Manifest, in tabular format containing the following information:
 - Aircraft Type
 - Aircraft Number
 - Pilot Name
 - Pilot Registration Number
 - Photographer / Operator
- (x) Camera Details, in tabular format containing the following information:
 - Camera Type
 - Cone Number
 - Lens Details including Spectral Band and Serial Number
 - Camera Port hole Details
 - Filter Type
 - Filter Number
 - Camera Temperature Control
 - Camera Humidity Control
 - Navigation Sight Type
 - Intervalometer
 - Exposure Meter
- (xi) Job imagery information in tabular format under the following headings:
 - Strip No. (e.g. 01)
 - Image range (e.g. 0001 – 0048)
 - Altimeter setting: Outside temp (e.g. GPS Height; 2°)
 - Flight Altitude: Planned (e.g. 5200m)

- Flight Altitude: Reading (e.g. 5210m)
- Date of strip (e.g. 2010/02/28)
- Strip start time (SA Standard time) (e.g. 11h55)
- Strip finish time (SA Standard time) (e.g. 12h09)
- Direction of flight (e.g. East-West)
- Weather conditions (e.g. Clear)
- Remarks (Applicable comments)

(xii) Authorised signature of company representative.

B 7.5 Flight index

A comprehensive flight index shall be submitted with delivery of the job, and shall contain the following information:

- (i) To be compiled in A4 portrait format
- (ii) Company letterhead
- (iii) Company business address and contact details
- (iv) Date of report
- (v) Job Number
- (vi) Bid Reference
- (vii) Job imagery information in tabular format under the following headings:
 - Strip No. (e.g. 01)
 - Image Range (e.g. 0001 - 0048)
 - Date (e.g. 2010/02/28)
 - GSD (e.g. 0.5m GSD)
 - Direction of flight (e.g. East-West)
 - Remarks (Applicable comments)

(i) Authorised signature of company representative.

B 7.6 Certificate of Lens / Camera non disturbance

(a) A detailed affidavit stating that the camera, mount and lenses have not been disturbed in any way since the last calibration shall be submitted in digital format containing the following information.

- (i) To be compiled in A4 portrait format
- (ii) Company letterhead
- (iii) Company business address and contact details
- (iv) Page Number
- (v) Date of affidavit
- (vi) Job Number
- (vii) Bid reference
- (viii) Camera Make, model and serial number,
- (ix) Lenses, and respective focal distances, spectral bands, and serial numbers
- (x) Statement of non-disturbance
- (xi) Date of last calibration

(xii) Authorised signature of company representative.

B 7.7 Data to be submitted

- (a) All data submitted shall be in the folder structure as required by the CD: NGI on the storage device specified in the relevant bid document.
- (b) Raw data as retrieved from the sensor system before any conversion to a pre-processed format.
- (c) Processed images, radiometrically and geometrically corrected;
- (d) All GNSS air-station/IMU data, including RINEX data
- (e) PDF flightplan
- (f) Mission Planning data
- (g) Reports and Delivery in digital form
- (h) A space delimited flat ASCII file containing:
 - The photo job number
 - Degree squares covered by the flight index/flightplans.
 - Area of the flight index/flightplan in square metres.
 - Date of imagery.
 - Scale of imagery.
 - Camera name and serial number.
 - Lens name and serial number.
 - Focal length.
 - Image formatThe naming convention to be Job Number_Panel info.txt.
- (i) A space delimited flat ASCII Panel Info file containing:
 - The photo job number
 - Each strip number
 - The images that occur on each strip
 - The date and time each strip was flown.
 - The height, latitude and longitude of the centre of each image flown.
- (j) All other ancillary information considered as being relevant including restrictions and underlying jobs, sheets or photography shall be included in the imagery report

B 7.8 Data Labelling

- (a) All hardware / envelopes / packages shall be clearly labelled with the project name, collection date(s), contractor's name and disk / package contents.
- (b) All hard drives shall have an Inventory.txt file in the root directory listing the contents of the hard drive and having the remainder of the required information as the header to the file.
- (c) The media for the deliverables shall be a portable hard drive. A copy of the data shall be retained by the contracting supplier until the receipt and acceptance thereof is acknowledged in writing by the CD: NGI.

SECTION C

Supplementary Informative Elements

C 1 References

1. British Columbia. 2007. *Integrated Land Management Bureau: Small and Medium Format Digital Camera Specifications*. March. [Online] Available: <http://ilmbwww.gov.bc.ca> Accessed: 6 August 2007.
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4. Co-operative Research Centre for Spatial Information. 2006. *Orthoimage Resolution and Quality Standards*. October. [Online] Available: <http://www.crcsi.com.au> Accessed: 6 August 2007.
5. Federal Geographic Data Committee. 1999. *Content Standards for Digital Orthoimagery*. February. [Online] Available: <http://www.fgdc.gov> Accessed: 4 September 2007.
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8. State of Missouri. 2003. *Digital Orthophotography Standards*. April. [Online] Available: http://oa.mp.gov/itsd/cio/architecture/domains/information/imagery_standard.pdf Accessed: 4 September 2007.
9. United States Department of Commerce. 2004. *Draft Digital Imagery Acquisition Requirements – Version 4*. February. [Online] Available: <http://www.ngs.noaa.gov> Accessed: 4 September 2007.
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11. United States Geological Survey. 1996. *Standards for Digital Orthophotos*. December. [Online] Available: <http://www.usgs.gov> Accessed: 4 September 2007.
12. Jansen 2004. *Image Quality Assessment and Statistical Evaluation*, Department of Geography, University of South Carolina, Columbia, SC 29208
13. Natural Resources Canada, 2011, <http://www.nrc-cnrc.gc.ca/eng/services/hia/sunrise-sunset/angle-calculator.html>

SECTION D

Refer to Annexure A

and corresponding supplementary file formats which are to be supplied with the standard.

- **sample_GNNS_INS_DATA.TXT**
- **sample_camera.txt**
- **sample_model.txt**
- **sample_photo.txt**
- **sample_project.txt**

