# Standard for the Acquisition of Digital Aerial Imagery

Document Reference: QLAS.SD.2
Version: v1

# SECTION A

## Preliminary Informative Elements

# A 1 Document Control

## Version and Amendment Schedule

| Version No. | Version Date | Compiler | Description of Amendments |
|---|---|---|---|
| | | | |
| Draft 1 | 01 October 2007 | Standards Committee | Document Created |
| Draft 2 | 03 September 2010 | S Kay | Public Review Process |
| Draft 3 | 19 November 2010 | Standards Committee | Public Review Amendments |
| Draft 4 | 19 November 2010 | S Kay | Senior Management Review Process |
| Draft 5 | 06 December 2010 | S Kay | Added Annexure A |
| Draft 6 | 14 December 2010 | Standards Committee<br>Dr D.G. Clarke | Senior Management Review Amendments |
| v1 | 14 December 2010 | S Kay | Versioning |

## Approval and Control Schedule

| Version No. | Approved By | Designation | Signature | Date Approved | Copy Status |
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| | | | | | |
| v1 | Dr D.G. Clarke | Chief Director | | | *Master Copy* |
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# A 2 Table of Contents

# 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 compilations of orthophoto maps, topographical maps, special-purpose maps, rectified imagery, and for natural resources evaluation.

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 developed by the following members of the Standards Committee:

M. Denner (Convenor)
A. Parker
T. Zakiewicz
R. Duesimi
R. Martin
S. Jansen

## 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 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 NGI and its contractors in the acquisition of digital imagery, and in support of the aerial imagery and mapping programmes of the 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 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 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 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 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 Analogue Methods

## B 1.1 General

(a) For standards relating to the acquisition of film-based aerial photography, reference must be made to the Standard for the Acquisition of Film-based Aerial Photography.

# B 2 Acquisition of Aerial Imagery Using Digital Sensor Systems

## B 2.1 Scoping

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

# B 3 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. The digital aerial imagery shall be flown with a high precision digital sensor system.

## B 3.1 Digital Sensor System Frame

(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 3.2 Sensor Lens Protection

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

## B 3.3 Digital Sensor Shutter

For sensors with shutters:

(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 3.4 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 3.5 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 NGI medium scale mapping purposes.

## B 3.6 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) The digital sensor system shall be able to capture imagery in such a manner as to not generate excessive and unnecessary data.

(c) There shall be minimal spectral overlap of multispectral bands.

## B 3.7 Stereo Coverage

(a) The digital sensor system shall be capable of acquiring stereo imagery with a fore and aft overlap ranging between 45 and 90 percent in a single pass.

## B 3.8 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 Civil Aviation Authority (CAA) and suitable for geodetic quality carrier-phase multi-channel receptions (channels L1 and L2 for GPS and GLONASS) and installed in accordance with the CAA airframe modification requirements. Antenna should be located as close as possible to the digital imaging sensor, and also in a location to provide optimal GNSS signal quality and continuous reception in an appropriate, unobstructed location on the plane.

(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 surveyor, registered with the South African Council for Technical and Professional Surveyors (PLATO).

## B 3.9 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 3.10 Spatial Resolution of the Imagery

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

## B 3.11 Radiometric Resolution of the Imagery

(a) The digital sensor system shall capture imagery with a minimum 12-bit radiometric resolution for each spectral sensor (Panchromatic, RGB and near infrared).

## B 3.12 Radiometric Accuracy

(a) The individual digital images captured shall have a radiometric quality of a minimum of 12 bit raw images and that further enables the creation of processed RGB digital ortho imagery with the following measures:

The mean histogram (luminosity) has a value of between 90 and 141 as follows:

i) Red band mean = 110 +/-15% (94 to 126); 30 < Std Deviation > 40.

ii) Green band mean = 118 +/-15% (100 to 136); 28 < Std Deviation > 38.

iii) Blue band mean = 90 +/- 20% (72 to 108); 23 < Std Deviation > 33

iv) Colour band to conform across the whole block supplied.

In areas where this specification cannot be met, the mean values should remain, yet the following relaxations in the Standard Deviations will be allowed:

i) Red band Standard deviation > 25

ii) Green band Standard deviation > 25

iii) Blue band Standard deviation > 12

## B 3.13 Radiometric Consistency

(a) The individual digital images captured shall be processed in blocks where radiometric consistency is paramount. This includes such aspects as dodging of the imagery and colour balancing. The sensor shall further ensure radiometric accuracy over time to provide for a comparison of images from different epochs.

## B 3.14 Geometric Accuracy

(a) The geometric accuracy of the calibrated apparent pixel co-ordinates shall be to within ±3 microns, for each format of imagery and each lens system. True rectangularity of objects shall be maintained to within ±3 microns.

(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 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 3.15 Sensor Maintenance

(a) The digital sensor shall be maintained in accordance with the manufacturer's recommended and established procedures.

(b) A complete record of all maintenance done to the digital sensor system shall be kept and made available for inspection by the NGI.

(c) Certification shall be provided that the system has been maintained, preventive maintenance and calibration performed, to the manufacturer's requirements. Such certification shall be submitted with any bid proposal for work to be undertaken for the NGI or for any other work undertaken using the NGI owned digital sensor system.

## B 3.16 Calibration of Proposed Digital Sensor Systems

(a) The digital sensor system shall be radiometrically and geometrically calibrated. Proof of such calibration shall be provided to the 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 will be evaluated to determine if they meet the bid specifications, based on current technical descriptions and samples. The NGI shall, in their 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 camera shall be calibrated and tested at least every three years by a competent testing organisation.

(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 autocollimation 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 3.17 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, identified by NGI shall be flown at 0.2m GSD. An even number of strips shall be flown, with a minimum of 2 strips flown in opposite directions. Each strip should consist of a minimum of 9 exposures (of which there shall be 2 infly and 2 outfly exposures that fall fully outside the test area). A forward overlap of between 55% and 65% and a side lap of between 25% and 40% is required.

(c) The entire area shall be stereoscopically covered within the usable portions of the images.

(d) In addition to (c), 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.

(e) The test area must be aerial triangulated with the resultant RMS values being within the allowable limits as specified by the camera manufacturer.

(f) A boresight calibration shall be performed annually, prior to the commencement of imagery acquisition for NGI and at any stage when the camera is disturbed in the aircraft.

(g) The following records shall be submitted to 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

## B 3.18 Operational Test

(a) Annually, prior to the commencement of imagery acquisition for NGI, and at any stage when the camera is disturbed in the aircraft, imagery of a NGI approved test area shall be acquired for the purposes of an operational test.

(b) The sensor test area shall be flown at a ground sample distance of 0.2m, or as specified by the NGI, with the same aircraft/sensor/peripheral equipment combination as will be used in the image acquisition programme of 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 25% and 40%.

(d) The entire area shall be stereoscopically covered within the usable portions of the images.

(e) In addition to (d), 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.

(f) Ground control points (GCP) shall be used as supplied by NGI. The expected error, at a confidence level of 2σ, in the individual easting and northing components, after aerial triangulation, shall not exceed ±0.068m when the ground sample distance is 0.2m, to a maximum permissible error of ±0.10m.

(g) The expected error, at a confidence level of 2σ, in the height, after aerial triangulation, shall not exceed ±0.12m when the ground sample distance is 0.2m, to a maximum permissible error of ±0.30m.

(h) 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 B9.

(i) 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 3.19 Calibration Reports

(a) A report detailing the calibration of the sensor system, sensor calibration maintenance schedules, instructions and costs shall be submitted to the NGI prior to the commencement with any acquisition of digital aerial imagery programme in that year. Any incomplete reports shall be sufficient reason for the rejection of the job.

(b) The calibration reports shall include a discussion on the system calibration, boresight calibration values, determination of offsets in accordance with the documentation requirements below.
   i) The system calibration shall address the geometric and radiometric performance.
   ii) Parameters to be tested include the calibrated focal length, lens distortion parameters and if applicable, the principal point location.
   iii) Any radiometric calibration parameters and files shall be provided to the NGI.

# B 4 Aircraft Requirements

## B 4.1 Aircraft Requirements

(a) The aircraft shall be a pressurised, twin-engined aircraft and have a ceiling flying altitude of at least 28 000 feet above mean sea level. The aircraft will be required to provide adequate and secure electrical power for the operation of the complete digital aerial sensor system installed in the aircraft.

(b) All equipment shall be connected, attached, mounted and secured to the aircraft airframe in a manner to provide a safe environment for the crew.

(c) All aircraft and airframe modifications used in the performance of any work for the NGI and/or for any other organisation in the instance of the NGI owned Intergraph DMC digital sensor system, shall be maintained and operated in accordance with all the regulations required by the Civil Aviation Authority (CAA) of South Africa.

(d) Any inspections or maintenance of the aircraft for performance of any work mentioned in (b) above shall be scheduled to minimise delays in the flying period.

(e) The aircraft to be used shall be assured of a proven service ceiling, with operating load, including fuel, crew, sensor and other required equipment, of not less than the highest altitude required to acquire the imagery at the specified GSD.

(f) The digital sensor and its mount shall be checked for proper operation prior to each mission. The sensor mount shall be serviced in accordance with the service intervals and maintained and shall be insulated against aircraft vibration.

## B 4.2 Digital Sensor Port Glass

(a) The design of the port opening(s) in the aircraft shall be such that the field of view is unobstructed when a sensor is mounted with all its parts above the outer structure. The field of view shall, so far as is practicable, be shielded from air turbulence and from any outward flows, such as exhaust gases, oil, etc.

(b) The port glass shall be constructed of clear material that does not interfere with the true optical signal and shall be optically flat.

## B 4.3 Altimeter

(a) The aircraft shall be equipped with a calibrated altimeter and with calibrated internal and external temperature gauges.
(b) The altimeter shall be set and maintained at the closest applicable reading for the area being imaged.

## B 4.4 Digital Sensor Mounting

(a) The camera mount shall be gyro stabilised and insulated from the vibrations of the aircraft.
(b) The insulation of the camera mount shall be such that vibration is not a limiting factor in the selection of shutter speeds (where applicable).
(c) The suitable camera mount shall provide for the following:
    - Levelling the camera in flight.
    - Compensating for crab of the aircraft.

# B 5 Digital Imagery Acquisition

## B 5.1 General

(a) The same sensor shall be used throughout the entire job unless written permission has been granted by the Chief Director to use more than one sensor.

(b) An automatic exposure control device shall be used unless the terrain type requires that a manual override be utilised to achieve proper exposure.

## B 5.2 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 5.3 Ground Sample Distance (GSD)

(a) The ground sample distance shall be stipulated in the documentation of a specific contract.

(b) The average nominal GSD at nadir, over the specified project area shall not vary by more than 10% from flying height above mean terrain. At least 90% of checkpoints shall be within stipulated 10% of GSD variation.

(c) No deviation from the limits specified in B 5.4 (b) shall be permitted without the prior written permission from NGI.

(d) The panchromatic bands shall be collected at the required GSD to provide true panchromatic imagery at the specified GSD. The creation of interpreted, interpolated or sharpened panchromatic imagery is prohibited.

(e) For multispectral imagery, colour interpretation or pan sharpening shall be permitted to achieve the specified GSD requirements.

## B 5.4 Image Quality

(a) New imagery shall be quality-controlled to ensure acceptable image quality 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) 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.

(d) The image shall be free from clouds and cloud shadows, fire, smoke, haze, light streaks, shadows, excessive snow and other blemishes.

(e) Colour shall be consistent across the project. The appearance of the image shall be a realistic representation of the true colour on the ground.

(f) Contrast shall be consistent across the project area.

(g) The image shall be sharp when viewed at actual pixel resolution (1:1) and shall not show softness due to flying conditions or image processing.

(h) Image smearing, blurring or ghosting shall not be accepted even where this is localised.

(i) The image shall enable an enlargement factor of 15 times without resulting in a soft image.

(j) Colour bleeding shall not be detrimental to the image appearance.

(k) There shall be sufficient shadow and highlight detail to facilitate accurate image interpretation.

(l) There shall be no missing pixels in both the imagery and overviews.

(m) Poor image quality shall be sufficient grounds for rejection of imagery.

## B 5.5 Flying Height and Speed

(a) Flying heights of the normal strips (east-west / north-south, as prescribed) shall be determined, based on the ground height of the terrain.

(b) Flying heights of the cross-strips shall be a mean of the height of the normal strips, which they intersect.

(c) Flying height shall be maintained in accordance with the mission planning and, in order to satisfy requirements stipulated in B 5.4 (b), shall be within 6% of the predetermined flying heights.

(d) No deviation from the limits specified in B 5.6(c) shall be permitted without the prior written permission from NGI.

(e) Flying speed shall be maintained throughout to ensure acceptable image quality. The camera manufacturer's specifications shall be followed when determining flying speed.

## B 5.6 Flight Lines

(a) All flight lines shall be approved by the Chief Director, prior to the commencement of flying.

(b) All strips shall be flown in an east-west direction, unless otherwise stated by the Chief Director.

(c) For all jobs, cross strips shall be flown traversing the beginning and end of the normal strips (east-west / north-south, as prescribed).

(d) Cross strips, including for water bodies, coastal and border strips, shall be flown such that all the requirements of the applicable aerial triangulation adjustment software, with GNSS/IMU assisted air-stations, are satisfied.

(e) To facilitate aerial triangulation adjustment by avoiding tie points shadow, all cross strips in the mountainous areas, shall be flown at the similar time of a day as the normal strips (east-west / north-south, as prescribed), which they intersect.

(f) Separate cross strips must be flown for each individual job.

(g) Care shall be exercised to ensure that flight lines are as straight and as parallel as possible.

(h) Each flight line shall be continuous and unbroken for its entire length over the area being imaged. No break in strip continuity shall be allowed.

(i) If images are rejected within a strip, the entire strip shall be reflown, in the same direction as the original strip.

(j) For imagery with 60% forward overlap, where applicable, the first two and last two images of each strip shall be completely outside the area being imaged.

(k) 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 shall be suitable for aerial triangulation and permit stereoscopic viewing.

(l) Images with more than 25% of their area covered by sea and large water bodies shall not be accepted unless supplemented by additional strips.

(m) Where the border of the Republic of South Africa forms a boundary of the area being imaged, additional strips shall be flown.

(n) The maximum deviation of any strip, from the planned flight line, shall not exceed 5% of the image size across flight direction.

## B 5.7 Sidelap

(a) Adjacent images shall have an average sidelap of 25% of the image size across the flight direction and shall be within a range of 25% and 40%.

(b) 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.

(c) In the instance of short auxiliary strips having been flown between the main strips, additional cross strips shall be flown, to satisfy the requirements of the bundle adjustment software.

## B 5.8 Forward Overlap

(a) Forward overlap shall average 60% of the mean image size in the flight direction, and shall be within a range of 55% to 65%.

(b) In cases of extreme variation in elevation within an area, deviations from the above requirement may be permitted.

## B 5.9 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 5.10 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 ±1degree.

## B 5.11 Course Correction

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

## B 5.12 Weather Conditions and Time of Year

(a) No clouds or cloud shadows shall appear on the images. High, thin overcast 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 discernable reduction in the light levels and/or ground object shadows.

(b) Digital imaging shall not be conducted when clouds or cloud shadows appear in the scene.

(c) Digital imaging shall furthermore, not be conducted when the ground is obscured by snow or smoke.

(d) Digital imaging shall not be conducted when the presence of excessive haze will negatively influence the quality of the imagery.

(e) The Chief Director shall specify any special requirements regarding the season, foliage, floods or other limiting conditions.

## B 5.13 Time of Day Considerations

(a) The solar altitude shall be at least 30 degrees.

(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 may accept imagery flown during the time intervals before or after local noon, as indicated in Table B 3 – Time intervals of digitally acquired aerial imagery below:

| **HOURS BEFORE OR AFTER LOCAL NOON** | | | | |
|---|---|---|---|---|
| **Latitude South** | **Average Terrain** | | **Very Mountainous Terrain** | |
| | **Mid Summer** | **Mid Winter** | **Mid Summer** | **Mid Winter** |
| 35° | 4 | 2 | 3 | 1½ |
| 30° | 3½ | 2½ | 2½ | 1½ |
| 20° | 3 | 3 | 2 | 2 |

**Table B 3 - Time Intervals of Digitally Acquired Aerial Imagery**

(d) Precautions shall be taken to minimise the effect of hot spots on the uniformity of the illumination.

## B 5.14 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 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 (minimum L1 and L2 channels for both 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 6 Post-Acquisition Position and Orientation Processing and Accuracies

## B 6.1 GNSS solution processing

(a) The positions of the GNSS air-stations shall be determined relative to the South African national control survey network (Hartebeesthoek94 datum) and the South African Land Levelling datum.

(b) The GNSS antennae offset, in *d*y, *d*x and *d*Ht, 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://igscb.jpl.nasa.gov/igscb/data /format/rinex2.txt for documentation describing the format.

(e) A space delimited flat ASCII file, containing the information, as shown in Annexure B, 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) Easting, in international metres (Transverse Mercator projection)
iv) Northing, in international metres (Transverse Mercator projection)
v) $Ht_{msl}$ (orthometric height – international metres).
vi) Orientation parameters (omega, phi, kappa,).
vii) Time stamp (seconds of week)
viii) Standard deviation for position (separately for every component of position)
ix) Standard deviation for orientation (separately for every component of orientation)

## B 6.2 GNSS Accuracies Required

(a) The air-station co-ordinates shall be referenced to the same longitude of origin (Lo.), per job as identified by NGI.

(b) The air-station co-ordinates shall be positioned relative to the latest ITRF coordinates system as computed by NGI coordinates.

(c) The air-station co-ordinates shall have absolute accuracies of better than or equal to 0.3 metres.

# B 7 Image Pre-processing

## B 7.1 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, 12-bit, colour (RGB) and/or panchromatic and/or CIR imagery shall be supplied, radiometrically and geometrically corrected and compressed in accordance with paragraph B7.2, B7.3 and B7.4 respectively, that is capable of being immediately absorbed into the current photogrammetric workstations at the NGI.

## B 7.2 Radiometric Processing

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

(b) This process results in a set of intermediate images.

## B 7.3 Geometric Processing

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

(b) This process results in a set of calibrated images.

## B 7.4 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 7.5 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 7.6 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_year flown_job number_strip_photo_RGB,
      e.g. 2727A_2010_22_01_0493_RGB
   ii) Quarter degree square_year flown_job number _strip_photo_CIR,
      e.g. 2727A_2010_22_01_0493_CIR
   iii) Quarter degree square_year flown_job number _strip_photo_PAN,
      e.g. 2727A_2010_22_01_0493_PAN

# B 8 Flight Plan Data

## B 8.1 Flight plan Index

(a) The flight plans shall be supplied in digital and hard-copy formats, where the size and scale of the hard-copy plot is specified by the NGI, with all detail clearly legible.

(b) The digital data shall be supplied in CAD and GIS data structure formats, as indicated below.

## B 8.2 CAD Data Structure

(a) The CAD data structure can be submitted in any of the following formats:
- (i) Microstation® DGN™
- (ii) .PDF

(b) The file must contain the following on their own separate level layer:
- (i) Flight index outline
- (ii) Flight strip
- (iii) Image centres for each image
- (iv) Annotation text and tables
- (v) Grid lines and north arrow
- (vi) 1:50 000 sheet with labelling
- (vii) 1:10 000 sheet with labelling

(c) All drawing entities and text must use the standard line styles, colours and fonts available in the drawing software.

(d) All drawing entities must be annotated.

(e) At least four graticule points encompassing the flight index/flight plan must be show at a suitable interval to the closest integer second. The graticule points must be annotated.

(f) A North arrow must be shown.

(g) A table containing:
- (viii) The job number
- (ix) Degree squares covered by the flight index/flightplans.
- (x) Area of the flight index/flightplan in square metres.
- (xi) Date of imagery
- (xii) GSD of imagery.
- (xiii) Camera name and serial number.
- (xiv) Lens name and serial number.
- (xv) Focal length.
- (xvi) Imagery format.

(h) A table containing:
- (i) List of strips flown.
- (ii) The image range that occurs per strip.
- (iii) The date that each strip was flown.

(i) All entities that are drawn must be neat and contain no “over shoots” or “under shoots” of all line work.

(j) A report, in digital and hardcopy format shall accompany the data file(s) list in paragraph B 8.2 and B 8.3 below. The report shall detail:
- (xvii) The data structure used to submit the data or how the data is organised in the file (layers/features, etc).
- (xviii) The file format used to store the data.
- (xix) Line and styles used.

(xx) Colours and colour table used.
(xxi) Text fonts used.
(xxii) Description of the attributes (text length, integer, etc) if a GIS data structure is used.
(xxiii) Reference datum.
(xxiv) Co-ordinates used for GNSS reference stations.
(xxv) Any general information relating to the files.

## B 8.3 GIS Data Structure

A digital flight index shall be prepared for each job consisting of the following entities:

- INDX_AERIAL_FLIGHTPLANS - an area feature
- INDX_AERIAL_PHOTOSTRIPS - a line feature
- INDX_AERIAL_PHOTOCENTRES - a point feature

The above flight index entities shall carry the following attributes

**INDX_AERIAL_FLIGHTPLANS:**

| Attribute | Domain/Description | DataType | Constraint |
|---|---|---|---|
| GID | Unique database key | NUMBER(38) | NOT NULL |
| GEOMETRY | Spatial Object - geometry | | |
| FEAT_TYPE_ID | “256” | NUMBER(4) | NOT NULL |
| ENTITY_NAME | | VARCHAR2(50) | NOT NULL |
| GEOMETRY_TYPE | “AREA” | VARCHAR2(5) | NOT NULL |
| FLIGHT_PLAN_YEAR | The year that an aerial photograph was flown. | NUMBER(4) | NOT NULL (e.g. 2010) |
| JOB_NUMBER | A reference to the job number assigned to a sequence of photographs taken during a flight. | VARCHAR2 (30) | NOT NULL |
| COLOR_SPECTRUM_ID | 0 - Undefined<br>1 - PAN<br>2 - RGB<br>3 - CIR | NOT NULL NUMBER(4) | Foreign Key in INDX_FLIGHT_COLOR_SPECTRUM_LKP |
| IMAGE_SCALE_ID | 0 - Undefined.<br>1 – 42 - Scales from 1:200 to 1:160 000, a pull down list will be presented | NOT NULL NUMBER(4) | Foreign Key in META_SCALES_LKP |
| ACCURATE_IMAGE_SCALE_ID | For example 1:32 000, 1:34 000, General IMAGE_SCALE_ID is 1:30 000 | NUMBER(4) | Foreign Key in META_SCALES_LKP |
| CLIENT_ID | | NUMBER(38) | Foreign Key in CLIENTS table |
| OPERATOR | Company responsible for acquisition. | VARCHAR2(255) | |
| PRODUCT_ID | Unique-ID embedded in the marketing and sales system. | NUMBER(38) | |
| NR_OF_STRIPS | Number of strips in job | NUMBER(4) | |
| NR_OF_SHEETS | Number of flight plan sheets in job. | NUMBER(4) | |
| COMMENTS | Remarks | VARCHAR2(255) | |
| WITHDRAWN_FLAG | Flag for job restriction | NUMBER(1) | |
| WITHDRAWN_DATE | Restricted date | DATE | |
| DISTRIBUTION_CAVEATS | Remarks related to distribution/restriction | VARCHAR2(255) | |
| WHEN_PUBLISHED | Published date | DATE | e.g. 2010/09/05 |
| GROUND_SAMPLING_DISTANCE | In meters, for example, 0.5 | NUMBER(10,2) | |
| FLIGHTPLAN_TYPE_ID | 2 Digital<br>1 Analogue (Film-based) | Number (4,0) | INDX_AERIAL_PLANS_TYPE_LKP |

**INDX_AERIAL_PHOTOSTRIPS:**

| Attribute | Domain/Description | DataType | Constraint |
|---|---|---|---|
| GID | Unique database key | NUMBER(38) | NOT NULL |
| GEOMETRY | Spatial Object – geometry | | |
| FEAT_TYPE_ID | “258” | | NOT NULL |
| GEOMETRY_TYPE | “LINE” | | |
| JOB_NR | A reference to the job number assigned to a sequence of photographs taken during a flight. | VARCHAR2(30) | NOT NULL |
| STRIP_NR | A reference to the strip assigned to a sequence of photographs taken during a flight.<br>**NO leading zero’s allowed!!**<br>Strip numbers may contain characters. | VARCHAR2(10) | NOT NULL |

**INDX_AERIAL_PHOTOCENTRES:**

| Attribute | Domain/Description | DataType | Constraint |
|---|---|---|---|
| GID | Unique database key | NUMBER(38) | NOT NULL |
| GEOMETRY | Spatial object - geometry | | |
| FEAT_TYPE_ID | "257" | | |
| GEOMETRY_TYPE | "POINT" | VARCHAR2(5) | NOT NULL |
| REFERENCE_10 | | VARCHAR2(20) | |
| REFERENCE_50 | | VARCHAR2(20) | |
| JOB_NR | A reference to the job number assigned to a sequence of photographs taken during a flight. | VARCHAR2(30) | NOT NULL |
| STRIP_NR | A reference to the strip assigned to a sequence of photographs taken during a flight.<br>**NO leading zero's allowed!!**<br>Strip numbers can contain characters . | VARCHAR2(10) | NOT NULL |
| PHOTO_NR | A reference to the number assigned to a photograph taken during a flight.<br>**NO leading zero's allowed!!** | VARCHAR2(10) | NOT NULL |
| CALIBRATION_CERT_ID | 0 – Unknown<br>388 – 604 – Define unique camera calibrations.<br>A pull down list will be presented. | NUMBER(4) | NOT NULL<br>Foreign key in CALIBRATION_CERTIFICATE_ID lookup table |
| TRIANGULATION_FILE_ID | | NUMBER(1) | |
| FLIGHT_DATE | Date of acquisition | DATE | NOT NULL |
| HIST_FLIGHT_DATE | Date of acquisition, historical jobs only have a year date | VARCHAR2(20) | |
| DIRECTION_ID | Defines the direction of flight and contained in lookup table<br><br>0 - Unknown<br>1 - SN<br>2 - EW<br>3 - WE<br>4 - NS<br>5 - NWSE<br>6 - SENW<br>7 - NESW<br>8 - SWNE<br><br>Note:<br>(S=South,N=North,E=East, W=West) | NUMBER(4) | NOT NULL<br>Foreign key in DIRECTION_ID lookup table |
| PRODUCT_ID | Unique-ID embedded in the marketing and sales system. | NUMBER(38) | |
| TRANSFERRED_CONTROLLED_FLAG | | NUMBER(1) | |

| | | | |
|---|---|---|---|
| PHOTO_SHEET_NR | | NUMBER(4) | |
| CANNISTER_NR | Filmed based jobs | VARCHAR2(50) | |
| COMMENTS | Remarks/notes | VARCHAR2(255) | |
| WITHDRAWN_FLAG | Flag for restriction | NUMBER(1) | |
| WITHDRAWN_DATE | Restricted date | DATE | |
| DISTRIBUTION_CAVEATS | Remarks related to distribution/restriction | VARCHAR2(255) | |

# B 9 Reports and Data to be submitted to NGI

## B 9.1 Survey Report

(b) A detailed report on the airborne positioning and orientation reporting shall be submitted in digital and hard copy 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: Discuss 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: Discuss 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: Discuss the following:

- Description of the datasets,
- Date of imagery of each strip flown,
- Strips rejected and reflown,
- 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 9.2 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 9.3 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 9.4 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 9.5 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 and hardcopy 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 10 Submission to NGI

## B 10.1 Delivery note and reports

(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) Survey Report

(c) Image Processing Report;

(d) The Operations Report;

(e) The Flight Index.

(f) The flight plan in .pdf and .dgn format, printable at A2 paper size, such that all type in legible and line work is crisp and easily identifiable.

(g) One paper copy of the flightplan at A2 paper size with all type and line work legible.

(h) The Calibration Certificate of the camera.

(i) A certificate of non-disturbance of the lens and camera.

## B 10.2 Data to be submitted

(a) All data submitted shall be in the folder structure as required by the NGI on the storage device specified in the relevant bid document.

(b) Raw imagery 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) DGN flightplan

(g) Mission Planning data

(h) Reports and Delivery in digital form

(i) 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 format

The naming convention to be Job Number_Panel info.txt.

(j) 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.

(k) All other ancillary information considered as being relevant including restrictions and underlying jobs, sheets or photography shall be included in the imagery report

## B 10.3 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 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.

2. Chief Directorate: Surveys and Mapping. 1985. *Mapping Instruction No. 15 – Specification for Aerial Photography.* October.

3. City of Tshwane Metropolitan Municipality. 2006. *Tender for Ortho Photos.* Tshwane.

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.

6. Graham, R. & Koh, A. 2002. *Digital Aerial Survey: Theory and Practice*. Caithness, Scotland. Whittles Publishing.

7. Read, R. & Graham, R. 2002. *Manual of Aerial Survey: Primary Data Acquisition*. Caithness, Scotland. Whittles Publishing.

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.

10. United States Geological Survey. 2007. *Federal Digital Imagery General Contract Guideline – Version 1.0*. March. [Online] Available: http://calval.cr.usgs.gov Accessed: 4 September 2007.

11. United States Geological Survey. 1996. *Standards for Digital Orthophotos*. December. [Online] Available: http://www.usgs.gov Accessed: 4 September 2007.

# D 1 Annexure

## Annexure A

**Below is a sample co-ordinate list for GNSS Assisted Aerial Photography Submissions**

*****Note:*** only one final co-ordinate file must be supplied per job,
unless otherwise requested.

**Air Station Co-ordinates**
GNSS ASSISTED AERIAL PHOTOGRAPHY

Job : 3318D_2008_19_GNSS_INS.txt

Contracting Company : JOE BLOGS AIR SURVEY
35 Tunner Street
SUNDOWNS 7785

Contact Person : Ed Frange (021) 6854070 Ed.Frange@airsurvey.com

Reference Ellipsoid : WGS84
Datum : ITRF2005
Projection and Lo : Transverse Mercator (Lo 19)
Heights : Orthometric

Date of photography : 20-23 October 2010
Base 1 Station Position : CTWN (Cape Town TrigNet) S: 33:57:05.1640 E: 18:28:06.7832 H: 83.600
Base 2 Station Position : HNUS (Hermanus TrigNet) S: 34:25:28.6699 E: 19:13:23.0234 H: 63.041

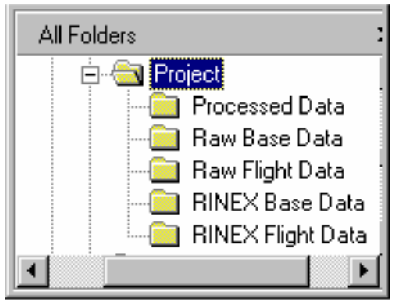
Antenna Offset applied during
differential corrections : Yes

| Strip | Photo | Time Stamp | Easting | Northing | Height | Omega | Phi | Kappa | SDhor | SDhor | SDvert | SDOmega | SDPhi | SDKappa |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 01 | 0051 | 382596.1110 | -60176.774 | -3709868.828 | 5468.674 | -4.5883 | 2.1078 | -176.4146 | 0.030 | 0.030 | 0.040 | 0.0031 | 0.0031 | 0.0073 |
| 01 | 0052 | 382613.2160 | -61711.917 | -3709809.527 | 5473.164 | -1.4154 | 2.8387 | 178.8656 | 0.030 | 0.030 | 0.040 | 0.0031 | 0.0031 | 0.0071 |
| 01 | 0053 | 382630.3970 | -63248.270 | -3709814.426 | 5475.985 | -2.1616 | 3.2061 | -179.6026 | 0.030 | 0.030 | 0.040 | 0.0031 | 0.0031 | 0.0069 |
| 01 | 0054 | 382647.5541 | -64784.772 | -3709815.638 | 5470.998 | -3.5258 | 3.1126 | -179.3746 | 0.030 | 0.030 | 0.040 | 0.0031 | 0.0031 | 0.0067 |
| 01 | 0055 | 382664.6030 | -66319.521 | -3709798.930 | 5471.781 | -0.9591 | 1.7626 | 179.7759 | 0.030 | 0.030 | 0.040 | 0.0031 | 0.0031 | 0.0064 |
| 02 | 0086 | 382903.2687 | -66296.747 | -3714593.105 | 5469.691 | 3.5190 | -2.0166 | 2.6987 | 0.030 | 0.030 | 0.040 | 0.0031 | 0.0031 | 0.0062 |
| 02 | 0087 | 382917.0015 | -64761.741 | -3714598.494 | 5474.136 | 2.1276 | -1.5035 | 0.3967 | 0.030 | 0.030 | 0.040 | 0.0031 | 0.0031 | 0.0064 |
| 02 | 0088 | 382930.8063 | -63225.484 | -3714592.023 | 5474.376 | 3.0600 | -3.1860 | 0.9170 | 0.030 | 0.030 | 0.040 | 0.0031 | 0.0031 | 0.0066 |
| 02 | 0089 | 382944.6631 | -61688.823 | -3714611.442 | 5475.826 | 2.9599 | -1.7939 | -0.9299 | 0.029 | 0.029 | 0.040 | 0.0031 | 0.0031 | 0.0068 |
| 02 | 0090 | 382958.5119 | -60152.488 | -3714642.293 | 5474.533 | 2.0216 | -1.3934 | -1.2998 | 0.028 | 0.028 | 0.037 | 0.0031 | 0.0031 | 0.0070 |

Annexure B

**Data Formats and Directory Structures of GNSS Assisted Aerial Photography Submissions.**

- The data must be supplied on a CD with the following directory structure:




- Rover and base observation data in both proprietary RINEX format must be supplied.