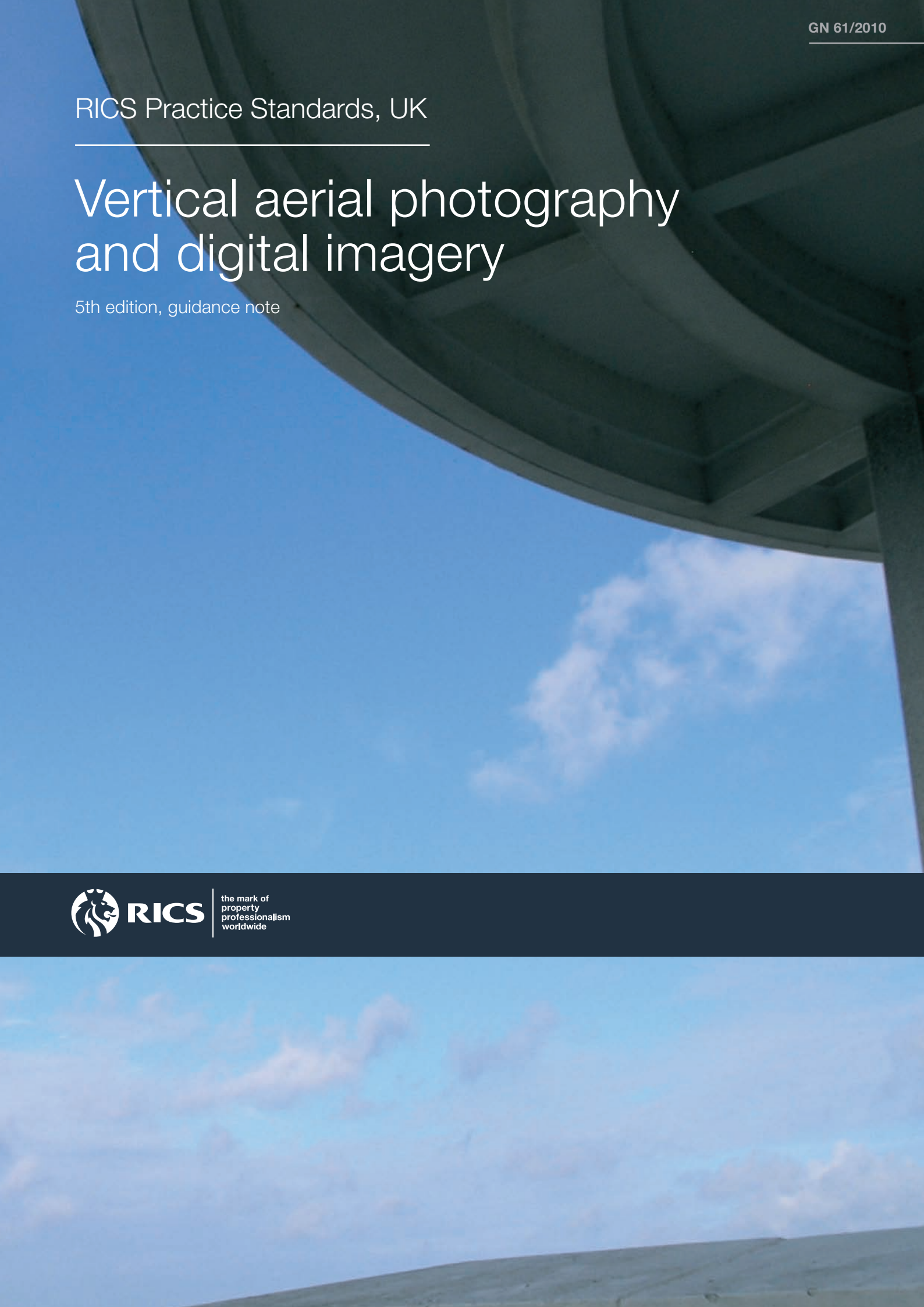
GN 61/2010

RICS Practice Standards, UK

Vertical aerial photography and digital imagery

5th edition, guidance note



RICS the mark of property professionalism worldwide

Vertical aerial photography and digital imagery

RICS guidance note

5th edition (GN 61/2010)

RICS
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Contents

RICS guidance notes

This is a guidance note. It provides advice to members of RICS on aspects of the profession. Where procedures are recommended for specific professional tasks, these are intended to embody 'best practice', that is, procedures which in the opinion of RICS meet a high standard of professional competence.

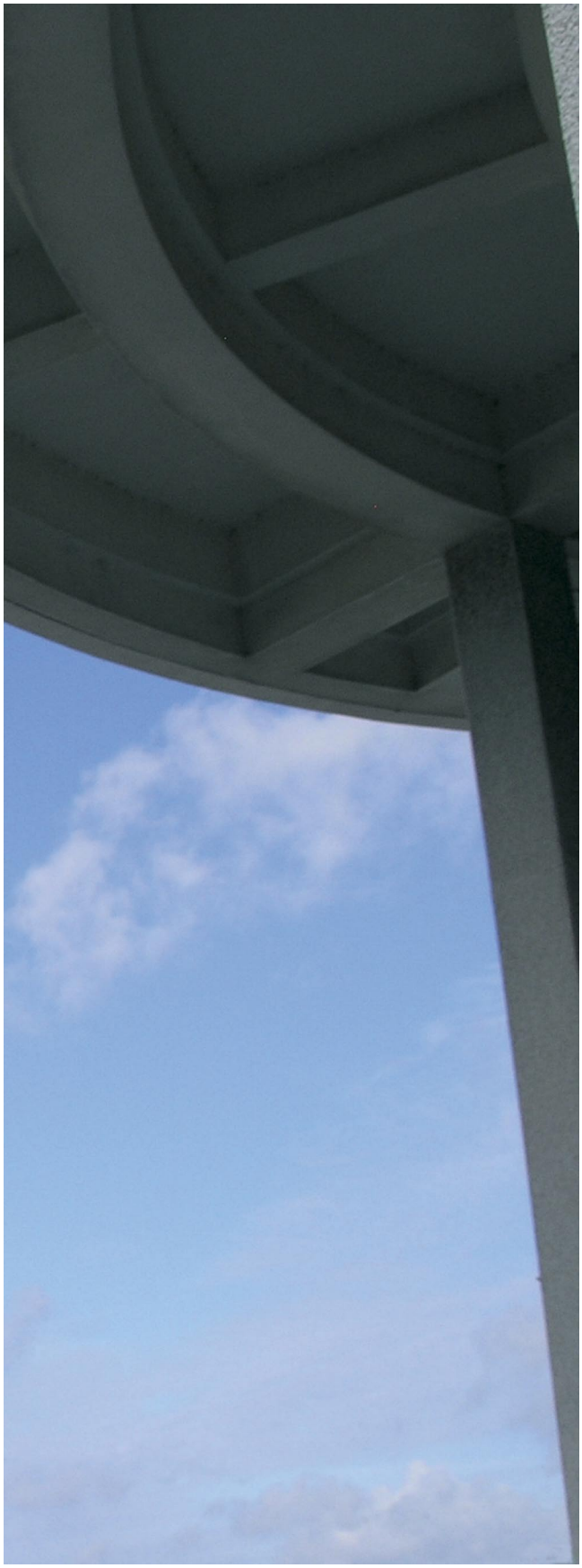
Members are not required to follow the advice and recommendations contained in the guidance note. They should, however, note the following points.

When an allegation of professional negligence is made against a surveyor, the court is likely to take account of the contents of any relevant guidance notes published by RICS in deciding whether or not the surveyor has acted with reasonable competence.

In the opinion of RICS, a member conforming to the practices recommended in this guidance note should have at least a partial defence to an allegation of negligence by virtue of having followed those practices. However, members have the responsibility of deciding when it is appropriate to follow the guidance. If it is followed in an inappropriate case, the member will not be exonerated merely because the recommendations were found in an RICS guidance note.

On the other hand, it does not follow that a member will be adjudged negligent if he or she has not followed the practices recommended in this guidance note. It is for each individual chartered surveyor to decide on the appropriate procedure to follow in any professional task. However, where members depart from the good practice recommended in this guidance note, they should do so only for good reason. In the event of litigation, the court may require them to explain why they decided not to adopt the recommended practice.

In addition, guidance notes are relevant to professional competence in that each surveyor should be up to date and should have informed him or herself of guidance notes within a reasonable time of their promulgation.



Preface

This guidance note and client specification has been developed from the fourth edition of the RICS *Specification for vertical air photography and derived digital imagery*. It is part of a series of specifications intended to assist all those connected with the requesting, purchase and production of surveys and mapping material at all scales by spreading good practice and seeking to avoid duplication of effort. The RICS Mapping and Positioning Practice Panel (MAPPP) is one of the foremost technical practice panels within RICS and is comprised of private and public sector surveying and mapping industry experts, academics and survey instrument manufacturers. This broad expertise enables MAPPP professional/technical guidance and output to adhere to industry best practice.

RICS and MAPPP would like to thank the following main authors and reviewers of this fifth edition:

- Stuart Trigg FRICS, lead author and MAPPP – Blom Aerofilms
- Richard Groom FRICS, lead author and MAPPP – Environment Agency
- Dr Martin Smith FRICS – IESSG, University of Nottingham
- Mark Breach FRICS, MAPPP – Nottingham Trent University
- Simon Kraetor MRICS, MAPPP – Blom Aerofilms
- James Kavanagh MRICS, RICS – Director of Land Group

This document has been extensively reviewed by the global surveying, mapping and imagery community and by members of the Remote Sensing and Photogrammetric Society (RSPsoc).

It is intended to be used directly, or as a model that could be adopted in other countries (subject to any necessary changes to reflect local practice and legislation).

This document is designed as a specification for vertical aerial photography typically required for photogrammetric mapping and digital data collection, production of orthophotography and digital mosaics, and environmental information gathering and general interpretation.

It is not a specification for remote sensing, except in the context of vertical aerial photography.

It does not include the capture of oblique photography.

Appendix A to this document contains additional terms and conditions of contract to be used in conjunction with the Terms and Conditions of Contract for Land Surveying Services 3rd ed 2009, published by the RICS. Other terms and conditions may be used if preferred. It is recommended that the advice of a professional survey consultant should be sought.

There are a number of other publications related to the full range of land surveying services:

Surveys of land, buildings and utility services at scales of 1:500 and larger: Client specification guidelines (2nd edition 1997)

Terms and conditions of contract for land surveying services (3rd edition 2009)

Introduction

Historical background

The first edition of the *Specification for Vertical Air Photography* was presented at the Congress of the International Society of Photogrammetry and Remote Sensing in 1980 and was amended as a result of suggestions received from users and discussions at the ISPRS Congresses in 1980, 1984 and 1988.

Changing user requirements, technological advances and experience in using the RICS specifications under widely differing conditions resulted in the need for substantial amendments and additions to the earlier documents. The need for a new document provided the opportunity to produce a fully international specification.

This publication recognises the shift in demand away from panchromatic film and photographic products, including digital imagery derived from those products, towards the increasing use of digital cameras and sensors in the capture of vertical photography to be used for mapping projects and the use of the Global Navigation Satellite Systems (GNSS) as a navigational aid, Differential GNSS (DGNSS) and Inertial Measurement Units (IMU) to provide camera station coordinates (which reduces the requirement for ground control).

The superseded documents held a significant technical content. Where possible this edition has been simplified by adopting standard requirements which generally satisfy most user needs and by using only a minimum of technical terms. A glossary of these terms is included in the appendices.

The specification

This document is intended for use in drawing up clear specifications for aerial photography and digital imagery obtained directly from digital cameras and sensors or derived from analogue aerial photography using digital scanners. The specification may be prepared by the client (the individual or organisation requesting information) or by the contractor (those who will be tendering or undertaking the provision of information). The client is advised to undertake preparation of the specification in conjunction with a suitably qualified consultant (who may be from within the client organisation or an independent consultant) or with the contractors).

The product

In general this series of specifications defines the product(s) to be delivered and not the detailed methods to be used. Exceptions may be made in special cases where particular methods have a significant effect on the quality and costs of the product(s). For clarity these specifications refer to both film and digital cameras.

Within this Specification the term ‘original image’ is used within general descriptive text to refer to the film exposed in the camera or the image captured by a digital camera. The term ‘Imagery’ applies to both analogue (film) and digital images.

The method

Where clients commissioning aerial photography have their own specialist expertise, they may wish to make amendments to this specification, but non-specialists are advised to seek expert advice before making changes other than the options shown.

The client is strongly advised to leave the choice of the most efficient methods to the contractor. Failure to do so may increase the costs or impair the results. Where particular circumstances require a predetermined method to be used this should be clearly stated.

The cameras

The specification is based on the use of:

- Analogue air survey cameras with a format of 230 x 230mm, with either a 6” (150mm) or 12” (300mm) lens designed for photogrammetric mapping. The use of larger or smaller format

cameras may require substantial modification and is considered to be outside the scope of this document.

- Digital photogrammetric frame (typically, CCD array) cameras and pushbroom sensors. [NB: the cameras must be specialist high resolution calibrated cameras capable of supplying imagery for the intended purpose,] There are technical differences between digital frame cameras and pushbroom sensors. Each has its own characteristics and relative advantages/ disadvantages in various scenarios.

Digital imagery

Digital camera and sensor manufacturers have developed their own systems to provide imagery which replicates the traditional air survey camera. Digital cameras and sensors normally directly capture monochrome, true colour and near infrared imagery.

The film (either colour or monochrome) from analogue air survey cameras may be scanned using photogrammetric quality calibrated scanners to produce a digital image. The section on digital imagery is designed to set basic standards for scanning aerial photographs.

Digital imagery can be used to produce seamless digital mosaics from the monoscopic coverage or digital orthophotography from the full stereoscopic coverage.

These specifications do not provide a detailed specification for the production of digital products such as digital terrain models, orthophotography or orthophotos mapping. The term ‘orthoimage’ is often used instead of orthophotography when derived from digital imagery.

How to use the specification and guidelines

Part 1 of this document is a survey brief. Part 2 is a combined standard specification and guidelines.

Part 1 is completed by the client to contain all the essential information for the project in question that is required by a contractor to carry out the work. It is intended that the client will edit the document in Microsoft Word to suit his requirements. The client may decide to delete sections of the brief that are not relevant for the particular project.

**Items marked with an asterisk*: indicate an instruction, usually that the client is required to add detail or information.

blue text is used for defaults. The client can change these values to suit his or her own requirements.

Each section of Part 1 has a corresponding section in Part 2. This gives a standard specification that is intended to specify details that will always apply and give explanations in italics for the standard specification and for options offered in Part 1.

It will be necessary for both parties to have access to Part 2 in order to interpret the survey brief correctly.

At all stages, the contractor can advise on the most appropriate and effective Specification for a particular project application and can assist with the use of this document.

Part 1: The survey brief

1 Project information

1.1 Project designation

Name……

Reference No ……

1.1.1 Purpose of project

**State purpose of project and how the client will use the survey products*.

1.1.2 End product(s)

Under this project the following is to be produced by the contractor:

- original processed film (section 4)
- film diapositives and contact prints (section 4)
- scanned images of film (section 4.7)
- digital photographs (section 5)
- coordinates and attitude of camera at each exposure (section 3)
- geocoded photographs (section 6)
- digital mosaics (section 6)
- digital orthophotography (section 6)

**Delete options that do not apply*.

1.1.3 Client provisions

Where GNSS/IMU data is required, the camera exposure coordinates shall:

- be based upon survey control stations provided by the client together with details of spheroid, datum and map projection. Copies are provided with these documents, or
- be based upon the national survey control framework.

The client provides the results of previous surveys with this bid document for information. This information may not be copied or retained longer than necessary for the purpose of preparing a bid or the period of any resulting contract.

**State any additional facilities that the client will provide to assist the contractor*.

1.1.4 Project constraints

- Photography shall be taken within 2 hours of low/high tide.
- Photography shall be taken between 1 April and 31 October.
- Photography shall be taken under lighting conditions specified in section 3.4.
- Only security cleared staff may be employed on the aircraft and/or handling films/photographic data.
- It is the contractor's responsibility to obtain flight permission from air traffic control authorities.
- Contractor is to provide Health and Safety risk assessments covering work required under this contract.

**State any additional constraints or specific variations to meet the contract requirements*.

1.1.5 Proposed/estimated start and completion dates

The project start date is **add date*
Completion date for the project is **add date*

Interim deliveries are required as follows:

(i) Progress reports

The contractor shall submit:

A report at significant milestones informing the client of:

- the intention to commence flying
- that acquisition is complete
- that photography has been checked and passed acceptance testing
- the production of derivative products has commenced/is complete

A brief progress report at fortnightly intervals on the progress of the flying of the photography and the production of the derivative products.

(ii) Project report

A Project Report shall be delivered by the contractor upon completion of the Project.

(iii) Form of contract

This specification is based upon *Vertical aerial photography and digital imagery: client specification and guidelines* published by RICS. To avoid misinterpretation, the client and contractor shall refer to the full document when preparing project specifications and when bidding for work.

The Terms and Conditions of Contract are the current RICS *Terms and conditions of contract for land surveying services*, with aerial photography appendix.

1.1.6 Ownership and copyright

All films exposed, and digital data acquired or created, in the contract shall:

- remain the property and copyright of the contractor
- be stored at the premises of the contractor on behalf of the client, who holds title and copyright of any photographic images, film, or digital data acquired or created. In return for the provision of such storage, the contractor shall have the right to resell the imagery under a separate marketing agreement, or
- become the property and copyright of the client on completion and final payment of the contract.

Client organisation

1.2 Project contacts

The principal contact names and addresses relating to this project are given in the clauses which follow:

1.2.1 Primary client

Name .....
Tel .....
Fax .....
e-mail .....

Address .....
.....
.....
.....

1.2.2 Client Representative for matters concerning the Project

Name .....
Tel .....
Fax .....
e-mail .....

Address .....
.....
.....
.....

1.2.3 Client contact for day-to-day contact Position

Name .....
Tel .....
Fax .....
e-mail .....

Address .....
.....
.....
.....

1.2.4 Finance department for invoicing

Name .....
Tel .....
Fax .....
e-mail .....

Address .....
.....
.....
.....

1.2.5 Others (known Local and Statutory Authorities, etc.)

Name .....
Tel .....
Fax .....
e-mail .....

Address .....
.....
.....
.....

2 Camera equipment

2.1 Camera

- For analogue film cameras a 230 x 230mm format metric air survey camera shall be used, fitted with a lens unit that of 152mm focal length and shall be colour corrected for the spectral range of the film used.
- For digital aerial photography a photogrammetric quality digital frame air survey camera or a 'pushbroom' sensor capable of meeting the requirements of the contract shall be used.

2.1.1 Restriction of image movement

Image movement shall not exceed 25 micrometres over three or more consecutive exposures.

2.2 Calibration

Contractor shall supply the camera calibration certificate in accordance with the standard specification.

3 Flying and photo coverage

Near-vertical photography shall be flown in approximately straight and level runs (strips) to achieve full stereoscopic coverage of the contract area at the nominal photo-scale.

3.1 Flight lines

Flight lines shall be

either		the most economical or appropriate with respect to the terrain
or	(a)	aligned east-west
	(b)	aligned north-south
	(c)	a series of straight strips following a route alignment
	(d)	as defined in the client specified flight plan attached
or		as defined by the client specified flight plan attached

3.2 Overlap

3.2.1 Frame cameras (film and digital)

The forward overlap between successive exposures in each run shall be 60 per cent (normal stereoscopic cover).

The lateral overlap (sidelap) between adjacent strips shall normally be between 15 and 35 per cent.

3.2.2 Pushbroom sensors

Must be flown in a continuous swathe along flight lines with a minimum sidelap of 20 per cent (with 25 per cent in urban areas).

3.3 Camera orientation

Camera tilt should not exceed 2 degrees
Crab should not exceed 5 degrees

3.4 Flying conditions

The photography may be taken at any solar altitude above 15 degrees.

3.5 Airborne GNSS and inertial measurement unit (IMU)

GNSS is to be used for in-flight navigation and production of photo index plots.

Camera exposure coordinates shall be computed from GNSS coupled with IMU observations for photo control suitable for the project purpose. Data is to be supplied in a format suitable for photogrammetric mapping.

The GNSS/IMU system shall be tested by flying a test area and by comparison of neighbouring strips of photography.

3.6 Index plots

Indexing of the photographs shall be by means of:

- standard index plots
- digital index plots in …… format (and attribute table completed as appropriate), or
- photo-indices

4 Film and photographic products

Where a film camera is to be used, this section applies. If a digital camera is to be used, see section 5.

4.1 Scale of photography

Photography shall be flown at a scale of 1:3000

4.2 Areas to be photographed

- The area or areas to be covered by photography are defined on the contract maps supplied with this specification
- The area to be covered is specified in the existing flight diagram provided by the client with this specification, *or*
- The area to be photographed is defined by the following geographic limits

  **Add details*.

4.3 Film type and quality

The following types of film are required for this project:

- colour negative
- colour reversal
- panchromatic negative
- colour infrared reversal, or
- black and white infrared negative.

Quality assurance for the exposure of the file shall be obtained by sensitometric analysis and control of the process. The film speed, contrast and fog shall be measured for each roll of processed film.

4.4 Photographic film products

Contractor is to provide 2 sets of contact prints under this contract.

Contractor is to provide 1 set of diapositives on stable based film.

4.5 Sortie and film reports

The following reports are to be delivered:

- Flight Report, as .pdf file(s)
- Flight Index, as .pdf file/text file/.dwg

Two copies of each film report shall be supplied. One copy shall be retained in the film container, and one copy shall be delivered in the project report folder.

4.6 Storage and preservation

While photographic materials remain in the care of the contractor they shall be stored in containers at all times with reasonable protection against foreseeable causes of damage.

4.7 Scanning of film to obtain digital photographs

The original photographic images or diapositives shall be scanned.

Scanning shall be carried out at 14μm resolution.

All photographs shall be scanned to give stereographic cover.

All photographs shall also be provided at a resampled resolution of 300 dpi.

5 Digital imagery

Where a digital camera system is to be used then this section applies.

5.1 Scale of photography/GSD

Photography shall be flown with a ground sampled distance of 4cm.

5.2 Areas to be photographed

- The area or areas to be covered by photography are defined on the contract maps supplied with this specification, or
- The area to be photographed is defined by the following geographic limits:

  **Add details*.

5.3 Digital camera data processing

- Contractor shall supply a copy of the data processed to level 2.
- Contractor shall retain a copy (inc GNNS/IMU data) for security purposes.
- Data shall be supplied as Geo-Tif data format
- Data shall be delivered on a removable hard disk drive.

5.4 Sortie reports

The following reports are to be delivered:

- Flight report, as .pdf file(s)
- Flight index, as .pdf file/text file/.dwg

6 Digital imagery product details

This section covers the production of digital photographic products from either digital camera images or scanned analogue photographs.

6.1 Product details

6.1.1 Mosaic layout

Where specified in 1.1.2, digital mosaics shall be produced to the following user defined specification:

- Colour/greyscale (specify) .....
- Scale 1: .....
- Sheet size and layout .....
- Digital data as specified in section 6.2 .....
- Hardcopy as specified in section 6.2 .....

6.1.2 Digital orthophotography

Where specified in 1.1.2, digital orthophotography shall be produced to the following user defined specification:

- colour/greyscale (specify) .....
- Scale 1: .....
- output pixel size/GSD (m) .....
- Sheet size and layout .....
- digital terrain model representing the ground surface shall be supplied by the client

  or:
- digital terrain model representing the ground surface shall be supplied by the contractor
- digital data as specified in section 6.2 .....
- hardcopy as specified in section 6.2 .....

6.1.3 Radiometric values

Imagery shall conform to the following:

- mean histogram luminosity values shall be (see guidelines)
- mean of the individual colour bands shall be (see guidelines)
- standard deviation for each colour band shall be (see guidelines)

6.2 Supply of digital imagery products

The imagery produced is to be supplied in accordance with the following section which also describes the data transfer medium and formats

6.2.1 Hardcopy

Hardcopy of the digital mosaic/orthophotography shall be supplied:

- one copy of each sheet on 60g/m^2 paper
- one copy of each sheet to a photo quality of reproduction on paper of at least 100g/m^2.

6.2.2 Digital imagery

- Contractor shall supply all deliverable digital imagery in a format which can be viewed, manipulated and plotted using (state name of GIS/image viewing/editing software package name).
- The contractor shall investigate and recommend viewer software to display, manipulate and plot the deliverable digital imagery on the client computer system.

6.2.3 Data format

Data format shall be Geo-Tif.

6.2.4 Compression

Data shall be compressed using .jpg.

6.2.5 Transfer medium

The data shall be supplied on removable hard-drive.

With interim (part) deliveries on DVD.

Part 2: The specification and guidelines

1 Project information

Section 1 enables the client to summarise the purpose of the project and the work to be undertaken, to provide details of the contacts within the client organisation and to specify constraints.

1.1.1 Purpose of project

This information is crucial in guiding the contractor in their interpretation of the requirement and the specification. The photography needs to be fit for purpose and may be required for one or more uses including photogrammetric mapping, raster scanning, digital orthophotomapping, land use and land cover interpretation.

1.1.2 End product

The derived product scale or required resolution, ground sample distance (GSD) will be the largest scale at which the data provided will be used for accurate purposes. If this is not compatible with the requested photographic scale then the contractor may suggest alternative options to the client.

Under this project the following is to be produced by the contractor:

- original processed film (section 4)
- film diapositives and contact prints (section 4)
- scanned images of film (section 4.7)
- digital photographs (section 5)
- coordinates and attitude of camera at each exposure (section 3)
- geocoded photographs (section 6)
- digital mosaics (section 6)
- digital orthophotography (section 6)

**Select the options*.

1.1.3 Client provisions

It is possible to obtain the coordinates and elevation of each camera exposure position using GNSS/IMU observations. These are covered in section 3.5 of this specification. The options in this section concern the coordinate system to be used.

Option – where GNSS/IMU data is required, the camera exposure coordinates shall be based upon survey control stations provided by the client together with details of spheroid, datum and map projection. Copies are provided with these documents. (Note: is required if subsequent mapping has to fit with an existing client-specified survey control systems for which the client has survey control stations).

Option – the camera exposure coordinates shall be based upon the national survey control framework. (Note: is required where the national survey control framework is to be used and the contractor is to obtain the data he needs from a third party – e.g. the national mapping agency).

The client provides the results of previous surveys with this bid document for information. This information may not be copied or retained longer than necessary for the purpose of preparing a bid or the period of any resulting contract. (Note: This is information that may be helpful for bidding purposes. The client should also supply any adjacent or overlapping surveys which may be needed by the contractor for edge matching or to maintain consistency with previous work).

**The client should include here any other facilities that will be made available.*

1.1.4 Project constraints

Provide information on any restrictions to the work, such as:

- Security clearances required – in some instances this is required to fly over, photograph, and process data of particular locations or to be able to operate in certain countries.
- Air Traffic Control requirements – this is required for any project but may be difficult to obtain or will be restricted in areas of high traffic such as approaches to major airports, military training areas, or in certain countries.

- Special requirements for flying – such as summer/winter photography. The 'normal' flying season in the northern hemisphere is from April to October as this gives the greatest opportunity to capture the photography in optimal lighting and weather conditions.
- Special requirements for state of tides – high/low/normal/spring, etc. along with the limits either side. Also include the harbour or local tide tables to be used in calculating the timings or, if the tidal state is difficult to calculate from tables, where for example particular harbours/estuaries in the target area may be slow in draining, and the client has specific detailed knowledge, then the client should specify the tidal window along with a buffer amount.
- Requirements for minimum sun angles – these must take into account and be flexible to allow for the capture of seasonal (e.g. winter) photography and tidal window requirements.
- Special limitations relating to dates or times of flying – but not related to the quality of photography (such as religious days).
- Health and Safety/Environmental requirements – some clients may require Risk Assessments to be provided for example low level flights over areas of scientific interest or areas which provide a high risk of bird strikes over estuaries or nature reserves.

See also 3.4.1 below.

1.1.5 Proposed/estimated start date

Realistic start and completion dates should be stated. Allowance needs to be made for the time required to mobilise the aircraft and consideration should be given to the likely weather conditions, which may preclude flying at certain times of the year.

1.1.6 Progress reports

The contractor shall submit a brief progress report at regular intervals on the flying of the photography and of production of the derivative products.

Clients may also request that they be informed of progress at significant milestones, e.g. immediately prior to the commencement of flying, on completion of flying and when the photography data has been checked to confirm that specified times/windows/quality requirements are being met. The time between the acquisition and quality acceptance of photography/data should be kept to a minimum in case it is subsequently rejected and there is a need to refly, which could compromise time or project constraints.

The method and format of reporting by the contractor should be agreed by the client. See also below.

1.1.7 Project report

A project report shall be delivered by the contractor upon completion of the project.

See also 4.5 and 5.4 below.

1.1.8 Form of contract

It is recommended that the RICS *Terms and conditions of contract for land surveying services*, together with the Aerial Photography Appendix from this document are used. If different terms and conditions are required they should be specified.

1.1.9 Ownership and copyright

Under this section the client must now decide if they wish to retain control of the original films. The films are then delivered to the client unless a separate contract is entered in to regarding the storage of the films by the contractor.

In the case of material which has security sensitivity it is expected that the film would be delivered to the client. In most other cases the contractor will have better facilities for the handling, storage and subsequent reproduction of the film.

All films exposed, and digital data acquired or created, in the contract shall:

either (a) remain the property and copyright of the contractor

or (b) be stored at the premises of the contractor on behalf of the client, who holds title and copyright of any photographic images, film, or digital data acquire or created. In return for the provision of such storage, the contractor shall have the right to resell the imagery under a separate marketing agreement

or (c) become the property and copyright of the client on completion and final payment of the contract.

Where option (b) is selected it will be necessary to provide a separate agreement for royalty payments. The storage and conservation of archive photography is a specialist activity and the cost of such maintenance has to be considered when arriving at the rates for royalty payments.

Where option (c) is selected the client should ensure that adequate facilities for the storage of the films are available, if the value of the investment made is to be maintained. Films have to be kept in a controlled environment or will deteriorate.

Client organisation

1.2 Project contacts

Providing information on the essential contacts of the project avoids unnecessary delays. On any project an individual or organisation may act in one or more of the following capacities.

1.2.1 Primary client

The primary client organisation is the individual or organisation whose proposals generated the request for the survey information and who will be the source of the project's finance.

1.2.2 Client representative

The client representative is the individual or organisation who is responsible for matters concerning the project and the management of the task.

1.2.3 Client contact

The client contact is the individual with whom day-to-day contact is made.

1.2.4 Finance department

The finance department, to whom invoices are to be addressed, should be clearly indicated.

1.2.5 Others

When appropriate, the contact information for Local and Statutory Authorities should be provided. This clause should be repeated as necessary to ensure a separate entry is supplied for each essential contact.

2 Camera equipment

2.1 Camera

The requirements will be *either*:

> A 230 x 230mm format metric air survey camera shall be used, fitted with a lens unit that is designed to give a residual distortion not exceeding 5 micrometres except in the corners of the image. The lens will normally be of 152mm focal length and shall be colour corrected for the spectral range of the film used. A film flattening device shall be used to maintain sharp focus and hold image distortion within the limits specified in clause 4.2. Exposed surfaces of the lens unit should be cleaned regularly in accordance with the manufacturer's recommendations.

or:

> A photogrammetric quality digital frame air survey camera or a 'pushbroom' sensor capable of meeting the requirements of the contract.

The term 'metric' is used to identify a film camera which has been specifically made or modified for photogrammetry. It will provide a largely distortion free image, which can be calibrated by means of inbuilt marks (fiducial marks) which appear on each image. The universal size used for air survey is the 230 x 230mm format. Other sizes of metric camera exist but these are largely designed for ground based photogrammetric applications. Some may be suitable for certain types of air survey work, but their use might require substantial alteration to this specification.

The typical multi-purpose lens in use is one of 150mm. However, a lens with an alternative focal length of 88mm (a wide angle lens giving better height precision), 210mm or 306mm (a long focal length giving better detail definition in urban areas) may be selected by the contractor if the project or area conditions make this desirable.

Digital cameras may also be 'metric' in that they are factory calibrated and the calibration parameters must be used to remove distortions in the assembled digital images. Normally, digital frame cameras will use multi CCD arrays in their construction and the images from the individual CCDs are 'stitched' together by the processing software to form a larger image or 'footprint' on the ground. Whilst medium or small format cameras may make use of high definition CCDs, a reduced number of CCDs may make the use of medium and small format cameras impractical for large survey tasks due to the smaller footprint and more swathes or strips of photography to be flown for a particular task.

2.1.1 Restriction of image movement

Image movement shall not exceed 25 micrometres over three or more consecutive exposures. This may require the use of a camera with forward-motion compensation (FMC) and a gyro-stabilised mount during turbulent conditions.

Most current air survey cameras offer forward-motion compensation (FMC). This mechanism removes most of the image movement due to the flight of the aircraft over the ground but cannot remove random image movement due to rotations of the aircraft caused by turbulence. The improvement in image quality is very significant at large scales but has less benefit at small scales. The speed of the aircraft, the exposure time, and the scale of the photography, determine the amount of image movement.

[Note: analogue (film) cameras will have a mechanical FMC system, digital cameras may have digital processing software that will remove image movement]

Gyro-stabilised camera mounts are designed to reduce camera tilts and sudden rotations.

The contractor will select the equipment necessary to provide the product quality required under the flying conditions at the time of photography. Significant image movement degrades the quality and subsequent obtainable accuracy.

2.2 Calibration

Each camera lens unit to be used on the contract will have been calibrated, cleaned, tested and certified by the camera manufacturer or by a calibration centre, recognised internationally or approved by the camera manufacturer, within two years prior to the date of the photography. The measured distortion shall fall within the limit defined by the manufacturer for the lens type.

The calibration certificate shall contain the following information:

- name and address of the calibration centre and name of authorised signatory
- date of calibration
- camera manufacturer's serial number of the lens unit
- calibrated focal length of the lens unit in accordance with the manufacturer's recommendations
- radial distortion in micrometres
- position of the principal point of autocollimation or of best symmetry with respect to the image coordinate system.

If the contractor becomes aware of any cause which may affect the calibration of the camera the client should be informed immediately.

The calibration period for camera lenses is now specified to be two years, recognising that modern lenses remain very stable and that the cost of an annual recalibration within countries without local laboratories may be considered excessive. When the contractor already has a camera on location for other work it would be permissible to accept a short extension to the period of calibration if facilities were not readily available locally for recalibration.

Digital cameras are calibrated and 'electronically adjusted' by the manufacturer to bring the system to a 'zero' state or within the manufactured tolerances as sated on the calibration certificate. The calibration data file which is produced during the calibration process is used in the first stages of image data processing. This data file would not normally be provided to the client unless the supply of raw data is specified as part of the contract.

Aerial Survey Cameras, both analogue and digital, may have a GNSS and an inertial measurement unit (IMU) which will also require calibrating along with the associated camera (see section 3.5)

3 Flying and photo coverage

Near-vertical photography shall be flown in approximately straight and level runs (strips) to achieve full stereoscopic coverage of the contract area at the nominal photo-scale.

Since there is little cost saving to be obtained by reducing the overlaps between exposures to a minimum, it is strongly recommended that near-vertical photography is flown to achieve stereoscopic coverage. This will maximise opportunities for future use.

3.1 Flight lines

Flight lines shall

either: be prepared by the contractor and be:

or (a) the most economical or appropriate with respect to the terrain

or (b) aligned east-west

or (c) aligned north-south

or (d) as defined in flight plan attached

or (e) a series of straight strips following a route alignment.

or Where a few exposures in a run are rejected for any reason, they may be replaced by a short filler run, provided an overlap of at least two stereoscopic models is supplied at both ends of the run

Or be defined by the client in an attached flight diagram.

**Select the option required*.

The general alignment of the dominant relief to the mapping area may determine the choice of option (b), (c) or (d). Option (e) will be chosen when a long narrow area is required. Option (a) may be chosen for an irregular area or series of areas when there is no requirement by the client for specific orientation of the photography. Once the minimum number of runs required to cover the target area has been calculated, the spacing between flight lines may be adjusted to increase and equalise the lateral overlap between each run.

There should be no duplicate run/strip or frame numbers. The sequence should be maintained even if the target area is subsequently flown in several flights/sorties.

Clients may provide their own existing flight diagram. This is extremely helpful when there is a requirement for an on-going repeat or monitoring survey (e.g. year on year), which may be in progress, to ensure that flight runs and individual frames are maintained over several epochs. Contractors should then comply with the position of exposures according to the flight diagram, and maintain existing frame and run numbers from previous epochs.

3.2 Overlap

3.2.1 Frame cameras (film and digital)

The forward overlap between successive exposures in each run shall be:

either (a) 60 per cent (normal stereoscopic cover)

or (b) per cent (greater percentage, dependant upon purpose)

or (c) pinpoint.

An allowance of ± 5 per cent of the selected overlap is permissible.

The lateral overlap (sidelap) between adjacent strips shall normally be between 15 and 35 per cent for flying heights greater than 1,500 metres above mean ground level, increasing to between 20 and 40 per cent for lower flying heights.

Where ground heights within the area of overlap vary by more than 10 per cent of the flying height, a reasonable variation in the stated overlaps shall be permitted, provided the forward overlap does not fall below the selected percentage and the lateral overlap does not fall below 10 per cent or exceed 45 per cent.

In mountainous areas, where it is impossible to maintain the lateral overlap specified above, short

infill runs shall be flown, parallel to and between the main runs, to fill the gaps.

In coastal areas where a run crosses the shoreline the forward overlap shall be increased to a 90 per cent overlap. The increase in overlap should include at least three photo-centres over land.

Film cameras have a square format, Some digital frame cameras may have a rectangular (not square) format but the same principles apply. The usual fore and aft overlap to give stereo coverage is 55% and sidelap is normally 20%.

The forward overlap is required to ensure adequate formation of stereoscopic coverage. The lateral overlap is required only to ensure that no areas are missed between adjacent flying strips. Where substantial changes of height occur across the path of the flight lines the lateral overlap may be lost and infill runs may be needed.

80% fore and aft overlap and 25% sidelap would normally be selected for the production of orthoimages of urban areas with high rise buildings. By increasing the coverage each tall building will appear in more frames, thus increasing the choice of images which show the building to appear vertical. Exceptionally, the sidelap may be increased to 60% (along with a fore and aft overlap of 80%) by clients who intend to use imagery for the production of 3D city models.

A client may also specify a precise position for the centre point of an image, along with a required photo scale or GSD.

Photo or image centres may be defined using airborne GNSS positioning.

The proposed flight lines are calculated in advance on the basis of minimum overlap. This usually results in the final run covering an area mainly outside the contract area. The spacing of all runs is adjusted to distribute the 'spare' coverage equally between all the runs.

3.2.2 Pushbroom sensors

Must be flown in a continuous swathe along flight lines with a minimum sidelap of 20% (with 25% in urban areas).

Pushbroom sensors acquire multiple strips of images simultaneously (forward, nadir and backward) as apposed to a series of separate exposures. Stereo viewing is derived from the fixed geometry of the sensor. Scanner based imagery must therefore be flown in a continuous swathe with a minimum 20% sidelap (25% in elevated or urban areas).

3.3 Camera orientation

Excessive tilt and crab should be avoided as it can result in loss of overlap between exposures. Turbulent weather conditions and strong cross winds are the primary cause.

Camera tilt should not normally exceed 2 degrees. An occasional exposure with up to 4 degrees may be permitted, provided the minimum forward and lateral overlaps are maintained.

Crab shall not exceed 5 degrees, as measured between the base line and a line parallel to the frame of the negative, provided the minimum forward and lateral overlaps are maintained.

3.4 Flying conditions

The photography may be taken at any solar altitude above 15 degrees, unless special restrictions are included.

The photography shall only be flown in conditions when the visibility does not significantly impair the tone reproduction in the negative or digital image and detail is not lost as a result of atmospheric haze, dust, smoke, or any other conditions detrimental to the photographic image.

The photography shall be substantially free of cloud, dense shadow or smoke. Isolated areas of cloud, dense shadow or smoke shall not be cause for rejection of the photography provided the intended use is not impaired.

Weather and atmospheric conditions are outside the control of the contractor.

The 'normal' flying season in the Northern hemisphere is from April to October to take the opportunity of capturing photography in optimal lighting and weather conditions. The need for adherence to a contract requirements and a completion date must be tempered by the need to produce an acceptable product.

Some contracts may specify maximum amounts of cloud/haze, e.g. 5% on any individual photograph frame or 2% of total photography flown.

Some contracts may stipulate the minimum sun angle, e.g. 15 or 20 degrees. Low sun angles may result in deep shadows particularly in urban areas or where there are considerable differences in the height of the terrain.

While digital systems can accommodate poor light conditions and are more tolerant of deep shadows, specific requirements will limit the time of day and time of year effectively available for the acquisition of imagery.

3.4.1 Timing and special conditions for photography

The photography may be flown at any time when the weather conditions and sun altitude are suitable to achieve the specified standards of image quality, except where special time constraints are defined.

The intended use of the photography may impose limitations upon times of flying examples being:

- Winter/seasonal photography; acquiring photographs when trees are not in leaf, there is no snow cover, or the state of crops, vegetation cover.
- Coastal photography; flying at high/low/normal/ spring tides or at specified tidal windows.
- Specific dates or time of events; for measuring crowd/traffic density at sport events/festivals, the extent of flooding.

Other limitations might include restricted use of airspace/air traffic control requirement or religious/ public holidays. See also 1.1.4.

3.5 Airborne GNSS and inertial measurement unit (IMU)

either GNSS is to be used for in-flight navigation and production of photo index plots

or GNSS coupled with observations from an inertial measurement unit is:

either (a) not required for this project

or (b) to be used for in-flight navigation and for photo control purposes.

The camera station coordinates supplied will be for use as photo-control on 1:…… scale mapping.

They shall be given in the

……grid referencing system applied to the

…… geodetic datum.

The accuracy of camera station plan and height coordinates, for not less than 95 per cent of the values, relative to the geodetic referencing system defined above shall be better than ± 20 centimetres when used for photo-control and ±100 metres when used only for the provision of the index plot.

If GNSS/IMU systems are specified to be used, evidence must be provided that the GNSS and associated IMU and camera are calibrated on a test area at regular intervals, particularly when the camera may have been removed and re-installed in the aircraft, to provide angular misalignments which are then applied to the data when producing positioning and exterior orientation files.

The contract may specify if a test is flown in the vicinity of the flying target area.

Note: the descriptive term Inertial Navigation System (INS) may be used as an alternate to Inertial Measurement Unit (IMU).

The use of GNSS aided IMU direct georeferencing systems make for significant savings in the amount of ground control and air triangulation effort required to provide accurate positioning of imagery both for a subsequent mapping project and for the production of digital orthophotos or orthomosaics.

The contractor will normally decide if airborne GNSS is to be used and must state if the GNSS data, along with base station data, is required to be delivered as part of the contract. However the collection and supply of such data should now be considered as a standard practice and be included in the costs of the contract (see section 6.5).

3.6 Index plots

Indexing of the photographs shall be by means of

either:

(a) standard index plots, or

(b) photo-indices

or

(c) digital index plots

(a) standard index plots

Index plot(s) of the photography shall be supplied, based on topographical maps to be provided by the client. The contractor shall supply one set of transparent overlays with folded paper copies enclosed in the Project Report and with each set of contact prints delivered.

The index plots shall indicate the position of alternate exposures with sufficient exposure numbers annotated for identification with no duplication in run or frame numbers.

Index plots shall contain the following information:

- scale, grid system, grid North and grid values of the base map
- Client's name
- Contractor's name and address
- name of project or contract area
- boundary of contract area
- dates of photography
- nominal scale of photography
- camera manufacturer, type and focal length of lens unit
- film numbers and run (strip) numbers at both edges of each sheet and where changes occur within a sheet
- positions and numbers of selected individual exposures.

Sheets to be numbered if more than one is within the project.

Where the client holds copyright or a licence to reproduce the base mapping the index plots may be incorporated into a master transparency. In other situations the index plot shall consist of an overlay at the map scale, with paper copies made from the overlay superimposed upon the base map.

(b) digital index plots

Standard index plots overlay a topographical map provided by the client. A digital index plot is intended to overlay the equivalent raster data and to act as a further layer within the GIS system. Proper integration into the client system will enable details to be recalled by clicking on the photo image.

If required, the index plot(s) shall be supplied as a digital file suitable for use in a geographic information system (GIS). The content and title information shall be as specified. The cartographic presentation shall be suitable to use as an overlay to the topographical base map provided. The attribute table should also be completed as appropriate. The data format and transfer medium shall be agreed with the client.

(c) photo-indices

A photo-index is a simple non-matched mosaic print which acts as an index. It may be specified when appropriate mapping is not available for use with the other indexing options.

If required, a photo-index shall be supplied instead of a map-based index plot. These shall be supplied at a reduced scale using the first, last and alternate prints, which shall be trimmed to the edge of the photographic image. The photo-number shall be clearly marked on the first and last print and on every fifth print. The content and title information shall be as specified.

4 Film and photographic products

Where a film camera is to be used, this section applies. If a digital camera is to be used, see section 5.

4.1 Scale of photography

The requirements are normally stated as:

- *either*: The principal scale(s) of photography to be provided for this Project is 1: ……

  or

- The Ground Sample Distance (GSD) of the digital imagery is required to be: ……cm

The photograph scale is normally quoted for analogue film cameras and is dependent upon the camera format, focal length of the lens and the flying height.

In most cases the film will be scanned. Scanning resolutions are typically between 10 and 25 microns and a ground sampling distance (GSD) is created for each digital pixel.

The parameters for digital cameras relate to the pixel size of the CCD array and the GSD is a function of pixel size, the focal length of the camera and flying height. It is normal for output to be quoted as a GSD rather than photographic scale.

Table relating film scale, digital imagery resolution to potential photogrammetric mapping scale and accuracy

Photo Scale	GSD	Mapping Scale	Hz RMSE	Vertical RMSE
1:3000	4cm	1:500	+/- 0.100m	+/- 0.050m
1:5000	7.5cm	1:1250	+/- 0.225m	+/- 0.125m
1:10000	15cm	1:2500	+/- 0.500m	+/- 0.250m

Other scales may be used for specialist products. Some clients may have their own specific standards.

4.2 Areas to be photographed

The client should clearly define the boundary for photography, preferably by a map or by the supply of a digital file to assist flight planning. Care is required in the preparation of such a map and failure to do so can lead to insufficient coverage. It is important not to mark beyond the required limits, since this will result in unnecessary photography and increases costs.

The client may provide their own or existing flight diagram which will define the area of photography, flight runs/strips required and the position of specific frames/exposures. This is extremely helpful when the contract is part of a repeat or an on-going monitoring survey involving different epochs of time, in which case it could be important, from the client's point of view, to adhere to the existing flight diagram.

4.3 Film type and quality

All film used shall be within the manufacturer's recommended expiry date and kept in accordance with the manufacturer's recommended storage conditions. When specified for use, colour infrared film shall be thawed 24 hours before use.

The following types of film are required for this Project:

- colour negative (masked or unmasked)
- colour reversal (or processed to a colour negative)
- panchromatic (black and white) negative
- colour infrared reversal
- black and white infrared negative.

  **Delete any of the options not required.* The intended use will determine the film type to be used.

Colour negative film is now used as the general purpose film for most applications. It enables the provision of natural colour photography and imagery and assists in the interpretation of detail, both by visual inspection and during the process of photogrammetric plotting.

Colour infrared film is particularly advantageous in vegetation studies where it is required to record the differences within healthy vegetation. The alternative for such use is black and white infrared film, but the tonal contrasts provided are less prominent.

Colour diapositives can generally be produced to good quality from colour negatives. Direct transparency (colour reversal) film has less exposure tolerance than negative film and is therefore more likely to produce a slightly degraded image, if incorrectly exposed or processed.

4.3.1 Metric quality of original films

A stable base film shall be used and the processing and drying of the film shall be carried out without affecting its dimensional stability. In any original image the differential lengths between any pairs of fiducial marks shall not exceed 15 micrometres. Original images and diapositives shall not contain residual y-parallaxes after relative orientation in excess of 15 micrometres anywhere in the model.

All film intended for air photography is manufactured with a suitable stable base. The processing must be carried out with care in order that subsequent distortions are not created. Limits are given for variations which can be measured between the fiducial marks imprinted onto the film by the camera. Refer to the notes for clause 2.

4.3.2 Image quality of original films

The image quality of the processed film shall be of a standard that allows the production of prints or diapositives suitable for the intended application as stated in clause 1.1.1. Such products will have a standard of tone and colour reproduction (if appropriate), together with a level of detail throughout the image to ensure suitability for purpose.

Processing of the film shall be monitored by sensitometric analysis and records of the results shall be included with the film report.

All processed film used for the work shall be substantially free of blisters, bubbles, inclusions, coating lines, stress or static marks, bar marks, pin holes, abrasions, streaks, chemical marks, drying marks or scratches.

Image quality is comprised of tone/colour reproduction and the degree of small detail visible in the image. The quality is dependent upon the degree of control exercised over storage, exposure and processing of the film.

A high standard of quality assurance should be maintained in film processing. This is necessary in order to provide a satisfactory basis for tone/colour reproduction in particular and to achieve good spatial resolution. Quality assurance can be provided by sensitometric analysis and process control. It may also include an assessment of micro-image detail in the photography.

Physical damage to the film should always be avoided. Refer also to the notes for clause 4.6.

4.3.3 Process control records

Quality assurance for the exposure and processing of the film shall be obtained by sensitometric analysis and control of the process. The film speed, contrast and fog shall be measured for each roll of processed film. These characteristics are to be determined from sensitometric exposures made on an area of the leader and/or trailer of the film that is clear of any other exposure. There shall be not less than three such sensitometric exposures made per film to ensure that at least one is suitable for measurement.

The contractor may process such control exposures in advance of the main film in order to facilitate fine adjustment of the processing to obtain optimum results.

The determination of the film characteristics shall take into account the individual sensitive layers when processing colour material. Within the usable range of densities the characteristic curves should remain substantially parallel.

Sensitometric exposures are made on the leader or trailer of the film to be processed, in an area which has not otherwise been exposed. After processing the densities in each step of the sensitometric exposure (either monochrome or RGB) are measured and recorded. When the values are plotted in the form of D/log(io)H the resultant characteristic curves can be used to determine the film speed, contrast and fog level.

The test section of film can be cut from the main film and processed in advance as part of the

contractor's normal quality control or may remain as part of the film, when it acts as a record of the processed film.

The sensitometer used to produce the grey scale exposures used for measurement should have a spectral output similar to the irradiation received at the surface of the earth from the sun, over the range 380 to 900nm. The sensitometer should provide a single exposure comprising varying levels of irradiance by use of a calibrated step wedge. The step wedge should have a uniform spectral transmission over the range 380 to 900nm.

4.3.4 Film speed

The sensitivity of the film shall be measured by a procedure that is in general agreement with an appropriate national or international sensitometric standard for the determination of film speed in relation to aerial photography *either*:

either	(a)	Relative film speed shall be determined
or	(b)	It is necessary that absolute film speed be determined.

**Select the option required.*

Absolute film speed determination would only be required in exceptional circumstances. For such determinations a sensitometer with a calibrated radiant source must be used.

4.3.5 Film contrast

The conditions of development shall ensure a standard of contrast in the original image that, when printed using an automatic dodging printer, will provide sufficient detail in areas of both cloud shadow and very reflective terrain to meet the needs of the application.

Contrast should be measured as the average gradient of the characteristic curve determined from the sensitometric exposures, in accordance with an appropriate national or international sensitometric standard.

4.3.6 Base plus fog density

The base plus fog density shall be measured in an unexposed area of the processed film. It shall not normally exceed a value greater than the limits for normal use recommended by the manufacturer. An exception may be made for this when solar irradiation is too low to allow normal exposures to be made and the development times for the film need to be increased. The client must always be advised when this is likely to occur.

Under certain lighting conditions an extended development time may be required to provide an effective increase in film speed. This will generate a higher base fog density.

4.3.7 Measurement of spatial resolution

The spatial resolution in an original image is an indication of the resolving power which the photographic system can achieve under practical conditions. It is expressed as the average Ground Sampled Distance (GSD), which is the product of the photo scale of the image and a measured value known as the Image Spread Function (ISF), representing the smallest discernible object.

For this contract the average GSD for an image:

either	(a)	is not required
or	(b)	shall be measured for each film/camera combination used on the contract.

**Select the option required*.

Option (b) would-normally be selected only when the client is fully aware of the technical uses of the ISF. Features selected for measurement of the ISF should be chosen from as many areas of an original image as possible, with three or four images being selected at random from the processed films. Not less than twelve linear or point response features having a cross section close to the smallest discernible blur spot (otherwise known as the disc of least confusion) would normally be selected in each image and their widths measured.

The coefficient of variation (CoV) in each set of measurements made should normally not exceed 30 per cent, where CoV=100 x (standard deviation/mean).

The value of the ISF is the arithmetic mean of the set of measurements and is expressed in micrometres.

The GSD is calculated by the formula GSD=ISF x photo scale, stated in metres.

The microscope used for measuring the ISF should be of a standard comparable to a good quality

instrument having a magnification range of between x40 and xlOQ and have a reticule calibrated in steps of not greater than 10 micrometres.

4.3.8 Fiducial marks and marginal sata

All fiducial marks shall be clearly visible and sharp on every frame. Digital data and camera instruments recorded on the film shall be clearly legible on all processed negatives. Failure of instrument illumination during a single sortie shall not be cause for rejection of the photography.

The fiducial marks are essential for the accurate production of information from the film. The ancillary information recorded on each exposure provides additional quality control. Failure of the camera illumination which imprints this data cannot be rectified during flight and would result in exposures from that occasion not carrying the ancillary information. A single failure would not be a cause for rejection of the photography but further flights should not be undertaken until the illumination has been replaced.

4.4 Photographic film products

The principal photographic products produced from film aerial photography are contact prints and diapositives. Digital orthophotography and mosaics are included in section 6.

The principal analogue photographic product is the set of diapositives made from the original images. Contact prints should be supplied for normal day-to-day inspection. Mosaics may be created from digital imagery as an accompaniment to the data, either directly from digital data or from digital data obtained from scanning film. Consideration needs to be paid to the resolution of, and use of digital products as clients may only want a set of low resolution images. Section 6 provides more user guide information, including file format and delivery media considerations. It is important that these are correctly specified if the delivered data is to be manageable.

4.4.1 Contact prints

Contact prints shall be made on an automatic dodging printer on medium weight resin- coated paper or double weight fibre-based paper, on which ink can be used on both sides. The prints shall be boxed and sets shall be supplied

The contractor shall agree with the client any specific requirements for details of trimming for the prints, use of title strip and the surface finish for the print.

**State number of sets required.*

The image quality of contact prints should provide good tone reproduction showing detail in light toned areas and, as far as possible, in areas of shadow or dark terrain. The selection of the surface finish will affect the visual sharpness of the image.

4.4.2 Diapositives

Diapositives will normally be produced using a dodging printer. Care should be exercised to ensure close contact between the original image and the diapositive material.

The diapositives shall be produced on:

either (a) stable based film
or (b) glass plate.

**Select the option required*. Glass plates are only required under exceptional circumstances.

4.4.3 Storage of diapositives

Diapositives produced from the processed film shall be stored:

either (a) in boxes containing a number of diapositives
or (b) in individual sleeves.

4.5 Reports

The format and method of delivery of reports by the contractor should be agreed in advance by the client. Contractors may be required to include their proposals for delivery, frequency, contents and layout of reports either in their tender submission or be included in a Quality Plan approved by the client.

The following reports are required during the course of the contract.

4.5.1 Film reports

The film report provides a technical summary of each sortie and should contain Date; Aircraft Registration; Camera/Sensor type and serial

number; Lens (focal length); Weather and flying conditions; Exposure settings; Flying height; Sortie Number/flight runs as taken; Film Number/data storage device number as appropriate

The film report provides valuable archive information which will be of benefit should the images be used at a future date for other purposes.

Two copies of each film report shall be supplied. One copy shall be retained in the film container, and one copy shall be delivered in the Project Report Folder. Each report shall contain the following information:

- name of client
- name and address of contractor
- film number
- camera manufacturer, type, serial number, lens type, number and focal length
- filter type and number
- film type and manufacturer's emulsion number
- lens aperture and shutter speed
- run number and flight direction
- dates of photography (years, months and days)
- aircraft type and identification
- names of pilots, navigators and photographers
- start and end time for each run in local time
- photo numbers of all offered photography
- camera station coordinates
- computed altitude above mean sea level
- nominal scale of photography
- weather conditions – cloud type, degree of haze and turbulence, etc.
- date of processing
- method of development
- developer used and dilution
- time and temperature of development and film transport speed
- length of film processed
- record of the sensitometric analysis results
- ground sampled distance
- general comment on quality.

4.5.2 Progress reports

The contractor shall submit a brief progress report at agreed intervals on the flying of the photography and of production of the derivative products.

The client may request, or expect, reports at significant milestones such as being informed of:

- the commencement of flying
- the completion of acquisition of photography
- the quality acceptance of photography
- the commencement/completion of production of derivative products.

4.5.3 Project report

A project report shall be delivered by the contractor upon completion of the project. The project report shall contain the following information:

- a brief project report recording planned and actual delivery dates, any problems encountered and any changes or variations to the original contract requirement
- one set of folded paper copies of the index plots
- one set of film reports
- one set of camera calibration certificates
- a copy of the contract technical specification
- metadata
- a certificate confirming that the photography has been validated by the contractor and conforms to the specification.

4.5.4 Navigation/positioning data

GNSS data and associated observations from an inertial measurement unit data base station data.

GNSS data and associated observations from an inertial measurement unit data is now normally collected as standard practice and should be supplied as a matter of course at no extra charge. It is important that third party base (reference) station data is requested and ordered from suppliers and, where appropriate, national mapping organisations promptly as such data may not be archived in the precision required.

4.6 Storage and preservation

This specification introduces specific clauses relating to the ownership, storage, copyright and marketing of the films, in line with copyright legislation. Where appropriate, this will allow the contractor to generate an income from sales, to contribute towards the long term storage and

preservation of the archive. Individual agreements may be made between the client and the contractor, e.g. long term free storage of films which may be reproduced with the permission of the client.

See also 1.1.9, Ownership and copyright.

While photographic materials remain in the care of the contractor they shall be stored in containers at all times.

Film containers shall be stored in a secure and clean film vault with reasonable protection against foreseeable causes of damage. The client shall have the right to inspect the storage facilities at any time during the contract while films remain in the care of the contractor.

All photography represents an historical record. Specialist care is required to conserve the material in a good condition. When the client does not wish to retain the contract material, consideration could be given to offering the material to an appropriate national, international or commercial archive. Only in exceptional circumstances should disposal of the film be contemplated.

4.6.1 Archival quality of original films

The original film represents a record which may be irreplaceable. It should be processed for permanence. Specialist information is available regarding the care of material for which absolute permanence is required.

Film is less likely to be damaged during handling if it is kept in a roll and inspected only through an appropriate viewer. Note: to avoid handling/splicing of film, some clients may request that a dedicated film is used for their project and that the remaining film left should not be used for any other client's project.

The original films are required to be of archival quality and shall be processed, washed and dried according to the film manufacturer's instructions to minimise the residual thiosulphate content and any other chemicals which would reduce the long-term storage properties of the film.

Each processed film shall be kept in roll form on a spool and in a metal or plastic container. Rejected frames shall not be removed from the roll. Individual frames may not be cut from the roll for scanning or enlargement without the written consent of the client.

4.6.2 Annotation of photographic material

All photographic material should be clearly labelled to protect against accidental separation of the product from the storage container. A standardised system makes for easy indexing.

During the contract and prior to the client taking possession of the photographic product the contractor is responsible for the safe storage of all films and other material.

The information in the following table shall be annotated permanently on the film leaders, film containers and on each image and contact print, where ticked in the table below. Standard strips may be provided with each film for titling contact prints, instead of numbering each image individually.

Data	Start and end of each film	Film container labels	Images and prints
Start or end	✓		✓
Name of client	✓	✓	✓
Name of contractor	✓	✓	✓
Contract area or project number	✓	✓	✓
Camera manufacturer and type	✓	✓	
Film number	✓	✓	✓
Run number		✓	✓
Exposure numbers		✓	✓
Dates of photography (yy,mm,dd)	✓	✓	✓
Nominal photo scale	✓	✓	✓
Flying height above mean ground level	✓	✓	✓
Calibrated focal length of lens unit			✓

4.6.3 Insurance for Storage of Film and Digital Imagery

It should be noted that where photography relates to a specific event or moment in time the replacement of the original image is impossible. In such cases the client should consider if an arrangement is necessary to hold duplicate material at a separate location. Normal insurance covers only the replacement costs of the material.

Where the contractor has the responsibility of storing material on behalf of the client insurance cover will be required, appropriate to the expected income to be derived from the material. The agreement may include full or partial payment of the cover by the client.

The liability of the contractor for loss of or damage to the films, digital imagery and other documents shall in no circumstances exceed the following:

- where films/images are less than 12 months old, the replacement cost of new unexposed films.
- where films/images are more than 12 months old, an amount equal to one years loss of royalty income, subject to the terms of a pre-existing marketing agreement.

4.7 Scanning of film to obtain 'derived' digital imagery

The user guide notes for this section provide guidance for:

- scanning of film to provide derived digital imagery which can either be used in digital photogrammetric 'plotting' equipment to produce mapping, or be used to create digital imagery products
- processing of imagery captured by digital camera and sensor systems
- quality requirements for digital imagery
- digital imagery products.

The contract or specification may provide a choice between the use of film cameras or digital cameras, so either sections 1 or 2 will apply to the contract. Section 3 applies to the quality of all imagery either derived or directly captured.

If the user finds it difficult to decide which options should be taken then professional advice should be sought. Consideration of the long term possible usage of the data should be borne in mind when seeking such advice.

The photography shall be scanned to produce raster imagery suitable for display and manipulation in computer systems including geographic information systems (GIS). Clause 1 indicates the intended use of digital imagery from this project.

All scanning shall be carried out to comply with the technical specification and the product specification.

4.7.1 Scan type

The original photographic images or diapositives shall be scanned:

either (a) in accordance with film type
or (b) in greyscale
or (c) Other (specify)

**Select the option required*.

Greyscale scans from colour originals may be specified when the principal product is photographic but a digital image is required for reference. Greyscale scans occupy substantially less storage than full colour. A low resolution scan may also be specified in addition, to provide a compact reference set for ease of data management.

4.7.2 Scanning resolution

**State the required ground sample distance* (see table below). The scanned product cannot achieve a higher resolution than the original photographic image but high quality photography may yield a slightly better resolution in the scanned image. Features smaller than the nominal ground sample distance may not be discernible on the scanned image.

Examples of ground sample distance (GSD) of a single pixel at different scanning resolutions

Photo Scale	14 μm	21 μm	28 μm
1:3000	0.042m	0.063m	0.105m
1:5000	0.070m	0.105m	0.140m
1:10000	0.140m	0.210m	0.280m
1:20000	0.280m	0.420m	0.560m

4.7.3 Geometric accuracy

For use in orthophotography, the geometric location of each pixel shall be within half the ground sample distance specified above. For scanning of individual frames or production of digital mosaics from alternate exposures, the geometric location of each pixel shall be within twice that specified resolution.

The nominal ground sampled distance obtainable from the scanned product shall be ..... metres.

Scanning should be undertaken using an approved precision photogrammetric scanner. The contractor should provide details of their scanner and software, including calibration details where appropriate, together with the available scan ranges.

4.7.4 Coverage

Scanning shall be carried out to provide:

either (a) full stereoscopic coverage of the contract area to a quality suitable for orthophotos mapping

or (b) complete monoscopic coverage of the contract area, suitable for use as single frames or for compilation into a digital mosaic.

**Select the option required*. Stereoscopic coverage enables the final product to be produced with full corrections applied for changes in relief. Height information can be abstracted from such coverage. Monoscopic coverage is suitable only for the production of generalised images which will not be fully true to scale.

4.7.5 Geocoding

With the exception of raw scans, all other deliverable digital imagery shall be geocoded:

either (a) in the following grid coordinate system with the pixels aligned to the grid

or (b) other (specify).

5 Digital Imagery

Where a digital camera system has been used to capture the imagery under clause 2 then this section of the Specification will apply.

5.1 Scale of Photography/GSD

The requirements are normally stated as:

either the principal scale(s) of photography to be provided for this Project is 1: .....

or the ground sample distance (GSD) of the digital imagery is required to be: .....cm

- The photograph scale is normally quoted for analogue film cameras and is dependent upon the camera format, focal length of the lens and the flying height.
- The parameters for digital cameras relate to the pixel size of the CCD array and the GSD is a function of pixel size, the focal length of the camera and flying height. It is normal for output to be quoted as a GSD rather than photographic scale (see table below).

5.2 Areas to be photographed

The client should clearly define the boundary for photography, preferably by a map. Care is required in the preparation of such a map and failure to do so can lead to insufficient coverage. It is important not to mark beyond the required limits, since this will result in unnecessary photography and increases costs.

5.3 Digital camera data processing

The client should consider the benefits of the use of digital cameras in that they are normally multispectoral and directly capture monochrome, true colour and near infrared imagery, and the opportunity may be available to acquire more than one 'product' from a single sortie.

5.3.1 Security of data

The contract should state at which level of processing a copy of the data is taken, either to be retained for security purposes or to be supplied to the client.

It would be prudent to retain a copy of the original data prior to any processing or to provide a security copy of data being transported between airfield and processing facility. A copy of the GNNS/IMU data should also be retained.

Table relating film scale, digital imagery, resolution to potential photogrammatric mapping scale and accuracy

Photo Scale	GSD	Mapping Scale	Hz RMSE	Vertical RMSE
1:3000	4cm	1:500	+/-0.100m	+/-0.050m
1:5000	7.5cm	1:1250	+/-0.225m	+/-0.125m
1:10000	15cm	1:2500	+/-0.500m	+/-0.250m

Other scales may be used for specialist products. Some clients may have their own specific standards.

5.3.2 Digital camera data processing

The data set should be checked for completeness to confirm the contract has been satisfied and be subject to quality testing to ensure that the requirements of the contract have been met.

The various levels of digital camera data can include:

- raw data as collected and stored in the aircraft
- level 0, as verified on transfer from the storage unit in the aircraft
- level 1, radiometrically corrected
- level 2, geometrically corrected – incorporating calibration data.
- level 3, user defined output.

5.3.3 Acceptable quality levels

These apply equally to scanned images (see clause 6) and imagery from digital cameras.

Appearance

CCD arrays in digital cameras may collect the different colour bands separately and they are reassembled during processing – it is important to build in checks for miss registration.

Shadows from high buildings within built up areas, from cliffs in coastal areas, and from significant changes in the terrain in mountainous areas, must not obscure detail – it must be possible for operators to interpret features within the shadow.

Typical tolerances for cloud and cloud shadows may be less than 5% for a single image and 1% over a contiguous block of images.

It may be difficult to satisfy radiometric values where imagery covers a variety of topography, therefore different values for urban, rural and moorland may be used.

The digital imagery must be pleasing to the eye, be a true representation of the nature of the ground being captured and be fit for intended purpose.

The image should be checked for:

- Image quality and visual appearance:
  - colour registration across the colour bands
  - the image must be sharp
  - there must not be excessive shadows obscuring detail
  - cloud and haze must not obscure important detail
  - flare, from expanses of glass, water, or from cars, must be a minimum
  - colour and light balance should be uniform
  - contrast must be consistent across the block of imagery
  - there should be a good match between flight runs and adjacent images.
- Radiometric values; the client may specify:
  - Mean histogram luminosity values
  - Mean of the individual colour bands
  - Standard deviation for each colour band.

Geo-referencing

With the exception of raw scans all digital imagery will be geo-referenced and coded.

Absolute accuracy values will be specified as part of the contract details, and will be consistent with the mapping or digital product requirements.

The referencing system must be that as specified by, or agreed with the client. The grid system will be identified

The geo referencing will be obtained using ground control, and subsequent aerial triangulation methods, or directly from GNSS/INS data.

The client may request copies of the raw information including GNSS base station data and the results of data processing.

5.4 Reports

The format and method of delivery of reports by the contractor should be agreed in advance by the client. Contractors may be required to include their proposals for delivery, frequency, contents and layout of reports either in their tender submission or be included in a Quality Plan approved by the client.

The following reports are required during the course of the contract.

5.4.1 Flight reports

The flight report provides a technical summary of each sortie and should contain Date; Aircraft Registration; Camera/Sensor type and serial number; Lens (focal length); Weather and flying conditions; Exposure settings; Flying height; Sortie Number/flight runs as taken; data storage device number as appropriate

The report provides valuable archive information which will be of benefit should the images be used at a future date for other purposes.

Each report shall contain the following information:

- name of client
- name and address of contractor
- camera manufacturer, type, serial number, lens type, number and focal length
- film type and manufacturer's emulsion number
- lens aperture and shutter speed
- run number and flight direction
- dates of photography (years, months and days)
- aircraft type and identification
- names of pilots, navigators and photographers
- start and end time for each run in local time
- photo numbers of all offered photography
- camera station coordinates
- computed altitude above mean sea level
- nominal scale of photography
- weather conditions – cloud type, degree of haze and turbulence, etc.
- ground sampled distance
- general comment on quality.

5.4.2 Progress reports

The contractor shall submit a brief progress report at fortnightly intervals on the flying of the photography and of production of the derivative products.

The client may request, or expect, reports at significant milestones such as being informed of:

- the commencement of flying,
- the completion of acquisition of imagery,
- the quality acceptance of imagery,
- the commencement/completion of production of derivative products.

5.4.3 Project report

A Project Report shall be delivered by the contractor upon completion of the project. The project report shall contain the following information:

- a brief project report recording planned and actual delivery dates, any problems

  encountered and any changes or variations to the original contract requirement
- one set of folded paper copies of the index plots
- one set of film reports
- one set of camera calibration certificates
- a copy of the contract technical specification metada
- a certificate confirming that the photography has been validated by the contractor

  and conforms to the specification.

5.4.4 Navigation/positioning data

GNSS data and associated

- observations from an inertial measurement unit data
- base station data.

GNSS data and associated observations from an inertial measurement unit data is now normally collected as standard practice and should be supplied as a matter of course at no extra charge. It is important that third party base (reference) station data is requested and ordered from suppliers and, where appropriate, national mapping organisations promptly as such data may not be archived in the precision required.

6 Digital Imagery Product Details

The type of digital imagery is specified under clause 1. This section provides the detailed specification for the production of that data either obtained from digital cameras or derived from the scanning of film. The area to be covered is shown on the contract mapping.

6.1 Product Details

6.1.1 Digital Mosaic (if required)

A digital mosaic is a combination of a number of photographic images to create a map-like product which appears visually attractive but is not strictly to scale and contains distortions due to height variations of the ground. It is usually produced to match existing map sheets.

Where required, a seamless digital mosaic shall be produced from alternate exposures of the photography. The individual scanned images shall be warped to fit a minimum of eight points of detail per exposure, identified on existing topographical maps to be supplied by the client. In hilly terrain, additional detail points shall be selected along breaks of slope to contain the distortion within ± 5 mm at the supplied map scale. The contractor shall advise the client of any areas of the mosaic where the terrain is too steep or irregular, or there are insufficient points of detail shown on the topographical maps, to contain the displacement between mosaic and map within this tolerance.

6.1.2 Mosaic layout

**Delete any of the options not required and provide the additional information relating to size and type.*

Digital mosaics shall be produced to the following user defined specification:

- Colour/greyscale (specify) .....
- Scale 1: .....
- Sheet size and layout .....
- Digital data as specified in section 6.3 .....
- Hardcopy as specified in section 6.3 .....

6.1.3 Digital orthophotography

The use of stereoscopic coverage enables the scanned imagery to be corrected for height distortions and the resultant product will be true to scale and may be produced to overlay existing mapping.

For engineering purposes the digital terrain model should truly represent the ground surface. The requirements for digital terrain models should be separately specified and must provide for a consistent quality to ensure positional accuracy of features.

Where orthophotos mapping is required with overlay vectors and annotations, a detailed specification of the content and presentation of the orthophotos maps should be attached. The *1:500 and 1:1000 Mapping Specifications* from this series are appropriate documents for these purposes.

Where required, digital orthophotography shall be produced to the following user defined specification:

- Colour/greyscale (specify) .....
- Scale 1: .....
- Output pixel size/GSD (m) .....
- Sheet size and layout .....
- Digital terrain model representing the ground surface
- Digital data as specified in section 6.3 .....
- Hardcopy as specified in section 6.3 .....

Acceptable quality levels may be specified in addition to those at section 5.2 and include:

Geometry; shapes and alignments in the imagery must correspond with the shape and alignment of those features in the real world.

Pixel stretch and smearing; on steep slopes and cliffs during orthorectification must be kept be avoided.

Seam lines; there should be no discernable boundaries between adjacent scenes or images.

Artefacts; should be avoided and removed where necessary.

6.1.4 Radiometric values

Radiometric accuracy is a measure of the colour balance, luminosity and contrast of the image.

Measurables are:

- Mean histogramme (luminosity)
- Mean of the individual colour bands
- Standard deviation of each colour band.

Different values may be acceptable for the variety in the nature of the topography e.g. be it urban, rural or areas which contain significant surface features such as water or exposed rock.

6.2 Supply of digital imagery products

The imagery produced is to be supplied in accordance with the following section which also describes the data transfer medium and formats

6.2.1 Hardcopy

**Select the option required and provide additional information if necessary*.

There is a significant cost implication to option (b) where the copies would normally be printed on a colour proofer. Standard quality copies would typically be produced on a normal colour desktop printer. If in doubt, the contractor should be requested to submit samples with prices for alternative qualities of hardcopy reproductions for selection by the client.

The print size will normally be the same as the original image size, or to the specified scale of the mosaic/orthophotography.

Hardcopy of the individual frame, digital mosaic or orthophotography defined above shall be supplied as:

(a) as copies of each sheet to the contractor's normal quality of reproduction

(b) as copies of each sheet to a photo quality of reproduction, or

(c) to the following agreed specification.

6.2.2 Digital imagery

(a) The contractor shall supply all deliverable digital imagery in a format which can be viewed, manipulated and plotted using the GIS or image viewing and editing software currently used by the client and described below, or

(b) The contractor shall investigate and recommend viewer software to display, manipulate and plot the deliverable digital imagery on the client computer system described below

**Select the option required*. When the client already possesses appropriate software and hardware then option (a) will normally be chosen. In other cases the contractor will recommend suitable software for the client's existing hardware system. For reasons of supply and maintenance it is generally preferable that the client makes direct arrangements for the supply of the software recommended.

All digital data, whichever format and media is used, should be clearly labelled as to content.

'Metada' is information about data or other information managed within an application and would be made available to client organisations for onward supply to their customer clients. It may be specified for digital product data or for specific and individual ortho images.

Metadata standards will normally be specified by the client organisation. Examples of metadata: date flown, geographic reference, flying height, resolution, file size, control system, date of production etc.

The following clauses enable the client to specify the preferred format for the transfer of data from the contractor to the client's system

All deliverables shall be labelled with:

- Project name
- file name
- photo numbers (not required for mosaics)
- tile geographical name (for mosaics only)

  copy commands (e.g. TAR or SCPIO)
- other (specify).

Data format shall be *either*

(a) GEO-TIFF

(b) other (*specify*).

6.2.3 Compression

File compression shall be

(a) uncompressed state.

(b) other (specify).

Select the option required. File compression technology is developing rapidly. For small files which can fit onto a single disc/cartridge uncompressed data is acceptable. In other cases the client should state the required method of compression. The contractor can advise on the most suitable method.

Consideration should be given to the recovery of data held in long term archive. Whilst photography is well suited to storage, changes in data storage and compression techniques may create a significant recovery overhead.

6.2.4 Transfer medium

The transfer medium used shall be:

(a) removable hard drive

(b) external hard drive

(c) DLT

(d) LT03

(e) 4 mm DAT cassette, tape, etc. (specify densities)

(f) DVD.

(g) CD-ROM

(h) other (specify).

The transfer medium may be separately specified for the final delivery of the final data set (e.g. a removable/external hard drive may be essential to take the volume of data) as compared with interim or staged deliveries (e.g. a DVD may be sufficient to take a part data set).

More use is being made of the use of the electronic transfer via ftp.

Appendix A – Terms and conditions

The RICS *Terms and conditions of Contract for land surveying services* are modified and enlarged by the following clauses which relate specifically to aerial photography.

Modify 1

The term 'contractor' shall be taken as synonymous with 'surveyor';

The term 'plans' shall include all films, imagery and derived products and shall be taken as

synonymous with 'products'.

Modify 5

When a request for extension of time is due to weather conditions the contractor shall also indicate to the client the possible extent of such delays.

Modify 11

Insurance cover in respect of loss of revenue deriving from any products which may be lost or damaged shall be the subject of a separate agreement and not included within the general insurance cover.

Modify 16

When specified that the copyright and ownership of the product passes to the client on a permanent or periodic basis such transfer shall take place only after all payments have been made in full. A condition of such transfer shall be that identification markings on original exposed film shall not be subsequently removed and that this condition shall be imposed on any subsequent transfer of rights and title.

Add 19 Permissions to Fly

When the work is carried out within the Country of Domicile of the contractor the client is responsible for arrangements and costs incurred in organising the necessary flying clearances and conditions, including the provision of military observers when required.

Add 20 Increase in Fuel Costs

The contractor shall be compensated for unexpected significant increases in the price of fuel after submission of the tender document.

(Note: Such increases would probably be due to national government action and do not include routine price changes by oil companies.)

Appendix B – Glossary

Explanations for various technical terms relating to air photography (B1) and satellite navigation systems (B2) are included within this glossary. Some terms are not used within the main document but are included as they will frequently occur in related material which may be read by the user of this document.

B1 Terms relating to air photography

Autocollimator

An optical device for the fine measurement of small angles.

Contact Prints

Prints made by placing a photographic paper in close contact with the original image and then exposing the paper through the original image. Traditional fibre based photographic paper may still be used if hand processing methods are adopted, though most contact prints are machine processed using resin coated photographic paper. Resin coated paper offers improved dimensional stability over the fibre based products, but has a lower spatial resolution.

Densitometer

A precision instrument for measuring the amount of silver present in the image of a processed photographic material. This determines its light stopping power. Densitometers are used to quantify the response of a material to a sensitometric exposure in terms of density. Density is defined as the logioopacity, where opacity is the reciprocal of transmission for the image.

Diapositive

A positive image on a sheet of stable base film or a glass plate. It is usually understood to imply a positive image produced by contact printing from the original image, where this is a black and white or colour negative. It is also possible to produce colour diapositives from original images on colour reversal film, although this can have the effect of reducing the range of brightness values which can be reproduced from the original scene.

Elevation Mask

The lowest elevation in degrees above the horizon at which a GNSS receiver is set to track a satellite. It is usually set to 10° or 15 ° to avoid atmospheric effects and signal interference.

Fiducial Marks

Reference marks provided along the edges of an original image, which are physically created at the film plane of the camera. When opposite marks are joined, the point of intersection between the resultant pair of lines will indicate the principal point of the photograph.

Fog Level

Unwanted silver in the photographic image. A small proportion of the silver halide crystals in a photographic emulsion become spontaneously developable due to the effects of ageing, heat, processing conditions or as a result of certain gases or fumes coming into contact with the emulsion.

Geocoding

Referencing an image, document, feature or other entity by its geographical coordinates.

Ground Resolved Distance (GRD)

The minimum detectable distance between two small features on the ground. In practice the GRD is established by assessing an imaging systems spatial resolution through measurements made in a laboratory.

Ground Sampled Distance (GSD)

More correctly known as the Nominal Ground Sampled Distance, this is the smallest patch on the ground detected by an imaging system. GSD may be assessed directly in an original image through measurement of the image's ISF, or through measurements made in the laboratory.

Hardcopy

Reproduction on a paper based material of digital imagery and/or alpha-numeric data. Hardcopy may

be produced directly using a printer or indirectly via a filmwriter. Use of a filmwriter provides a photographic master negative or diapositive from which any number of hardcopies can be produced by photo-reproduction, the image scale of which can be selected to suit the application. Such master negatives or diapositives provide a long term archival record of valuable data.

Iinertial Measurement Unit (IMU)

An IMU is an electronic device that measures and reports on a craft's velocity, orientation, and gravitational forces, using a combination of accelerometers and gyroscopes. The IMU is the main component of inertial guidance systems used in air-, space-, and watercraft, including guided missiles. In this capacity, the data collected from the IMU's sensors allows a computer to track a craft's position

Inertial Navigation System (INS)

An INS is a navigation aid that uses a computer, motion sensors (accelerometers) and rotation sensors (gyroscopes) to continuously calculate the position, orientation, and velocity (direction and speed of movement) of a moving object without the need for external references. It is used on vehicles such as ships, aircraft, submarines, guided missiles, and spacecraft. Other terms used to refer to inertial navigation systems or closely related devices include inertial guidance system and many other variations. Inertial guidance systems are now usually combined with satellite navigation systems. The inertial system provides short term data, while the satellite system corrects accumulated errors of the inertial system.

Image Spread Function (ISF)

The representation in an image of a small point or feature on the ground that is at the threshold of spatial resolution. The ISF for an original image represents the characteristic blur spot of a lens as recorded on film or an opto-electronic sensor. As such it may be compared to the disc of least confusion. When an ISF is multiplied by the image scale appropriate for a scene the product is a close approximation of the GSD for that scene.

Mask Angle

See definition of Elevation Mask. Micrometre

Unit of length in the International System (SI) of measurement.

One micrometre = one millionth (1 x 10-6) of a metre or a thousandth (1 x 10-3) of a millimetre.

Monoscopic Photography

In aerial survey monoscopic indicates that the overlap between successive photographs or between adjacent flight lines is insufficient to allow any, or a significant part, of a scene photographed to be viewed stereoscopically for information on height relief in the terrain.

Mosaic

An assembly of contact prints that have been carefully cut and joined to produce a composite image of an area of terrain larger than could be covered in a single aerial photograph at the same scale.

Negative Image

A hard or softcopy image in which the tone reproduction is opposite to the original scene. Bright areas of the original are dark in the tone of the image and shadowed areas become light.

Orthophotography or orthoimages (digital images)

A procedure by which changes in image scale due to photographic perspective and height relief in the terrain with aerial photography are removed by differential rectification. The technique requires stereoscopic photography, special instrumentation and/or suitable computer software.

Orthophoto map

The use of differential rectification and digital elevation models to produce an image map having the characteristic of a constant image scale throughout the scene.

Photogrammetry

Simplified: The science of making accurate measurements on photographs (or digital images) normally for the measurement of an object, mapping or GIS data collection.

Pinpoint

The taking of a photograph at a specified location.

Panchromatic

A photographic material that is sensitive to all radiation in the visible region of the spectrum.

Positive Image

A hard or softcopy image in which the tone reproduction corresponds with the original scene. Bright areas of the original are light in the tone of the image and shadowed areas remain dark.

Principal Point

The position on the focal plane of a theoretically perfect camera where a perpendicular line passed through the perspective centre.

Rectification

A procedure to reduce or eliminate the effects of tip or tilt in the photography, or changes in image scale due to sloping ground. It is carried out using specialised photographic printers or by computer using digital images. Differential rectification or orthorectification provides a more precise degree of correction for relief displacement and photographic perspective in an image, using a digital elevation model in conjunction with an original image.

Radiometric

The measurement of radiant energy across the whole electromagnetic spectrum, as distinct from photometric quantities which relate only to light, the visible region of the spectrum. The units of measurement used in radiometry are different to those used for light.

Sensitometer

A precision instrument for producing a controlled greyscale exposure on photographic material. Sensitometers used in aerospace photography will always need to be of the constant time, variable intensity type, with a spectral output of 5000 K.

Sensitometry

A procedure by which the many factors that govern correct exposure of photographic material are quantified. Among the factors important in governing the response of photographic material to exposure are the processing conditions employed. Sensitometry provides an accurate method of assessing and controlling the relationship between correct exposure and processing.

Stereoscopic Photography

The provision of pairs of photographs, each pair being able to give a visual impression of depth. In aerial survey a series of photographs is produced in which each image overlaps the preceding one by at least 60 per cent. The area of common overlap between two images forms a stereoscopic view of the scene photographed.

B2 Terms relating to satellite navigation systems

Almanac

A set of parameters transmitted by each GNSS satellite that enables a receiver to predict the approximate location of the satellite. The data includes orbit information on all the satellites, clock correction, and atmospheric delay parameters. This data is used to facilitate rapid SV acquisition. The orbit information is a subset of the ephemeris data, with reduced accuracy.

Ambiguity

The unknown integer number of carrier phase cycles in an unbroken set of GNSS measurements. In GNSS processing mathematical calculations are made to compute this number, thus ‘resolving the ambiguity’.

Antenna swap

A method of initialisation of kinematic surveys.

Atomic clock

A clock whose precise output frequency is maintained using radio frequency (RF) energy emitted or absorbed in the transmission of atomic particles between energy states, resulting in a very stable clock reference. GNSS satellites carry either a caesium or rubidium clock and the master control station uses caesium and hydrogen master clocks.

Baseline

The three-dimensional vector distance between a pair of stations for which simultaneous GNSS data has been collected and processed with static differential techniques. This is the most accurate GNSS result.

Bias

(See integer bias terms)

C/A (Coarse/Acquisition) Code

Two pseudo random noise (PRN) codes are transmitted by each GPS satellite, C/A and P (Precision). C/A is the simpler, non-military code which is modulated onto the GPS L1 signal. The code is a sequence of 1024 pseudo random binary bi-phase modulations of the GPS carrier at a chipping rate of 1.023MHz, thus having a code repetition period of one millisecond. This code was selected to provide good acquisition properties.

Carrier

An unmodulated radio wave having characteristics of frequency, amplitude, phase.

Carrier frequency

The frequency of the unmodulated fundamental output of a radio transmitter. The GPS L1 carrier frequency is 1575.42MHz.

Chip

The length of time to transmit either a zero or a one in a binary pulse code.

Chip rate

Number of chips per second (e.g. C/A code = 1.023MHz).

CIO/BIH

Conventional International Origin/Bureau International d'Heure

Clock offset

The difference in the time reading between a satellite clock and a receiver clock.

Code division multiple access (CDMA)

A method of frequency reuse whereby many radios use the same frequency but with each one having a separate and unique code. GPS uses CDMA techniques with Gold's codes for their unique cross-correlation properties.

Correlation-type channel

A GNSS receiver channel which uses a delay lock loop to maintain an alignment (correlation peak) between the replica of the GNSS code generated in the receiver and the received code.

Cycle slip

The loss of lock of the satellite signal by the receiver. When lock is resumed the fractional part of the measured phase would still be the same as if tracking had been maintained. The integer number of cycles exhibits a discontinuity or 'cycle slip'.

Data set

The simultaneous data collected at two or more stations.

Delay lock

The technique whereby the received code (generated by the satellite clock) is compared with the internal code (generated by the receiver clock) and the latter is shifted in time until the two codes match. Delay lock loops can be implemented in several ways; tau dither and early-minus-late gating.

Differential processing

GNSS measurements can be differenced between receivers, satellites, and epochs. Although many combinations are possible, the present convention for differential processing of GNSS phase measurements is to take differences between receivers (single difference), then between satellites (double difference), then between measurement epochs (triple difference).

A single difference measurement between receivers is the instantaneous difference in phase of the signal from the same satellite, measured by two receivers simultaneously. A double difference measurement is obtained by differencing the single difference for one satellite with respect to the corresponding single difference for a chosen reference satellite. A triple difference measurement is the difference between a double difference at one epoch of time and the same double difference at the previous epoch of time.

Differential positioning

Determination of relative coordinates of two or more receivers which are simultaneously tracking the same satellites. Dynamic differential positioning is a real time calibration technique achieved by sending corrections to the roving user from one or more monitor stations. Static differential GNSS involves determining baseline vectors between pairs of receivers.

Dilution of precision (DOP)

A computed unitless scalar value which describes the geometric contribution to the uncertainty of a

GNSS position solution. For any GNSS fix a DOP value is computed. It is usually either geometric DOP (GDOP), position DOP (PDOP) or horizontal DOP (HDOP). In addition, other values exist such as vertical, time and relative DOP. See definition of PDOP for further details.

Doppler aiding

The use of Doppler carrier-phase measurements to smooth code phase position measurements.

Doppler shift

The apparent change in frequency of a received signal due to the rate of change of the range between the transmitter and receiver.

Double difference method

A method to determine that set of ambiguity values which minimises the variance of the solution for a receiver pair baseline vector.

Dynamic differential

See Differential (relative) positioning.

Dynamic positioning

Determination of a time series of sets of coordinates for a moving receiver, each set of coordinates being determined from a single data sample, and usually computed in real time.

Earth-centred earth-fixed (ECEF)

Cartesian coordinate system where the X direction is through the intersection of the prime meridian (Greenwich) with the equator. The axes rotate with the earth. Z is the direction of the spin axis.

Elevation

Height above a defined level datum eg mean sea level or the geoid.

Elevation mask

The lowest elevation in degrees above the horizon at which a GNSS receiver is set to track a satellite. It is usually set to 10 degrees or 15 degrees to avoid atmospheric effects and signal interference. A lower mask angle would increase ionospheric distortion and also tropospheric effects.

Ellipsoid

In geodesy, unless otherwise specified, a mathematical figure formed by revolving an ellipse about its minor axis. Used interchangeably with spheroid.

Ephemeris

The set of data which describes the position of a celestial object as a function of time. The GNSS ephemeris is used in the processing of GNSS observations. Either the broadcast ephemeris from the satellite navigation message or a precise ephemeris calculated from GNSS tracking stations can be used, depending on application.

Epoch

A point in time which is the reference for a set of coordinates. The measurement interval or data frequency, as in recording observations every 15 seconds. In this example loading data using 30-second epochs means loading every other measurement.

ETRF (European terrestrial reference frame)

see reference frame

ETRS (European terrestrial reference system)

see reference system

Fast switching channel

A switching channel with a sequence time short enough to recover (through software prediction) the integer part of the carrier beat phase.

Fixed integers

See integer bias search.

Float solution

A baseline solution that does not fix the integer ambiguity values to whole numbers. The values are left as non-integer real numbers giving the baseline a higher rms. than a fixed baseline. In general float solutions are not acceptable as final baseline measurements.

Full wave

Term used to differentiate between measurements made with single-squared (codeless) and code-tracking receivers. Specifically, a receiver tracking

L2 P-code can make measurement using the whole L2 wavelength (24cm): the full wave.

Fundamental frequency

The fundamental frequency used in GPS is 10.23MHz. The carrier frequencies L1 and L2 are integer multiples of this fundamental frequency. L1=154F=1575.42MHz, L2=120F=1227.60MHz.

Geocentre

The mass centre of the earth.

Geodetic datum

A mathematical model designed to best fit part or all of the geoid. Conventional datums depended upon an ellipsoid and an initial station on the topographic surface established as the origin of the datum. Such datums were defined by the dimensions of the spheroid, by the geodetic latitude, longitude and the height of geoid above the ellipsoid at the origin, by the two components of the deflection of the vertical at the origin, and by the geodetic azimuth of a line from the origin to some other point. Geocentric datums are designed to give the best possible fit worldwide rather than to depend upon values determined at an initial station. Their origin is the geocentre of the earth (see WGS 84 below).

Geoid

The particular equipotential surface which most closely approximates to mean sea level in the open oceans and which may be imagined to extend through the continents. This surface is everywhere perpendicular to the force of gravity.

Geoidal separation

Height of the geoid relative to the ellipsoid.

GDOP (Geometric dilution of precision)

The relationship between errors in user position and time and in satellite range. GDOP = PDOP + TDOP . See PDOP.

GNSS

Global Navigation Satellite System. This term encompasses all satellite systems that are used for navigation purposes including GPS, GLONASS, Galileo and Compass.

GPS (Global Positioning System)

A system employing satellites in high orbit, computers and receivers on the ground, or in an aircraft or ship, to determine and display the geolocation and height above a reference datum of a particular receiver. The system consists of:

a space segment, currently (April 2002) 28 satellites. (NAVSTAR GPS satellites carry extremely accurate atomic clocks and broadcast coherent simultaneous signals.)

the control segment (five monitor stations, one master control station and three upload stations)

the user segment (individual GNSS receivers).

GPS-ICD-200

The GPS interface control document is a US government document that contains the full technical description of the interface between the satellites and the user. GPS receivers must comply with this specification if they are to receive and process GPS signals properly.

GPS week

GPS time started at Saturday/Sunday midnight on 6 January 1980 and the weeks are numbered from that date, up to 1024 weeks. The first week 'rollover', the start of the next renumbering, occurred on 21 August 1999.

Gravitational constant

The proportionality constant in Newton's Law of Gravitation: G = 6.672 x 10-11m3kg-1s-2.

Half wave

Measurements made using L2 squared measurements. The squaring process results in only half of the original L2 wavelength being available, a doubling of the original L2 frequency.

HDOP (Horizontal dilution of precision)

See DOP and PDOP.

Height – ellipsoidal

The distance above or below the ellipsoid measured along the normal to the ellipsoid at that point. Not the same as elevation above sea level. GNSS receivers output position-fix height as the height above the ITRS89 ellipsoid.

HOW (Handover word)

The word is the GNSS message that contains time synchronisation information for the transfer from the C/A code to the P-code.

IERS (International Earth Rotation Service)

Initialisation

The moment when a rover GNSS receiver in a high precision real time dynamic system (RTK) solves the integer ambiguity and gains a real time high precision fixed baseline solution.

Integer bias search

The biases calculated in the float solution are fixed to integers. A search is then undertaken to find closely related sets of integers. These sets are compared to the initial set by dividing the sum of the squares of residuals of the trial set by that of the original set. A strong data set allows only one set of integers, and produces a ratio factor greater than 3.0. A weak data set may accept several different sets of integers with only small changes in its sum of the squares fit, thus producing a small ratio factor.

Integer bias terms

The receiver counts the radio waves from the satellite, as they pass the antenna, to a high degree of accuracy. However, it has no information on the number of waves to the satellite at the time it started counting. This unknown number of wavelengths between the satellite and the antenna is the integer bias term.

Integrated Doppler

A measurement of Doppler shift frequency of phase over time.

Ionospheric delay

The ionosphere is a non homogeneous (both in space and time) and dispersive medium. A wave propagating through the ionosphere experiences variable delay. Phase delay depends on electron content and affects carrier signals. Group delay depends on dispersion in the ionosphere as well, and affects signal modulation. The phase and group delay are of the same magnitude but opposite sign.

ITRF (International terrestrial reference frame)

see reference frame

JPO

Joint Program Office for GPS located at the USAF Space Division at El Segundo, California. The JPO consists of the USAF Program Manager and Deputy Program Managers representing the Army, Navy, Marine Corps, Coastguard, National Imagery and Mapping Agency (NIMA) and NATO.

Kalman filter

A numerical method used to track a time-varying signal in the presence of noise. If the signal can be characterised by some number of parameters that vary slowly with time, then Kalman filtering can be used to tell how incoming raw measurements should be processed to best estimate those parameters as a function of time.

Kinematic surveying

A dynamic method of GNSS surveying using carrier phase observations in which one receiver is moving and one receiver is stationary. It is a highly productive survey method, useful for ground control or camera positioning, but is sensitive to high DOP values, multipath interference and loss of signal lock. Operational constraints include starting from or determining a known baseline, and tracking a minimum of four satellites. One receiver is statically located at a control point, while others are moved between points to be measured.

L1 frequency

The 1575.42MHz GPS carrier frequency used for the GPS system containing the coarse acquisition (C/A) code as well as the encrypted P-code used by the military. In addition, the L1 carrier contains the navigation signal used by commercial, non-military users.

L2 frequency

A secondary GPS carrier frequency of 1227.60MHz containing only the encrypted P-code. This frequency is used in GPS surveying to calculate signal delays caused by the ionosphere.

L band

The radio-frequency band extending from 390MHz to (nominally) 1550MHz.

MAC

Master Auxilliary Concept – used to transmit network corrections from network RTK provideer to rover receiver

Mask angle

See definition of elevation mask.

Monitor station

Worldwide group of stations used in the GNSS control segment to monitor satellite clock and orbital parameters. Data collected here is linked to the master station where corrections are calculated and controlled. These data are uploaded to each satellite at least once per day from an upload station.

Multichannel receiver

A receiver containing many independent channels. Such a receiver offers highest signal to noise ratio because each channel tracks one satellite continuously.

Multipath errors

Signals can arrive at a GNSS receiver either by direct line of sight or can be reflected off nearby objects (hills, buildings, etc), in which case the differences in path length will cause interference at the antenna and corrupt the pseudorange measurements and subsequent positional reliability. (An interference similar to ghosting on a television screen).

Multiplexing channel

A receiver channel which is sequenced through several satellite signals (each from a specific satellite and at a specific frequency) at a rate which is synchronous with the satellite message bit-rate (50 bits per second, equivalent to 20 milliseconds per bit). One complete sequence is completed in a multiple of 20 milliseconds.

Narrow lane

A baseline solution that is a linear combination of the L1 and L2 frequencies. It is often an intermediate solution used for statistical testing in the process of obtaining a final L1 or iono free fixed solution.

NAVDATA

The 1500-bit navigation message broadcast by each satellite at 50bps on both L1 and L2 frequencies. This message contains system time, clock correction parameters, ionospheric delay model parameters, and the vehicles ephemeris and health. This information is used to process GNSS signals to obtain user position and velocity.

NAVSTAR

The name given to GPS satellites, built by Rockwell International, which is an acronym formed from NAVigation System with Time and Ranging.

Observing session

The period of time over which GNSS data is collected simultaneously by two ore more receivers.

PDOP (Position dilution of precision)

PDOP is a unitless scalar value expressing the relationship between the error in user position and the error in satellite position. Geometrically, for four satellites PDOP is proportional to the inverse of the volume of the pyramid formed by unit vectors from the receiver to the four satellites observed. Values considered good for position are small, say 3. Values greater than 7 are considered poor. Thus, small PDOP is associated with widely separated satellites. PDOP is related to horizontal and vertical DOP by PDOP2 = HDOP2 + VDOP2. Small PDOP is important in dynamic surveys, which are sensitive to larger PDOP values, but much less so in static techniques.

Phase lock

The technique whereby the phase of an oscillator signal is made to follow exactly the phase of a reference signal by first comparing the phases of the two signals, and then using the resulting phase difference signal to adjust the reference oscillator frequency to eliminate phase difference when the two signals are next compared.

Phase observable

See reconstructed carrier phase.

Point positioning

A geographic position produced from one receiver in a stand-alone mode. At best, position accuracy obtained from a stand-alone receiver is 20-30m, depending on the geometry of the satellites.

Precise (P)-code

The protected or precise code transmitted on both L1 and L2 GPS frequencies. This code is made available by the DoD only to authorised users. The P-code is a very long (about 1014 bits) sequence of pseudo random binary bi-phase modulations of the GPS carrier at a chipping rate of 10.23 MHz. It repeats every seven days but is a section of a full 37 week code. Each satellite uses a one-week segment of this code which is unique to each GPS satellite, and is reset each week.

Precise positioning service (PPS)

The full accuracy, single receiver GPS positioning service provided to the United States military organisations and other selected agencies.

Pseudo random noise (PRN)

PRN is a sequence of binary digits that appear to be randomly distributed. This is used in the GNSS C/A and P codes, with each GNSS satellite transmitting a unique PRN. GNSS receivers use this PRN to identify which satellites they are tracking. The important property of PRN codes is that they have a low auto correlation value for all delays or lags except when they are exactly coincident. Each NAVSTAR satellite has its own unique C/A and P pseudo random noise codes.

Pseudo static

A technique involving the observation of two separate simultaneous data sets at two or more stations with a time gap between observations (60 minutes is recommended). Data sets can be computed with the kinematic processor or as a static GNSS observation set with two files at each station. Baseline vectors can be computed and applied to the known station(s) within a network. A good method when continuous lock is unlikely to be maintained due to vegetation or other obstructions.

Pseudolite

A ground-based GNSS transmitter station which broadcasts a signal with a structure similar to that of an actual GNSS satellite.

Pseudorange

The apparent distance from a satellite to the phase centre of a GNSS receiver antenna. This is computed from the C/A or P code which gives a signal propagation time. This time can then be multiplied by the speed of light to give an apparent distance, which is not the true distance.

Pseudorange differs from the actual range by the amount that the satellite and user clocks are offset, by propagation delays, and other errors. The apparent propagation time is determined from the time shift required to align (correlate) a replica of the GNSS code generated in the receiver with the received GNSS code. The time shift is the difference between the time of signal reception (measured in the receiver time frame) and the time of emission (measured in the satellite time frame).

Pseudorange difference

See reconstructed carrier phase.

Ratio quality factor

See integer bias search.

RDOP (Relative dilution of precision)

Multiplying RDOP by the uncertainty of a double difference measurement yields the spherical relative-position error.

Reconstructed carrier phase

The difference between the phase of the incoming Doppler-shifted GNSS carrier and the phase of a nominally constant reference frequency generated in the receiver. For static positioning, the reconstructed carrier phase is sampled at epochs determined by a clock in the receiver. The reconstructed carrier phase changes according to the continuously integrated Doppler shift of the incoming signal, biased by the integral of the frequency offset between the satellite and receiver reference oscillators. The reconstructed carrier phase can be related to the satellite-to-receiver range, once the initial range (or phase ambiguity) has been determined. A change in the satellite-to-receiver range of one wavelength of the GNSS

carrier (19cm for L1) will result in a one-cycle change in the phase of the reconstructed carrier.

Reference frame

The realisation of any particular coordinate reference system by the measurement of points using survey instruments. There can be several realisations of any system as survey techniques and methods change.

Reference system

A mathematical definition of the particular coordinate system, including the origin, scale position and orientation of the reference ellipsoid.

Relative-positioning

The process of determining the relative difference in position between two points with greater precision than that to which the position of a single point can be determined. Here, a receiver (antenna) is placed over each point and measurements are made by observing the same satellites at the same time. This technique allows cancellation (during computations) of all errors which are common to both observation sets, such as satellite clock errors, satellite ephemeris errors and the majority of propagation delays, etc. See differential positioning.

RINEX (Receiver Independent EXchange format)

A set of standard definitions and formats to promote the free exchange of GNSS data and facilitate the use of data from any GNSS receiver with any software package. The format includes definitions for three fundamental GNSS observables: time, phase, and range. A complete description of the RINEX format is found in the Commission VIII International Coordination of Space Techniques for Geodesy and Geodynamics GNSS BULLETIN, May-June 1989.

RMS, RMSE (root mean square (error))

In general, when accuracies or tolerances have been specified, they refer to vector errors and are defined statistically as root mean square errors (rmse.), or as maximum tolerances. The rmse is equivalent to a 67% tolerance, and a 90% tolerance is 1.65 times the rmse when a representative sample of points is tested. Thus an rmse. of ± 0.01m indicates that in a representative sample of 100 points, it is expected that not less than 67 will be correct to better than ± 0.01m, and not less then 90 points will be correct to better than ± 0.016m. Any errors exceeding three times the rmse, in this case ± 0.03m, can be regarded as mistakes.

Selective availability (SA)

A United States Department of Defense programme to limit the accuracy of C/A code GPS receivers to the 100m level. It introduced deliberate errors to the C/A code information and affected the satellite clocks. It can be switched on or off according to the current US Government policy. It was set to zero by Presidential Decree on 1 May 2000, but it is possible for it to be reinstated at any time.

Session

A period when data is collected simultaneously at two or more stations, numbered using the Julian day, i.e. 121-1 is the first session on Julian day 121.

Sigma (One Sigma)

The 68 percentile or one standard deviation measure in a statistical population.

Simultaneous measurements

Measurements referenced to time frame epochs which are either exactly equal, or else so closely spaced in time that the time misalignment can be accommodated by correction terms in the observation equation, rather than by parameter estimation.

Slope distance

The magnitude of the three-dimensional vector from one station to another. The shortest distance (a chord) between two points.

Slow switching channel

A switching channel with a sequencing period which is too long to allow recovery of the integer part of the carrier beat phase.

Spheroid

See ellipsoid.

SPP (Single point position)

An averaged GNSS position resulting from the processing of several consecutive minutes of autonomous GNSS position data at a single location.

Squaring-type channel

A GNSS receiver channel which multiplies the received signal by itself to obtain a second harmonic of the carrier which does not contain the code modulation. Used in so-called codeless receiver channels.

Standard positioning service (SPS)

The positioning service made available by the US Department of Defense to all civilian GPS users on a continuous worldwide basis, using the C/A code. The accuracy of this service is set at a level consistent with US national security. See selective availability.

Static differential

See Differential (relative) positioning.

Static positioning

Positioning applications in which the positions of static or near static points are determined.

SV (Satellite vehicle)

Abbreviation used to indicate a GNSS satellite, followed by an individual identifying number. Also an abbreviation for space or satellite vehicle.

SV sync time

The epoch interval used on the receiver.

TDOP (Time Dilution of Precision)

See DOP.

TOW

Time of week, in seconds, from 0000 hrs Sunday GPS time.

Tropo or Tropospheric correction

The correction applied to the measurement to account for tropospheric delay. This value is obtained from a model such as that of Hopfield.

Universal time

Local solar mean time at Greenwich Meridian. Some commonly used versions of Universal Time are:

UT0 Universal Time as deduced directly from observations of stars and the fixed relationship between Universal and Sidereal Time; 3mins 56.555 secs

UT1 is UT0 corrected for secular change

UT2 is UT1 corrected for seasonal variations in the earth's rotation rate

UTC is Universal Time co-ordinated; a uniform atomic time system kept very close to UT2 by leap second offsets. GNSS time is continuous and directly related to UTC. UTC – GNSS time = an interval with a magnitude of seconds, 13 seconds in 2002.

Update rate

GNSS receiver specification which indicates the solution rate provided by the receiver when operating normally. This would be expressed as a number of updates per second.

User range error (URE)

The contribution to the range-measurement error from an individual error source (apparent clock and ephemeris prediction accuracies), converted into range units, assuming that the error source is un-correlated with all other error sources.

VDOP (Vertical Dilution of Precision)

See DOP and PDOP.

Virtual reference station (VRS)

A specialised processing technique that generates a virtual base station for a GNSS survey from a network of other fixed real base stations. Data from the real base stations is used with their known positions to solve atmospheric refraction and other parameters. These are then modelled and applied to rover measurements, just as if a real base station were at the location of the rover.

WGS 84 World Geodetic System (1984)

The geocentric datum used by GNSS since January 1987. It has its own reference ellipsoid. WGS 84 is fully defined in publications by the US. National Imagery and Mapping Agency (NIMA).

Wide lane

A linear combination of L1 and L2 observations (L1-L2) used to partially remove ionospheric errors. This combination yields a solution in about one-third the time of a complete ionosphere-free solution.

Z-count

The GNSS satellite clock time at the leading edge of the next data sub-frame of the transmitted GNSS message (usually expressed as an integer multiple of six seconds).

Zero baseline

Collection of data by two or more receivers from the same antenna. Any relative baseline thus computed should be zero. It is used to check receivers at the start of tasks. (warning – to avoid damage to antenna, a special zero baseline DC block should be used).

Vertical aerial photography and digital imagery

5th edition, guidance note

This combined RICS guidance note and client specification has been developed and fully updated from the 2001 4th edition of the RICS specification for Vertical aerial photography and derived digital imagery. This new fully international publication recognises the shift in demand from panchromatic film and photographic products, including digital imagery derived from those products, towards the increasing use of digital cameras and sensors in the capture of vertical photography used in mapping projects and the use of Global Navigation Satellite Systems (GNSS) as navigational aids.

It is intended to assist all those connected with the requesting, purchase and production of surveys and mapping material by advising best practice and seeking to avoid duplication of effort. This document is intended for use in drawing up clear 'specifications' for aerial photography and digital imagery obtained directly from digital cameras and sensors or derived from analogue aerial photography using digital scanners. The specification may be prepared by the client (the individual or organisation requesting information) or by the contractor (those who will be tendering or undertaking the provision of information).

This document is designed as a specification for vertical aerial photography typically required for:

- photogrammetric mapping and digital data collection
- production of orthophotography and digital mosaics
- environmental information gathering and general interpretation.

It is not a specification for remote sensing, except in the context of vertical aerial photography and derived digital products.

Part 1 of this document is a survey brief. Part 2 is a combined standard specification and guidelines and covers the following:

- Project information
- Camera equipment – including calibration and digital camera specifications
- Flying and photo coverage
- Navigation and ground control
- Digital photographic output including scanning of 'film' products
- Digital imagery
- Digital imagery product details

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