Section 4 Appendix A

CALLDOWN CONTRACT

Framework Agreement with: AECOM Ltd

Framework Agreement for: Goods and Equipment Procurement Supplier Framework Agreement

Framework Agreement Purchase Order Number: 7387

Call-down Contract For: Procurement of Aerial Photography for Land Investment for Transformation (LIFT) Programme

Contract Purchase Order Number: 8101

I refer to the following:

1. The above mentioned Framework Agreement dated 29 March 2016;

2. Your proposal of 21 September 2017

and I confirm that DFID requires you to provide the Services under the Terms and Conditions of the Framework Agreement which shall apply to this Call-down Contract as if expressly incorporated herein.

1. Commencement and Duration of the Services

1.1 The Supplier shall start the Services no later than 29 September 2017 ("the Start Date") and the Services shall be completed by 31 July 2018 ("the End Date") unless the Call-down Contract is terminated earlier in accordance with the Terms and Conditions of the Framework Agreement.

2. Recipient

2.1 DFID requires the Supplier to provide the Services Department of International Development Ethiopia ("the Recipient").

3. Financial Limit

3.1 Payments under this Call-down Contract shall not, exceed £1,698,465.85 ("the Financial Limit") and is inclusive of any government tax, as detailed in Annex D**.**

4. DFID Officials

4.1 The Project Officer is:

[redacted]

British Embassy, [redacted]

Cell [redacted]

4.2 The Contract Officer is:

[redacted]

[redacted]
DFID Abercrombie House, East Kilbride
[redacted]

5. Key Personnel

N/A

6. Reports

6.1 The Supplier shall submit project reports in accordance with the Terms of Reference/Scope of Work at Annex A.

7. Duty of Care

All Supplier Personnel (as defined in Section 2 of the Agreement) engaged under this Call-down Contract will come under the duty of care of the Supplier:

I. The Supplier will be responsible for all security arrangements and Her Majesty's Government accepts no responsibility for the health, safety and security of individuals or property whilst travelling.

II. The Supplier will be responsible for taking out insurance in respect of death or personal injury, damage to or loss of property, and will indemnify and keep indemnified DFID in respect of:

II.1. Any loss, damage or claim, howsoever arising out of, or relating to negligence by the Supplier, the Supplier's Personnel, or by any person employed or otherwise engaged by the Supplier, in connection with the performance of the Call-down Contract;

II.2. Any claim, howsoever arising, by the Supplier's Personnel or any person employed or otherwise engaged by the Supplier, in connection with their performance under this Call-down Contract.

III. The Supplier will ensure that such insurance arrangements as are made in respect of the Supplier's Personnel, or any person employed or otherwise engaged by the Supplier are reasonable and prudent in all circumstances, including in respect of death, injury or disablement, and emergency medical expenses.

IV. The costs of any insurance specifically taken out by the Supplier to support the performance of this Call-down Contract in relation to Duty of Care may be included as part of the management costs of the project, and must be separately identified in all financial reporting relating to the project.

V. Where DFID is providing any specific security arrangements for Suppliers in relation to the Call-down Contract, these will be detailed in the Terms of Reference.

8. Call-down Contract Signature

8.1 If the original Form of Call-down Contract is not returned to the Contract Officer (as identified at clause 4 above) duly completed, signed and dated on behalf of the Supplier within 15 working days of the date of signature on behalf of DFID, DFID will be entitled, at its sole discretion, to declare this Call-down Contract void.

For and on behalf of The Secretary of State for International Development	Name:
	Position:
	Signature:
	Date:

For and on behalf of	Name:
AECOM Ltd	Position:
	Signature:
	Date:

Terms of Reference

Terms of Reference for the procurement of Aerial Photography for Land Investment for Transformation (LIFT) Programme

Procurement Supplier – AECOM

1. Context

DFID Ethiopia has agreed to contract AECOM to procure aerial photography, as detailed at Annex B, to Land Investment for Transformation (LIFT) Programme under the Ministry of Agriculture.

2. Objectives

AECOM will manage the procurement exercise and delivery of Aerial Photography, as detailed at Annex B, through the AECOM framework dated 29th March 2016, as agreed between AECOM and its partner suppliers. Delivery should be made no later than 31 July 2018.

3. Recipient

The recipient of the services shall be DFID Ethiopia.

4. Scope

AECOM will provide Aerial Photography as per the required specifications as detailed in Annex B.

5. Method

In accordance to the Overarching Framework Agreement PO 7387, response times for key procurement activities against which the agents' performance shall be measured as detailed in Annex E.

Timing and procurement planning are critical to the successful implementation of the project. AECOM will be expected to demonstrate efficiency, effectiveness, accountability and transparency, and measure and record its associated value added.

Clear communication channels and/or approval process will be established between AECOM and DFID at the onset of contract.

The DFID Commercial Adviser and DFID Programme Manager will be kept informed of all relevant issues likely to affect the implementation of the programme.

6. Reporting

DPSA will provide a report of the procurement process at the end of the contract period. In addition AECOM will provide a weekly email update to the contract officer on the ongoing progress of the order throughout the duration of the contract.

7. Time frame

AECOM will commence the procurement exercise on 28 September 2017 with delivery to be made no later than 31 July 2018.

8. DFID Co-ordination

AECOM will report to DFID Procurement Officer and DFID Programme Officer. A communication matrix is attached in Annex G.

9. Payment

Payments will be made upon delivery of the Aerial Photography, as per the milestones delayed at Annex D. Procurement agent fees will be a percentage of the value of the procured goods and equipment, as detailed in Annex D.

AECOM will be required to maintain a record of any relevant expenditure incurred in the programme activities and keep original copies for the record for the entire duration of the programme.
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10. Background

The programme will support the Government of Ethiopia in the provision of map based land certification and administration in four highland regions and assist small farmers to fully benefit from increased investment and productivity through the development of the land market and its supporting operations. It will also undertake cross-cutting policy work to ensure the existing policy, regulations and procedures are in line with international good practices and human right obligations.

LIFT will be implemented in a stepped approach, with 3 million parcels certified in the first 2.5 years. Experience and evidence at that point will establish whether a further 5 million parcels will be certified at a total cost of £[redacted], or whether a scaled up trajectory of a further 11 million parcels at a cost of £[redacted] will be pursued. Complementary interventions will be implemented to ensure that the benefits of second level certification are maximised. The results expected of LIFT in the maximum investment scenario, attributable to DFID, include:

- Second stage certification of up to 14 million parcels in approximately 140 woredas in the four Highland Regional States for approximately 6.1 million households (around 70% of parcels being jointly or individually owned by women), contributing to the DFID global result on access to land/property rights;
- Land administration systems implemented in the same 140 woredas;
- Number of land rental agreements increased by 13%, particularly benefiting female headed households;
- Up to 1.36 million smallholder farmers increase their income by at least 20.5% as a result of programme activities, contributing to this headline result in DFID E’s Operation Plan;
- Percentage of households involved in land-related disputes reduced from 21.1% to 15%;
- A total of 40 regulations, strategies, procedures and plans at different levels drafted and approved to improve the functioning of the land sector’s productivity and investment;
- 25 research and evidence-based assessments, action plans and progress assessments, action plans produced to allow the GoE to make informed decisions on land governance and to help bring policies and practices into line with international good practice and human rights obligations; and
- Ethiopia’s domestic resource mobilisation enhanced through an increased rural tax base and more effective land tax system.

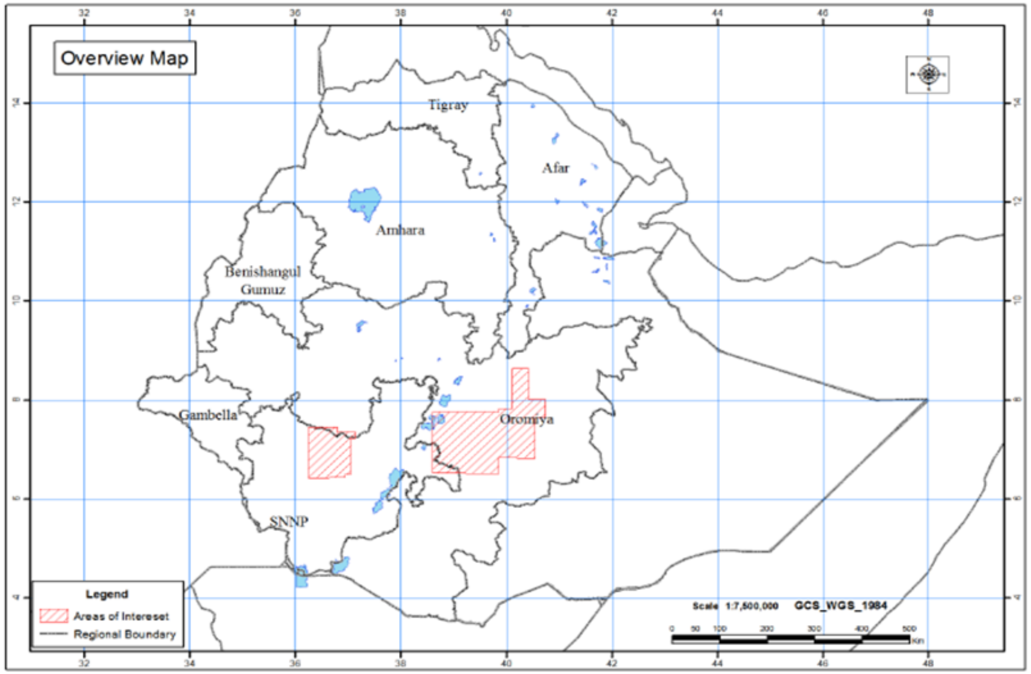
LIFT will synergise its capacity building interventions with other existing donor funded programmes so that, while the capacity building and systems development at the federal level will be largely carried out them, with -LIFT concentrating on on-the-job training in the regional and woreda level structures, targeted at implementation skills.

September 2017

DFID Ethiopia

Annex B
Specifications

1. The total anticipated survey will be acquired in three exercises. The first of these is expected to cover approximately 46,000 km² in the two regional states of Oromiya and SNNPR with varying block sizes. The map on the next page shows the distribution and location of the two blocks for which digital aerial photography will be acquired and digital orthophotos will be produced during the first exercise.



2.	Comments on the received Request for Proposal. Suggestions and proposed	According to the terms of reference (ToR) the current Government of Ethiopia policy states that all aerial photography and digital mapping falls under the purview of the Information Network Security Agency (INSA) for national security reasons. The following provisions have been agreed by the DfID with INSA to ensure that INSA's national mandate is respected, but also to improve INSA's technical capacity in high quality production and processing of ortho-photography:

	improvements to its content	The Information Network Security Agency (INSA) in conjunction with the International Service Provider (ISP) procured by DfID will be responsible for the aerial photography required under LIFT.
3.	The role of INSA and EMA	INSA will be responsible for data capturing and processing, including the provision of a plane and camera that meet the programme requirement. The ISP will be responsible for the oversight, overall management, and quality control of the work including providing any additional experts and equipment to ensure the timely completion and quality of the project. HANSA (the ISP (Consultant) under the previously stated provisions) will develop an arrangement with INSA to carry out the works required in the ToR, within this allocation of responsibilities. In accordance with the ToR the consultant plans to involve the Ethiopian Mapping Agency (EMA) in the surveying of the ground control points required in the project.
4.	The role of Hansa	Hansa Luftbild has been active and executing projects in Ethiopia since 2009. Due to the nature of services provided by the company it has been cooperating and coordinating different tasks and assignments with INSA and EMA. Thus, Hansa Luftbild is fully aware of the sensitivity of high resolution airborne data to the security of Ethiopia. In addition Hansa Luftbild was involved as the consultant in the LIFT 1st Acquisition Aerial Photography Project.This project covered the aerial image acquisition and orthophoto production of 80,000 km². The Hansa Luftbild involvement in this project is identical to the one currently requested for the 120,000 km² area coverage. That is, Hansa Luftbild contracted INSA to perform the aerial image acquisition and orthophoto production, and EMA to determine and survey the ground control points. The company managed the works of the two agencies. The requirement to acquire aerial imagery at 30cm GSD makes the usage of an inertial measurement unit (IMU) an imperative to obtain the INS/DGPS orientation parameters. This usage is also stated in the terms of reference of the tender document. Thus, aerial triangulation

		will be applied to adjust the photogrammetric blocks and consequently a small number of ground control points will be required. GPS ground reference stations will be run by INSA during the flight missions. As an alternative INSA can use GPS augmentation services. This would eliminate the need for GPS ground reference stations while maintaining the high accuracy requirements.
5.	The complete workflow including the optional services is illustrated in the table below	

Processing Site	Processing Step	Details In Step
Office	Pre-Processing (INSA/ Hansa Luftbild) and LIFT Programme Manager for approval	Mission Planning
Aircraft	Airborne Data Acquisition	Navigation and Flight Management System

6.	Methodology and Approach

Processing Step	Processing Step	Details In Step	
	(INSA)	Camera Software Control Module Data Storage	
Office	Post-processing (INSA)	Connection of Flight Data Storage (FDS) or IDE disks from Copy Station Post-processing • Radiometric correction • Geometric correction • Generating virtual images • Colour image generation Data distribution	
At Site	Ground Control (EMA) GPS Ground Reference Stations or GPS Augmentation Services (INSA)	Choosing the location of the ground control (Hansa Luftbild) Determination and surveying of ground control and check points Manning of GPS ground reference station during flight or Application of GPS augmentation services such as Trimble RTX	
Office	Processing of IMU and GPS data Aerial triangulation (INSA)	Processing of IMU and GPS data using Applanix POSPac MMS technology in order to obtain through direct geo-referencing the exterior orientation parameters of aerial imagery	

7.	The following paragraphs outline the methodology to be applied during project execution. To acquire digital colour aerial photography a state of the art digital large format camera is proposed. All production steps have been arranged in order to facilitate a smooth workflow. **Critical Comments** Though the flying season can be extended from April to May there is no guarantee that during May suitable weather conditions will prevail in order to acquire medium resolution aerial imagery. Experience have shown that it is nearly impossible to acquire aerial imagery with 30cm GSD during the month of May		
1	**Aerial Photography**		
1.1	General	Latest technology advances will be applied during the aerial photography phase. To plan each of the aerial surveying missions accurately in accordance with client's requirements, GPS methods for aircraft navigation and camera positioning will be applied. The systems to be used provide complete and comprehensive solutions to mission planning, aircraft guidance, camera control, data management, and complete documentation for any sized mission. In addition, the digital camera system on board the aircraft provides the latest technology for aerial photography of the highest geometric and radiometric quality.	
1.2	Survey Aircraft	The aircraft to be used for the aerial surveying missions will meet certain requirements such as: □ stable in flight, □ medium to long range, and □ a payload sufficient to carry three crew members and camera systems. INSA is currently operating a Beechcraft King Air 250 to acquire the airborne data. This aircraft has the following specifications:	

		Beechcraft King Air 250 Horsepower: Two Pratt & Whitney Canada, PT6A-52 Top Speed: 574 km/h (310kt) Range: 2,982 km (1,610 nm) Ceiling: Max certificated altitude 35,000ft During the LIFT 1st Acquisition Aerial Photography Project INSA also chartered a second turboprop aircraft to speed up the aerial image acquisition. Hansa Luftbild itself operates three aircraft one of which is also suitable to acquire aerial imagery at 30cm GSD.
1.3	Flight Planning	The software to be applied for flight planning is dependent on the navigation system and the Inertial Measurement Unit (IMU) which will be used in the project. INSA uses TrackAir for flight planning and flight navigation while Hansa Luftbild has navigation systems and IMUs from IGI Systems, Germany. The navigation software is used to plan flights and document aerial photography missions. The results of the planning are the data input system for the airborne computer controlled navigation system. With knowledge of the geographical conditions prevailing in the area a detailed flight planning will be carried out. The mission planning will consist of waypoints, segments, flight lines and polygons. Digital elevation models (DEM) produced from the SRTM Shuttle Radar Topography Mission (SRTM) will be used to counter the effect of large ground undulations. This will ensure that no gaps in aerial coverage will be introduced. The mission planning and documentation will be generated by using the ITRF geodetic reference system and planning will take place in Lat/Lon co-ordinates and automatically transformed to WGS84 co-ordinates for flight operations. A camera / sensor database will be created which takes all details with regard to the camera system and therefore facilitates further mission planning steps. For later in-flight use, all relevant data will be stored on a PC data card which will be loaded in the aircraft's computer. The card delivers the planning data to the on-board system and stores the in-flight data for post- flight processing. Hansa Luftbild recommends dividing the Oromiya block into 3 sub-blocks to facilitating the processing. However, the final number of sub-blocks

		will be decided by Hansa Luftbild and INSA during the flight planning process. The block in the SNNPR can stay as one. A metadata file and a database will be created to manage the blocks during aerial photography and all subsequent photogrammetric work. INSA will perform the flight planning which will be checked by Hansa Luftbild prior to its approval by the LIFT Programme Manager.
1.4	Digital Camera	INSA owns and operates two Vexcel UltraCam Eagle 100 large format digital cameras. Both cameras were used during the LIFT 1st Acquisition Aerial Photography Project. Hansa Luftbild has also one identical camera to the ones of INSA and thus can offer it if the required. The UltraCam cameras have set new industry standards for digital aerial photography, enabling the camera users to soar to new heights with their mapping projects. The technical specifications of the Vexcel UltraCam Eagle are attached to the proposal, as Annex 1. Nevertheless, the following paragraphs describe the UltraCam Eagle in detail. The UltraCam Eagle introduces a modular housing concept, setting a new standard in component integration, which reduces sensor head size and balances weight. The updated sensor head includes an exchangeable lens system with three lens different focal lengths—a groundbreaking enhancement in digital photogrammetry—and is specifically designed for high-resolution digital aerial photography. UltraCam Eagle also presents filters with curved characteristics and silent-board camera electronics, further ushering in revolutionary aerial photogrammetric technology. The result is an ultra-reliable, ultra-efficient; ultra-large-footprint camera that screams through image acquisitions, captures the smallest details, and enables direct and swift flights that are not limited by technology. **<u>Features</u>** UltraCam Eagle offers the ultimate in reliability and efficiency for digital aerial photography. With a frame size of 20,000 pixels x 13,000 pixel (260 megapixels in total), and an image capture rate of 3.7 gigabits per second, it soars beyond the traditional large-format cameras. The solid-state storage system stores 3,800 superior-quality images and can be exchanged in flight to meet any storage need. UltraCam Eagle features the latest in revolutionary enhancements, including: PAN image footprint of more than 20,000 pixels across the flight strip.

 Imaging-specific electronics and automated workflow that deliver 3.7 gigabits per second of image collection, resulting in a frame rate of less than 1.80 seconds and forward overlapping of 80 percent at 284 kts.

 An integrated package that contains all components in the sensor head, including an embedded OEM UltraNav GPS/INS/FMS system, and modular solid-state storage, providing flexibility for on-board orientation of equipment.

 A solid-state image storage system to store more than 3,800 images—and storage units that can be exchanged in flight, resulting in minimal ground time.

- Exchangeable lens system configurations with three lens different focal lengths for greater flexibility, from lower-altitude engineering applications to high-altitude orthophotography projects.

- Pixel size of 5.2 µm, as well as enhanced PAN 16,000 grey values per pixel, offered by the latest CCD technology and silent-board camera electronics.

- A user-focused interface with touchscreen technology to ease configuration and operation and allow in-flight control of each image.

- A compact unit weighing less than 75 kg (165 lbs) and reduced power consumption of 350 watts @ 24-28 VDC for increased flight efficiency.

Despite its expansive digital footprint, the UltraCam Eagle is a lightweight, integrated system that features a smaller physical footprint—taking up less aircraft space and providing the utmost in fuel economy. It also consumes less power than other cameras for even more cost savings. With UltraCam Eagle, one can take to the skies, capture more data in less time, and complete mapping projects in fewer flight lines and with greater efficiency than ever before.

Image Product Specification

- Image format analogous to an aerial film image at a format of 23 cm x 15 cm, scanned at 12 µm

- Image data formats: JPEG; TIFF with options for 8 and 16 bits, standard TIFF format

- Image storage format in level 2: full resolution panchromatic, separate colour channels at colour

resolution

Camera Digital Sensor Subsystem

- Panchromatic image size: 20,010 x 13,080 pixels

- Panchromatic physical pixel size: 5.2 µm

- Input data quantity per image: 842 megabytes, 260 megapixels

- Lens system 1: 80 mm PAN and 27 mm RGBNIR – proposed for the project
- Lens system 2: 210 mm PAN and 70 mm RGBNIR, exchangeable by a trained end user, no recalibration required after lens exchange
- Maximum frame rate <1.8 seconds per frame
- CCD signal to noise ratio: 72 dB
- CCD image dynamic: 14 bit; workflow dynamic: 16 bit
- Physical dimensions with 80 mm (210 mm) PAN lenses, including computer and storage module: 43 cm x 43 cm x 76 cm (86 cm)
- Weight with 80 mm (210 mm) PAN lenses, including computer and storage module: approximately 75 kg (80 kg)
- Power consumption at full performance, including computer and storage module: 350 watts

Camera Computer and Data Storage Subsystem (CEDE)

- Solid-state disc pack, with optional storing of mirror images of the data on the data unit
- Unlimited with use of multiple data units with approximately 3.3 terabytes (3,800 images) per unit

Camera Operational Specification

- Data recording time @ 10 cm GSD, 60 percent forward overlap, 140kts @ 8 hours per data unit
- Maximum forward overlap @ 10 cm GSD (@ 5 cm GSD) with 140kts @ 90 percent (80 percent)
- Maximum flight speed @ 10 cm GSD (@ 5 cm GSD) with 80 percent forward overlap @ 268kts

(134kts)

As mentioned previously the camera specification sheet is included in the proposal under Annex 1. The camera is installed inside the aircraft to

<table>
<tr><td></td><td></td><td>ensure system reliability and error free performance. The following image and capture parameters, which were also used in the LIFT 1st Acquisition, will be applied for the 30cm GSD aerial imagery using the UltraCam Eagle camera with the 100mm lens, if the proposal is accepted by the client:
<table><tr><td></td><td></td></tr><tr><td>GSD</td><td>30cm</td></tr><tr><td>Flying height above ground</td><td>5,769m</td></tr><tr><td>Forward Overlap</td><td>70% ±5 %</td></tr><tr><td>Side lap</td><td>40% ±10%</td></tr></table></td></tr>
<tr><td>1.5</td><td>IMU / DGPS</td><td>An inertial measurement unit (IMU) and GPS will be used by INSA in order to determine the exterior orientation parameters of the aerial imagery. INSA owns and operates the Applanix POSAV 510 too. POS AV is a hardware and software system specifically designed for direct geo-referencing of airborne sensor data. By integrating precision GNSS with inertial technology, POS AV enables geospatial projects to be completed more efficiently, effectively, and economically.</td></tr>
</table>

		 Components of the POSAV system are: - PCS: POS Computer System. Ruggedized, low-power, light-weight, small format, with built-in logging. Includes embedded state-of-the-art survey grade GPS receiver. - IMU: Inertial Measurement Unit. Ruggedized, state-of-the-art, small format, light-weight, with high measurement rates - POSPac MMS: Post-processing software bundle. Includes Carrier Phase DGPS processing, Integrated Inertial/GPS processing, and optional photogrammetry tools for EO generation, IMU boresight calibration and quality control. - Track'air Flight Management System: Mission planning, pilot display, and in-air POS AV and sensor control for maximum in-flight task automation and operational efficiency The application of an IMU with GPS during aerial photography allows the direct geo-referencing of aerial imagery. The post-processing of data registered during aerial photography with an INS provides exterior orientation angles and position of camera perspective centre at the time of exposure.
1.6	Aerial Surveying	During aerial image acquisition Hansa Luftbild will temporarily deploy an aerial photography specialist at INSA in Ethiopia to support the agency at the start of the flight missions. Prior to each mission the crew will meet with the Hansa Luftbild aerial photography specialist to discuss the areas which will be covered by the next mission. The GPS ground team will be informed where the next mission will take place and where to place the

	Missions	GPS ground reference stations, if no GPS augmentation service is used. The permanent calibration field of INSA at Meki will first be covered with aerial imagery and boresight calibrated in order to determine the boresight misalignment necessary to derive the direct geo-referencing parameters of the LIFT aerial imagery. After performing the boresight calibration of the Meki field the aerial image acquisition for the LIFT Programme will commence. Provided the atmosphere is free of haze and dust as well as the light conditions are being favourable the day times with the sun angle 30 degrees and larger will be used completely for aerial photography. During each mission GPS based navigation will make use of the on-board GPS sensor coupled to the aircraft's directional gyro and to the on-board computer running the electronic flight information system. As mentioned previously the relevant UltraCam camera system is also connected to this circuit. This provides for maintaining control of crab, overlap and V/H (velocity/height). Prior to take-off the centres of exposures determined during mission planning will be downloaded to the computer via a PC data card. During the mission the pilot will be guided to each flight line and notified of the bearing and the distance to each exposure station (waypoint) via a display monitor. Photographs will be taken automatically, controlled by the system, ensuring that the actual photo centres fall within the GPS real-time accuracy tolerance of the pre-planned centres. During the flight missions the camera operator will have to monitor the system including the GPS receiver, and set and check all exposure parameters. At the end of a mission, the logged data will be written back to the PC data card for automatic plotting of flight line indices and analysis. The post-mission quick look analysis allows an early decision on whether or not a re-flight portion of the mission is required. After each mission the planned data within the management system of TrackAir is updated with the actual mission parameters contained in the exposure data and planned photo centres are updated to reflect true photo centres. POSPac MMS software will be used to extract the GPS recordings, which will be processed in order to calculate the DGPS photo centre co-ordinates. In addition, POSPac MMS software will be used as to check the quality of data and coverage. The POSPac MMS software is the necessary addition for the POSAV 510 system to precisely compute the position and attitude of the UltraCam camera which are projection centre co-ordinates together with the omega, phi and kappa angles recorded at the instant of exposure. The software will be the data handling and post-processing software for the Applanix POSAV 510 including all functions necessary for the handling

		and the evaluation of collected GPS and IMU data
1.7	Image Post-Processing	Once the images are acquired and a mission for a photo flight is complete, the imagery will be downloaded from the solid state disc pack to portable hard disks with a backup system. Microsoft UltraMap is a state-of-the-art, end-to-end, complete photogrammetric workflow system that provides highly automated processing capabilities to allow organisations to rapidly generate quality data products from one UltraCam flight. UltraMap is designed to handle all kind of projects ranging from projects with a few hundred images up to projects with ten thousands of images and it is optimized for UltraCam images. For this, it implements a new, revolutionary technology and concept of image handling, a direct spin off from the latest available Microsoft technology.The RawDataCenter is responsible for processing the UltraCam imagery from Level-0 to Level-2. By exploiting the distributed UltraMap Framework, processing tasks can be handled in parallel. The UltraMap Radiometry module is responsible for defining the final colour of the Level-2 input data. It also provides model-based radiometric correction to compensate for or remove hotspots, atmospheric effects and haze, exploiting Dragonfly technology for image interaction and visualization of large image blocks. The delivery of post-processed aerial imagery with regard to format (ie 24 bit TIFF RGB) and media will be according to requirements.
1.	**<u>Establishment of Ground Control Points</u>**	
	Hansa Luftbild recommends the post-flight ground control point determination. The recommendation is based on the experience gained during the 1st Acqusition Project of LIFT. For the 46,000 km^2 areas in Oromiya and SNNPR around100 ground control points will be chosen from the aerial photography to be newly acquired. This number of ground points will provide on average 25 points in each of the 4 aerial photography sub-blocks which were mentioned under section 1.3 of the proposed approach. The 100 ground control points will be used to triangulate and adjust the sub-blocks. The ground control will be surveyed and determined at an accuracy which is better than 10cm at the x and y coordinates and better than 20cm in the z coordinate. Hansa Luftbild is planning to contract the Ethiopian Mapping Agency (EMA) to determine and survey the 100 ground control points.	

2.	**Aerial Triangulation**
	Aerial triangulation is a process through which the exterior orientation parameters of aerial photographs are determined. Though these can be obtained through direct geo-referencing, the high accuracy standard requested in the terms of reference makes the application of aerial triangulation necessary. During aerial triangulation tie or pass points are collected and adjusted simultaneously with known ground control points. The automatic aerial triangulation method has become a standard procedure for aerial triangulation. In this method tie or pass points are collected and adjusted automatically. Hansa Luftbild has gained extensive experience in the field of automatic aerial triangulation by applying the technique in many projects. Hence the aerial triangulation with the automatic digital method will be applied using the INS and DGPS observations recorded during the flight missions. Aerial triangulation is the corner stone and the basis for quality assurance in any photogrammetric project. Without redundancy there is no way to guarantee the quality, i.e. the precision and reliability of the results. Ultimately the aim of the aerial triangulation is the determination of the best physical position and orientation of the camera at the instant of exposure. Automatic aerial triangulation will be carried out using MATCH-AT software of INPHO (Trimble). MATCH-AT is INPHO's advanced solution for highly automated aerial triangulation. It incorporates leading edge image matching technology that provides a high number of redundant tie-points over the entire block. This ensures very strong block geometry resulting in high precision and reliability. The time-consuming manual measuring and editing actions is reduced to a minimum. All components of the INPHO product suite (MATCH-T, OrthoMaster, etc.) have a smooth interface with MATCH-AT as it delivers the quality controlled orientation data sets for most of processing steps in a photogrammetric project. The main features are: - Handling of very large blocks - Sub-block handling with free block adjustment - Integrated block adjustment - GPS/INS data handling - Graphical representation of results for analysis of block - Support of various interfaces used in the photogrammetic community

Under MATCH-AT aerial triangulation can be divided in three tasks:

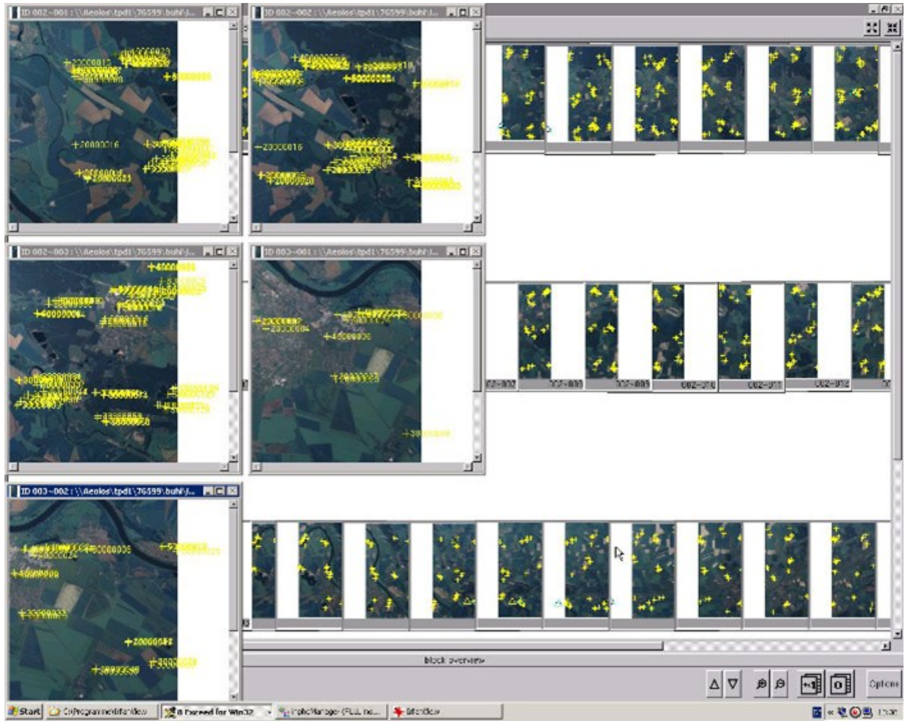
TASK	ACTIVITY	PROCEDURE
Preparation	GCP identification	Automatic/Manual
Data collection	Measurement	Automatic/Manual
Data processing	Block Adjustment	Automatic

First, the permanent calibration field at Meki, which was established by INSA, will be triangulated and adjusted in order to determine the boresight misalignment; this field is a small block consisting of less than 40 stereo models distributed over 4 strips. INSA uses this calibration field to calibrate the boresight and determine the misalignment of the IMU to the aerial imagery. The calibration field is covered with 25 ground control points which are used in the adjustment. After the adjustment of this calibration field the exterior orientation parameters of its images will be used to determine the boresight misalignment. That is, the misalignment angles between the IMU orientation and the camera orientation will be determined. The IMU is mechanically connected to the camera. This mechanical connection cannot be realized so precise such that the IMU and the camera have the same orientation. The misalignment angles are then applied to the orientation parameters, which are derived from the IMU/GPS processing, of all the aerial imagery covering a sub-block. The exterior orientation parameters will then be determined and prepared for the aerial triangulation of the relevant sub-block.

As mentioned previously POSPac MMS will be used to calculate the photo centre co-ordinates and the orientation parameters of all the aerial imagery, which is captured during the flight missions. The aerial image orientation parameters and the photo centre co-ordinates will be used as weighted observations during the aerial triangulation.

In MATCH-AT for each image clusters of tie points will be generated automatically at the 3x3 von Gruber positions. This would guarantee that at least 9 tie points will be available for each image inside the project area, even though experience has shown that at least 30 points per aerial image are usually matched and adjusted. Operator input will take place when matched tie points exhibit high residuals. Such an input will consist of the operator manually re-measuring the suspect tie points or measuring additional tie points in order to strengthen the ties in the blocks. PATB is integrated in MATCH-AT hence the bundle block method is used to adjust the photogrammetric blocks. Sigma of the adjusted blocks will be in the order of 1/4 of the pixel size.

During the aerial triangulation process of the sub-blocks a substantial amount of tie points (at least one hundred points in each sub-block) will be manually measured to be used as check points to qualify the accuracy and quality requirement of the orthophotos which are to be produced. These points will be adjusted with the relevant sub-block and its coordinates used to compare with the results of the ortho-rectification. These tie points will be chosen in clear areas were the objects which define the tie points can easily be measured in the orthophotos in order to assess later the level of accuracy.



Screen shot showing the tie points during aerial triangulation with MATCH-AT

	For each adjusted block/sub-block a report will be prepared and submitted which will include the details specified in the terms of reference and the complete adjustment report, which is generated through MATCH- AT, will be attached to the relevant report.
3.	**Elevation Capture and DEM Generation**
	A prerequisite for digital production of ortho-imagery, is that the camera shifts and tilts and the terrain heights of the area under survey should be known in advance. While the attitude determination of the camera is performed during IMU and GPS processing (ie INS/DGPS) and aerial triangulation, the terrain heights are obtained by generating a digital elevation model (DEM). Generation of DEM data for the 30cm GSD aerial imagery will take place applying the auto-correlation photogrammetric technique implemented in MATCH-T DSM. MATCH-T is Trimble INPHO's automated DEM generation environment providing highly precise digital terrain models derived from aerial imagery. MATCH-T automatically generates digital terrain models interpolated from extremely dense 3D point clouds which are extracted from the imagery. Best accuracy is achieved by applying advanced algorithms for image matching and data filtering. Some key features of MATCH-T: - Automatically derives digital terrain models from aerial and satellite imagery. - Extremely dense DEM by using feature-based matching techniques. - Automatic adaptive DEM grid width depending on the surface curvature. - Considers pre-measured morphological data (breaklines, 2D and 3D exclusion areas, borderlines). - Eliminates outliers, e.g. trees, houses, by robust finite element interpolation. - The project area may be subdivided into polygonal areas with individual, appropriate parametersettings for terrain type and terrain coverage.

Optimized point extraction by dynamic filtering of sensor noise.

- Increased number of points in poorly textured image areas through local auto-optimization of parameter settings.
- High quality terrain representation near break-lines by adaptive parallax bound strategy.
- Numerous functions for internal quality control.
- On-line epipolar image resampling:
  - No extra processing step
  - Necessary disk capacity reduced, no intermediate storage
- Several DEM exchange formats:
  - XYZ, SCOP RDH
  - Several other DEM formats are supported if MATCH-T is combined with DTMaster or Summit Evolution
- Support of analogue and digital frame sensors:
  - Flexible custom sensor definition
  - Predefined DMC and UltraCam sensors
  - RPC formats for IKONOS and Quickbird
- Image formats supported:
  - TIFF, TIFF JPEG
  - 8-12-16 bit
  - ECW (ER Mapper)

- Plug-in technology for third-party proprietary image formats

In addition MATCH-T can handle digital aerial photography of different radiometric resolutions such as 8, 12 and 16-bit. As the UltraCam sensor is already predefined in MATCH-T it is easily accommodated in the production process.

All auto-correlated elevation data will be checked and edited where necessary using INPHO's DTMaster. DTMaster provides up-to-date technology for fast and precise DEM editing and comes also as a photogrammetric DEM editing station (DTMaster Stereo).

DTMaster efficiently handles large amounts of DEM data with access to 10+ million points at the same time. Data is managed in an efficient layer-oriented data structure. Extremely fast and compact data handling is guaranteed through binary, tiled data storage. Some key features of DTMaster:

 DTMaster provides a comprehensive set of efficient tools for quality assurance of DEM data, including data visualization, numeric plausibility checking, as well as interactive data editing and 3D measurement:

- Visual data checking:

o Color Superimposition – DEM data overlaying raster imagery, such as

o Stereo imagery with automatic selection of best-fit stereo image pair**

o Orthophotos

o Digital maps

o On-line contour generation

o Perspective view with on-line 3D panning and draping of geo-referenced raster

imagery

o Hill-shading

o Z-coding

o Advanced side-view for easy interactive classification of LIDAR data, with on-line

panning and axial rotation

- Automated plausibility checks:

o Detection of line crossings

o Detection of height outliers

o Detection of gaps in a point cloud

- Automated data modifications:

o Thin-out algorithm

o Deletion of double points

o Semi-automated correction of line crossings

- Data editing and measurement :

o Editing in all views (stereo-, ortho-, perspective-, and side-view)

o Efficient editing of points and lines

o Stereoscopic measurement of points and lines

o Various editing functions for polygon areas (classification, deletion, constant height

setting, ...)

 DTMaster easily integrates into any production workflow by supporting numerous data formats:

- DEM data formats (import/export):

o XYZ, DXF, Winput, SCOP RDH (import),

o LAS (ASPRS Lidar Data Exchange Format),

o MATCH-T XYZ, MATCH-T RAS,

o ArcGIS Shapefile

- Geo-reference raster formats (import):

o E.g. orthophotos, digital maps

o GeoTIFF, TiffWorld (tfw)

o ERS (ER Mapper

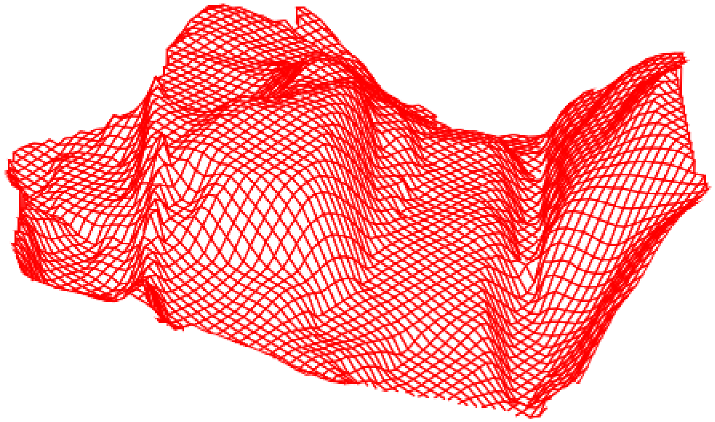
The checking and the editing facilities within DTMaster will be used to check for the quality and correctness of auto-correlated mass points. The following points will be fully considered during the DEM generation:

- DEM to be generated for the Project will just be used in the production of digital orthophotos
- DEM generation shall be in accordance with international standards
- DEM grid interval shall be 10 meters
- In each photogrammetric block 1000 check points are to be measured which will be used in the

quality control during orthophoto production

- Vertical accuracy of the DEM to be RMSE 1m at 95% confidence level (for bare earth)

If required by the client, then INSA will cut the DEM into tiles that match the size and the position of the tiles of the ortho-imagery.



Sample of a wire frame DEM

4.	**Digital Ortho-rectification and Mosaicking**
	In order to use aerial photographs e.g. as backdrop to vector maps or as photomaps, digital images of the terrain must be transformed into the geometry of the maps. The change of image geometry can only be achieved via the process of ortho-rectification. The most efficient and flexible approach to rectifying aerial photographs is differential rectification. In order to apply this approach an aerial image of the depicted terrain is first resolved in tiny or differential area units, usually squares. These small area units within the image are then geometrically transformed into an orthographic image projection while eliminating influences of camera tilt as well as relief displacement on the image geometry. As a prerequisite for

performing this process the camera tilts and the terrain heights must be known in advance.

Camera tilts will be obtained from the results of the aerial triangulation, elevation data (DEM) for differential rectification will be obtained through auto-correlation or height capture. Ortho-rectification of the digital aerial photography itself will be performed by means of Inpho's OrthoMaster.

The main features of OrthoMaster are:

− Orthophoto generation from aerial images (frame and line sensors), and from various types of satellite imagery.

− Automated processing of single images.

− Automated one-step batch processing of complete aerial image blocks; also in batch mode. Projects with 20000 aerial images and more can be processed in one go

− Orthophoto generation in pre-set area-of-interest; flexible definition/import of optimal ortho areas.

− Automatic ortho-area generation:

 For excluding fiducial marks from orthophotos

 By defining the overlap percentage of adjacent orthophotosOn-the-fly generation of hybrid grid-

based DEMs or TIN modelsDEM data import:

 SCOP DTM, Winput

 GeoTIFF, TiffWorld (tfw)

 ERS, JPEG2000 (ER Mapper)

 XYZ mass points, break/form lines

 DXF, NED Float

 ArcGIS Shapefile, ArcGIS ASCII Grid

 LAS (ASPRS Lidar Data Exchange Format) Import of multiple raw data files, and merging with SCOP functionality exterior orientation of single

aerial images by spatial resection.Refinement of orientation data of satellite imagery by interactive

measurement of control points.Output georeference formats:

 GeoTIFF, TiffWorld (tfw)

 ERS (ER Mapper)

Digital ortho-rectification transforms a digital aerial photograph into a digital orthophoto by means of mathematical relations between the different co-ordinate systems of the orthophoto, the terrain and the input image. Methodically founded on the mathematical model of projective relations, the transformation of the photographs from a central perspective to an orthographic projection is performed fully automatically.

Every single aerial image used in DEM capture will also be used in its entirety in the ortho-rectification process. This will guarantee a minimum level of image displacement.

The ortho-rectification will be carried out in batch mode. As an interpolation method the cubic convolution method will be applied because it will achieve superior results even though it takes longer to process.

Quality control checks will be carried out on each ortho-rectified aerial image. Hansa Luftbild is an ISO 9001 certified company and has accordingly its own quality control assurance procedures. These will be made available to INSA.

The check points measured during the aerial triangulation process will be measured in the orthophotos. The measured coordinates of the check points will be compared with the adjusted coordinates of the check points to determine the accuracy which has been achieved. Where coordinate differences exceed the specified RMSE value the reason for such differences will be analysed and errors will be rectified. Results of the quality control checks will be documented in the quality control records.

The ortho-rectified images will then be input to OrthoVista software in order to mosaic the entire block or sub-blocks, into one or more seamless image(s). Prior to mosaicking, the ortho-rectified imagery can be dodged to produce harmonised and balanced seamless ortho-image mosaics.

OrthoVista is a powerful professional mosaicking product in use world-wide. It utilizes advanced image processing techniques to automatically adjust and combine orthophotos from any source into one single seamless, colour-balanced mosaic.

OrthoVista automatically compensates for a wide range of image intensity and colour variations originating from the imaging process. It computes radiometric adjustments that compensate for visual effects within individual images, such as hot spots, lens vignetting and colour variations. Further, OrthoVista performs a blockwide colour balancing by adjusting adjacent images to match in colour and brightness. Multiple orthophotos are combined into one seamless, colour balanced and geometrically perfect ortho-mosaic. Key features of OrthoVista:

- Handles orthophotos from any source.
- Powerful intra-image tools for automatic:
  - Reduction of lens vignetting effects
  - Reduction of hot spot effects
  - Reduction of radiometric variations
- Powerful inter-image tools for automatic:
  - Block-wide balancing of colour & brightness (individual image characteristics preserved)
- Interactive editing of radiometric parameters:
  - Adjustment of intensity and contrast
  - Adjustment of colour and colour saturation
- Versatile seam line functionality:
  - Fully automatic seam line detection
  - Interactive seam line definition & editing
- Automatic feathering functionality:

	- Automatic adaptive width of the seam line - Narrow seam in “urban canyons” - Wide seam in open terrain Automatic tiling of the mosaic: - Mosaic is cut into map sheets Flexible processing procedure: - Processing steps done independently - Processing steps combined with each other Excellent processing capacity: - Handles very large orthophoto blocks Support for multi-channel imagery. Cut lines (seam lines) between images will in the main be defined automatically. Where necessary manual cut line definition will be applied in order to achieve a seamless image for each project area. For this task, OrthoVista Seam Editor for the interactive editing and manual definition of the seam lines will be used. Visual checks will be applied after mosaicking to guarantee homogenous geometry and radiometry across the orthophoto mosaic. After the visual checks are conducted cutting of the mosaic into tiles will be performed. Checking of the quality and accuracy of orthophoto mosaics for each block will be on the basis of the 100 check points measured during aerial triangulation and the 1000 check points during DEM generation. Tiling (cutting) of orthophoto imagery will be in accordance with the sizes to be defined by the client. The digital ortho-rectified image data with 30cm GSD will be delivered in accordance with the requirements of image format, i.e. TIFF with World File (TFW).
5.	**Quality Assurance Procedures**

	Hansa Luftbild is an ISO 9001 certified firm and as such will apply it quality control standards and procedures during the contract period. These standards and procedures are in line with international mapping and accuracy standards. Hansa Luftbild has included the proposed quality management plan with its QA manual for orthophoto production in the proposal (see Annex 2). Upon contract conclusion it will be finalised with INSA and EMA in order to apply it during project execution.
6.	**Project Management and Human Resources.**
	Hansa Luftbild will structure its project team in accordance with the services specified in the terms of reference. The team will be organized in line with the attached project management and organization chart (Annex 3 and Annex 4). All reports compiled and prepared for the services by EMA and INSA will be checked by Hansa Luftbild and the LIFT project management. Hansa Luftbild plans to temporarily deploy aerial photography, aerial triangulation and DEM and digital orthophoto production specialists in Addis Ababa to support INSA during the aerial image acquisition and orthophoto production. These specialists will be deployed at INSA premises in Addis Ababa. They will supervise INSA's aerial mapping engineers who will perform the project works. The specialists deployed at site will also provide know-how and transfer their knowledge to INSA and EMA, where and when necessary.
7.	**Reporting**
	Hansa Luftbild is an ISO 9001 certified firm and as such will apply it quality control standards and procedures during the contract period. The services to be provided and rendered require that project reporting follows standardised norms of review, revision, drafting and finalisation. The contents of all the reports including the progress reports will be defined by Hansa Luftbild and INSA in cooperation with the client and prepared and submitted in accordance with the terms of reference. Progress reports will be prepared and submitted to the client on a monthly basis. In addition to the progress reports a flight mission report as well as the final project report will be prepared and submitted.

	Coordination meetings will be conducted with the LIFT project management during project execution. The first meeting will be conducted to kick start the project and finalize the flight planning. Subsequent meetings will be to discuss the progress of works.
8.	**Work Plan and Schedule**
	INSA has prepared a tentative work plan and schedule for the execution of the project. The plan sees a total project duration of 9 months. Annex 5 shows a tentative work plan and schedule which was prepared by Hansa Luftbild based on the INSA plan.
10.	**Delivery of Products**
	All deliverables will be supplied to the client in the format and on the requested media as specified in the terms of reference (section 1.6 of the terms of reference). Hansa Loftily will be in cooperation with the client, INSA and EMA and prepare a delivery schedule. This schedule will be followed throughout the project execution. The following will be delivered by EMA and INSA: EMA - Final project report ground control determination and surveying with lists of coordinates and accuracies achieved INSA - Flight planning as plots at scale 1:100,000, as PDF files, and in ASCII/CSV and Trackair format and mission planning report in a text file format - Digital aerial photography in RGB (24 bit (each band 8 bit) RGB TIFF, uncompressed, untiled, no overviews); on external storage devices – non

returnable

- Processed IMU/GPS (GNSS) data (Excel sheet and CSV format or text format)
- Precisely surveyed (<1cm accuracy) xyz lever arms of GPS antenna to IMU
- Precise lever arms (<5mm accuracy) from IMU to camera
- Flight reports according to HANSA standard (sample of standard is attached to the Agreement)
- Flight index according to HANSA standard (sample of standard is attached to the Agreement)
- Calibration certificates from manufacturer of digital camera and IMU
- Flight mission report
- Aerial triangulation report
- Generated DEM (10m grid) on external storage devices – non returnable
- Orthophoto mosaics at 30cm GSD tiled and named in according to Ethiopian standard; on external

storage devices – non returnable

- DEM generation and orthophoto production quality control report
- Final project report.

UltraCamEagle - Technical Specifications

Image Product Specification

Image format	*Analogous to an aerial film image at a format of 23 cm x 15 cm, scanned at 12 µm*
Image data formats	*JPEG; TIFF with options for 8 and 16 bits, standard tiff format*
Image storage format in level 2	*Full resolution panchromatic, separate color channels at color resolution*
Color at level 3	*Full resolution R, G, B, Near-IR channels, planar or pixel-interleaved*

Camera Digital Sensor Subsystem

Panchromatic image size	*20,010 * 13,080 pixels*
Panchromatic physical pixel size	*5.2 µm*
Input data quantity per image	*842 Mega Bytes*
Physical format of the focal plane	*104,05 mm * 68,02 mm*
Color (multi-spectral capability)	*4 channels – R, G, B & NIR*
Color image size	*6,670 * 4,360 pixels*
Color physical pixel size	*5.2 µm*
PAN-sharpen ratio	*1:3*
Lens system 1	*Linos Vexcel Apo-Sironar digital HR*
Panchromatic lens focal distance	*80 mm*
Lens aperture	*f= 1/5.6*
Total field of view, cross track (along track)	*66° (46°)*
PAN Pixel size on the ground (GSD) at flying height of 1000 m (at 500 m)	*6.5 cm (3.25 cm)*
Color lens system focal distance	*27 mm*
Color lens aperture	*f = 1/4.0*
Total color field of view, cross track (along track)	*66° (46°)*
Lens system 2	*Linos Vexcel Apo-Sironar digital HR*
Panchromatic lens focal distance	*210 mm*
Lens aperture	*f= 1/5.6*
Total field of view, cross track (along track)	*28° (20°)*
PAN Pixel size on the ground (GSD) at flying height of 1000 m	*2.5 cm*
Color lens system focal distance	*70 mm*
Color lens aperture	*f = 1/4.0*
Total color field of view, cross track (along track)	*28° (20°)*
Shutter speed options	*1/500 to 1/32*
Forward-motion compensation (FMC)	*TDI controlled*
Maximum FMC-capability	*50 pixels*
Frame rate per second (minimum inter-image interval)	*1 frame per 1.8 seconds*
CCD signal to noise ratio	*72 dB*
Radiometric resolution in each channel	*>>12 bit*
Analog-to-digital conversion at	*14 bits*
Workflow dynamic	*16 bits*
Physical dimensions of the camera with 80 mm (210 mm) PAN lenses; including computer and storage module (CEDE)	*43 cm x 43 cm x 76 cm (86 cm)*
Weight of the camera with 80 mm (210 mm) PAN lenses; including computer and storage module (CEDE)	*~ 75 kg (~ 80 kg)*
Power consumption at full performance; including computer and storage module (CEDE)	*350 W*

Camera Computer And Data Storage Subsystem (CEDE)

Concept	*Modular stack, stacked onto sensor head or released with cabling to sensor head*
In-flight storage system	*Solid state disc pack, optional storing of mirror images of the data on the DE unit*
In-flight storage capacity	*Unlimited with use of multiple data units DE; per DE unit ~3.3 TB, ~ 3,800 images*
Weight of DE unit	*< 3 kg*
Method of exchanging DE units in-flight	*In less than 2 minutes*
Physical dimensions of CEDE module	*Width 43 cm x Depth 43 cm x Height 35 cm*
Weight of CEDE	*< 30 kg*
Power consumption at full performance	*150 W*

Camera Operational Specification

Data recording time @ 10 cm GSD, 60% forward overlap, 140 kts	*8 hours per DE unit*
Max. forward overlap @ 10 cm GSD (@ 5 cm GSD) with 140 kts	*90 % (80 %)*
Max. flight speed @ 10 cm GSD (@ 5 cm GSD) with 80% forward overlap	*268 kts (134 kts)*
Data transfer from aircraft to office	*Shipping of DE, or transfer by high capacity storage medium*
Post-processing of collected raw images	*UltraMap, UM/AT extension, PC network or Laptop*

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Photogrammetric Production	*TIFF-output compatible with Customer's photogrammetric production software*
Extended Ortho Workflow	*Full ortho workflow by GXL Aerial*
Mounting of the camera	*Using adapter ring for all current film camera mounts (UltraMounts, PAV-30, -80, T-AS)*
Integrated GPS/INS/FMS system	*Applanix POSTrack OEM full embedded into camera head*
Flight planning support (external FMS)	*Compatible with all major commercial systems (TrackAir, CCNS-4, ...)*
Exterior orientation support (external GPS/INS system)	*Compatible with all major DGPS/IMU systems (Applanix POS-AV , IGI Aero-Control, …)*
Image geometric accuracy	*Better ±2 µm*

***For more Information, contact*:**
Microsoft Photogrammetry Division
Anzengrubergasse 8
A-8010 Graz, Austria
mpsinfo@microsoft.com |
www.iFlyUltraCam.com

Quality Management Plan - Table of Contents

1 Key Issues

Based on the terms of reference there are 3 key issues that are essential to achieve the aims of producing the orthophotos: image capture (aerial photography), ground control determination as check points, IMU and GPS processing, DEM generation and ortho-rectification.

1.1 *Image Capture*

Considering the overall objective to produce digital orthophotos the aerial photography is considered as the initial result number 1.

It is most important that this result is

- of perfect image quality (sharpness, contrast, colours, …)

- without any clouds, cloud shadows, haze or snow coverage

- covering the project area without any gaps

1.2 *IMU and GPS Processing and Aerial Triangulation*

Considering the overall objective to produce digital orthophotos the aerial triangulation with direct- geo-referencing is considered as the intermediate result number 2.

It is most important that this result is

- the output of IMU and GPS processing in terms of the geodetic reference system is specified in the terms of reference. The accuracy of the INS/DGPS will determine the final accuracy of the DTM and orthophotos;

- achieved after processing IMU and GPS data with RMSE better than 15cm for the 30cm GSD aerial photography;

- the output of the aerial triangulation using the ground control check points are the exterior orientation parameters with RMSE 1/4 x pixel size (30cm).

1.3 *DEM Generation and Ortho-rectification*

Considering the overall objective to produce digital orthophotos the ortho-rectification of aerial photography is considered as the result number 3.

It is most important that this result is

- obtained by DEMs generated from captured height data with a 10m grid and break lines, and accurate to give errors in accordance with ASPRS accuracy standards;

- orthophotos with a ground sampling distance of 30cm and accurate to give errors in accordance with ASPRS accuracy standards;

- of perfect image quality; and

- the outcome of seamless mosaics cut into tiles.

1. **Strategy**

2.1 *Approach proposed for Contract Implementation*

The implementation stage of a project is recognised by the quoting company as the most critical stage, as the results of the project planning phase, the specifications and the technical feasibility have to be reflected against each other and updated to agree on a consistent operational plan for the execution of the project.

The most important steps of this phase are in line with the PCM guidelines of the European Commission which are the following:

- Conclude contracting arrangements

- Mobilize resources

- Establish working relationship with stakeholders

- Hold inception meeting

- Review and revise project plan

Besides the contracting arrangements there will be a plan presented to the client on the steps of mobilizing resources to the project. While the project manager will be active in the project from the beginning, some of the experts will only be involved during the respective period of activities in their field of expertise. The project manager will be active throughout the whole project duration.

The inception plan will be prepared and later discussed during the inception meeting. A full implementation will only take place once all parties agree to the steps of project execution.

2.2 *Proposed Activities to achieve Contract Objectives*

There are three main groups of activities within the frame of the project:

a. Carrying out aerial photography with the following components:

- preparatory work and flight planning of aerial photography for the entire project areas;

- capturing digital colour aerial photography;

- delivery of flight line indices etc.;

- quality control of aerial photography.

b. Carrying out IMU and GPS processing and aerial triangulation:

- processing of IMU recordings and airborne GPS data using GNSS constellations;

- delivery of INS / DGPS photo centre co-ordinates, and accuracy report;

- performing aerial triangulation using ground control points as check points to adjust the photogrammetric blocks;

- delivery of exterior orientation parameters with the stereo imagery.

c. DEM generation and ortho-rectification:

- creation of DEM for orthophoto production;

- production of digital colour orthophotos;

- quality control of digital orthophotos;

- delivery of digital terrain data and digital colour orthophotos of the project areas

.

In addition to the main activities explained above there are several management activities like

- production and delivery of all required reports (project plan, aerial photography report, progress report, and orthophoto production report);

- observation that all activities are according to the agreed to time schedule.

2.3 *Inputs and Outputs*

To achieve the three main outputs of the project several inputs are necessary. These inputs will be checked by the quoting company.

Inputs	Outputs
- digital aerial photography (30cm GSD)	- Delivery of *.tif files, 8 bit x 3 band imagery - Stereo models compatible with INPHO software
− IMU / GPS data (air data) − Processing of INS / DGPS data to get projection centre coordinates and orientation angles for each aerial photo − Determination of ground control points − Aerial triangulation to obtain the final exterior orientation parameters	- Delivery of ASCII-file with: image-no., X, Y, Z, omega, phi, kappa and in EXCEL sheet format
- DEM capture and generation (10m) - Additional manual measurement of break-lines - Digital ortho-rectification (GSD = 30cm) - Production of orthophoto mosaics	- DEM in format compatible with INPHO software for DTM generated from aerial imagery - DEM; TIN and other outputs (optional) -Seamlines in Shape file format Delivery of *.tif and *.tfw-files

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Quality Assurance Procedures

3.*1 Production Flow Chart*

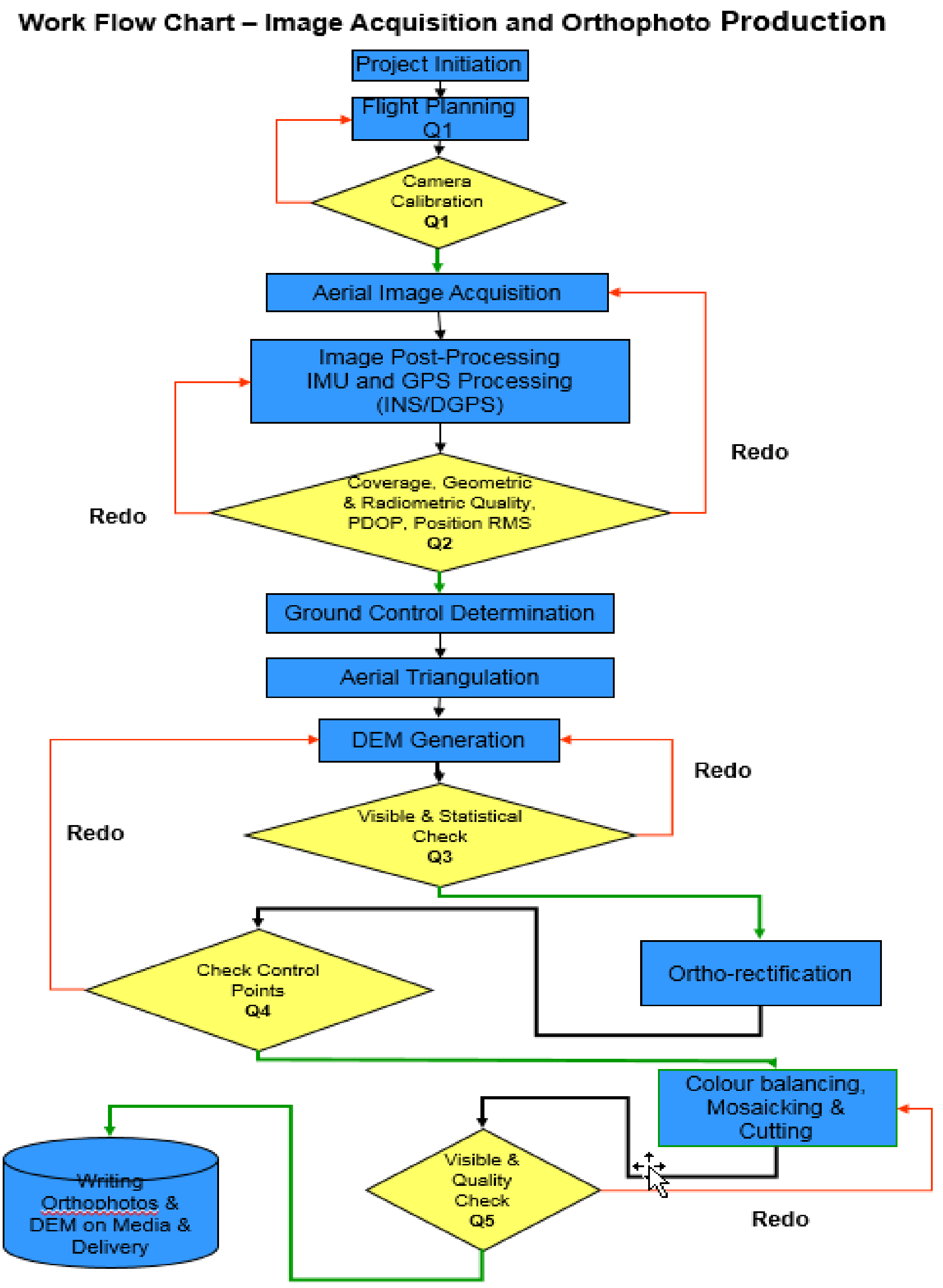
Based on the key issues raised in section 1 and the strategy mentioned in section 2 a production flow chart has been established showing the steps and processes involved in producing the digital aerial photography, DEM creation (and editing), and orthophotos production. Figure 1 shows the flow chart which will be applied during project execution.

3.2 *Quality Control Procedures*

The flow chart clearly shows the quality procedures which will be applied when producing the products. These procedures are described in detail in Appendix I.

At each production step a Qn procedure will be carried out and the results of it will be documented in a quality control report (QCR).

Figure 1: Flow chart showing steps involved in orthophoto production - on the next page


Work Flow Chart – Image Acquisition and Orthophoto Production
Project Initiation
Flight Planning Q1
Camera Calibration Q1
Aerial Image Acquisition
Image Post-Processing IMU and GPS Processing (INS/DGPS)
Redo
Redo
Coverage, Geometric & Radiometric Quality, PDOP, Position RMS Q2
Ground Control Determination
Aerial Triangulation
DEM Generation
Redo
Redo
Visible & Statistical Check Q3
Check Control Points Q4
Ortho-rectification
Colour balancing, Mosaicking & Cutting
Writing Orthophotos & DEM on Media & Delivery
Visible & Quality Check Q5
Redo

1.	**Appendix** ACRONYMS AND ABBREVIATIONS ASCII American Standard Code for Information Interchange AT Aerial Triangulation BI Bilinear Interpolation CAPI Computer Assisted Photo-Interpretation CC (bi-)Cubic Convolution DEM Digital Terrain Model DGPS Differential Global Positioning System DPW Digital Photogrammetric Workstation GCP Ground Control Point GIF Graphics Interchange File GIS Geographic Information System GPS Global Positioning System GSD Ground Sampling Distance GUI Graphical User Interface IACS Integrated Administration and Control System IDQA Input Data Quality Assessment IMU Inertial Measurement Unit INS Inertial Navigation System NN Nearest Neighbour OS Operating System PRESS Prediction Error Sum of Squares QA Quality Assurance QC Quality Control QCR Quality Control Record RF Representative Fraction RMSE Root Mean Squared Error TIFF Tagged Image File Format TOR Terms of Reference
2	**Appendix** DEFINITIONS Within the separate literature on geometric correction of orthophoto images, map accuracy assessment and photogrammetry and map production, different terms are sometimes assigned the same meaning when they can usefully be assigned more precise and distinct meanings (e.g. discrepancy and residual). The following definitions apply to terms as used in this document and have been phrased, where possible, to be applicable to aerial photography rectification and mapping. Cross references to other definitions are indicated with italics.

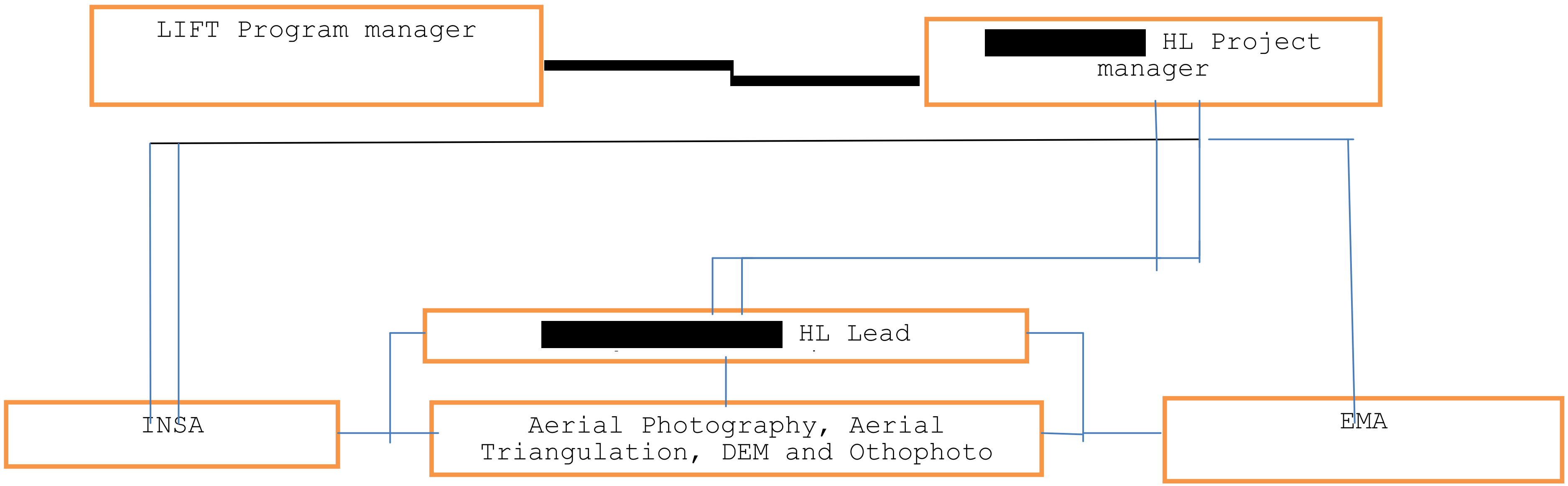
Term	Definition
Accuracy	Accuracy is the relationship of a set of features to a defined reference system and is expressed as the rms error of a set of derived points (if possible expressed as a ground distance in metres, but sometimes given as pixels or microns).
Aerial Triangulation	The process of aerial triangulation is the densification of geometric control to the individual stereo-model level by the identification of ground co- ordinates for tie points based on the network of known survey data. This process computes a project-wide network of control and confirms the integrity of the ground control points.
Blunder	See Error
Block	Two or more image strips having a lateral overlap, usually a set of aerial images.
Check point	A well-defined ground reference point used for checking the accuracy of a geometrically corrected image or image mosaic. The location accuracy of the check point must exceed the tolerable accuracy of the image by a factor of at least three. Check points must not be the same as GCPs and must not be used in the geometric correction process.
Discrepancy	A discrepancy is the linear distance between a point on the image and a check point. A discrepancy is not the same as a residual; because a discrepancy is an error at each point measured using a reference point known to a higher order of accuracy.
Error	Geometric error in an image which has been corrected to fit a map projection. Three classes of error are commonly recognized: A random error is not predictable at any given location but the population of random geometric errors commonly follows a normal (Gaussian) probability distribution. If random errors are normally distributed the mean error is zero for a large sample of points. A systematic error is predictable at any given location once it has been identified and its pattern of variation is understood. For a large sample of points, a mean error that is not zero can sometimes indicate presence of a systematic error. A blunder is a (large) error at one location arising from a mistake or equipment fault whilst marking the location or recording its co-ordinates. An error at a single point that exceeds 3 x standard deviation of a large sample (0.13% probability) is usually due to a blunder.
Exposure Station	The planimetric position of an aerial camera at the time of film exposure. Usually expressed as the ground co-ordinates at nadir.
Geo-coding	Synonym for ortho-rectification, but more commonly used when discussing SAR data. Generally avoided here because the same word is also used for automatic postal address matching in GIS.
Geometric correction	Informal term for rectification.
Geo-referencing	The process of assigning ground co-ordinates to an image. This process does not change the image grid.

Ground control point	A well-defined point used for orientation and rectification. The position of a GCP is known both in ground reference co-ordinates and in the co-ordinate image to be corrected. If 2D (x,y) ground reference co-ordinates are given, it is a horizontal or planimetric GCP; if the height (z co-ordinate) is kr the point is a vertical GCP.
Ground Reference	The source used to obtain ground reference co-ordinates for a ground control point or check point. May be a topographic map, a field surv triangulation, a geodetic bench mark, a field survey by GPS, or a geocoded image. Ground reference co-ordinates are given in (or converted to) th national map projection.
Image	A digital earth observation picture in raster form may be scanned from an aerial photograph or produced directly from a satellite sensor.
Interpolation	Method used to estimate a pixel value for a corrected image grid, when re- sampling from pixel values in the original grid. Common methods a nearest neighbour, bilinear interpolation and cubic convolution.
Model	Contraction of Stereoscopic Model.
Object catalogue	Catalogue defining how objects are geometrically represented and what attribution shall be applied for it.
Object class	Geometry types of an object in GIS, these could contain a point, line or polygon features.
Orientation	Orientation can have two or three stages. Interior orientation establishes precise relationships between a real image and the focal plane of a perfect imaging system. Relative orientation establishes precise relationships between the focal planes of a perfect stereo-pair to establish a precise stereo-model Absolute orientation establishes a precise relationship between the stereo- model and a geographic reference system (map projection). Absolute orientation follows relative orientation. Exterior orientation establishes precise relationships between the focal plane co-ordinates and a geographic reference system (map projection). It car achieved by relative and absolute orientation or can be carried out in a single step.
Ortho-rectification	Rectification of an image (or image stereo pair) using 3D ground reference and a DEM to position all image features in their true orthographic locations process eliminates displacements due to image geometry (especially tilt) and topographic relief, and results in an image having the same geometric properties as a map projection.
Pass point	A synonym for tie point.
Pixel size	Distance represented by each pixel in an image or DEM in x and y components. Pixel size can be expressed as a distance on the ground or a distance c scanned hardcopy (e.g. microns). It is not a measure of resolution.
Polynomial rectification (also called Warping)	Rectification of an image to a ground reference using horizontal ground control points. It assumes that the local distortion of the image is uniforn continuous since it ignores effects of terrain.

PRESS	The cross validation estimate or 'jacknife method', also referred to as the Prediction Sum of Squares (PRESS) statistic. In this statistic the best-fit model is refitted 'n' times. Each time it is fitted to a subset of the GCPs from which one point has been removed. By using the best fit to all the other points, the predicted location of the omitted point is computed and the difference from its actual location is then obtained. The average of these squared differences computed on the complete set of 'n' differences is the PRESS value and the square root provides a figure in the measurement units of the residuals.
Precision	The precision of a GCP or check point is the standard deviation of its position (in x, y and z) as determined from repeated trials under identical conditions. Precision indicates the internal consistency of a set of data and is expressed as the standard deviation. Note: Data can be precise yet inaccurate; precision is not used when comparing a set of data to an external reference, RMSE is used to express this.
Principal distance (f)	Also known as the camera constant (c). The calibrated perpendicular distance from the exit node of the lens to the focal plane. This value is imilar to the focal length, which is a property of the lens.
Rectification	The process of resampling pixels of an image into a new grid which is referenced to a specific geographic projection, using a spatial transformation (matrix). The resampling is achieved through interpolation.
Registration	Rectification of an image to conform to another image.
Residual	A residual is the linear distance between a fixed reference point [ground control point] and the position determined by the transformation applied to the observed data to give a best fit to the reference points. Note: This is not the same as a discrepancy because the computed error of a residual is based only on the internal (statistical) consistency of a set of points and not on comparison to independent locations known to higher accuracy. The smallest visible separation between similar objects that can be clearly reproduced by a remote sensing system – usually expressed as the resolution resolving power
	For small samples (n < 30) this is not the same as the rms error. If there is no systematic error, standard deviation is equal to the RMSE for large samples. Or some sample s (n<30) this is not the same as ms error. If there is no systematic error standard deviation is equal to RMse for large samples Or small samples (n<30) or if the systematic error is present, this is not the same as standard deviation of the mean discrepancy
RMSE (Absolute)	RMSE based on check points obtained from a ground reference of recognized higher accuracy.
Standard Deviation	The square root of the variance of n observations, where the variance is the average of the squared deviations about the estimate of the true mean value. –
Stereoscopic Model (or Stereo model)	Three-dimensional model created by viewing or analyzing the overlapping area of two images obtained from different positions.

Tie points	Points that appear on the overlap area of adjacent images. They are used for orientation and aerial triangulation.
Tolerance	The tolerance is the permissible degree of error in a geometrically corrected image or mosaic as determined using a well distributed set of check points. Tolerance is specified with two values: a) the maximum allowable RMS error of all check points b) the maximum allowable discrepancy at any check point.
Warping	Synonym for Polynomial Rectification

Annex 3 -Project Management and Organization Chart



Please note that the chart assumes that EMA will carry out the ground control

	Roles and Responsibilities of Proposed Staff The following project team will be assigned by Hansa Luftbild to supervise and manage the works:

		Years of experience (general)	Years of experience proposed position	in
Project Manager	[redacted]	41	24	
Lead Photogrammetrist DTM and Orthophoto Specialist	[redacted]	17	17	
Aerial Mapping Engineer	[redacted]	33	20	
Airborne Image Acquisition Manager	[redacted]	23	17	
Aerial Photography Specialist	[redacted]	11	8	
Senior Flight Planner	[redacted]	38	17	
INS/DGPS Data Processing and AT Engineer	[redacted]	34	22	
Senior Surveyor / Aerial Triangulation Specialist	[redacted]	16	12	
Senior Surveyor / DTM and Orthophoto Specialist	[redacted]	16	12	

	The work plan is attached separately – see annex 1 – page 111

Quality Assurance Manual for Orthophoto Production

Chapter 1: The proposal

1.1 This Proposal

This proposal contains procedures which the supplier will implement in order to control and assure the quality of ortho-rectified imagery. These procedures apply to digital aerial photography for applications related to orthophoto production. All stages of the production chain affecting geometric accuracy of the final product considered, including data capture specifications.

1.2 Justification and Applicability

The purpose of this proposal is to set out definitive and robust methods for effective quality assurance of ortho-imagery.

1.3 Nature and Scope of these Procedures

The nature of these procedures is to be prescriptive that is: to state what will be done. These procedures avoid assumptions that specific software or equipment will be used. However, in order to assure the quality it has been assumed that equipment/software possesses certain features or functions.

The scope of these procedures is defined both by the processes to be considered and by the type of image data to be processed.

The process scope relates to the control and quantification of positional errors in all aspects of geometric correction from acquisition to use of digital products. It also controls the capture of geographic data based on stereo aerial imagery.

The data scope is shown in the table 1 below

Image Type	Resolution	Channels for Raster - RGBI	Equivalent Output Scale	Notes
Aerial Photography	30cm	Colour Raster	1:3,000	Scope of work for medium scale orthophotos: colour aerial photography, DEM generation, ortho-rectification, mosaicking to seamless blocks and cutting into tiles

Table 1 Scope of Data Sources

1.4 Geometric Correction Overview

Several GIS applications allow digitisation of map features directly from various remotely sensed data sources (aerial photography, satellite images, etc.). In order to collect accurate features, it is necessary to remove geometric distortions caused by platform orientation, sensor anomalies and variations in the underlying terrain. The removal of these distortions is achieved through the geometric correction process.

Aerial imagery is usually ortho-rectified, whereas some satellite imagery can be corrected using a simpler (but less rigorous) polynomial warp based on a statistical best-fit to ground control points.

Required inputs to the ortho-rectification process are:

- image
- orientation parameters
- digital elevation model (DEM)
- Details of the sensor, and systematic anomalies.

The workflow to achieve the final results consists of the following production steps:

- flight planning
- colour image capture (digital aerial photography)
- post-processing of captured image data
- processing of IMU and GPS data
- ground control determination
- aerial triangulation
- DEM capture and generation
- ortho-rectification, colour balancing, mosaicking and cutting of ortho-imagery into tiles (orthophoto maps)

1.5 Report Contents

Chapter 2 specifies practical tolerances and levels of accuracy required for the final products. Chapter 3 provides a specification for Internal QA and Quality Auditing of aerial ortho-image production.

2 Requirements

2. 1: Quality Assurance

Quality assurance (QA) is a set of approaches, which is consciously applied and, when taken together, tends to lead to a satisfactory outcome for a particular process. A QA system based on these guidelines will employ documented procedural rules, templates and closely managed processes into which various checks are built. Quality controls (QC) and quality audits are important checks within a QA system. The bidding company will be responsible for internal quality assurance procedures (also called on-line or producer QA) and the client will be responsible for external quality assurance procedures, including acceptance testing

2.1.1 Quality Control

A quality control is a clearly specified task which scrutinises all, or a sample of the items arising during, or at the end of the ortho-rectification or mapping process in order to ensure that the final product is of specified quality. The scrutiny involves review, inspection or quantitative measurement, against well-defined pass/fail criteria which are set out in these procedures.

2.1.2 Quality Audits

A quality audit is a qualitative quality control which covers an area of activity as a whole. Quality audits will be carried out by comparison of actual practice with the applicable quality assurance procedures contained in this document.

2.1.3 Quality Control Records

The information used in a Quality Audit will mainly be provided by quality control records (QCRs) which are generated during the work, by the people doing the work. QCRs take a variety of formats, such as paper forms completed manually, printouts or computer files recording the result of a particular procedure, or hand-written records in log books.

The key features of any QCR are that it

- is marked with a date
- uniquely identifies the item, operation or product to which it relates
- identifies the operator who generated the QCR
- may be countersigned by a supervisor or other independent scrutinizer (only for the most important records)
- is stored in a well-defined and predictable location so that it can be found easily by others.

These procedures identify the essential (minimum) set of QCRs required for QA of geometric correction and mapping.

2.2 QA Phases

Procurement of ortho-rectified imagery and mapping by the client occurs through a process of competitive tendering. The technical execution of the work is therefore not directly under the control of the client so the QA process takes this into account. There is a sequence of three activities which can be controlled by the client and which affects the quality of the outcome:

a) Technical specification and tender evaluation
These procedures can be used to separate work components that are explicitly requested in the invitation to tender and those that are looked for in the response.

b) Quality Control during ortho-rectification, including input data
The purpose of QC during this work is to identify potential problems early. Potential problems are defined as those which could cause the geometric or capture error in a product to exceed the specified tolerance. Internal quality assurance will be the responsibility of the contractor and will result in the production of QCRs. External quality assurance will be carried out by a representative of the client who is independent of the contractor. The External QA will consist of audits (physical checks of conformity to specifications and scrutiny of QCRs produced by the Internal QA) and a limited amount of sample-based QC.

c) Measurement of geometric error in the output ortho-images
An independent quality check will be carried out by the client on a sample of orthophoto in order to establish an overall accuracy. The acceptance criteria for this check are the tolerances stated in the technical specifications.

2.3 Ortho-rectification Requirements

Ortho-rectification tolerance is defined using two parameters: the maximum permissible RMSE of the check points and the maximum permissible discrepancy of all check points. Note: it is important to refer to the Definitions in order to understand terminology in this section correctly.

Tolerances and accuracies are stated in the technical specifications as follows:

DEM (Created from Aerial Imagery)

Orthophoto Ground Resolution	DEM Resolution	DEM Accuracy (meters) 95% Level
30cm	10m	1m

Orthophoto

Orthophoto Ground Resolution	Orthophoto Map Scale	Orthophoto Accuracy (meters) 95% Level
30cm	1:3,000	73.2cm

Conformance with tolerances will be assessed on a sample of images using independent measurements of image accuracy using check points which are at least twice more accurate than the tolerance.

3 AERIAL IMAGE ORTHO-RECTIFICATIONS QA

3.1 Introduction

This section specifies the process of creating digital orthophotos from digital aerial photography using a DEM generated from aerial photography.

3.2 Input Data

The quality of materials and equipment which will be used to create the input data is critical to a satisfactory result. Digital processing will carry out an input data quality assessment (IDQA) which will check that the images were captured and processed correctly

Table 2 below:

Item	Specification	Internal QCR/QA
Camera Q1	High quality, large format digital aerial camera with forward motion compensation and computer controlled exposure.	Physical inspection. Date-stamped camera calibration certificate (not older than 2 year)
Flight Navigation Q1	Camera linked to IMU and on-board navigation system. GPS controlled photo logging.	Physical inspection. Inspection of flight log data
Post-processing of captured airborne image data Q2	Software used to process captured raw airborne data.	Analysis of histogram and checking dynamic range.
Overlap Completeness Overlap variation Q2	Forward 70%, lateral 40% 100% coverage with specified overlap <±5% for forward and 10% for lateral	Analyse log of photo centres and flying height for conformance with completeness, overlap and scale variation
Image Ground Resolution Q2	30cm GSD Tolerance ±15%	Analyse log of flight missions with flying height and ground height to determine actual GSD achieved

Table 2 Specification for Aerial Photography Acquisition - Note that Table 2 does not include radiometric QA and QC, however these will be performed.

Post-processing checks will examine image histograms to ensure that the available dynamic range is fully used but without saturation or cut-off. Initial checks will ensure that solar angles relative to the flight direction and time are acceptable to avoid excessive glare/shadowing, and that individual photos are free of cloud and have sufficient contrast in the features of interest.

Input files will be self-documenting (e.g. flight, photo number) as specified in the technical specifications, with additional metadata in tables linked to the file name. The following information will be recorded:

For each flight: Camera identifier and calibration certificate, weather conditions

For each photo: Flight identifier, image number, ground resolution, ground co-ordinates of exposure station (from GPS), time and date of exposure

3.3 INS / DGPS Processing and Aerial Triangulation

Source

The source of data will be the recordings of the IMU, the airborne GPS dual frequency receiver and the precise satellite orbits and clocks data. The software to be used in this process is POSPac MMS.

Method and Checks - Table 3

Purpose/Method	Accuracy Checks and Tolerances
Obtaining the orientation parameters from boresight calibration Q2	PDOP, position accuracy and it RMS, number of satellites (BAR) and the quality factor
Ground control points (GCP)determination for check points Q2	GCP absolute accuracy: horizontal better than 10cm, and vertical accuracy than 20cm
Processing and adjustment Q2	RMS < 15cm for 30cm GSD
Aerial triangulation Q2	RMS 1/4 of pixel size (30cm)

Table 3 Method of determining the exterior orientation parameters and accuracy checks

3.4 QCRs and Quality Audits for Aerial Image Ortho-rectification

The following QCRs will be generated by the bidder for its Internal QA. They will be made available for inspection, if required, during a quality audit by the client. The type of quality audit is shown in Table 4 as "Normal" or "Tightened".

"Normal" audit checks which are carried out 'Once' will be repeated again if a corrective measure is requested.

"Tightened" audit checks will follow an audit trail for suspect products or regions and could be introduced if

earlier audits result in doubts about performance results from QC do not meet the specifications given in previous sections results from External QC do not meet the tolerances in the technical specifications.

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Development

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