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USGS QUALITY ASSURANCE PLAN FOR DIGITAL AERIAL IMAGERY

DIGITAL AERIAL SENSOR TYPE CERTIFICATION

Certification Report for the M7VI Iris One 50™ Aerial Camera System

October 2009

science for a changing world

DIGITAL AERIAL SENSOR CERTIFICATION REPORT FOR THE M7 VISUAL INTELLIGENCE IRIS ONE 50™ DIGITAL AERIAL CAMERA SYSTEM

Reviewed By:

26 Oct '09

George Y.G. Lee — Date
National Raster Program Manager
National Geospatial Program
U.S. Geological Survey

10/6/09

Michael G. Benson — Date
Remote Sensing Technologies Project
Earth Resources Observation and Science Center (EROS)
U.S. Geological Survey

Reviewed and Approved By:

10/15/09

Joe McCoy — Date
IRIS One 50 Program Manager
M7 Visual Intelligence

10/6/09

Gregory L. Stensaas — Date
Project Chief, Remote Sensing Technologies Project
Earth Resources Observation and Science Center
U.S. Geological Survey

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1 Executive Summary

This document is a record of the U.S Geological Survey (USGS) certification of the Iris[1] One 50™ digital aerial imaging system manufactured by M7 Visual Intelligence. The USGS Certification team visited M7 Visual Intelligence (hereafter referred to as M7VI) in Houston, Texas July 14 - 16, 2009 (3-day review). The primary purpose of the visit was to ascertain and verify M7VI's answers to USGS Manufacturer Certification requirements contained in the manufacturer certification document and checklist provided to M7VI prior to the visit. This visit was conducted under Technical Assistance Agreement No. T-09-707 (ACIS Ref. ID: 9548) between M7VI and the USGS signed October 20, 2008. This TAA allows M7VI to undertake USGS Certification of the Iris One 50™ imaging system.

The Iris One 50™ (hereafter referred to the Iris system) is based on an architecture designed and patented by M7VI [USPatent2005a]. The Iris is a multi-camera system comprised of the Arched Retinal Camera Array (ARCA™), five digital camera modules and an acquisition computer (with sensor control hardware and software).

Key components of the Iris system are manufactured and assembled by qualified suppliers under contract to M7VI. Individual subsystems of the Iris system are integrated and tested at M7VI's facilities in Houston, Texas. The overall system is assembled at the M7 Aerospace's facilities in San Antonio, Texas. The finished product is calibrated, tested in the laboratory, and field-tested at M7VI's facilities in Houston, Texas.

The Iris system is based on a modular and scalable design using one to five individual camera modules. When using three cameras, the system is known as the Iris One 30™ system and with five camera modules it is the Iris One 50™. This USGS certification pertains to the five-camera system and configuration.

The Iris™ and ARCA™ basic concepts, designs and prototype sensor implementations have been in operation since 2003. The Iris system was introduced to the international mapping market in August 2009.

The USGS team found the Iris One 50™ system to be designed, manufactured, tested, and supported to the level required to meet the performance claims of the manufacturer when operated within manufacturer's intended operational parameters. When operated properly by technically qualified operators and processors, this system is capable of delivering orthographic digital aerial data.

[1] All proprietary names used throughout this report (e.g. Iris, ARCA, Isis, etc.) are trademarked property of M7 Visual Intelligence whether or not accompanied by the ™ indicator in this report.

2 Purpose and Report Organization

This report summarizes the information provided by M7VI to the USGS and also information gathered through observations made by the USGS team during the visit to the M7VI facility in Houston, Texas. Proprietary information has not been included in this report. ***Inquiries for technical information beyond what is in this report should be made directly to the manufacturer.***

The USGS team was provided numerous presentations, technical information, datasheets, and documentation material by M7VI prior to the visit, during the visit, and subsequent to the visit to M7VI. The team also took considerable notes during the visit, reviewed system data and components and researched outside sources of information needed to augment a complete understanding of the Iris system. The team notes and various materials contain M7VI proprietary information and are not included in this report but are kept on file within the USGS for future internal reference.

The remainder of this document is organized as follows:

Section 3: Site Visit - provides an overview of the trip to M7VI, dates and personnel involved.

Section 4: Manufacturer's System - provides the system description and design, operational concepts, intended use and the quality program for the system.

Section 5: Documentation - provides a synopsis of the documentation provided to the USGS, including the documentation submitted in the certification effort.

Section 6: USGS Findings - provides the findings of the USGS Certification team.

Section 7: Technical Specifications - provides the Technical Specifications for the Iris One 50™ System.

Section 8: References - provides a list of references.

3 The Site Visit

The USGS Digital Sensor Type Certification Team traveled to Houston, Texas July 14 - 16, 2009 to meet with staff from M7VI and visit the integration site where critical elements of the Iris One 50™ are tested and calibrated.

The USGS Certification team included the following personnel and expertise:

- Gregory Stensaas, USGS Remote Sensing Technologies Project Chief, EROS Center, Sioux Falls, SD – Certification Lead, Manufacturing and Quality Assurance
- Michael Benson, USGS, Remote Sensing Technologies Project Team, EROS Center, Sioux Falls, SD – Imagery and System Processing
- Dr. George Lee, USGS National Geospatial Program, Menlo Park, California – Camera Design and Operations
- Donald Moe, SGT, Contractor to the USGS EROS, Sioux Falls, SD – System Geometry and Photogrammetry
- Jon Christopherson, SGT, Contractor to the USGS EROS, Sioux Falls, SD (absent) – Systems Engineering and Spatial/Radiometric/Optical Engineering

M7VI staff that presented material and answered USGS questions included:

- Dr. Armando Guevara – President & Chief Executive Officer (System Architect)
- Joseph McCoy – Product Manager
- Dr. Mohan Baro – Chief EE & Systems Engineering
- Vy Bui – Senior Systems Software Engineer
- Dr. Fei Ma – Senior Photogrammetrist
- Piyush Sharma – Computer & Software Engineer
- Dr. Donald L. Light – Chief Photogrammetrist
- David Wilkins – Senior Systems QA/QC
- Dr. Kenneth R. Castleman – Chief Technology Officer
- Donna Lavey – Systems Documentation & Technology Writer
- Kimberly Waas – Technical Sales Manager
- Bob Blocksidge - Executive Director of Sales

The USGS team additionally took part in a video conference meeting with the senior executives and technical staff of M7 Aerospace in San Antonio, Texas to review the manufacturing, supply chain management, assembly, and overall QA/QC process of the Iris systems. M7 Aerospace is the principal supplier, manufacturer, and integrator of key components of the Iris systems.

M7 Aerospace staff members who presented material and answered USGS questions included:

- Kevin Brown, President & COO
- Todd Lazar, Vice President Quality Assurance
- Brian Dannewitz, Vice President Supply Chain Management and Spare Sales
- Mark Provost, Director Engineering Support
- Robert Frizzell, Team Leader Avionics Engineer
- John Davenport, Senior Manager of Procurement

4 Manufacturer's System: Description, Intended Use, Workflow and Quality Program

4.1 System Description

System Submitted for Certification: The Iris One 50™ System is the color (RGB) digital aerial mapping system being certified as a result of this USGS visit to M7VI. The Iris One 50™ System is comprised of an Arched Retinal Camera Array (ARCA™), with five digital camera modules, and an acquisition computer with sensor control hardware and software.

The Integrated Retinal Imaging System™ (Iris™) - Iris™ is a modular and scalable system architecture implemented with an integrated imaging workflow that is about 30% hardware and 70% software using primarily commercial off the shelf hardware and optical components [Guevara1]. The foundation of Iris One™ is a structure called the Arched Retinal Camera Array (ARCA™) [USPatent2007p, Guevara1].

The ARCA™ is a "cross-eyed", lateral array of digital cameras that M7VI describes as electronically "locked together" at the pixel level [Guevara 2]. M7VI refers to this as "pixel-clock-locked". The ARCA™ in the Iris System consists of five digital cameras (See Figure 1). The Iris One 50™ camera system, based on the ARCA patent, is an integrated system comprised of modular and scalable components and is scalable through the use of co-mounted and co-registered camera modules.

Figure 1: The Arched Retinal Camera Array (ARCA™) for the Iris One 50™ System

The CCD sensor in each camera module within the Iris System is 4008 x 2672 pixels (11 megapixels) in size. This patented ARCA technology allows the digital cameras to be locked together, as previously described, and treated as a "single camera" generating a virtual frame image as large as 19,382 x 2672 pixels and covering a swath of 2.65 miles wide at 10,000 feet above ground level (AGL).

The formula for image width is given by: image_width= ccd_width x N – pixel_overlap x (N-1), where N is the number of cameras in the ARCA array. The color sensor chip uses an overlaid standard Bayer (BGGR) pattern with a CCD pixel well size of 9µm x 9µm and detector pitch of 9µm.

The output image generated by each camera module is called a single image or, in M7VI parlance, a “SImage” (SI). The geographic coverage and resolution of each SI is dependent, among other base parameters, on the flight altitude. The aligned union of single images in the ARCA™ array is called a Frame. The overall number of pixels in the Frame is directly proportional to the number of camera modules (5 in the Iris One 50™) resulting in a large virtual frame (See Figure 2).

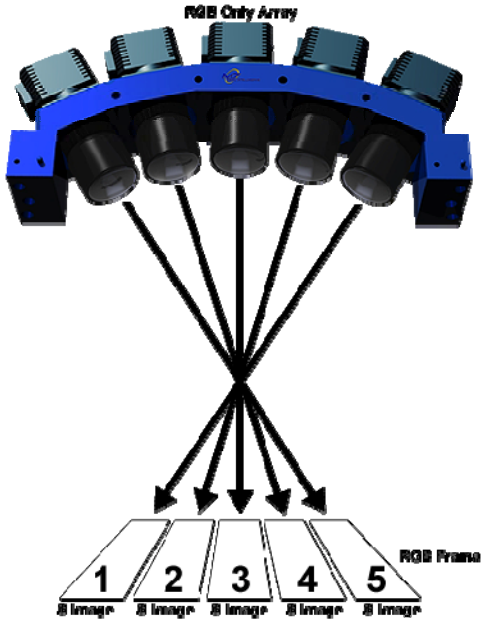

Figure 2: Iris One 50™ Design Concept

The Iris system is designed to be modular and can be reconfigured to occupy different footprint requirements. Figure 3 illustrates the ability of the ARCA™ (here shown co-mounted with a lidar system on the same base plate) with the acquisition computer and related hardware are installed in a modular extended configuration at an alternate location. Figure 4 shows the Iris system in a rack mount configuration. This system was demonstrated to the USGS. Figure 5, shown for informative purposes, illustrate two ARCAs mounted together in a dual configuration. This was discussed with the USGS but is not yet part of the certified ARCA Iris One 50 system.

Figure 3: Iris One 50 RGB Camera Array in a Setup with LIDAR, Acquisition Computer and Image Processing Station

Figure 4: Complete Iris One 50 System in a Rack Mount Configuration

Figure 5: Dual ARCA™ with RGB and NIR Sensor Modules

Software – The Iris system is driven and integrated by several software components. The main components interface with the sensor and are named Visual Navigator™ and for imagery product delivery, Isis™. The former is used for image acquisition, while the latter is used for orthoimage processing. Visual Navigator™ is responsible for collecting the imagery and GPS/IMU positional data, and flight management. Visual Navigator has three modules (all managed by Visual Navigator™ and are not user addressable): PhotoADU for image acquisition, CamCtrl for camera control, flight line management, and navigation, and BMPCopy for data management.

Two modes of operation of the Isis™ Orthoimagery processing software: Isis Sky™ and Isis Earth™. Isis Sky™ is used to process imagery with GPS/IMU data collected onboard the aircraft while Isis Earth™ is utilized for accurate orthoimagery processing using refined GPS/IMU data obtained from ground control stations.

Isis™ also includes radiometric correction software (Iris Radiometric Correction) to de-mosaic the Bayer images into separate RGB imagery plus correct for any radiometric distortions.

4.2 System Intended Use

The Iris One 50™ is a digital aerial imaging system capable of gathering imagery, and when combined with elevation data obtained elsewhere, can be used to produce orthophoto mosaics. It should be noted that the Iris system is not designed to generate stereo imagery and derived elevation data.

As presented by M7VI, the Iris system is used in “direct georeferencing” image collection, using exposure station information derived from onboard GPS data.

M7VI states that the Iris system is intended for use in aerial imaging applications such as (but not limited to) forestry management, land use surveys, census mapping, corridor mapping, and line sag analysis.

The first deployed Iris system has been used for these applications in various projects. For example, M7VI used this Iris One 50™ system to collect imagery of Hurricane Ike's damage to the Galveston-Houston area of Texas in 2008.

Typical resolutions of Iris One 50™ at different altitudes:

a. 25cm pixels at 3,000m AGL
b. 13cm pixels at 1500m AGL
c. 6cm pixels at 750m AGL

Typical swath widths (along direction of flight) of Iris One 50™ at various altitudes:

a. 4,300m at 3,000m AGL
b. 2,100m at 1500m AGL
c. 1,100m at 750m AGL

4.2.1 Manufacturer's Accuracy Claim

M7VI has responded to a USGS questionnaire regarding typical planimetric accuracies which a user of the Iris One 50™ may expect to obtain at several operational resolutions. These responses are given in the table below and are also illustrated in a subsequent chart (See Figure 6). M7VI claims 8 cm (3 inch) as their highest operational ground sample distance (GSD).

Table of Claimed Accuracies for the Iris One 50™ System

Resolution (GSD)	**CE95 Accuracy using Direct Georeferencing**	**CE95 Accuracy using Ground Control Points**
1 Meter	--NA---	
12-inch (30cm)	5.70 feet or 1.739 meters	*(Not applicable)**
6-inch (15cm)	4.15 feet or 1.264 meters	*(Not applicable)**
3-inch (7.5cm)	4.00 feet or 1.219 meters	*(Not applicable)**
Highest advertised resolution	**3-inch**	

** M7VI does not use Ground Control in their processing of imagery.*

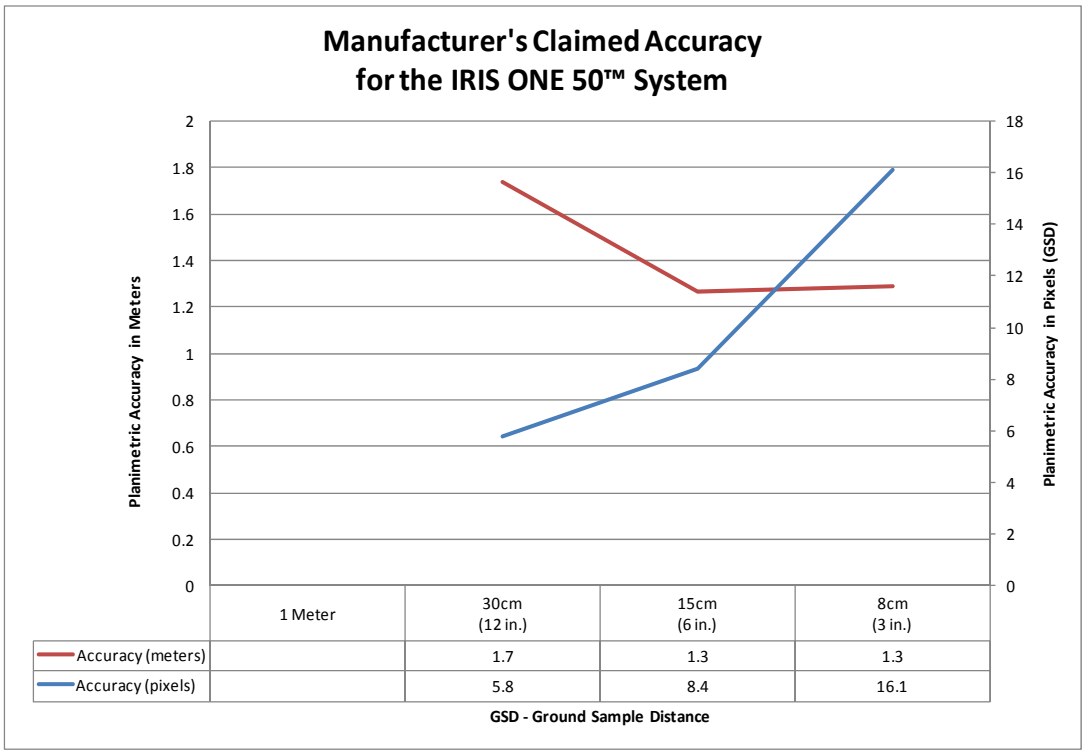

Figure 6: Chart of Claimed Accuracies

4.3 System Workflow

The Iris One 50™ system workflow can be broken down into five major steps (See Figure 7):

Calibration
Boresighting
Image Acquisition
GPS/IMU data processing
Orthoimagery Processing

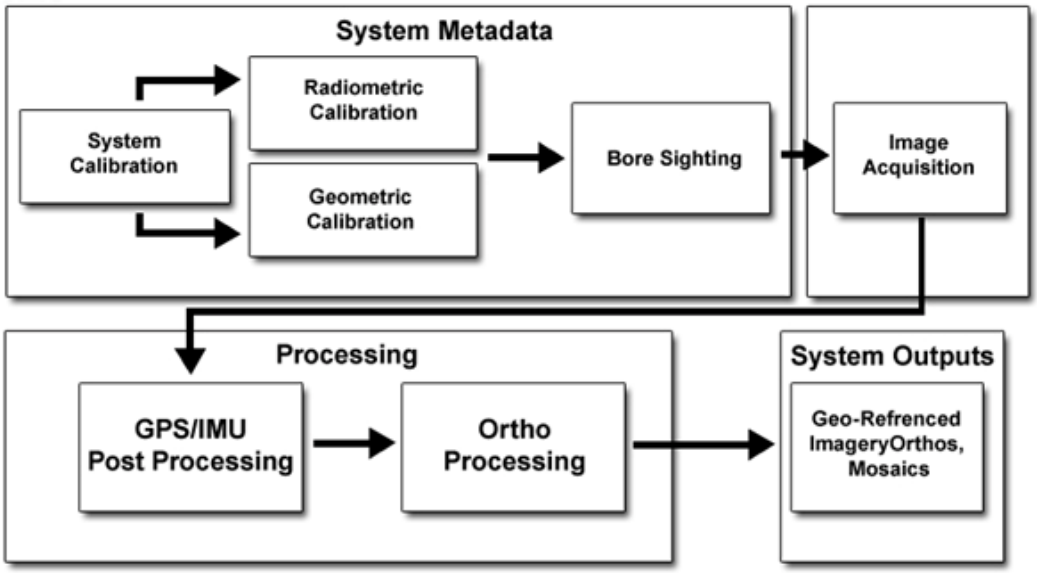

Figure 7: Iris One System Workflow

4.3.1 Calibration

The process starts with the calibration procedure where the camera modules are focused, radiometrically and geometrically characterized. At this stage camera calibration, data and correction lookup tables are generated.

4.3.1.1 Geometric Calibration

There are two types of geometric calibration performed at the M7VI calibration laboratory; first, the determination of each camera module's interior orientation and the distortion parameters of each lens and second, the determination of the alignment of the camera modules in the ARCA™. M7VI provides the calibration services to ensure full Iris One 50™ system

calibration. The calibration of each of the Iris One™ camera modules utilizes M7VI's calibration cage (See Figure 8) and the Australis® software system. The cage has a uniformly well-distributed set of coded and ancillary target points having a retro-reflective property. The dimensions of the cage are 11 feet wide, 8.5 feet high, and 8.5 feet deep, with front, middle, and back tiers. A black background surrounds the cage on the walls and ceiling to prevent background reflection.

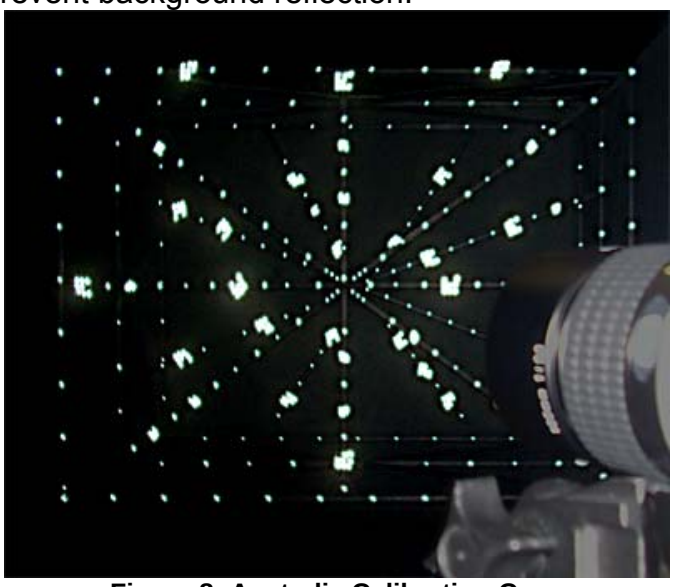

Figure 8: Australis Calibration Cage

The Australis® software is a close-range photogrammetric system for industrial and engineering metrology and features automatic measurement of the cage's retro-reflective targets. A set of nine images with strong convergent geometry are collected of the calibration cage. The software uses the measurements from these images to perform a bundle adjustment with self calibration. The results of this adjustment are the camera model constants including focal length, principal point offsets, and lens distortion parameters. A report on the quality of the calibration results is made available once the process has completed.

The individual camera modules are then integrated into the ARCA™ and an initial interlock angle calibration is performed. Once this calibration operation is complete, M7VI delivers the system to the client. M7VI then performs an in-flight calibration with a pre-determined flight plan which is flown either at the client's base range, a regional range, or at the M7VI control site. The client must collect ABGPS/IMU data which is subsequently post processed. The post-processed imagery and GPS/IMU data, along with the Ground Control Points (GCPs), are used to determine the final installation angles of the cameras mounted in the system. Even though the calibration usually holds after system delivery, periodic calibration

verification on individual cameras and system integration are available and recommended. M7VI strongly recommends annual factory servicing of the Iris One 50™ and provides a Service Plan for this purpose.

4.3.1.2 Radiometric Calibration

The M7VI system uses relative radiometric calibration. The distortion, noise, and nonlinearities of the camera system are removed, or reduced to the extent possible, leaving the image as a reliable visual representation of the Earth's surface. The brightness and contrast are adjusted for proper appearance of the surface, but not for quantitative radiometry. Following calibration, the user is able to adjust contrast, brightness, and sharpness to suit the particular application.

The radiometric calibration procedure is the multi-step process listed below. A series of calibration tests are conducted on each system prior to installation. This produces a data file containing a set of calibration constants that are then used in the algorithms that are applied to each incoming image.

Shading Correction – This is carried out by a flat fielding technique. It uses a lookup table having the same size as the image itself, with a piecewise linear grayscale transformation implemented for each pixel in each color channel. Prior to installation, calibration is done by shooting images of uniformly black and uniformly white targets under natural lighting, with the lens focused at infinity (See Figure 9). These two images then define a linear grayscale transformation at each pixel, and this is used to create the shading correction, lookup table. The lookup table that corresponds to the camera with which it was taken is used to correct each incoming image.

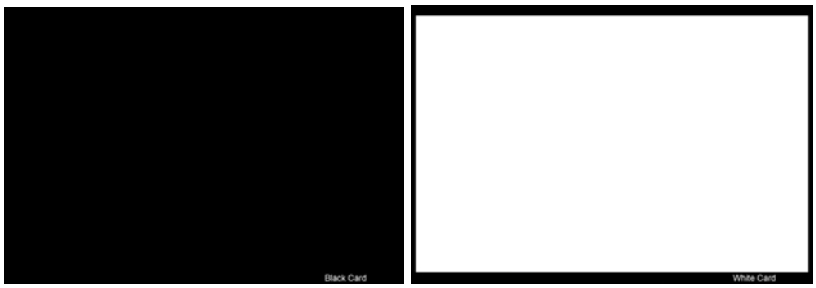

Figure 9: Uniform Targets

Smear Removal – (USGS note: this is smear as defined by M7VI and refers to electronic effects within the CCD. It is not motion-related “smear”, another term often used in aerial imaging.) A mathematical model is used to remove

the visible effects of smear from individual digitized images. For the Kodak 11000 and 11002 sensor chips M7VI-VI conducted a case study to characterize and model the CCD smear phenomena that are evident in the images produced. The smear removal algorithm works one column at a time by subtracting a correction factor from each pixel as it moves down the column *[Castleman1]*. The correction factor is based on the cumulative gray level of the pixels above it. In other words, for the jth pixel, the correction factor is C_0 times the sum of the first j-1 corrected pixels, where C_0 is a camera-specific calibration factor.

De-mosaicking – Bayer filter de-mosaicking is the process of separating a single (monochrome) image from a CCD with an overlaid Bayer filter into a three-color (RGB) image of the same size. It fills in the missing pixels in each color channel using bilinear interpolation. The software supports all four possible Bayer alignment patterns, but the standard Bayer alignment pattern for M7VI is BGGR (See Figure 10).

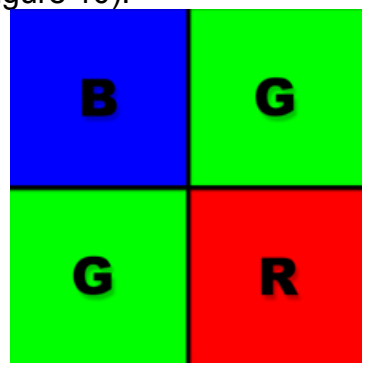

Figure 10: Bayer Filter Pattern Used by M7VI

Color Balancing - Proper color balance for each single image is established by a "color un-mixing" procedure. This is done by capturing an image of a Macbeth color target (Munsell) and comparing the mean gray level within each of the 24 color squares with their nominal values (See Figure 11). M7VI then generates a grayscale transformation for each color channel by fitting a cubic function through the mean gray levels of the 24 color squares. This grayscale transformation is applied to each incoming image during processing.

Figure 11: Macbeth Color Rendition Chart

To ensure color balance across the image frame, M7VI performs a histogram matching technique to make the overlapping regions of adjacent camera images match one another (See Figure 12). First, the edges of the right and left images are matched to the center image. Then the far left and far right images are matched to the left and right images respectively. The overlapping area is corrected by histogram matching, and a linear gradient is then applied to *N* pixels beyond the overlapping area to taper off the transformation and smooth out the transition. The value of *N* is adjustable.

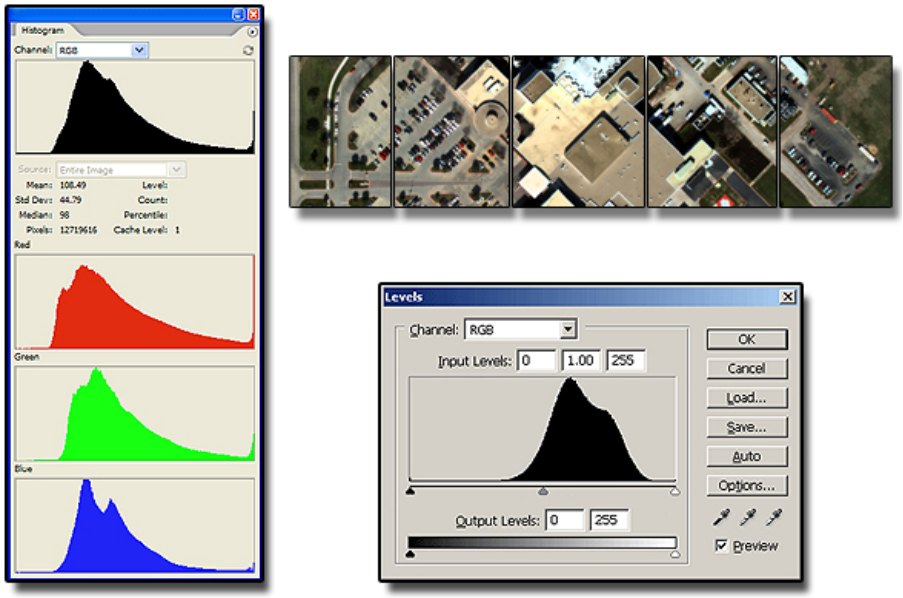

Figure 12: Histogram Matching Technique

4.3.2 Boresighting

System boresighting is carried out next where the integrated system is calibrated to determine the interlock angles of the camera modules within the ARCA™. At this stage, the ARCA™ camera modules and the IMU device are rigidly mounted on the same base plate. Movement of modules or IMU relative to each other will invalidate the boresighting calibration. This step requires both laboratory and in-flight test firing of the Iris system. The images captured along with the GPS/IMU data are used to calculate the interlock angles. The output of the calculation results in the deliverable Iris system complete with metadata file.

4.3.3 Image Acquisition

With the system metadata in place, the sensor is available for projects to capture imagery. Images are captured along with GPS/IMU data utilizing Visual Navigator™. Each captured image array is linked with an associated image metadata file that records a frame sequence number and the GPS/IMU data such as longitude, latitude, yaw, pitch, and roll corresponding with each frame.

4.3.4 GPS/IMU Data Processing

Once the flight is complete the imagery, image metadata, and GPS/IMU data sets are downloaded for processing. GPS/IMU is further processed along with ground CORS data to generate refined GPS/IMU data sets. The minimum GPS/IMU requirements to achieve stated accuracies are as follows for post processed GPS/IMU data: Position (m) 0.05-0.30, Velocity (m/s) 0.005, Roll and Pitch (deg) 0.005, and True Heading (deg) 0.008.

4.3.5 Orthoimagery Processing

For rough quality orthoimagery, Isis Sky™ is utilized to process the imagery to generate ortho-mosaics. The refined GPS/IMU data sets are utilized with Isis Earth™ to process the imagery to generate higher quality ortho-mosaics. A digital elevation model (DEM) in the USGS Quad format is also required and is utilized by the Isis software for ortho rectification.

4.4 Manufacturing Quality Program

M7VI's quality program follows the guidelines set by M7 Aerospace manufacturing requirements. M7 Aerospace is an ISO certified sister company of M7VI and is the major supplier of Iris system components. The entirety of the M7 Aerospace Quality System meets the requirements of ISO 9001:2000 and the requirements for AS9100 Rev. B, Quality Management Systems for Aerospace industries. M7 Aerospace carries out the final assembly and integration of each Iris system in San Antonio, Texas. Prior to integration by M7 Aerospace, all components including camera modules (with lenses) are calibrated and tested at M7VI. M7VI also follows strict guidelines for quality

control and after assembly and integration, each complete Iris One™ system is calibrated, flight-tested, and quality checked prior to delivery to the customer. The quality program ensures that:

1. Individual hardware components conform to specifications: All procured components receive testing against manufacturer/vendor specifications. All functions are carefully tested and defects characterized. M7VI returns all components, not meeting specifications, back to the manufacturer/vendor for replacement or repair.
2. Individual hardware components follow a rigorous testing plan: Each component has a sequence of additional tests whereby each component is integrated into a subsystem of an existing prototype Iris system. M7VI documents and returns each component failing the integration test to the vendor for diagnosis and repair. Individual components passing the test plan are then integrated into subsystems.
3. Subsystem components follow a rigorous testing process: Assembled subsystems forming a new Iris system are then tested in-house and in the field to assess their integrated performance. The subsystems are then sent to M7 Aerospace for final build and testing.
4. The complete system follows a rigorous pre-sale testing process: The complete system is tested in the field for 3-5 hours of flight under different flying conditions. A characteristics report is generated for each complete build.
5. The complete system follows a post-sale maintenance process: Each sold system has a scheduled maintenance plan as part of the product warranty.

5. Documentation

M7VI provided various documents to the USGS prior to the visit and additional documents that M7VI staff presented during the visit. These documents included the following:

1. Information on facilities at M7 Aerospace in San Antonio, Texas
2. Pictures of Iris One 50™ assembly at M7 Aerospace
3. Iris One 50™ System and Calibration Workflow
4. Iris One™ Swath and Resolution Chart
5. M7VI's Quality Program

Additional information was provided after the visit in response to USGS questions. All documentation came from M7VI directly or from their suppliers.

The USGS team also referenced additional documents obtained from public presentations and M7VI's promotional material. All of these materials are current as of the visit. Appendix B of this document, part of the shared materials, contains the Iris One 50™ Technical Specifications.

Finally, the individual members of the USGS team took notes, pictures, and wrote comments regarding what they saw and heard during the visit to M7VI and while researching the M7VI Iris system. Copies of these notes have been collected and are filed with the M7VI Certification files at the USGS EROS.

Copies of all documentation described above are kept in the Iris One 50™ Certification files at the USGS EROS for reference by the USGS team. Many of these documents and the information within or derived from are M7VI proprietary information.

M7VI shared this information with the USGS for the purpose of type certification under a non-disclosure agreement. This type of information is not contained in this report. Due to the proprietary nature of detailed technical information used during certification, USGS suggests that external requests for any information about this unique camera system be directed to M7VI.

6. USGS Team Findings

The design of the Iris One 50™ is modular and scalable and allows for flexibility based on the customer's application and use of the product. M7VI has presented a design for certification which included the following characteristics:

1. Arched Retinal Camera Array, ARCA, accommodating five cameras and lenses for RGB applications
2. Sensor generated imagery produced from virtual (focal) plane overlap of the five cameras.
3. Software packages - as previously described an operational 64-bit software system and subsequent data processing.
4. Camera and sensor infrastructure – e.g. the GPS/IMU, CPU, and data storage drives.

The Quality Program at M7VI is sound and thorough. M7VI enjoys a very close relationship with their primary supplier, M7 Aerospace, in nearby San Antonio, Texas. The close working relationship between M7VI and M7 Aerospace allows for physical collaboration between engineers and assemblers and thus gives M7VI the ability to monitor quality and performance at the subsystem level during assembly and testing. System engineering processes, including configuration control and management, in use at M7VI follow standard industry practices, as do manufacturing engineering, testing, and quality monitoring processes.

Geometric calibration of the Iris system is performed in-house at M7VI in Houston, Texas, using multiple images taken in a control-point chamber (calibration laboratory). The interlock angles from this calibration are then further refined using aerial imagery over a survey-controlled test range. The geometric calibration addresses photogrammetric qualities of the imagery including focal length, radial distortion, lens de-centering, and principal point offsets, as well as the determination of the interlock angles between camera modules. Radiometric calibration for the Iris system is a relative calibration (not absolute) and includes color and tonal balancing, shading and aperture correction, and smearing removal. These measures control the qualitative radiometry of the produced imagery. M7VI strongly recommends annual factory servicing of the Iris system and provides a Service Plan for this purpose. During annual servicing, the calibration of the system is verified using the methods detailed above.

The USGS Team was presented with overviews of the M7VI software used for processing the Iris system output into orthophotos and ortho-mosaics. These

orthophotos and ortho-mosaics can further be processed with third party photogrammetry software. The M7VI software is designed and implemented following the ISO IEC 90003 guidelines established for software engineering. It follows object oriented conceptual, logical, and physical design approaches.

M7VI's service and support operations were also briefed to the USGS Team and were found to be well implemented. M7VI has tested and verified the technical performance of the Iris system, including test flights under harsh environmental conditions. Each system is flown and verified before delivery. M7VI's incentives to purchasers to enroll in the service plan, which will provide verification of performance, were also discussed.

The M7VI system has the ability to improve its performance in the future with system and process changes. The system could realize improved geometric performance using an enhanced, integrated photogrammetric solution that better ties together the system math model, calibration and boresight processes, and data processing. The current design of the system allows for the creation of orthophotos with varying accuracies at different resolutions as shown in the table of manufacturer's claimed accuracies in section 4.2.1 of this report. The orthophotos evaluated by the USGS Team had good image balance and tonal constancy but minor pixel-line discontinuities (such as mosaic line discontinuities) that could be fixed for customers via software processes.

The USGS Team has found the Iris One 50™ system to be designed, manufactured, tested, and supported to the level required to meet the performance claims of the manufacturer and when operated within manufacturer's intended operational parameters. The Iris One 50 system, when operated properly by a conscientious and technically qualified operator and at the performance levels provided in this report, are capable of delivering orthographic digital aerial data.

7. Iris One 50™ Technical Specifications

Component	Capability	Specification
System		
	System Nomenclature	Iris One 50
	Number of Lens Cones	5
	Number of Sensor Chips/Lines	5
	On-board Storage (GB/TB)	500GB/ removable
	On-board Storage (images)	9090 frames (x5single images)
	Image Storage Redundancy (Y/N)	N
	Power Consumption (Watts)	750-1200 (max)
	Camera Temperature Range (°C)	5-50C
	Computer Temperature Range (°C)	5-45C
	Output Pixel Size(s)	9µmx9µm
	Fwd Motion Comp (FMC) Type	NONE
	Recommended Forward Overlap (%)	40%
	Recommended Side Overlap (%)	30%
Size/Weight		
	Camera Size/Weight	51x25x33cm & 23kg
	Processing System Size/Weight	48x73x25cm & 18kg
	Total System Weight	90KG
Controls		
	Exposure Control Options	YES
	Light Metering Type	NO
	Shutter Type	ELECTRONIC
	Shutter Speed Range	1500µs-2000µs
	Exposure Compensation	NO

Component	Capability	Specification
Sensor		
	Sensor Type	Frame
	Sensor Nomenclature	Iris One 50
	Manufacturer CCD Nomenclature	KAI-11002
	Total Pixels (MP)	11MP
	Along Track Pixels	2672
	Cross Track Pixels	4008
	Aspect Ratio	3:2
	Pixel Size (mm)	9µmx9µm
	Radiometric Resolution (bits)	8
	Max Exposure Rate (sec)	1 image per sec
Lens		
	Lens Type	Manual Focus/ Telephoto
	Lens Nomenclature	Nikon Series E AIS 135mm f/2.8s Telephoto
	Focal Length (mm)	135mm
	Aperture Range (f-stop)	8
	Along Track FOV (deg)	10
	Cross Track FOV (deg)	15
Virtual Image	(if applicable)	
	Total Pixels (MP)	52MP
	Along Track Pixels	2672
	Cross Track Pixels	19,382
	Aspect Ratio	7.2:1
	Pixel Size (mm)	9µm × 9µm
	Along Track FOV (deg)	10
	Cross Track FOV (deg)	70
	Radiometric Resolution (bits)	8

8. References

[Guevara1] Guevara et.al, *"Iris/Isis Basic Concepts, Architectural and Component Definitions,"* (M7VI Internal Document). Last revised September 2008.

[Patent2006a] U.S. Pat. No. 7,127,348 for *"Vehicle Based Data Collecting and Processing System,"* awarded October 24, 2006

[Patent2005a] U.S. Pat. No. 6,928,194 for *"System for Mosaicking Digital OrthoImages Having At Least Three Imaging Sensors,"* awarded August 9 2005

[Patent2007a] U.S. Pat. 7,212,938 for *'A Method of Using a Self-Locking Travel Pattern to Achieve In-Travel Calibration of Remote Sensors,'* awarded May 1, 2007.

[Guevara2] Armando Guevara*, "The ARCA of IRIS,"* ASPRS 2009 Annual Conference Baltimore, Maryland * March 9-13, 2009

[Light1] Don Light and Fei Ma*, "Calibrating Film Cameras Then and Digital Cameras Now,"* ASPRS 2009 Annual Conference, Baltimore, Maryland, March 9-13, 2009

[Castleman1] Kenneth Castleman, *"Internal Report on Smearing Algorithms," M7 Visual Intelligence* (Internal Document). Last revised May 2003.

[Patent 2007p] US Patent number 11/805,109 for *"Retinal Array Compound Camera System Having At Least 3 Imaging Sensors".* Patent pending.

[Patent2006p] U.S. Pat. App. No. 11/581,235 ("the CoCo™ Application") was filed on October 11, 2006 as a continuation-in-part of U.S. Pat. App. No. 10/664,737 granted as U.S. Pat. No. 7,127,348. The pending claims are directed toward the incorporation of the co-mounted and co-registered features of M7VI's sensor technology.