Document for Operation

Survey Operation Manual for Digital Ortho Production (for National Base Map)

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Infrastructure Management Department

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Survey Operation Manual for Digital Ortho Production (for National Base Map)

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[Preface] General

1. Introduction

Orthophoto production refers to the execution of orthographic transformation on aerial photos and satellite images and, if required, mosaicking the resultant data to produce orthophotos.

As the survey operations are getting more computerized, the digital technology is being introduced to the orthophoto production, causing thus significant changes in required devices and operation processes.

On the other hand, the devices used for orthophoto creation consist of computer hardware and software. The specifications and operation methods for these devices greatly vary compared with those for the conventional orthophoto producing processes using analog devices so that no operation is performed based on unified specifications. Therefore, common specifications or criteria are not yet available for the quality of survey results to be produced.

The Survey Operation Manual for Digital Ortho Production (for National Base Map) (hereinafter referred to as "this Manual"), with respect to the aforementioned circumstances, describes "digital ortho production," i.e., producing digital images through orthographic transformation of digitized aerial photos, satellite images, etc. It defines also the standard operation methods and quality criteria for survey results, for an efficient creation and use of digital orthophotos produced in the survey operation (national base map creation) to be implemented by the Japan International Cooperation Agency (hereinafter referred to as "JICA").

2. What are Digital Orthos?

Conventional orthophotos based on an analog method are created by mechanically transforming aerial photos into orthographic photos using orthographic devices such as Topocarte Orthophoto, Ortho Projector GZ-1, and Avioplan OR-1, and printing them on films and photographic paper. Digital orthos are digital images created by rearranging the pixels of digitized aerial photos and satellite images into orthographic projection position using exterior orientation parameters and digital terrain models. This rearrangement is called orthographic transformation in which horizontal dislocations due to central and elevations on aerial photos are removed using digital terrain models.

Figure 1 shows an aerial photo (left), in central projection, and a digital ortho (right), a result of orthographic transformation of this aerial photo. The mountains surrounding the dam lake on the aerial photo (left) look closer to the dam lake (principal point in the photo) on the digital ortho (right), showing thus black areas where no image is available, on the edge of the digital ortho (right). On the aerial photo (left), subjects closer to the camera look larger and those more distant from the

camera look smaller. This distortion results from the relative elevation difference of the subjects and the undulation of the ground surface. On the digital ortho, this distortion has been corrected through orthographic transformation using exterior orientation parameters and topographic feature height information.

Figure 1 Aerial photo (left) and digital ortho (right)

Whereas aerial photos show central projection images obtained when the light beams reflected by a subject travel in straight lines through the center of a lens (Figure 2(a)), the digital orthos show images obtained by transforming aerial photos, etc. into orthographic projection images (Figure 2(b)), in the same format as for maps. Therefore, it is possible to use digital orthos by superimposing them on the map data.

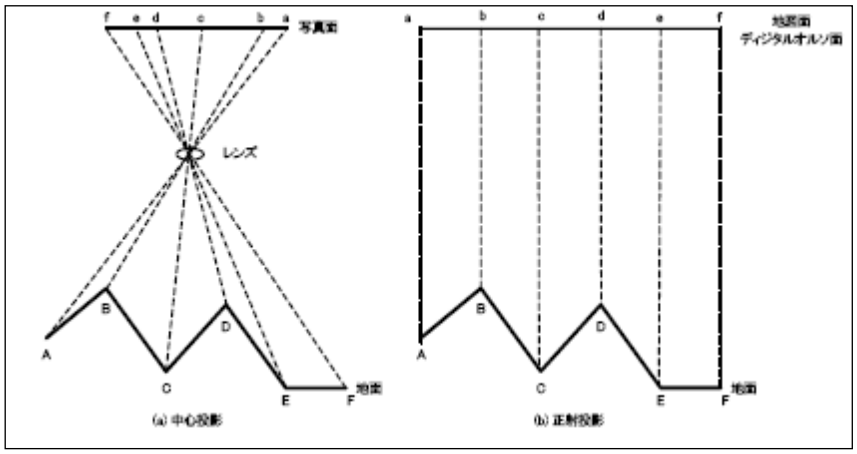


Figure 2 Central projection ((a) aerial photo) and orthographic projection ((b) digital ortho)

The principle of orthographic transformation is shown in Figure 3. While Point A in this figure must be projected to the Point A' location on a map showing an orthographic projection, it is projected to the Point B' location on an aerial photo showing a central projection. Therefore, Point A is mapped to Point-a on a photo but must be displaced to Point-a' in order to obtain an orthographic projection equivalent to a map. This transformation from Point-a to a' can be

realized, as shown in Figure 3, by obtaining the relative height from Point A to A' and the angle θ that the vertical line from the center of projection to the photo forms with Point A, then moving the image to a location obtained as h･tan θ.
In this case, h can be obtained through measurement using digital stereoplotter, etc. and θ can be obtained from an exterior orientation parameter of the aerial photo.

Many satellite images have been obtained by a line sensor and are combinations of central and parallel projections. Though not being central projections in a strict sense, the satellite images can be transformed to orthographic projections in the same way as for aerial photos, using the exterior orientation parameters and heights of topographic features.

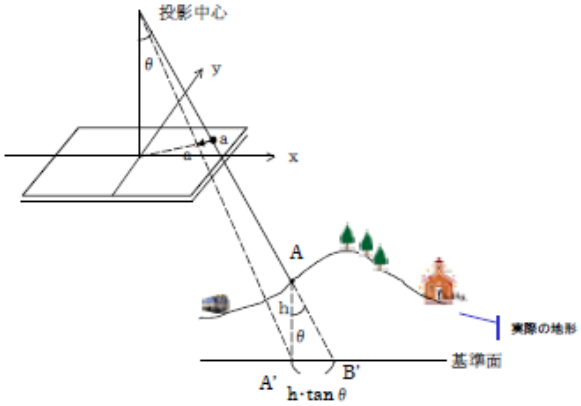


Figure 3　Orthographic transformation

When they are classified by differences in data structures, the digital terrain models used for orthographic transformation come in the following types:

- Grids that represent elevation information as a lattices
- Triangulated irregular network (TIN) that represents topographic features as a set of triangular planes,

When classified by differences in criteria for the location of getting elevations, the digital terrain models come in the following types (Figure 4):

- Digital Terrain Model (DTM) that represents the elevations of the ground level
- Digital Surface Model (DSM) that has the elevations of the surface level including artificial structures and land cover such as vegetation

Digital topographic models to be used for orthographic transformation are basically DSMs. In this Manual, however, DTMs such as a model created from contour lines of topographic maps may also be used.

Figure 4　DTM and DSM

3.　Operation Manual for Digital Ortho Production

1) Purpose and scope

This Manual describes the standard operation methods for producing digital orthos in overseas survey to be implemented based on Article 11 (Special exceptions to instruments, etc. and survey methods) of the Work Specifications of JICA for National Base Map, contributing thus to unifying specifications, standardizing results, and ensuring the required accuracy.

2) Organization of this Manual

This Manual specifies the standard operation methods for producing digital orthos, devices to be used, and other necessary items.

This Manual also provides the explanations in addition to articles and operation criteria, in order to facilitate the understanding of digital ortho production as a survey technique, while promoting and popularizing the use of digital orthos.　The overall organization of this Manual is as follows:

(1) Part 1　General

Part 1 specifies the purpose of this Manual, as well as the conditions for producing digital orthos, and handling of data, etc.

(2) Part 2　Digital Ortho Production

Part 2 specifies the specifications for digital ortho production as well as the work processes and their order production methods, etc.

(3) Part 3　Materials

Part 3 provides the standard forms for accuracy control and mosaic quality classification charts for producing digital terrain models and digital orthos as well as the samples for periodical check certificate for aerial photo scanners.

Part 1 General

(Purpose)

Article 1 This Manual describes the standard operation methods for producing digital orthos in overseas survey (national base map creation) to be implemented based on the Article 10, "Special Exceptions" of the Work Specifications of JICA for National Base Map (February 2022), contributing thus to unifying specifications, standardizing results, and ensuring the required accuracy.

[Explanation]

The following shows Article 10 of the Work Specifications of JICA for National Base Map.

(Special Exceptions)

Article 10 The instruments and the survey methods other than those specified in the Specification may only be used in parts of the works subject to the approval of JICA and provided that their use will not cause any problems to ensure the required accuracy and maintain the work efficiency.

2. The survey methods, references, items, processes, etc. specified in the Specifications may only change with the approval of JICA.

(Application of the Work Specifications of JICA for National Base Map)

Article 2 The Work Specifications of JICA for National Base Map shall apply to items not specified in this Manual.

[Explanation]

This manual specifies only the items pertinent to digital ortho production. Items not specified in this Manual must comply with the specifications in the Work Specifications of JICA for National Base Map.

(Overseas survey using digital orthos)

Article 3 Digital ortho production in overseas survey operation (for national base map) refers to the orthographic transformation of digital photos obtained from digitizing aerial photos by aerial photo scanners, photo images captured by aerial digital cameras, satellite images, etc. (hereinafter generically referred to as "digital photos") on digital stereoplotters, etc., creating thus the digital ortho data files. This process includes producing mosaic images by joining adjacent orthographic projection images through digital processing.

[Explanation]

The standard configuration of devices and software to be used to produce digital orthos includes

aerial photo scanners, digital stereoplotters, orthographic transformation software, and mosaic software.

1. Aerial photo scanner

   The aerial photo scanner shall be used to digitize aerial photo films and produce digital photos.

2. Digital stereoplotter

   The digital stereoplotter shall automatically extract the elevations or shall perform digital mapping from a pair of digital photos that make up stereo models in order to create a digital terrain model.

3. Orthographic transformation software

   The orthographic transformation software shall transform digital photos into orthographic projection images using the exterior orientation parameters and digital terrain models of the digital photos.

4. Mosaic software

   The mosaic software shall overlay and join the adjacent orthographic projection images through digital processing to produce a continuous mosaic images. It shall also produce digital ortho data files by dividing a mosaic image into arbitrary ranges.

(Devices to be used)

Article 4 The major devices to be used to produce digital orthos shall include the following devices or those provided with an equivalent or better performance:

(1) Aerial photo scanner

An aerial photo scanner refers to a system consisting of a scanner, computer program, computer, and peripherals. It shall have functions to scan aerial photo films and obtain and record digital photos in image format and a performance that ensures a prescribed accuracy.

(2) Digital stereoplotter

A digital stereoplotter refers to a system consisting of a computer program, computer, and peripherals. It shall have functions to create and display a stereo model from digital photos that enable stereographic view and obtain and record map information in digital format and a performance that ensures a prescribed accuracy.

<Article 4 Operation criteria>

1. An aerial photo scanner shall consist of a computer, image display, roll film loader, film pressing unit, etc.
2. An aerial photo scanner shall comply with the following accuracy requirements:

Item	Performance (accuracy)
Optical resolution	21 μm or less
Minimum scan size	240 mm x 240 mm or larger
Scan image dynamic range	24 bit full color or higher
Scan image geometric accuracy	2 μm (mean squared error) or less

3. The aerial photo scanners shall be checked by a third-party organization with proper inspection technology and checking validity of six months. The certificate for periodical inspection for aerial photo scanners shall be in a periodical inspection report format used by the manufacturer of the device and it shall be approved by JICA.
4. The grid plate to be used for checking shall be a precision device attached to an aerial photo scanner, with a grid density of 5 by 5 points and a capability to verify the geometric precision in a range of 240 mm by 240 mm and certified by a third-party organization.
5. The digital stereoplotters shall have the following configuration and functions:
   1) A digital stereoplotter shall consist of a computer, stereoscopic device, display, and 3D mouse or XY handle and Z disk, etc.
   2) A digital stereoplotter shall provide a stereoscopic view using the interior orientation, relative orientation, or absolute orientation function or exterior orientation parameters.
   3) A digital stereoplotter shall have functions to enter and record X, Y, and Z coordinates and prescribed codes.
   4) A digital stereoplotter shall have functions such as orthographic transformation.
6. A digital stereoplotter shall have a performance to read coordinates down to subpixel units.

[Explanation]

A subpixel is a virtual pixel unit into which a pixel, the minimum unit of digital photos, is subdivided and the degree of subdivision shall not be defined.

(Operation plan)

Article 5 The organization (hereinafter referred to as the "executing organization") that executes surveys, before starting the operation, shall make an appropriate operation plan on the operation method, major devices to be used, personnel, schedule, etc. and submit

the plan to JICA for approval. The same procedure shall be necessary to make changes in the said operation plan.

（Process control）

Article 6 The executing organization must perform adequate process control based on the operation plan specified in the previous article.

2. The executing organization must report the progress status of operation to JICA, as required.

（Accuracy control）

Article 7 The executing organization must perform adequate accuracy control to ensure the accuracy of survey, and create and submit an accuracy control record to JICA, based on the survey result.

2. The executing organization must perform the required inspections at the end of each process of operation and appropriate times.

＜Article 7 Operation criteria＞

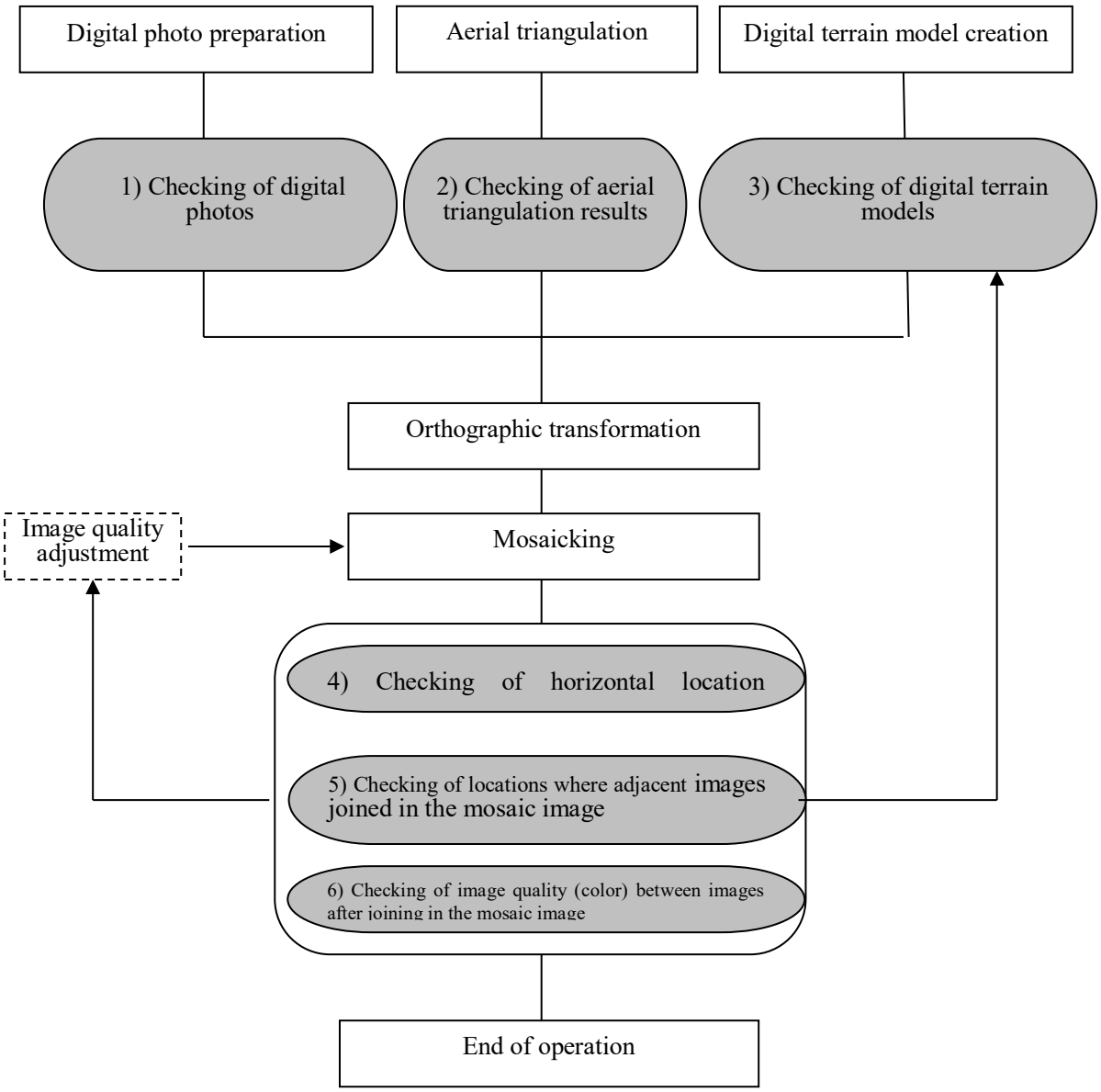
1. The digital topographic model files and digital ortho data files shall be subject to accuracy control for each sheet frame.
2. Processes not specified in this Manual shall conform to the specifications in Part 3 "Digital Topographic Map Production Process" of the Work Specification of JICA for National Base Map
3. Unless otherwise specified, the inspection measurement ratio shall conform to the specification in Article 7 "Accuracy control" of the Work Specification of JICA for National Base Map.

[Explanation]

1．The standard flow of accuracy control is shown in the following figure. Some steps must be repeated after checking.

1) Checking of digital photos refers to checking whether images to be used have uniform color tones. However, it is technically difficult to provide the entire images with uniform color tones. Since color tones are subjectively interpreted, it is advisable that JICA and the executing organization reach an agreement about the pass/fail criteria for color tones before starting the operation.

2) Checking of aerial triangulation results refers to checking whether the result of aerial triangulation are free of problems and that a stereo pair can be created normally using the exterior orientation parameters. In case of a problem, aerial triangulation shall be performed again or other measures shall be taken.
3) Accuracy control of digital terrain models refers to overlaying a created digital terrain model over a stereo model and correcting elevation points that do not comply with the specifications of Item 2, Article 11
4) Checking of horizontal location accuracy refers to the selection of distinct planimetric features on digital photos that make up a 3D model, measuring their horizontal location coordinates, and measuring again these points on digital orthos to check the horizontal locations. As for the locations that do not comply with the specifications of Item2, Article 11, the digital terrain models related to these locations shall be corrected.
5) Accuracy control on locations of joining between images in a mosaic image refers to a visual control of misalignments in the joined parts of orthographic projection images after mosaicking and, the correction of the digital topographic models related to the corresponding locations, as for the locations that do not comply with the specifications of Item 2, Article 11.
6) Accuracy control on image quality (color) of joining between images in the mosaic image refers to a visual control of the image quality differences between orthographic projection images after mosaicking and the correction of the quality of the corresponding orthographic images, as for nonconforming parts.



(Formats of materials and results, etc.)

Article 8 The materials, results, etc. that concern the creation of digital orthos shall be created in standard forms. However, they may be created in different formats only if JICA judges that they will not cause any problem in using, storing, and handling the results, etc.

<Article 8 Operation criteria>

The standard forms shall be specified in this Manual.

Part 2 Digital Ortho Production

Chapter 1 General

Section 1 Outline

(Outline)

Article 9 Digital ortho production refers to the orthographic transformation on digital photos to create orthographic projection images, then creating digital ortho data files and includes the process of creating mosaic images, if required.

(Method)

Article 10 The digital orthos shall be created using the orthographic projection method.

[Explanation]

The orthographic projection method refers to the transformation of digital photos into orthographic projection images using the exterior orientation parameters and digital terrain models.

(Specifications of digital orthos)

Article 11 The digital orthos shall be digital images obtained through orthographic transformation from digital photos and shall not include data such as annotations to be overlaid on the images for the purpose of creating orthophoto maps.

2. The accuracy of digital orthos shall comply with the values in the following table:

Accuracy of digital orthos			Specifications		
Map information level	Horizontal location accuracy	Ground resolution	Photo scale	Digital terrain model	
				Grid interval	Elevation point accuracy
2500	1.75m or less	0.4m or less	1/10,000 ～ 1/15,000	17.5m or less	1.0m or less
5000	3.5m or less	0.8m or less	1/20,000 ～ 1/25,000	35m or less	2.5m or less
10000	7.0m or less	1.0m or less	1/30,000 ～ 1/35,000	70m or less	5.0m or less
25000	17.5m or less	2.5m or less	1/40,000 ～ 1/45,000	175m or less	5.0m or less
50000	35.0m or less	5.0m or less	1/50,000 ～ 1/60,000	350m or less	10.0m or less
100000	70.0m or less	10.0m or less	1/50,000 ～ 1/60,000	700m or less	25.0m or less

<Article 11 Operation criteria>

The horizontal location accuracy of digital orthos shall vary according to the combination of the ground resolution, photo scale, and grid interval and elevation point accuracy of digital terrain models. Since the horizontal location accuracy is also greatly affected by the topographic form, the method for obtaining the elevation must be determined with respect to the topographic form.

[Explanation]

1. The horizontal location accuracy of digital orthos refer to that of parts which represent the earth surface such as bottoms buildings and trees tops of buildings and trees are not required for satisfying the accuracies specified in the table above.
2. The ground resolution is the size of a pixel of digital photos when projected on the ground and expressed in the length of one side.

3. In case photo are taken by a digital aerial camera, these are regarded as analog aerial photo scanned in about 20 μ m pitch.
4. The standard values are classified according to the horizontal location accuracy of 0.7 mm or less on the map (standard deviation) for digital topographic maps, provided in the specifications in Part 3, "Digital Topographic Map Production Process" of the Work Specifications of JICA for National Base Mapping. The ground resolution shall be approximately one-fifth or less of the horizontal location accuracy considering horizontal location accuracy and information obtained from photo interpretation. As a guideline, the grid interval for digital terrain models shall be 10 times or less of the horizontal location accuracy. The elevation point accuracy for digital terrain models shall be one half or less of the contour interval used for topographic map production.

Scale	Contour interval
1/2,500	2.0m
1/5,000	5.0m
1/10,000	10.0m
1/25,000	10.0m
1/50,000	20.0m
1/100,000	50.0m

5. The photo scale or ground resolution, grid interval, and elevation point accuracy of digital topographic models shall be determined according to the horizontal location accuracy required. The amount of work for adjusting the color tones and mosaic and compiling digital terrain models in order to remove local distortions shall be determined based on the image quality (appearance) required, resulting thus in significant differences in work costs and periods. As for these items, JICA and the executing organization will discuss among them to eliminate any misunderstandings in full consideration of not only operation purposes but also costs, deadlines, etc.
6. When interpolated to grid intervals, the density of triangular planes in a triangulated irregular network shall be the one from which an elevation point accuracy specified as the standard value can be obtained.
7. The major data items to be overlaid on digital ortho data files shall be as follows:
    (1) Contour lines
    (2) Annotations
    (3) Administrative boundaries
    (4) Others

The following additional operations are required to add contour lines, annotations, etc. to measurement results. These operations may be performed according to the specifications of Chapter 7, "Digital Plotting," Part 3 of the Work Specifications for National Base Mapping.

(1) The contour lines may be created by either automatically generating ones from digital terrain models or drawing through digital plotting. The method for automatically generating contour lines from digital terrain models needs the following operations in order to adjust the automatically generated contour lines to equivalent representations to the map specifications:

- Compiling contour lines in relation to planimetric features such as intersect with roads and detours around buildings
- Interruptions in symbols such as roads and rivers

(2) The annotations may be created by either entering data from field verification and the existing materials or transforming the existing data.

(3) Administrative boundaries may be created by entering the data from the existing materials or transforming the existing data.

8. The data to be overlaid on digital ortho data files shall be created as separate files so that the pixels in the digital ortho data files shall not be overwritten.

(Work processes and their order)

Article 12 Work processes and their order shall be as follows. Either of these may be changed or partially omitted, in case of instruction or approval by JICA.

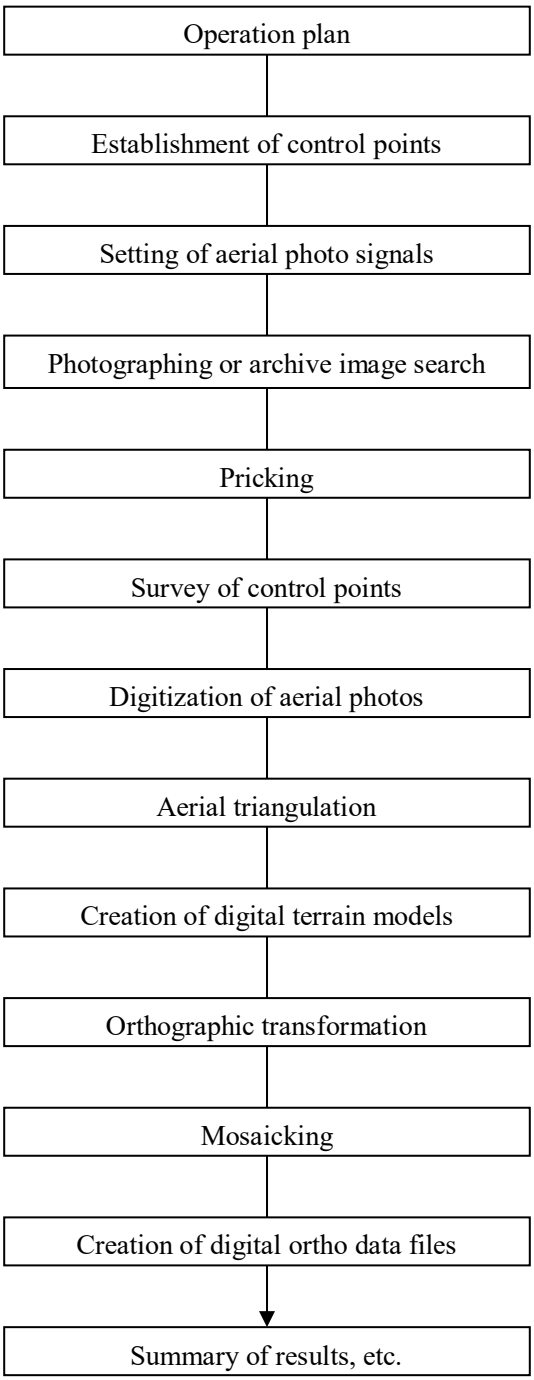
(1) Operation plan
(2) Establishment of control points
(3) Setting of aerial photo signals
(4) Photographing (or archive image search)
(5) Pricking
(6) Acquisition of coordinates of control points
(7) Digitization of aerial photos
(8) Aerial triangulation
(9) Creation of digital terrain models
(10) Orthographic transformation
(11) Mosaicking
(12) Creation of digital ortho data files
(13) Summary of results, etc.

[Explanation]

1. The aerial photos taken shall be digitized from a developed roll film to create image files of digital photos in units of a photo (However, photos taken on a digital camera need not to be subject to the developing and digitizing processes). The digital photos shall be subject to orthographic transformation using exterior orientation parameters that are the results of aerial triangulation and digital terrain models created separately on a digital stereoplotter, etc. to produce orthographic projection images in units of a photo. The orthographic projection images shall be joined to match the neat line or mapping area to create mosaic images. In this case, when the orthographic projection images are created, only the central part that has little geometric distortion shall be used. In the end, the mosaic images shall be divided into units of result storage and summarized into digital ortho data files. The same operation process for aerial photos is applied when the satellite images are used.

2. When the contour lines, annotations, etc. must be overlaid on digital orthos, the process shall comply with the specifications in Chapter 7, "Digital Plotting," Part 3 of the Work Specifications for National Base Mapping and the digital ortho processes shall include also the field verification, digital compilation, and digital plotting.

[Standard flow of work processes for creating digital orthos]



Chapter 2　Digital Ortho Production

Section 1　Operation plan

(Outline)

Article 13　An operation plan shall be made for each process according to the specifications of Article 5 (Operation plan), Part 1 of the Work Specifications for National Base Mapping).

(Digital photos to be used)

Article 14　In principle, the digital photos to be used shall be those taken within one year before starting the operation.

<Article 14　Operation criteria>

The digital photos to be used shall be adopted with respect to the photographing periods, weather conditions, relations of flight courses to solar positions, etc. for the difference of color tones and changes in subjects being encountered.

[Explanation]

1. Photographing shall be performed according to the specifications of Section 1, "Aerial Photography," Chapter 4, Part 3 of the Work Specifications for National Base Mapping. Since the aerial photos vary in image quality, particularly the color tones, with respect to the photographing periods, weather conditions, relations of flight courses to solar positions, etc., it is difficult to unify the color tones in the entire mapping area by adjusting the image data in the processes from digitization of aerial photos and mosaicking. When the existing aerial photos must be used, it is advisable to adopt those taken under the same conditions for a uniform image quality. The adoption of satellite images shall also comply with that of the aerial photos.
2. If the adjustment of color tones is difficult due to a difference in photographing conditions, JICA and the executing organization shall discuss the matter.

Section 2　Digitizing of aerial photos

(Outline)

Article 15　Digitization of aerial photos refers to scanning aerial photos using an aerial photo scanner to create digital photos.

(Scanning)

Article 16　In principle, scanning shall be performed directly from a roll film.

<Article 16　Operation criteria>

1. Before scanning, a roll film shall be cleaned to remove dust, stain, dirt, etc. and it shall also be checked for scratches, dents, etc.
2. Immediately before loading a roll film, the film mount of an aerial photo scanner shall be cleaned to remove dust, stain, dirt, etc.
3. Prescanning shall be performed to correct color tones, in principle, at the beginning and end of each flight course.　If there are areas between which the color tones significantly change in a flight course, prescanning shall be performed separately on each of them.
4. Digital photos obtained through scanning shall be sampled with respect to land covers, photographing periods, weather conditions, relations of flight courses to solar positions, etc. and they shall be checked to ensure that the overall color tones are unified.

[Explanation]

1. Pressing of a roll film during scanning shall be performed differently by some models that check the operation with a sensor and others that depend on interior orientation for checking.　The errors encountered during pressing are expressed in the interior orientation results.　If any abnormality found in the interior orientation results, the pressing device must be checked.
2. The aerial photos do not have uniform color tones due to the extinction in the periphery of an optical lens as well as shadow spots, halation, etc. encountered with respect to the solar direction. The color tones are also changed in development of films and digitizing of aerial photos. Particularly, for color photos, a large color tone difference in an overlapping image section of adjacent photos results in an emphasized color tone difference in the mosaicked boundary.　For this reason, the color tones of overlapping images must be unified to a certain degree before mosaicking and the changes of density in the joined part must be adjusted after mosaicking. However, a complete adjustment is difficult to realize.　It is thus important to perform a proper color correction at the time of digitizing aerial photos.

(Scanning resolution)

Article 17 The minimum ground resolving power for scanning shall be determined based on the relations between photo scales and ground resolution according to Item 2, Article 11.

2. The color gradation shall be 24 bit full color or higher.

[Explanation]

1. The relations between photo scales and scanning resolution and ground resolution shall be as shown in the following table:

Scanning resolving power / Photographing scale	10 μm	20 μm	30 μm
1/10,000	0.10	0.20	0.30
1/20,000	0.20	0.40	0.60
1/30,000	0.30	0.60	0.90
1/40,000	0.40	0.80	1.20
1/50,000	0.50	1.00	1.50

＊ Unit of ground resolution [m]

２． The images shall be compressed using loss less compression.

Section 3 Resolution of satellite images

(Outline)

Article 18 The minimum ground resolution of satellite images shall be determined according to Item 2, Article 11, based on the relations between map information levels and ground resolution.

2. The relationships between map information levels and ground resolution shall be as shown in the following table:

Map information level	Ground resolving power
5000	0.8m or less
10000	1.0m or less
25000	2.5m or less
50000	5.0m or less
100000	10.0m or less

3. The satellite images and ground resolution to be used shall be as shown in the following table:

Name	Ground resolving power
QuickBird	0.61～0.72m (Pan) 2.44～2.88m (MX)
IKONOS	0.82～1.0m (Pan) 3.3～4.0m (MX)
OrbView-3	1.0m (Pan、nadir) 4.0m (MX、nadir)
ALOS	2.5m (Pan、nadir) 10m (MX、nadir)
SPOT-5	5m(2.5 m after image processing) (Pan、nadir) 10m (MX、nadir)
SPOT-1/2/3/4	10m (Pan、nadir) 20m (MX、nadir)

Note: Pan=Panchromatic, MX=Multi Spectral

Section 4 Production of digital topographic models

(Outline)

Article 19 Creation of digital terrain models refers to obtaining elevations using automatic elevation selection technology, etc. to create digital terrain model files.

(Acquisition of elevations)

Article 20 The elevations shall be obtained using a digital stereoplotter, etc. to ensure a necessary and sufficient grid interval for digital terrain models according to the specifications of Item 2, Article 11 and, if required, to obtain basic relief lines, etc. to be used to correct local distortions.

2. The elevations shall be obtained through the automatic elevation selection technology, contour line method, break line method, elevation point measuring method, or a combination of these methods.

<Article 20 Operation criteria>

1. The grid interval obtained using the automatic elevation selection technology shall comply with the relative image interval specified in Item 2, Article 11.
2. The interval of contour lines obtained through the contour line method shall be twice as large as the elevation points accuracy specified in Article 11, but it may be enlarged in the area of topography with equal inclination.
3. The break lines may be selected at the following locations using the break line method,:
   1) Upper and lower ends of artificial slopes, concrete side surface, etc. with large elevation differences
   2) Road edges of elevated roads and grade crossings
   3) Ridges, valleys, or major shorelines
   4) Basic relief lines that represent continuous changes in terrain slopes
   5) Other topographic forms required to define topographic features
4. Through the elevation point measurement method, the elevation points shall be selected according to the specifications in Article 166 (Selection of elevation points), Chapter 7, Part 3 of the Work Specifications for National Base Mapping.
5. The scope of obtaining elevation points shall completely cover the area for which digital ortho data files must be created.
6. Land waters such as rivers and small lakes and marshes shall be regarded as ground surface. Their elevation values shall be given through interpolation processing from the nearest neighbor value in the surrounding land area.
7. If an existing digital terrain model must be used, the quality, secular changes, etc. of data shall be checked.

[Explanation]

1. The automatic elevation selection technology refers to detecting the same point in a pair of digital photos for a 3D model through image correlation, etc. to calculate and transform a parallax difference

of the digital photos to an elevation.

2. The contour line method refers to obtaining elevation data in a contour line format through digital mapping.

3. The break line method refers to obtaining a 3D line from the upper and lower ends of concrete side surface and basic relief lines where topographic form continuously changes through digital mapping.

4. The elevation point measurement method refers to obtaining elevations through digital mapping and shall be used for areas where a sufficient number of elevation points cannot be obtained using other methods in order to create digital terrain models.

5. The merits and demerits of the methods for obtaining elevations vary according to topographic forms. However, the break line method is effective in creating high-precision digital terrain models. A triangulated irregular network created with break lines as constraints is the digital terrain model that reproduces the topographic features most faithfully. Using the automatic elevation selection technology and contour line method, on the other hand, the smaller the intervals of elevation points and contour lines, the more faithfully the topographic features can be reproduced. However, there are limits when reducing the intervals. The transformation of data into digital terrain models normally smoothes the topographic forms and may cause local distortions.

(Transformation to digital terrain models)

Article 21 Transformation to digital terrain models refers to the transformation of elevations obtained as described in the previous article into grids or triangulated irregular networks according to the specifications of Item 2, Article 11.

<Article 21 Operation criteria>

1. When the form of a digital terrain model must be created as grids, the grid interval shall comply with the specification in Item 2, Article 11.
2. A triangulated irregular network, when used, shall be in a form that enables topographic representation equal to grids or better.
3. The scope of creating a digital terrain model shall completely cover the area for which digital ortho data files must be created.

[Explanation]

The following shows examples of standard digital terrain models.

1. The classification of digital terrain models to be obtained shall be as shown in the following table:

Example)

Major classification	Classification	Name	Remarks
Topographic feature, etc.	Digital terrain model	Grid data	Created using the automatic elevation selection technology or created from contour lines, random points, and break lines
		Triangulated irregular network	Created from grid data, random points, break lines, contour lines, etc.

☆ Random point: Obtained using elevation point measurement

☆ Break line: Obtain using the break line method

2. The digital terrain models shall be classified, according to the locations where elevations are obtained, by figure components shown in the following table:

Example)

Code	Description	Remarks
00	Ground level	Digital terrain models
51	Surface level	
52	Sea level	

3. The sea level shall include large lakes and marshes.

(Compiling of digital terrain models)

Article 22 Compiling of digital terrain models refers to displaying the created elevation data on a stereo model and correcting significant differences from the ground level.

<Article 22 Operation criteria>

The digital terrain models shall be corrected using a digital stereoplotter, etc.

(Creation of digital topographic model files)

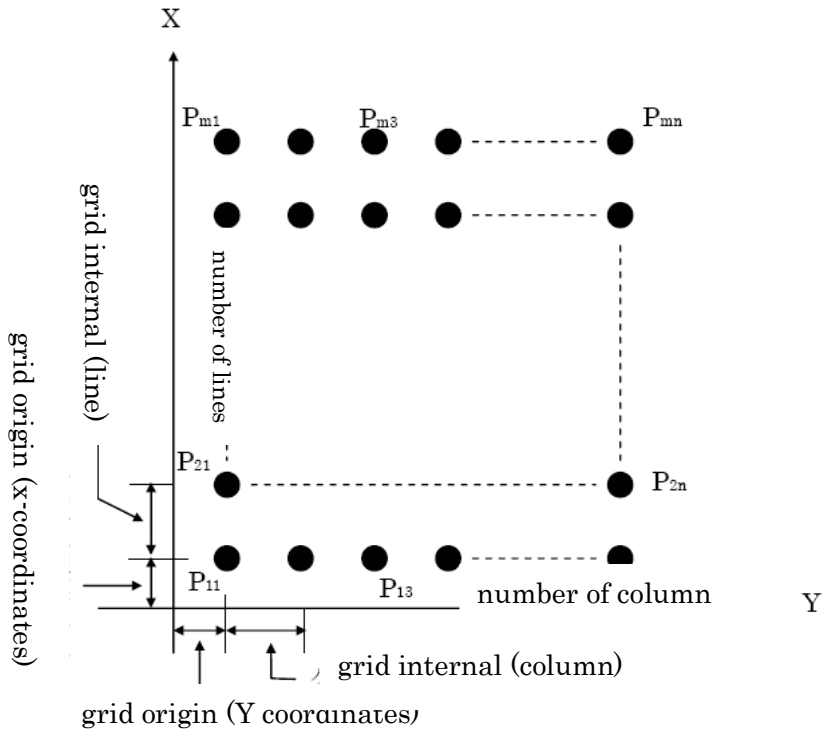
Article 23 The digital terrain model files shall be created from compiled digital terrain models in a prescribed format.

<Article 23 Operation criteria>

1. The digital terrain model files shall be in a standard format and its specifications shall be clearly defined.
2. The digital terrain model files shall be stored in the same storage units as for digital ortho data files.
3. When the digital terrain model files of triangulated irregular networks must be stored, a triangle that extends over neat lines shall be divided by the neat lines into multiple triangles.

[Explanation]

1. As examples, the digital terrain model files are shown in the following standard formats:
   ASCII DTM, ASCII ARC Grid, DTED, USGS SDTS, etc.
2. The digital terrain models (grids) shall use grid records.
3. The origin coordinates of digital terrain models (grids) shall be at the location of half the grid interval from the neat line origin.
4. The digital terrain models (triangulated irregular networks) shall be in a standard format and their specifications shall be clearly defined.



(Checking of digital terrain model files)

Article 24 The digital terrain model files shall be checked using digital terrain models created as described in the previous article.

2. The elevation point accuracy for digital topographic models shall comply with the specifications of Item 2, Article 11.

<Article 24 Operation criteria>

1. The check locations shall be elevation points randomly selected from digital terrain model files.

2. Checking shall be performed by comparing the elevation points obtained through 3D measurements using digital stereoplotters, etc. against those selected from digital terrain model files and summarizing the results in accuracy control record.

[Explanation]

Regarding the intermediate and mountainous areas, forest areas, and other areas where a sufficient number of distinct planimetric features that can be used for checking of elevations are not available, JICA and the executing organization shall discuss the number and locations of check points.

Section 5　Orthographic transformation

(Outline)

Article 25　Orthographic transformation refers to the transformation of digital photos from central projections to orthographic projections to create orthographic projection images.

[Explanation]

1. An aerial photo is a central projection with a camera lens serving as the center and has a distortion due to relative height of the ground, i.e., a higher place looks larger.　In contrast, a digital ortho obtained through orthographic transformation is an orthographic projection in the same way as for a map and therefore it has an accuracy equivalent to the one of a map.

   Note1: The satellite images obtained from a line sensor are a combination of central and parallel projections.

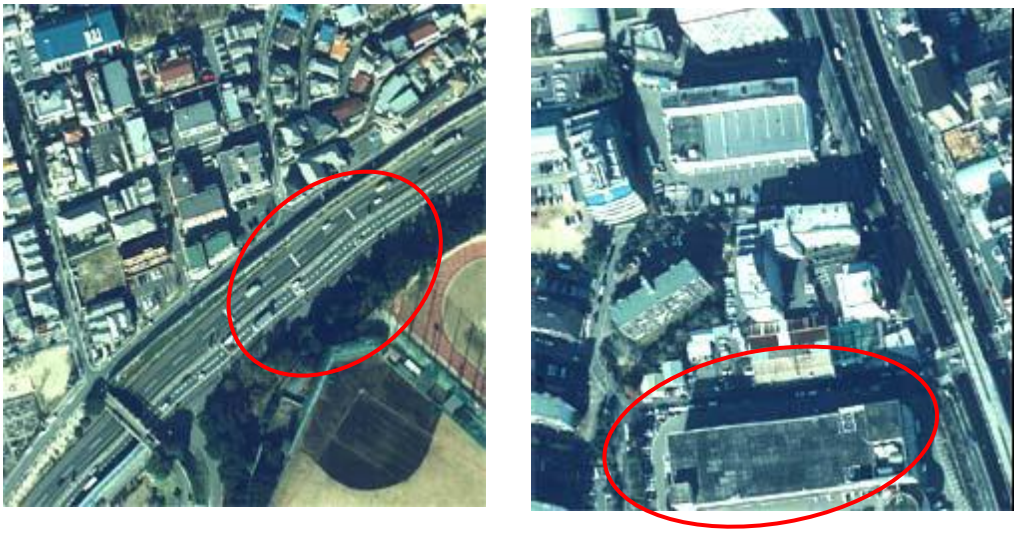
   Note2:.　Sometimes, orthos created with respect to high buildings are called true orthos while orthos not created this way are simply called orthos.　In this Manual, orthos mean the latter.

2. The digital terrain models shall be used for orthographic transformation.　Therefore, in the resultant orthographic projection images, only planimetric features that match the digital terrain model shall have the same location as in a map.　If the ground level data is adopted for a digital terrain model, only the planimetric features that match the ground level shall have the same location as in a map but those with relative elevation differences with the ground level such as building roofs and tree crowns shall not have the same location as in a map.

Slanting of buildings due to relative elevation differences (aerial photo example)

Slanting of buildings due to relative elevation differences (IKONOS satellite image example)

3. Local distortions may occur according to the relations of grid intervals of digital terrain models and topographic forms. A local distortion occurs when the interval of grids in a digital terrain model is denser through interpolation processing so that the interpolated elevation points can correspond to pixels of the digital photo on a one-to-one basis and orthographic transformation is performed using them. The cause of a local distortion is a difference between the digital terrain model and the actual topographic form which does not change linearly in the interpolated section in the digital photo The denser the grid interval, the more the local distortions are likely to occur. The following photos are examples of local distortions in orthographic transformation images using the digital surface models on the surface levels. The characteristic local distortions are seen on the roads in the left photo and on the buildings in the right photo. Whereas it is possible to reduce local distortions by adding elevation points using the break line method, it is difficult to completely remove all of them.



Local distortion of roads (aerial photo example) Local distortion of buildings (aerial photo example)

Local distortion of roads (IKONOS satellite image example)

Local distortion of buildings (IKONOS satellite image example)

(Creation of orthographic projection images)

Article 26 The orthographic projection images shall be created based on digital terrain models after performing the orientation of digital photos .

2. The ground resolution of orthographic projection images shall comply with the specifications of Item 2, Article 11.

<Article 26 Operation criteria>

1. The interior orientation shall be performed according to the specifications in Article 127 (Interior orientation), Chapter 6, Part 3 of the Work Specification for National Base Mapping).

2. The absolute orientation shall be performed using the results obtained in aerial triangulation, etc.

[Explanation]

1. The absolute orientation shall be performed with the functions of a digital stereoplotter using geodetic coordinates of pass points and tie points obtained in aerial triangulation and the observed coordinates of the corresponding points on digital photos or exterior orientation parameters directly.

2. The absolute orientation may be performed using the results obtained in aerial triangulation or the control points that have equivalent accuracies and locations to these results.

Section 6 Mosaicking

(Outline)

Article 27 Mosaicking refers to joining adjacent orthographic projection images through digital processing and creating mosaic images.

(Methods)

Article 28 Mosaicking shall be performed so that no significant misalignment of planimetric features or difference of color tones is caused in the joined parts of adjacent orthographic projection images.

2. Mosaicking shall be performed using orthographic projection images corresponding to the central part of digital photos.

<Article 28 Operation criteria>

1. When the orthographic projection images are joined and the adjacent neat line area images are connected, best efforts shall be made to avoid any inconsistency in linear objects and exceeding the horizontal location limits for other objects.
2. The digital photos that have not undergone orthographic transformation shall not be mosaicked.
3. Best efforts shall be made to prevent a difference in color tones between orthographic projection images.

[Explanation]

1. Mosaicking refers to matching the locations and color tones of adjacent images using the overlapping parts and then joining adjacent orthographic projection images. When digital orthos must be mosaicked, multiple orthographic projection images with unified locations and coordinates shall be subject to the following operation procedures:

(1) Density correction

Density correction refers to matching the different gradations and color tones between digital photos as much as possible.

(2) Color matching through density transformation

Color matching through density transformation refers to matching as much as possible, using the images of the overlapping parts, the systematically uncorrectable differences of gradations and color tones between images, out of those differences between multiple digital photos.

(3) Search for connecting points

Search for connecting points refers to searching for the most easily connectable points

in cross-sections to be joined. The easily connectable points may be those with the smallest density difference between digital photos or those for which the density suddenly changes in the images. The density suddenly changes at such points as roads and ridge and valley lines.

(4) Smoothing the density around connecting points

Smoothing the density around connecting points refers to smoothing the discontinuous colors in the boundaries at which images are joined by performing proportional distribution on certain areas on both sides of connecting points for each cross-section.

2. When orthographic projection images created according to the instructions of this Manual must be mosaicked with different-quality orthographic projection images or digital photos, the range and quality of the latter shall be distinctly discriminable.

(Checking of mosaic images)

Article 29 The mosaic images shall be checked for misalignments of joined parts of major planimetric features (roads, etc.) and differences of color tones between orthographic projection images.

<Article 29 Operation criteria>

1. Misalignments of joined parts, significant distortions, and disconnecting shall be checked.
2. Out of color tone differences of joined parts and significant differences shall be checked.

[Explanation]

1. If joining is difficult due to high buildings, etc., JICA and the executing organization shall discuss the matter.

2. Check that the distortions and disconnecting included in misalignments comply with the requirements mentioned in the following table:

Map information level	Misalignment tolerance
2500	1.75 m or less
5000	3.50 m or less
10000	7.00 m or less
25000	17.50 m or less
50000	35.00 m or less
100000	70.00 m or less

3. Since the color tone differences tend to be evaluated subjectively, checking shall be performed using samples, etc. already discussed by JICA and the executing organization before the start

of the operation.

Section 7 Production of digital ortho data files

(Outline)

Article 30 Production of digital ortho data files refers to cutting out digital ortho data files from mosaic images for each neat line area as well as creating location information files as location information for digital ortho data files, then storing them on electronic storage media according to the specifications.

<Article 30 Operation criteria>

1. For the adjacent neat line areas, the data files shall be cut out from the same mosaic image for each neat line area.
2. When data of annotations, administrative boundaries, etc. are obtained, they shall be stored according to the specifications in Chapter 7, "Digital Plotting," Part 3 of the Work Specifications for National Base Mapping).

[Explanation]

If an orthographic projection image to be used in adjacent neat line areas at a location extending over neat lines is changed to improve the appearance, a misalignment may occur in the joined part. To solve this problem, the data files should be cut out from a mosaic image that uses the same orthographic projection image for each neat line area.

(Storage of digital ortho data files, etc.)

Article 31 The digital ortho data files shall be stored for each neat line area and may be divided, if required.

2. A location information file shall be created for each neat line area as an index file to be used to add location information to digital ortho data files.

<Article 31 Operation criteria>

1. In principle, the digital ortho data files shall be stored in TIFF format.
2. The location information files shall be stored in World file format.

[Explanation]

1. When the data files are cut out for each neat line area, a mosaic image for the entire scope of

mapping shall be used whenever possible in order to avoid inconsistency between the neat line areas.

2. The images in digital ortho data files shall be compressed using loss less compression.

3. The location information files shall be stored in World file format, a text format proposed by ESRI of the U.S. to provide geodetic information to images. A file in World file format shall contain six parameters of affine transformation used to transform the image coordinate system to the ground coordinate system.

Affine transformation is defined by Equation (1):

$$\begin{cases} x' = ax + by + c \\ y' = dx + ey + f \end{cases} \quad (1)$$

Where

x': x-coordinate of the ground coordinate system (mathematical system, east-west, unit: m)

y': y-coordinate of the ground coordinate system (mathematical system, north-south, unit: m)

x: x-coordinate of the image coordinate system (column, unit: pixel)

y: y-coordinate of the image coordinate system (row, unit: pixel)

a to f: Affine parameters

This transformation enables moving the origin, and scaling and rotation in each of the axis directions. However, no rotation will be applied and an equal scale is used for both axis directions. The following shows an example of a location information file to be used when no rotation is applied.

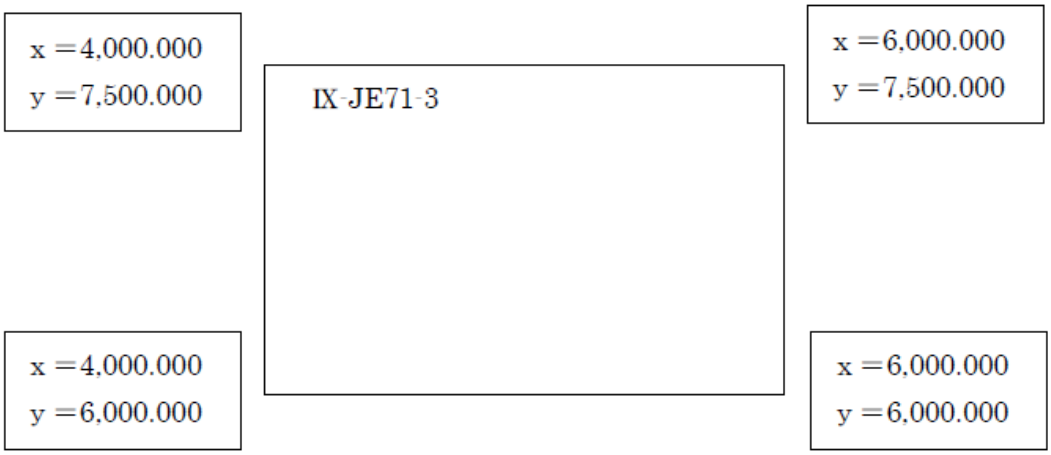
0.1	a
0.0	d
0.0	b
-0.1	e
-28500.00	c
-33000.00	f

Parameters “a” and “e” represent the scales in the x-axis and y-axis directions and have an equal absolute value if the scales are identical in both x-axis and y-axis directions. Since the ground coordinate system and the image coordinate system have different origins, a value in the y-axis direction will show a negative (-) sign. This value corresponds to the scale of one pixel of an image in the ground coordinate system, i.e., the size of one pixel of an image in the ground coordinate system namely the ground resolution.

Parameters “d” and “b” represent the rotation around the origin but both take value 0.0 because, generally, no rotation is applied.

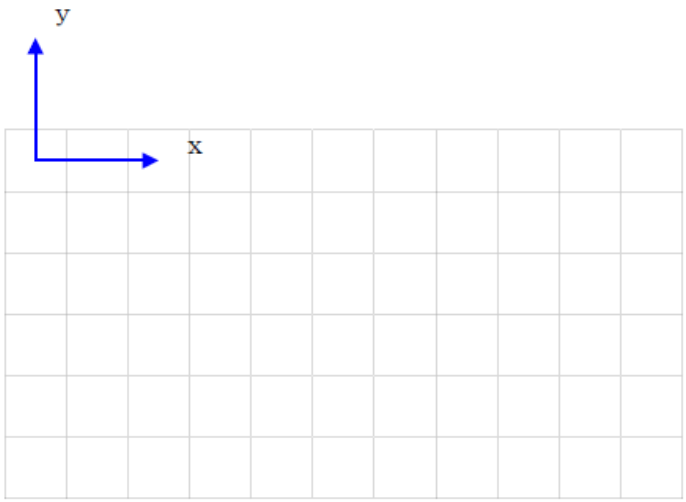
Parameters “c” and “f” represent the amount of parallel translation in both x-axis and y-axis directions. They correspond to the amount for which the image origin 0,0 position (the upper left corner of an image) should be moved in parallel translation, i.e., what coordinate values the pixel center of the upper left corner of an image should take in the ground coordinate system. The unit is in meters in the mathematical system. A location information file shall be usually stored together with the image files.

The following shows an example of creating a location information file when the neat line area number IX-JE71-3 with map information level 2500 is mapped at a ground resolution of 0.4 meters. Note that all the coordinate values are shown in the mathematical system.



a = 0.4 : Pixel resolution in x-axis direction 40cm
d = 0.0 : No resolution
b = 0.0 : No resolution
e = -0.4 : Pixel resolution in y-axis resolution 40cm
c = 4000.20 : x-coordinates of pixel center of upper left corner of an image
f = 7499.80 : y-coordinate of pixel center of upper left corner of an image

The origin of coordinate system is the pixel center of the upper left center shown in the figure below



4. As the naming convention, a World file shall be given the name of an image file with a "W" added to the end. For example, SAMPLE.TIFF shall be named SAMPLE.TIFFW. However, a file name generally conforms to the "8.3 naming convention" (meaning a file name of eight characters followed by an extension of three characters). In this example, the file name shall be followed by an extension consisting of the first and third characters of the image file extension and a "W". The

World File of SAMPLE.TIF shall be named SAMPLE.TFW.

(Checking of digital ortho data files, etc.)

Article 32 The digital ortho data files shall be checked for horizontal locations, color tones, local distortions, and joined parts.

<Article 32 Operation criteria>

1. Checking shall be performed for each neat line area.
2. Checking of horizontal locations shall be performed on distinct planimetric features randomly selected on digital ortho data files.
3. Checking of horizontal locations shall be performed by comparing horizontal coordinates measured using digital stereoplotters, etc. against horizontal coordinates obtained through single-image measurement on digital orthos and summarizing the results in accuracy control records.
4. The accuracy of horizontal locations shall conform to the specifications in Item 2, Article 11.
5. Regarding color tones, local distortions, and joined parts, significant differences and disconnection that exceed the horizontal location accuracy in Item 2, Article 11 shall be checked.
6. Location information files shall be checked for contents by using a check program or displaying it on a graphic display, etc.

[Explanation]

1. Before checking the horizontal locations as for the intermediate and mountainous areas, forest areas, and other areas where there is not a sufficient number of distinct planimetric features that can be used for checking of horizontal locations, JICA and the executing organization shall discuss the number and locations of check points.
2. Since the color tones and local distortions tend to be subjectively evaluated, JICA and the executing organization shall establish a consensus about the pass-fail criteria using samples, etc. before the start of the operation.
3. The digital ortho data files shall be 2D digital images that include the elevation point accuracy of digital terrain models as the horizontal location accuracy and shall not include the height information.

Section 8 Summary of results

(Results)

Article 33 The results shall be as follows:

(1) Digital ortho data file

(2) Location information file

(3) Digital terrain model file

(4) Accuracy control sheet

(5) Other materials

<Article 33 Operation criteria>

The survey results, etc. shall be submitted in electronic data.

[Explanation]

If the survey results are inspected, an inspection certificate and an inspection record shall be submitted.

Part 3 Materials

Chapter 1 Standard Forms

1. Accuracy control record

   The accuracy control for the creation of digital topographic models and digital ortho data files shall be performed according to the indications of the digital ortho creation accuracy control record.

2. Mosaic quality classification chart

   When orthographic projection images or digital photos with different levels of quality are mosaicked, their range shall be indicated in the mosaic quality classification chart.

3. Product control

   The product control shall be performed according to the Checking Process Guidelines for Product Control (Draft).

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ディジタルオルソ作成精度管理表

作業名		作業機関		主任技術者		検査者	
地区名	図郭名	作業期間	自　　年　　月　　日 ～ 至　　年　　月　　日				

Executing organization (作業機関) / Chief surveyor (主任技術者) / Inspector (検査者)

ディジタルオルソデータファイル

番号	測定値		検測値		残差
	x	y	X	Y	
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					
11					
12					
13					
14					
15					
16					
17					
18					
19					
20					
21					

色調	歪み	写真接合	図郭接合		
				平均値	
				最大値	
				標準偏差	

数値地形モデル

番号	平面位置		測定値	検測値	残差
	X	Y	z	Z	
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					
11					
12					
13					
14					
15					
16					
17					
18					
19					
20					
21					
				平均値	
				最大値	
				標準偏差	

＊点検箇所数は 21 点以上を原則とする。

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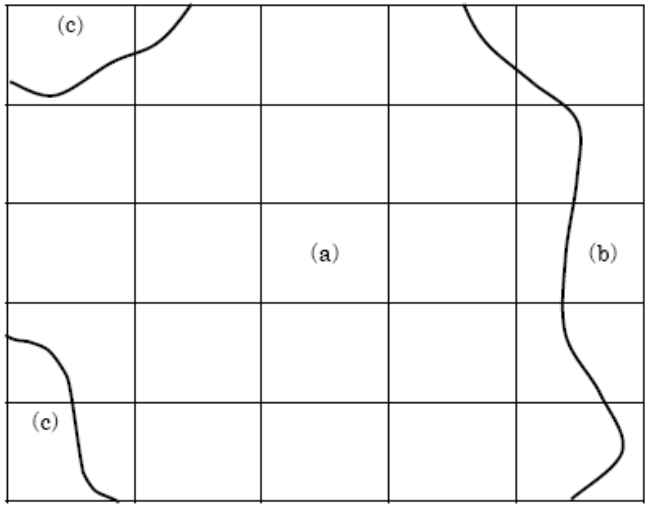
モ ザ イ ク 品 質 分 類 図

作業名又は地区名	計 画 機 関	作 業 機 関	作 業 期 間	主 任 技 術 者
			自 平成 年 月 日 ～ 至 平成 年 月 日	



地域	空中写真			数値地形モデル		公共測量助言番号	備考
	撮影年月	撮影縮尺	地上分解能	グリッド間隔	標高点精度		
(a)							
(b)							
(c)							

注１． この品質管理表は本マニュアルと異なる品質の正射投影画像や数値写真をモザイクする場合に用いる。
２． 品質境界線を太線にて表示する。

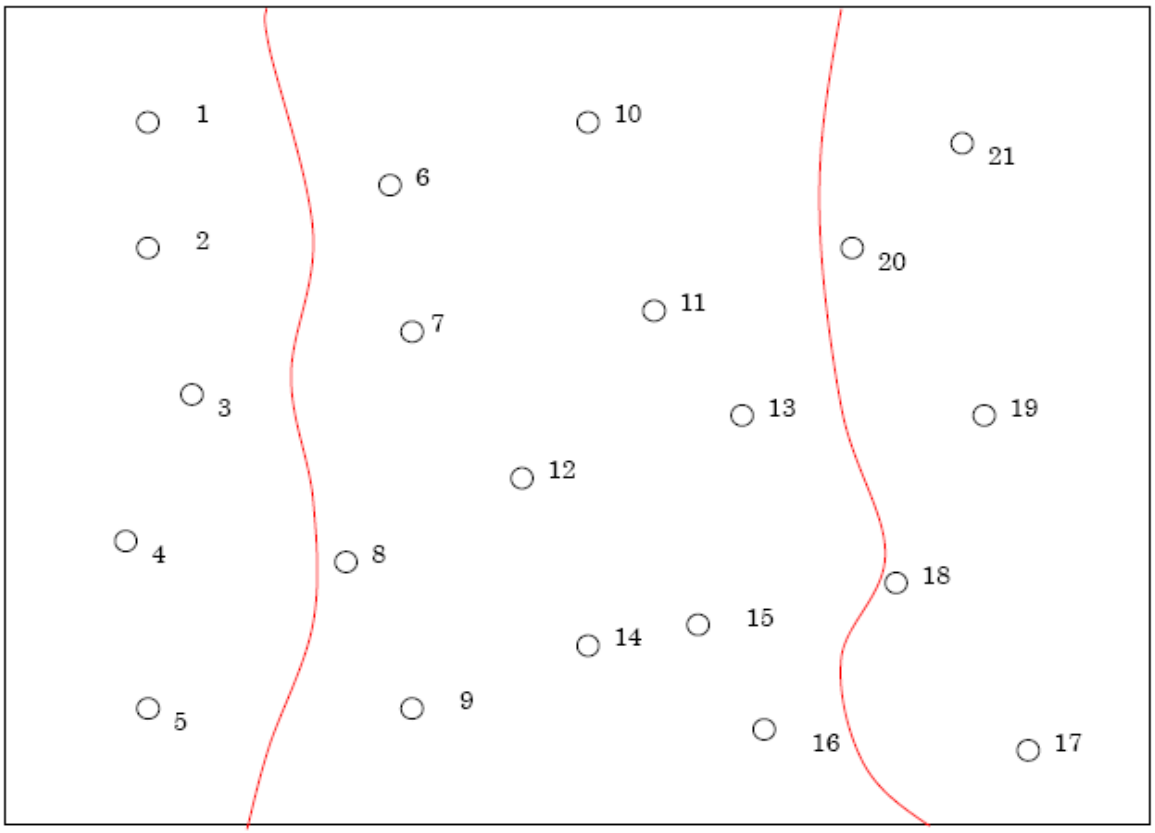
Checking Process Guidelines for Product Control (Draft).

Item	43. Guidelines (draft)	Remarks
Survey type	Digital ortho production	
Total amount of checking	2% of the total area of survey area	
Amount of unit checking for each block	・ Amount of checking specified by the supervisor ・ The amount of inspection measurement for each block shall be determined according to the area and conditions of a survey area by dividing it into units of each area or worker so that the total amount of inspection measurement shall be 2%.	
Description of checking	The locations of planimetric and topographic features, local distortions, joined parts, color tones, etc. shall be checked through digital mapping and visual inspection.	
Check points	Complies with the specifications given by the supervisor.	
How to select check points	・ Areas including planimetric and topographic features ・ Areas that extend over two models, or parts between mosaics	
Guidelines for checking	・ Checking of horizontal location refers to performing digital plotting on major distinct planimetric features and linear objects, etc. in images and comparing the coordinate values of them against those of the same points measured on digital ortho data files. ・ Color tones, local distortions, and joined parts shall be checked through visual inspection. ・ Digital ortho data files (format, location information, ground resolution) shall be checked using a check program or through visual inspection.	
Pass/fail criteria	・ Digital ortho data files and digital plotting data shall be overlaid on each other and checked to ensure that the misalignments are found within the required limits. ・ Check whether the local distortions exist and the misalignments in joined mosaics are found within the required limits. ・ Check whether the color tones are correct. ・ Check whether the files comply with the specifications of the Survey Operation Manual.	The conformity of color tones shall be discussed with the supervisor using samples, etc.
Summary and submission (delivery) formats	・ The digital plotting and other data shall be overlaid on digital ortho data files to create output maps, and check points, numbers, and mosaic joining locations shall be indicated in red on the output maps. The survey operation name, inspector, neat line area number, check period, photographic scale, ground resolution, scanning resolution, and grid interval shall be summarized in an "product control chart," to be submitted. ・ As for the location accuracies, the misalignments of the checked points shall be summarized in a "Location Accuracy Check Results," to be submitted. ・ Check whether the local distortions and defects in joined parts and color tones are complying, and the results shall be summarized in "Check Results for Color Tones, Distortions,	

	and Joined Parts." The images of major check points shall be selected, and a checking chart shall be created and submitted based on the said images.	

Product Control Chart

Surveyor		Checker	
Neat line area name		Check period	Y/M/D ～Y/M/D
Photo scale (denominator)		Ground resolution [m]	
Scanning resolution [μm]		Grid interval [m]	



Locations where models are joined　○ 1：Check locations and their number

Check the results for the Horizontal Location Accuracy

Surveyor		Checker	
Neat line area name		Check period	Y/M/D ～Y/M/D
Photo scale (denominator)		Ground resolution [m]	
Scanning resolution [μm]		Grid interval [m]	

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番号	測定値[m]		点検値[m]		較差[m]			備考
	X	Y	X	Y	ΔX	ΔY	ΔXY	計測箇所
1								
2								
3								
4								
5								
6								
7								
8								
9								
10								
11								
12								
13								
14								
15								
16								
17								
18								
19								
20								
21								
注 1) 水平位置精度は使用した数値地形モデル上以外の地物については対象外とする。 注 2) 水平位置の点検に使用できる明瞭な地物が十分には存在しない地域については、監督員と点検数及び場所を協議する。				点数				
				平均値				
				最大				
				標準偏差				

Checking the Results for Color Tones, Resolutions, and Joined Parts

Surveyor		Checker	
Neat line area name		Check period	Y/M/D ～Y/M/D
Photo scale (denominator)		Ground resolution [m]	
Scanning resolution [μm]		Grid interval [m]	

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	点検項目	点検方法	指摘事項	判定	
ファイル	ファイル形式	所定の仕様で記録してあるか点検する。		合	否
	位置情報	位置情報の入力値の適否を点検する。		合	否
	地上分解能	画素数を計測し所定の地上分解能を満たしているか点検する。		合	否
色調等	色調の統一	隣接する画像間で色調、濃度及び画質の相異の有無とその良否を点検する。		合	否
	階調	画像の濃度に極端な偏りが無いか、中間調を基準として、その良否を点検する。		合	否
	暗影部	暗影の有無及び濃淡による被写地形等の細部を不明な範囲とその良否を点検する。		合	否
	鮮明度	画像の色ずれ、ボケの有無とその良否を点検する。		合	否
	像のむら、汚れ、キズ	スキャニング時のネガのキズ、汚れ、ごみや埃などの有無とその良否を点検する。		合	否
歪み	局所歪み	局所的な画像の歪みの有無とその良否を点検する。		合	否
接合	モデル（コース）の接合部	隣接するモデル間、コース間での被写地形の位置のずれ、画像の重複及びボケの有無とその良否を点検する。		合	否
	図郭間接合部	隣接する図郭間での被写地物の位置ずれの有無とその良否を点検する。		合	否

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色調点検付図

	No.	No.	No.
画像			
指摘事項			

歪み点検付図

	No.	No.	No.
画像			
指摘事項			

接合点検付図

	No.	No.	No.
画像			
指摘事項			

Some examples of periodical inspection certificates for aerial photo scanners are given as follows:

1) PhotoScan, a ZI Imaging product

Geometric Calibration Report for PhotoScan ser. No. xxxxxx

Intersections read from: C:¥Program Files¥PhotoScan TD¥CalibFiles¥25NominalPoints.dat

Title: # Calibration plate: Using all 25 nominal points

		Calibrated		Observed		Residuals	
Status	#	X (mm)	Y (mm)	X (mm)	Y (mm)	X (um)	Y (um)
SM	1	0.000	0.000	0.761	1.511	1.527	-0.930
SM	2	50.000	0.000	50.764	1.177	1.813	0.851
SM	3	100.000	0.000	100.771	0.844	-1.167	1.694
SM	4	150.000	0.000	150.775	0.512	-1.374	2.045
SM	5	200.000	0.000	200.778	0.183	-1.362	-0.557
SM	6	0.000	50.000	1.159	51.509	0.408	-1.526
SM	7	50.000	50.000	51.163	51.177	-0.182	-1.066
SM	8	100.000	50.000	101.166	50.844	-0.279	-0.005
SM	9	150.000	50.000	151.170	50.512	-0.377	0.401
SM	10	200.000	50.000	201.173	50.183	-0.857	-1.639
SM	11	0.000	100.000	1.555	101.506	0.968	0.165
SM	12	50.000	100.000	51.558	101.173	0.706	0.899
SM	13	100.000	100.000	101.562	100.841	0.444	1.304
SM	14	150.000	100.000	151.565	100.512	0.019	-0.806
SM	15	200.000	100.000	201.569	100.180	0.194	-1.275
SM	16	0.000	150.000	1.954	151.506	-1.753	-1.816
SM *	17	50.000	150.000	51.957	151.170	-2.125	1.871
SM	18	100.000	150.000	101.961	150.841	-1.722	-0.340
SM	19	150.000	150.000	151.961	150.508	0.797	0.557
SM	20	200.000	150.000	201.964	150.176	0.754	0.853
SM	21	0.000	200.000	2.349	201.502	-1.085	0.048
SM	22	50.000	200.000	52.353	201.170	-1.401	0.399
SM	23	100.000	200.000	102.353	200.841	1.556	-1.711
SM	24	150.000	200.000	152.356	200.505	1.575	1.694
SM	25	200.000	200.000	202.360	200.176	1.423	-1.009

1.2244335709 = Standard Deviation (sigma)

1.1198752752 = Root Mean Square X

1.1324583540 = Root Mean Square Y

0.9999132339 = Scale X

1.0000055996 = Scale Y

-0.0738295933 = Non-orthogonality (degrees)

x = 1.0000861650 * X + -0.0016963593 * Y + X Offset (microns)

y = 0.0029846409 * X + 0.9999899463 * Y + Y Offset (microns)

2) DSW500, a Leica product

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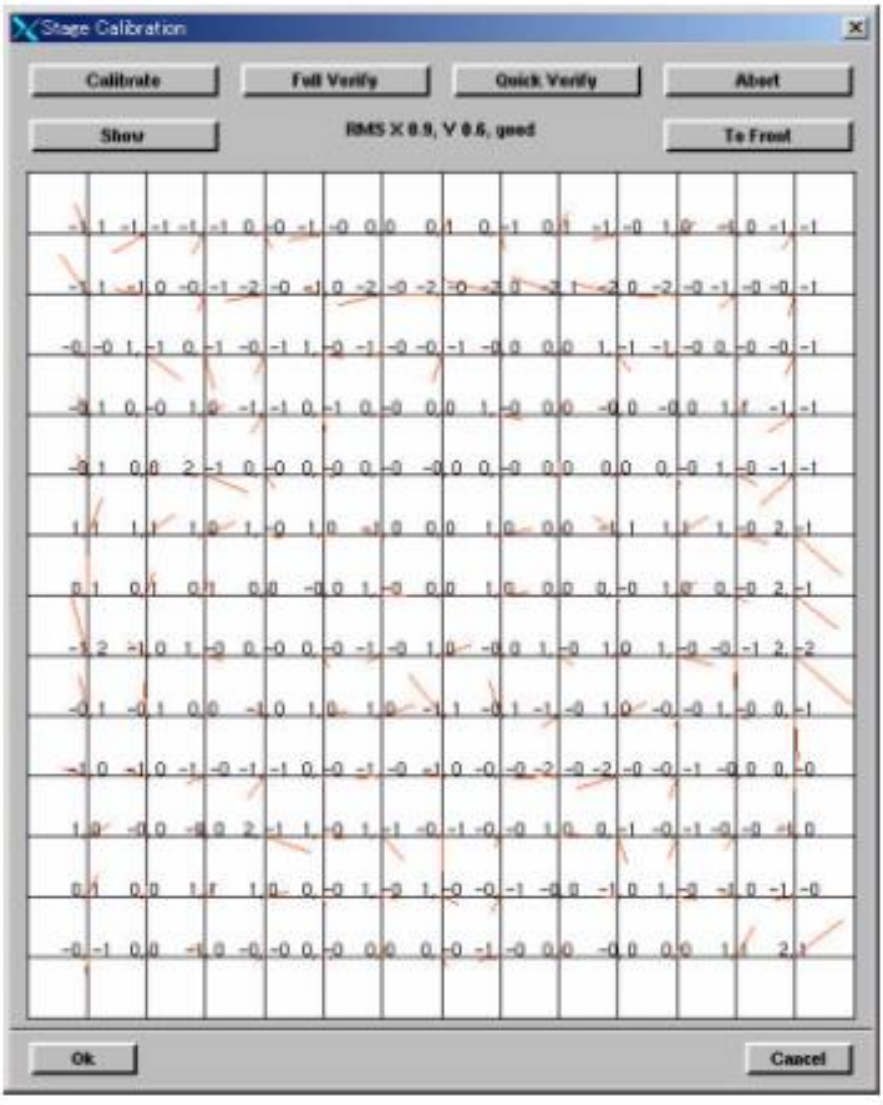
Photogrammetric instrument DSW５００ No. ｘｘｘ

As for the result of the inspection of inclination and length of the instrument above, we certify the result in tolerance as below

検定項目	許容値（μm）	検査結果（μm）	
Full Verify 時の座標誤差の RMS	2.0	X 軸	0.9
	2.0	Y 軸	0.6

Measurement values are in Figure 1

Fig.1 Result of Stage Calibration



70. Digital Ortho Creation Accuracy Control Record

71. Operation name

Area name

Digital ortho data file Digital terrain model

72. Neat line area name

73. Executing organization

Operation period

74. Chief surveyor

75. Inspector

76. Measurement value

77. Inspection measurement value

78. Residual error

79. Horizontal location

80. Color tone Distortion Photo joined parts Neat line area joined parts

81. Average value

Maximum value

Standard deviation

82. * In principle, the number of check points shall be 21 or more.

83. Mosaic Quality Classification Chart

84. Operation name or area name Planning organization Executing organization

Operation period Chief surveyor

85. Area

86. Aerial photo

87. Month/day of photographing Photo scale Ground resolution

88. Digital terrain model

89. Grid interval Elevation point accuracy

90. Public survey advice number

91. Remarks

Notes:

1. This quality control92. Measurement value [m]

93. Check value [m]

94. Difference [m]

95. Remarks

96. Measurement point

97. Number of points

Average value

Maximum

Standard deviation

98. Notes:

1. It is not necessary to check the horizontal location accuracy of the planimetric features other than the digital terrain models to be used.

2. Regarding the areas with an insufficient number of distinct planimetric features that can be used for checking of horizontal locations, the number and locations of check points shall be discussed with the supervisor.

52. File

53. Color tone, etc.

54. Distortion

55. Joined part

56. Check item

File format

Location information

Ground resolution

Unification of color tones

Gradation

Black Area

Sharpness

Inconsistencies, dirt, and scratches of images

Local distortion

Joined part of model (course)

Joined part between neat line areas

57. How to check

Check if the data are stored in a specified format.

Check the conformity of input values of location information.

Measure the number of pixels to check if it meets the prescribed ground resolution.

Check the presence and conformity of differences in color tone, density, and quality between adjacent images.
Check the presence of excessive deviations in density of images and their conformity against the halftone.
Check the presence and conformity of black areas and the range of obscurity in details of photographed topographic features, etc.
Check the presence and conformity of shifts and blurs in images.
Check the presence and conformity of scratches, stains, dusts, and dirt on negatives during scanning.

Check the presence and conformity of local distortions in images.

Check the presence and conformity of misalignments of photographed topographic features and overlapping and blurring of images between adjacent models or courses.
Check the presence and conformity of misalignments of photographed planimetric features between adjacent neat line areas.

58. Problems
59. Evaluation
60. Conforming not Conforming

61. Color tone checking chart
62. Image
63. Problems
64. Distortion checking chart
65. Joined part checking chart

66. Inspection item
67. RMS of coordinate errors at the time of Full Verify
68. Tolerance (μm)
69. Inspection result (μm)

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