Province of British Columbia

Ministry of Sustainable Resource Management

SPECIFICATIONS
FOR
AERIAL TRIANGULATION

Release 2.0 MAY 1998

Geographic Data BC
810 Blanshard Street
Victoria BC V8W 3E1

TABLE OF CONTENTS

FOREWORD

This guidebook of specifications for **Aerial Triangulation** has been documented by a Technical Committee comprising of members from Engineering and Photogrammetry of Geographic Data BC **(BMGS)**. This manual is intended to be used for aerial triangulation with or without differential global positioning system (**GPS**) on board the aircraft to provide densified control points for large, medium and small scale digital and analogue mapping produced for B.C. Provincial Government and any other mapping projects in British Columbia.

Appendix "**I**" related to the use of GPS on board was provided through a contract to Hermann Klein, K2 - Photogrammetry.

1.0 INTRODUCTION

The main objective of aerial triangulation is to produce from ground control, sufficient points in the photogrammetric models to ensure that each model can be oriented accurately as required for stereo compilation in either orthophoto or line mapping in digital or analogue form.

The determination of accurate coordinates for targeted points to be used as cadastral ties or for other purposes can be considered as the by-product of the aerial triangulation process.

2.0 INPUT SPECIFICATIONS

2.1 Instruments

2.11 Point Transfer Device

The device to be used in point marking shall be a precise point transfer device that either cuts or burns circular marks in the emulsion with a maximum diameter of sixty (60) micrometres.

2.1.2 Measuring Device

First order instruments and methods capable of producing precise data for either analytical or semi-analytical (independent model) aerial triangulation shall be used.

The size of the measuring mark shall fall within the range of 65% to 100% of the size of the point marks made by the point transfer device, inclusive.

A copy of the manufacturer's calibration report completed not earlier than twelve (12) months before the first measurements, shall be available for inspection.

If an analogue instrument is used, the means of measurement shall be by encoded X, Y, bX, bY or Omega and the effective recording count shall be five (5) micrometres or better. Independent model techniques where relative orientations are performed manually will not be acceptable unless is recommended by Geographic Data BC **(BMGS)**. Analogue plotters acceptable for this task are: Wild A10, Wild A7, Jena Stereometrograph or equivalent. Instrumentation shall be approved by the **BMGS**.

Grid Tests:

A copy of instrument test report completed not earlier than six (6) months before the first measurements shall be available for inspection.

The test shall be performed in accordance with the following:

- Standard glass grid plates of two (2) micrometres accuracy (one standard deviation) or better shall be used.

- Monocular grid test
  Standard deviation, using a regular array of at least 4X5 points well distributed over the model area for analogue instruments, in a monocular grid test at two (2) widely separated projection planes shall be five (%) micrometres or better at image scale for each photo stage and each projection plane. Monocular grid tests for stereocomparator, analytical plotter, or monocomparator shall use a regular array of at least 5X5 points well distributed over each photo stage

- Stereo grid test
  standard deviation between projection plane coordinates, using a regular array of 4X5 points well distributed over the model area in a stereo grid test at two (2) widely separated projection planes, for analogue universal instruments shall be 0.05 parts per thousand of z or better in each projection plan, where z is the projection distance used in the test.

- the two projection planes in monocular and stereo grid tests shall be separated by at least one-third of the z range for analogue universal instruments.

2.1.3 Distortion Correction Devices

Lens distortion, earth curvature and atmosphere refraction corrections will all be applied analytically, and the use of distortion correction devices will **not** be acceptable.

2.2 Materials

2.2.1 Diapositives

Shall be polyester stable base film with a minimum thickness of 0.17 millimetres.

2.2.2 Contact prints

Shall be double weight and resin coated.

2.2.3 Photo Index Map

Shall show B.C. roll numbers, photo centres and every fifth photo number, ground control/block tie numbers and location, project boundary, large water bodies, river points, and other landmark features (labeled), overlap with adjacent block, if any, project number, project name, mean photo scales, north arrow and shall be prepared on mylar at 1:50,000 scale unless otherwise stated by the **BMGS**

2.2.4 Control points - With Target

Shall be properly coded (see Appendix A and B) and symbolized on contact prints and symbolized only on film diapositives. A concise description and/or sketch will be provided by the **BMGS** for each control point according to Specifications for Control Surveys

2.2.5 Control points - Without Target

Shall be properly coded (see Appendix A and B) and symbolized on contact prints and mark and symbolized or circumscribed on diapositives. A concise description and/or sketch will be provided by the **BMGS** for each control point according to Specifications for Control Surveys.

2.2.6 Lake Shorepoints

Shall be properly coded (see Appendix A and B) and symbolized on contact prints.

2.2.7 Extra points

Shall be coded (see Appendix A and B) and symbolized on contact prints. A concise description and/or sketch will be provided by the **BMGS** whenever Extra points are required.

2.2.8 Block Ties

Shall be coded (see Appendix A and B) and symbolized on contact prints and mark and symbolized only on diapositives used in aerial triangulation of the adjacent block. A listing of Block Tie coordinates will be provided by the **BMGS**.

2.3 Ground Control

Accuracies of ground control points shall be stated in the project specifications according to the Specifications for Control Surveys. A listing of Ground Control coordinates will be provided by the **BMGS**

NAD'83 coordinates are to be utilized unless otherwise stated by the **BMGS**.

3.0 Operational Specifications
(see Appendix "I" for Kinematic GPS on Board)

3.1 Preparation

3.1.1 Point Selection

No point shall be selected closer than 1.0 centimetre from the edge of the photo.

3.1.1.1 Pass Points/Tie Points

Each model shall have a minimum of 5 pass points per side. Lateral sides shall have no less than 2 tie points per side. Tie points shall be staggered as much as possible to avoid any hinge effect during adjustment. Pass points shall be evenly distributed over the topography of the model.

At a change of photo roll within a line, the new line shall have at least 4 points common to the previous line. Model numbers shall skip by at least one (1) across the line break. Forward overlap between the previous and new lines should fall within a range of one half to one full model.

Pass points and strip ties which are transferred along the line shall be symbolized and coded on the photos:

The arrows show the direction of additional tie.

Cross lines or control lines of photography shall be tied to each other where possible and then cross-tied to the other direction of flight lines.

For "Cascade" Aerial Triangulation (i.e. simultaneous) aerial triangulation of two or more blocks/lines of photography having different mean photo scales), each model in the larger scale block/line shall be tied to the smaller scale block by at least 3 well distributed cross-tie points.

Tie points falling in a position which could be used as a pass point shall replace that particular pass point. When this occurs, the point shall be numbered as a tie point.

3.1.1.2 Lake Shorepoints

Are points at which water level measurements race performed. They shall be selected on shores of lakes with minimum dimensions approximately one-half of the model base and clearly visible shorelines. At least 4 well separated points shall be selected on the same lake within the same model.

3.1.1.3 Block Tie Points

Whenever the project adjoins a block whose photogrammetric points have been marked previously, it may be required that such points which fall within the project area be transferred. This will be specified for each project.

3.1.2 Coding and Symbolization

Shall be as per Appendix "A and B".

3.1.3 Photogrammetric Line/Photo Numbers

This section differentiates between the B.C. Roll/Photo Number which appears in the annotation

block on each photograph, and photogrammetric Strip/Photo Numbers assigned during the Aerial Triangulation process.

Lines of Aerial Photography used to form strips of stereo models shall be assigned unique 2 digit line numbers. Unless specified otherwise, lines shall be numbered consecutively from a project boundary commencing at "01".

Each photo along each line shall be assigned a 2 digit photo number. Photos shall be numbered consecutively from left to right.

3.1.4 Model Numbers

Models shall be indexed by combination of the 2 digit photogrammetric line number and the 2 digit left photogrammetric photo number, eg. line 01, photo numbers 29 and 30 shall be model 0129.

In bundle adjustment each photo shall be numbered using the photogrammetric line number and its photogrammetric photo number.

3.1.5 Photogrammetric Control Numbers

A Cross-reference List relating photogrammetric control numbers to actual control numbers and names as assigned by Geographic Data BC **(BMGS)**, Ministry of Environment Lands and Parks shall be included with the project returns (Appendix "E"). It should also include a Control Transfer Report (Appendix "F"), Cadastral Ties Cross-reference List (Appendix "G") and Cadastral Transfer Report (Appendix"H").

3.2 Measurement and Computation

The measuring method will depend on the instrument used. Calibrated focal length given on the NRC camera calibration report, shall be used in all computations.

3.2.1 Precision Analogue Stereoplotters

When analogue instrumentation is used, encoded X, Y, bY or Omega shall be the means of measurements. In this case, perspective centres shall be measured and computed immediately before the first measurements, after completion of the project, at the start of each shift, and at the start of each line break in photography.

Measurements shall be by analytic or semi-analytic (independent model) methods. When analytic methods are employed, encoded **BY**, **BX-BY** or **OMEGA** shall be the means of measurement. Model formation may be on-line or off-line.

Each model shall be computed with Y-parallax not exceeding thirty (30) micrometres at image scale and RMS not exceeding ten (10) micrometres. In strip formation computation, discrepancies (in micrometres at image scale) on model ties from the mean coordinates shall not exceed; X=15, Y=20, and Z=30.

3.2.2 Analytical Plotters, Stereocomparators, or Monocomparators

Measurements shall be done in either mono - or stereocomparator mode.

Lens distortion, earth curvature, and atmospheric refraction corrections shall be applied either on-line or off-line, unless the diapositives are printed with each corrections.

Residual Y-parallaxes during model formation shall not exceed thirty (30) micrometres at image scale and RMS not exceeding ten (10) micrometres.

Discrepancies (in micrometres at image scale) on model ties, from the mean coordinates during strip formation shall not exceed X=15, Y=20 and Z=30.

3.3 Adjustment

3.3.1 General

Unless specified otherwise, all stereo models within a project shall be adjusted simultaneously, including all levels of photography in a specific project.

3.3.2 Computer Program

Any of the following computer programs may be used in final block adjustment:

a) EMR SPACE-M

b) U. of Stuttgart PAT-M, PAT-M43, or PAT-B

c) NRC MODELS

d) NRC BUNDLE (not to be used with lake shorepoints)

Revised versions of the above-mentioned programs and other block adjustment programs must be pre-approved by Geographic Data BC **(BMGS)**, Ministry of Environment Lands and Parks.

Use of additional parameters shall also require pre-approval.

The adjustment shall undergo at least 2 iterations depending on the program and the data used or until convergence is assured.

Point Type	**X,Y**	**Z**
Tie Point	1.0	1.0
Perspective	0.2	1.0
Lake Points	--	0.5
Block Ties	--	0.5

3.3.3 Weights

Weights for SPACE-M and MODELS preliminary adjustment shall be as follows:

Point Type	X,Y	Z
Tie Point	1.0	1.0
Perspective	0.2	1.0
Lake Points	--	0.5
Block Ties	--	0.5

Note: Since control points which occur in more than one model are transferred as 'first generation' transfers, they should not be used as tie points.

	Control Classes and Weighing	X,Y	Z
1.	H2, V3 or better (including GPS points) with 'A' transfer	2.0	2.0
2.	H3, V4 or better (after 1950) with 'C' transfer or better	1.0	1.0
3.	Poor Transfer but good for vertical	---	1.0
4.	H3, V4 or better (before 1950) with 'C' transfer or better	0.5	0.5
5.	H3, V5 and 'C' transfer or better	1.0	---
6.	Class 2 or 3 points above with 5 to 10 m on horizontal residuals (*)	---	0.5
7.	Block ties: - for preliminary adjustment	0.0	0.0
	- for final adjustment (follows)		
8.	Rejected points, 'D' transfers	0.0	0.0

(*) Excessive horizontal residuals which are evident at the preliminary adjustment stage may necessitate revising the weighting for final adjustment.

Note: There are obviously many variations of these control weights which will result from individual circumstances on some points such as flatness of terrain, transfer ratings, unusual orders of survey accuracy, etc.

Retransfer tie points with excessive residuals and reset the model. If a weak model results from over rejection of the points, don't drop points until you have an acceptable RMS. After retransferring and resetting the model, unacceptable tie points shall be rejected by deleting the leading '1' and changing the weight to '0' and adding note "poor point" on the photos. If an excessive tie point residual is caused by a poor transfer between lines, it should be re-coded as a pass point where applicable and re-coded on the photos.

Control points with excessive horizontal residuals may be selectively weighted in height only after a stereo check confirms the flatness of terrain along the horizontal vector. Such points shall retain the original code number and survey coordinates, and only the weight is changed. These must be noted and described in the adjustment report.

All control points within the overlap between adjoining blocks shall be weighted the same in each block.

For other adjustment programs, weights shall be proportional to SPACE-M weights.

Depending on ground control accuracy variations and the quality of point identification and transfer, it may be required that the weights for control points be varied for the final block adjustment run upon approval of the **BMGS**.

3.3.4 Preliminary Adjustment

Shall be performed utilizing perimeter control points and lake shorepoints only. All other control shall be carried in the adjustment as check points. Weights shall be as specified in Section 3.3.3.

3.3.5 Final Adjustment

Shall be performed only after Geographic Data BC **(BMGS)** has approved the preliminary adjustment. Instructions regarding changes to weights and deletion of points may be issued with preliminary adjustment approval.

3.3.6 Adjustment Results

Root Mean Square Errors (RMS) in micrometres at image scale shall not exceed the following:

a) Tie and Pass points: 15 in X,Y and Z;
b) Ground control points: 30 in X,Y and Z;
c) Lake points: 20 in Z.

No residual error in microns at image scale shall exceed the following:

a) Tie and Pass points: 50 in X,Y and 55 in Z;
b) Control Points: 60 in X,Y and Z;
c) Lake Points: 50 in Z;
d) Block Ties: 70 in X,Y and Z.

Changes to weights specified in Section 3.3.3 and/or deletion of Tie, Pass or Control Points other than those mentioned in Section 3.3.5 shall be reported along with the adjustment results.

This report, preferably in tabular form, shall give a brief explanation of the reason for the weight changes and/or point deletion.

Any control point rejected shall be retained as transformed only. Discrepancies at block tie points with respect to the adjusted coordinates from adjacent blocks shall not exceed 0.25 mm at map scale in X,Y and 0.25 times the contour interval in Z. the final values to be adopted for block tie points shall be the mean of the two sets unless specified otherwise.

The evaluation of the adjustment results will not be totally according to the statistical results and the following elements should also be evident in the adjustment.

a) Proper aerial triangulation with respect to control point and tie point locations;

b) No evidence of a systematic nature to the residuals on either control points or photogrammetric points;

c) The block and individual models remain structurally sound while meeting point rejection criteria;

d) The data will be iterated until further iterations will not produce significant change in adjusted coordinates

In general the block must be geometrically well controlled and meet the requirements of sound photogrammetric practice. Simple compliance with RMS value does not necessarily indicate an acceptable adjustment.

3.3.7 Returns for Inspection

3.3.7.1 General

It is important to fully complete all returns prior to submission of preliminary adjustment to enable a full and conclusive assessment. It is recommended that samples of recently completed block returns be loaded to contractors when necessary to ensure uniform returns.

3.3.7.2 SPACE-M Output

The numerical output listing shall be submitted with notes and comments during analysis.

3.3.7.3 Key Plans

- Key plans are prepared on reproducible mylar at 1:50,000 scale for each NTS sheet. Information required is as follows:
- Models with model numbers;
- Control with point numbers;

- Large water bodies showing limits of coded sub-lakes;
- Landmark features including major rivers;
- BCGS sheets with numbers;
- Overlap with adjacent blocks, if any, and block ties with numbers and notation "block tied to -- or from" -- as applicable;
- Photo information including roll numbers and approximately every fifth frame number;
- Cloud gap photography with roll numbers and frame numbers;
- Control points symbolized by how they were used in the adjustment;
- Symbolized permanently marked control with survey identifier;
- Adjusted elevations for lakes;
- Adjusted river elevations in key locations (to verify proper flow in slow-flowing areas and 20 metre contour locations, if possible);
- Block and sheet identifier;
- Geographic latitudes and longitudes at corners of the NTS sheet;
- Legend showing control symbology.
  Refer to Appendix "C" for a sample final key plan.
  Permanently marked control (designated by G or M in survey coordinates lists supplied by the Ministry) shall be symbolized as such only if they meet the following criteria:
- H3V4 survey order or better, including GPS points;
- They were used in the adjustment;
- Targeted on the monument -- i.e., not offset targets nor picture points.
- A control point used both horizontally and vertically, or solely horizontally, shall be symbolized on the key plan as a permanently Marked Horizontal point. A point intended and used solely for vertical (because of a low H survey rating -- i.e. H4V4, or a Bench Mark) shall be symbolized on the key plan as a permanently Marked Vertical point. The criteria is to indicate control points that have been proven to be reliable by the aerial triangulation process.

3.3.7.4 Vector and Residual Plots

These shall be computer-generated and shall include horizontal vectors with residual values for all control points and block ties, as well as vertical with residual values, on separate plots covering the full block at 1:500,000 or at an appropriate scale.

3.3.7.5 Numerical Lake Report

All lake points with their residuals shall be extracted from the SPACE-M report sorted numerically by lake numbers with blank lines separating lakes. This will allow easy assessment of lakes.

3.3.7.6 Control Problem Report

A separate report shall be prepared listing all control with excessive residuals or other anomalies. Each point shall include all pertinent information such as: point number, model number, survey identifier, year and order of survey, transfer rate, current residuals and weight, and special comments. Points shall be highlighted where survey coordinate checks are required (due to excessive residuals with no apparent photogrammetric reason). Refer to Appendix "D" for a sample control problem Report.

3.3.7.7 Written Report

A complete report shall be written which covers all work carried out on the block. This report will include:

- Block work history;
- Photography and control used;
- Equipment and Software used;
- Methodology and specifications used;
- Numerical adjustment results;
- Additional information such as items of concerns, weak areas in the block, recommendations, etc.;
- Note any stereo gaps or any stereo dead areas encountered;
- Summary and block accuracy classification.

3.3.7.8 Source Materials

All source materials shall be included in returns for adjustment inspection. These materials include survey planning maps with various overlays, control coordinate lists supplied, and original transfer reports.

3.4 Base Control Manuscripts

Photogrammetric manuscripts at a required scale and format shall be plotted from adjustment output using an automatic plotter or mechanical coordinatograph capable of achieving the required accuracy given below. The manuscript shall be a polyester base material 0.1 millimetre thick minimum with a suitable texture to take pencil or ink.

Each manuscript shall show:

- All triangulated points for the full models required to compile the mapsheet data. Each point is to be properly coded and symbolized per Appendix "A" and "B". The precise location is to be indicated with the point number (from Aerial Triangulation) and elevation (meters) legibly printed to one side;
- BCGS Mapsheet(s) corner ticks and/or Neat line(s);
- UTM Grid lines/Grid ticks (at the appropriate spacing) extended to encompass all plotted points and the sheet corners;
- Grid line values in meters at the edge of the gridded area;
- Beyond the gridded area in the R.H. corner :
- BCGS sheet No.(s);
- Project No. and Name;
- Mapsheet scale.

All points shall be plotted with an accuracy of 0.15 millimetres (one standard deviation) at map scale with respect to the given coordinates.

4.0 Output Specifications (see Appendix "I" for Kinematic GPS on Board

4.1 Calibration Report and Instrument Test Results

Shall indicate the instrument used, its corresponding serial number, date, name of operator, number of points used and standard deviation.

4.2 Perspective Centre Computations

Shall indicate the instrument used, its serial number, name of operator, date, measurement, and computations.

4.3 Model Diagram

Shall be prepared at a suitable scale on reproducible film material and shall show all neat models, every other model number, line numbers, ground control/block tie location and numbers, including those points deleted from the adjustment, graphic depiction of control/block tie residuals shown in vector form, vector scale, mean photo scale, project boundary, large water bodies and other landmark features (labelled), overlap with adjacent blocks if any, project number, north arrow at 1:50,000 scale unless otherwise specified by the **BMGS**.

4.4 Block Adjustment Input

Shall be original unrefined data on **"ANSI"** Standard tape unless specified otherwise. The information required with the tape shall be per Section 4.9 (d).

4.5 Photo Coordinate Refinement Listing

Shall be on **"ANSI"** Standard tape unless specified otherwise. the information required with the tape shall be per Section 4.9 (d).

Refinement of image coordinates shall be reported including reduced distance between fiducial marks and also including camera calibration reports/data used in this refinement process. Additional coordinate refinement processes may be specified for any project.

4.6 Model Formation Listing

Shall show model numbers, point numbers, residual Y-parallaxes, and RMS.

4.7 Strip Formation Listing

Shall show model numbers, point numbers, and discrepancies at model ties.

4.8 Preliminary Adjustment

Shall consist of the following:

- Model Diagram per Section 4.3. The diagram need not be submitted on reproducible film material at this stage of the project
- Computer listing of Block Adjustment input per Section 4.4, model formation listing per Section 4.6, and strip formation listing per 4.7.
- Computer listing of Block Adjustment output showing project number, date, photo scale, model or photo numbers, point numbers, preliminary adjusted coordinates, residual errors, and RMS's of tie points and control points. The control datum (e.g. NAD'83) must be clearly indicated

4.9 Final Adjustment

Shall consist of the following:

- Model Diagram per Section 4.3
- Computer listing of Block Adjustment input per Section 4.4, Photo coordinate refinement listing per Section 4.5, model formation listing per Section 4.6, and strip formation per 4.7.
- Computer listing of Block Adjustment output showing project number, date, photo scale, model or photo numbers, point numbers, adjusted coordinates, residual errors, and RMS's of tie points and control points. The control datum (e.g. NAD'83) must be clearly indicated.

- Data Interchange by FTP and diskette, compressed if necessary

5. SUMMARY OF RETURNS

5.1 Materials to be delivered

a) All materials supplied for the project;
b) Calibration report and instrumental test results of instrument used in easurement if requested;
c) Perspective Centre computations;
d) Photo Index map;
e) Model Diagram;
f) Block Adjustment input;
g) Photo coordinates if different from f) above;
h) Computer listing of model formation computations;
i) Computer listing of strip formation computations;
j) Computer listing of preliminary adjustment;
k) Computer listing of final adjustment;
l) Detailed report on the project;
m) Adjusted data of final adjustment on diskette and;
n) Base control manuscripts, if required for the project.
o) Model Orientation Record

REFERENCES

- Specifications for Aerial Triangulation Edition - March 1984, Surveys and Resource Mapping Branch, B.C. Ministry of Environment.

- Manual of Procedures for TRIM Aerial Triangulation, Digital Mapping Group Ltd., October 1989, Draft 2.0.

APPENDIX "A"

POINT TYPE CODES

SYMBOLIZATION AND COLOUR CODE

Symbol	Colour	Code	Type of Point

		0	Perspective Centre
	Blue	1	Vertical Control Point
	Red	3	Block Tie Point
	Black	4	Lake Point
	Red	5	Horizontal Control Point
	Blue	6	Tie Point - Cross Lines
	Black	7	Extra Points (including targeted Cadastral tie points)
	Red	8	Tie Point - Parallel Lines
	Red	9	Pass Point
X	Blue	2	River Point - For Flow Check

APPENDIX "B"

<u>Examples of Coding Procedures for A.T.</u>

Vertical Control Point:

58|10|8|1

58 = Line Number
10 = Model Number
8 = Model Position
1 = Vertical Code

Block Tie:

58|10|8|3

58 = Line Number
10 = Model Number
8 = Model Position
3 = Block Tie Code

Lake Point:

02|48|6|4

02 = Lake Point Counter (the second lake point on 48)
48 = Line Number
6 = Lake Number
4 = Lake Point Code

Horizontal Control Point:

10|14|2|5

10 = Line Number
14 = Model Number
2 = Model Position
5 = Horizontal Point Code

Tie Point Cross Lines:

14|02|6|6

14 = Line Number
02 = Model Number
6 = Model Position
6 = Tie Point Cross Line Point Code

Extra Point - Cad Tie:

10|01|1|7

10 = Line Number
01 = Model Number
1 = Model Position

7 = Cad Tie Code

Tie Point - Parallel Line:

12|04|4|8

12 = Line Number
04 = Model Number
4 = Model Position
8 = Tie Point - Parallel Line Code

Pass Point:

11|11|3|9

11 = Line Number
11 = Model Number
3 = Model Position
9 = Pass Point Code

River Point:

12|12|1|2

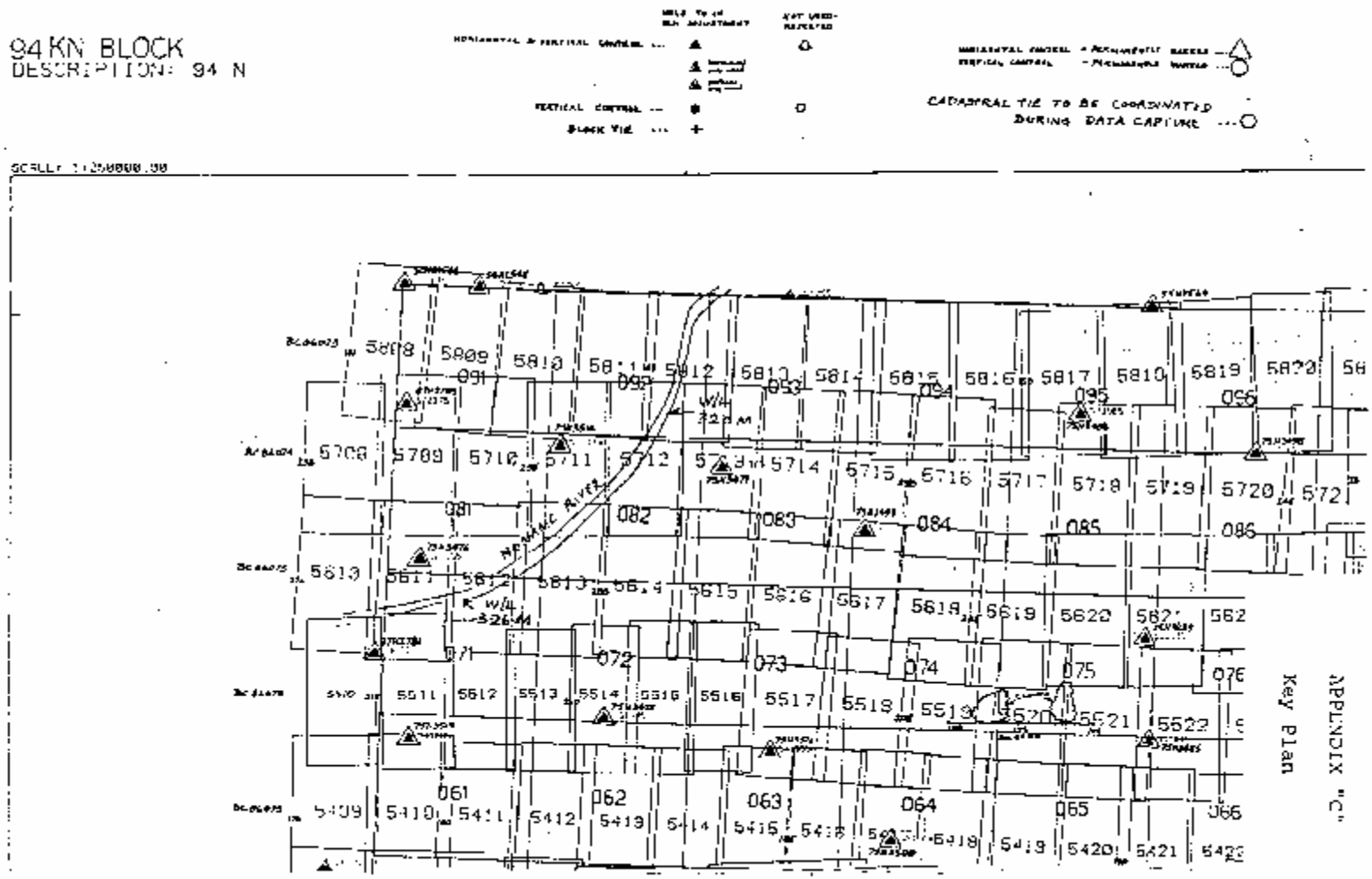
12 = Line Number
12 = Model Number
1 = Position on River Source
2 = River Point Code

13|11|2|2

13 = Line Number
11 = Model Number
2 = Position on River Further Downstream than 1
2 = River Point Code

APPENDIX "C" KEY PLAN

94 KN BLOCK
DESCRIPTION: 94 N



APPENDIX "D"

CONTROL PROBLEM REPORT

APPENDIX "D"

Control Problem Report

A/T BLOCK 94K, N — March 23, 1989

CONTROL WITH EXCESSIVE RESIDUALS — page 1 of 1

MODEL NO.	AT CODE	MINISTRY IDENT	ORDER/ YEAR	TRANS RATE	RESIDUALS E	N	Elev.	WEIGHT	COMMENTS
3430	343055	72H7752 CHEEZ	H3V4 1972	B	-7	-3	+33	000	Reason unknown — in 94F block — leave weight 000 *
3617	361885	71H9262 GLUM	H3V4 1971	C-	-54	+63	+15	000	Reason unknown — leave weight 000
3716	"	"	"	"	-53	+59	+16	000	
3418	341875	72H7796 ICE	H3V4 1972	C+	-10	+1	0	00.5	Poor transfer — in 94F block
3423	342365	72H7759 THAT	H3V4 1972	D	+16	+7	+2	00.5	Poor transfer — in 94F block
3425	332971	72H7763 ARE	H3V4 1972	D	+7	-8	+4	00.5	Poor transfer — in 94F block
3526	352651	72H7762 HERE	H3V4 1972	D	+9	+23	-2	000	Ground appears flat along res. dual vector but for residual is too large to accept for test
3530	353075	72H7749 CAT	H3V4 1972	C	+2	-7	-3	001	Poor transfer — good for vertical
3703	370345	71H9225 LINGUS	H3V4 1971	C	+10	0	+3	001	Poor transfer — vert. residual agrees with apparent ground slope
4527	452725	74H2321 DUN	H3V4 1974	C	+8	-6	-1	00.5	Poor transfer — good for vert.
4126	412655	74H2345 ELLEN	H3V4 1974	B	-5	+1	+1	111	Leave weight 111
4713	471375	51705 KAESU	H170 1951	C	0	-2	+6	110	VC survey order — will fit if vertical is weighted
4811	"	"	"		0	+1	+5	110	
5311	531125	87H2780	GPS 1987	B	+2	+8	-1	001	Reason unknown — good for vert. *
5310	531025	55H7551 MINSS	H3V3 1955	C-	-70	+4	-4	000	Mk. not found

* Denotes Coordinate Check is required by MOCL

Weights should not be changed for final adjustment unless otherwise noted in 'comments'.

APPENDIX "E"

CONTROL CROSS-REFERENCE LIST

APPENDIX "E"

1:10,000 PHOTO GROUND CONTROL CROSS-REFERENCE LIST

Bolt Identifier	Index Equivalent	Photogrammetric Equivalent
5231	5231	252315/1
5440	5440	254405/1
5616	5616	256161
5494	5494	254945/1
5483	5483	254835/1
8635	8635	286355/1
5589	5589	255895/1
80H2023	2023	220235/1
5640	5640	356401
5637	5637	356371
5496	5496	354965/1
5620	5620	356201
80H2098	2098	420985/1
80H2096	2096	420965/1
84H0585	0585	405855/1
5638	5638	456381
5036	5036	550365/1
5038	5038	550385/1
8636	8636	586365/1
5930	5930	559305/1
5630	5630	556305/1
5643	5643	556435/1
5627	5627	556275/1
5429	5429	654295/1
5027	5027	650275/1
8740	8740	687405/1
5020	5020	650205/1
5022	5022	650225/1
5024	5024	650245/1
5114	5114	551145/1
5068	5068	750685/1

APPENDIX "F"

CONTROL TRANSFER REPORT

APPENDIX "F"
Control Transfer Report

TRIM CONTROL TRANSFER REPORT

MAPSHEET 94K PAGE 4 of 5

	STATION		①	②	PHOTOGRAPHY							
	DMG/MCEP Ident	Name	Survey Order Year/type	Transfer Rate	A/T Code	A/T Line Model #	Roll #	Ident Photo/year	Date	Person	PUG Ratio	Remarks
	71H 9225	BSHI	71 H3V4	D	460955	46-4619	[illegible] 116	(6mm) 41-77	88/11/26	RO	6:1B	
	71H 9218	ANGLE	71 H4V4	D	430981	43-4309	[illegible] 110	(ANA) 110	88/11/16	RO		TRANSFERRED BY INSPECTION ONE 88 1987
				D	"	42-4159	[illegible] 137		88/11/16	RO		
	87H2808		GPS	B+	421665	42-4216	87049 38	(70mm) 53-216	88/12/7	A.N.		ONE TARGET ARM VISIBLE
	87H2796		87 GPS #1	C	461675	46-4616	88060 169	(70mm) 54-420	88/11/21	RO		SEE ALSO PAGE 4 TRANSFER RPT. SUN
				C		47-4720	88060 146		88/11/21	RO		
	71H9254	MINER		B+	411545	41-4115	87049 16	(70mm) 66-311	88/12/7	A.N.		FAINT TARGET
	60H2677	MUNCHO	1960 H3V4	B	461055	46-4610	88065 146	(70mm) 65-212	88/12/7	A.N.		
	74H2369	SNAKE		B	452555	45-4525	88062 87	(70mm) 59-429	88/12/7	A.N.		
	60H2688	STANS	H1V4	A	432155	43-4321	87049 87	(70mm) 64-432	88/12/7	A.N.		TARGET VISIBLE
	71H9252	ULTRA		B-	389955	38-3809	86098 140	(70mm) 50-218	88/12/7	A.N.		
94L	57H2547	HIGH	71 H3V4	B	430165	43-4308	88062 239	(70mm) 41-70	89/1/3	R.O.	6:18	
94L	71H9209	KITTY	71 H3V4	C	410935	41-4109	87049 22	KMB(3)-179	89/1/3	R.O.		TRANSFERRED BY INSPECTION — INSUFFICIENT ANLARGE
94L	87H2814		GPS	B+	411085	41-4110	87049 21 87049	(70mm) 55-135	89/1/6	D.D.	6:17	FAINT TARGET — PUGGED TARGET VISIBLE

① Survey order
- H3 V4 or better
- latest year surveyed
- Dop, trav, trian, GSC, GPS

② Transfer Rate
- A - target visible on mapping photo
- B - accurate >40mm on mapping photo
- C - 40 - 80 mm on mapping photo
- D - >80mm: poor transfer
- E - rejected: not transferred

APPENDIX "G"

CADASTRAL TIES CROSS-REFERENCE LIST

APPENDIX "G"

Cadastral Ties Cross-Reference List

CADASTRAL TIES QUEEN CHARLOTTE ISLANDS 1033,C,F,G,J,K 23 AUG 1989

COORDS ARE UTM ZONE8

ENTCS	(CD88X319)	5849735.630	698340.490	1.85	104557	103C	B
ENTCS	(CD88X320)	5849361.130	700209.440	6.01	104567	103C	B
ENTCS	(CD88X323)	5845900.960	714048.390	6.88	114767	103B	B
ENTCS	(CD88X325)	5848425.350	715793.960	5.44	114777	103B	C
ENTCS	(CD88X328)	5843686.070	718292.480	3.13	114867	103B	B
ENTCS	(CD88X318)	5858026.120	710149.920	7.63	124537	103B	C
ENTCS	(CD88X265)	5977889.320	622926.270	6.65	131587	103F	B
ENTCS	(CD88X290)	5915071.970	666832.180	4.37	133337	103F	B
ENTCS	(CD88X279)	5955578.160	651866.910	44.60	142157	103F	C
ENTCS	(CD88X280)	5946308.860	659111.100	4.91	142357	103F	C
ENTCS	(CD88X284)	5937932.680	666845.440	7.08	142567	103F	D
ENTCS	(CD88X293)	5904449.630	695371.220	12.61	143447	103F	B
ENTCS	(CD880304)	5873955.330	727790.230	11.63	144477	103B	B
ENTCS	(CD88X276)	5955431.200	669146.360	4.28	152277	103F	C
ENTCS	(CD88X288)	5933557.080	683321.450	149.36	152847	103F	C
ENTCS	(CD880551)	5923878.220	704933.500	7.56	163157	103G	B
ENTCS	(CD88X259)	6000171.780	643635.770	4.77	171337	103K	C
ENTCS	(CD88X264)	5986361.350	653947.040	6.81	171627	103K	D
ENTCS	(CD88X267)	5984776.540	658347.470	2.24	171737	103F	C
ENTCS	(CD880354)	5944856.020	697413.150	34.30	172747	103F	B
ENTCS	(CD88X286)	5943488.980	699396.510	28.90	172757	103G	B
ENTCS	(CD88X355)	5942101.840	701476.750	22.56	172857	103F	C
ENTCS	(CD880268)	5983145.930	674752.890	100.83	181857	103F	B
ENTCS	(CD88X271)	5968427.270	690894.450	24.21	182267	103F	C
ENTCS	(CD88X269)	5976502.520	691184.370	3.29	192137	103F	B
ENTCS	(CD880262)	5990756.380	690103.230	6.00	201947	103K	B
ENTCS	(CD880263)	5992908.830	702737.740	6.97	212157	103J	B
ENTCS	(CD88X261)	5999672.500	716775.400	10.33	232137	103J	B

TOTAL 28 CADTIES FROM QUEEN_CHARLOTTES BLOCK

APPENDIX "H" CADASTRAL TRANSFER REPORT

APPENDIX "H"
Cadastral Transfer Report

TRIM CADASTRAL TRANSFER REPORT

MAPSHEET 94K
PAGE 1 OF 2

STATION		PHOTOGRAPHY							
CAD Ident	A/T Code	A/T Line # / Model #	Roll #	Ident / Photo/year	Date	Person	PUG ratio	Transfer Rate	Remarks
CD870408	352947	35-3529	B6102 204	(70mm)55-400	88/12/7	A.N.	6:19	B	
CD87X409	372457	37-3724	B6102 15	(70mm)55-499	88/12/7	A.N.	6:20	B+	
CD87X410	372567	37-3725	B6102 14	(70mm)55-502	88/12/7	A.N.	6:19	B	
CD870411	382977	38-3829	B6102 47	(70mm)55-337	88/12/7	A.N.	6:21	B-	
CD870412	382957	38-3829	B6102 47	(70mm)55-334	88/12/7	A.N.	6:21	B+	
CD870413	401567	40-4015	B6102 72	(70mm)55-78	88/12/8	A.N.	6:20	B	
CD870414	401557	40-4015	B6102 72	(70mm)55-81	88/12/8	A.N.	6:20	B+	
CD870415	401747	40-4017	B6102 30	(70mm)55-75	88/12/8	A.N.	6:20	B-	
CD870416	411837	41-4118	B7049 13	(70mm)55-71	88/12/8	A.N.	6:20	B	
CD870417	411847	41-4118	B7049 13	(70mm)55-69	88/12/8	A.N.	6:22	B	
CD870418	411947	41-4119	B7049 12	(70mm)55-64	88/12/8	A.N.	6:22	B	
CD870419	411977	41-4119	B7049 12	(70mm)55-63	88/12/8	A.N.	6:22	B+	TARGET FAINTLY VISIBLE
CD870420	421647	42-4216	B7049 38	(70mm)55-87	88/12/8	A.N.	6:22	B	
CD870421	421657	42-4216	B7049 38	(70mm)55-84	88/12/8	A.N.	6:22	B	
CD87X422	422457	42-4224	B7049 46	(70mm)55-91	88/12/8	A.N.	6:22	B+	TARGET FAINTLY VISIBLE
CD870423	422557	42-4225	B7049 47	(70mm)55-54	88/12/8	A.N.	6:22	B	

READER'S COMMENT FORM
SPECIFICATIONS FOR AERIAL TRIANGULATION

The Ministry of Environment Lands and Parks **(MELP)** is assigned to review these specifications on a regular basis. The Specifications Committee would certainly appreciate comments and suggestions from users and reviewers regarding clarity, accuracy, completeness and organization.

Please provide the following information along with your comments:

Name:_____

Title:_____

Company/Government Dept._____

_____

Address & Phone:_____

_____

_____

Comments:_____

_____

_____

_____

_____

Send To:

Ministry of Environment Lands and Parks

Geographic Data BC
Parliament Buildings
Victoria, British Columbia
Canada, V8V 1X4

Attention: Dr. Rostam Yazdani, P.Eng.
Head, Engineering/Digital Image Application

APPENDIX "I"

KINEMATIC GPS ON BOARD

Province of British Columbia

Geographic Data BC

Specifications for Aerial Triangulation

Introduction*: All theoretical accuracy assumptions used for planning photogrammetric projects are based on the fact that systematic errors are corrected, blunders are rejected and the observations are used with properly assigned a priory standard deviations. One main part of aerial triangulation is an adjustment thus one fundamental is good redundancy. These specifications therefor pay special attention on proper preparation in order to achieve good redundancy and deal especially with self-calibration, data cleaning and proper assignment of a priori standard deviations in order to achieve reliable results in accordance with theory.*

Dipl.-Math. Hermann Klein

1. Terminology

1.1. Absolute or Exterior Orientation

Determining of the position of the camera station (perspective center or focal point) and the attitude of the taking camera at the instant of exposure.

1.2. Affine Transformation

It is a transformation in which strait lines remain strait and parallel lines remain parallel. The scale along one coordinate axis will be changed against the scale of the other coordinate axis.

1.3. Antenna Offset

The co-ordinates obtained from a GPS receiver are the co-ordinates of the phase center of the GPS antenna but the block adjustment requires the co-ordinates of the perspective center. The vector from the perspective center to the phase center of the antenna is called the antenna offset.

1.4. Average Redundancy

The average redundancy of an adjustment is the redundancy per observation:

Average redundancy = redundancy / number of observations

The reliability of adjustment results depends highly on a good redundancy. To obtain reliable results of photogrammetric block adjustment, the average redundancy should be better than 0.5.

1.5. Control Points

Points in the terrain with known co-ordinates in the terrain system, which are identified and measured in an aerial photograph. Both, the terrain co-ordinates and the photogrammetric measured co-ordinates are used in block adjustment as observations.

1.6. Drift Correction

The term drift correction is used by mistake because GPS observations principally don=t have a drift error. Nevertheless the term is used for a constant and linear correction of systematic errors of GPS observations independent from their sources.

Drift correction:

$$X_{Corr} = cx + t * lx + X_{GPS}$$

$$Y_{Corr} = cy + t * ly + Y_{GPS}$$

$$Z_{Corr} = cz + t * lz + Y_{GPS}$$

With: cx, cy, cz = constant correction terms

lx, ly, lz = linear correction terms

t = GPS time

X_{Corr}, Y_{Corr}, Z_{Corr} = corrected GPS observations

X_{GPS}, Y_{GPS}, Z_{GPS} = GPS observations

1.7. Interior or Inner Orientation

Determination of the interior perspective of the photograph as it was at the instant of exposure. Elements of the inner orientation are the calibrated focal length, location of the calibrated principal point and the calibrated lens distortion related to a coordinate system defined by the calibrated fiducial marks.

1.8. Kinematic GPS Observations

Observations from a GPS receiver used during the photo flight mission for navigation purposes and indirectly used to obtain co-ordinates of the perspective centers. These observations are used in a simultaneous block adjustment in order to reduce the number of required control points.

1.9. Minimum Control

Used for GPS supported aerial triangulation, necessary to provide the datum to the adjusted block. In general minimum control means control or better pairs of independent measured control points at the external corners of the block.

1.10. Redundancy

Redundancy is the number of redundant observations in an adjustment:

Redundancy = number of observations B number of unknowns

1.11. RMS Value of Residuals

The square root of the weighted mean values of residuals.

RMS = sqrt (Ó P(R(/ Ó P( )

with: P(= weight of observation i and R(= residual of bservation i,

1.12. Relative Orientation

Determining of the position and attitude of a pair of overlapping photographs with respect to each other.

1.13. Robust Estimator

Robust estimators are used in an adjustment. A least squares adjustment assumes constant weights for the observations with the consequence that the influence of an observation onto the result of the adjustment is proportional to its error. In opposite the method of robust estimators uses weight functions such as the influence of an observation becomes less with increasing error and will be zero for blunders.

1.14. Self-Calibration

Self-calibration is a method to correct systematic image errors. Additional unknown parameters, used also as observations, are determined in the simultaneous adjustment to compensate systematic image errors.

1.15. Side Lap

The overlap of photographs in adjacent parallel photo flights.

1.16. Sigma Naught

Sigma naught is the degree of deviation from an assumed a priori accuracy. In block adjustment normally the a priory weight of 1 is assumed as a priori weight for the photogrammetric observations, thus sigma naught is the accuracy of the photogrammetric measurements.

1.17. Tie Points

Present rigorous aerial triangulation does not distinguish between pass points and tie points, because pass points are also used as tie points, thus only the term tie point is used for all image points measured in two or more photographs.

2. Preparation

2.1. Point Selection

2.1.1. Two points shall be selected in the middle Gruber position on the centerline vertical to the flight direction.

2.1.2. Two points shall be selected in the upper and lower Gruber position on the centerline vertical to the flight direction if visible in at least three models.

2.1.3. Three points shall be selected in the upper and lower Gruber position on the centerline vertical to the flight direction if visible in only two models.

2.1.4. Four points shall be selected in the upper and lower Gruber position on the centerline vertical to the flight direction if visible in only one model.

2.1.5. No point shall be selected less than 1 cm from the perimeter of the photograph.

2.1.6. The distance between selected points shall be at least 1 cm.

2.1.7. The distance between selected points should be wide enough to make full use of the side lap between adjacent flight lines.

2.1.8. If the side lap is more than 30% one additional point shall be selected in this Gruber position.

2.1.9. All points must be chosen stereoscopically and must be placed (if possible) on flat terrain.

2.1.10. In incomplete models at least 12 well-distributed points must be selected.

2.2. Point Marking

2.2.1. All points at the centerline vertical to the flight direction must be marked.

2.2.2. Replacing point marking by point sketches or image patches need permission of Geographic Data BC.

2.2.3. In order to be measured in at least 3 photographs, water level points shall be chosen in the overlapping area of models and shall be marked.

2.3. Paper Prints

2.3.1. All points at the centerline shall be symbolized on the paper prints as follows:

Horizontal or full control point
Vertical control point
Tie point

2.3.2. The symbols shall be drawn using a stencil and water-resistant ink and a 0.2 B 0.25-mm line.

2.3.3. The point numbers shall be aligned horizontally with the symbols in the same direction on the paper prints for the entire project.

2.4. Diapositives

2.4.1. Symbols or point numbers must not be drawn on the diapositives.

2.5. Point Transfer (Stereo Instruments)

2.5.1. All points at the centerline in the side lap of two photographs shall be transferred to the adjacent photograph in one direction if the transferred points are situated also at the centerline of the adjacent photograph.

2.5.2. All points at the centerline in the side lap of two photographs shall be transferred to the adjacent photographs in both directions if the transferred points are situated not at the centerline in the adjacent photograph.

2.5.3. All marked points of a cross strip shall be transferred to all photographs of the regular flight lines flown in one and the same direction.

2.6. Point Transfer (Mono Instruments)

2.6.1. All points selected at the centerline of a photograph shall be transferred to all adjacent photographs within the strip and to all photographs of adjacent strips.

2.6.2. All marked points of a cross strip shall be transferred to all photographs of the regular flight lines flown in one and the same direction.

2.7. Devices

2.7.1. Point marking and point transfer shall be done with precision instruments e.g. PMG2, CPM1, PUG4, PUG5, PM1 or equivalent. The diameter of the marks must not exceed 60 microns.

3. Measurements

3.1. Inner Orientation

3.1.1 The inner orientation shall take into account all information available from the camera calibration report e.g. focal length, fiducial mark co-ordinates or distances, displacement of the principal point of autocollimation and the lens distortion values.

3.1.2. The camera calibration report must not be older than 2 years at the time of the photo flight.

3.1.3. All available fiducial marks shall be measured and used during inner orientation

3.1.4. If only 4 fiducial marks are available then a similarity transformation (4-parameter solution) shall be used during measurements in order to detect possible
problems.

3.1.5. The final calculation shall be performed with an affine transformation.

3.1.6. Residuals at the fiducial marks must be # 15 microns.

3.1.7. Sigma naught of the inner orientation must be # 10 microns.

3.1.8. If (3.1.6) or (3.1.7) can not be reached for a photograph a notice must be included in the final report submitted to Geographic Data BC.

3.1.9. If (3.1.6) or (3.1.7) can not be reached for more than 5% of the photographs, measurements shall be stopped and Geographic Data BC must be informed immediately to discuss the matter.

3.2. Relative Orientation (Stereo Instruments)

3.2.1. In order to get an approximate relative orientation; points in the six Gruber positions can be measured to obtain an initial relative orientation.

3.2.2. For the final relative orientation all marked tie points and all control points to be used in the block adjustment shall be measured and used in the calculation.

3.2.3. All tie points and control points visible in a model shall be also measured and be used for the relative orientation of that model.

3.2.4. Correction of earth curvature and refraction shall be done during rigorous block adjustment and not within the relative orientation.

3.2.5. Residuals at the measured points must be # 10 microns.

3.2.6. If (3.2.5) can not be reached for a model a notice must be included in the final report submitted to Geographic Data BC.

3.2.7. If (3.2.5) can not be reached for more than 5% of the models, measurements shall be stopped and Geographic Data BC must be informed immediately to discuss the matter.

3.3. Image Co-ordinate System

3.3.1. The co-ordinate system of the measured points within all photographs shall be equal with respect to flight direction for all photographs used in the same block adjustment.

3.3.2. If the measuring device does not support unique co-ordinate systems for all photographs with respect to flight directions then the co-ordinate systems of the photographs with opposite co-ordinate systems must be reversed accordingly before block adjustment.

3.4. Instruments

3.4.1. Only mono comparators, stereo comparators, analytical plotters and softcopy devices shall be used for the measurements of the inner and relative orientation.

4. Absolute Orientation

4.1. Features of Block Adjustment Programs

4.1.1. The block adjustment program shall perform a rigorous bundle adjustment.

4.1.2. The block adjustment program shall feature simultaneous adjustment of additional unknown parameters used also as observations to correct for systematic image deformations (self-calibration).

4.1.3. The block adjustment program shall supply sufficient statistical information about the determinability and significance of the added self-calibration parameters.

4.1.4. The block adjustment program shall allow proper a priory standard deviations (or weights) for all groups of observations (photogrammetric observations, terrain measurements of control points, GPS observations).

4.1.5. The block adjustment program shall allow different a priori standard

deviations (or weights) within each group of observations.

4.1.6. The block adjustment program shall support proper data cleaning by providing RMS values for all types of observations and all groups used with different a priory standard deviations (or weights) and marking of all observations with residuals > 4*their respective RMS value.

4.1.7. For GPS supported aerial triangulation the block adjustment program shall do a simultaneous adjustment of all observations including observations from kinematic GPS.

4.1.8. The block adjustment program shall provide the correction of the antenna offset for different strips in case the antenna offset of the kinematic GPS observations is not corrected by GPS post-processing or on the flight.

4.1.9. The block adjustment program shall allow a drift correction (constant and linear term) for all three co-ordinates of kinematic GPS observations.

4.1.10. The block adjustment program shall allow different drift corrections for different parts of the kinematic GPS observations.

4.2. Self-Calibration

4.2.1. Self-calibration shall be used in the bundle adjustment.

4.2.2. Because the co-ordinate systems of all photographs are in accordance with flight direction (3.3), different sets of self-calibration parameters must not be used because of different flight directions.

4.2.3. If changes of physical circumstances (camera, film, date of flight, measuring instrument) let assume different systematic of the photogrammetric measurements, then different sets of self-calibration parameters should be applied.

4.2.4. Self-calibration parameters which turn out to be equal (analysis of first adjustment) shall be applied as common parameters only for the block. Only significant different parameters shall be applied locally.

4.2.5. Not determinable or not significant self-calibration parameters must not be used for the final correction.

4.3. Antenna Offset of GPS Observations

Problem description:

The co-ordinates of the perspective centers (focal points) are unknown exterior orientation parameters in a bundle adjustment. Therefore in GPS supported aerotriangulation the co-ordinates of the perspective centers are required as observations, but with a GPS receiver the co-ordinates of the phase center of the GPS antenna is observed. The difference is called

antenna offset and must be corrected by GPS post-processing before or within the simultaneous bundle adjustment.

The antenna offset is a constant vector in the aircraft system and must be transformed to the co-ordinate system of the photographs in order to be corrected within the block adjustment. This transformation changes as soon as the camera is rotated within the aircraft. In order to minimize the effect of different rotations, the GPS antenna should be mounted vertical above the focal point of the camera.

4.3.1. For fixed mounted cameras the antenna offset is approximately constant for one flight line, but different for the opposite flight direction because of a different camera rotation related to an opposite crab. Drift correction therefor shall be applied separate for each flight line in order to correct for the different antenna offset related to the different crab.

4.3.2. For stabilized camera systems the antenna offset is different for each exposure. he effect shall be minimized to the influence of the crab by mounting the antenna vertically above the camera system. Drift correction shall be applied separate for each flight line in order to correct for the different crab in opposite flight lines.

4.3.3. By measuring the spatial antenna offset in the airplane on the ground with respect to the zero position of the camera system, the antenna offset can be calculated and corrected using the camera recordings of the crab for fixed mounted cameras or the recordings of the deviations from the zero settings in a stabilized camera system. In this exceptional case (a priori correction, antenna sufficient close and vertical above the focal point) a common drift correction for opposite flight directions can be applied, but has to be approved by Geographic Data BC.

4.4. Drift Correction for GPS Observations

Problem description:

The NAVSTAR Global Positioning System (GPS) has become generally available and can be considered operational. The use for aerial triangulation is based on the precise phase measurements of the GPS L1/L2 carrier waves with the problem of initial phase ambiguity that normally requires post-processing.

Carrier phase observations have the problem that the total number of integer cycles from the satellite to the receiver is unknown. Calibrating the GPS receiver before take-off can perform an initial ambiguity solution. But any interruption (loss of signal, changing satellites) during the flight means that the ambiguity solution is lost and must be restored. So called >fast ambiguity solutions@ or Aambiguity solutions on the fly@ in combination

with dual frequency receivers might solve this problem but up to now not complete. Erroneous solutions lead to systematic drift errors. Thus some drift errors have to be generally expected in kinematic camera positioning.

4.4.1. Principally different sets of drift correction parameters shall be used for different flight lines.

4.4.2. In case so called >fast ambiguity solutions@ or Aambiguity solutions on the fly@ in combination with dual frequency receivers and precise initial ambiguity solutions in combination with post mission stationary baseline determination have solved the ambiguity problem, one set of drift parameters for the block is sufficient. It shall be proofed by comparing the drift corrections due to (4.3.1) and must be approved by Geographic Data BC.

4.4.3. One set of drift parameters shall be applied in any case for the photogrammetric block to correct for systematic effects related to photogrammetry (use of calibrated focal length because the focal length under flight condition is unknown or other not correctable systematic image errors),

4.5. Standard Deviations of Observations

4.5.1. Proper a priori standard deviations shall be used for all different types and groups of observations. They shall be chosen in accordance with the actual accuracy of the observations.

4.5.2. If the assumption of the a priori standard deviations can not be confirmed by the block adjustment (chapter 4.6 and 4.7) they shall be modified in accordance of the preliminary result and the block adjustment shall be repeated.

4.5.3. The a priori standard deviation of the main group of photogrammetric image observations shall be:

$$Std_{image} = \text{sigma naught} \quad '' \ 10\%$$

Sigma naught shall be < 10 microns. If this can not be achieved it shall be immediately reported to Geographic Data BC.

4.5.4. The internal (after drift correction) precision of GPS observations is in the range of 2 B 3 cm. Thus the a priori standard deviation for GPS observations shall be < 10 cm. If this can not be achieved it shall be immediately reported to Geographic Data BC.

4.5.5. The correct a priori standard deviation of control points shall be determined iteratively by subsequent modifying it, subsequent data cleaning and comparisons due to the following chapters.

4.6. Manual Determination of Standard Deviations

4.6.1. For all groups of observations with more than 50 observations or with more than 2% of the total number of observations the a priori standard deviations shall be confirmed (after proper data cleaning) by

A priori standard deviation * average redundancy = RMS value " 30% for each group with separate a priori standard deviations applied.

4.6.2. If the RMS value after data cleaning is too big the a priori standard deviation shall be increased, if it is too small the a priori standard deviation shall be decreased up to condition (4.6.1) is reached.

4.7. Determination of Standard Deviations by Robust Estimators

The feature of automatic error detection with robust estimators is principally a method for the a posteriori determination of the accuracy of all observations within the adjustment and used to eliminate

Photogrammetric observations that are erroneous related to sigma naught.

Non photogrammetric observations that are erroneous related to their respective a priori standard deviations.

Automatic error detection with robust estimators therefor can be used to determine the proper a priori standard deviations of observations related to b.

4.7.1. If after automatic error detection observations are not rejected which still seem to be blunders, the a priori standard deviation of this group of observations shall be decreased.

4.7.2. If after automatic error detection too many observations are rejected which seem not to be blunders, the a priori standard deviation of this group of observations shall be increased.

4.8. Data Cleaning

4.8.1. Elimination of observations shall be done either by renumbering of the observation or by assigning a priori standard deviation = zero (weight = 8), thus eliminated observations will have no influence onto the result of the adjustment, their residuals are supposed to be the true errors. Elimination of the original measurements from the data is not allowed.

4.8.2. Numbering errors, which cause wrong connections, shall be renumbered thus the observation will be re-included correctly into the adjustment.

4.8.3. Single observations (points measured only in one photograph) lead to singular equation systems and therefore are not used in the adjustment, but a warning is reported. That shall be checked. In case wrong point numbers caused that, the respective observation shall be re-numbered.

4.8.4. With manual data cleaning all observations within all groups of

observations, with different a priori standard deviations assigned, shall be rejected if :

Residuals > 4 * RMS value

4.8.5. A program with proper features for data cleaning will automatically take care that condition (4.8.4) is fulfilled.

4.8.6. Bad or wrong point transfers will cause the elimination of all points in one strip. All points eliminated because of a bad or wrong point transfer shall be renumbered thus they will be kept as pass points and improve the reliability of the result.

4.9. Drift Correction, Cross Flights and Distribution of Control Points

4.9.1. Assuming the following conditions:

The antenna offset can be corrected in GPS post-processing or in the adjustment directly without applying separate drift corrections for separate flight lines.

The problem of the ambiguity solution can be solved without applying separate drift corrections for different flight lines or parts of it.

The GPS receiver can stay locked onto the carrier waves for the complete project.

Then only one set of drift parameters is necessary - see (4.4.3). The adjustment would then be possible without cross profiles and with minimum control only in order to provide the datum to the adjusted block.

4.9.2. If a drift correction has to be applied separate for each flight line in order to correct for the antenna offset or to correct systematic effects related to erroneous ambiguity solutions, then minimum control can be used in planimetry only. In height chains of height control ore an equivalent distributions are necessary for a sufficient stable geometry to obtain reliable results from block adjustment. To avoid the terrain measurements of these additional height control points cross flights with GPS can be a substitute.

4.9.3. To rely at present on the solution without separate drift corrections is too risky because it can be confirmed only after the block adjustment. Additional control then shall be measured or cross flights with GPS have to be performed. In most cases this will cause not acceptable delays.

4.9.4. In practice the solution will always somewhere in between. If not sufficient height control available additional cross flights shall be flown in order to include them into the simultaneous adjustment if necessary. It only can be proved in the final adjustment whether the result meets the requested accuracy.

4.10. Preliminary Adjustment

A preliminary adjustment has to be performed using:

4.10.1. Self-calibration due to 4.2
4.10.2. Correction of earth curvature and refraction.
4.10.3. Adjustment of GPS observations with respect to 4.3 B 4.4
4.10.4. Properly assigned a priori standard deviations due to 4.5 B 4.7
4.10.5. Proper final data cleaning due to 4.8

The corrected and clean image coordinates, control point coordinates and corrected GPS observations shall be outputted onto a file in order to be used as input in the final adjustment.

4.11. Final Adjustment

4.11.1. Using the cleaned and corrected observations from the preliminary adjustment the final adjustment shall be performed.

4.11.2. Self-calibration and correction of earth curvature and refraction shall not be applied again; data cleaning has been already done and shall not be anymore necessary.

4.11.3. The a priori standard deviations shall be identical with the one approved in the preliminary adjustment.

4.11.4. Drift correction should be applied exactly as in the preliminary adjustment, but already corrected, the drift will be turn out to be zero.

4.11.5. A posteriori variances of the final adjusted terrain coordinates shall be calculated by inversion of the normal equation system.

4.11.6. Mean values of the a posteriori variances shall confirm the requested accuracy of the adjustment due to the project specifications. If it does not confirm it shall be reported immediately to Geographic Data BC.

5. Deliverables

5.1.1. Original measurements on a file.

5.1.2. The printout (not necessarily as hardcopy) of the preliminary adjustment including corrected observations, control points and GPS observations and all respective residuals (eliminated observations marked) and a statistic with information about a priori standard deviations, redundancy, self-calibration parameters, RMS values and sigma naught.

5.1.3. A list of eliminated observations due to 4.8

5.1.4. A list of disconnected due to 4.8

5.1.5. The corrected and cleaned image coordinates, control points and GPS measurements (output of (5.1.2) and input to (5.1.6)) on a file.

5.1.6. The printout (not necessarily as hardcopy) of the final adjustment with the in (5.1.2) mentioned printout and in addition the final adjusted terrain coordinates including the a posteriori variances and final exterior orientation parameters.

5.1.7. Final adjusted coordinates on a file.

5.1.8. Final exterior orientation parameters on a file.

5.1.9. Flight index map - mylar and digital (MOEP or dgn format) - see 3.3.7.3 "Key Plans"

5.1.10. All paper prints and diapositives received.

5.1.11. Report about the project.

Return to: TABLE OF CONTENTS

APPENDIX "J"
Specifications for Softcopy Aerial Triangulation

APPENDIX J

SPECIFICATION FOR SOFTCOPY AERIAL TRIANGULATION

CONTENTS

J4.1 AT report, output from PAT-B
J4.2 Control chips – recording and transfer
J4.3 Use of softcopy AT data

APPENDICES

Appendix JA PAT – B typical output

File: q:\admin\specsappend J Date: 29 May 2000
Revision 9
Date: 24-Jan-01

PREAMBLE

This specification Appendix for softcopy aerial triangulation (AT) has been prepared as a generic document applicable to any appropriate project[1] whether an original mapping project where control data is produced for the project, or a revision mapping project where some or all of the control data is sourced from an earlier project. Where specific projects have requirements which deviate from this specification or for which further information or more detailed specification is required, instructions shall be issued to the project contractor by Base Mapping and Geomatic Services (BMGS) elaborating on unique project requirements. It is expected that these supplementary requirements will be issued either in the project Contract Documents or as special instructions during execution of the project.

‘Softcopy’ as distinct from ‘digital’ has been used in the title and will be used throughout this document to distinguish the methods herein specified from the digital computing methods used for example in analytical plotter aerial triangulation.

It is the objective of this document to address only specification topics. What may be considered to be detail operating processes or procedures will be addressed by mapping industry contractors. In order to achieve the
data output as specified herein, contractors will likely adopt a variety of processes and procedures some of which may include proprietary hardware and software. The intent of the specification, unless stated otherwise, is to permit individual contractors freedom of choice with regard to process, procedure and computing software. BMGS at its discretion may perform Quality Assurance audits against the contractors' published procedural documentation as required by the contract documents.

It is the objective of BMGS to ensure that data in general, as referred to in this document, shall be able to be used by a wide audience which includes users other than those in the base mapping and AT industry and who may not have the most up-to-date tools and equipment routinely used by mapping industry participants. Certain specification requirements for output data can be interpreted in light of this objective.

In addition, it is BMGS’s objective to ensure that, as far as possible, at all stages of production data are interchangeable between mapping industry contractors and BMGS and also between end users who may wish to interpret or analyse the map data but who may not be in the mapping industry.

In order to ensure that data which have been produced under the existing Aerial Triangulation Specification Release 2.0 May 1998 can continue to be used by the mapping industry at large and by other end users and will be compatible with data produced according to the requirements of this document, BMGS has directed that the Softcopy Aerial Triangulation Specification shall be included as an appendix to the basic 1998 Aerial Triangulation Specification. Hence all of the requirements of the 1998 document which will be referred to as the 'base specification' will apply, as appropriate, to the Appendix. Should a conflict arise between the base specification and this Appendix, the matter shall be referred to BMGS for resolution.

---

[1] At the date of first publication (August 2000) the project to which this specification is directed is the Terrain Resource Information Management II (TRIM II) 1:20,000 and 1:10,000 scale mapping project directed by Base Mapping and Geomatic Services (BMGS) of the BC Ministry of Sustainable Resource Management. TRIM II can be considered as revision mapping project using as it does the control and mapping data produced for the earlier TRIM I project.

J1 AERIAL TRIANGULATION CLASSIFICATION

J1.1 Aerial triangulation types

AT for the purposes of this specification may be classified into two types as follows. BMGS shall advise in the
Tender and Contract documents the AT classification for the work to be undertaken.

J1.1.1 Type A AT

Type A AT data will be used as an image control resource for mono or stereo image orientation within the inherent mapping accuracy of the digital imagery regardless of the immediate mapping application, or for extracting image feature coordinates as control for thematic mapping.

J1.1.2 Type B AT

J1.2 Control source

Type B At data will be used only to support image orientation within a current project and not as a general control resource.

J1.2.1 Control source for Type A AT

All geo-spatial control points used for Type A AT, especially those used as perimeter control points in conjunction with GPS exposure station coordinates shall be signalized i.e. pre-marked or targeted for unambiguous identification in a digital image.

J1.2.2 Control source for Type B AT

Geo-spatial control points, signalized in the imagery together with the surveyed or adjusted coordinates, may be
used in the following order of preference:

- Pre-marked points: imaged target points, used with the surveyed coordinates.
- Post-marked points: cross-marks derived from imaged target panels in target photography, used with the surveyed coordinates.
- Model pass points: generally primary PUG marks, used with adjusted coordinates.
- Line tie points: cross-marks derived from primary PUG marks, used with adjusted coordinates.

Point transfer may be effected via conventional cross-marking methods, or digital cross-marking techniques. In order to minimize unavoidable cross-marking errors, BMGS shall make available the original diapositives for either conventional cross marking or for image scanning in digital cross-marking.

J1.2.3 Coding

Provincially funded including FRBC A/T
Projects must adhere to the provincial numbering system. Whenever possible projects must tie to the provincial A/T Database. Exceptions to this system may be granted by BMGS. Contact BMGS for provincial numbering system..

J2 INPUT DATA MATERIAL

Input data for softcopy AT may be provided by Base Mapping and Geomatic Services (BMGS) of the Ministry of
Sustainable Resource Management or may be supplied by the project contractor as requested in the contract
documents.

Various components of the input data are more fully described in the base specification or in the following
paragraphs and one or more of these components may be supplied by either BMGS or the project contractor. In the case where the project contractor supplies any component of the input data, such data shall be submitted to BMGS for review and may only be used on the project with prior approval by BMGS.

Irrespective of the source of supply of the input data they shall meet the requirements of this specification and/or of the specification to which they were produced.

J2.1 Images

J2.1.1 Aerial photography

All mapping photography supplied by BMGS shall meet or exceed the requirements of the latest edition of
'Specifications for Aerial Photography' Province of British Columbia Ministry of Sustainable Resource Management, Base Mapping and Geomatic Services and shall be as in section 2.2 of the base specification.

For new photography for BMGS projects it is expected that BMGS exclusively will contract directly for aerial
photography flying. If however in special circumstances photography is provided to BMGS by a project contractor it shall meet the requirements of the above noted specification and shall be submitted to BMGS for review and approval prior to the commencement of softcopy AT work.

J2.1.2 Aerial camera calibration data

The camera used for the project aerial photography shall have been calibrated and the camera calibration report
shall have been submitted to BMGS prior to the undertaking of photography all as required by the latest edition of 'Specifications for Aerial Photography' Province of British Columbia Ministry of Sustainable Resource Management, Base Mapping and Geomatic Services. BMGS shall supply a copy of the camera calibration report to project contractors undertaking softcopy AT.

J2.1.3 Diapositives, negative film

Film projects shall be produced in accordance with the latest edtion of 'Specifications for Aerial Photography
Products', Province of British Columbia, Ministry of Sustainable Resource Management, Base Mapping and
Geomatic Services ISBN 0-7726-1446-6.

Softcopy AT may be undertaken with the use of scanned images from diapositives or from the source film negative. In the normal case, where the project flying contract is undertaken by BMGS, and when the negative film is being used as the source imagery for scanned data, then BMGS will provide access to the source film negative to enable the project contractor to scan the film for use in the softcopy AT work. When the source film negatives are provided to project contractors they shall be handled and stored according to BMGS directives (reference BMGS Procedure….).

In special cases where the project flying is undertaken by the project contractor, unless specified otherwise in the contract documents, the source film negatives shall be retained by the contractor subject to Quality Assurance inspection by BMGS and the project contractor shall supply scanned image files.

J2.1.4 Scanned imagery

All imagery for use in softcopy AT, whether diapositives or negatives or whether provided by BMGS or project contractors, shall be scanned according to the requirements of the latest edition of SCANNING AERIAL PHOTOGRAPHS

SPECIFICATIONS, Base Mapping and Geomatic Services, Ministry of Sustainable Resource Management.

It is recognized that for any given aerial photograph resolution, the resolution at which the aerial photograph is scanned i.e. the scan pixel size, will affect the accuracy of the softcopy aerial triangulation.

J2.2 Geo-Spatial Control

J2.2.1 General

General requirements for geo-spatial control shall be as in sections 2.2, 2.3 and 3.1 of the base specification and for on-board GPS, as in Appendix 1. Geo-spatial control data i.e. ground control survey, will be supplied by BMGS according to the requirements of the latest edition of British Columbia Standards, Specifications and Guidelines for Resource and Control Surveys using GPS or Conventional Survey Technologies. In addition, photogrammetrically derived control (conventionally known as pass and tie points) which has had prior review and approval by BMGS may also be used.

If geo-spatial control data is supplied by the project contractor it shall be subject to review and approval by BMGS.

J2.2.2 Aerial GPS

Where a project is designed on the basis of using primarily aerial GPS control, this control shall be supplemented with ground control survey and/or photogrammetrically derived control points.

Each project is expected to have specific requirements and individual circumstances. Therefore the following guidelines for control layout can be considered generic only. Each project shall be reviewed by BMGS prior to acquisition and use of the control data to confirm its suitability – see also section J3.2

The number of supplementary control points for a block, unless otherwise approved in advance by BMGS, shall not be less than the following:

1 For 1 metre contours

√ Perimeter Control Distribution:

- 1 point at start and end of every 2nd flight line,
- 1 point near block perimeter on every 8th photo along perimeter flight lines

√ Interior Control Distribution

- 1 point every 8th photo every 4th flight line

√ Survey Coordinate Accuracy required for the points <0.05metre

2 For 2 metre contours

√ Perimeter Control Distribution:

- 1 point at start and end of every 3rd flight line,
- 1 point near block perimeter on every 10th photo along perimeter flight lines

√ Interior Control Distribution

- 1 point every 10th photo every 5th flight line

√ Survey Coordinate Accuracy required for the points <0.10metre

3 For 5 to 10 metre contours

√ Perimeter Control Distribution:

- 1 point at start and end of every 4th flight line,
- 1 point near block perimeter on every 20th photo along perimeter flight lines

√ Interior Control Distribution

- 1 point every 20th photo every 5th flight line

√ Survey Coordinate Accuracy required for the points <0.25metre

For blocks of small size e.g. less than 100 images, BMGS will consider alternatives to these specifications. Small
blocks shall have a minimum of 5 points: 1 point on each corner and 1 point in the centre. It is recognized that strip photography for corridor mapping cannot be adequately controlled using a GPS.

J2.2.3 Control transfer

Geo-spatial control point transfer from existing imagery to new photography by PUG methods will not be mandated, but for certain contracts may be requested by BMGS or by the project contractor. If requested by the project contractor, PUG transfer to BMGS new photography shall proceed only with prior approval by BMGS. Where control has to be transferred from pre existing photography, such photography may be scanned as in section J2.1.4 and control points digitally transferred to the new photography. Tie point transfers will be by digital transfer only and may be performed simultaneously within the mensuration process.

J2.2.4 Control Coordinates

J2.2.4.1 Data reporting format

Where BMGS provides ground control data as photogrammetric image points or surveyed points obtained from the TRIM project, the data will be supplied in the form of "tape 4" listings from the SPACE M adjustment file or from the PAT-M43 adjustment

report file produced for the TRIM I project. Details of the ‘tape 4’ listing or the PAT-M43 report can be obtained from BMGS on request.

J2.2.4.2 Accuracy

Accuracy of the geo-spatial ground control survey coordinates supplied by BMGS to project contractors will meet the following specification:

	Horizontal Control, NAD83 (CSRS)		Vertical Control, CVD28
Scale	**Absolute "network" Accuracy at 95% Confidence level**	**Relative "local" Accuracy at 95% Confidence level**	**Spirit Leveled, Mean Sea Level**
1:20,000	<2 m.	<50 ppm	<1 m.
1:10,000	<1 m.	<50 ppm	<0.5 m.
1:5,000	<0.5 m.	<50 ppm	<0.2 m.
1:2,000	<0.25 m.	<50 ppm	<0.07 m.
1:1,000	<0.1 m.	<50 ppm	<0.03 m.
1:500	<0.05 m.	<100 ppm	<0.02 m.

Geodetic control monument coordinates available from the BMGS MASCOT data base at website http://www.pwccanada.:8001/mascot/ or from BMGS in hard copy form publish ‘standard deviations’ for the
"absolute" or "network" accuracy (at this time relative to the nearly globally compatible NAD83 datum). As well,
"relative" or "local" accuracies are shown with each monument in relation to surrounding monuments that may
have been directly tied during the control survey. Network and Local accuracy are terms nationally developed for absolute and relative accuracy, respectively.

In cases where coordinates for ground control survey points have changed since the date on which they were first acquired and published, BMGS shall advise on which coordinates to use for any specific project e.g. new
coordinates have been established for certain survey points used in the original TRIM I project and the same points may now be required for the TRIM II revision mapping project, in which case BMGS will advise on which coordinates to use.

J3 PROCESSES

J3.1 Softcopy aerial triangulation procedures

Project contractors undertaking softcopy AT for a BMGS project shall submit annually to BMGS a Softcopy Aerial Triangulation Processing Procedure (PP) developed in accordance with the requirements of this specification. BMGS at its option will review and if acceptable approve this processing procedure for a period of one year. All softcopy aerial triangulation for the project shall then be carried out in accordance with the approved PP. BMGS at its discretion shall use the PP as a document against which it can perform Quality Assurance audits of project contractors.

J3.2 Mensuration

The PP shall record the sequence of measuring the fiducial points. Automated image point selection and coding
techniques and automated image point mensuration techniques are acceptable.

For TYPE A AT, mensuration precision shall be to +-1 micron. For type B AT, mensuration precision shall be to
+- scan pixel size as specified by BMGS in the tender and/or contract documents.

J3.2.1 Image points

Except in perimeter images image points appearing only within a flight line i.e. points not located in any overlap
regions of a flight line, shall be transferred and mensurated in stereo-comparator mode with the preceding and
succeeding images in that flight line, providing three-fold mensuration and three-fold image points.

Except in perimeter images, all image points appearing in overlapping flight lines i.e. points located in the lateral
overlap regions in the current flight line, shall also be transferred and mensurated in stereo comparator mode and each with the successive and preceding images, providing six-fold mensuration and six-fold image points. In cases where the image centres in the overlapping flight lines are inadvertently staggered, five-fold mensuration and five-fold image points are acceptable.

In projects where 5 von Gruber points per image are specified, two image points in each of the two lateral overlap regions plus one point near the principal point are indicated. The maximum mensuration opportunity or maximum fold mensuration is:

(2(L/R) x 2 lateral points x 6 fold) + (1 central point X 3 fold) = 27 data entries / model

The data entries in a six-fold point are evenly distributed over two flight lines, resulting in the image in each line logging not less than:

> (2(L/R) x 2 lateral points x 3 entries) + (1 central point x 3 entries) = 15 data entries / model

J3.2.2 Control points

Control points are ideally located near the lateral image point positions and shall therfore undergo maximum fold mensuration yielding not less than five-fold data entries.

J3.3 Adjustment

The computer program for the block adjustment shall be PAT-B. Requirements for implementation of PAT-B shall be as in section 3.3 of the base specification with output as in section J4.

Mean values of the posteriori standard deviations for adjusted terrain coordinates, calculated by inversion of the normal equations, shall confirm the accuracy meets the following:

- <20 micron in horizontal
- <30 micron in vertical

J4 OUTPUT DATA

J4.1 AT report, output from PAT-B

Project contractors shall submit to BMGS a report on the soft copy AT which shall include the output from PAT-B typically as in Appendix JA.

Project contractors shall grade the quality of the softcopy AT in terms of positional accuracy and relate it to the
input geo-spatial control data as in section J1.2.

J4.2 Control chips – recording and transfer

Where geo-spatial control is supplied as a digital file scanned from control photography, or produced as a result of the soft copy AT procedure, at the discretion of the supplier, the scan need not be of the complete area of the photograph but of a control chip. The control chip shall encompass an area on the photograph of not less than 25 mm x 25 mm. The scan pixel size of the control chip shall be not less than 15 microns. A hard

copy image of the control chip with the control point identified by a graphic object and the control point identification number shall be provided.

The data format for the scanned imagery of control chips shall be the same as that for the scanned imagery and shall include a digital and hard copy report of statistics relating to all control transferred in this manner. The data content, indexing and description of the control patch shall be such that it can be used on subsequent projects where control in the form of conventional geo-spatial ground control survey or photogrammetrically derived control on photographic film i.e. PUG points may not be available or may not be used i.e. all control transfer will be by digital methods. BMGS will advise on the system for numbering and indexing these digital control points.

In the course of carrying out soft copy aerial triangulation, a number of photogrammetrically derived control points will be developed in the process of automated image point selection, coding and mensuration (Section J3.2). These photogrammetrically derived control points will be identified and report on in hard copy form in the report (Section J4.1).

BMGS wishes to maintain a data base of these photogrammetrically derived control points so that they may be used in future projects with photography of varying scales. The control points shall be identified on a separate image file from the scanned image file of the original aerial photography. The image file which contains the control points shall have a scanned pixel size of not less than 15 microns.

Three methods of identifying the photogrammetrically derived control points shall be adopted as follows:

- the location of the control point will be established on the control point image file by changing the pixel value of five (5) pixels to white (255 PV) in the shape of a cross i.e. one centre pixel surrounded by one pixel at top, bottom, right, left of the centre pixel.
- To facilitate the location of the control points on the image a generic JPEG file will be created that has a large square or circle with the control point located in the centre. The JPEG file size will be 640 X 480 or a reduction of about 100.
- The location of the centre pixel shall be recorded in the file header of the scanned image file and shall contain the following information:

√ The point name or identification number referred to in the AT report.
√ Source film roll number and frame number
√ The date of the photo
√ The point terrain coordinates, east north, elevation
√ Control source i.e. survey, AT, other
√ Pixel size: micron

√ Number of rows and columns
√ Row major or column major
√ Number of bands i.e. B&W or colour
√ Row and column for the control point
√ Terrain x, y of the upper left corner of the patch
√ Terrain azimuth (azimuth) of patch in degrees

The control points may be saved as ‘control chips’ in a single image file.

J4.3 Use of softcopy AT data

Users of soft copy AT data should recognize that there are three files which should be used to achieve highest accuracy in stereomodel setups as follows:

- exterior orientation (typical file extension .ori)
- photo coordinates (typical file extension .im)
- adjusted terrain coordinates (typical file extension .adj)

Appendix JA

PAT – B typical output

The soft copy AT report to BMGS shall include the output from PATB-NT and shall include but not be limited to the following. The report shall be in hard copy format.

1 Photographic coverage

- Source, scale, date.
- Overlaps.
- Film roll identification.

2 Control

- Point coding system.
- Control coordinates source.
- Classes and weights.

3 Equipment and Software

- Point transfer device.
- Scanner.
- Mensuration device.
- Block adjustment software including version date.

4 Methodology, Procedures

- Point selection, number, source.
- Marking, control point transfer including description of method of transfer between aerial photography of different scale and age.
- Scanning.
- Relevant specifications used in each (sub) process.
- Mensuration method and corrections.
- Preliminary adjustment method and weightings.
- List of control points rejected with location and reason for rejection.

- Description of difficulties or problems.

5 Block Adjustment

- Features and procedure.
- Redundancy factor.
- Parameters used in GPS runs.
- Standard deviations of the adjusted terrain coordinates
- Results

6 Summary

- Statement on the overall quality of the AT, including relative and absolute accuracy.

7 Plots

- Vertical and horizontal control error distribution plots.
- A small scale plot of the project location.

Digital files shall be supplied as follows.

1. A digital index map

- Index map showing major background planimetry, photo centres, mapsheet and block numbers and model numbers.

2. Input files

- Control file listing horizontal, vertical and GPS sources (file type *.con).
- Original plate coordinates (file type *.im).

3 Output files

- Adjusted coordinate file (file type *.adj)
- Full printout from PATB-NT adjustment with self calibration (file type *4.pr)
- Printout file from PATB-NT adjustment with Inversion of Normal Equations (file type *5.pri)
- Exterior orientations with standard deviations (file type *.ori)
- Output plate coordinates (file type *.cor)

Release Date: May, 1998
Last updated: November 20, 2001
Contact:

For more information on aerial triangulation specifications, contact Amin Kassam at Amin.Kassam@gov.bc.ca or (250) 387-9321