APPLICATION OF AERODIST MEASURING EQUIPMENT TO MAPPING CONTROL

BY

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ABSTRACT

This paper deals with the employment of 3 Channel Aerodist equipment in PAPUA and NEW GUINEA during the period 1964–66, and the proposed employment of it in ARNHEM LAND IN 1967.

INTRODUCTION

1. 'Aerodist' is an electronic distance measuring equipment that continuously measures the range between a master unit in an aircraft and one, two, or three remote units on the ground. It enables the distances to be measured between ground points that are not in line of sight of each other, or a ground point or aircraft to be fixed with reference to two known ground points.

2. In Papua New Guinea where optical lines of sight are difficult to obtain due to dense jungle and continuous cloud conditions, Aerodist has proved particularly economical, and has provided results of suitable accuracy, in establishing rapid horizontal control over extensive areas for medium scale mapping. Conventional triangulation or traverse in such areas entails time consuming, major clearing commitments, to be followed almost immediately by instrumental observations so as to avoid jungle regrowth problems. Aerodist patterns can normally be designed to take advantage of natural clearings, air strips, river sandbanks, rock hilltops etc and obviate the majority of clearing. Ground movement in Western Papua New Guinea is very difficult and extremely slow, by foot track, so that helicopters are essential for movement of ground station equipment and personnel to ensure that repositioning of ground stations keeps pace with the speed of measurement possible with Aerodist.

3. A first order geodetic survey of Papua New Guinea was completed in 1965 and the Aerodist Net is to be adjusted to this framework (See Fig 1).

CHARACTERISTICS OF AERODIST

4. The Aerodist equipment generally comprises three channels, although two channels are sufficient for single line measurement techniques. The master units are installed in an aircraft and the corresponding remotes of each channel are positioned on ground stations. Simultaneous measurements can be made from the aircraft to up to three remotes of differing channel frequencies. For simple reference the channels are called RED, WHITE and BLUE. The third channel is necessary only when controlled photography (i.e. fixing the aircraft position) is envisaged, but it may also be used in combination with either of the other two channels in conventional trilateration. The equipment provides a continuous chart recording of ranges between the aircraft and the relevant ground stations. The frequencies of the carrier wave are in the 1200 to 1500 Mc/s band.

Channel Frequencies

Colour	Master Freq	IF	Remote Freq
RED	1298	34.65	1263.35
WHITE	1390	29.20	1360.80
BLUE	1218	31.50	1249.50

OPERATIONAL TECHNIQUES

Line Crossing

5. Simple line measurements are normally made by flying for a distance of two or three miles backwards and forward across the line joining two remote stations, using two channels of the equipment. The sum of the two distances, in any one crossing, will become minimum when the aircraft is in line between the two ground stations. The two minima will occur simultaneously when the aircraft flies at right angles to the line between to two ground stations. Although it is not essential to fly exactly at right angles, it is improtant that the flight path during crossings is straight and level, as any deviation will cause error to the reduced distance. (Figure 11A)

6. The resultant slope distances, through the aircraft station, for each of the line crossings, may then be reduced graphically by plotting the sums of the measurements through their respective minima, or computed mathematically.

Geometry

7. The Aerodist equipment measures the slope distances from aircraft to ground stations (Figure 11 B). The absolute heights of the aircraft and the ground stations are therefore required for the reduction of the sea level distance. They may be obtained by simultaneously taking altimeter readings at the aircraft and ground stations at the instant of the line crossing. The altimeter in the aircraft should be connected to a static line and frequently indexed by comparison with Aerodist heights, measured vertically to a remote station of known height, whilst flying at the approximate altitude of the line crossing. The absolute heights of the ground stations may be established by separate altimeter heighting techniques, or higher order levelling.

Horizontal Control Pattern

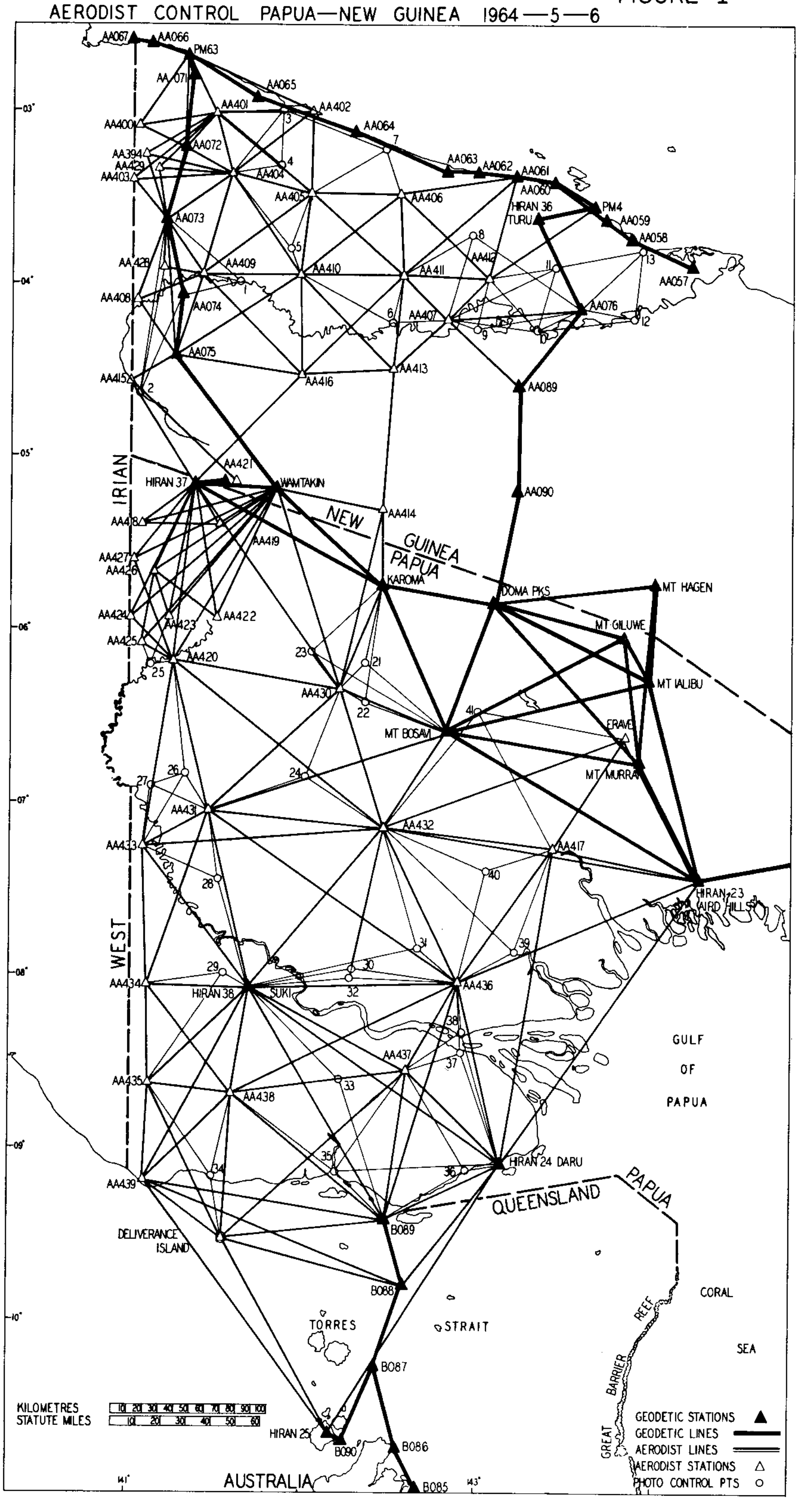
8. Initially, in PAPUA-NEW GUINEA, it was intended to establish a regular 30 minute pattern of points by Aerodist for photo control, but due to the nature of the terrain, and the random photographic cover, networks for adjustment had to be treated separately from those for detailed photo control. The main network was designed in longer lengths, using open ground such as air fields, kunai patches etc, for remote stations and secondary connections were made from these main stations to the specific location of points required to control the photography. It should be stated that the terrain in the border area ranges from palm covered swamps and rain forest, through kunai slopes, low jungle covered hills, large rivers with some sandbanks, to peaks of 12000 feet and then large tracts of savannah covered flats with very occasional clearings.

Main Adjustment Network

10. The main network was designed to contain as many redundant lines as possible, and be connected to as many first order geodetic stations as possible. This simplified the solution of ambiguities resulting from the use of scaled position from small scale maps in reduction of line measurements. The main stations were chosen as far as possible on airfields because they provided access by fixed wing aircraft, as well as helicopter, and the vertical clearances for Aerodist lines of sight were good. Telescopic towers, up to 70 feet high, were also used to raise the antenna of the remote instrument clear of local obstructions. All stations were targetted and then photographed by the Aerodist aircraft. The longest line planned was 150 miles, and signal strength was excellent, indicating that this was not the limit. The shortest line, used for fourth order connection, was 10 miles, but index error and inaccuracies in ground station and aircraft heights significantly reduces accuracy on short lines. The average length of line planned was 50-60 miles although many lines exceeded 100 miles. The targets were white plastic sheets, each 10 ft. x 4 ft, laid in the form of a cross about the ground mark. All stations were additionally identified on the survey photography by ground parties.

FIGURE I

AERODIST CONTROL PAPUA—NEW GUINEA 1964—5—6



11. The lines forming the main network were measured by a minimum of 5 crossings, at an altitude of between 8,000 and 10,000 feet. The position of the crossings along the line was usually central, although not essentially so, and the point of each crossing was deliberately varied to sample, as far as possible, the meteorological conditions along the line. The altitude of 8,000-10,000 feet was dictated by the height of the terrain, vertical angle of clearance from ground station, and cloud. Normally a height range of 3-7000 feet above terrain is the optimum, dependent of course on the length of line. The best altitude is the lowest height at which a good signal is received.

12. The photographic cover of PAPUA-NEW GUINEA is irregular and disjointed due to the continuous prevalence of cloud. In order to design a control pattern for photogrammetric adjustment, a composite mosaic of all available photography was assembled. The best of the East/West and North/South runs were selected to form the framework for ultimate strip adjustment and control was positioned accordingly. These points were selected at villages, airstrips, in river beds or any natural clearings, where possible.

13. Whereas the selected photo strips were to be controlled and adjusted numerically, the areas contained within these strips were to be adjusted and plotted by multiplex bridging and semi graphical means, so that an extra distribution of heights was required within these areas.

14. The accurate identification of the ground control on the survey photography demanded great care and attention, mainly to avoid gross error. For this reason, as stated earlier, all points were identified on the survey photographs by ground inspection, and in addition, were targetted and photographed individually by the Aerodist aircraft. Because of the sporadic photographic weather it was not feasible to pre-target before survey photography was taken.

15. The lines to the photo control points were measured with a minimum of three crossings from each of at least three main stations, by the line crossing technique. Supplementary heighting of all Aerodist stations and strip and block control was obtained by barometric means - by helicopter.

ORGANISATION OF THE PROJECT

Planning

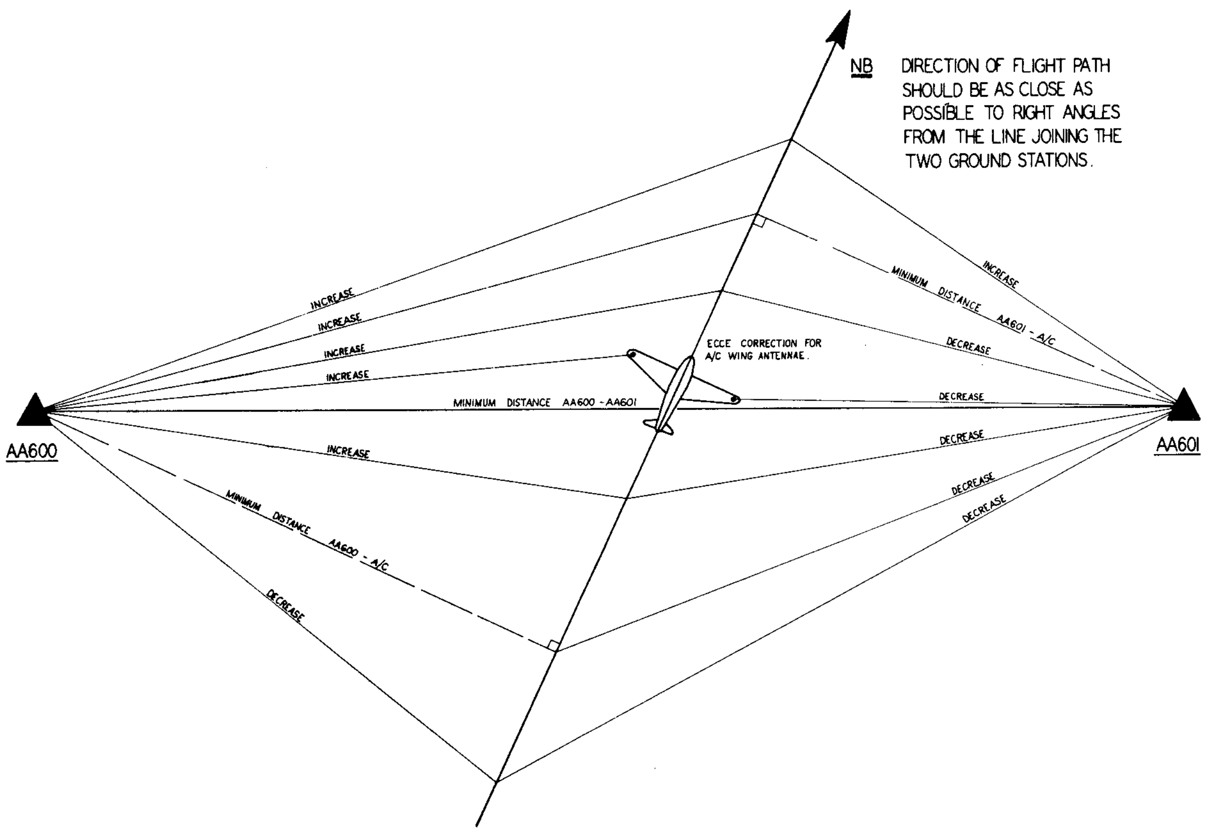
16. Detailed planning for such a project is of utmost importance. Due to the intense use of aircraft, fuel must be pre-positioned if the project is to run smoothly. Stores and equipment must be grouped, weighed and tested. Registered and unregistered airfield location and classification must be known. The technical plan must be clearly understood by all technical staff involved and aircrews briefed thoroughly.

Manpower

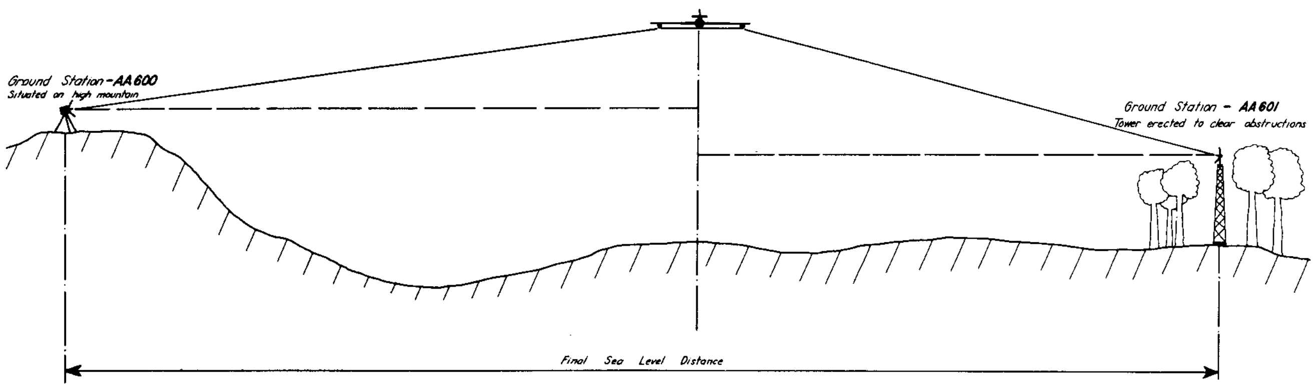
17. Altogether about 50 men, including aircrews, were employed on the project, and the outline organisation is shown in Figure 111. An Aerodist remote party of two men, with their equipment can normally be moved in two light helicopter lifts, depending upon distance and altitude of their stations above sea level. The Aerodist aircraft crew comprised pilot, navigator, camera operator Aerodist operator, meteorological data recorder and a co-ordinator who controlled the operational flying and the air to ground communications to all stations. Use of a smaller and less complicated aircraft of course would reduce the crew required. Six personnel were required to examine charts as they became available to ensure that measurements were acceptable and to keep pace with the measurement rate.

18. The administrative staff required to support the project amounted to six. Two radio operators were required to maintain continuous contact during daylight hours with forward stations and aircraft operating over mountainous jungle terrain in bad weather conditions.

FIGURE II



PLAN (A)



ELEVATION (B)

GEOMETRY OF LINE CROSSING TECHNIQUE

SUMMARY OF OUTPUT

19. In the main trilateration network, 45 points were fixed, and from these a further 34 photo control points were established. 149 lines were measured (5 crossings per line) in the main net, and 103 lines (3 crossings per line) to photo control points. (See Figure 1). This was accomplished in a total of eight months field effort. Altogether, the control so established provided data for the production of 77 maps at a scale of 1 in 100,000, or 46,000 square miles approximately.

20. The rate of measurement by Aerodist depends largely on the time taken to fly from the aircraft base to the operations area, from one line to the next, and the number of crossings per line; the rate of progress of the project depends upon weather conditions, the nature of the terrain, and the means of movement, which dictate the rate at which the ground parties can be maintained and repositioned. One main line of 5 crossings can be measured in as little as 15 minutes flying over the line and a subsidiary line of 3 crossings in 7 minutes when conditions are satisfactory.

21. The overall accuracy of the instrument is expressed by the manufacturers as plus or minus 1 metre plus or minus 1 part in 100,000 of the distance. This has been shown to be possible by comparison of Aerodist measurements with known lines, where elevations of remote stations were accurately fixed. In Papua New Guinea where there is no basic level network and long range barometer techniques have been used, the accuracy is naturally expected to fall away.

22. Provisional results of a rectangular adjustment are shown in Annexures A and B,but these values will be re-examined for ambiguities before finally passing on to a more rigorous spheroidal adjustment. Positional accuracy, at this provisional stage of the adjustment is about 5 or 6 metres. Annex C shows some provisional comparisons with Hiran measurements and computed Geodetic lengths, these also are yet to be checked for ambiguities.

23. In the application of Aerodist to mapping control in Papua and New Guinea, two important points arise, namely

a. Aerodist has provided a means of establishing photogrammetric control in the otherwise inaccessible terrain and clouded conditions, such as those which prevail in Papua and New Guinea.

b. Aerodist has provided medium scale mapping accuracies when operated under the conditions which prevail in Papua and New Guinea.

PROPOSED TECHNIQUES IN 1967

General Comparisons

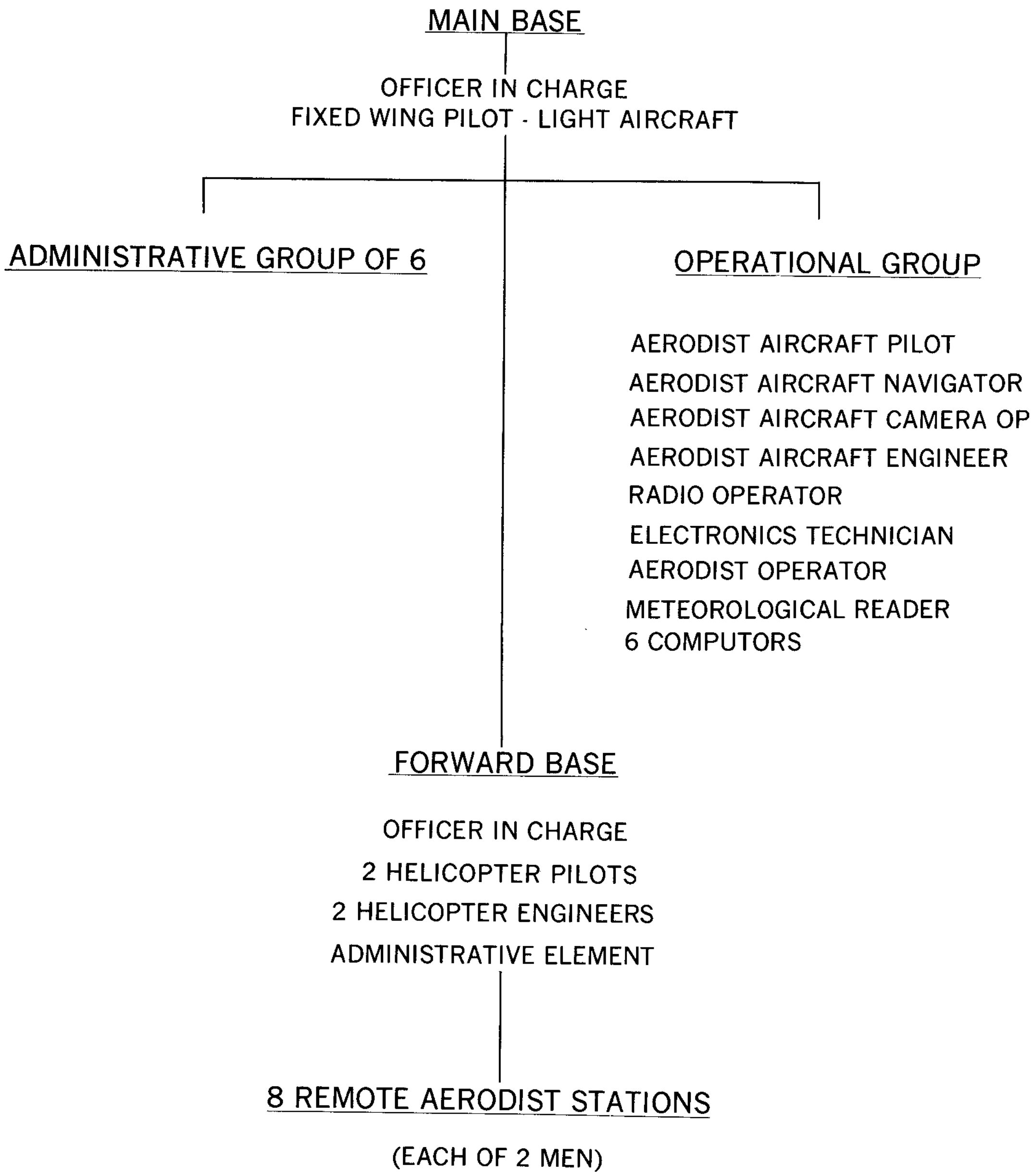
24. By comparisons with Papua and New Guinea the better conditions of terrain and weather characteristics in Arnhem Land will permit improved techniques such that greater accuracy in the Geodetic sense may be achieved, as well as producing photogrammetric control for medium scale mapping economically.

25. Refinements to previous techniques will reduce the inherent errors in aircraft flight path and elevation, ground elevation, index of refraction and ground swing, and more comparisons will be made in an effort to identify a value for indexing.

26. The general horizontal control pattern will be stronger because of the systematic form of the block photography, and the resultant photogrammetric adjustment will be stronger because of the systematic symmetry of control.

FIGURE III

ORGANISATION NEW GUINEA AERODIST PROJECT



Horizontal Control Pattern

27. The Main Geodetic Network of Aerodist adjustment will be designed as braced quadrilaterals which conform to the graticule of the 1:250,000 map series. Block superwide angle photography also conforms to the 1:250,000 map format. A block is normally flown in East-West strips at an altitude of 25,000 feet above Mean Sea Level. Eight or nine runs of approximately forty pictures cover a unit 1:250,000 area which is one degree thirty minutes of longitude by one degree of latitude. BERVOETS nine control points method of horizontal block adjustment is currently adopted for the photogrammetric adjustment.

28. The secondary network of Aerodist adjustment will be designed to co-ordinate the remaining five control points required in addition to the four Geodetic corner points of the photogrammetric block. These additional five points will occur in the centre of the block and in the mid point of each side of the surrounding graticule. Random points for irregular coastal and off-shore island forms, of course, must be treated independantly as far as any flight planning and photogrammetric adjustment is concerned, but in principle an intersection of three lines measured from either first order or main aerodist stations would apply.

Broad Specificati ons

29. The Main Geodetic Network of lines will be measured by two sets of six crossings. Each pair of crossings will be approximately 100 metres apart in altitude and each set will be 10 miles apart in the length of the line. They will be flown at about the mid point of the line and at the lowest workable altitude.

30. The Secondary network of lines will be measured by one set of six crossings and each pair of crossings will be 200 metres apart in altitude. They will be flown as near as possible to the midpoint of the line at the lowest workable altitude

31. Detailed specifications, which are not considered relevant to this paper, will also apply to the techniques concerning the refinements outlined in para 25.

CONCLUSIONS

32. Some of the more important lessons learned from experience with Aerodist over the last three years are :-

a. An area of operations should be sufficiently extensive to warrant the effort of mounting a major control project.

b. The main Aerodist trilateration for adjustment within the geodetic framework, and the supplementary photo control for photogrammetric adjustment, should be planned and measured conjointly, though designed for different purposes.

c. The detailed planning of the administrative and logistic support for an Aerodist project is of utmost importance.

d. The rate of repositioning the ground stations must be in balance with the rate of the Aerodist measurements.

e. Sufficient computors must be available in the field to prove line measurement charts before leaving the area.

f. A two channel Aerodist system would normally be sufficient for line measurement techniques.

g. The accuracy of the system is within the manufacturers stated limits subject to conditions stated previously.

Annex 'A' to

OPERATION OF AERODIST DISTANCE MEASURING EQUIPMENT IN PAPUA NEW GUINEA

AERODIST ADJUSTMENT – PAPUA AND NEW GUINEA

SUMMARY OF REDUCED AND ADJUSTED MEASUREMENTS

PROVISIONAL VALUES – SEPIK NET ADJUSTMENT

Spheroid:	ANS (160)	
Projection:	UTM (Zone 54)	
Datum:	Horizontal:	Johnston origin
	Vertical:	MSL
Unit:	Metres	

LINE	Reduced Measurement	Number of Measures	Range from Mean	Adj Corrtn and parts ratio	Adjusted Length
AA 405 AA 410	52 744.27	8	+6.40 −4.25	+0.39 13 525	52 744.66
AA 404 AA 405	51 744.06	7	+1.60 −3.44	−9.17 5 642	51 734.89
AA 073 AA 404	49 338.84	6	+3.29 −3.72	−2.46 20 055	49 336.38
AA 410 AA 409	61 500.75	8	+5.27 −7.06	−9.67 6 359	61 491.08
AA 404 AA 409	64 469.30	6	+2.02 −2.26	−7.99 8 068	64 461.31
AA 404 AA 410	77 665.07	6	+1.19 −1.92	−7.32 10 609	77 657.75
AA 073 AA 409	42 791.90	7	+2.41 −2.09	−9.38 4 561	42 782.52
AA 411 AA 410	56 332.10	4	+2.72 −5.20	−20.80 2 707	56 311.30
AA 406 AA 410	81 077.43	6	+1.38 −1.11	−1.09 74 381	81 076.34
AA 406 AA 411	52 698.67	5	+2.85 −5.79	−0.06 878 160	52 698.61
AA 405 AA 406	55 535.08	4	+2.86 −4.72	−21.54 2 577	55 513.54
AA 405 AA 411	72 369.91	7	+4.33 −7.03	+3.55 20 386	72 373.46

AA 405 AA 409	84 554.48	8	+3.15 −4.09	−8.05 10 503	84 546.43
AA 406 AA 061	73 624.01	5	+7.40 −5.40	−22.03 3 341	73 601.98
AA 406 AA 412	79 980.40	6	+2.09 −1.07	−0.61 131 114	79 979.79
AA 411 AA 412	57 653.67	5	+6.29 −6.78	−0.32 180 167	57 653.35
AA 411 AA 061	97 190.39	4	+1.55 −1.50	−0.47 206 787	97 189.92
AA 394 AA 401	54 184.02	5	+2.48 −3.34	−3.94 13 751	54 180.08
AA 394 AA 404	56 933.71	7	+4.25 −5.52	+4.56 12 486	56 938.27
AA 394 AA 073	41 255.20	5	+5.55 −4.41	−3.24 12 732	41 251.96
AA 429 AA 401	50 057.26	5	+6.71 −9.41	−2.21 22 649	50 055.04
AA 429 AA 404	48 411.21	5	+0.59 −1.58	+2.03 23 848	48 413.24
AA 429 AA 073	35 416.49	5	+2.81 −2.60	−1.81 19 567	35 414.68
AA 403 AA 401	66 881.62	5	+2.80 −4.39	−0.05 1 337 631	66 881.57
AA 403 AA 404	60 573.71	7	+3.18 −3.88	+0.06 1 009 563	60 573.77
AA 403 AA 073	30 568.38	7	+8.08 −4.12	−0.04 764 209	30 568.34
AA 401 AA 405	79 581.46	9	+2.84 −2.76	−4.84 16 441	79 576.62
AA 428 AA 409	29 307.01	5	+3.89 −3.31	00	29 307.01
AA 416 HIRAN 37	99 778.23	7	+4.44 −3.96	−2.85 35 009	99 775.38
AA 428 AA 073	28 727.64	TELLE		00	28 727.64
AA 412 PM 4	88 414.90	7	+1.40 −2.21	−3.33 26 550	88 411.57
AA 412 AA 061	69 037.69	3	+0.62 −0.40	+0.50 138 076	69 038.19

AA 407 AA 412	32 403.60	TELLE		−2.65 12 227	32 400.95
AA 407 AA 413	44 644.82	TELLE		−5.15 8 668	44 639.67
AA 407 AA 411	44 740.81	5	+1.87 −1.94	−9.41 4 754	44 731.40
AA 407 AA 089	61 789.70	TELLE		−7.75 7 972	61 781.95
AA 407 AA 076	90 750.71	TELLE		−3.38 26 848	90 747.33
PM 63 AA 401	42 842.85	5	+1.18 −2.36	−11.60 3 692	42 831.25
AA 072 AA 401	28 743.40	4	+1.91 −3.78	+3.84 7 486	28 747.24
AA 072 AA 400	32 587.99	12	+25.46 −6.26	00	32 587.99
PM 63 AA 400	50 810.29	5	+5.78 −4.79	00	50 810.29
AA 401 AA 402	61 443.28	6	+4.33 −3.78	−2.39 25 707	61 440.89
AA 072 AA 404	36 216.20	6	+4.33 −3.78	−19.00 1 905	36 197.20
AA 401 AA 404	41 760.57	9	+5.93 −5.12	−6.51 6 414	41 754.06
AA 402 AA 404	65 450.39	6	+3.02 −5.87	−2.33 28 089	65 448.06
AA 075 AA 409	54 187.46	5	+10.17 −9.30	−13.54 4 001	54 173.92
AA 075 AA 408	44 190.83	7	+16.16 −13.34	+10.77 4 104	44 201.60
AA 073 AA 408	54 726.05	6	+1.54 −2.50	+13.63 4 016	54 739.68
AA 410 AA 416	62 164.79	5	+3.79 −3.24	−11.15 5 574	62 153.64
AA 416 AA 075	81 883.14	6	+2.17 −2.59	+6.70 12 222	81 889.84
AA 416 AA 409	89 252.05	7	+3.89 −3.18	−4.62 19 318	89 247.43
AA 075 AA 410	93 905.44	6	+2.85 −1.56	−2.76 34 023	93 902.68

AA 411 AA 413	58 254.54	6	+2.15 −1.82	−3.46 16 836	58 251.08
AA 413 AA 416	53 588.69	6	+0.64 −4.20	−9.72 5 512	53 578.97
AA 413 AA 410	79 502.63	9	+6.94 −2.51	+8.13 9 779	79 510.76
AA 416 AA 411	83 364.00	5	+8.04 −6.29	+16.30 5 115	83 380.30
PM 63 AA 402	89 518.26	6	+3.25 −4.36	+4.60 19 461	89 522.86
AA 409 AA 408	47 416.47	6	+2.41 −1.45	−12.21 3 882	47 404.26
AA 402 AA 405	51 593.20	5	+5.21 −9.78	+3.40 15 175	51 596.60

Annex 'B' to

OPERATION OF AERODIST DISTANCE MEASURING EQUIPMENT IN PAPUA NEW GUINEA

AERODIST ADJUSTMENT – PAPUA AND NEW GUINEA
SUMMARY OF REDUCED AND ADJUSTED MEASUREMENTS
PROVISIONAL VALUES – FLY NET ADJUSTMENT

Spheroid: ANS (160)

Projection: UTM (Zone 54)

Datum: Horizontal: Johnston origin

Vertical: MSL

Unit: Metres

LINE	Reduced Measurement	Number of Measures	Range from Mean	Adj Corrtn and parts ratio	Adjusted Length
HIRAN 25 AA 439	201 030.17	5	+1.69 −2.82	−1.74 115 534	201 028.43
HIRAN 25 DELIVERANCE	143 525.10	10	+8.88 −6.13	−3.02 47 524	143 522.08
HIRAN 25 AA 440	204 645.13	4	+1.27 −1.34	+3.23 63 359	204 648.36
B 088 DELIVERANCE	119 664.90	4	+3.25 −1.61	−6.35 18 844	119 658.55
B 088 AA 439	173 036.03	6	+1.36 −2.75	+5.86 29 529	173 041.89
B 088 AA 440	98 706.48	5	+2.04 −1.66	−0.24 411 276	98 706.24
B 089 AA 440	82 754.95	5	+2.76 −3.12	−1.73 47 834	82 752.58
B 089 DELIVERANCE	106 820.95	4	+2.13 −3.36	−3.67 29 106	106 817.28
B 089 AA 439	151 617.07	4	+2.02 −0.27	+2.02 75 059	151 619.09
B 089 AA 438	125 883.48	4	+3.73 −2.29	−8.41 14 967	125 875.07
B 089 AA 437	97 790.33	4	+10.25 −10.79	−10.00 9 778	97 780.33
B 089 AA 436	158 279.94	5	+8.54 −6.90	−4.99 31 718	158 274.95
AA 439 DELIVERANCE	59 182.79	5	+2.09 −2.91	−13.03 4 541	59 169.76

AA 439 AA 435	59 439.50	6	+1.14 −2.41	−16.12 3 686	59 423.38
AA 439 HIRAN 38	135 789.56	5	+2.53 −0.84	+14.06 9 659	135 803.63
AA 439 AA 438	69 854.08	4	+0.24 −0.45	−6.28 11 122	69 847.80
AA 435 DELIVERANCE	111 005.19	6	+0.84 −2.81	+6.75 16 446	111 011.94
AA 438 DELIVERANCE	90 142.93	4	+2.07 −1.55	−5.59 16 125	90 137.34
AA 437 DELIVERANCE	160 825.18	6	+4.80 −6.73	+7.22 22 276	160 832.40
AA 437 AA 438	112 655.00	5	+1.68 −1.64	−3.48 32 371	112 651.52
AA 435 AA 438	56 021.10	5	+0.69 −0.88	−6.39 8 766	56 014.71
HIRAN 38 AA 440	199 528.50	1		+1.83 109 033	199 530.33
AA 437 AA 440	85 764.29	5	+0.87 −1.44	−0.16 536 026	85 764.13
AA 437 HIRAN 38	115 676.51	6	+0.72 −1.11	−3.54 32 676	115 672.97
AA 438 HIRAN 38	74 103.88	4	+3.06 −3.18	−21.51 3 444	74 082.37
AA 435 HIRAN 38	89 908.56	8	+5.56 −5.83	+8.17 11 006	89 916.73
AA 435 AA 434	63 829.57	6	+5.86 −8.79	−16.93 3 769	63 812.64
AA 434 HIRAN 38	60 009.51	5	+13.60 −9.33	−4.40 13 638	60 005.10
AA 434 AA 438	89 948.97	5	+0.87 −0.42	+6.47 13 903	89 955.44
AA 434 AA 433	88 639.25	5	+1.55 −1.03	−7.48 11 849	88 631.77
AA 433 AA 431	51 210.80	5	+7.75 −5.05	−7.33 6 985	51 203.47
AA 433 HIRAN 38	113 218.47	5	+1.98 −2.06	+4.89 23 154	113 223.36
AA 434 AA 431	119 089.26	5	+1.06 −1.13	−4.36 27 313	119 084.90
AA 431 HIRAN 38	117 917.12	6	+4.80 −3.84	−8.42 14 003	117 908.70

AA 438 AA 436	161 049.05	6	+4.52 −0.64	+5.72 28 156	161 054.78
AA 440 AA 436	118 362.56	5	+1.47 −2.07	−0.84 140 907	118 361.72
AA 437 AA 436	63 607.24	5	+1.41 −2.00	−4.71 13 504	63 602.53
HIRAN 38 AA 436	134 053.47	6	+2.36 −3.15	−2.74 48 924	134 050.73
AA 440 AIRD HILLS (DLS)	221 239.63	4	+1.15 −1.23	+2.11 104 854	221 241.74
AA 436 AIRD HILLS (DLS)	169 763.54	3	+0.99 −0.78	+1.03 164 820	169 764.57
AA 436 AA 431	197 208.59	6	+1.81 −4.13	+2.33 84 640	197 210.92
HIRAN 38 AA 432	124 479.55	4	+1.54 −1.19	−2.62 47 510	124 476.93
AA 433 AA 432	150 742.21	5	+1.62 −1.14	+4.13 36 500	150 746.35
AA 431 AA 432	108 443.56	6	+1.99 −2.49	−5.11 21 221	108 438.45
AA 433 AA 420	126 010.55	4	+0.83 −0.50	−0.02 6 300 527	126 010.53
AA 431 AA 420	100 341.61	5	+2.39 −2.05	−12.27 8 177	100 329.34
AA 431 NM/J/28	154 585.73	6	+1.99 −2.79	−2.12 72 896	154 583.61
AA 432 NM/J/28	78 324.61	TELLE		−3.34 23 449	78 321.27
AA 432 AA 436	109 122.11	5	+0.63 −1.53	−5.21 20 944	109 116.90
AA 432 AIRD HILLS (DLS)	211 759.51	3	+0.46 −0.81	+6.20 34 156	211 765.71
AA 432 AA 417	112 076.31	5	+2.07 −1.78	−10.88 10 300	112 065.43
AA 436 AA 417	104 004.98	4	+2.04 −0.83	−5.15 20 194	103 999.93
AA 417 AIRD HILLS (DLS)	100 094.47	5	+1.37 −0.86	−10.33 9 689	100 084.14
ERAVE AIRD HILLS (DLS)	105 904.02	7	+2.54 −3.39	+3.79 27 944	105 907.81
ERAVE AA 417	87 761.50	5	+2.52 −3.13	−6.61 13 276	87 754.89

AA 420 AA 430	105 279.68	6	+2.56 −1.70	+2.35 44 801	105 282.03
AA 420 AA 432	174 339.90	7	+1.18 −1.02	+0.35 498 115	174 340.25
HIRAN 37 AA 418	42 817.17	5	+1.61 −1.09	−1.12 38 229	42 816.05
AA 418 AA 419	50 412.65	6	+3.26 −3.32	−1.51 33 385	50 411.14
HIRAN 37 AA 419	29 731.70	3	+4.32 −1.49	+0.80 37 166	29 732.50
NM/J/30 AA 419	45 461.99	4	+18.96 −25.05	−1.28 35 516	45 460.71
NM/J/30 AA 418	92 129.09	4	+2.20 −1.29	+2.50 36 853	92 131.59
AA 427 NM/J/30	103 843.71	4	+1.15 −3.84	+0.72 144 227	103 843.71
AA 427 HIRAN 37	64 224.44	5	+1.46 −1.46	−0.81 79 288	64 223.63
AA 426 HIRAN 37	63 368.74	7	+6.72 −2.92	−1.41 44 941	63 367.33
AA 426 NM/J/30	96 952.58	5	+2.43 −5.16	+0.59 164 327	96 953.17
AA 426 AA 422	49 274.50	4	+2.74 −4.55	−0.80 61 592	49 273.70
NM/J/30 AA 422	90 448.06	4	+0.52 −0.43	−0.99 91 361	90 447.07
NM/J/30 AA 423	102 671.56	6	+3.41 −1.84	+0.88 116 673	102 672.44
NM/J/30 AA 424	122 885.07	7	+1.77 −1.45	+1.24 99 102	122 886.31
AA 426 AA 423	28 660.55	4	+3.38 −4.38	+0.74 38 731	28 661.29
HIRAN 37 AA 424	92 351.14	4	+1.61 −2.33	−1.24 74 476	92 349.90
AA 432 AA 430	102 332.51	8	+2.02 −3.02	−5.17 19 793	102 327.34
NM/J/28 AA 430	73 061.71	9	+1.58 −1.09	+1.31 55 773	73 063.02
NM/J/29 AA 430	69 371.50	TELLE		−4.52 15 347	69 366.98
NM/J/30 AA 425	129 928.87	5	+1.70 −2.80	+1.06 122 575	129 929.93
AA 425 AA 426	44 540.43	3	+2.78 −1.96	−0.96 46 395	44 539.47

HIRAN 37 AA 420	107 935.55	5	+0.08 −3.04	−10.39 10 387	107 925.16
NM/J/30 AA 420	121 252.43	6	+7.66 −2.51	−0.23 527 183	121 252.20
AA 420 AA 424	39 064.94	4	+3.95 −3.95	−0.53 73 706	39 064.41
AA 420 AA 427	63 007.61	3	+1.39 −0.61	−0.36 175 020	63 007.25
HIRAN 37 AA 430	157 189.41	3	+0.22 −0.23	+0.54 291 093	157 189.95
AA 431 AA 430	113 915.60	8	+2.22 −1.96	−4.44 25 656	113 911.16
AA 425 AA 420	23 282.07	2	+1.33 −1.33	−0.62 37 552	23 282.07
NM/J/30 AA 430	128 006.29	6	+1.63 −2.81	−4.49 28 508	128 001.80
AA 414 NM/J/30	68 942.06	6	+11.99 −10.51	00	68 942.06
AA 414 AA 430	109 315.25	3	+1.50 −0.98	00	109 315.25
AA 432 ERAVE	172 278.60	2	+2.73 −2.71	+5.84 29 501	172 284.44
AA 440 AA 417	203 022.57	3	+0.57 −0.83	−0.08 2 537 781	203 022.49

Annex 'C' to

OPERATION OF AERODIST DISTANCE MEASURING EQUIPMENT IN PAPUA NEW GUINEA

SUMMARY OF AERODIST AND GEODETIC COMPARISONS

Spheroid:	ANS (160)		
Projection:	UTM (Zone 54)		
Datum:	Horizontal:	Johnston origin	
	Vertical:	MSL	
Unit:	Metres		

AERODIST AND HIRAN COMPARISONS

LINE	Numbers of Measurements and Range	Aerodist Reduced Measurement (a)	Hiran Reduced Measurement (b)	Diff and Parts ratio (a)–(b)	Geodetic Adjusted Length (c)	Diff and Parts ratio (a)–(c)
HIRAN 24 HIRAN 23	4 +1.15 −1.23	221 444.90	221 443.44	+1.46 151 674	221 448.02	−3.12 70 977
HIRAN 24 HIRAN 25	4 +1.27 −1.34	204 441.26	204 434.09	+7.17 28 512	204 438.66	+2.60 78 630
HIRAN 24 HIRAN 38	1	199 506.20	199 492.43	+13.77 14 487	199 500.86	+5.34 37 360

AERODIST AND COMPUTED COMPARISONS

LINE	Number of Measurements and Range	Aerodist Reduced Measurement (a)			Geodetic Computed Length (b)	Diff and Parts ratio (a)–(b)
HIRAN 24 B 089	5 +3.03 −3.12	82 562.94			82 552.34	+10.60 7 788
HIRAN 24 B 088	5 +2.04 −1.66	98 500.04			98 492.99	+7.05 13 971
HIRAN 38 B 089	5 +3.98 −5.13	176 135.67			176 132.35	+3.32 53 052
PM 63 AA 072	6 +3.21 −3.05	58 634.97			58 630.86	+4.11 14 265
AA 073 AA 075	6 +2.38 −2.71	86 398.28			86 392.20	+6.08 14 209
AA 061 AA 412	3 +0.62 −0.50	69 037.69			69 027.55	+10.14 6 807
PM 4 AA 412	7 +1.40 −2.21	88 414.90			88 411.51	+3.39 26 080