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НАУКОВО-ДОСЛІДНИЙ ІНСТИТУТ ГЕОДЕЗІЇ І КАРТОГРАФІЇ

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Conclusion made by Scientific and research institute of geodesy and cartography concerning 3-DAS-1 digital camera availability for creation of orthophotoplans 1:1000, 1:2000, 1:5000 and 1:10000 scale.

1. System structure and its technical parameters

The system of digital aerial survey consists of following components:

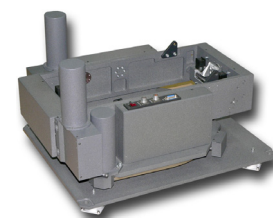
1) Digital scanning camera "3-DAS-1"



Technical specification

Parameter	Measurement unit	Value
Flying height	m	550-4400
Swath width	m	360-2880
Ground sample distance	cm	4.5-36
Number of channels		3
Radiometric resolution	bit	42
Angles between nadir and other channels	degree	16/26
Focal distance of lenses	mm	110
Field of view (across the strip)	degree	36
Line rate	Hz	250-750
Power requirements		= 28V/20A
Weight	kg	32
CCD sensor		
Active elements		8000xRGB
Pixel size	micron	9

2) Automatic stabilized platform "ASP"



Technical specification

Parameter	Measurement unit	Value
Residual angular deviation from horizontal plane	degree	0.2
Maximum angle (pitch and roll)	degree	±5
Maximum angle (yaw)	degree	±30
Nominal working load on the platform	kg	40
Weight	kg	30

3) Control computer

**2xOpteron64/PCI-X/RAM 4Gb
RAID-3 2.0Tb/UltraSCSI-320
Touchscreen monitor**



4) Direct georeferencing system (GPS/IMU) "Applanix POS AV 510"



Technical specification

Parameter	Measurement unit	Value
Error of coordinate determination	m	0.05-0.3
Error of angle determination (pitch and roll)	degree	0.005
Error of angle determination (yaw)	degree	0.008
Weight	kg	15

2. Technology of system calibration

System calibration consists of three stages:

1) Laboratory calibration for accurate determination of focal length and error values using distortion of each camera channel.

Laboratory calibration is performed on special rotary test site equipped with high precision angular encoder.

This test site measures angular coordinate of each CCD sensor pixel with accuracy of 3 angular seconds (it equals to 0.2 pixels).

When measurement results have been processed one calculates photogrammetric focal length of the camera, principal point position and error table by distortion.

2) Measurement of base distances from GPS antenna to camera reference system center.

It is performed with electronic tachymeter after the camera and GPS antenna have been mounted on the plane which will be used for aerial survey.

Distances from projection center of each RGB channel to camera reference system center are known from camera drawings with high precision.

3) On-flight calibration for accurate calculation of angles between CCD sensors and measurement head of Applanix POS AV 510 system.

It is performed by image measurement results which have been received during survey of special calibration site with 2000x1000 m size (see figure 1).



Figure 1: Scheme of ground point location on calibration site

Calibration site includes 28 marked ground points which coordinates have been calculated via GPS measurements in local reference system - WGS84 (UTM, zone 35).

Coordinates of point №1000 were fixed as base ones for calculation of relative coordinates for other points in differential mode (see Table 1). Error of ground point coordinate calculation does not exceed 0.05 meters.

Base GPS station is mounted on point №1000 during each aerial survey. Coordinates of this point are used during post processing for calculation of flight finite trajectory via PosPack software of Applanix POS AV 510 system.

Thereby reference system of camera images is reduced to fixed site reference system.

Point number	X (east)	Y (north)	Height	Latitude	Longitude
1000	613033.342	5453641.626	319.414	49°13'30,43415"	28°33'08,71521"
1001	614118.674	5453180.424	315.232	49°13'14,78016"	28°34'01,88414"
1002	613854.304	5453240.741	315.332	49°13'16,90975"	28°33'48,88077"
1003	613657.165	5453321.408	315.325	49°13'19,65283"	28°33'39,22037"
1004	613472.148	5453397.224	314.592	49°13'22,23055"	28°33'30,15389"
1005	613285.790	5453473.472	313.299	49°13'24,82293"	28°33'21,02127"
1006	612915.912	5453625.174	310.668	49°13'29,97955"	28°33'02,89469"
1007	612697.194	5453710.411	306.804	49°13'32,88380"	28°32'52,17100"
1008	612546.150	5453776.632	306.609	49°13'35,12742"	28°32'44,77254"
1009	612360.980	5453852.331	304.978	49°13'37,70029"	28°32'35,69674"
1010	612267.884	5453889.995	304.807	49°13'38,98100"	28°32'31,13332"
1011	612438.025	5454263.570	312.185	49°13'50,96167"	28°32'39,91982"
1012	612816.249	5453999.611	312.719	49°13'42,16660"	28°32'58,34807"
1013	612983.754	5453971.568	312.915	49°13'41,14765"	28°33'06,59893"
1014	613211.541	5453877.832	314.117	49°13'37,96191"	28°33'17,76254"
1015	613426.868	5453783.463	314.976	49°13'34,76365"	28°33'28,30919"
1016	613644.907	5453693.765	315.481	49°13'31,71456"	28°33'38,99430"
1017	613813.367	5453619.907	314.731	49°13'29,21108"	28°33'47,24488"
1018	614018.272	5453520.929	314.964	49°13'25,86988"	28°33'57,27071"
1019	614202.706	5453998.213	305.412	49°13'41,19627"	28°34'06,87503"
1020	614003.604	5454186.951	305.201	49°13'47,43942"	28°33'57,22718"
1021	613771.877	5454175.318	307.637	49°13'47,21799"	28°33'45,76140"
1022	613645.679	5454330.644	305.929	49°13'52,33036"	28°33'39,68209"
1023	613467.981	5454432.168	304.921	49°13'55,73543"	28°33'31,00192"
1024	613288.618	5454495.761	303.988	49°13'57,91354"	28°33'22,20050"
1025	613132.154	5454563.161	304.053	49°14'00,19950"	28°33'14,53471"
1026	612906.602	5454513.143	308.173	49°13'58,73025"	28°33'03,33446"
1027	612721.081	5454650.337	308.119	49°14'03,29439"	28°32'54,30262"

Table 1: Coordinates of site points in local reference system based on WGS84.

Calibration site is designed for aerial survey with 8000, 1:12000 та 1:16000 scale providing minimum two rows of ground points on swath of each scale.

The following tasks are performed by calibration site survey and measurement of ground point location on all the images:

- 1) Angles between CCD sensors and IMU/GPS measurement head are calculated using method of relative measurement matching on the images of each scale. These angles are suggested to be constants. It is provided by mounting measurement head to camera housing and using invar alloy to prevent significant temperature deformation of camera case.

- 2) Independent estimation of whole scanning system is performed with measurement of ground point coordinates on the images and calculation of residuals using ground points as control ones.

3. Measurement results of calibration site test flights

1) Scale 1:8000, ground sample distance 7.2 cm, height 880 m



Monocular measurements for separate images of each RGB channel (19 points)

Backward (16°)		
Point	DX, m	DY, m
1000	-0.01	0.01
1001	0.06	-0.04
1002	0.03	-0.02
1003	0.03	-0.02
1004	0.00	-0.03
1005	0.01	0.02
1006	-0.02	0.01
1007	-0.01	-0.01
1008	-0.01	0.02
1009	-0.03	0.00
1010	0.00	0.02
1011	-0.08	0.03
1012	-0.03	-0.00
1013	-0.03	-0.02
1014	-0.01	0.00
1015	0.00	0.00
1016	0.03	-0.08
1017	0.04	-0.05
1018	0.06	-0.08
RMS	0.03	0.03

Nadir (0°)		
Point	DX, m	DY, m
1000	0.01	0.02
1001	0.04	0.08
1002	0.04	0.08
1003	0.02	0.01
1004	0.02	0.02
1005	0.01	-0.01
1006	-0.02	0.03
1007	-0.02	-0.03
1008	-0.02	-0.02
1009	-0.04	-0.03
1010	-0.02	0.01
1011	-0.07	-0.01
1012	-0.02	-0.03
1013	-0.03	-0.02
1014	-0.01	0.00
1015	0.01	-0.00
1016	0.04	-0.03
1017	0.05	-0.01
1018	0.06	0.03
RMS	0.03	0.03

Forward (26°)		
Point	DX, m	DY, m
1000	-0.01	0.02
1001	0.07	0.08
1002	0.03	0.05
1003	0.03	0.04
1004	0.03	0.02
1005	0.00	0.01
1006	-0.03	0.00
1007	-0.04	-0.02
1008	-0.03	-0.04
1009	-0.06	-0.05
1010	-0.06	-0.04
1011	-0.07	-0.05
1012	-0.04	-0.02
1013	-0.03	-0.02
1014	0.00	0.00
1015	0.01	0.00
1016	0.03	0.02
1017	0.03	0.03
1018	0.06	0.04
RMS	0.04	0.04

Stereoscopic measurements for stereo images of RGB channels (19 points)

Backward-Nadir (16°)			
Point	DX, m	DY, m	DZ, m
1000	-0.01	0.02	0.02
1001	0.04	0.07	0.15
1002	0.03	0.05	0.05
1003	0.02	0.01	0.05
1004	0.01	-0.01	-0.03
1005	0.01	0.00	0.00
1006	-0.02	0.04	0.06
1007	-0.02	0.01	0.07
1008	-0.02	0.02	0.05
1009	-0.04	0.01	0.08
1010	-0.02	0.04	0.08
1011	-0.07	0.02	-0.03
1012	-0.01	-0.01	-0.06
1013	-0.03	-0.02	0.01
1014	-0.02	0.00	0.01
1015	0.01	0.01	-0.05
1016	0.04	-0.05	-0.03
1017	0.04	-0.03	-0.02
1018	0.04	-0.04	0.10
RMS	0.03	0.03	0.06

Backward-Forward (42°)			
Point	DX, m	DY, m	DZ, m
1000	0.01	0.03	0.04
1001	0.04	0.07	0.03
1002	0.02	0.05	0.05
1003	0.02	0.03	0.02
1004	0.01	0.00	-0.02
1005	0.01	0.02	0.01
1006	-0.01	0.01	0.02
1007	-0.01	-0.02	0.07
1008	-0.01	-0.03	0.01
1009	-0.03	-0.04	0.05
1010	-0.02	-0.02	0.09
1011	-0.05	-0.03	-0.03
1012	-0.02	-0.03	0.01
1013	-0.02	-0.04	0.01
1014	-0.01	0.00	-0.02
1015	0.01	0.01	-0.03
1016	0.02	-0.02	0.02
1017	0.02	0.01	0.04
1018	0.04	-0.01	0.03
RMS	0.02	0.03	0.03

Forward-Nadir (26°)			
Point	DX, m	DY, m	DZ, m
1000	0.00	0.02	0.06
1001	0.05	0.08	-0.06
1002	0.04	0.06	0.04
1003	0.03	0.04	0.01
1004	0.02	0.02	-0.02
1005	0.01	0.01	0.03
1006	0.03	0.01	0.00
1007	-0.02	-0.02	0.06
1008	-0.03	-0.04	-0.01
1009	-0.05	-0.05	0.04
1010	-0.03	-0.02	0.09
1011	-0.07	-0.03	-0.04
1012	-0.02	-0.04	0.07
1013	-0.03	-0.02	0.01
1014	0.01	0.01	-0.04
1015	0.01	0.01	-0.02
1016	0.04	-0.01	0.05
1017	0.04	0.01	0.08
1018	0.05	0.04	-0.01
RMS	0.03	0.03	0.04

2) Scale 1:12000, ground sample distance 10.8 cm, height 1320 m



Monocular measurements for separate images of each RGB channel (17 points)

Backward (16°)		
Point	DX, m	DY, m
1011	-0.03	-0.07
1012	0.02	-0.05
1013	0.00	-0.02
1014	0.01	0.00
1015	0.04	0.02
1016	0.05	0.03
1017	0.06	0.07
1018	0.07	0.10
1019	0.15	0.05
1020	0.11	0.03
1021	0.10	0.02
1022	0.06	0.00
1023	0.04	0.01
1024	0.02	0.00
1025	0.01	-0.01
1026	-0.01	-0.03
1027	-0.05	-0.07
RMS	0.05	0.04

Nadir (0°)		
Point	DX, m	DY, m
1011	-0.01	-0.08
1012	0.08	0.00
1013	0.01	-0.04
1014	0.01	0.00
1015	0.04	-0.02
1016	0.04	-0.01
1017	0.05	0.04
1018	0.05	0.04
1019	0.08	0.01
1020	0.06	0.01
1021	0.06	0.01
1022	0.03	0.01
1023	0.02	0.03
1024	0.01	-0.01
1025	-0.01	0.00
1026	-0.03	-0.05
1027	-0.03	-0.05
RMS	0.03	0.03

Forward (26°)		
Point	DX, m	DY, m
1011	0.03	-0.05
1012	0.06	0.05
1013	0.04	0.04
1014	0.05	-0.04
1015	-0.06	-0.03
1016	0.09	0.02
1017	0.08	0.03
1018	0.06	0.03
1019	0.09	0.02
1020	0.07	0.04
1021	0.07	0.04
1022	0.03	-0.05
1023	0.02	0.05
1024	0.00	0.06
1025	-0.02	0.07
1026	-0.02	-0.06
1027	-0.03	0.08
RMS	0.04	0.04

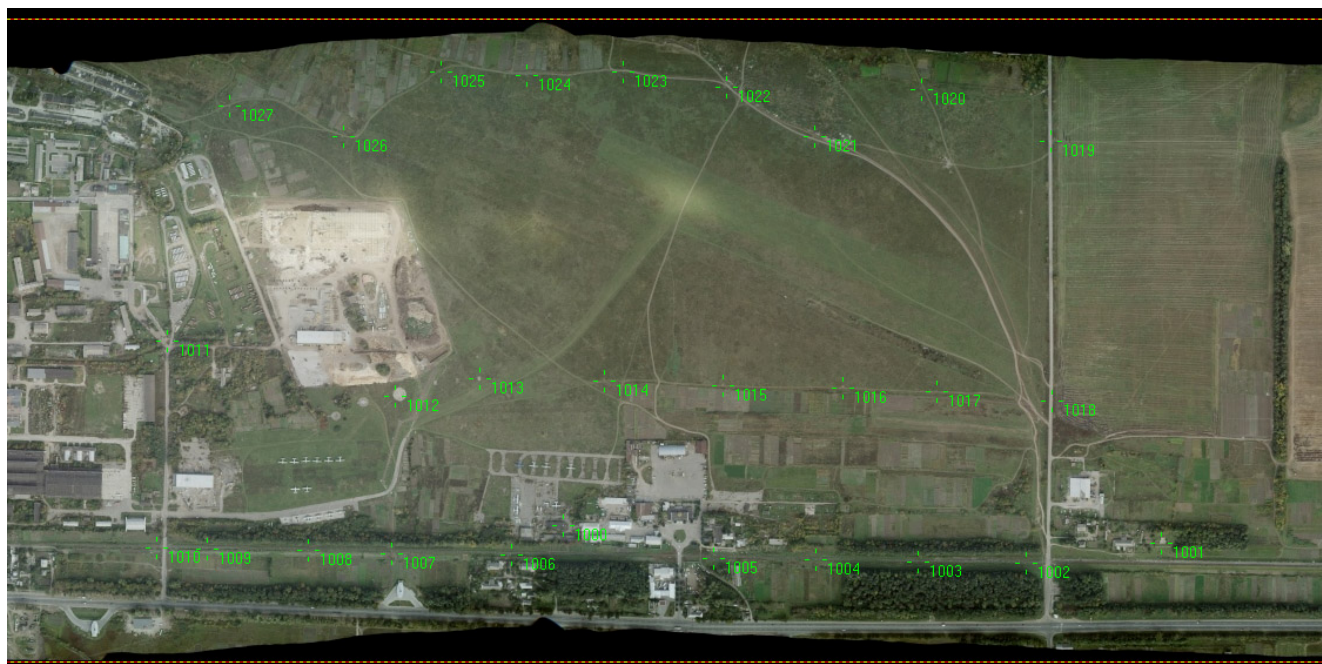
Stereoscopic measurements for stereo images of RGB channels (17 points)

Backward-Nadir (16°)			
Point	DX, m	DY, m	DZ, m
1011	-0.01	-0.06	0.05
1012	-0.08	0.00	0.25
1013	0.02	-0.02	0.08
1014	0.01	0.00	0.02
1015	0.05	0.01	0.13
1016	0.05	0.02	0.10
1017	-0.05	0.05	0.08
1018	0.06	0.06	0.12
1019	0.09	0.03	-0.07
1020	0.06	0.04	-0.09
1021	0.06	0.01	-0.06
1022	0.03	0.02	-0.08
1023	0.02	0.03	-0.09
1024	0.01	0.00	-0.04
1025	0.00	0.00	-0.04
1026	-0.02	-0.03	-0.06
1027	-0.04	-0.04	-0.05
RMS	0.04	0.03	0.10

Backward-Forward (42°)			
Point	DX, m	DY, m	DZ, m
1011	0.00	-0.01	0.02
1012	0.02	0.00	0.02
1013	0.01	0.02	0.02
1014	0.02	0.03	0.04
1015	-0.03	-0.03	0.06
1016	0.03	-0.04	0.10
1017	-0.03	0.06	0.08
1018	0.03	0.07	0.06
1019	0.04	0.03	-0.01
1020	0.04	0.03	0.00
1021	0.03	-0.03	-0.02
1022	0.02	0.03	-0.05
1023	0.02	0.04	-0.05
1024	-0.01	0.04	-0.07
1025	0.00	-0.05	-0.09
1026	-0.01	0.02	-0.08
1027	-0.01	-0.02	-0.06
RMS	0.02	0.03	0.06

Forward-Nadir (26°)			
Point	DX, m	DY, m	DZ, m
1011	0.01	0.01	-0.01
1012	0.06	0.00	-0.10
1013	-0.02	0.01	0.00
1014	0.02	0.03	0.06
1015	0.04	-0.01	0.03
1016	-0.04	0.03	0.10
1017	0.04	0.05	0.09
1018	0.04	-0.04	0.04
1019	-0.06	0.01	0.03
1020	0.05	-0.02	0.04
1021	0.05	-0.02	0.00
1022	0.03	0.03	-0.04
1023	0.02	0.04	-0.03
1024	0.01	0.04	-0.09
1025	0.01	0.05	-0.12
1026	0.00	-0.02	-0.09
1027	-0.01	-0.03	-0.07
RMS	0.03	0.03	0.07

3) Scale 1:16000, ground sample distance 14.4 cm, height 1760 m



Monocular measurements for separate images of each RGB channel (28 points)

Backward (16°)		
Point	DX, m	DY, m
1000	-0.01	0.01
1001	0.07	0.08
1002	0.05	0.05
1003	0.02	0.05
1004	0.01	0.03
1005	0.01	0.01
1006	-0.04	-0.01
1007	-0.03	-0.02
1008	-0.04	-0.04
1009	-0.05	-0.06
1010	-0.06	-0.07
1011	-0.09	-0.07
1012	-0.03	-0.03
1013	-0.02	-0.03
1014	-0.01	0.01
1015	0.01	0.02
1016	0.01	0.02
1017	0.03	0.03
1018	0.05	0.05
1019	0.09	0.03
1020	0.09	0.03
1021	0.05	0.01
1022	0.03	0.01
1023	0.00	0.01
1024	0.00	0.00
1025	-0.03	0.00
1026	-0.06	-0.04
1027	-0.08	-0.03
RMS	0.05	0.04

Nadir (0°)		
Point	DX, m	DY, m
1000	-0.02	0.01
1001	0.07	0.02
1002	0.03	0.09
1003	0.03	0.07
1004	0.01	0.06
1005	0.01	0.01
1006	-0.03	0.01
1007	-0.02	-0.05
1008	-0.02	-0.02
1009	-0.03	-0.07
1010	-0.03	-0.04
1011	-0.10	-0.11
1012	-0.02	-0.04
1013	-0.04	-0.06
1014	-0.01	-0.02
1015	0.01	-0.01
1016	0.03	-0.01
1017	0.03	0.05
1018	0.03	0.04
1019	0.11	0.01
1020	0.11	0.03
1021	0.07	0.01
1022	0.03	-0.02
1023	0.00	0.03
1024	-0.01	0.02
1025	-0.04	0.02
1026	-0.06	-0.01
1027	-0.11	-0.03
RMS	0.05	0.04

Forward (26°)		
Point	DX, m	DY, m
1000	0.00	0.02
1001	0.02	-0.04
1002	0.04	0.01
1003	0.03	0.00
1004	-0.01	0.00
1005	0.00	0.02
1006	-0.05	0.02
1007	-0.02	0.02
1008	0.01	0.02
1009	0.01	0.02
1010	0.05	0.03
1011	-0.02	0.00
1012	0.00	0.00
1013	-0.03	0.01
1014	-0.02	0.00
1015	0.00	0.00
1016	0.00	0.00
1017	0.03	-0.03
1018	0.07	-0.06
1019	0.14	-0.10
1020	0.10	-0.05
1021	0.07	-0.02
1022	0.02	0.00
1023	-0.01	0.00
1024	-0.01	0.02
1025	-0.03	0.07
1026	-0.07	0.04
1027	-0.07	0.07
RMS	0.05	0.03

Stereoscopic measurements for stereo images of RGB channels (28 points)

Backward-Nadir (16°)			
Point	DX, m	DY, m	DZ, m
1000	-0.02	0.01	-0.01
1001	0.10	0.08	0.15
1002	0.02	0.06	-0.24
1003	0.04	0.07	0.08
1004	0.01	0.04	0.01
1005	0.01	0.01	0.00
1006	-0.03	0.01	0.10
1007	-0.01	-0.03	0.14
1008	-0.02	-0.02	0.18
1009	-0.03	-0.06	0.20
1010	-0.03	-0.05	0.24
1011	-0.10	-0.10	0.04
1012	-0.02	-0.04	0.08
1013	-0.04	-0.05	-0.10
1014	-0.01	0.00	0.10
1015	0.01	0.01	0.01
1016	0.04	0.01	0.24
1017	0.04	0.04	0.05
1018	0.03	0.05	-0.21
1019	0.11	0.03	0.00
1020	0.11	0.03	0.05
1021	0.06	0.00	0.08
1022	0.03	0.00	0.03
1023	0.00	0.02	-0.01
1024	-0.01	0.02	-0.07
1025	-0.04	0.02	-0.12
1026	-0.07	-0.03	0.01
1027	-0.11	-0.02	-0.10
RMS	0.05	0.04	0.12

Backward-Forward (42°)			
Point	DX, m	DY, m	DZ, m
1000	-0.02	0.05	0.04
1001	0.08	0.08	-0.06
1002	0.06	0.10	-0.01
1003	0.04	0.09	0.06
1004	0.00	0.06	-0.00
1005	0.01	0.02	-0.04
1006	-0.06	0.01	0.01
1007	-0.04	-0.01	0.04
1008	-0.04	-0.01	0.13
1009	-0.04	-0.06	0.15
1010	-0.03	-0.03	0.24
1011	-0.10	-0.12	0.20
1012	-0.03	-0.05	0.05
1013	-0.03	-0.04	-0.02
1014	-0.02	0.01	0.00
1015	0.02	0.03	-0.02
1016	0.01	0.04	-0.01
1017	0.04	0.03	0.04
1018	0.08	0.02	0.10
1019	0.15	-0.07	0.11
1020	0.13	-0.00	-0.01
1021	0.08	-0.00	0.00
1022	0.04	0.03	-0.03
1023	0.00	0.02	-0.01
1024	-0.01	0.04	-0.03
1025	-0.04	0.07	-0.01
1026	-0.08	-0.01	-0.02
1027	-0.11	0.01	0.05
RMS	0.06	0.05	0.08

Forward-Nadir (26°)			
Point	DX, m	DY, m	DZ, m
1000	-0.02	0.05	0.06
1001	0.08	-0.08	-0.15
1002	0.03	0.13	0.10
1003	0.04	0.06	0.04
1004	0.00	0.05	-0.01
1005	0.01	0.01	-0.05
1006	-0.04	0.02	-0.04
1007	-0.02	-0.03	-0.02
1008	-0.02	0.03	0.06
1009	-0.03	-0.01	0.09
1010	-0.01	0.06	0.19
1011	-0.11	-0.06	0.23
1012	-0.02	-0.02	0.03
1013	-0.05	-0.04	0.03
1014	-0.02	-0.03	-0.04
1015	0.01	-0.01	-0.02
1016	0.04	-0.04	-0.14
1017	0.03	0.02	0.03
1018	0.02	0.02	0.23
1019	0.12	-0.11	0.14
1020	0.14	-0.02	-0.04
1021	0.09	-0.01	-0.04
1022	0.04	-0.01	-0.06
1023	0.01	0.03	-0.02
1024	-0.01	0.05	-0.01
1025	-0.05	0.07	0.05
1026	-0.07	0.04	-0.02
1027	-0.13	0.03	0.10
RMS	0.06	0.05	0.09

3. Conclusion and recommendations for application

Taking into account the material described above and results of Scientific and research institute of geodesy and cartography scientific council (Report №3 dated March 20, 2007) it has been decided that digital scanning system composed of 3-DAS-1 camera and *GPS/IMU Applanix POS AV 510* system is well suited for creation of topographic maps and orthoplans with 1:1000, 1:2000, 1:5000 and 1:10000 scales.

Recommended scales

Scale of a plan to be created	Accuracy tolerance (RMS), m	Survey scale (not less)	Resolution, m
1:1000	0.2	1:8000	0.072
1:2000	0.4	1:16000	0.144
1:5000	1.0	1:40000	0.36
1:10000	2.0	1:40000	0.36

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