Evaluating the Horizontal Accuracy of GeoEye OrbView-3 Orthorectified Products Over the Kaintuck Hollow, Missouri, Test Site

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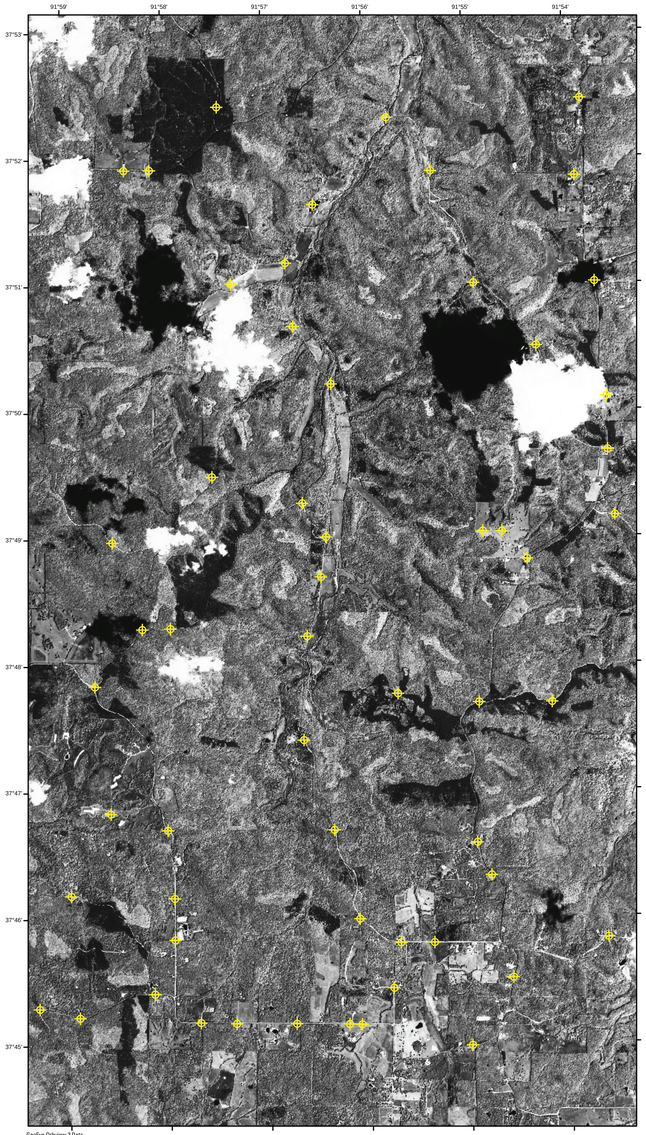


GeoEye Orbview-3 Data
Acquisition data: June 23, 2005
Universal Transverse Mercator projection
Zone 15
Horizontal coordinate information is referenced to
North American Datum of 1983 (NAD83)

Distribution of control points within the Kaintuck Hollow Quadrangle.

Background

The U.S. Geological Survey (USGS) has established procurement contracts to access high-resolution commercial satellite imagery to serve its science, mapping, and homeland security missions, and to provide cost effective centralized procurement services for other government agencies. To ensure that products from these systems can reliably meet USGS and other agency requirements, the USGS has partnered with the National Geospatial-Intelligence Agency and National Aeronautics and Space Administration to combine resources in validating and characterizing high-resolution satellite imagery products of high common interest. This tri-agency partnership is known as the Joint Agency Commercial Imagery Evaluation (JACIE) team. The USGS acquired and tested GeoEye (formerly ORBIMAGE, Inc.) orthorectified panchromatic imagery at 1:24,000-scale acquired on June 23, 2005, over the Kaintuck Hollow, Missouri, test site.

The Independent Control Dataset

Independently surveyed horizontal control points were established on the Kaintuck Hollow, Missouri, quadrangle during the fall of 2002 by the USGS Data Acquisition Response Team (DART). The Global Positioning System (GPS) equipment used to collect data were seven Ashtech Z12 dual-frequency receivers with Ashtech geodetic microstrip antennas, and seven identical fixed-height GPS antenna tripods. The GPS data collection was completed by occupying four National Geodetic Survey control (base) stations, and using three GPS roving receivers to collect the ground control points. Post-processing was performed using Ashtech Prism version 2.4, and adjusted with Ashtech Fillnet version 3.0.00 to determine the final adjusted positions. This quadrangle and control dataset have been used in previous JACIE horizontal control evaluations.

Testing Methodology

ArcView Geographic Information System software was utilized to display the OrbView-3 image. USGS cartographic technicians used hardcopy orthophoto plots provided by the DART to identify ground control points on the OrbView-3 imagery. Each plot included a magnified view of the control point and a detailed field description. Two technicians, working independently, collected the observed positions for 51 control points in the panchromatic image. The technicians used a zoom factor that enabled the best image measurement for each point. Horizontal differences were calculated between the independent GPS points and the observed image points were displayed. The actual measurements recorded by the two cartographic technicians and the calculated horizontal errors are shown in table 1.

The OrbView-3 imagery used for this test was acquired in June 2005 during leaf-on conditions. Since most of the area in the Kaintuck Hollow quadrangle is heavily forested, some of the GPS control points used in previous horizontal accuracy tests could not be used in this evaluation because of the trees and shadows in the image.

Preliminary Positional Accuracy Results

The test measurements on this image indicate there is a horizontal bias in the image. The simple root mean square error (RMSE) measurement did not work well for this particular orthorectified image because RMSE does not separate the effects of random and systematic error. Instead of calculating RMSE, the results are presented in a manner that attempts to separate the horizontal bias from the random error. To accomplish this, the mean of the differences between the measured points and the control points was calculated for the X and Y directions. This value represents systematic error and provides a simple representation of bias. These values are shown for both cartographic technicians in table 2.

To calculate the standard deviation for the test points while factoring out the systematic error, the following equations were used. This value represents the random error and is shown in table 2.

$$\sqrt{\frac{\sum (X_i - X_{mean})^2}{n-1}} \qquad \sqrt{\frac{\sum (Y_i - Y_{mean})^2}{n-1}}$$

The results indicate the random error is approximately circular and can be approximated by averaging the standard deviations in the X and Y directions. The circular map accuracy standard (CMAS), equivalent to the National Map Accuracy Standard at the 90 percent confidence level is defined as the circular standard deviation multiplied by 2.146. The results of that calculation are shown in table 2.

Table 2. Accuracy Test Results

	Systematic Error (meters)		Random Error (meters)			
OrbView-3 Orthorectified Data	Mean difference in X direction	Mean difference in Y direction	Standard deviation in the X direction	Standard deviation in the Y direction	Circular standard deviation	Calculated CMAS at 90 percent confidence
Panchromatic 1:24,000 Cartographic Technician A	10.46	3.61	2.70	2.66	2.68	5.75
Panchromatic 1:24,000 Cartographic Technician B	10.60	3.21	3.08	3.07	3.075	6.60

The results indicate that the OrbView-3 orthorectified product tested has a systematic shift to the northeast in the observed values compared to the control values. The results also indicate the random error is circular, and can be approximated by averaging the standard deviations in the X and Y directions. Furthermore, the standard deviations for X and Y about the mean error demonstrate that if bias shift is removed, the accuracy of the imagery would be 5 to 7 meters circular error at the 90 percent confidence level. The random error for the image is reasonable, but the systematic error should be investigated further.

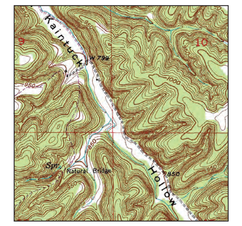
Table 1. Data Collected and Horizontal Acccuracy Calculations

Cartographic Technician A

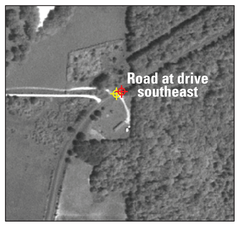
POINT	DESCRIPTION	FIELD Y	FIELD X	OBSERVED X	OBSERVED Y	ΔX	$\Delta X-X_{mean}$	$(\Delta X-X_{mean})^2$	ΔY	$\Delta Y-Y_{mean}$	$(\Delta Y-Y_{mean})^2$	$\Delta X^2+\Delta Y^2$
NE1	CTR OF LOOP	4188253.59	593362.99	593373.51	4188258.07	10.58	0.12	0.02	5.44	1.83	3.33	141.56
NE10	RD @ FENCE E-W	4191330.12	596916.24	596926.75	4191332.45	10.51	0.05	0.00	2.33	-1.28	1.64	115.90
NE11	RD @ DRV E (S 1 OF 2)	4192445.74	596986.97	596996.82	4192448.19	9.85	-0.61	0.37	3.45	-0.16	0.02	108.93
NE12	RD @ DRV SSW	4187439.66	598053.26	598065.46	4187441.14	12.20	1.74	3.01	1.49	-2.13	4.50	150.95
NE13	RD @ ENTR N	4186355.67	597514.30	597523.62	4186362.27	9.32	-1.14	1.29	6.60	2.99	8.96	130.53
NE14	TRAIL @ FENCE (CATTLE	4186116.40	595573.81	595584.69	4186116.35	10.88	0.28	0.08	-0.05	-3.26	10.66	118.37
NE2	RD @ DRAIN	4192157.20	594168.54	594176.06	4192162.11	7.52	-3.08	9.49	4.91	1.70	2.89	80.66
NE3	RD @ TRAIL E	4191391.04	594816.48	594827.14	4191393.83	10.66	0.06	0.00	2.79	-0.42	0.18	121.33
NE4	RD @ TRAIL ENE-WSW	4189742.14	595452.90	595448.02	4189741.38	-4.88	-15.48	239.78	-0.76	-3.97	15.72	24.43
NE5	T-RD NE	4188808.28	596364.00	596372.38	4188835.25	8.38	-2.22	4.92	6.97	3.76	14.12	118.81
NE6	T-RD E	4187316.55	597401.02	597412.24	4187321.02	11.22	0.62	0.38	4.46	1.25	1.57	145.77
NE8	RD @ DRV ENE	4189775.12	597203.26	597215.77	4189779.07	12.52	1.92	3.67	3.95	0.74	0.54	172.21
NE9	RD @ DRV E	4190523.01	597042.71	597050.85	4190526.92	8.14	-2.46	6.04	3.91	0.70	0.49	81.57
NW1	T-RD WSW	4186522.36	592940.90	592953.02	4186517.07	12.12	1.52	2.31	-5.28	-8.49	72.15	174.83
NW10	RD @ TRAIL ENTR WNW	4192302.18	591686.93	591697.32	4192306.42	10.39	-0.21	0.04	4.24	1.03	1.06	125.93
NW11	BOAT DOCK @ LAND	4190879.16	593094.15	593104.29	4190880.90	10.14	-0.46	0.21	1.75	-1.46	2.15	105.88
NW12	FEN CORNER	4189718.85	591894.33	591905.67	4189719.23	11.34	0.74	0.55	0.38	-2.83	8.00	128.75
NW13	T-RD WSW	4190032.00	592681.95	592693.56	4190032.82	11.61	1.01	1.01	0.82	-2.39	5.73	135.35
NW14	RD @ FENCE NE	4189091.76	592794.08	592805.87	4189097.11	11.79	1.19	1.42	5.35	2.14	4.58	167.71
NW15	RD @ TRAIL E	4186888.91	591618.91	591629.11	4186893.21	10.20	-0.40	0.16	4.30	1.09	1.19	122.46
NW8	RD @ DRV N	4191375.59	590334.14	590334.68	4191378.72	10.74	0.14	0.02	3.13	-0.08	0.01	125.18
NW9	RD @ DRV N	4191370.16	590706.83	590717.45	4191370.78	10.63	0.03	0.00	0.62	-2.59	6.70	113.37
SE1	RD @ FENCE NORTH	4180096.41	594871.61	594881.59	4180101.82	9.99	-0.61	0.38	5.41	2.20	4.84	128.98
SE10	T-RD SE	4183616.23	595524.05	595533.81	4183618.15	9.77	-0.83	0.70	1.91	-1.30	1.68	99.03
SE11	RD @ TRAIL S	4183623.09	596586.77	596596.87	4183625.70	10.10	-0.50	0.25	2.61	-0.60	0.36	108.87
SE12	RD @ LONE TREES N & S	4183732.30	594338.57	594342.89	4183738.98	4.32	-6.28	39.50	6.69	3.48	12.08	63.32
SE13	RD @ DRV E	4181562.60	595501.07	595511.66	4181567.39	10.59	-0.01	0.00	4.80	1.59	2.52	135.11
SE14	RD @ DRV WSW	4181095.28	595709.35	595720.34	4181098.86	10.99	0.39	0.15	3.57	0.36	0.13	133.54
SE2	RD @ DRV NNW	4180897.29	594381.72	594390.64	4181033.67	9.12	-1.48	2.19	6.39	3.18	10.11	124.60
SE3	RD @ DRV W	4179436.79	594277.27	594287.90	4179439.23	10.63	0.03	0.00	2.44	-0.77	0.59	119.01
SE4	RD @ DRV SW EXT	4178901.51	593813.17	593825.15	4178901.64	11.98	1.38	1.90	0.13	-3.08	9.48	143.49
SE5	RD @ DRV NNW	4178600.22	595420.33	595434.10	4178602.27	13.76	3.16	10.01	2.06	-1.15	1.33	193.70
SE6	RD @ DRV WNW	4179602.50	596022.71	596033.69	4179605.19	10.98	0.38	0.14	2.69	-0.52	0.27	127.79
SE7	RD @ DRV NNW	4180182.74	597412.74	597426.90	4180187.64	14.17	3.57	12.71	4.90	1.69	2.85	224.65
SE9	RD @ DRV SE	4185711.93	596235.32	596245.83	4185713.89	10.51	-0.09	0.01	1.96	-1.25	1.57	114.23
SW10	X-DRIVES	4180119.32	591082.08	591093.74	4180125.15	11.66	1.06	1.13	5.83	2.42	5.85	167.74
SW11	RD @ DRV WNW	4180726.37	591081.24	591091.35	4180732.77	10.11	-0.49	0.24	6.40	3.19	10.18	143.18
SW13	N-S FENCE @ GATE	4181969.18	590139.78	590153.13	4181969.25	13.35	2.75	7.58	0.07	-3.14	9.88	178.30
SW14	T-RD S	4183822.31	589914.13	589921.50	4183828.47	7.37	-3.23	10.45	6.16	2.95	8.69	92.21
SW17	T-RD NNW	4184664.64	590602.65	590612.46	4184667.35	9.81	-0.79	0.63	2.71	-0.50	0.25	103.56
SW18	T-RD SSW EXT	4184668.66	591022.70	591032.79	4184672.05	10.10	-0.50	0.25	3.39	0.18	0.03	113.47
SW2	SW EDGE RD @ T-RD SW	4179106.12	589105.04	589114.58	4179111.03	9.54	-1.06	1.12	4.91	1.70	2.89	115.13
SW20	W EDGE RD @ DRAIN	4184567.40	593010.02	593022.29	4184569.86	12.27	1.67	2.78	2.46	-1.15	1.32	249.63
SW21	RD @ ENTRANCE SW	4183064.03	592957.39	592971.14	4183061.99	13.75	3.15	9.93	-2.04	-5.25	27.61	193.27
SW22	RD @ ENTRANCE WEST	4181743.49	593409.11	593419.13	4181746.19	10.02	-0.58	0.34	2.70	-0.51	0.26	107.69
SW23	E TIP OF TRIANGLE	4180448.00	593774.16	593791.57	4180447.49	17.41	6.81	46.32	-0.51	-3.72	13.83	303.23
SW3	S EDGE RD @ X-TRAIL	4178980.91	589690.11	589700.66	4178989.38	10.55	-0.05	0.00	8.47	5.26	27.65	182.99
SW4	S EDGE RD @ DRV N	4179313.50	590780.02	590783.83	4179314.25	3.81	-6.65	44.16	0.75	-2.86	8.20	15.11
SW6	N EDGE RD @ DRV N	4178918.15	591457.03	591469.77	4178919.46	12.74	2.14	4.60	1.31	-1.90	3.62	164.13
SW7	S EDGE RD @ DRIVE NORT	4178905.74	591984.16	591996.34	4178908.79	12.18	1.72	2.96	3.05	-0.56	0.31	157.64
SW8	N EDGE RD@ C/L DRV N	4178908.05	592852.67	592859.96	4178908.69	7.29	-3.17	10.02	0.64	-2.97	8.81	53.63
						X_{mean} 10.46		Σ 364.50	Y_{mean} 3.61		Σ 354.65	Σ 6963.93
								Std Dev. (X) 2.70			Std Dev. (Y) 2.66	ave. 136.55
												RMSE 11.69

Cartographic Technician B

POINT	DESCRIPTION	FIELD Y	FIELD X	OBSERVED X	OBSERVED Y	ΔX	$\Delta X-X_{mean}$	$(\Delta X-X_{mean})^2$	ΔY	$\Delta Y-Y_{mean}$	$(\Delta Y-Y_{mean})^2$	$\Delta X^2+\Delta Y^2$
NE1	CTR OF LOOP	4188253.59	593362.99	593373.51	4188258.07	10.52	-0.08	0.01	4.48	1.27	1.61	130.74
NE10	RD @ FENCE E-W	4191330.12	596916.24	596925.57	4191332.82	9.33	-1.27	1.61	2.70	-0.51	0.26	94.36
NE11	RD @ DRV E (S 1 OF 2)	4192445.74	596986.97	596999.16	4192449.41	12.19	1.59	2.53	3.67	0.46	0.21	162.07
NE12	RD @ DRV SSW	4187439.66	598053.26	598065.51	4187441.64	12.25	1.65	2.71	1.98	-1.23	1.51	153.90
NE13	RD @ ENTR N	4186355.67	597514.30	597521.05	4186362.49	6.75	-3.85	14.84	6.82	3.61	13.03	92.03
NE14	TRAIL @ FENCE (CATTLE	4186116.40	595573.81	595584.69	4186116.35	10.88	0.28	0.08	-0.05	-3.26	10.66	118.37
NE2	RD @ DRAIN	4192157.20	594168.54	594176.06	4192162.11	7.52	-3.08	9.49	4.91	1.70	2.89	80.66
NE3	RD @ TRAIL E	4191391.04	594816.48	594827.14	4191393.83	10.66	0.06	0.00	2.79	-0.42	0.18	121.33
NE4	RD @ TRAIL ENE-WSW	4189742.14	595452.90	595448.02	4189741.38	-4.88	-15.48	239.78	-0.76	-3.97	15.72	24.43
NE5	T-RD NE	4188808.28	596364.00	596372.38	4188835.25	8.38	-2.22	4.92	6.97	3.76	14.12	118.81
NE6	T-RD E	4187316.55	597401.02	597412.24	4187321.02	11.22	0.62	0.38	4.46	1.25	1.57	145.77
NE8	RD @ DRV ENE	4189775.12	597203.26	597215.77	4189779.07	12.52	1.92	3.67	3.95	0.74	0.54	172.21
NE9	RD @ DRV E	4190523.01	597042.71	597050.85	4190526.92	8.14	-2.46	6.04	3.91	0.70	0.49	81.57
NW1	T-RD WSW	4186522.36	592940.90	592953.02	4186517.07	12.12	1.52	2.31	-5.28	-8.49	72.15	174.83
NW10	RD @ TRAIL ENTR WNW	4192302.18	591686.93	591697.32	4192306.42	10.39	-0.21	0.04	4.24	1.03	1.06	125.93
NW11	BOAT DOCK @ LAND	4190879.16	593094.15	593104.29	4190880.90	10.14	-0.46	0.21	1.75	-1.46	2.15	105.88
NW12	FEN CORNER	4189718.85	591894.33	591905.67	4189719.23	11.34	0.74	0.55	0.38	-2.83	8.00	128.75
NW13	T-RD WSW	4190032.00	592681.95	592693.56	4190032.82	11.61	1.01	1.01	0.82	-2.39	5.73	135.35
NW14	RD @ FENCE NE	4189091.76	592794.08	592805.87	4189097.11	11.79	1.19	1.42	5.35	2.14	4.58	167.71
NW15	RD @ TRAIL E	4186888.91	591618.91	591629.11	4186893.21	10.20	-0.40	0.16	4.30	1.09	1.19	122.46
NW8	RD @ DRV N	4191375.59	590334.14	590334.68	4191378.72	10.74	0.14	0.02	3.13	-0.08	0.01	125.18
NW9	RD @ DRV N	4191370.16	590706.83	590717.45	4191370.78	10.63	0.03	0.00	0.62	-2.59	6.70	113.37
SE1	RD @ FENCE NORTH	4180096.41	594871.61	594881.59	4180101.82	9.99	-0.61	0.38	5.41	2.20	4.84	128.98
SE10	T-RD SE	4183616.23	595524.05	595533.81	4183618.15	9.77	-0.83	0.70	1.91	-1.30	1.68	99.03
SE11	RD @ TRAIL S	4183623.09	596586.77	596596.87	4183625.70	10.10	-0.50	0.25	2.61	-0.60	0.36	108.87
SE12	RD @ LONE TREES N & S	4183732.30	594338.57	594342.89	4183738.98	4.32	-6.28	39.50	6.69	3.48	12.08	63.32
SE13	RD @ DRV E	4181562.60	595501.07	595511.66	4181567.39	10.59	-0.01	0.00	4.80	1.59	2.52	135.11
SE14	RD @ DRV WSW	4181095.28	595709.35	595720.34	4181098.86	10.99	0.39	0.15	3.57	0.36	0.13	133.54
SE2	RD @ DRV NNW	4180897.29	594381.72	594390.64	4181033.67	9.12	-1.48	2.19	6.39	3.18	10.11	124.60
SE3	RD @ DRV W	4179436.79	594277.27	594287.90	4179439.23	10.63	0.03	0.00	2.44	-0.77	0.59	119.01
SE4	RD @ DRV SW EXT	4178901.51	593813.17	593825.15	4178901.64	11.98	1.38	1.90	0.13	-3.08	9.48	143.49
SE5	RD @ DRV NNW	4178600.22	595420.33	595434.10	4178602.27	13.76	3.16	10.01	2.06	-1.15	1.33	193.70
SE6	RD @ DRV WNW	4179602.50	596022.71	596033.69	4179605.19	10.98	0.38	0.14	2.69	-0.52	0.27	127.79
SE7	RD @ DRV NNW	4180182.74	597412.74	597426.90	4180187.64	14.17	3.57	12.71	4.90	1.69	2.85	224.65
SE9	RD @ DRV SE	4185711.93	596235.32	596245.83	4185713.89	10.51	-0.09	0.01	1.96	-1.25	1.57	114.23
SW10	X-DRIVES	4180119.32	591082.08	591093.74	4180125.15	11.66	1.06	1.13	5.83	2.42	5.85	167.74
SW11	RD @ DRV WNW	4180726.37	591081.24	591091.35	4180732.77	10.11	-0.49	0.24	6.40	3.19	10.18	143.18
SW13	N-S FENCE @ GATE	4181969.18	590139.78	590153.13	4181969.25	13.35	2.75	7.58	0.07	-3.14	9.88	178.30
SW14	T-RD S	4183822.31	589914.13	589921.50	4183828.47	7.37	-3.23	10.45	6.16	2.95	8.69	92.21
SW17	T-RD NNW	4184664.64	590602.65	590612.46	4184667.35	9.81	-0.79	0.63	2.71	-0.50	0.25	103.56
SW18	T-RD SSW EXT	4184668.66	591022.70	591032.79	4184672.05	10.10	-0.50	0.25	3.39	0.18	0.03	113.47
SW2	SW EDGE RD @ T-RD SW	4179106.12	589105.04	589114.58	4179111.03	9.54	-1.06	1.12	4.91	1.70	2.89	115.13
SW20	W EDGE RD @ DRAIN	4184567.40	593010.02	593022.29	4184565.79	12.27	1.67	2.78	-1.61	-4.82	23.24	153.11
SW21	RD @ ENTRANCE SW	4183064.03	592957.39	592971.14	4183061.99	13.75	3.15	9.93	-2.04	-5.25	27.61	193.27
SW22	RD @ ENTRANCE WEST	4181743.49	593409.11	593419.13	4181746.19	10.02	-0.58	0.34	2.70	-0.51	0.26	107.69
SW23	E TIP OF TRIANGLE	4180448.00	593774.16	593791.57	4180447.49	17.41	6.81	46.32	-0.51	-3.72	13.83	303.23
SW3	S EDGE RD @ X-TRAIL	4178980.91	589690.11	589700.66	4178989.38	10.55	-0.05	0.00	8.47	5.26	27.65	182.99
SW4	S EDGE RD @ DRV N	4179313.50	590780.02	590783.23	4179327.85	13.22	2.62	6.85	14.35	11.14	124.06	380.59
SW6	N EDGE RD @ DRV N	4178918.15	591457.03	591469.77	4178919.46	12.74	2.14	4.60	1.31	-1.90	3.62	164.13
SW7	S EDGE RD @ DRIVE NORT	4178905.74	591984.16	591996.66	4178908.94	12.50	1.90	3.61	3.20	-0.01	0.00	166.52
SW8	N EDGE RD@ C/L DRV N	4178908.05	592852.67	592867.67	4178909.74	15.00	4.40	19.37	1.69	-1.52	2.31	227.91
						X_{mean} 10.60		Σ 474.95	Y_{mean} 3.21		Σ 472.54	Σ 7204.45
								Std Dev. (X) 3.08			Std Dev. (Y) 3.07	ave. 141.26
												RMSE 11.89



Terrain of Kaintuck Hollow Quadrangle is heavily forested and steep.



Example showing the typical offset from the observed image point (red) to the control point (yellow).