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

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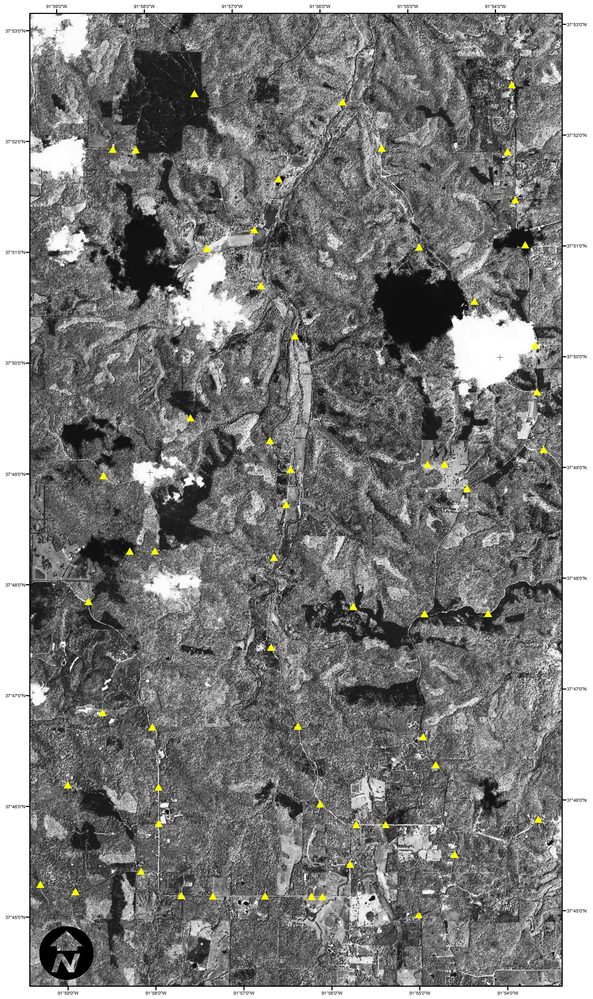
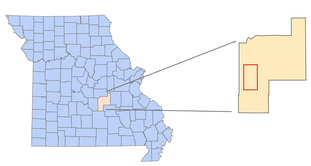


Distribution of control points within the Kaintuck Hollow Quadrangle.

GeoEye Orbview-3 Data: Acquisition data: June 23, 2005, Projection: Universal Transverse Mercator, Datum: NAD83, Zone 15



Phelps County Missouri
Study location

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 end products from these systems can reliably meet USGS and other agency requirements, the USGS has partnered with NGA and NASA to leverage resources in validating and characterizing high-resolution satellite imagery of high common interest. This tri-agency partnership is the Joint Agency Commercial Imagery Evaluation (JACIE) team. The USGS acquired and tested GeoEye (formerly ORBIMAGE Inc.) OrbView-3 products over the Kaintuck Hollow, Missouri test site.

The Tested Dataset

GeoEye OrbView-3 Orthorectified Panchromatic Imagery at 1:24,000-scale acquired on June 23, 2005 was tested for horizontal accuracy.

The Independent Control Dataset

Independently surveyed horizontal control points were established over the Kaintuck Hollow, MO 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. 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. The GPS data collection was completed by occupying four NGS control (base) stations, and using three GPS roving receivers to collect the ground control points. This quadrangle and control dataset have been used in previous JACIE horizontal control evaluations.

Testing Methodology

ArcView GIS software was utilized to display the OrbView-3 image. For identification of the ground control points on the OrbView-3 imagery, the evaluators used hardcopy orthophoto plots provided by the DART. Each plot included a magnified view of the control point and a detailed field description. Two evaluators working independently collected the observed positions for 51 control points in the panchromatic image. The evaluators 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 displayed.

The OrbView-3 imagery used for this test was acquired in June with 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 simple measurement of root mean square error RMSE does not work well for this particular orthorectified image because RMSE does not separate the effects of random and systematic error, and the test measurements on this image show that there is a horizontal bias in the image. 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 both the X and Y directions. This value represents systematic error and provides a simple representation of bias. These values are shown for both evaluators in the results table.

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 for the both evaluators in the results table.

$$\text{Standard deviation (X)} = \sqrt{\frac{\sum (X_i - X_{mean})^2}{n-1}} \qquad \text{Standard deviation (Y)} = \sqrt{\frac{\sum (Y_i - Y_{mean})^2}{n-1}}$$

The results show that 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 (NMAS) at the 90% confidence level is defined as the circular standard deviation multiplied by 2.146. The results of that calculation are shown in the results table.

Accuracy Test Results

	Systematic Error		Random Error			
OrbView-3 Orthorectified Data	Mean diff. in X direction (m)	Mean diff. in Y direction (m)	Std. Dev. in the X direction (m)	Std. Dev. in the Y direction (m)	Circular std. dev. (m)	Calculated CMAS at 90% confidence (m)
Panchromatic 1:24,000 Evaluator A	10.46	3.61	2.70	2.66	2.68	5.75
Panchromatic 1:24,000 Evaluator B	10.60	3.21	3.08	3.07	3.075	6.60

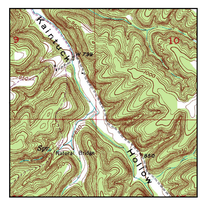
The results show that the OrbView-3 orthorectified product tested has a systematic shift to the northeast in the observed values compared to the control values. The results also show that the random error is approximately circular and can be approximated by averaging the standard deviations in the X 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 5-7 meters CE90. This random error for the image is reasonable, but the systematic error will need to be investigated further.

Evaluator A

POINT	DESCRIPTION	FIELD Y		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	4188253.58	593362.99	593373.51	4188259.02		10.38	0.12	0.02		5.44	1.83	3.33	141.66
NE10	RD @ FENCE E-W	4191330.12	596916.24	596926.75	4191332.43		10.51	0.05	0.00		2.31	-1.28	1.64	115.90
NE11	RD @ DRV E (S 1 OF 2)	4192445.74	596986.97	596996.82	4192449.19		9.85	-0.61	0.37		3.45	-0.16	0.02	108.93
NE12	RD @ DRV NSW	4187439.64	598053.20	598065.44	4187441.11		12.24	1.78	3.01		1.48	-2.12	4.50	150.92
NE13	RD @ ENTR N	4186555.67	597514.30	597527.62	4186562.27		9.32	-1.14	1.29		6.60	2.99	8.96	130.53
NE14	TRAIL @ FENCE (CATTLE	4186116.49	595373.81	595388.23	4186116.46		14.41	3.95	15.57		0.03	-3.58	12.64	207.52
NE2	RD @ DRAIN	4192137.70	594368.54	594379.96	4192383.10		7.42	-3.04	9.22		5.97	2.16	5.34	90.77
NE3	RD @ TRAIL E	4191393.04	594816.48	594826.81	4191393.65		10.33	-0.13	0.02		2.61	-1.00	1.00	113.46
NE4	RD @ TRAIL ENE-WSW	4189742.14	595453.90	595463.07	4189750.15		10.16	-0.30	0.09		8.01	4.40	19.38	167.44
NE5	T-RD NE	4188828.28	596364.60	596372.56	4188833.93		8.28	-1.90	3.61		5.74	1.13	9.92	118.78
NE6	T-RD E	4187316.55	597401.02	597417.40	4187320.79		11.38	0.92	0.85		4.23	0.62	0.39	147.45
NE8	RD @ DRV ENE	4189779.15	597201.26	597213.41	4189780.52		12.18	1.72	2.96		1.40	1.70	2.88	157.52
NE9	RD @ DRV E	4190523.01	597082.72	597092.55	4190526.44		9.84	-0.62	0.39		3.44	-0.17	0.03	108.58
NW1	T-RD WSW	4186537.36	592960.90	592969.25	4186519.17		9.13	-1.33	1.78		-18.19	-8.93	49.96	97.35
NW10	RD @ TRAIL ENTR WNW	4192502.18	591686.93	591697.91	4192305.90		10.98	0.52	0.27		3.73	0.12	0.01	134.50
NW11	BOAT DOCK @ LAND	4190879.14	593094.15	593104.86	4190881.83		10.83	0.35	0.12		2.67	-0.14	0.02	122.98
NW12	FEN CORNER	4189718.85	591894.33	591904.44	4189723.70		10.11	-0.35	0.13		4.84	2.23	1.52	125.61
NW13	T-RD WSW	4190027.00	592041.93	592042.48	4190031.85		0.53	0.07	0.00		-0.14	-3.75	14.10	170.86
NW14	RD @ FENCE NE	4189091.74	592784.03	592805.61	4189097.37		11.53	1.07	1.15		5.63	2.00	3.99	164.48
NW15	RD @ TRAIL E	4186885.91	591819.91	591828.83	4186894.25		9.92	-0.54	0.29		5.34	1.73	2.99	126.92
NW8	RD @ DRV N	4191375.98	590324.14	590335.00	4191378.75		10.87	0.41	0.17		3.18	-0.43	0.20	128.09
NW9	RD @ DRV N	4191370.14	590706.83	590718.38	4191371.03		11.54	1.10	1.21		0.87	-2.74	7.51	134.38
NE7	RD @ FENCE NORTH	4188096.41	594871.61	594881.08	4188101.41		9.47	-0.96	0.93		5.00	-1.39	1.93	114.72
NE10	T-RD SE	4186616.32	595324.05	595333.38	4186618.61		9.28	-1.15	1.30		2.42	-3.98	14.41	91.20
NE11	RD @ TRAIL S	4185623.09	596386.77	596397.96	4185625.81		10.79	0.31	0.11		2.72	-0.89	0.79	123.93
NE12	RD @ LONE TREES N & S	4185735.38	594318.57	594329.20	4185739.69		10.63	0.14	0.02		4.31	-3.78	14.31	93.68
NE13	RD @ DRV E	4185562.68	595301.07	595312.13	4185567.05		11.05	0.59	0.35		4.45	0.84	0.71	141.99
NE14	RD @ DRV WSW	4184399.29	595709.88	595720.13	4184399.45		10.38	0.06	0.00		0.16	-3.96	15.68	107.96
NE2	RD @ DRV NNW	4188097.29	594381.72	594390.82	4188103.65		9.10	-1.36	1.84		6.36	2.73	7.47	123.08
NE3	RD @ DRV W	4187636.79	594127.29	594287.10	4187640.61		9.81	-0.65	0.42		3.82	0.20	0.04	192.22
NE4	RD @ DRV SW EXT	4187601.51	591813.13	591821.14	4187601.21		9.97	-0.49	0.24		-0.28	-3.93	14.83	99.60
NE5	RD @ DRV NNW	4187660.22	594215.35	594224.13	4187665.11		14.11	3.67	13.48		4.89	-0.21	0.04	218.13
NE6	RD @ DRV NNW	4187662.54	594022.71	594034.24	4187667.56		11.53	1.07	1.14		5.04	1.43	2.05	158.01
NE7	RD @ DRV NNW	4187660.22	593822.13	593832.67	4187665.11		10.54	0.08	0.01		4.89	1.28	1.64	138.10
NE9	RD @ DRV SE	4187113.30	596215.75	596246.14	4187117.49		10.62	0.16	0.03		4.19	0.57	0.32	114.77
NW10	N.ORIVES	4180119.52	591086.08	591093.73	4180125.29		11.65	1.19	1.43		5.77	2.16	4.65	169.07
NW11	RD @ DRV WNW	4180726.37	591081.24	591089.81	4180732.43		8.57	-1.89	3.57		6.06	2.45	6.00	110.03
NW13	N.FENCE @ GATE	4181909.18	590139.78	590130.53	4181909.29		10.37	-0.31	0.10		0.09	-3.52	12.38	118.02
NW14	T-RD S	4189832.31	589914.18	589920.62	4189837.78		6.44	-3.72	13.83		5.46	-3.82	3.49	74.72
NW17	T-RD NNW	4184664.64	590042.65	590061.29	4184668.81		8.64	-1.52	3.11		4.17	0.56	0.32	92.10
NW18	T-RD SNW EXT	4184664.64	591022.79	591033.39	4184671.76		10.28	-0.20	0.07		7.12	-0.31	0.24	113.87
NW2	NW EDGE RD @ T-RD SW	4179108.12	589105.04	589114.00	4179110.50		8.96	-1.52	2.25		4.38	0.77	0.59	99.47
NW20	W EDGE RD @ DRAIN	4184567.40	593010.02	593022.29	4184565.79		15.32	4.86	23.58		2.44	-3.13	3.32	260.63
NW21	RD @ ENTRANCE SW	4183064.03	592957.39	592970.17	4183061.97		13.17	2.91	8.50		-2.06	-5.76	32.43	183.24
NW22	RD @ ENTRANCE WEST	4181743.49	593409.11	593419.90	4181754.37		7.79	-2.47	5.14		10.88	3.27	32.82	178.97
NW23	E TIP OF TRIANGLE	4180448.00	593774.16	593791.57	4180447.49		17.46	7.43	55.16		-0.51	-4.62	21.36	320.93
NW3	S EDGE RD @ X-TRAIL	4179980.91	589690.11	589708.66	4179986.04		13.96	3.50	12.24		5.09	1.44	2.14	220.37
NW4	S EDGE RD @ DRV N	4179311.50	590780.02	590793.83	4179314.25		3.83	-6.63	44.16		0.75	-2.86	8.20	15.11
NW6	N EDGE RD @ DRV N	4178918.15	591437.03	591469.77	4178919.46		32.62	22.26	495.39		1.31	-1.98	3.82	1064.33
NW7	S EDGE RD @ DRIVE NORT	4178905.74	591984.16	591996.46	4178908.94		12.58	1.92	3.63		3.20	-0.01	0.00	166.52
NW8	N EDGE RDG C1, DRV N	4178908.05	592852.67	592867.67	4178909.74		15.04	4.40	19.37		1.69	-1.52	2.31	227.91
						X_{mean}	10.60	Σ	364.50	Y_{mean}	3.61	Σ	354.62	Σ 6963.93
											Std Dev. (X)	2.70		Std Dev. (Y) 2.66 circular 136.53
														RMSE 11.09

Evaluator B

POINT	DESCRIPTION	FIELD X	FIELD Y	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	4188256.07		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	1.58	2.51		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	4186555.67	597514.30	597527.05	4186562.49		8.75	-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	118.27
NE2	RD @ DRAIN	4192137.70	594368.54	594376.96	4192362.11		7.52	-3.08	9.49		4.93	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	121.13
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	4188828.28	596364.60	596372.38	4188835.25		8.38	-2.22	4.92		6.97	3.26	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	597215.37	4189779.07		12.32	1.92	3.67		3.95	0.74	0.54	172.21
NE9	RD @ DRV E	4190523.01	597082.72	597088.83	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	4192502.18	591686.93	591697.32	4192306.42		10.39	-0.21	0.04		-4.24	-1.83	3.06	225.93
NW11	BOAT DOCK @ LAND	4190879.14	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	591905.18	4189719.23		10.85	0.24	0.05		0.38	-2.83	8.00	118.75
NW13	T-RD WNW	4190034.00	592681.95	592691.50	4190032.82		11.83	1.01	1.01		0.82	-2.79	5.73	135.32
NW14	RD @ FENCE NE	4189091.74	592784.03	592803.87	4189097.11		11.79	1.38	1.82		5.37	2.14	4.58	167.71
NW15	RD @ TRAIL E	4186885.91	591819.91	591829.11	4186892.21		10.20	-0.40	0.16		6.30	2.67	7.13	122.46
NW8	RD @ DRV N	4191375.59	590324.14	590334.88	4191378.72		10.74	0.14	0.02		3.13	-0.08	0.01	125.18
NW9	RD @ DRV N	4191370.14	590706.83	590717.45	4191370.79		10.63	0.03	0.00		0.62	-2.99	8.70	113.21
NE7	RD @ FENCE NORTH	4188096.41	594871.61	594881.59	4188101.82		9.99	-0.61	0.38		5.41	2.28	4.84	129.98
NE10	T-RD SE	4186616.32	595324.05	595333.81	4186618.17		9.77	-0.83	0.70		1.85	-1.58	1.68	99.03
NE11	RD @ TRAIL S	4185623.09	596386.77	596396.87	4185625.70		10.10	-0.50	0.25		2.61	-0.60	0.36	108.87
NE12	RD @ LONE TREES N & S	4185735.38	594318.57	594342.89	4185738.98		4.33	-6.28	39.50		6.09	3.48	12.08	63.32
NE13	RD @ DRV E	4185562.68	595501.07	595511.66	4185567.39		10.59	-0.01	0.00		4.80	1.59	2.52	135.11
NE14	RD @ DRV WSW	4184399.29	595709.88	595720.34	4184398.84		10.46	0.38	0.15		-0.45	-3.57	14.16	113.56
NE2	RD @ DRV NNW	4188097.29	594381.72	594390.84	4188103.67		9.12	-1.48	2.19		6.39	3.18	10.11	124.00
NE3	RD @ DRV W	4187636.79	594277.23	594287.90	4187639.22		10.63	0.03	0.00		2.44	-0.77	0.59	119.05
NE4	RD @ DRV SW EXT	4187601.51	593813.13	593825.12	4187601.64		11.98	1.38	1.90		0.13	-3.08	9.48	143.49
NE5	RD @ DRV NNW	4187660.22	595420.35	595434.10	4187662.27		13.74	3.18	10.01		2.06	-1.15	1.33	193.70
NE6	RD @ DRV WNW	4187662.54	596022.71	596033.69	4187665.10		10.98	0.38	0.14		2.69	-0.52	0.27	122.29
NE7	RD @ DRV NNW	4188182.74	597412.74	597426.96	4188187.64		14.17	3.57	12.71		4.90	1.69	2.85	224.65
NE9	RD @ DRV SE	4187511.93	596235.32	596245.83	4187513.89		10.51	-0.06	0.01		1.96	-1.25	1.57	114.23
NW10	N.ORIVES	4180119.52	591082.08	591093.54	4180125.15		11.46	1.06	1.13		5.63	2.42	5.85	167.74
NW11	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
NW13	N.FENCE @ GATE	4181909.18	590139.78	590133.13	4181909.27		13.35	2.73	7.45		0.07	-3.14	9.88	178.30
NW14	T-RD S	4189832.31	589914.18	589921.50	4189828.47		7.33	-3.23	10.45		6.16	2.95	8.69	92.21
NW17	T-RD NNW	4184664.64	590042.65	590052.69	4184667.55		9.61	-0.79	0.63		2.71	-0.50	0.25	101.54
NW18	T-RD SNW EXT	4184664.64	591022.79	591033.39	4184672.05		10.10	-0.30	0.23		7.39	4.18	0.03	113.87
NW2	NW EDGE RD @ T-RD SW	4179108.12	589105.04	589114.58	4179111.03		9.54	-1.06	1.12		4.91	1.70	2.89	113.13
NW20	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
NW21	RD @ ENTRANCE SW	4183064.03	592957.39	592971.14	4183061.99		13.75	3.15	9.93		-2.04	-5.25	27.61	193.37
NW22	RD @ ENTRANCE WEST	4181743.49	593409.11	593419.13	4181746.19		10.02	-0.58	0.34		2.70	-0.93	0.86	107.69
NW23	E TIP OF TRIANGLE	4180448.00	593774.16	593791.57	4180447.49		17.41	6.83	46.52		-0.51	-3.72	13.83	303.23
NW3	S EDGE RD @ X-TRAIL	4179980.91	589690.11	589708.66	4179989.10		10.55	-0.05	0.00		8.19	5.26	27.67	182.99
NW4	S EDGE RD @ DRV N	4179311.50	590780.02	590793.83	4179317.83		13.22	2.62	6.85		16.33	11.14	124.06	380.59
NW6	N EDGE RD @ DRV N	4178918.15	591437.03	591469.77	4178919.46		32.74	24.14	4.68		1.31	-1.98	3.82	164.33
NW7	S EDGE RD @ DRIVE NORT	4178905.74	591984.16	591996.46	4178908.94		12.58	1.90	3.61		3.20	-0.01	0.00	166.52
NW8	N EDGE RDG C1, DRV N	4178908.05	592852.67	592867.67	4178909.74		15.04	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 circular 141.26
														RMSE 11.89



Kaintuck Hollow Quadrangle is heavily timbered steep terain.

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

MCGSC web address: http://mcmcweb.er.usgs.gov/msgsc

Printed: March 8, 2006, Provisional, Plotter has not yet been formally reviewed.