

NASA/SDSU Geopositional Characterization



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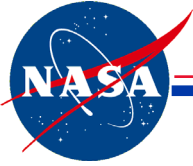
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JACIE Civil Commercial Imagery Evaluation Workshop
Laurel, Maryland, USA
15 MAR 2006



Contributors

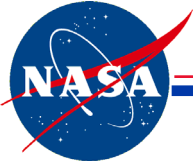
Stennis Space Center

NASA: Thomas Stanley

Science Systems & Applications, Inc.: Mary Pagnutti

Computer Sciences Corporation: Debbie Fendley

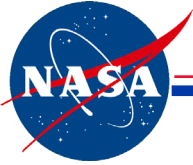
South Dakota State University: Jason Choi and Seth Cooper



Outline

Stennis Space Center

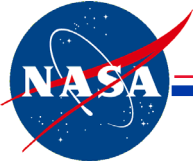
- Ground Reference Sites
 - Brookings, SD
 - Stennis Space Center, MS
- Methods
- IKONOS Characterization
 - Data Collections
 - Results
- QuickBird Characterization
 - Data Collections
 - Results
- OrbView Characterization
 - Data Collections
 - Results



Characterization Overview

Stennis Space Center

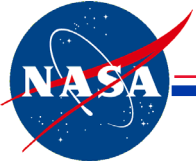
- Objective
 - Compare vendor-provided image coordinates with known references visible in the imagery
- Approach
 - Use multiple, well-characterized sites with >40 ground control points (GCPs); sites that are
 - Well distributed
 - Accurately surveyed
 - Easily found in imagery
 - Perform independent characterizations with independent teams. Each team has slightly different measurement techniques and data processing methods.
 - NASA Stennis Space Center
 - South Dakota State University



Data Providers

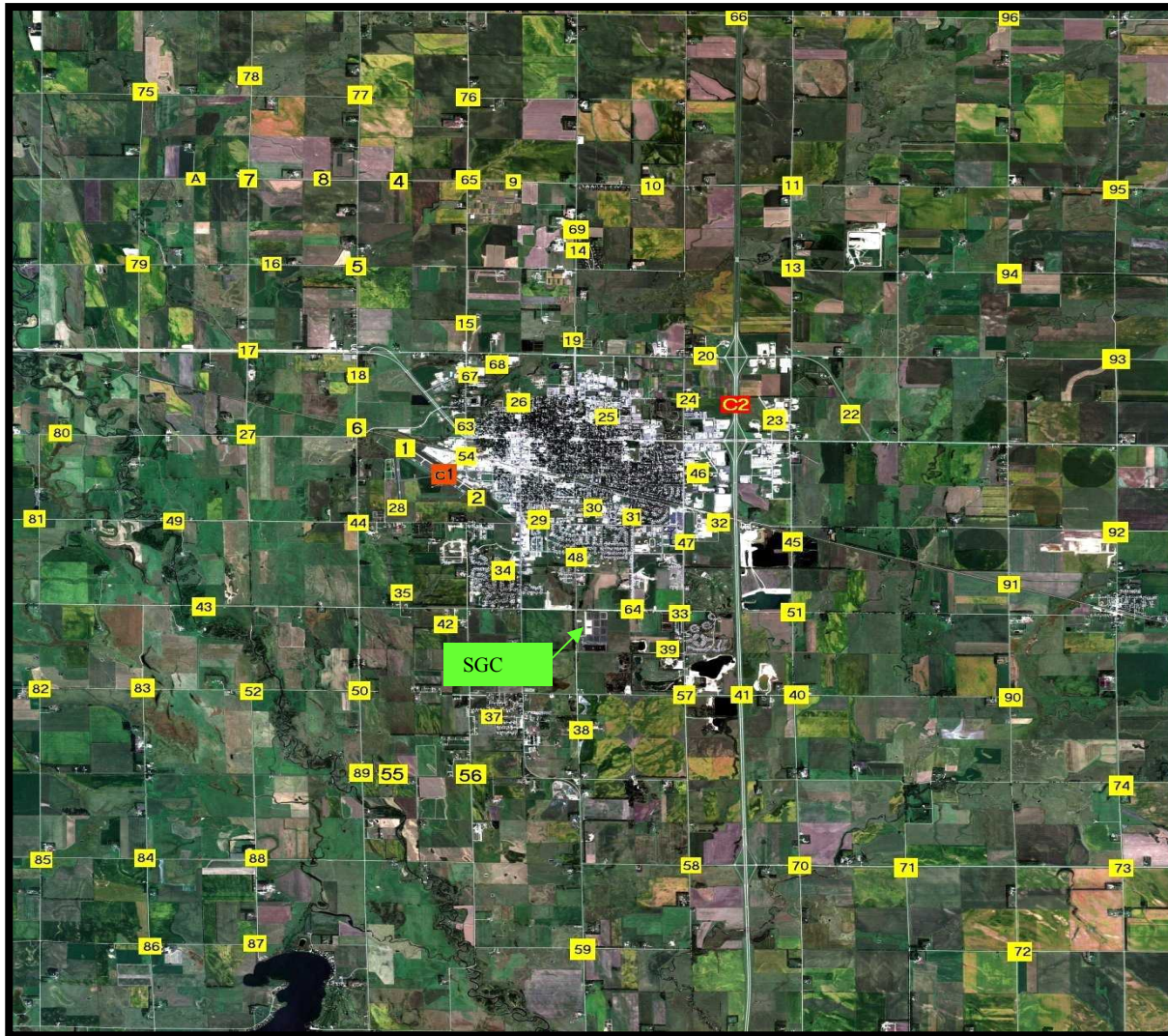
Stennis Space Center

- DigitalGlobe, Inc.
 - Imagery acquired by the QuickBird sensor
- GeoEye™
 - Imagery acquired by the OrbView-3 and IKONOS sensors

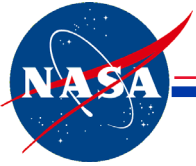


Sites

Brookings Targets



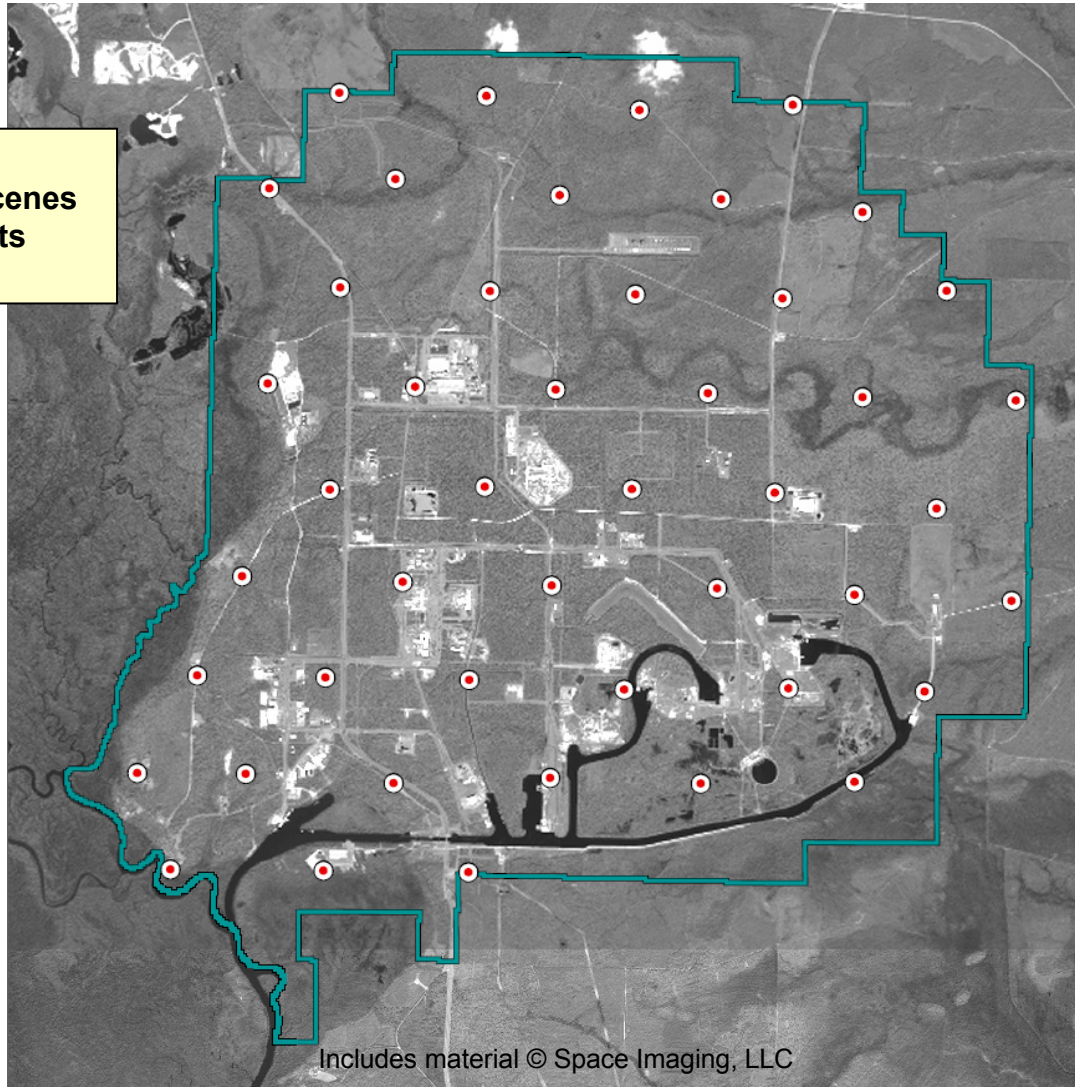
■ GCP Locations ■ Base Stations



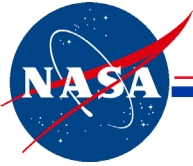
SSC Targets

Stennis Space Center

2 SEP 2005
IKONOS Geo scenes
with SSC Targets
Overlaid



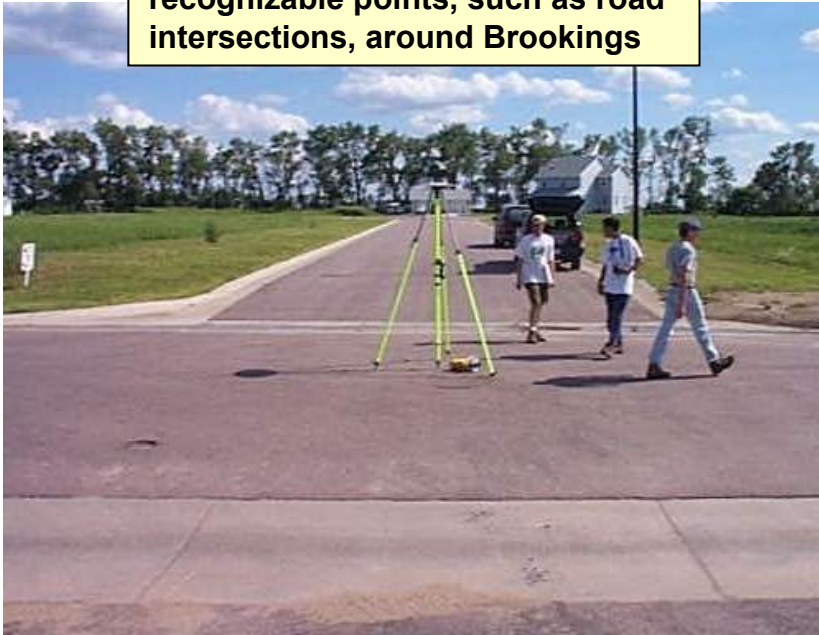
Includes material © Space Imaging, LLC



Brookings and Stennis Ground Control

Stennis Space Center

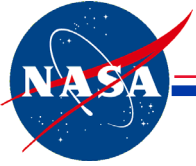
SDSU uses a distribution of 96 recognizable points, such as road intersections, around Brookings



SSC uses 45 circular targets, 2.44 m in diameter, distributed across the Fee Area



Both sets of GCPs were real-time kinematic GPS-located by the SSC survey team to absolute horizontal accuracies in the 3–6 cm range

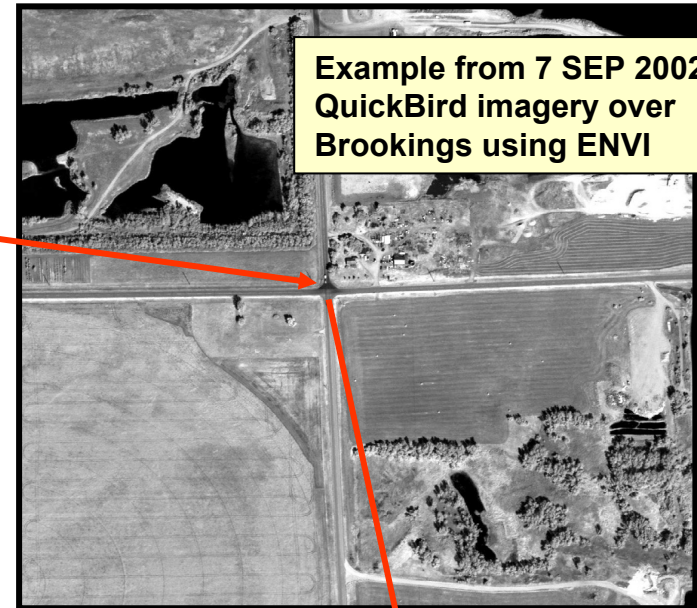


Methods

Finding Image Coordinates

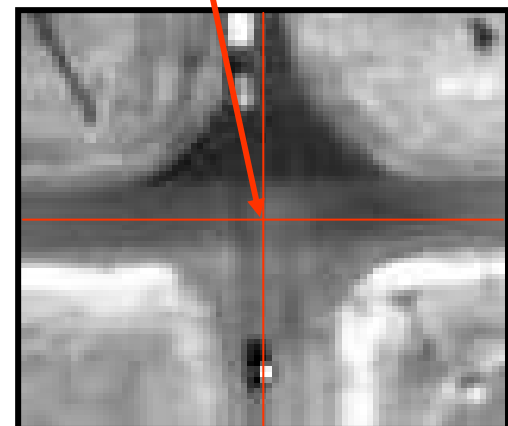


Step 1



Example from 7 SEP 2002 QuickBird imagery over Brookings using ENVI

Step 2

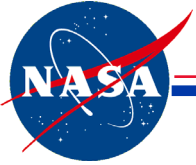


Step 3

Disp #1 (8749.250,16600.250) Scrn: R:110 G:110 B:110
Projection: UTM Zone #14 North
Map: **678122.55E, 4904054.85N Meters**
LL: 44°16'4.58"N, 96°46'5.70"W
Data: 249

Cursor Location/Value of Point 33

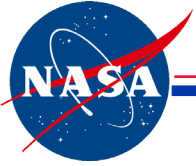
Includes material © DigitalGlobe, Inc.



Additional Notes on Methods

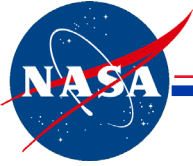
Stennis Space Center

- At South Dakota State University, images were analyzed by three individuals using ENVI[®] software
 - Visible points are determined for the group
 - Each individual finds points independently
 - If individual mistakes are found, individual is asked to re-do the point in question
 - Final image points are averaged before comparison with reference coordinates and generation of results
- SSC images were analyzed by a single individual using ERDAS IMAGINE[®] software to select image coordinates and using MATLAB[®] to generate results
 - Results are reviewed for indications of mistakes



QuickBird

Geopositional Characterization

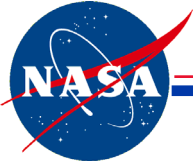


QuickBird Acquisitions

Stennis Space Center

- Brookings, SD
 - 30 AUG 2004
 - 5 OCT 2004
 - 22 JUN 2005
 - 18 OCT 2005

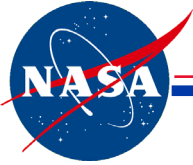
- Stennis Space Center, MS
 - 23 JAN 2004
 - 28 JAN 2004
 - 21 JUL 2004
 - 17 JAN 2005
 - 12 MAR 2005
 - 6 SEP 2005



Scientific Data Purchase Specifications for QuickBird Products Assessed

Stennis Space Center

- *Standard (2A) imagery products (PAN & Multispectral)*
 - “Standard Imagery products are radiometrically corrected, sensor corrected, geometrically corrected, and mapped to a cartographic projection...Geometric corrections remove spacecraft orbit position and attitude uncertainty, Earth rotation and curvature, and panoramic distortion...Standard Imagery has a coarse DEM applied to it, which is used to normalize for topographic relief with respect to the reference ellipsoid. The degree of normalization is relatively small, so while this product has terrain corrections, it is not considered orthorectified.”
 - 23 meters CE_{90} (see next slide)

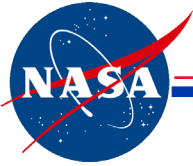


QuickBird *Standard* Specification Note

Stennis Space Center

Accuracies: Standard Imagery products have an average absolute geolocation accuracy of 23-meter CE90%, excluding any topographic displacement and off-nadir viewing angle. Ground location is derived from refined satellite attitude and ephemeris information without requiring the use of Ground Control Points (GCPs).¹

¹ DigitalGlobe, 2006. *QuickBird Imagery Products - Product Guide*. Revision 4.7. February 3, p. 19. <http://www.digitalglobe.com/downloads/QuickBird%20Imagery%20Products%20-%20Product%20Guide.pdf> (accessed March 10, 2006).

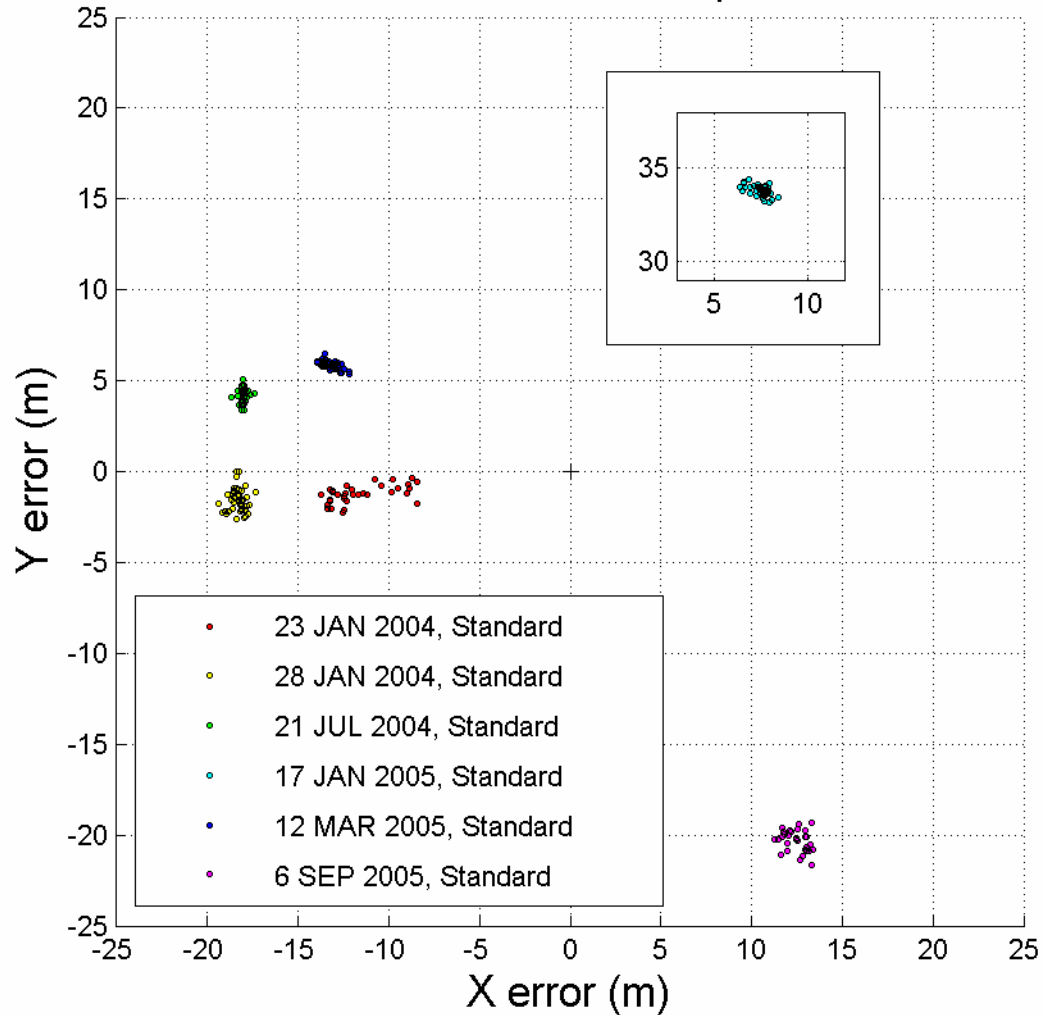


SSC 2004-2005 QuickBird PAN

Standard

Stennis Space Center

QuickBird Scatterplot

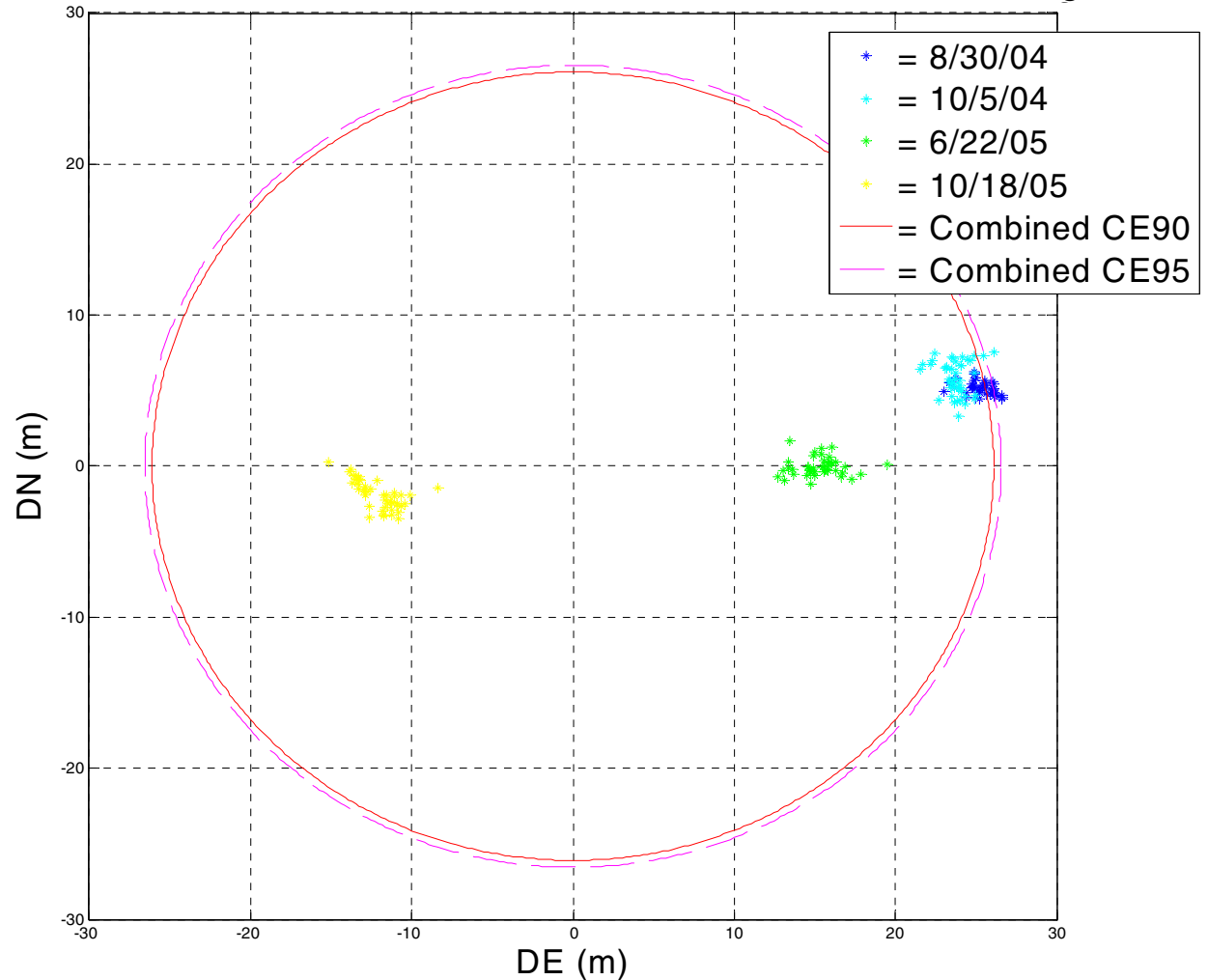


SDSU 2004-2005 QuickBird PAN Standard



QuickBird Panchromatic
Combined
CE90 = 26.10 m
CE95 = 26.56 m

Combined CE90 & CE95 Plot for all QuickBird Panchromatic Images

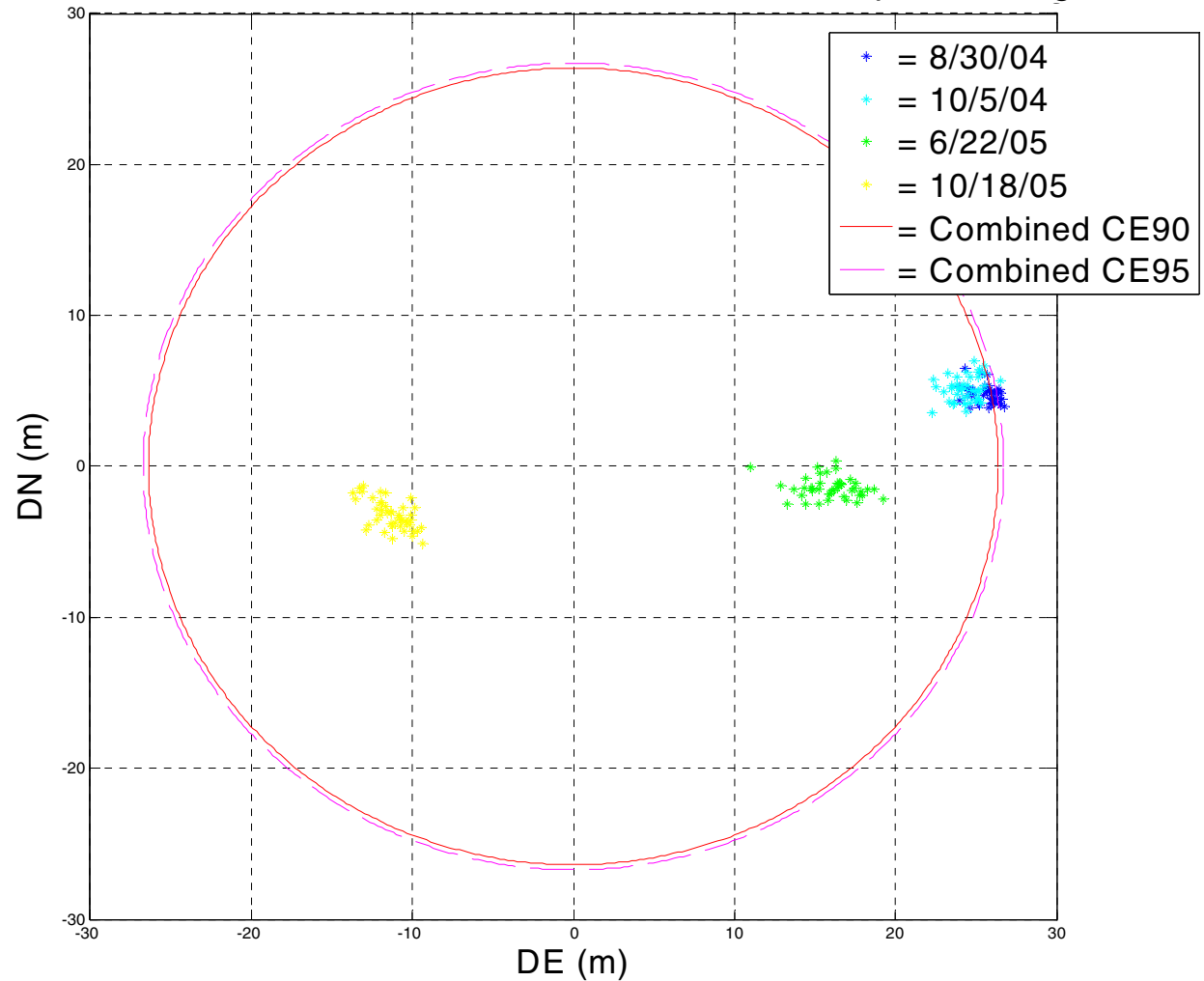


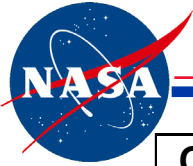
SDSU 2004-2005 QuickBird Multispectral *Standard*



QuickBird Multispectral
Combined
CE90 = 26.39 m
CE95 = 26.72 m

Combined CE90 & CE95 Plot for all QuickBird Multispectral Images

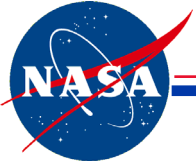




Summary

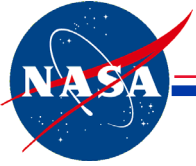
QuickBird Product	Acquisition Date	Elevation Angle (deg.)	Horizontal Bias (m)	Circular Std. Error (m)	Empirical CE ₉₀ (m)	Empirical CE ₉₅ (m)
QuickBird Panchromatic Standard	23 JAN 2004	73.0°	11.58	1.11	13.36	13.49
	28 JAN 2004	74.6°	18.37	0.53	18.98	19.21
	21 JUL 2004	85.9°	18.47	0.31	18.75	18.84
	30 AUG 2004	83.2°	25.76	0.66	26.66	26.99
	5 OCT 2004	76.1°	24.50	1.01	25.62	25.93
	17 JAN 2005	81.1°	34.60	0.36	34.87	34.95
	12 MAR 2005	78.0°	14.39	0.34	14.99	15.16
	22 JUN 2005	72.5°	15.31	0.97	16.71	17.31
	6 SEP 2005	48.6°	23.84	0.61	24.73	24.85
QuickBird Multispectral Standard	18 OCT 2005	73.2°	12.28	1.12	13.60	13.80
	30 AUG 2004	83.2°	26.05	0.66	26.86	26.94
	5 OCT 2004	76.1°	24.94	0.88	25.98	26.27
	22 JUN 2005	72.5°	16.06	1.15	17.97	18.32
	18 OCT 2005	73.2°	11.80	1.06	13.34	13.55

- The mean CE₉₀ of QuickBird panchromatic *Standard* images (excluding 6 SEP 2005 because of low elevation angle) was 21.9 m
 - 95% confidence interval from 16.2 m to 27.6 m
- The mean CE₉₀ of QuickBird multispectral *Standard* images was 21.0 m
 - 95% confidence interval from 9.1 m to 33.0 m
- Three of nine acquisition dates with reasonable elevation angles had estimated CE₉₀ above the Scientific Data Purchase specification of 23 m (no clear relationship with elevation angle)



OrbView-3

Geopositional Characterization

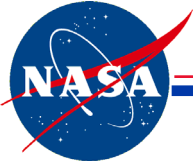


OrbView-3 Acquisitions

Stennis Space Center

- Brookings, SD
 - 30 AUG 2004
 - 8 OCT 2004
 - 18 JUL 2005
 - 7 OCT 2005

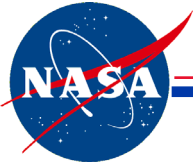
- Stennis Space Center, MS
 - 6 NOV 2004
 - 12 APR 2005
 - 2 SEP 2005
 - 29 DEC 2005



GeoEye Self-Stated Specifications for OrbView-3 Products Assessed

Stennis Space Center

- *GEO Express* PAN configuration
 - Geopositional information based on real-time downlinked telemetry only
 - 60 meters CE₉₀ (see next slide)
- *GEO Enhanced* PAN configuration
 - Geopositional information based on refined GPS ephemeris and post-processed attitude data
 - 25 meters CE₉₀ (see next slide)
- *ORTHO 1:50K* PAN configuration
 - *ORTHO* geopositional processing adds correction for the effects of systematic distortions, Earth rotation and curvature effects, variations in orbital altitude, and variations in the Earth's surface
 - 25 meters CE₉₀ (see next slide)

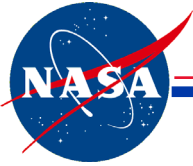


OrbView-3 *GEO* Specification Note

Stennis Space Center

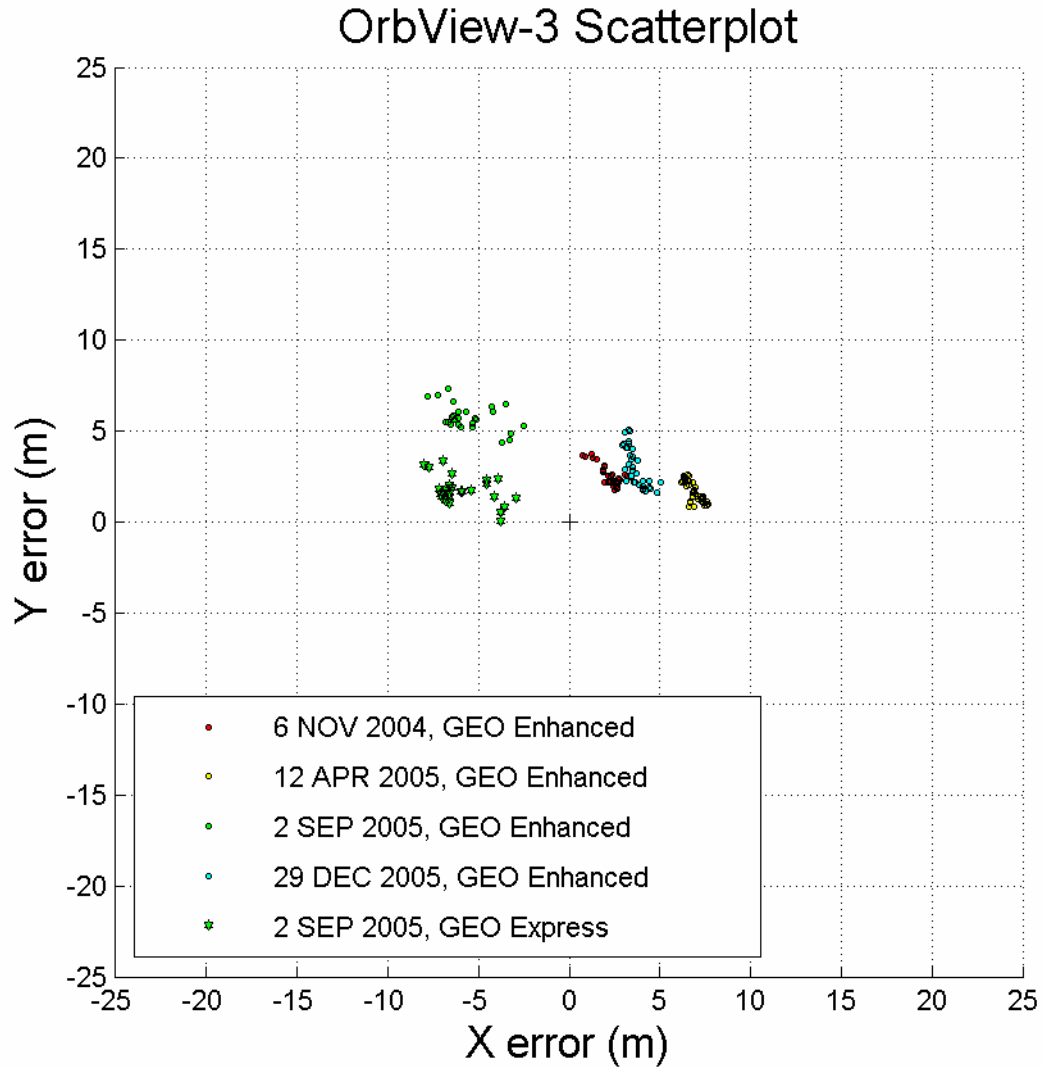
NOTE: While the geocorrected image is presented in a map-like manner and is delivered with a reference point (corner coordinate) and spacing parameters, geographic coordinates should be derived from the image by using the supplied 3-D RFCs and not by using the corners and spacing. The corner coordinates and spacing should only be used for deriving gross geographical positions. In most cases, the accuracy of coordinates derived using the corner coordinates and spacing will not meet the product accuracies specified above. On the other hand, coordinates of points derived using the 3-D RFCs along with a stereomate or suitable elevation data will allow determination of latitude and longitude to the specified accuracies. In addition, using the RFCs, it is possible to improve accuracies and refine the geopositioning further by introducing additional images and/or control points in the solution.¹

¹ GeoEye, 2006. *OrbView-3 Commercial Satellite Imagery Product Catalog*. January 23, p. 6. http://www.orbimage.com/docs/OV-3_Catalog_1_25_06.pdf (accessed March 10, 2006).



SSC 2004-2005 OrbView-3 GEO

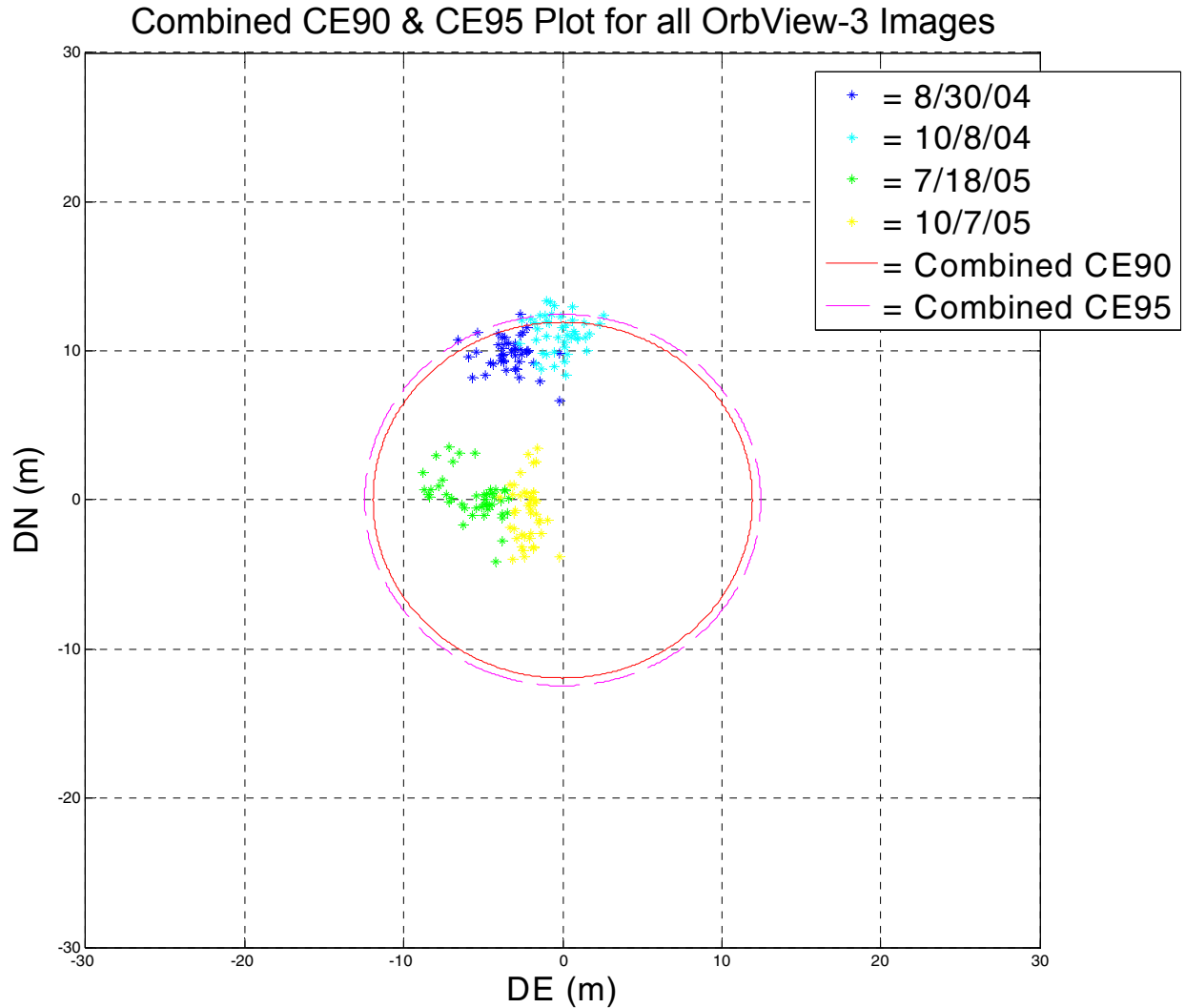
Stennis Space Center

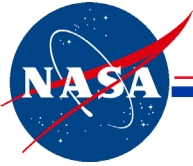


SDSU 2004-2005 OrbView-3 ORTHO 1:50K



OrbView-3
Combined
CE90 = 11.93 m
CE95 = 12.45 m

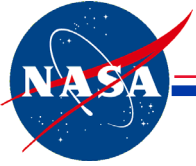




Summary

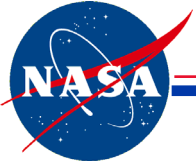
OrbView-3 Product	Acquisition Date	Elevation Angle (deg.)	Horizontal Bias (m)	Circular Std. Error (m)	Empirical CE ₉₀ (m)	Empirical CE ₉₅ (m)
OrbView-3 <i>GEO Enhanced</i>	6 NOV 2004	81.2°	3.38	0.55	3.88	4.05
	12 APR 2005	86.4°	7.06	0.50	7.52	7.65
	2 SEP 2005	77.5°	7.97	1.04	9.79	10.11
	29 DEC 2005	86.9°	4.75	0.82	5.53	5.98
OrbView-3 <i>GEO Express</i>	2 SEP 2005	77.5°	6.10	1.09	7.65	8.35
OrbView-3 <i>ORTHO 1:50K</i>	30 AUG 2004	80.9°	10.45	1.19	11.76	12.46
	8 OCT 2004	75.7°	11.23	1.24	12.67	13.08
	18 JUL 2005	79.2°	5.82	1.54	8.38	8.54
	7 OCT 2005	82.3°	2.96	1.30	3.99	4.18

- The mean CE₉₀ of OrbView-3 *GEO Enhanced* images was 6.7 m
 - 95% confidence interval from 2.0 m to 11.4 m
- The mean CE₉₀ of OrbView-3 *ORTHO 1:50K* images was 9.2 m
 - 95% confidence interval from 2.0 m to 16.4 m
- Interestingly, for the single date of comparison, the *GEO Express* product performed slightly better than the *GEO Enhanced* product
- All OrbView-3 images characterized in this reporting period met ORBIMAGE's self-stated specifications for any *GEO* product configuration



IKONOS

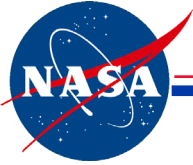
Geopositional Characterization



IKONOS Acquisitions

Stennis Space Center

- Stennis Space Center, MS
 - 15 DEC 2004
 - 17 JAN 2005
 - 15 APR 2005
 - 2 SEP 2005
 - 13 SEP 2005



GeoEye Self-Stated Specifications for IKONOS Imagery Assessed

Stennis Space Center

- *Geo*
 - Geopositional information based on “correction process that removes image distortions introduced by the collection geometry and then resamples the imagery to a uniform ground sample distance (GSD) and a specified map projection. Because Geo images are not orthorectified, their accuracy is limited by terrain displacement.”¹
 - “Accuracy: 15m CE90 not including effects of terrain. True accuracy including effects of terrain displacement, may vary several hundred meters in regions of high relief.”²

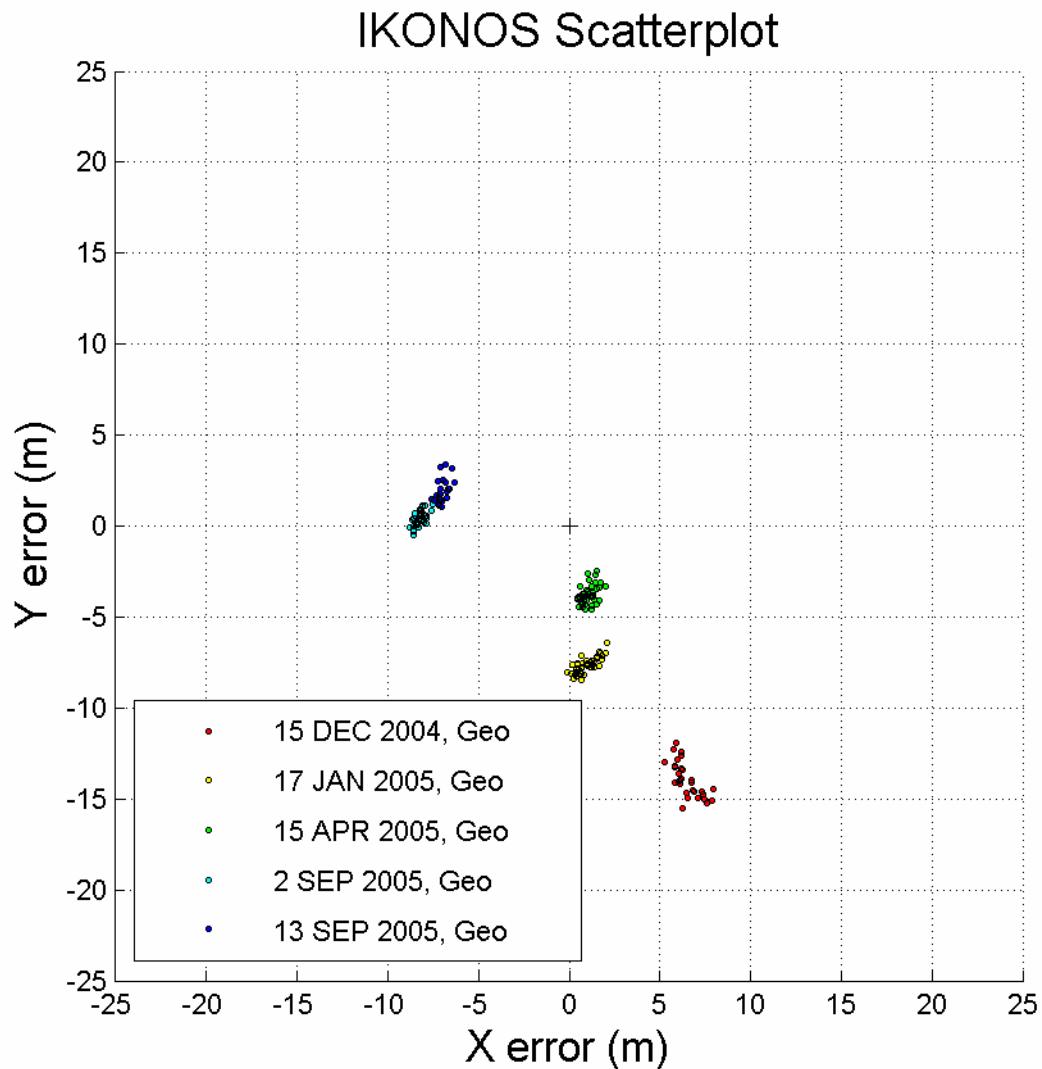
¹ Space Imaging, Inc., 2005. *IKONOS Image Products and Product Guide*. p. 3. http://www.spaceimaging.com/whitepapers_pdfs/IKONOS_Product_Guide.pdf (accessed February 13, 2006).

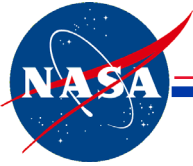
² Space Imaging, Inc., 2005. *Geo 1m & 4m (Technical Overview)*. http://www.spaceimaging.com/products/ikonos/geo_techspec.htm (accessed March 10, 2006).



SSC 2004-2005 IKONOS Geo

Stennis Space Center



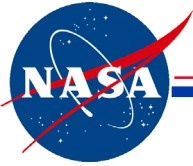


Summary

Stennis Space Center

IKONOS Product	Acquisition Date	Elevation Angle (deg.)	Horizontal Bias (m)	Circular Std. Error (m)	Empirical CE₉₀ (m)	Empirical CE₉₅ (m)
IKONOS Geo	15 DEC 2004	68.9°	15.40	0.81	16.72	17.00
	17 JAN 2005	86.6°	7.73	0.49	8.18	8.29
	15 APR 2005	72.7°	3.93	0.44	4.51	4.60
	2 SEP 2005	82.6°	8.20	0.40	8.59	8.61
	13 SEP 2005	80.7°	7.27	0.49	7.62	7.74

- The mean CE₉₀ of IKONOS panchromatic Geo images was 9.1 m
 - 95% confidence interval from 2.8 m to 15.4 m
- The 15 DEC 2004 image, with a CE₉₀ of 16.7 m, was about 10% above the self-stated GeoEye specification of 15 m



Questions?

Further Information



South Dakota State
Analyses

QuickBird

OrbView-3

Extended Summary

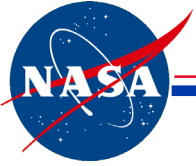


SSC
Analyses

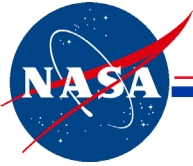
IKONOS

QuickBird

OrbView-3



Additional Information

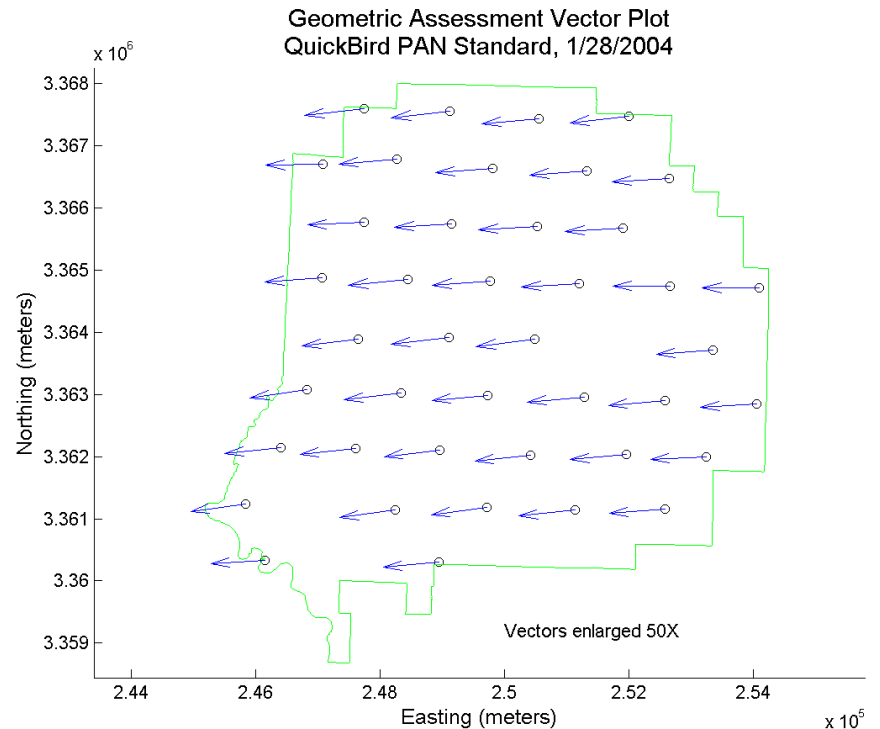
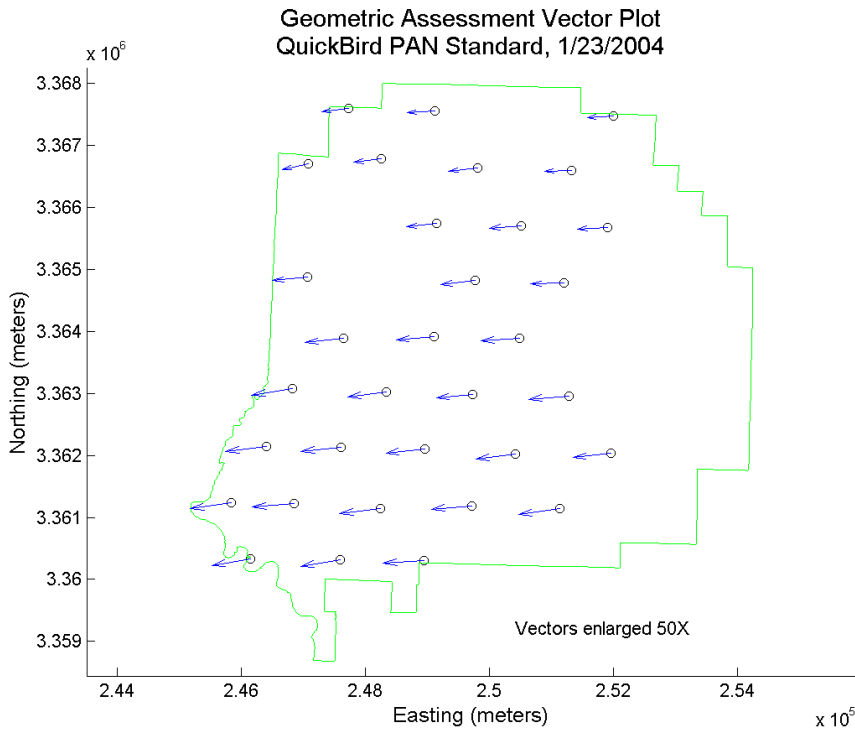


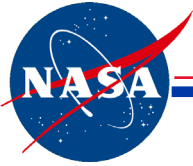
SSC – QuickBird PAN Standard

Stennis Space Center

23 JAN 2004
CE₉₀: 13.36 m
CE₉₅: 13.49 m
Circular Standard Error: 1.11 m

28 JAN 2004
CE₉₀: 18.98 m
CE₉₅: 19.21 m
Circular Standard Error: 0.53 m



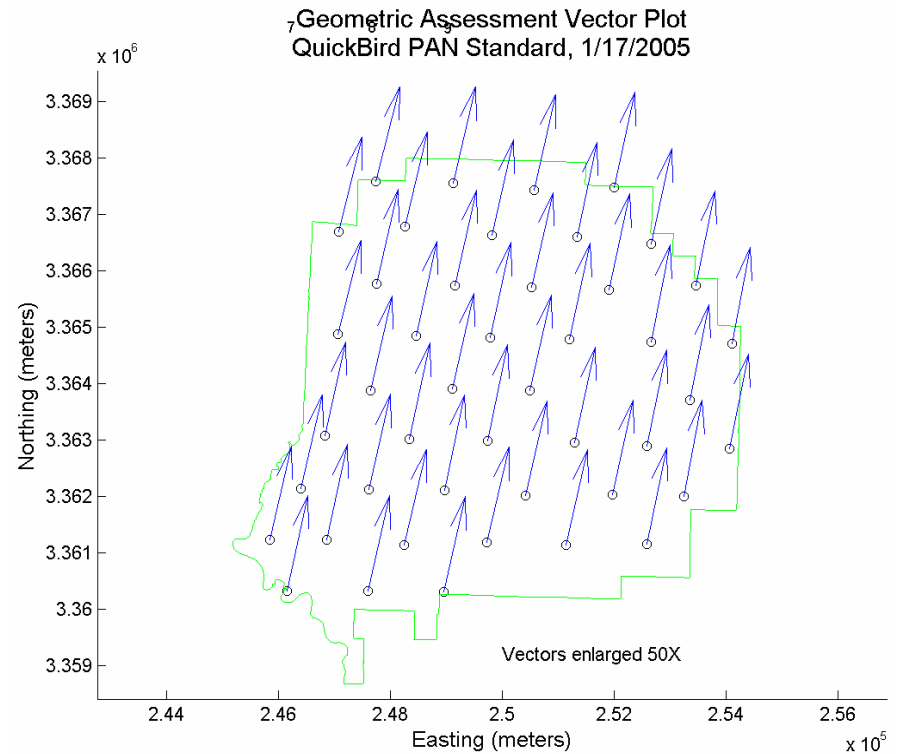
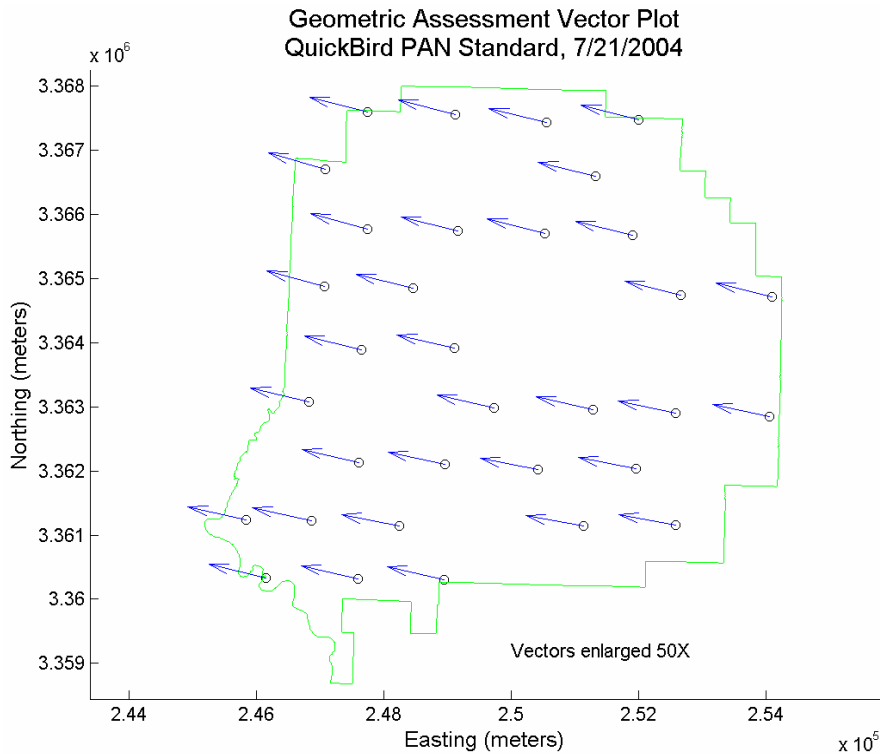


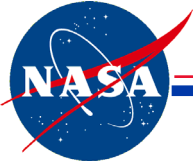
SSC – QuickBird PAN Standard

Stennis Space Center

21 JUL 2004
CE₉₀: 18.75 m
CE₉₅: 18.84 m
Circular Standard Error: 0.31 m

17 JAN 2005
CE₉₀: 34.87 m
CE₉₅: 34.95 m
Circular Standard Error: 0.36 m



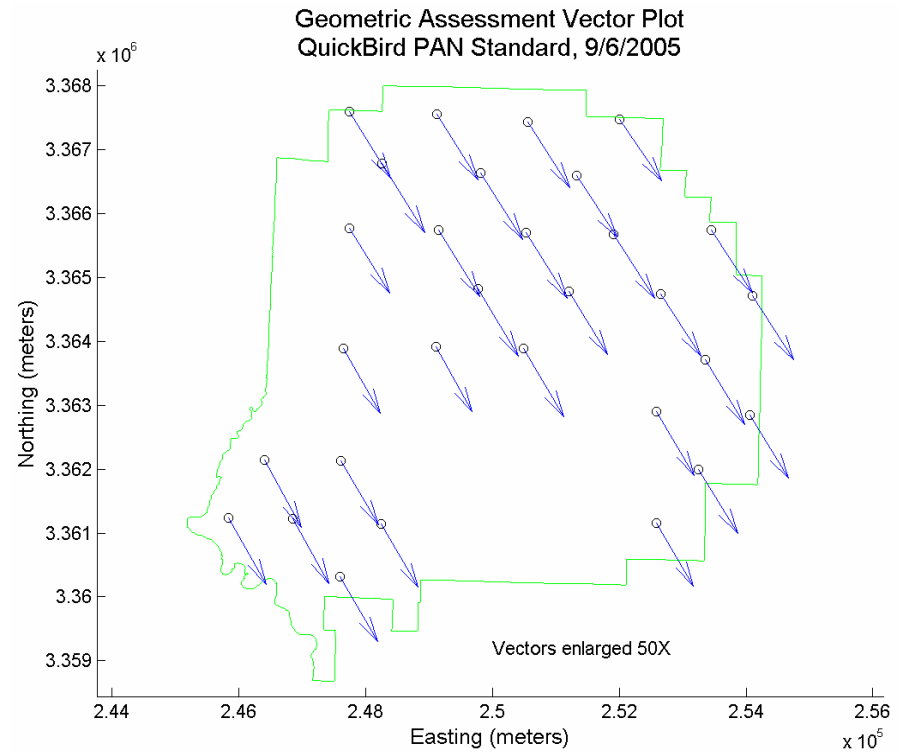
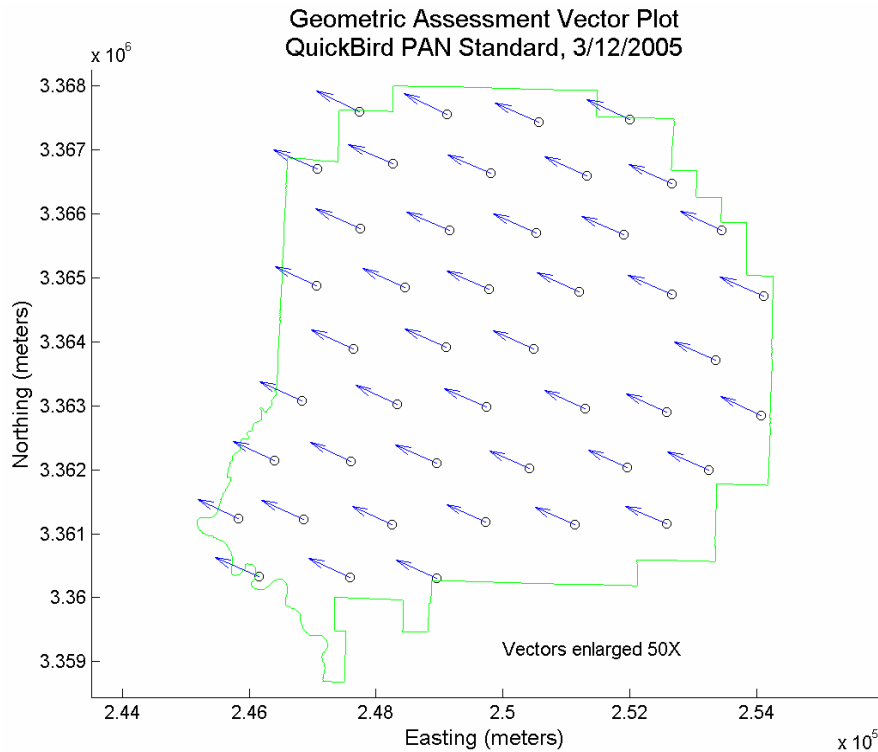


SSC – QuickBird PAN Standard

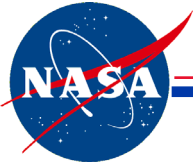
Stennis Space Center

12 MAR 2004
CE₉₀: 14.99 m
CE₉₅: 15.16 m
Circular Standard Error: 0.34 m

6 SEP 2005*
CE₉₀: 24.73 m
CE₉₅: 24.85 m
Circular Standard Error: 0.61 m



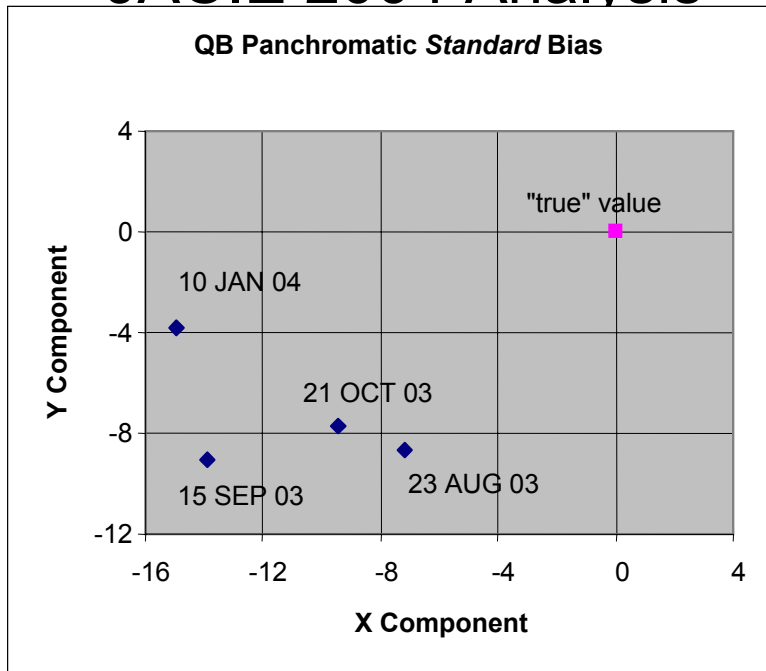
***Satellite viewing angle of 48.6°**



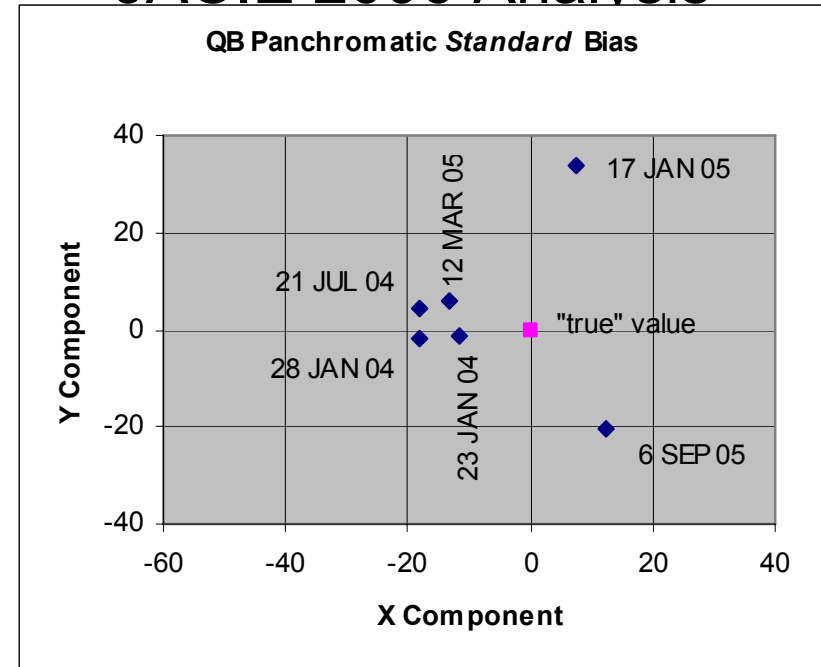
QuickBird Bias Trend

Stennis Space Center

JACIE 2004 Analysis



JACIE 2006 Analysis

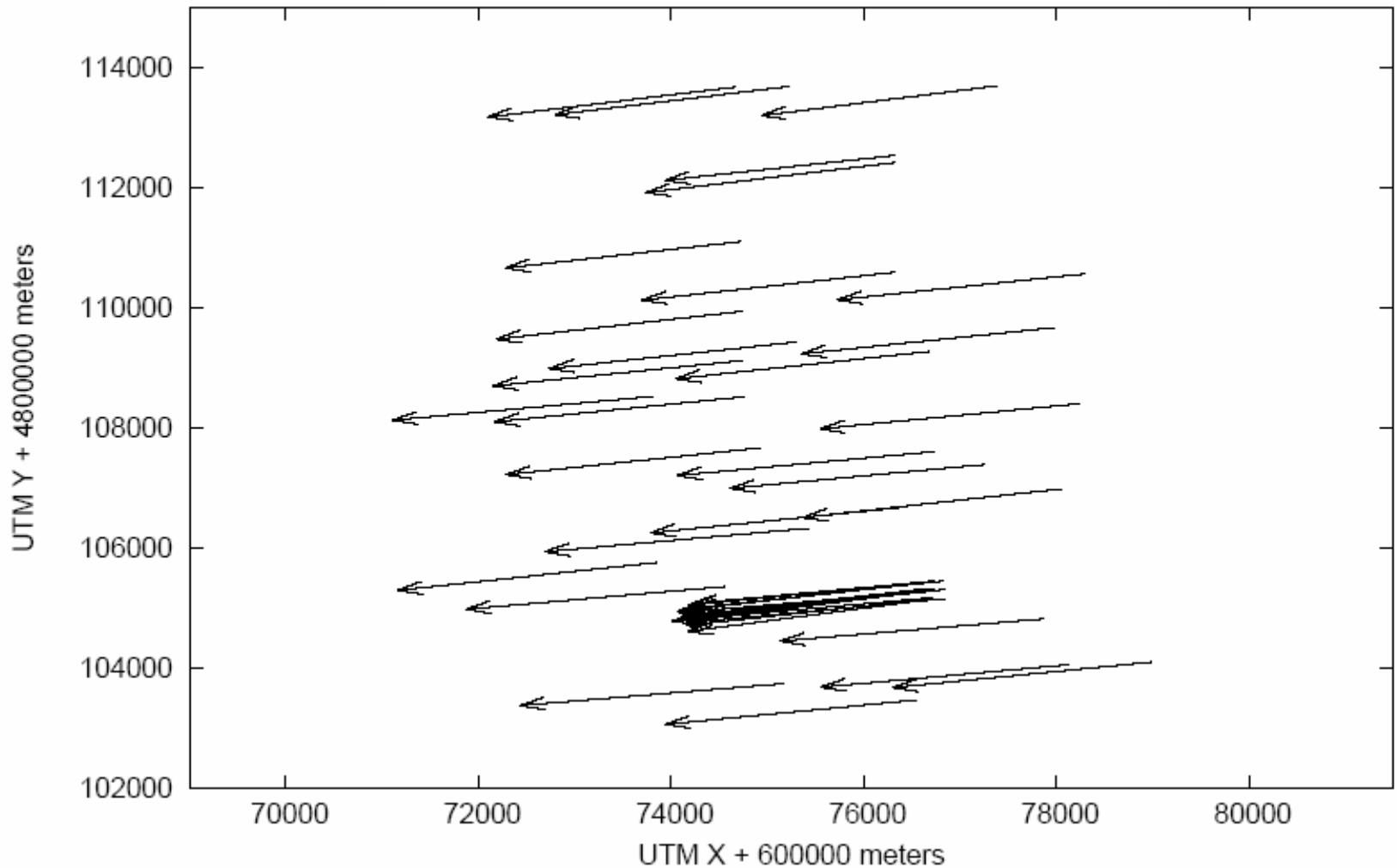


For *Standard* images characterized, the bias generally continued to trend toward the west. However, the two acquisitions with the largest error ran against this trend.

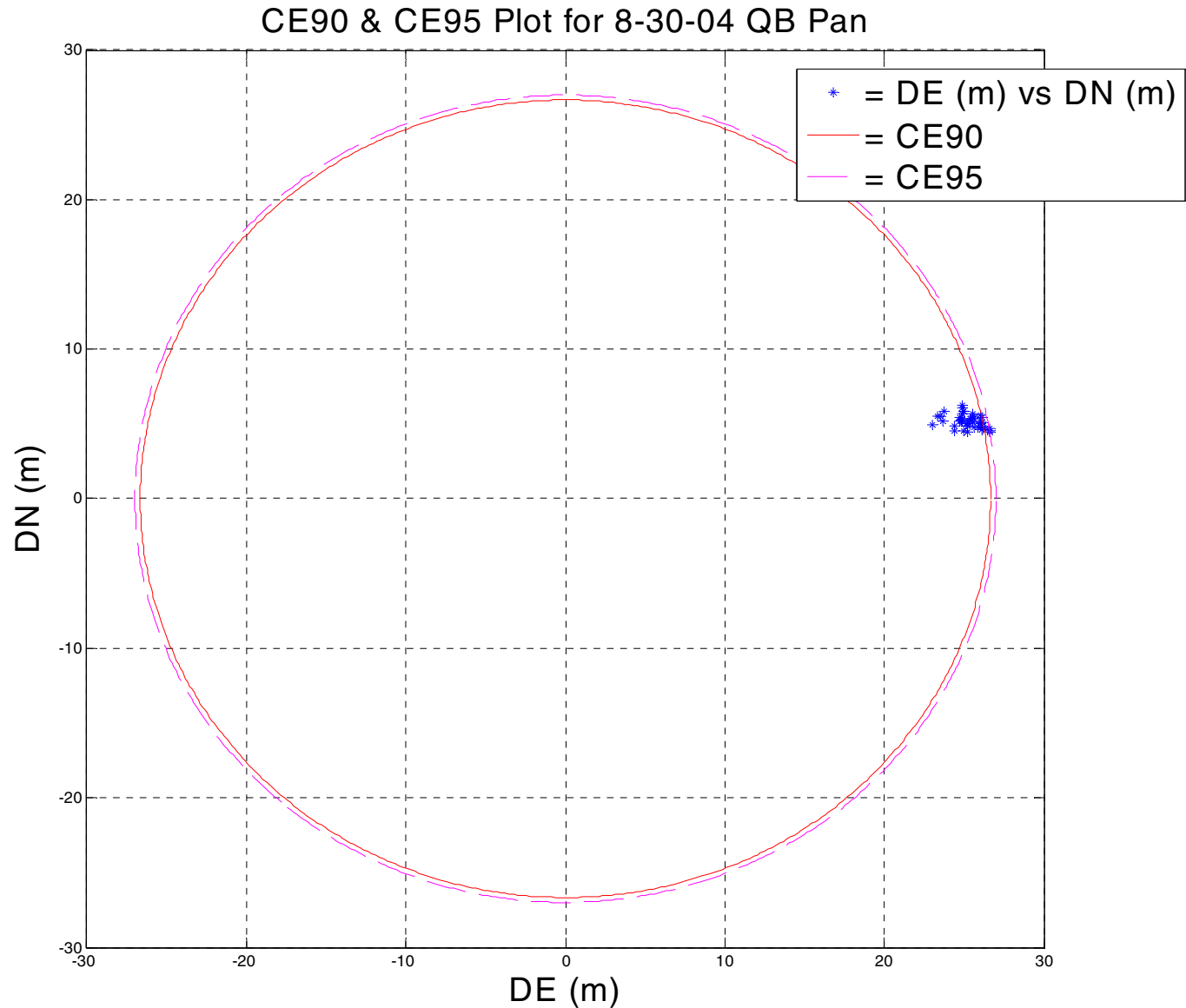
QuickBird 8-30-2004 Panchromatic Band



QuickBird Geolocation Errors for Brookings, SD, 08-30-2004
Errors Scaled 100x



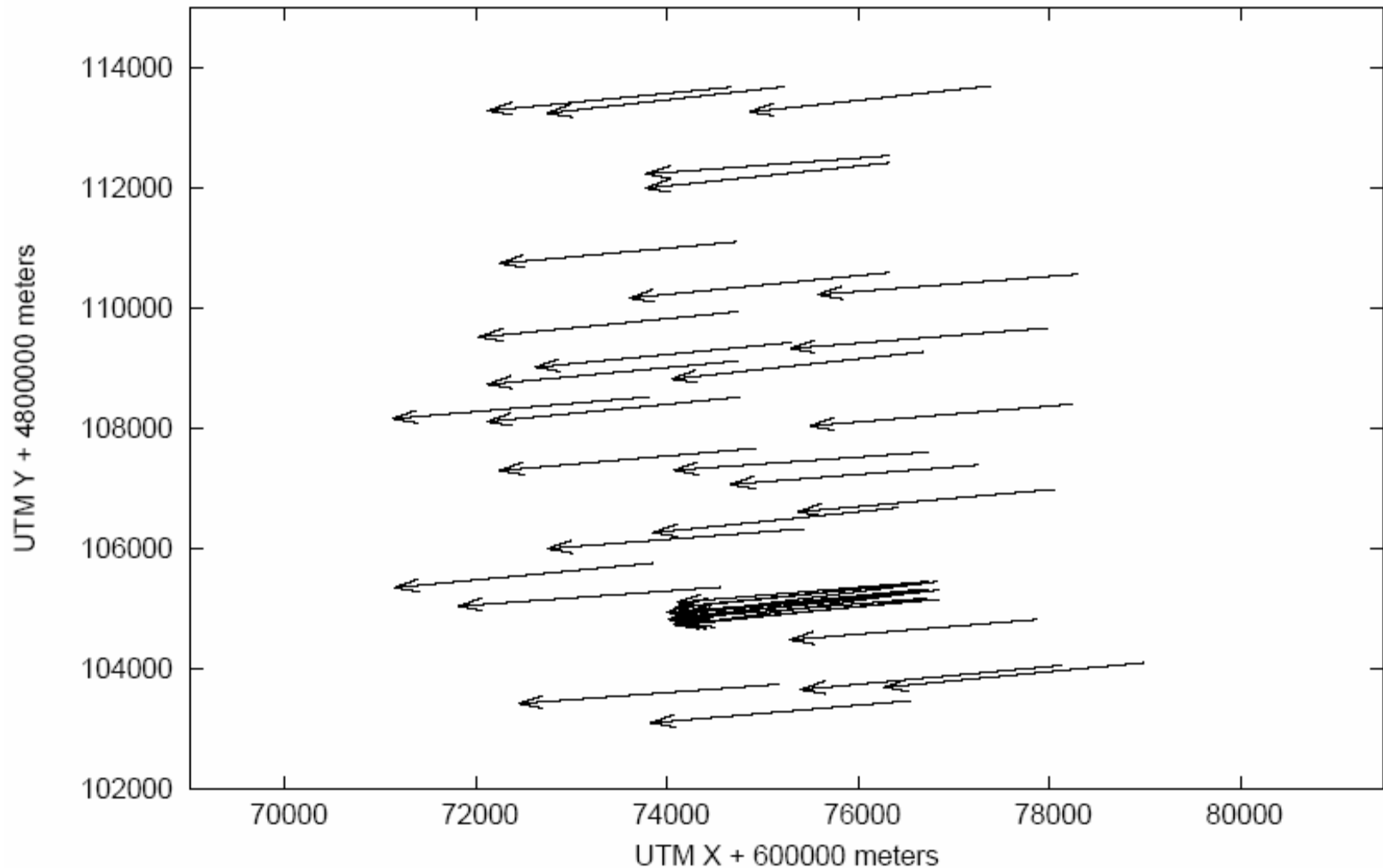
QuickBird 8-30-2004 Panchromatic Band (CE90 = 26.6623 m & CE95 = 26.9906 m)



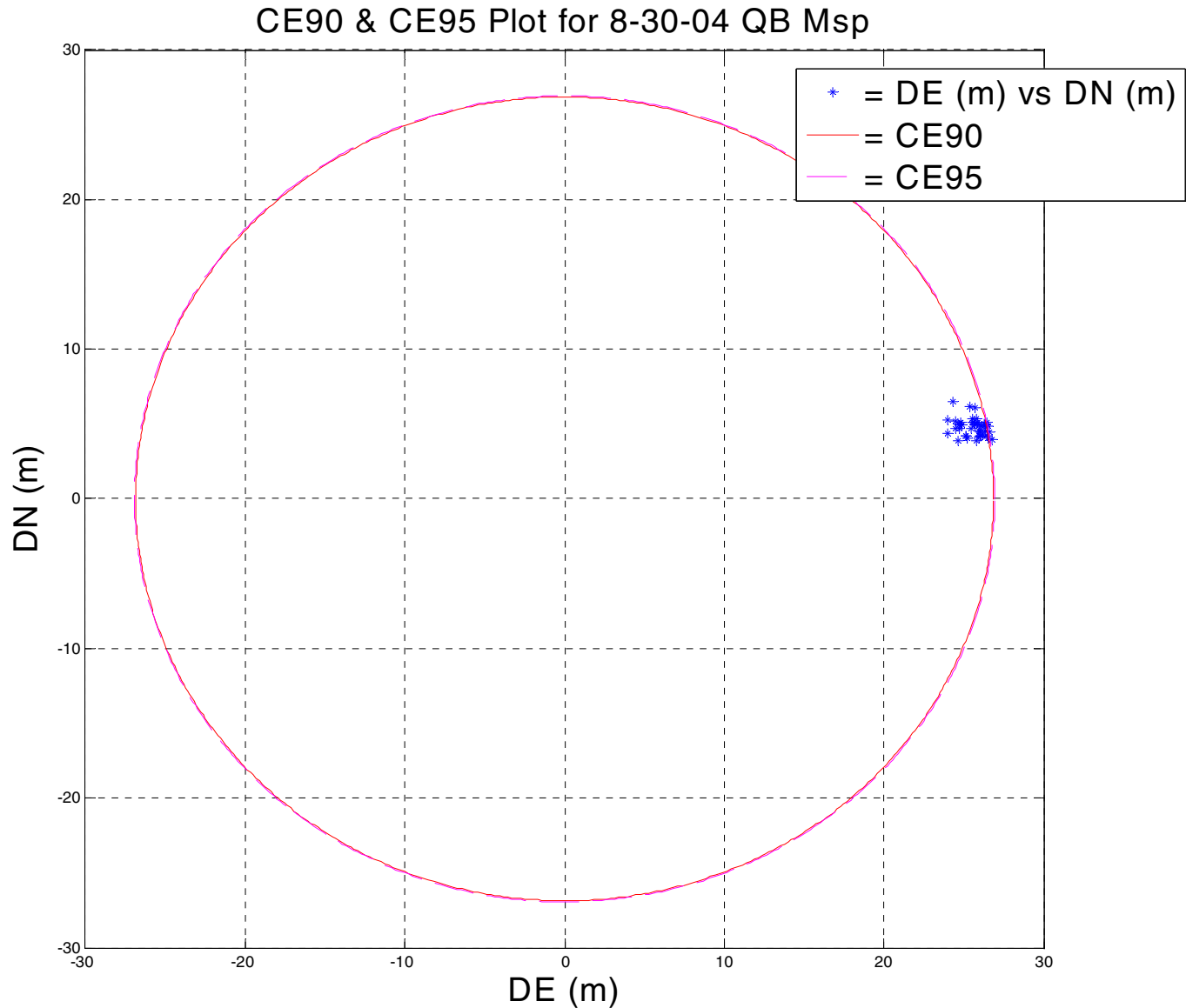
QuickBird 8-30-2004 Multispectral Band



QuickBird Geolocation Errors for Brookings, SD, 08-30-2004
Errors Scaled 100x



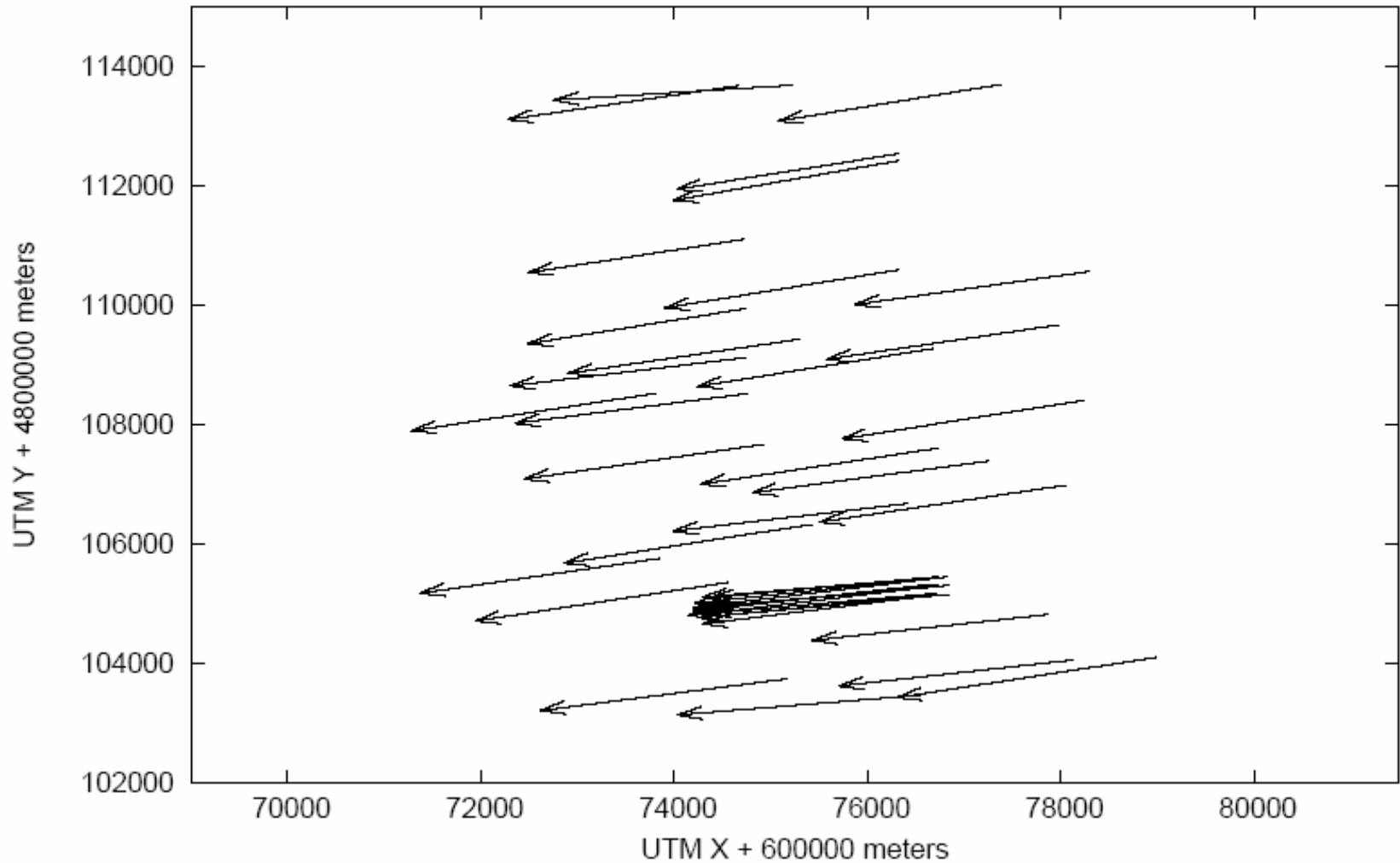
QuickBird 8-30-2004 Multispectral Band (CE90 = 26.8610 m & CE95 = 26.9368 m)



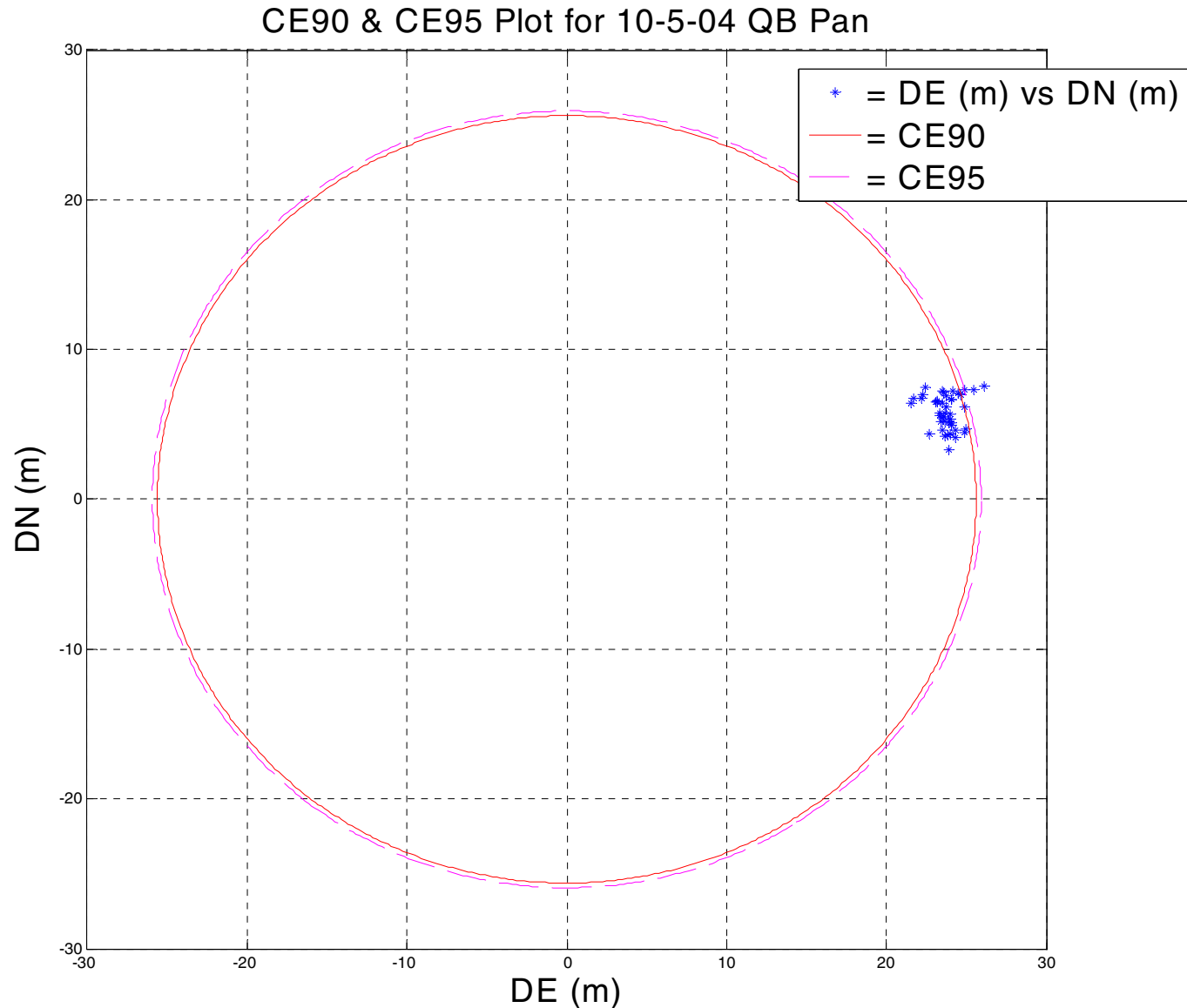
QuickBird 10-5-2004 Panchromatic Band



QuickBird Geolocation Errors for Brookings, SD, 10-05-2004
Errors Scaled 100x



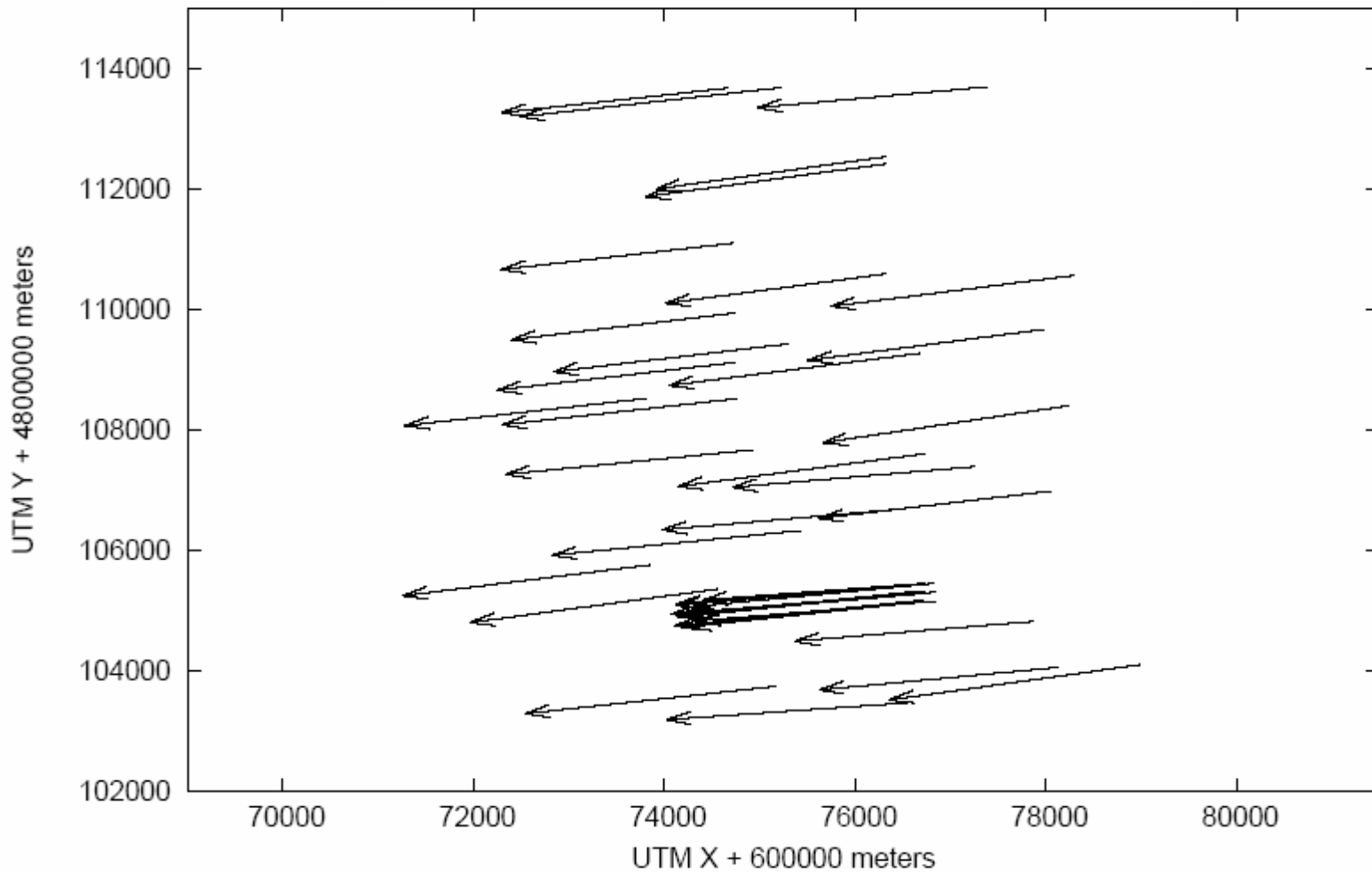
QuickBird 10-5-2004 Panchromatic Band (CE90 = 25.6153 m & CE95 = 25.9286 m)



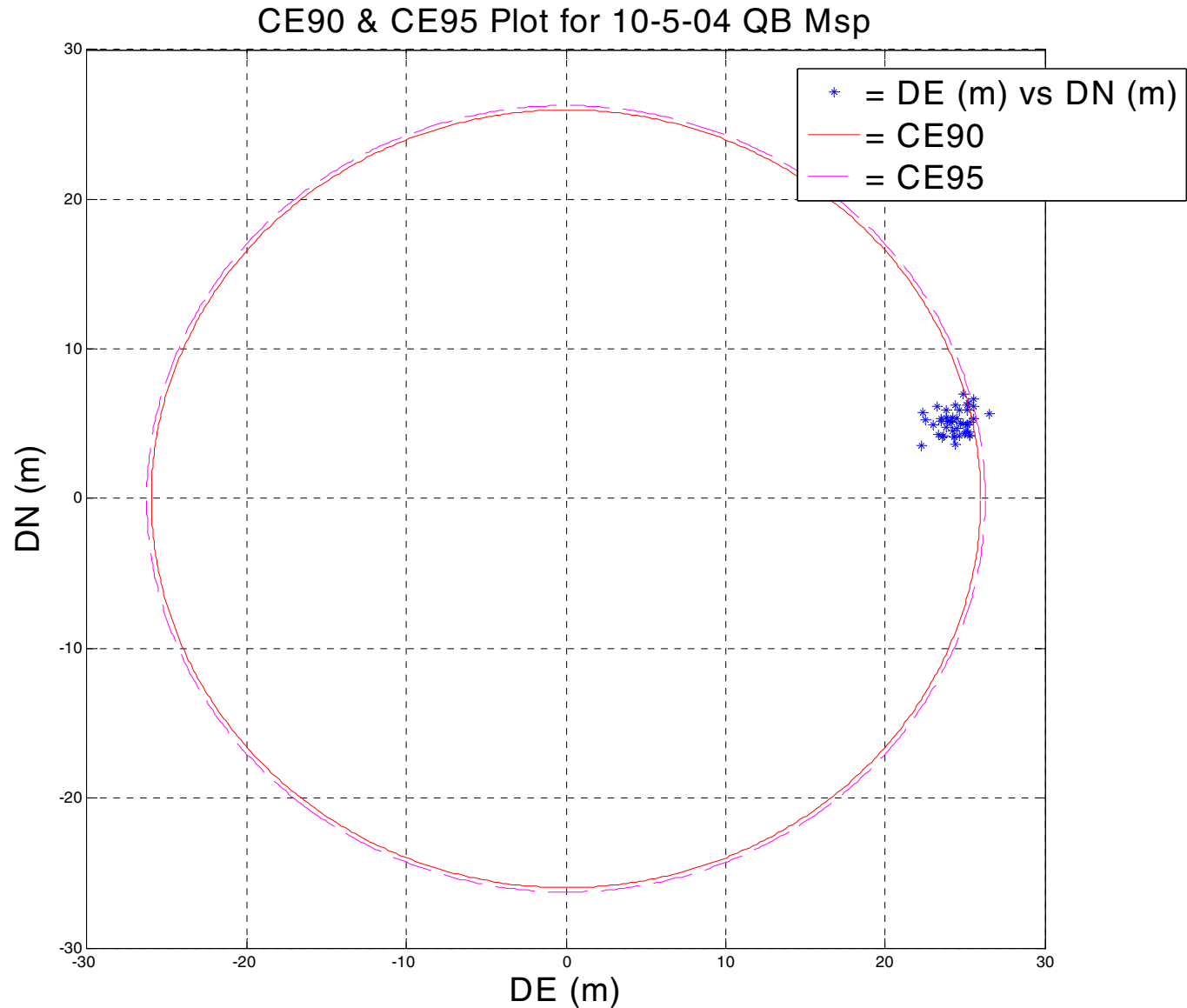
QuickBird 10-5-2004 Multispectral Band



QuickBird Geolocation Errors for Brookings, SD, 10-05-2004
Errors Scaled 100x



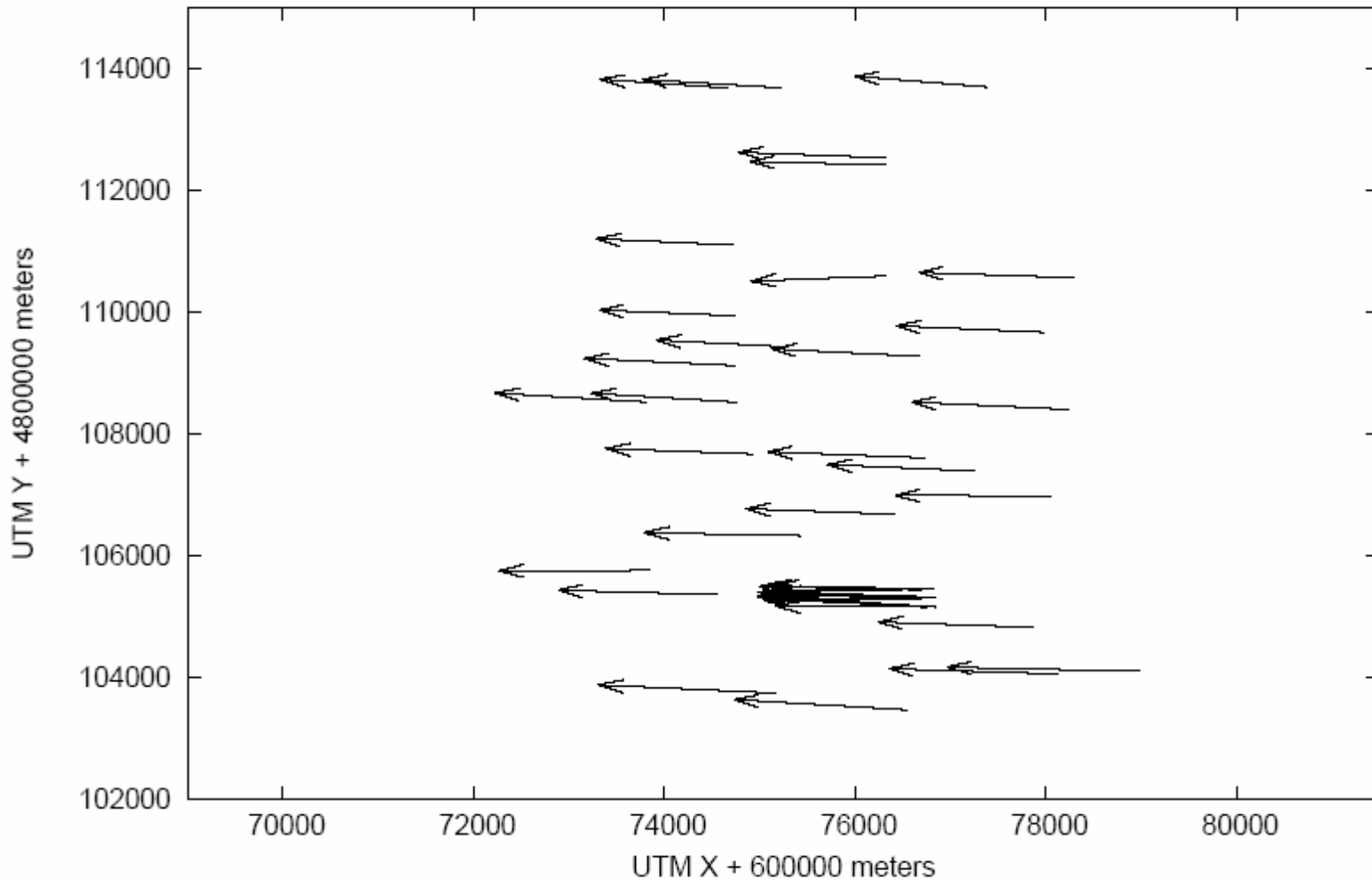
QuickBird 10-5-2004 Multispectral Band (CE90 = 25.9796 m & CE95 = 26.2656 m)



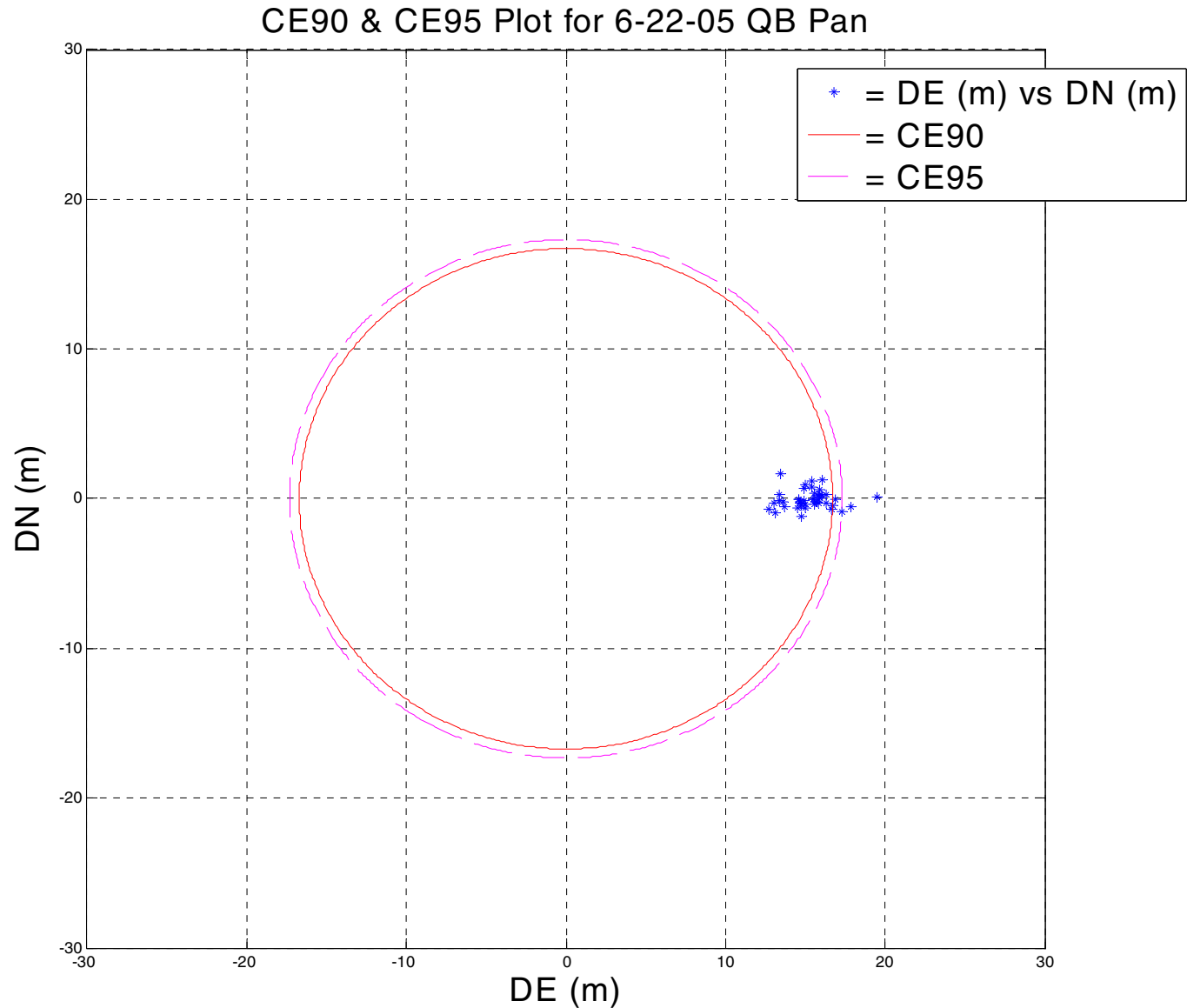
QuickBird 6-22-2005 Panchromatic Band



QuickBird Geolocation Errors for Brookings, SD, 06-22-2005
Errors Scaled 100x



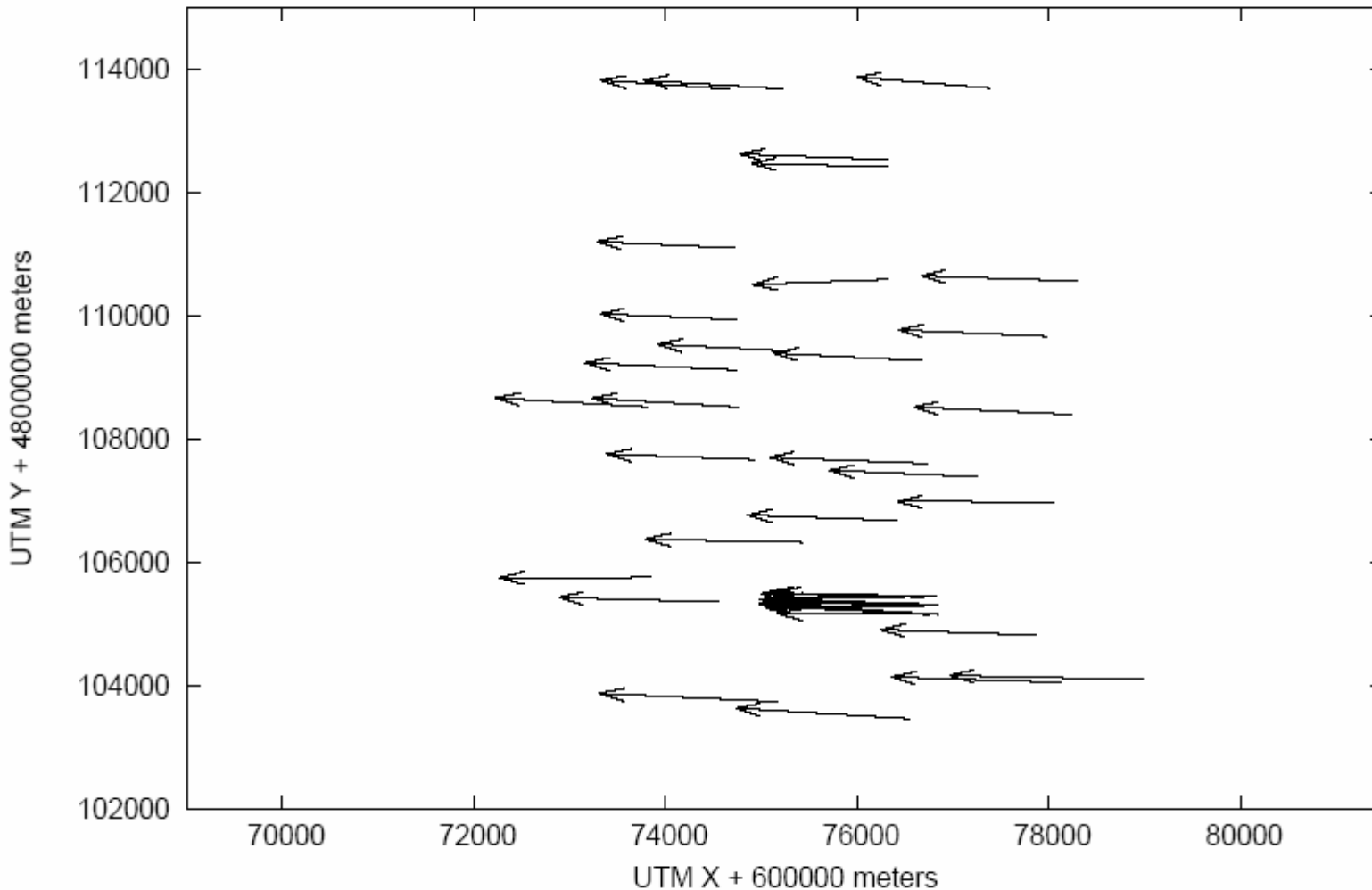
QuickBird 6-22-2005 Panchromatic Band (CE90 = 16.7135 m & CE95 = 17.3145 m)



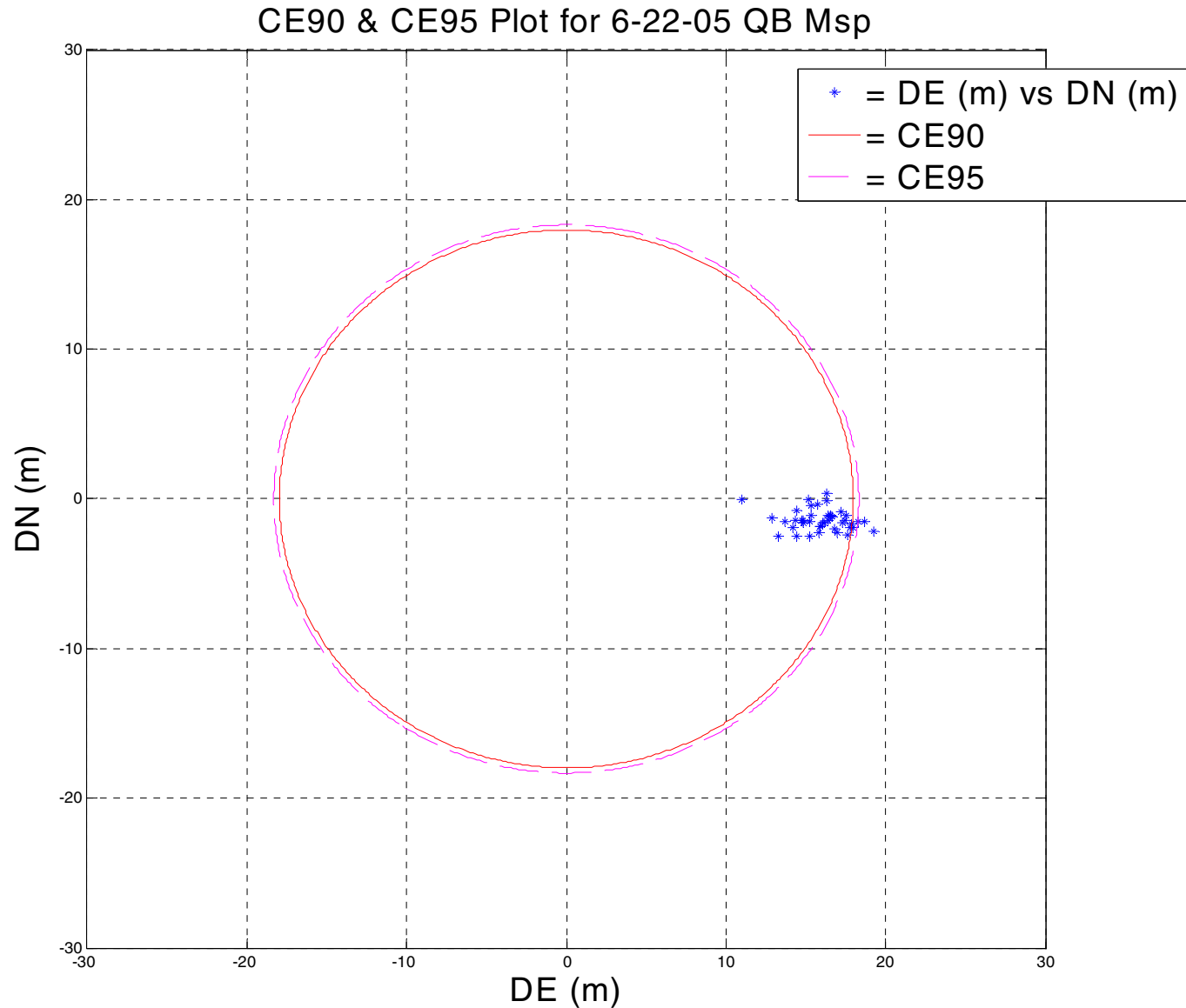
QuickBird 6-22-2005 Multispectral Band



QuickBird Geolocation Errors for Brookings, SD, 06-22-2005
Errors Scaled 100x



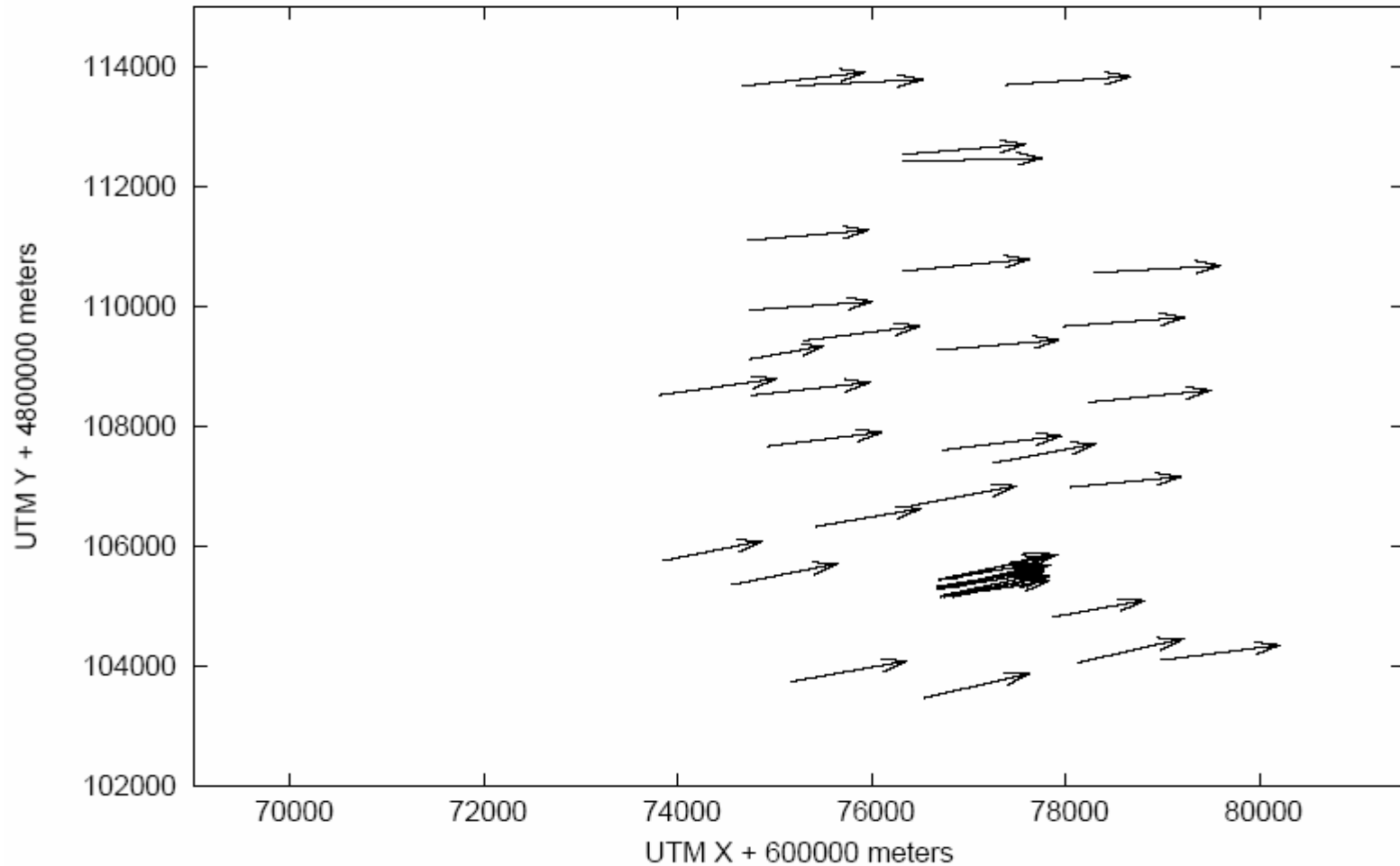
QuickBird 6-22-2005 Multispectral Band (CE90 = 17.9719 m & CE95 = 18.3163 m)



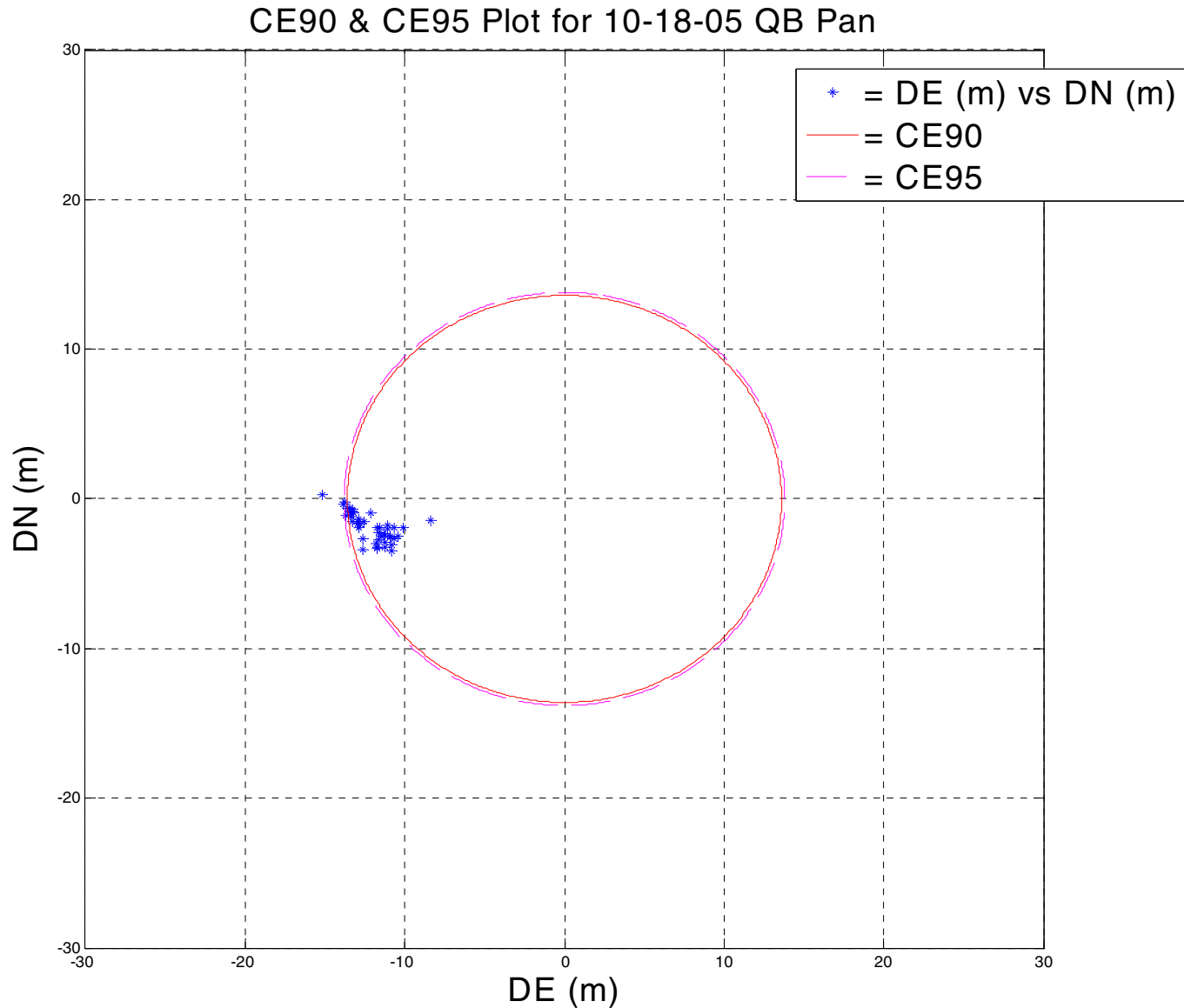
QuickBird 10-18-2005 Panchromatic Band



QuickBird Geolocation Errors for Brookings, SD, 10-18-2005
Errors Scaled 100x



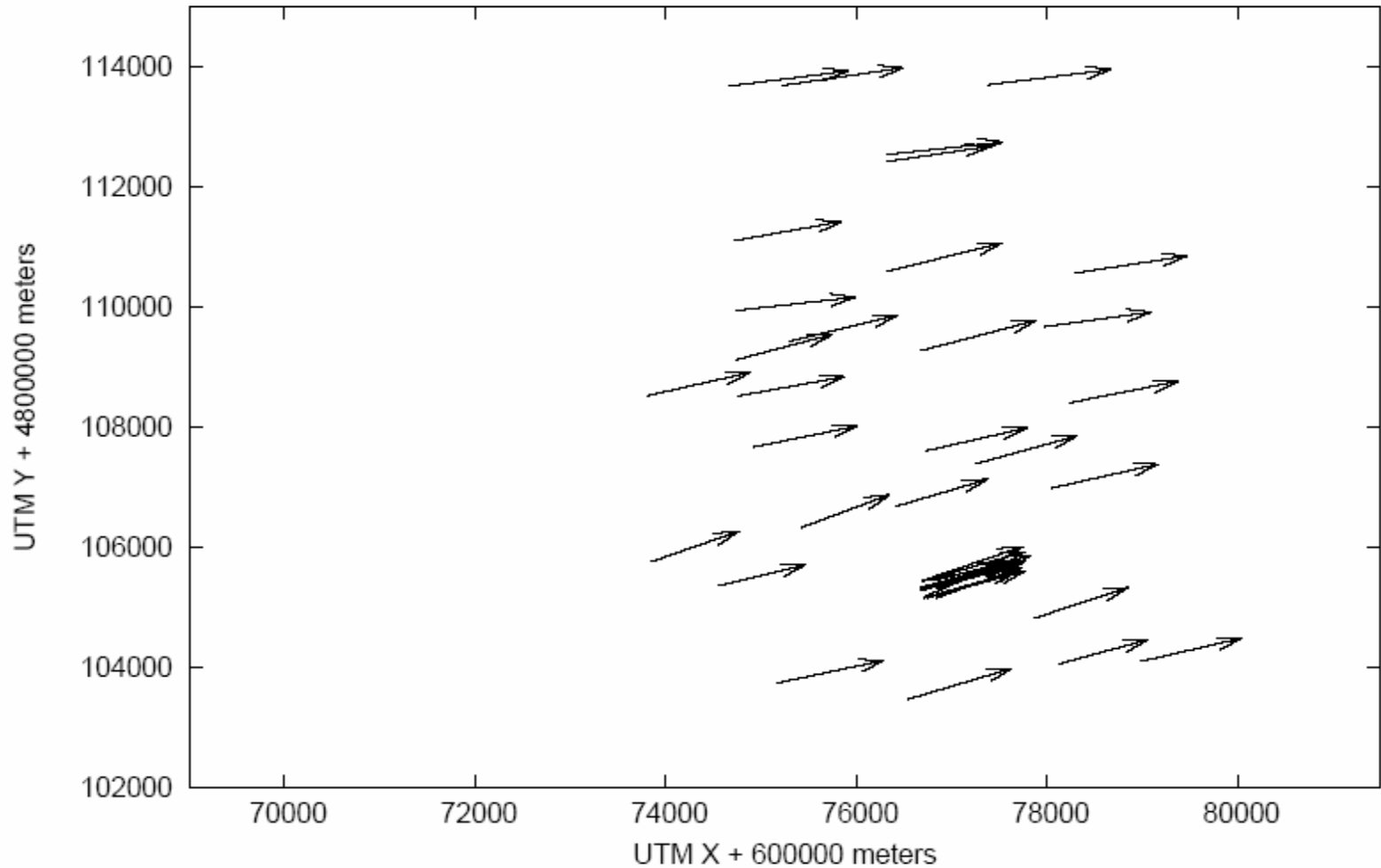
QuickBird 10-18-2005 Panchromatic Band (CE90 = 13.5985 m & CE95 = 13.8037 m)



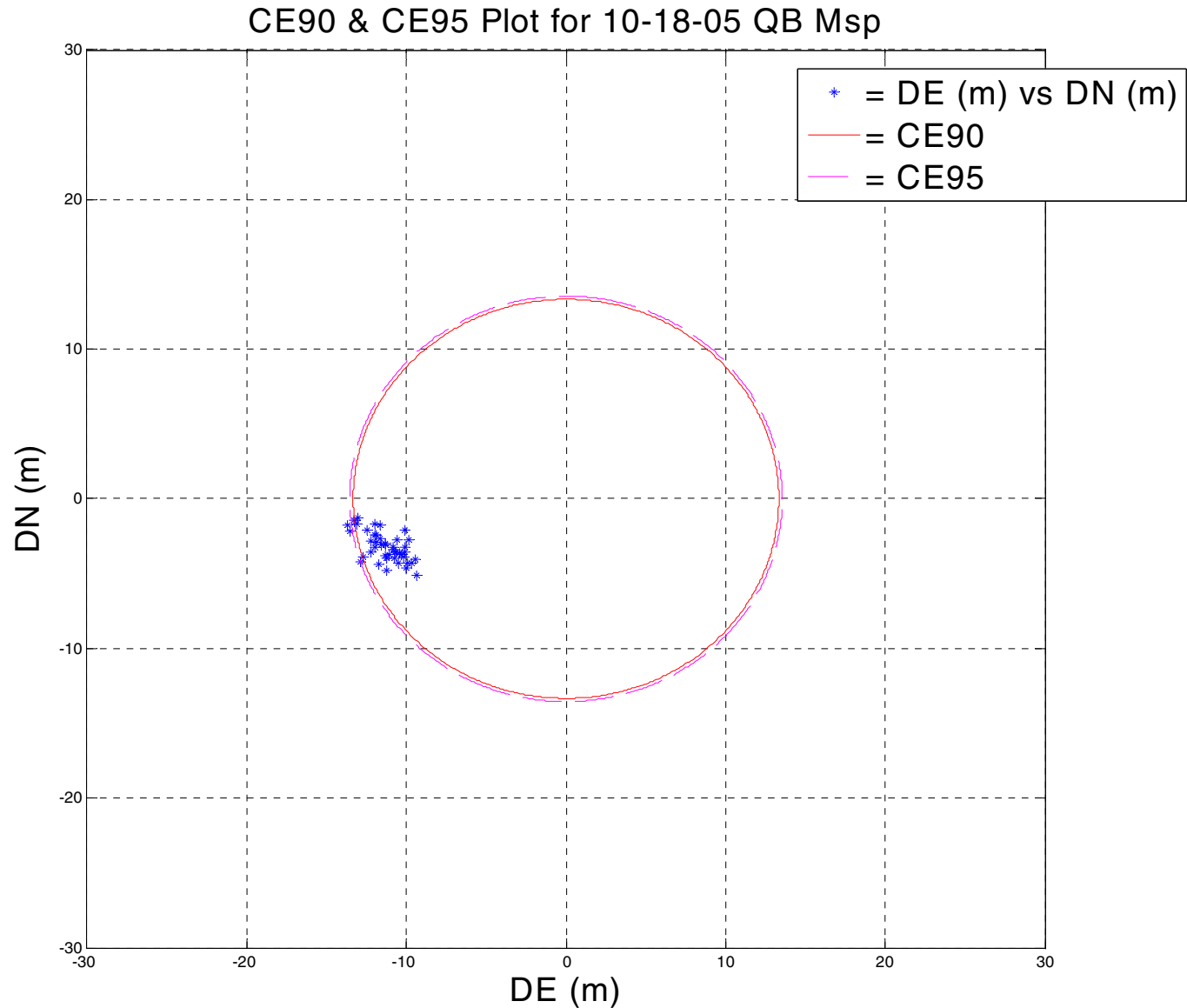
QuickBird 10-18-2005 Multispectral Band

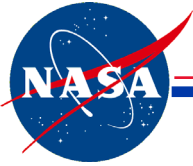


QuickBird Geolocation Errors for Brookings, SD, 10-18-2005
Errors Scaled 100x



QuickBird 10-18-2005 Multispectral Band (CE90 = 13.3361 m & CE95 = 13.5476 m)



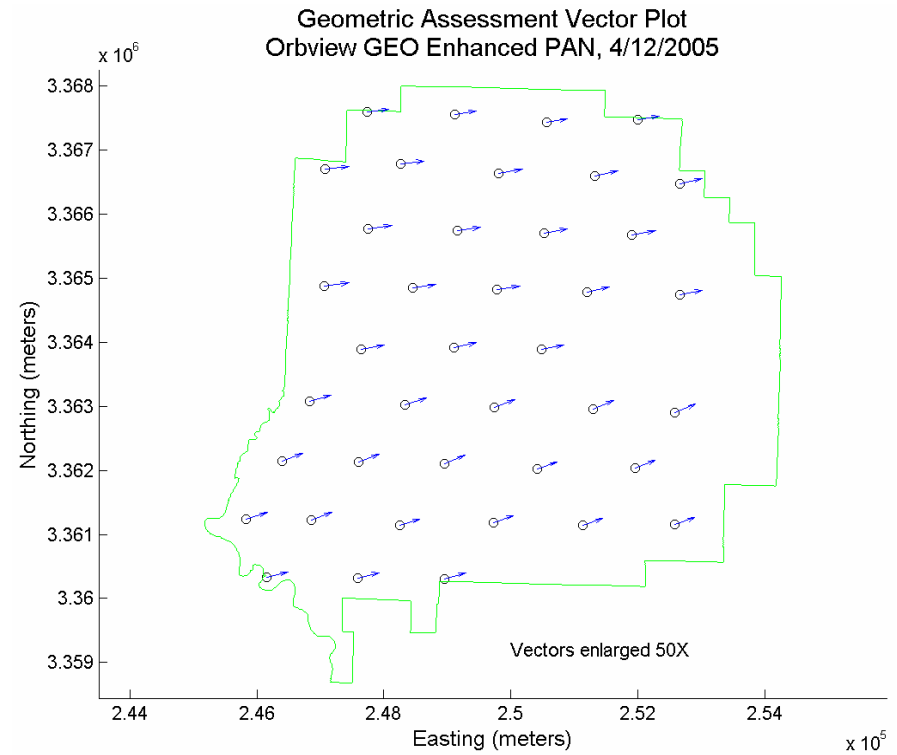
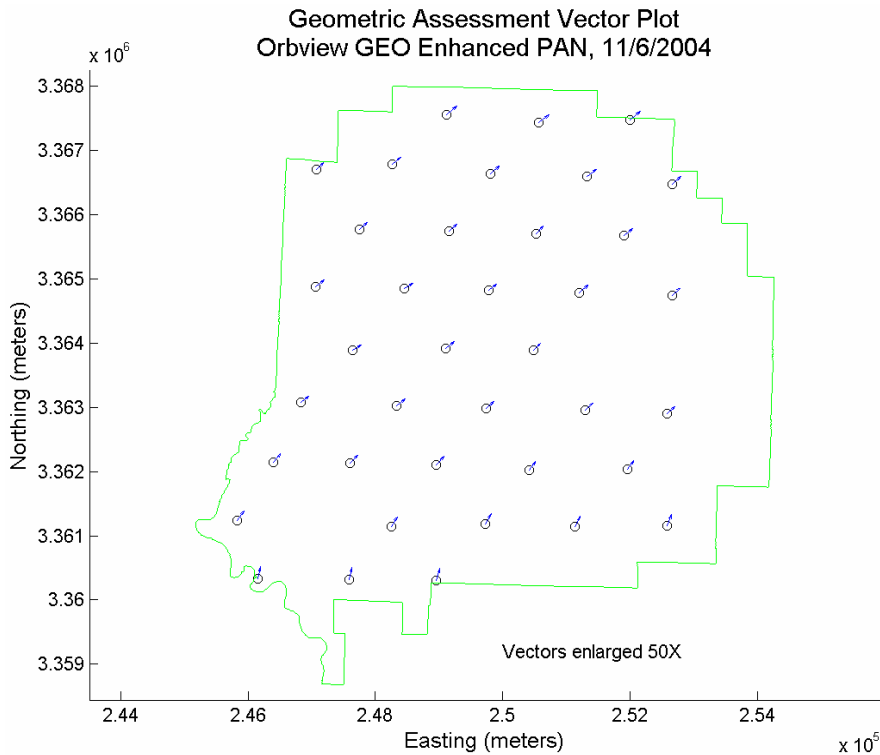


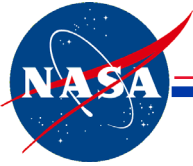
SSC – OrbView-3 *GEO Enhanced PAN*

Stennis Space Center

6 NOV 2004
CE₉₀: 3.88 m
CE₉₅: 4.05 m
Circular Standard Error: 0.55 m

12 APR 2005
CE₉₀: 7.52 m
CE₉₅: 7.65 m
Circular Standard Error: 0.50 m



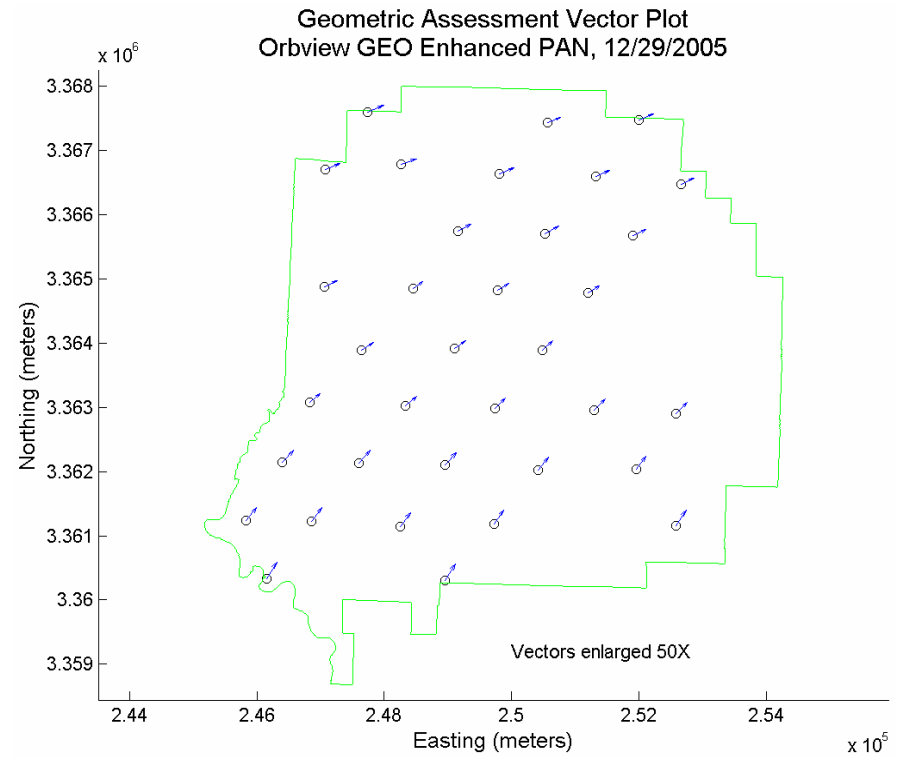
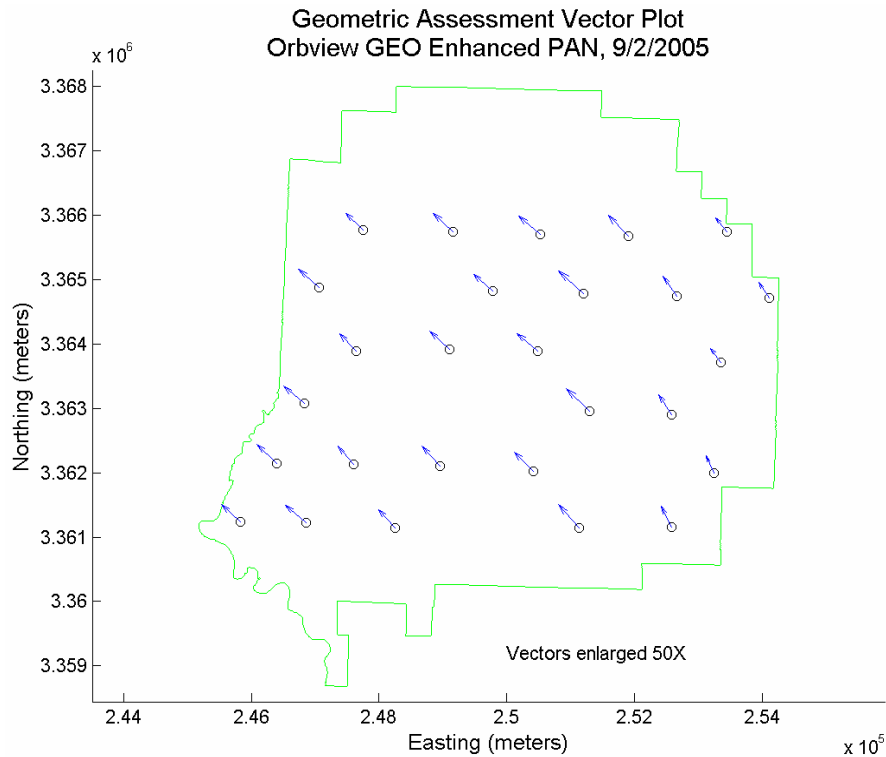


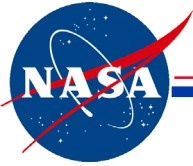
SSC – OrbView-3 *GEO Enhanced PAN*

Stennis Space Center

2 SEP 2005
CE₉₀: 9.79 m
CE₉₅: 10.11 m
Circular Standard Error: 1.04 m

29 DEC 2005
CE₉₀: 5.53 m
CE₉₅: 5.98 m
Circular Standard Error: 0.82 m





SSC – OrbView-3 GEO Express PAN

Stennis Space Center

2 SEP 2005 (GEO Enhanced)

CE₉₀: 9.79 m

CE₉₅: 10.11 m

Circular Standard Error: 1.04 m

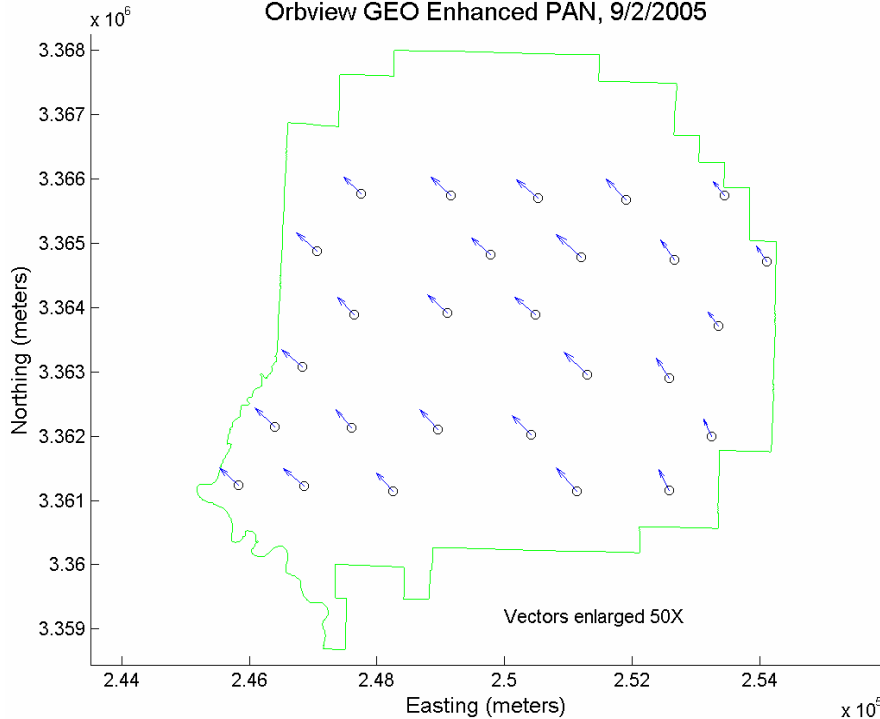
2 SEP 2005 (GEO Express)

CE₉₀: 7.65 m

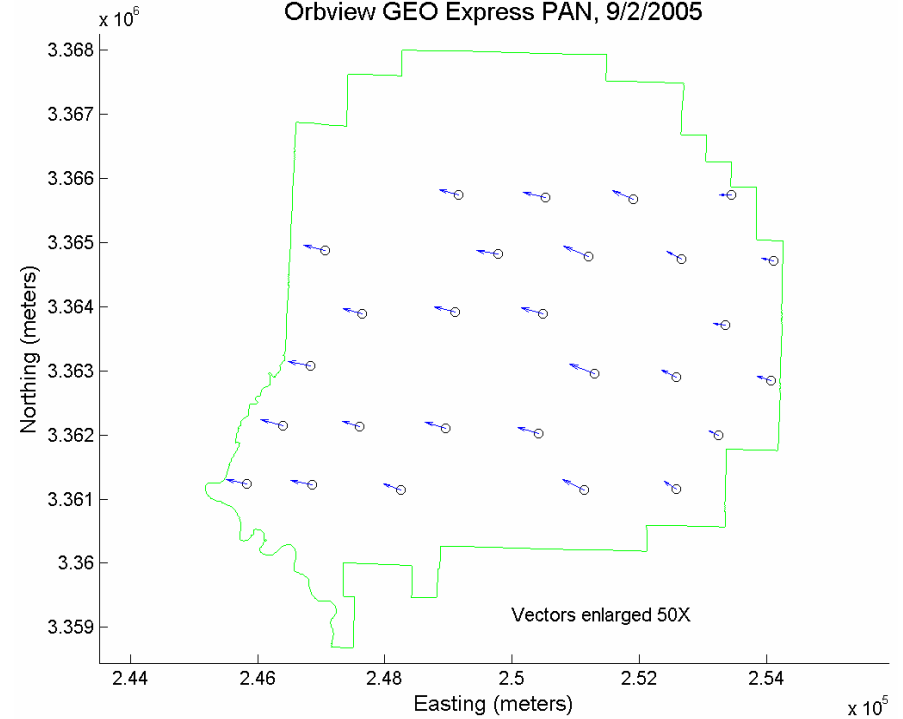
CE₉₅: 8.35 m

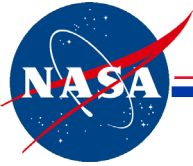
Circular Standard Error: 1.09 m

Geometric Assessment Vector Plot
Orbview GEO Enhanced PAN, 9/2/2005



Geometric Assessment Vector Plot
Orbview GEO Express PAN, 9/2/2005

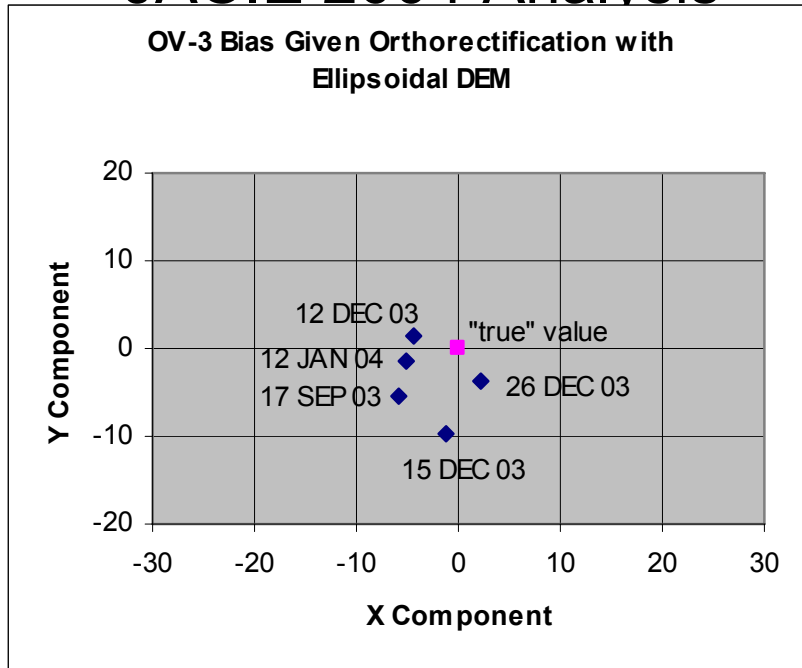




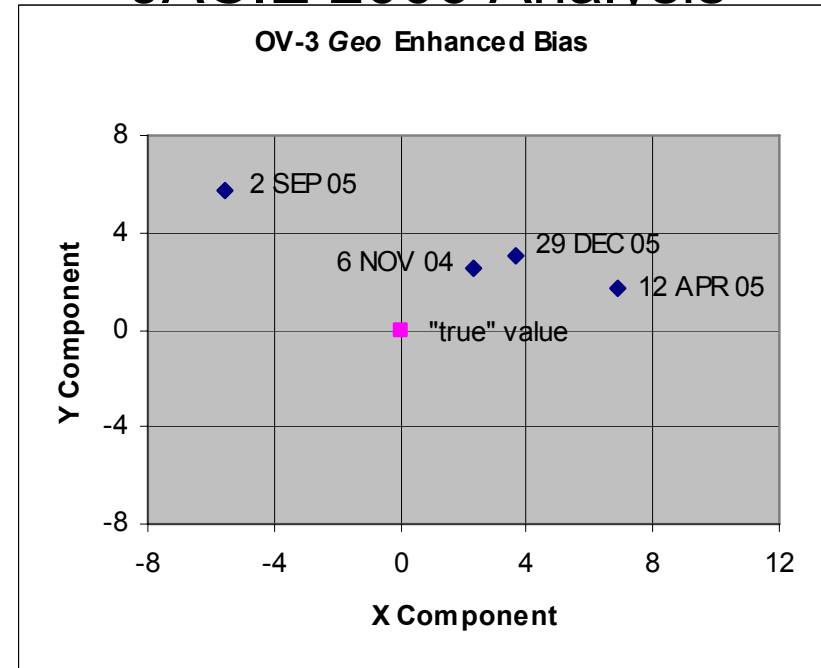
OrbView-3 – No Clear Bias Trend

Stennis Space Center

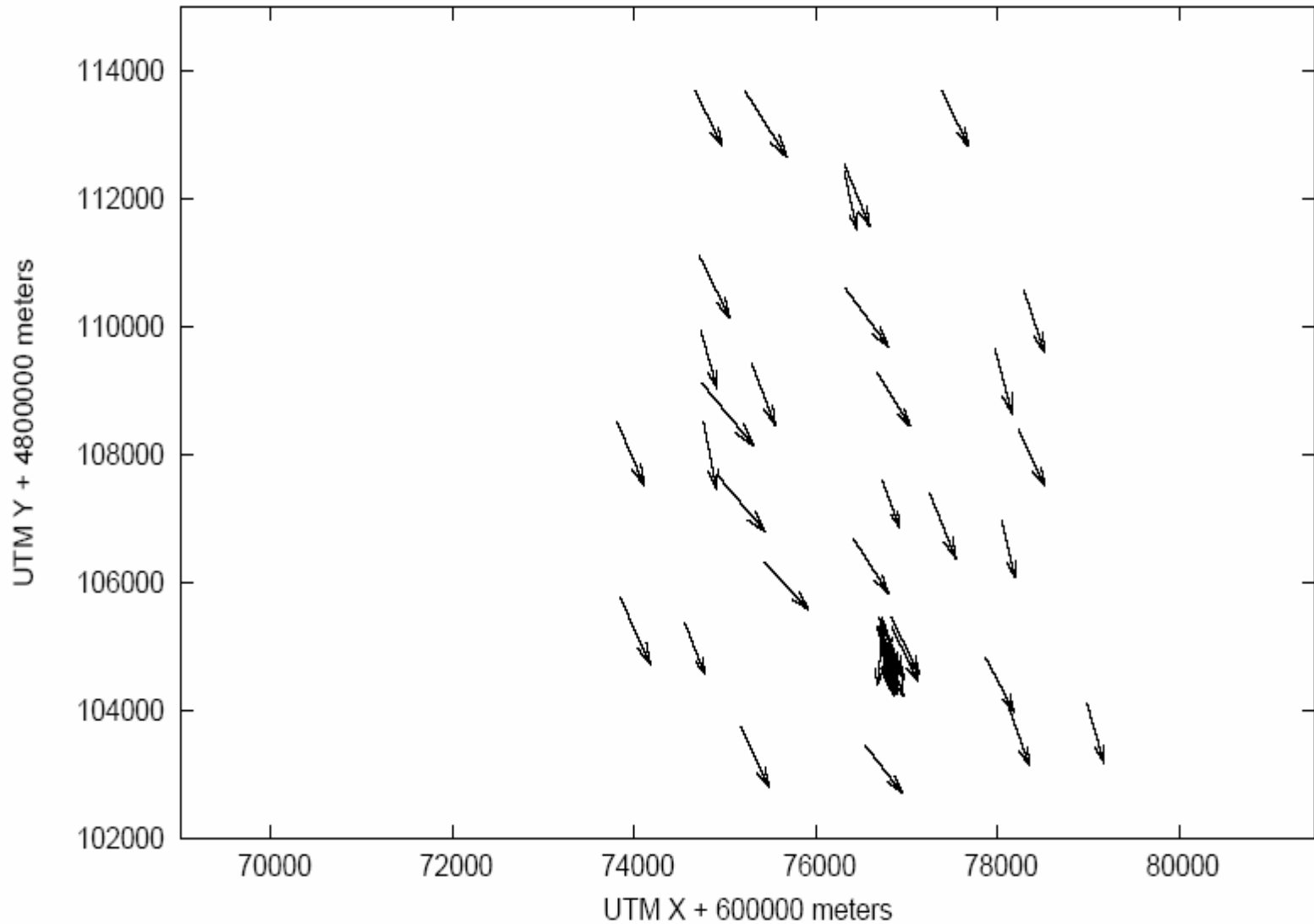
JACIE 2004 Analysis



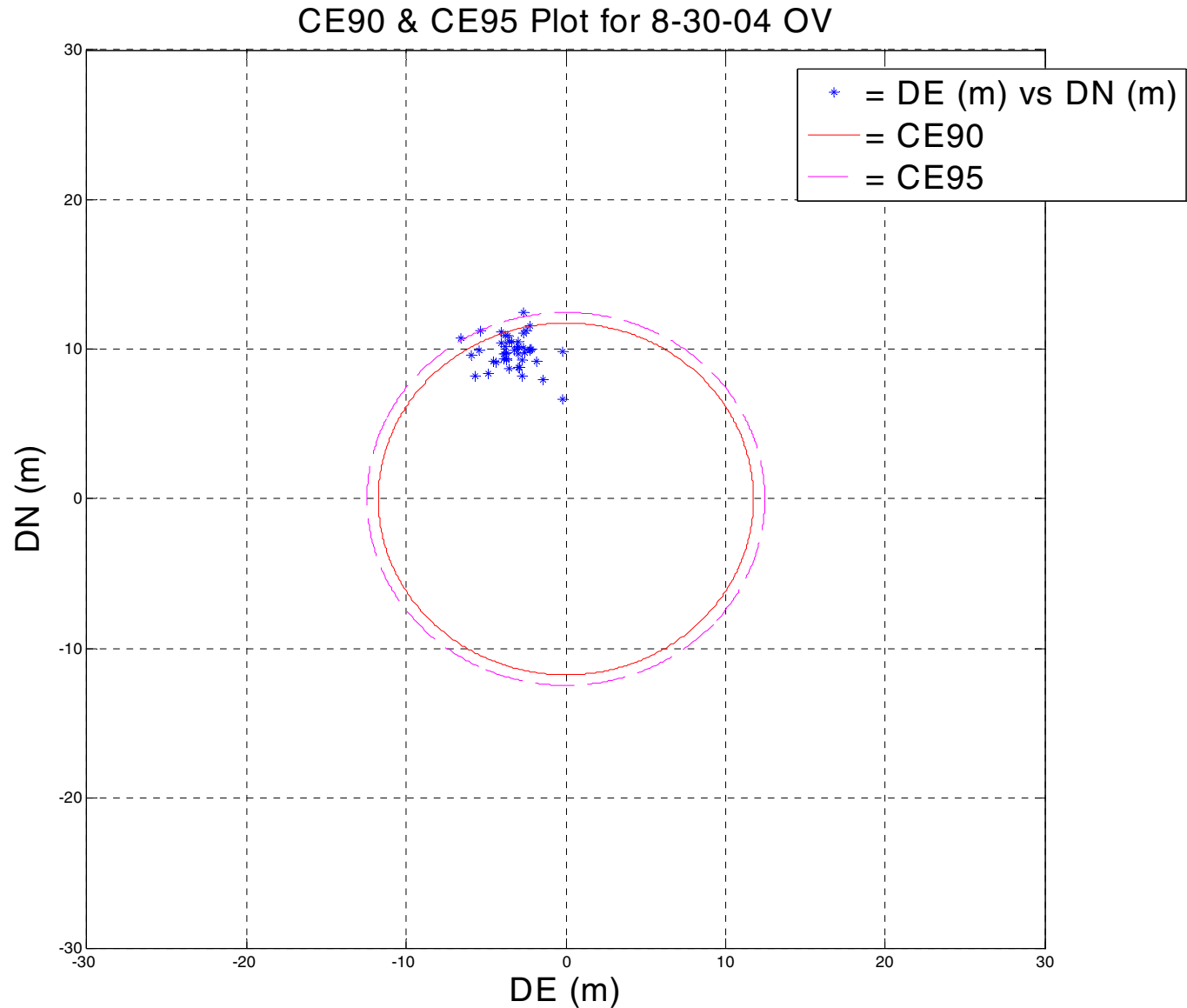
JACIE 2006 Analysis



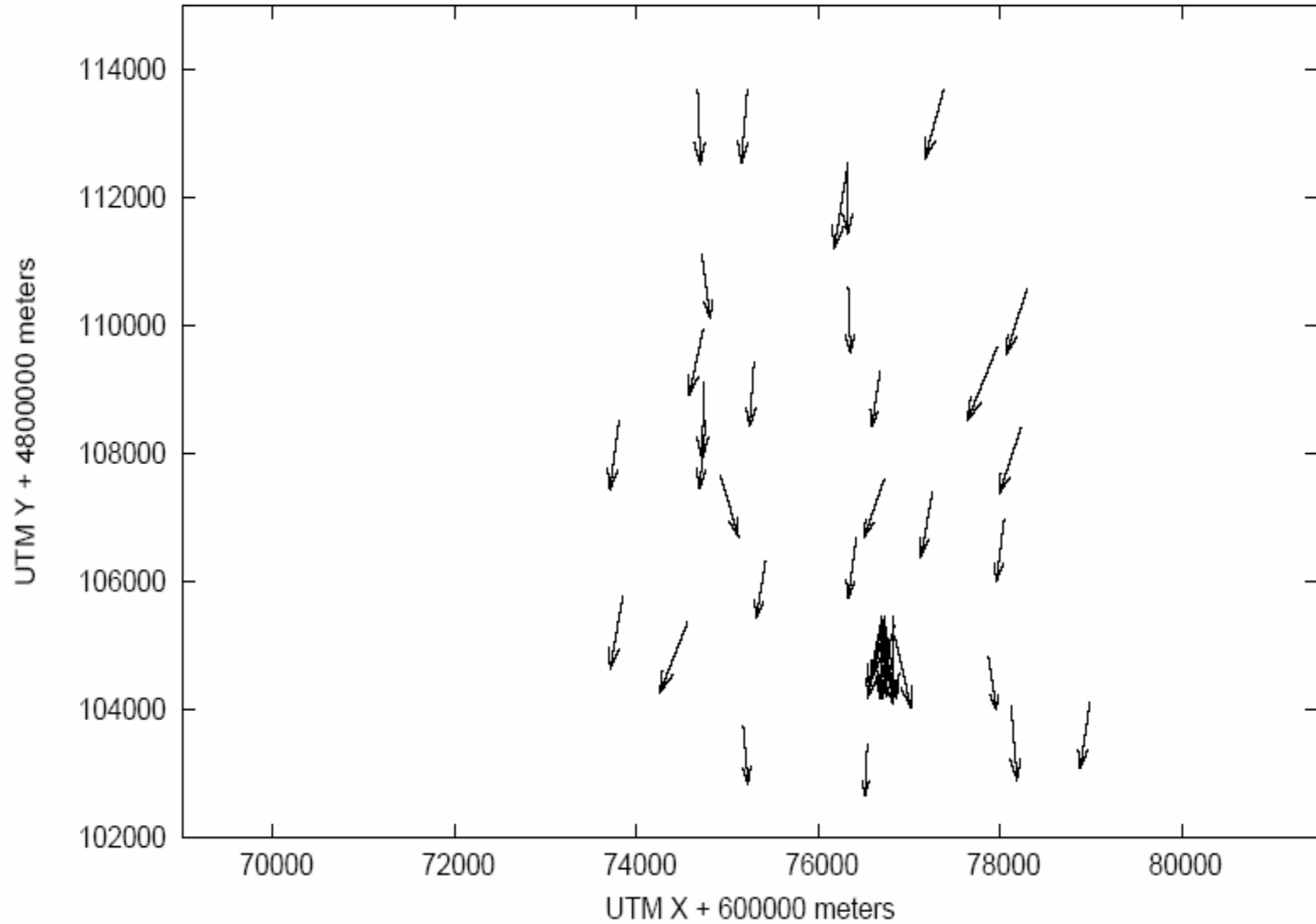
OrbView-3 8-30-2004 Orthorectified



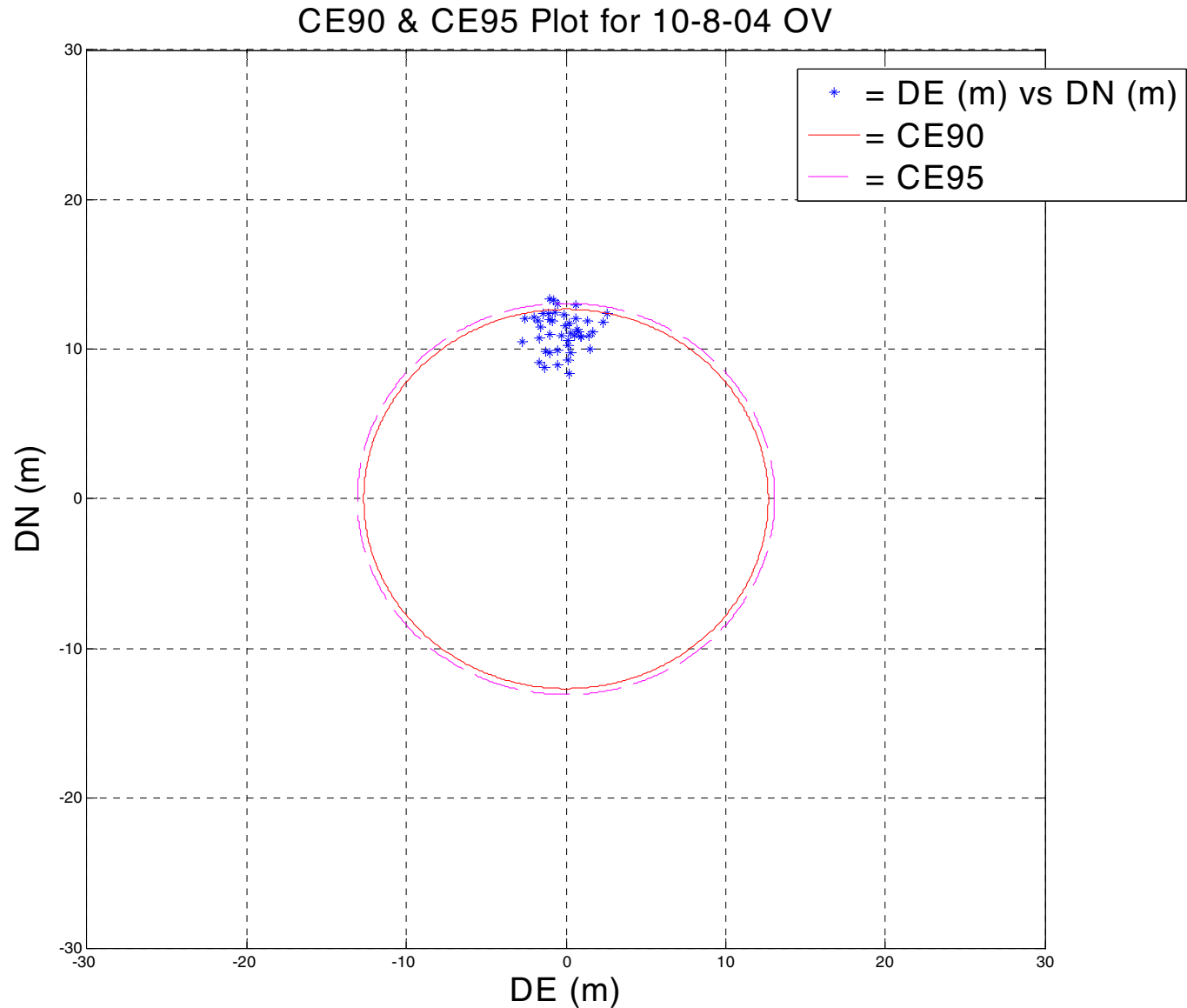
OrbView-3 8-30-2004 Orthorectified (CE90 = 11.7554 m & CE95 = 12.4592 m)



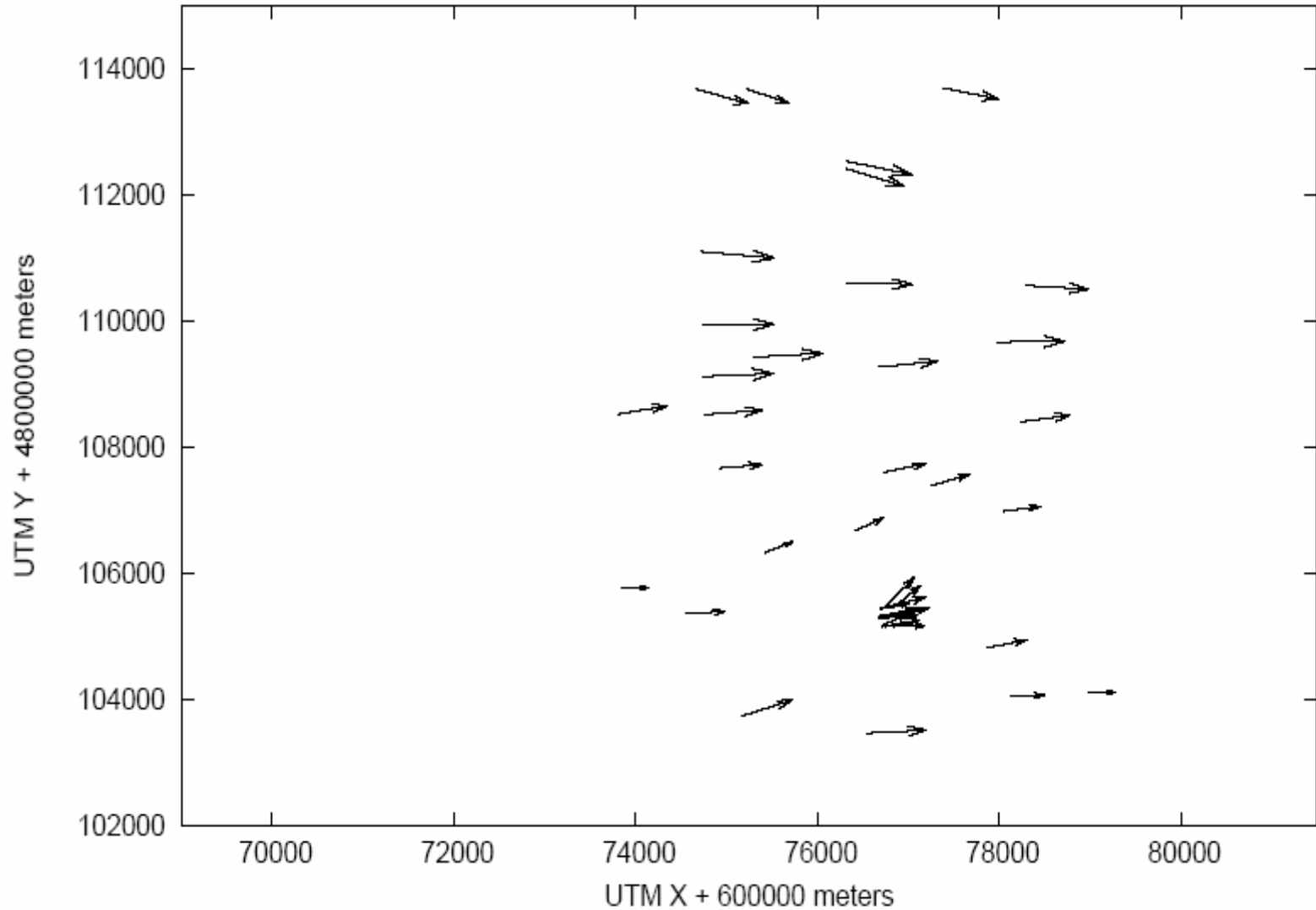
OrbView-3 10-8-2004 Orthorectified



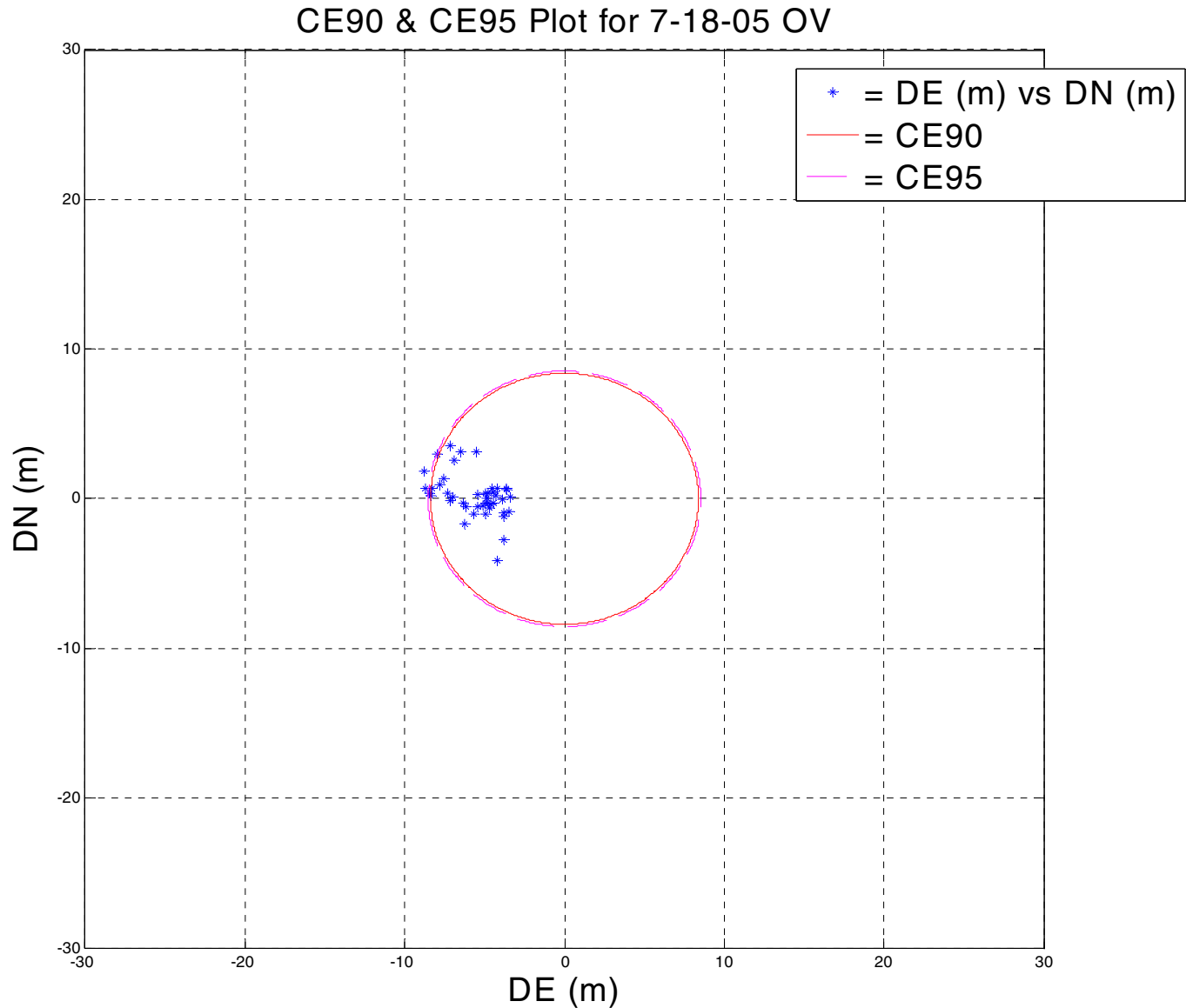
OrbView-3 10-8-2004 Orthorectified (CE90 = 12.6743 m & CE95 = 13.0767 m)



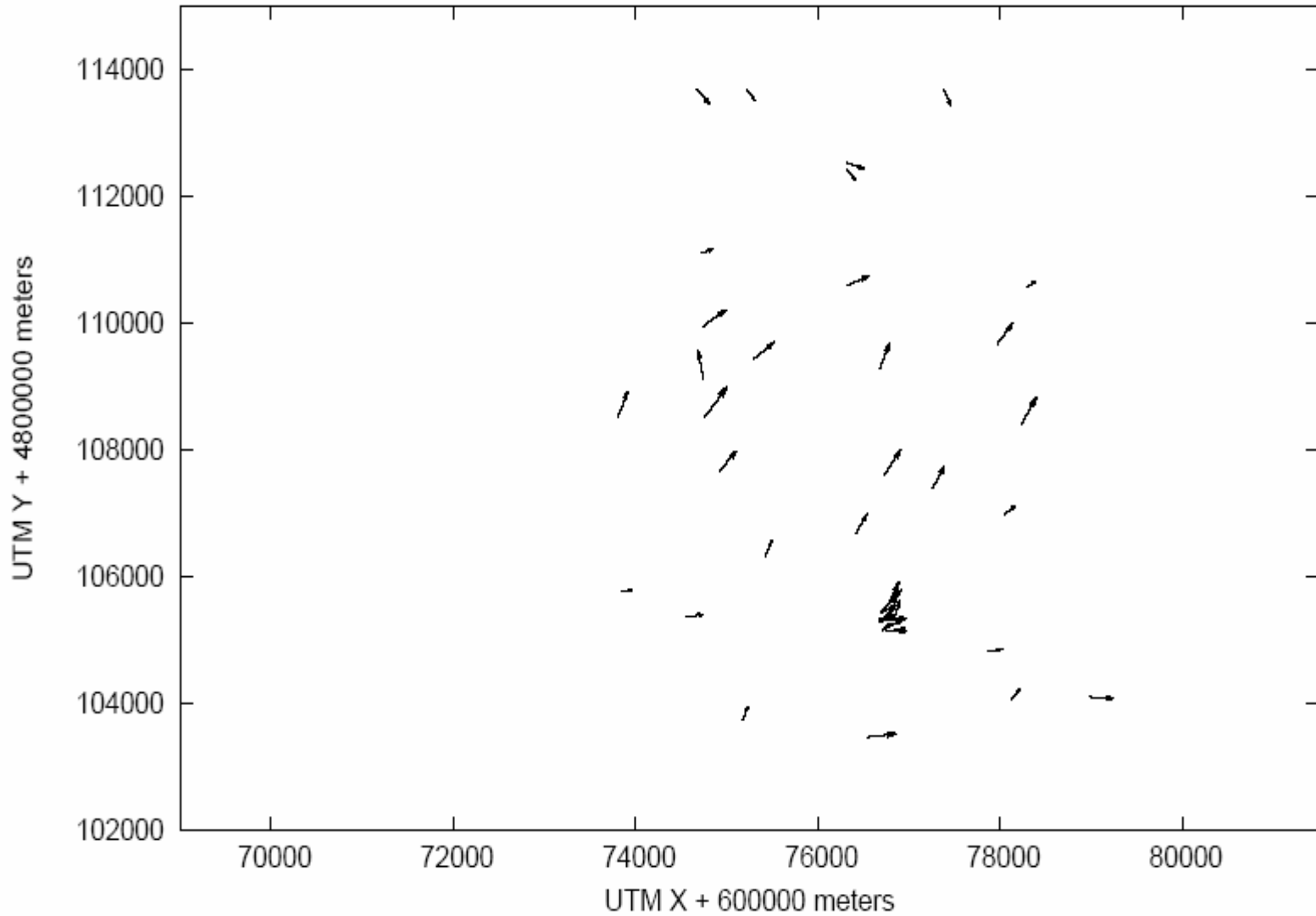
OrbView-3 7-18-2005 Orthorectified



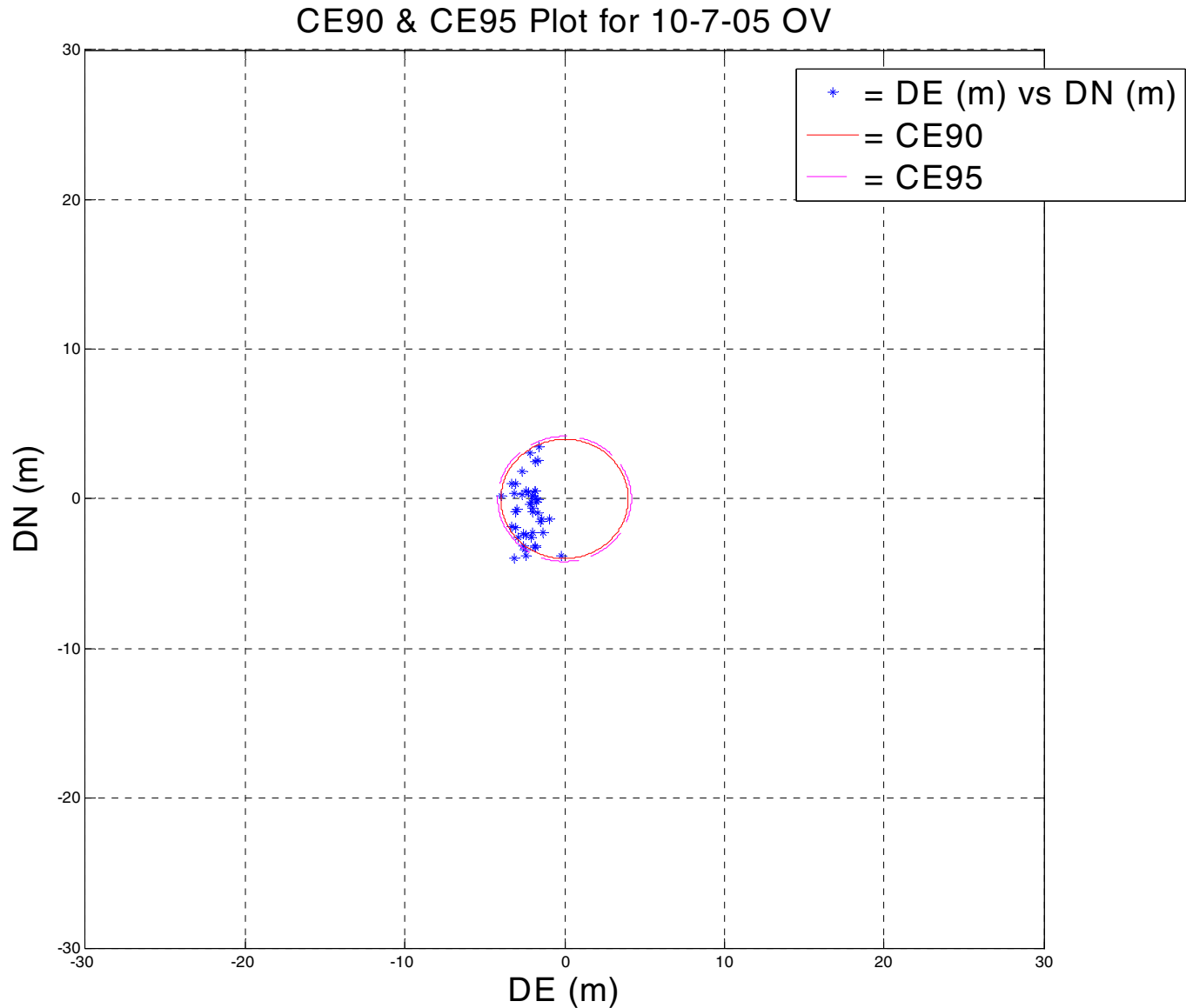
OrbView-3 7-18-2005 Orthorectified (CE90 = 8.3848 m & CE95 = 8.5358 m)

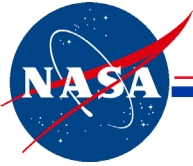


OrbView-3 10-7-2005 Orthorectified



OrbView-3 10-7-2005 Orthorectified (CE90 = 3.9851 m & CE95 = 4.1801 m)



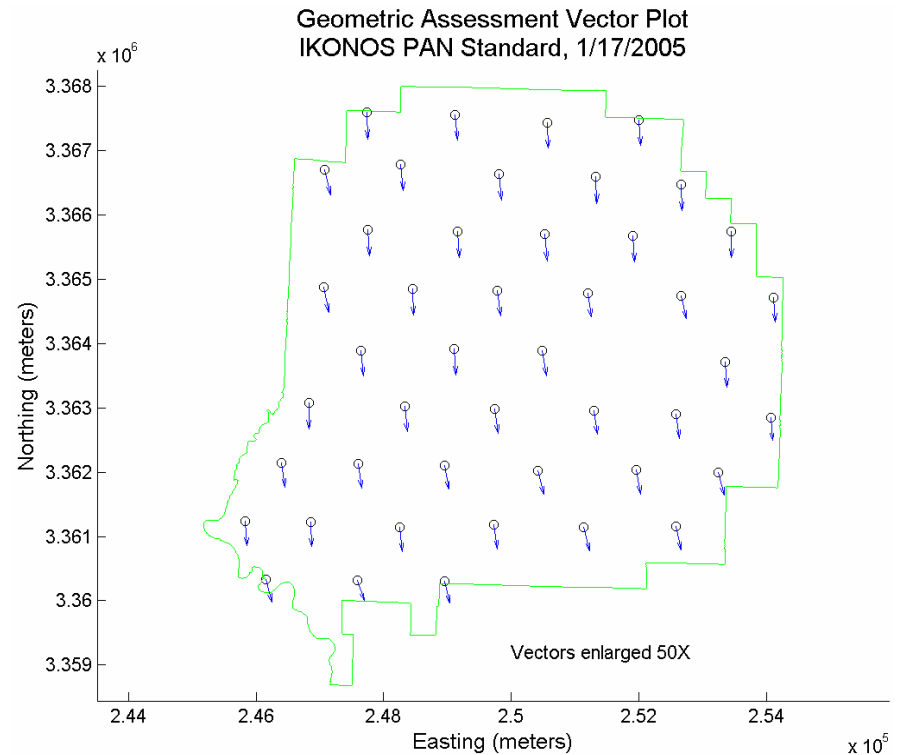
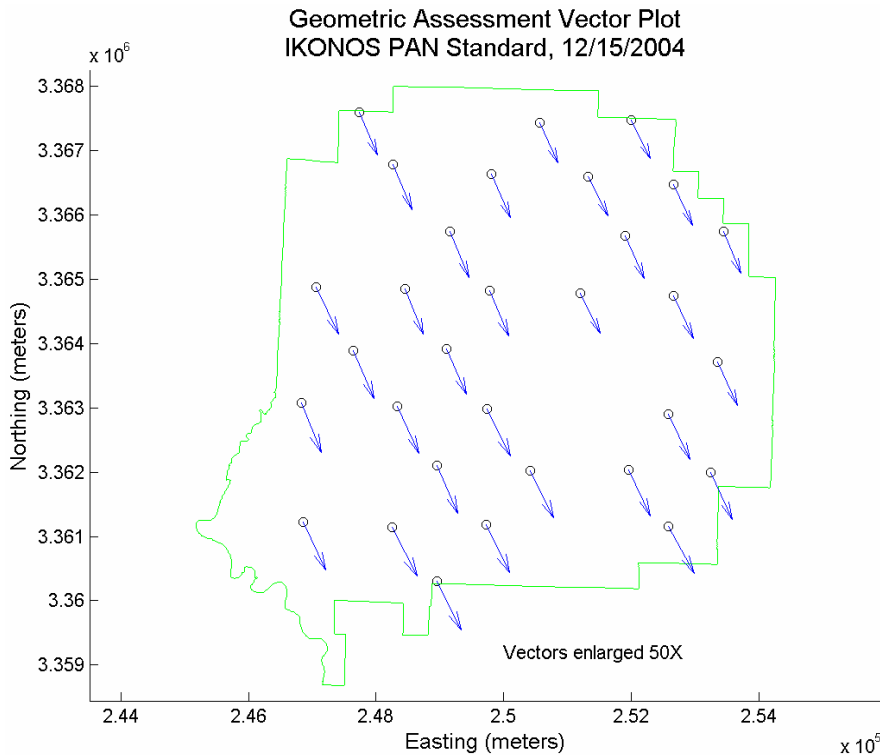


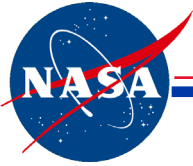
SSC – IKONOS Geo PAN

Stennis Space Center

15 DEC 2004
CE₉₀: 16.72 m
CE₉₅: 17.00 m
Circular Standard Error: 0.81 m

17 JAN 2005
CE₉₀: 8.18 m
CE₉₅: 8.29 m
Circular Standard Error: 0.49 m



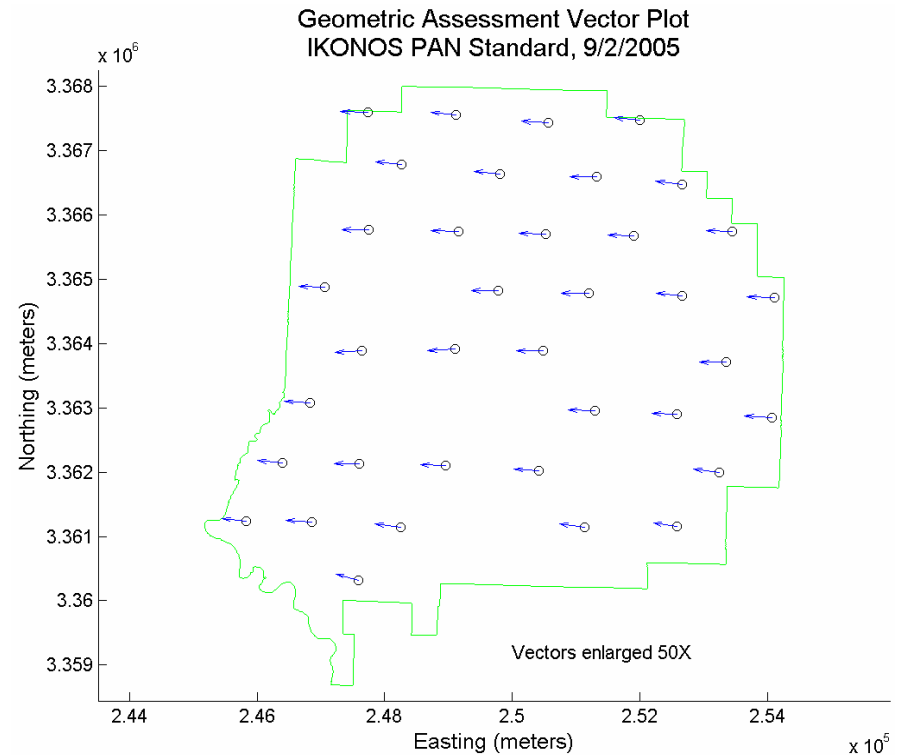
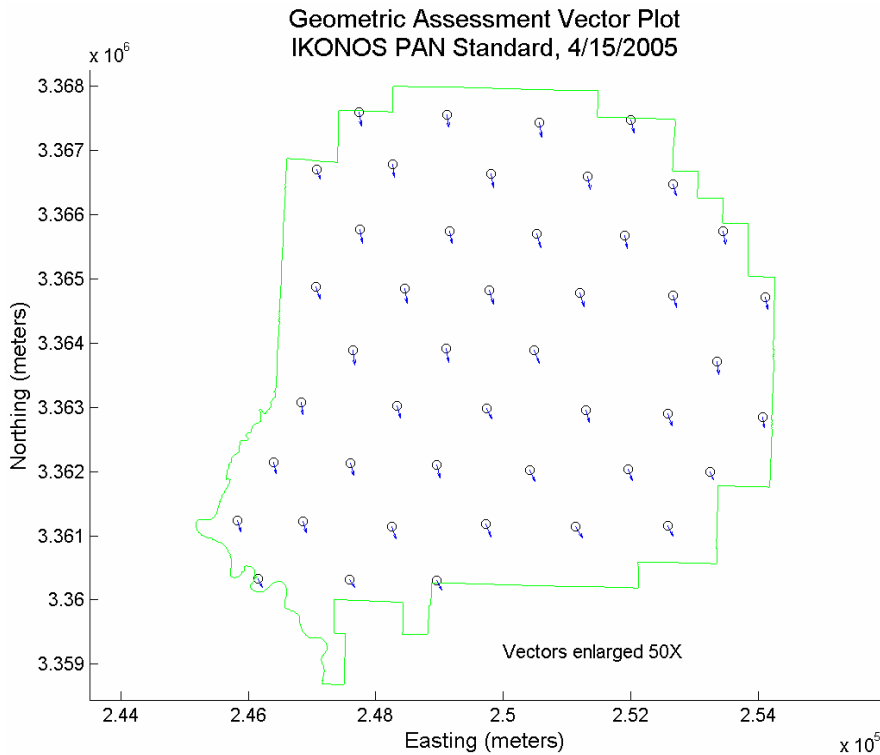


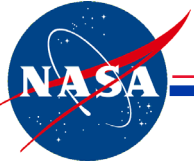
SSC – IKONOS Geo PAN

Stennis Space Center

15 APR 2005
CE₉₀: 4.51 m
CE₉₅: 4.60 m
Circular Standard Error: 0.44 m

2 SEP 2005
CE₉₀: 8.59 m
CE₉₅: 8.61 m
Circular Standard Error: 0.40 m

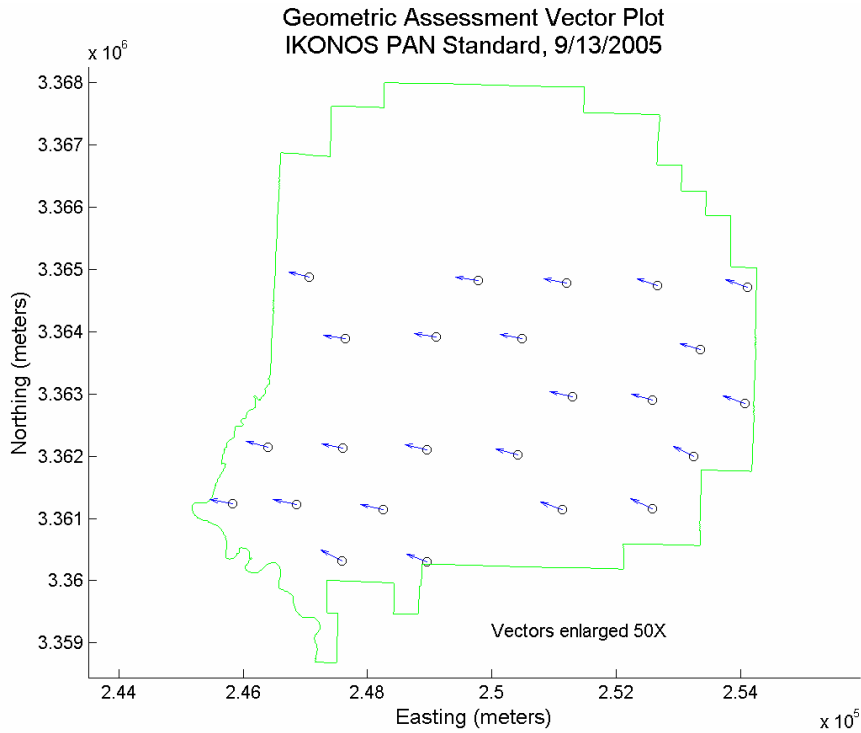


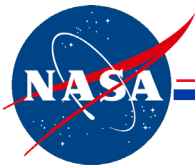


SSC – IKONOS Geo PAN

Stennis Space Center

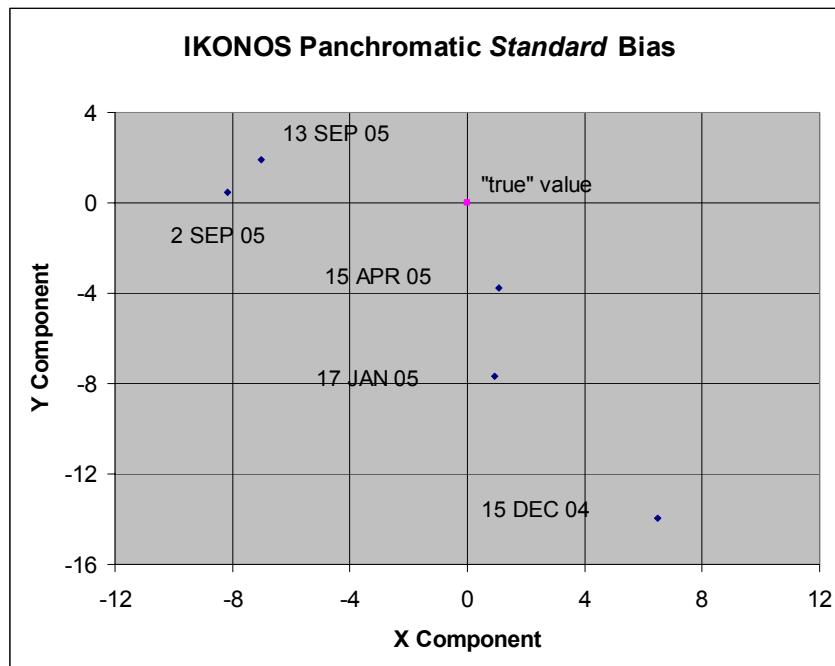
13 SEP 2005
CE₉₀: 7.62 m
CE₉₅: 7.74 m
Circular Standard Error: 0.49 m





IKONOS – No Clear Bias Trend

Stennis Space Center



Extended Summary for 2006 Geopositional Assessments -South Dakota State University-



OrbView-3

Date	Mean Northing Error	Northing Error Standard Deviation	Mean Easting Error	Easting Error Standard Deviation	Mean Error	Error Standard Deviation	Northing RMSE	Easting RMSE	RMSE	CE ₉₀	CE ₉₅
8/30/2004	9.8228	1.0682	-3.3512	1.3142	10.4526	1.1374	9.8794	3.5942	10.5129	11.7554	12.4592
10/8/2004	11.161	1.2401	-0.2337	1.2379	11.2295	1.2469	11.2281	1.2459	11.297	12.6743	13.0767
7/18/2005	0.2067	1.4499	-5.6424	1.6348	5.8175	1.6629	1.4482	5.8693	6.0453	8.3848	8.5358
10/7/2005	-0.7442	1.8939	-2.2215	0.7126	2.9552	0.8803	2.0147	2.3305	3.0806	3.9851	4.1801

QuickBird - Panchromatic Band

Date	Mean Northing Error	Northing Error Standard Deviation	Mean Easting Error	Easting Error Standard Deviation	Mean Error	Error Standard Deviation	Northing RMSE	Easting RMSE	RMSE	CE ₉₀	CE ₉₅
8/30/2004	5.174	0.4462	25.2305	0.8804	25.7608	0.8345	5.1927	25.2455	25.774	26.6623	26.9906
10/5/2004	5.8763	1.1221	23.7566	0.8954	24.4978	0.8938	5.9801	23.7731	24.5137	25.6153	25.9286
6/22/2005	-0.0415	0.5975	15.294	1.3369	15.3058	1.3328	0.5921	15.351	15.3624	16.7135	17.3145
10/18/2005	-1.8816	0.9526	-12.0947	1.2938	12.2848	1.2085	2.1041	12.1621	12.3428	13.5985	13.8037

QuickBird - Multispectral Band

Date	Mean Northing Error	Northing Error Standard Deviation	Mean Easting Error	Easting Error Standard Deviation	Mean Error	Error Standard Deviation	Northing RMSE	Easting RMSE	RMSE	CE ₉₀	CE ₉₅
8/30/2004	4.7736	0.5806	25.5976	0.7466	26.0462	0.7115	4.808	25.6083	26.0557	26.861	26.9368
10/5/2004	5.1087	0.8253	24.3941	0.9249	24.9354	0.9563	5.1734	24.4112	24.9534	25.9796	26.2656
6/22/2005	-1.4035	0.6809	15.9864	1.6215	16.0621	1.6209	1.5566	16.0666	16.1418	17.9719	18.3163
10/18/2005	-3.2157	0.9717	-11.3015	1.142	11.804	0.9738	3.3561	11.3577	11.8432	13.3361	13.5476

NOTE: All data is measured and calculated in meters; measurements are based around 44 GCPs in and around Brookings, SD; and three different individuals were involved in the analysis of each scene.