

Stennis Space Center

# QuickBird and OrbView-3 Geopositional Accuracy Assessment



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High Spatial Resolution Commercial Imagery Workshop  
Reston, Virginia, USA  
November 8, 2004



# Contributors

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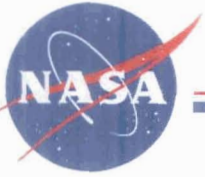
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This work was directed by the NASA Applied Sciences Directorate (formerly the Earth Science Applications Directorate) at the John C. Stennis Space Center, Mississippi. Participation in this work by Lockheed Martin Space Operations – Stennis Programs was supported under contract number NAS 13-650. Participation in this work by Computer Sciences Corporation and by Science Systems and Applications, Inc., was supported under NASA Task Order NNS04AB54T.



# Outline

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- Ground Reference Sites
  - Brookings, SD
  - Stennis Space Center, MS
- Methods
- OrbView-3 Assessment
  - Data Collections
  - Results
- QuickBird Assessment
  - Data Collections
  - Results



# Assessment Overview

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- 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 assessments with independent teams. Each team has slightly different measurement techniques and data processing methods.
    - NASA Stennis Space Center
    - South Dakota State University



# Data Providers

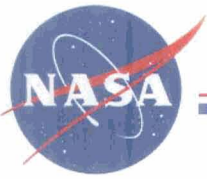
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- DigitalGlobe, Inc.
  - Imagery acquired by the QuickBird sensor
  - Data purchased by NASA through the Scientific Data Purchase project
  - Assessment is a continuation from the previous year
  
- OSC/ORBIMAGE, Inc.
  - Imagery acquired by the OrbView-3 sensor
  - Data received through a Space Act Agreement among NASA, Orbital Sciences Corporation, and ORBIMAGE, Inc.
  - Independent assessment performed on pre-initial on-orbit checkout (pre-IOC) data



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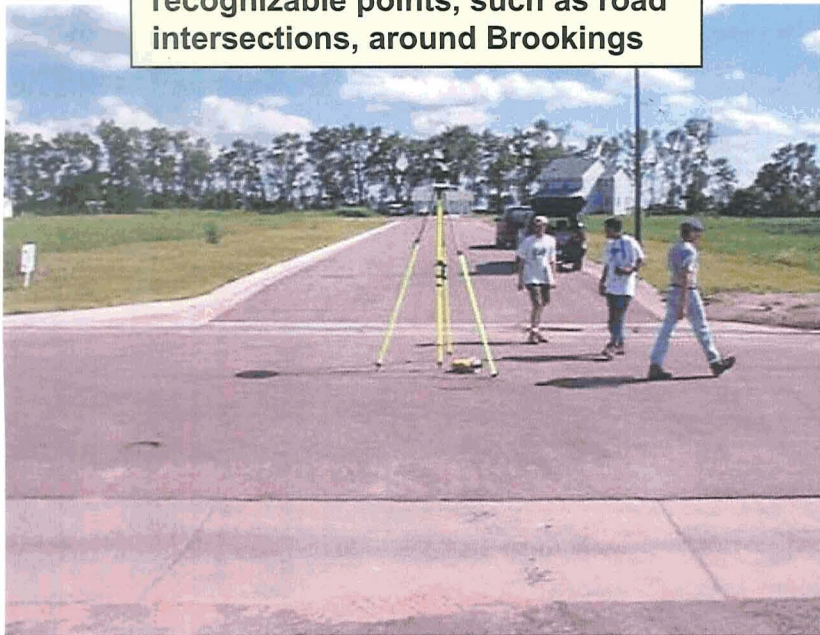
# Sites



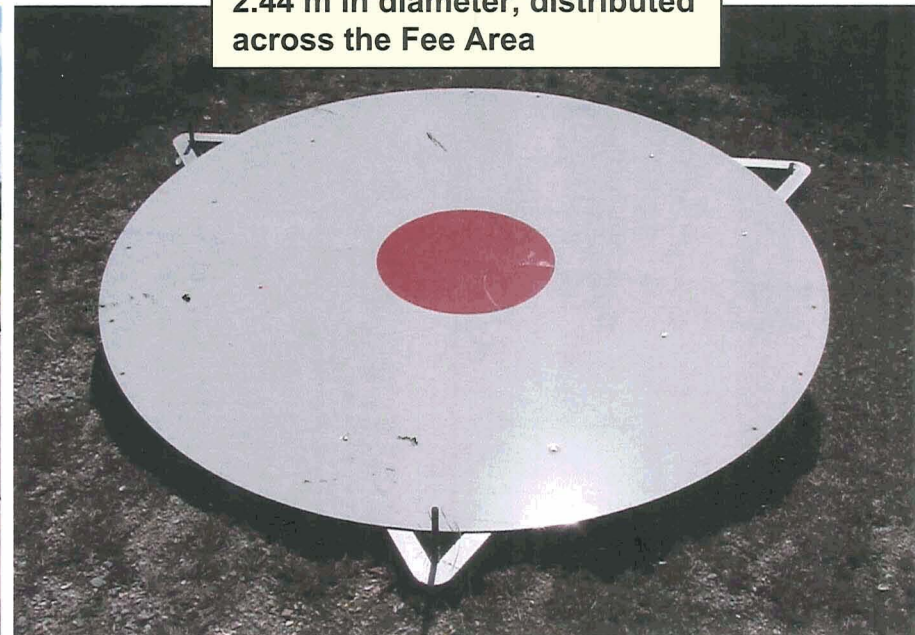
# Brookings and Stennis Ground Control

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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



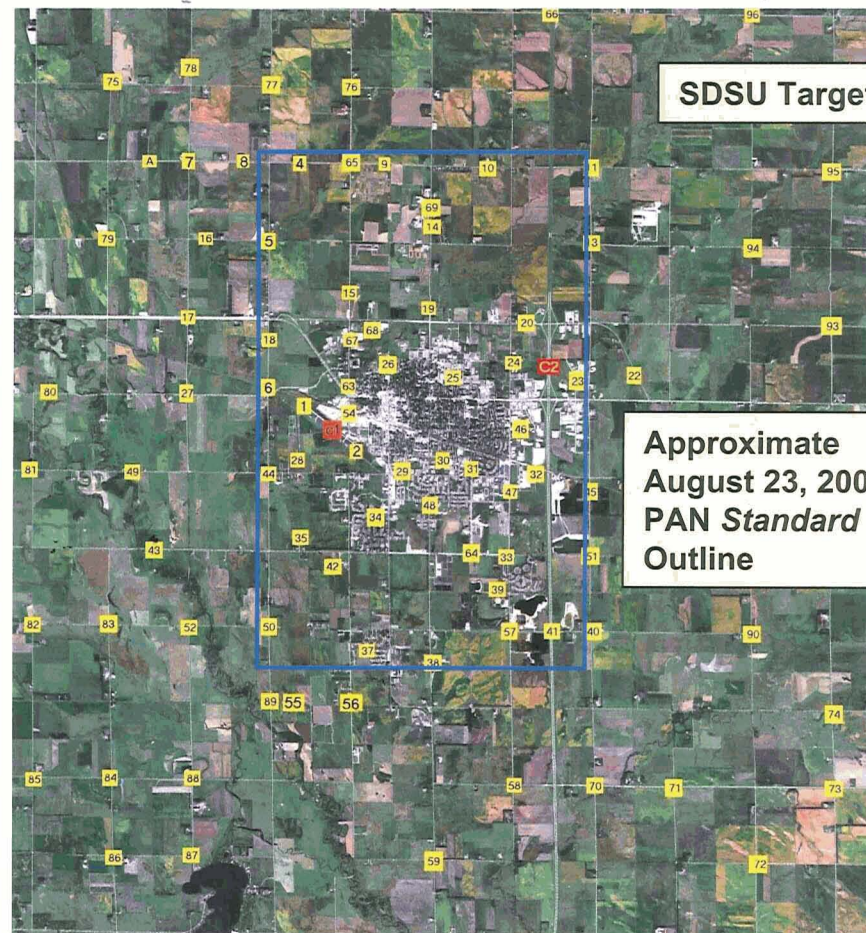
Both sets of GCPs were RTK GPS located by the SSC survey team to absolute horizontal accuracies in the 3-6 cm range



# Brookings: QuickBird Image and Targets

Stennis Space Center

August 23, 2003  
PAN Standard



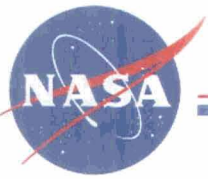
SDSU Targets

Approximate  
August 23, 2003  
PAN Standard  
Outline

■ GCP Locations ■ Base Stations

Includes material ©  
Space Imaging, LLC

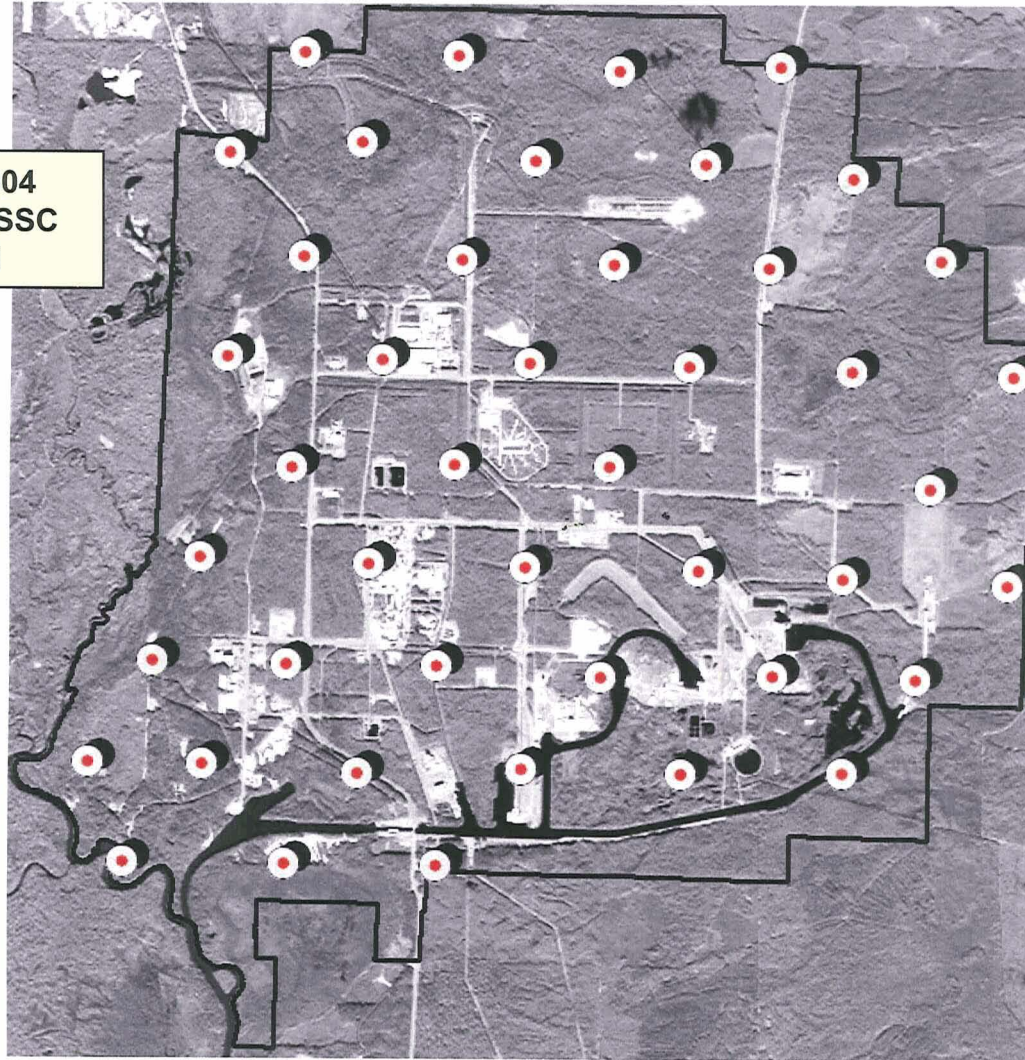




# SSC: OrbView-3 Image and Targets

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December 15, 2004  
PAN *Basic* with SSC  
Targets Overlaid



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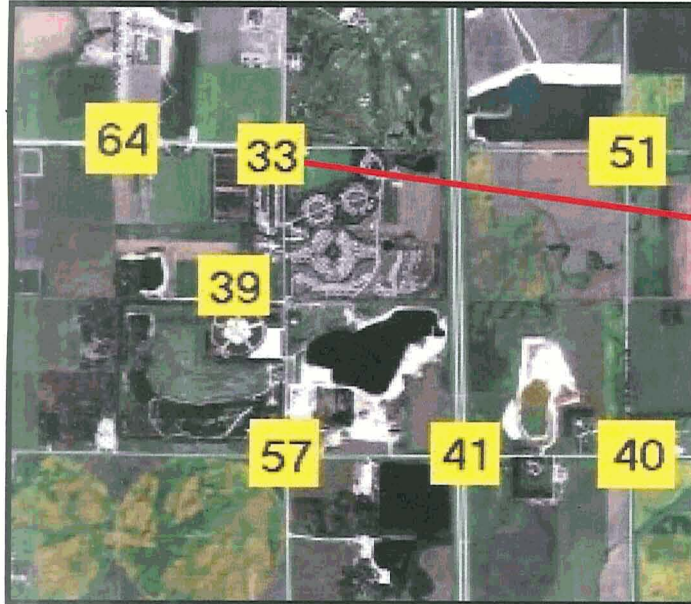
# Methods



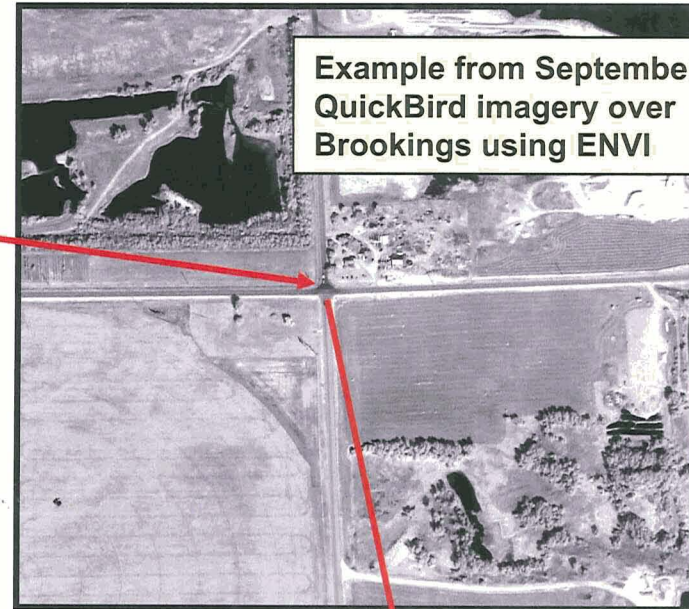
# Finding Image Coordinates over Brookings

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Includes material © Space Imaging, LLC

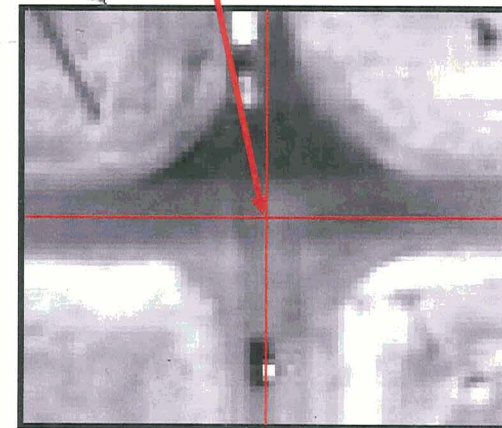


Step 1



Example from September 7, 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™



# Finding Image Coordinates over SSC

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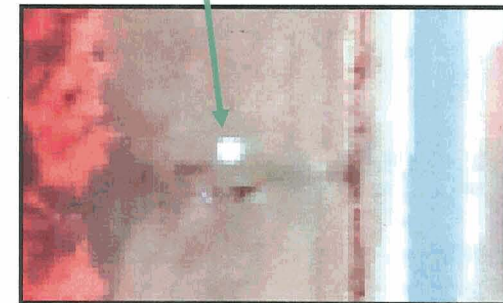


Step 1



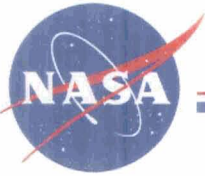
Step 2

Example from February 17, 2002 QuickBird pan-merged imagery over SSC



Step 3

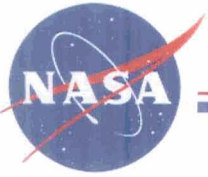
Includes material © DigitalGlobe™



## Additional Notes on Methods

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- At South Dakota State, 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-select 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 MATLAB® to generate results
  - Results are reviewed for indications of mistakes



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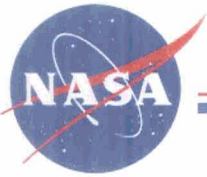
# **OrbView-3 Geopositional Assessment (pre-IOC)**



# OrbView-3 Geopositional Assessment Notes

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- The OrbView-3 images were not delivered as geocorrected products as has been the case with JACIE geopositional assessments to date
- OrbView-3 images were delivered as the OrbView-3 *Basic* product, which is not geocorrected but is delivered with rational functions for customers to apply
- The OrbView-3 rational functions were applied for this assessment using a local photogrammetrically generated DEM for the SSC Fee Area
- DEM metadata
  - Elevations referenced to ellipsoid
  - Estimated accuracy: 30 cm, LE90
  - Rasterized to 3 m grid



# Data Acquisitions

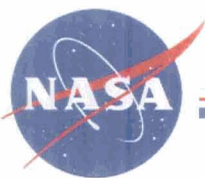
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- All acquisitions were OrbView-3 *Basic Enhanced*, panchromatic
  - 25 meters CE<sub>90</sub> product specification
- All over Stennis Space Center, MS
  - September 17, 2003
  - December 12, 2003
  - December 15, 2003
  - December 26, 2003
  - January 12, 2004

## OrbView-3 Basic Enhanced:

- *Includes satellite telemetry data, rational functions, post processed GPS data and sufficient metadata to allow rigorous photogrammetric triangulation. (from product catalog)*



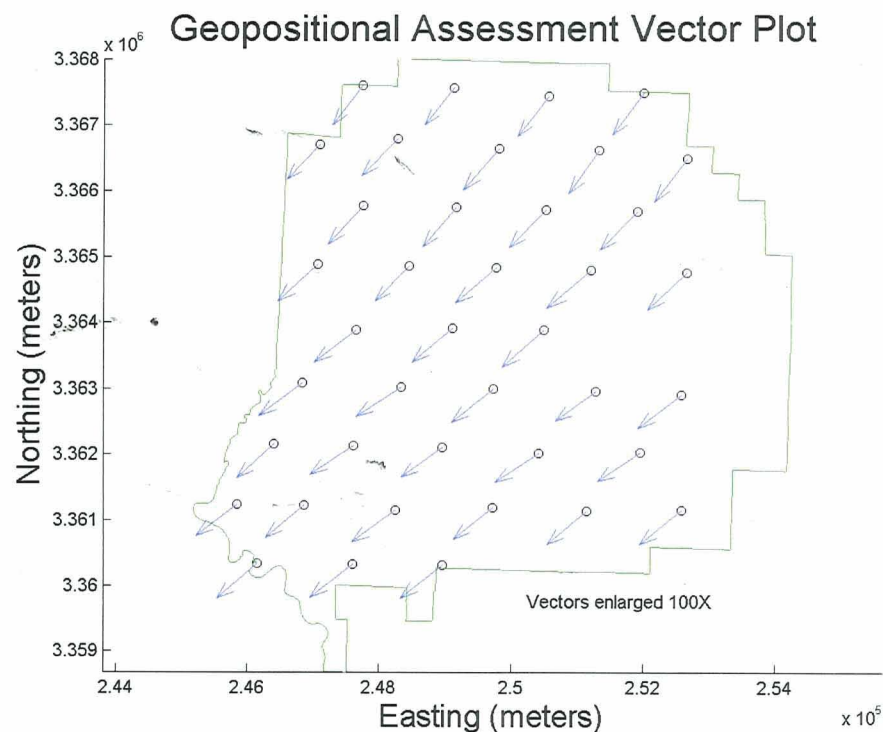


# SSC, Sep 17, 2003 – PAN Basic

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OrbView-3			
<b>Acquisition Date</b>	9/17/2003	<b>Imagery Band</b>	PAN
<b>Number Targets Used</b>		<b>Error Components</b>	
<i>n</i>	40	$\mu_H$ (Bias)	7.92 m
<b>Test for Departure from Circular Distribution</b>		$\sigma_C$ (Circular Standard Error)	0.64 m
<b>St. Dev. Min Max Ratio</b>	0.84	$\mu_H/\sigma_C$	12.40
St. Dev. Min Max Ratio should be at least 0.6 for Circular Error assumptions.		If $\mu_H/\sigma_C$ is greater than 0.1, then error calculations should account for bias.	
<b>Circular Error</b>			
<b>Empirical CE<sub>90</sub></b>	8.32 m	<b>Empirical CE<sub>95</sub></b>	8.44 m

**CE<sub>90</sub> 8.32 m**



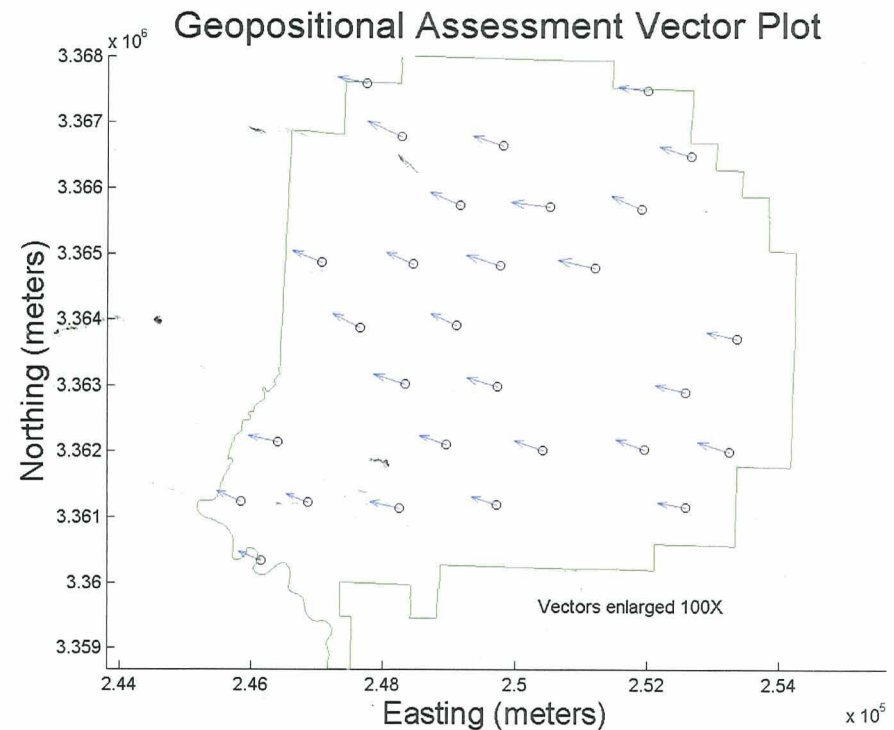


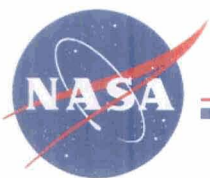
# SSC, Dec 12, 2003 – PAN Basic

Stennis Space Center

OrbView-3			
<b>Acquisition Date</b>	12/12/2003	<b>Imagery Band</b>	PAN
<b>Number Targets Used</b>		<b>Error Components</b>	
<i>n</i>	29	$\mu_H$ (Bias)	4.69 m
<b>Test for Departure from Circular Distribution</b>		$\sigma_C$ (Circular Standard Error)	0.50 m
<b>St. Dev. Min Max Ratio</b>	0.74	$\mu_H/\sigma_C$	9.43
St. Dev. Min Max Ratio should be at least 0.6 for Circular Error assumptions.		If $\mu_H/\sigma_C$ is greater than 0.1, then error calculations should account for bias.	
Circular Error			
<b>Empirical CE<sub>90</sub></b>	5.57 m	<b>Empirical CE<sub>95</sub></b>	5.68 m

**CE<sub>90</sub> 5.57 m**



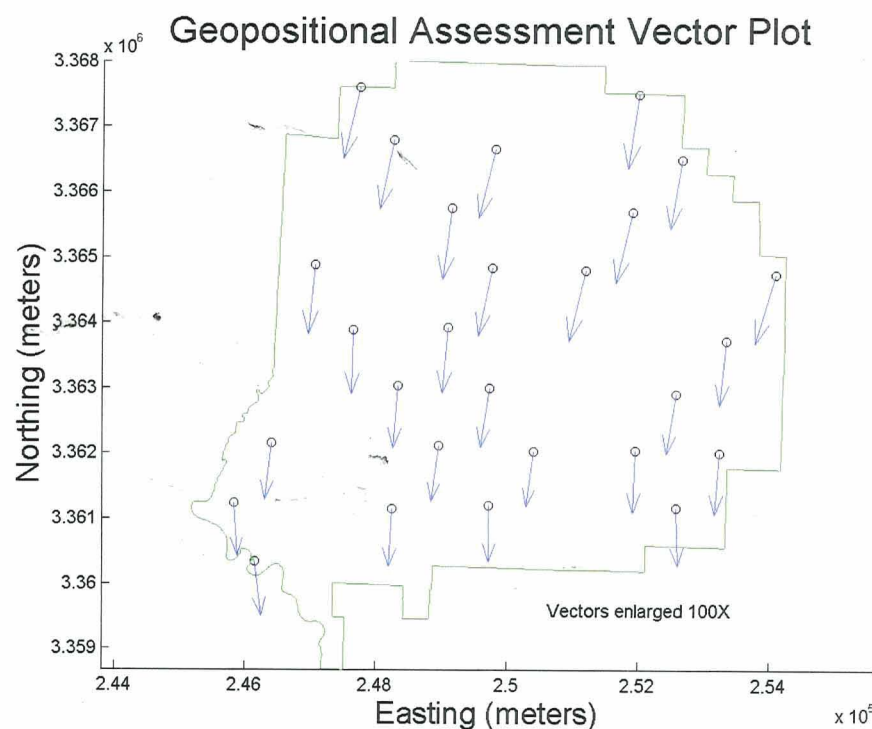


# SSC, Dec 15, 2003 – PAN Basic

Stennis Space Center

OrbView-3			
<b>Acquisition Date</b>	12/15/2003	<b>Imagery Band</b>	PAN
<b>Number Targets Used</b>		<b>Error Components</b>	
<i>n</i>	27	$\mu_H$ (Bias)	9.80 m
<b>Test for Departure from Circular Distribution</b>		$\sigma_C$ (Circular Standard Error)	1.00 m
<b>St. Dev. Min Max Ratio</b>	0.91	$\mu_H/\sigma_C$	9.83
St. Dev. Min Max Ratio should be at least 0.6 for Circular Error assumptions.		If $\mu_H/\sigma_C$ is greater than 0.1, then error calculations should account for bias.	
<b>Circular Error</b>			
<b>Empirical CE<sub>90</sub></b>	11.11 m	<b>Empirical CE<sub>95</sub></b>	11.25 m

**CE<sub>90</sub> 11.11 m**



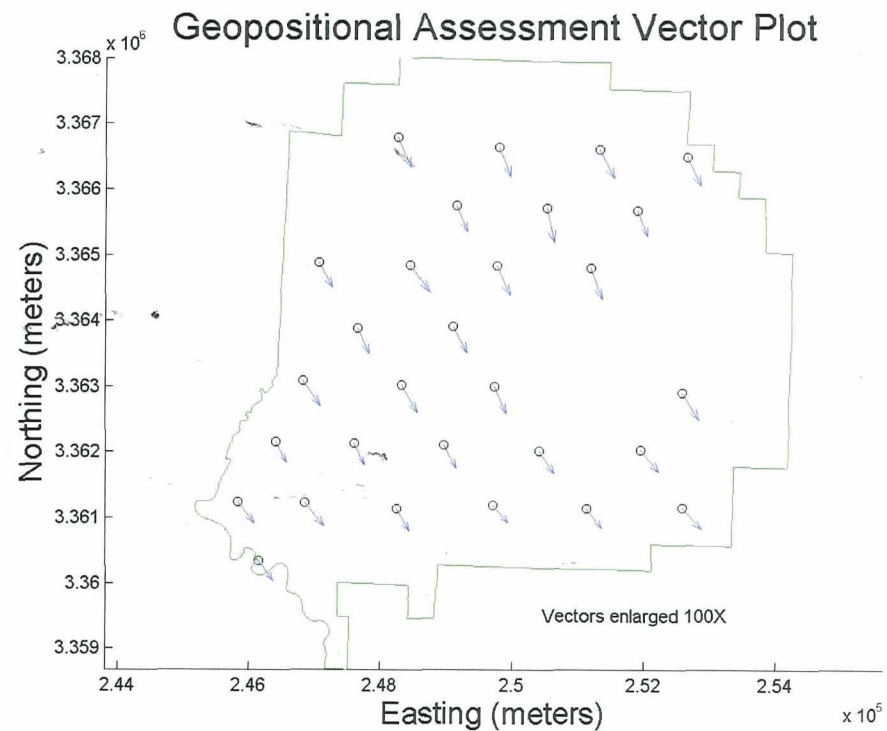


# SSC, Dec 26, 2003 – PAN Basic

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OrbView-3					
<b>Acquisition Date</b>		12/26/2003	<b>Imagery Band</b>		PAN
<b>Number Targets Used</b>		<b>Error Components</b>			
<i>n</i>	29	$\mu_H$ (Bias)	4.38 m		
<b>Test for Departure from Circular Distribution</b>		$\sigma_C$ (Circular Standard Error)	0.53 m		
<b>St. Dev. Min Max Ratio</b>	0.80	$\mu_H/\sigma_C$	8.28		
St. Dev. Min Max Ratio should be at least 0.6 for Circular Error assumptions.		If $\mu_H/\sigma_C$ is greater than 0.1, then error calculations should account for bias.			
<b>Circular Error</b>					
<b>Empirical CE<sub>90</sub></b>	4.98 m	<b>Empirical CE<sub>95</sub></b>	5.24 m		

**CE<sub>90</sub> 4.98 m**



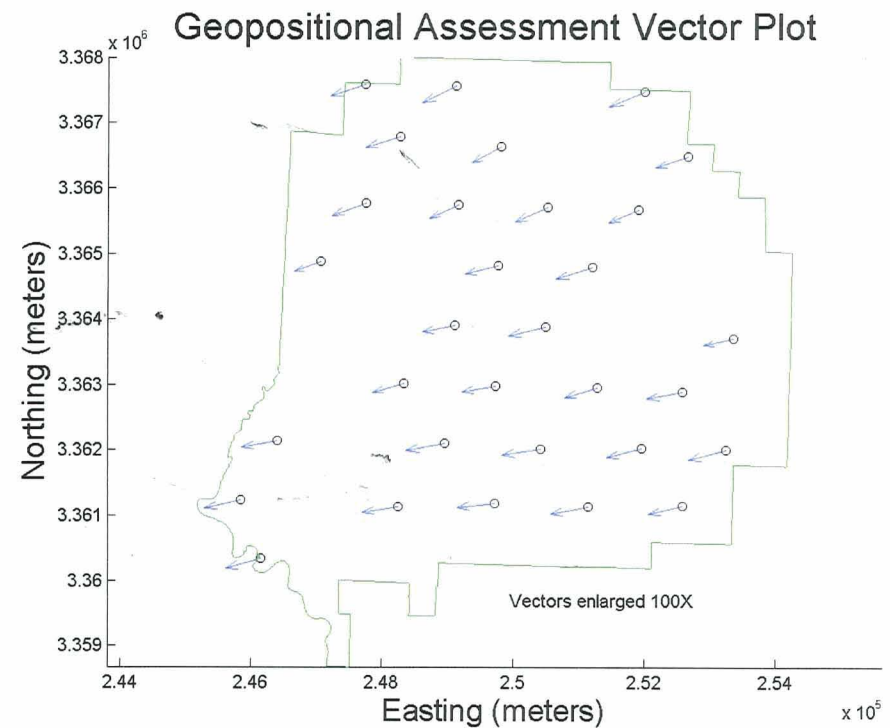


# SSC, Jan 12, 2004 – PAN Basic

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OrbView-3			
<b>Acquisition Date</b>	1/12/2004	<b>Imagery Band</b>	PAN
<b>Number Targets Used</b>		<b>Error Components</b>	
<i>n</i>	31	$\mu_H$ (Bias)	5.42 m
<b>Test for Departure from Circular Distribution</b>		$\sigma_C$ (Circular Standard Error)	0.48 m
<b>St. Dev. Min Max Ratio</b>	0.99	$\mu_H/\sigma_C$	11.37
St. Dev. Min Max Ratio should be at least 0.6 for Circular Error assumptions.		If $\mu_H/\sigma_C$ is greater than 0.1, then error calculations should account for bias.	
<b>Circular Error</b>			
<b>Empirical CE<sub>90</sub></b>	5.93 m	<b>Empirical CE<sub>95</sub></b>	5.96 m

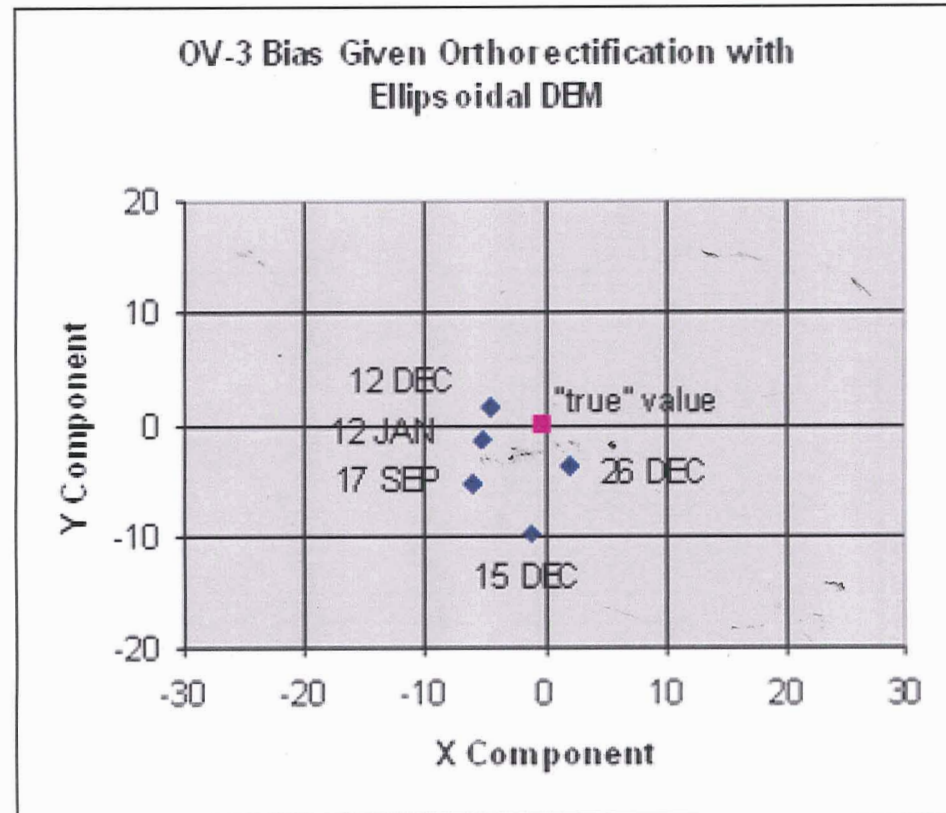
**CE<sub>90</sub> 5.93 m**



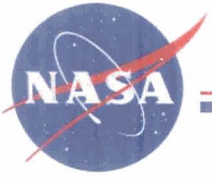


# No Clear Bias Trend

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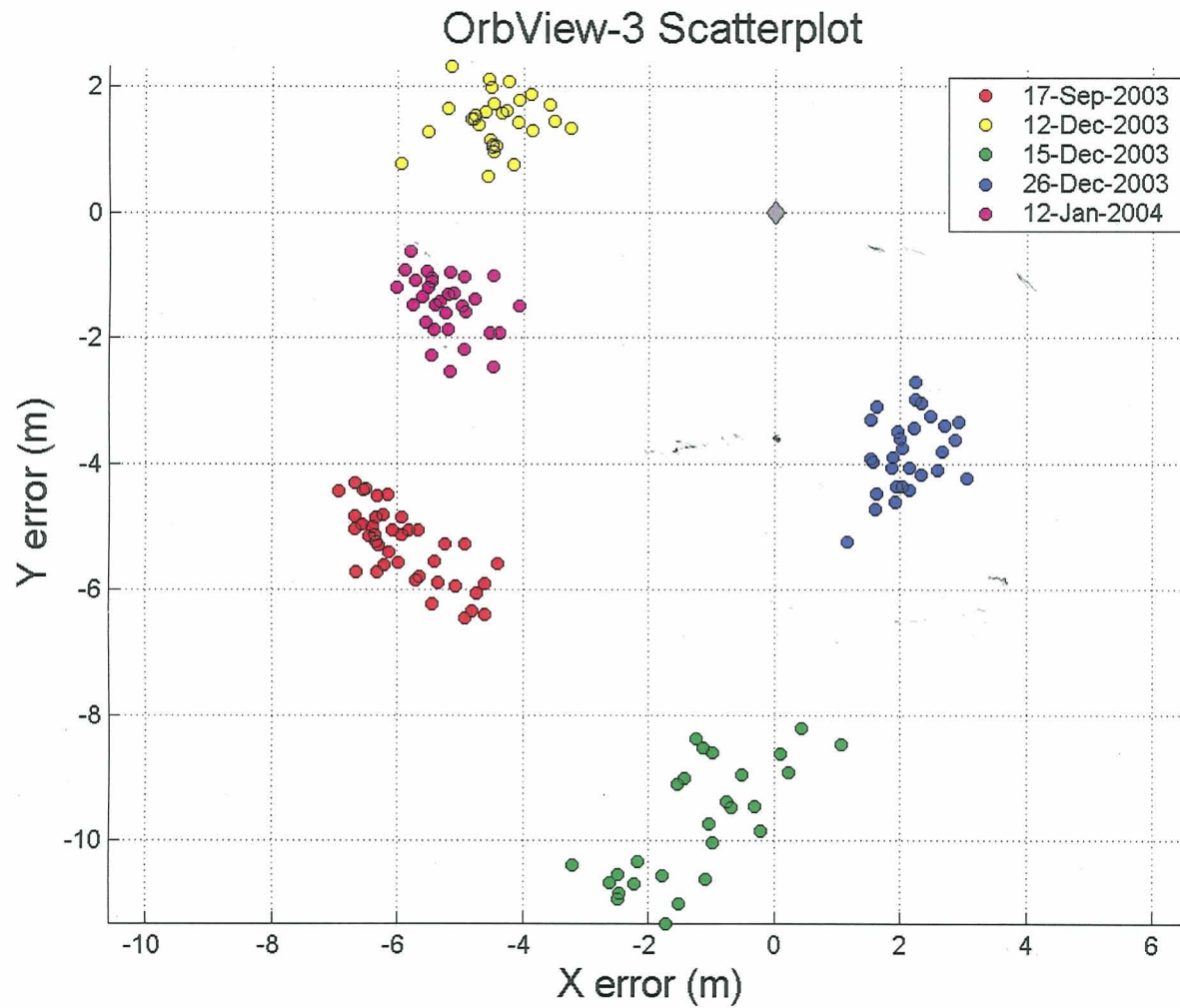


Direction of bias (with bias = image – reference) ranged from southeast to northwest



# OrbView-3 Error Scatterplot

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# Summary



OrbView-3 Product	Acquisition Date	Empirical CE <sub>90</sub> (m)	Empirical CE <sub>95</sub> (m)	Elevation Angle (deg)
<i>Panchromatic Basic</i>	9/17/2003	8.29	8.37	79.3
	12/12/2003	5.49	5.66	65.8
	12/15/2003	11.11	11.19	52.7
	12/26/2003	4.98	5.13	80.2
	1/12/2004	5.92	5.96	61.6

- The mean CE<sub>90</sub> of OrbView-3 panchromatic *Basic* images characterized was 7.2 m
  - 95% confidence interval from 4.0 m to 10.3 m
- All OrbView-3 images characterized in this reporting period met ORBIMAGE's self-stated specifications for *Basic Enhanced* product configuration





# Extended OrbView-3 Summary

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OrbView-3 Product	Image Tracking ID	Acquisition Date	Bias X (m)	Bias Y (m)	$\mu_H$ - Bias (m)	$\sigma_C$ - Circular Standard Error (m)	Empirical CE <sub>90</sub> (m)	Empirical CE <sub>95</sub> (m)	Elevation Angle (deg)
<b>Panchromatic Basic</b>	14442	9/17/2003	-5.88	-5.31	7.92	0.64	8.29	8.37	79.3
	24790	12/12/2003	-4.46	1.45	4.69	0.50	5.49	5.66	65.8
	22760	12/15/2003	-1.21	-9.73	9.80	1.00	11.11	11.19	52.7
	23539	12/26/2003	2.11	-3.84	4.38	0.53	4.98	5.13	80.2
	24515	1/12/2004	-5.21	-1.48	5.42	0.48	5.92	5.96	61.6



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# **QuickBird Geopositional Assessment**



# Data Acquisitions

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- Acquisitions Types
  - *Standard* (2A) – 23 meters CE<sub>90</sub>
  - *Orthorectified* (3E – 1:10,000) – 8.3 meters CE<sub>90</sub>
- Brookings, SD (both panchromatic & multispectral)
  - August 23, 2003 (both *Standard* & *Orthorectified*)
  - September 15, 2003 (*Standard*)
  - October 21, 2003 (*Standard*)
- Stennis Space Center, MS (panchromatic only)
  - January 10, 2004 (*Standard*)

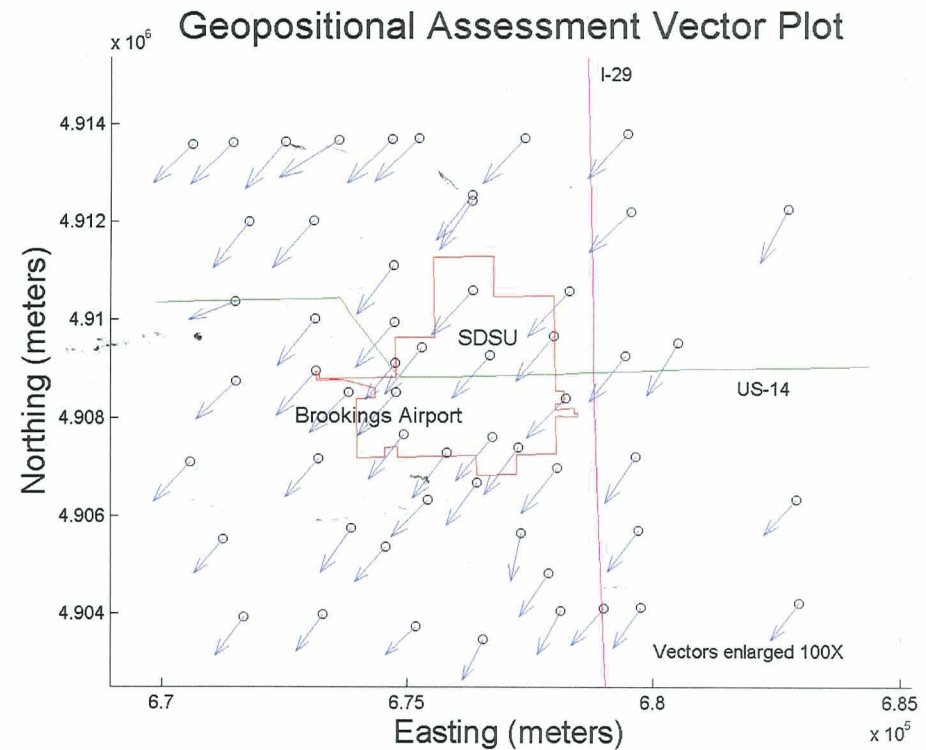


# Brookings, Aug 23, 2003 – PAN Standard

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QuickBird					
<b>Acquisition Date</b>		8/23/2003	<b>Imagery Band</b>		PAN
<b>Number Targets Used</b>		<b>Error Components</b>			
<i>n</i>	56	$\mu_H$ (Bias)	11.24 m		
<b>Test for Departure from Circular Distribution</b>		$\sigma_C$ (Circular Standard Error)	1.33 m		
<b>St. Dev. Min Max Ratio</b>	0.79	$\mu_H/\sigma_C$	8.45		
St. Dev. Min Max Ratio should be at least 0.6 for Circular Error assumptions.		If $\mu_H/\sigma_C$ is greater than 0.1, then error calculations should account for bias.			
Circular Error					
<b>Empirical CE<sub>90</sub></b>	12.67 m	<b>Empirical CE<sub>95</sub></b>	12.76 m		

**CE<sub>90</sub> 12.67 m**



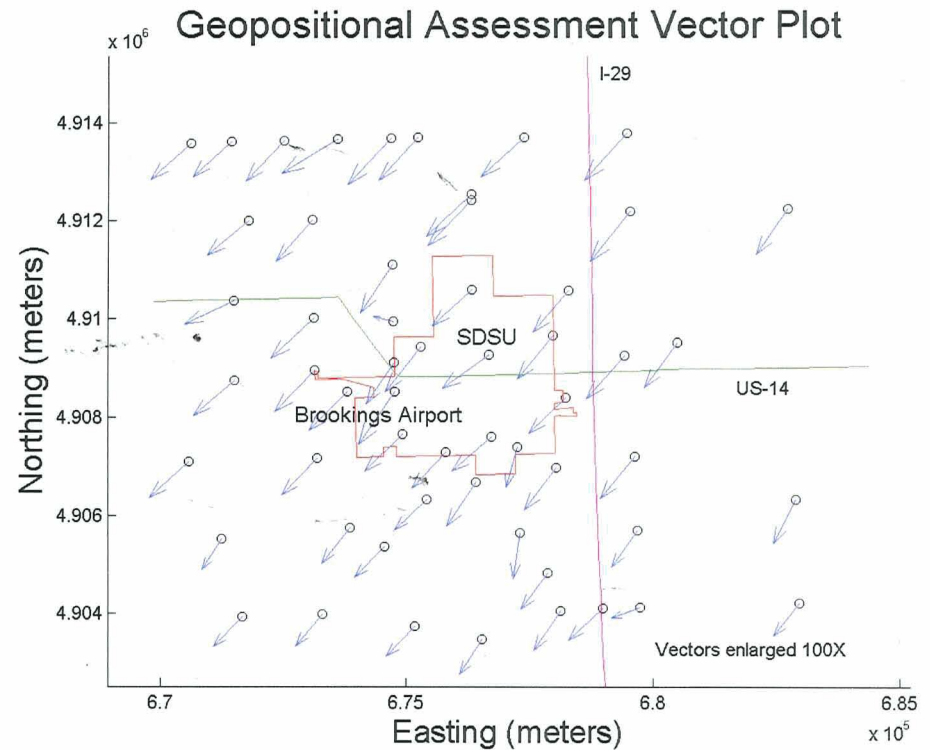


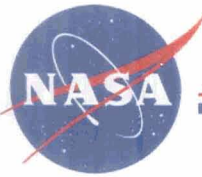
# Brookings, Aug 23, 2003 – MS Standard

Stennis Space Center

QuickBird					
<b>Acquisition Date</b>		8/23/2003	<b>Imagery Band</b>		MS
<b>Number Targets Used</b>		<b>Error Components</b>			
<i>n</i>	56	$\mu_H$ (Bias)	10.33 m		
<b>Test for Departure from Circular Distribution</b>		$\sigma_C$ (Circular Standard Error)	1.81 m		
<b>St. Dev. Min Max Ratio</b>	0.98	$\mu_H/\sigma_C$	5.71		
St. Dev. Min Max Ratio should be at least 0.6 for Circular Error assumptions.		If $\mu_H/\sigma_C$ is greater than 0.1, then error calculations should account for bias.			
Circular Error					
<b>Empirical CE<sub>90</sub></b>	12.78 m	<b>Empirical CE<sub>95</sub></b>	12.93 m		

**CE<sub>90</sub> 12.78 m**



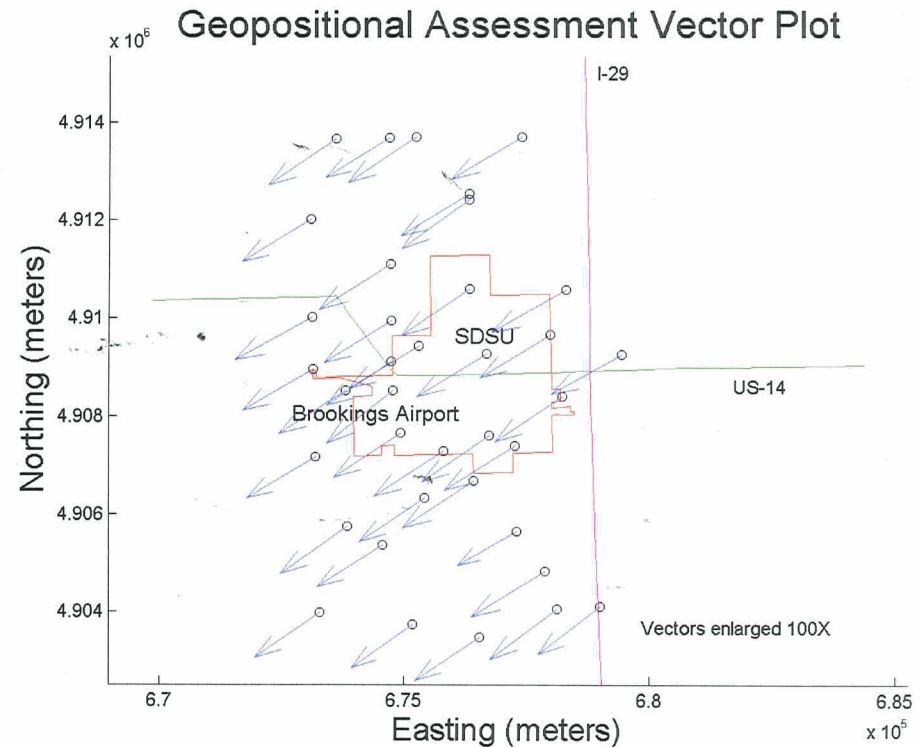


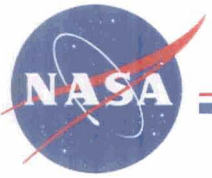
# Brookings, Sep 15, 2003 – PAN Standard

Stennis Space Center

QuickBird					
<b>Acquisition Date</b>		9/15/2003	<b>Imagery Band</b>		PAN
<b>Number Targets Used</b>		<b>Error Components</b>			
<i>n</i>	37	$\mu_H$ (Bias)	16.53 m		
<b>Test for Departure from Circular Distribution</b>		$\sigma_C$ (Circular Standard Error)	0.71 m		
<b>St. Dev. Min</b>	0.94	$\mu_H/\sigma_C$	23.22		
<b>Max Ratio</b>					
St. Dev. Min Max Ratio should be at least 0.6 for Circular Error assumptions.		If $\mu_H/\sigma_C$ is greater than 0.1, then error calculations should account for bias.			
Circular Error					
<b>Empirical CE<sub>90</sub></b>	17.40 m	<b>Empirical CE<sub>95</sub></b>	17.62 m		

**CE<sub>90</sub> 17.40 m**



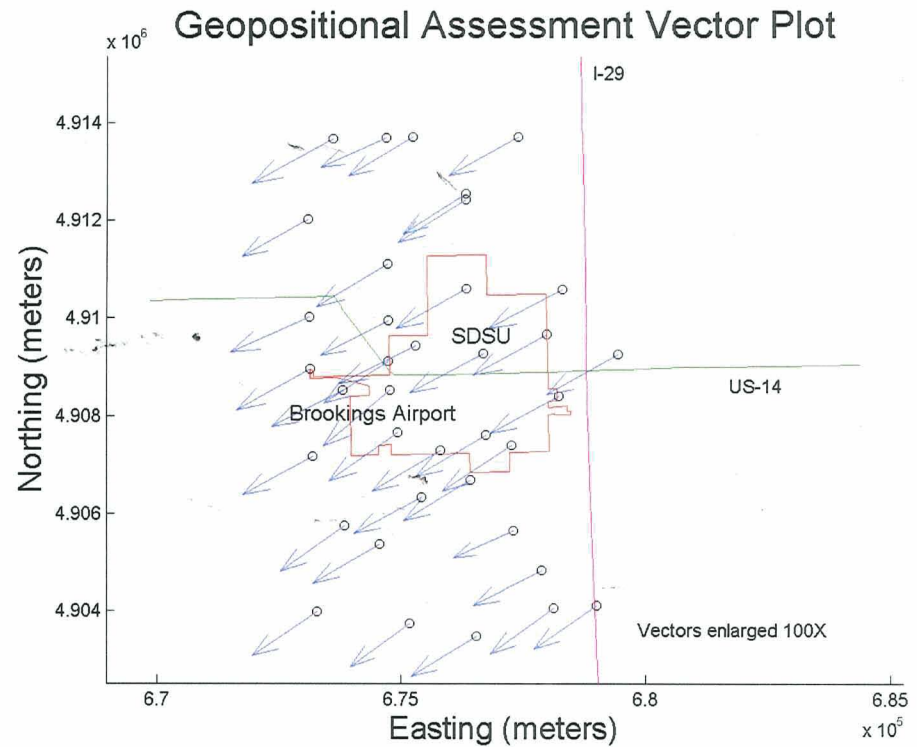


# Brookings, Sep 15, 2003 – MS Standard

Stennis Space Center

QuickBird					
<b>Acquisition Date</b>		9/15/2003	<b>Imagery Band</b>		MS
<b>Number Targets Used</b>		<b>Error Components</b>			
<i>n</i>	37	$\mu_H$ (Bias)	16.26 m		
<b>Test for Departure from Circular Distribution</b>		$\sigma_C$ (Circular Standard Error)	1.01 m		
<b>St. Dev. Min Max Ratio</b>	0.91	$\mu_H/\sigma_C$	16.17		
St. Dev. Min Max Ratio should be at least 0.6 for Circular Error assumptions.		If $\mu_H/\sigma_C$ is greater than 0.1, then error calculations should account for bias.			
Circular Error					
<b>Empirical CE<sub>90</sub></b>	17.34 m	<b>Empirical CE<sub>95</sub></b>	17.66 m		

**CE<sub>90</sub> 17.34 m**



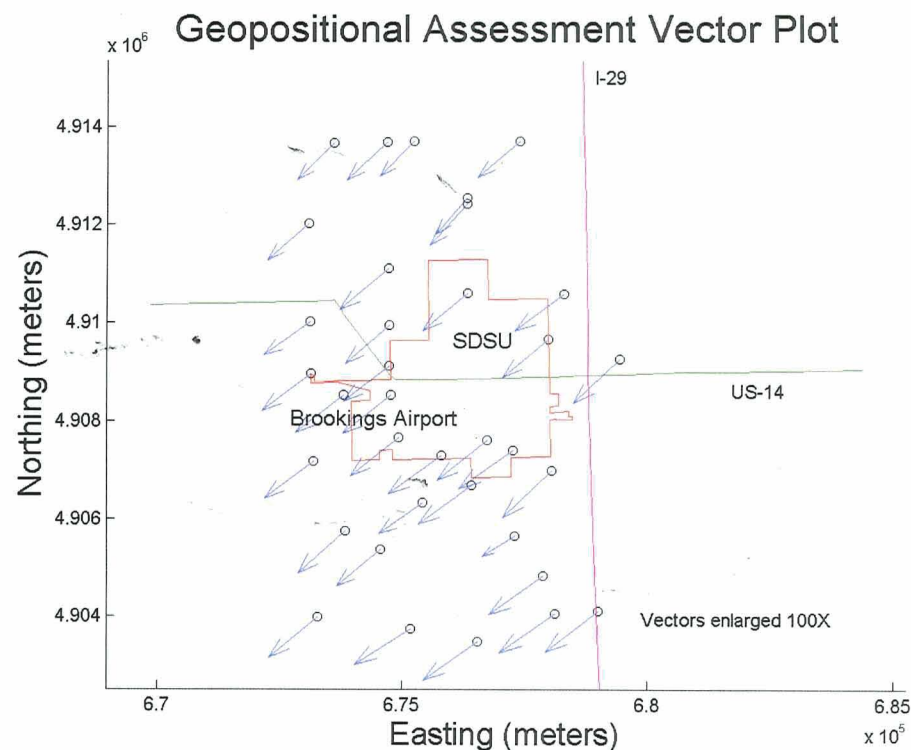


# Brookings, Oct 21, 2003 – PAN Standard

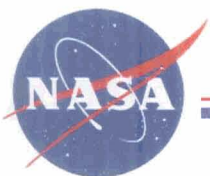
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QuickBird				
Acquisition Date		10/21/2003	Imagery Band PAN	
Number Targets Used		Error Components		
<i>n</i>	35	$\mu_H$ (Bias)	12.20 m	
Test for Departure from Circular Distribution		$\sigma_C$ (Circular Standard Error)	1.09 m	
St. Dev. Min	0.65	$\mu_H/\sigma_C$	11.18	
Max Ratio		St. Dev. Min Max Ratio should be at least 0.6 for Circular Error assumptions. If $\mu_H/\sigma_C$ is greater than 0.1, then error calculations should account for bias.		
Circular Error				
Empirical $CE_{90}$	13.63 m	Empirical $CE_{95}$	13.72 m	

**CE<sub>90</sub> 13.63 m**



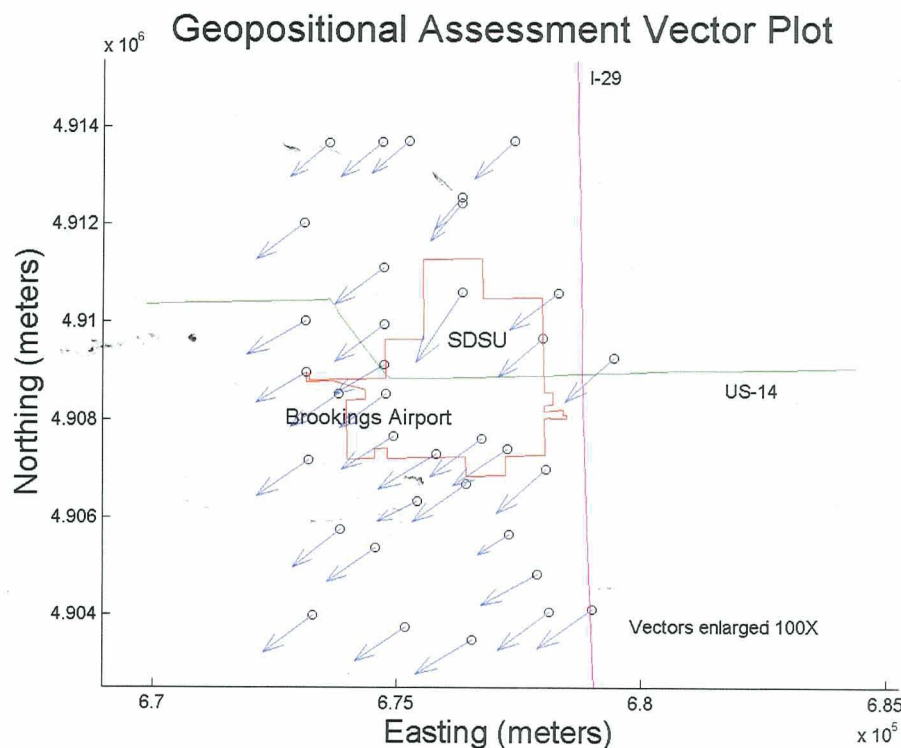




# Brookings, Oct 21, 2003 – MS Standard

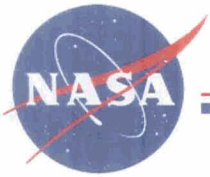
Stennis Space Center

QuickBird			
<b>Acquisition Date</b>		10/21/2003	<b>Imagery Band</b> MS
<b>Number Targets Used</b>		<b>Error Components</b>	
<i>n</i>	35	$\mu_H$ (Bias)	12.21 m
<b>Test for Departure from Circular Distribution</b>		$\sigma_C$ (Circular Standard Error)	1.53 m
<b>St. Dev. Min</b>	0.97	$\mu_H/\sigma_C$	7.97
<b>Max Ratio</b>		If $\mu_H/\sigma_C$ is greater than 0.1, then error calculations should account for bias.	
St. Dev. Min Max Ratio should be at least 0.6 for Circular Error assumptions.			
<b>Circular Error</b>			
<b>Empirical CE<sub>90</sub></b>	13.76 m	<b>Empirical CE<sub>95</sub></b>	13.77 m *



**CE<sub>90</sub> 13.76 m**

\* Note that CE<sub>90</sub> and CE<sub>95</sub> determined empirically can be almost equal if the outermost errors happen to be close

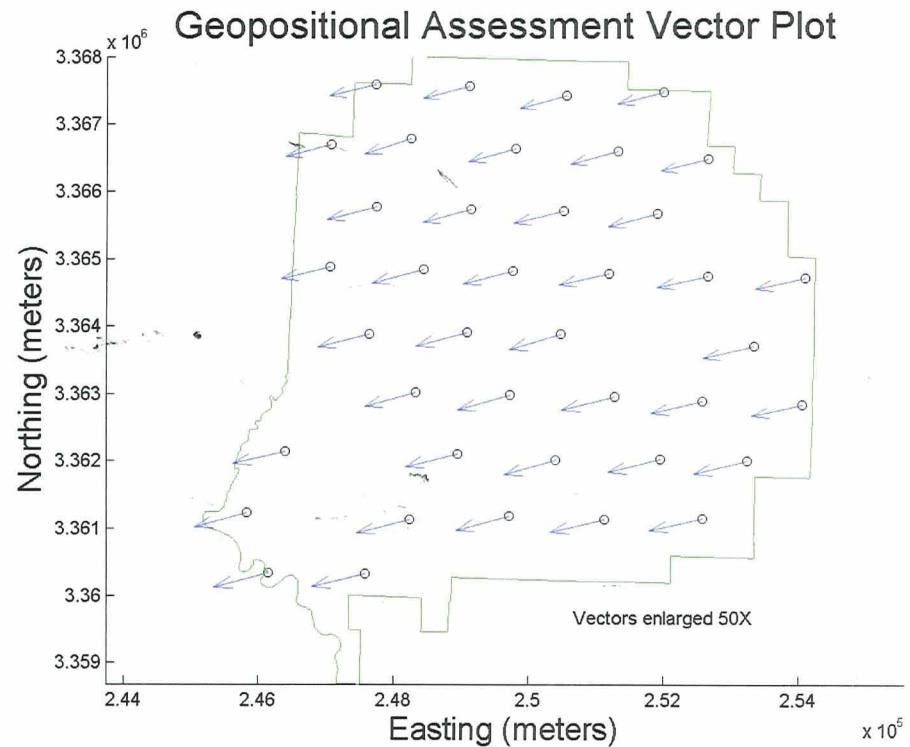


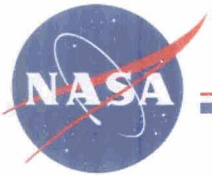
# SSC, Jan 10, 2004 – PAN Standard

Stennis Space Center

QuickBird			
<b>Acquisition Date</b>	1/10/2004	<b>Imagery Band</b>	PAN
<b>Number Targets Used</b>		<b>Error Components</b>	
<i>n</i>	40	$\mu_H$ (Bias)	15.41 m
<b>Test for Departure from Circular Distribution</b>		$\sigma_C$ (Circular Standard Error)	0.54 m
<b>St. Dev. Min Max Ratio</b>	0.41	$\mu_H/\sigma_C$	28.47
St. Dev. Min Max Ratio should be at least 0.6 for Circular Error assumptions.		If $\mu_H/\sigma_C$ is greater than 0.1, then error calculations should account for bias.	
<b>Circular Error</b>			
<b>Empirical CE<sub>90</sub></b>	16.27 m	<b>Empirical CE<sub>95</sub></b>	16.39 m

**CE<sub>90</sub> 16.27 m**



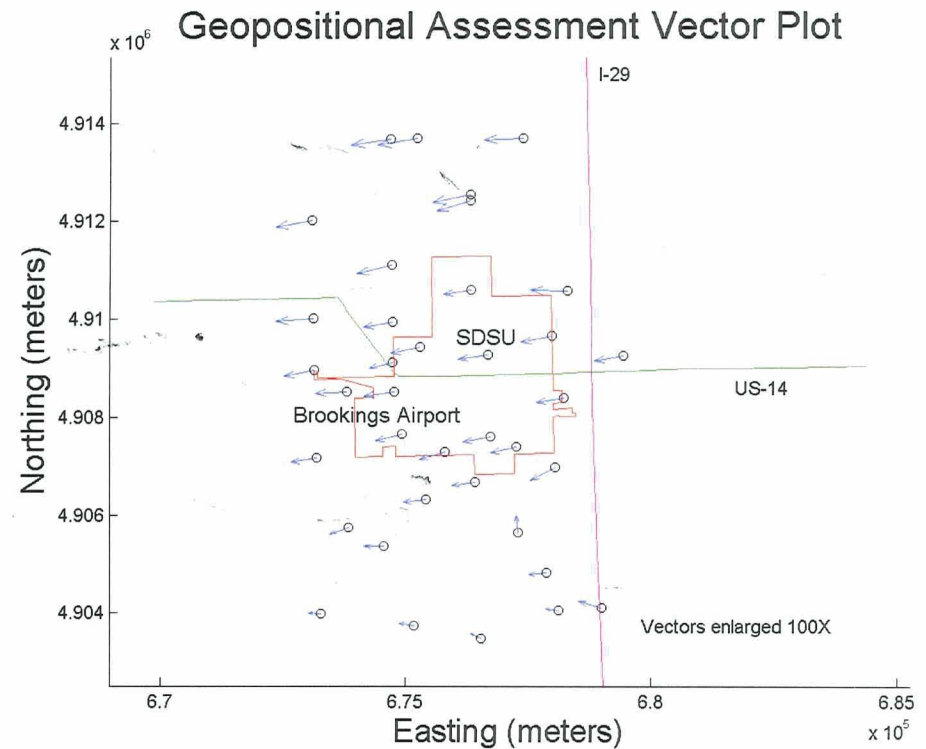


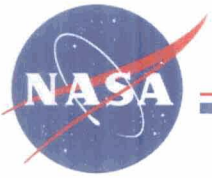
# Brookings, Aug 23, 2003 – PAN Orthorectified

Stennis Space Center

QuickBird			
<b>Acquisition Date</b>	8/23/2003	<b>Imagery Band</b>	PAN-ORTHO
<b>Number Targets Used</b>		<b>Error Components</b>	
<i>n</i>	37	$\mu_H$ (Bias)	5.52 m
<b>Test for Departure from Circular Distribution</b>		$\sigma_C$ (Circular Standard Error)	1.45 m
<b>St. Dev. Min Max Ratio</b>	0.63	$\mu_H/\sigma_C$	3.81
St. Dev. Min Max Ratio should be at least 0.6 for Circular Error assumptions.		If $\mu_H/\sigma_C$ is greater than 0.1, then error calculations should account for bias.	
Circular Error			
<b>Empirical <math>CE_{90}</math></b>	7.93 m	<b>Empirical <math>CE_{95}</math></b>	8.11 m

**$CE_{90}$  7.93 m**



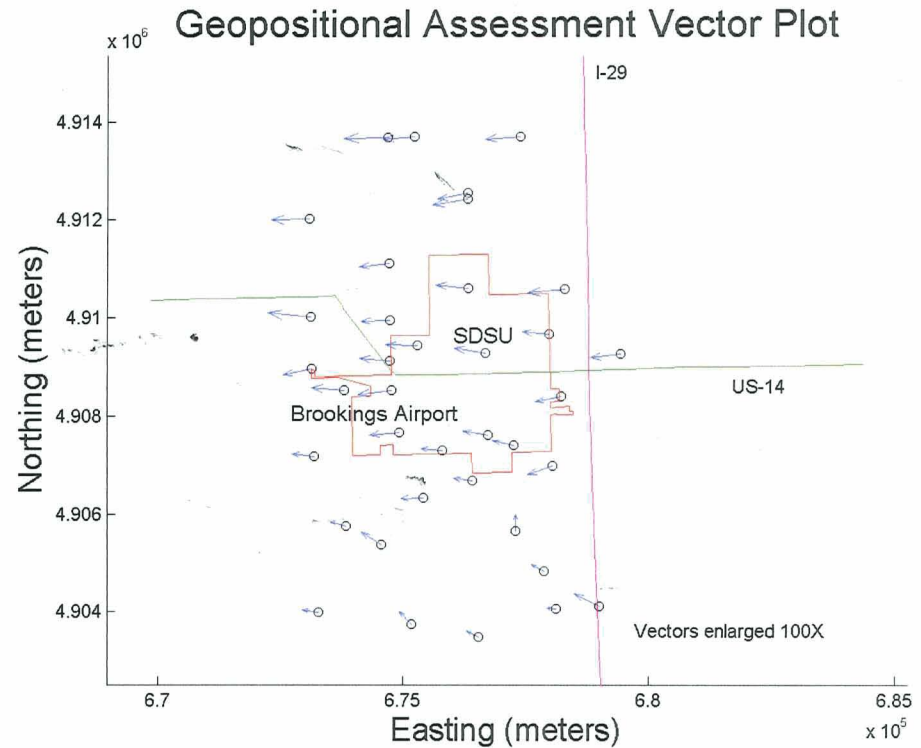


# Brookings, Aug 23, 2003 – MS Orthorectified

Stennis Space Center

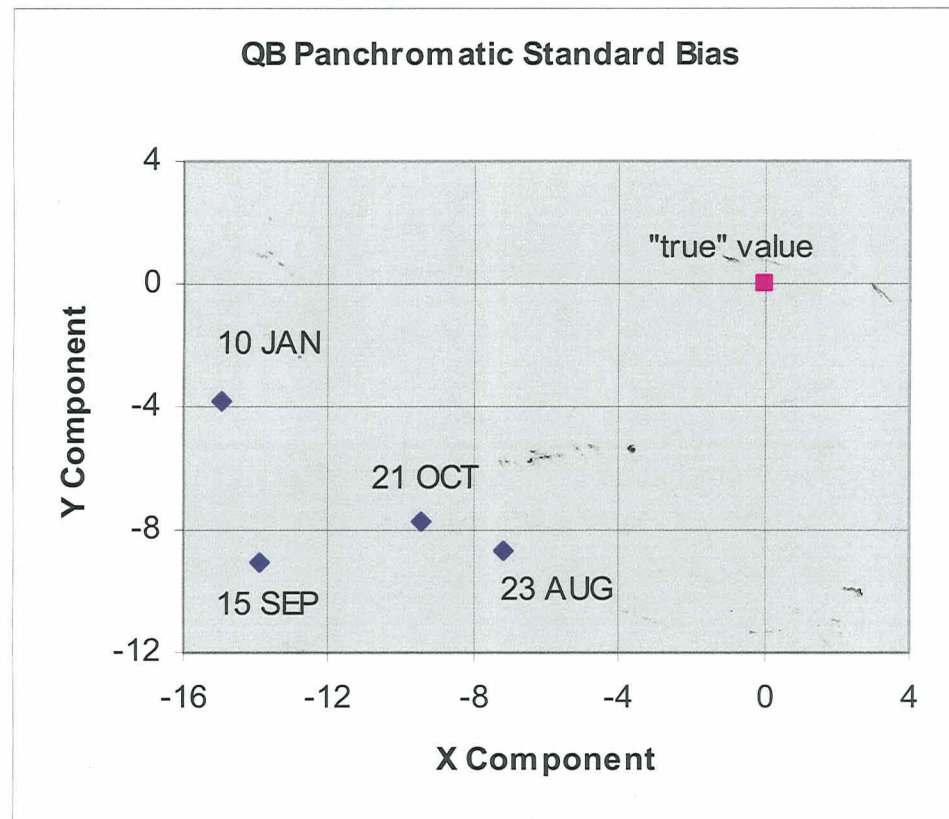
QuickBird			
<b>Acquisition Date</b>		8/23/2003	<b>Imagery Band</b> MS-ORTHO
<b>Number Targets Used</b>		<b>Error Components</b>	
<i>n</i>	37	$\mu_H$ (Bias)	5.34 m
<b>Test for Departure from Circular Distribution</b>		$\sigma_C$ (Circular Standard Error)	1.57 m
<b>St. Dev. Min</b>	0.63	$\mu_H/\sigma_C$	3.40
<b>Max Ratio</b>			
St. Dev. Min Max Ratio should be at least 0.6 for Circular Error assumptions.		If $\mu_H/\sigma_C$ is greater than 0.1, then error calculations should account for bias.	
Circular Error			
<b>Empirical CE<sub>90</sub></b>	7.50 m	<b>Empirical CE<sub>95</sub></b>	8.43 m

**CE<sub>90</sub> 7.50 m**

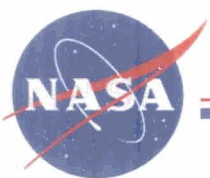




# Bias Trend



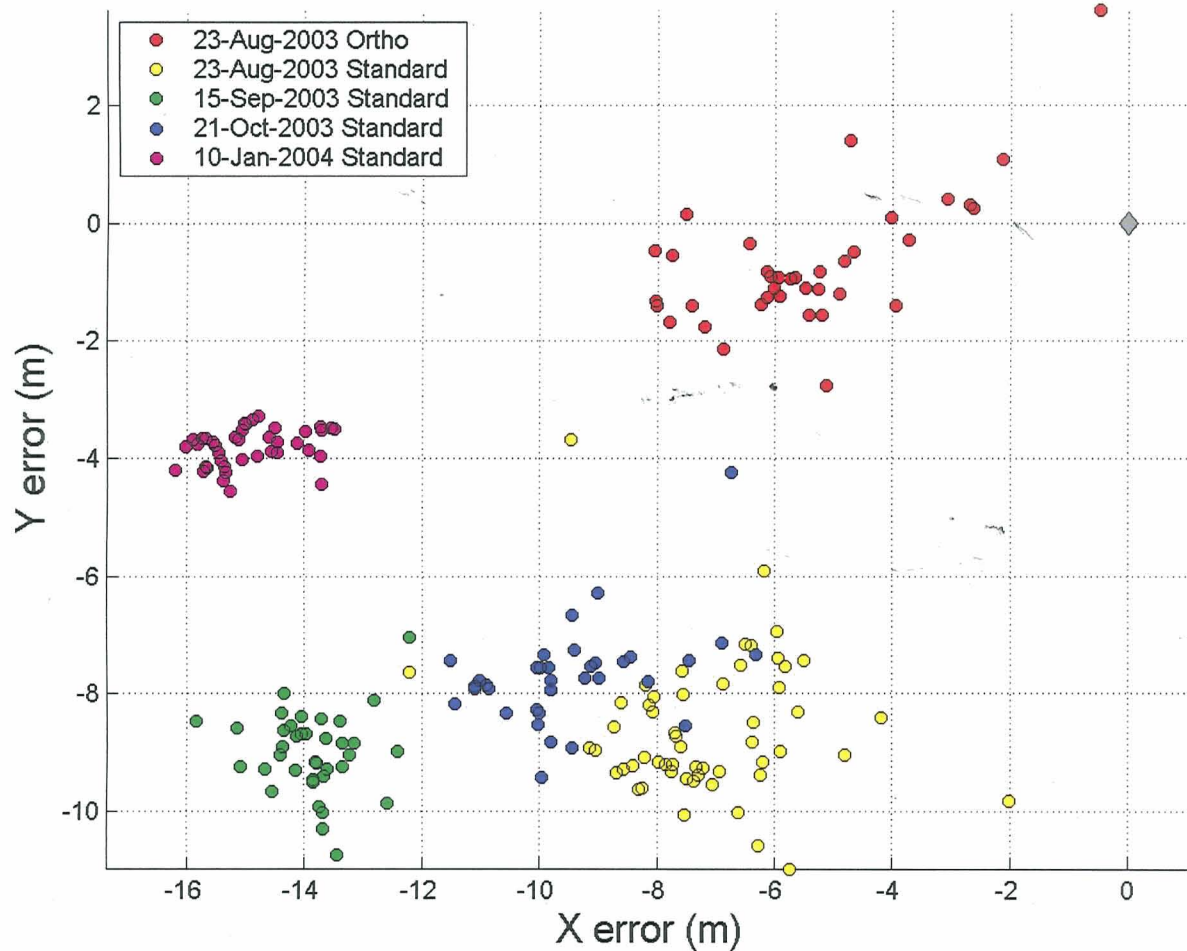
Bias trends to the southwest (with bias = image – reference) for all *Standard* images characterized



# QuickBird Error Scatterplot

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## QuickBird Scatterplot (PAN only)



# Summary



QuickBird Product	Acquisition Date	Empirical CE <sub>90</sub> (m)	Empirical CE <sub>95</sub> (m)	Elevation Angle (deg)
<b>Panchromatic <i>Standard</i></b>	8/23/2003	12.67	12.76	76.8
	9/15/2003	17.40	17.62	83.3
	10/21/2003	13.63	13.72	81.3
	1/10/2004	16.27	16.39	89.2
<b>Panchromatic <i>Orthorectified</i></b>	8/23/2003	7.93	8.11	76.8
<b>Multispectral <i>Standard</i></b>	8/23/2003	12.78	12.93	76.8
	9/15/2003	17.34	17.66	83.3
	10/21/2003	13.76	13.77	81.3
<b>Multispectral <i>Orthorectified</i></b>	8/23/2003	7.50	8.43	76.8

- The mean CE<sub>90</sub> of QuickBird panchromatic *Standard* images characterized was 15.0 m
  - 95% confidence interval from 11.5 m to 18.5 m
- The mean CE<sub>90</sub> of QuickBird multispectral *Standard* images characterized was 14.6 m
  - 95% confidence interval from 8.7 m to 20.6 m
- The single panchromatic *Orthorectified* image had CE<sub>90</sub> of 7.9 m, and the single multispectral *Orthorectified* image had CE<sub>90</sub> of 7.5 m
- All QuickBird images characterized in this reporting period met specifications
  - *Standard 2A*: CE<sub>90</sub> 23 m, *Orthorectified 3E*: CE<sub>90</sub> 8.3 m



# Extended QuickBird Summary

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QuickBird Product	Image Tracking ID	Acquisition Date	Bias X (m)	Bias Y (m)	$\mu_H$ - Bias (m)	$\sigma_C$ - Circular Standard Error (m)	Empirical CE <sub>90</sub> (m)	Empirical CE <sub>95</sub> (m)	Elevation Angle (deg)
<b>Panchromatic Standard</b>	75234	8/23/2003	-7.20	-8.63	11.24	1.33	12.67	12.76	76.8
	76412	9/15/2003	-13.86	-9.01	16.53	0.71	17.40	17.62	83.3
	83586	10/21/2003	-9.47	-7.70	12.20	1.09	13.63	13.72	81.3
	98196	1/10/2004	-14.93	-3.80	15.41	0.54	16.27	16.39	89.2
<b>Panchromatic Orthorectified</b>	88508	8/23/2003	-5.47	-0.71	5.52	1.45	7.93	8.11	76.8
<b>Multispectral Standard</b>	75234	8/23/2003	-6.94	-7.66	10.33	1.81	12.78	12.93	76.8
	76412	9/15/2003	-14.02	-8.23	16.26	1.01	17.34	17.66	83.3
	83586	10/21/2003	-9.76	-7.33	12.21	1.53	13.76	13.77	81.3
<b>Multispectral Orthorectified</b>	88508	8/23/2003	-5.33	0.31	5.34	1.57	7.50	8.43	76.8