



Know the Earth...Show the Way

Geolocation Accuracy Evaluations of OrbView-3, EROS-A, and SPOT-5 Imagery

Civil and Commercial Applications Project (CCAP)

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Civil Commercial Imagery Evaluation Workshop

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► Outline

- Objective
- General Approach
- Accuracy Statistics
- Methodology
- Evaluations and Results
 - GeoEye OrbView-3 orthorectified images
 - EROS-A
 - SPOT-5
- Summary

► Objective

For each imagery type...

To determine whether a sample of panchromatic commercial imagery products meet the vendor-stated absolute geolocation accuracy specifications

► General Approach

- Evaluate absolute geolocation accuracy by comparing test imagery-derived ground coordinates to Ground Control Points (GCPs)
- SOCET Set photogrammetric software used to...
 - Measure photo-identifiable check points
 - Compute ground coordinates from test imagery support data
 - Difference computed and truth coordinates

► Statistical Method

- Definitions
 - Circular Error 90% (CE90)
 - In horizontal plane
 - Radial error distance within which 90% of data points fall
 - Linear Error 90% (LE90)
 - In vertical dimension
 - Absolute value error distance within which 90% of data points fall
- Implementation
 - CE90 and LE90 estimated by taking 90th percentile of the ordered statistics
 - “An Analysis of Metric Accuracy: Definitions and Methods of Computation,” 29 March 2004, by Thomas P. Ager, NGA/AED

► Methodology

1) Import images into SOCET Set

- OrbView-3 orthorectified images in GeoTIFF format
- EROS-A images in National Imagery Transmission Format (NITF) 2.0
 - Rational Polynomial Coefficient (RPC) support data
- SPOT-5 images in Digital Image Map (DIMAP) format
 - Level 1A rigorous ephemeris and attitude support data
 - SPOT-5 rigorous sensor model implemented in SOCET Set
 - Level 3A images in GeoTIFF format

2) Images minified to support zooming

3) Test imagery-derived ground coordinates computed using pixel measurements and imagery support data

- For mono images...
 - Imagery-derived ground coordinate heights fixed at truth height values

► Methodology (cont.)

- 4) Check point deltas computed by subtracting truth ground coordinates from test imagery-derived ground coordinates
- 5) Deltas sorted in ascending order and cutoff at 90% to estimate CE90 / LE90 statistics
- 6) Additional statistics:
 - Number of check points
 - Min/max deltas
 - Mean
 - Standard deviation
 - Percentage of check points within specification

► Product Evaluations

- GeoEye OrbView-3 ORTHO
 - 1:50k ORTHO
 - 1:24k ORTHO
- ImageSat International EROS-A
 - Standard Mode Mono
- SPOT Image Corporation SPOT-5
 - Level 1A
 - Level 3A (orthorectified)



GeoEye OrbView-3 ORTHO Results

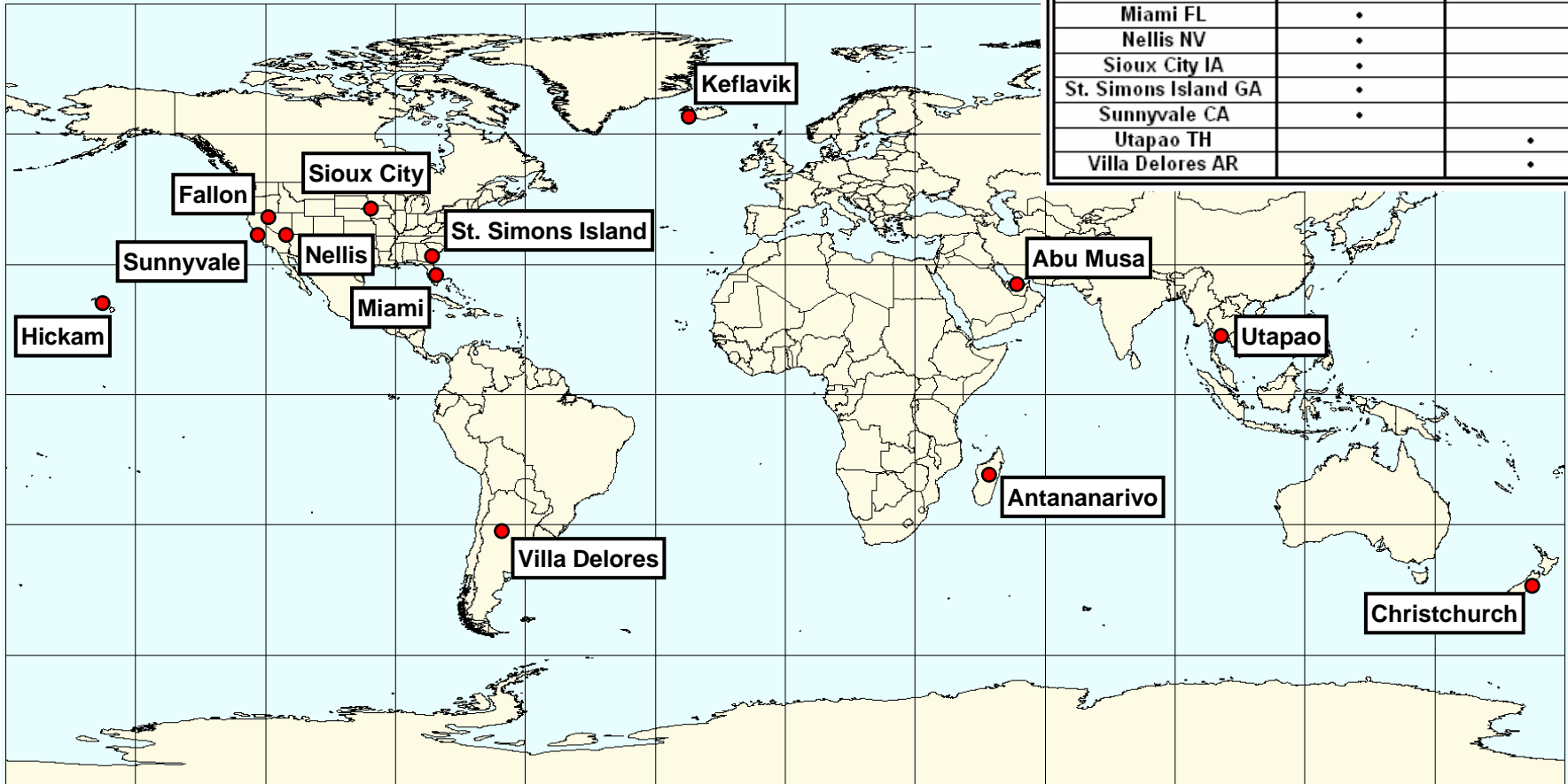
▶ GeoEye OrbView-3 ORTHO Imagery Product Characteristics

OrbView-3 Product Name	Accuracy Specification	Source of Image Geopositioning	Required Source of Elevation Data
	Horizontal (CE90)		
ORTHO 1:24k	12 meters	Tie Points between Overlapping Strips and GCPs	DTED [®] Level 2
ORTHO 1:50k	25 meters	Tie Points between Overlapping Strips	DTED [®] Level 1

- For CCAP Evaluation...
 - All products evaluated were 1 m panchromatic images
 - ORTHO 1:24k imagery products over Continental U.S. (CONUS)
 - GeoEye provided with GCPs and elevation data
 - CCAP evaluation excluded use of GCPs provided to GeoEye for product processing
 - ORTHO 1:50k imagery products Outside CONUS
 - GeoEye provided with elevation data

GeoEye OrbView-3 ORTHO Test Sites and Product Matrix

Test Site	1:24k ORTHO	1:50k ORTHO
	12 m CE90 Specification	25 m CE90 Specification
Abu Musa TC		•
Antananarivo MA		•
Christchurch NZ		•
Fallon NV	•	
Hickam HI		•
Keflavik IC		•
Miami FL	•	
Nellis NV	•	
Sioux City IA	•	
St. Simons Island GA	•	
Sunnyvale CA	•	
Utapao TH		•
Villa Delores AR		•



▶ GeoEye OrbView-3 ORTHO

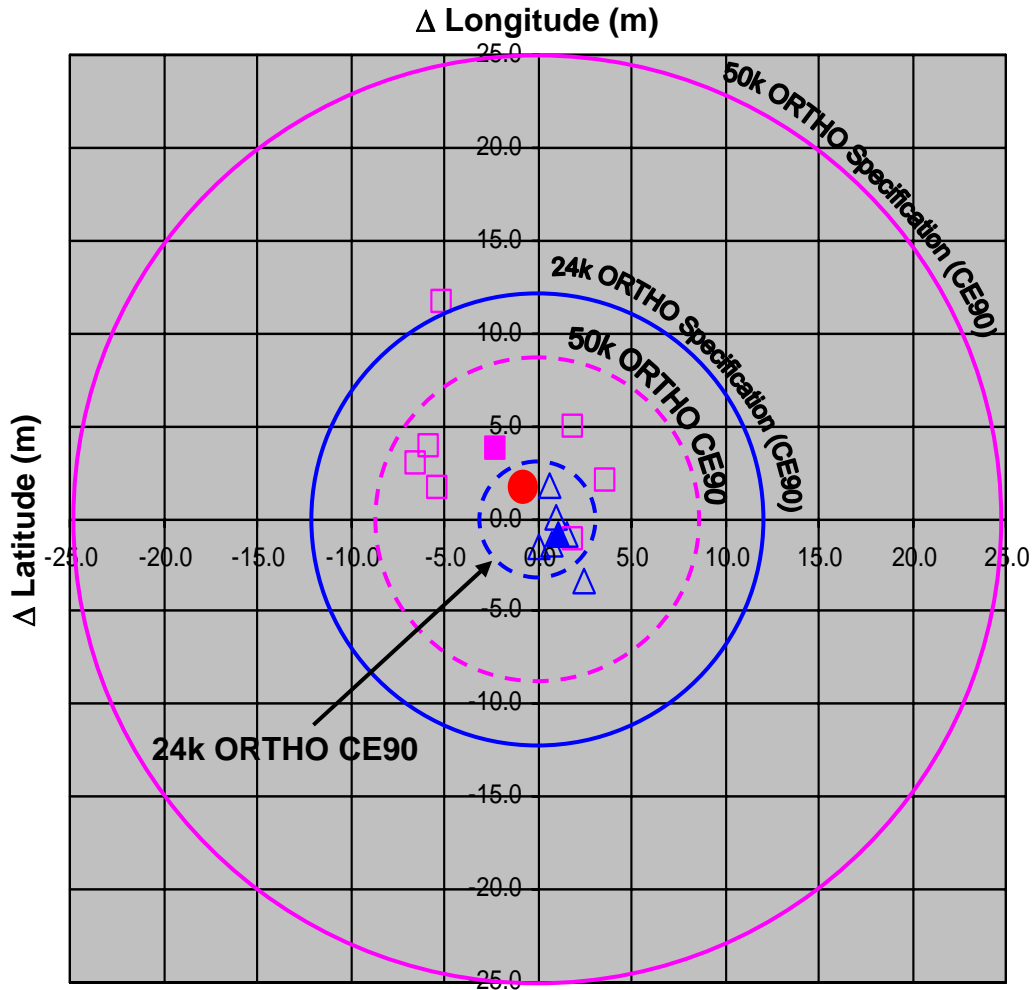
1:24k and 1:50k ORTHO Results

Test Site	Product Level	Collection Date	DPs	Absolute CE90 (m)	Mean Δ Long. (X) (m)	Mean Δ Lat. (Y) (m)
				90% Cutoff		
Abu Musa	50k	25-Mar-2004	32	5.6	3.67	2.08
Antananarivo	50k	18-Jul-2004	21	8.1	-5.85	3.85
Christchurch	50k	16-Dec-2003	27	8.2	-5.35	1.65
Fallon	24k	19-Jan-2004	24	3.2	0.67	1.83
Hickam	50k	15-Dec-2003	47	10.3	-6.48	2.96
Keflavik	50k	28-Apr-2004	18	3.4	1.86	-1.11
Miami	24k	24-Jan-2004	16	2.9	0.01	-1.52
Nellis	24k	17-Dec-2003	41	2.7	0.97	0.11
Sioux City	24k	12-Mar-2004	35	6.4	2.47	-3.32
St. Simons Island	24k	29-May-2004	25	2.7	1.50	-0.80
Sunnyvale	24k	16-Dec-2003	17	3.0	0.77	-1.37
Utapao	50k	21-Dec-2003	30	6.5	1.93	4.92
Villa Delores	50k	19-Jan-2004	30	14.8	-5.15	11.61
Site Means (All)			13	7.1	-0.69	1.61
Site Means (24k Only)			6	2.8	1.07	-0.85
Site Means (50k Only)			7	8.8	-2.20	3.71

- Using each image mean bias as a single data point...
 - 24k ORTHO absolute CE90 assessed to be 2.8 m
 - 50k ORTHO absolute CE90 assessed to be 8.8 m

GeoEye OrbView-3 ORTHO

1:24k and 1:50k ORTHO Scatter Plot



OrbView-3 Orthos

- △ 24k ORTHO Means
- 50k ORTHO Means
- Mean of All Means
- ▲ Mean of 24k Means
- Mean of 50k Means



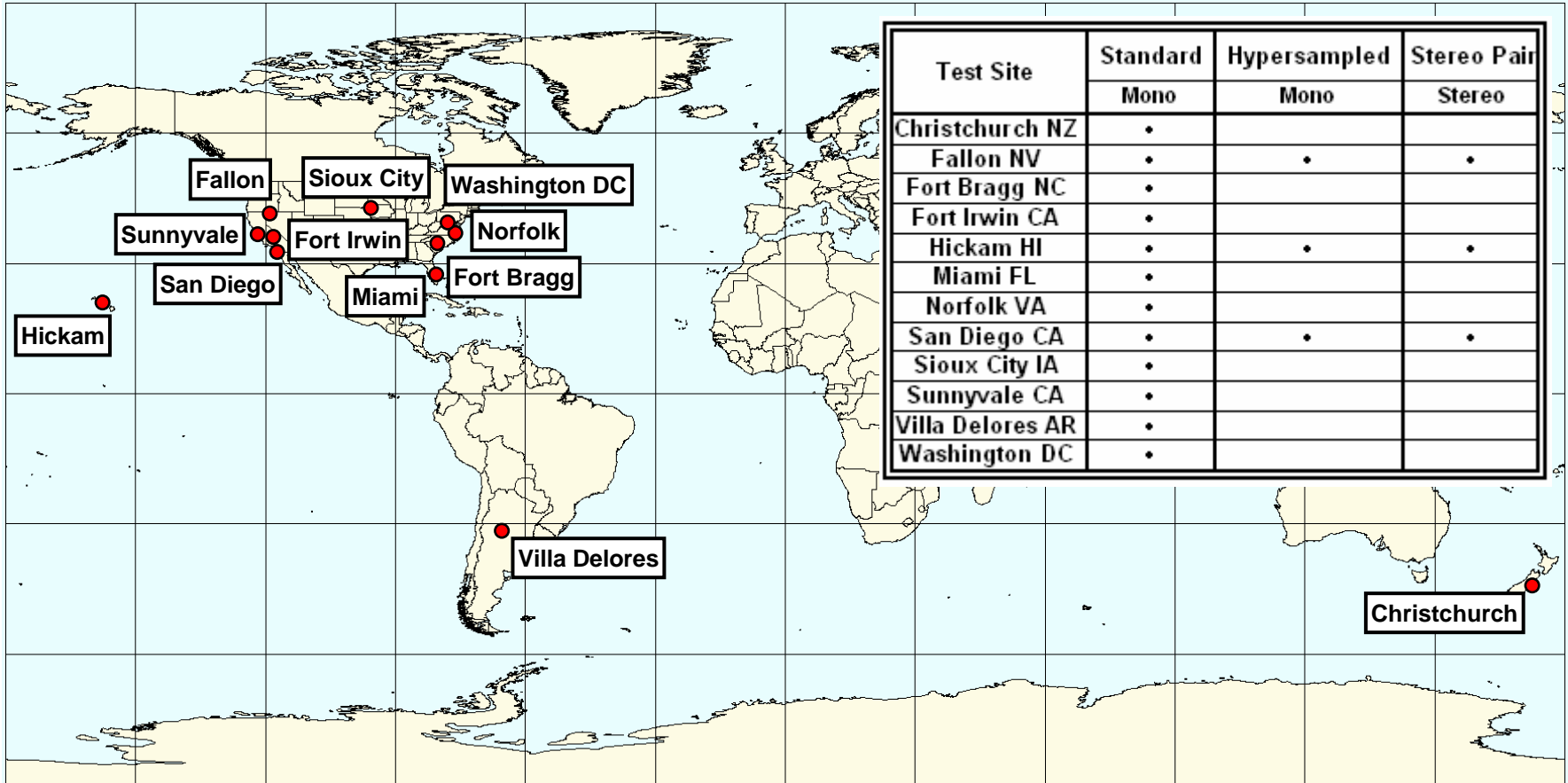
ImageSat International EROS-A

► ImageSat International EROS-A Imagery Product Characteristics

EROS A Product	Processing	Scene Size (km)	GSD (m)	Geolocation Accuracy
Standard Mode Mono	"Plane-rectified" to Base Elevation	10 x 10	1.8	Depends upon number and accuracy of GCPs used by ImageSat International for product generation
Hypersampled Mode Mono		7 x 7	1.0	
Standard Mode Stereo (not relatively oriented)		10 x 10	1.8	

- Evaluated panchromatic images only

ImageSat International EROS-A Test Sites and Product Matrix

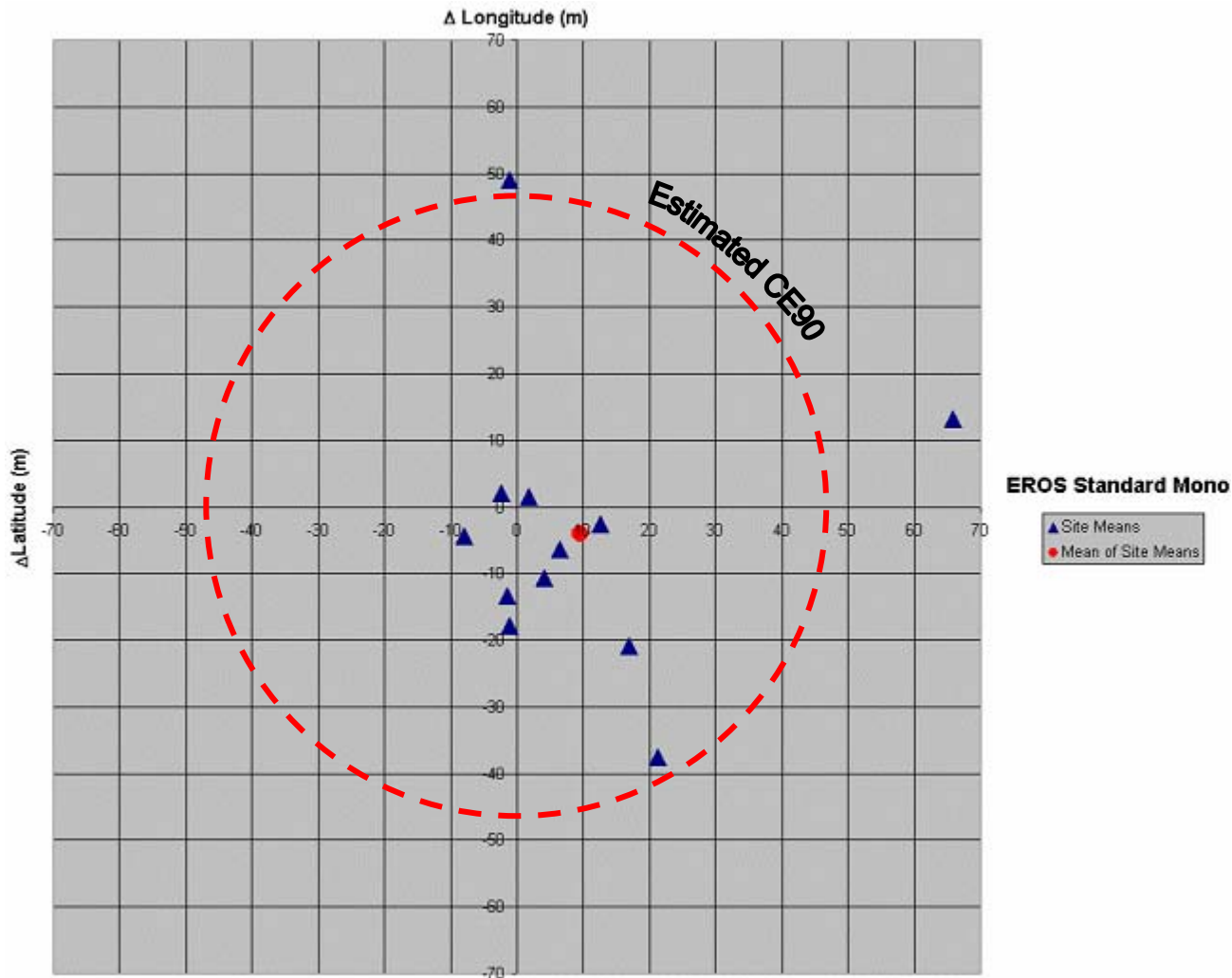


ImageSat International EROS-A Standard Mode Mono Results

Test Site	Image Identifier	Collection Date	DPs	Absolute CE90 (m)	Mean Δ Long. (X) (m)	Mean Δ Lat. (Y) (m)
				90% Cutoff		
Christchurch	JPN1-E1166261	28-Nov-2003	2	28.5	17.0	-21.0
Fallon	MBT1-E1166994	3-Dec-2003	9	7.6	-2.4	2.1
Fort Bragg	MBT1-E1187841	8-Apr-2004	13	12.1	-8.0	-4.4
Fort Irwin	MBT1-E1186641	10-Apr-2004	3	12.9	4.2	-10.7
Hickam	TAW1-E1172051	5-Jan-2004	10	16.2	-1.4	-13.3
Miami	MBT1-E1186322	8-Apr-2004	10	69.1	65.8	13.2
Norfolk	MBT1-E1191183	10-May-2004	4	12.2	6.4	-6.3
San Diego	MBT1-E11887403	15-Apr-2004	3	47.4	21.4	-37.5
Sioux City	MBT1-E1190424	5-May-2004	10	16.5	12.7	-2.6
Sunnyvale	MBT1-E1188764	24-Apr-2004	8	4.0	1.8	1.6
Villa Delores	ARG1-E1175484	28-Jan-2004	6	52.2	-1.2	49.0
Washington DC	MBT1-E1190272	4-May-2004	6	21.4	-1.1	-17.8
Site Means			12	47.8	9.6	-4.0

- Using each image mean bias as a single data point...
 - Standard Mode Mono absolute CE90 assessed to be 47.8 m

ImageSat International EROS-A Standard Mode Mono Scatter Plot





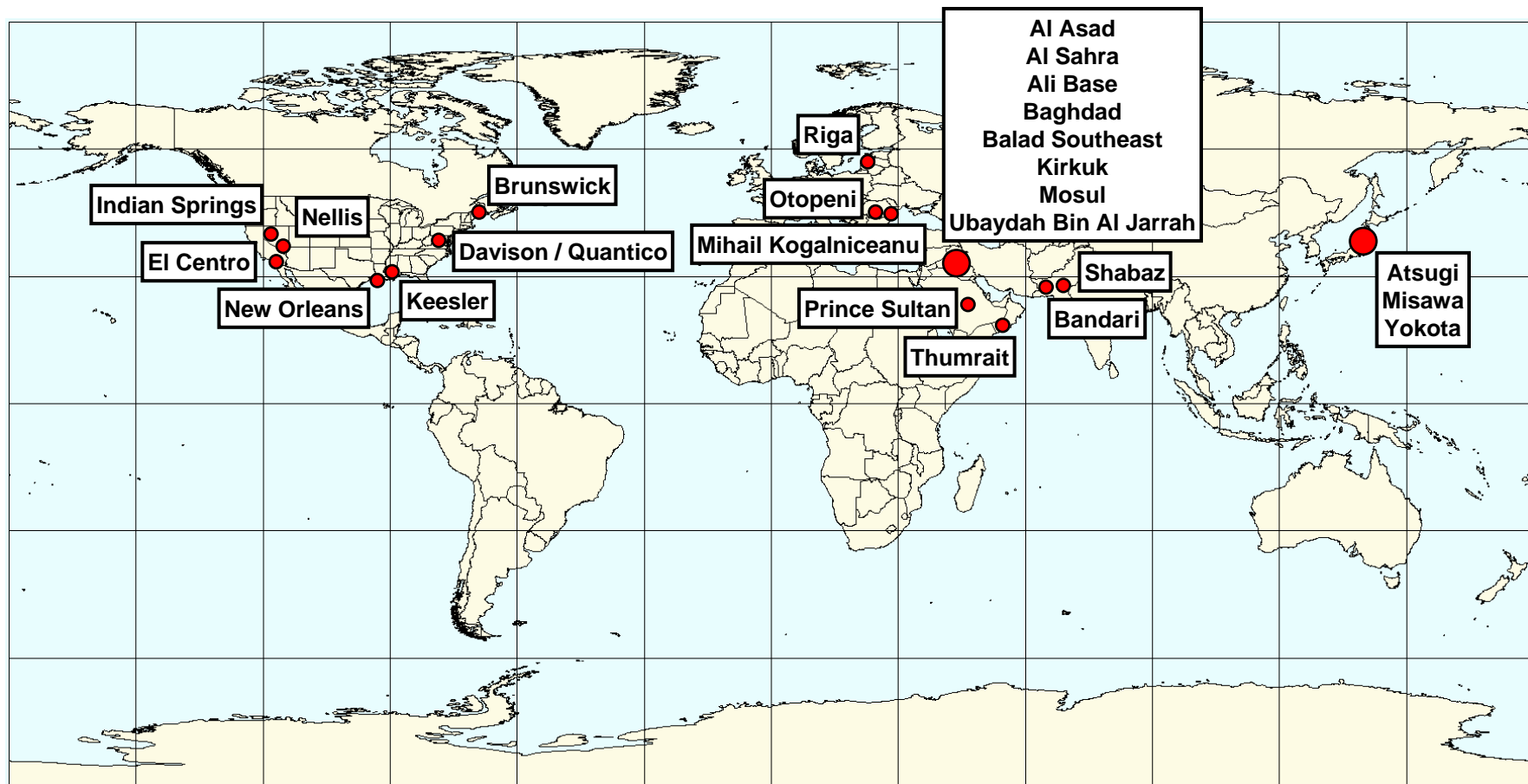
SPOT Image Corporation SPOT-5 Results

▶ SPOT Image Corporation SPOT-5 Imagery Product Characteristics

SPOT-5 Product Name	Geometric Processing	GSD (m)	Scene Size (km)	Horizontal Accuracy Specification		Source of Image Geopositioning	Source of Elevation Data
				1 σ (m)	Equivalent CE90 (m)		
Level 1A	Raw	2.5 or 5.0	60 x 60	50	107.3	Post-Processed Satellite Telemetry Data	Not Applicable
Level 3A	Orthorectified	2.5 or 5.0	60 x 60	15	32.2	SPOT Image Corporation Ground Control Points	SPOT Image Corporation Reference3D (similar to DTED Level 2)

- For CCAP Evaluation...
 - Evaluated panchromatic images only
 - Evaluated both 2.5 m and 5 m Ground Sampled Distance (GSD) imagery products
 - Some imagery products provided by SPOT Image Corporation and some obtained from Commercial Satellite Imagery Library (CSIL)

▶ SPOT Image Corporation SPOT-5 25 Test Sites



- 55 Imagery Products
 - 33 x 2.5m Level 1A and 14 x 5m Level 1A
 - 6 x 2.5m Level 3A and 2 x 5m Level 3A

▶ SPOT Image Corporation SPOT-5 Product Matrix

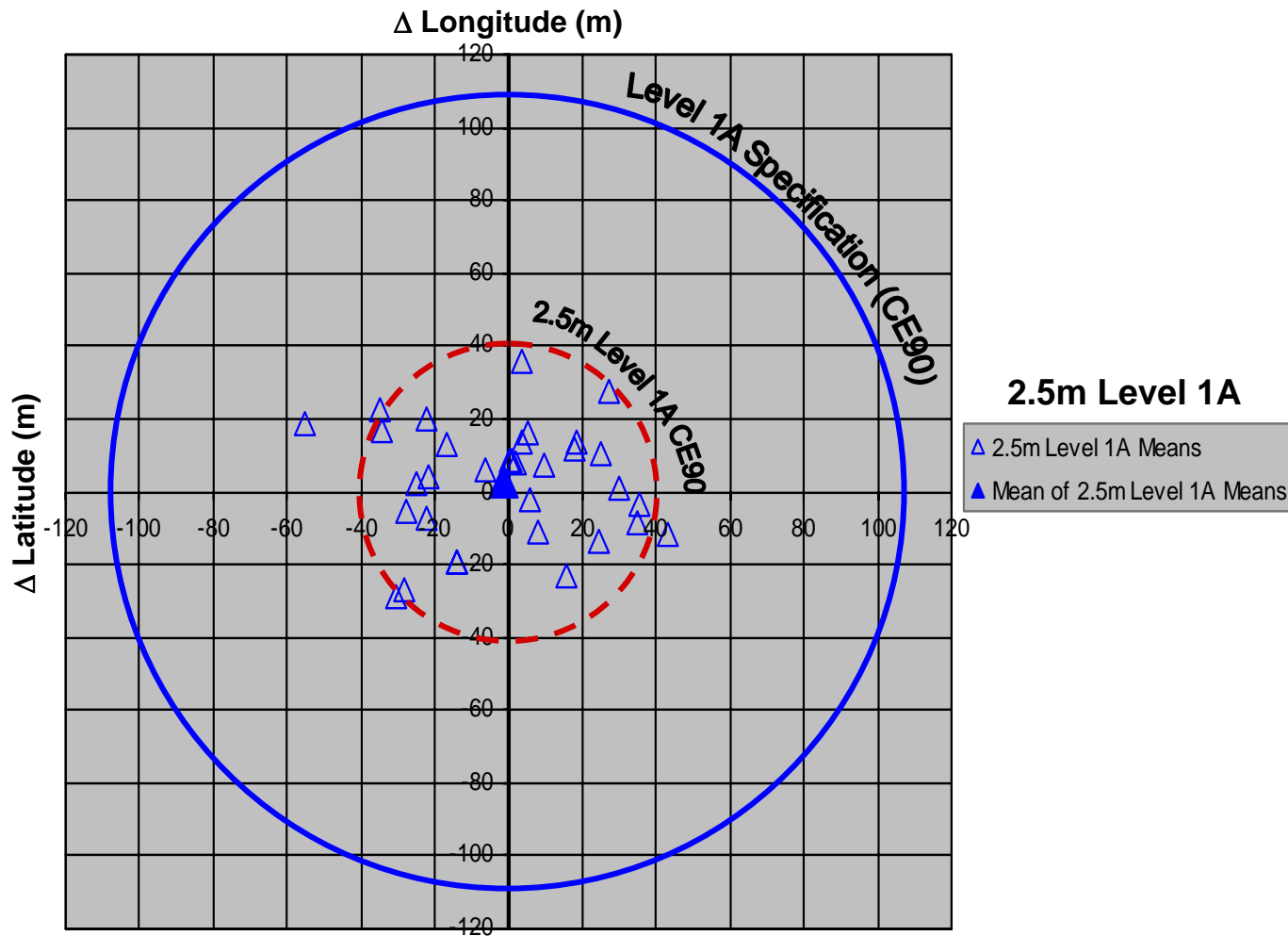
Test Site	Level 1A (Mono)		Level 3A (Mono)	
	2.5 m	5 m	2.5 m	5 m
Al Asad, Iraq	1		1	
Al Sahra, Iraq	3			1
Ali Base, Iraq	3		1	
Atsugi, Japan	1	1		
Baghdad, Iraq	1		1	
Balad Southeast, Iraq	2			
Bandari, Pakistan	1	1	1	
Brunswick NAS, Maine, USA	1			
Davison AAF / Quantico MCAF, Virginia, USA				1
El Centro NAF, California, USA	1	1		
Indian Springs AF Aux, Nevada, USA	1	1		
Keesler AFB, Mississippi, USA	2			
Kirkuk, Iraq	2			
Mihail Kogalniceanu, Romania		1		
Misawa, Japan	1	1		
Mosul, Iraq	2			
Nellis AFB, Nevada, USA	1	1		
New Orleans, Louisiana, USA	3			
Otopeni, Romania		1		
Prince Sultan, Saudi Arabia	1	1		
Riga, Latvia	1	1		
Shabaz, Pakistan	1	1	1	
Thumrait, Oman	1	1		
Ubaydah Bin Al Jarrah, Iraq	2	1	1	
Yokota, Japan	1	1		

▶ SPOT Image Corporation SPOT-5 2.5m Level 1A Results

Test Site	Collection Date	K	J	DPs	Absolute CE90 (m)	Mean Δ Long. (X) (m)	Mean Δ Lat. (Y) (m)
					90 % Cutoff		
Al Asad, Iraq	9-May-2003	133	282	12	31.1	-22.3	20.1
Al Sahra, Iraq	14-Oct-2002	135	280	6	25.9	-14.1	-19.4
	14-Oct-2002	135	281	10	25.7	-13.9	-19.2
	25-Jun-2003	134	280	10	24.0	-21.8	4.1
Ali Base, Iraq	25-Oct-2002	142	288	12	10.8	-6.4	6.3
	4-Nov-2002	141	288	12	59.9	-55.4	18.7
	30-Apr-2003	142	288	12	26.8	-24.8	2.2
Atsugi, Japan	5-May-2005	330	279	8	9.8	1.9	7.9
Baghdad, Iraq	5-Feb-2003	137	283	12	39.3	-28.2	-26.6
Balad Southeast, Iraq	2-Sep-2002	136	282	8	37.0	3.6	35.7
	5-Feb-2003	137	282	17	43.4	-30.7	-28.7
Bandari, Pakistan	15-Apr-2005	182	294	14	7.5	5.5	-2.0
Brunswick NAS, Maine, USA	10-Aug-2005	633	261	7	14.5	3.3	13.3
El Centro NAF, California, USA	26-Jun-2005	547	284	15	37.4	34.8	-8.3
Indian Springs AF Aux, Nevada, USA	26-Jun-2005	545	276	15	15.3	8.0	-10.9
Keesler AFB, Mississippi, USA	27-Dec-2004	603	289	16	43.0	-35.1	22.6
	3-Sep-2005	604	289	7	39.9	-34.5	17.0
Kirkuk, Iraq	2-Sep-2002	136	279	11	13.5	9.7	7.1
	9-Jun-2003	135	279	12	28.4	25.1	10.5
Misawa, Japan	17-Jun-2004	331	268	13	46.0	43.1	-11.8
Mosul, Iraq	14-Jun-2003	133	277	10	18.7	5.2	16.0
	19-Jun-2003	132	277	11	40.2	27.1	27.7
Nellis AFB, Nevada, USA	21-Jun-2005	546	277	16	25.5	-22.4	-7.5
New Orleans, Louisiana, USA	17-Aug-2005	601	290	11	23.0	-16.6	12.8
	22-Aug-2005	601	290	18	24.7	18.6	13.8
	7-Sep-2005	601	290	14	30.3	-28.0	-5.4
Prince Sultan, Saudi Arabia	9-Jun-2004	149	302	9	36.4	35.5	-3.2
Riga, Latvia	16-Apr-2004	077	234	16	11.2	0.3	8.8
Shabaz, Pakistan	7-May-2005	189	293	17	23.3	18.1	11.5
Thumrait, Oman	7-Feb-2004	165	315	13	29.2	15.9	-23.3
Ubaydah Bin Al Jarrah, Iraq	17-Apr-2005	140	285	13	28.9	24.2	-13.8
	22-Mar-2004	140	285	13	30.8	29.8	0.8
Yokota, Japan	5-May-2005	330	278	10	9.6	0.7	8.5
Site Means				33	40.8	-1.3	2.6

- Using each image mean bias as a single data point...
 - 2.5m Level 1A absolute CE90 assessed to be 40.8 m

▶ SPOT Image Corporation SPOT-5 2.5m Level 1A Scatter Plot

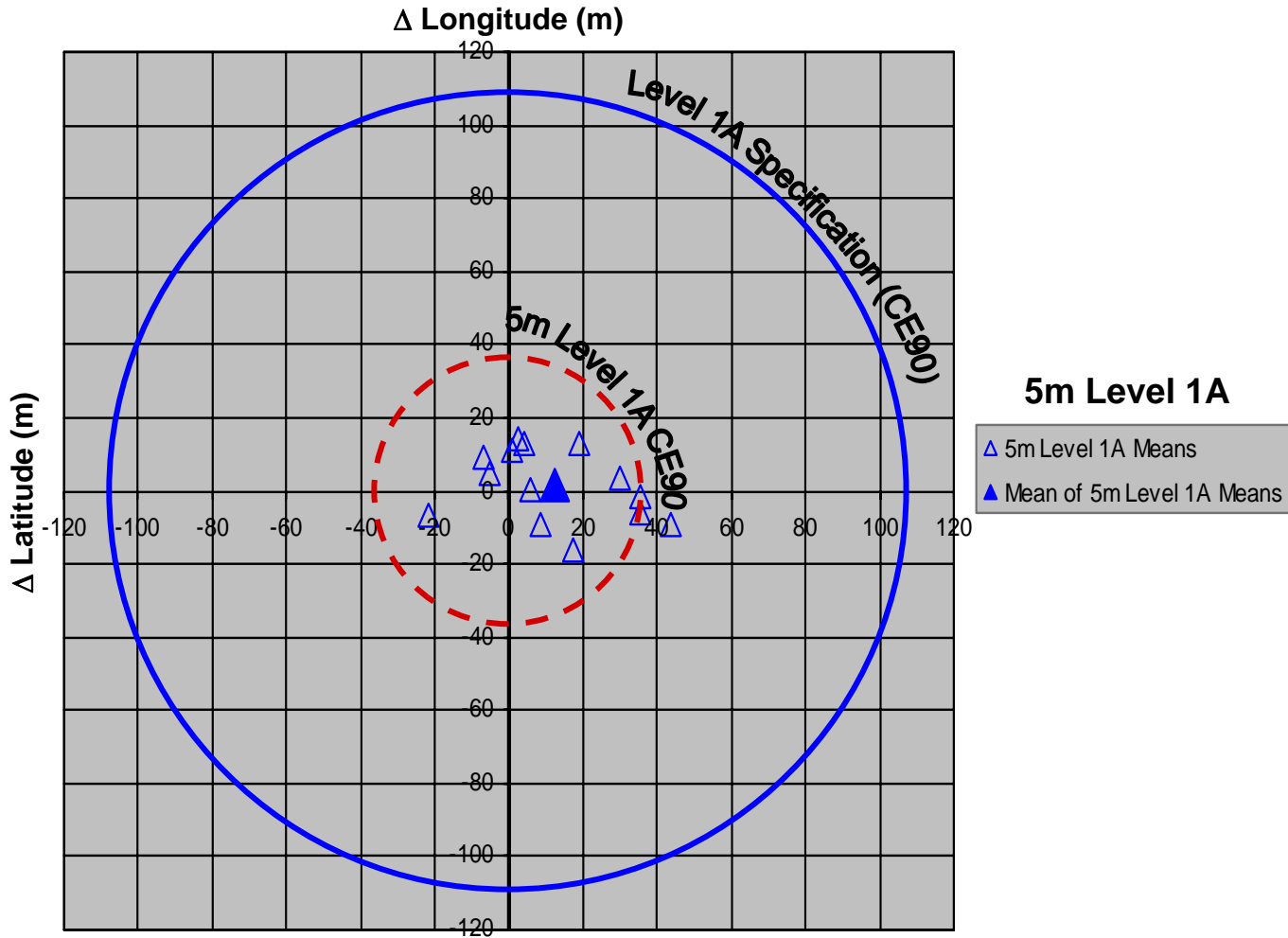


▶ SPOT Image Corporation SPOT-5 5m Level 1A Results

Test Site	Collection Date	K	J	DPs	Absolute CE90 (m)	Mean Δ Long. (X) (m)	Mean Δ Lat. (Y) (m)
					90% Cutoff		
Atsugi, Japan	5-May-2005	330	279	8	17.6	4.0	12.9
Bandari, Pakistan	15-Apr-2005	182	294	14	8.8	6.0	0.4
El Centro NAF, California, USA	26-Jun-2005	547	284	15	37.7	35.4	-5.9
Indian Springs AF Aux, Nevada, USA	26-Jun-2005	545	276	15	15.1	8.7	-9.1
Mihail Kogalniceanu, Romania	24-Jan-2005	097	261	9	8.8	-5.1	4.7
Misawa, Japan	17-Jun-2004	331	268	13	45.9	43.7	-9.3
Nellis AFB, Nevada, USA	21-Jun-2005	546	277	16	24.7	-21.8	-6.7
Otopeni, Romania	1-Oct-2004	092	260	13	12.9	-7.1	9.0
Prince Sultan, Saudi Arabia	9-Jun-2004	149	302	9	37.2	35.6	-1.3
Riga, Latvia	16-Apr-2004	077	234	16	14.6	1.0	11.2
Shabaz, Pakistan	7-May-2005	189	293	17	25.8	18.7	12.9
Thumrait, Oman	7-Feb-2004	165	315	13	25.2	17.5	-16.0
Ubaydah Bin Al Jarrah, Iraq	22-Mar-2004	140	285	13	31.6	30.1	3.2
Yokota, Japan	5-May-2005	330	278	10	16.1	2.4	14.5
Site Means				14	35.8	12.1	1.5

- Using each image mean bias as a single data point...
 - 5m Level 1A absolute CE90 assessed to be 35.8 m

▶ SPOT Image Corporation SPOT-5 5m Level 1A Scatter Plot

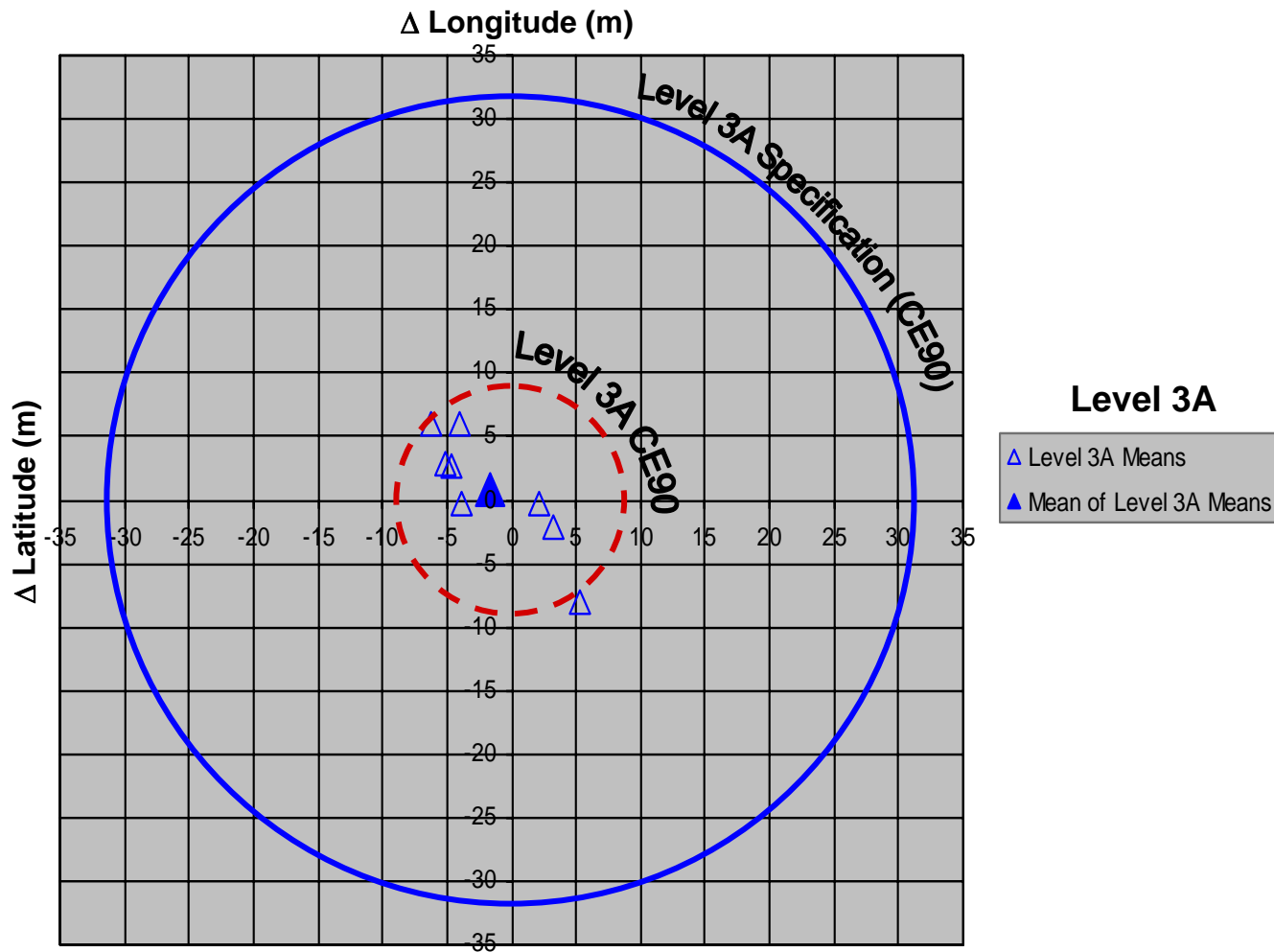


▶ SPOT Image Corporation SPOT-5 Level 3A Results

Test Site	GSD (m)	Collection Date	K	J	DPs	Absolute CE90 (m)	Mean Δ Long. (X) (m)	Mean Δ Lat. (Y) (m)
						90% Cutoff		
Al Asad, Iraq	2.5	9-May-2003	133	282	12	9.9	-6.2	6.0
Al Sahra, Iraq	5	25-Jun-2003	134	280	11	7.3	-5.2	2.8
Ali Base, Iraq	2.5	30-Apr-2003	142	288	12	5.3	-3.8	-0.2
Baghdad, Iraq	2.5	5-Feb-2003	137	283	13	8.5	-4.1	6.0
Bandari, Pakistan	2.5	15-Apr-2005	182	294	14	5.3	3.2	-2.2
Davison AAF / Quantico MCAF, Virginia, USA	5	13-Oct-2003	622	271	8	14.1	5.3	-8.0
Shabaz, Pakistan	2.5	7-May-2005	189	293	17	5.3	2.2	-0.2
Ubaydah Bin Al Jarrah, Iraq	2.5	22-Mar-2004	140	285	13	6.2	-4.6	2.6
Site Means					8	8.8	-1.7	0.8

- Combined 2.5m and 5.m images into single statistic
- Using each image mean bias as a single data point...
 - Level 3A absolute CE90 assessed to be 8.8 m

▶ SPOT Image Corporation SPOT-5 Level 3A Scatter Plot



► Summary

- GeoEye OrbView-3 ORTHO
 - ORTHO 24k and ORTHO 50k panchromatic products met vendor-stated absolute accuracy specifications
- ImageSat International EROS-A
 - Absolute CE90 assessed for Standard Mode Mono panchromatic products
- SPOT Image Corporation SPOT-5
 - Level 1A and Level 3A panchromatic products met vendor-stated absolute accuracy specifications

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➤ *Know the Earth...Show the Way*

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