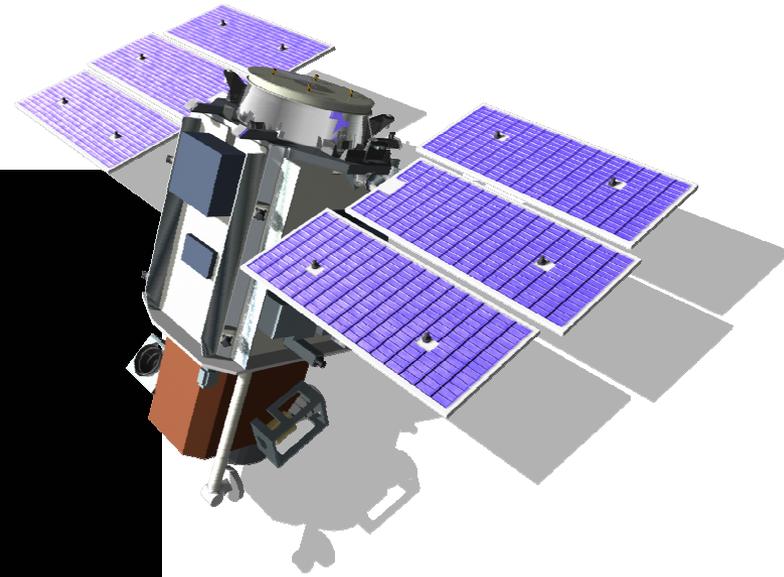


QuickBird Post Launch Geopositional Characterization Update



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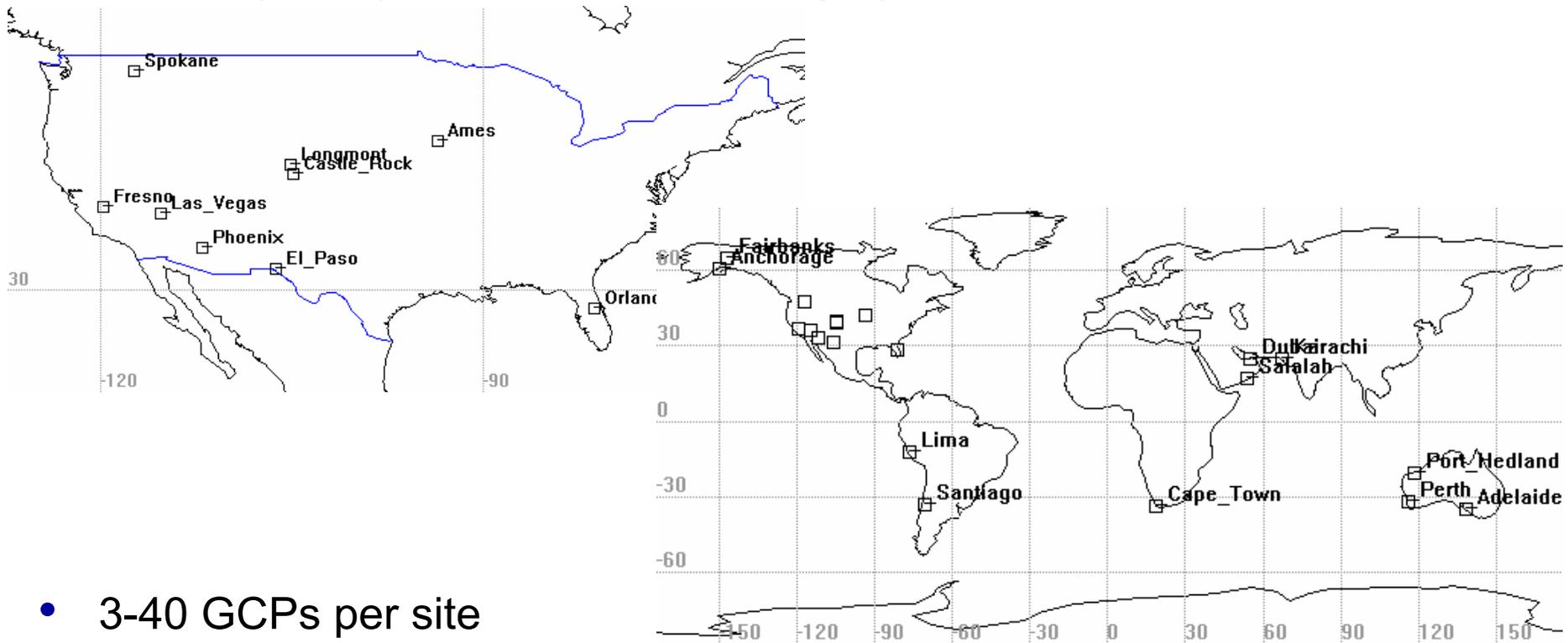
Quick Bird 60-cm Natural Color Image
Ras Tanurah, Saudi Arabia

QuickBird Geolocation Accuracy

- QuickBird Basic Products satisfy 23m CE90 specification
 - at nadir, excluding terrain effects
 - correction with GCPs can greatly increase the accuracy
- Average Geolocation Accuracies (over images in test set) :
 - Absolute Accuracy: 13.3 m CE90 (uncorrected products)
 - 1σ of Absolute Errors: 1.5m
 - Relative Accuracy: 4.7 m CE90
- Improvements :
 - Attitude Determination Refinement (latest version is ADP 2.1.4)
 - Ephemeris Determination Refinement (at ~9m 3σ error)
 - New data added for 3Q 2004

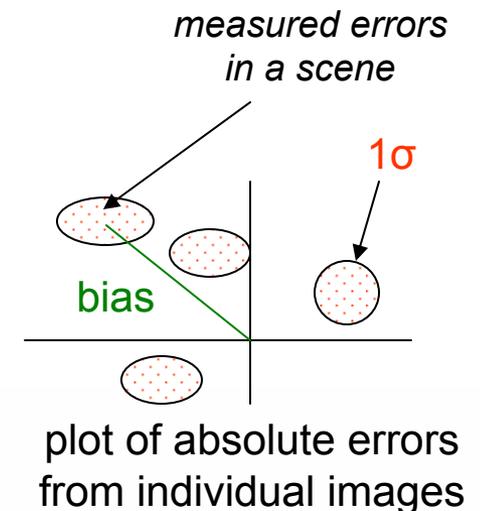
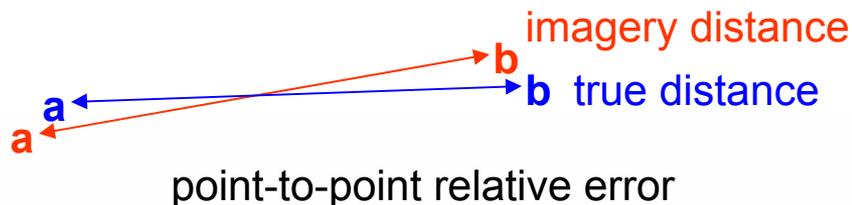
Ground Control

- DigitalGlobe is using >20 sites, >160 scenes for geospatial accuracy analyses of QuickBird imagery



- 3-40 GCPs per site
- GCPs are sub-meter accuracy
- surveyed by CompassCom, Fugro, and DigitalGlobe

- Geolocation Error Measurement
 - we use rigorous camera model
 - measure vector from Ground “Truth” GCP to Measured Image GCP
 - method eliminates terrain effects
 - verified measurements with RPCs
- Horizontal Error Metrics
 - Errors are calculated for each individual image (~17 x 17 km each)
 - Absolute Error = CE90 of absolute errors within the scene
 - Relative Error = measures distortion between GCPs within the scene
 - 1σ of absolute errors
 - CE90 of point-to-point relative errors
- Reported accuracies are for the entire ~160 image archive



- Bias of a scene = average of the absolute errors
- QuickBird scenes currently meet 23m CE90 specification
 - specification is at-nadir, so excludes terrain effects
 - studies by BAE and EarthSat confirm analysis measurements
 - current archive uses version ADP 2.1.4 for attitude
- Calculated in CE90 as specified by NIMA (Tom Ager)
 - “An Analysis of Metric Accuracy Definitions and Methods of Computation”
 - CE90 is calculated for each individual scene (each ~17 x 17 km)
 - can be calculated as either the 90th percentile of data points or polynomial combination of means and sigmas
 - previous definition in MIL-STD-60001 “Mapping, Charting and Geodesy Accuracy” did not adequately address horizontal biases in imagery
- Basic Imagery Performance
 - Average Absolute Geolocation Accuracy of archive : 13.3m CE90
 - greater than 90% of images in archive meet 23m CE90

- **Image-level metrics:**

- $\Delta_j = [G_{observed} - G_{truth}]$ = geolocation error at j^{th} GCP
- $\mu_{abs} = \text{mean}(\Delta_j)$ = bias of GCP errors for image
- $\sigma_{abs} = \text{std}(\Delta_j)$ = standard deviation of GCP errors for image

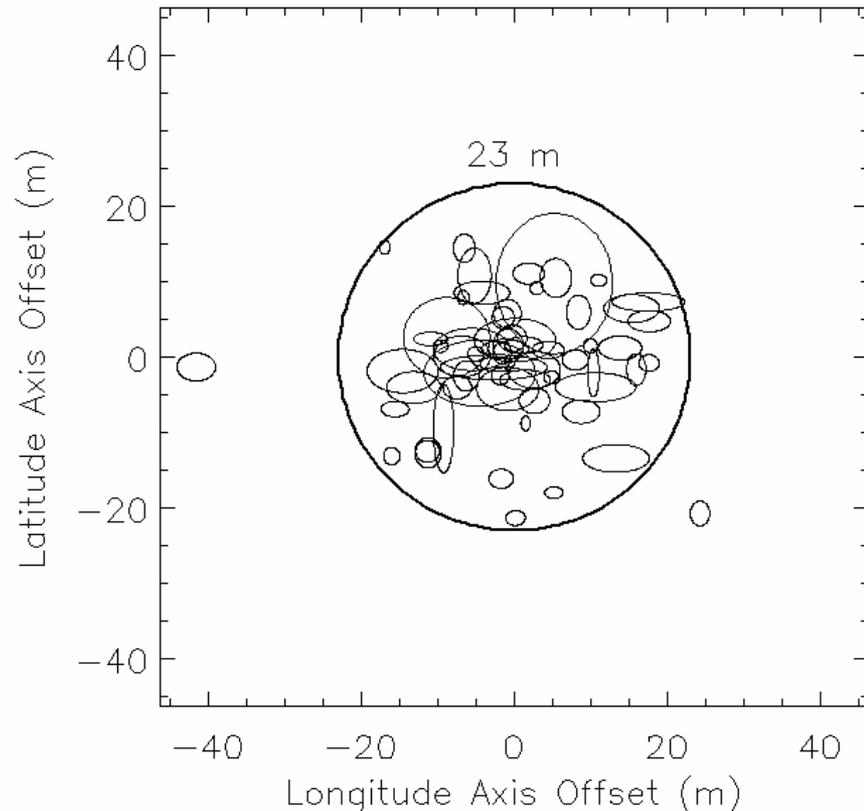
- **CE90_{abs} = 90th percentile of Δ 's** [as per NIMA paper]

- **System-level metrics:**

- Average CE90_{abs} = mean(CE90_{abs} for all images in archive)

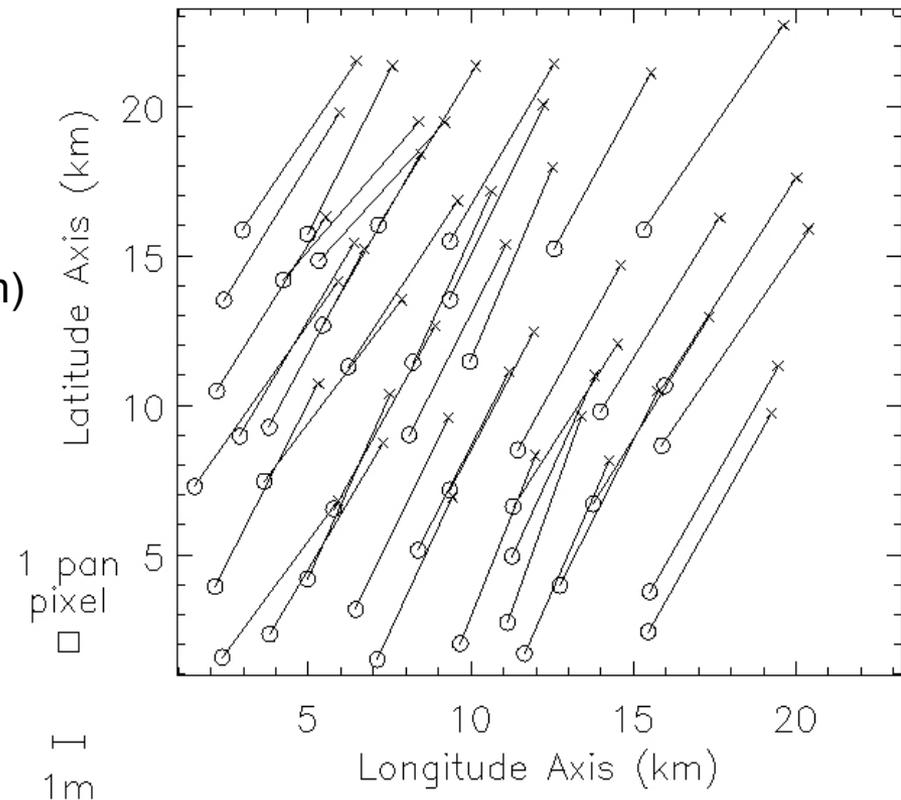
Absolute Geolocation Ellipse Plot

- Example of geolocation data
 - subset from recent period of time
- Each ellipse represents a single basic image product
 - **Bias:** average of errors for each image, the center of ellipse
 - **Size:** 1σ scatter of errors for each axis
- Circle denotes 23 m
- There are two outliers
 - 2 out of 62 images for this dataset
 - outliers are inherent in statistical systems
 - outliers usually have single star tracker attitude solutions
 - developing ADP improvements to reduce the occurrence of outliers



GCP Absolute Error Plot

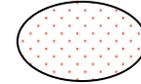
- GCP absolute geolocation errors for a single sample image (1010010000CDF101)
- Two scales in this figure
 - GCP locations on the surface (km)
 - circles: ground GCPs
 - GCP residual displacements with
 - ~1000 enlarged scale (m)
 - pluses: displacement to image GCPs
- Systematic bias is evident
 - Average Bias = 9m N, 3m W
- Variation in residual vectors represents scatter



**Average length of error vectors is ~9.5 meters.
Axes in kilometers only to show GCP locations.**

Relative Geolocation Accuracy

- Relative Accuracy can be expressed in two ways:

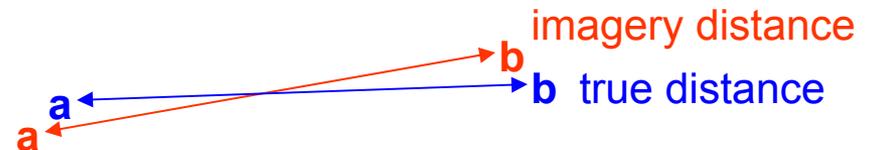


- 1σ of Absolute Errors

- standard deviation of the magnitudes of the absolute errors in a given image
- advantage : easy to calculate, easily understood, relates to CE90
- disadvantage : need good distribution of GCPs, rotation bias not apparent

- Point-to-Point Relative Error

- reported as CE90 of the magnitudes of the relative errors
- all possible pairs of GCPs are compared
- advantage : bias independent
- disadvantage : dependent on distribution and distance of GCPs, scene size



- Performance

- Average 1σ of Absolute Error : 1.5 m
- Average Point-to-Point Relative Error: 4.7 m CE90

- **Image-level metrics:**

- $\Delta_i = [G_{observed} - G_{truth}]_i$ = geolocation error at i^{th} GCP
- $\eta_{ij} = \Delta_i - \Delta_j$ = point-to-point relative error
- $\mu_{rel} = \text{mean}(\eta_{ij})$ = avg. of pt-to-pt relative errors within image
- $\sigma_{rel} = \text{std}(\eta_{ij})$ = standard deviation of pt-to-pt relative errors within image

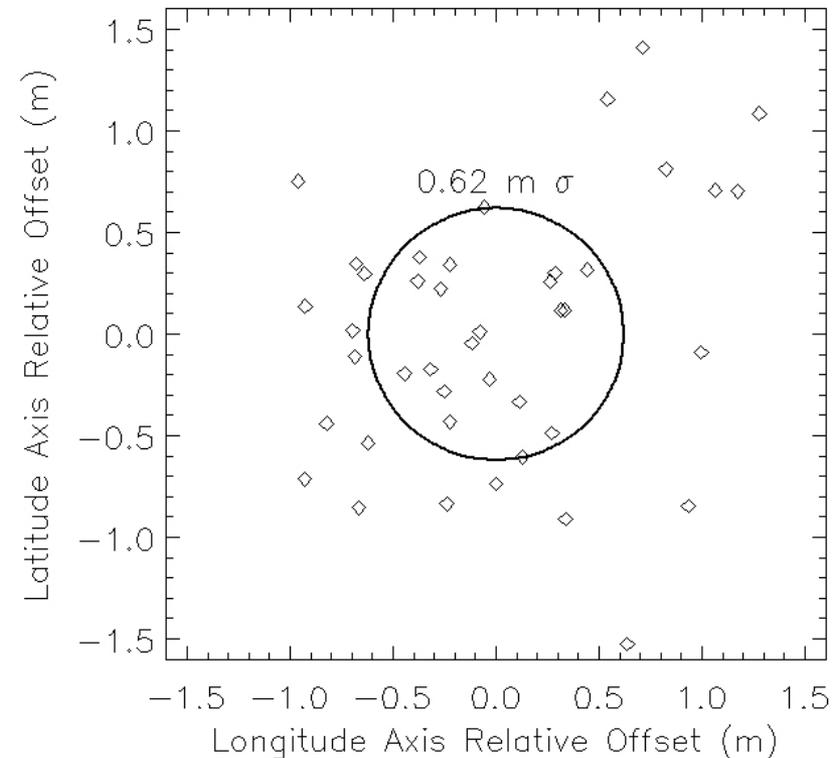
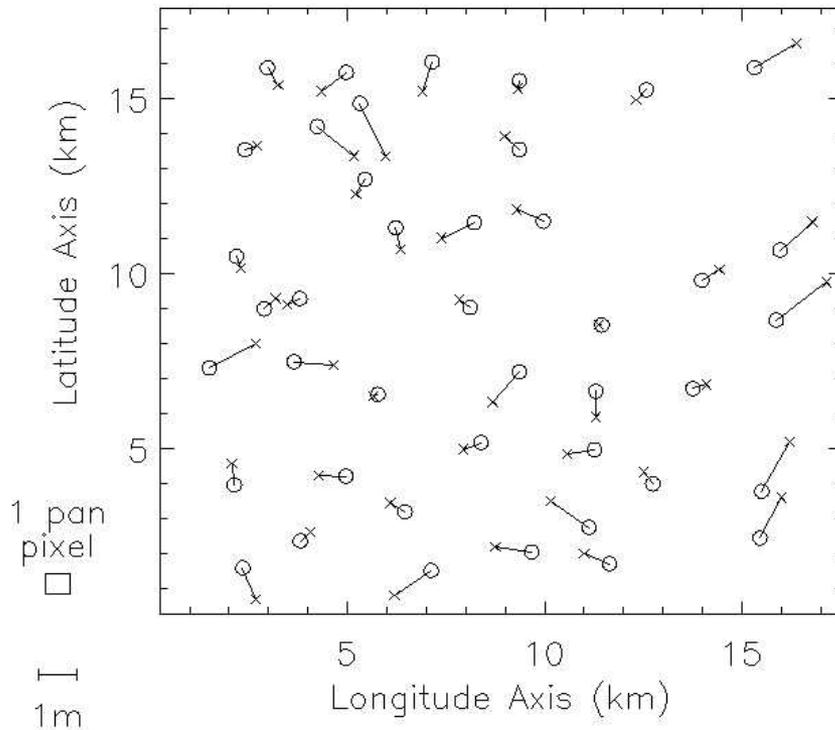
- **CE90_{rel} = 90th percentile of η 's** [as per NIMA paper]

- **System-level metrics:**

- Avg. CE90_{rel} = mean(CE90_{rel} for images in test set)

Relative Error Scatter Plot

- Sample errors for a single image (1010010000CDF101)
- each point is a GCP relative error



- Large circle represents the standard deviation of the residual error for this image

QuickBird Geolocation Summary

- Absolute Geolocation Accuracy of QuickBird System currently meets specification of 23m CE90 at nadir, excluding terrain
- Third Party Assessments Avg. CE90 (2003)
 - EarthSat 11.4 m
 - BAE 11.4 m
 - DigitalGlobe 13.6 m
- Primary Efforts : Improve Geolocation even more
 - Update ADP regularly
 - Reduce outliers
- Monitor Performance