UAS Payloads Conference
San Diego, CA

Real-Time Target Geo-Location and Web-Based Situational Awareness using Tactical UAVs

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Need for Timely Registered Imagery

- Multiple platforms carry sensors to support battlespace awareness
- Real-time video being downlinked to the battlefield
- Precision registration of imagery needed to allow sensor data to be used for targeting
- Near-real time mensurated imagery needed to support call-for-fire operations
- Registration also allows spatial data management of multiple sensor feeds for applications such as change detection

Benefits of Georegistered Image Downlink

Streaming Video Downlink

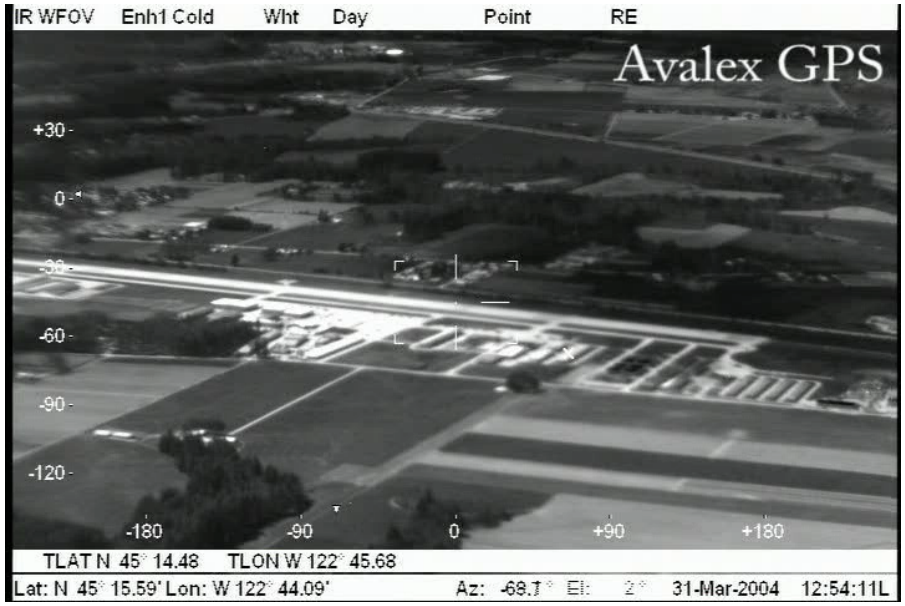
- Unstabilized real-time imagery difficult for operator to interpret
- Lack of bandwidth limits data quality
- Sophisticated ground stations needed for image registration and target mensuration

Sustained data rate ~ 5 Mbps (Assumes JPEG2000 compression)

Georegistered Image Downlink

- Real-time target-quality registered and stabilized imagery provided by GI-Eye
- Auto-mosaic generation on UAS provides stabilized near real-time mosaics
- GBO can view UAS imagery through existing Web software (e.g. Google Earth)
- Registered mosaics provide mensurated target coordinates

Sustained data rate 310 Kbps (full resolution images assuming lossless JPEG-LS compression)

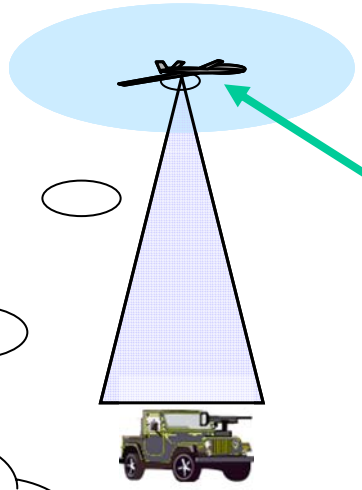

IR WFOV Enh1 Cold Wht Day Point RE
Avalex GPS
+30
0
-60
-90
-120
-180
-90
0
+90
+180
TLAT N 45° 14.48 TLON W 122° 45.68
Lat: N 45° 15.59' Lon: W 122° 44.09'
Az: -68.1° El: 2°
31-Mar-2004 12:54:11L

Ground Based Observer Overview

OBJECTIVE: Develop technology for ground-based observer (GBO) teams to determine coordinates of targets at ranges > 5 km with Target Location Errors (TLEs) < 10 m

NAVSYS developing GI-Eye payload to generate near real-time registered mosaics onboard UAS

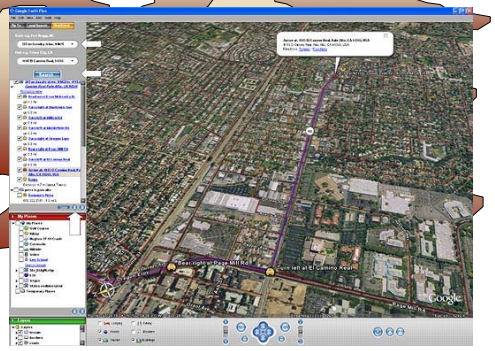
Currently, video imagery provided from UAS to Flight Ops Ground Station for analysis & mensuration. No real-time access for targeting by GBOs



UAV Flight Operations Crew

UAS provides WiFi access to registered mosaics to GBOs within 10 km

Ground Based Observers

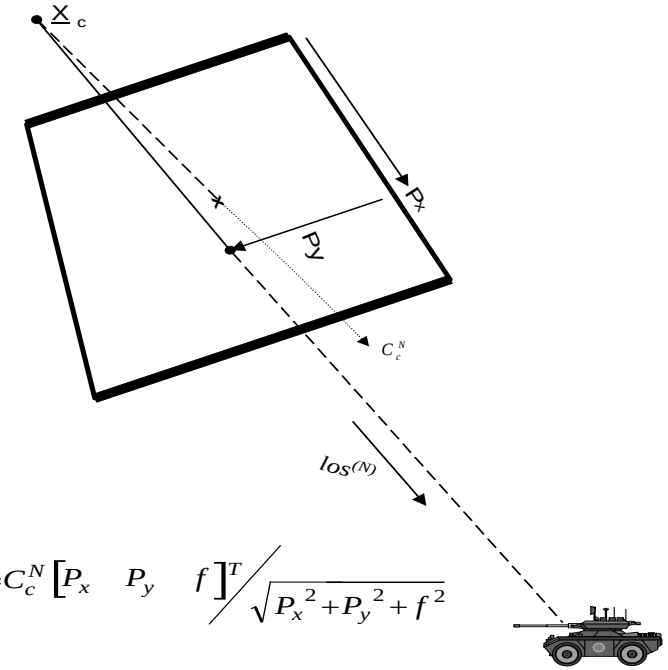


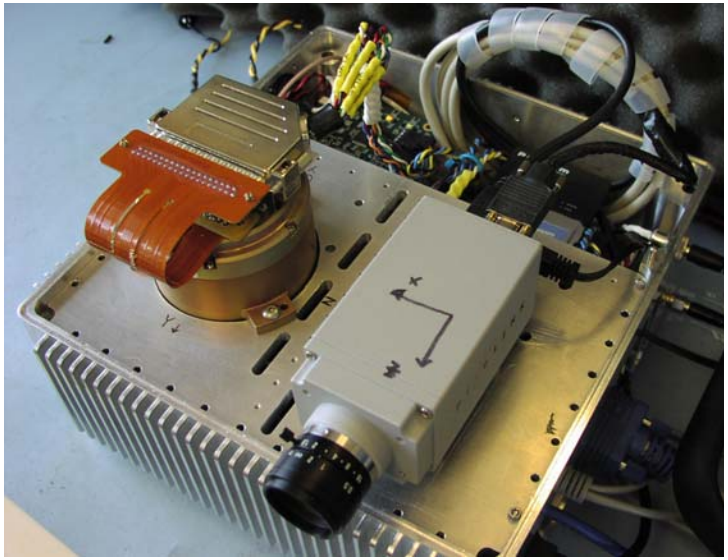
GBOs can generate mensurated targets from UAS imagery using Web Tools

GI-Eye Auto-Georegistration

"Provides coordinates

- **GI-Eye**
  - Provides registered images from which mensurated targets can be extracted





UAS GI-Eye Sensor Payload

FLIR StarSAFIRE III

- Includes GI-Eye for geopointing

Key Performance Issues for High Accuracy GeoRegistration

- Camera location
  - GPS accuracy gives 5 m
  - Precision GPS Ephemeris ZAOD gives < 1 m (absolute)

$$x_C^{(N)}$$

- Camera attitude
  - InterNav inertial alignment
  - <1 mrad using NAVSYS' kinematic GPS alignment

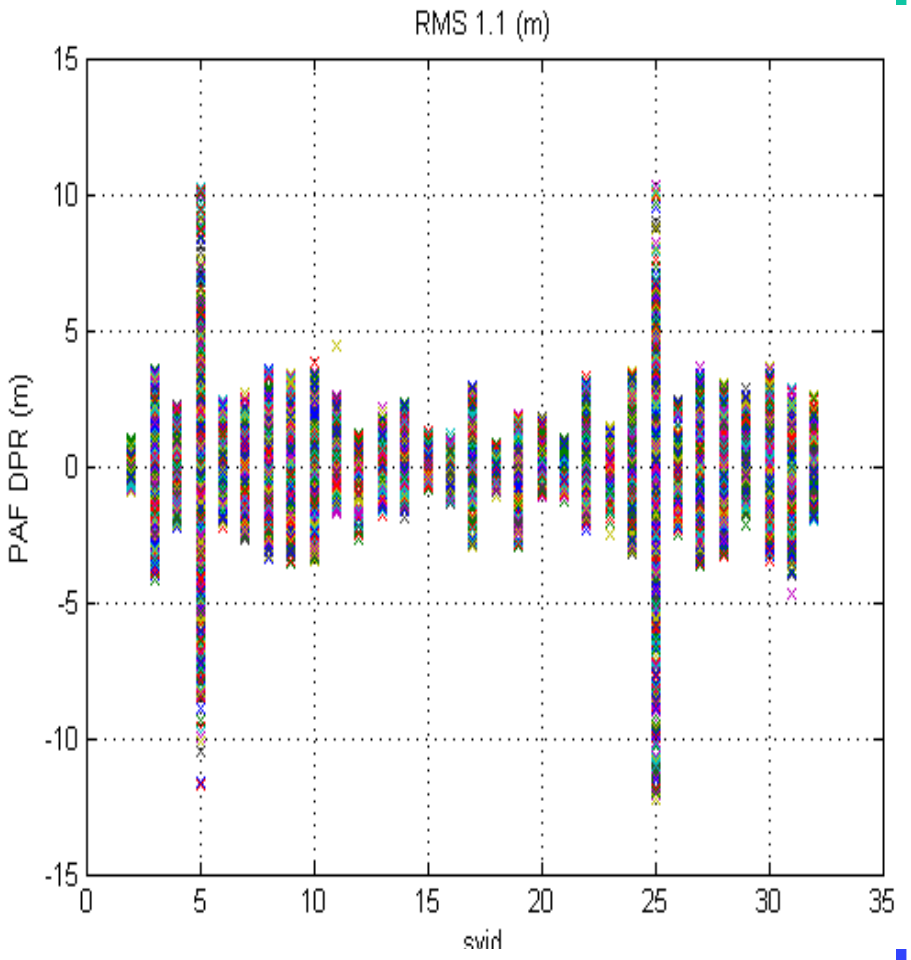
$$C_B^N$$

- Camera calibration errors
  - Misalignment, focal length and radial distortion
  - GI-Eye sensor calibration reduces to sub-pixel errors

$$C_C^B$$

Accuracy of Precision GPS Ephemeris (PGE)

- **Zero-Age of Data (ZAOD)**
  - Created at GPS Master Control Station
  - Used to generate Precision GPS Ephemeris (ZNAV) messages through Tactical Control Station (TCS)
- **ZAOD Accuracy**
  - Derived from analysis of operational data
  - Produces 0.22 meters accuracy with AF and NGA tracking stations



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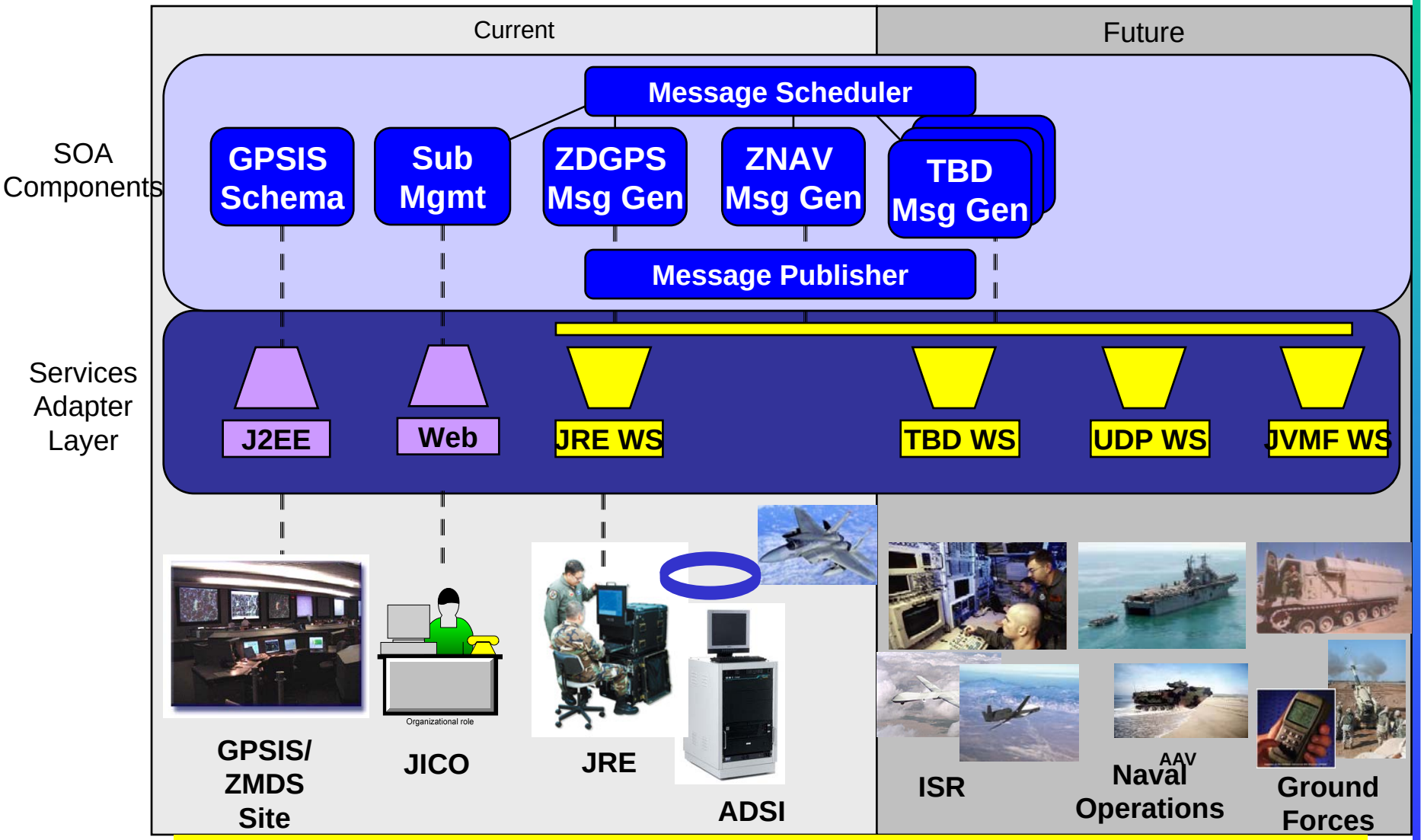
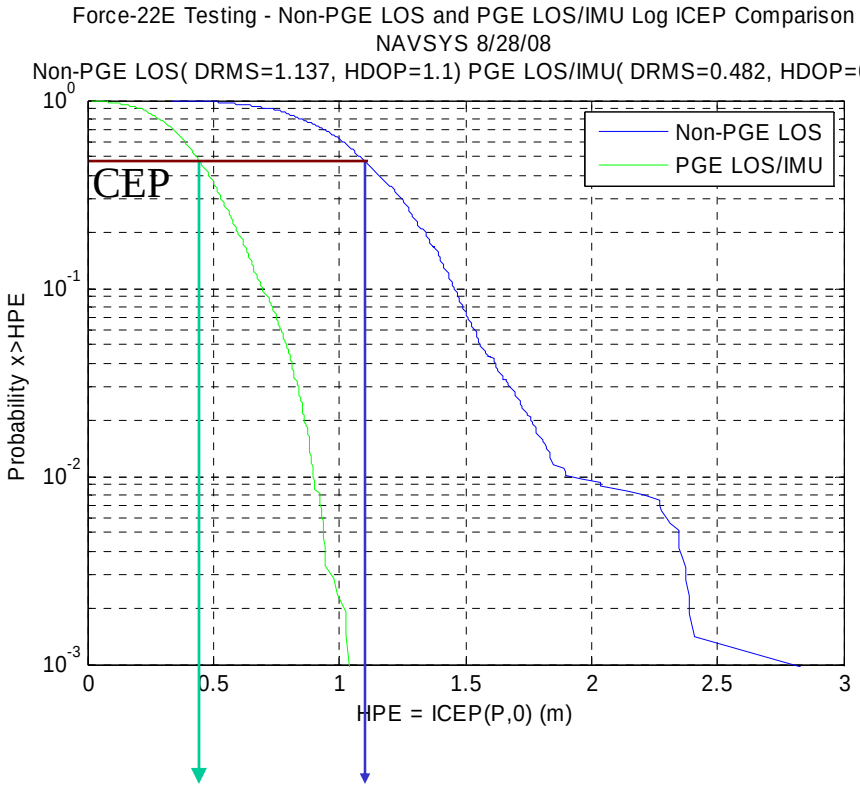
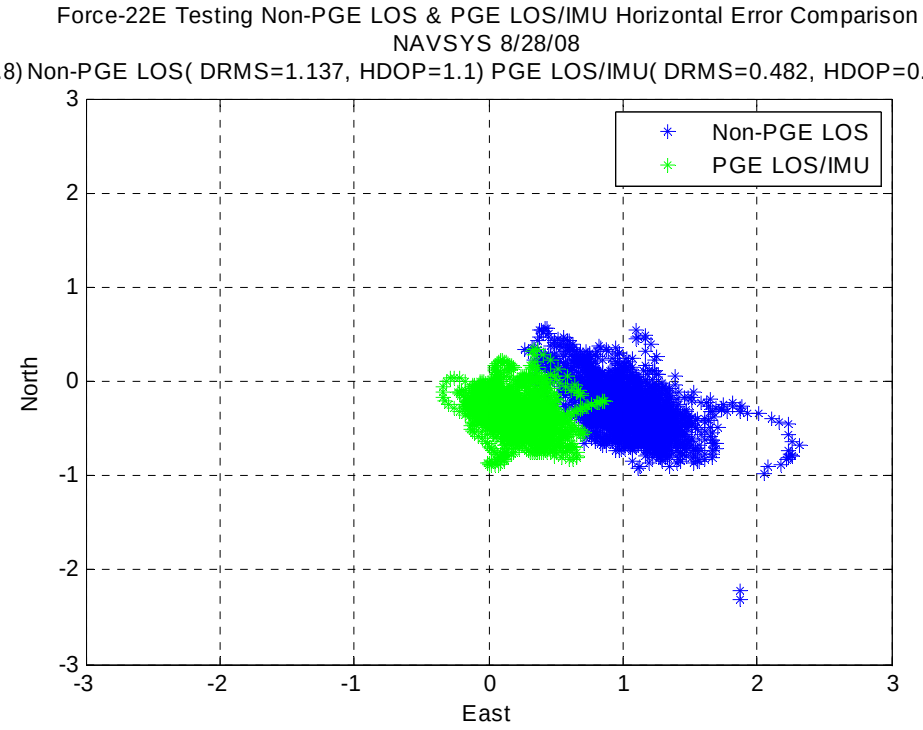
PGE Tactical Control Station SOA



AFEI's 2008 Excellence in Enterprise Integration Industry Award

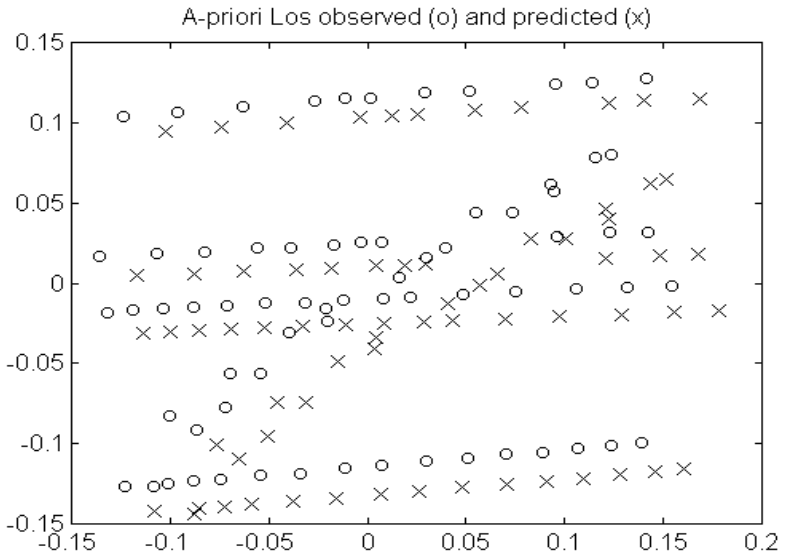
PGE Corrected Positioning Results



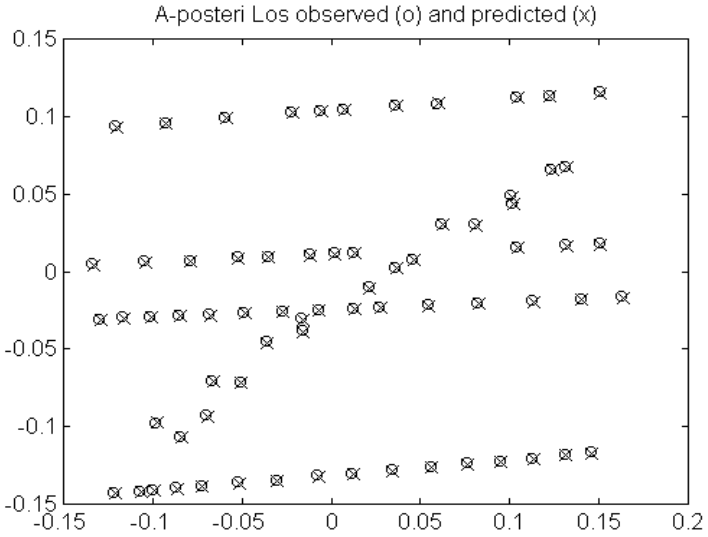


DRMS improves from 1.1m to 0.48 m

Camera-to-IMU Auto-Cal Example

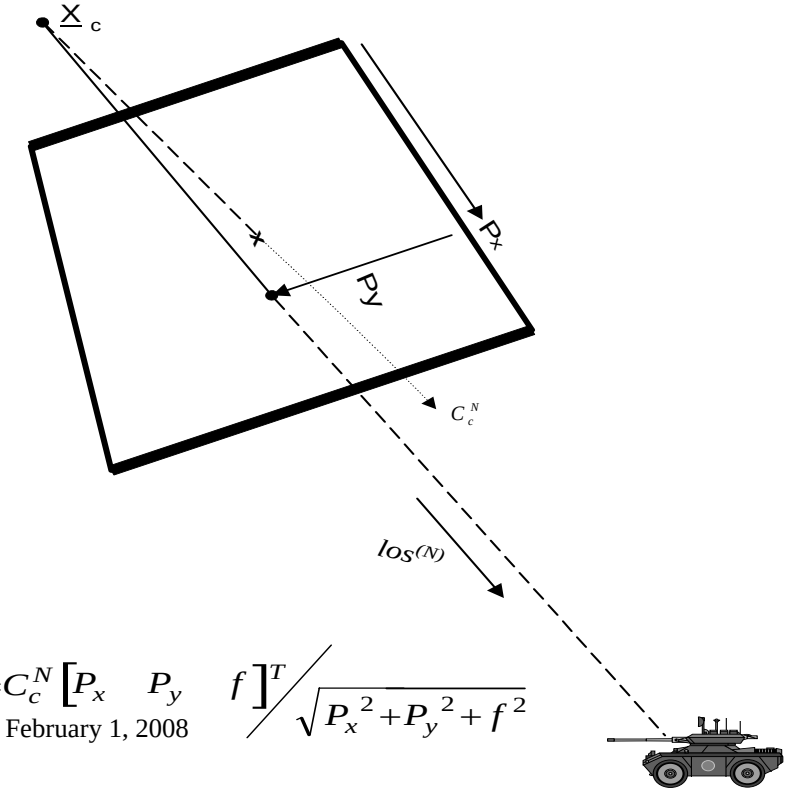


Typical residual
Misalignment <0.200 mrad



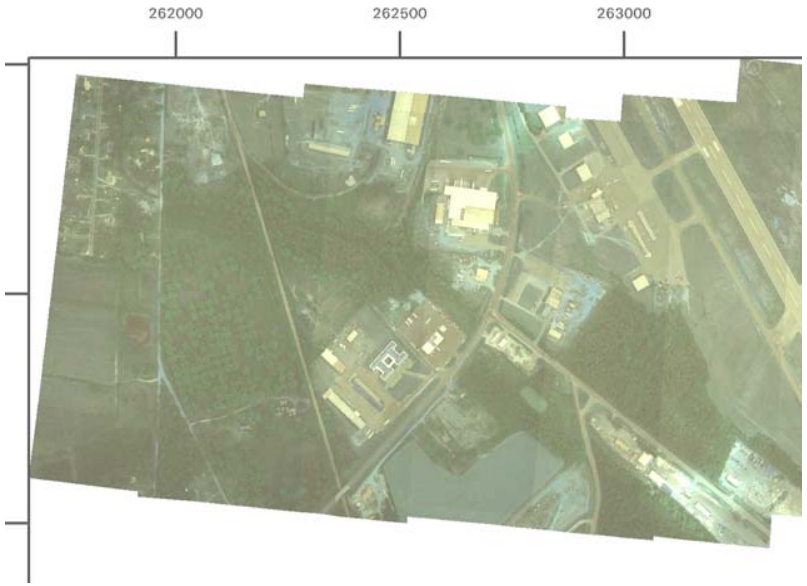
DTED Effects on Accuracy

- Single Shot Targeting
  - GPS gives position
  - Inertial gives attitude
  - Range to target estimated from DTED



$$los^{(N)} = C_c^N \begin{bmatrix} P_x & P_y & f \end{bmatrix}^T / \sqrt{P_x^2 + P_y^2 + f^2}$$

- Automosaic generation
  - DTED, GPS and inertial attitude used to rectify and register images
  - Accuracy is dependent on DTED resolution and quality



DTED Specifications

DTED LEVEL	POST SPACING (in arcsec)	GROUND DISTANCE (in m)	ABSOLUTE HORIZONTAL ACCURACY (90% CE in m)	ABSOLUTE VERTICAL ACCURACY (90% LE in m)	RELATIVE HORIZONTAL ACCURACY (90% CE in m)	RELATIVE VERTICAL ACCURACY (90% LE in m)
1	3	100	25	10	15	10
2	1	30	15	10	10	7
3	1/3	10	10	10	3	2
4	1/9	3	10	5	2	0.8
5	1/27	1	5	5	0.5	0.33

POST SPACING: THE SEPARATION BETWEEN AVAILABLE INDEPENDENT TERRAIN HEIGHT VALUES
ABSOLUTE ACCURACY: ABSOLUTE CELL ERROR (POSITION IN WGS84 COORDINATES)
RELATIVE ACCURACY: CELL-TO-CELL ERROR (DIFFERENCE BETWEEN TWO POST POSITIONS)
90% CE: HORIZONTAL IN-PLANE CIRCULAR ERROR 90-TH PERCENTILE
90% LE: VERTICAL LINEAR ERROR 90-TH PERCENTILE
Source: http://www.darpa.mil/sto/space/pdf/Morgan_KASSPER_04.pdf

GI-Eye Multi-Image Geolocation Results (MIG) vs. Surveyed Targets

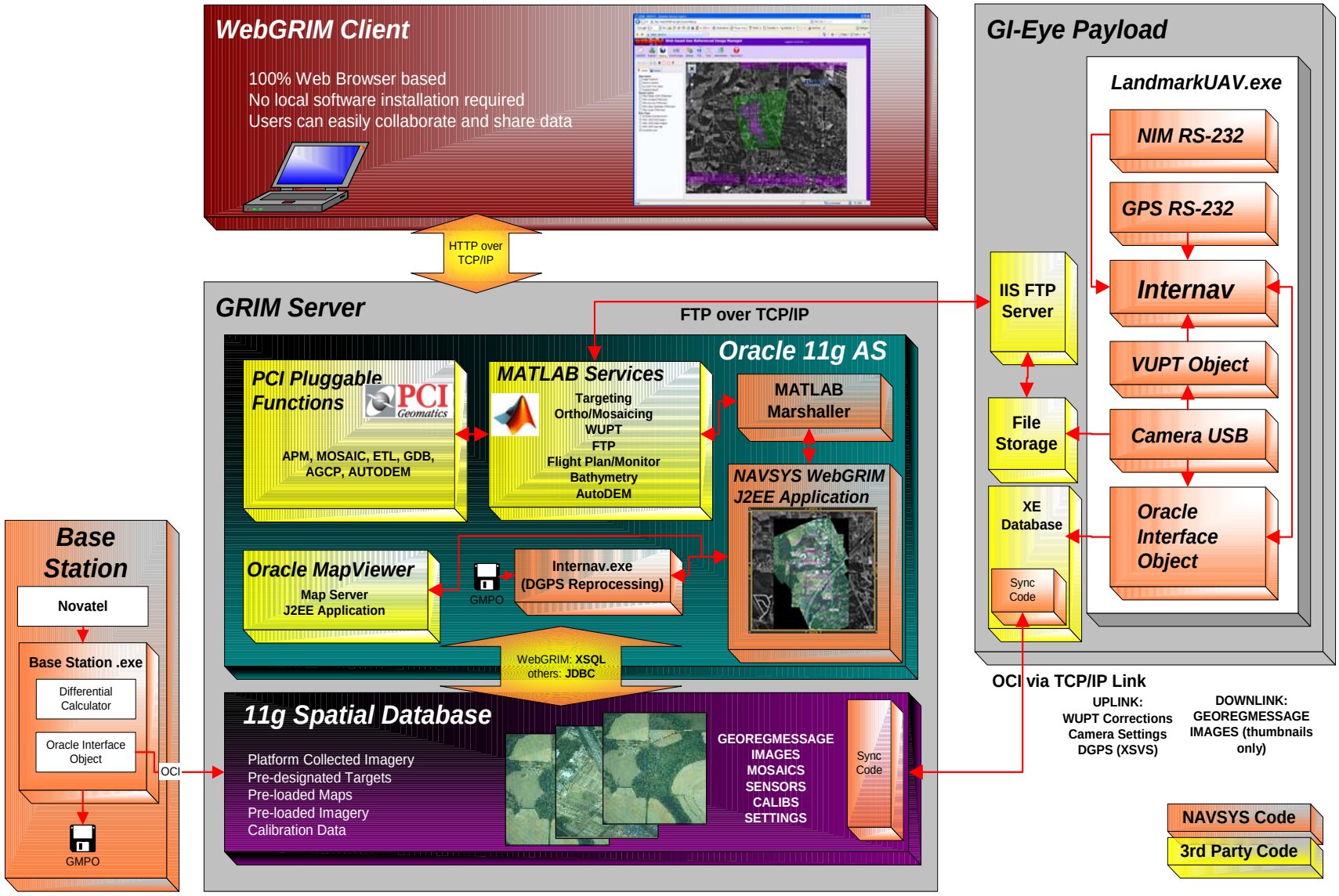
Point	Avg East Error (m)	Avg North Error (m)	Avg dist (m)
NSPL01	-0.11	-0.35	0.37
CPES Blueberry	0.43	-0.87	0.97
CPES Hort Hill	-0.49	-0.32	0.58
Tifton A - CoC	-0.35	-2.23	2.26
FAA TMA	0.20	1.14	1.16
Tifton CBL 150	-0.31	0.20	0.37
Tifton CBL 0	-0.15	0.28	0.32
Tifton CBL 100	-0.24	0.20	0.31
Excelsior reset	0.48	-1.77	1.83
M 157	0.65	1.80	1.91
Total RMS	0.47	1.27	0.92

TS2 Test Results COLUMBIA

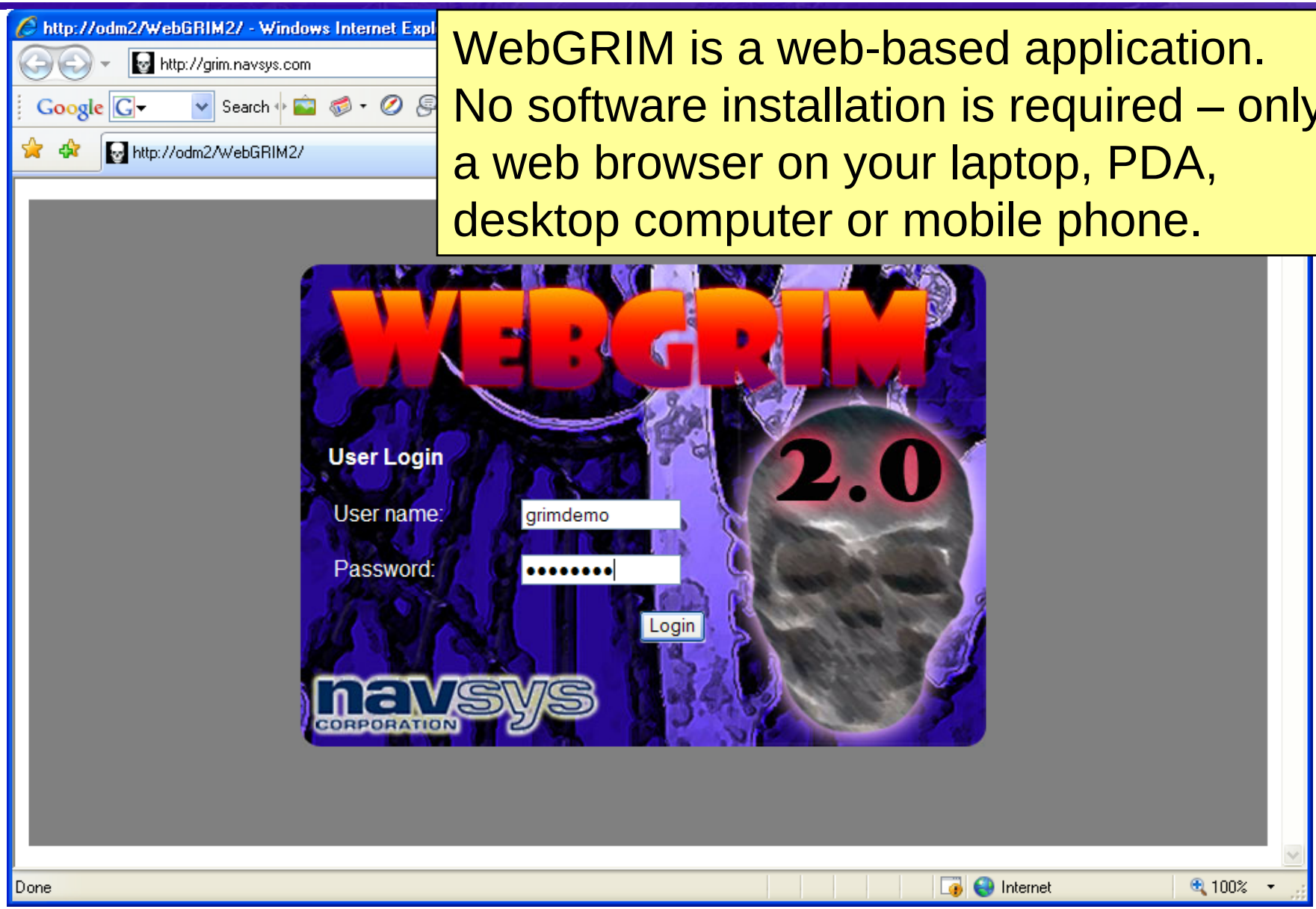
SITE DISTANCE 600 - 1500 METERS

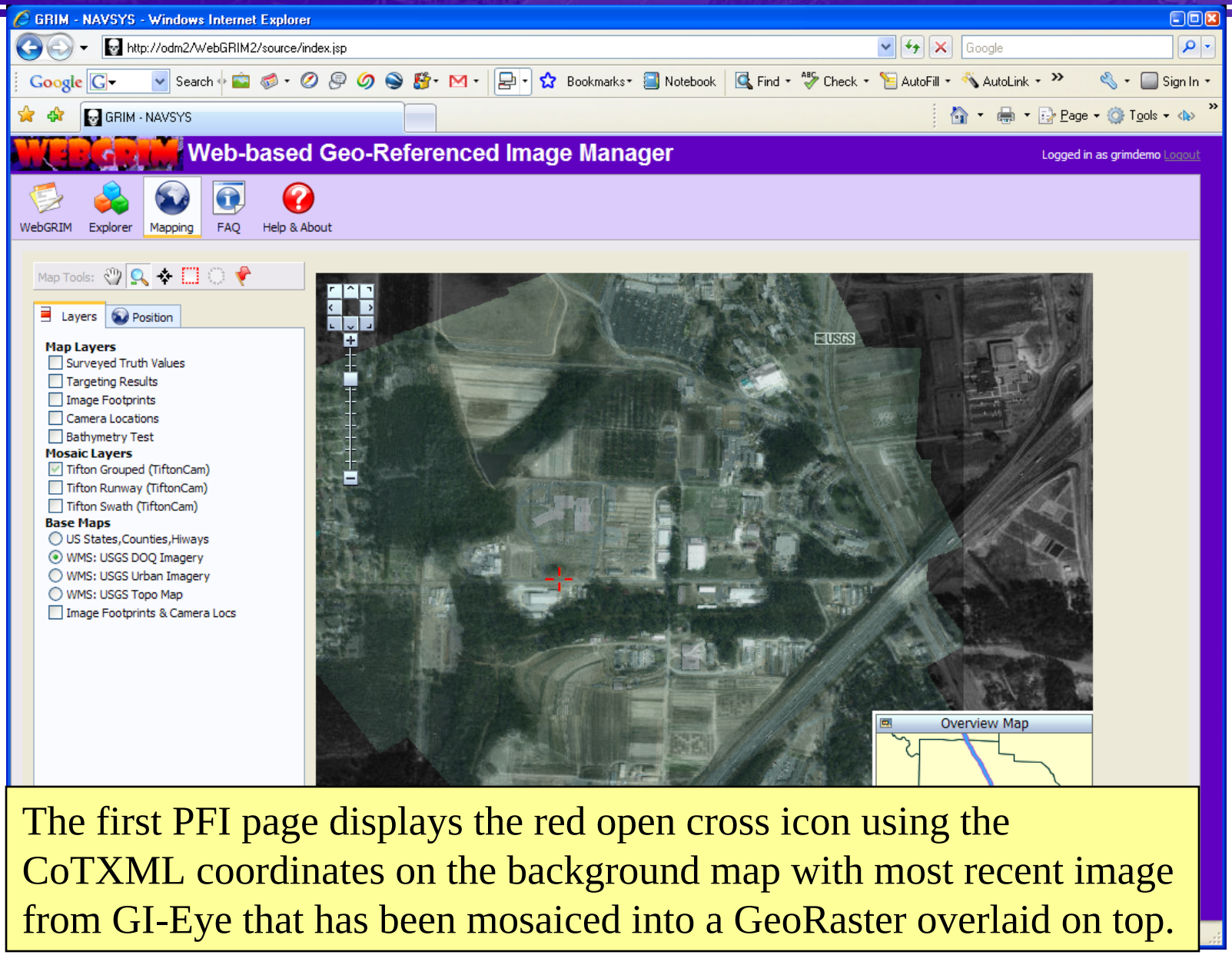
	D	M	S	D	M	S	H(targ)	sigma n	sigma e	sigma h	#
ALL OBSERVATIONS											
columbia pylon_east	38	26	48.938	-90	16	14.422	131.35	0.020	0.012	0.020	
TS2			48.947			14.400	132.06	0.859	0.823	0.806	31
delta (meters)			0.26			-0.53	0.72				
columbia pylon_west	38	26	49.031	-90	16	14.813	131.31	0.019	0.012	0.019	
TS2			49.050			14.789	131.87	0.368	0.265	0.592	26
delta (meters)			0.56			-0.56	0.56				
SOME SAMPLES ON WEST TARGET											
W1-4 on west			49.045			14.827	131.76	0.520	0.490	0.400	4
delta (meters)			0.42			0.35	0.45				
N3-6 W1-4			49.046			14.820	131.70	0.220	0.233	0.405	8
delta (meters)			0.45			0.18	0.39				
N3N6W1W4			49.044			14.826	131.65	0.276	0.337	0.408	4
delta (meters)			0.39			0.33	0.34				

Overall Web-based Georeferrenced Image Manager (WebGRIM) Architecture

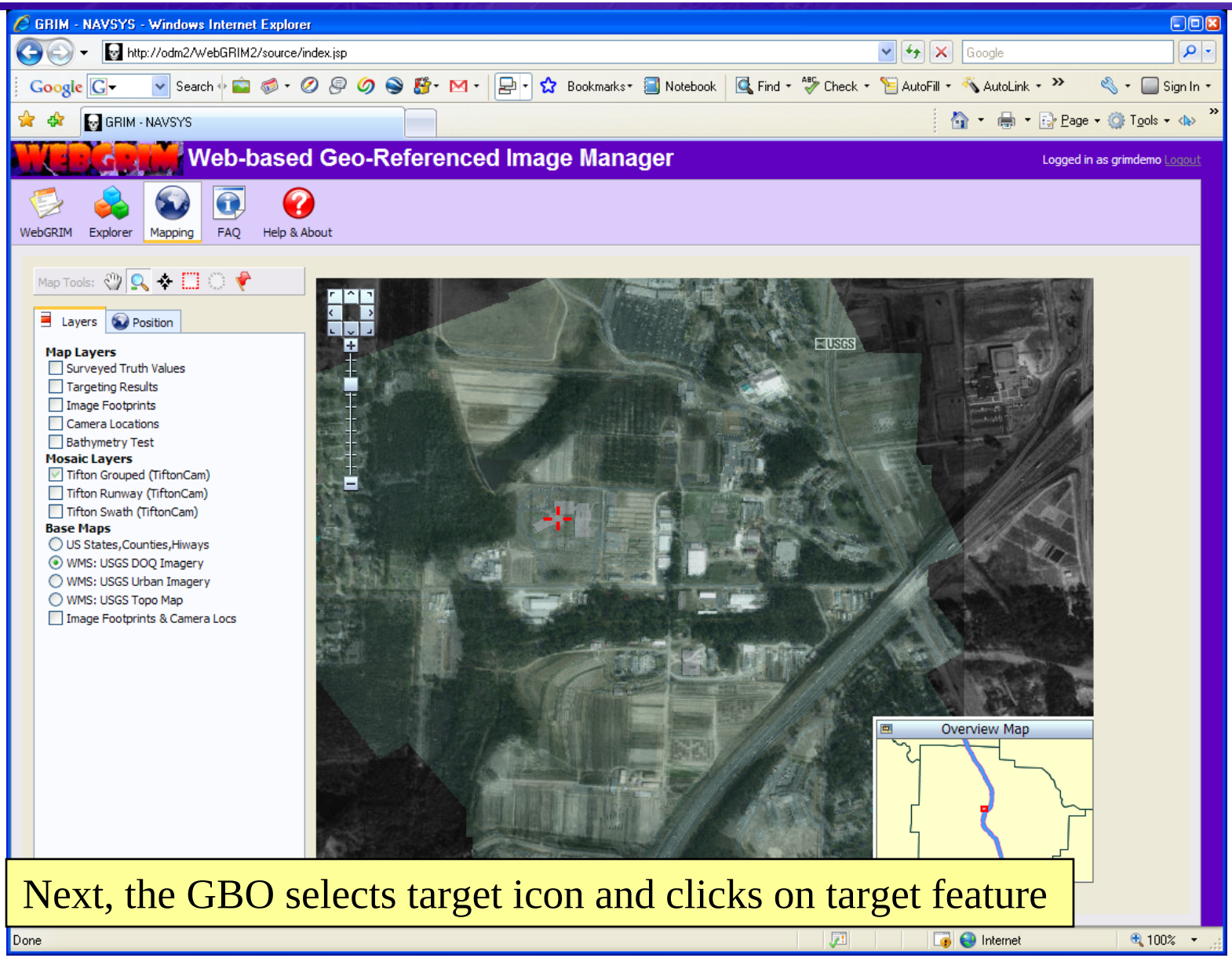


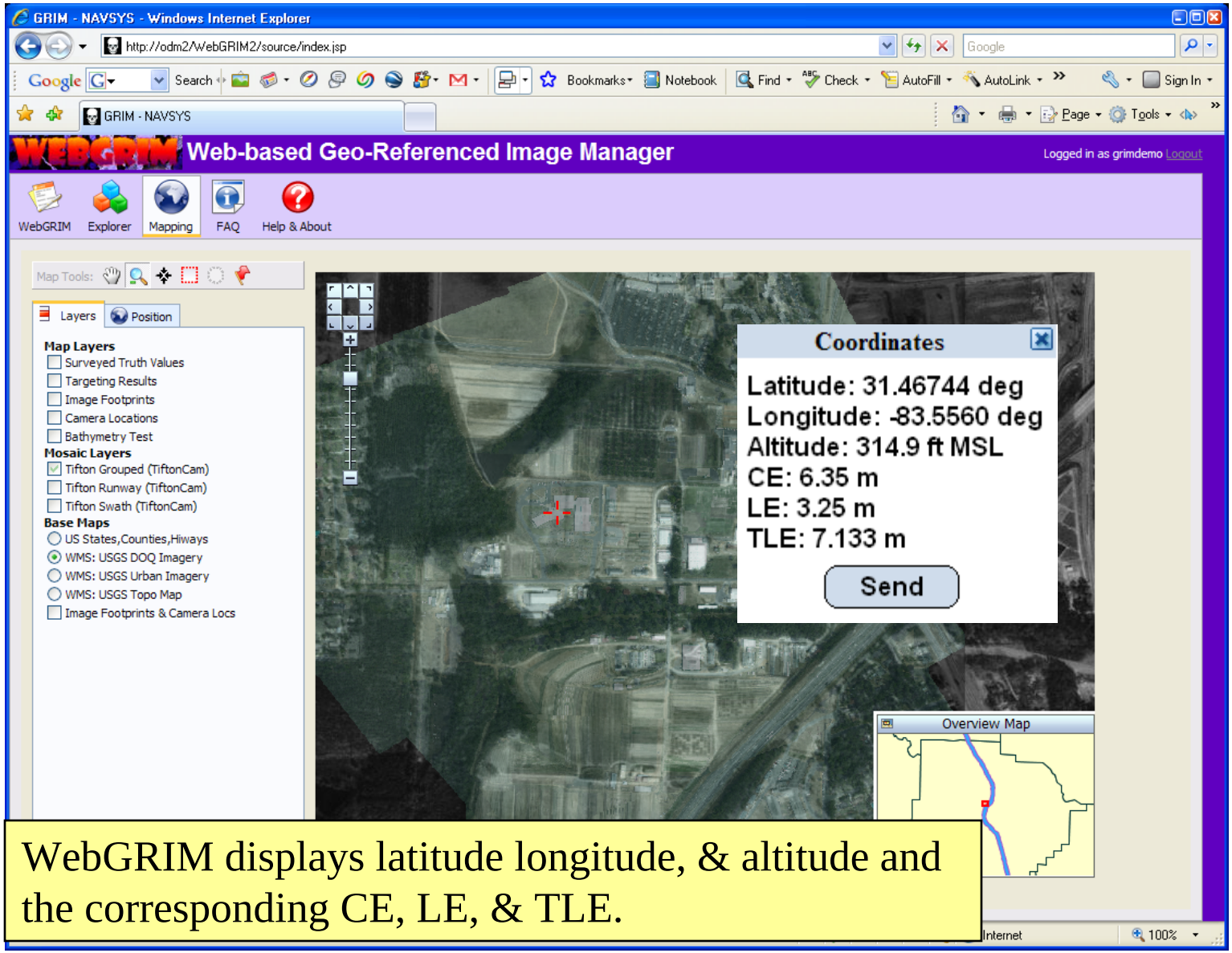
WebGRIM is a web-based application. No software installation is required – only a web browser on your laptop, PDA, desktop computer or mobile phone.



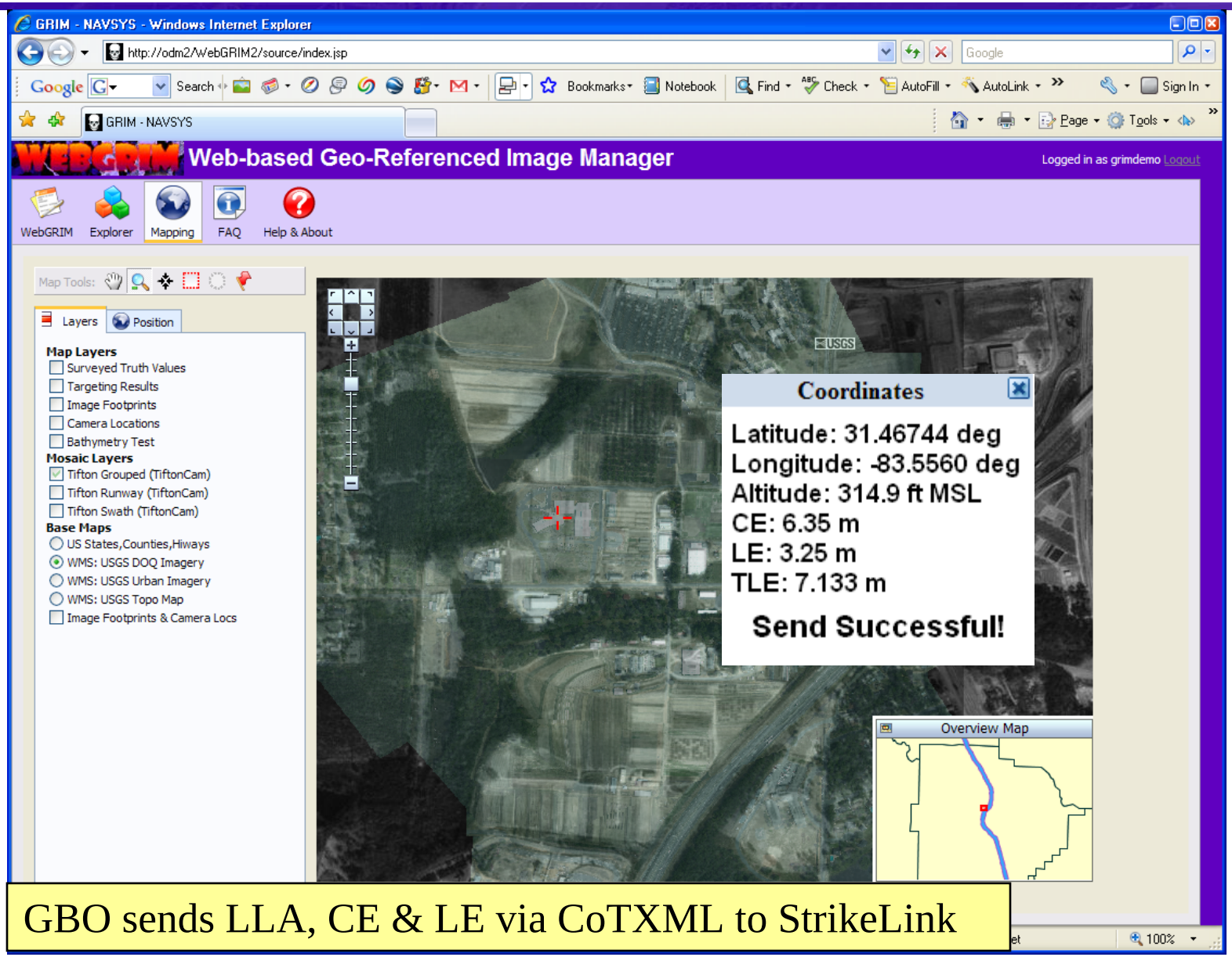


The first PFI page displays the red open cross icon using the CoTXML coordinates on the background map with most recent image from GI-Eye that has been mosaiced into a GeoRaster overlaid on top.

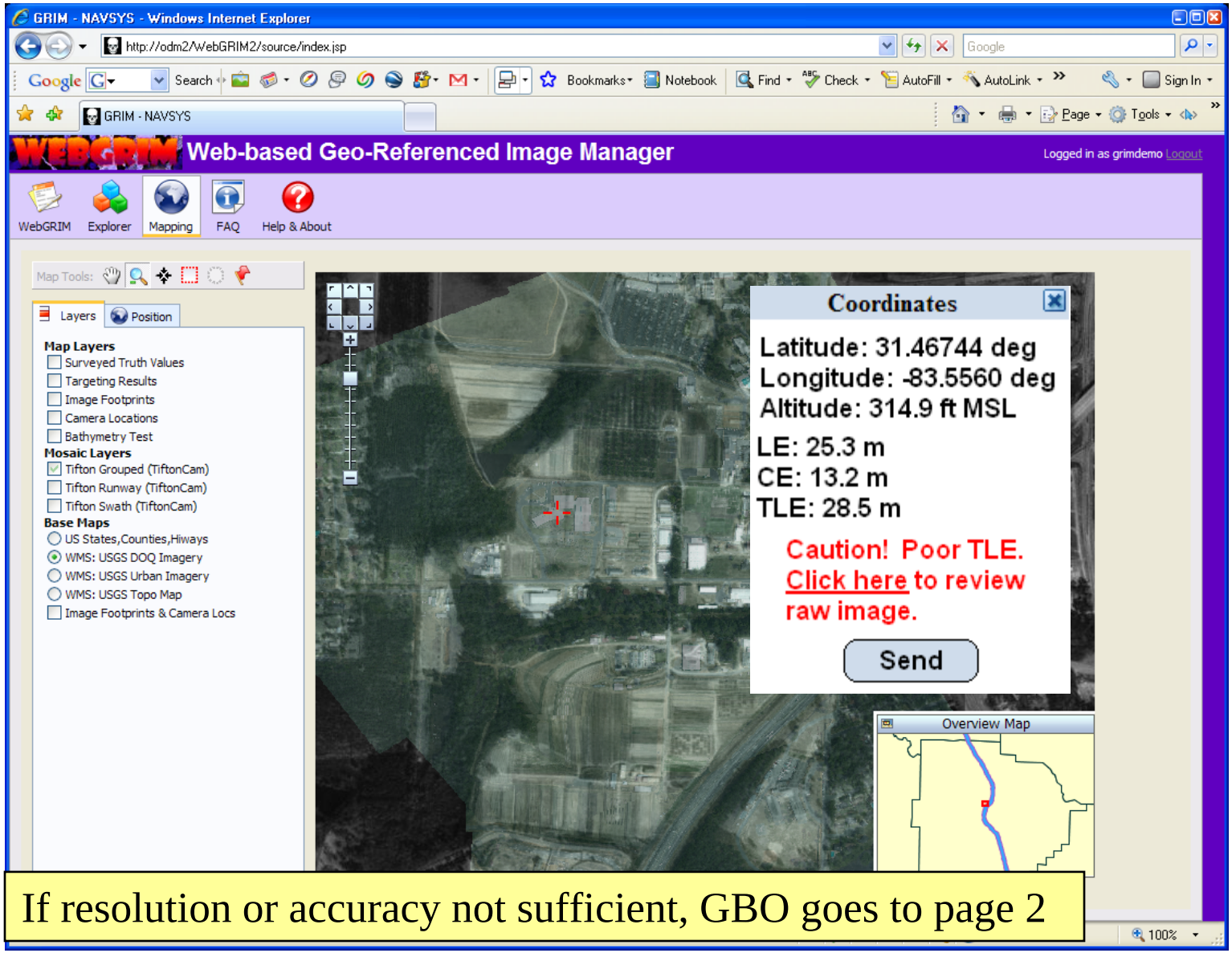

GRIM - NAVSYS - Windows Internet Explorer
http://odm2/WebGRIM2/source/index.jsp
GRIM - NAVSYS
Web-based Geo-Referenced Image Manager
Logged in as grimdemo Logout
WebGRIM
Explorer
Mapping
FAQ
Help & About
Map Tools:
Layers
Position
Map Layers
Surveyed Truth Values
Targeting Results
Image Footprints
Camera Locations
Bathymetry Test
Mosaic Layers
Tifton Grouped (TiftonCam)
Tifton Runway (TiftonCam)
Tifton Swath (TiftonCam)
Base Maps
US States,Counties,Hiways
WMS: USGS DOQ Imagery
WMS: USGS Urban Imagery
WMS: USGS Topo Map
Image Footprints & Camera Locs
USGS
Overview Map
Next, the GBO selects target icon and clicks on target feature
Done
Internet
100%



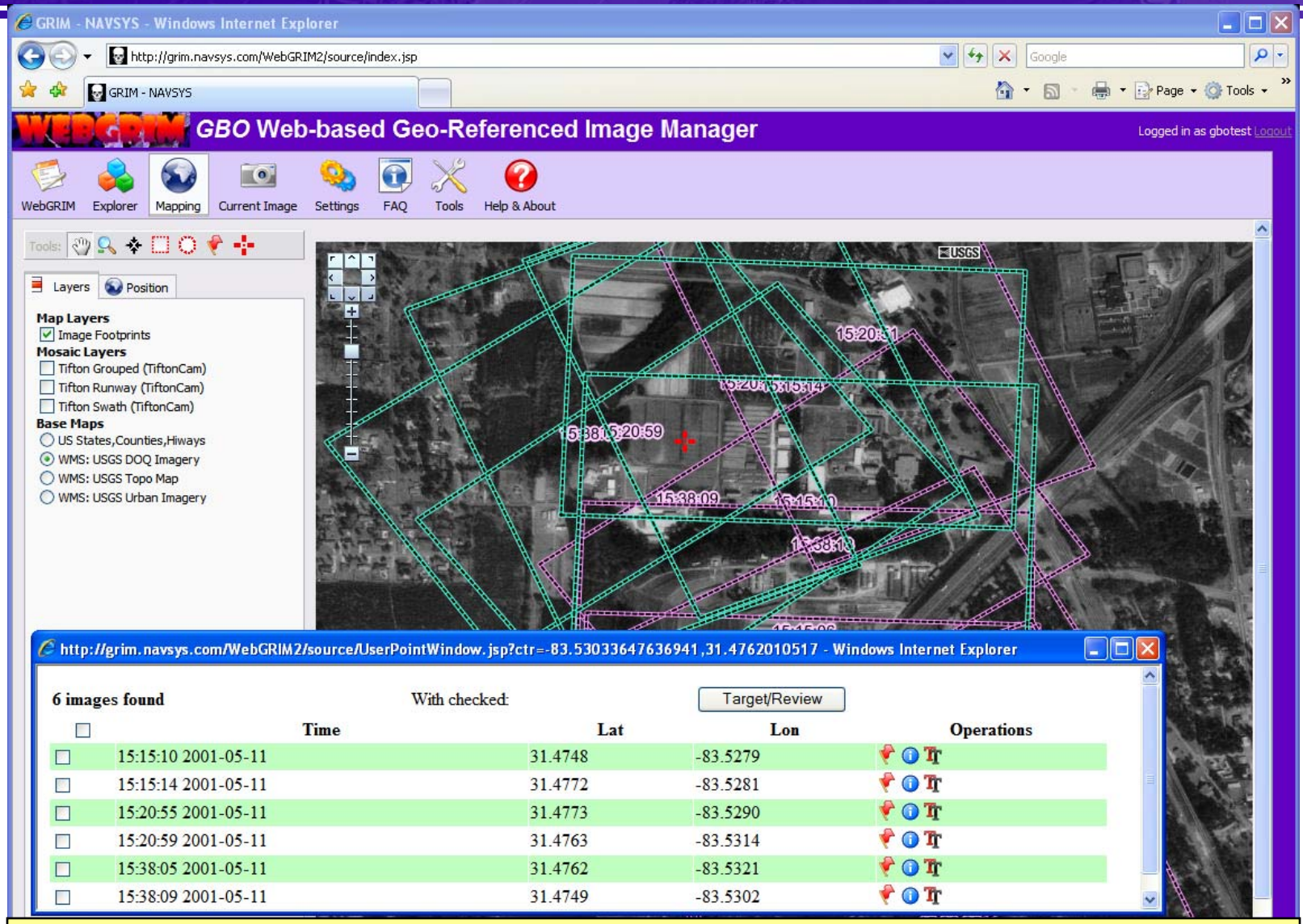
WebGRIM displays latitude longitude, & altitude and the corresponding CE, LE, & TLE.



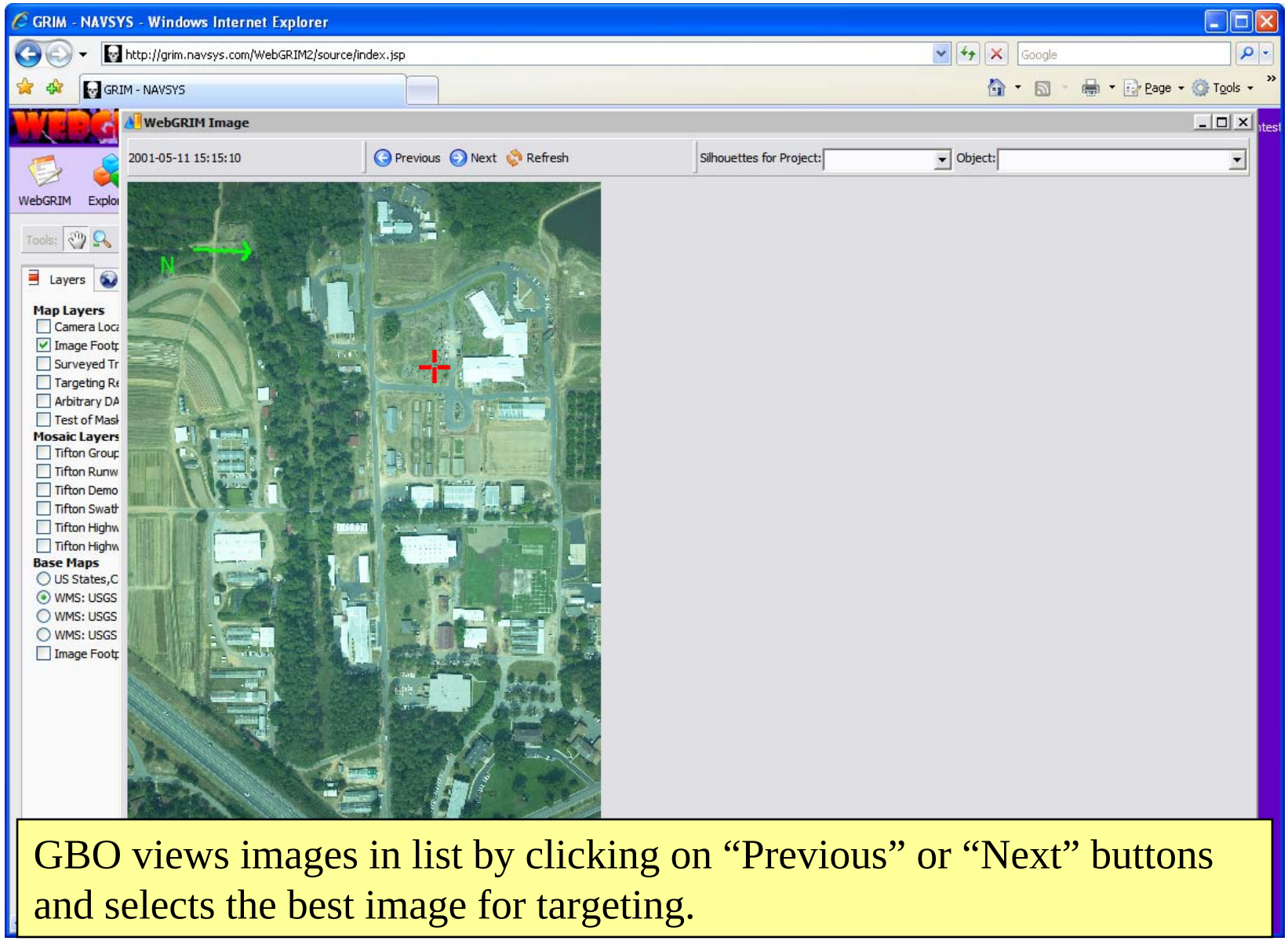
GBO sends LLA, CE & LE via CoTXML to StrikeLink



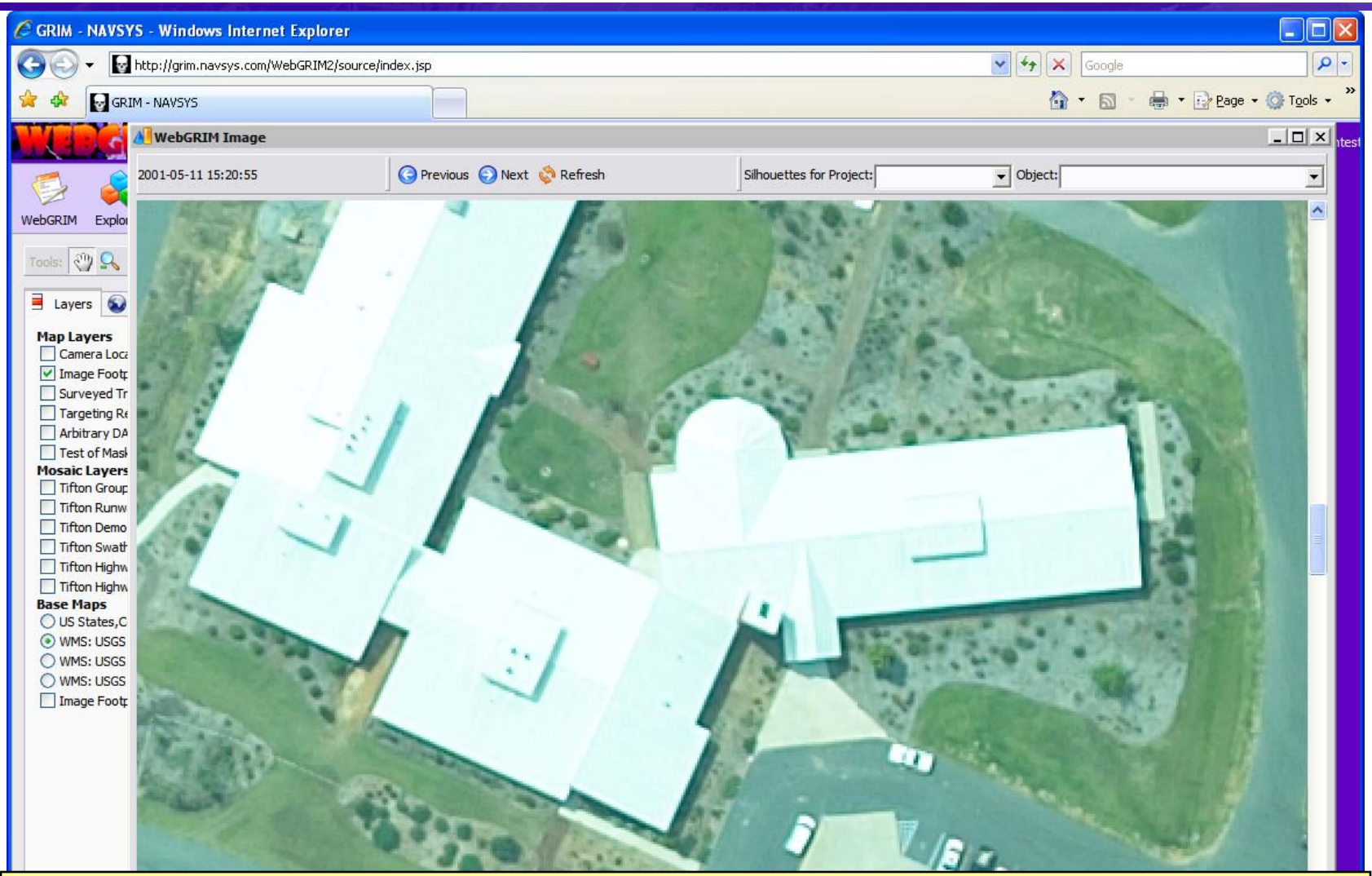
If resolution or accuracy not sufficient, GBO goes to page 2



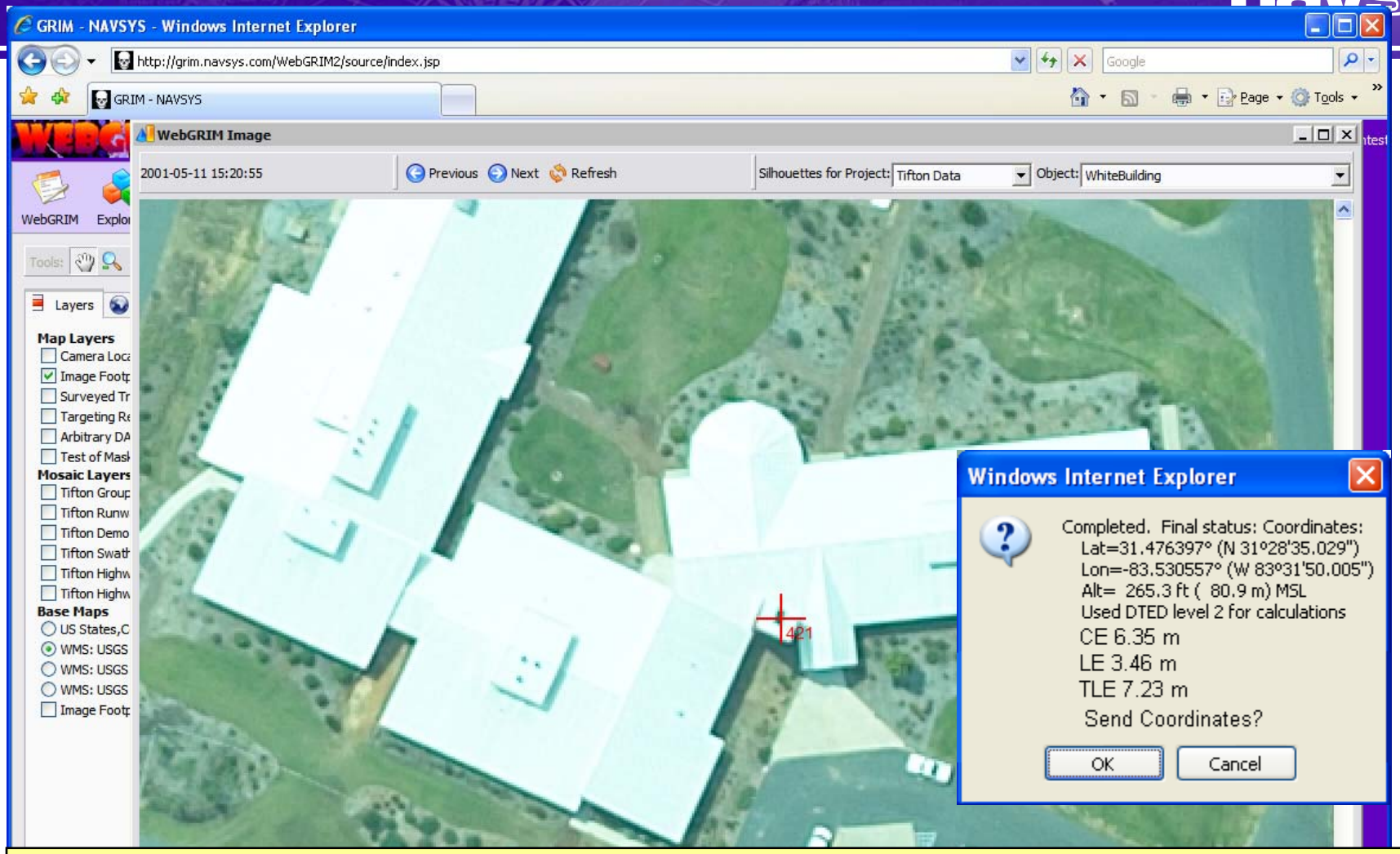
GBO provided list of recent raw images containing target coordinates



GBO views images in list by clicking on “Previous” or “Next” buttons and selects the best image for targeting.



When the GBO sees the target feature in the image, the GBO clicks on exact targeting location which zooms in on the feature



GBO clicks again on exact targeting location.

WebGRIM calculates target feature location & displays latitude, longitude & altitude and corresponding CE, LE, & TLE.

GBO sends LLA, CE & LE via CoTXML to StrikeLink

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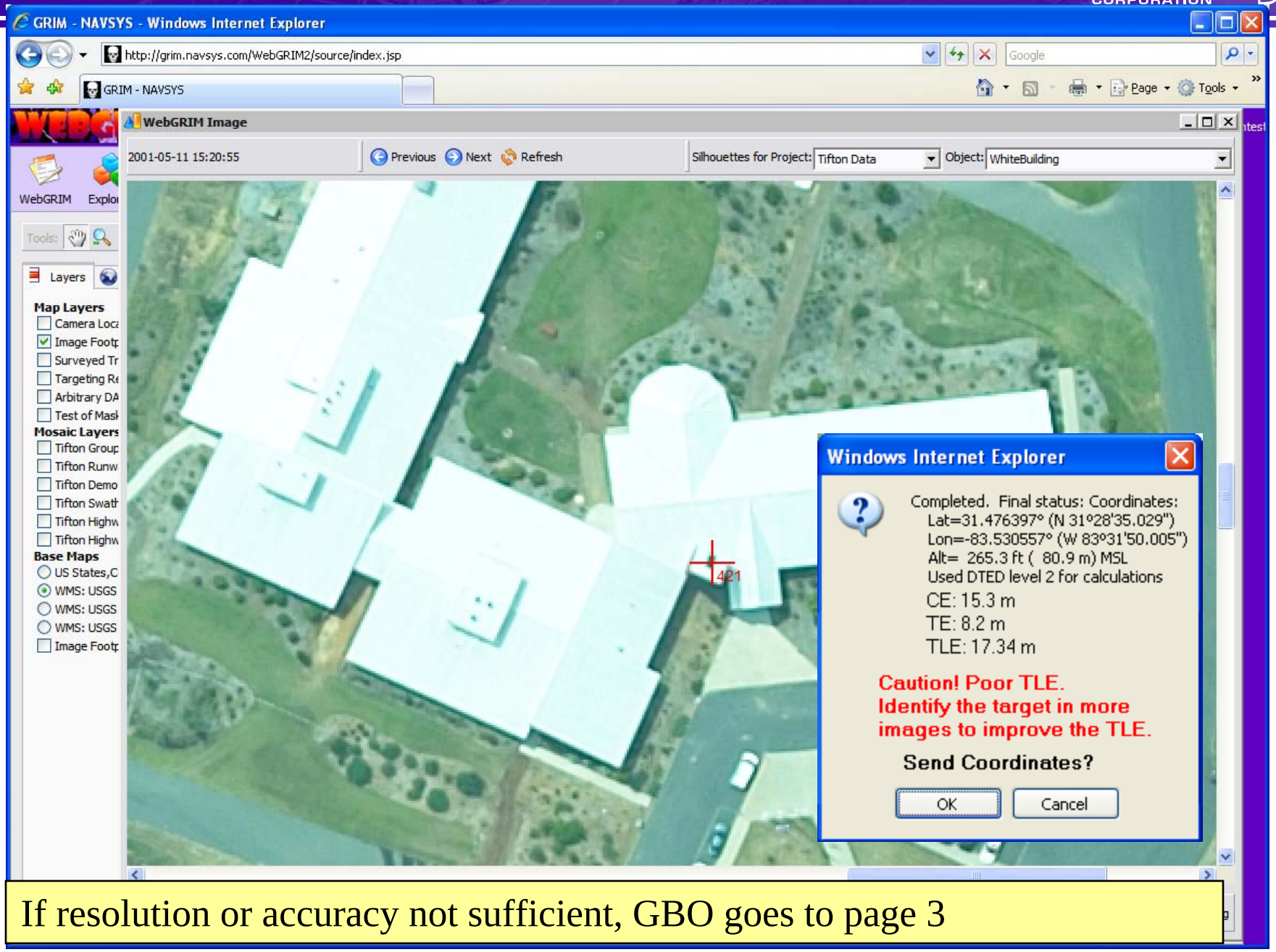
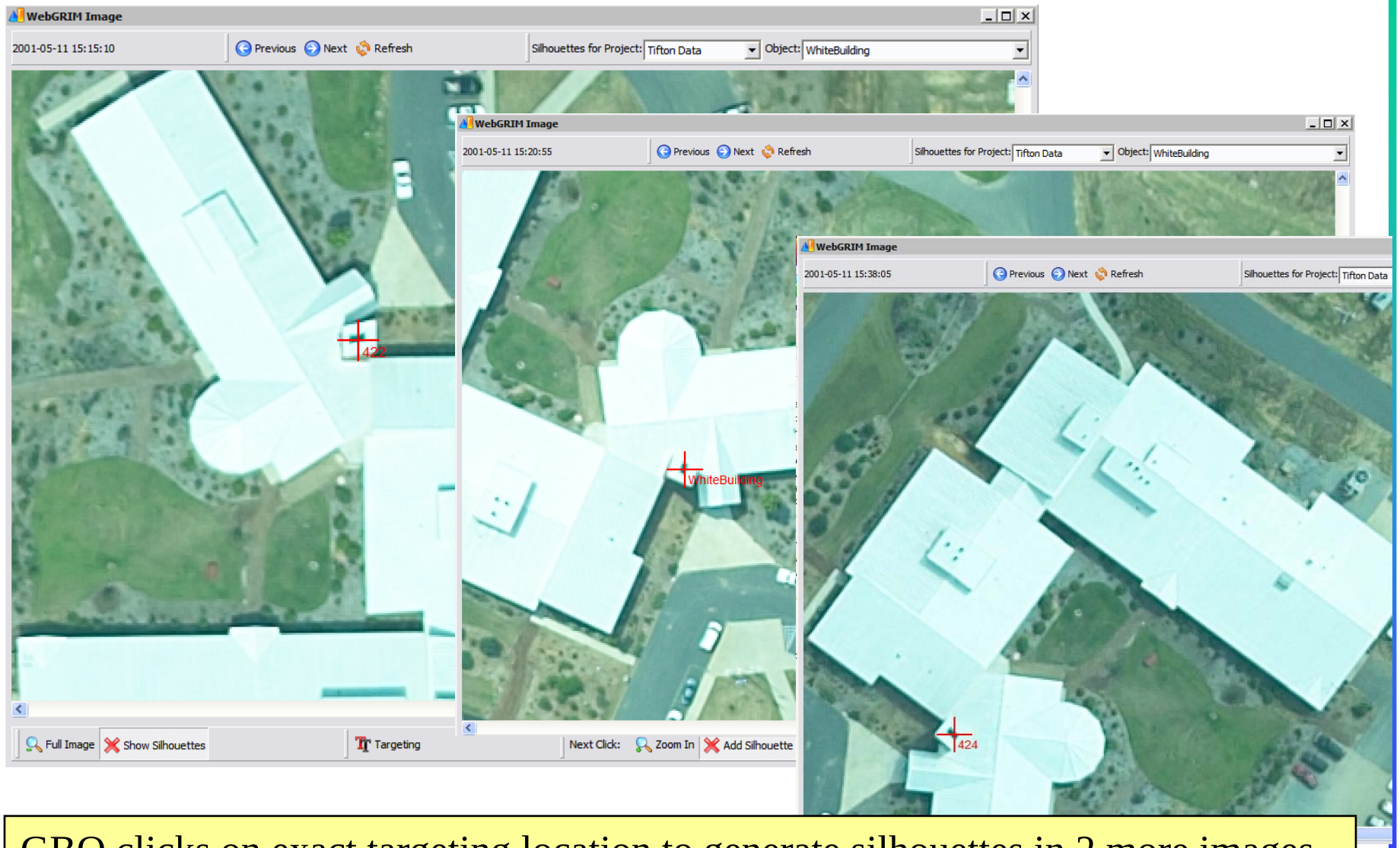
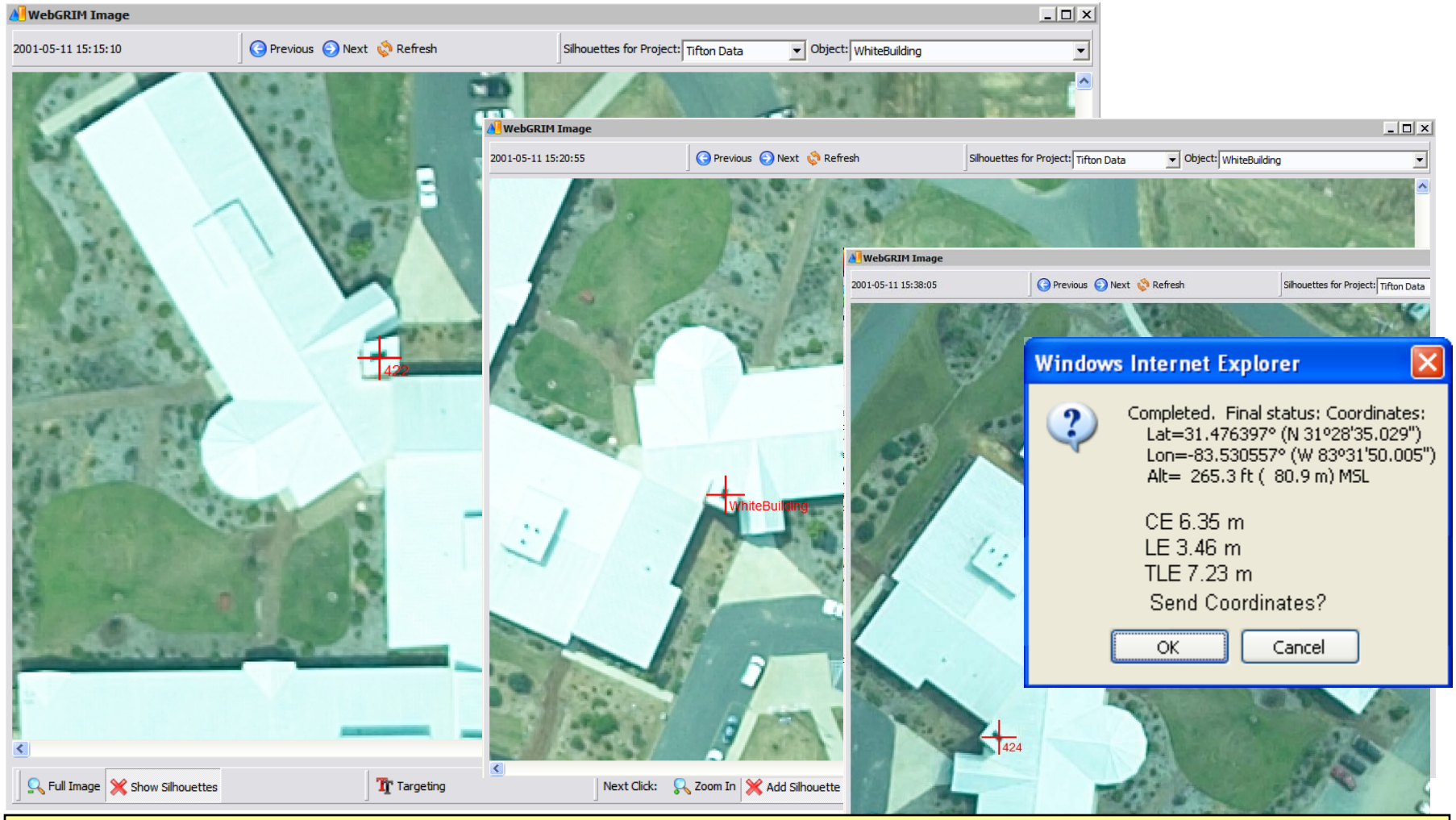


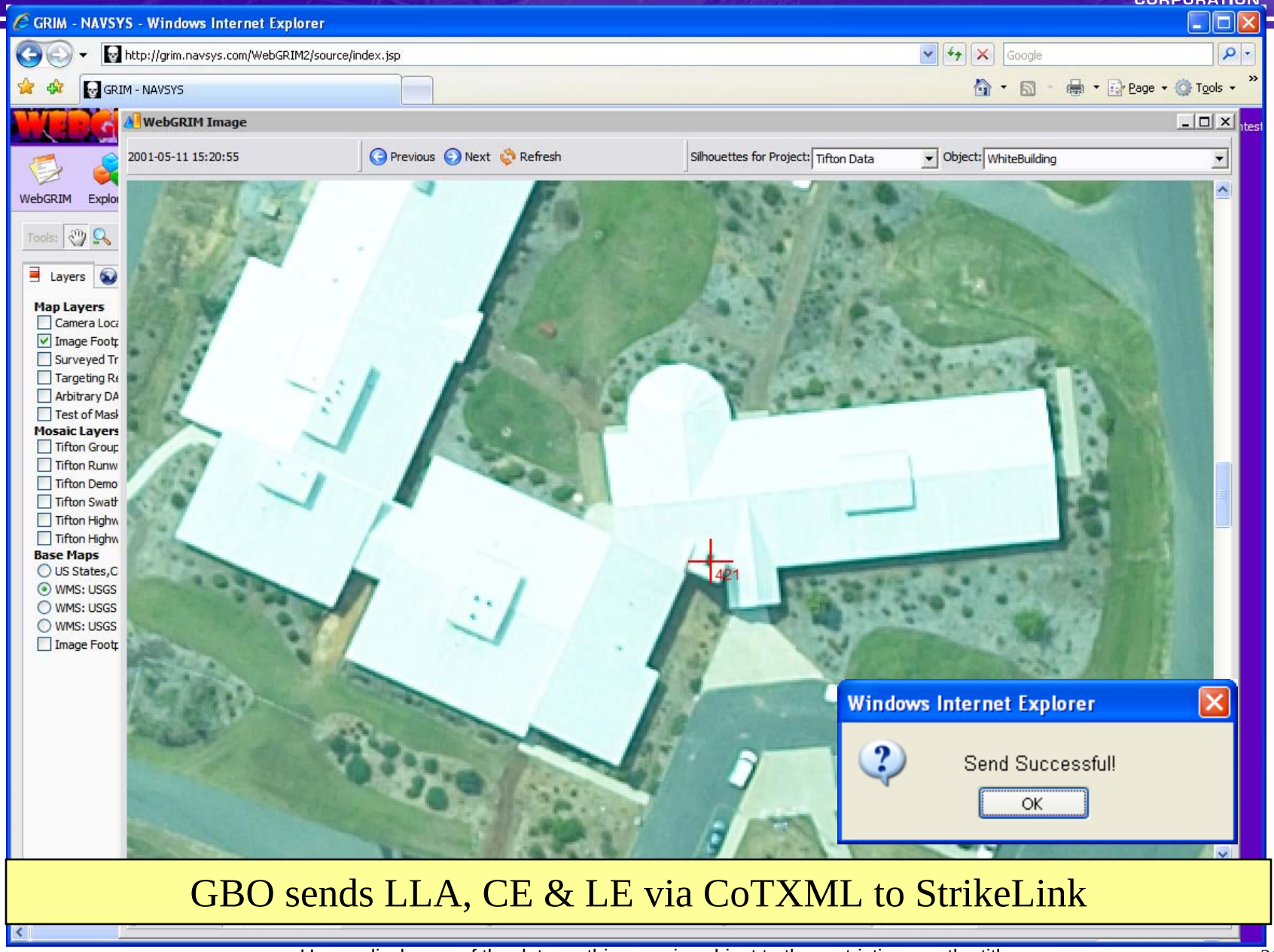
If resolution or accuracy not sufficient, GBO goes to page 3



GBO clicks on exact targeting location to generate silhouettes in 2 more images

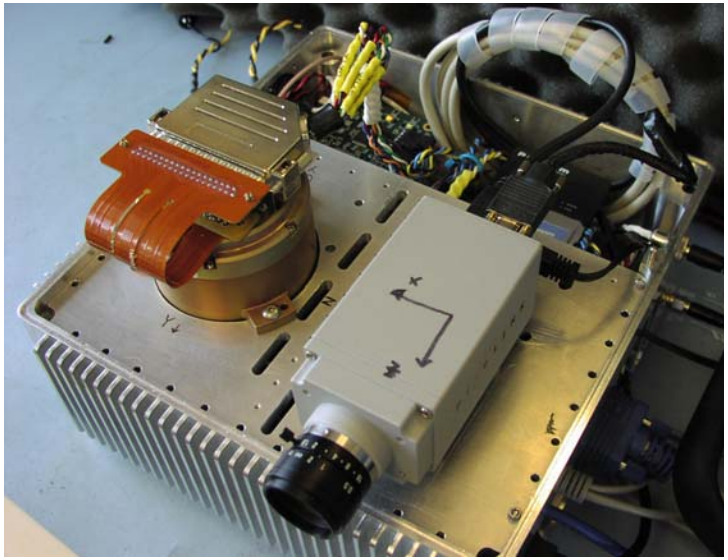


WebGRIM calculates target feature location & displays latitude, longitude & altitude and corresponding CE, LE, & TLE.

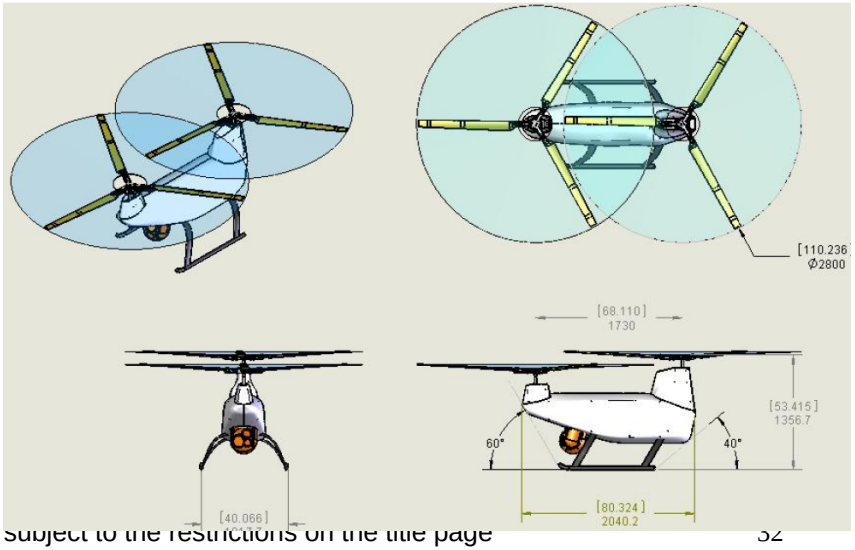


GBO sends LLA, CE & LE via CoTXML to StrikeLink

SBIR UAS Flight Demos



- Manned Test Flights
  - Cessna 206 at USAF Academy
- Planned flight tests with UAS
  - DPI payload capacity of 30 lbs suitable for Phase II demo
  - Available payload power of 50 W
- UAS Transition Plans
  - Develop GBO support payload for transition onto operational Tier II UAS



Conclusion

- Georeferenced imagery can be stored in Oracle GeoRaster database in near real-time
- GI-Eye payload can provide high accuracy meta-data from which GRIM can extract feature coordinates
- WebGRIM can display mosaiced imagery and WMS overlays from Oracle GeoRaster database
- Geospatial database management provides powerful capability for managing UAS imagery and for search, retrieval and viewing of multi-source data
- USMC funding GBO Phase II development & flight test of prototype UAS payload to demonstrate near real-time targeting using georeferenced imagery