

*UAS Payloads Conference  
San Diego, CA*

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

19 November 2008

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(DFARS 252.227-7018 (June 1995))

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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



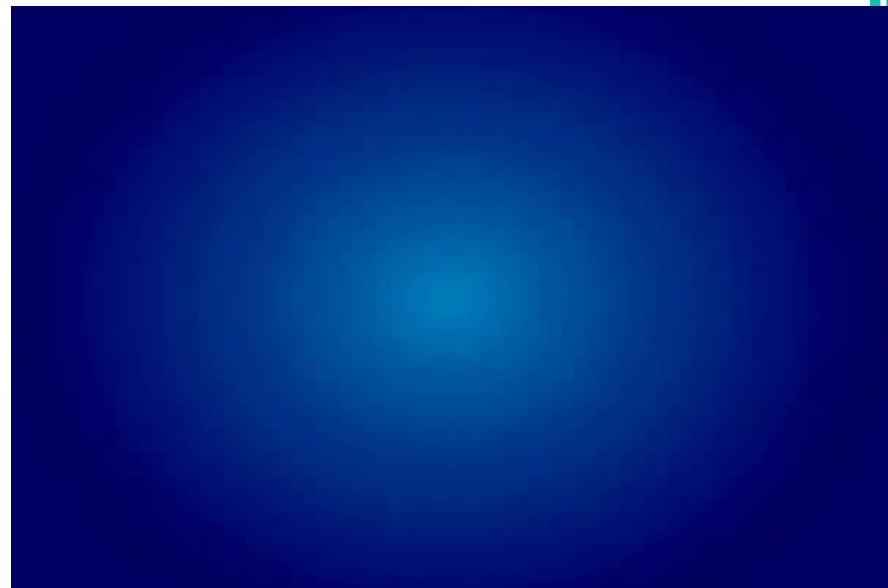
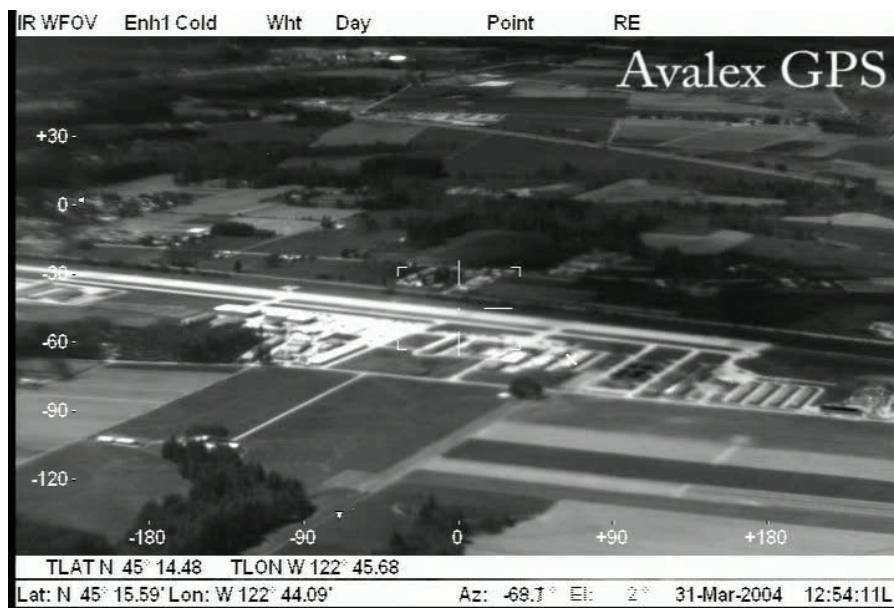
**Sustained data rate ~ 5 Mbps  
(Assumes JPEG2000 compression)**

## 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)**



# 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

UAS provides WiFi access to registered mosaics within 10 km

UAV Flight Operations Crew

GBOs can generate mensurated targets from UAS imagery using Web Tools

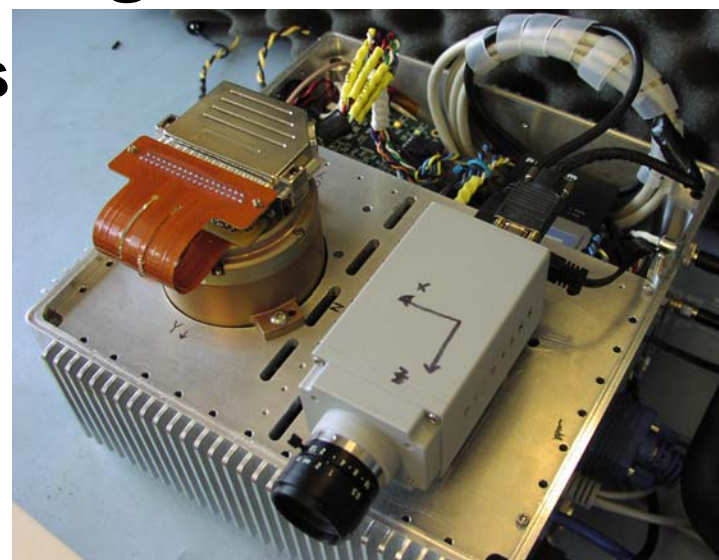
Ground Based Observers



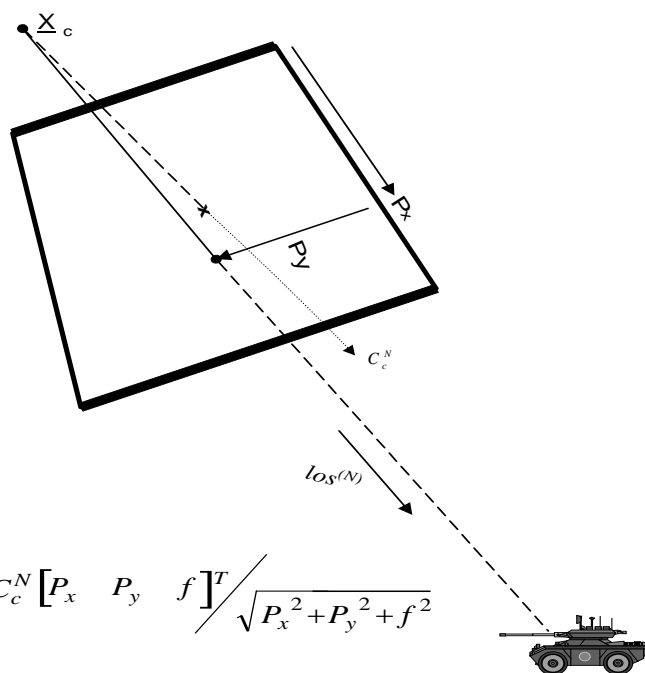
# GI-Eye Auto-Georegistration

“Provides coordinates

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



**UAS GI-Eye Sensor Payload**



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

## FLIR StarSAFIRE III

- Includes GI-Eye for geointing



# Key Performance Issues for High Accuracy GeoRegistration

- Camera location
  - GPS accuracy gives 5 m
  - Precision GPS Ephemeris ZAOD gives < 1 m (absolute)
  
- Camera attitude
  - InterNav inertial alignment
  - <1 mrad using NAVSYS' kinematic GPS alignment
  
- Camera calibration errors
  - Misalignment, focal length and radial distortion
  - GI-Eye sensor calibration reduces to sub-pixel errors

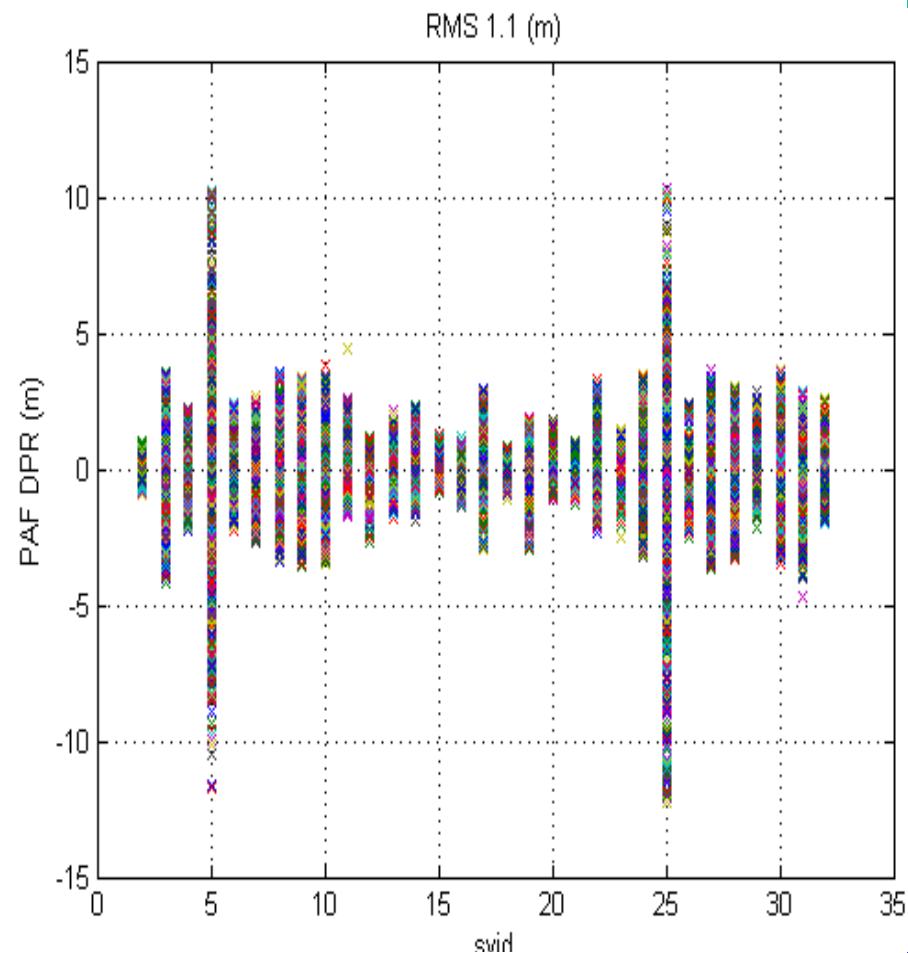
$$x_C^{(N)}$$

$$C_B^N$$

$$C_C^B$$

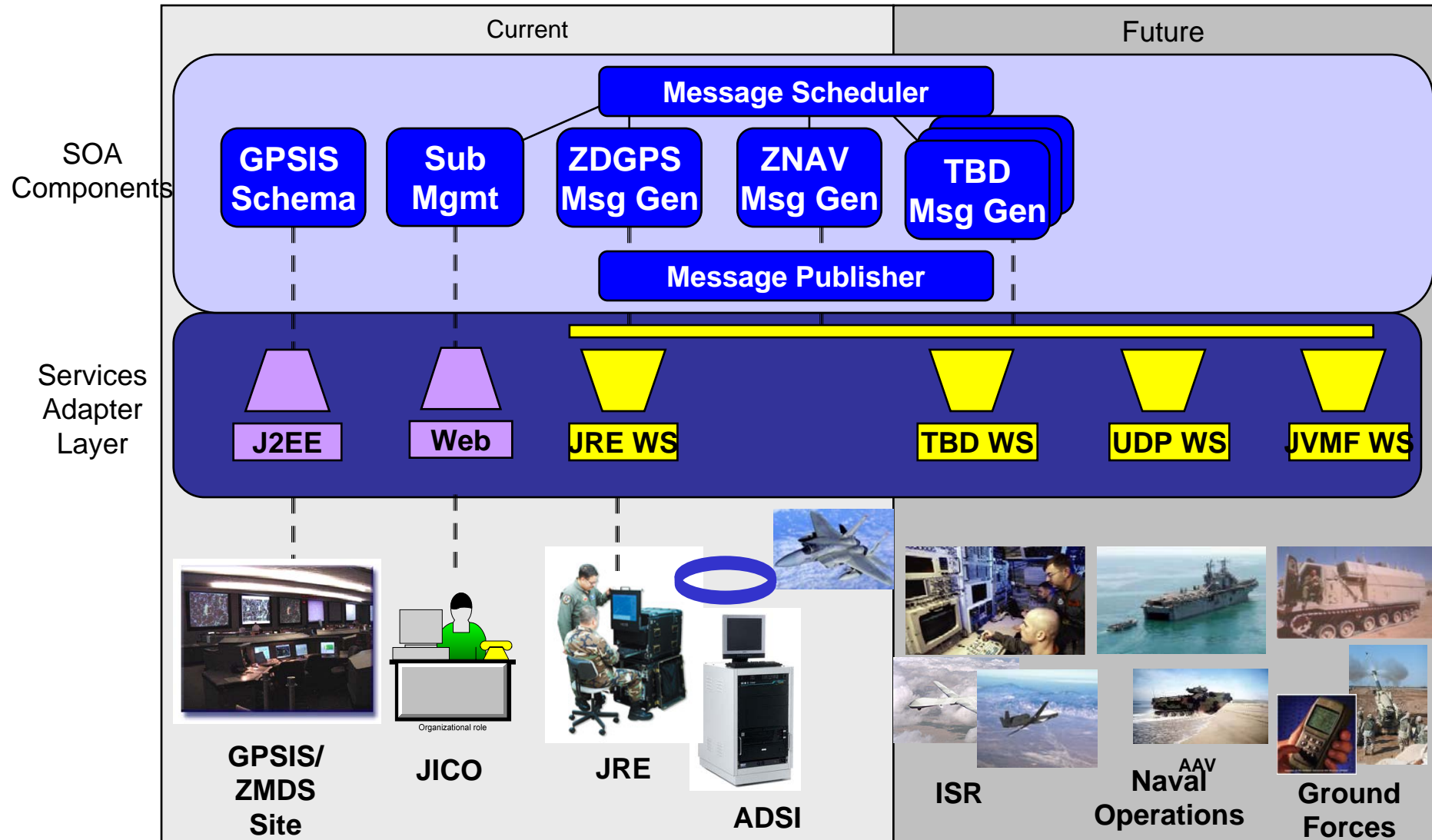
## Accuracy of Precision GPS Ephemeris (PGE)

- **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





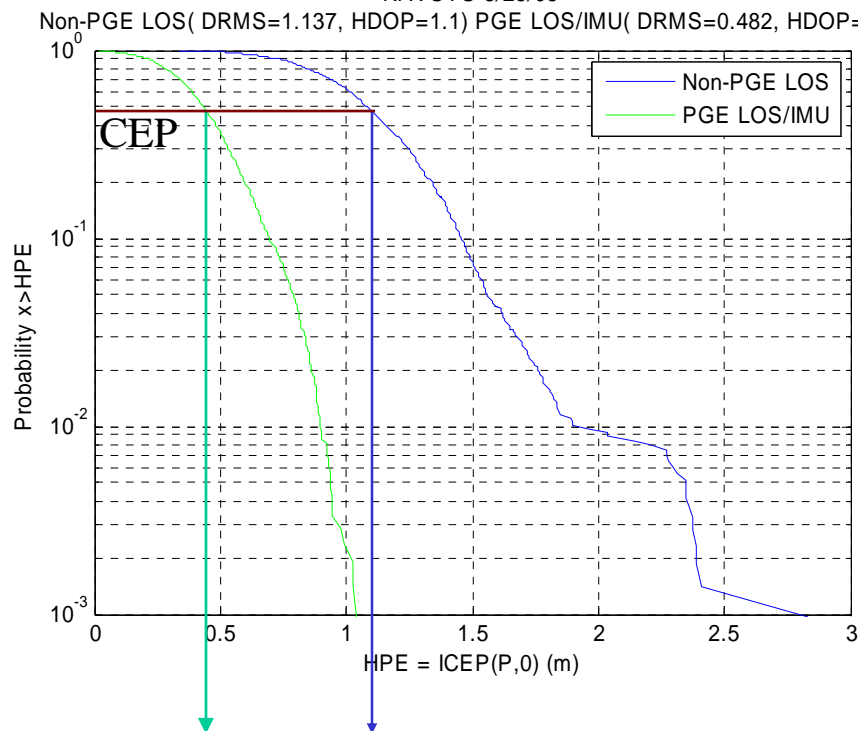
# PGE Tactical Control Station SOA



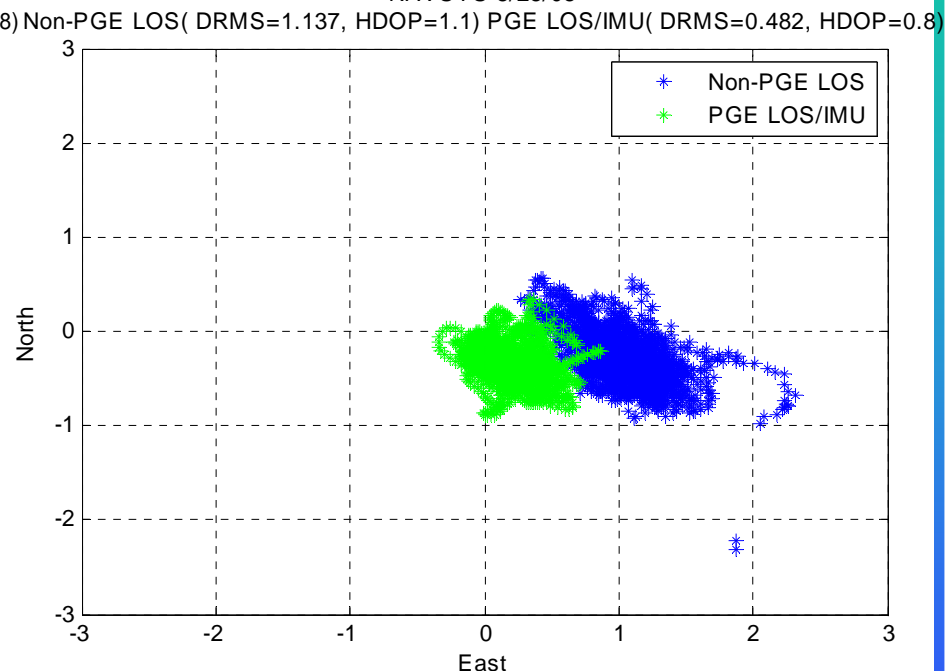
**AFEI's 2008 Excellence in Enterprise Integration Industry Award**

# PGE Corrected Positioning Results

Force-22E Testing - Non-PGE LOS and PGE LOS/IMU Log ICEP Comparison  
NAVSYS 8/28/08

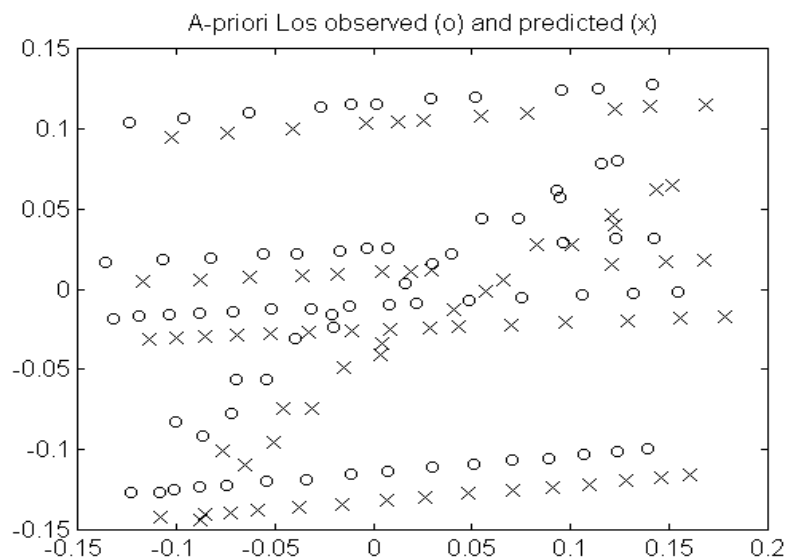


Force-22E Testing Non-PGE LOS & PGE LOS/IMU Horizontal Error Comparison  
NAVSYS 8/28/08

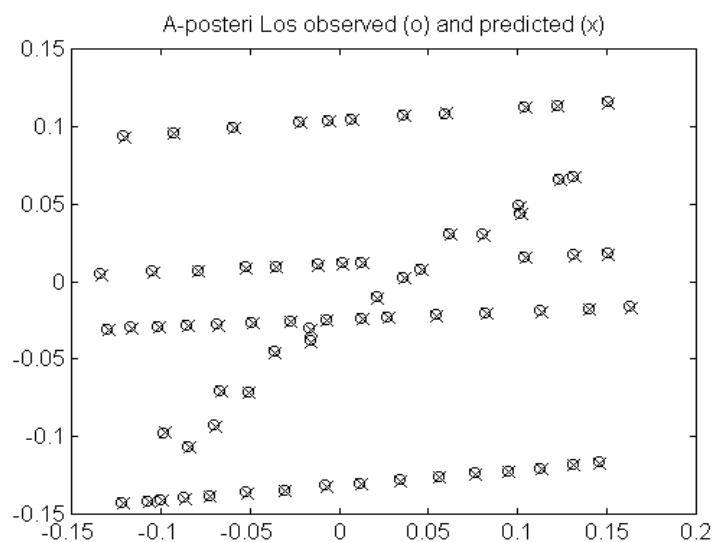
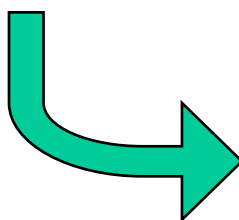


DRMS improves from 1.1m to 0.48 m

# Camera-to-IMU Auto-Cal Example

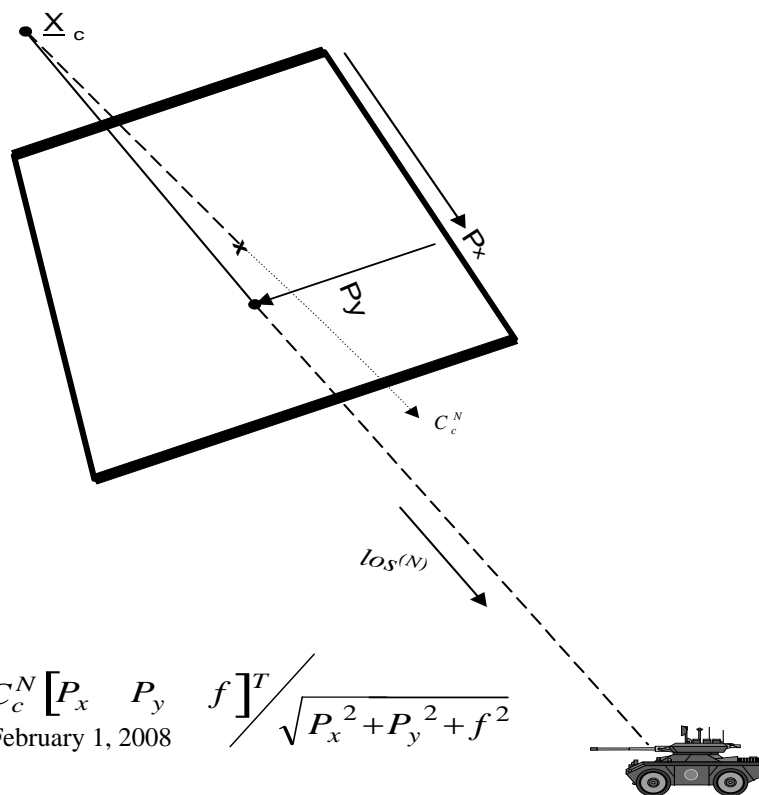


Typical residual  
Misalignment  $< 0.200$  mrad



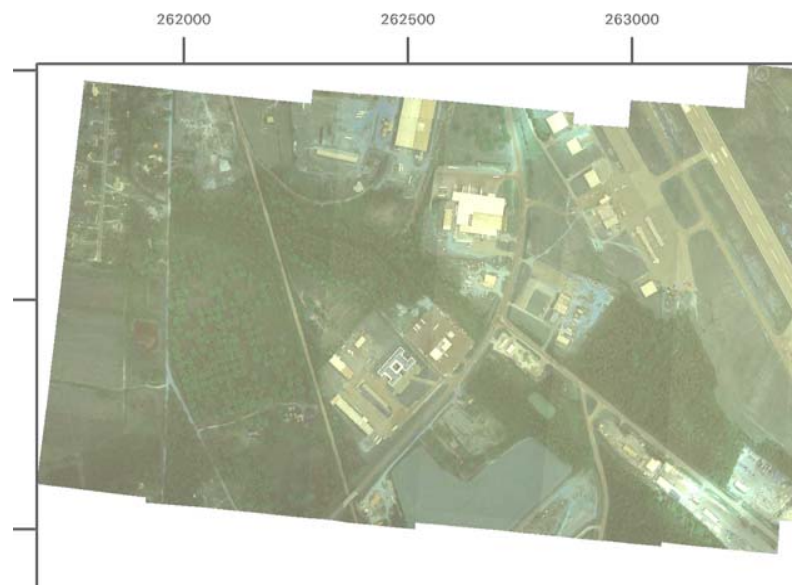
# DTED Effects on Accuracy

- Single Shot Targeting
  - GPS gives position
  - Inertial gives attitude
  - Range to target estimated from DTED
- Automosaic generation
  - DTED, GPS and inertial attitude used to rectify and register images
  - Accuracy is dependent on DTED resolution and quality



$$l_{os}^{(N)} = C_c^N \left[ P_x \quad P_y \quad f \right]^T / \sqrt{P_x^2 + P_y^2 + f^2}$$

February 1, 2008



# 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](http://www.darpa.mil/sto/space/pdf/Morgan_KASSPER_04.pdf)



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

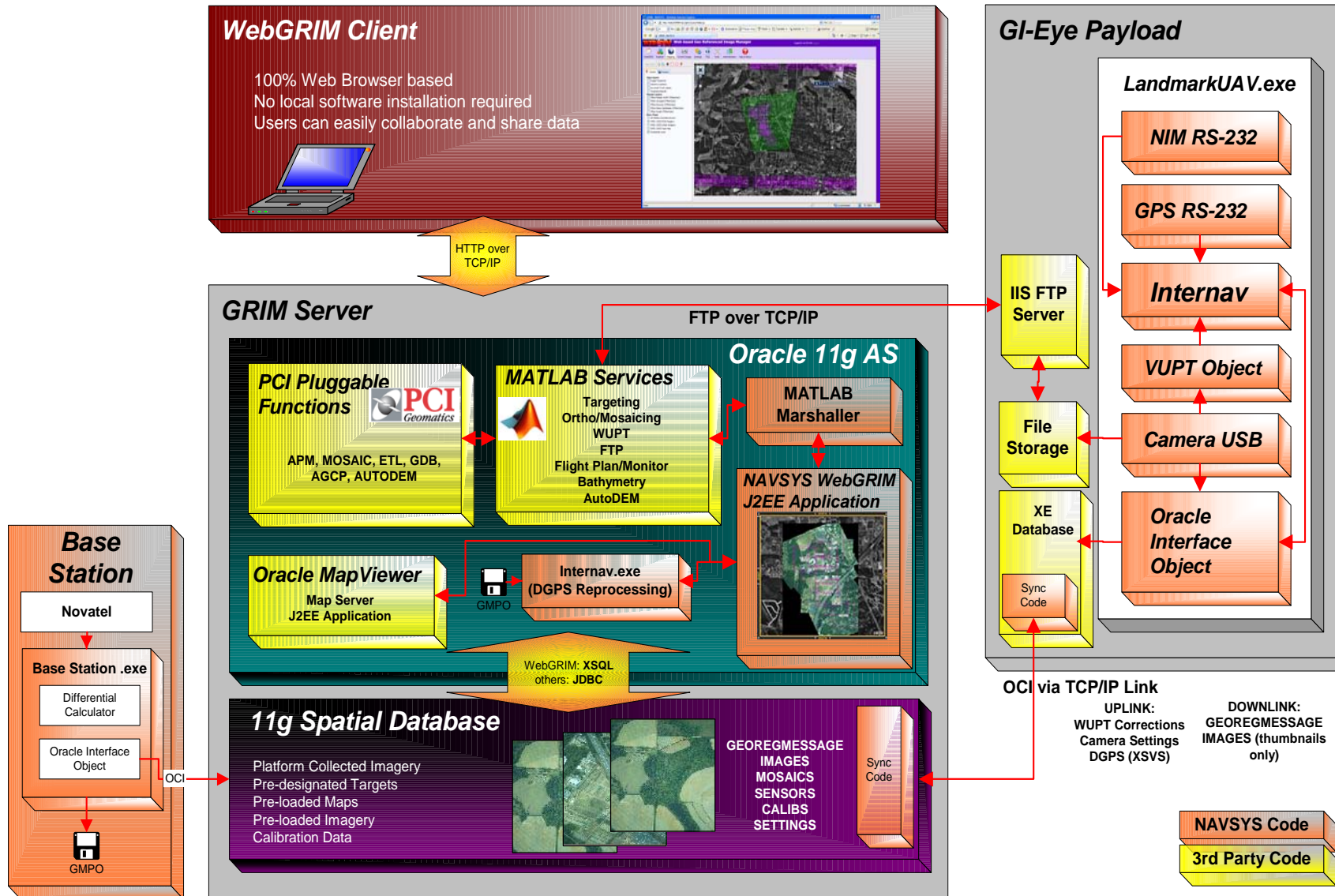
Point	Avg East Error (m)	Avg North Error (m)	Avg dist (m)
NSPL01	-0.11	-0.35	0.37
CPES Blueberry	0.43	-0.87	0.97
CPES Hort Hill	-0.49	-0.32	0.58
Tifton A - CoC	-0.35	-2.23	2.26
FAA TMA	0.20	1.14	1.16
Tifton CBL 150	-0.31	0.20	0.37
Tifton CBL 0	-0.15	0.28	0.32
Tifton CBL 100	-0.24	0.20	0.31
Excelsior 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

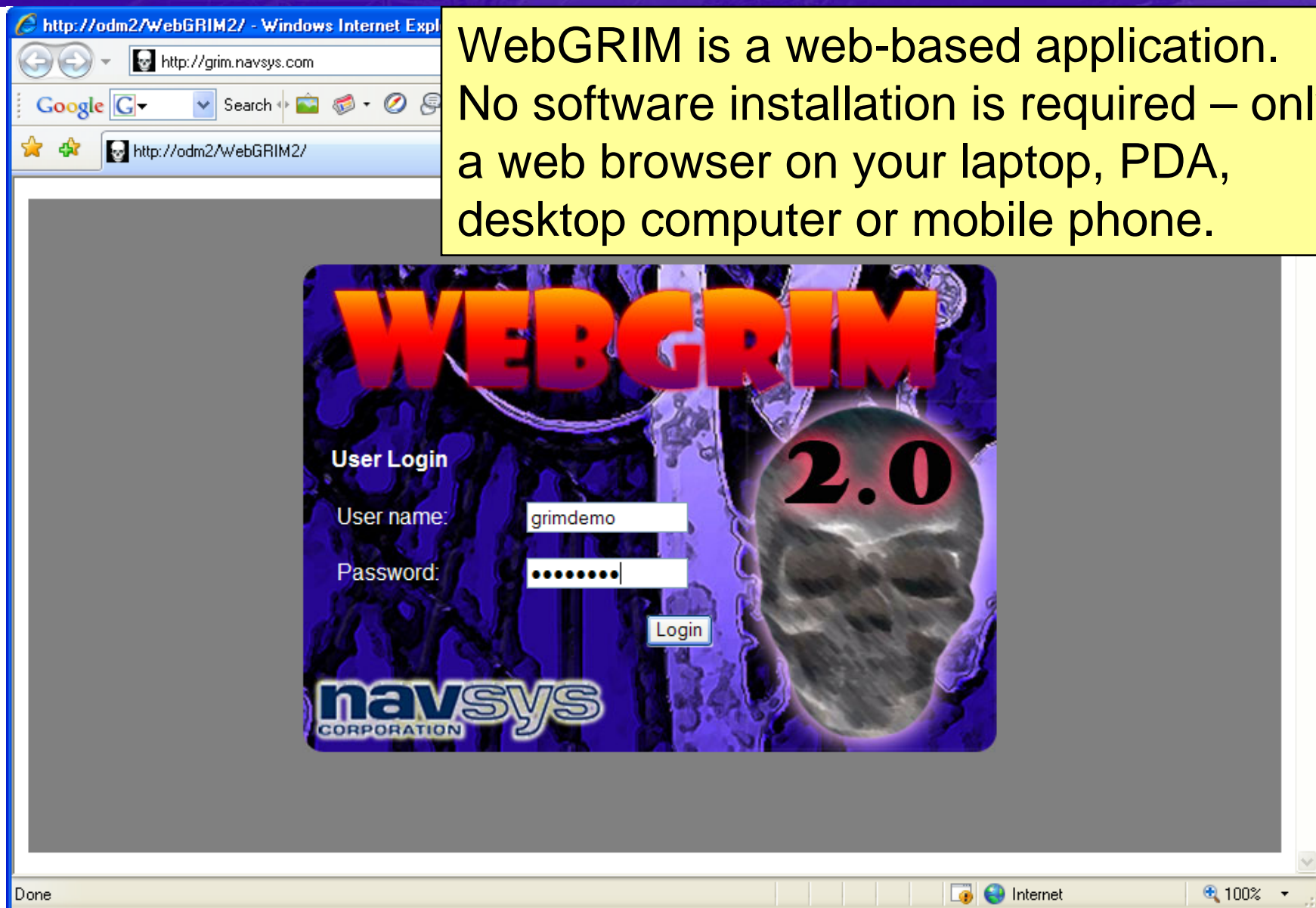
## SITE DISTANCE 600 - 1500 METERS

	D	M	S	D	M	S	H(targ)	sigma n	sigma e	sigma h	#
<b>ALL OBSERVATIONS</b>											
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				
<b>SOME SAMPLES ON WEST TARGET</b>											
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				

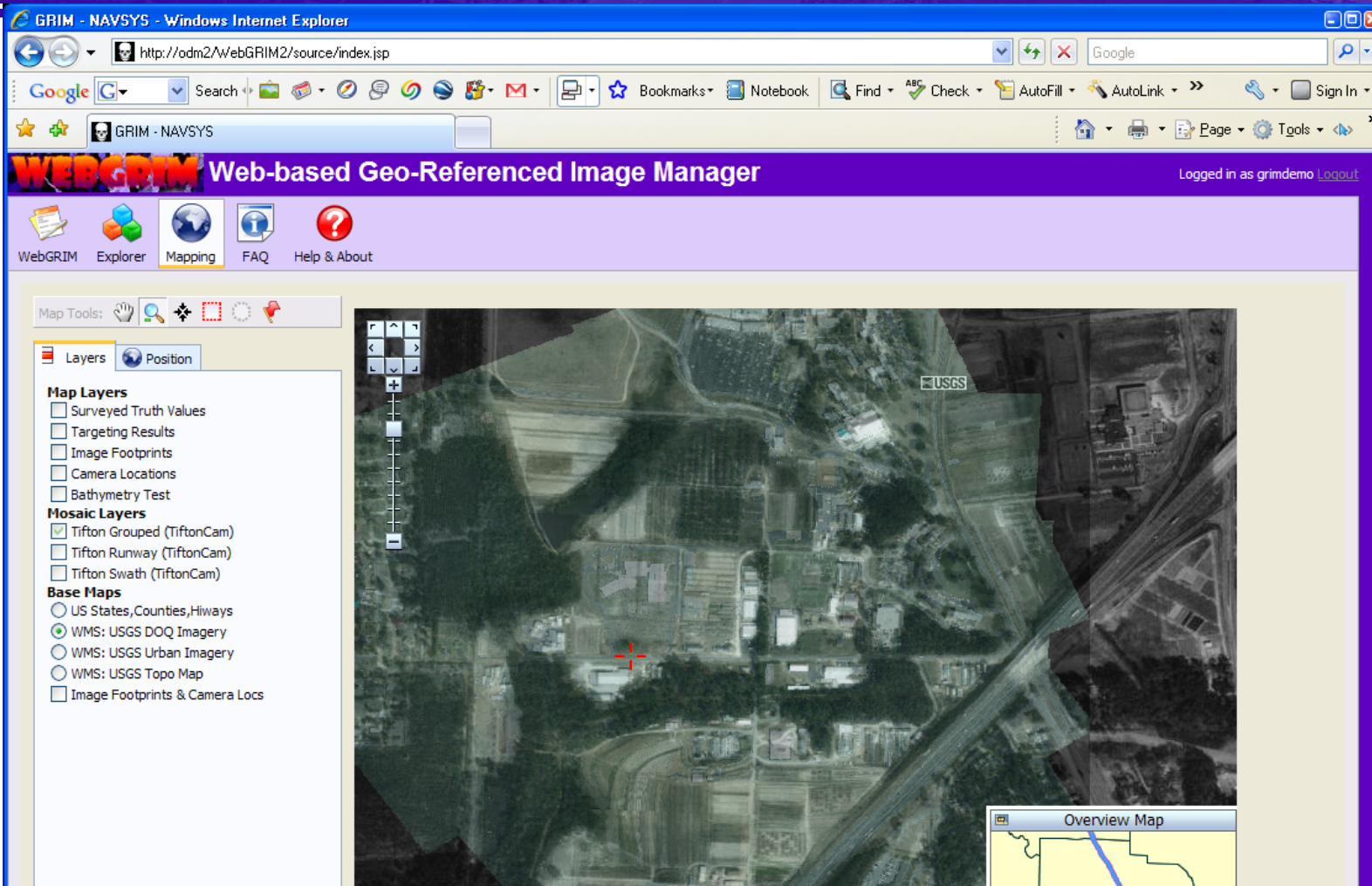
# Overall Web-based Georeferenced Image Manager (WebGRIM) Architecture



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

Google

Google Search

GRIM - NAVSYS

WebGRIM Web-based Geo-Referenced Image Manager

Logged in as grimdemo Logout

WebGRIM Explorer Mapping FAQ Help & About

Map Tools: [Icons]

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

Overview Map

Next, the GBO selects target icon and clicks on target feature

Done Internet 100%

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The screenshot shows the WebGRIM web application running in Internet Explorer. The browser title is "GRIM - NAVSYS - Windows Internet Explorer" and the address bar shows "http://odm2/WebGRIM2/source/index.jsp". The page header includes "WebGRIM Web-based Geo-Referenced Image Manager" and "Logged in as grimdemo". The interface features a navigation menu with "WebGRIM", "Explorer", "Mapping", "FAQ", and "Help & About". A "Map Tools" toolbar is visible above the main map area. On the left, a "Layers" panel is open, showing "Map Layers" (Surveyed Truth Values, Targeting Results, Image Footprints, Camera Locations, Bathymetry Test), "Mosaic Layers" (Tifton Grouped, Tifton Runway, Tifton Swath), and "Base Maps" (US States, Counties, Hiways, USGS DOQ Imagery, USGS Urban Imagery, USGS Topo Map, Image Footprints & Camera Locs). The main map displays an aerial view of a landscape with a red crosshair. A "Coordinates" popup window is overlaid on the map, displaying the following data:

Coordinates	
Latitude:	31.46744 deg
Longitude:	-83.5560 deg
Altitude:	314.9 ft MSL
CE:	6.35 m
LE:	3.25 m
TLE:	7.133 m

Below the main map is an "Overview Map" showing a larger geographic context. A "Send" button is located at the bottom of the coordinate popup. The browser status bar at the bottom indicates "Internet" and "100%".

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

The screenshot displays the WebGRIM application running in a Windows Internet Explorer browser. The browser's address bar shows the URL `http://odm2/WebGRIM2/source/index.jsp`. The application title is "GRIM - NAVSYS - Windows Internet Explorer". The main content area features a map of an aerial view with a red crosshair indicating a specific location. A popup window titled "Coordinates" displays the following data:

- Latitude: 31.46744 deg
- Longitude: -83.5560 deg
- Altitude: 314.9 ft MSL
- CE: 6.35 m
- LE: 3.25 m
- TLE: 7.133 m

Below the coordinate data, the popup displays the text "Send Successful!". To the left of the map is a "Layers" panel with the following sections:

- 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

At the bottom of the application window, a yellow banner contains the text: "GBO sends LLA, CE & LE via CoTXML to StrikeLink".

Use or disclosure of the data on this page is subject to the restrictions on the title page



The screenshot shows the WebGRIM web application in a Windows Internet Explorer browser. The browser address bar shows the URL `http://odm2/WebGRIM2/source/index.jsp`. The page title is "GRIM - NAVSYS - Windows Internet Explorer". The application header includes the "WebGRIM" logo and the text "Web-based Geo-Referenced Image Manager". A navigation bar contains icons for "WebGRIM", "Explorer", "Mapping", "FAQ", and "Help & About". The main content area features a map with a red crosshair. A "Coordinates" popup window displays the following data:

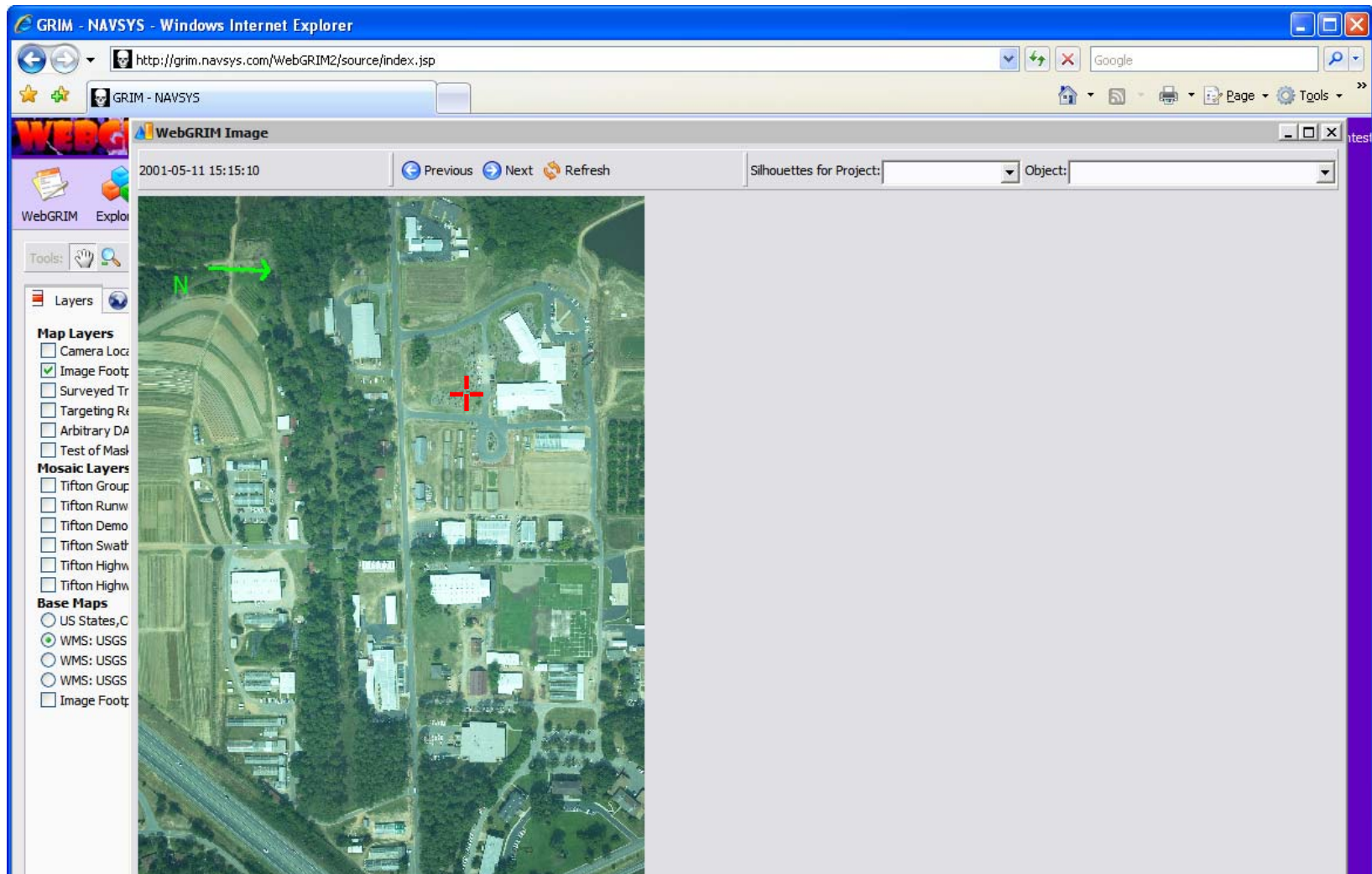
- Latitude: 31.46744 deg
- Longitude: -83.5560 deg
- Altitude: 314.9 ft MSL
- LE: 25.3 m
- CE: 13.2 m
- TLE: 28.5 m

Below the coordinates, a red warning message states: "Caution! Poor TLE. Click here to review raw image." A "Send" button is located at the bottom of the popup. An "Overview Map" window is visible in the bottom right corner of the main map area. The left sidebar contains a "Layers" panel with sections for "Map Layers", "Mosaic Layers", and "Base Maps".

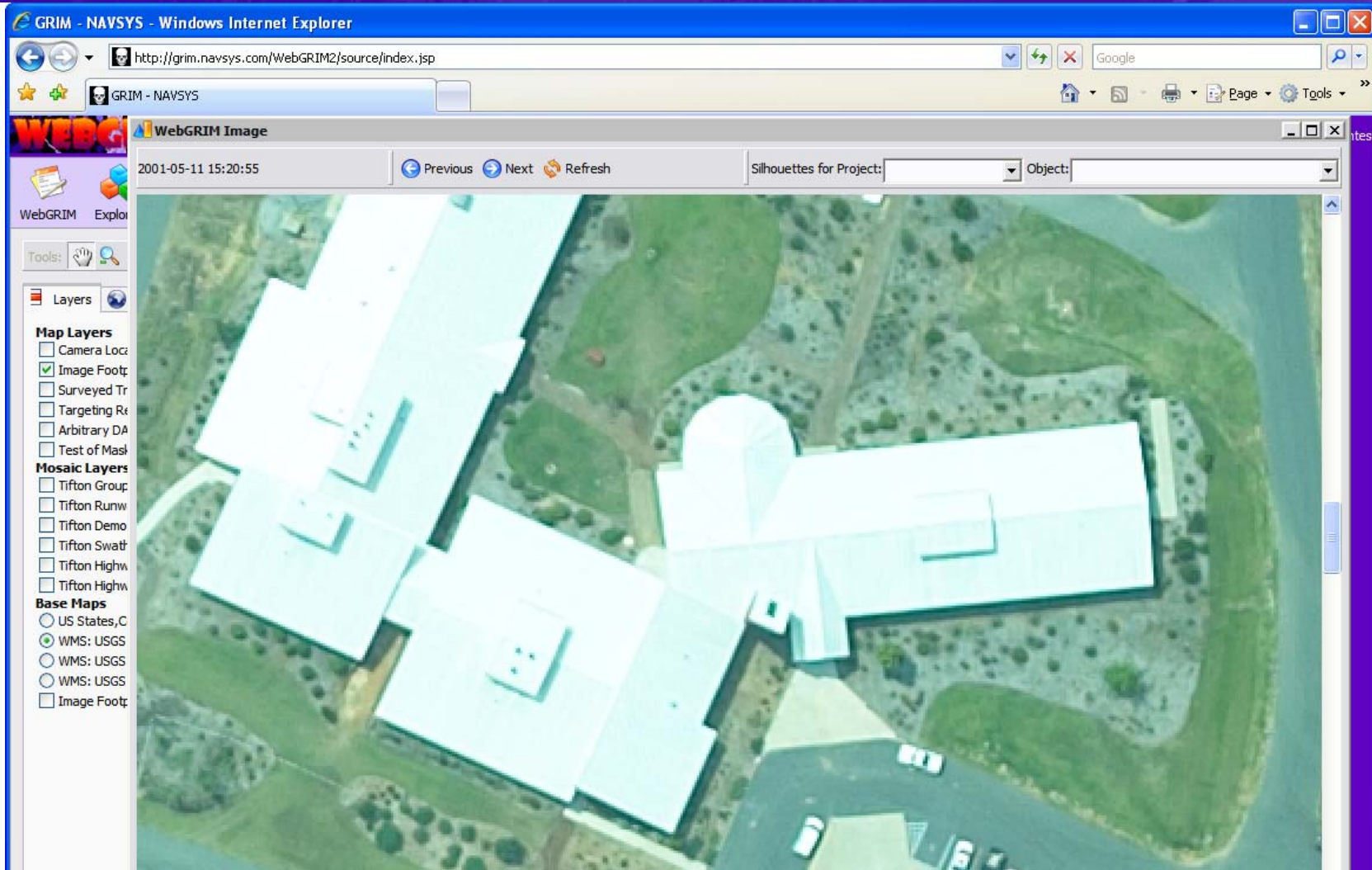
If resolution or accuracy not sufficient, GBO goes to page 2







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

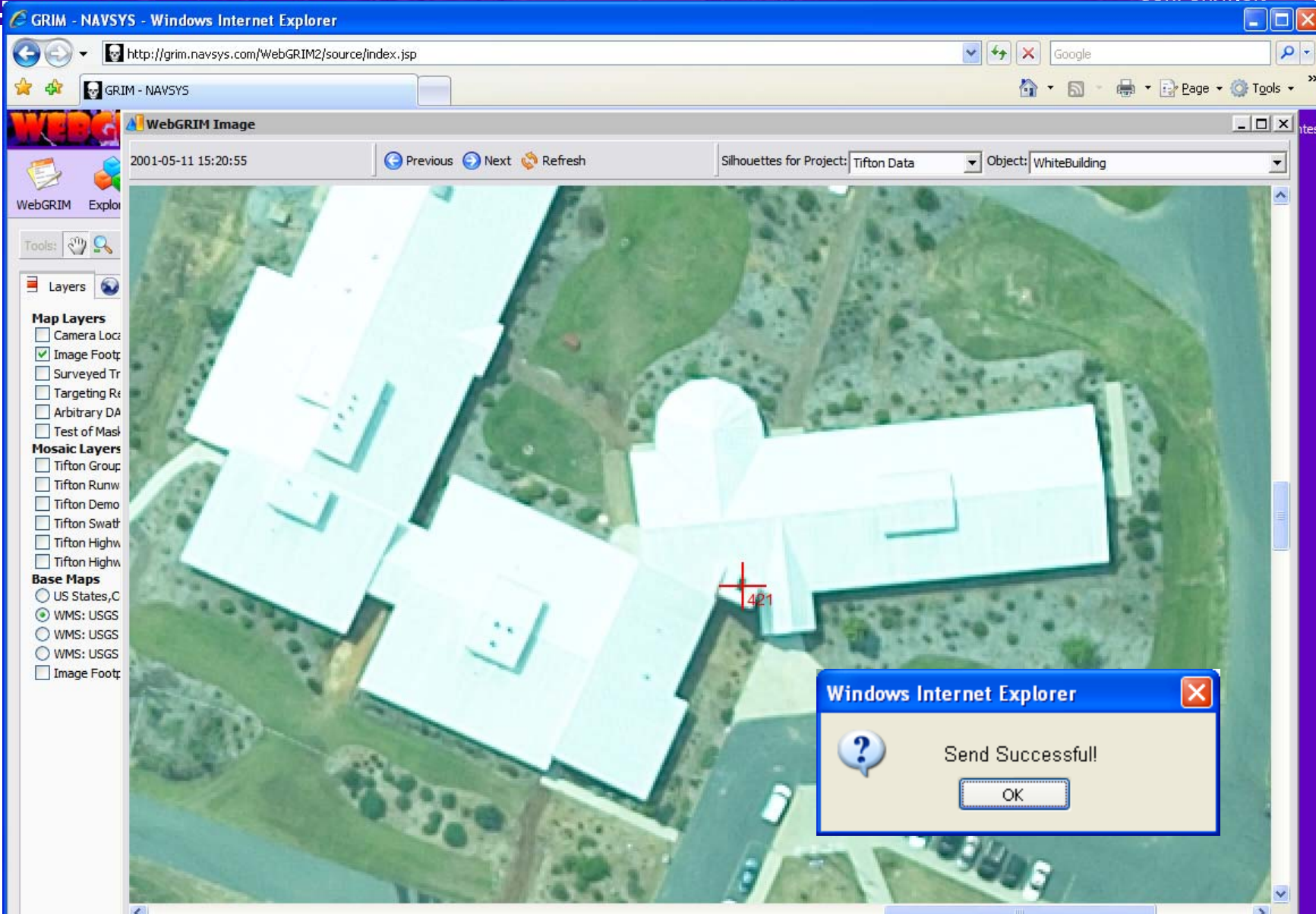


The screenshot shows the WebGRIM application running in Internet Explorer. The browser address bar displays `http://grim.navsys.com/WebGRIM2/source/index.jsp`. The application interface includes a toolbar with 'Previous', 'Next', and 'Refresh' buttons, and dropdown menus for 'Silhouettes for Project: Tifton Data' and 'Object: WhiteBuilding'. A 'Layers' panel on the left lists 'Map Layers' (Camera Location, Image Footprint, Surveyed Trajectory, Targeting Region, Arbitrary Data, Test of Mask) and 'Mosaic Layers' (Tifton Group, Tifton Runway, Tifton Demo, Tifton Swath, Tifton Highway, Tifton Highway). Under 'Base Maps', 'WMS: USGS' is selected. A red crosshair is positioned on a building in the aerial view, with the number '421' below it. An 'Internet Explorer' dialog box is open, showing the following information:

**Completed. Final status: Coordinates:**  
Lat=31.476397° (N 31°28'35.029")  
Lon=-83.530557° (W 83°31'50.005")  
Alt= 265.3 ft ( 80.9 m) MSL  
Used DTED level 2 for calculations  
CE 6.35 m  
LE 3.46 m  
TLE 7.23 m  
Send Coordinates?  
OK Cancel

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



GRIM - NAVSYS - Windows Internet Explorer

http://grim.navsys.com/WebGRIM2/source/index.jsp

WebGRIM Image

2001-05-11 15:20:55 Previous Next Refresh Silhouettes for Project: Tifton Data Object: WhiteBuilding

Layers

Map Layers

- Camera Loc
- Image Foot
- Surveyed Tr
- Targeting R
- Arbitrary DA
- Test of Mask

Mosaic Layers

- Tifton Group
- Tifton Runw
- Tifton Demo
- Tifton Swat
- Tifton Highw
- Tifton Highw

Base Maps

- US States,C
- WMS: USGS
- WMS: USGS
- WMS: USGS
- Image Foot

Windows Internet Explorer

Completed. Final status: Coordinates:  
 Lat=31.476397° (N 31°28'35.029")  
 Lon=-83.530557° (W 83°31'50.005")  
 Alt= 265.3 ft ( 80.9 m) MSL  
 Used DTED level 2 for calculations  
 CE: 15.3 m  
 TE: 8.2 m  
 TLE: 17.34 m

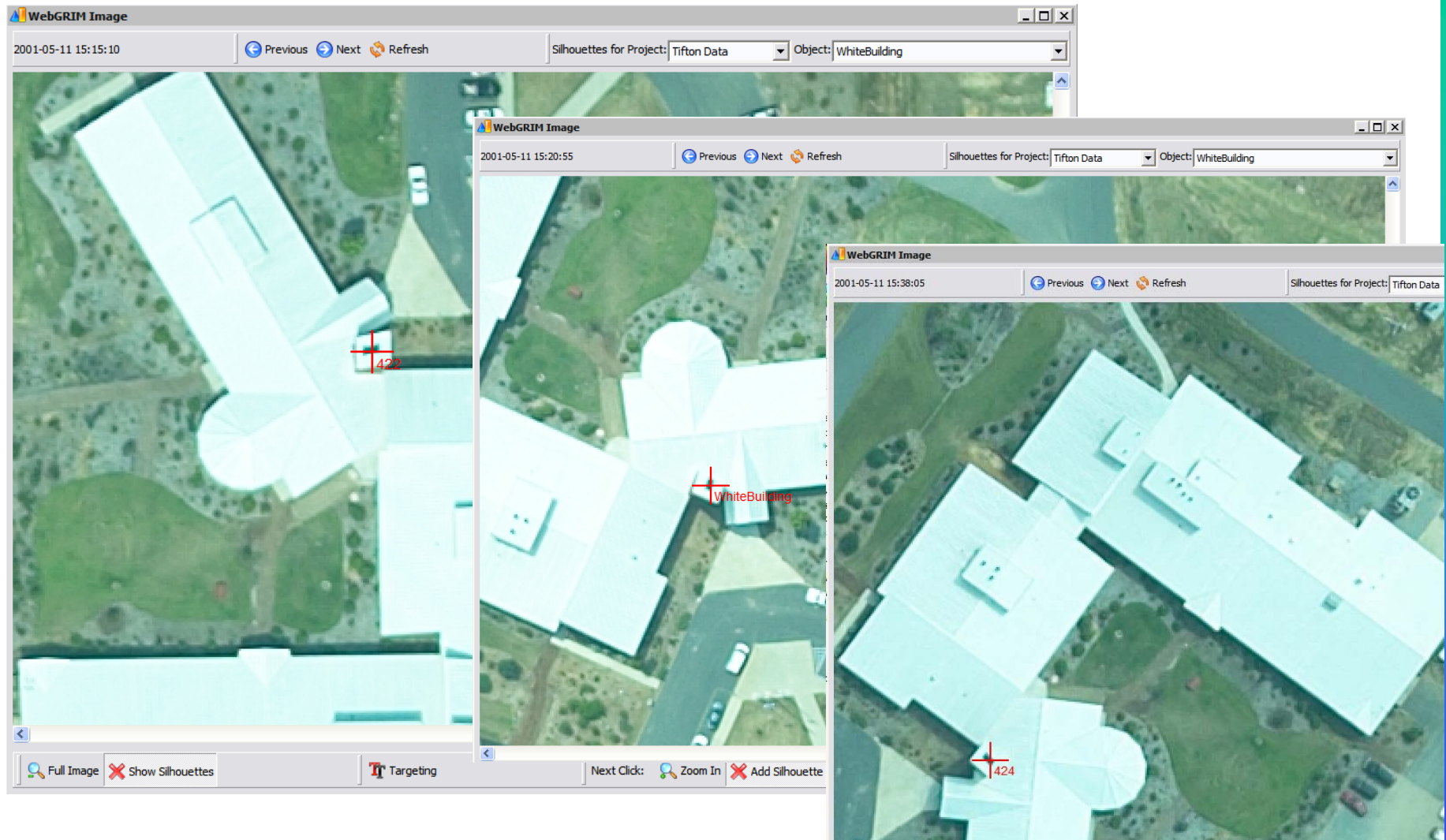
**Caution! Poor TLE.  
 Identify the target in more  
 images to improve the TLE.**

Send Coordinates?

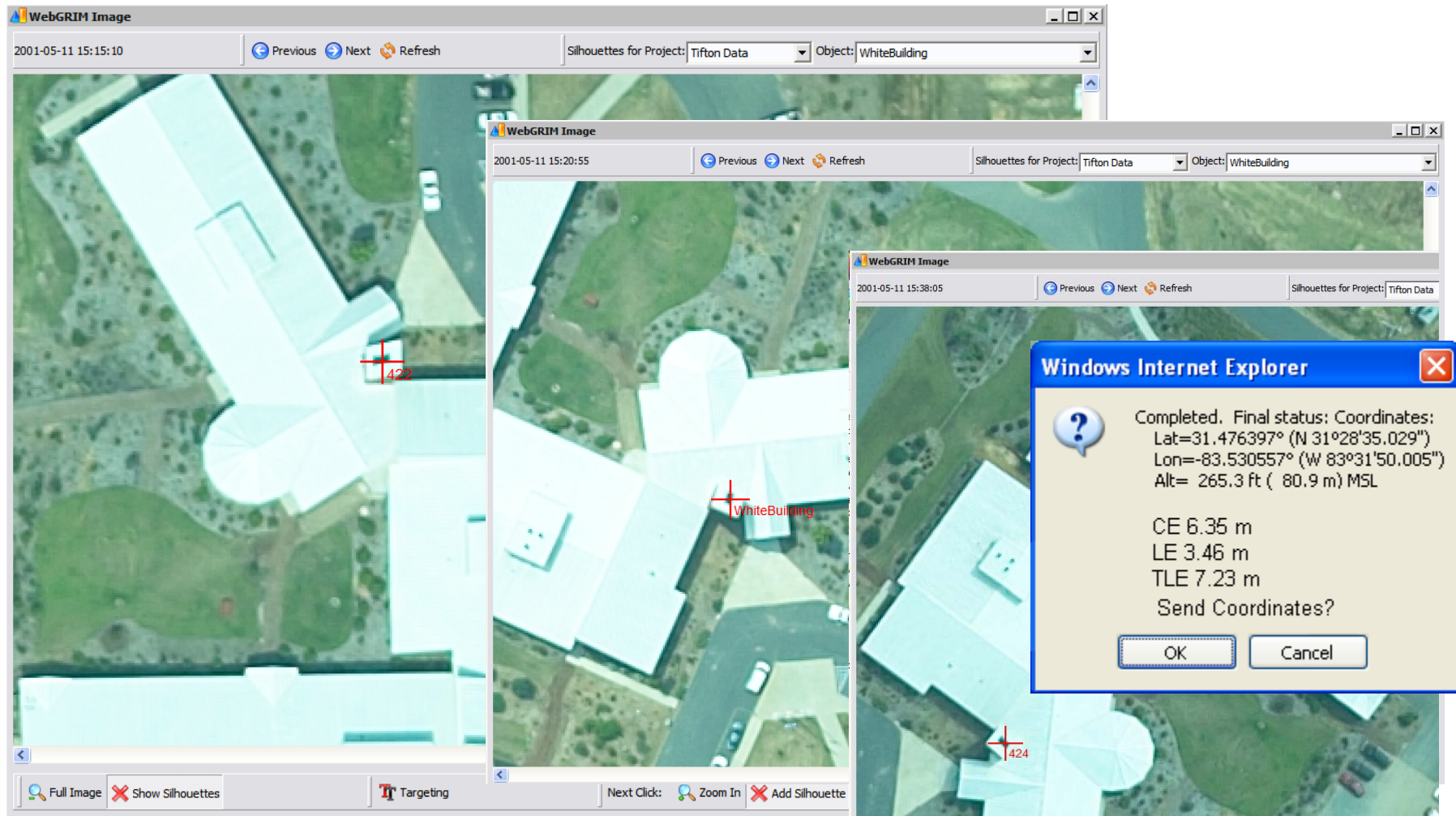
OK Cancel

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



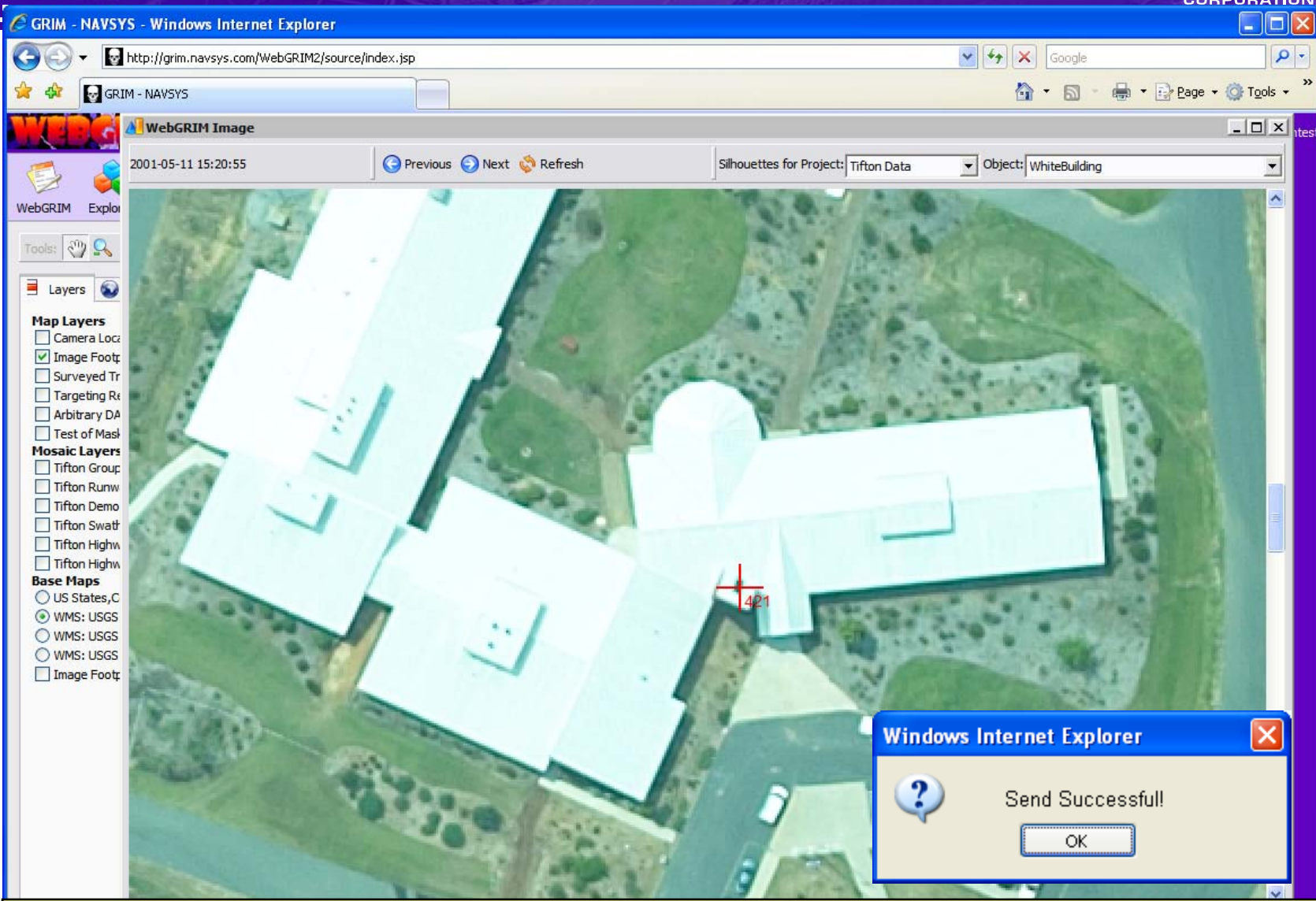


GBO clicks on exact targeting location to generate silhouettes in 2 more images



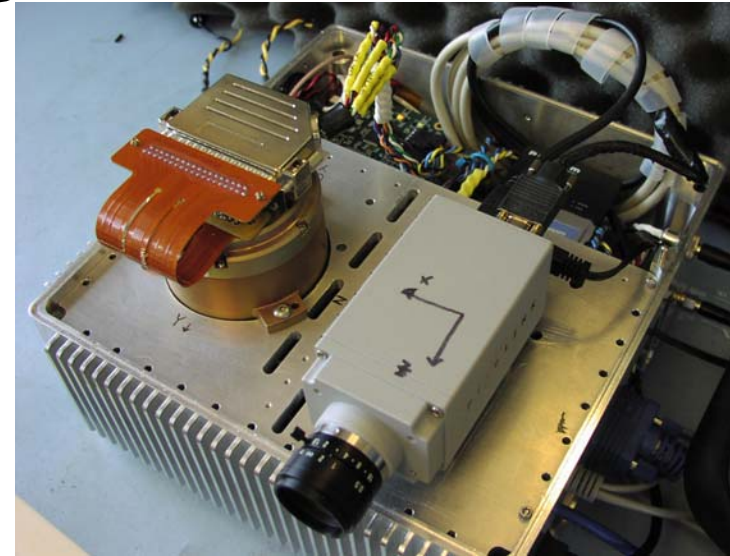
WebGRIM calculates target feature location & displays latitude, longitude & altitude and corresponding CE, LE, & TLE.



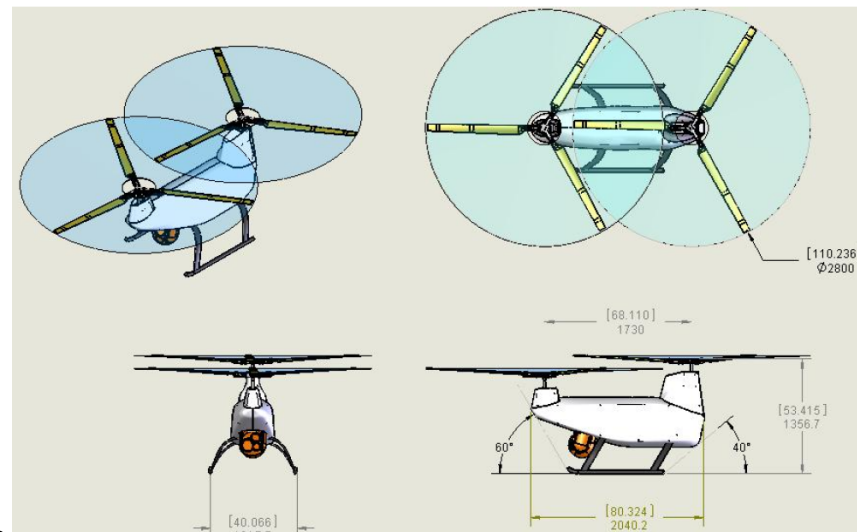


GBO sends LLA, CE & LE via CoTXML to StrikeLink

# 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



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## *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