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

IDGA's 5th Annual Unmanned Aircraft Systems Conference

Dr. Alison Brown
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www.navsys.com

Agenda

- Introduction
- Methods for near-real time image mensuration to support call-for-fire operations
- Key performance issues for high accuracy image georegistration
- Data management for multiple sensor feeds

NAVSYS Corporation

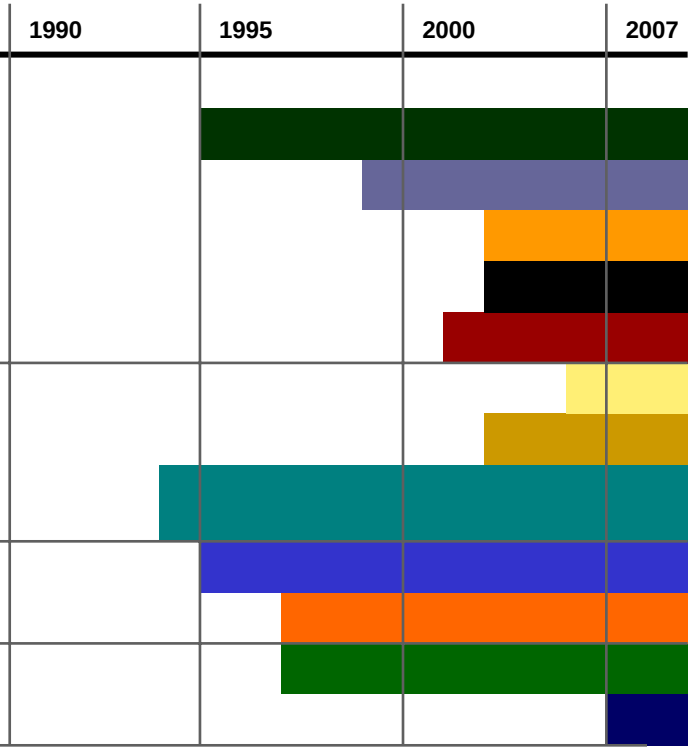
Founded in 1986

Mission Statement

To provide specialized GPS products & services for our customers by leveraging our core technologies, unique technical expertise, innovative engineering, strong work ethic, and high standards of excellence.

NAVSYS history of addressing GPS gaps through complementary technologies

Challenge	Technology	Description
Interference		
Terrain	Beamforming	Adaptive array to mitigate multipath
Jamming	JLOC	Identifies, locates source of GPS jamming
	GPS-NAP	GPS-free P-RELNAV solution through Link-16
Indoor navigation	NetAssist	Network assistance for weak signal tracking
	POSCOMM	RF ranging for indoor navigation
Accuracy	PGE	High accuracy ephemeris every 15 minutes
	Integrity Monitor	Monitors and rejects signal exceptions
	SIGGEN (WAAS)	Broadcasts corrections over WAAS satellites
Receiver power, size	TIDGET	Low power, low cost sensor
	LocatorNet	Processes GPS signal away from TIDGET
Geospatial integration	GI-Eye	Real-time "spatially aware" aerial imagery
	GRIM	Generates auto-mosaics from GI-Eye feeds



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Need for Timely Registered Imagery

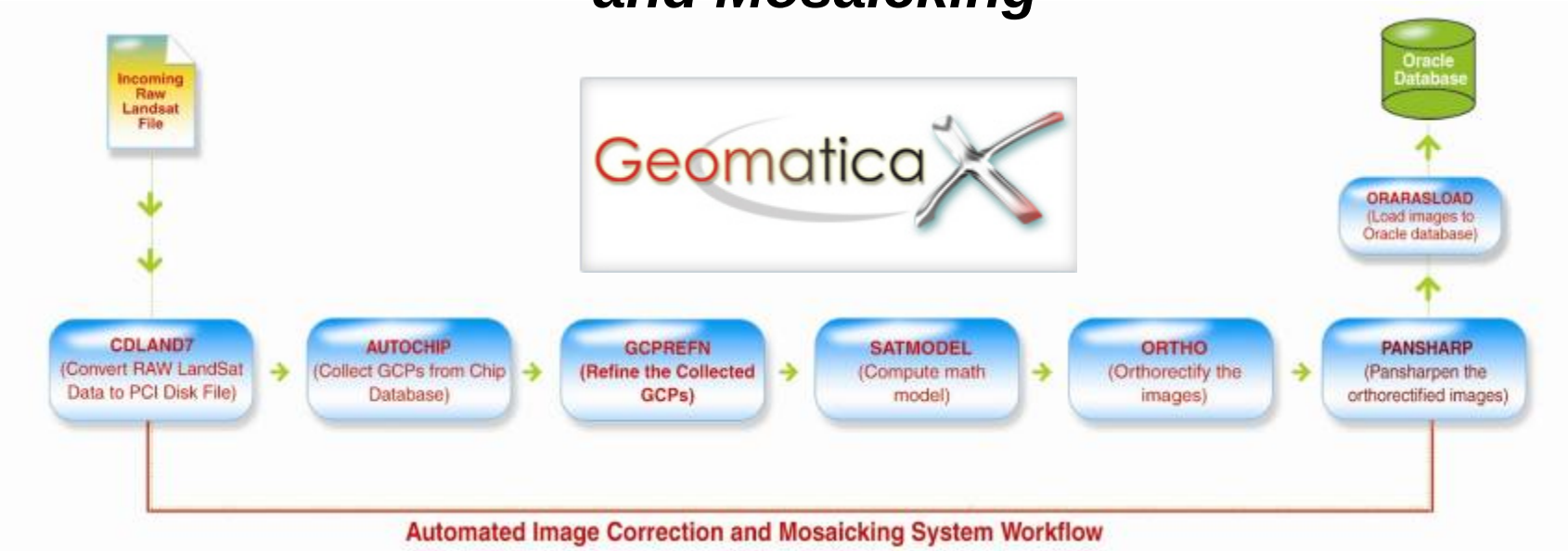
- Multiple platforms are carrying sensors to support battespace awareness
- Real-time video is being downlinked to the battlefield
- Precision registration of imagery is needed to allow sensor data to be used for targeting
- Near-real time mensurated imagery is needed to support call-for-fire operations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

Current Rover Real-Time Video Display

- 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)

Typical Image Mensuration WorkFlow for Targeting and Mosaicking



- Requires significant workstation processing to execute
- Accuracy dependent on reference imagery and DTED
- Targeting performance degrades when in 3D environment where Digital Surface Model deviates from DTED

Call for Fire with PSS-SOF and StrikeLink™

AV-8B F-16 F/A-18

F-16

Naval Gunfire

HIMARS

Mortars

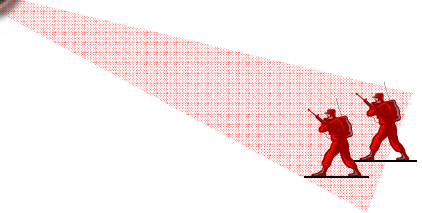
Artillery

PRC-117F

AFATDS

StrikeLink™

Vector 21B
(CLRF)



MIL-STD Cable
VHF/ SATCOM
UHF

Vector 21 or TLDHS Target Location Error (TLE) at 5 km

- **Current TLDHS**
  - Uses conventional GPS
  - Magnetic heading sensor
  - Laser rangefinder
- **Desired UAS System**
  - Uses Zero-Age GPS corrections from GPSOC
  - 3-axis IMU for attitude (az/el)
  - Multilateration or Precision DSM used to estimate range to target

Targeting Sensor	Current TLDHS	Desired UAS
GPS Accuracy	8 m	1.5 m
Azimuth Accuracy	10 mils	1 mil
Ranging Accuracy	5 m	4 m
TLE (CEP)	34 m	6 m

Precision Strike Suite for Special Operations Forces (PSS-SOF)

Requirement

- "Digital Divide" still exists for Precision Engagement by Tactical Users
- ✓ Strikes still called over voice nets using "non-integrated" GPS, LRF, map and compass
- ✓ Coordinates lack pedigree for PGMs
- ✓ Different delivery platforms require coordinates in different formats

Background

- National Geospatial Intelligence Agency (NGA) validated capability for PGM targeting and mission planning
- ✓ Hosted on user's existing systems
- ✓ First deployed to OEF in DEC 2001

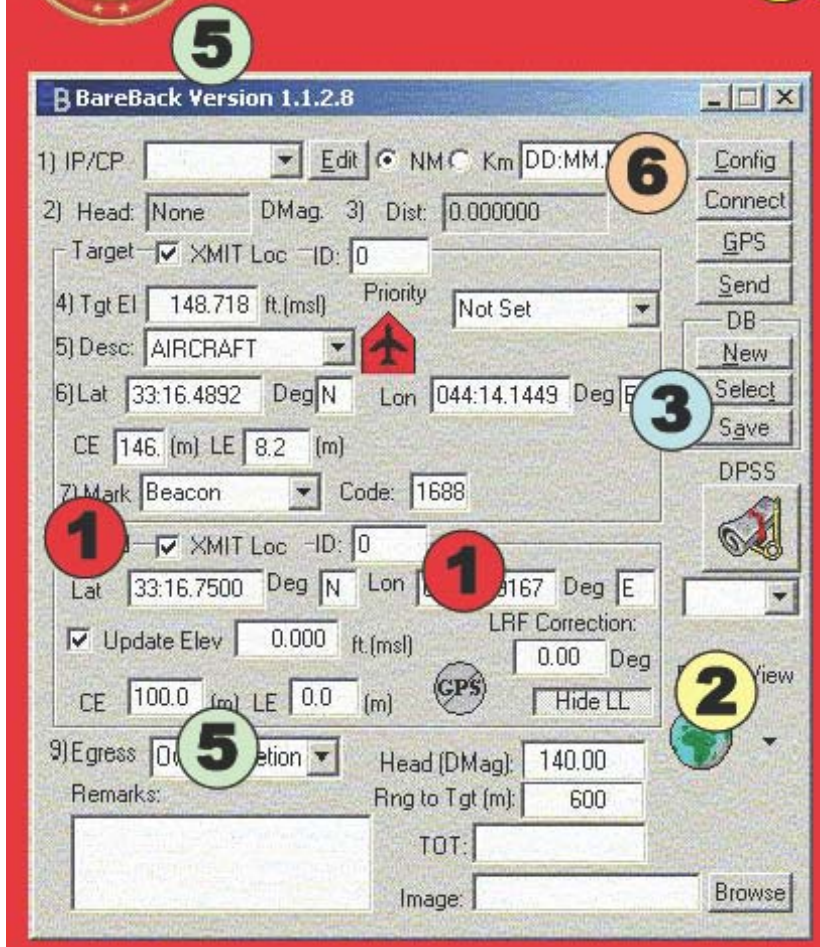
Discussion

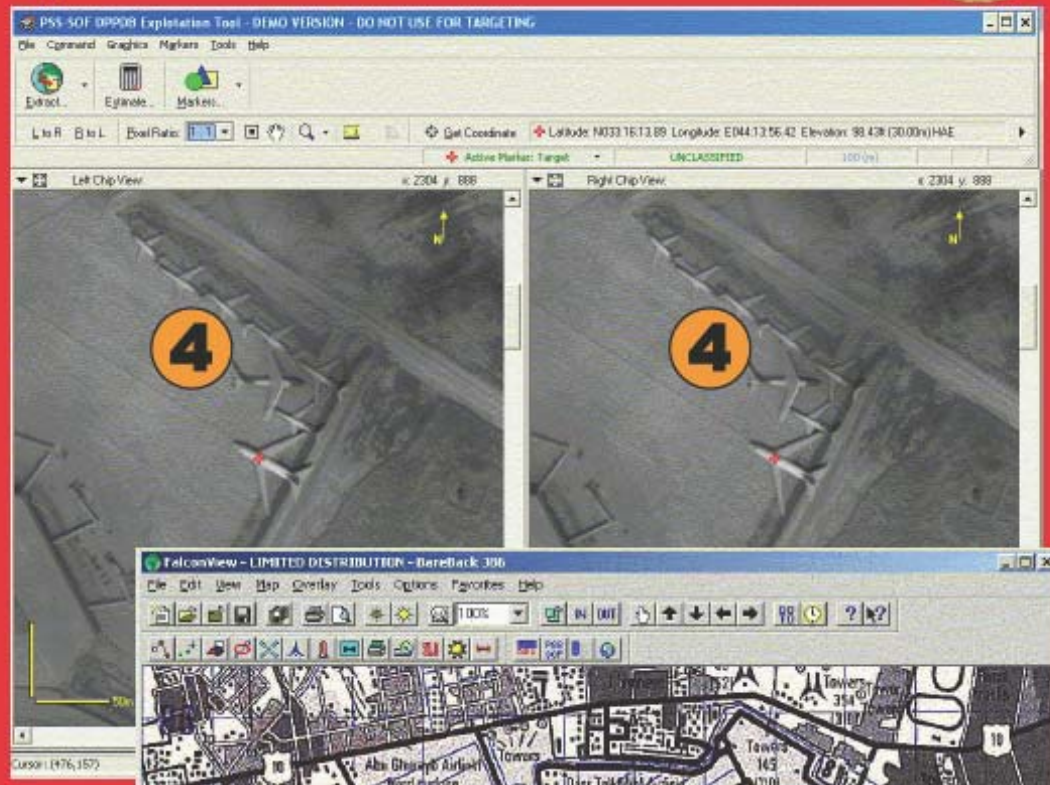
- Common component in emerging Service Programs of Record
- ✓ SOCOM Special Operations Mission Planning Enhancement
- ✓ USAF TACP-Modernization
- ✓ USMC StrikeLink
- ✓ AFSOC Battlefield Air Operations Kit
- ✓ USA Forward Observer System

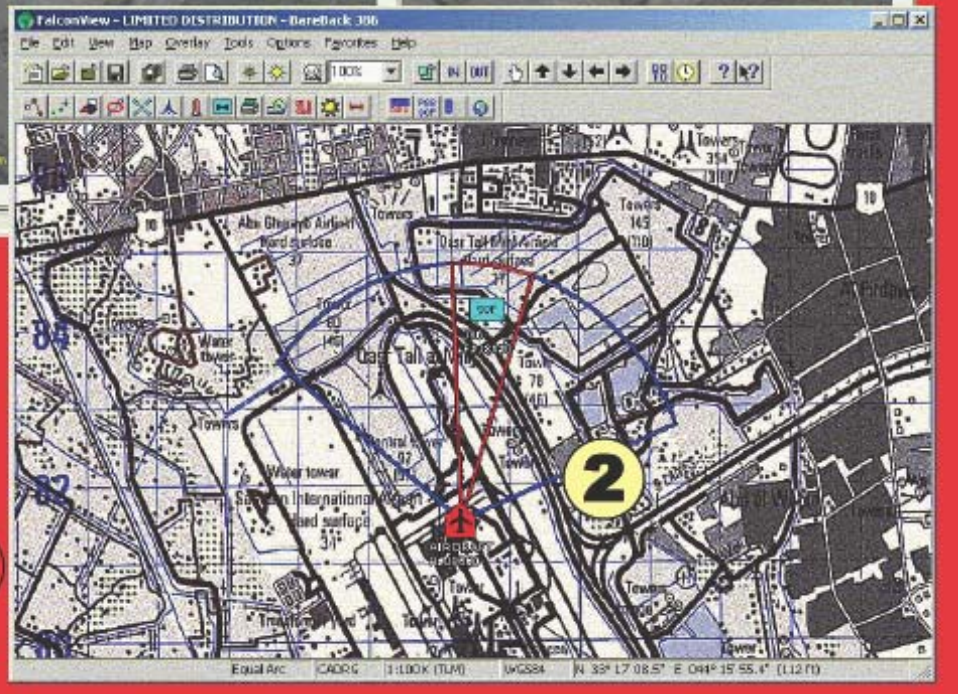
Status

- In use by SEALs, Special Forces, USA FECs, USAF Special Tactics, USMC Force RECON and MEU Intel
- Training integrated at JTAC and JFO Schools
- Transitions to USSOCOM in FY07 for sustainment
- Recognized by USCENTCOM for targeting

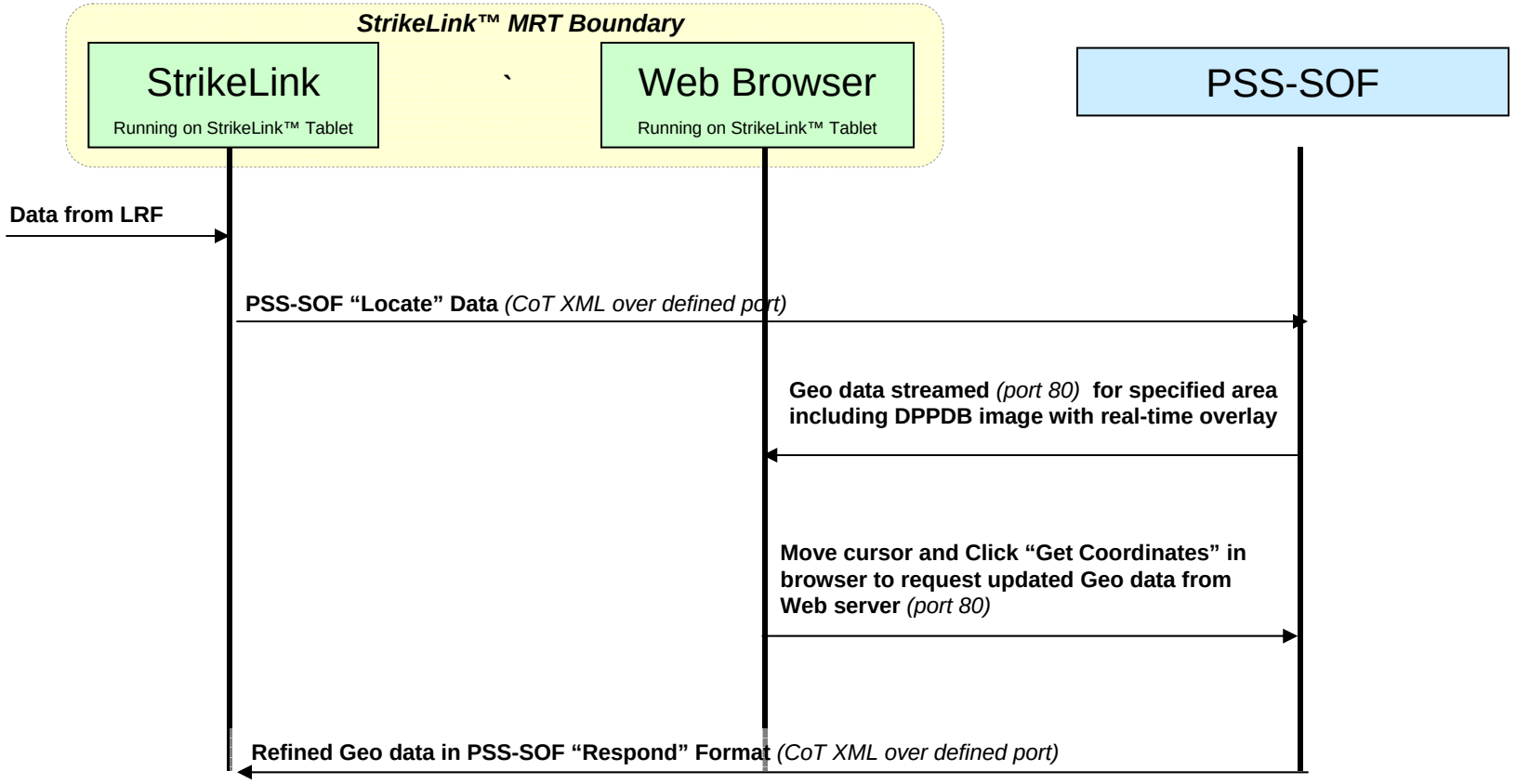
Example PSS-SOF Targeting Sequence





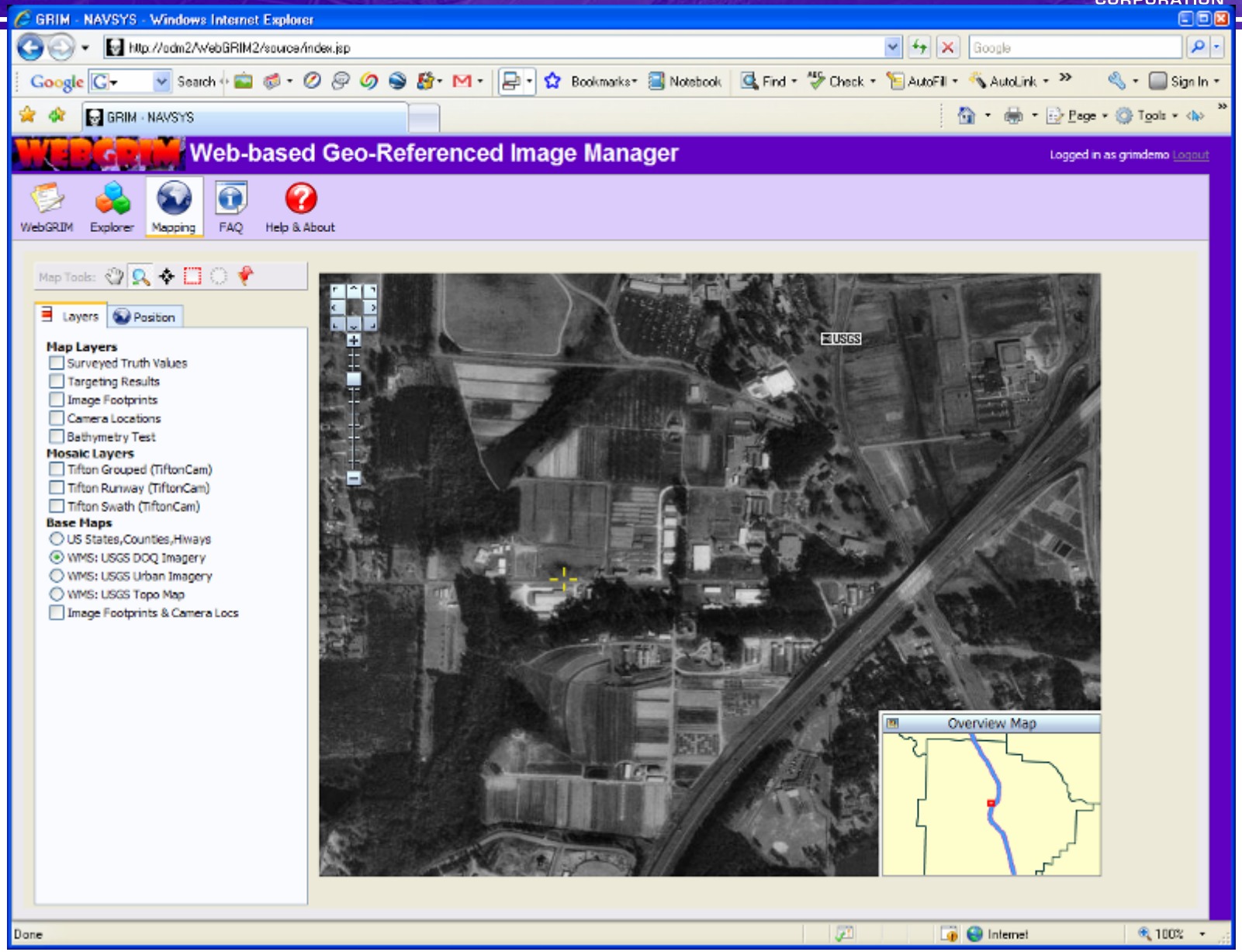


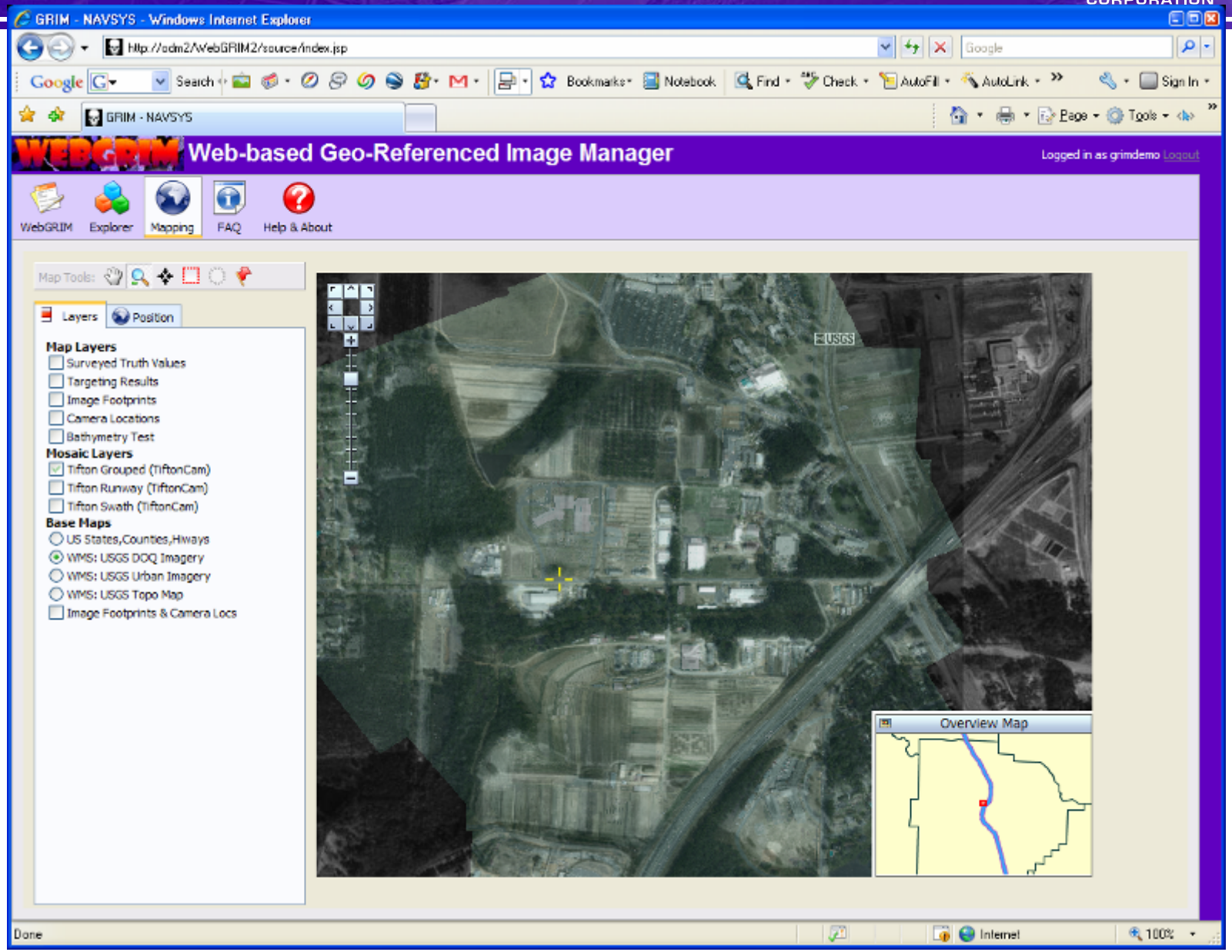
StrikeLink™ - PSS-SOF Sequencing



Cursor on Target XML

- Each CoT XML message describes an “event”
- Event attributes include globally unique identifier, timestamp, expiration time & type description among others
- An event can contain a “point” element, the primary field an application looks for & modifies
- Point attributes include latitude, longitude, elevation, & associated circular error (CE) & linear error (LE) in meters


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
Done
Internet
100%


GRIM - NAVSYS - Windows Internet Explorer
http://odm2/WebGRIM2/source/index.jsp
GRIM - NAVSYS
WEBGRIM
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
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USGS
Overview Map
Done
Internet
100%

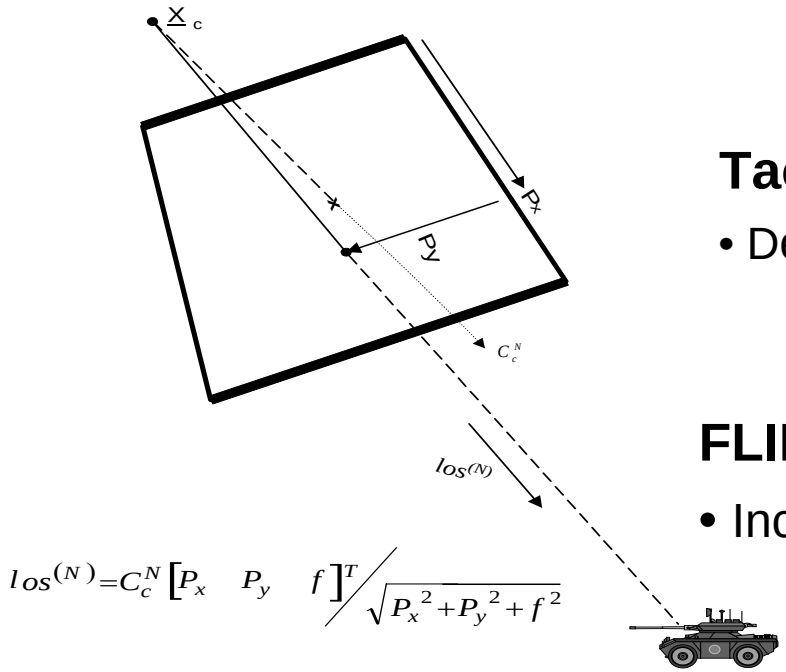
Issues with Current Real-Time Targeting Systems

- Vector-21
  - TLE limited by magnetic sensor heading errors
- Image Mensuration Tools
  - Require extensice processing power to operate at speed
- PSS-SOF
  - Can’t use for mobile targets or when reference image doesn’t match current view of battlespace
- UAS Video Imagery
  - Intensive processing required to mensurate against reference imagery

GI-Eye Auto-Georegistration

"Provides coordinates for every pixel"

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



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

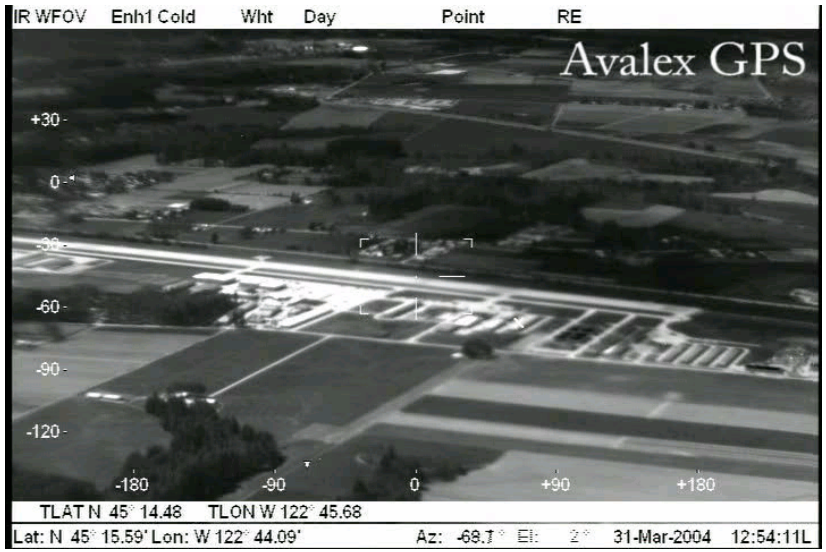
Tactical Survey/Targeting System (TS2)

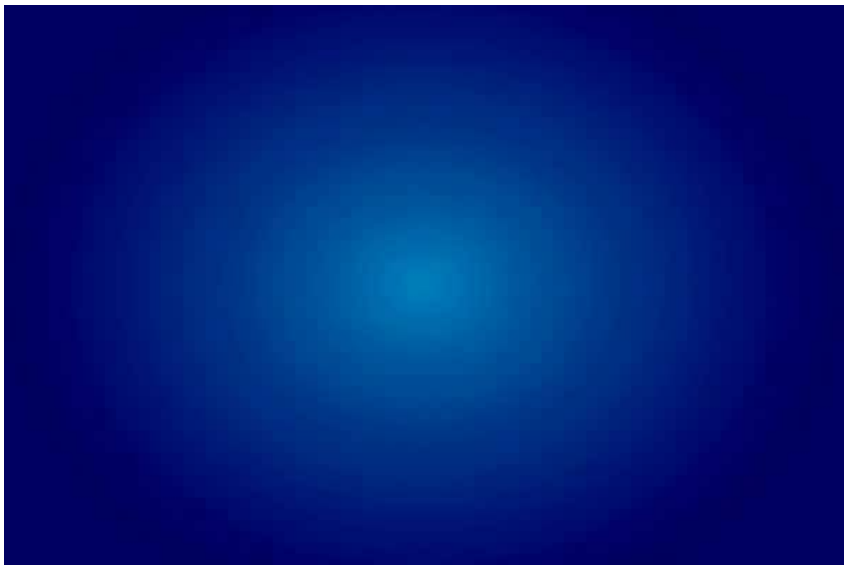
- Delivered to NGA with GI-Eye capability

FLIR StarSAFIRE III

- Includes GI-Eye for geopointing

FLIR GI-Eye Stabilized Imagery

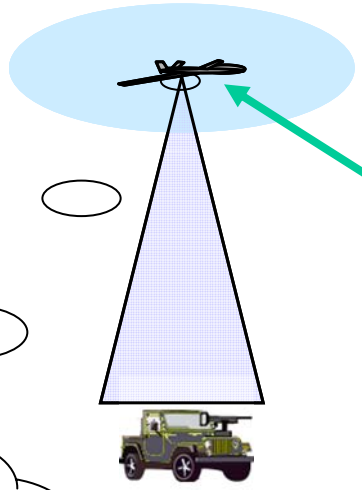




USMC SBIR N04-187 Overview

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

NAVSYS GI-Eye payload registers imagery onboard UAV using precision GPS/inertial meta data

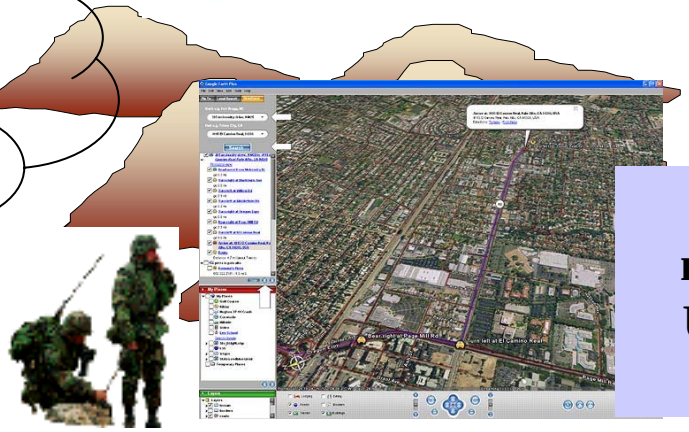


Currently video imagery provided from UAS to Flight Ops Ground Station for analysis and mensuration. No real-time access for targeting by GBOs

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 like Google Earth

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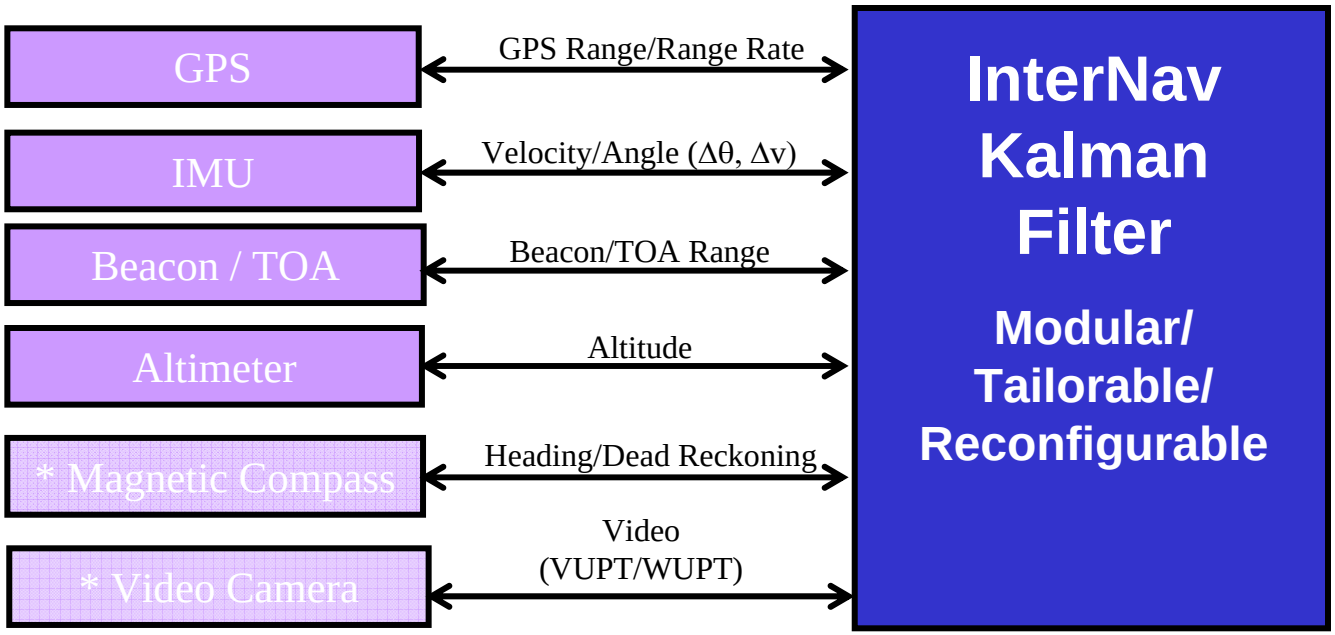
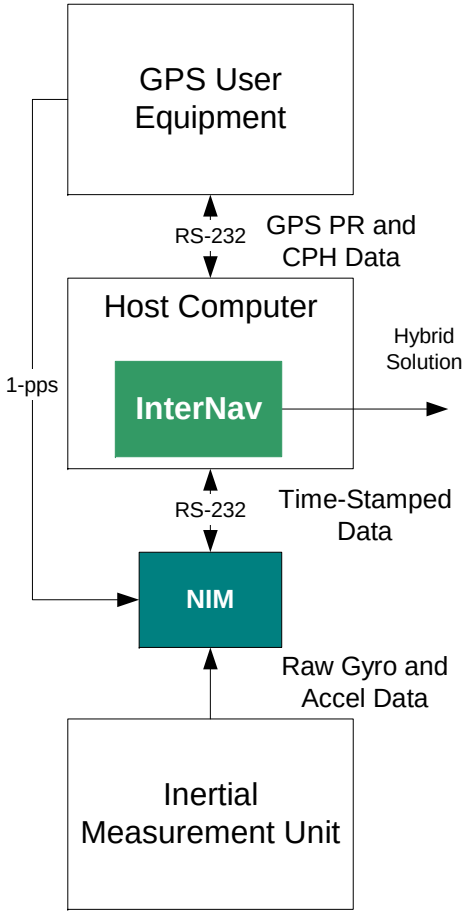
Integrated Navigation Filter Product - InterNav



Modular GPS/Inertial Integration Approach

- GPS UE provides GPS observations at the antenna and 1-pps time stamp
- IMU provides observed acceleration and angular rate at the sensor
- GPS/inertial filter (e.g InterNav) provides fused position & attitude
- Some Integration issues:
  - Lever arm between antenna and IMU must be known or estimated
  - IMU data must be time aligned with GPS
  - IMU must be inside gimbal or gimbal resolver angles must be precisely calibrated



Some GPS and Inertial products supported by modular InterNav approach

- Novatel
- Force 22E
- DAGR
- Itrax
- u-blox

- HG1700, 1900, 1930
- NG 2000
- LN-200, 210
- BAE P150
- KN-4073
- Crista MEMs
- ADIS16350

Selection for many UAS/sensor applications driven by SWAP

Key Performance Issues

- Camera attitude
  - GCP alignment a function of ground truth
  - GPS/inertial <1 mrad (using kinematic GPS alignment)
- Camera errors
  - Misalignment
  - focal length and radial distortion
- Camera or Reference Imagery Location
  - GPS accuracy gives 5 m
  - Precision GPS Ephemeris gives < 1 m (absolute)
  - KGPS accuracy gives 0.1 meters (relative)

$$C_B^N$$

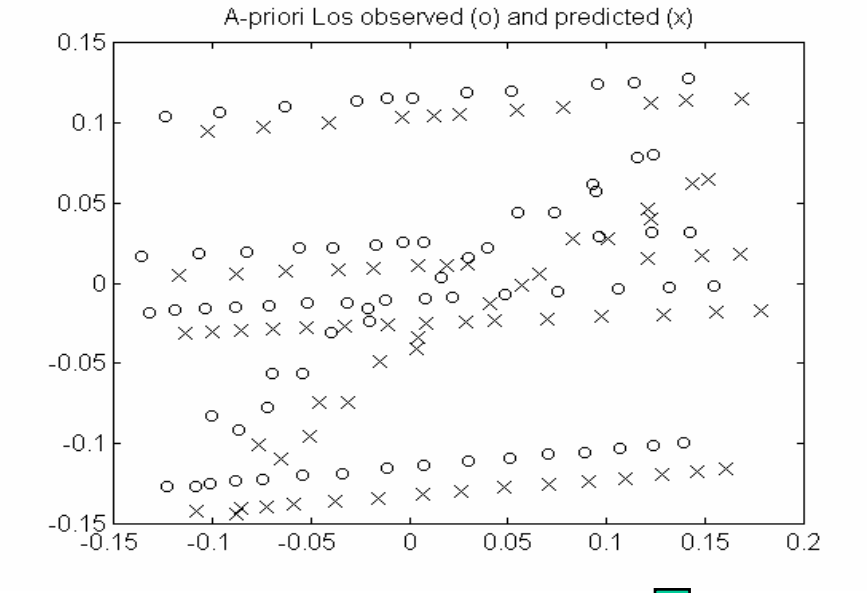
$$C_C^B$$

$$x_C^{(N)}$$

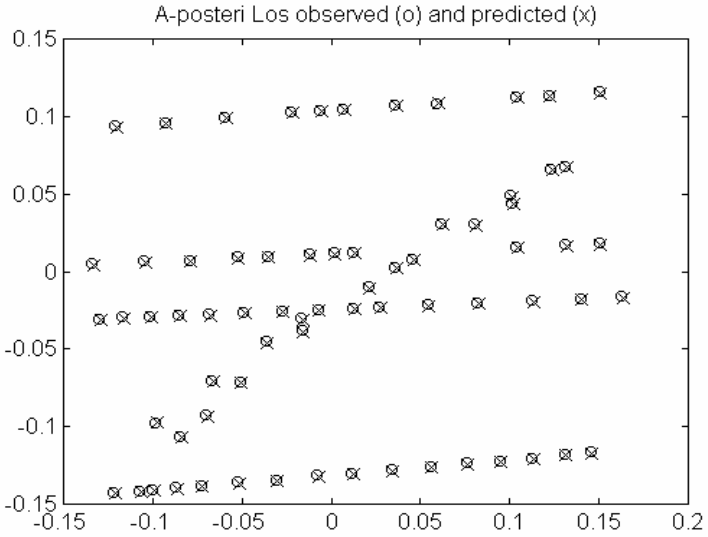
Inertial Alignment Techniques

- Gyrocompassing
  - Observes heading from earth rate
  - 1 mrad requires 0.01 deg/hr gyro
- Tightly Coupled GPS/inertial
  - Observes heading from vehicle acceleration
  - 1 – 4 mrad possible with tactical grade gyro (10 deg/hr)
  - Uses pseudo-range and delta-range updates
- Kinematic GPS alignment
  - Observes heading from relative motion
  - Uses pseudo-range and carrier-phase updates
  - < 1 mrad possible with tactical grade gyro (10 deg/hr)

Camera-to-IMU Auto-Cal Example



Typical residual
Misalignment <0.200 mrad



Options for Precision GPS Positioning

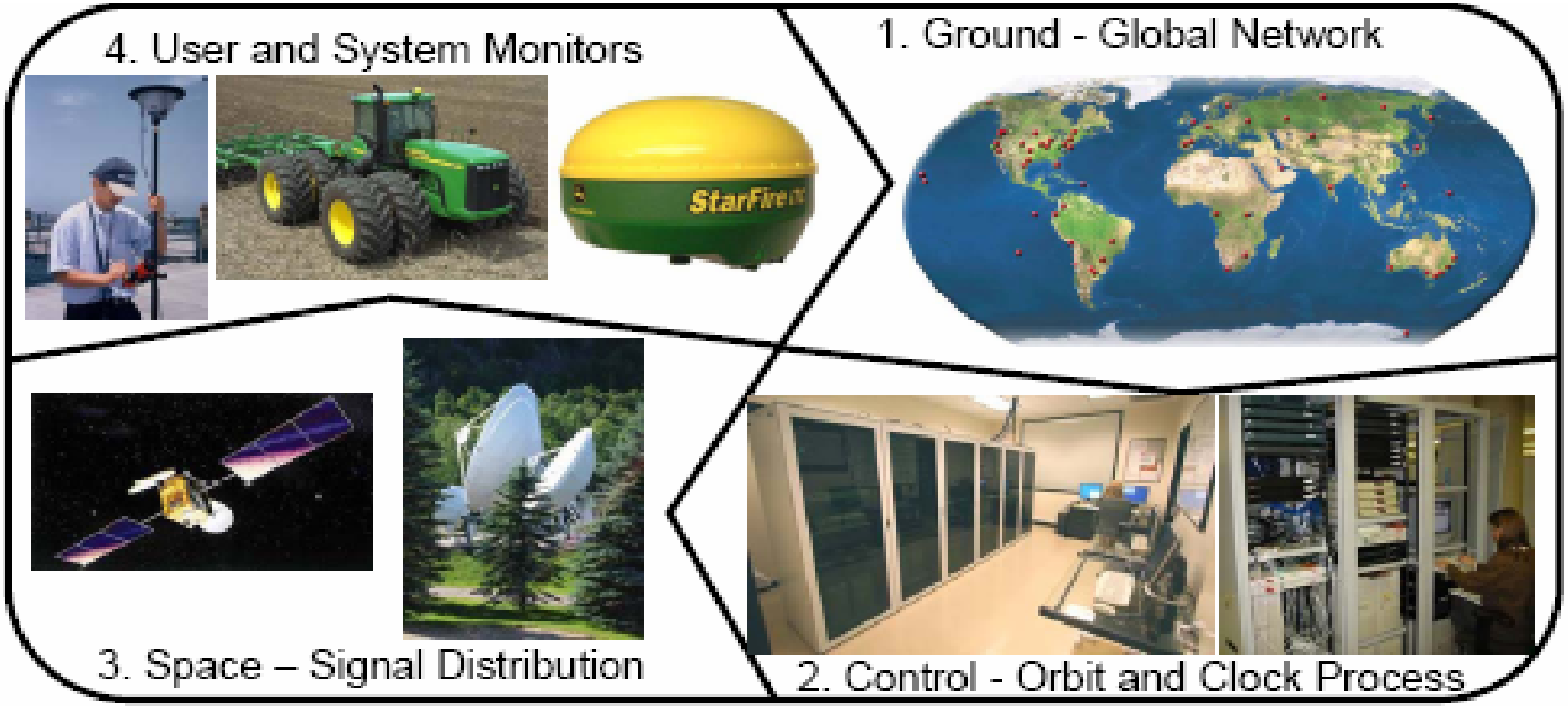
- Local Area Differential GPS (LADGPS)
  - Uses local ground stations to provide GPS error corrections
  - Examples are: NDGPS,
- Global Differential GPS Services
  - Commercial services provide GPS orbit corrections and precise GPS positioning services over SATCOM
  - Examples are: WAAS, EGNOS, MT-SAT, NavCom
- Precision GPS Ephemeris Services
  - Provide access to high accuracy real-time GPS orbits
  - Examples are: PGE TCS, GPSIS, IGS

Military UAS must comply with DoD Policy when using GPS

CJCSI 6130.01D 13 April 2007 CJCS Master Positioning, Navigation and Timing Plan (MPNTP)

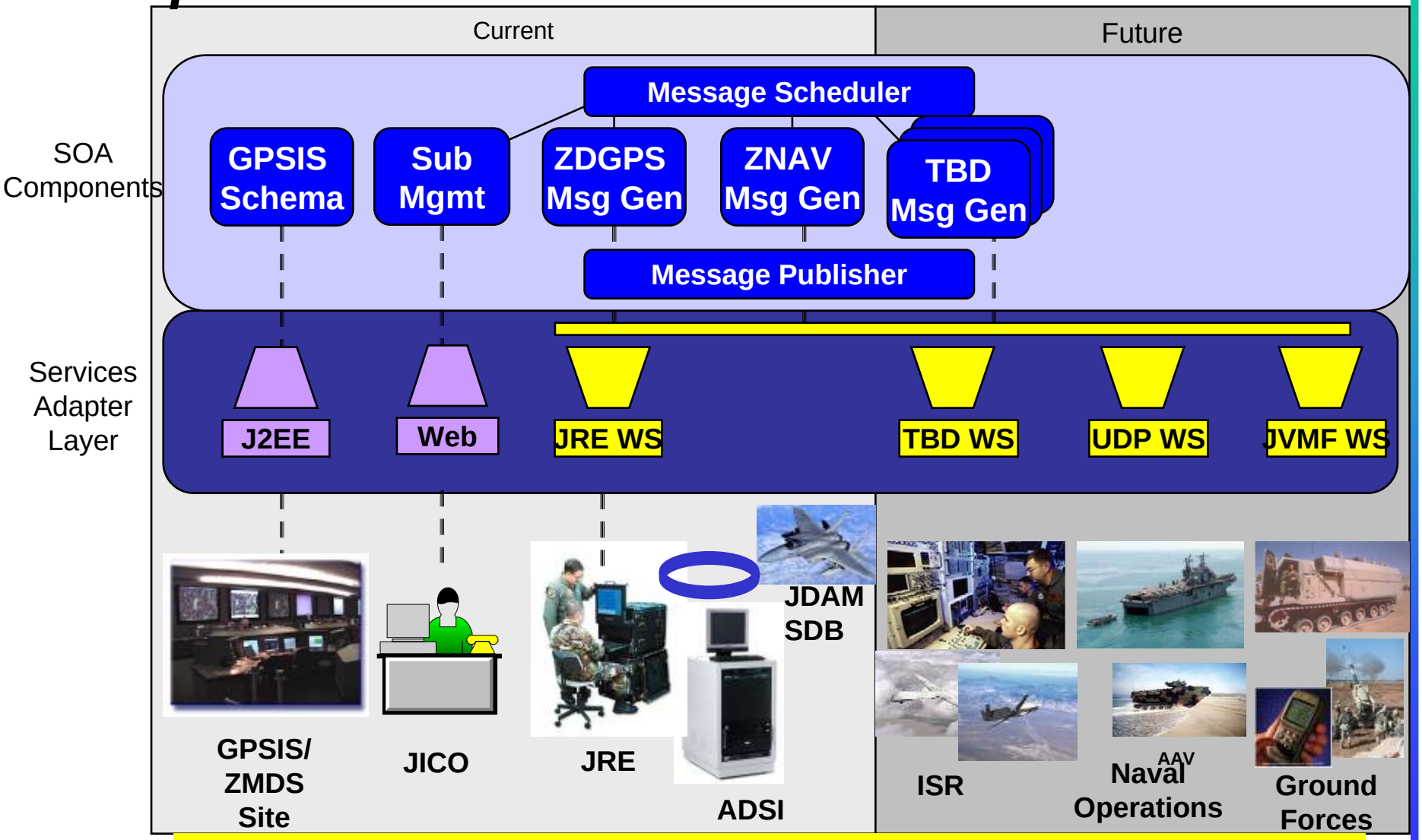
- Page A-2: DoD PNT users may use civilian GPS augmentations for peacetime operations where such use does not jeopardize carrying out military missions
- Page D-4: Should a DoD user need to use DGPS for combat, combat support or combat service support operations, the differential systems used must use PPS and the differential corrections must be encrypted for transmission and processing

NavCom StarFire GSBAS



Does not use PPS UE for creating DGPS corrections or PPS UE for PNT so can not be used for combat operations

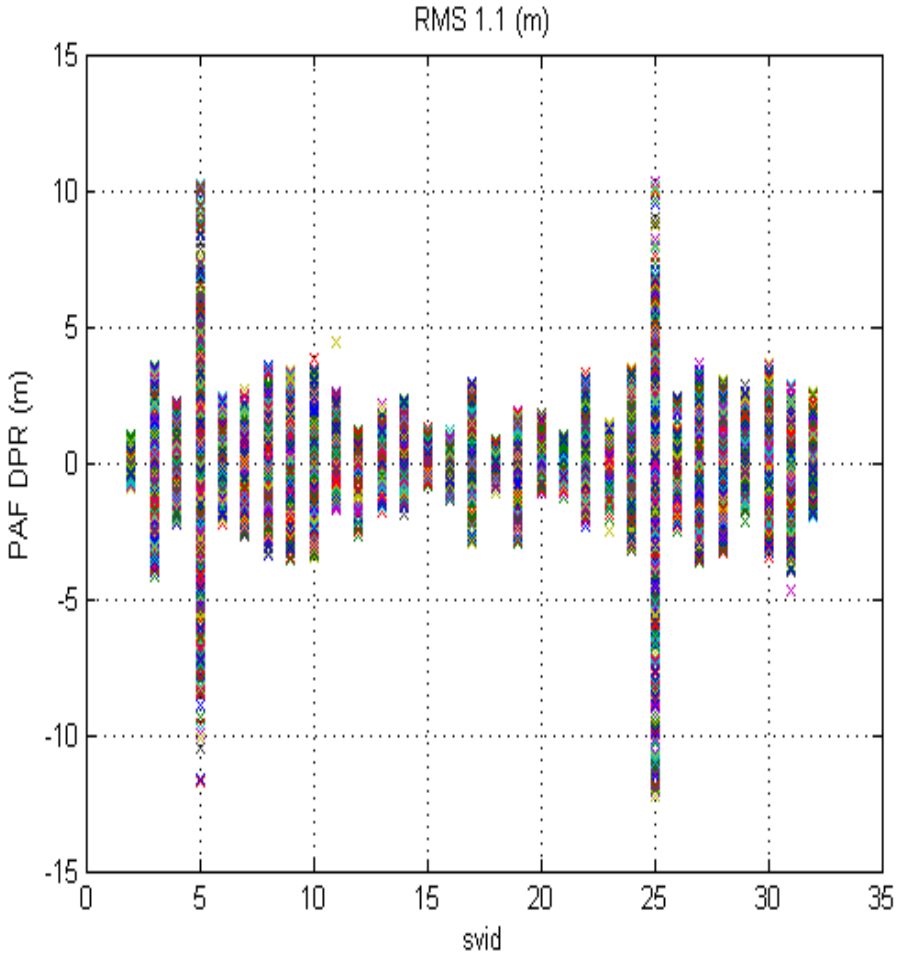
Precision GPS Ephemeris Tactical Control Station provides PPS Services for DoD PNT users



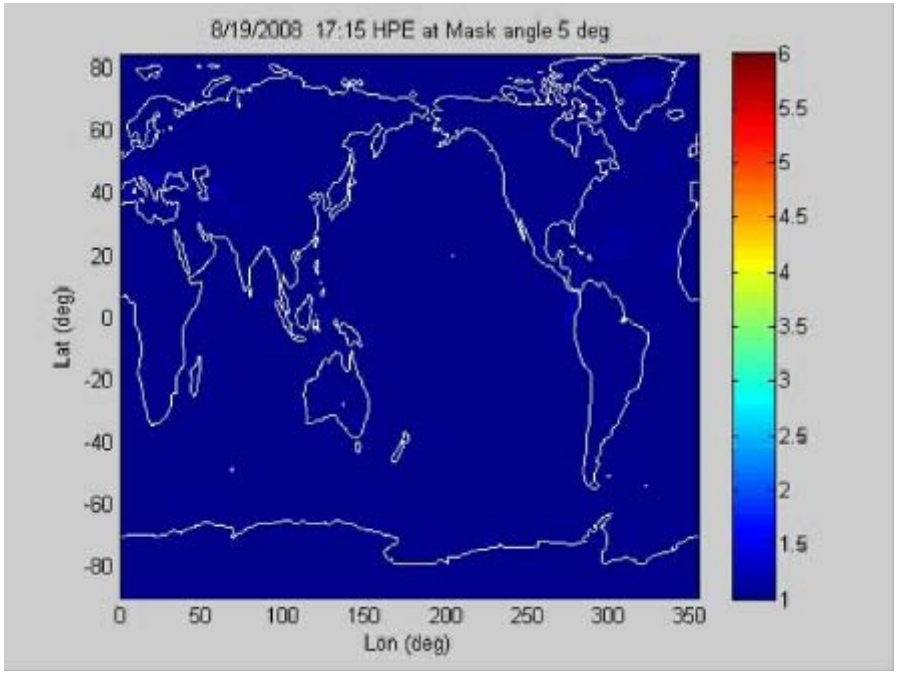
AFEI's 2008 Excellence in Enterprise Integration Industry Award

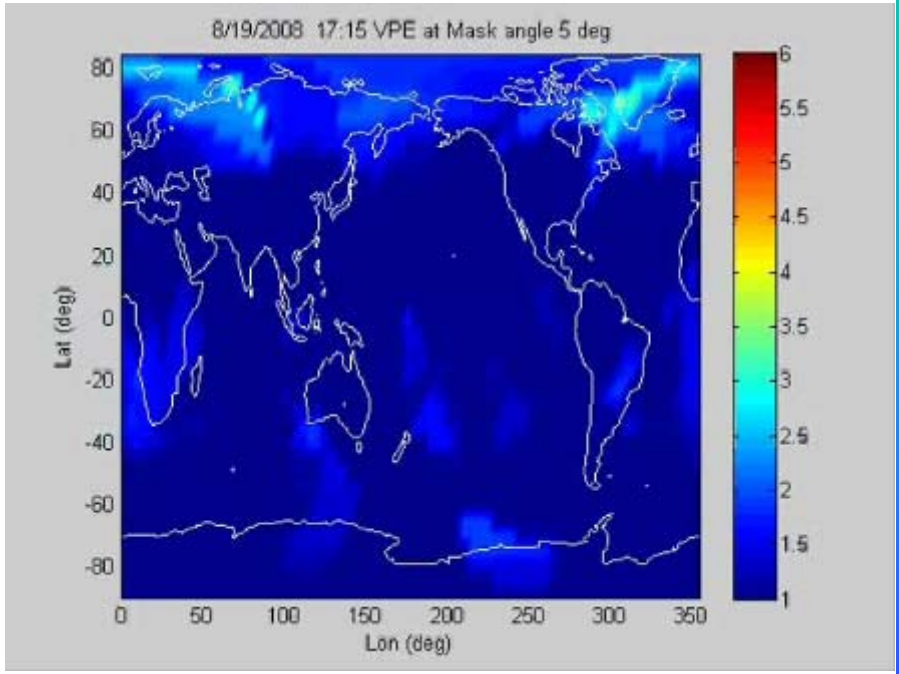
Accuracy of Precision GPS Ephemeris (PGE)

- **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

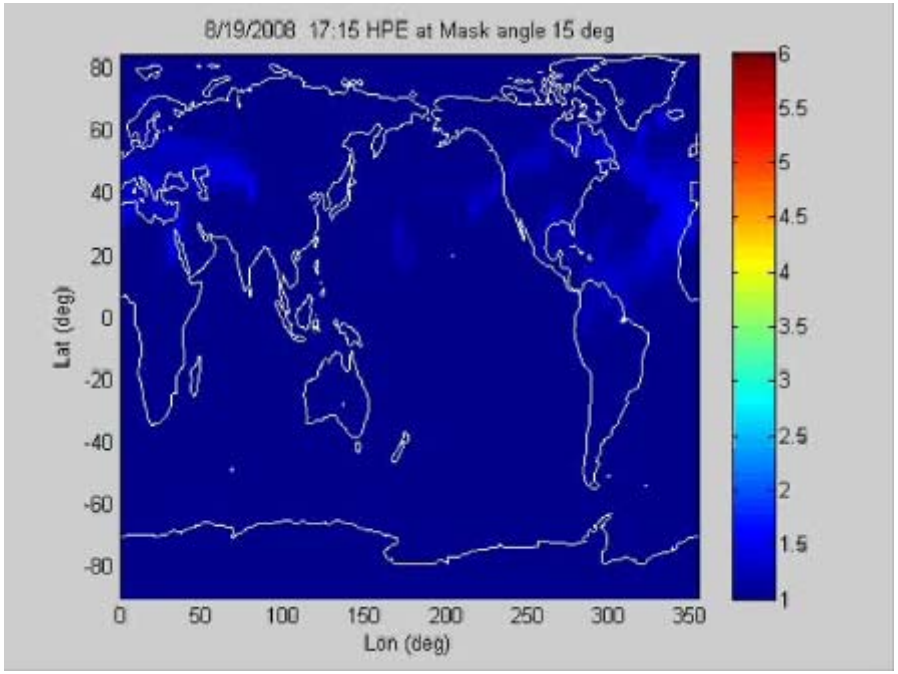


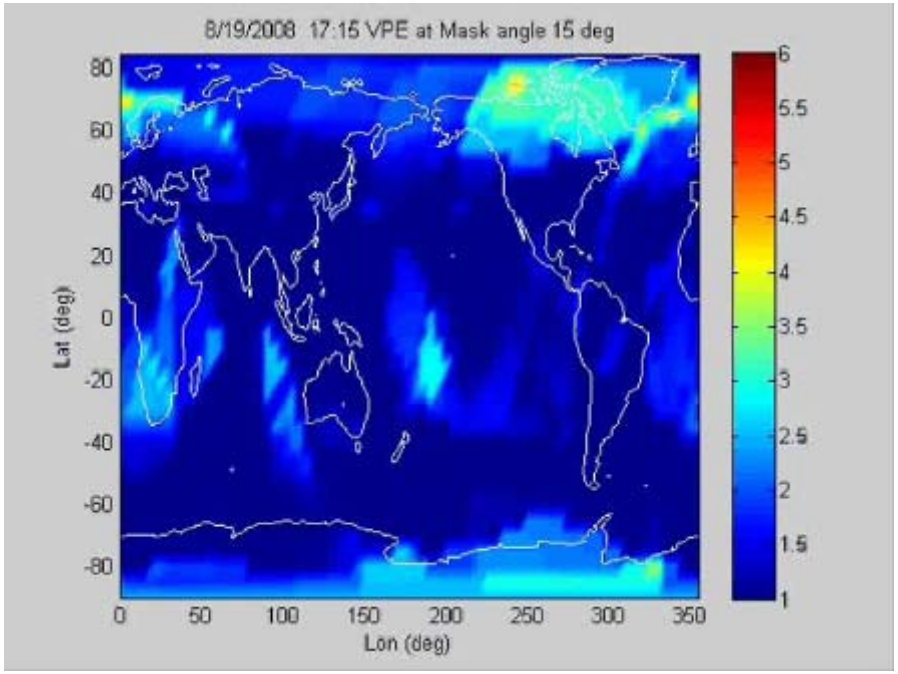
HPE and VPE
Antenna 5 Degree Mask Angle



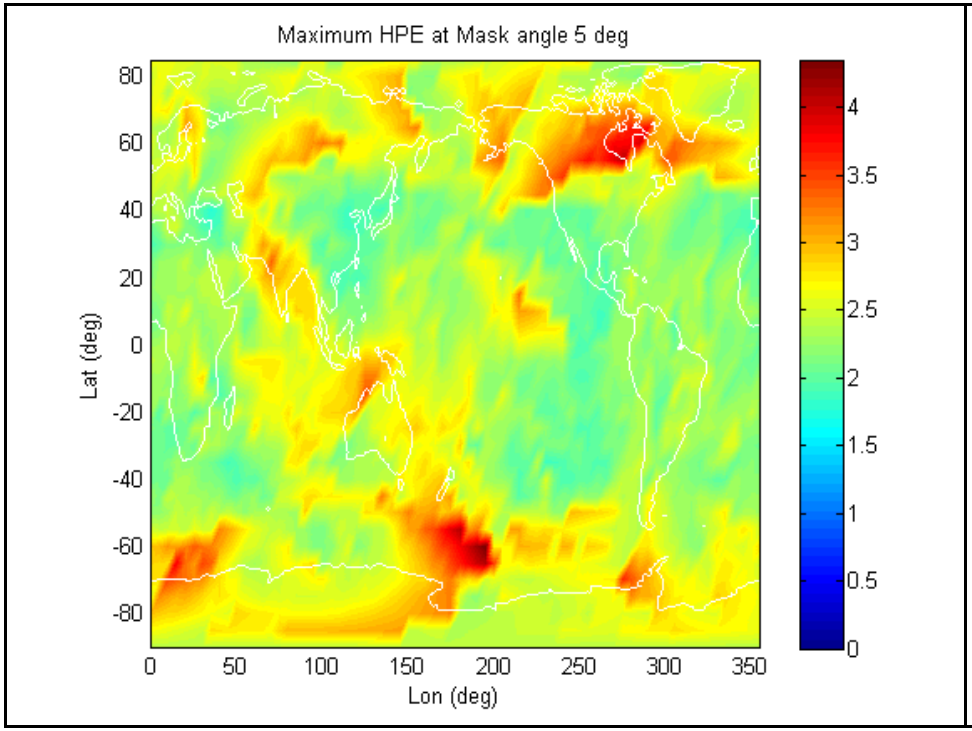


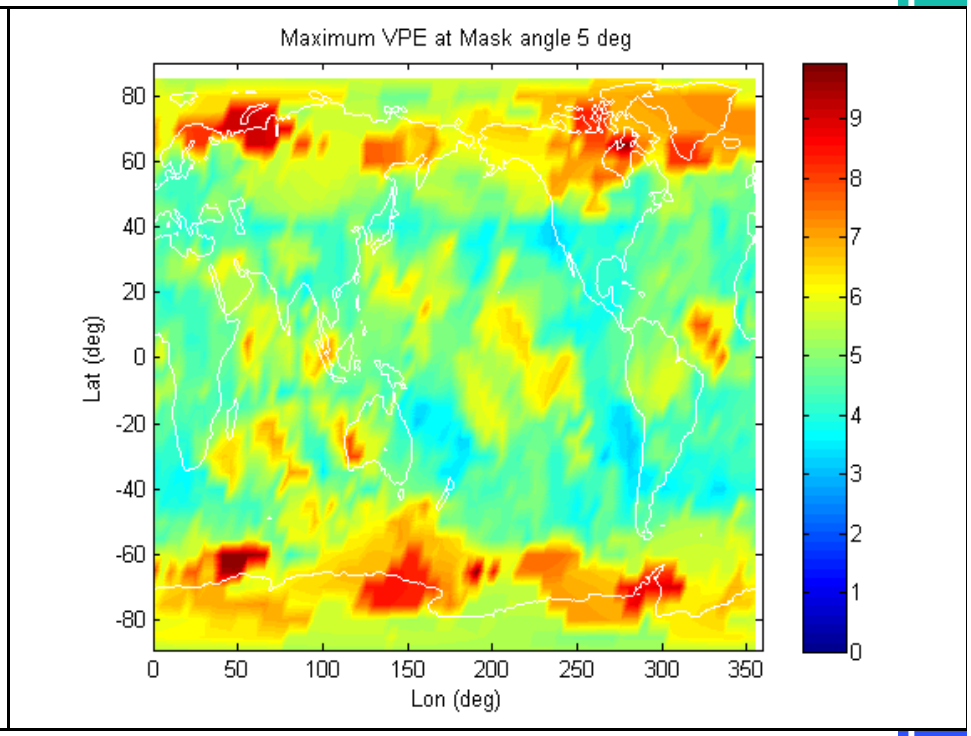
HPE and VPE
Antenna 15 Degree Mask Angle





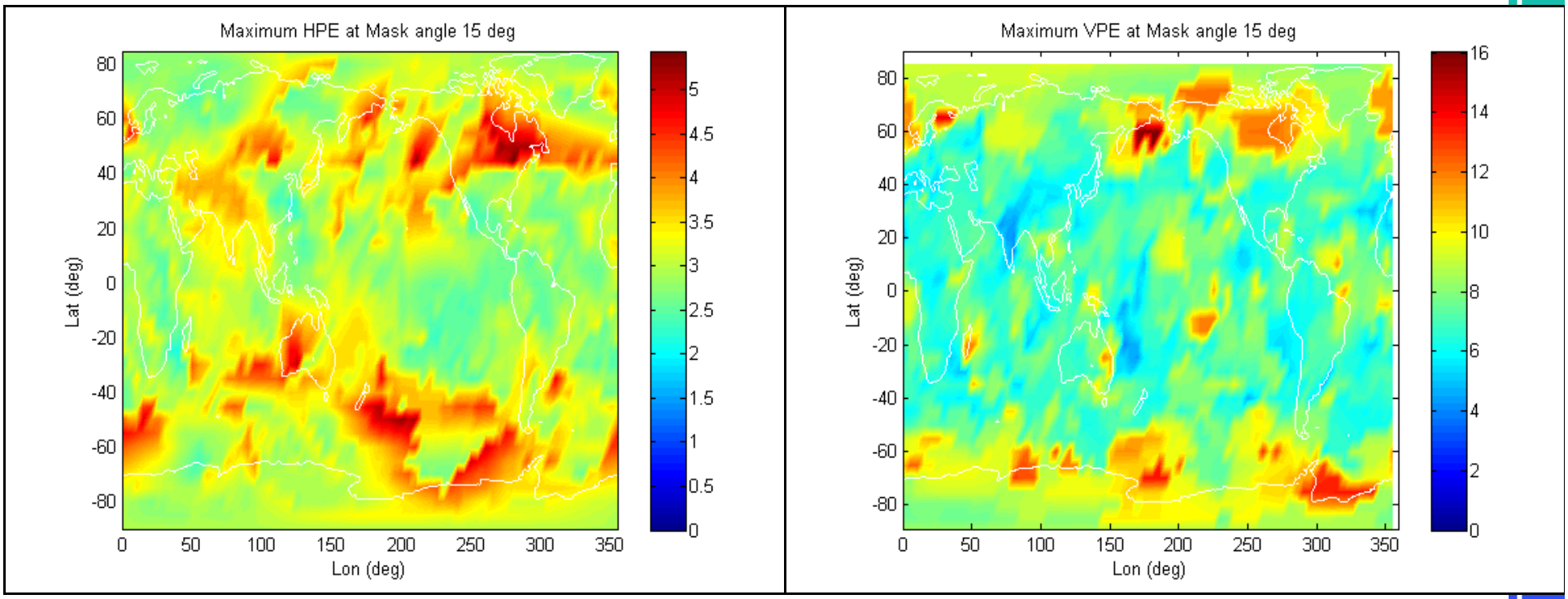
30 Day Maximum HPE and VPE Antenna 5 Degree Mask Angle





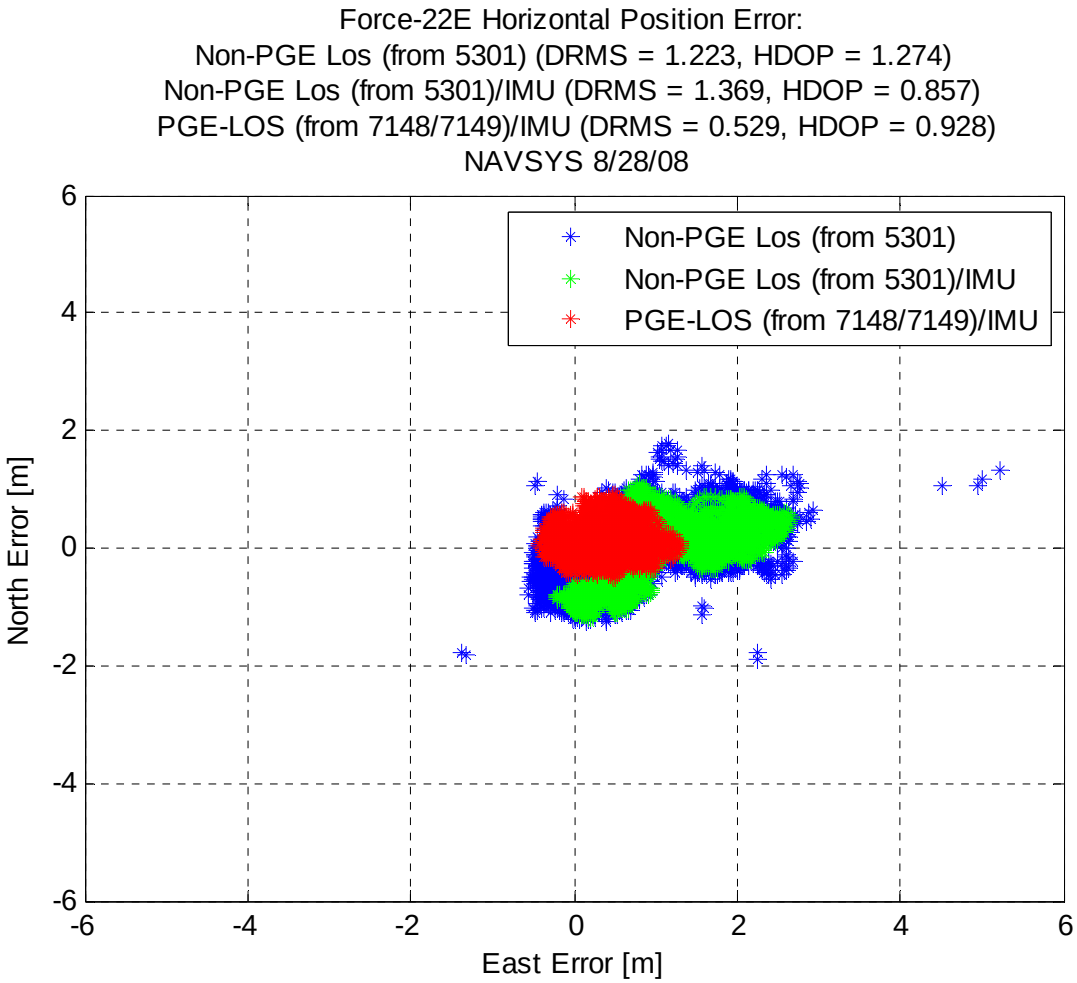
Note: Different meter error scale on side for HPE vs VPE

30 Day Maximum HPE and VPE Antenna 15 Degree Mask Angle

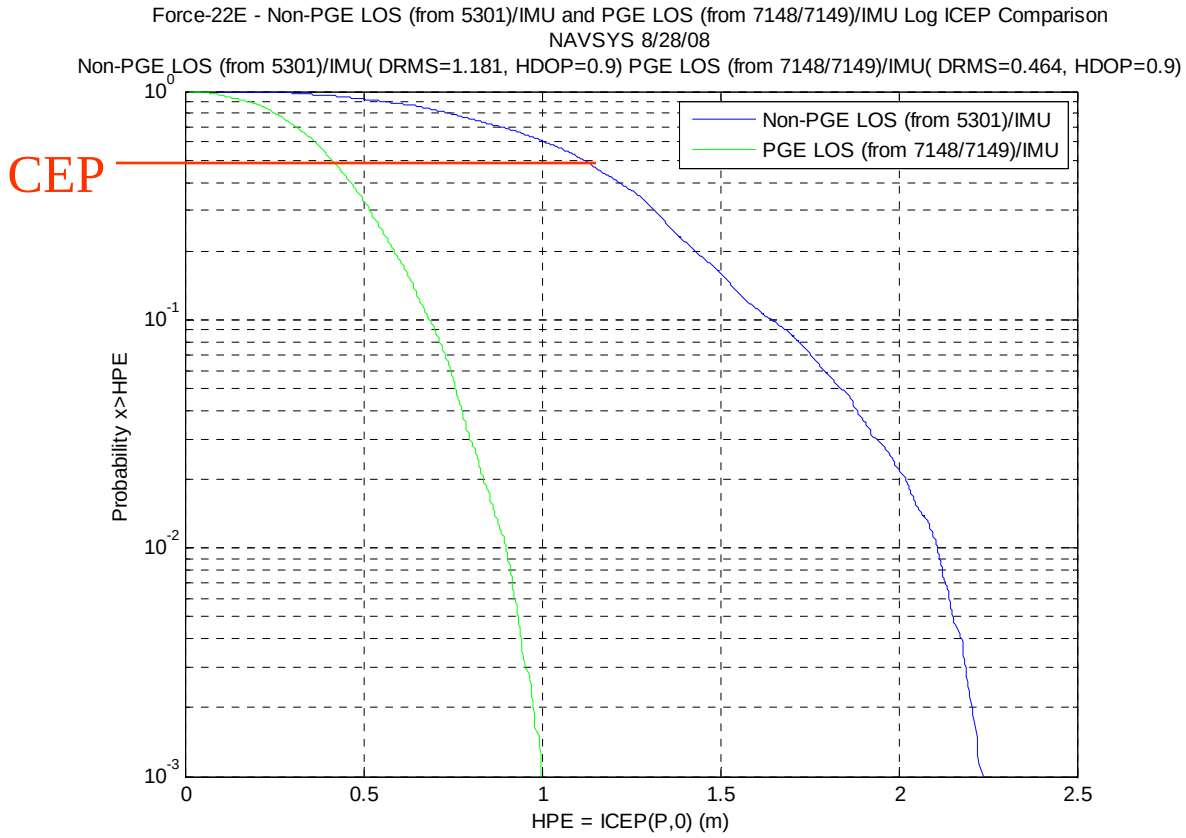


Note: Different meter error scale on side for HPE vs VPE

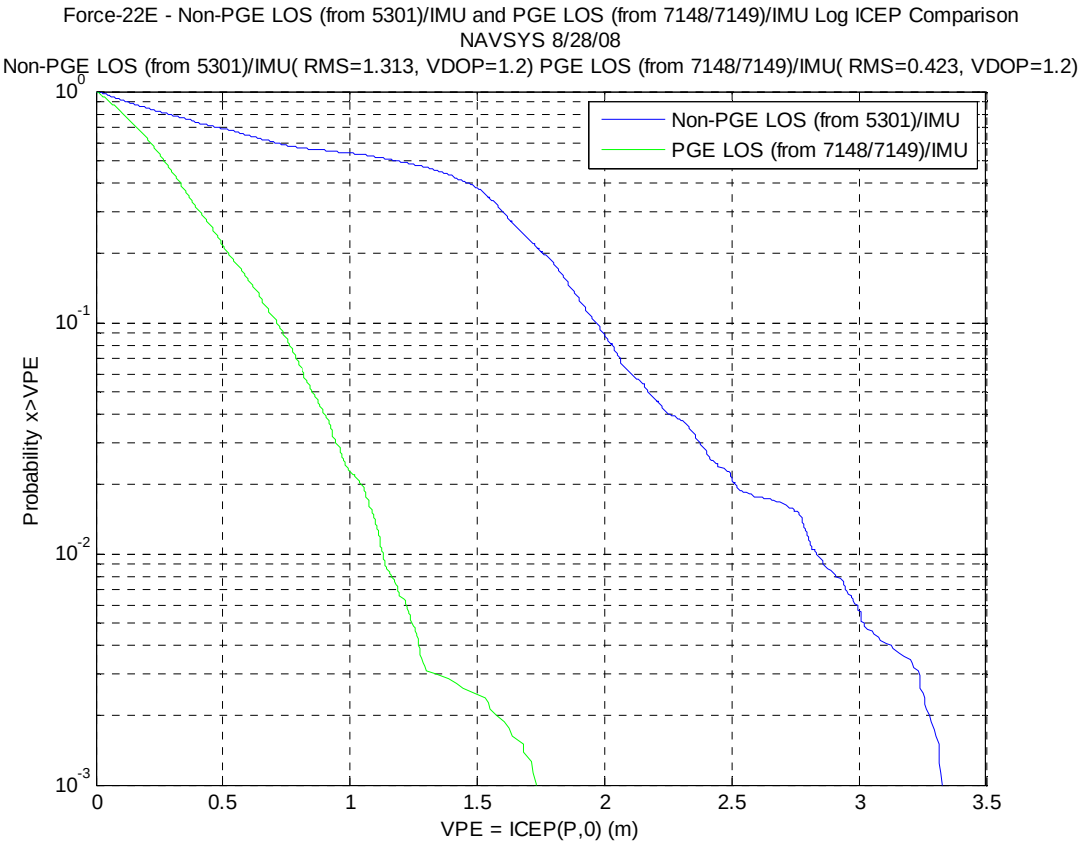
Force 22E Results with PGE and Inertial Filter



Force 22E Horizontal ICEP results with and without PGE



Force 22E Vertical ICEP results with and without PGE



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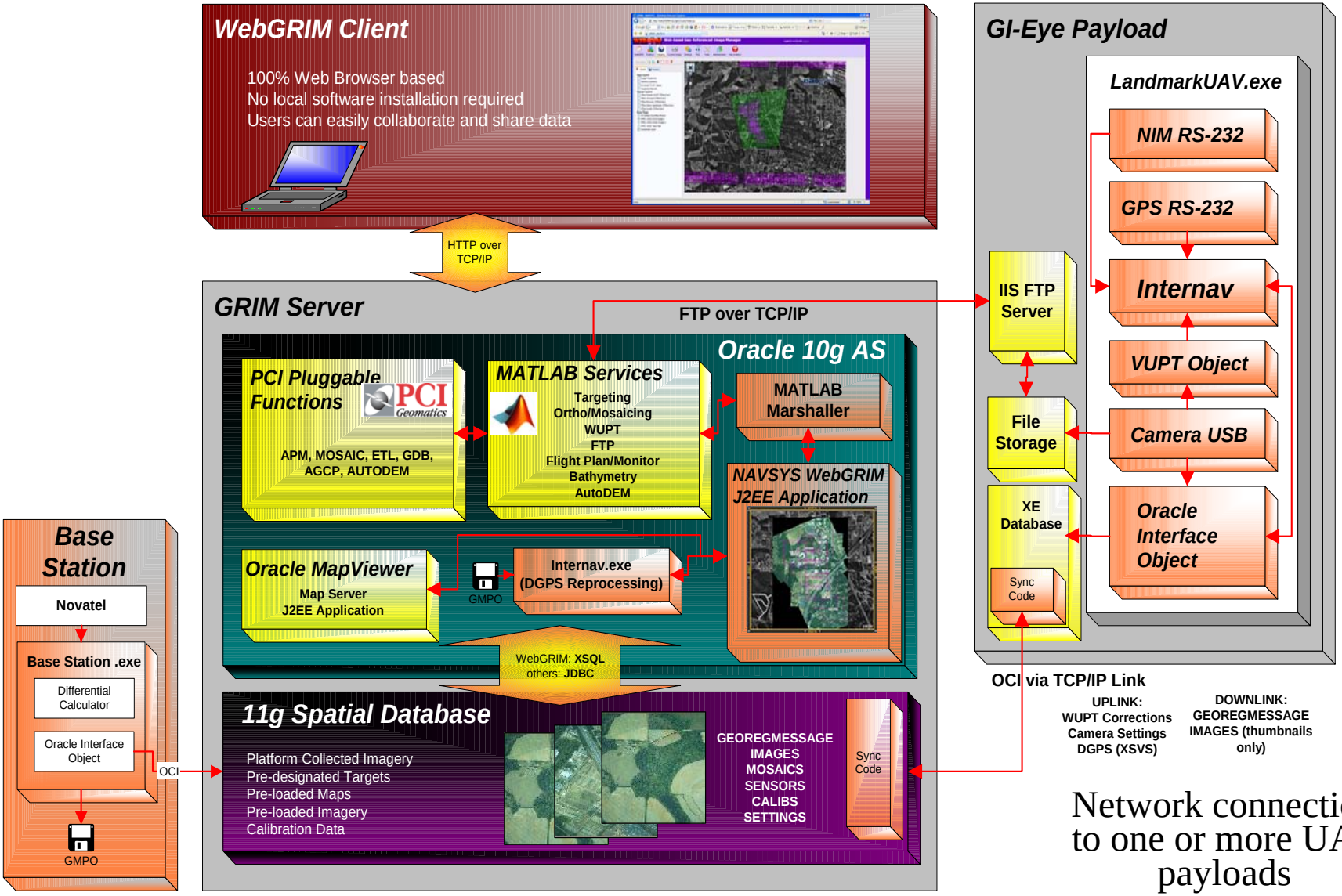
GeoReferenced Information Manager (GRIM)

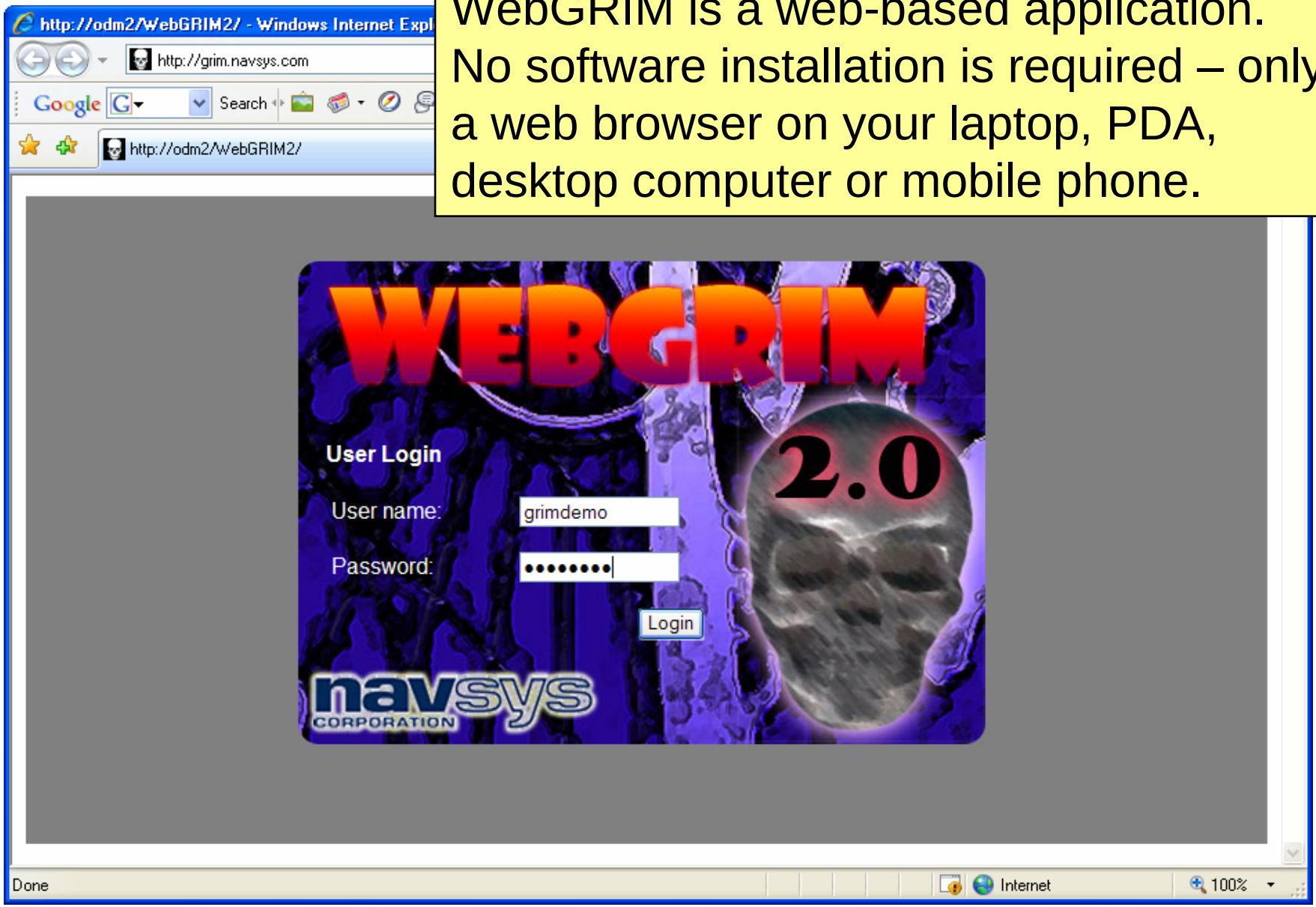
navsys CORPORATION

Overall GRIM SW Architecture

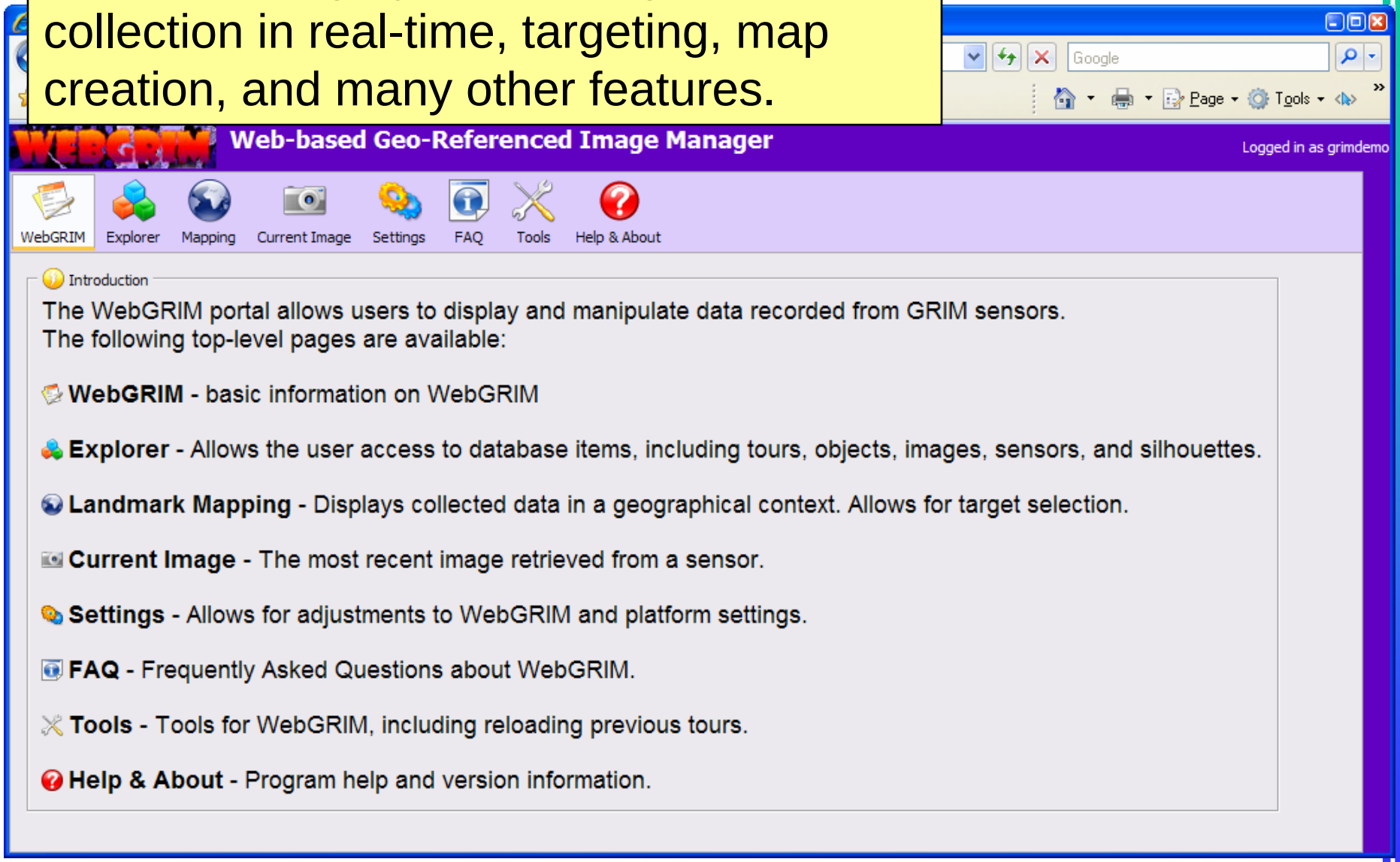


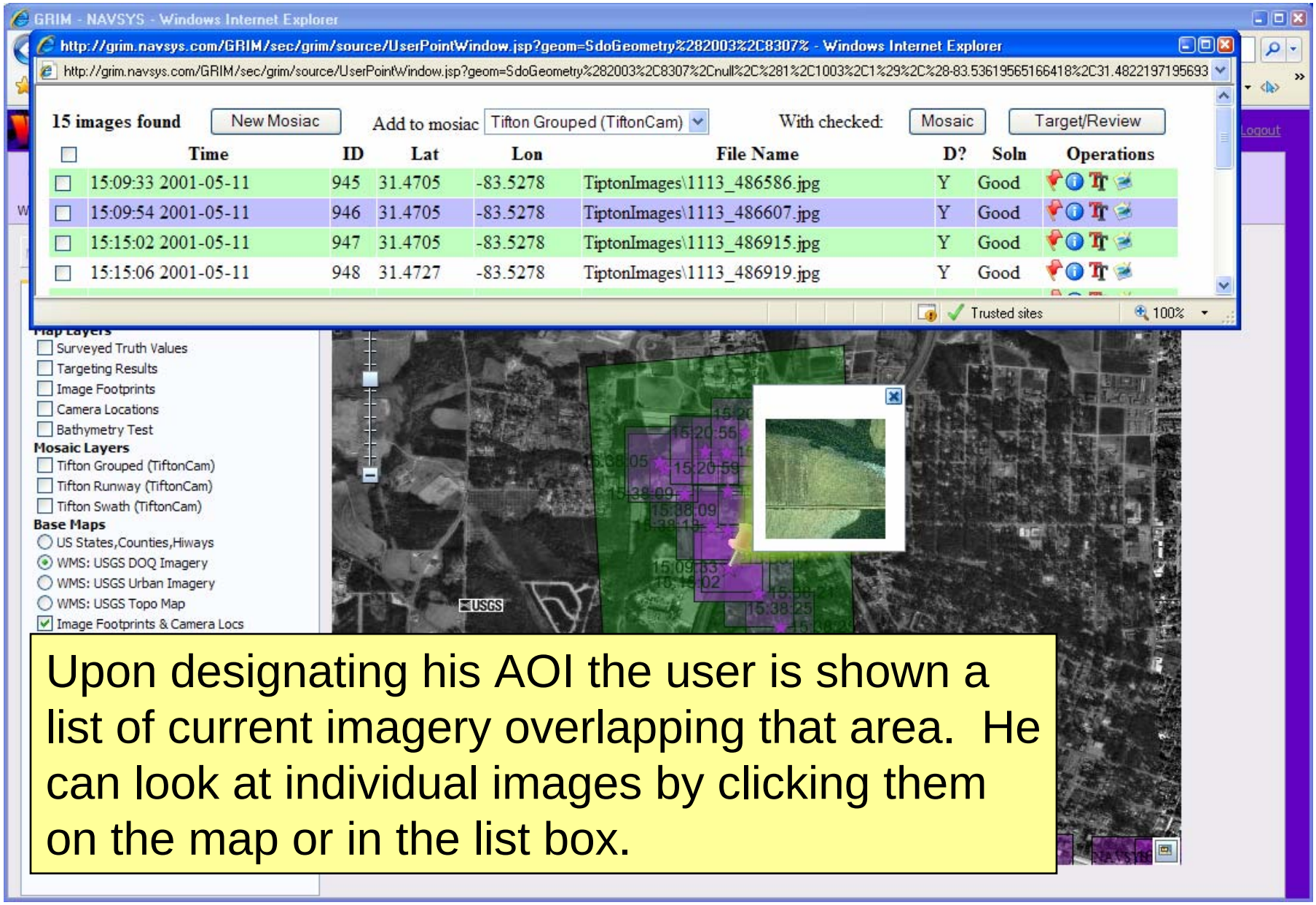
Network connection to one or more UAS payloads

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



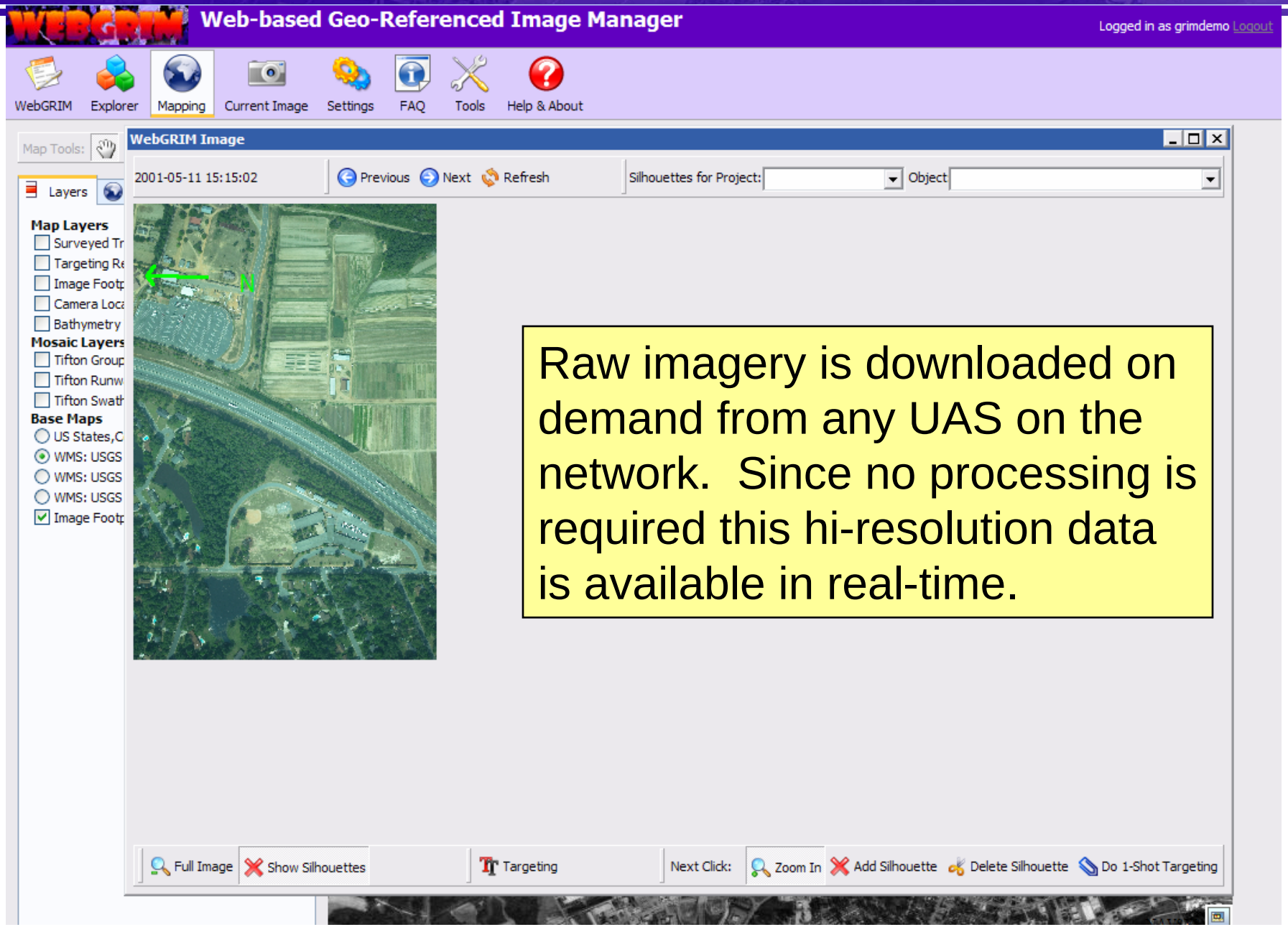
WebGRIM provides support for managing extensive databases of collected imagery, controlling data collection in real-time, targeting, map creation, and many other features.



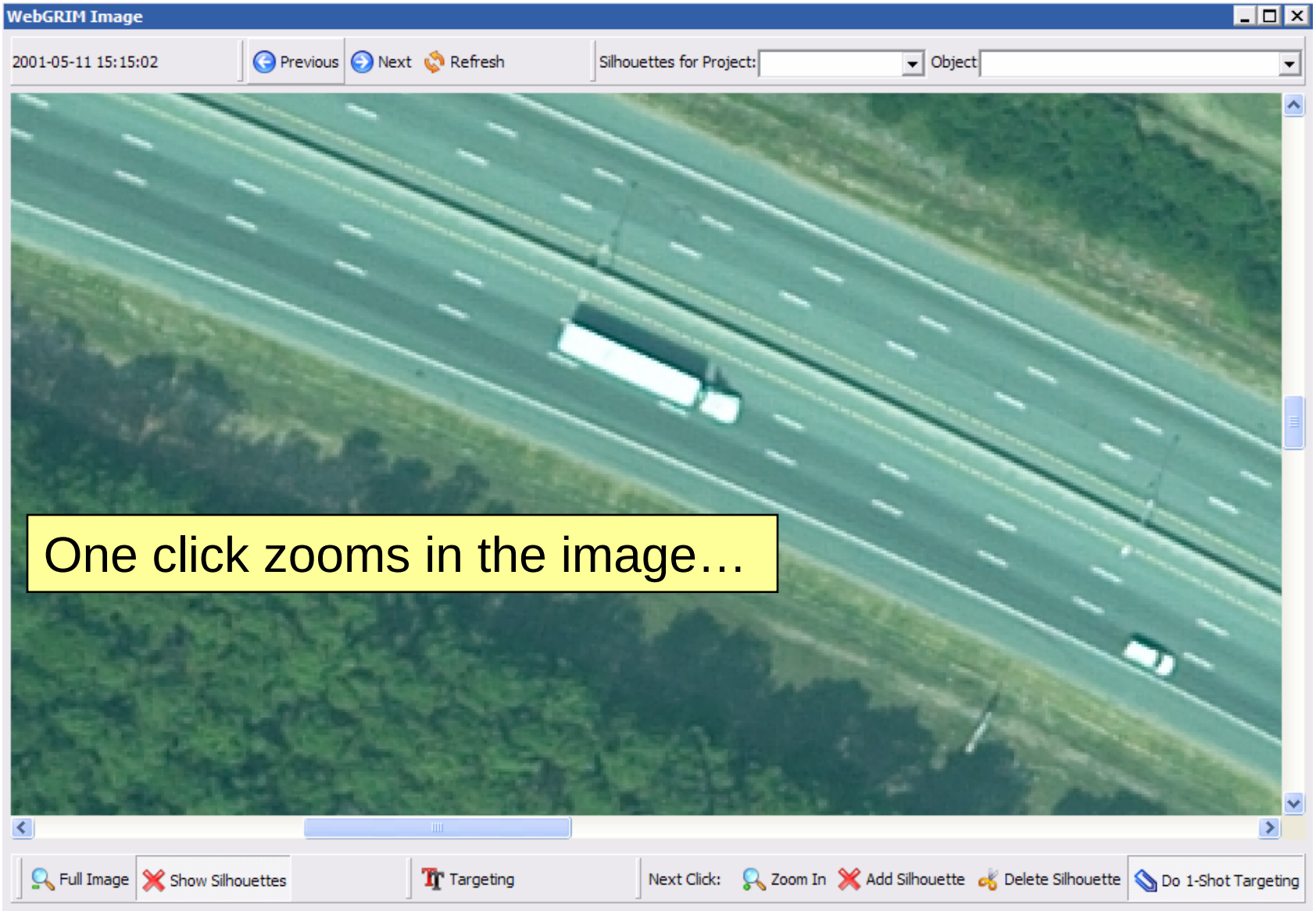


Upon designating his AOI the user is shown a list of current imagery overlapping that area. He can look at individual images by clicking them on the map or in the list box.

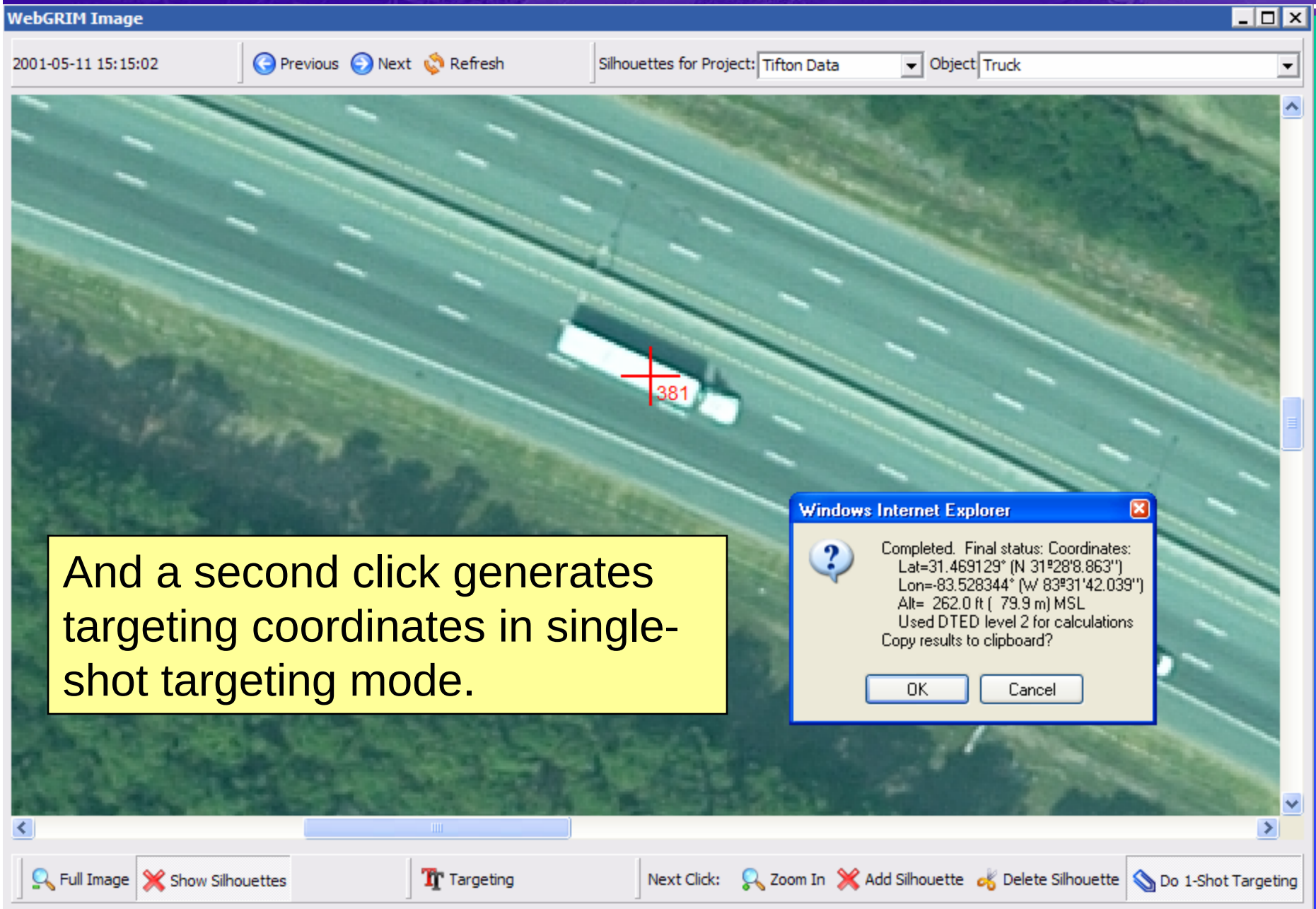
navsys CORPORATION



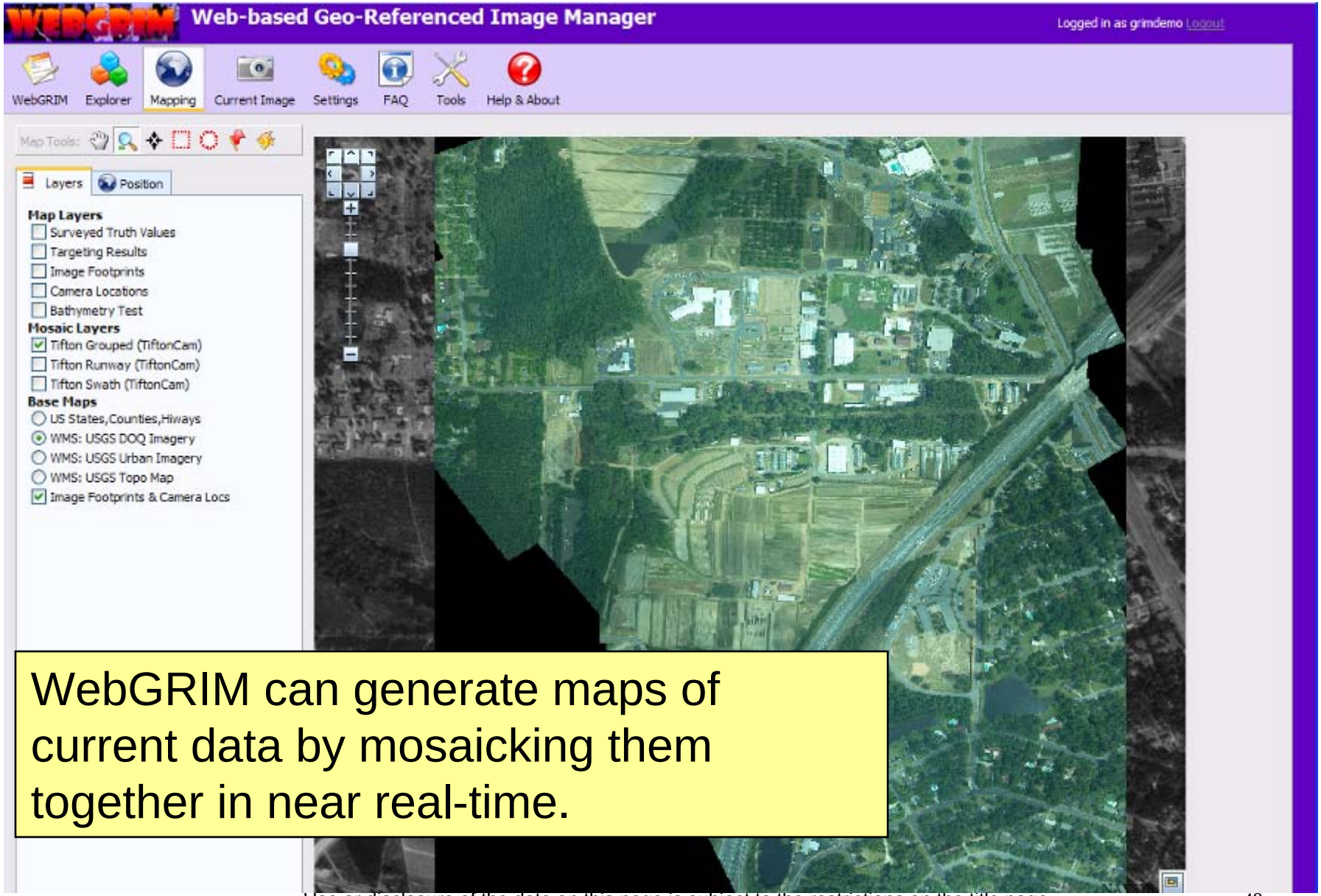
Raw imagery is downloaded on demand from any UAS on the network. Since no processing is required this hi-resolution data is available in real-time.


WebGRIM Image
2001-05-11 15:15:02
Previous
Next
Refresh
Silhouettes for Project:
Object
One click zooms in the image…
Full Image
Show Silhouettes
Targeting
Next Click:
Zoom In
Add Silhouette
Delete Silhouette
Do 1-Shot Targeting

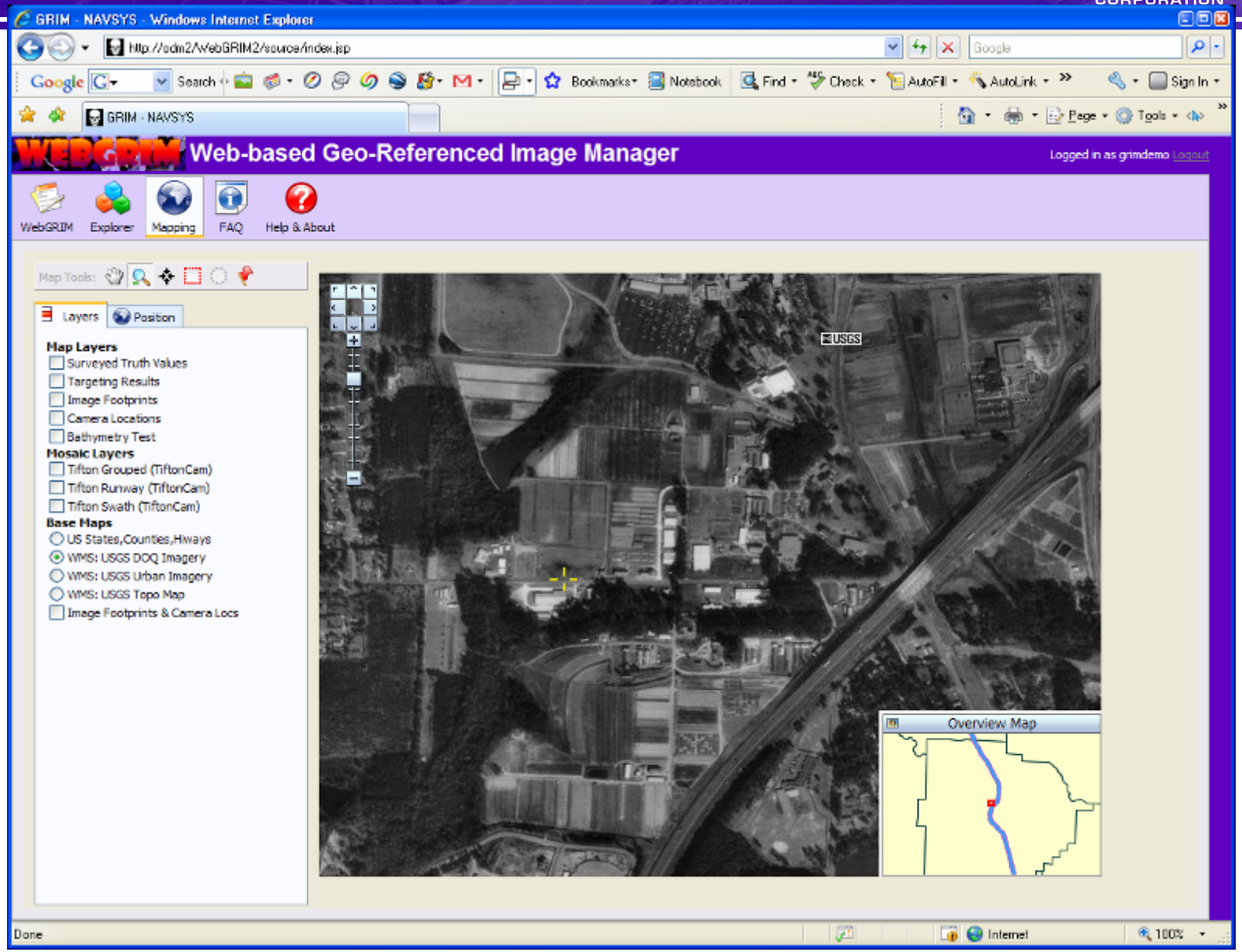
navsys CORPORATION

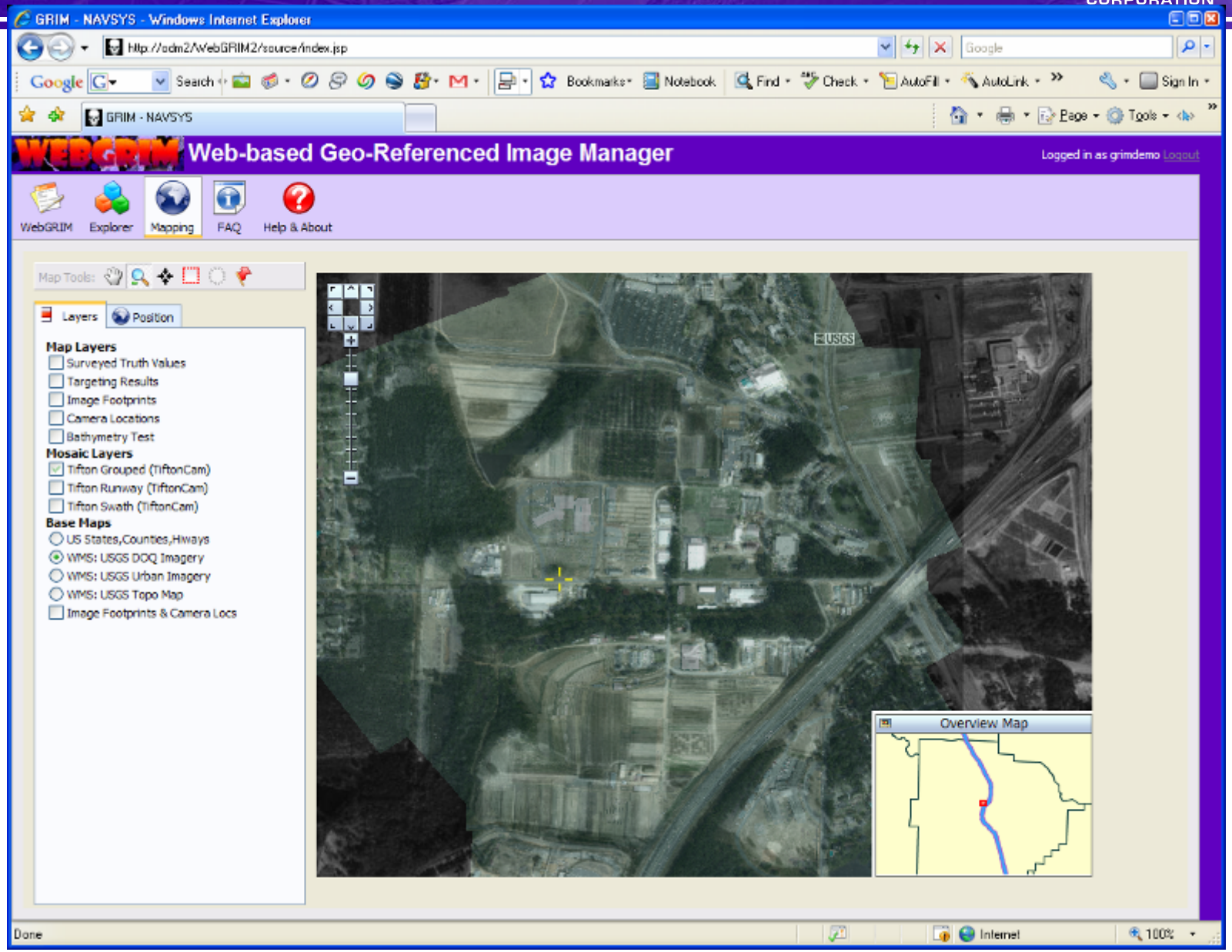


And a second click generates targeting coordinates in single-shot targeting mode.



WebGRIM can generate maps of current data by mosaicking them together in near real-time.


GRIM - NAVSYS - Windows Internet Explorer
http://odm2/WebGRIM2/source/index.jsp
GRIM - NAVSYS
WEBGRIM
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
Done
Internet
100%


GRIM - NAVSYS - Windows Internet Explorer
http://odm2/WebGRIM2/source/index.jsp
GRIM - NAVSYS
WEBGRIM
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Tifton Grouped (TiftonCam)
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Base Maps
US States,Counties,Hiways
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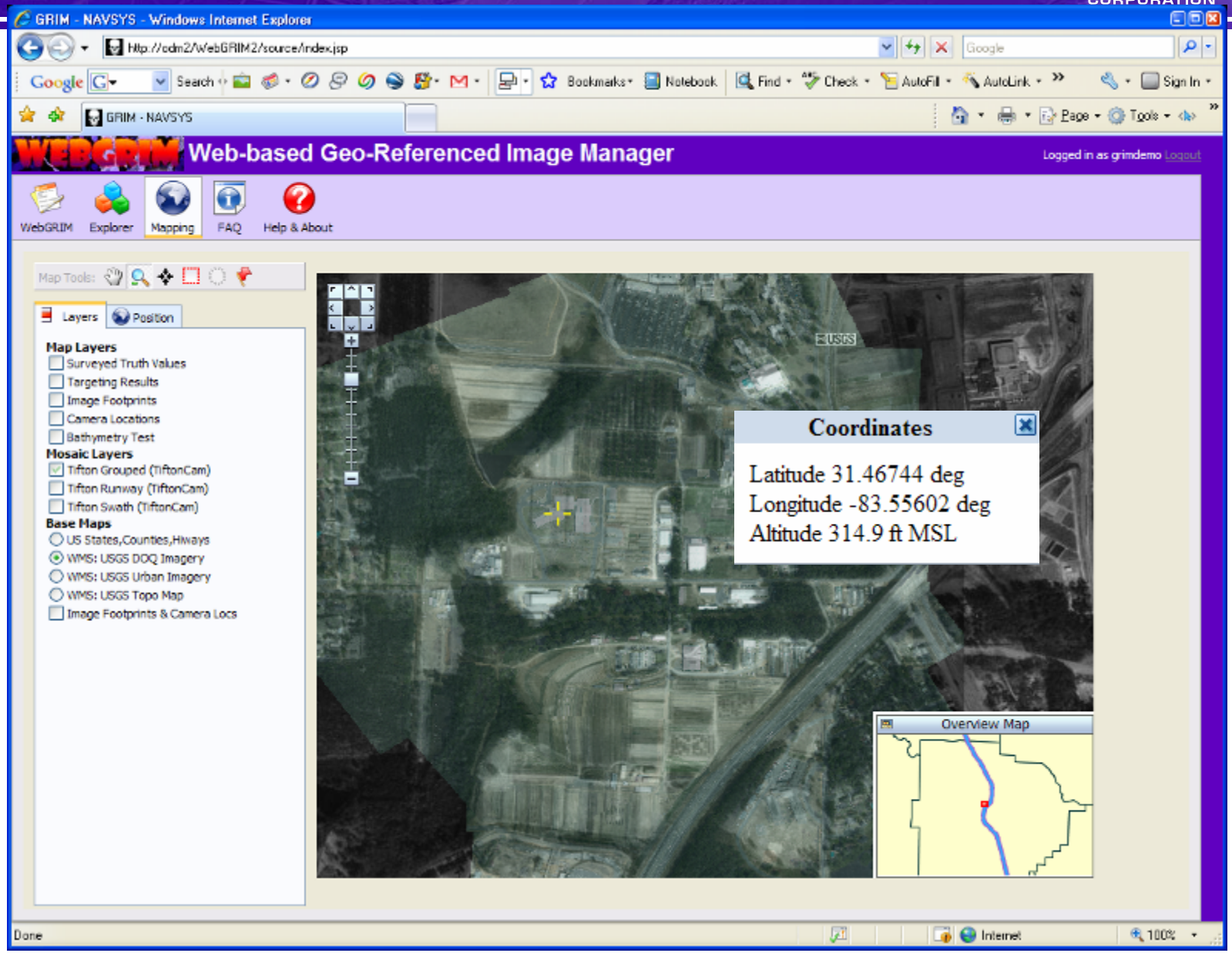
WMS: USGS Urban Imagery
WMS: USGS Topo Map
Image Footprints & Camera Locs
USGS
Overview Map
Done
Internet
100%


GRIM - NAVSYS - Windows Internet Explorer
http://cdm2/WebGRIM2/source/index.jsp
GRIM - NAVSYS
WEBGRIM
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Tifton Grouped (TiftonCam)
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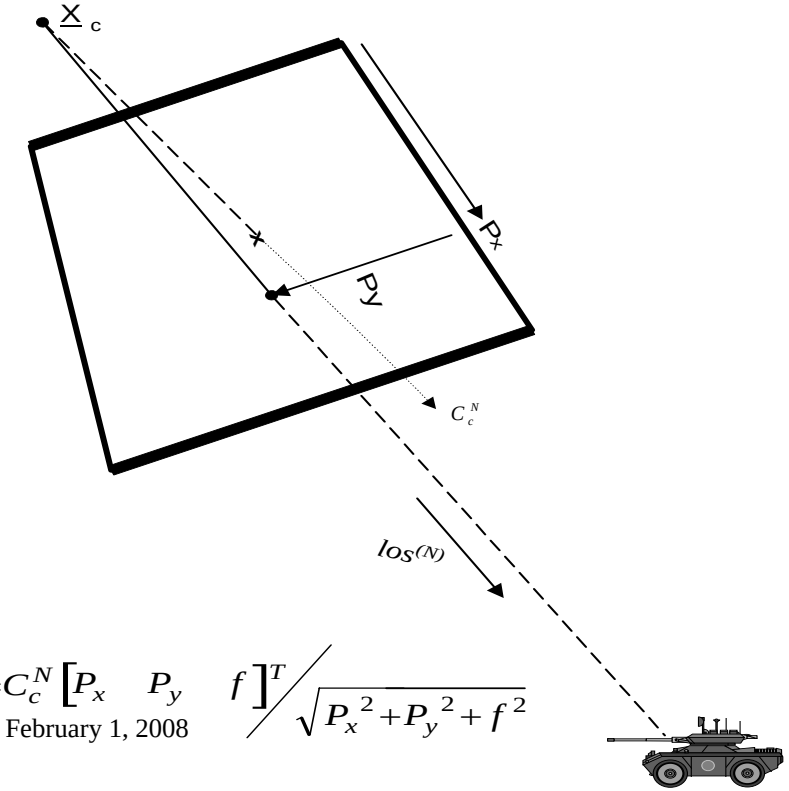
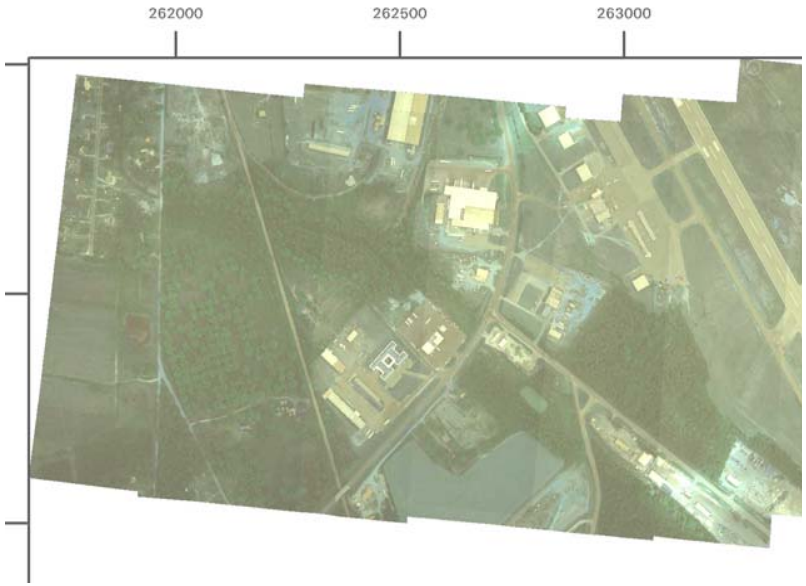
Tifton Swath (TiftonCam)
Base Maps
US States,Counties,Hiways
WMS: USGS DOQ Imagery
WMS: USGS Urban Imagery
WMS: USGS Topo Map
Image Footprints & Camera Locs
Coordinates
Latitude 31.46744 deg
Longitude -83.55602 deg
Altitude 314.9 ft MSL
Overview Map
Done
Internet
100%

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



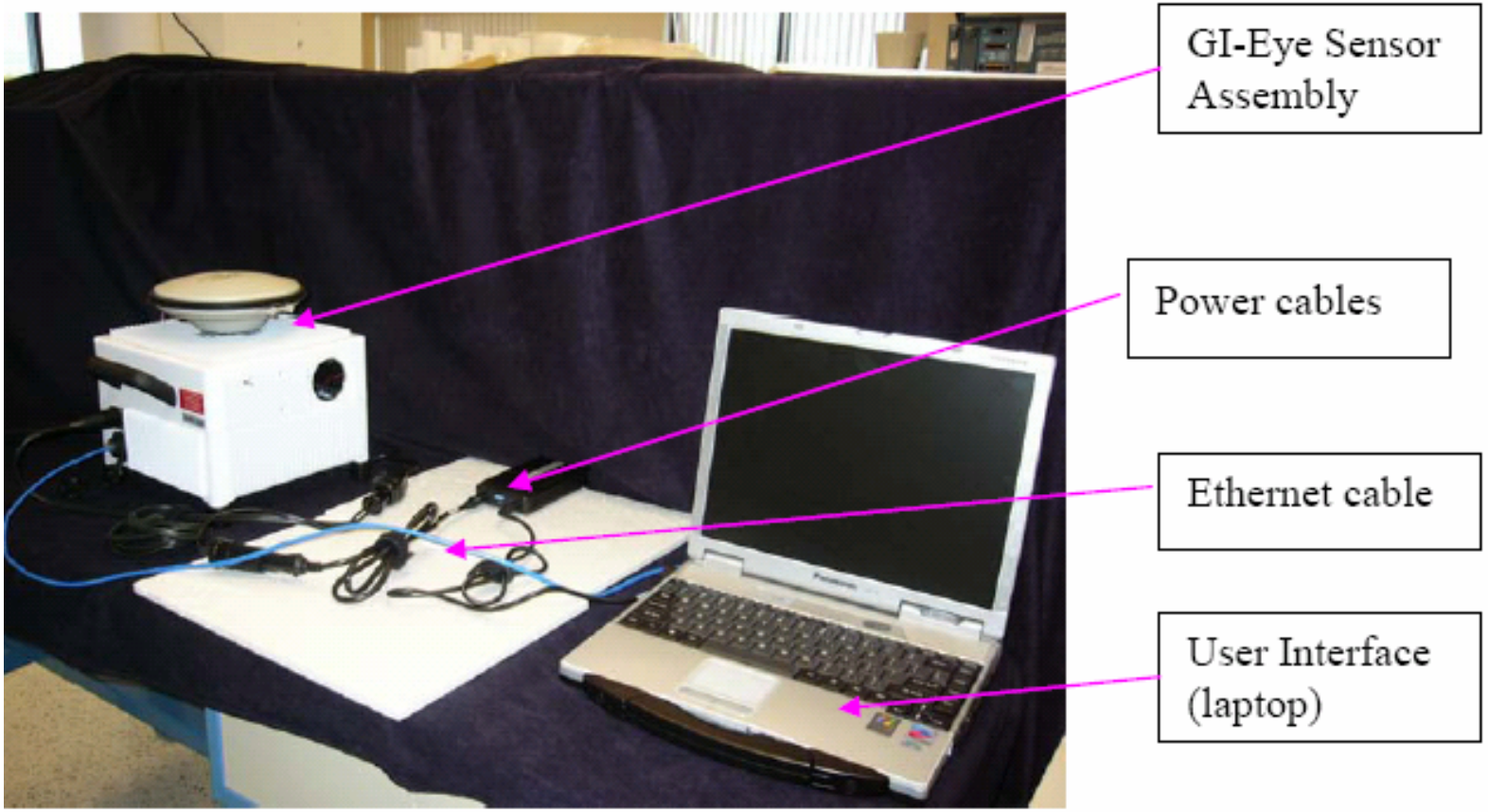
$$los^{(N)} = C_c^N \begin{bmatrix} P_x & P_y & f \end{bmatrix}^T \Big/ \sqrt{P_x^2 + P_y^2 + f^2}$$



Expected Targeting Accuracy Based on Prior Data Collections

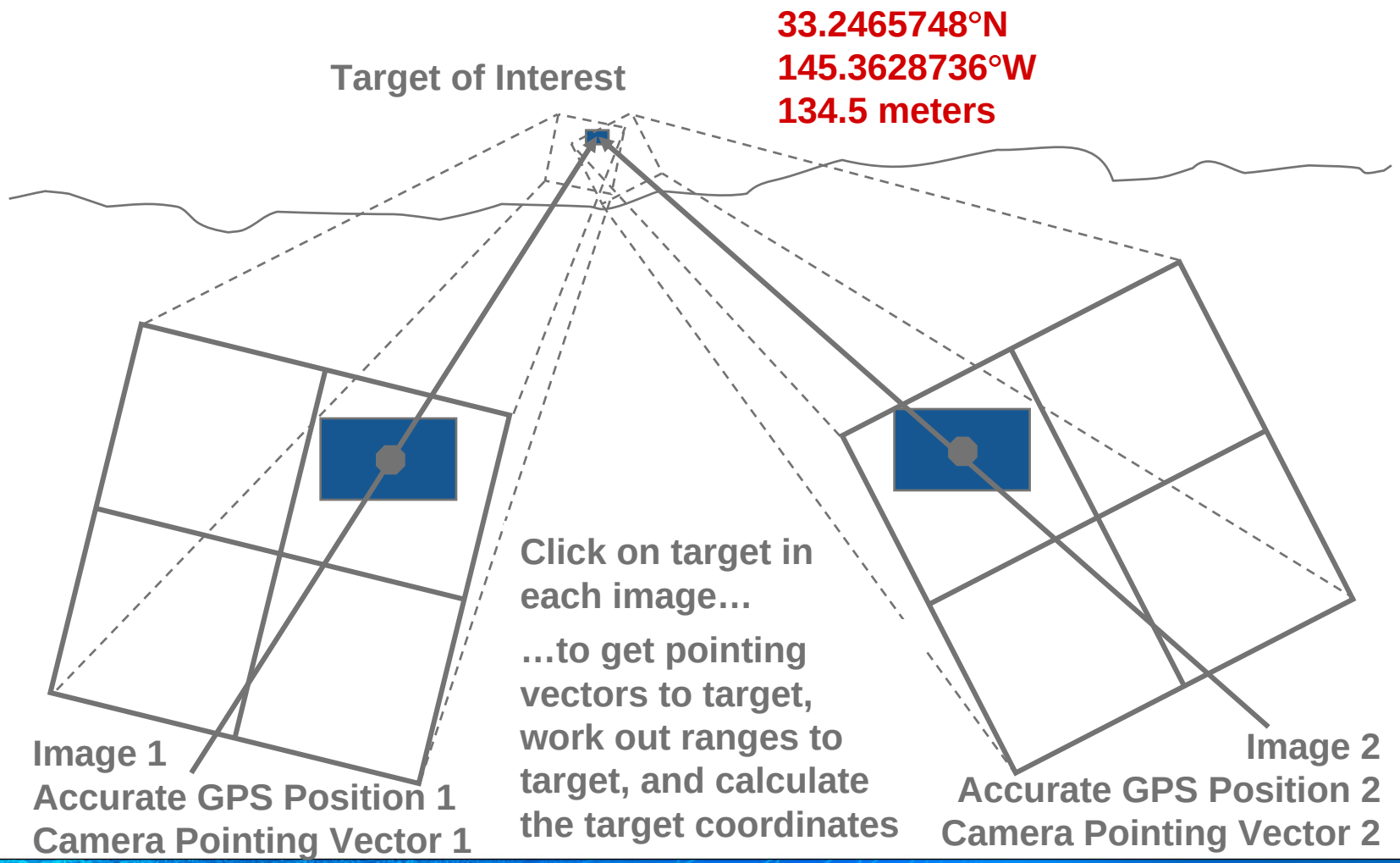
SYSTEM	DTED LEVEL	FLIGHT HEIGHT	IMAGE FOOTPRINT	IMAGE OVERLAP	DEM TARGETING ACCURACY (HORIZONTAL)	DEM TARGETING ACCURACY (VERTICAL)
GI-EYE (Tifton)	1	1200 m	900m × 600m	60 %	0.8 m	10 m
Landmark USAF	2	1600 m	160m × 160m	50~75 %	3 m	3.5 m
GBO	P-DSM	4000 m	255m x 320m	80%	6.4m	4.2m

Tactical Surveying and Targeting System (TS2)



TS2 is a cooperative program funded by the InnoVision Directorate and tested by Office of GEOINT Sciences (SNSS)

Passive Targeting Process

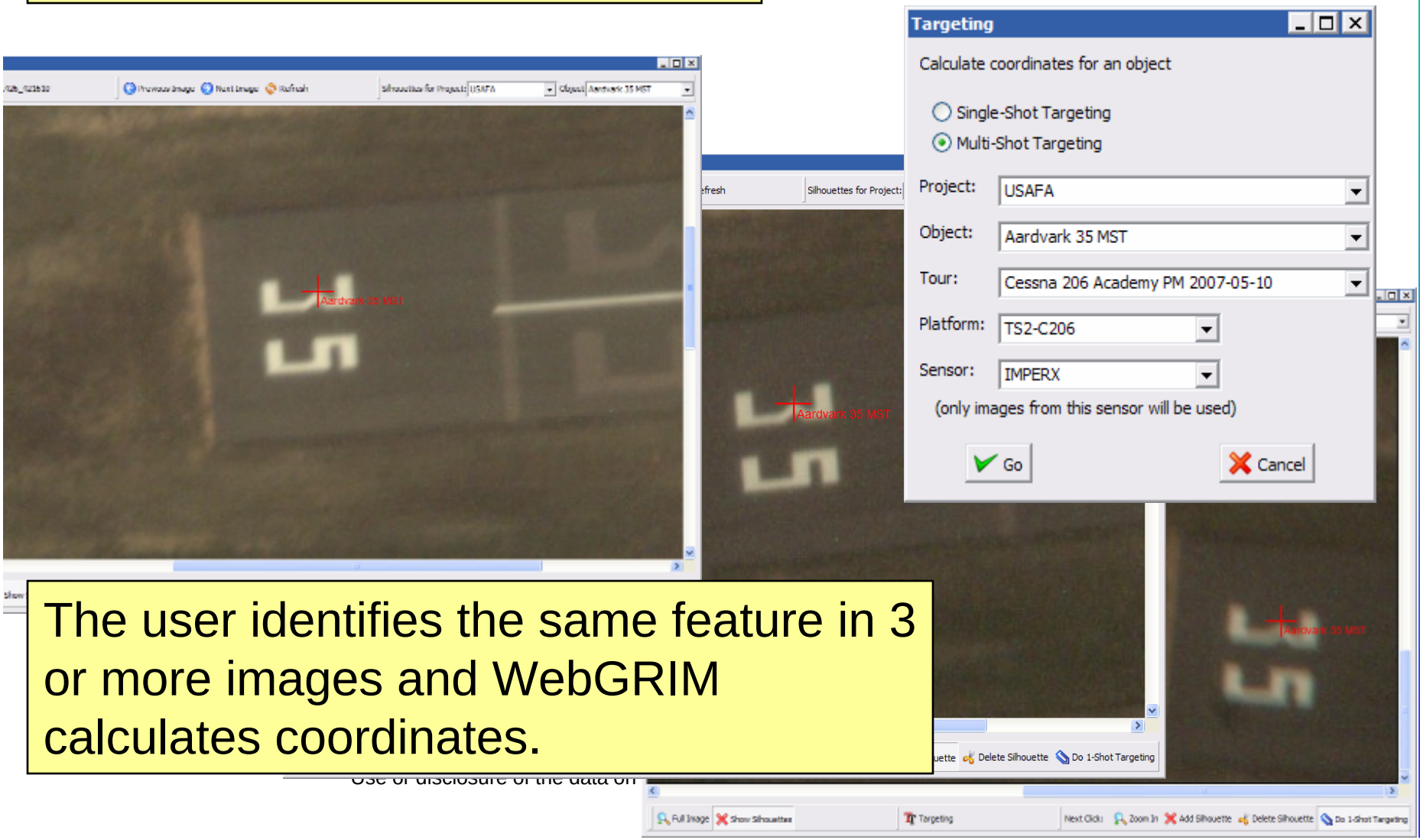


TS2 Test Results COLUMBIA

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				

Triple-shot targeting mode allows targeting without a DEM or for non-aerial imaging.



The user identifies the same feature in 3 or more images and WebGRIM calculates coordinates.

Some Benefits of using Real-Time Mensurated Data over Streaming Video

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)

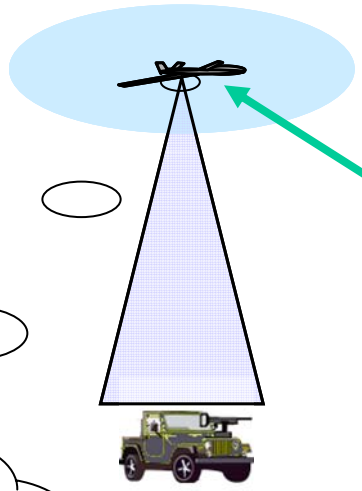
Mosaic Downlink

- Real-time target-quality registered 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
- Registered mosaics provide mensurated target coordinates

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

PM Fire Support Systems planned Flight Demonstrations with MCWL

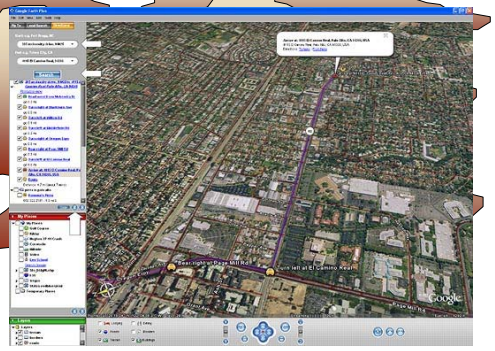
NAVSYS GI-Eye payload registers imagery onboard UAV using precision GPS/inertial meta data



UAV Flight Operations Crew

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

Ground Based Observers



Conclusion

- Precision GPS/inertial sensor integration can provide real-time meta data for image mensuration
- Target locations can be determined using precision mensurated imagery using either multi-image lateration or with single image and P-DSM
- Real-time meta data also allows for streamlined geographic search and retrieval of images from multiple UAS payloads
- Cursor-on-Target XML interface facilitates integration of new real-time targeting systems into the existing Call-For-Fire command processes

BackUp

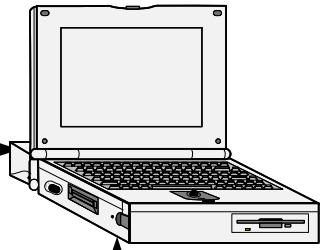
GBO Payload Hardware Components

Pixelink
PL-B776U
Imager

USB

3.3, 5, +/- 15V
Power Modules

WebGRIM
Server
Computer TBD



HG1900
IMU

RS-422
SDLC

RS-232

NAVSYS
Interface
Module (NIM)

Kontron
CPU Board

Ethernet Link

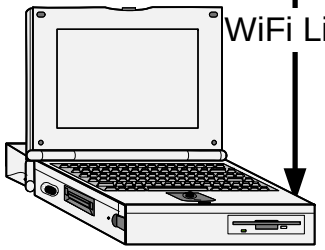
IDE

RS-232

AT2775
AeroAntenna
L1/L2

Novatel OEMV
GPS Receiver

Fujitsu
2.5" Hard
Drive



WiFi Link

GBO Work
Station

Know the Earth…Show the Way

Tactical Surveying and Targeting System (TS2)

Terry Timblin

Directorate of Source Operations and Management

Source Assessment and Global Foundation Group

Office of GEOINT Sciences

SYMPOSIUM

28 June 2006

National Geospatial-Intelligence Agency

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NATIONAL GEOSPATIAL-INTELLIGENCE AGENCY

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