Flight Test Results for Video-Aided Navigation

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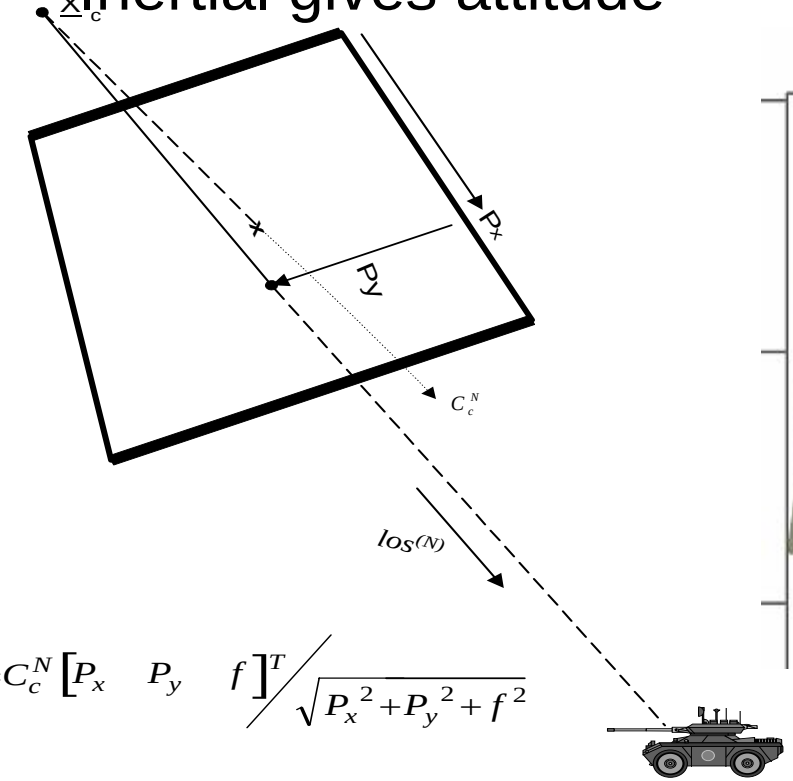
Problem Statement

- A key issue for small UAVs is their inability to operate during periods of GPS denial
- Current flight regulations require that UAVs land following loss of navigation
- Larger UAVs carry inertial navigation systems that can provide back-up navigation during GPS drop-out
- Smaller tactical UAVs generally have low quality IMUs that are unable to continue navigation solutions following GPS drops-out
- A back-up navigation solution to GPS is needed for use on these smaller, lower cost UAV platforms.

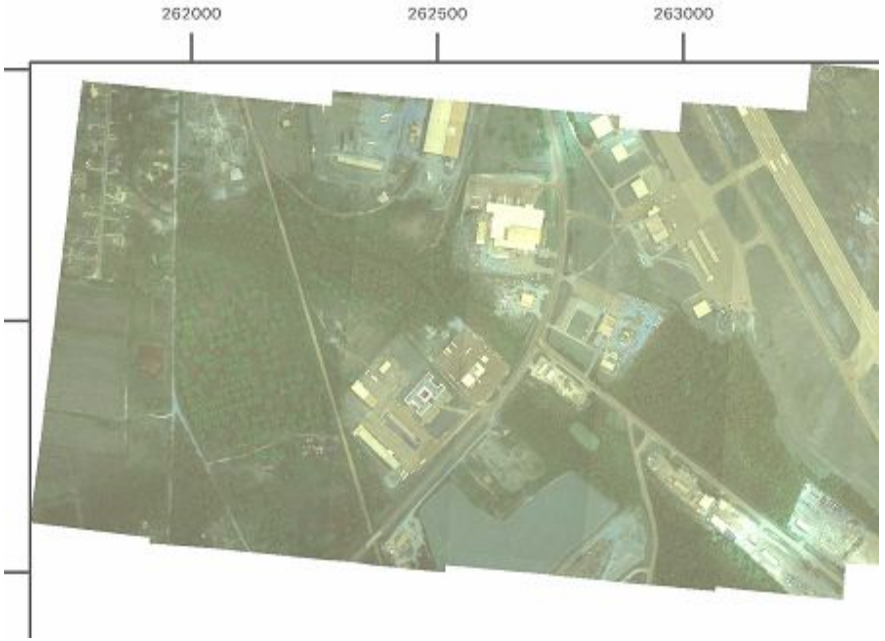
GI-Eye Sensor Registration

- GI-Eye Product
  - GPS gives position
  - Inertial gives attitude



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

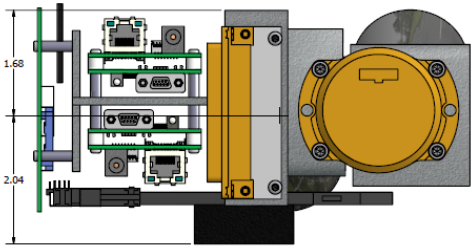
- GRIM Enterprise Server
  - Manages registered sensor imagery
  - Auto-mosaic generation

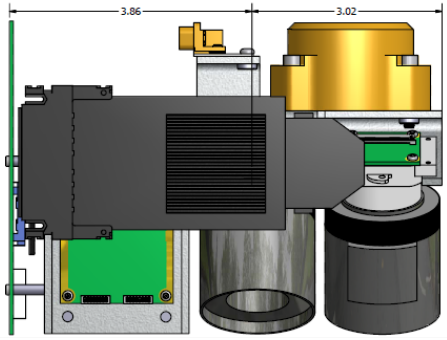


GI-Eye Systems

NGA Tactical Surveying and Targeting System (TS2)

FLIR StarSAFIRE III





Micro-Camera (Dual Camera)

Dual GI-Eye System Flown at USAFA

GI-Eye Payload

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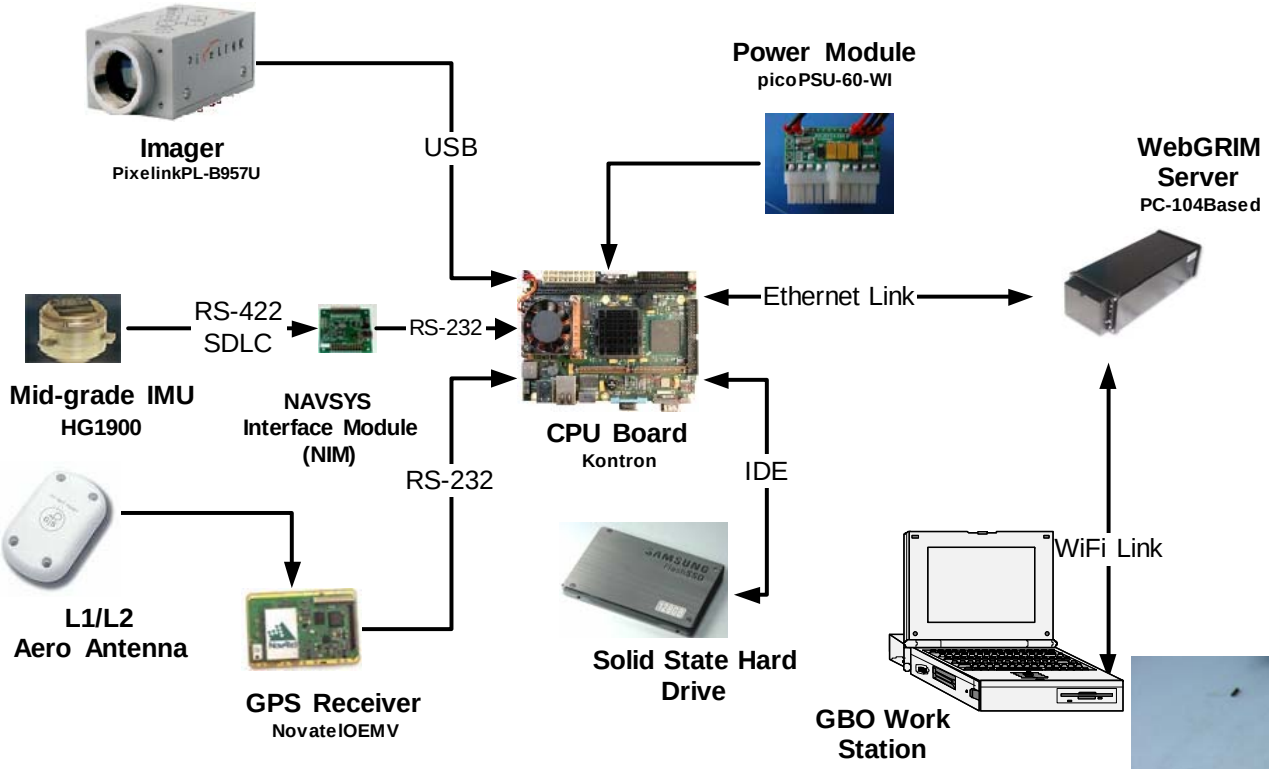
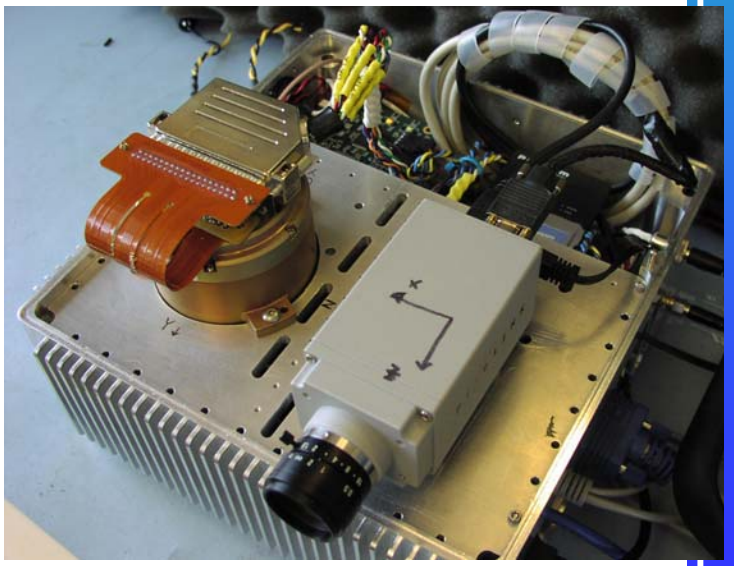
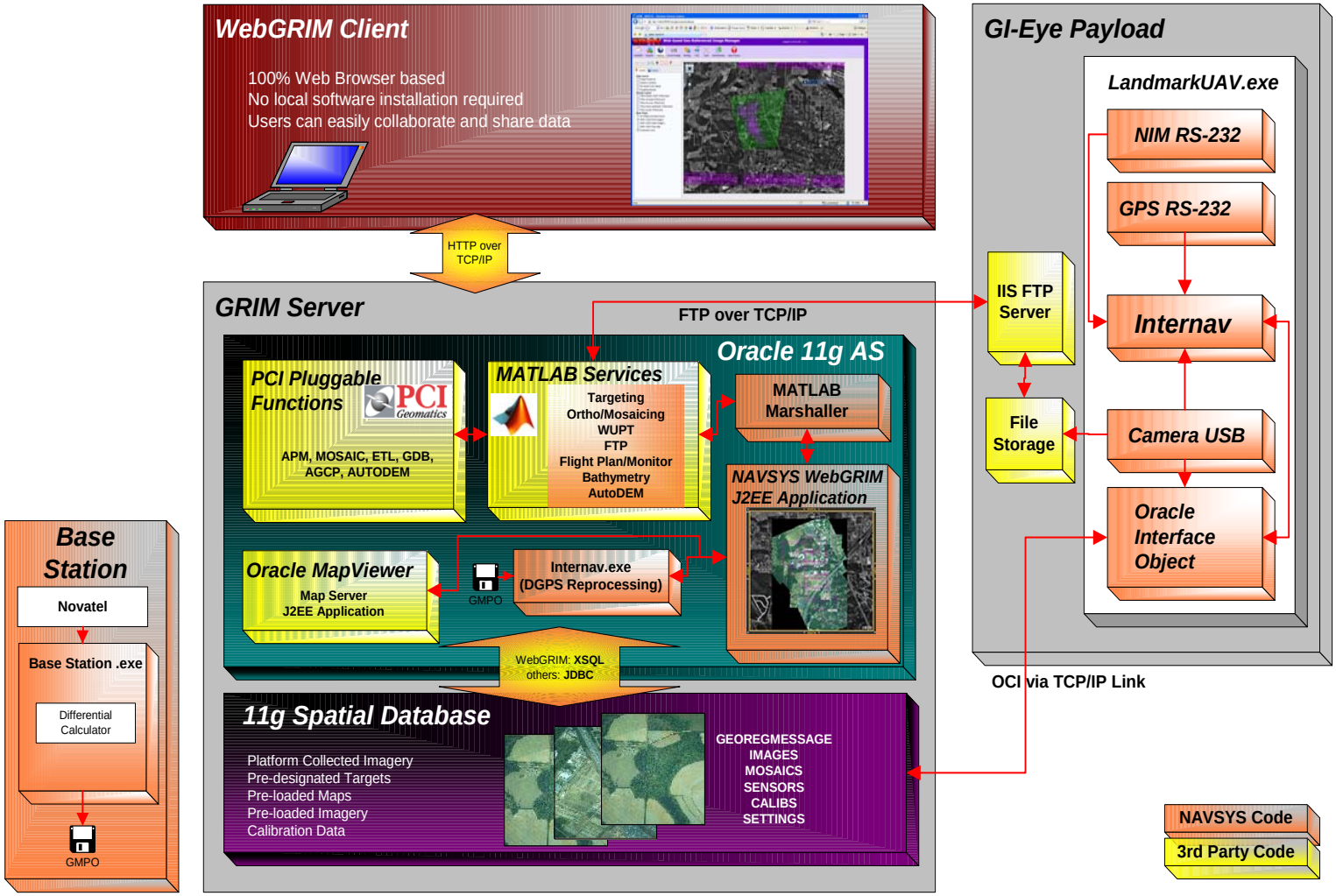


Component	Size	Weight	Power
As shown above	~ 300 Cubic Inches	~ 9 lbs	~ 175 Watts

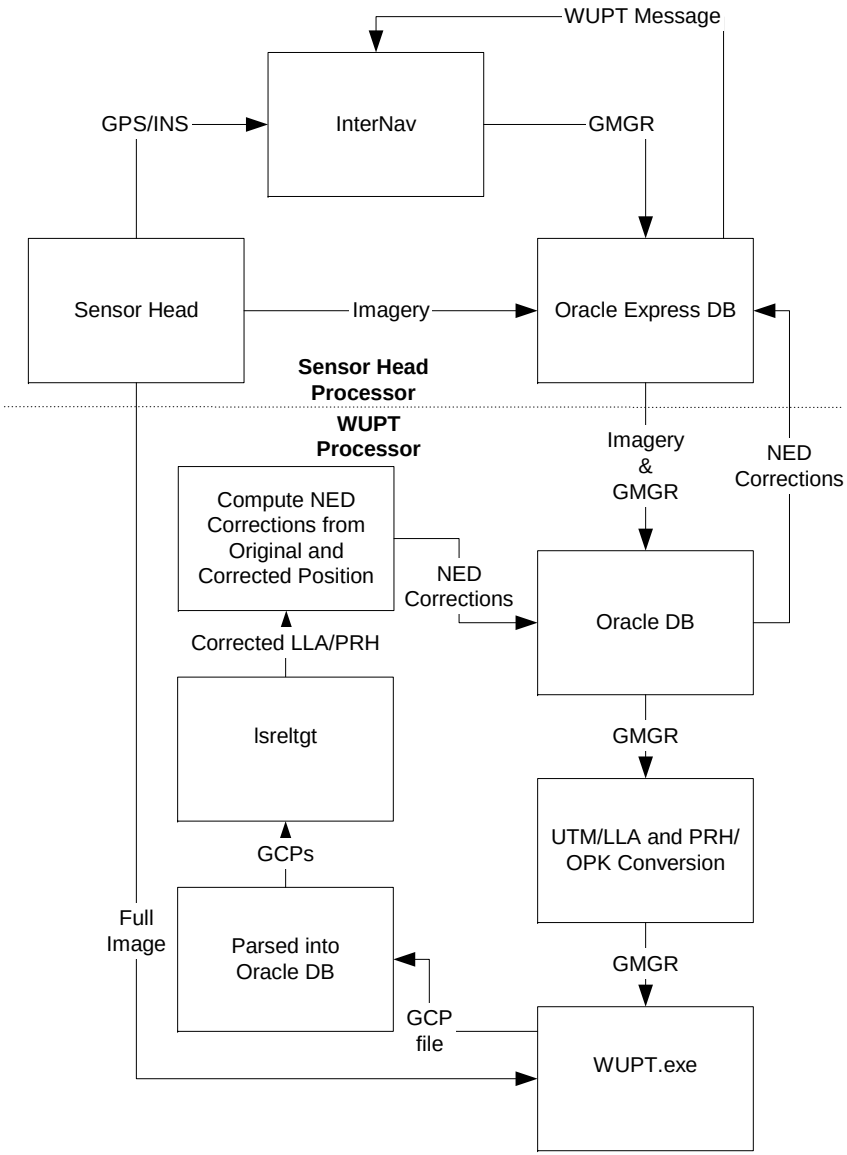


GI-Eye and WebGRIM Architecture

Overall Web-based Georeferrenced Image Manager (WebGRIM) Architecture



WUPT Process Flow



- Imagery and georegistration data is initially collected by the sensor and stored in Oracle database
- Covariance is monitored to indicate a potential issue with GPS data
- GRIM starts the WUPT process by pulling imagery and georegistration information from database
- WUPT library compares images to reference images to determine Ground Control Points (GCPs)
- Lsreltgt Software uses GCPs to generate position and attitude corrections
- Position/attitude updates sent to InterNav to assist navigation

WUPT Work Flow

- pci.crproj
  - Creates Orthoengine project
- pci.camimport
  - Imports camera calibration data from XML data extracted from database
- pci.eoimport
  - Import Exterior Orientation Data from GI-Eye Inertial position/attitude meta data
- pci.autogcp
  - Collects ground control points for an input image from a reference image
- Lsreltgt
  - Uses inertial aiding and GCP points to calculate position/attitude errors in inertial solution

Landmark Flight Test - 11 July 09

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- Rocky Mountain Aerial Surveys, Inc Cessna 206G
  - Based in Denver
- Collection Area
  - Northeast section of USAFA
  - 25 NGA surveyed Ground Control Points
- Landmark Payload
  - 1 Hz images, looking Nadir
- Micro-Camera Payload
  - 2 Hz images, 30 degrees off Nadir
- Post processed images used to:
  - Test single and multi-shot targeting through WebGRIM
  - Collect imagery for AutoDEM processing
  - Validate WUPT navigation algorithms

WebGRIM Ground Station Software

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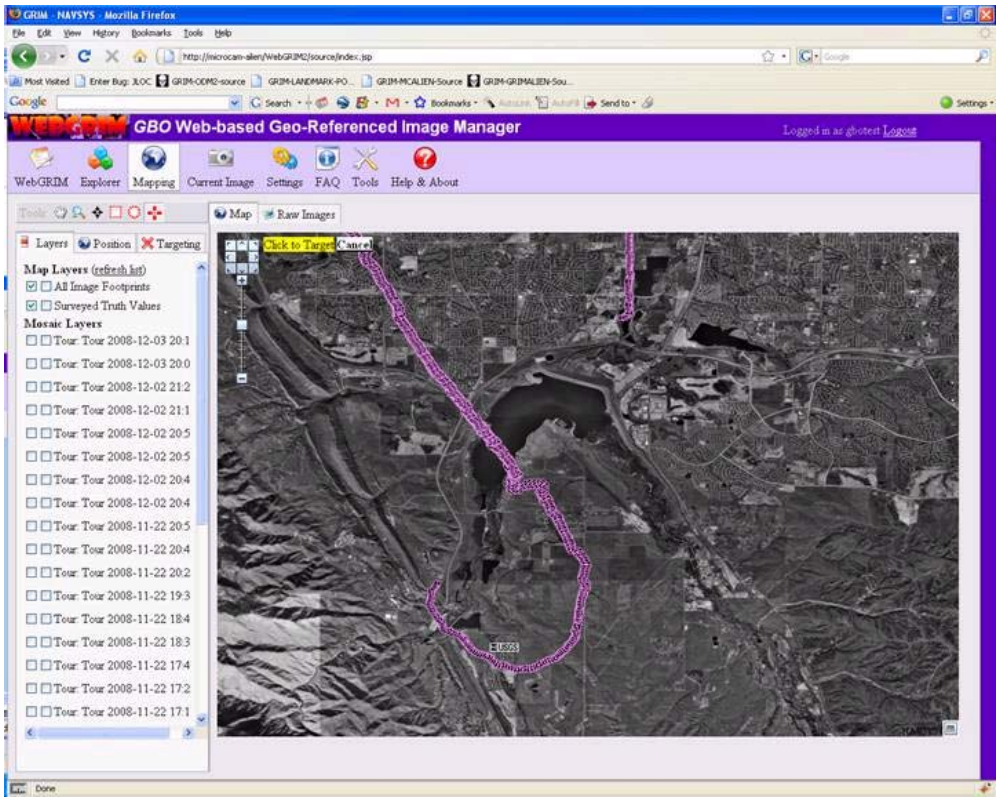
- Web Based
  - No new software to install
  - On-line collaboration between multiple users
- Quickly locate & manipulate collected imagery
  - Orthorectification & mosaicking
  - Point and click targeting
- User Customized Tools
  - Flight planning
  - Targeting
  - map generation
- Compliant with OGC
  - Display third party maps
  - Acts as Web Mapping Service
- Auto-DEM map generation from collected imagery



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WebGRIM - Zooming in to AOI

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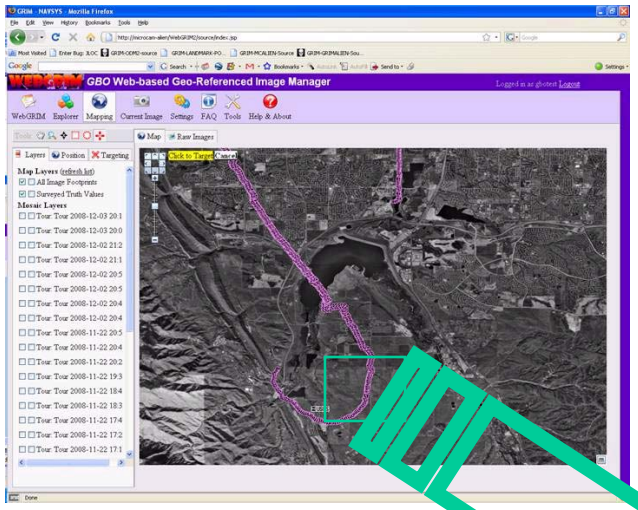
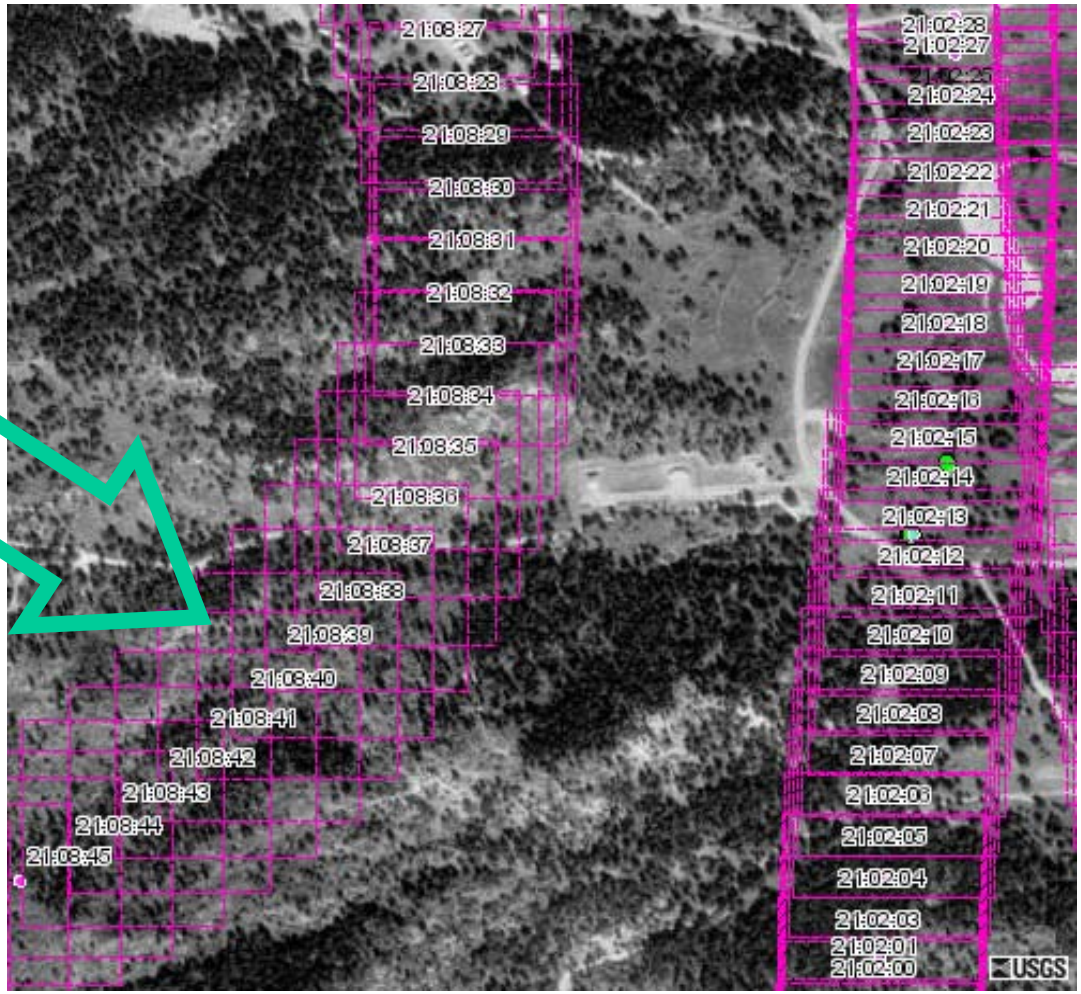


- User can zoom in to Area of Interest to see footprints of collected imagery



Ground Control Points

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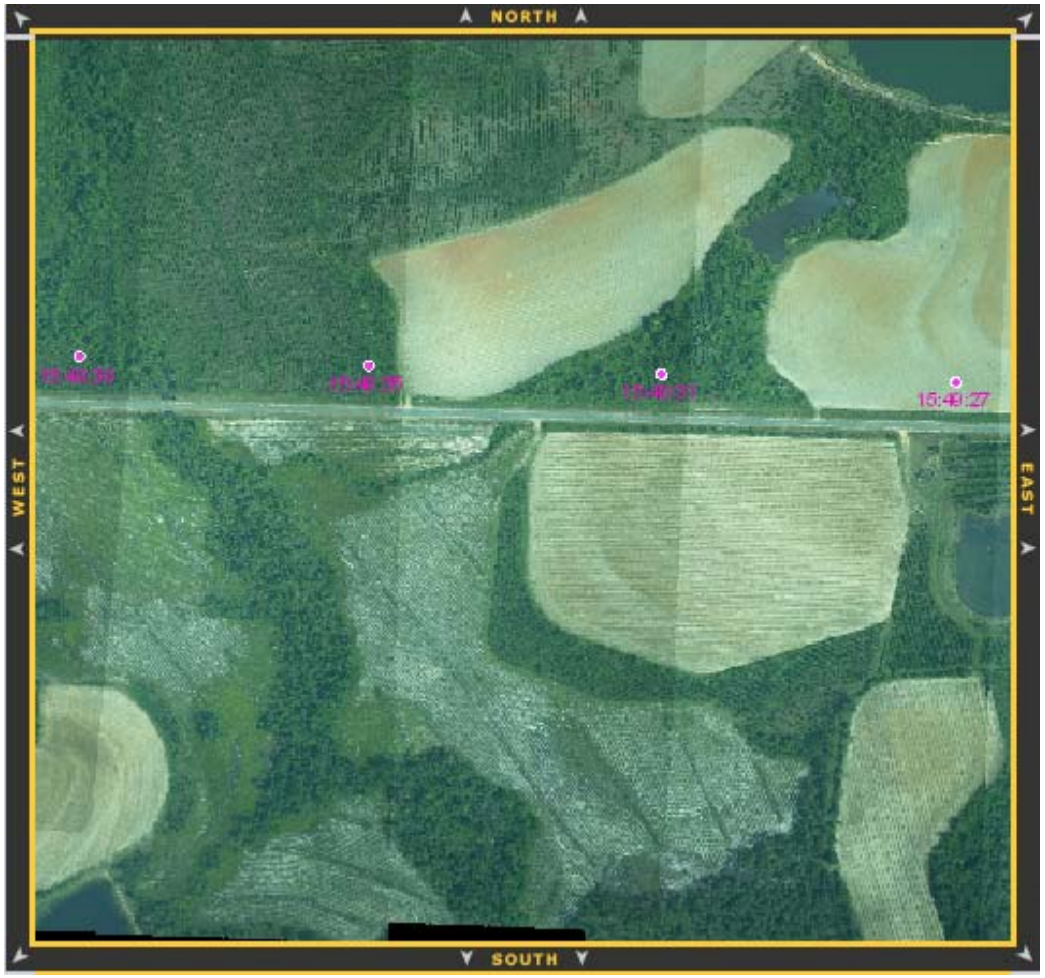
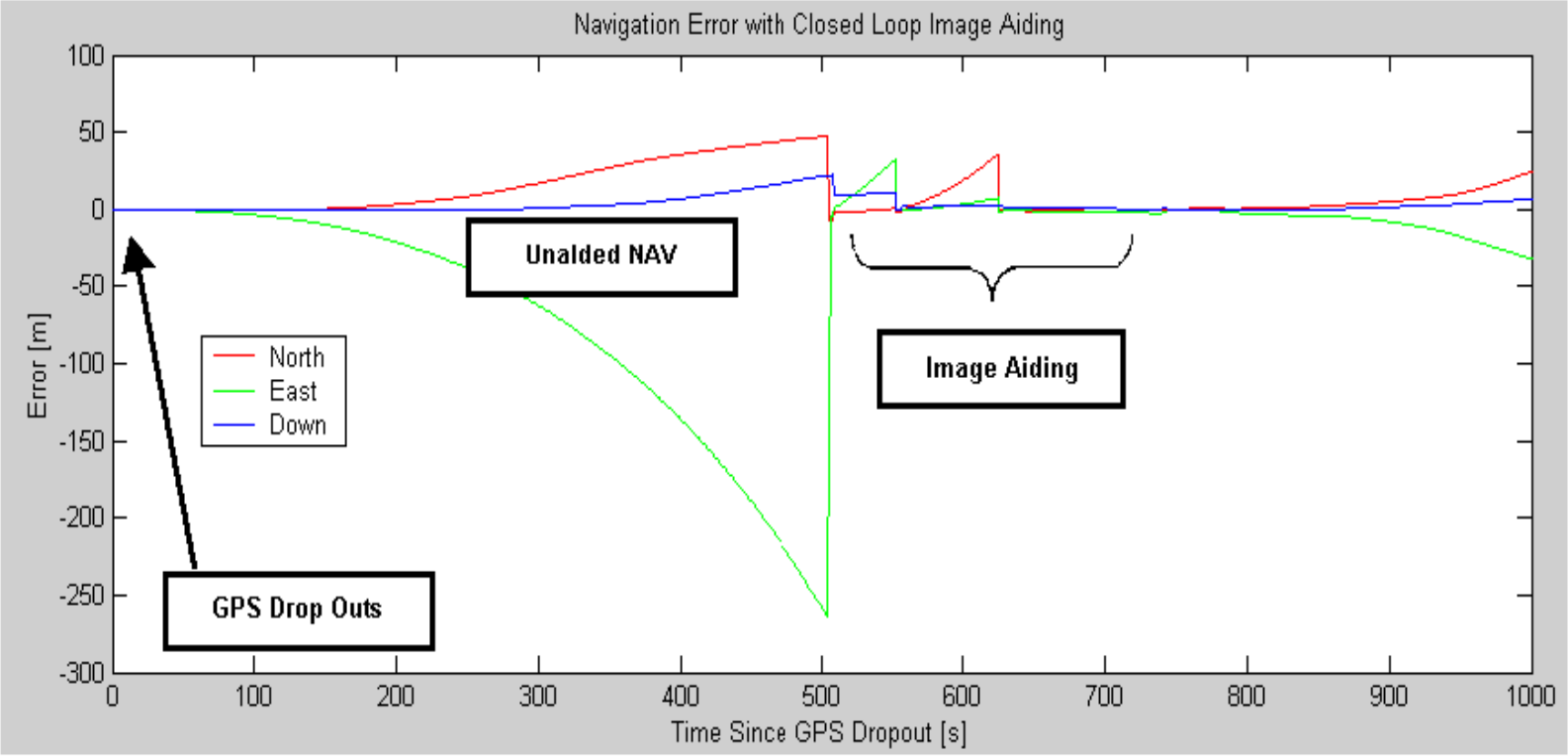
- WUPT Library compares images against the reference image in the database to determine GCP



WUPT Results

- Ground Control Points are automatically generated and compared against a reference mosaic.
- Corrections are generated for the position and attitude of the sensor based on the difference between common points in the images.
- Red indicates an accepted GCP
- Yellow indicates a rejected GCP

Airborne Navigation Performance with Image Aiding



Steady-State Nav Error < 5 m with 2 updates per minute

Conclusion

- GPS/inertial registered video can provide mosaiced reference image
- WUPT updates from current images to previous mosaic can bound inertial errors during GPS drop-outs
- Video aiding provides a cost effective back-up navigation solution for small UAVs using their onboard avionics and sensor payloads

Back-Up

NGA Truth Data