GPS/Inertial Micro-Camera for Oceanographic Properties and Shallow Water Hydrography

Joint Navigation Conference 2009
June 2, 2009

Session A1: Warfighter Requirements & Solutions

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Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE	2. REPORT TYPE	3. DATES COVERED
2009		**00-00-2009 to 00-00-2009**

4. TITLE AND SUBTITLE	5a. CONTRACT NUMBER
GPS/Inertial Micro-Camera for Oceanographic Properties and Shallow Water Hydrography	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER
	5e. TASK NUMBER
	5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Navsys Corporation,Colorado Springs,CO,80921**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S)
	11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES
2009 Joint Navigation Conference in Orlando, FL on 02 Jun 2009.

14. ABSTRACT

15. SUBJECT TERMS

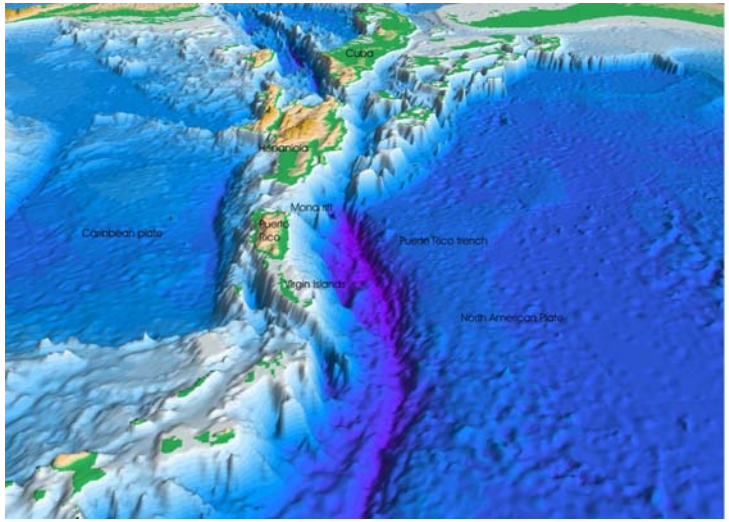
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			
unclassified	**unclassified**	**unclassified**	**Same as Report (SAR)**	**25**	

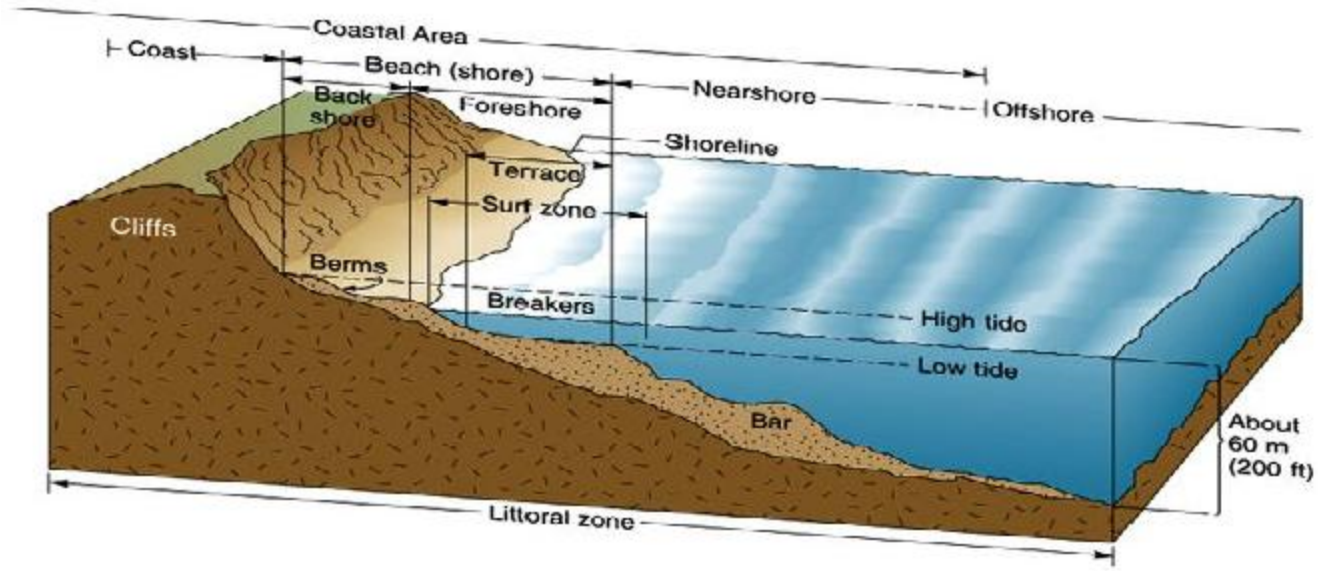
Overview

- Problem Statement
- Micro-Camera System
  - Payload
  - Image Processing / Ground Station Software
  - Bathymetry Software
- Test Results

Bathymetry is the underwater equivalent to topography

Littoral Zone is the ocean region extending from the high water mark to the shoreline areas that are permanently submerged





Key Technical Challenge

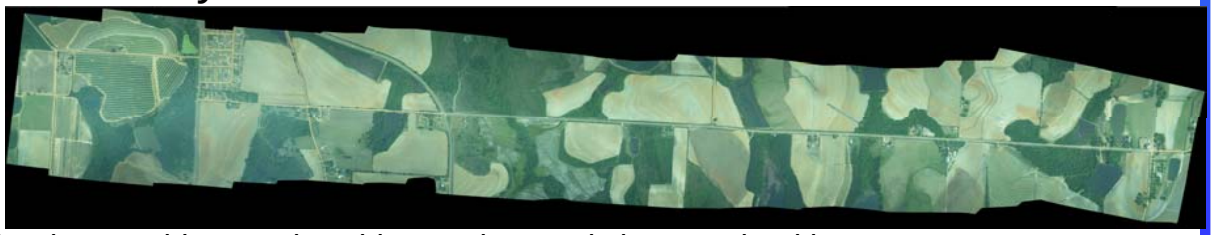
- Current AROSS system has proven use of registered imagery for depth inversion
- Naval METOC officers deployed with Special Operations teams need organic capability to recon multiple beaches and collect water depths
- Key challenge is for reduced SWAP payload to fit on small Tier I UAV

Typical Tier I UAV

- Range: 10 km
- Endurance: 2.5 – 9 hours
- Airspeed: 25-50 km/hr
- Nominal payload weight: 600 - 900g
- Power: 6 -12 W

Military & Civilian Need for UAV Based Bathymetry/Mapping/Targeting

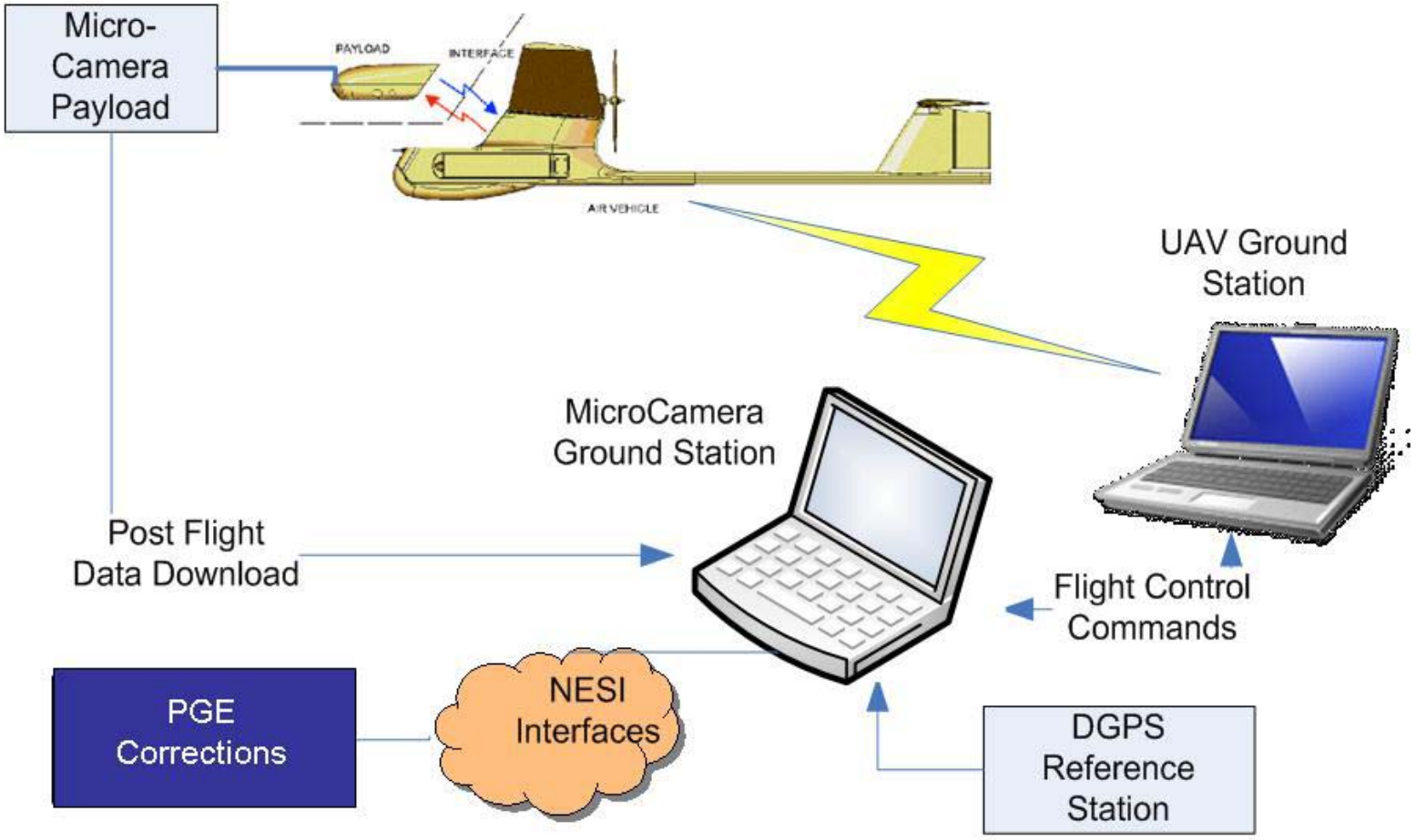
- Bathymetry
  - Army Corp of Engineers
    - High resolution shoreline data for modeling for forecasting
  - Littoral Battlespace Sensing, Fusion, and Integration (LBSF&I)
    - Bathymetry surveys critical for weather modeling and mission planning operations
  - Naval METOC Personnel
    - Bathymetry data from shallow regions in support of littoral operations
- Mapping/Targeting
  - NOAA and NGA
  - Military Mission Planners
    - Near real-time targeting data/Bomb Damage Assessment
- Civilian Commercial Applications
  - Low-cost Rapid Coastal Surveys
  - Precision Land Maps
  - Wave Modeling



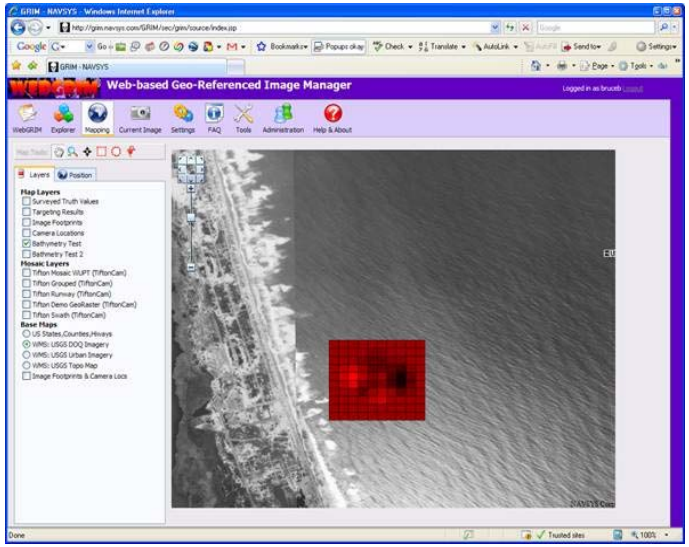
GPS/INS Requirements

- Why is bathymetry processing so difficult in a small UAV?
  - Region of Interest
    - 1 km x 5 km shoreline
    - Bathymetry grid - 100 m x 100m cells
  - Imaging Requirements
    - Image capture at 2 Hz over region of interest
    - ½ pixel smear (objective) and 1/5 pixel smear (Goal)
    - Average resolution of 1 meter/pixel
  - Absolute ground accuracy
    - Under 10 meters (objective) – Under 2 meters (Goal)
    - No need for ground control points
    - Relative accuracy of points sampled at same time in different ground images should be +/- 1 meter
  - Time over target for Bathymetry SW to estimate wave number
    - ~240 consecutive images of area of interest
  - Tier I UAV Payload size
    - Most UAVs are battery powered w/limited power available for the payload
    - Payload weight limited to ~ 2 lbs

NAVSYS Micro-Camera



Micro-Camera CONOPS

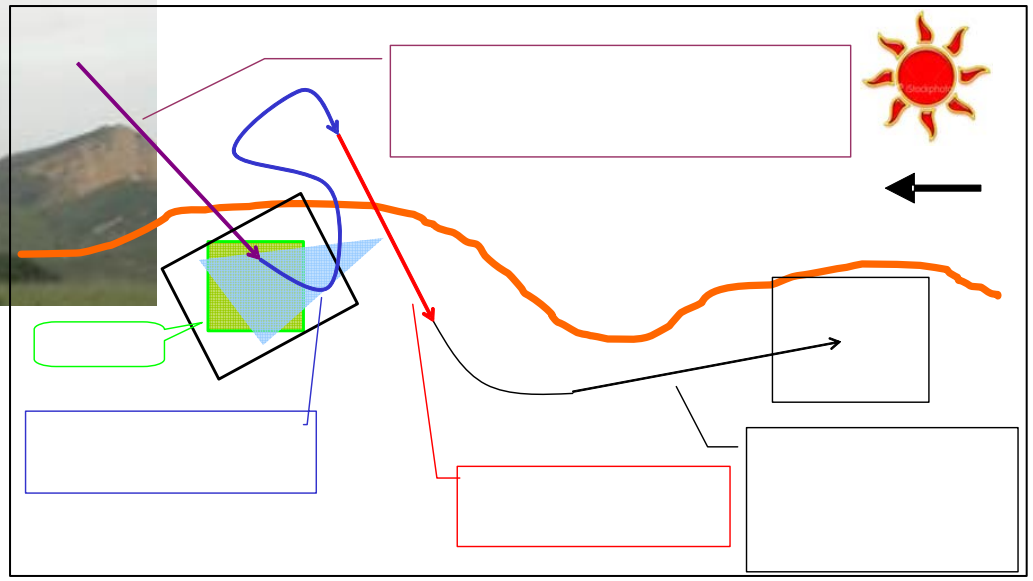


Operator designates AOI using WebGRIM Interface on Micro-Camera Ground Station Laptop

Micro-Camera CONOPS

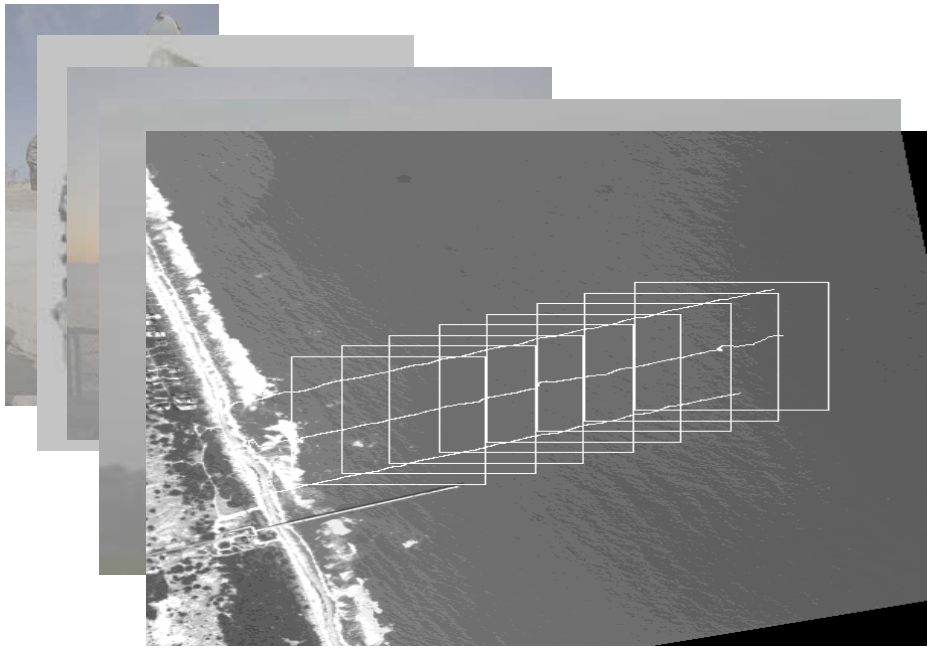
Operator launches the UAV

Micro-Camera CONOPS



- Micro-Camera payload measures winds aloft en route to AOI
- Micro-Camera Ground Station flight planning module calculates flight path waypoints over AOI based on sun angle and wind direction and sends updated flight plan to UAV

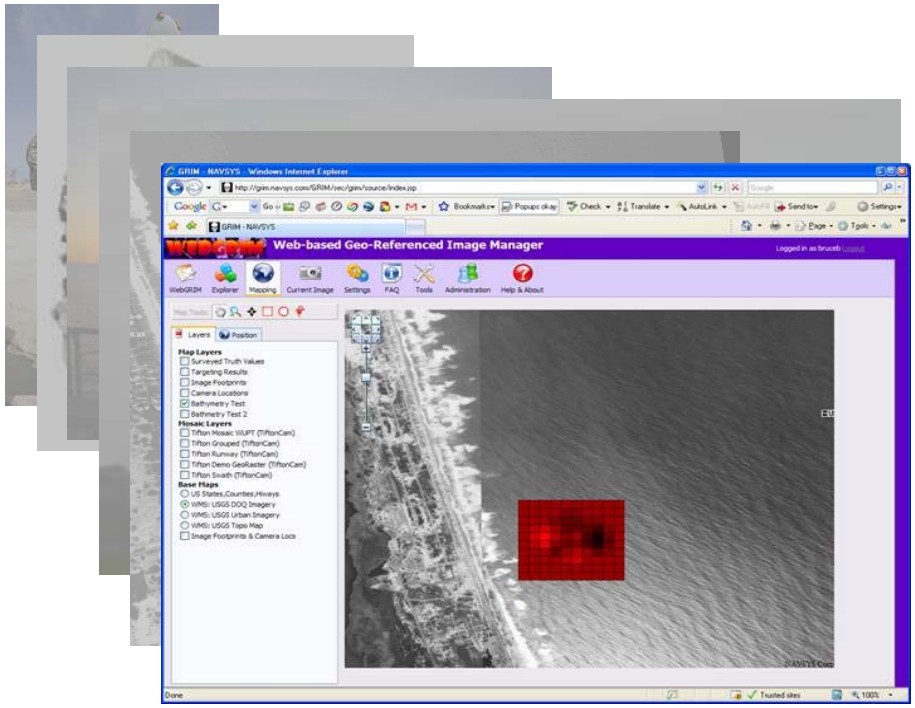
Micro-Camera CONOPS



UAV captures images over AOI

- Imagery and GPS/INS data logged in payload for post processing
- Thumbnails sent to Micro-Camera Ground Station during flight so operator can monitor image quality

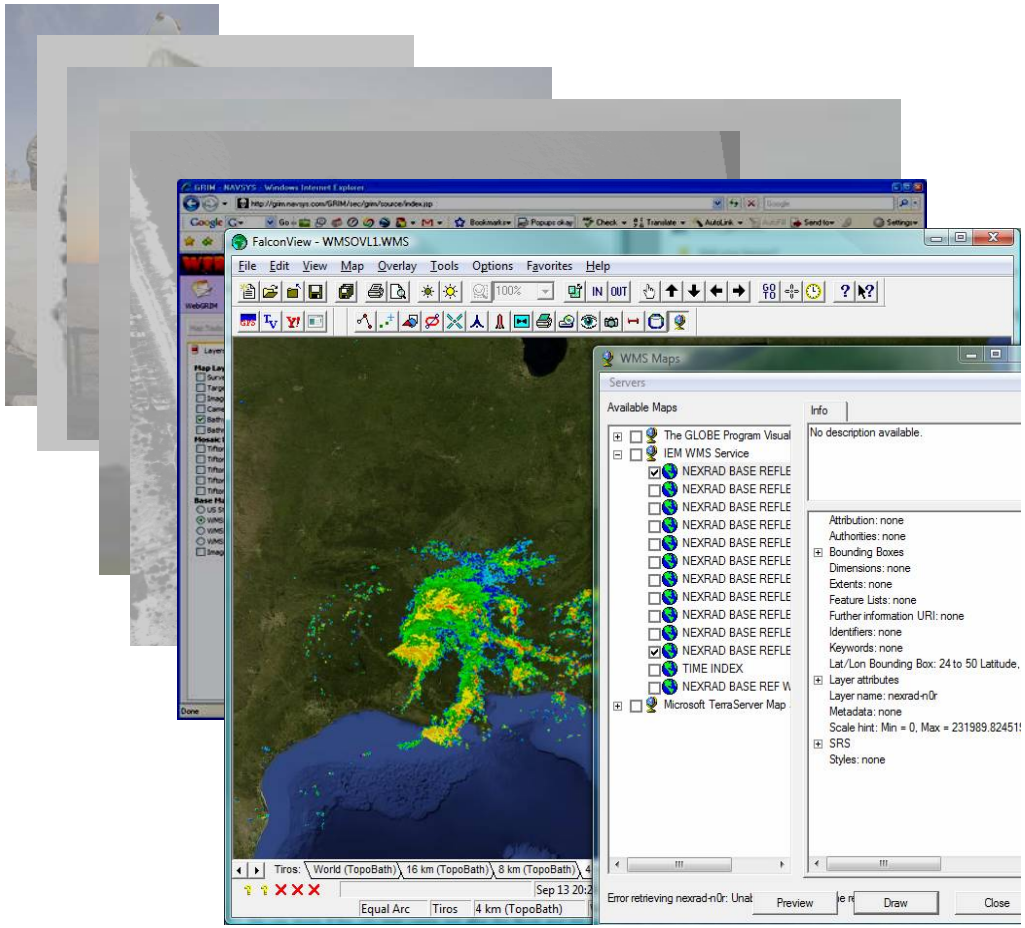
Micro-Camera CONOPS



Ground Station Post Processing

- Operators retrieve UAV
- GPS/IMU and imagery data transferred from payload compact flash to ground station
- DGPS data collected from on-site reference station
- InterNav processing
- Image Processing (Ortho)
- Image Selection/Stacking
- DepthWizard
- WMS Publishing

Micro-Camera CONOPS

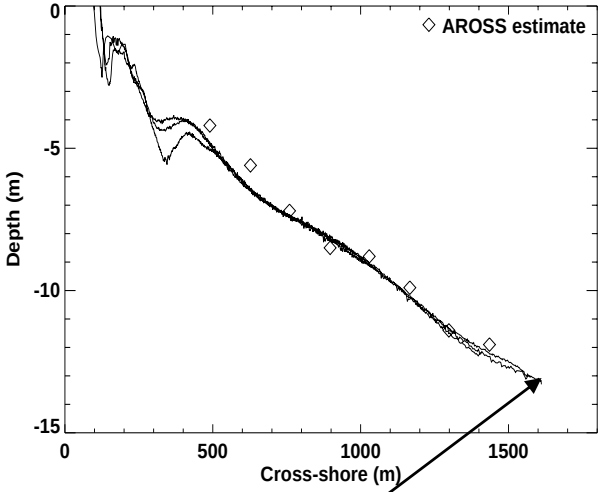


Under NESI guidance data is made available to other applications via a WMS data feed

Cross-Shore Bathymetry Profile

Errors using mean depth in subpatch:

- Bias = 0.12 m
- RMS error = 0.48 m
- Average % error = 5%



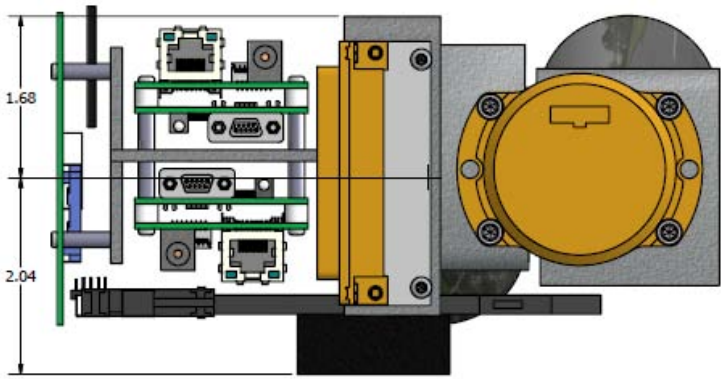
FRF bathy lines - (LARC 27 Oct 99) tide level of 0.2 m accounted for

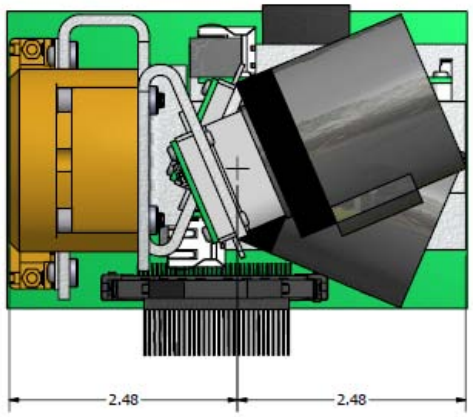
Courtesy of

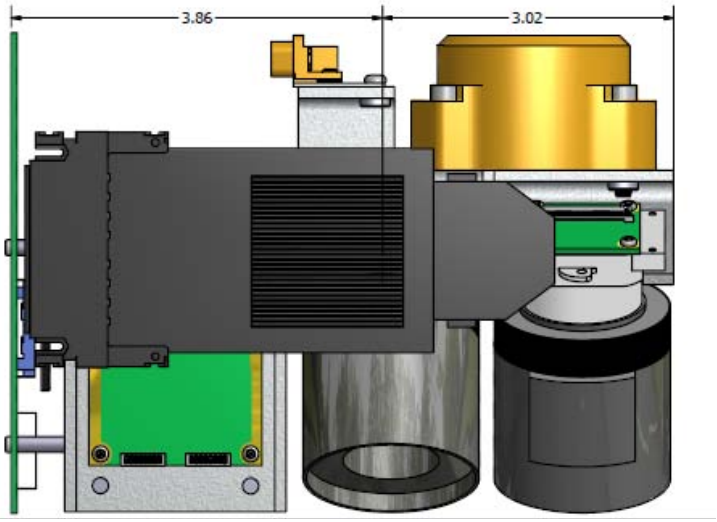
Z. Williams

Micro-Camera Payload

navsys CORPORATION



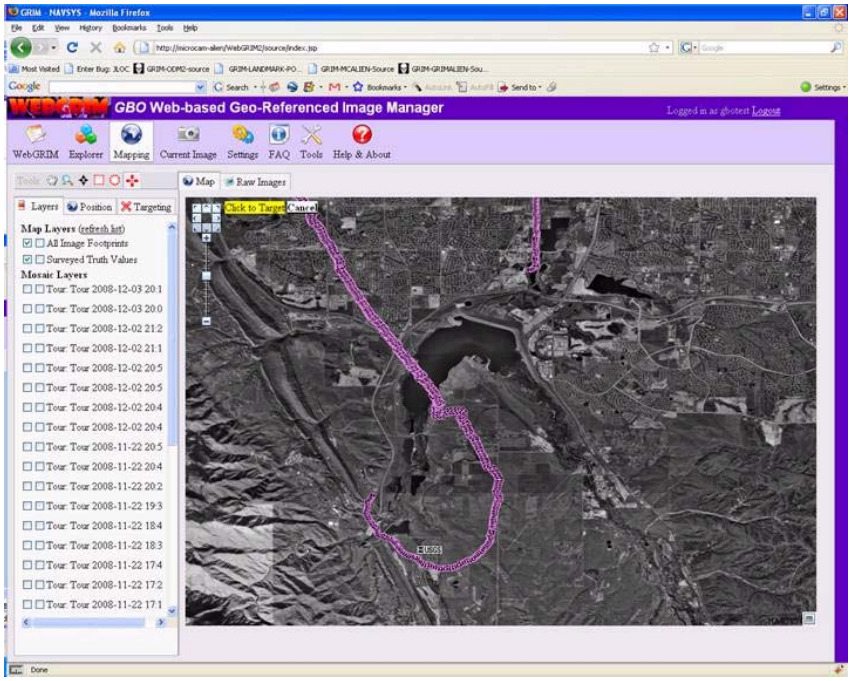




Features	
• Operation	In-flight, fully autonomous flight planning
Interface	
• Command	Serial over UAV platform wireless link
• Video Out	Serial over UAV platform wireless link
Electrical	
• Supply Voltage	12 Volts
• Power	10 W (typical)
Mechanical	
• Size	3.25” x 4” x 7”
• Weight	900 grams / 2 lbs
Video	
• Payload Camera	Dual side looking 3.1 megapixel color machine vision imaging modules
Operating Envelope	Limited by UAV platform and available memory
• Range	Up to 60 mph
• Speed	500 – 1500 ft AGL
• Operating Altitude	
Data Processing	
• Bathymetry	Post process data collected over littoral region
• Mapping	Mapping capability from mosaicked imagery

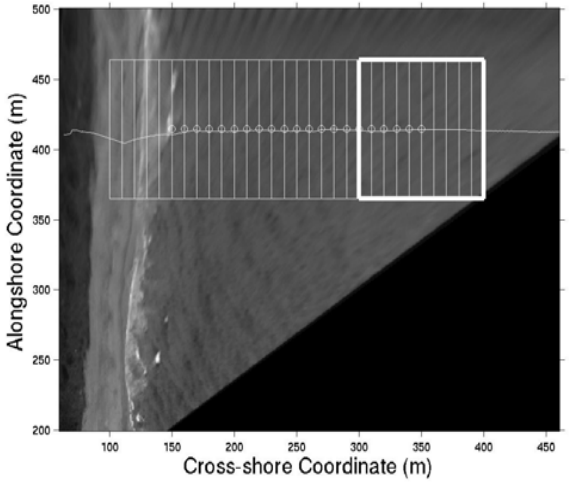
WebGRIM Ground Station Software

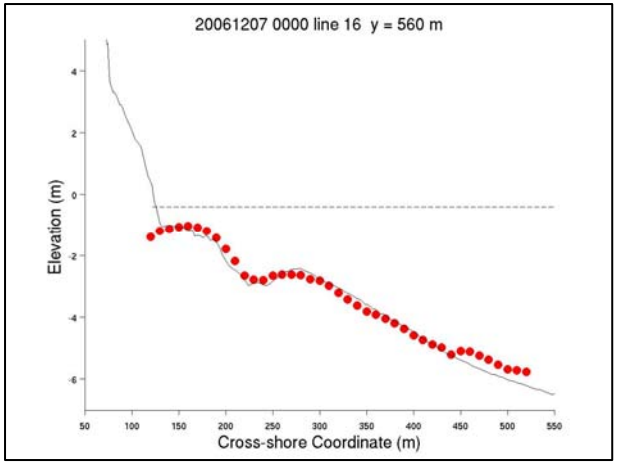
- Single, integrated SW environment
- Web Based
  - No new software to install
  - On-line collaboration between multiple users
- Quickly locate and manipulate collected imagery
  - Orthorectification and mosaicking
  - Point and click targeting
- Bathymetry tools
  - UAV Flight planning → Bathymetry map generation
- Compliant with OGC
  - Display third party maps
  - Acts as Web Mapping Service
- Auto-DEM map generation from collected imagery



DepthWizard Software

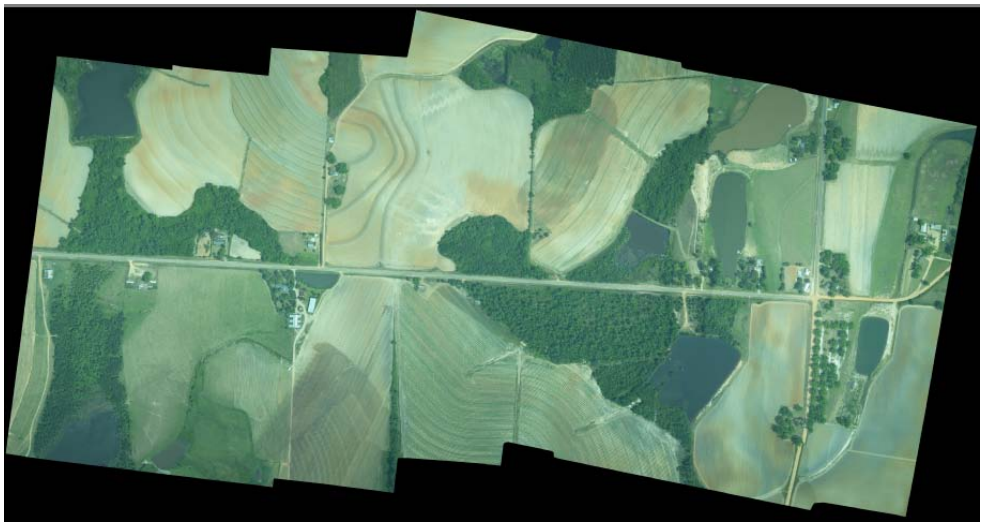
- Software for estimating water depth in shallow regions (0.5 - 30 m) from time series of airborne imagery
- Uses spectral (FFT) inversion techniques based on the physics of surface gravity waves
- Presently MATLAB code; Transitioning to C-coded GUI
- Versatile adaptation to variety of image data

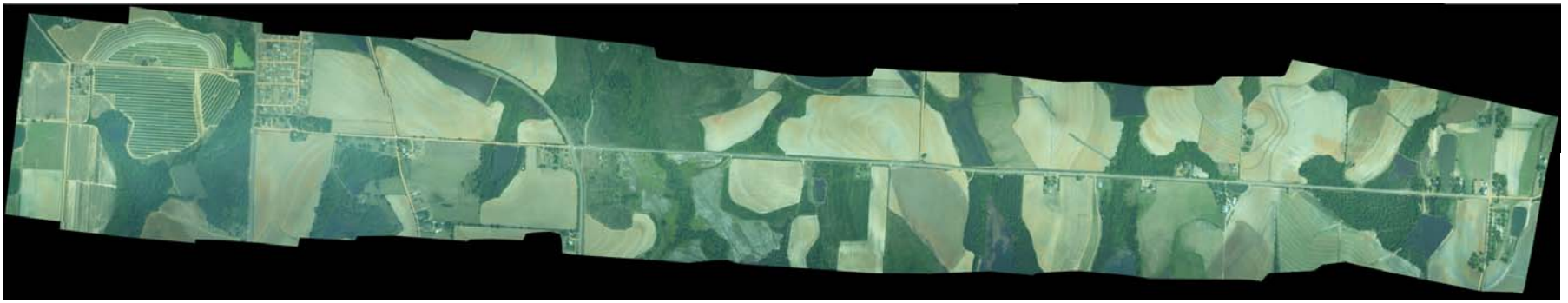




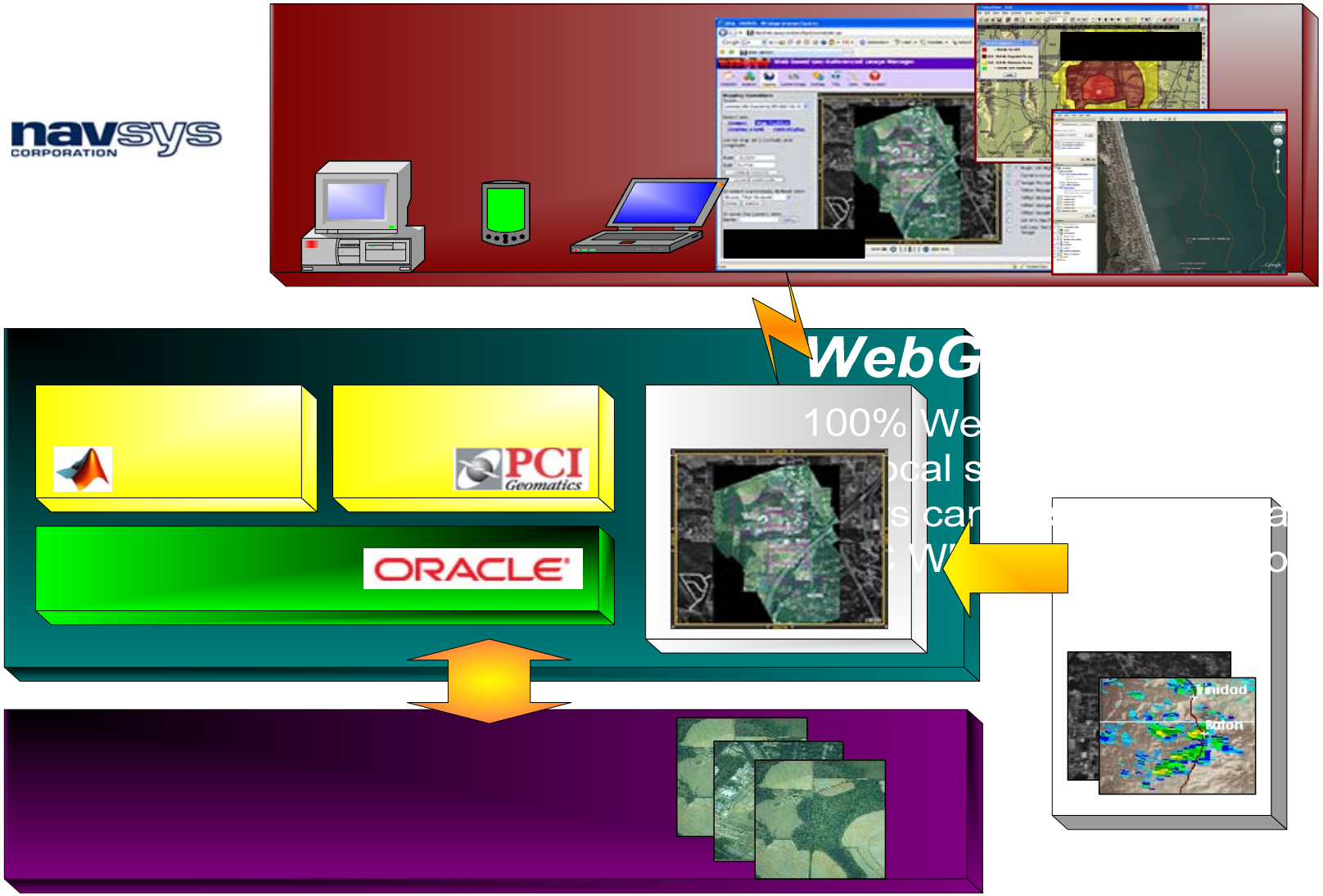
Auto-Mosaicking Results

- Transforms imagery into usable targeting information to facilitate decision making and mission planning





Micro-Camera Ground Station



Duck NC Bathymetry Test Range

- Flight Test & Data Collection w/ Cessna at Duck NC
  - U.S. Army Corps of Engineers Field Research Facility
  - Supports coastal engineering research
  - 1000 m of frontage along the Atlantic Ocean
  - 1,840 ft research pier
    - 20 ft wide
    - Extends to depth of 20 ft
  - (35-ft) tall Coastal Research Amphibious Buggy (CRAB) survey vehicle

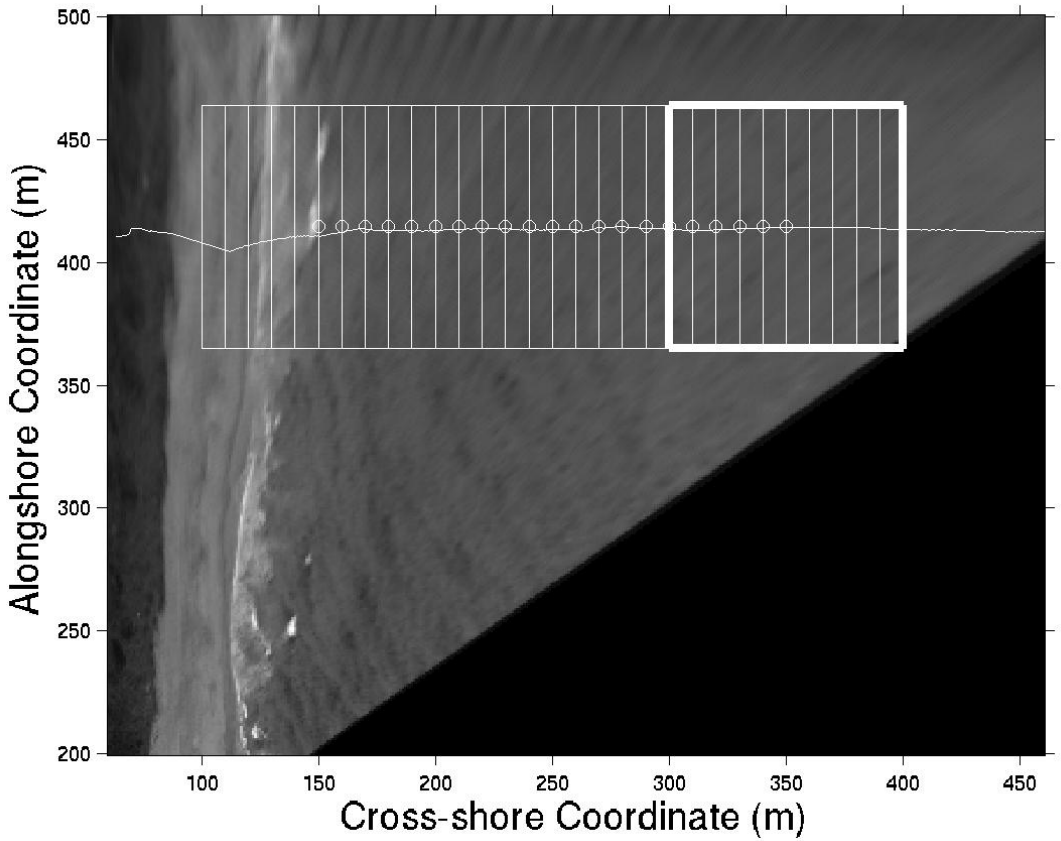
Bathymetric Inversion Field Tests

(Duck, NC; USACE Field Research Facility)

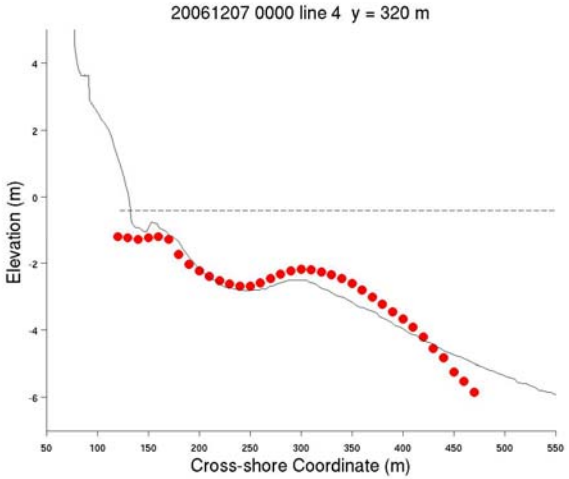
- 27 m above MSL
- High oblique camera view
- 1 MB, 8-bit digital camera
- 3 @ 4 min ensembles

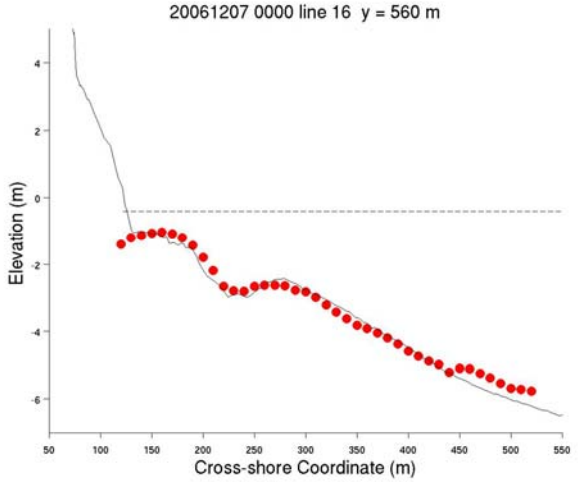
Example Ortho-normalized Snap Shot

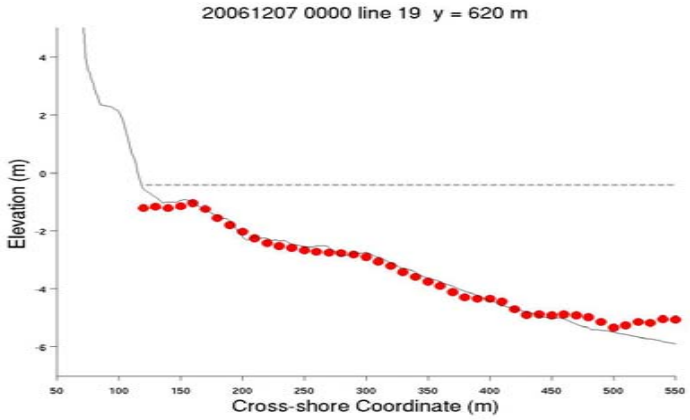
- 8 bit deep camera
- 1 m pixel resolution
- Pier structure in center region of image
- Decreasing resolution in the far field owing to high oblique camera view

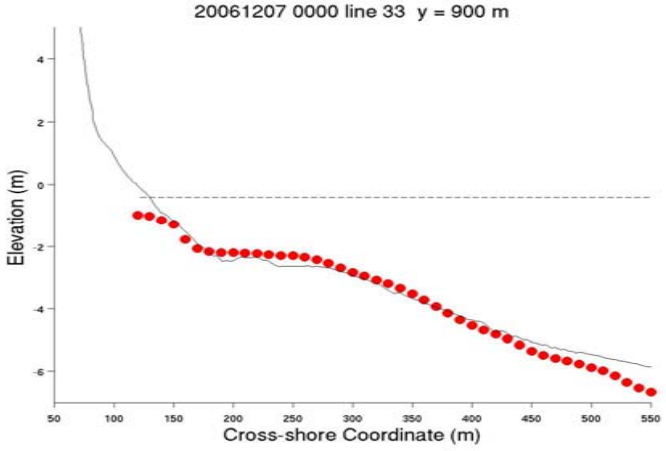


Profile Comparisons









Conclusion

- Micro-Camera payload can provide high accuracy meta-data from which we can extract feature coordinates
  - Bathymetry
  - Targeting
  - Mapping
- WebGRIM software 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
- Bathymetric inversion methods works reasonably well
  - TOP shore-based techniques, O(0.5 m) RMS errors in 1-6 m water depths for the 12 days examined
- Validation under variety of conditions not fully completed
  - Small waves only as no ground truth under large waves

Contact Information

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