

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

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**Session A1: Warfighter Requirements & Solutions**

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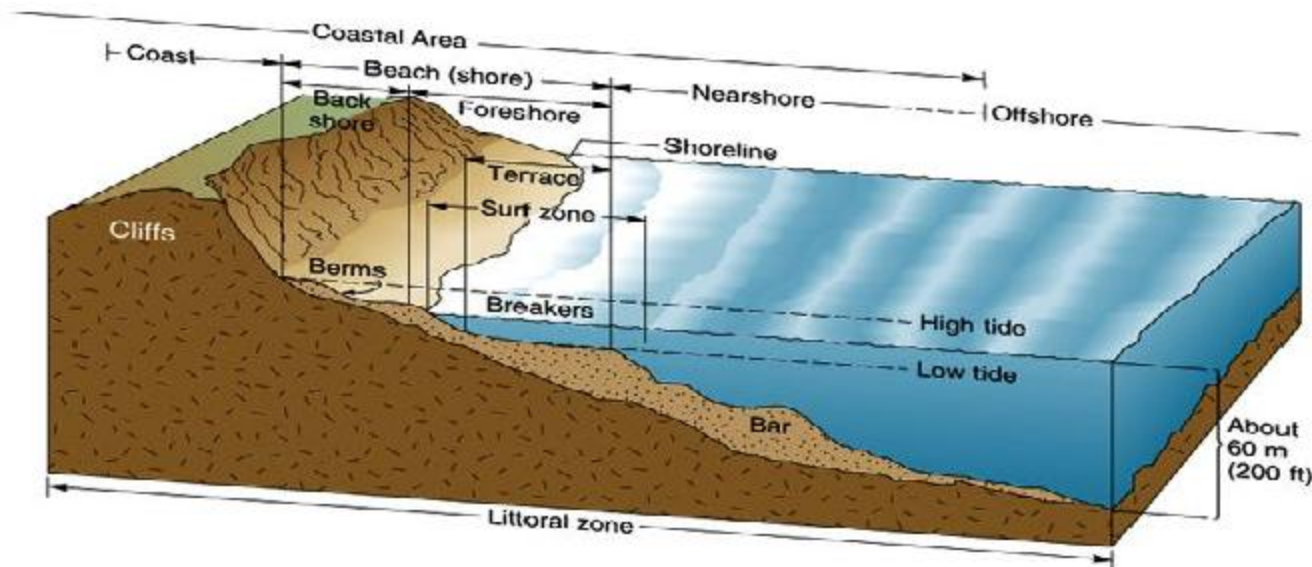
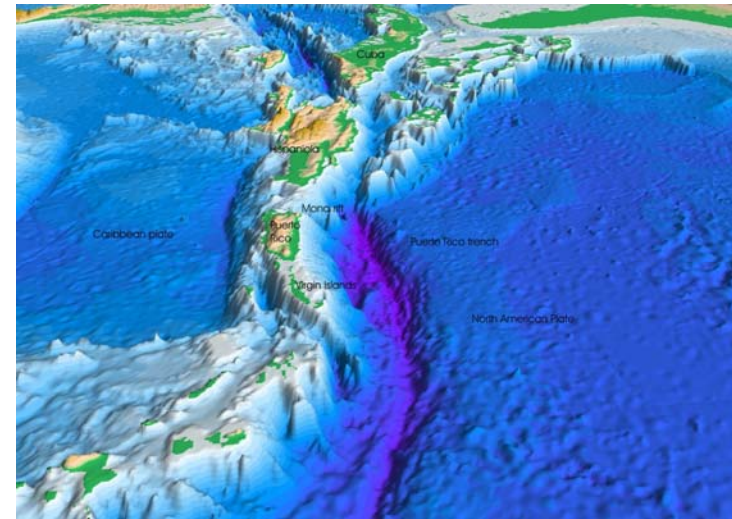
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# Overview

- 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***

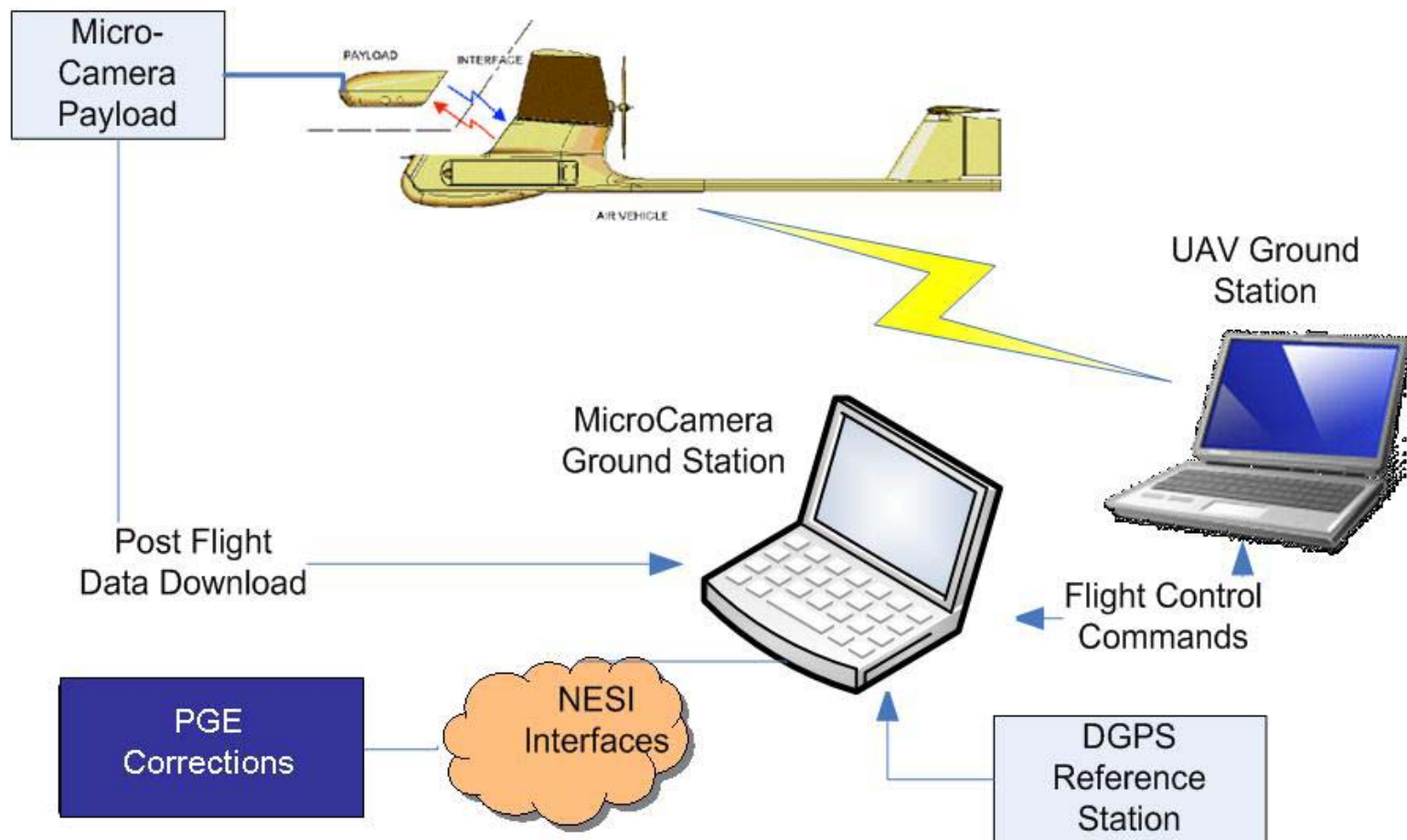
- Bathymetry
  - Army Corp of Engineers
    - High resolution shoreline data for modeling for forecasting
  - Littoral Battlespace Sensing, Fusion, and Integration (LBSF&I)
    - Bathymetry surveys critical for weather modeling and mission planning operations
  - Naval METOC Personnel
    - Bathymetry 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***

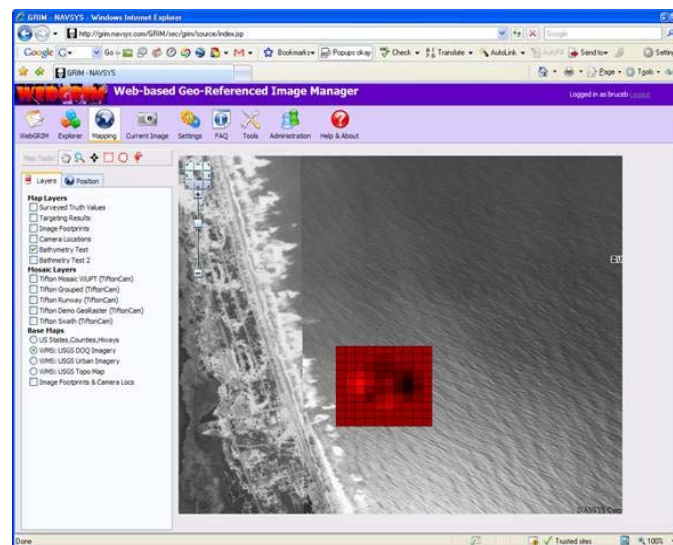
- Why is bathymetry processing so difficult in a small UAV?
  - Region of Interest
    - 1 km x 5 km shoreline
    - Bathymetry grid - 100 m x 100m cells
  - Imaging Requirements
    - Image capture at 2 Hz over region of interest
    - ½ pixel smear (objective) and 1/5 pixel smear (Goal)
    - Average 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



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# Micro-Camera CONOPS



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

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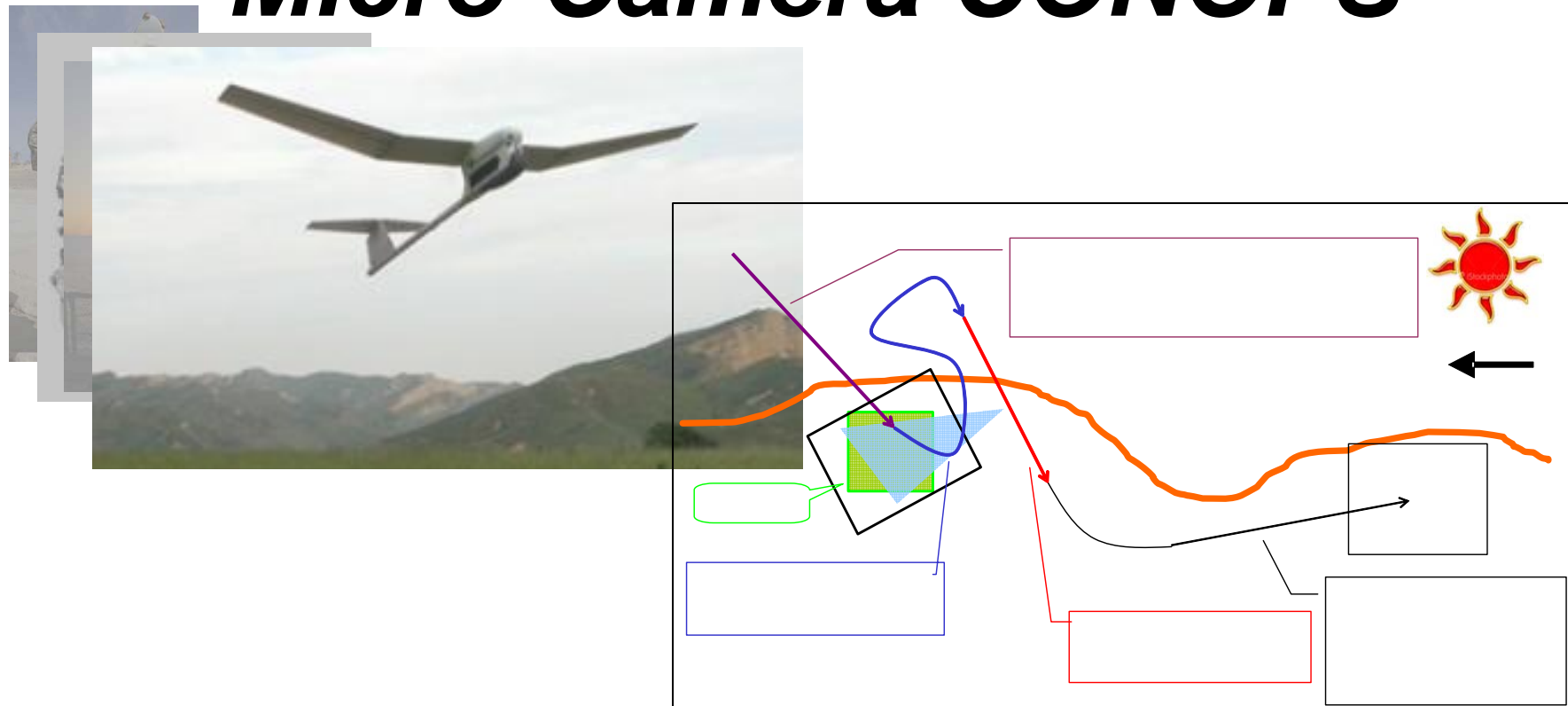
# *Micro-Camera CONOPS*



## **Operator launches the UAV**

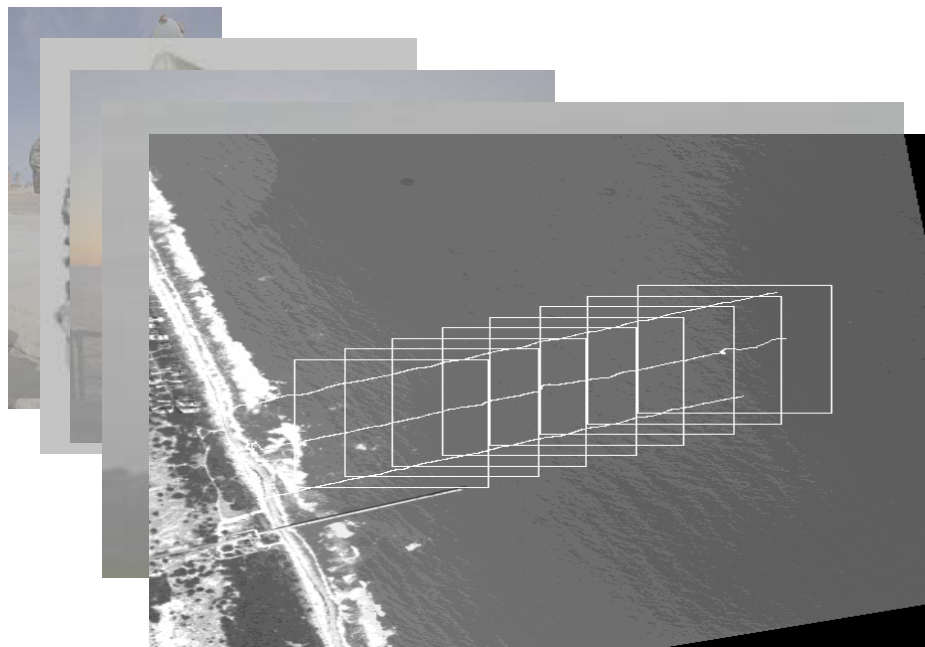
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# Micro-Camera CONOPS



- 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*



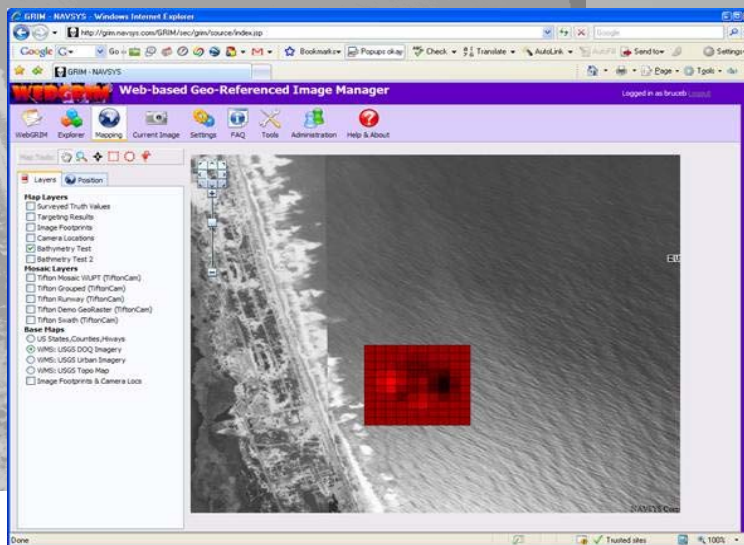
UAV captures images  
over AOI

- 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

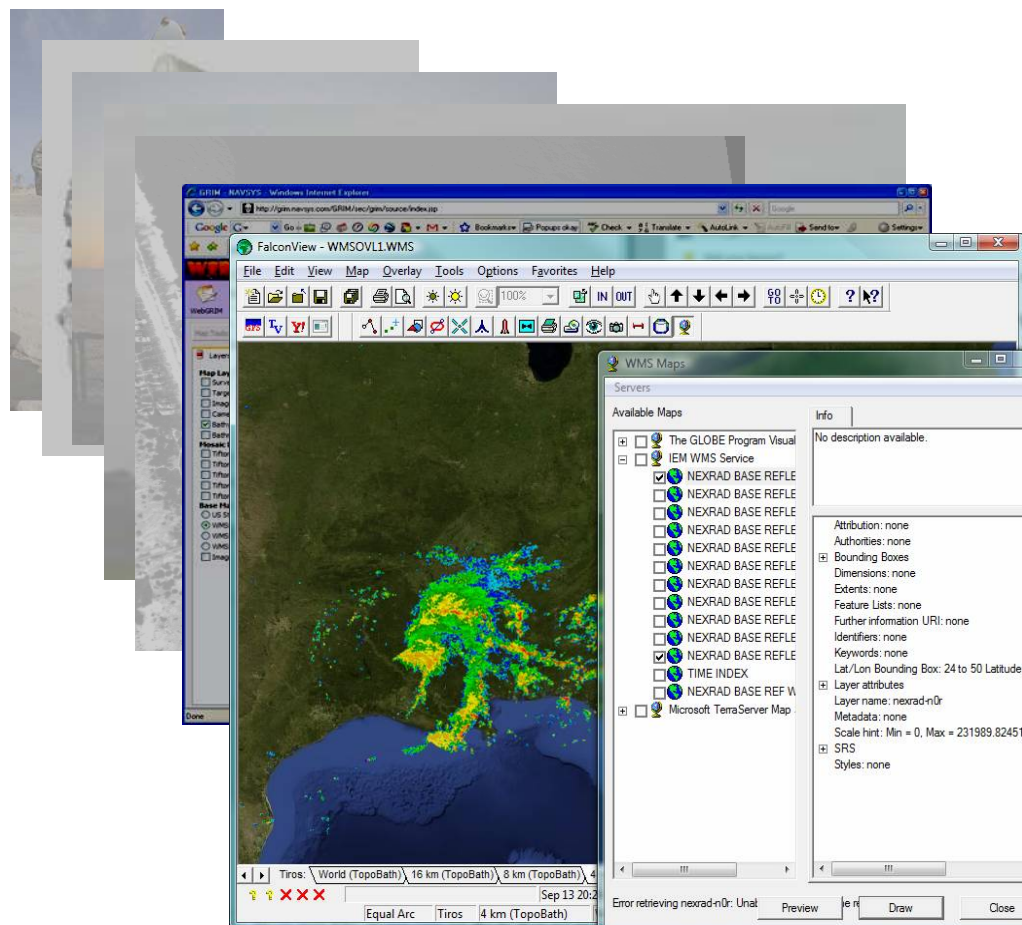
# Micro-Camera CONOPS

## 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



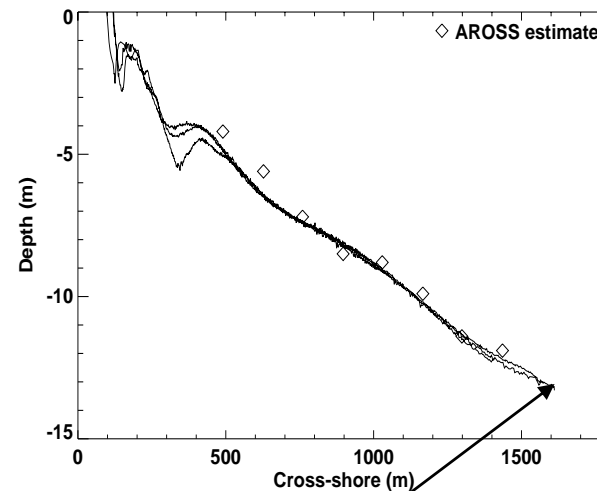
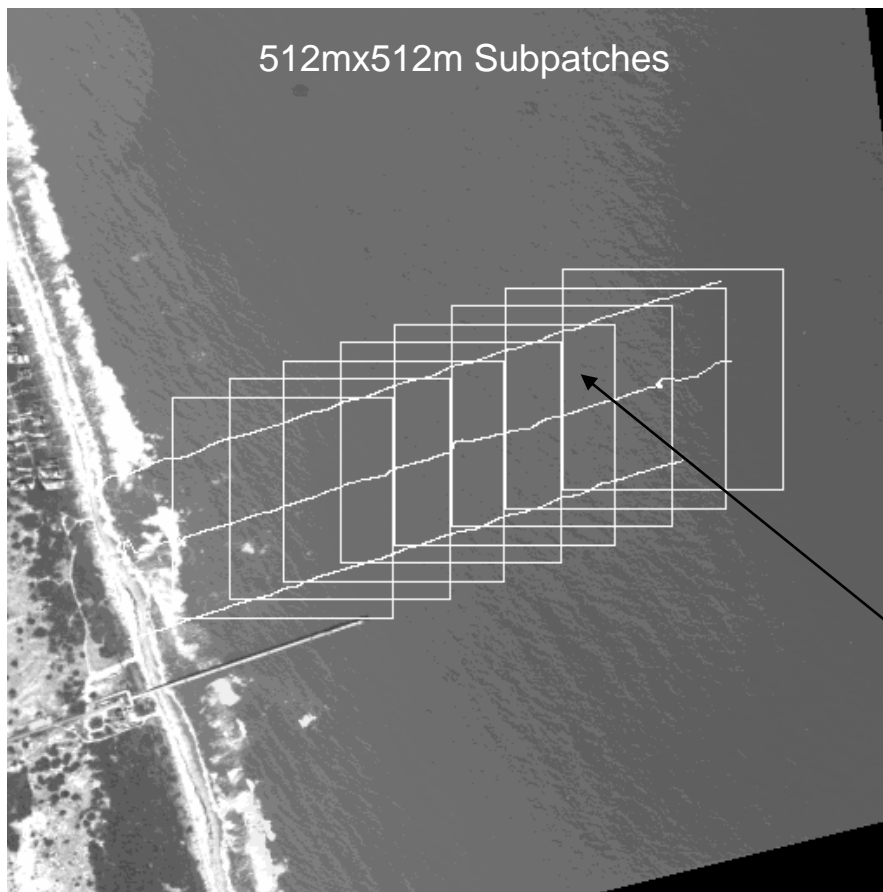
Under NESI  
guidance data is  
made available to  
other applications via  
a WMS data feed



# Cross-Shore Bathymetry Profile

Errors using mean depth in subpatch:

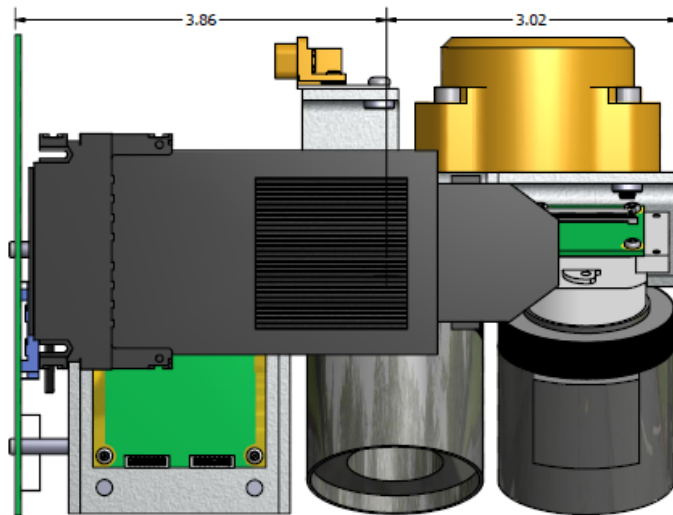
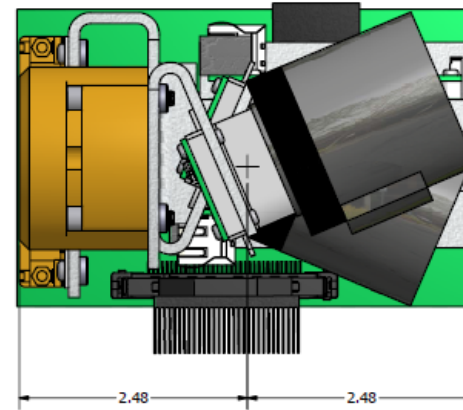
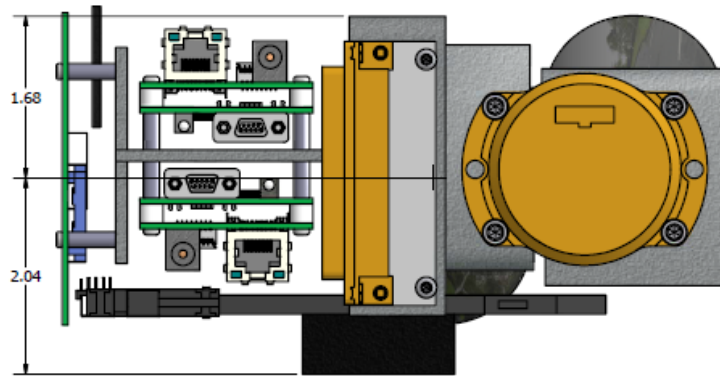
- Bias = 0.12 m
- RMS error = 0.48 m
- Average % error = 5%



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

Courtesy of  
Z. Williams

# Micro-Camera Payload



## Features

- Operation

In-flight, fully autonomous flight planning

## Interface

- Command
- Video Out

Serial over UAV platform wireless link  
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

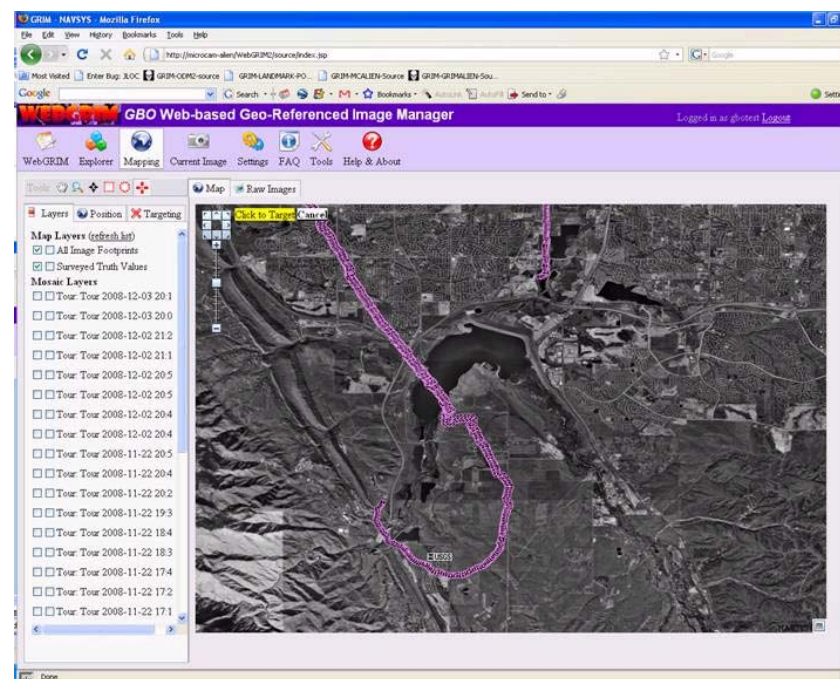
- Range Limited by UAV platform and available memory
- Speed Up to 60 mph
- Operating Altitude 500 – 1500 ft AGL

## Data Processing

- Bathymetry Post process data collected over littoral region
- Mapping Mapping capability from mosaicked imagery

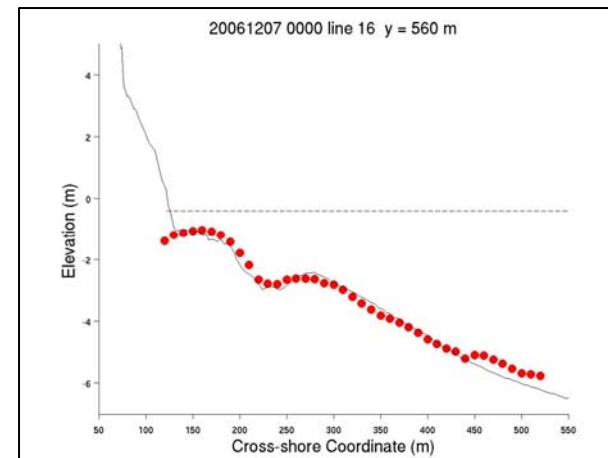
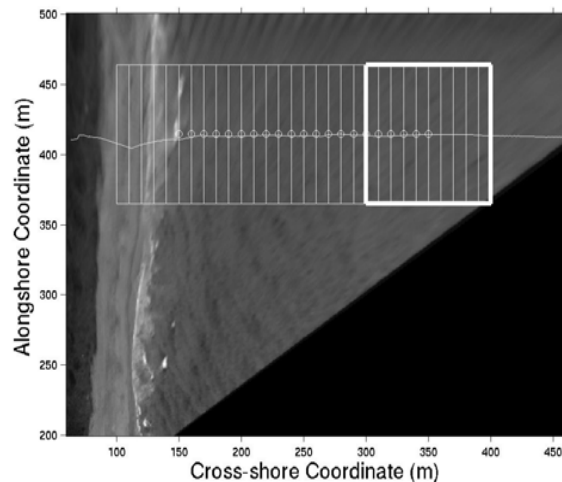
# WebGRIM Ground Station Software

- 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

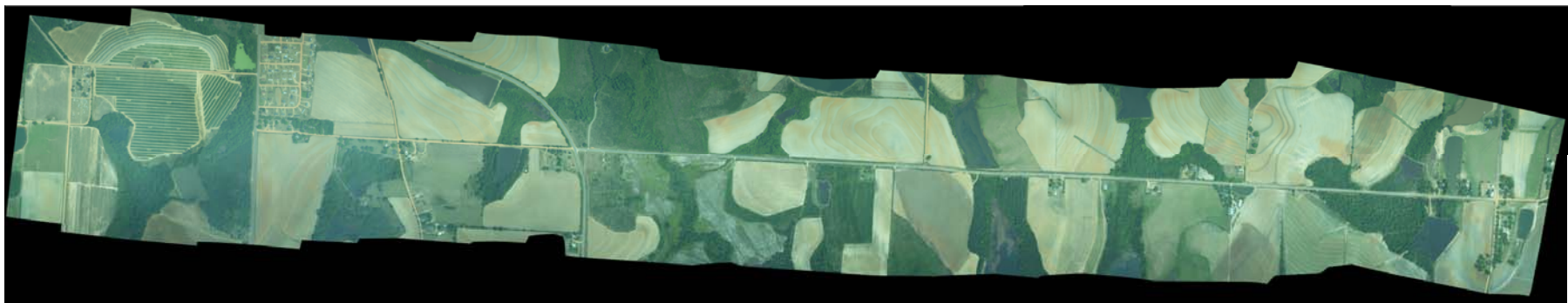
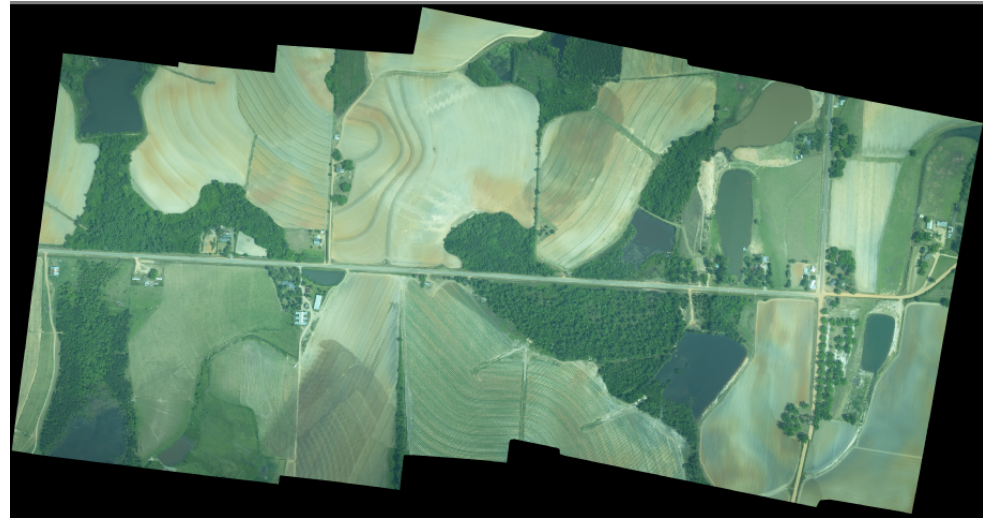
- Software for estimating water depth in shallow regions (0.5 - 30 m) from time series of airborne imagery
- Uses spectral (FFT) inversion techniques based on the physics of surface gravity waves
- Presently MATLAB code; Transitioning to C-coded GUI
- Versatile adaptation to variety of image data





# *Auto-Mosaicking Results*

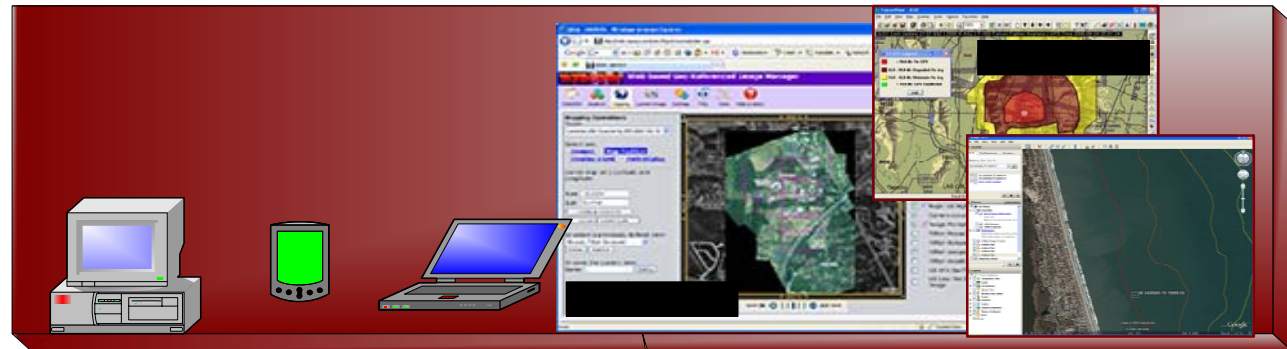
- Transforms imagery into usable targeting information to facilitate decision making and mission planning





# Micro-Camera Ground Station

navsys CORPORATION



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# *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)*

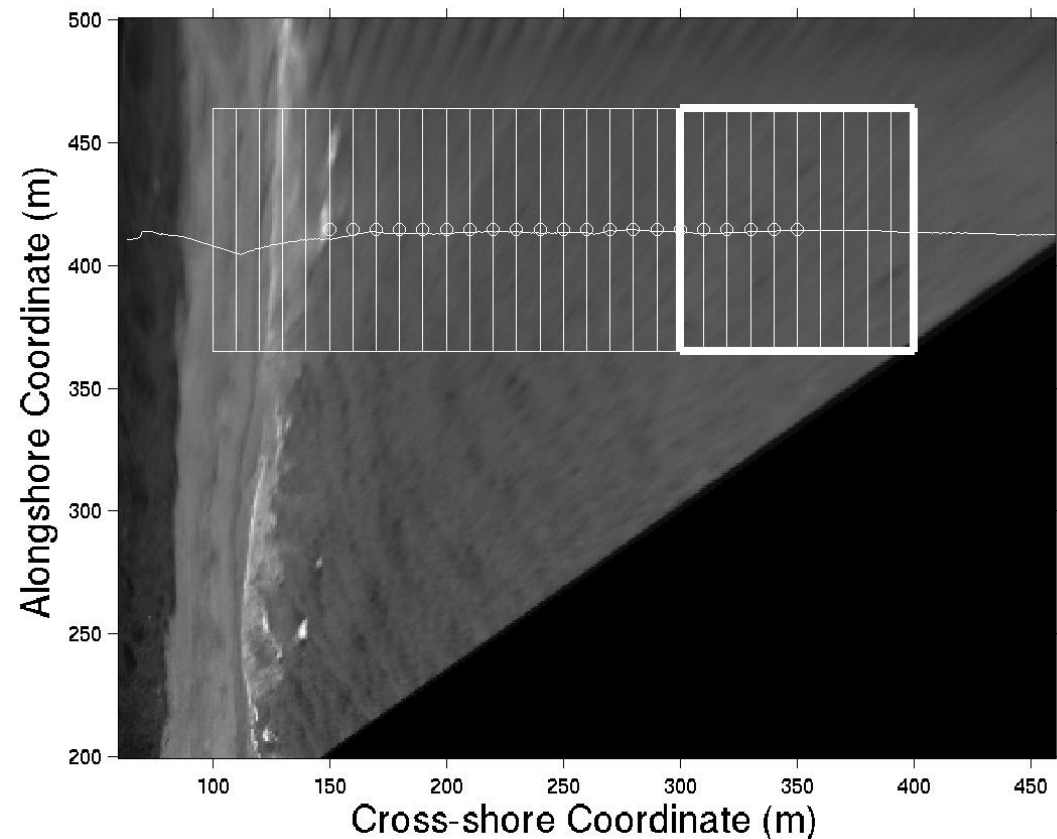


- 27 m above MSL
- High oblique camera view
- 1 MB, 8-bit digital camera
- 3 @ 4 min ensembles



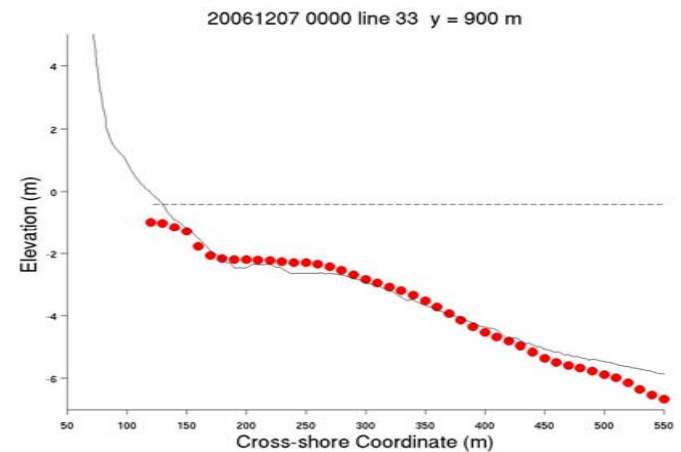
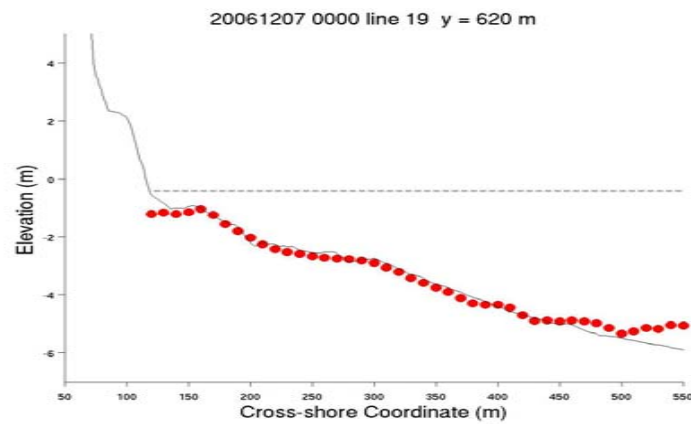
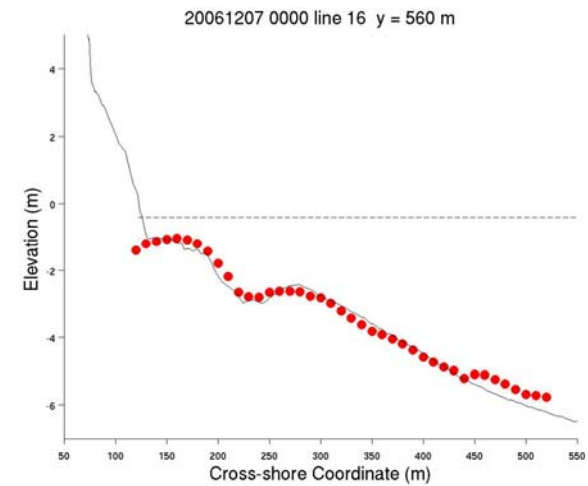
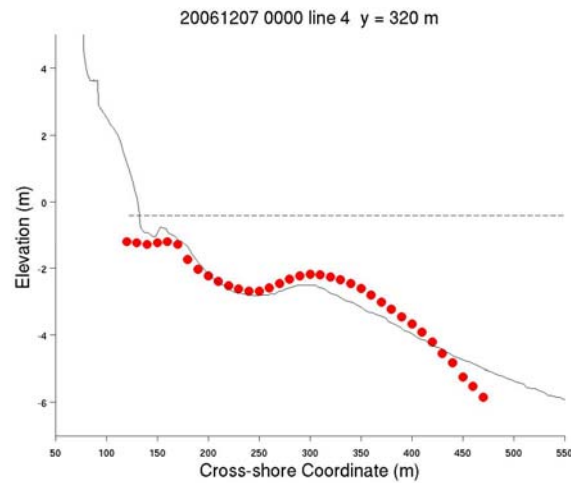
# Example Ortho-normalized Snap Shot

- 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

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