Benthic Habitat Mapping of the Main Eight Hawaiian Islands Using Hyperspectral Imagery

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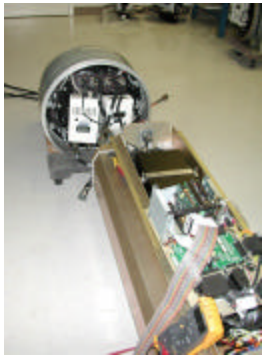
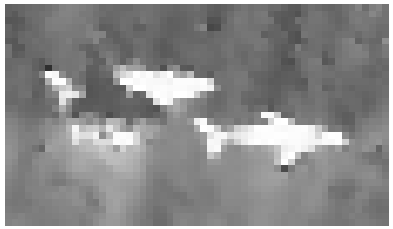
World Leader in Optical Imaging



- World leader in
  - Hyperspectral imaging (HSI) sensors
  - Multispectral imaging (MSI) sensors
  - Sensor integration
  - Near real-time image processing and algorithms
- Proven technologies for tactical intelligence, surveillance and reconnaissance (ISR)
  - Shallow-water naval applications
    - Anti-submarine warfare (ASW)
    - Mine countermeasures (MCM)
  - Overland object detection and identification
- First to demonstrate utility of Airships for
  - Marine Mammal Observations



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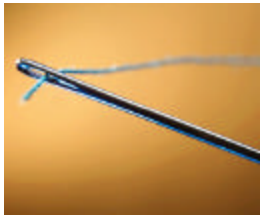
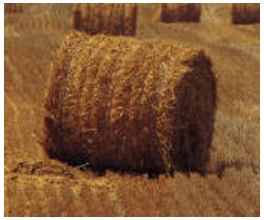
Spectral Imaging Overview

- Measure and store the “spectral fingerprint”



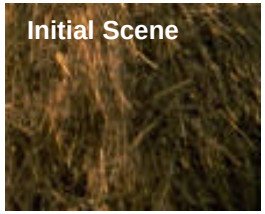
Simulated Needle
Spectral Fingerprint



Simulated Haystack
Spectral Fingerprint

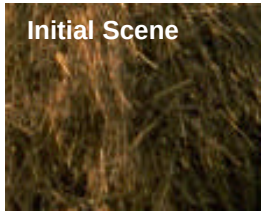
- Examine scene and use “spectral fingerprint” in one of two ways
  - Method 1: Spectral match (*i.e.*, look for the needle)
    Applications include: ASW, Marine mammal detection, *etc.*

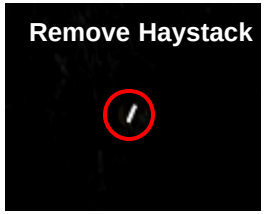
Simulated Needle
Spectral Fingerprint



  - Method 2: Anomaly detection (*i.e.*, remove the haystack)
    Applications include: MCM, camouflage detection, *etc.*

Simulated Haystack
Spectral Fingerprint





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The Emerging ASW Threat

- Problem - Identify and locate diesel submarines in the littoral environment
- Challenge – Deploy technology that will overcome the technical limitations of current ASW technology
- Demonstration – Participate in SHip Asw Readiness Evaluation/Measurement (SHARE) ASW exercises to validate proposed solution
  - Requirement – Detect Class 209 diesel subs at tactically significant depths in the Yellow Sea
- Results – STI's LASH-ASW equipped P-3 had the only kill in the exercise

North Korea has over 90 diesel submarines which are effectively undetectable in the littoral environment using sonar

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LASH-ASW System Optically Detects Submarines

LASH-ASW is the **only** system certified to fly on the P-3 that can show a picture of a submerged submarine at tactically significant depths

Five operational systems being used for deployment and testing

Selected System Specifications

System Type:	Passive Hyperspectral
Spectral Coverage:	390 – 710 nm
Spectral Resolution:	2.5 nm
Field of View:	40°
Spatial Resolution:	1.4’ at 1,000’ altitude 4.3’ at 3,000’ altitude <5’ at 12,500’ altitude (using advanced sub-pixel detection algorithms)
Swath Width:	728’ at 1,000’ altitude 2,185’ at 3,000’ altitude 9,104’ at 12,500’ altitude
Supported Platforms:	P3-C Orion, SH-60, Fixed- or rotary-wing aircraft with optical window
Additional Features:	Proprietary three-axis stabilization Near-real-time on-board processing Proven in operational situations Fleet operator ready
Price:	$1.5 million per system

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LASH ASW

Aviation Week and Space Technology (Jan. 15, 2001) has described STI's Littoral Airborne Sensor Hyperspectral (LASH) system as **"perhaps the farthest advanced hyperspectral imaging (HSI) system worldwide."**

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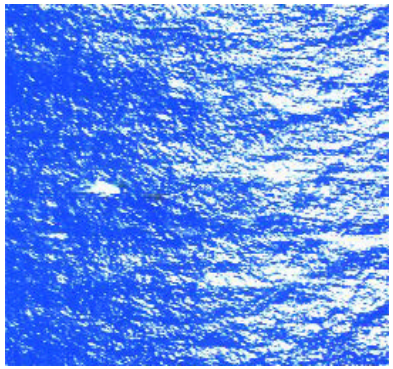
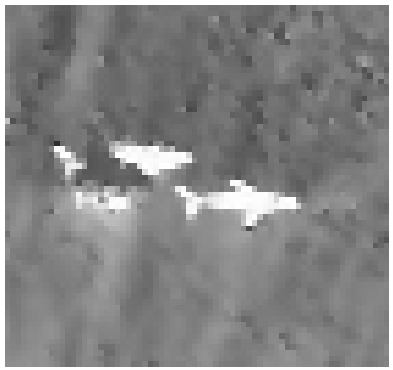
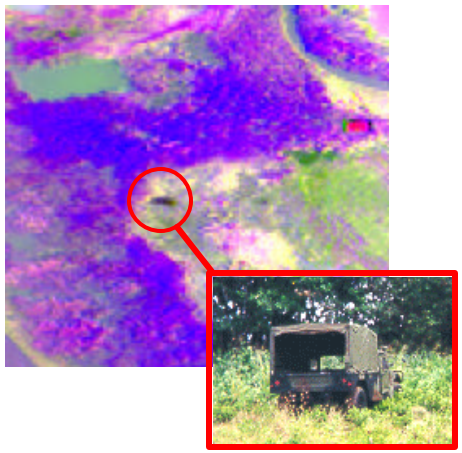
Sample LASH-ASW Detections





Submerged Objects
(humpback whales, submarines, *etc.*)



Camouflaged Objects
(equipment, personnel, *etc.*)

Objects Under Tree Cover
(tents, tarps, *etc.*)
Note: proven from 12,500' with advanced sub-pixel detection algorithms

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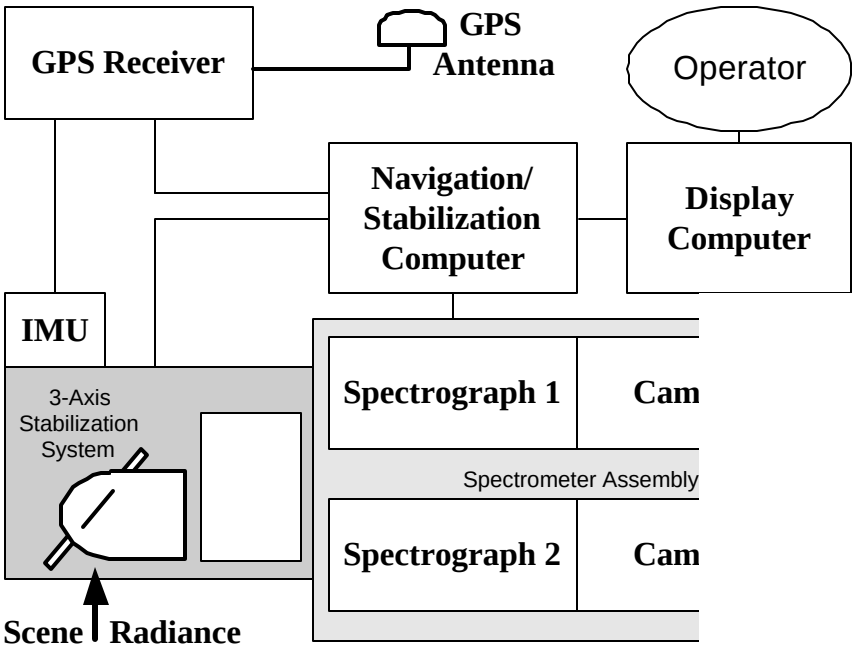
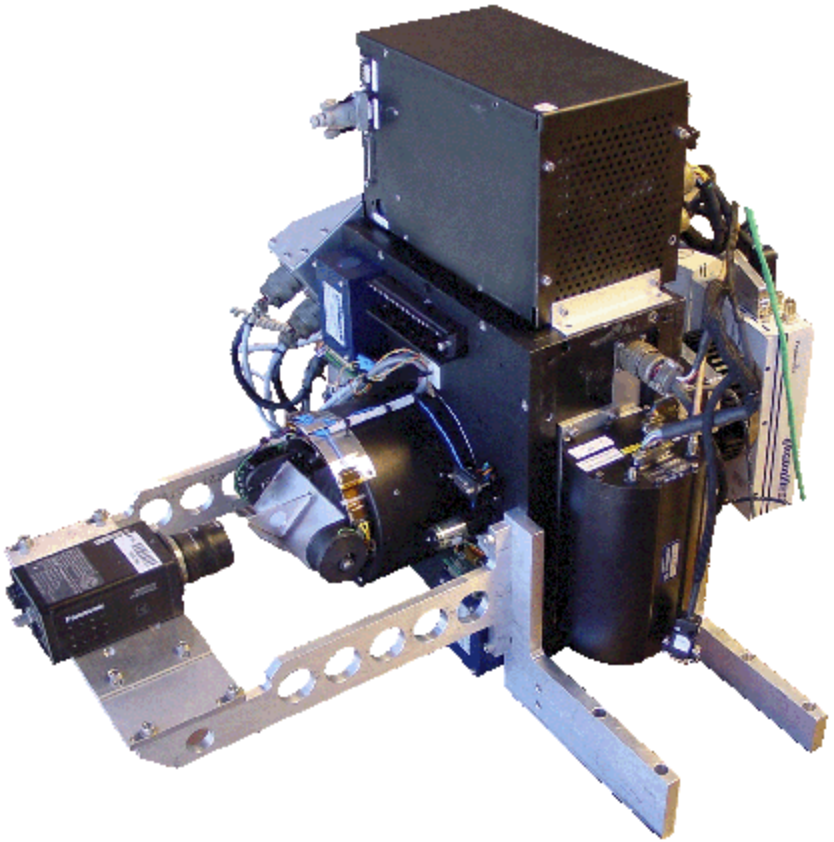
AAHIS-3+





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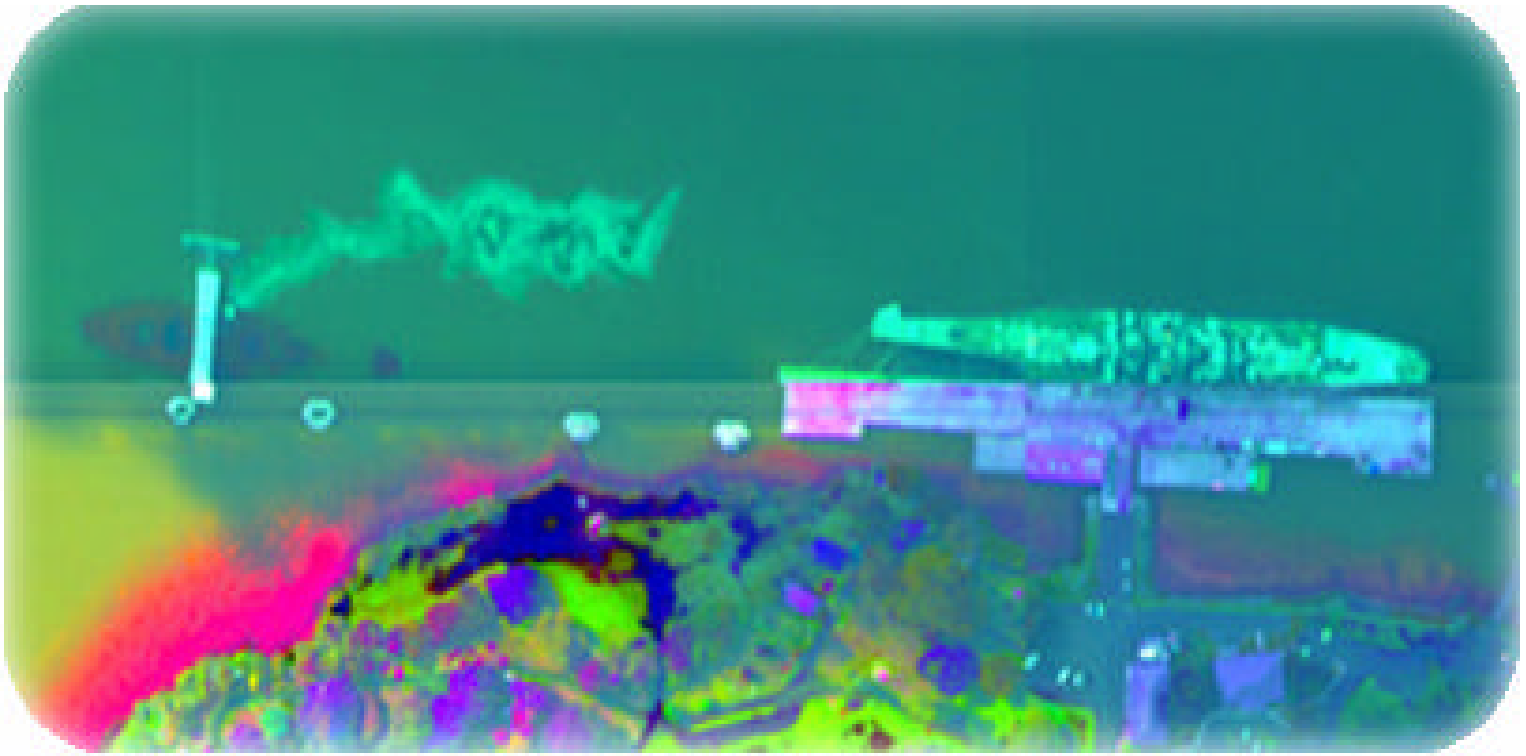
Marine Pollution Surveillance



Oil leakage from USS Arizona, USS Missouri in Pearl Harbor

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HSI Operations

Camera Controls

Camera 1:
Name : Camera_0
Data Dir Path : C:\CameraTesting\
Camera 2:
Name : Camera_1
Data Dir path : C:\CameraTesting\

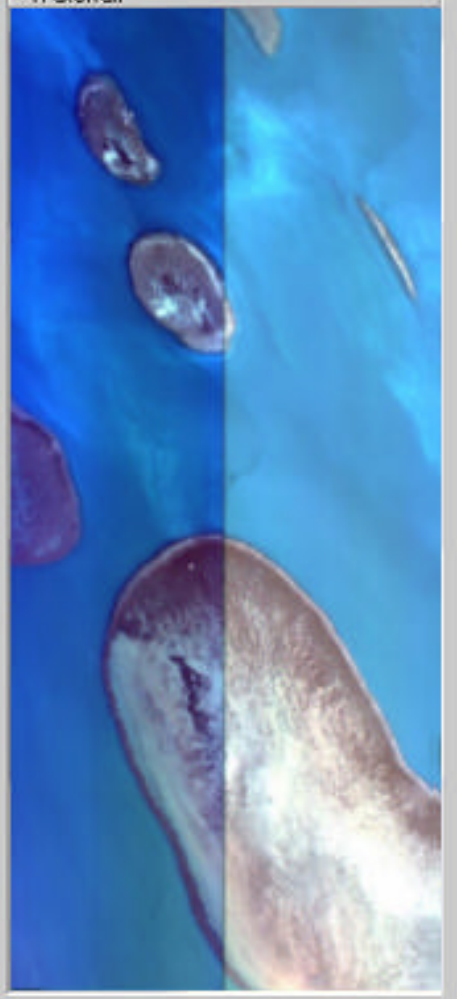
Sequence parameters
Frames per sequence : 437
Sequence number : 52
Incr. Write Size (KB): 64

Launch OmniStar Interface

Exposure Parameters
Serial: Parallel:
Region Size : 512 384
Bins : 2 12
Exposure Mode : Timed
Expose Time (ms) : 0
Clear Mode : Pre-sequence
Clear cycles : 0
Camera Speed (MHz) : 3.003
Gain : 1 x
Framing Freq (Hz) : 0.0081769
Update
Frames / Sec : 122.2950

Display
Brightness : 0.8
Scaling:
Red: 3
Green: 2
Blue: 1
Show Waterfall

Waterfall



Status

```
Camera_0: Armed (437 frames)
Camera_0: Creating image file Camera_0052.hsi
Camera_0: Imaging
Camera_0: Reading frames - buffer 1 filled with 8012832 bytes
Camera_0: Completed image capture
Camera_0: Archiving buffers - 8012832 bytes copied from buffer 1
Camera_0: Completed image archive
Camera_0: Completed RGB extracts for buffer 1
```

Exit | Arm cameras | Disarm cameras | Start cameras | Stop cameras | Abort cameras

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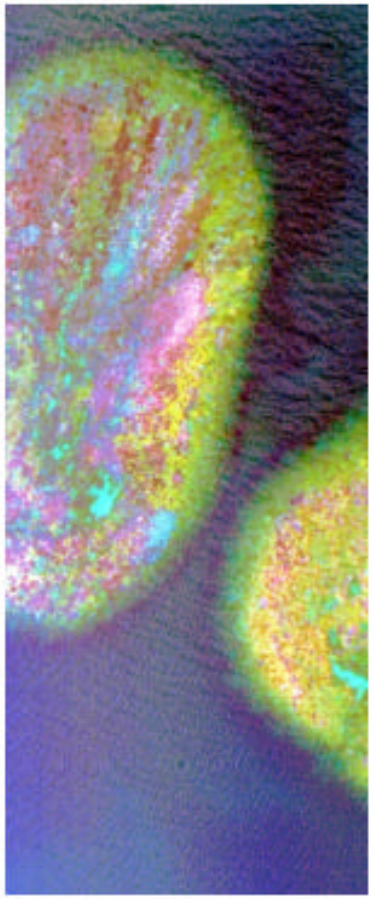
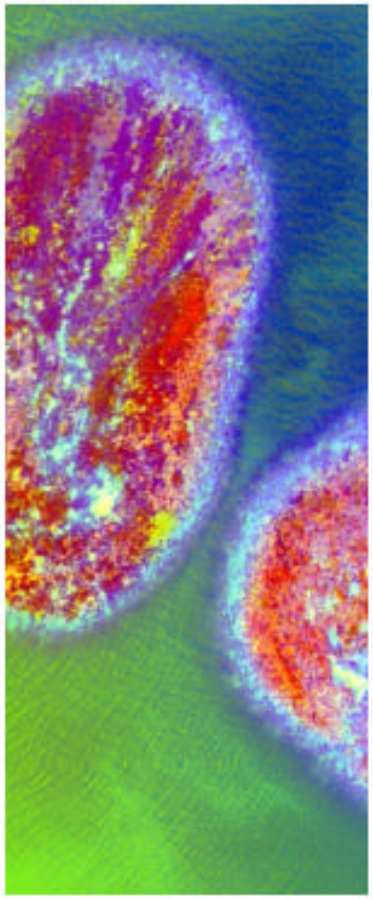
Benthic Habitat Classification

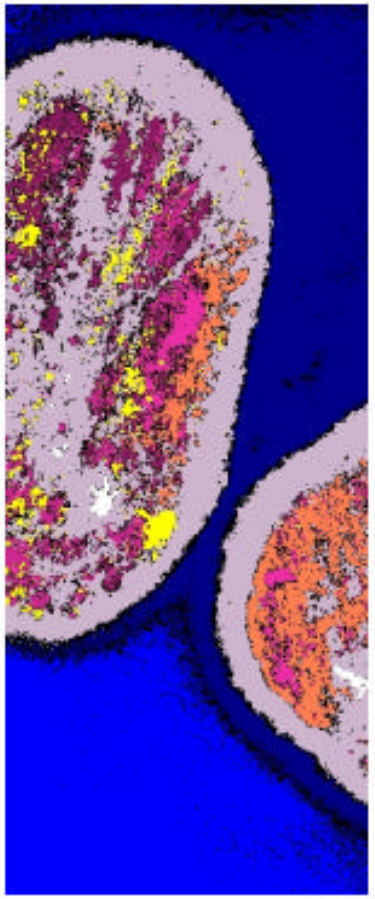
RGB



MNF



95% Probable Classes



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Airship Applications

- Airship Platforms
  - Skyship 600
  - Other Airships
- ISR Sensors
  - IMINT
    - Hyperspectral Imagery Systems
    - EO/IR Systems
    - Sniper Scope (VIPER) from NRL
  - RADAR
    - Raytheon
    - Furuno
  - SIGINT and other applications
- C4
  - Command & Control
  - Radios, Downlinks
  - Sensor Fusion

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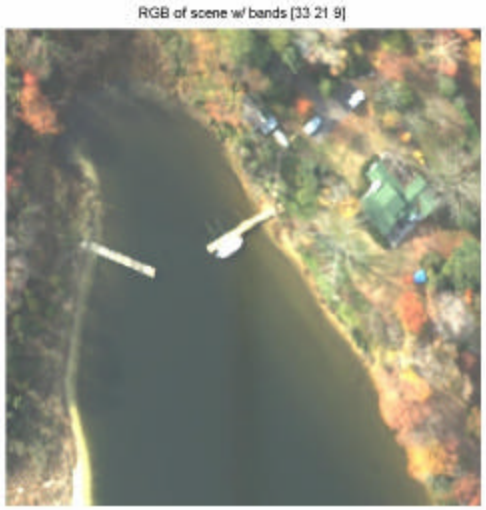
Mine Countermeasures



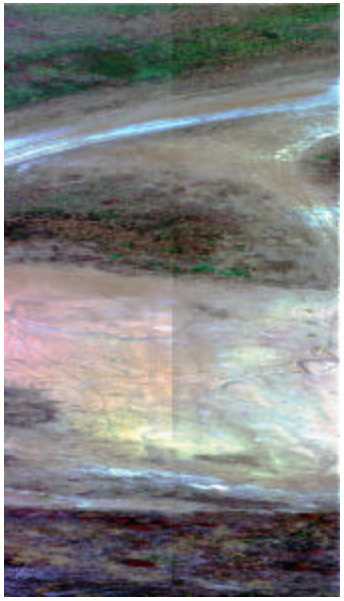
- Hyperspectral data collected over Pax River, Maryland
- 4 PVC 5-gallon buckets on surface
- 3 black discs (30” dia.) submerged about 2’
- Total of 7 MLOs: 4 proud, 3 submerged

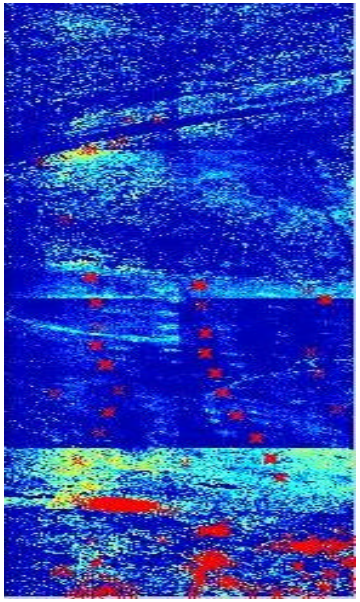
38.316 N
76.480 W

38.316 N
76.481W

38.317 N
76.480 W

38.317 N
76.481 W





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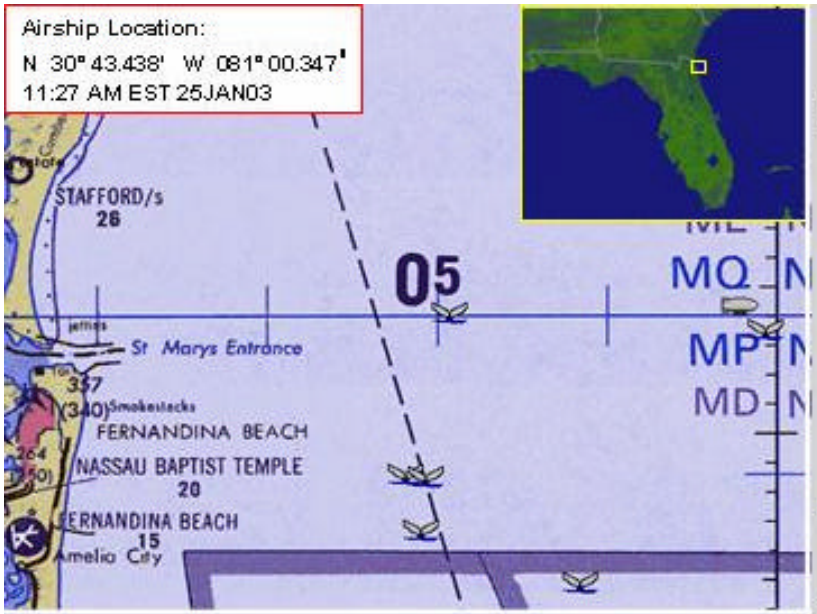
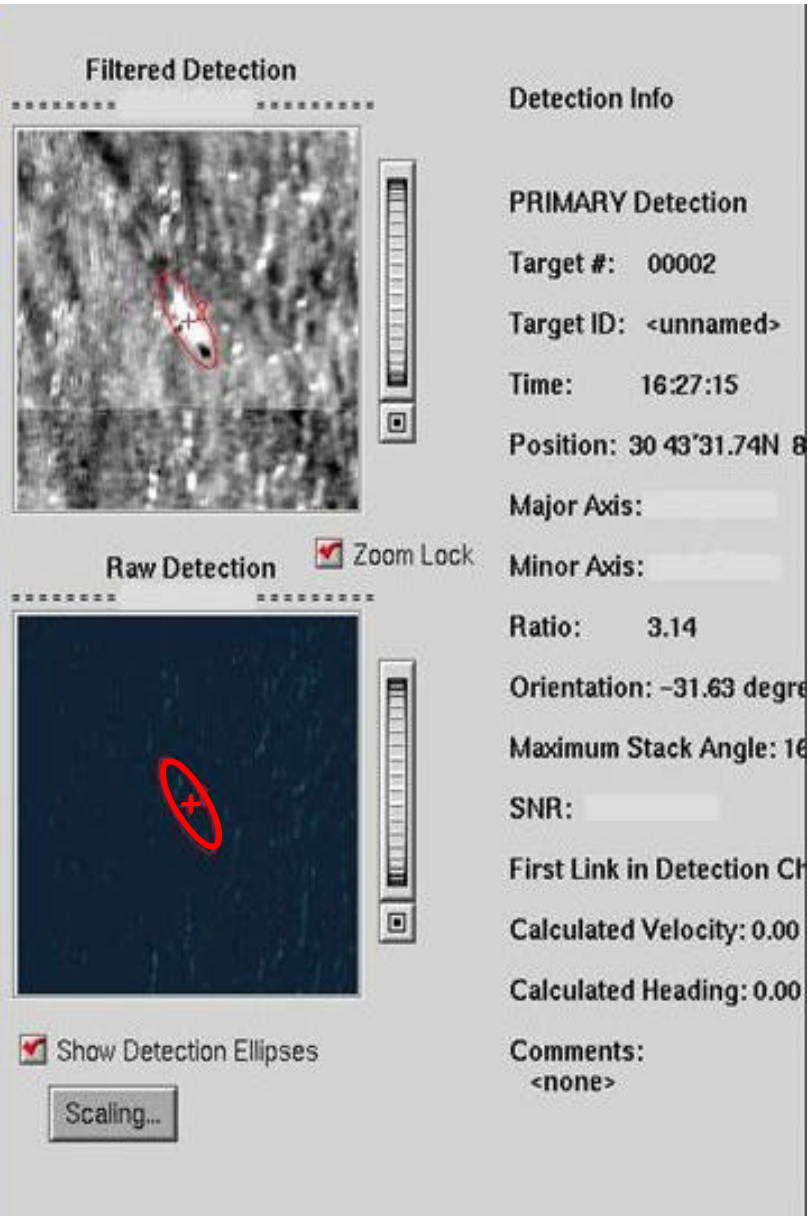
Range Clearance / Marine Mammal Surveillance



These images of an Automated LASH Detection of a Right Whale were collected by AirShip and transmitted to the Operations Center Ground Site within minutes by wireless data link.

AirShip Whale Search Network



Range Clearance / Marine Mammal Surveillance

These images of a Mother Right Whale and Calf were collected by AirShip based Sensors and transmitted to the Operations Center Ground Site within minutes by wireless data link.

AirShip Whale Search Network

Marine Mammal Obervations: Underwater

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Benthic Habitat Mapping

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Science Rationale

- **Federal Order 13089 (Coral Reef Task Force)**
- **Baseline of US coral reefs:**
  - Location of reef boundaries
  - Overall reef cover and habitats
  - Geomorphologic structures
  - Economic factors: tourism, fisheries, etc.
  - Sustainable management of reefs & coastlines
- **GIS compatible for broad application**
- **Demonstrate hyperspectral imaging as a mapping tool**

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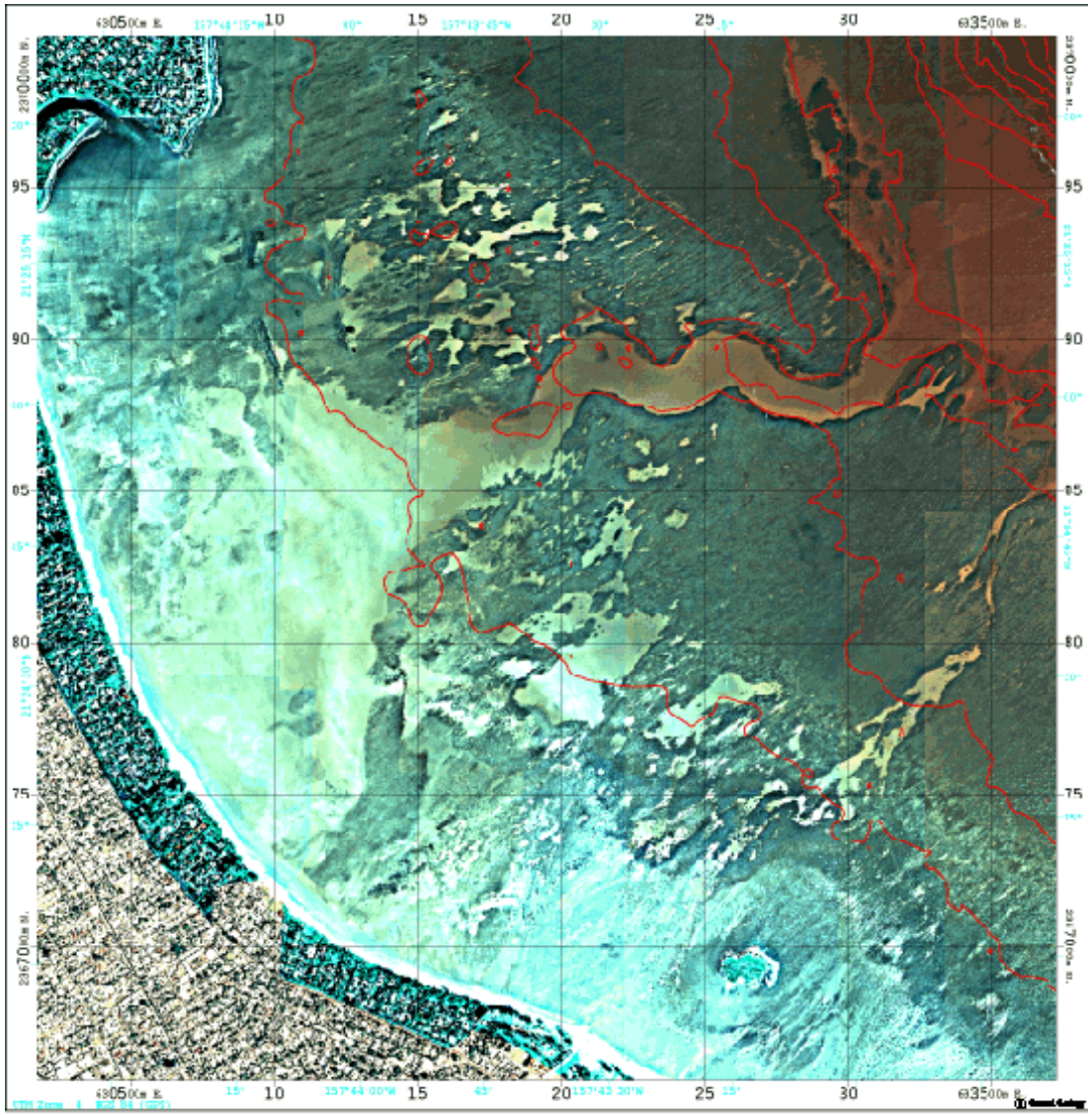
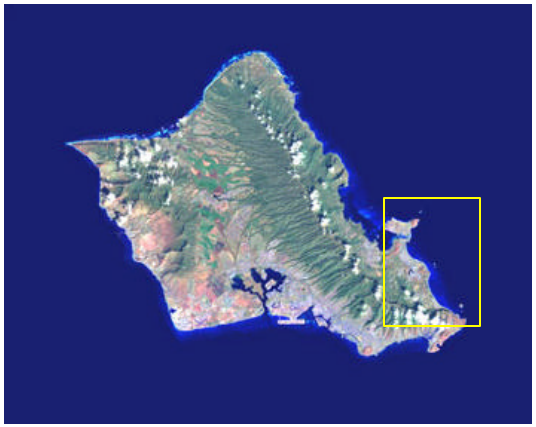
Benthic Mapping: Kailua Bay



- Hyperspectral imagery is used to “peel away” the water to see the bottom substrates
- High resolution imagery shows features to depths of > 30 meters
- Map-projection to give exact location of features



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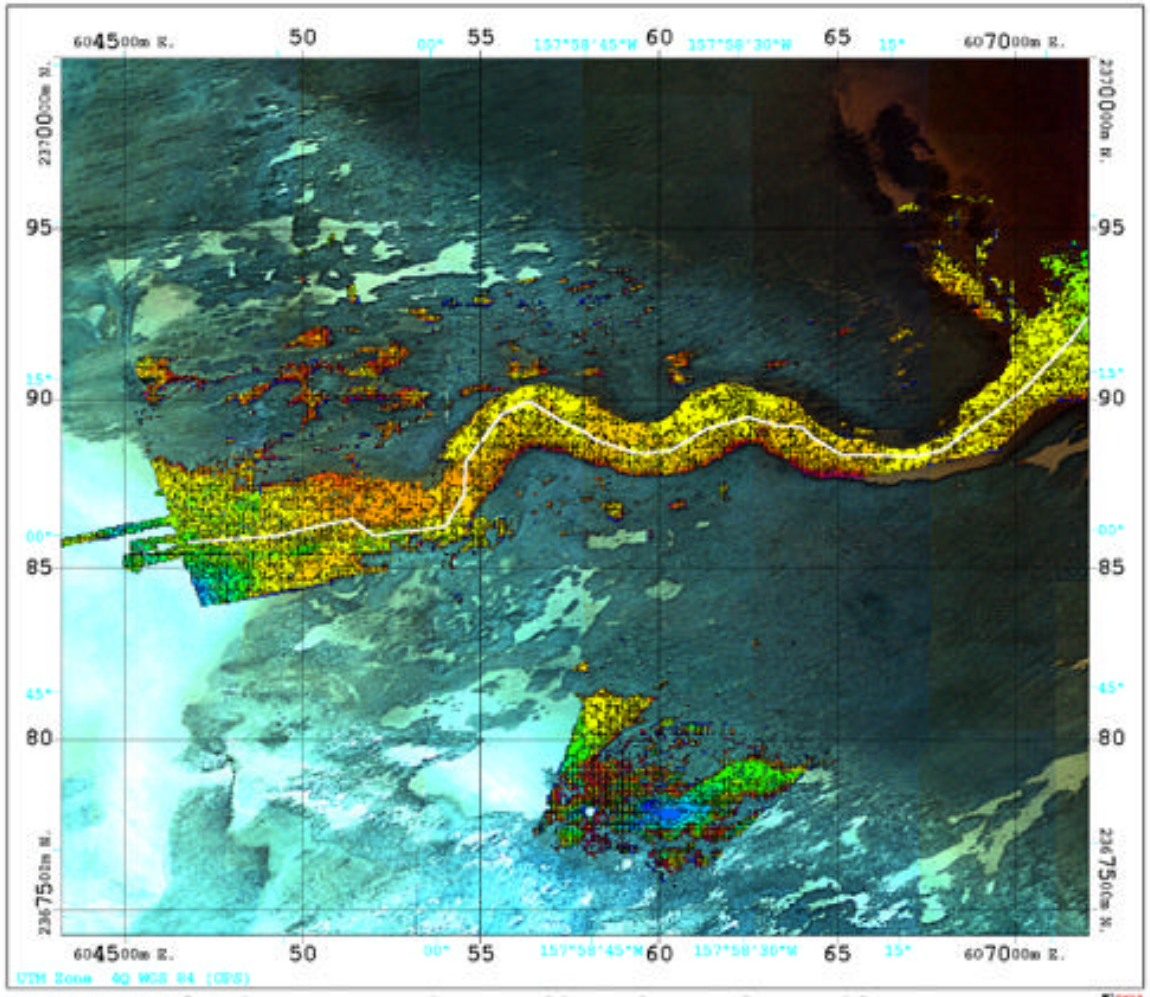
Bathymetry from HSI Data



Relative Error in Predicted Depth; Kailua Bay

Physical Model on Band 3 MS Data

1:18 500 Scale

Metres 500 0 500 1000

Yards 500 0 500 1000

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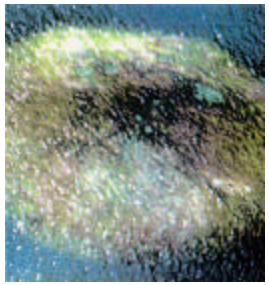
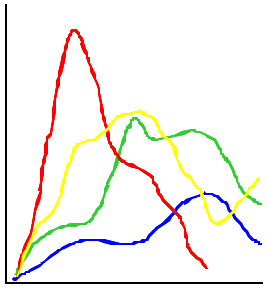
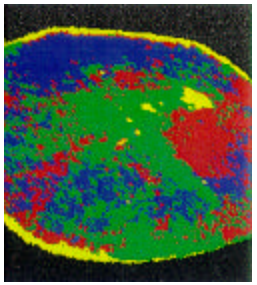
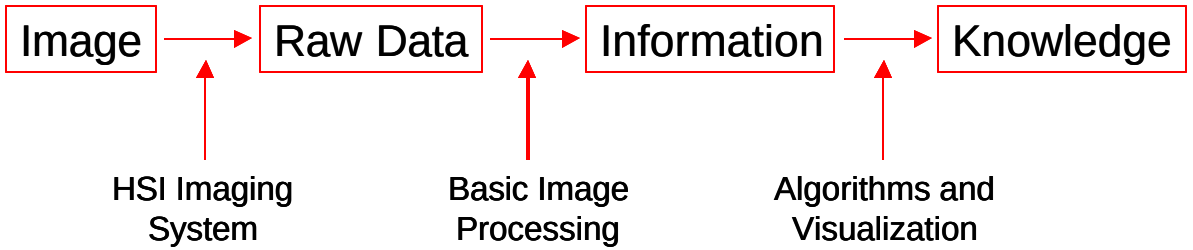
Spectral Imaging Overview







Coral Reef Mapping



- Hyperspectral Imaging (HSI) uses the properties of light and color to transform raw data into knowledge through the collection of spectral “fingerprints” and the application of complex algorithms that perform matching or anomaly detection

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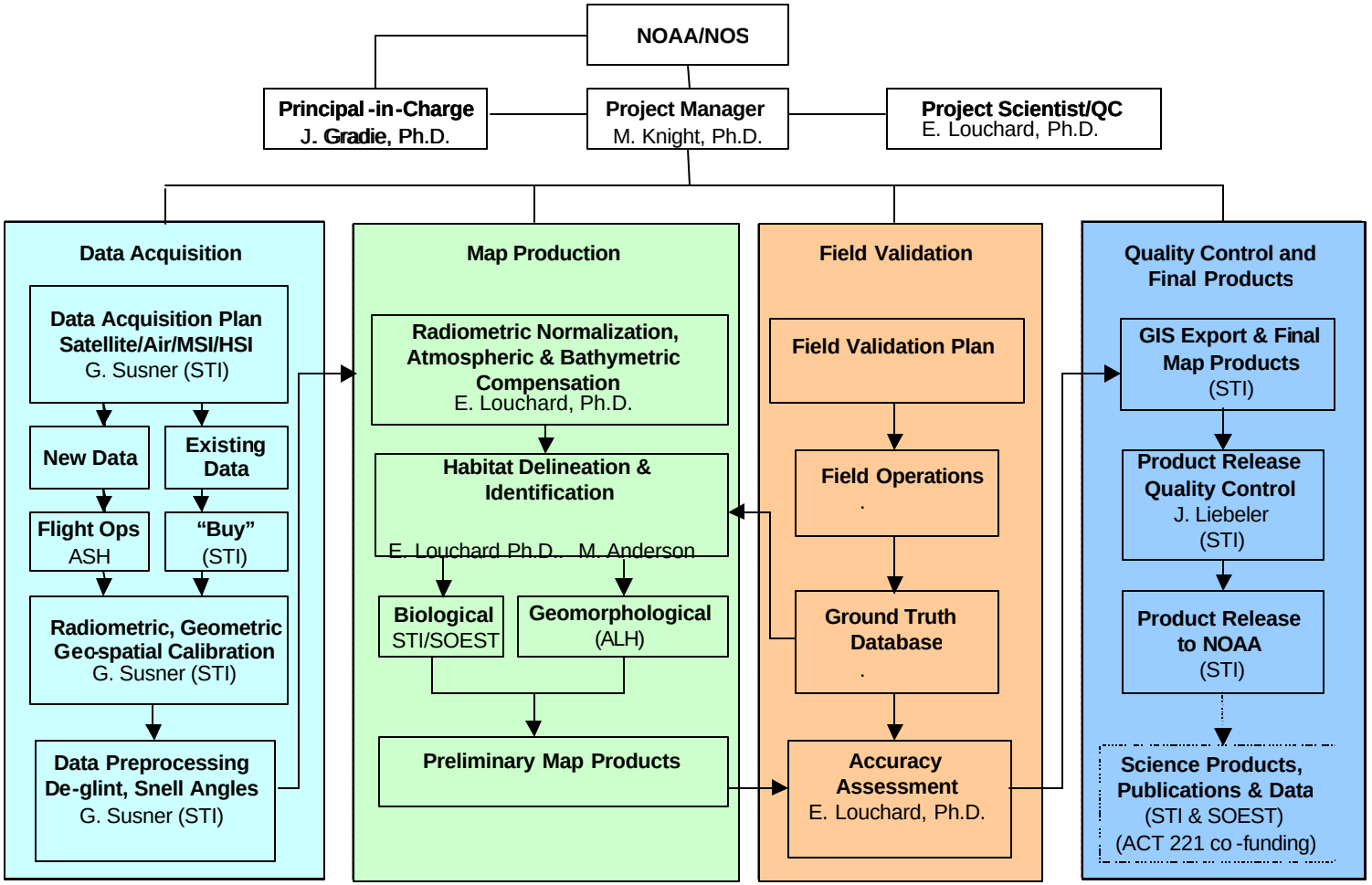
PROJECT ORGANIZATIONAL AND PROJECT WORK FLOW CHART



HSI & MSI — Mapping — Validation — GIS Products

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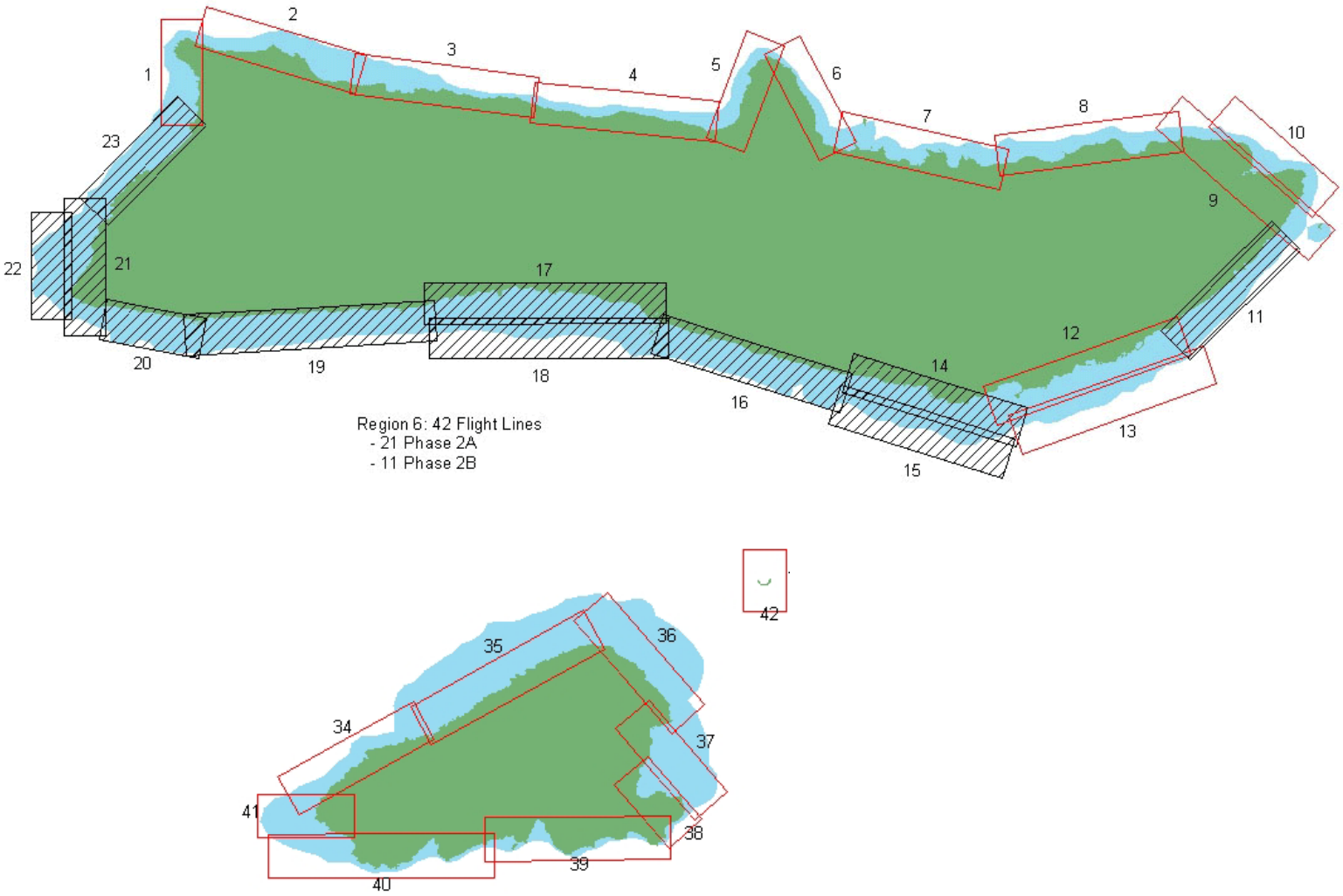
Example Flight Lines: Molokai



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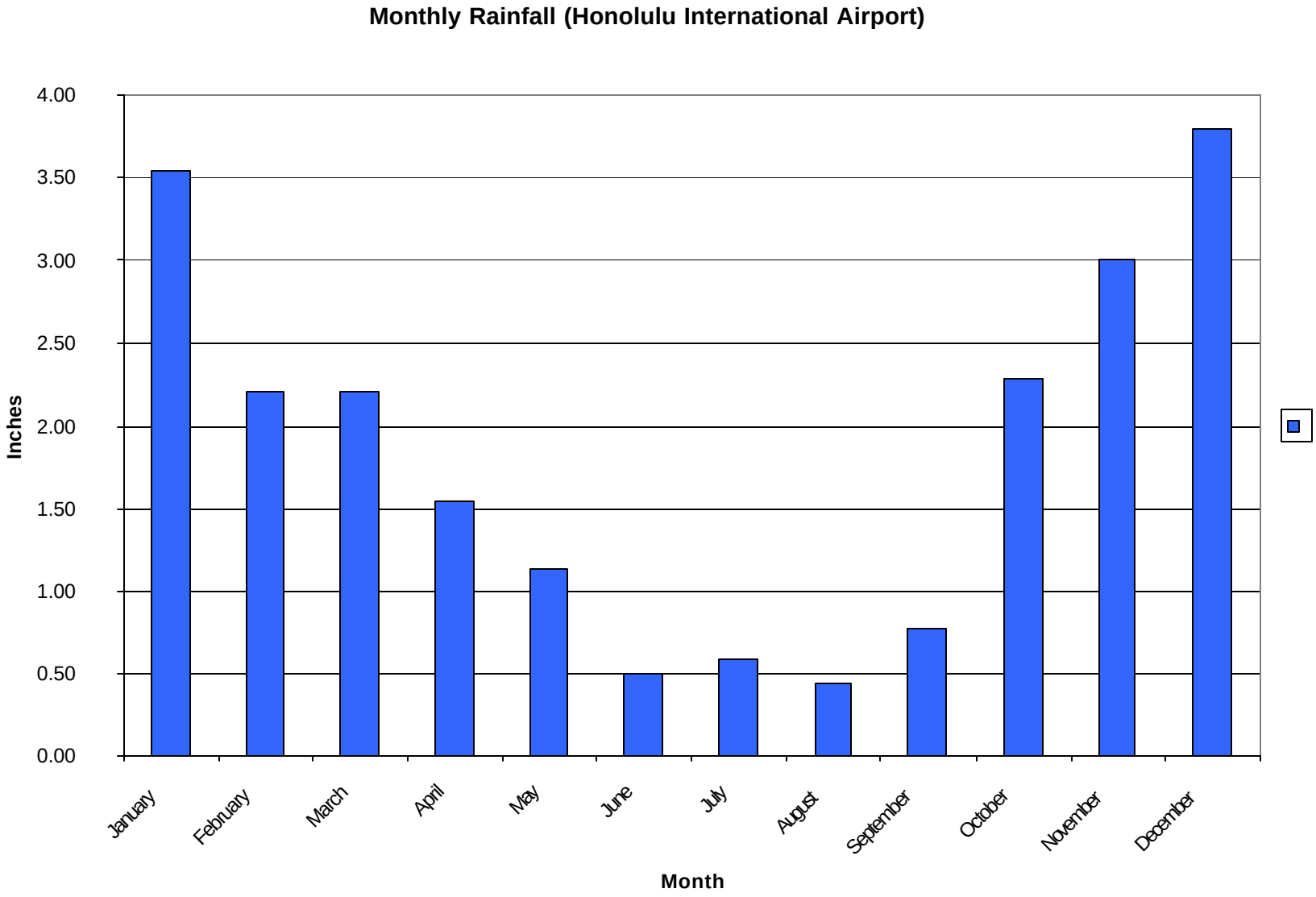

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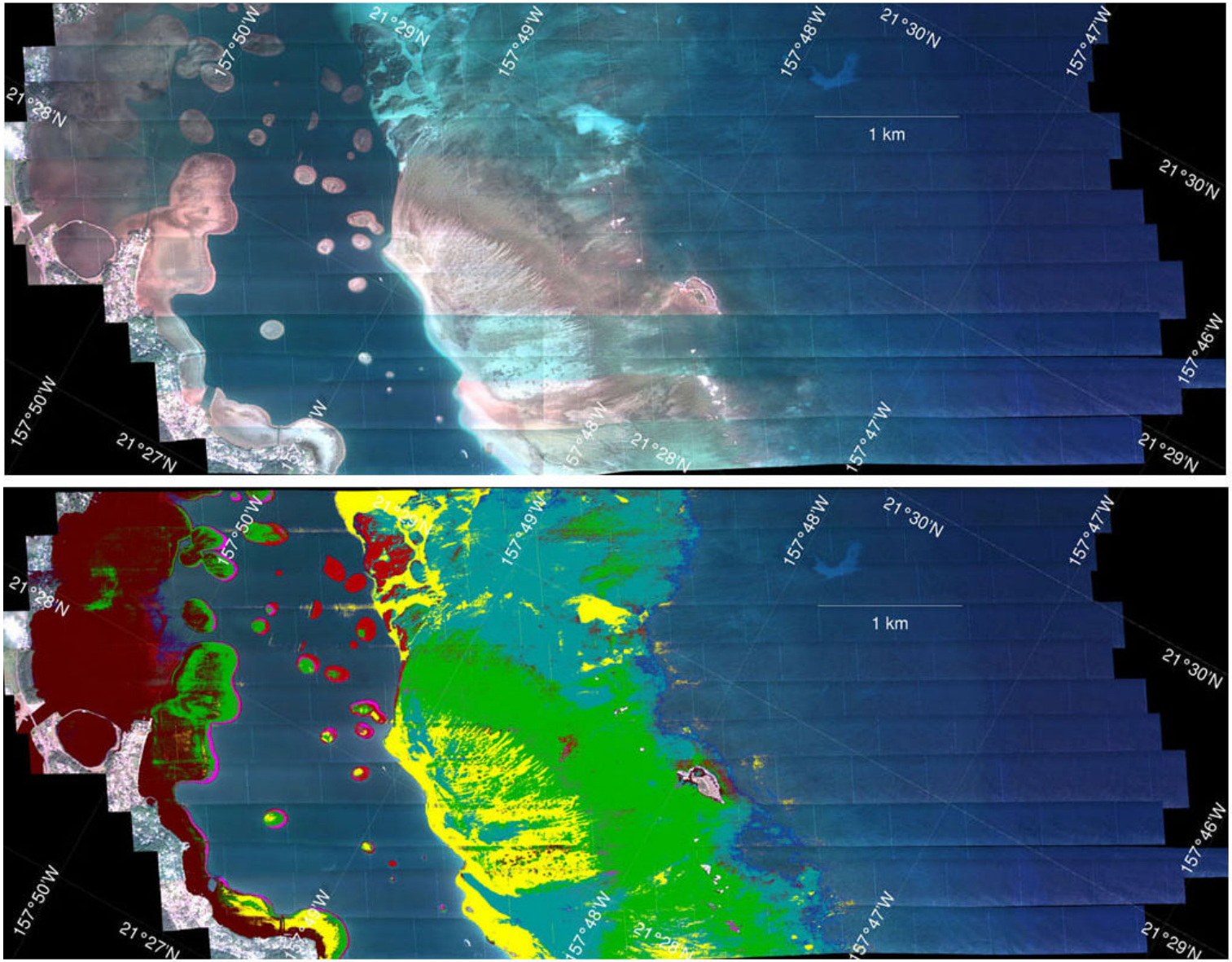
Turning Hyperspectral Imagery into Maps



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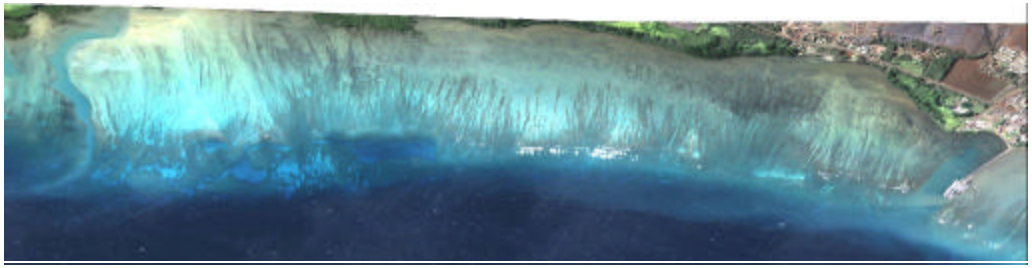
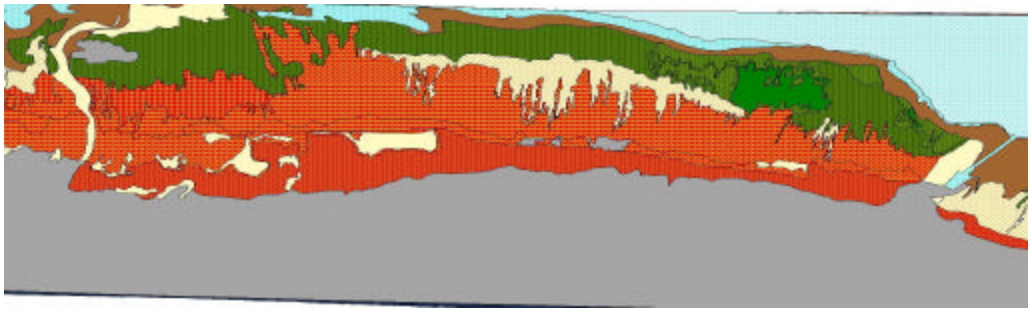
Mapping Process

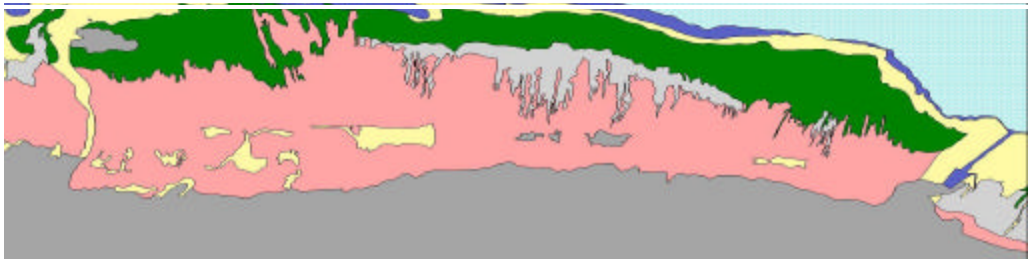


1) Molokai Test Area.

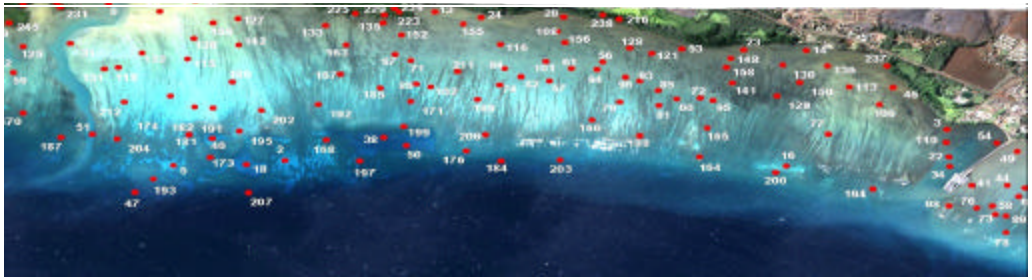


2) Digitized Detailed Habitat Map.

3) Add biological classes from HSI data analysis.



4) Detailed Habitat Map Aggregated to Major Habitats. Generate 50+ random sites per major habitat type.



5) Occupy accuracy assessment sites and conduct benthic habitat assessment

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