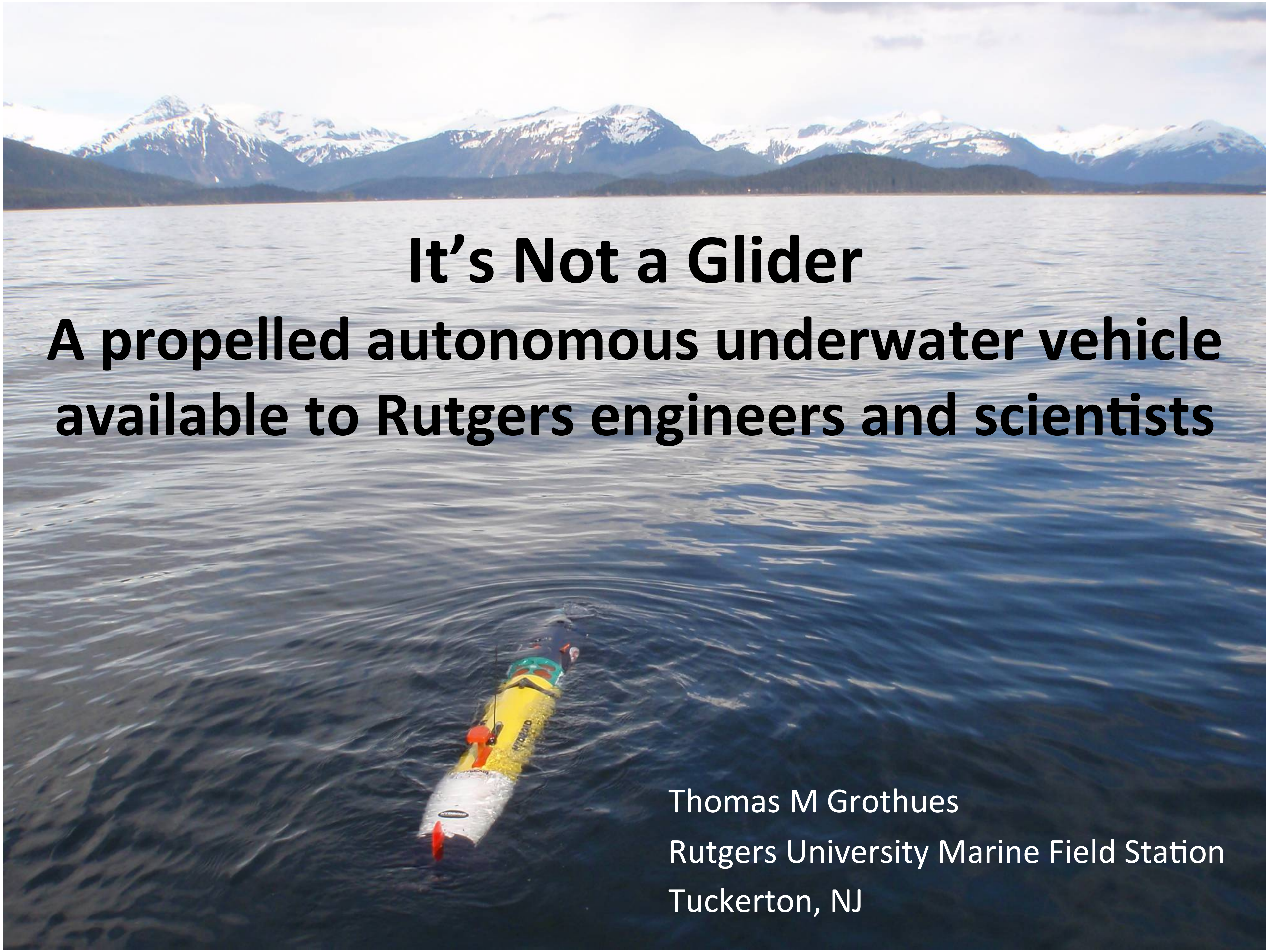
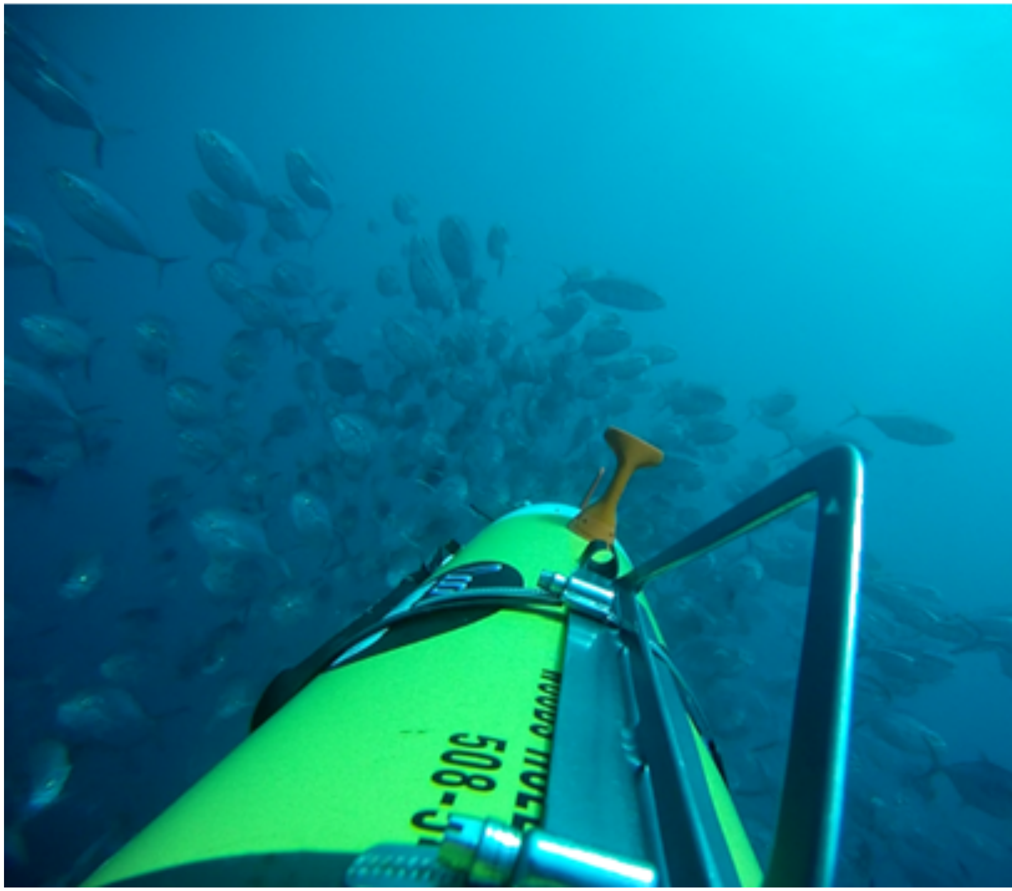


It’s Not a Glider
A propelled autonomous underwater vehicle available to Rutgers engineers and scientists

Thomas M Grothues
Rutgers University Marine Field Station
Tuckerton, NJ

Content

- Introduction to AUV diversity
- The Rutgers REMUS 100 AUV and Payload
- A Survey of Applications
- Payload Control
- Access



What is an AUV?

- Autonomous – AUVs are robots; programmed and <u>not</u> remot controlled
  - No wire
  - No pilot
  - No radio
- Underwater
- Vehicle

on to AUV diversity

Acronyms

UV - Unmanned Underwater Vehicle

- AUV –
  - Autonomous Underwater Vehicle
- ROV
  - Remotely Operated Vehicle

AV

- Unmanned Arial Vehicle

VA 400 nm–315 nm EMR

VB 315 nm- 280 nm EMR

on to AUV diversity

Vhat Do They Mean for Us?

- ccess to the dangerous, deep, dirty, or dull
- xpanded coverage
- o-location of sensors
  - At depth, where it counts
  - C, T, D, O_2, CDOM, Chl a, Currents, backscatter, sonar, bathymetry, fish telemetry, plankton
- gh accuracy and precision in space and in time
- inimally intrusive

on to AUV diversity

An AUV photo of the landing gear of the lost Air France flight on the ocean floor.

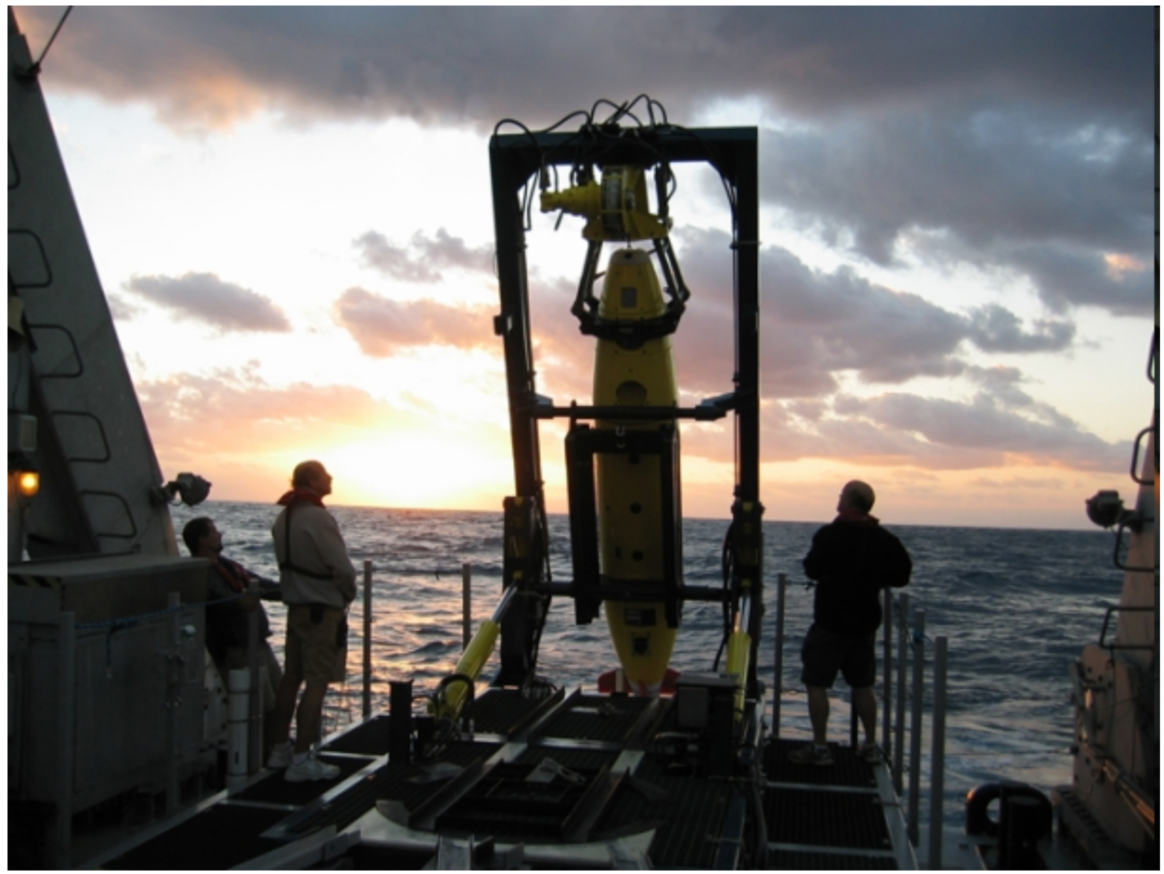
Deep
Dangerous
Dirty
Dull

AUVs locate lost Air France flight

06 Apr 2011

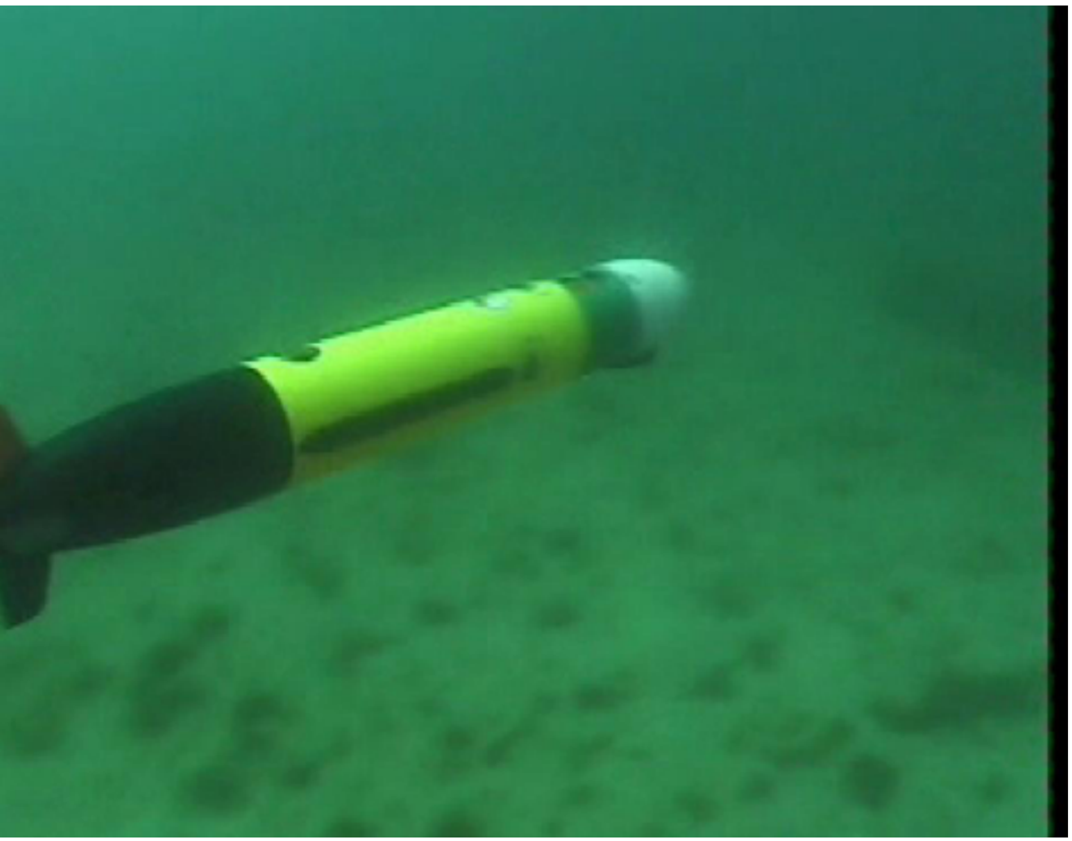
After two years, one of the strangest and most worrying puzzles of recent times, the loss of Air France Flight 447, may be about to be solved with the finding of the wreckage some two and a half miles down.

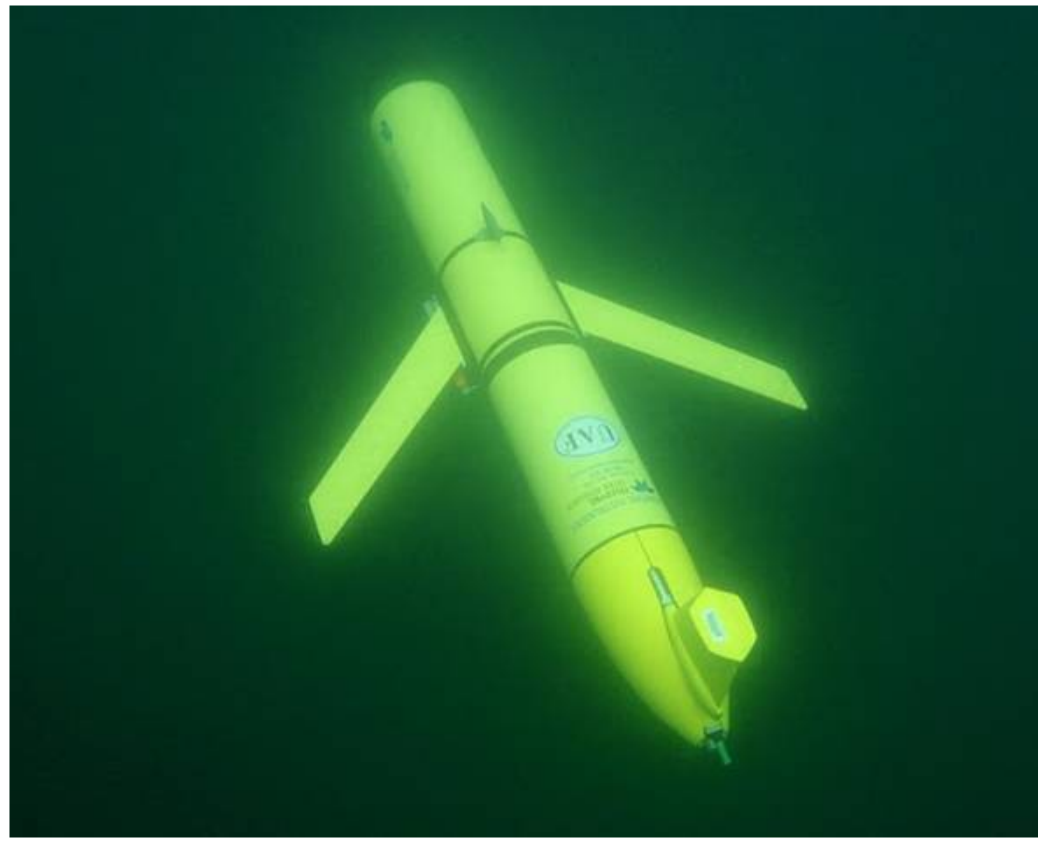
Apart from the bodies that will be recovered, there is hope that the plane's 'black box' is to be found amongst the wreckage of the lost plane which has been finally found by autonomous underwater vehicles (AUVs) in the Atlantic Ocean off Brazil's north eastern coast.



active swimmer

glider

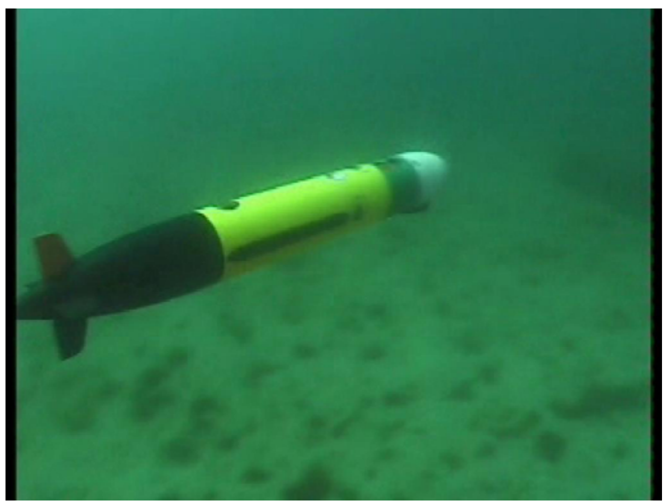


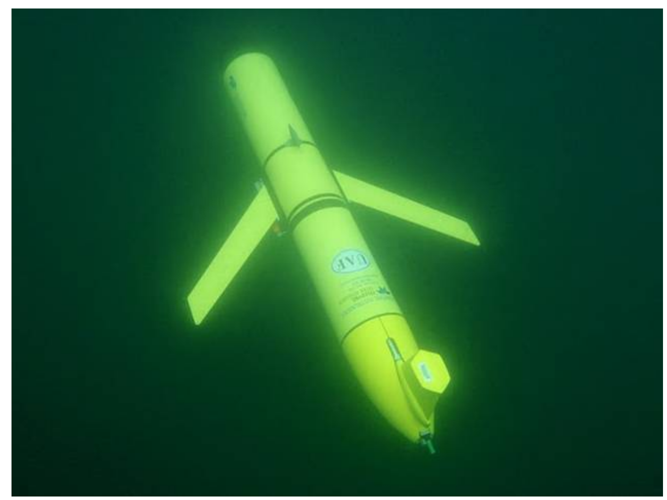


on to AUV diversity

Comparison

	Swimmer	Glider
opulsion	Electric or chemical motor driving rotor or fins	Buoyancy control with pressure vectoring
ssion Duration	8-24 hours	Days to months
pth control	Sub meter referenced to surface or bottom	Must oscillate
eed	~ 2 m/s	~0.3 m/s
mary Mission Design	Precision - Benthic mapping with sonar	Endurance - Spatially explicit Vertical profiling

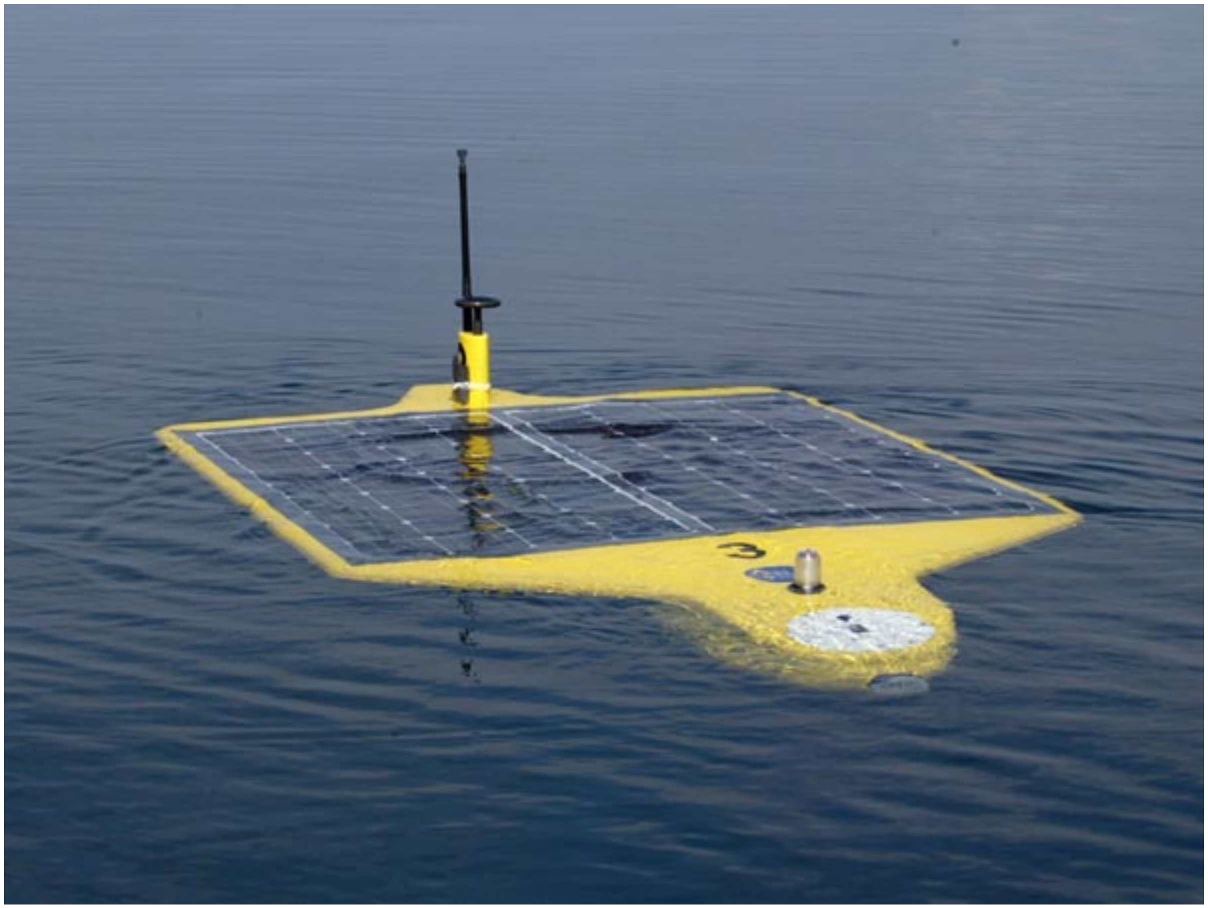




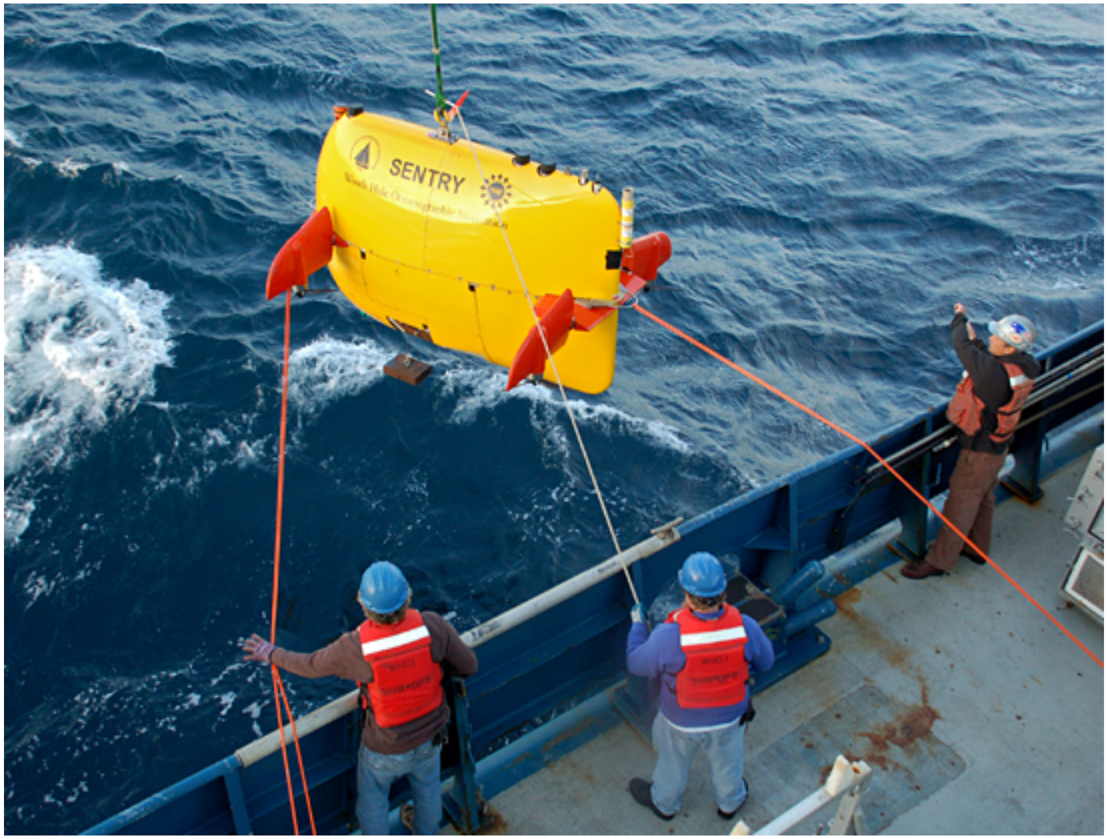
on to AUV diversity

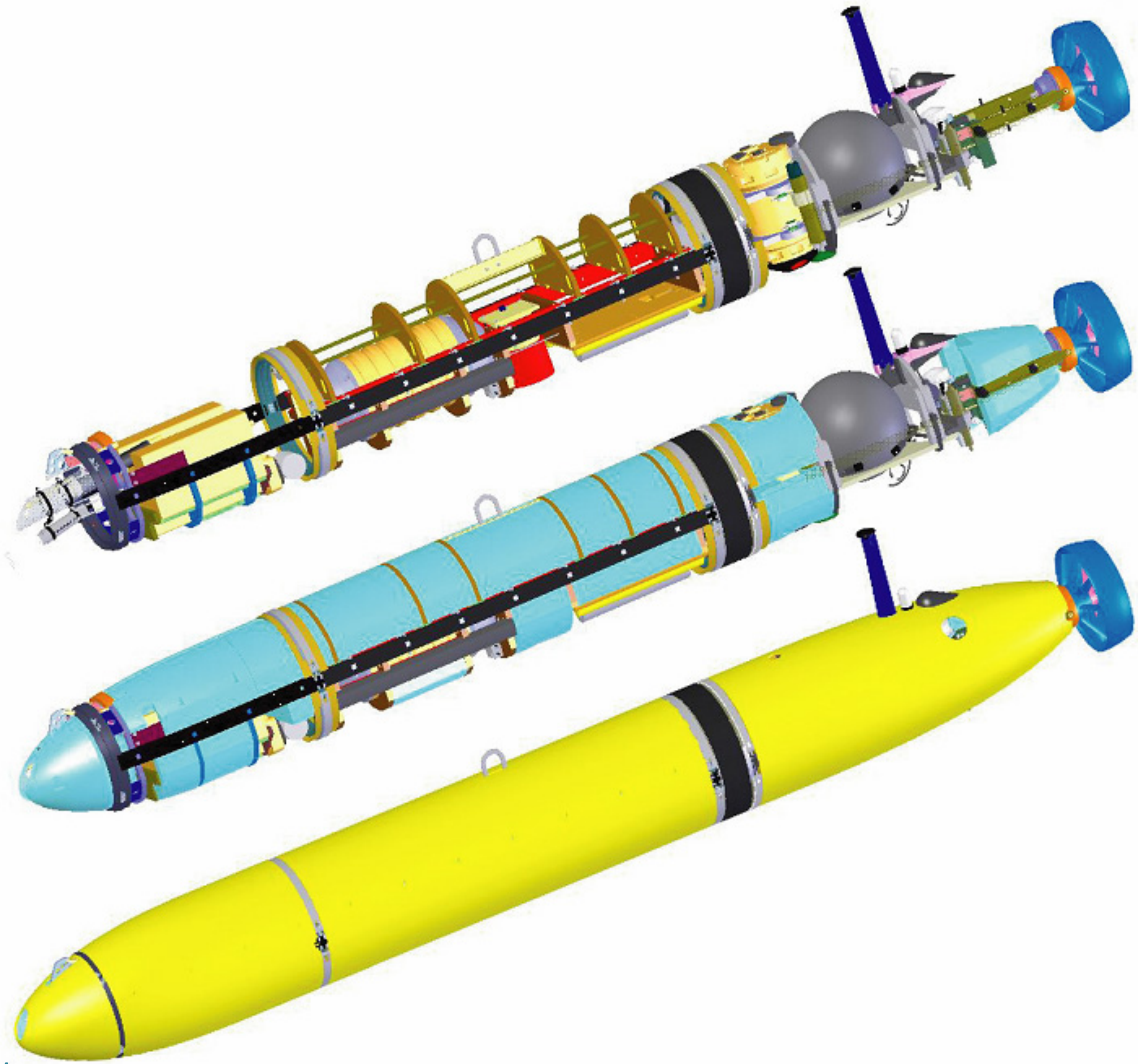
Challenge	Solutions
Risk	Redundancy, buoyancy
power capacity	Chemistry, management, solar, docking station
recharge time	Mission management, battery technology, modularity
endurance	Speed & drag mitigation, size, conservation
acoustic noise	Isolation mounting, electrical noise dampening
sensor function	Positioning
stability	Control surfaces, ballast, sensing
pressure	Compartmentalization, materials, shape
drag	Materials, shape (fusiform)
control	Control surfaces, ballast, sensing
communications	Acoustic & laser modems, daisy chaining, moored links
autonomy	Algorithms, sensory package
navigation	Sensing system, beacons, algorithms and computation
recovery	WiFi, Iridium, Sling, vessel support

Chassis Design Survey

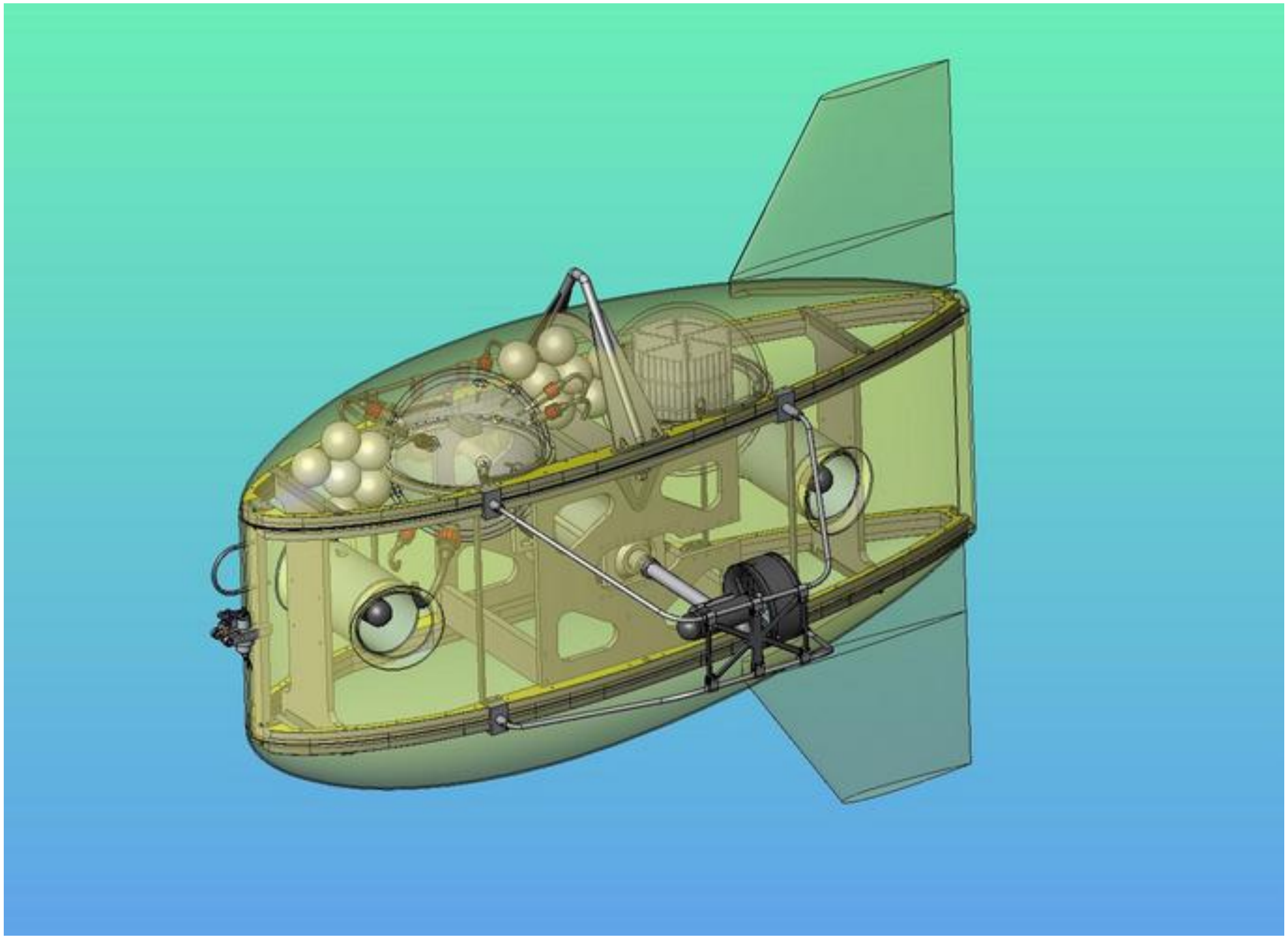


Deep submergence

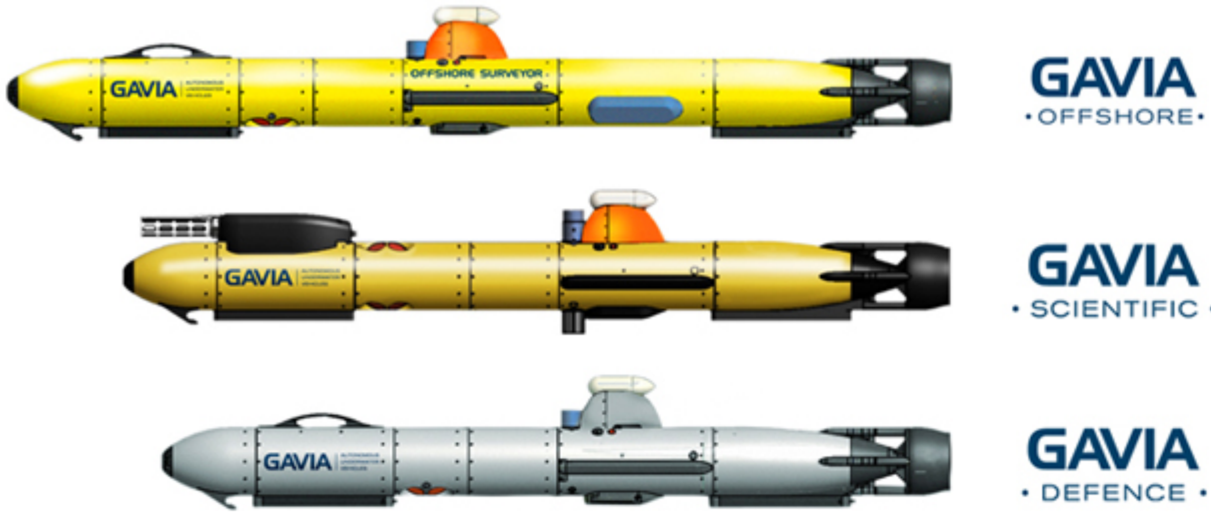




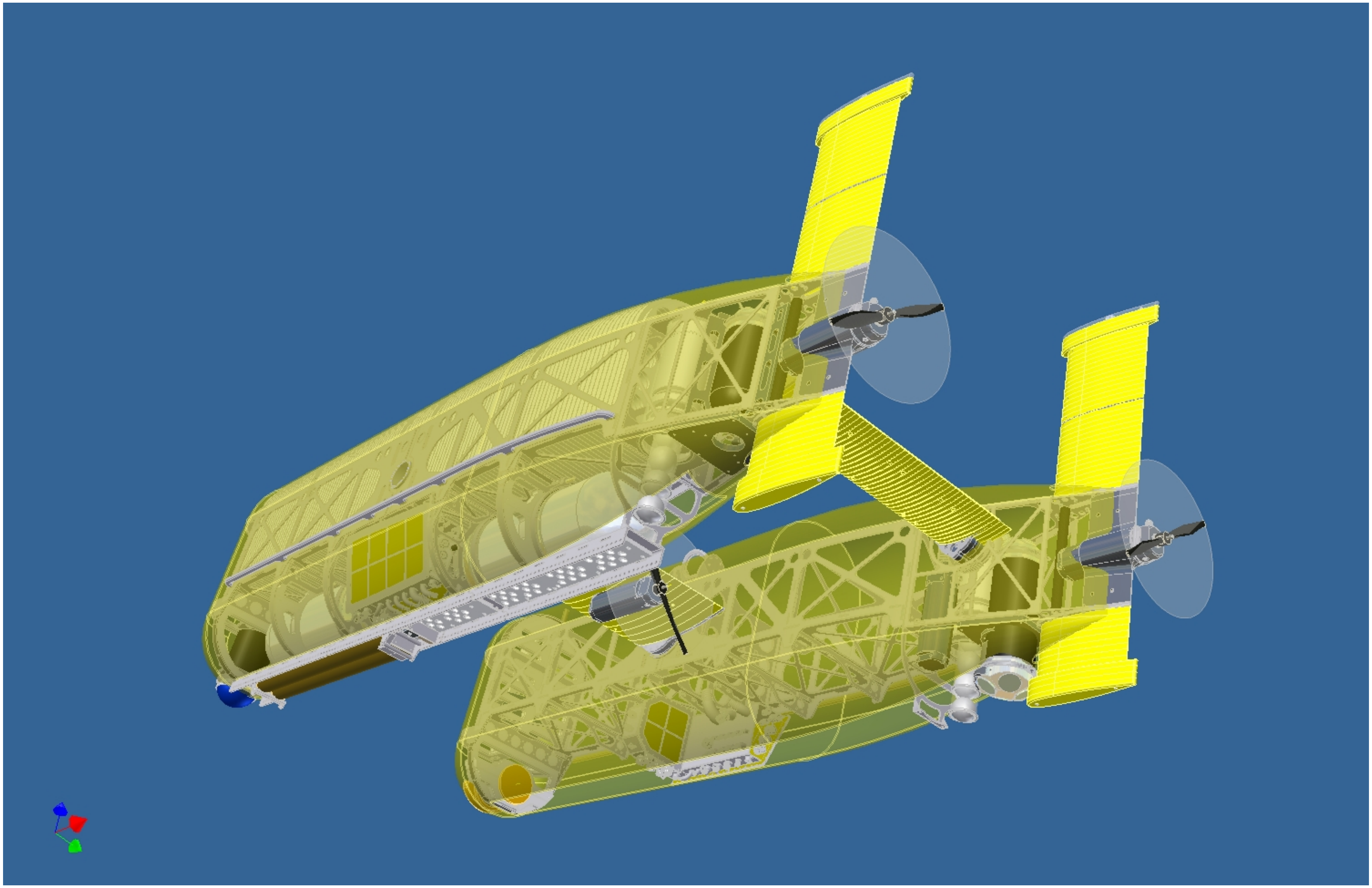
on to AUV diversity



on to AUV diversity

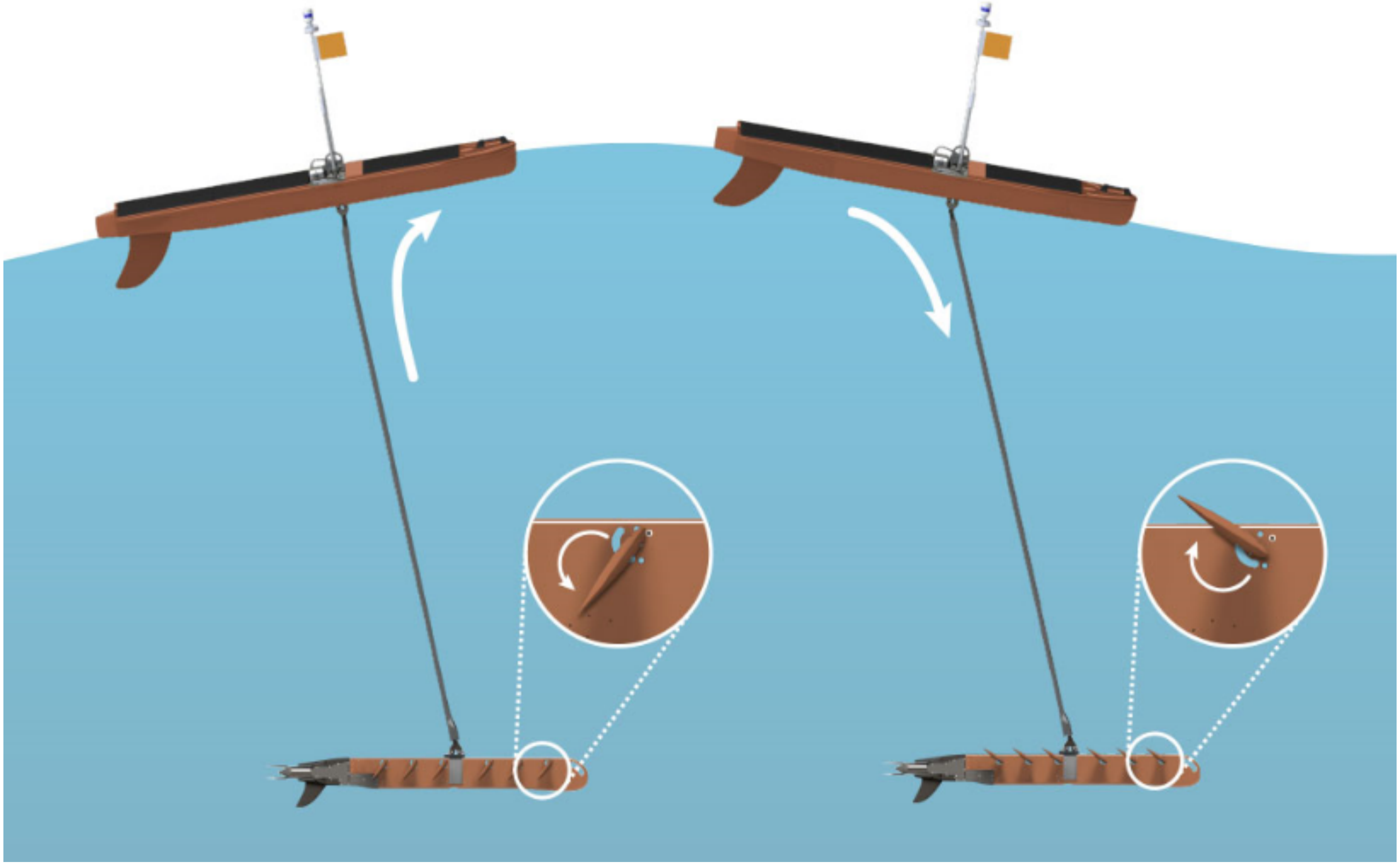


on to AUV diversity



on to AUV diversity

Liquid Robotics waveglider



Saildrone

he Rutgers REMUS-100 and Payload

- Surface to 100 m deep
- 55 km long path
- 2 – 4 knots
  (about 8 -10 hrs depending
  On speed and sensor load)
- Recharges 75% in 6 hrs, 100% in 12 hrs
- 2 people launch from ship, skiff, or beach

How does it work?

- Gather some preliminary information for informing AUV decisions
- Program objectives and desired sampling designs (rules)
- Let it swim
- Pick it up
- Download data

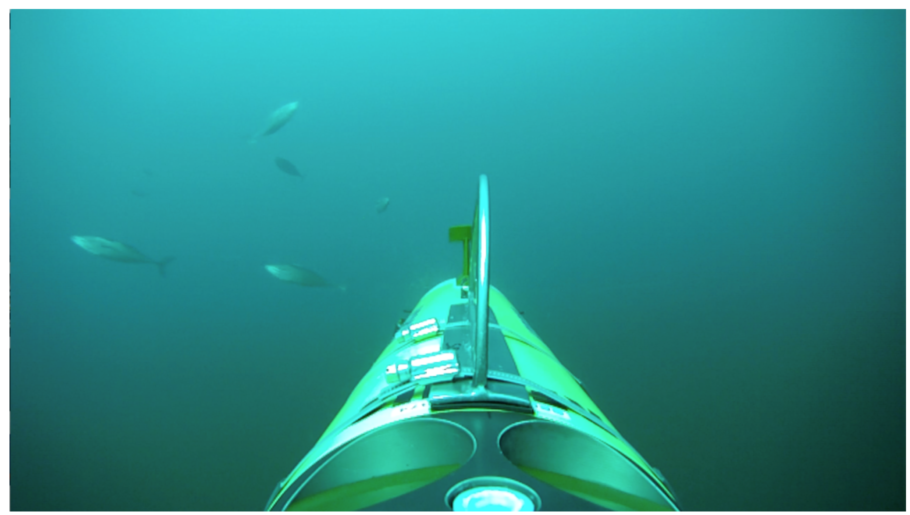
```
[Location]
type=Waypoint
label=Start
Position=  38N55.876   76W27.750
Offset direction=0
Offset distance (Meters)=0
Offset Y axis (Meters)=0
Transponder depth (Meter

[Objective]
type=Set Position
Destination=Start
Offset direction=157
Offset distance (Meters)=1
Offset Y axis (Meters)=0

[Objective]
type=Wait Magnet
Symbol Position on Chart=

[Objective]
type=Compass cal
```

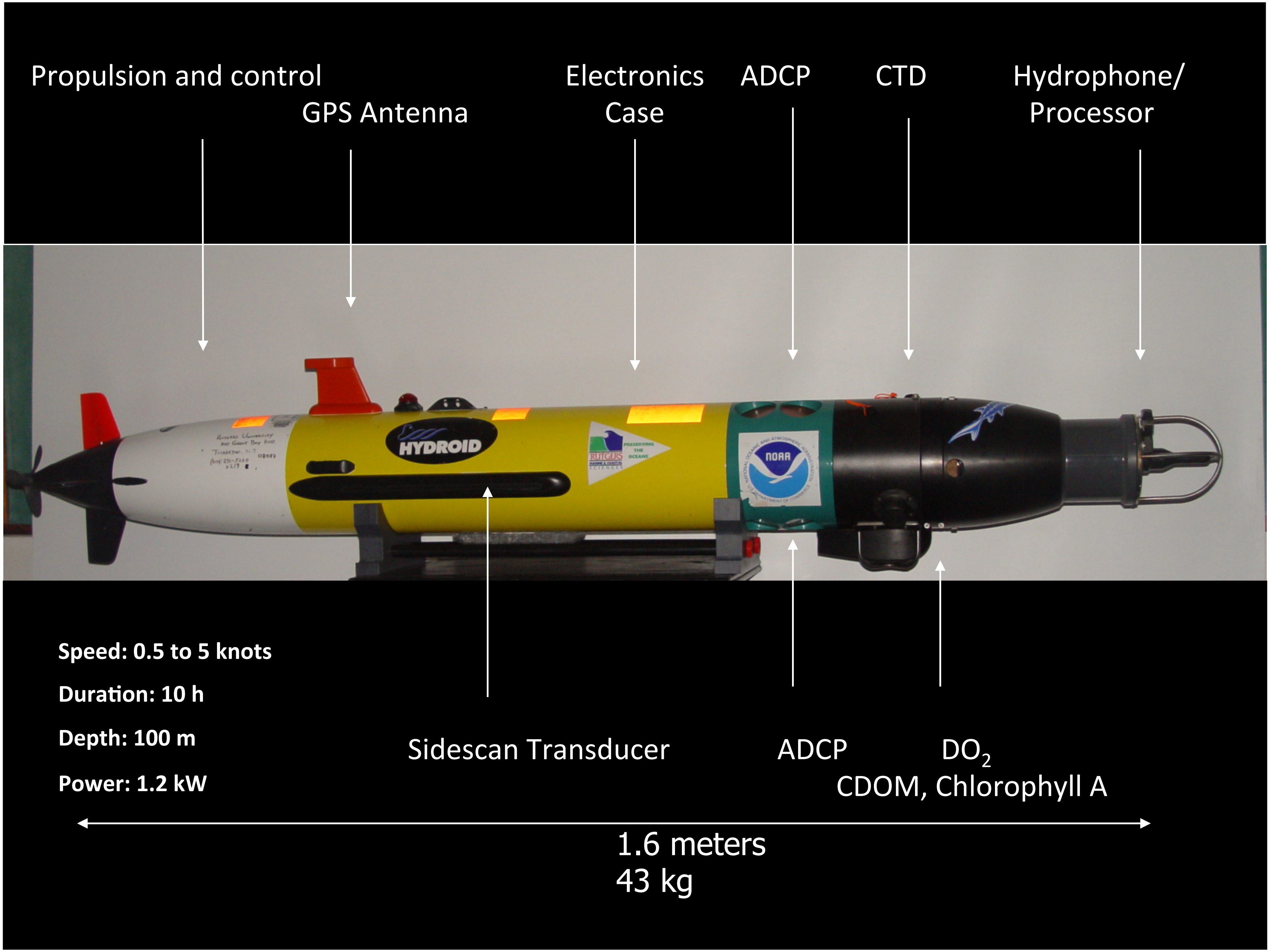
How does it know where it is going?

- Dead Reckoning
  - Keeps track of direction with compass
  - Keeps track of speed-through-water with propeller RPM and speed-over bottom (including side slip) with sonar (ADCP)
- Trilateration (Optional)
  - Uses acoustic homing signals to measure distance to known beacon buo
- Checks itself with GPS on the surface
- Inertial Navigation System (INS)
- SBL Transducers

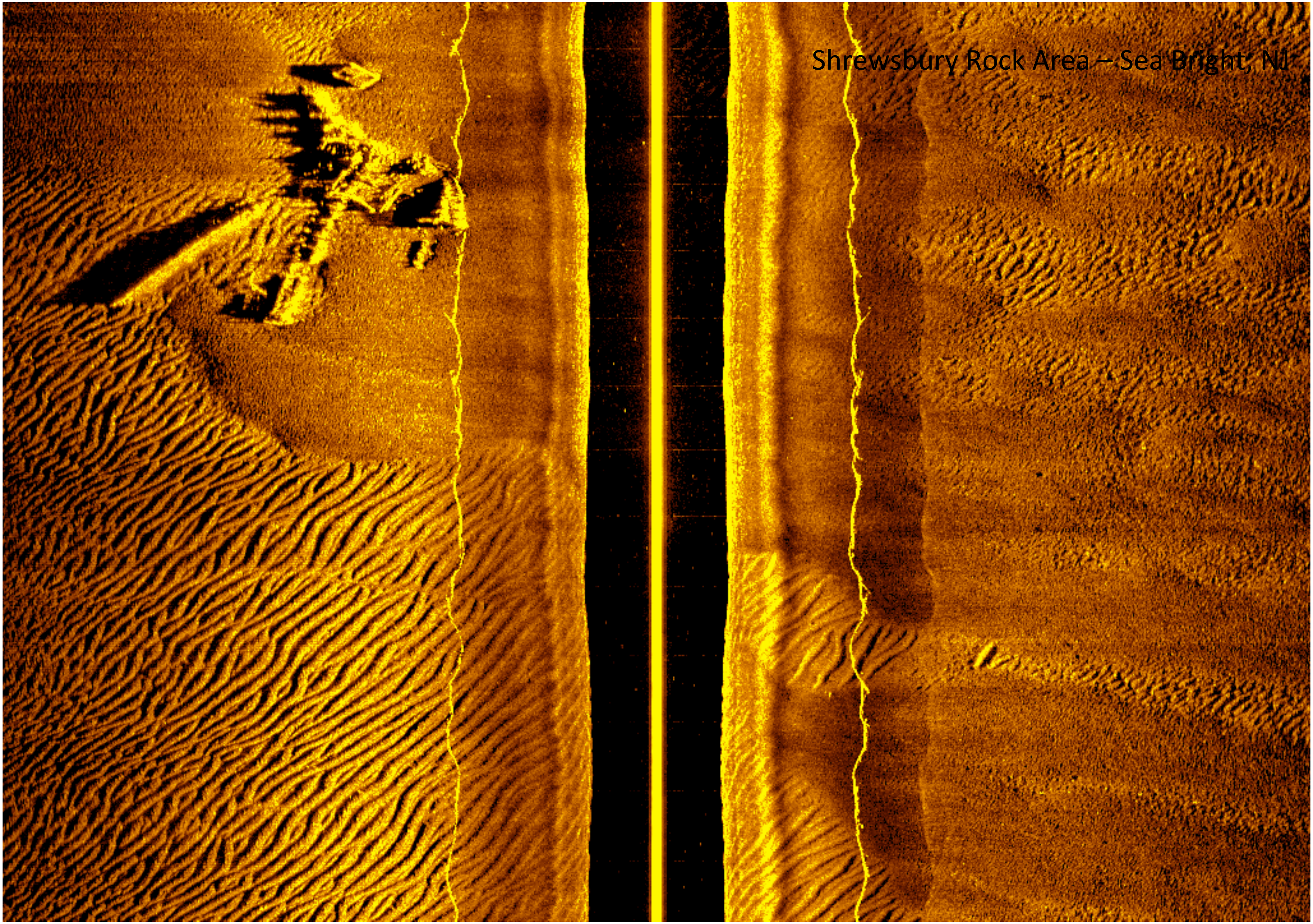
Sensors

- Acoustic
  - Passive (piezo or optic)
  - Active
    - SONAR
    - Doppler Shift
  - Coupled (Fish telemetry)
- Optic (scatter or fluorescence, imaging)
- Resistance
- Mechanical
- Magnetic
- Chemical

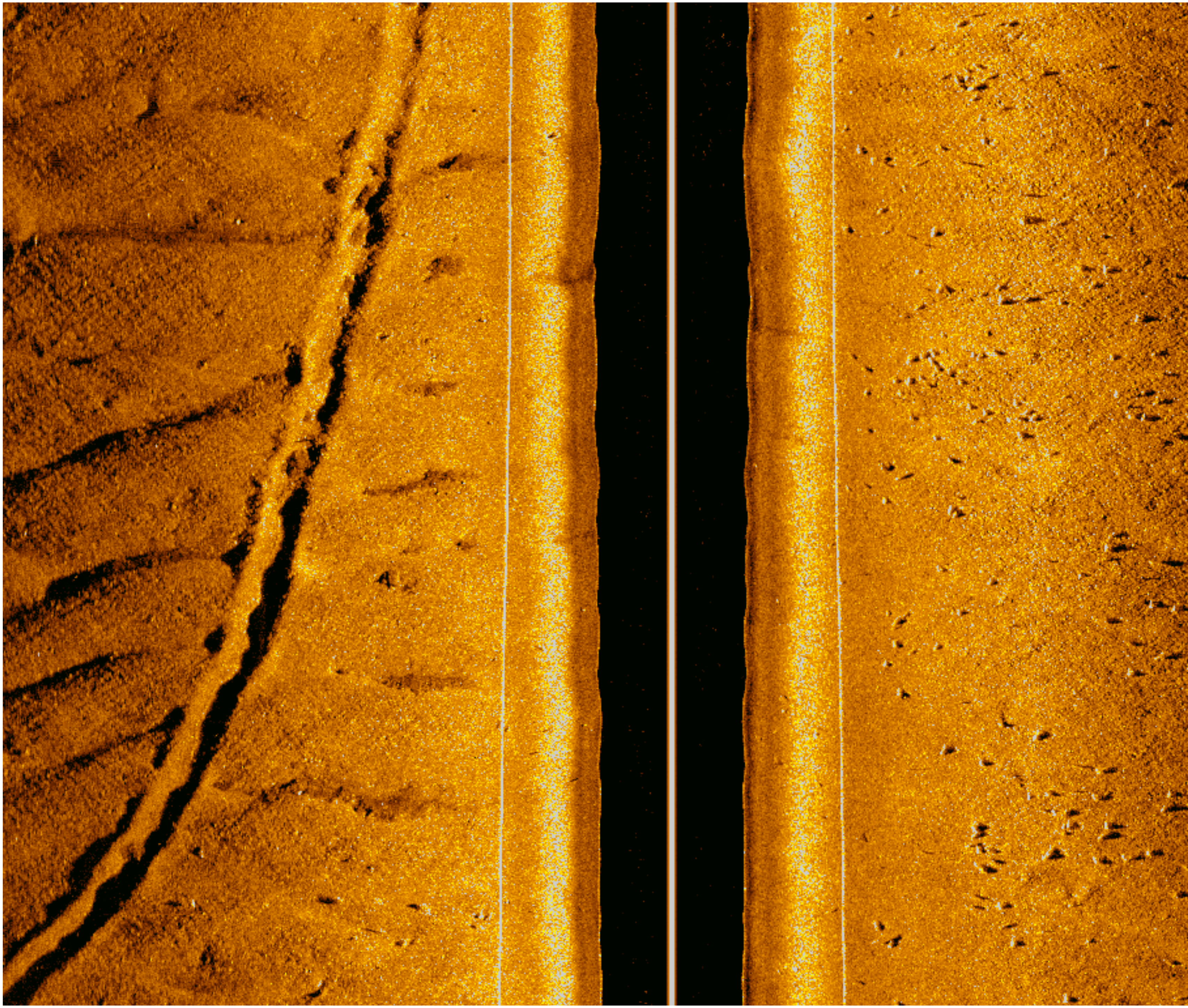




Propulsion and control
GPS Antenna
Electronics Case
ADCP
CTD
Hydrophone/ Processor
HYDROID
NOAA
Speed: 0.5 to 5 knots
Duration: 10 h
Depth: 100 m
Power: 1.2 kW
Sidescan Transducer
ADCP
DO_2
CDOM, Chlorophyll A
1.6 meters
43 kg

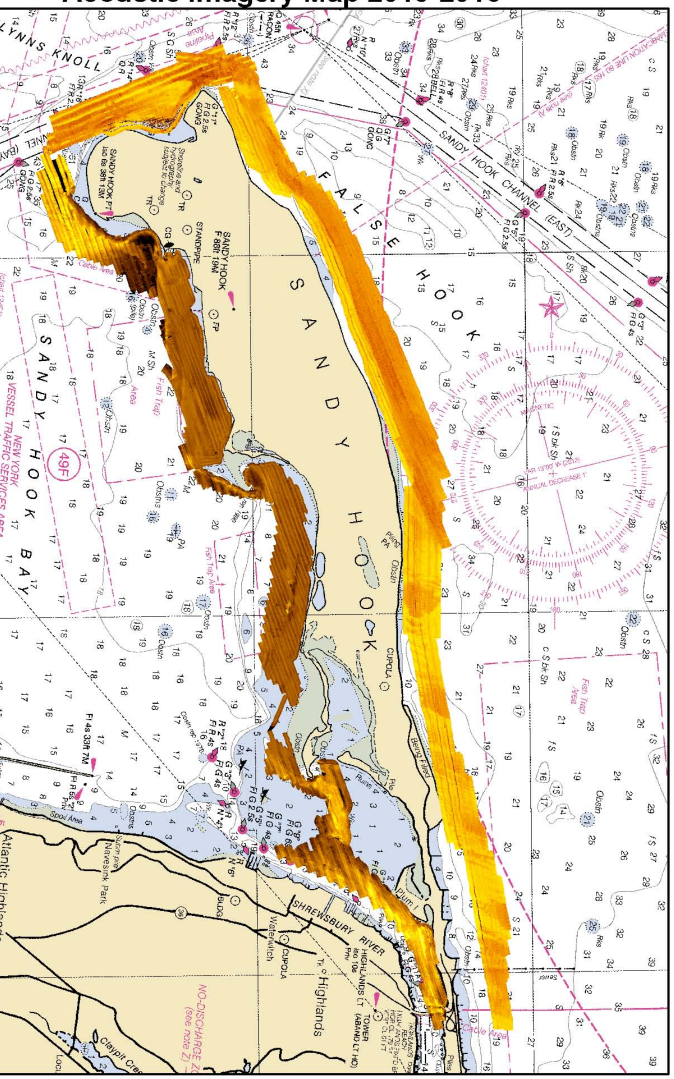

Shrewsbury Rock Area – Sea Bright, NJ

f Applications



upervised Classification of Benthic Habitat from Side Scan Son

andy Hook Gateway National Recreation Area
Acoustic Imagery Map 2015-2016



evin, Ph.D.
n College
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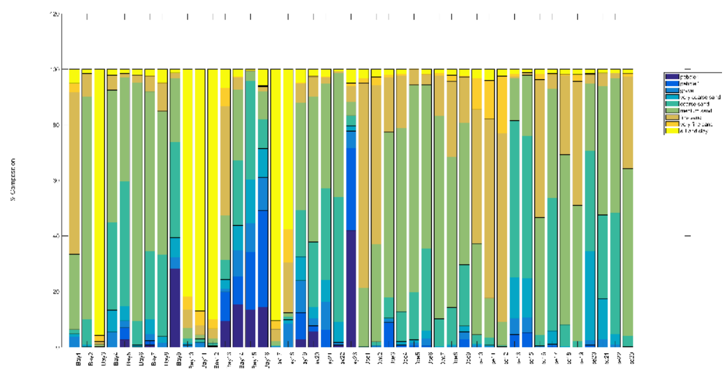
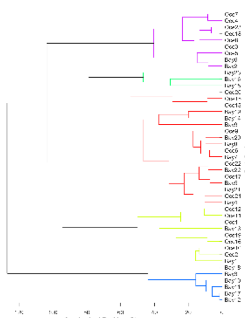
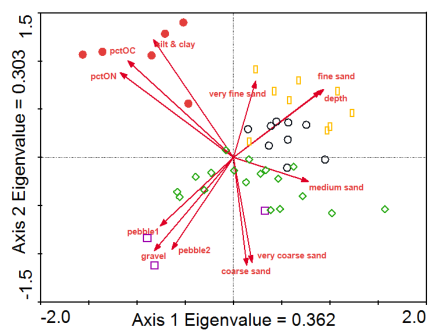
Center for Environment & Society







Sandy Hook GNRA Submerged I

Habitat Classification

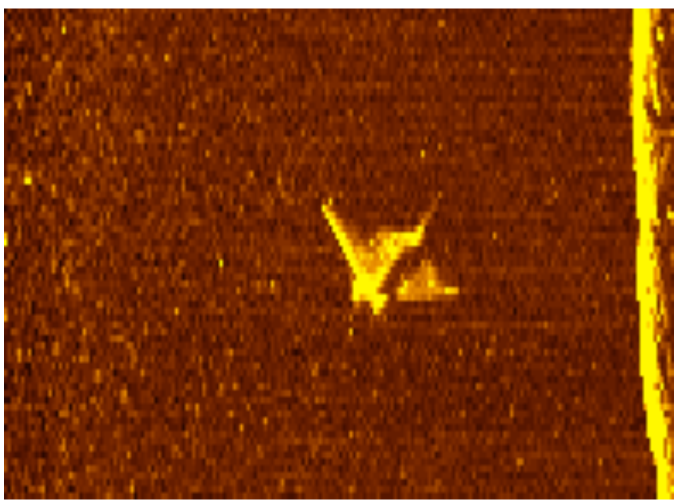
Gemma Bed on Poorly Sorted Sand

Exogone Bed on Gravelly Sand

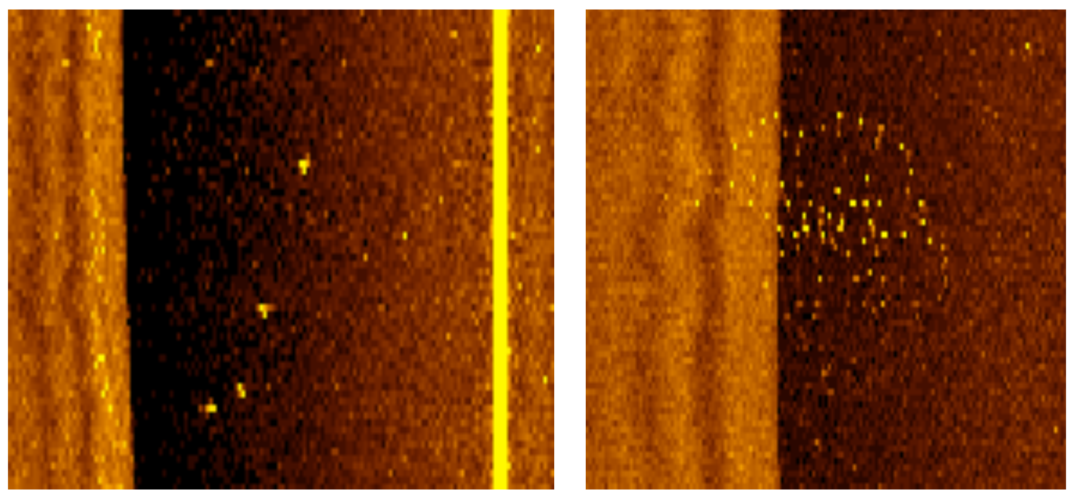
CMECS Sentence: Virginian Nearshore Subtidal Zone; in a Spit in Upper Poly

This your manta

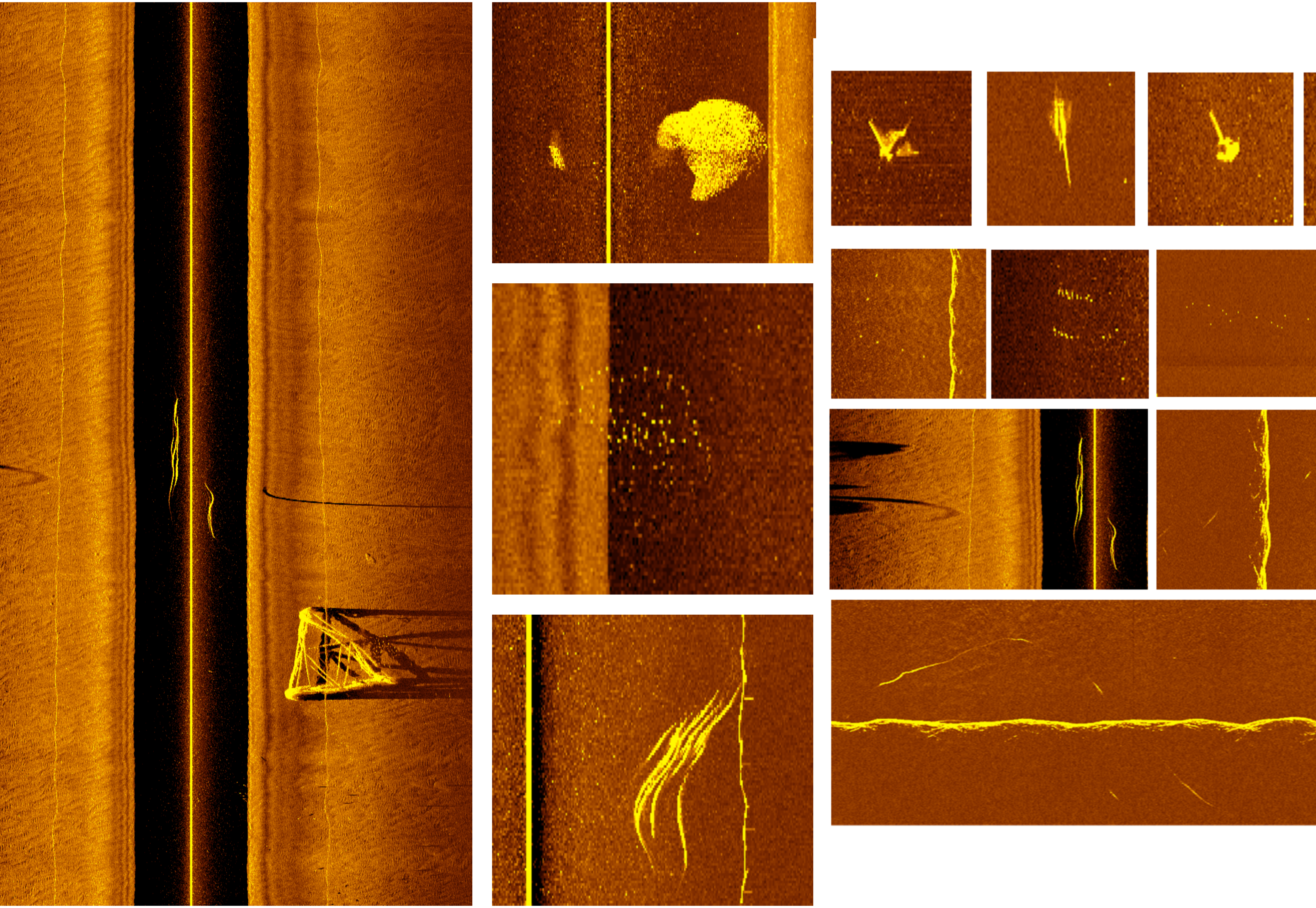
This is you Little Tunny



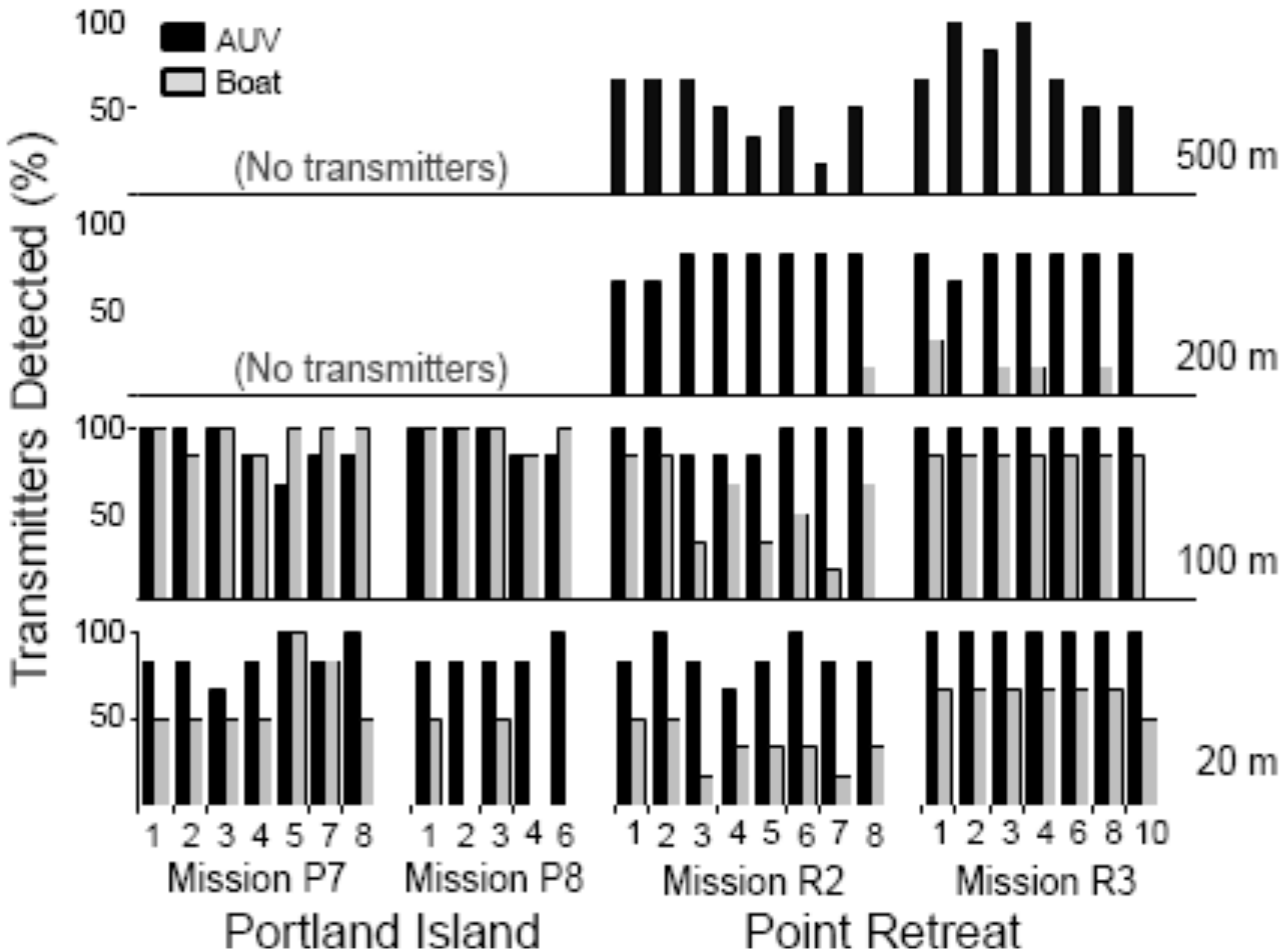
This your manta on sonar



Is this your Little Tunny on sonar?



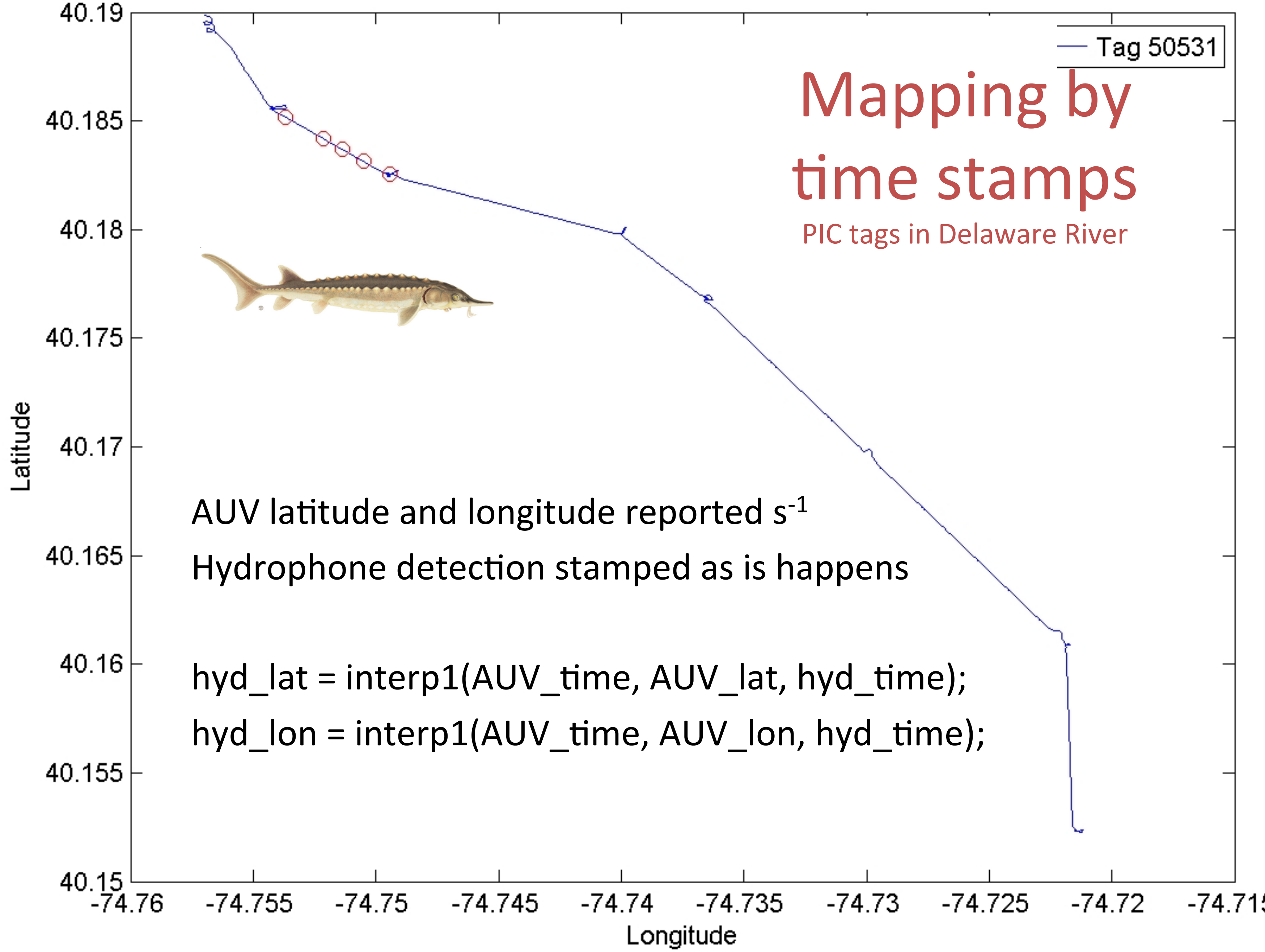
f Applications



f Applications

Mapping by time stamps

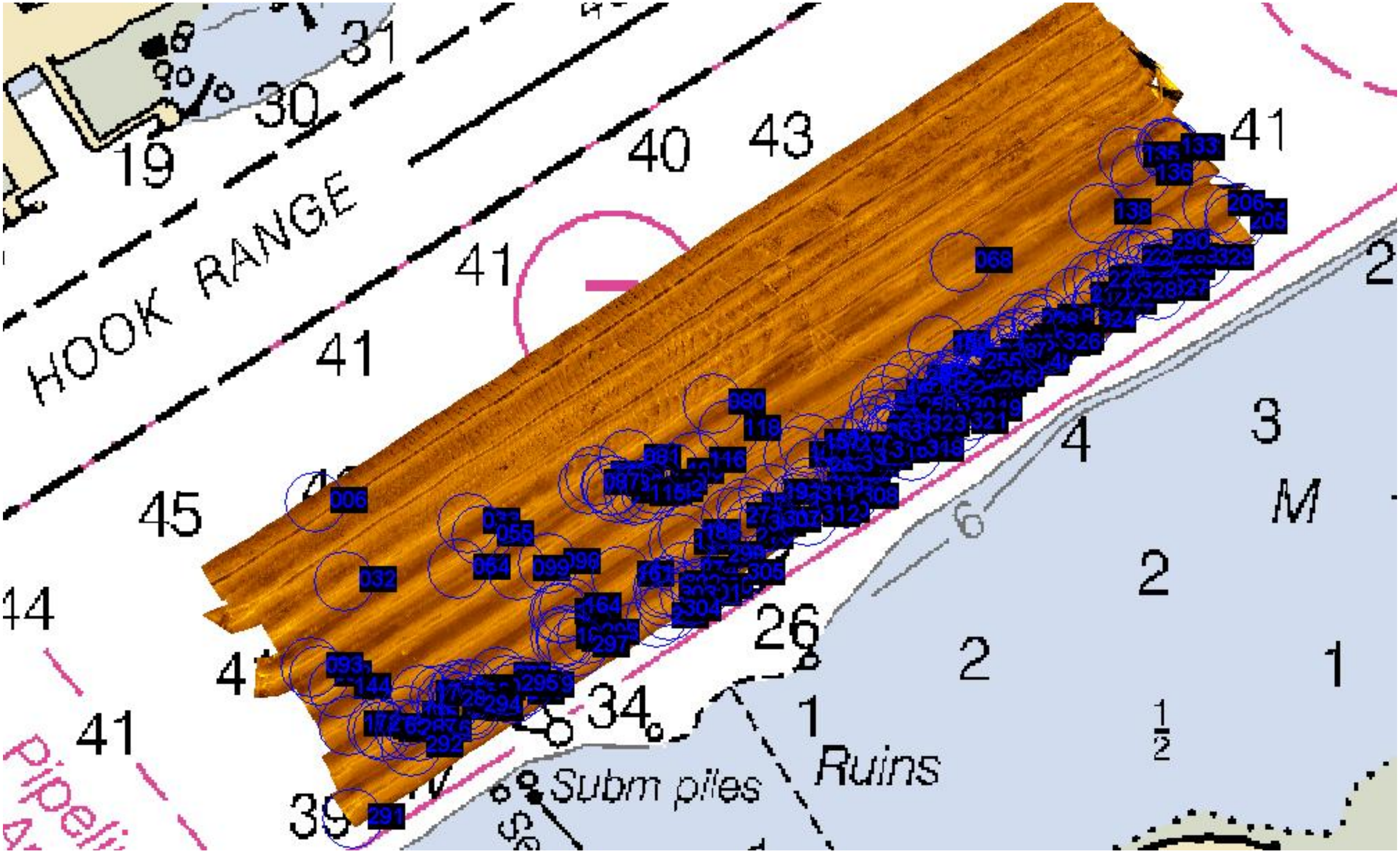
PIC tags in Delaware River



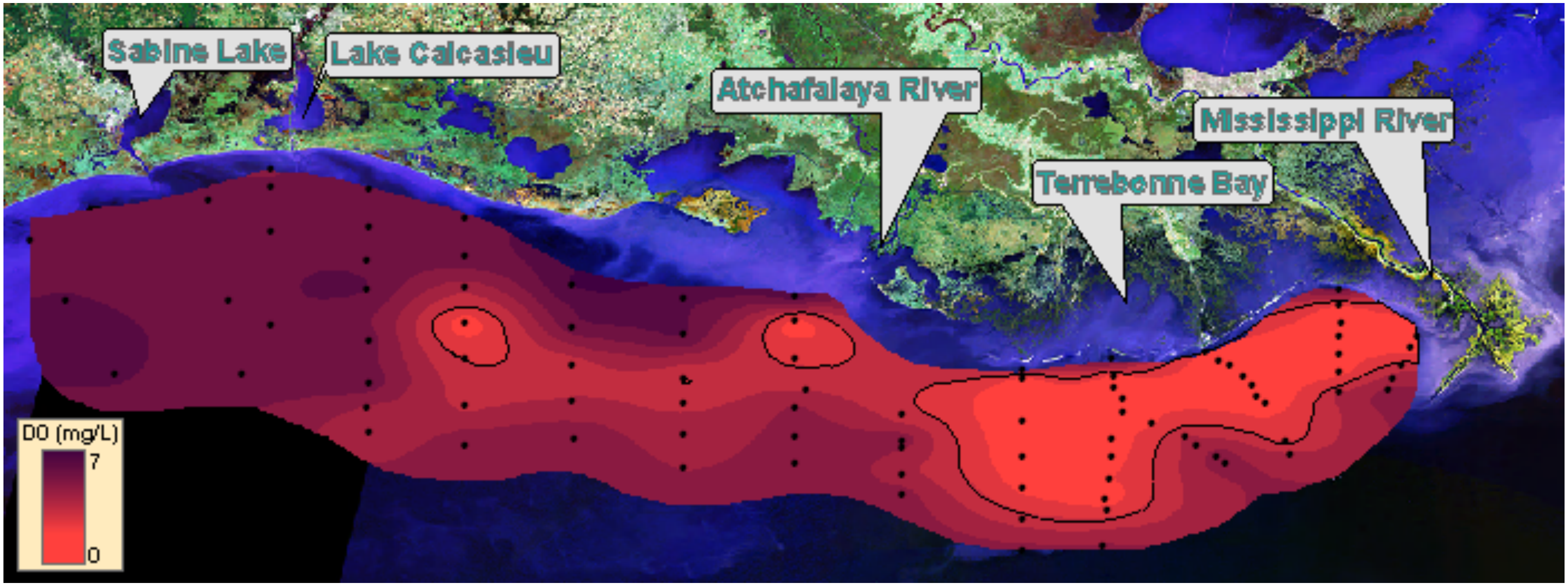
AUV latitude and longitude reported s^{-1}

Hydrophone detection stamped as is happens

```
hyd_lat = interp1(AUV_time, AUV_lat, hyd_time);
hyd_lon = interp1(AUV_time, AUV_lon, hyd_time);
```



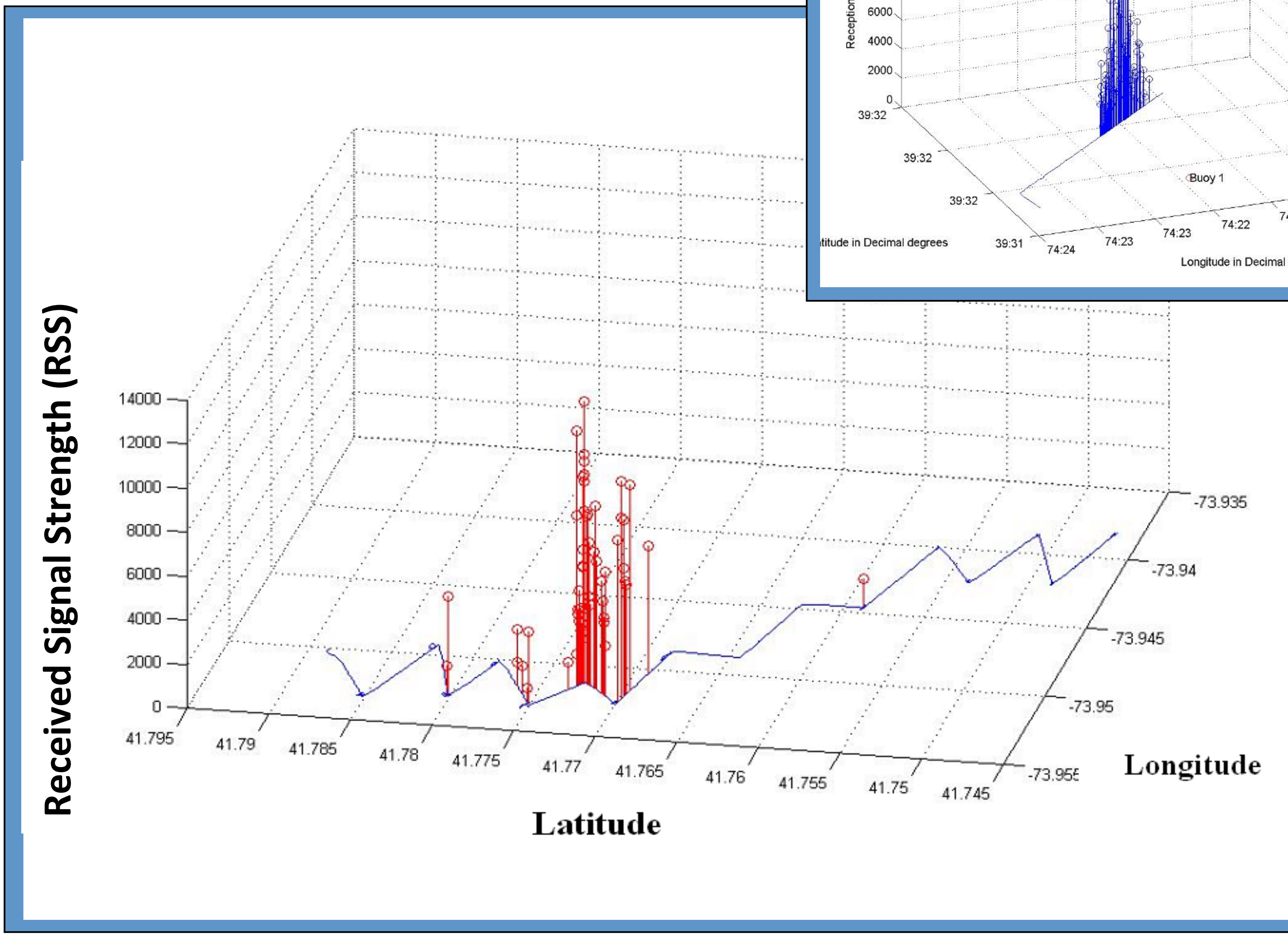
f Applications

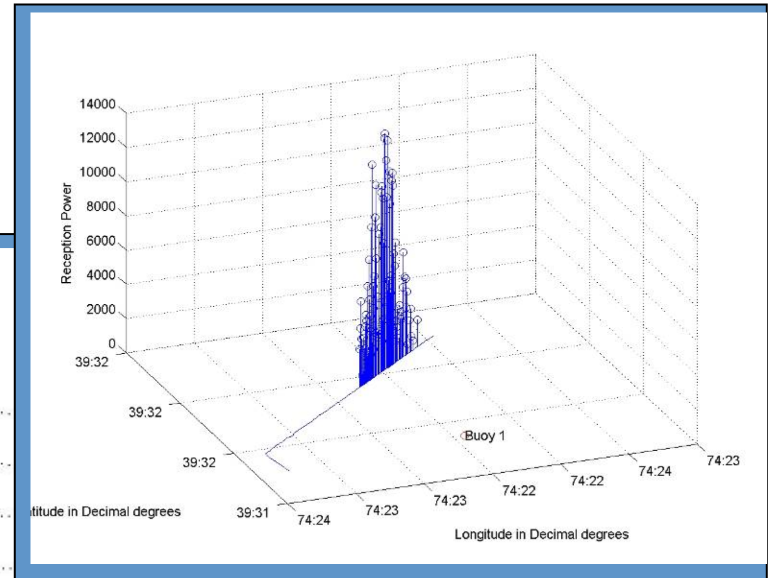


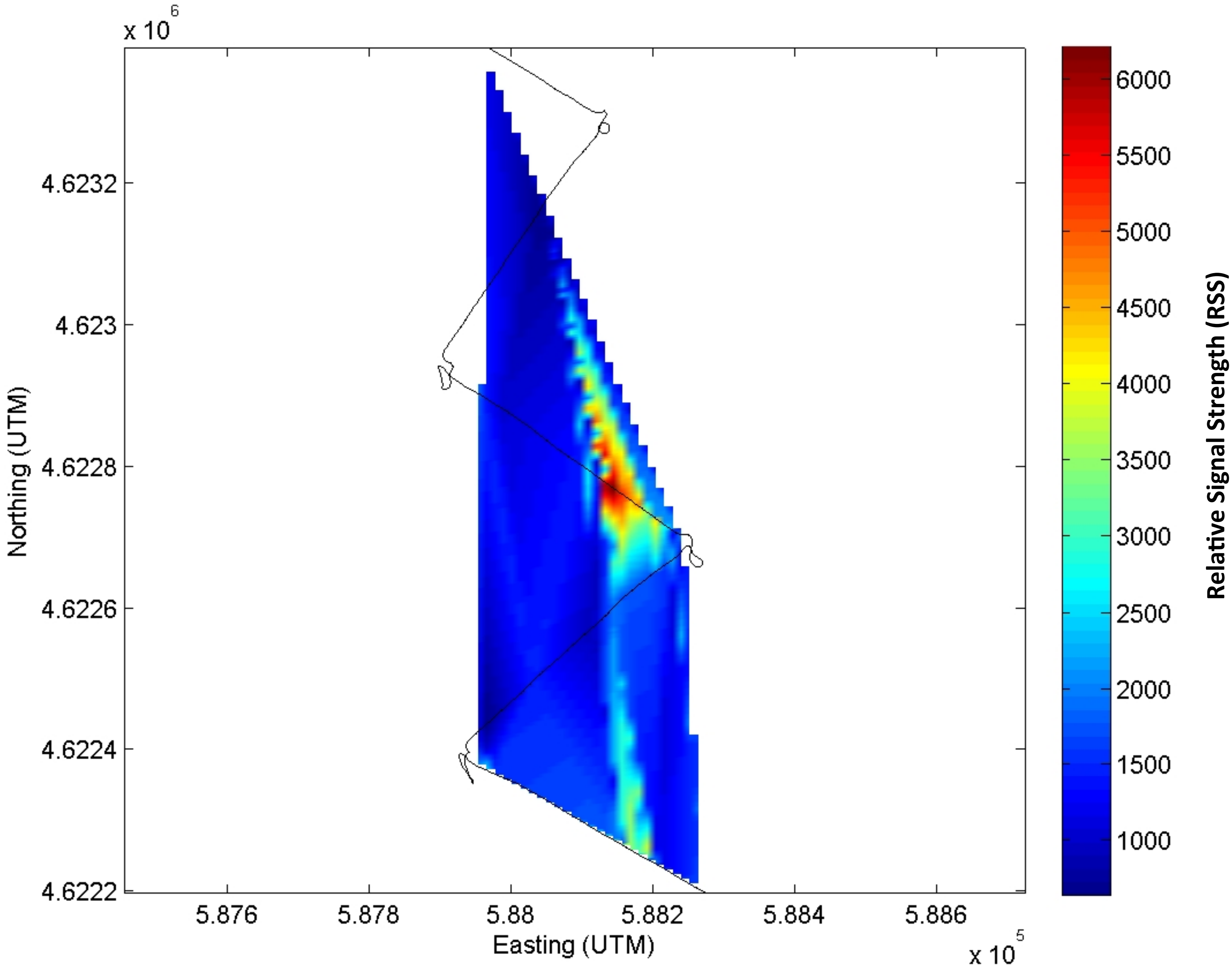
Atlantic croaker in lab won't mature under chronic hypoxia, but are found in hypoxic "Dead Zone".

Will hypoxia cost fish production?
Or
Can croaker find a way around chronic exposure?

Mapping Sound Pressure Level



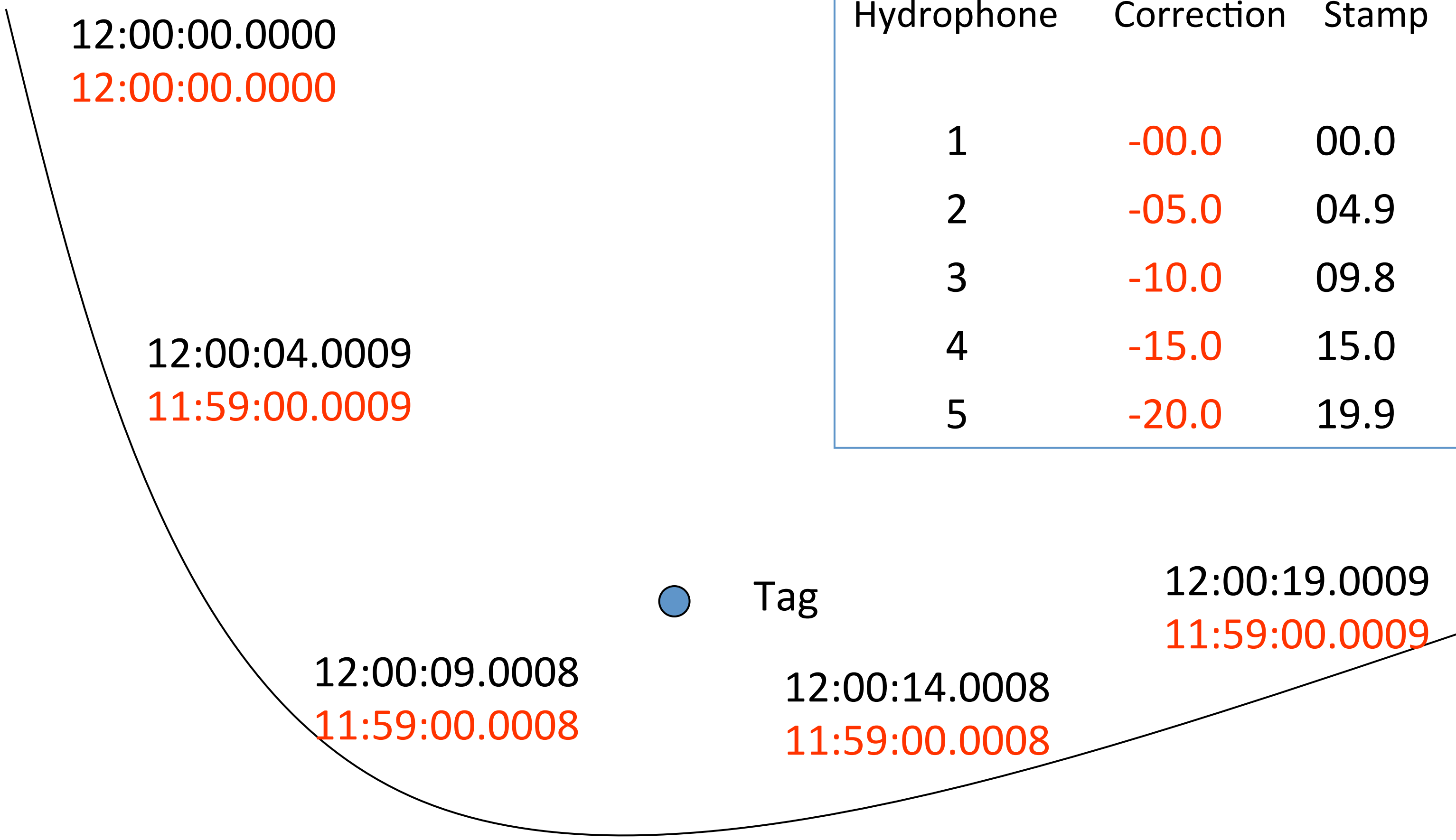


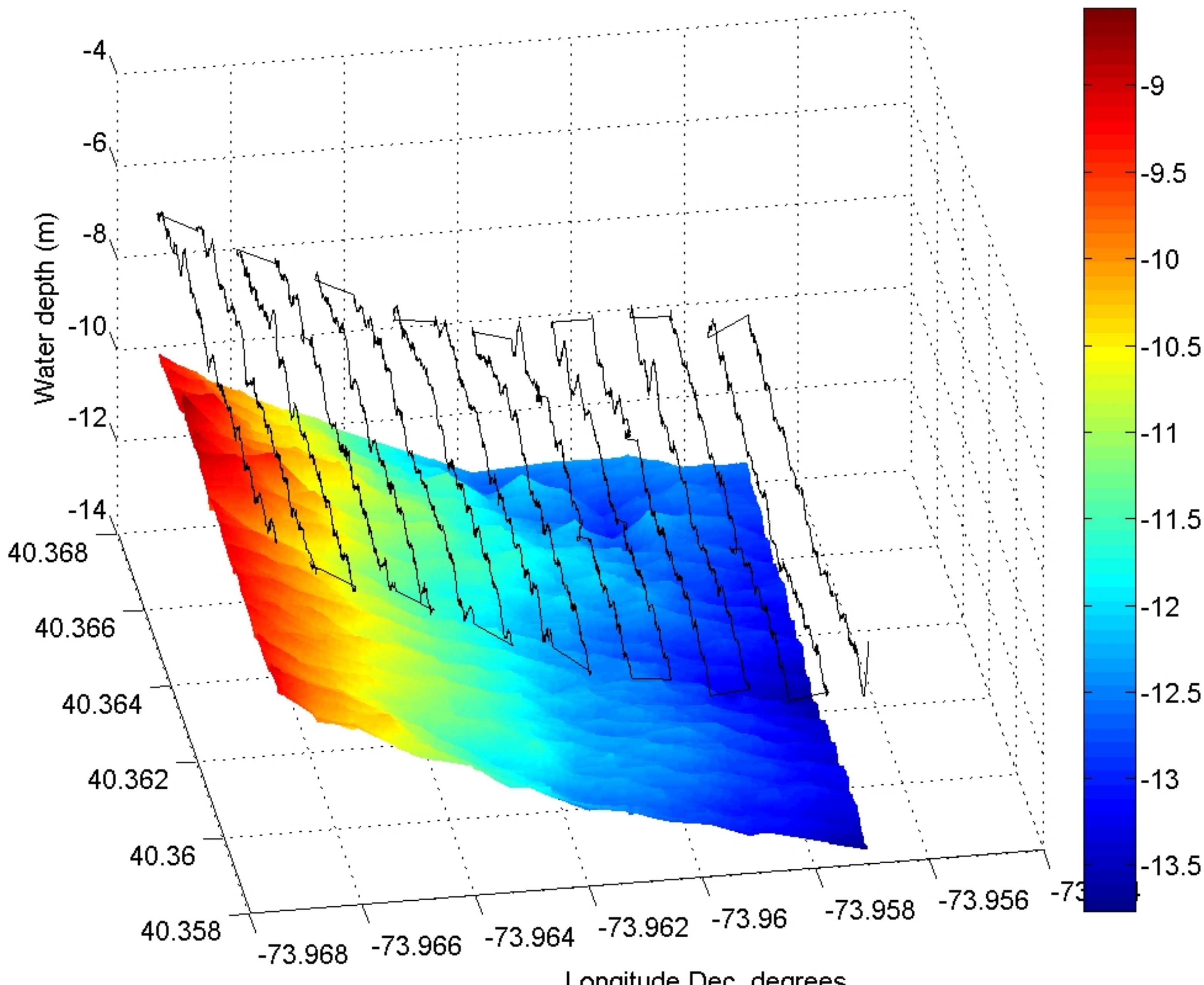


f Applications

Hyperbolic Positioning by Synthetic Aperture

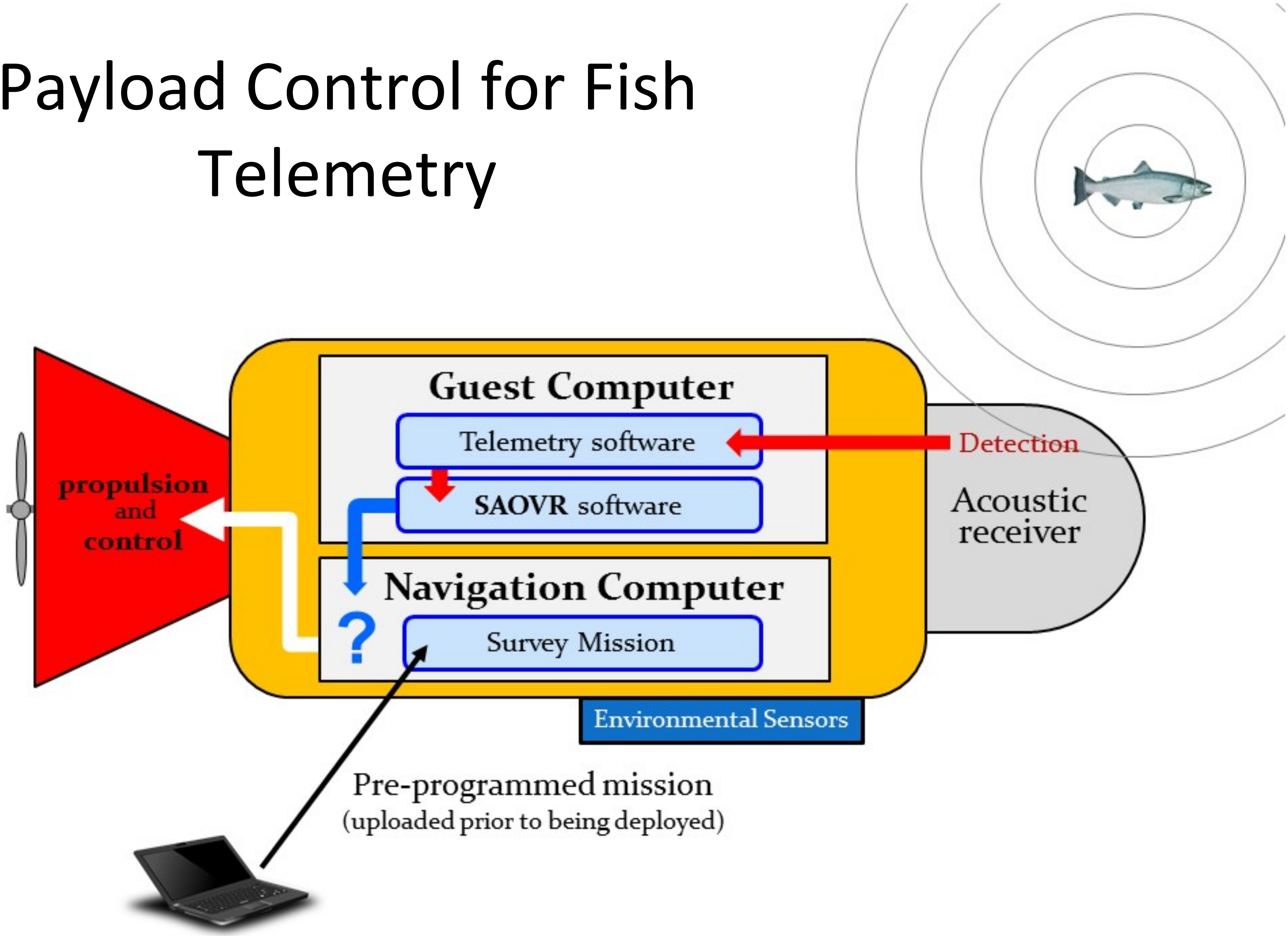
Synthetic Hydrophone	Sync Correction	Time Stamp	Difference from Expected
1	-00.0	00.0	00.0000
2	-05.0	04.9	-00.0001
3	-10.0	09.8	-00.0002
4	-15.0	15.0	00.0000
5	-20.0	19.9	00.0001





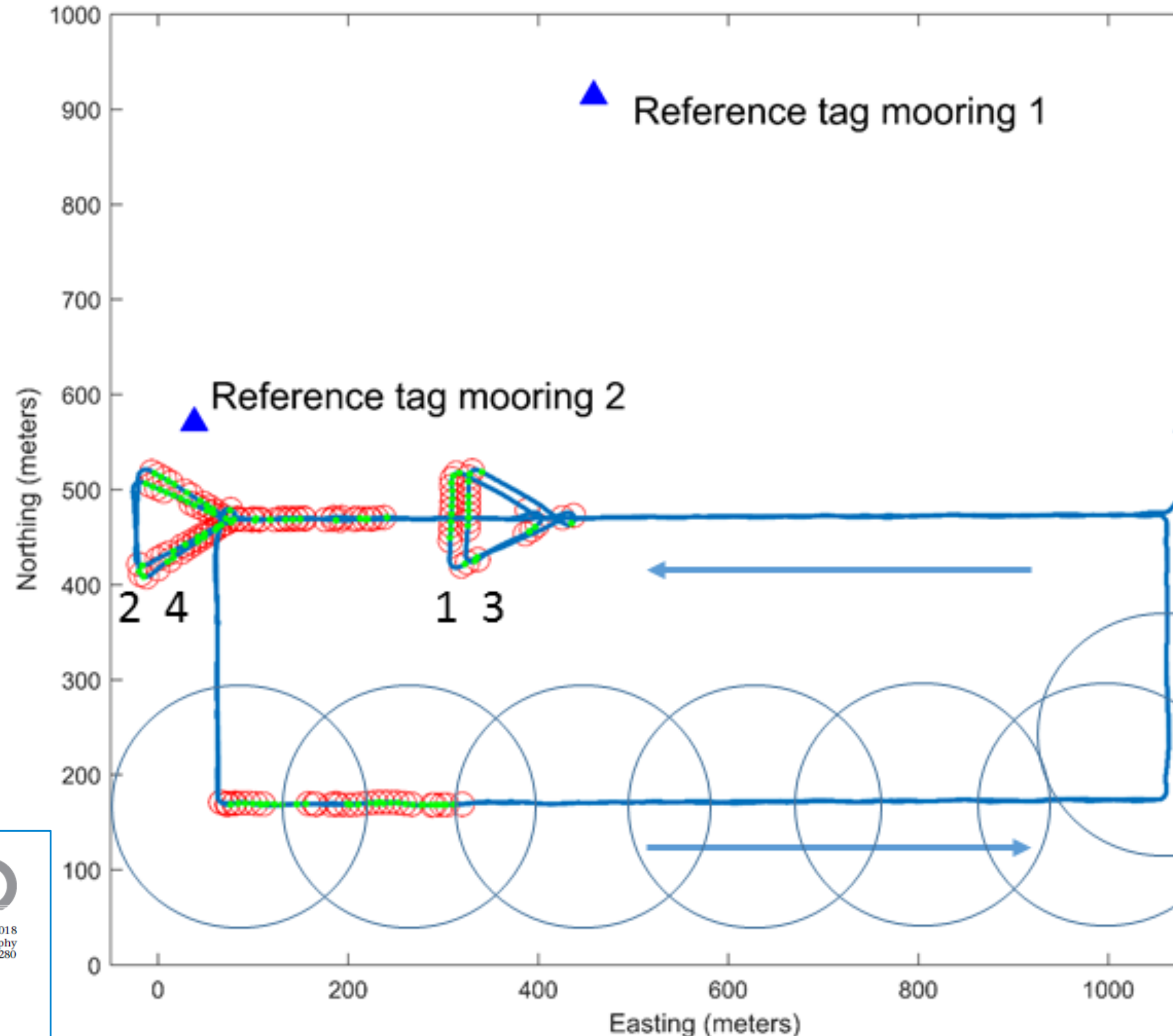
f Applications

Payload Control for Fish Telemetry



tag detection:
eck tag ID
elect appropriate maneuver template
ck timer re last maneuver on this tag
ck tag proximity by SPL proxy
ck timer re last maneuver on any tag
ck for start-up delay
ck position against exclusion zone
ck vehicle status
l go, execute chosen maneuver
tart tag and global timers

orward triangle maneuver chosen by
Search. Size is determined by animal type

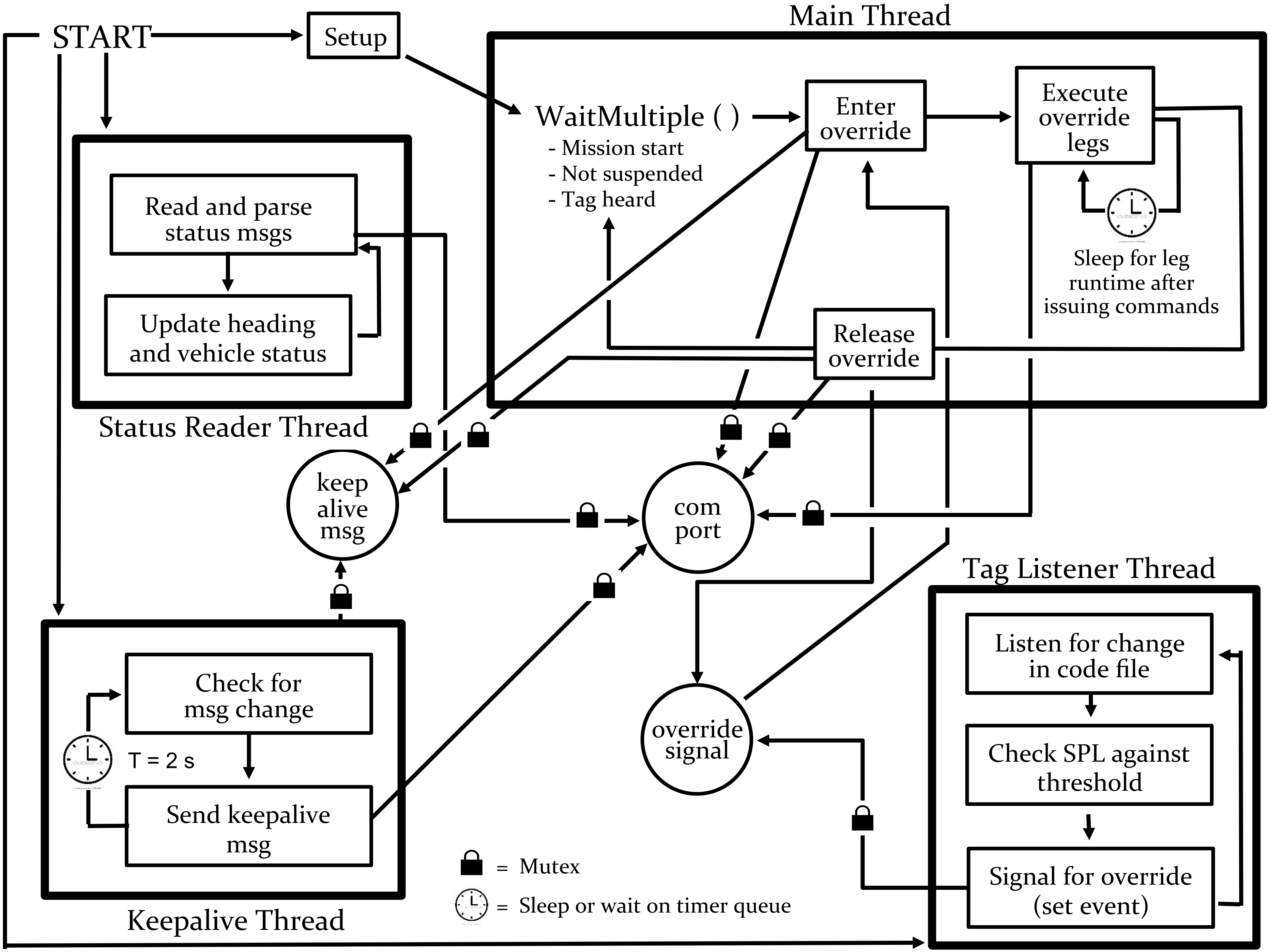


OGY
GRAPHY: METHODS
ASLO
Limnol. Oceanogr.: Methods 2018

doi: 10.1002/lom3.10280

lemetry payload control of an autonomous underwater mapping tagged fish

homas M. Grothues [2*], John H. Eiler,[3] Joseph A. Dobarro,[1] Rahul Shome[4]
ylvania Department of Physics and Astronomy, Philadelphia, Pennsylvania
Field Station, Tuckerton, New Jersey
sheries Science, National Oceanic and Atmospheric Administration, Auke Bay, Alaska
Department of Computer Science, New Brunswick, New Jersey


START
Setup
Main Thread
WaitMultiple ( )
- Mission start
- Not suspended
- Tag heard
Enter override
Execute override legs
Sleep for leg runtime after issuing commands
Release override
Read and parse status msgs
Update heading and vehicle status
Status Reader Thread
keep alive msg
com port
override signal
Tag Listener Thread
Listen for change in code file
Check SPL against threshold
Signal for override (set event)
Check for msg change
T = 2 s
Send keepalive msg
Keepalive Thread
= Mutex
= Sleep or wait on timer queue

Access

Administered as a NOAA-derived asset of the New Jersey Agricultural and Experimental Stations (NJAES)

Treated same as a Rutgers surface research vessel

Available on per-splash fee basis

With mission programmer and laptop support

With mobility/deployment/recovery support

Vessel support available

A real-life model for addressing CE challenges in application or as a development platform

– Payload control algorithms
– Constrained minimization search patterns
– Informed (Heuristic) search strategies
– Sensor development tests
– Real life tests of sonar or other acoustic classification algorithms
– Vehicle performance development
– Sensor data fusion
– Swarming/V2V linkage

Fee Structure

REMUS MISSION: $2000

- Assessed for each planned splash

MISSION PLANNING: $600/DAY

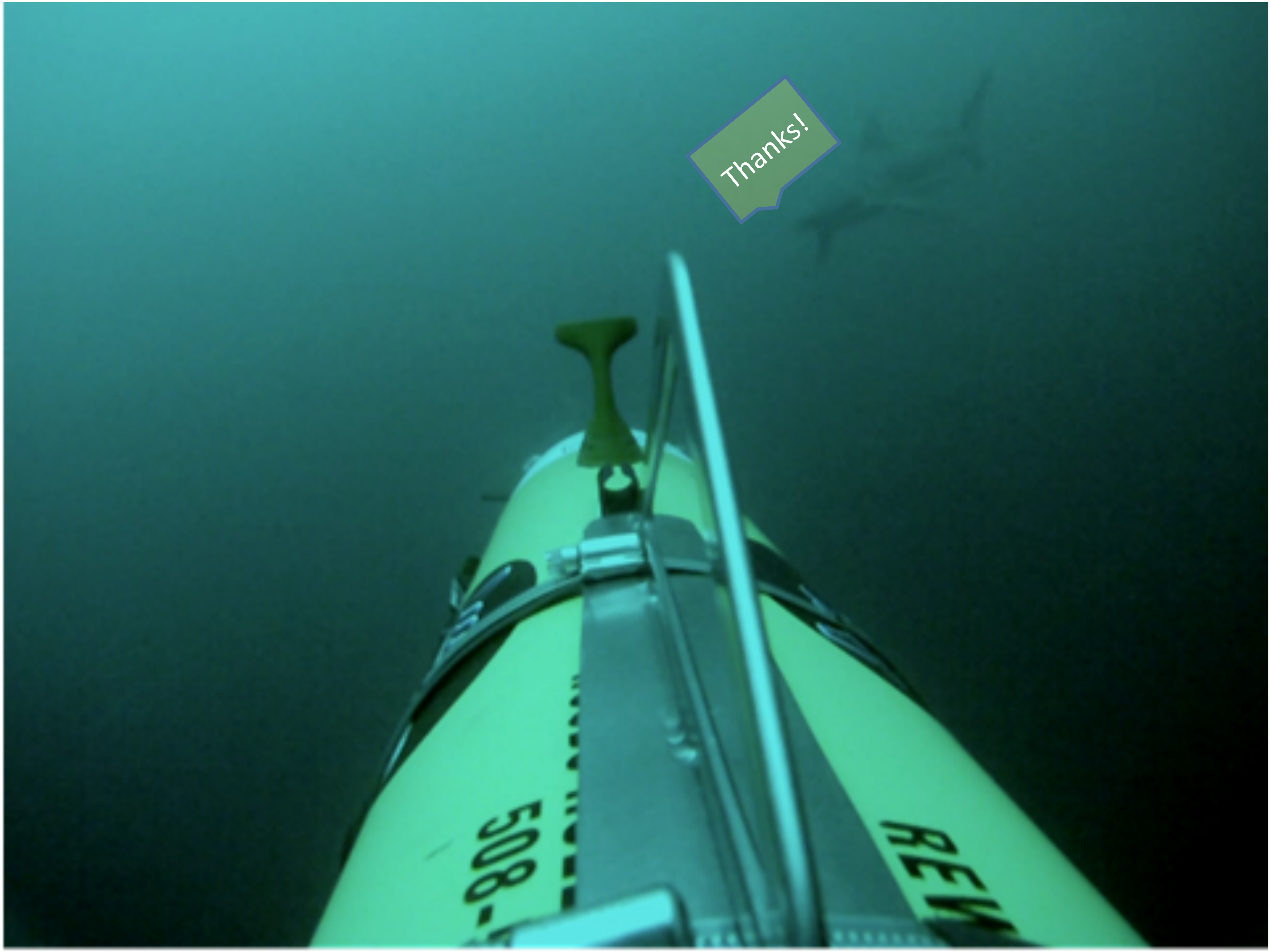
- Assessed when mission instructions to the AUV have to be written. Repetitive missions are assessed only single mission planning fee for the first mission of the series.

MISSION DATA PREPARATION: $400/DAY

- Assessed for every mission in which a REMUS support technician downloads and prepares gathered data a user.
- Includes the raw sensor data streams as well as the navigation and performance metrics in txt (csv) or MATLAB format.
- Side scan sonar is delivered as mst files and scanned for contacts.
- Data plotted relative to mission time, latitude, longitude, and depth.
- Not assessed to users who do not need data download service or plots of the vehicle path and performance. Data processing does not include analysis.

BENCH Fee: $50 per day

- Assessed when the AUV is being activated on the bench to test programming


Thanks!