

AUVs at MBARI

- Currently operate 2 Dorado Class vehicles
 - CTD Vehicle
 - Mapping Vehicle (D. Allan B.)
- One additional "mothballed" vehicle available
 - Previously used as the AUV docking test vehicle
 - Can be used for spare parts

Dorado Class AUV

- 21 inch diameter
- Length varies from 12 to 21 feet.
- Modular design
- Free flooded fairing
- Electronics are in discrete pressure housings
- Main vehicle computer (MVC) is housed in a 17" glass sphere
- Ducted tailcone for propulsion and steering
- Lithium ion or polymer rechargeable batteries





Dorado Class AUV

- Communication is via Freewave Ethernet link at surface (57kbps).
- Iridium telemetry capabilities (Short <u>Burst Data</u>)
- Ashtech DG16 GPS Receiver
- RD Instruments 300kHz Workhorse Navigator DVL
- Sonardyne USBL Transceiver for vehicle tracking.
- Strobe, RDF, Argos PTT, Homer beacon.
- Emergency dropweight (10 or 20 pounds).
- Benthos LF Acoustic Modem on Mapping Vehicle for subsea communication and position updates. (Model ATM-891, 8-15kHz)

(c) 2000 MBA

Dorado Class AUV

- Speed capabilities are from 2-4 knots.
- Turning radius of < 10 meters.
- Max dive rate is 30 meters/min.
- CTD vehicle depth limited to 300m because of optical instrumentation. Core components able to operate to 4000m.
- Mapping vehicle depth rated to 6000m.
- Able to operate on a variety of ships using various launch and recovery methods.

(c) 2000 MBA

Main Vehicle Computer (MVC)

- PC-104 format
- 300MHz Geode processor running QNX
- 12 port serial card
- 5 port ethernet switch
- Freewave radio modem
- Strobe and RDF boardsets
- Power supply board
- Backup batteries
- Autonomy computer



Tailcone Assembly





Vehicle Tethers



Low Current Charging and Copper Ethernet



High Current Battery Charging









Design Tools









Institutional Support

- Mechanical, electrical, and software engineers and technicians
- On site fully staffed machine shop (4 axis CNC mill capability, CNC lathe, abrasive waterjet, welding).
- 10 meter deep, 330,000 gallon saltwater test tank
- 3 ships with two ROVs.

Institutional Support









- We have operated these vehicles off of the following vessels using various launch and recovery mechanisms:
 - R/V Zephyr (MBARI)
 - R/V Western Flyer (MBARI)
 - R/V Spare Rhib (22ft. MBARI RHIB)
 - R/V Point Sur (MLML)
 - R/V Shana Rae (52ft. Fishing vessel)
 - R/V Sproul (Scripps)
 - R/V Thompson (UW)
 - R/V Atlantis (WHOI)
 - R/V Healy (USCG)









Testing and Tethered Operations



D. Allen B Mapping AUV



- Surface-aided during descent
 - Ship can perform other functions after touchdown
- 18 hour endurance/36 km² coverage
- Rapid turnaround of mapping products

Mapper Navigation

- Kearfott SeaDevil INS
- 24 cm Ring Laser Gyro
- RDI 300 kHz DVL
- Ashtech GPS Receiver
- Kalman Filter
- USBL position fixes pushed into Kalman over acoustic modem while diving
- Accuracy of 0.05% distance traveled with external aiding (ie. DVL in bottom track)



Mapper Mission Planning

- Interactive GUI in MB System.
- Operator defines box over imported bathymetry.
- Code generates lawnmower pattern, line spacing, and crosses based on user input.
- Drag and modify survey lines to user specs.
- Generates vehicle mission code with waypoints, speeds, behaviors, and sonar settings.



Sonar Data Products



Sonar Data Products



An area on the east side of the Axial caldera where several large sulfide chimneys were discovered on ROV ROPOS dive R1014, guided by this map. Scale bar is 50m.

El Guapo is one of the new chimneys found on R1014. It is venting water at 338 degC (640 degF) and stands 13m (43ft) tall, the largest active vent yet found at Axial.



CTD AUV

- Our "workhorse" AUV
- Performed ~3000km of UNATTENDED surveys in 2006
- Endurance of up to 22 hours (on 6kWhr)
- Turn around time of ~6 hours
- Typically flies a "yo-yo" pattern



Instrument Payload

- 2 SBE25 boardsets
- 2 SBE3 Temp Sensors
- 2 SBE4 Conductivity Sensors
- Paroscientific Pressure Sensor (UCB4000)
- SBE43 Dissolved Oxygen
- MBARI ISUS Optical Nitrate Sensor
- HobiLabs Hydroscat 2
- Satlantic OCR-507 Radiometer
- WetLabs ECO-CDOM Puck fluorometer
- BOT Laser Optical Plankton Counter
- Sequoia Scientific LISST-100
- Bathyphotometer (Jim Case Lab UCSB)
- 2 GEMS flow cells
- 2 SBE5T Pumps
- RD Instruments 300kHz Workhorse Navigator DVL
- Microstrain 3DM-GX1 Orientation Sensor
- 10 2 liter water samplers



Gulper

- Ten 2-liter samplers
- Syringe-like
- One-way valve through fairing
- Electromechanical pin puller actuated
- Samples analyzed after mission



CTD AUV Mission Planning

- Manual Mode
- Often modify existing missions
- New mission, receive waypoints or a box of interest from scientist
- Enter waypoints and survey line into electronic chart

CTD AUV Mission Planning

- Surfacing waypoint at least every 3300 meters (40 minutes at 3 kts)
- Sharp turns or landmass approach, break up leg into shorter segments
- Global definitions at top of file



Mission Behaviors

- Get GPS (acquire position fix)
- Setpoint (turn to heading, speed up on surface)
- Descend (usually to five meters)
- YoYo (to next waypoint)
- Ascend (at next waypoint)
- Repeat ...



Positions of the platforms today: Fri 24 Aug 2007

Moorings S	hips	AUVs
Mooring M0 (CIMT) Last updated: Thu Jun 21 10:13:19 2007 PDT Mooring M1 (OASIS) Last updated: Fri Aug 24 09:11:09 2007 PDT 236.67442	Last updated: Fri Aug 24 09:15:35 2007 PDT Latitude: 36.8021183 Longitude: -121.7871667 FLYER R// Western Flyer Last updated:	 DORADO Dorado - CTD Vehicle Last updated: Fri Aug 24 09:14:17 2007 PDT Vehicle time: 16:13:48 GMT Battery status: 5 29:53 3.57 2 29:54 3.60 2 29:69 3.66 2 Latitude: 36.712316 Longitude: -121.857388

Data Processing

Lauvetd] Survey Dorado389_2007_267_04_267_04 processed - Message (Plain Text)		
Eile Edit View Insert Format Tools Actions Help		
😂 Reply 🖓 Reply to All 🙈 Forward ᢖ 🐚 😼 🔻 🍅 🎦 🗙 🗢 🔻 🖈 🛧 🖓 🖓		
From: SSDS Admin [ssdsadmin@elvis.shore.mbari.org] Sent: Tue 9/25/2007 6:07 PM		
To: AUV CTD Project Discussion List		
Cc		
Subject: [auvctd] Survey Dorado389_2007_267_04_267_04 processed		
Hello,		
MEV survey Doredo380 2007 267 04 267 04 beginning on 24-Sen-2007 hes been processed		
Below are the science data products now available for review:		
Quick look plots:		
- http://ssds.shore.mbari.org/auvctd/surveys/2007/images/Dorado389 2007 267 04 267 04 biolume.png (fixed contour limits)		
- http://ssds.shore.mbari.org/auvctd/surveys/2007/images/Dorado389 2007 267 04 267 04 2column.png (free		
contour limits)		
- http://ssds.shore.mbari.org/auvctd/surveys/2007/images/Dorado389 2007 267 04 267 04 nav adjust.png		
- http://ssds.shore.mbar1.org/auvctd/surveys/2007/images/Dorado389 2007 267 04 267 04 hist stats.png		
Full resolution matlab data file: - http://ssds.shore.mbari.org/auvctd/surveys/2007/mat/Dorado389 2007 267 04 267 04.mat it's NetCDF counterpart (via OPeNDAP URL): - http://dods.mbari.org/cgi-bin/nph-nc/data/auvctd/surveys/2007/netcdf/Dorado389 2007 267 04 267		
04.nc.html		
Decimated NetCDF file (sampled at the ISUS or 2 sec sampling frequency) with all variables interpolated to the same time axis: - http://dods.mbari.org/cgi-bin/nph-nc/data/auvctd/surveys/2007/netcdf/Dorado389 2007 267 04 267 04 decim.nc.html		
Decimated Ocean Data View import data file:		
- http://ssds.shore.mbari.org/auvctd/surveys/2007/odv/Dorado389 2007 267 04 267 04.txt		
The above web links are a mapping from the <u>\\tornado\auvctd\surveys\2007</u> directory. You may get the data from this network share, the above URLs, or from HOOVES.		
The processing log output:		
- http://ssds.shore.mbari.org/auvctd/surveys/2007/logs/Dorado389 2007.267.04 267.04 diary.log		
The link(g) below will give you access to the original deployments, the processing store, and associated		
metadata via HOOVES:		
http://predator.shore.mbari.org/hooves/launch.cgi?dep1=2007.267.04		
- AUVprocess main run by ssdsadmin on elvis.shore.mbari.org at 25-Sep-2007 18:07:24		

Data Products





Survey Dorado389_2007_211_02_211_02



Data Products















Lessons Learned

- USBL Frequency
- Reset dropweight
- Missing Syntactic
 Foam
- Stand off Survey Line

- Cock the Gulpers
- Check and recheck mission scripts





On-going Work

- New blunt nose and midsection for Mapper with the addition of a second battery (18 hr endurance)
- Flyaway LARS system for ships of opportunity
- Tailcone actuator upgrade brushless DC motors
- Low power ARM9 processor as MVC
- Deliberative Autonomy project
 - Will allow realtime onboard mission updating and planning
 - Goal oriented mission planning
 - Runs on a separate processor



As a private, non-profit research center, MBARI is funded by **The David and Lucile Packard Foundation**.

Team Dorado



Get GPS Behavior

```
# acquire gps fix
behavior getgps {
duration = 600;
minHits = 30;
abortOnTimeout = True;
}
```

Setpoint Behavior

setpoint on surface to gather momentum

behavior setpoint {

duration = 30;

heading = 244;

speed = 1.5;

verticalMode = pitch;

pitch = 0;

}

Descend Behavior

Descend behavior to 5 meters

behavior descend {

horizontalMode = heading;

horizontal = 244;

pitch = -15;

speed = 1.5;

maxDepth = 5;

duration = 60;

}

Waypoint Yoyo Behavior

waypoint behavior

# Aiming for Wa	ypoint C1 - The End			
behavior waypoint_yoyo {				
latitude =	36.7960;			
longitude =	-121.8500;			
captureRadius = 10;				
duration =	3000;			
speed =	1.25;			
minDepth	= 3;			
maxDepth	= 175;			
minAltitude	= 20;			
maxCycles	= 1000;			
}				

Ascend Behavior

ascend behavior behavior ascend { duration = 1200; horizontalMode = rudder; horizontal = 10; pitch = 30; speed = 1.25; endDepth = 2; }

Mapping Missions to Date

- Monterey Canyon time series (repeat surveys)
- MARS cable route survey
- Davidson Seamount

- Axial Seamount
- Barkley Canyon
- Big Sur (Santa Lucia Canyon)
- Dana Point
- Santa Monica Basin
- Point Conception

