WHOI SDSL Data-Link

A Cruise-proven WHOI Development

Providing Ethernet on UNOLS Sea Cables

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WOODS HOLE OCEANOGRAPHIC INSTITUTION

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What could you do with Ethernet on your sea cable?

- Real-time LADCP?
- Water-column imagery?
- Plankton counter?
- Bottom camera?
- ROV communications?

SDSL Technology on Existing Sea Cables

- SDSL on long sea cables was first observed with Dr. Drew Remsen's SIPPER profiler (Univ. South Florida) onboard Knorr in 2008.
- WHOI designed and developed a prototype telemetry instrument ("Data-Link") using this technology during 2009.
- Prototype proven at sea onboard two Atlantis cruises in Fall 2009.

SDSL Data-Link Features

- Delivers data rates on existing 3-conductor A301592 (UNOLS CTD) cable > 40x greater than previously known methods.
- Proven compatible with SBE9/11/32 in simultaneous operation.
- Uses established technology and off-the-shelf parts.

Why continue to use Rochester A301592 Sea Cable?

- UNOLS has significant experience with this 'standard' 3-conductor sea cable.
- Available on many UNOLS vessels.
- Reliable operation with SBE9/11/32 CTD/sampler systems to beyond 10km on single conductors.

… But the cable has some significant telemetry limitations

- Attenuation limits ‘traditional’ telemetry rates to ~ 19kbits/sec on long cables.
- SeaBird 9*plus* CTD data DSPK telemetry at 34560Hz provides ~ 9.2kbits/sec over at least 10km.
- SeaBird 9*plus* option 9p11 serial data uplink provides maximum 9.6kbit/sec uplink- limited to 8km.

Symmetric Digital Subscriber Line Technologies

- Provides wideband digital telemetry over one or more copper pairs.
- Uses 4kHz frequency bins from 4kHz to 2.6MHz.
- Adaptively selects bins to optimize signal quality in presence of noise and cross-talk.

SDSL vs SHDSL

- SDSL equipment in field use for years, uses proprietary standards.
- SHDSL defined by more recent ITU 991.2 standards, allows multiple vendors.
- Updated Symmetric High-speed DSL (SHDSL) improves on SDSL data rates.

Evaluations on WHOI 7.4km Test Sea Cable

- Both SDSL and SHDSL were tested at WHOI on 7.6km test sea cable.
- SDSL prototype tested >800kbits/sec.
- SHDSL tested to 1.7Mbits/sec with 4msec latency using simultaneous bidirectional traffic.

Prototype Selection

- Due to size, an SDSL pair were selected for prototype and extensively tested in lab.
- ‘Provider’ unit used in lab, ‘Subscriber’ unit used in prototype.
- Multiple Moxa 5210 serial servers used for RS232 ports.
- Panasonic NTSC video server for images.
- WHOI designed and built wide-range power supply for internals, SBE9/32 and LADCP.

Using SDSL with SBE9, SBE11 and SBE32 - Two possible modes of operation:

- Use two RS232 serial ports on SDSL Data-Link to uplink SBE9 data and control the SBE32 in real time,

  or

- Operate the SDSL concurrently with SBE9/11/32 telemetry on sea cable.

Serial operation requires SBE9*plus* and SBE32 upgrades

- SBE9*plus* upgrade option 9p11 allows CTD to be powered externally and to directly output RS232 serial data.
- SBE32 with firmware ver 1.0C upgrade enables +15V power to SBE32 and full bidirectional RS232 control and replies.
- SeaSave ver 7+ software demonstrated fully compatible with these upgrades over SDSL.

First Applications Considered

- Uplink and control LADCP in real time
- Video feed from WHOI DSPL cameras on Towcam or rosette.
- Acquire TETHYS mass-spectrometer data on rosette.

SDSL Prototype Concept

- External battery powered.
- Full ocean depth pressure case.
- Provide serial and video link to rosette-mounted equipment.
- Demonstrate performance and SBE9/11/32 compatibility on cruises in 2009.

SDSL Prototype Minimum Requirements:

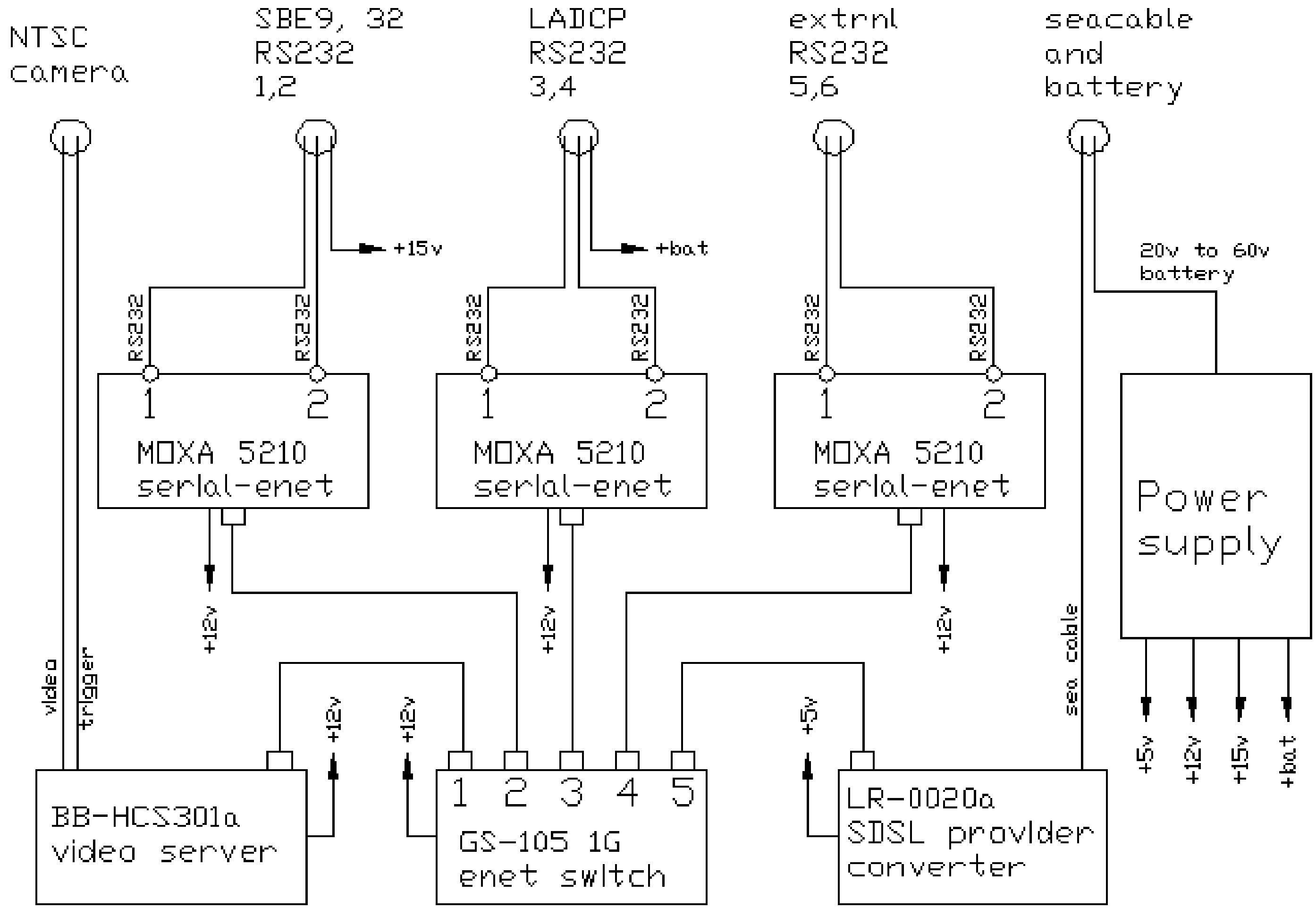
- Easily installed on existing SBE and WHOI rosettes.
- < 1A from 20V to 60V from external battery.
- Provides two to six bidirectional RS232 ports and NTSC video uplink.
- Must operate without interference to existing SBE9/11/32.

SDSL Data-Link Prototype Configuration

- Underwater unit housed in 6-in ID aluminum housing tested to 7000dbar.
- Multiple serial ports for two LADCPs, SBE9, SBE32 and other devices.
- Video server for NTSC uplink.
- Onboard power supply supports hotel load plus LADCP and SBE9/32 from external battery.

SDSL Data-Link Prototype

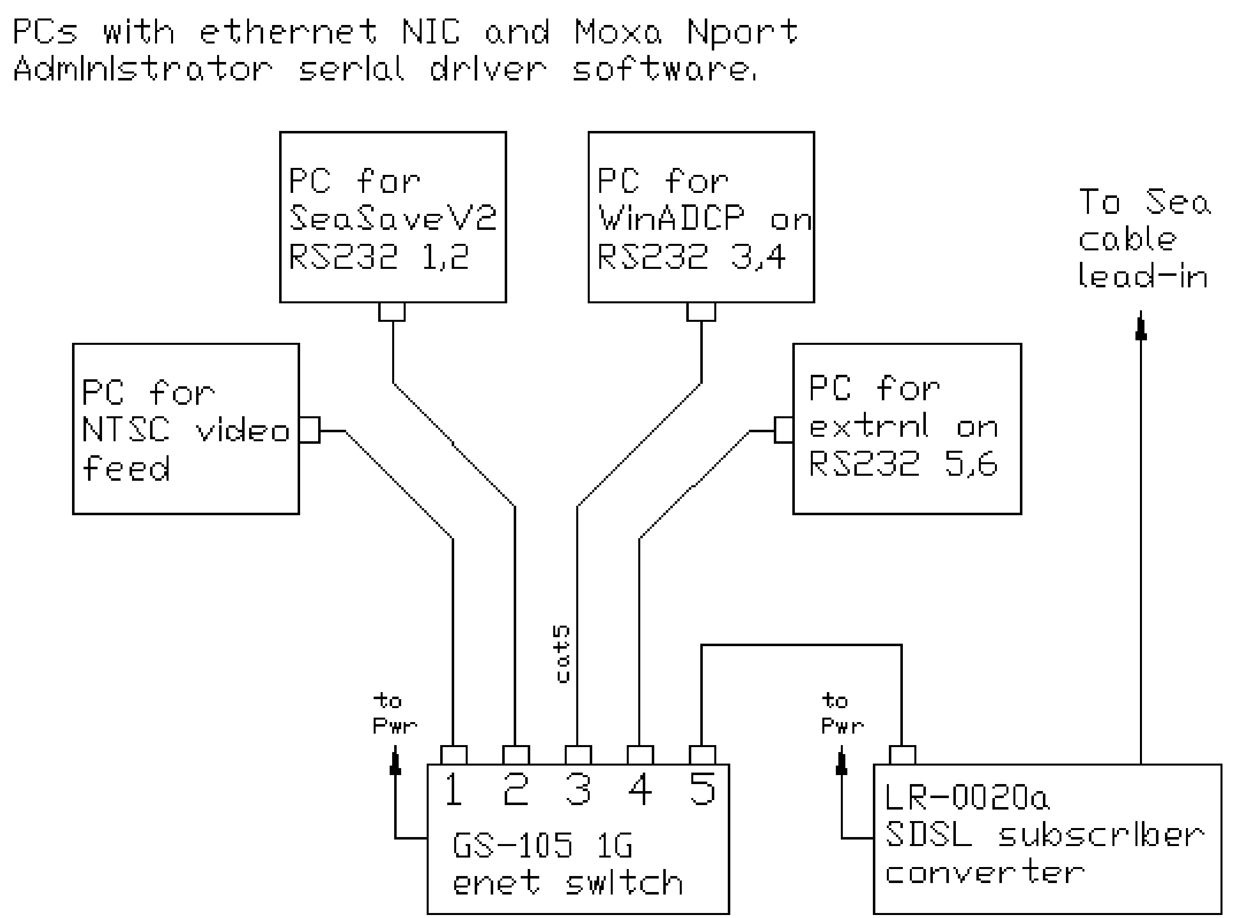
- Inside 6-in ID AL pressure case.
- Simple chassis fabrication.
- Pressure tested 7000dbar.



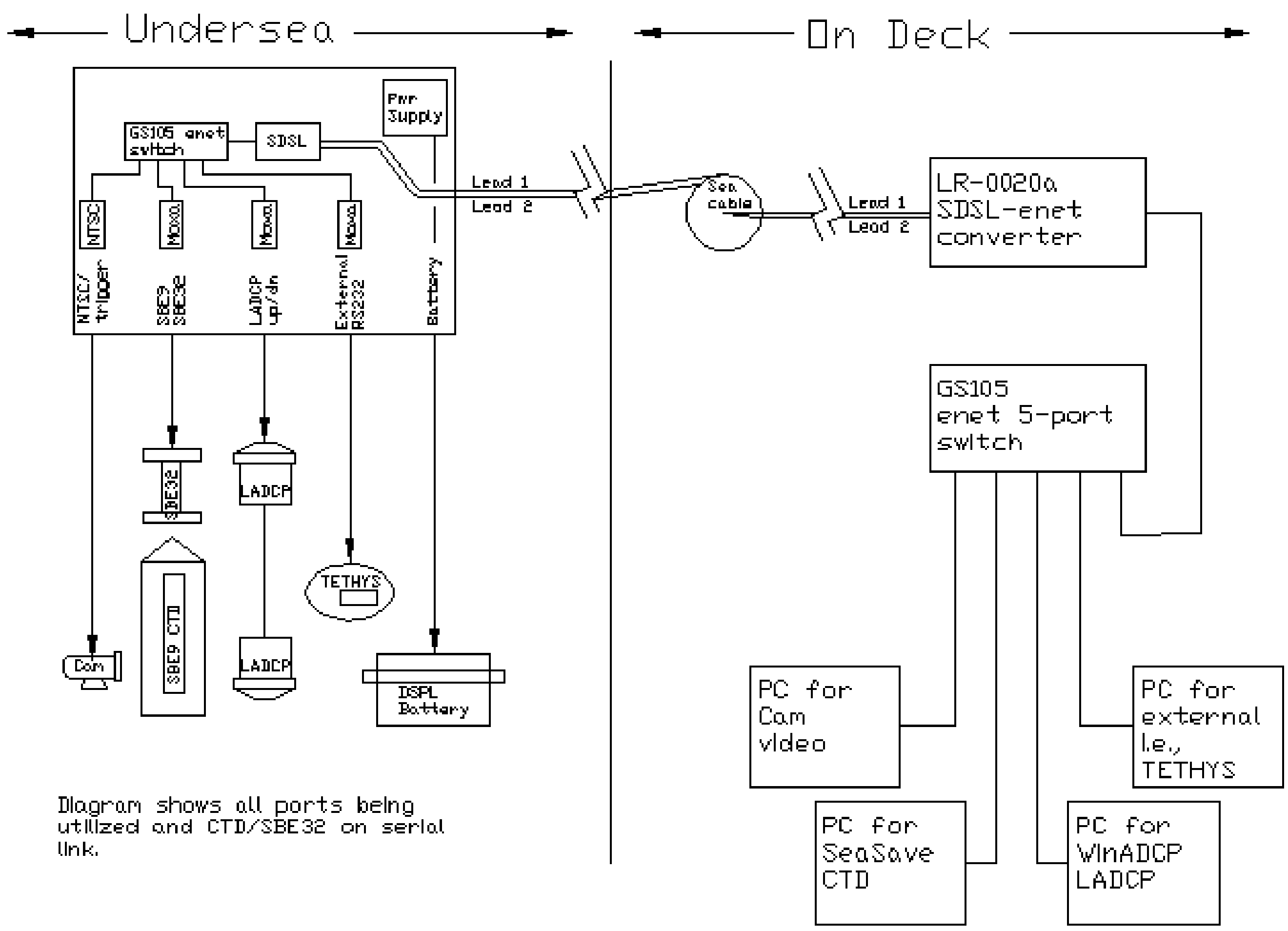
SDSL Data-link Underwater Unit Topology

SDSL Lab Configuration

- SDSL Provider unit attached to sea cable lead pair in lab.
- Network switch links acquisition computers.
- Not connected to ship's network to keep traffic to a minimum.
- User-provided computers for dedicated applications (SBE SeaSave, LADCP WinADCP, TETHYS, etc)



SDSL Data-link Top-side Topology



SDSL Data-link Block Diagram

Test Results on Atlantis Cruise AT15-52 (Valentine)

- First ever use was with Dr. Richard Camilli's TETHYS mass-spec on Atlantis rosette.
- SBE9/11/32 system used without modification or operational changes.
- Provided real-time methane and other trace gas in water column.
- Installed in 10 minutes, worked without failure on 26 consecutive CTD stations.

View of TETHYS mounted on Atlantis Rosette

Value of SDSL Data-Link on AT15-52

“The SDSL Data-Link provided a quantum improvement for water column profiling operations. I'm confident that it will be transformative for many other types of operations involving a sea cable. Hopefully the SDSL Data-Link technology will become a standard facility aboard all WHOI ships.” - Dr. Richard Camilli, WHOI, personal communication.

Atlantis Cruise AT15-54 (Soule/Lizarralde)

- Installed with RDI WHS-300 LADCP and DSPL camera on Atlantis rosette.
- Used with sidescan and Towcam.
- Successful initial tests pushed camera and Data-Link into immediate use.
- Unmodified SBE9/11/32 used concurrently with SDSL Data-Link, no errors in either system.

Atlantis SBE Carousel as used on AT15-54

SBE32 pylon

WHOI Video Jbox

Benthos 383 Strobe

WHOI SDSL Data-Link

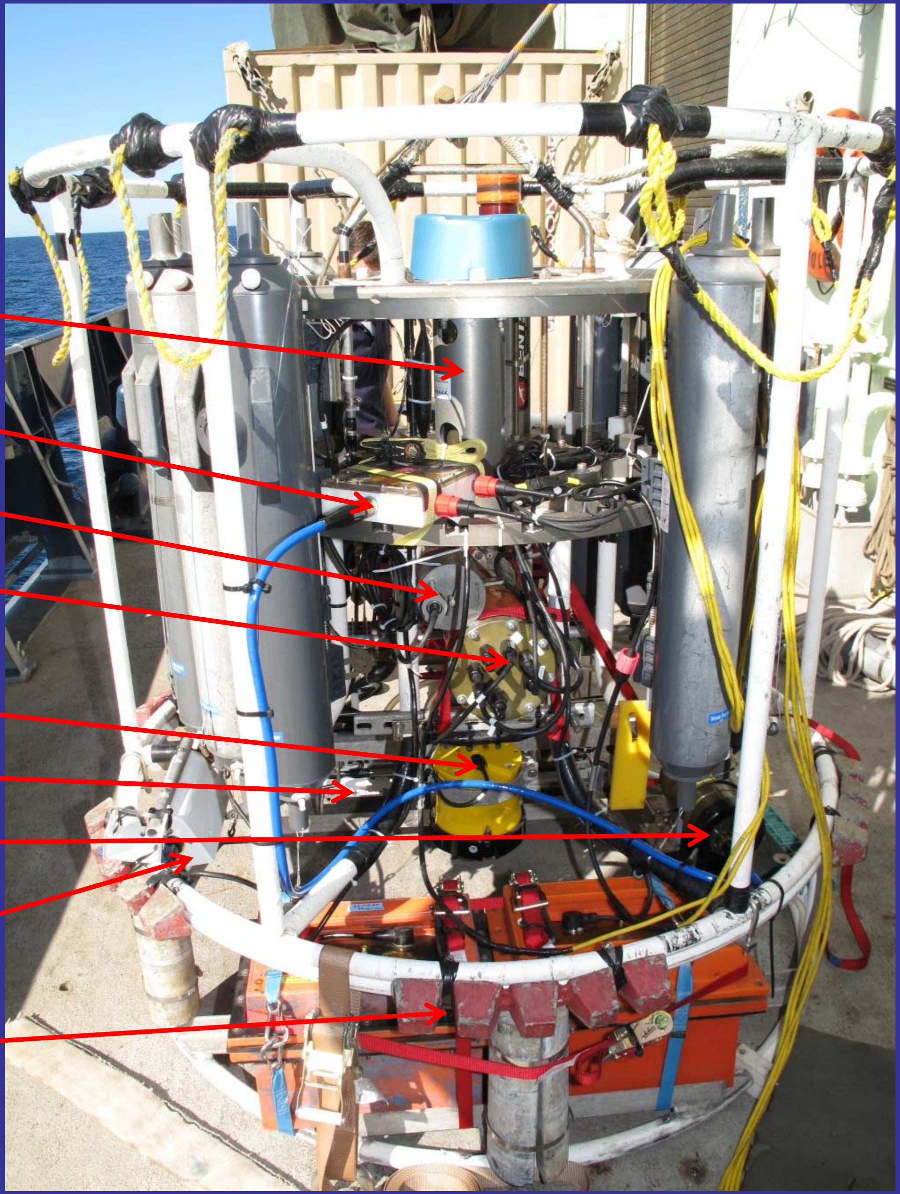
LADCP

SBE9 CTD

DSPL Camera

Benthos 386RH Flash Head

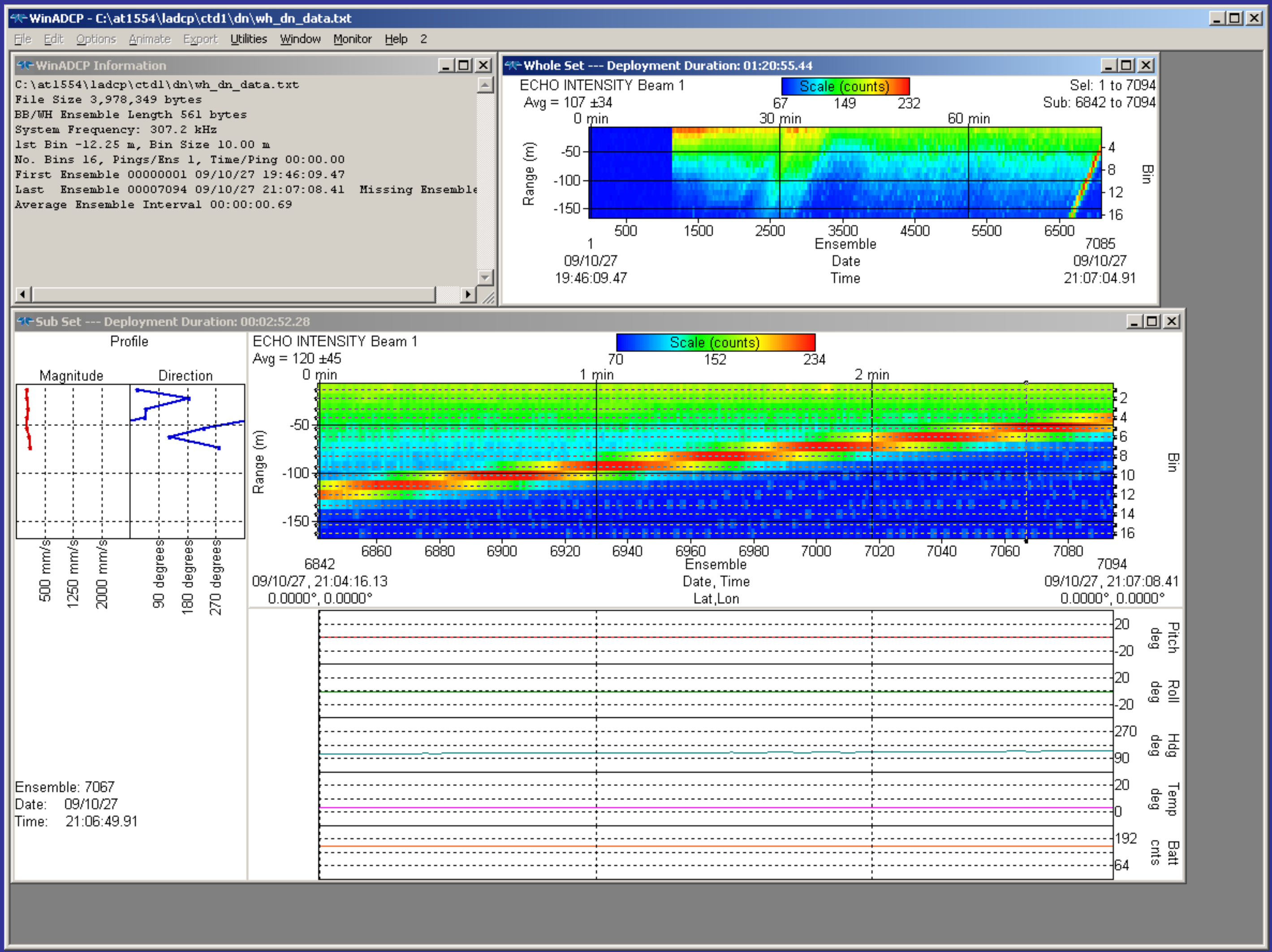
DSPL 24 and 48V batteries



AT15-54 LADCP Test Results

- Four stations of water-track and bottom-track mode LADCP data were acquired.
- Successfully switched between modes during station.
- Successfully monitored package dynamics (heading, pitch, and roll) during station.
- Comparison between uplink real-time and stored data showed no errors.
- Comparison of different bottom track modes now possible.
- In-situ compass calibrations now possible.
- Use of real-time LADCP data may eliminate need to download for closely spaced LADCP stations.

WinADCP Screenshot

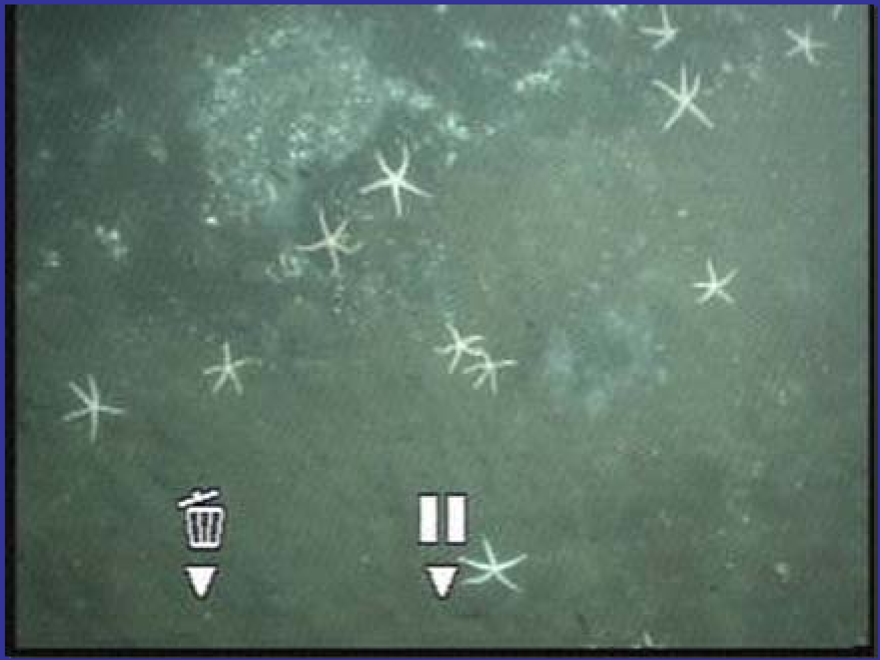


AT15-54 DSPL Camera Results

- WHOI MISO (Towcam) DSPL Nikon 995 camera used on nine stations to find features.
- Camera viewfinder (640x480) uplink used to verify imaging quality.
- Camera downloaded after station to provide stored images of highest quality.
- Uplinked images proved useful for determining whether to continue local survey or move on to next site.

Comparison of SDSL Uplinked to Stored Camera Image

SDSL Uplink from Camera (11kB JPG)



Downloaded from Camera Memory (287kB JPG)

Value of SDSL Data-Link on AT15-54

"As inclement weather prevented our surveying operations using the fiber optic cable on R/V Atlantis, our only option to continue working was to deploy a deep-sea digital camera mounted on the rosette from the CTD cable. Our imaging operations required us to have a real-time view of the seafloor so that we could precisely locate our targets."

Value of SDSL Data-Link on AT15-54 (cont'd)

"Without the SDSL Data-Link, our operations would have been severely handicapped. The real-time images that were passed up the wire were more than sufficient for us to recognize what we were seeing on the seafloor." – Dr. Adam Soule, Co-chief Scientist.

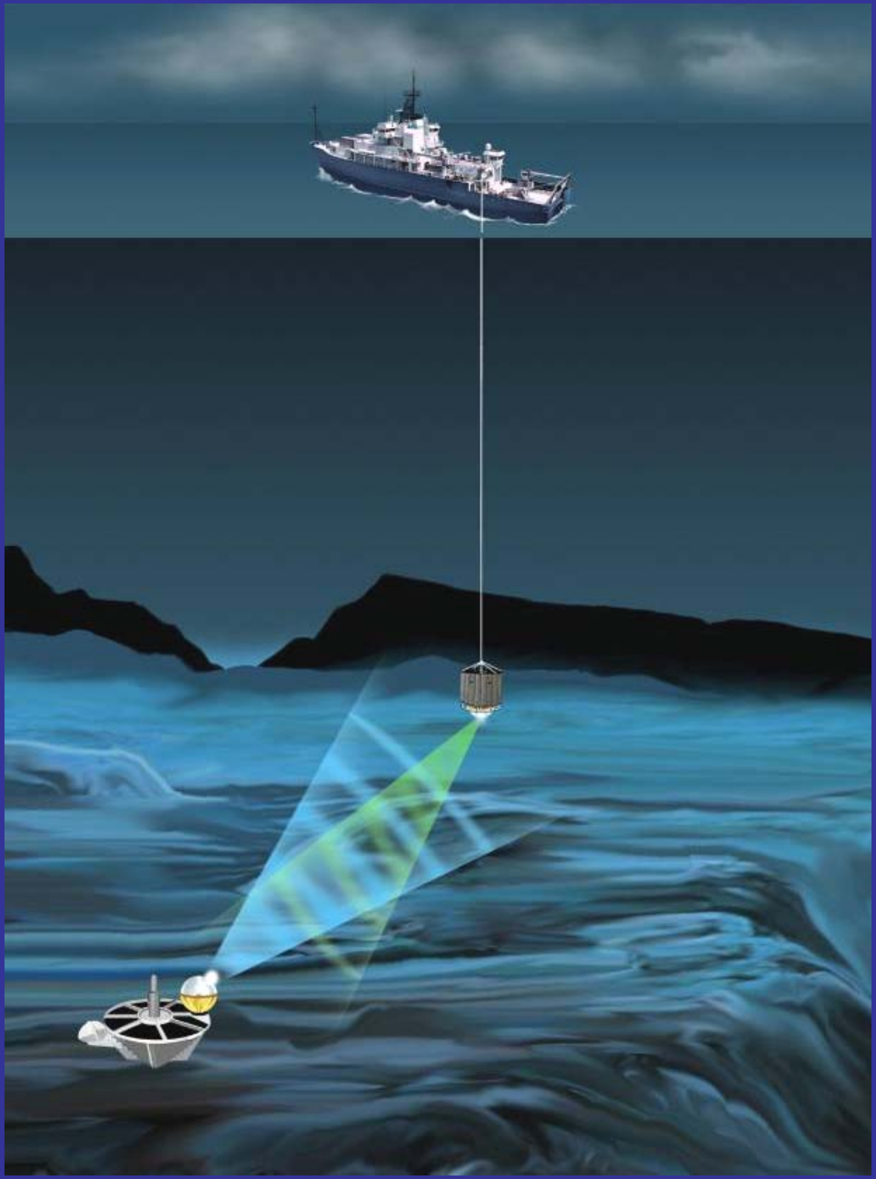
Future – KAUST Brines Research

- King Abdullah University of Science and Technology (KAUST) Red Sea Brines Research use with WHOI High-Range NCTD.
- HRNCTD serial data output requires high-speed of SDSL Data-Link.
- RS232 control permits targeted brine sampling with MacLane pumps.
- Supports use of video system on rosette.

Future – Un-Tethered ROV (UTROV)

- WHOI-developed *Nereus* Hybrid ROV (HROV) and similar vehicles can be used on extended missions.
- Missions require efficient data offload from HROV without resurfacing.
- Relatively few ships with fiber optic cables severely limit options for deployment and support.

- Long-range optical modems, combined with the SDSL Data-Link can provide an efficient method for data recovery.
- Using SDSL Data-Link, the number of ships available to support HROV operations is greatly increased.



Implementation Issues Critical to SDSL Data-Link Success

- Sea Cable Qualification
- Technician Support
- Power Supply for Client Instruments

Implementation Issues - Sea Cable Qualification

- All three conductors must be individually isolated and separate from the armor. Bonding of any two or three conductors anywhere in the circuit will not permit SDSL telemetry to be established.
- Sea cable and slip rings must have all three circuits meeting minimum electrical specifications.

Implementation Issues - Sea Cable Qualification (cont'd)

- SDSL tests suggest lead to lead and lead to armor insulation resistance > 1Gohm at 5 minutes at 500VDC.
- Internal conductor circuit resistance (sea cable, slip ring and lead in) should be less than 330 ohms on a 10km cable.

Implementation Issues - Technician Support

- Shipboard technicians should have ability to diagnose and maintain sea cables to specifications.
- Users should expect that every A301592 cable can provide three working circuits.
- Unknown or unstable condition of A301592 cable, slip rings and lead in on other ships may be issue.

Implementation Issues – Technician Support (cont'd)

- Automated cable testers and digital TDRs shown to help provide reliable, repeatable measurements.
- WHOI has spent significant time and funds to assure all WHOI ships have working sea cables and test equipment.

Implementation Issues – Power Supply

- SDSL Data-Link prototype and client instrumentation require external battery power.
- SDSL Data-Link prototype consumption approximately 22W- easily battery supported.
- Prototype provides 'pass-through' power to LADCP at external battery voltage.
- WHOI investigating tradeoffs for powering SDSL + client instruments on cable.

SDSL Data-Link Benefits

- Inexpensive, off-the-shelf technology.
- Easy to understand, operate and maintain.
- Provides at least 40x data throughput increase using existing UNOLS 3-conductor CTD cables.
- Fully compatible with existing SBE9/11/32 and SBE25/33 CTD telemetry.
- Extends the NSF dollar when used in place of fiber optic cables for some applications (Towcam, TETHYS)

Next Steps for SDSL Data-Link

- Prepared paper for publication.
- WHOI building second NSF funded unit.
- WHOI testing updated SHDSL and VDSL units for specific applications.
- SeaBird has been kept informed of the developments to assure compatibility.
- WHOI can build additional units and provide engineering services to support roll-out to the UNOLS fleet, if funded.

The SDSL Data-Link has been made possible by:

- Development team:
  - Marshall Swartz, Daniel Torres and Robert Millard, WHOI Physical Oceanography Dept.
  - Steven Liberatore, WHOI Applied Ocean Physics & Engineering Dept.
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