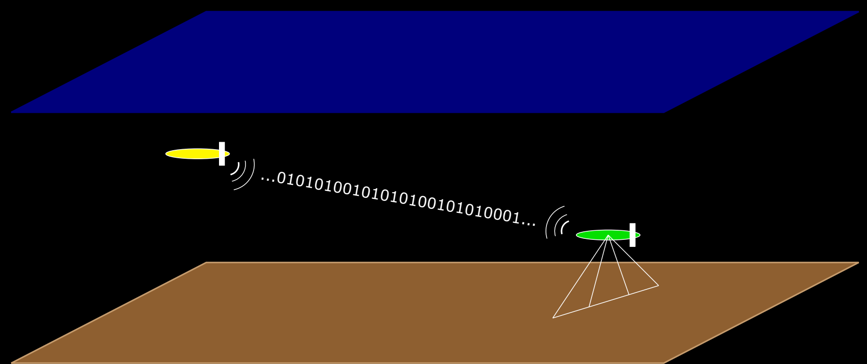
Goby-Acomms version 2:

extensible marshalling, queuing, and link layer interfacing for acoustic telemetry



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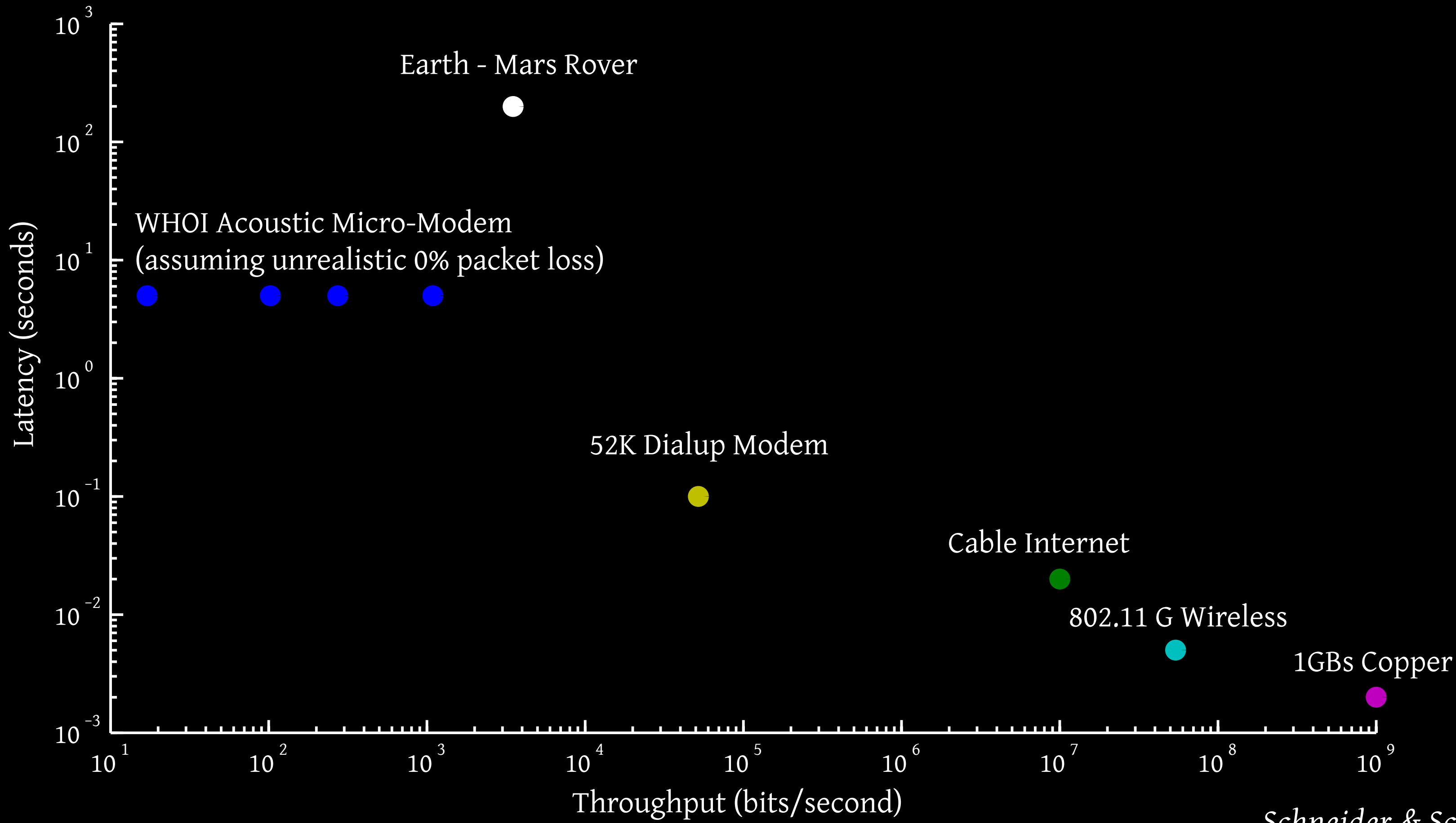
Problem

1. Many marine communication links (often acoustic) are extremely rate-limited (as low as 32 bytes / minute) with high latencies (seconds to minutes or more).



Problem

1. Marine communication links are low throughput and high latency.

2. Marine robots are increasingly used collaboratively: need to send positions, health, sensor data, commands, state, etc.

3. Research at sea demands robust & reconfigurable software.

How can we design a networking framework that satisfies these constraints?

Modular design with emphasis on efficiency instead of abstraction and where complexity is layered on simplicity.

Why not Internet Protocol (IP)?

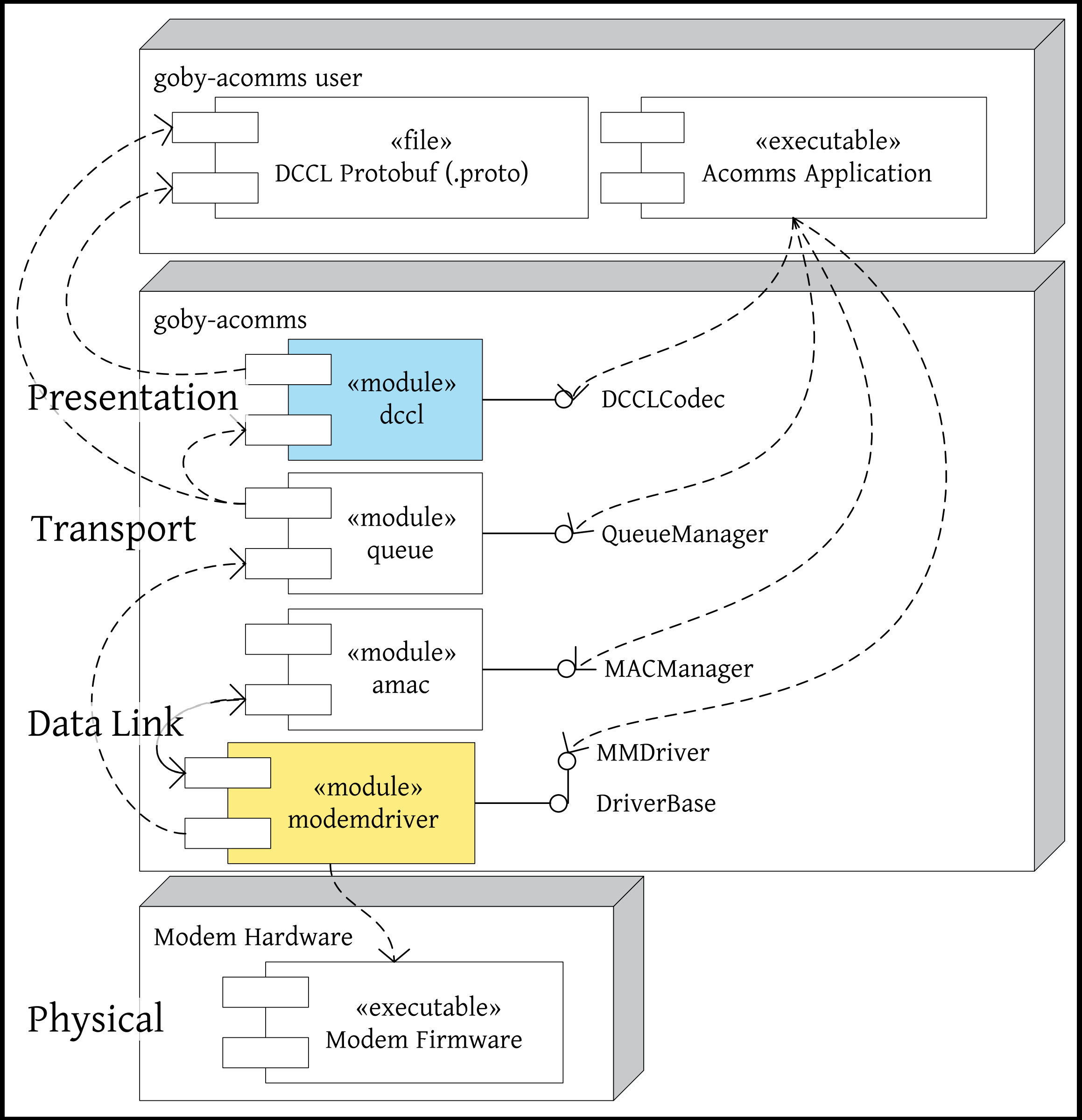
Advantages

- Extremely widely adopted
- Extended by stateless (UDP) and connection-based (TCP) protocols.

Disadvantages (IP designed for much higher throughput and lower latency links)

- Header size = $O(10^1)$ bytes = MTU of typical acoustic modems. Little room for data!
- Vast amount of existing IP traffic uses TCP, but TCP is not designed for links for latency $O(10^1)$ seconds.
- Lack of data source "tracking" - leads to inability to do physics based source coding.

Goby Structure Diagram



gobysoft.org

Schneider & Schmidt: Goby 2
MCMC 2012 - Arenzano, Italy

What is DCCL?

DCCL is the Dynamic Compact Control Language which is:

1. A structure language for defining *object-oriented* small messages:

- O(10-100) bytes
- suitable for acoustic modems
  (e.g. WHOI Micro-Modem)
- extension of Google Protocol Buffers (protobuf)
  - compile-time syntax checking & type safety
  - compatible with non-DCCL protobuf messages
  - usable with many common languages (Java, C++, Python, ...)

What is DCCL?

1. A structure language for object-oriented small messages.
2. A set of encoding & decoding algorithms:
    - efficient: bounded numbers & unaligned packing
    - simple: encoding based on unsigned integers
    - secure: provides pre-shared key AES encryption
    - customizable (v2): user-defined encoders (in C++) for any primitive or user-defined type where extra performance is desired.

DCCL Encoder: Defaults

Primitive Type	Size (bits)	Encode
bool	2	$x_{enc} = \begin{cases} 2 & \text{if } x \text{ is true} \\ 1 & \text{if } x \text{ is false} \\ 0 & \text{if } x \text{ is undefined} \end{cases}$
enum	$\lceil \log_2(1 + \sum \epsilon_i) \rceil$	$x_{enc} = \begin{cases} i+1 & \text{if } x \in \{\epsilon_i\} \\ 0 & \text{otherwise} \end{cases}$
string	$\text{length} \cdot 8$	ASCII
int (all)	$\lceil \log_2(x_{max} - x_{min} + 2) \rceil$	$x_{enc} = \begin{cases} \text{nint}(x - x_{min}) + 1 & \text{if } x \in [x_{min}, x_{max}] \\ 0 & \text{otherwise} \end{cases}$
double, float	$\lceil \log_2((x_{max} - x_{min}) \cdot 10^{prec} + 2) \rceil$	$x_{enc} = \begin{cases} \text{nint}((x - x_{min}) \cdot 10^{prec}) + 1 & \text{if } x \in [x_{min}, x_{max}] \\ 0 & \text{otherwise} \end{cases}$
bytes	$\text{num\_bytes} \cdot 8$	$x_{enc} = x$

Basically: arbitrary bit-sized integers and fixed point real numbers

(analogous to entropy source encoding with uniform probability distribution over a given range)

DCCL Example: Defaults

```
8   import "goby/common/protobuf/option_extensions.proto";
5
17  message CTDMessage
    {
      option (goby.msg).dccl.id = 102;
      option (goby.msg).dccl.max_bytes = 64;

100   required int32 destination = 1 [(goby.field).dccl.max=31,
                                      (goby.field).dccl.min=0,
                                      (goby.field).queue.is_dest=true
                                      (goby.field).dccl.in_head=true];

      required uint64 time = 2 [(goby.field).dccl.codec="_time",
                                (goby.field).queue.is_time=true];
30
      repeated int32 depth = 3 [(goby.field).dccl.max=1000,
                                (goby.field).dccl.min=0,
                                (goby.field).dccl.max_repeat=10];

      repeated int32 temperature = 4 [(goby.field).dccl.max=40,
                          (goby.field).dccl.min=0,
                          (goby.field).dccl.max_repeat=10];
110
      repeated double salinity = 5 [(goby.field).dccl.max=40,
                          (goby.field).dccl.min=25,
                          (goby.field).dccl.precision=2,
                          (goby.field).dccl.max_repeat=10];
    }
```

10 Conductivity-Temperature-Depth samples (CTD), used for collaborative environmental sampling

Unencoded: 1376 bits

Protobuf: 648 bits (-53%)

REMUS CCL: 344 bits (-75%)

DCCL (default): 270 bits (-80%)

Common acoustic modem MTUs:

256 - 2048 bits

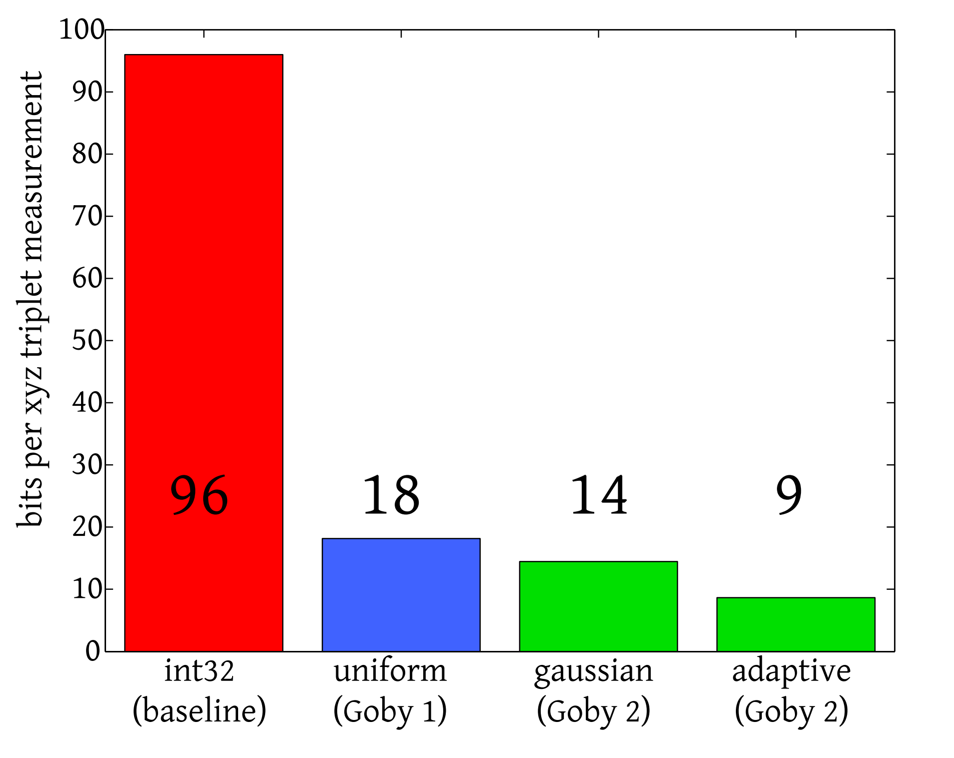
DCCL Example: Custom

- In version 2, custom encoders can be loaded into DCCL.
- E.g., arithmetic source coding provides near optimal encoding for a given data model.

AUV position sample (in Cartesian) used in most collaborative missions

```
message MinimalNodeStatus
{
  option (goby.msg).dccl.id = 21;
  option (goby.msg).dccl.max_bytes = 32;

  required int32 t = 1 [(goby.field).dccl.codec = "_arithmetic",
                        (goby.field).dccl.arithmetic.model = "lamss.time"];
  required int32 x = 2 [(goby.field).dccl.codec = "_arithmetic",
                        (goby.field).dccl.arithmetic.model = "lamss.dist.horizontal"];
  required int32 y = 3 [(goby.field).dccl.codec = "_arithmetic",
                        (goby.field).dccl.arithmetic.model = "lamss.dist.horizontal"];
  required int32 z = 4 [(goby.field).dccl.codec = "_arithmetic",
                        (goby.field).dccl.arithmetic.model = "lamss.dist.vertical"];
}
```



DCCL: Related work

	Multiple languages	Static type/syntax safety	Easily extensible	Custom encoders	Default compression
Goby DCCL version 2	X	X	X	X	X
Goby DCCL version 1			X		X
Compact Control Language (CCL)		X			X
Inter-Module Communication (IMC)		X	X		
Abstract Syntax Notation One (ASN.1)	X	X	X		X
Google Protocol Buffers (protobuf)	X	X	X		X

ModemDriver

Problem:

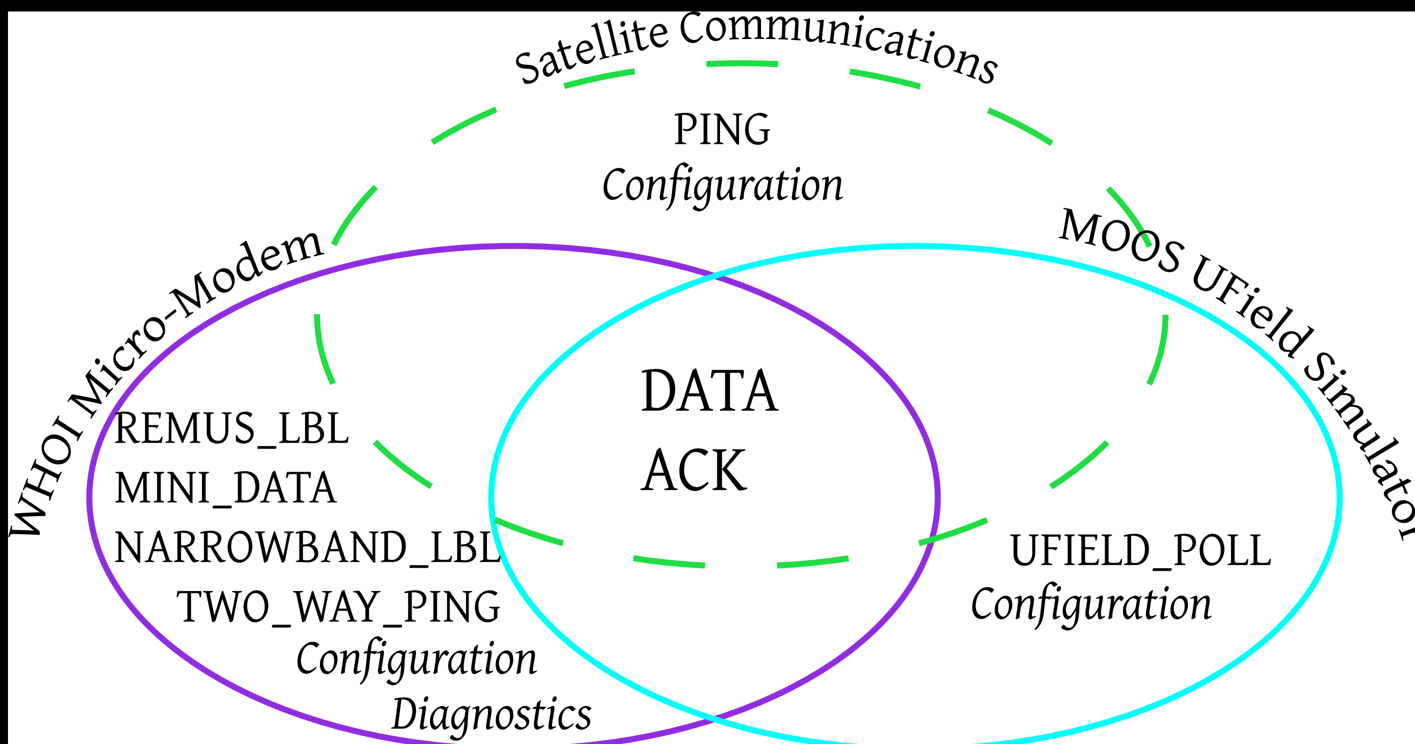
- No standard API to acoustic modems
- Modems provide useful features beyond strict functionality of a modem (send bytes from point A -> B)

Goby approach (complexity layed on simplicity):

- Define core requirement of modem driver as sending data (simple to implement)
- All other features (ranging pings, LBL, USBL) are extensions to modem driver
- User can ignore extensions if only data transmission is required (simple), and later add in extensions (complex) as needed.

ModemDriver

- can work with any system that can transmit datagrams (including existing systems such as UDP/IP)
- preserves access to unique & advanced hardware features.



Experiments: Case Studies

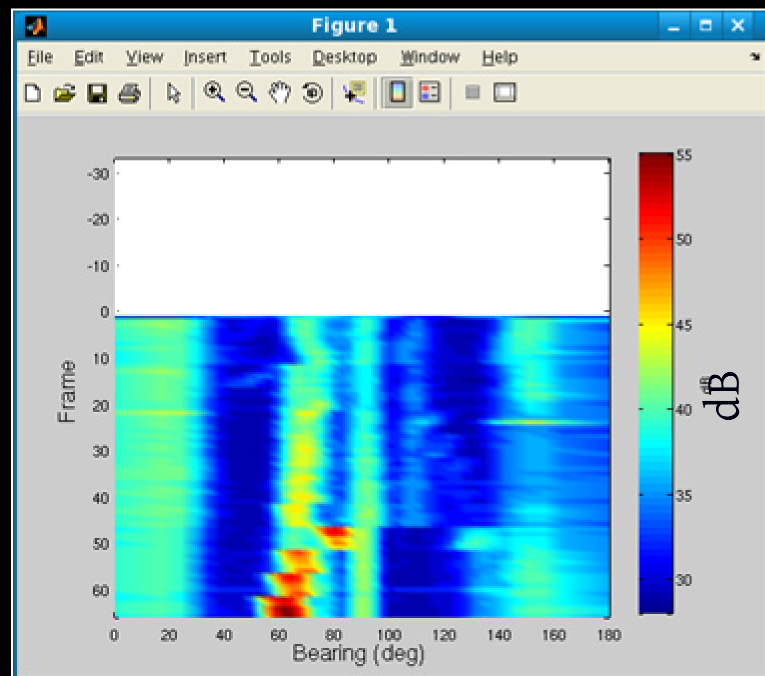
- SWAMSI09: Bistatic detection of mine-like targets with two AUVs. Messages: LAMSS_DEPLOY, LAMSS_STATUS, ACTIVE_CONTACTS, ACTIVE_TRACKS

Operator Display: AUVs are green / purple track

Experiments: Case Studies

- GLINT09: Active detection of submarine-like target with surface craft (gateway), AUV, and source buoy. Messages: LAMSS_DEPLOY, LAMSS_STATUS, WINCH_CONTROL, SOURCE_ACTIVATION

Frame # (~4 seconds)

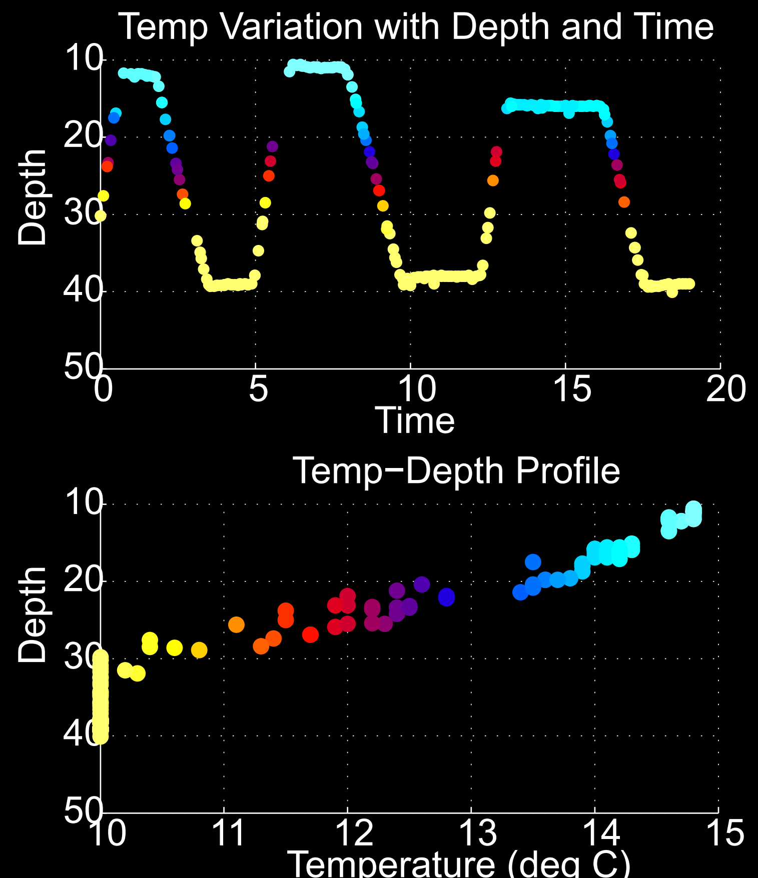


Beam-Time Record

Bearing

Experiments: Case Studies

- CHAMPLAIN09: Adaptive sampling of physical data (T, S, c) using an AUV
  - Messages: LAMSS_DEPLOY, LAMSS_STATUS, CTDCODEC



CTD Display

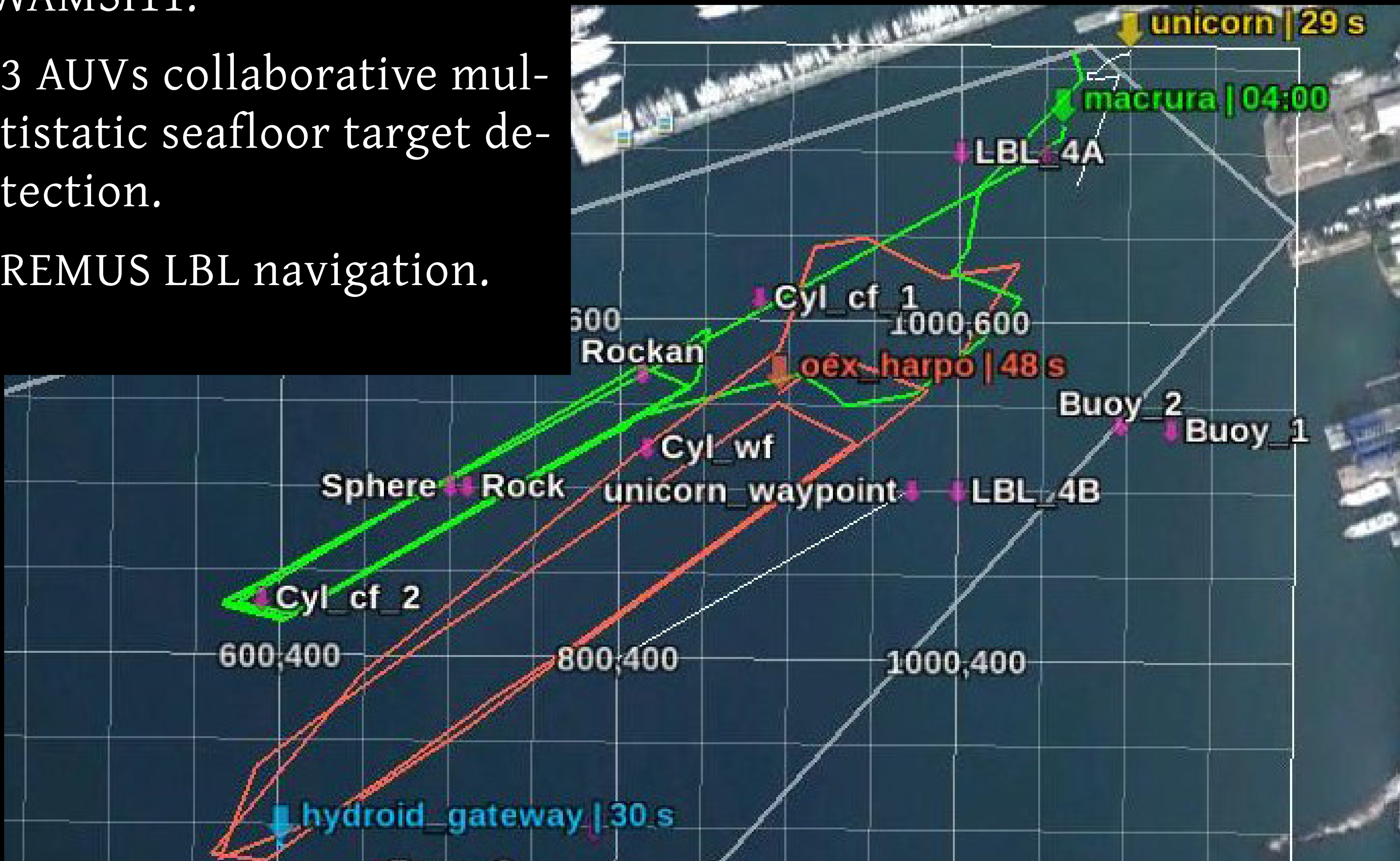
Experiments: Case Studies

- GLINT10: Historical "back-fill" of position to provide accurate track of vehicle position.
  Messages: LAMSS_STATUS, LAMSS_CTD, LAMSS_STATUS_FILL_IN

Experiments: Case Studies

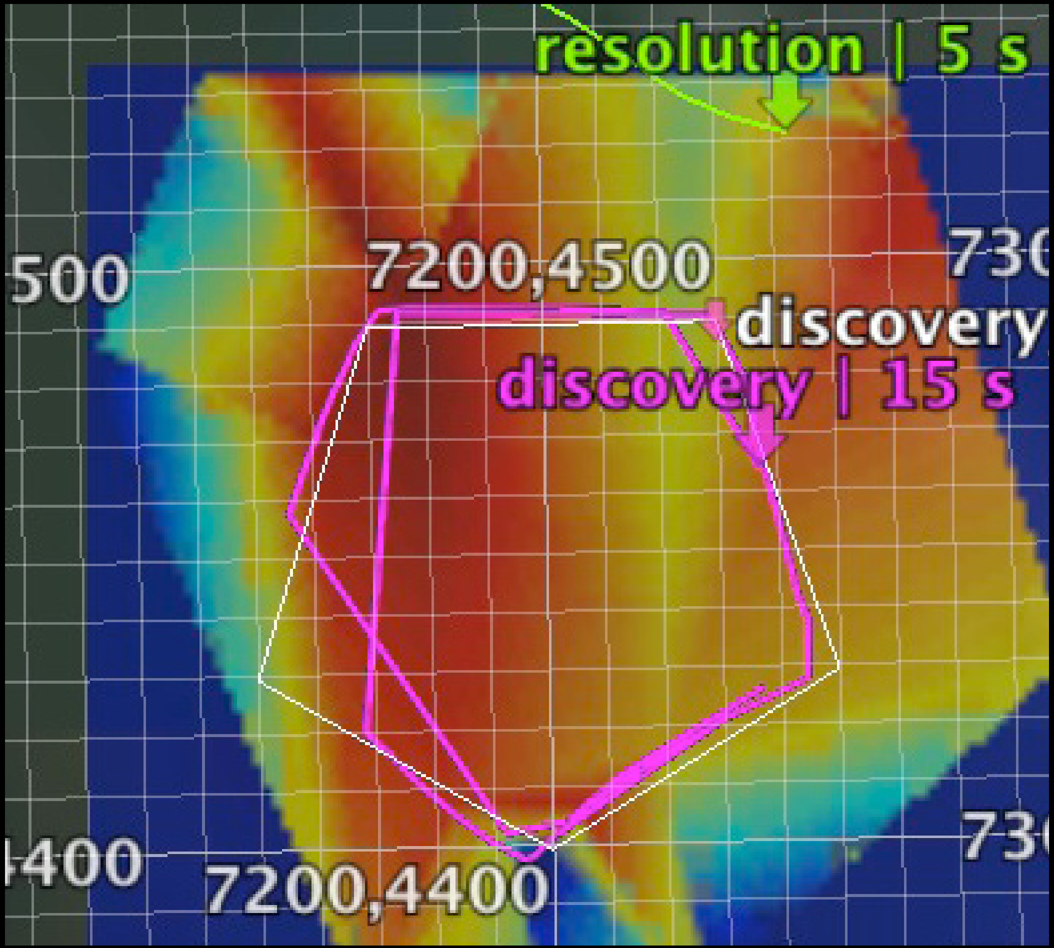
SWAMSI11:

- 3 AUVs collaborative multistatic seafloor target detection.
- REMUS LBL navigation.



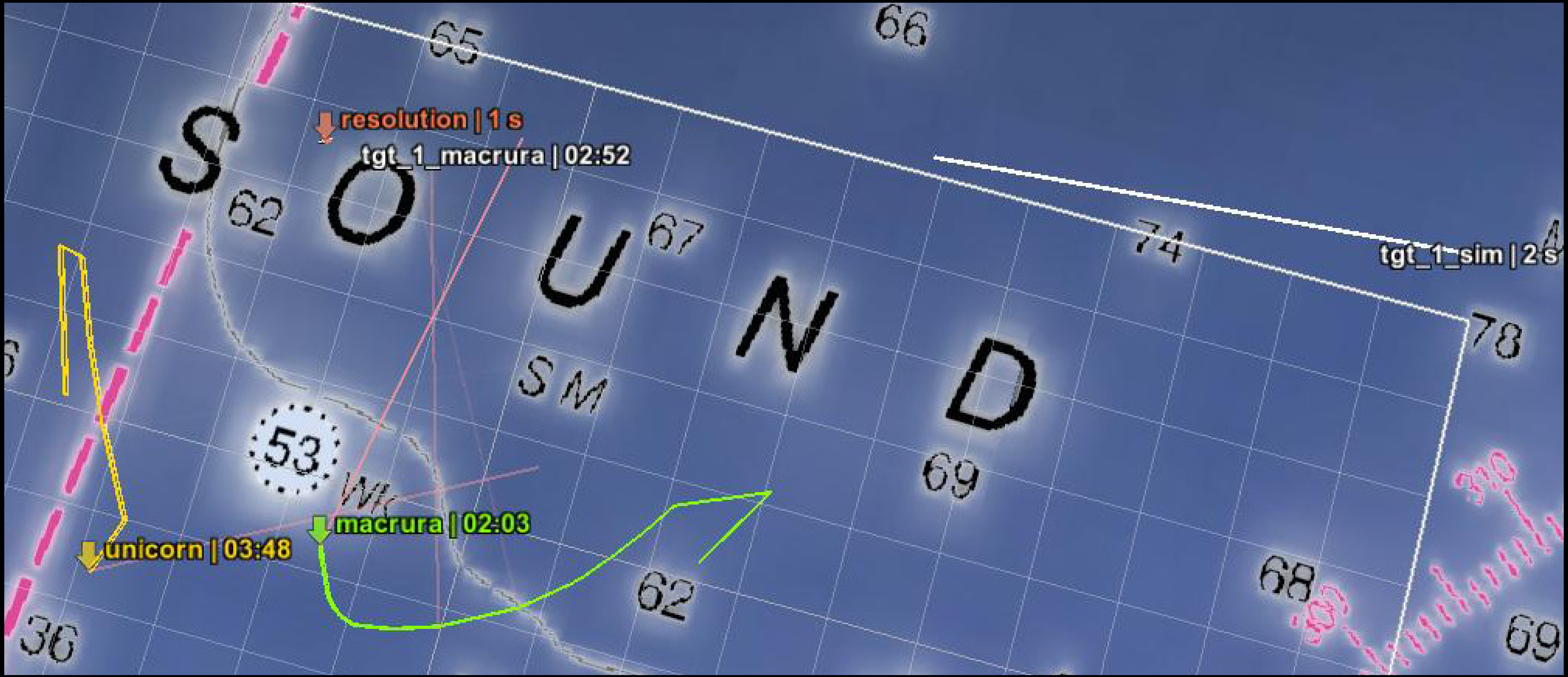
Experiments: Case Studies

- BF9_MAY11:
  Backend for C. Murphy's sidescan image sending CTD samples for real-time lat / lon slice display:

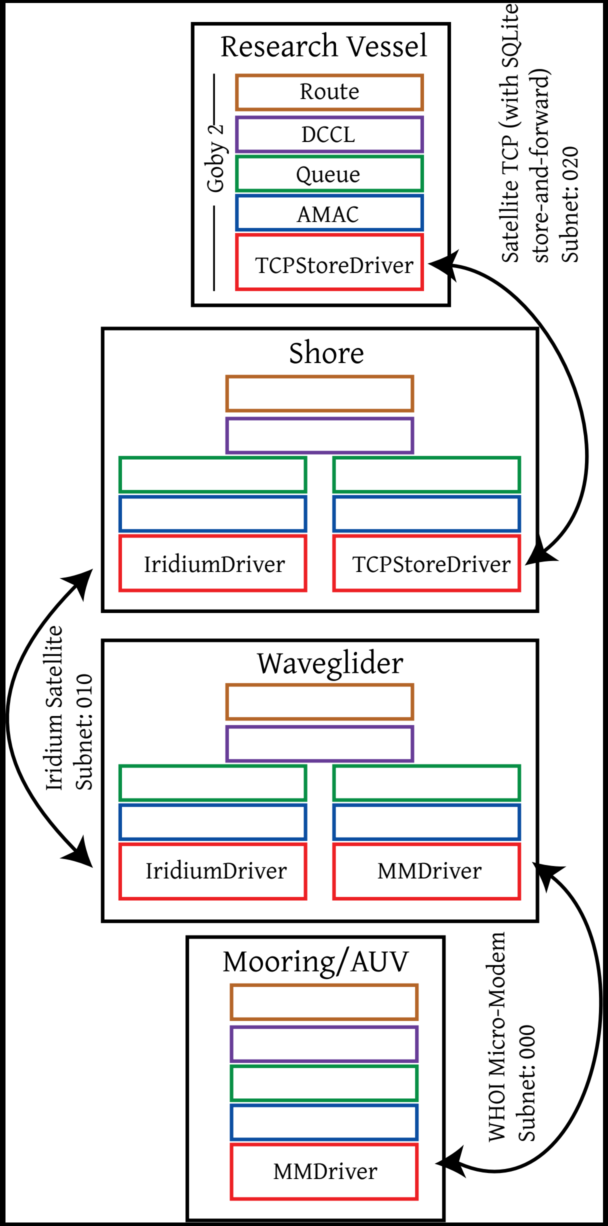


Experiments: Case Studies

- MBAT11
  Shallow-water mock-up test for deep sea collaborative passive/active target tracking.



Experiments: Case Studies



Tiger 12

Heterogeneous mix of physical links:

- Deep sea mooring <-> Waveglider: WHOI acoustic Micro-Modem
- Waveglider <-> Shore: Iridium satellite (RUDICS)
- Shore <-> Research Vessel: Iridium satellite (OpenPort)

Acknowledgments

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