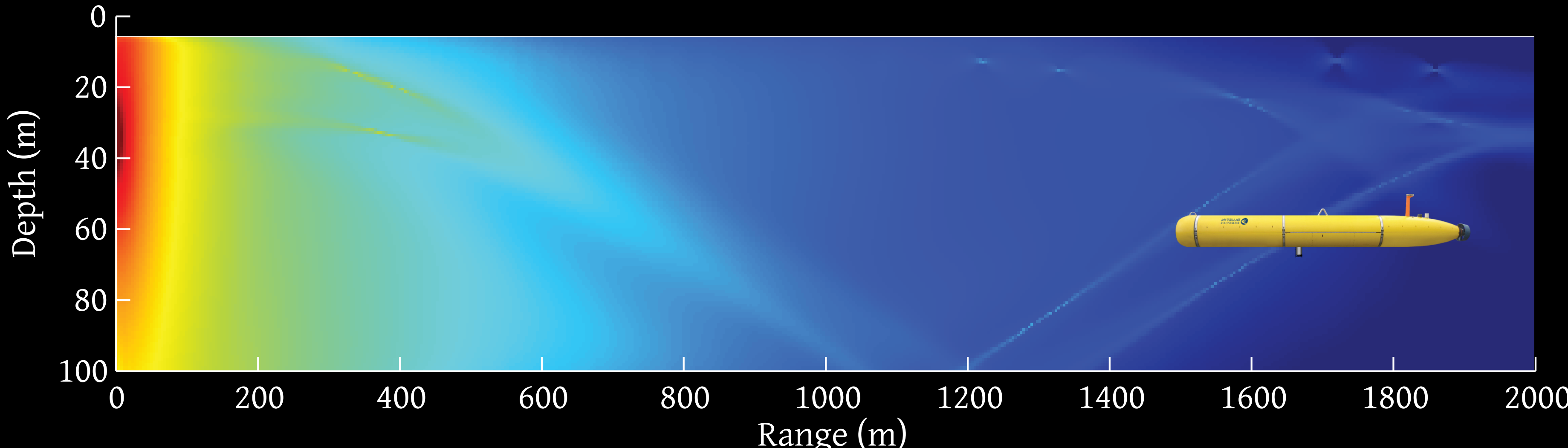
Pragmatic model-based adaptation for optimal acoustic communication and sensing on autonomous marine vehicles.



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1930

Overview

Given:

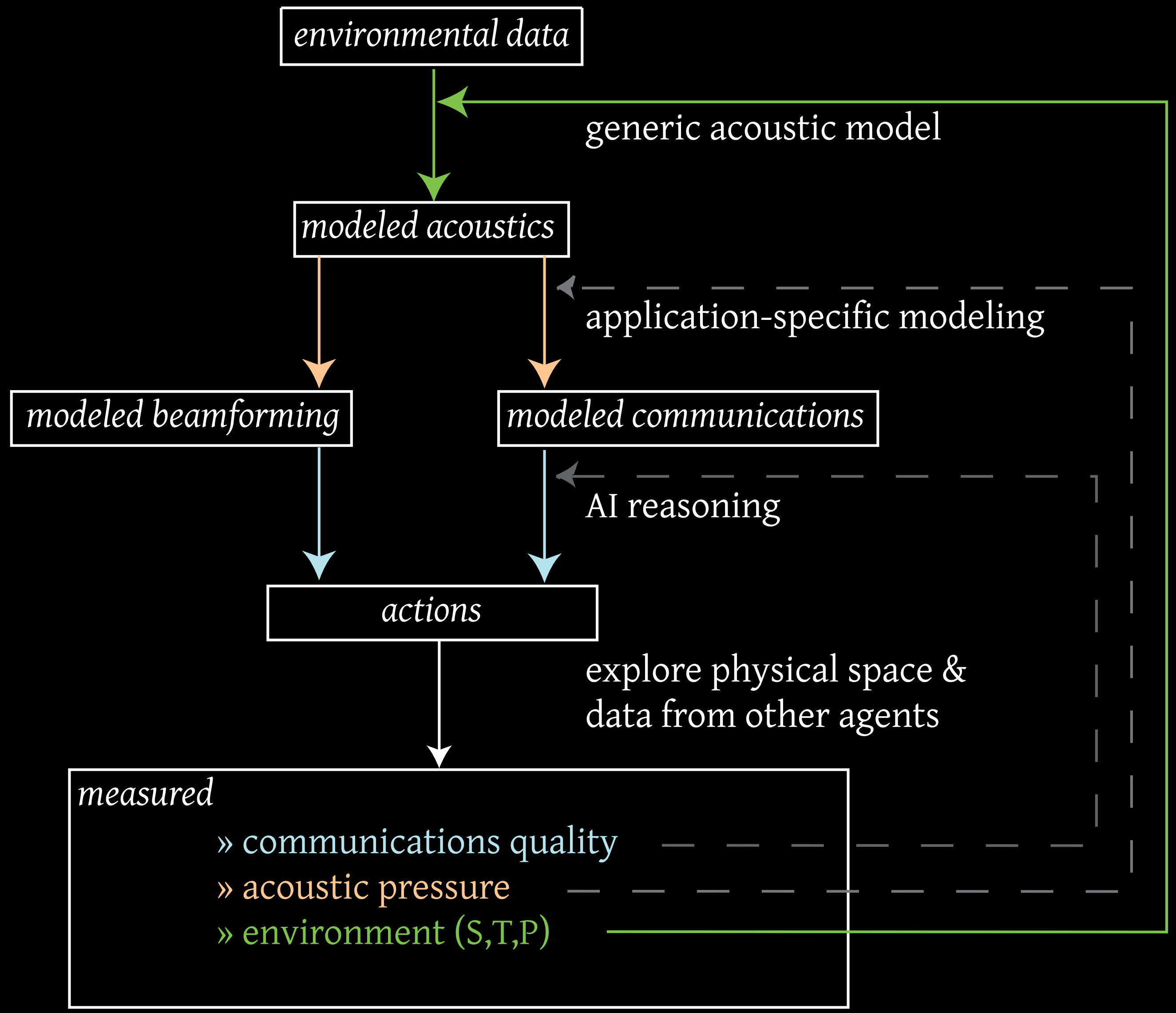
1. Ocean propagation of sound greatly influences acoustic instruments' performance.

2. AUVs are *new* compared to sonars: we *have* the acoustics knowledge: can we allow AUVs to use it?

Robotic platform (AUV) specific challenges:

- Power
- Computational performance
- Realtime constraints
- Managing (software) system complexity

Overview


environmental data
generic acoustic model
modeled acoustics
application-specific modeling
modeled beamforming
modeled communications
AI reasoning
actions
explore physical space &
data from other agents
measured
» communications quality
» acoustic pressure
» environment (S,T,P)

Build AUV Computer System I

Construct distributed AUV computer system from "bottom up":

1. "Frontseat" computer: specific to vehicle, may be mature hardware/software.

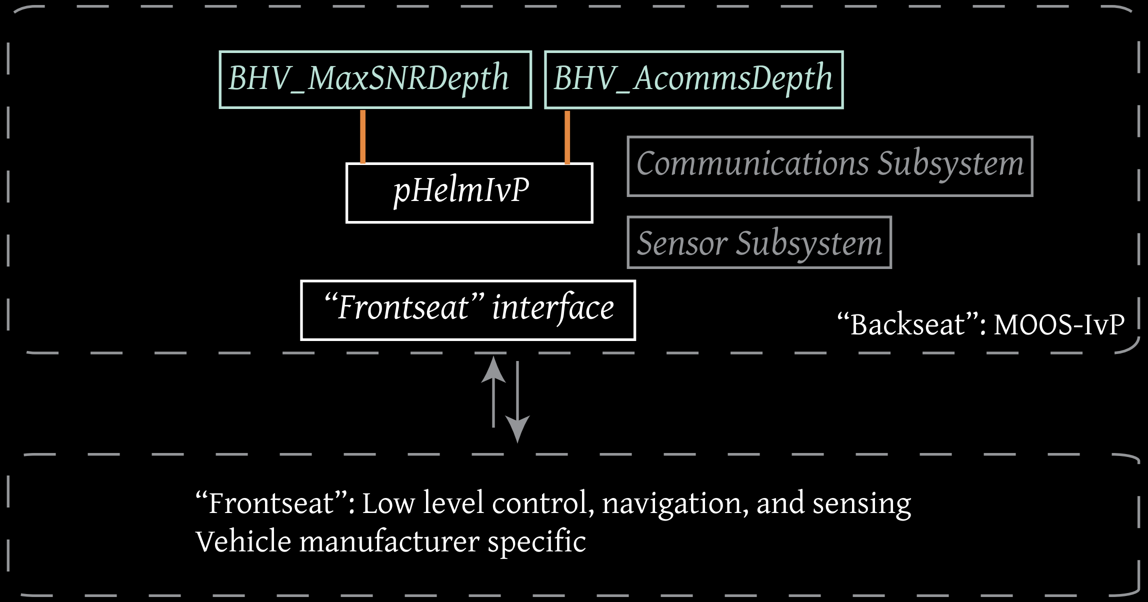
"Frontseat": Low level control, navigation, and sensing
Vehicle manufacturer specific

Build AUV Computer System II

Add autonomy ("intelligence"):

1. "Frontseat"

2. "Backseat" computer: MOOS-IvP in this case (behavior-based multi-objective optimization).



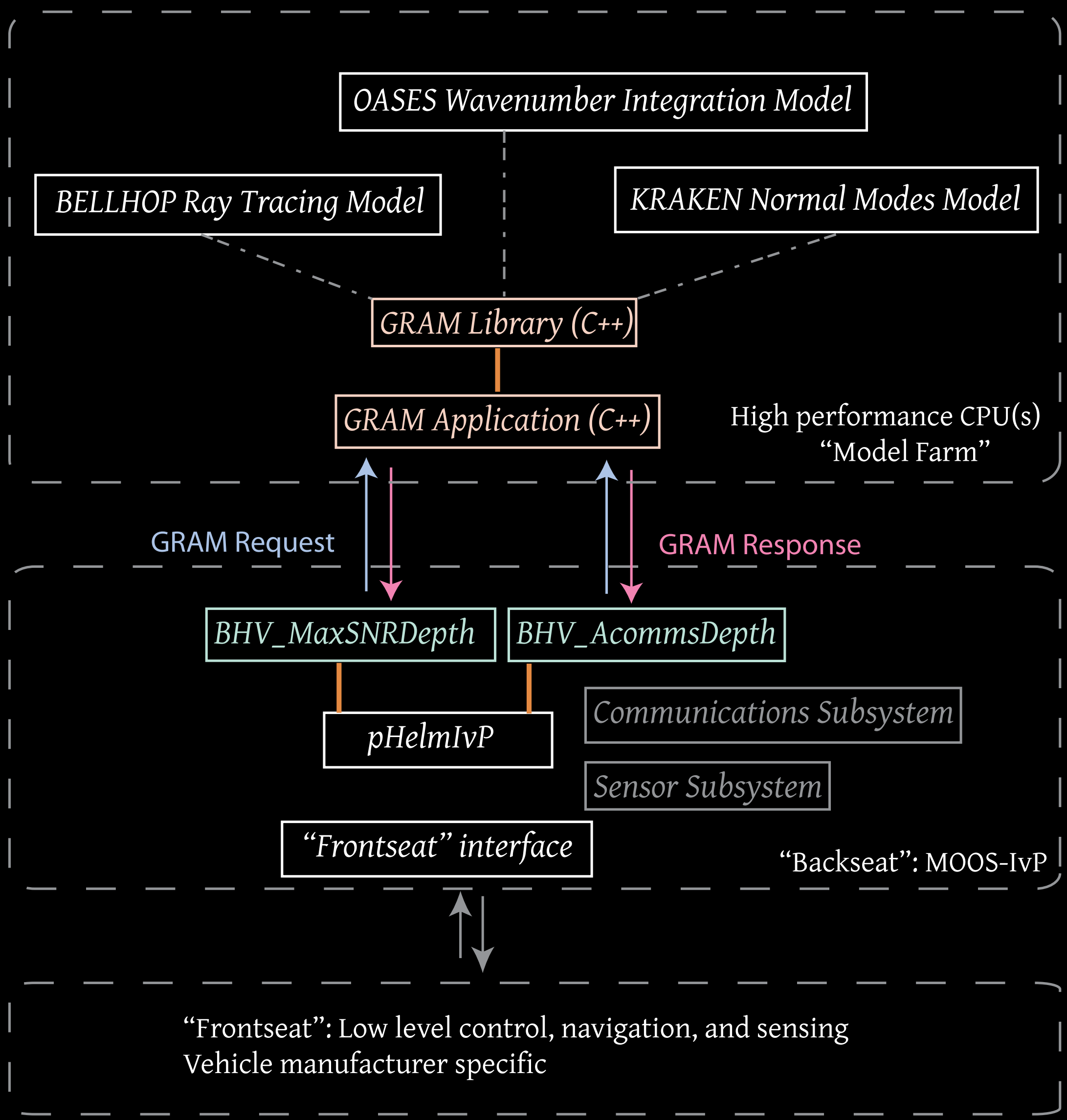
Build AUV Computer System III

Third layer: acoustic modeling via "Generic Robotic Acoustic Model" (GRAM)

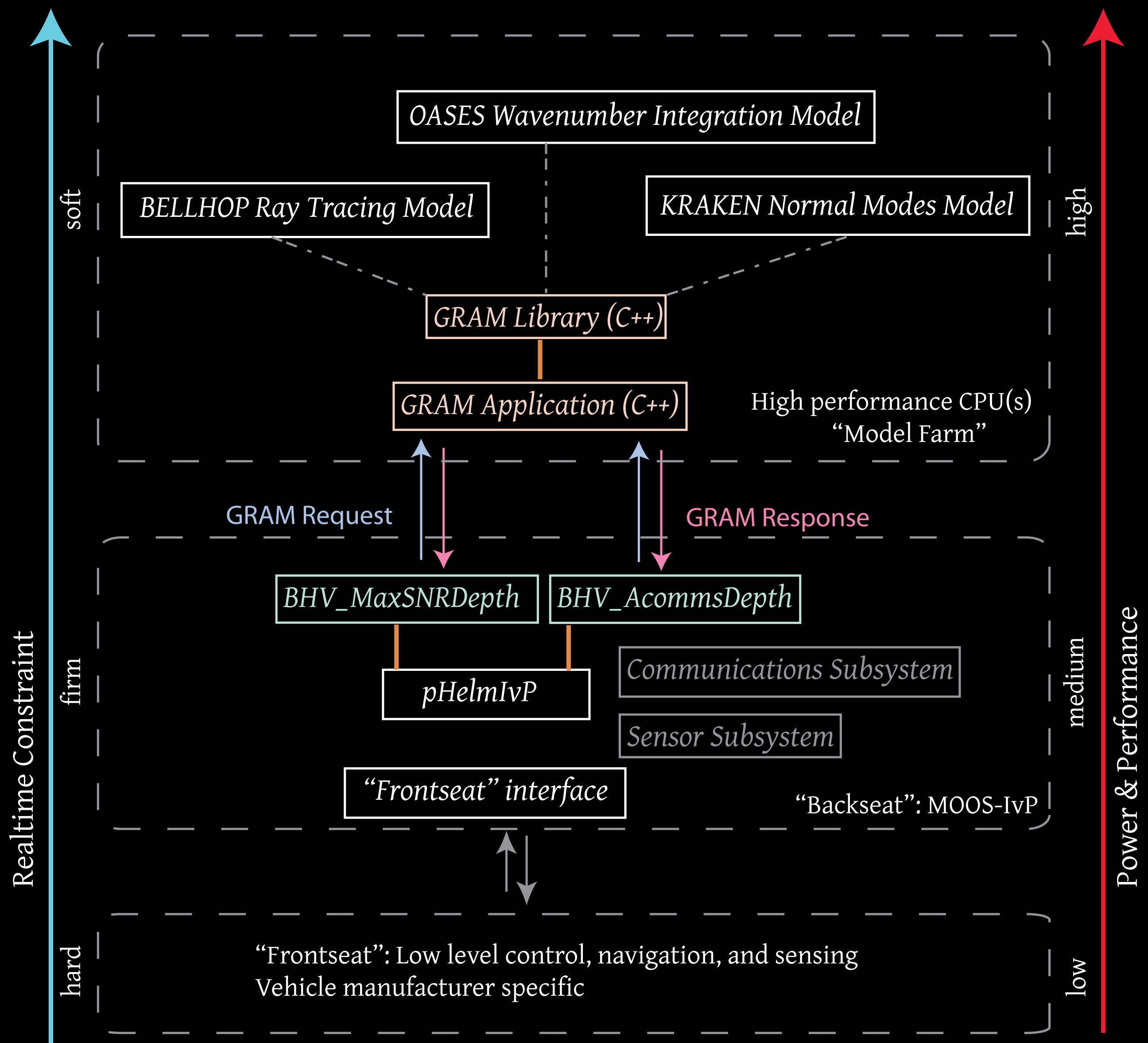
1. "Frontseat"
2. "Backseat"
3. Model farm computer(s):

- Generic Robotic Acoustic Model (GRAM)
- Interface to "Backseat" through Remote Procedure Call "Request-Reply"
  - scalability: users of models unaware of each other
  - asynchronous: realtime issues

Complete Computer System

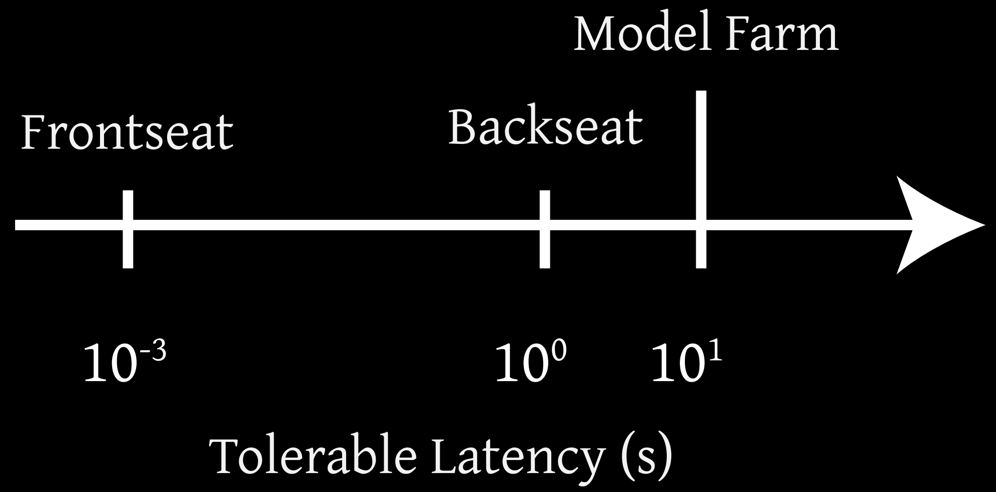


Why? Realtime & Power



Realtime constraints

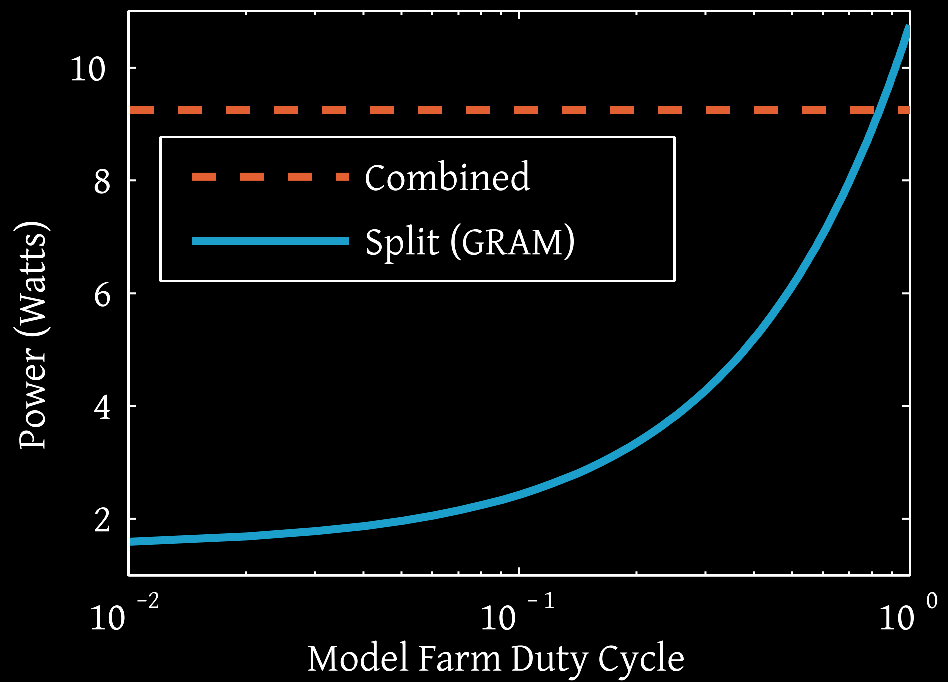
1. "Frontseat": *hard realtime:* delay intolerable (controllability). O(1 ms).
2. "Backseat": *firm realtime:* delay *occasionally* tolerable. O(1 s).
3. "Model farm": *soft realtime:* delays acceptable, but output must keep up with input. O(10 - 1000 s).



Power / Performance

To hit realtime constraints, need certain CPU performance.
Acoustic models are generally intensive on floating point calculations.

Splitting “backseat” from “model farm” can save power by taking advantage of lower power states.

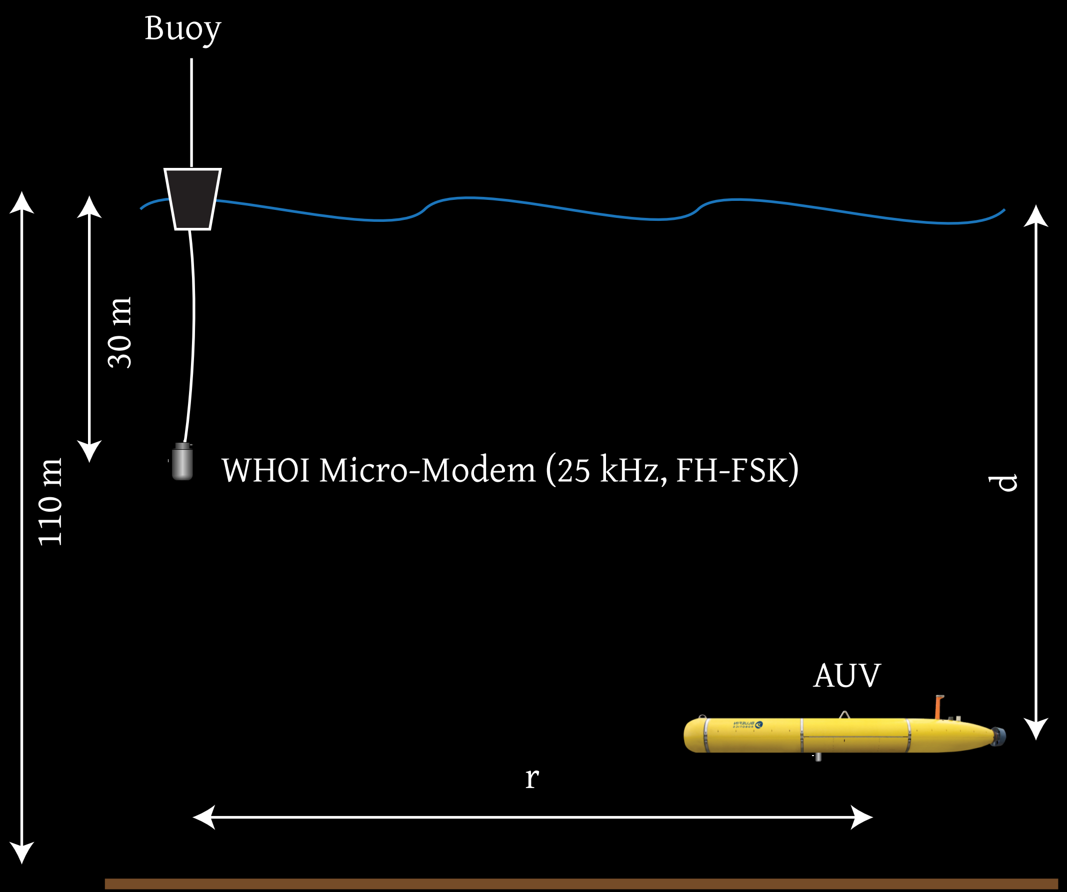


Combined: 1.8 GHz Intel Atom (backseat and model farm)

Split: 520 MHz Marvell XScale (backseat) and 1.8 GHz Intel Atom (model farm)

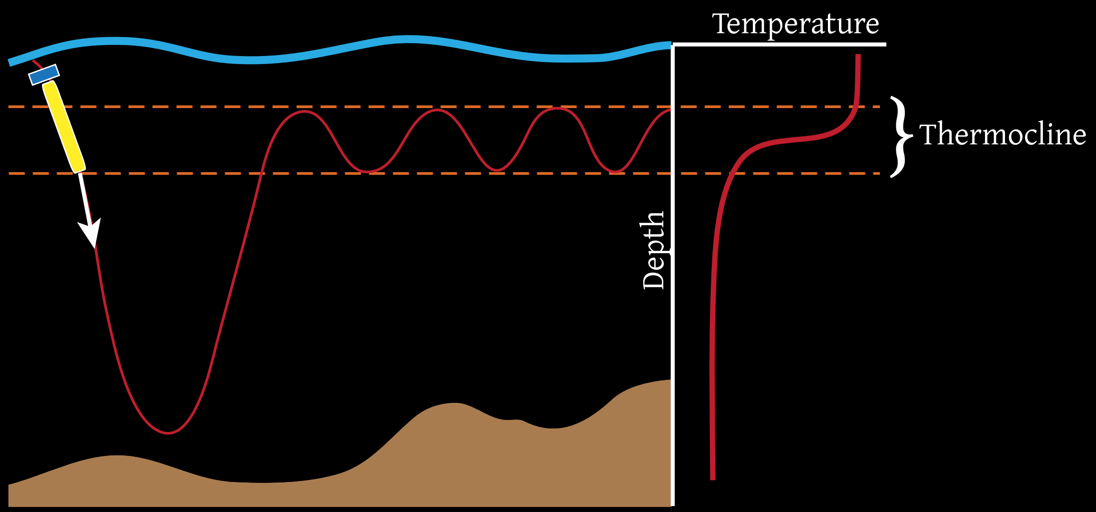
GLINT10: Communications

Use measured environment to generate acoustic model to drive adaptation in depth (assume range is out of our control). Goal: improve acoustic modem throughput.

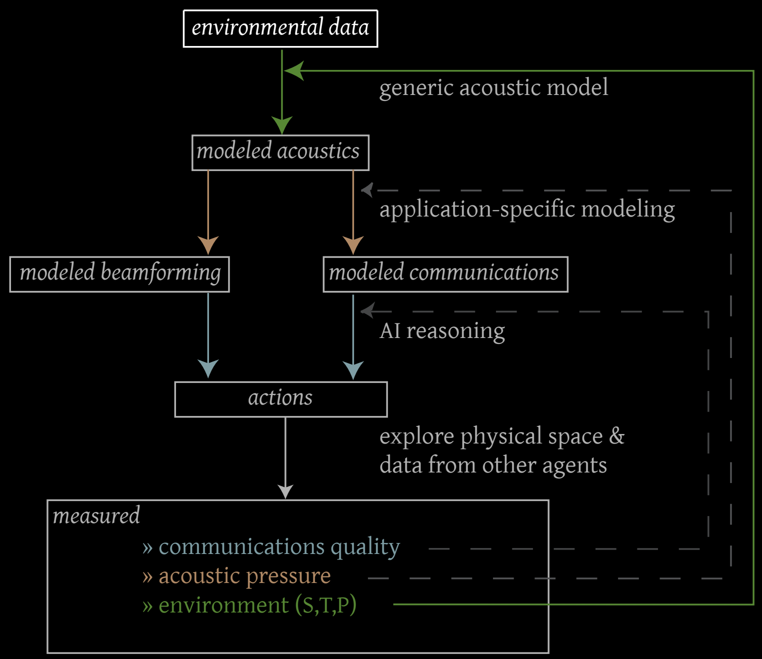


1. Measure Environment

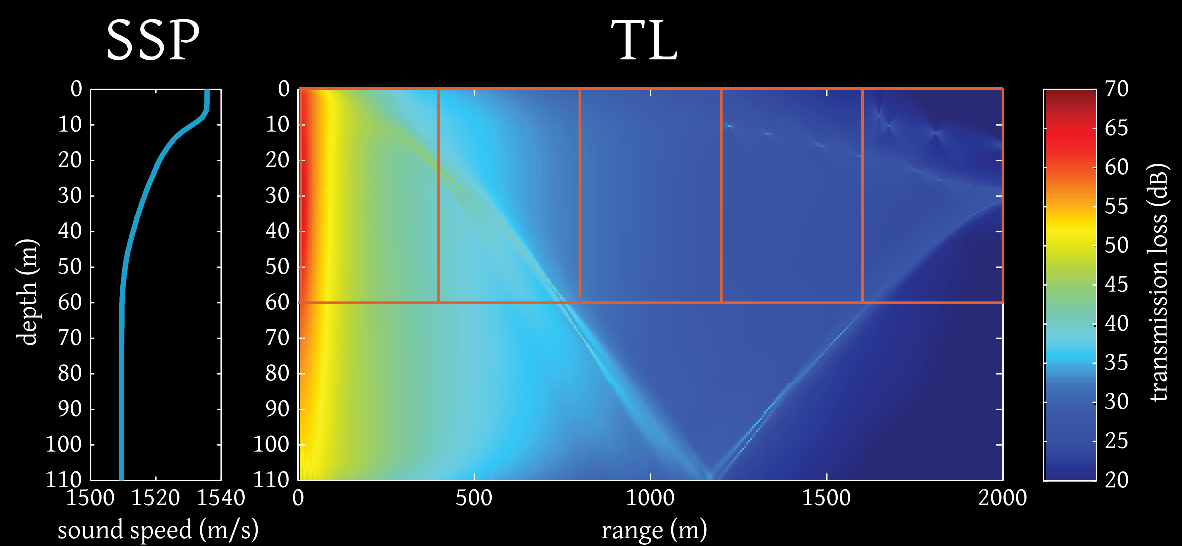
- AUV meaures SSP using CTD via "yoyo" depth excursions.
- Thermocline-adaptive sampling (Petillo 2010) used.

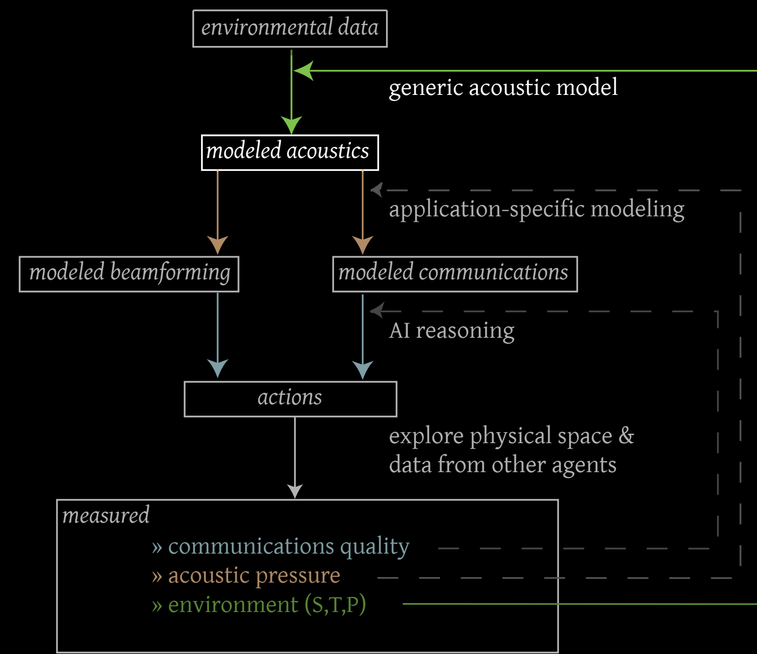


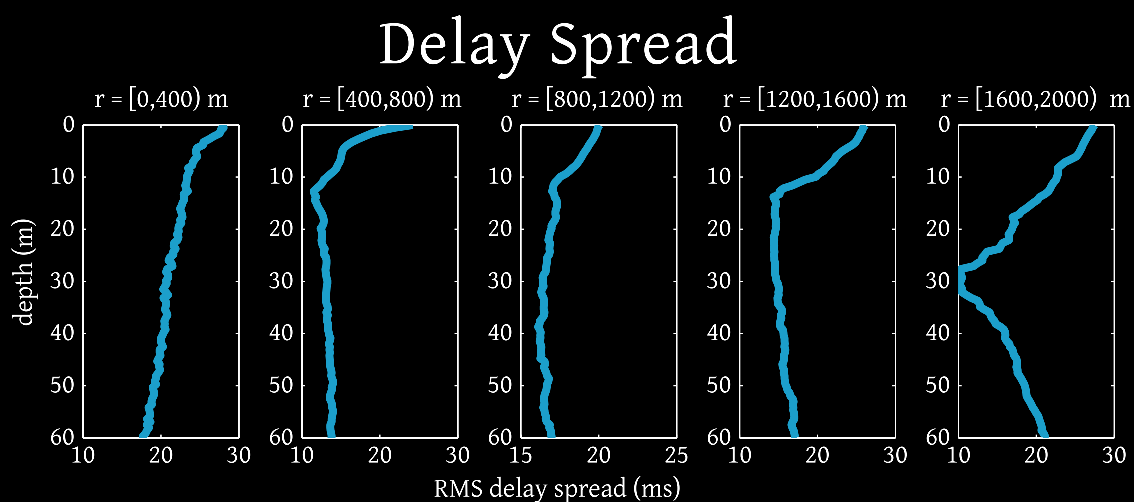
S. Petillo: Adapted with permission



2. Model Acoustics (GRAM + BELLHOP)



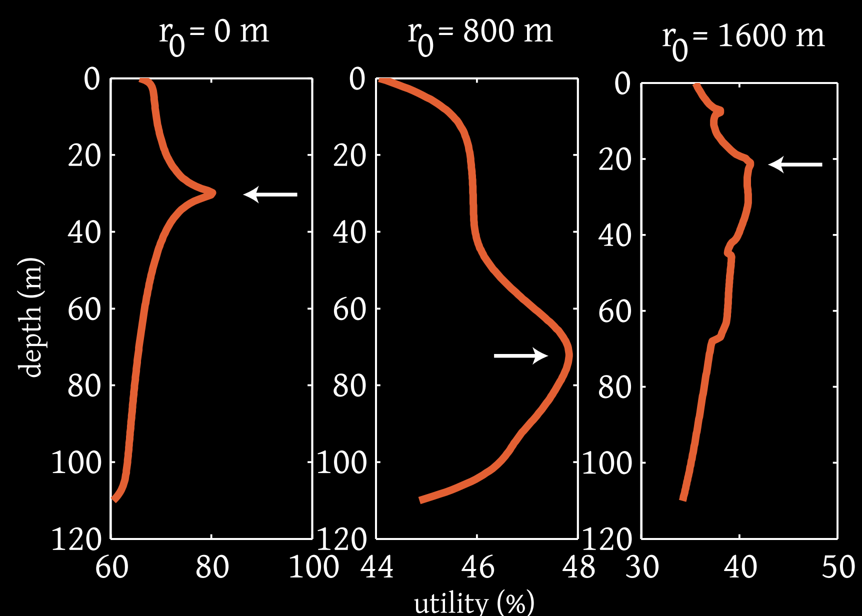


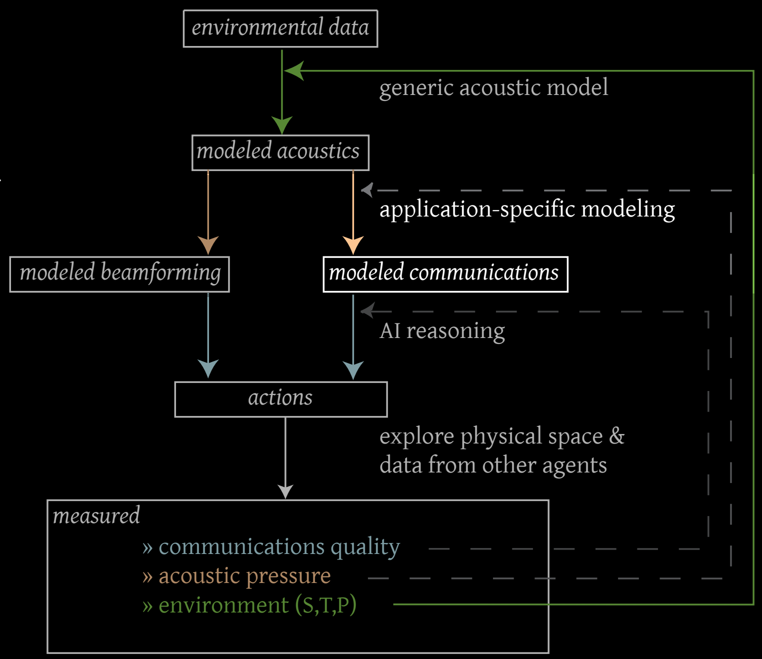


3. BHV_AcommsDepth Utility Function

Averaged modeled acoustic intensity in range for future horizon:

- based on AUV's instantaneous speed heading
- scaled by local extrema or overall utility metric from past data



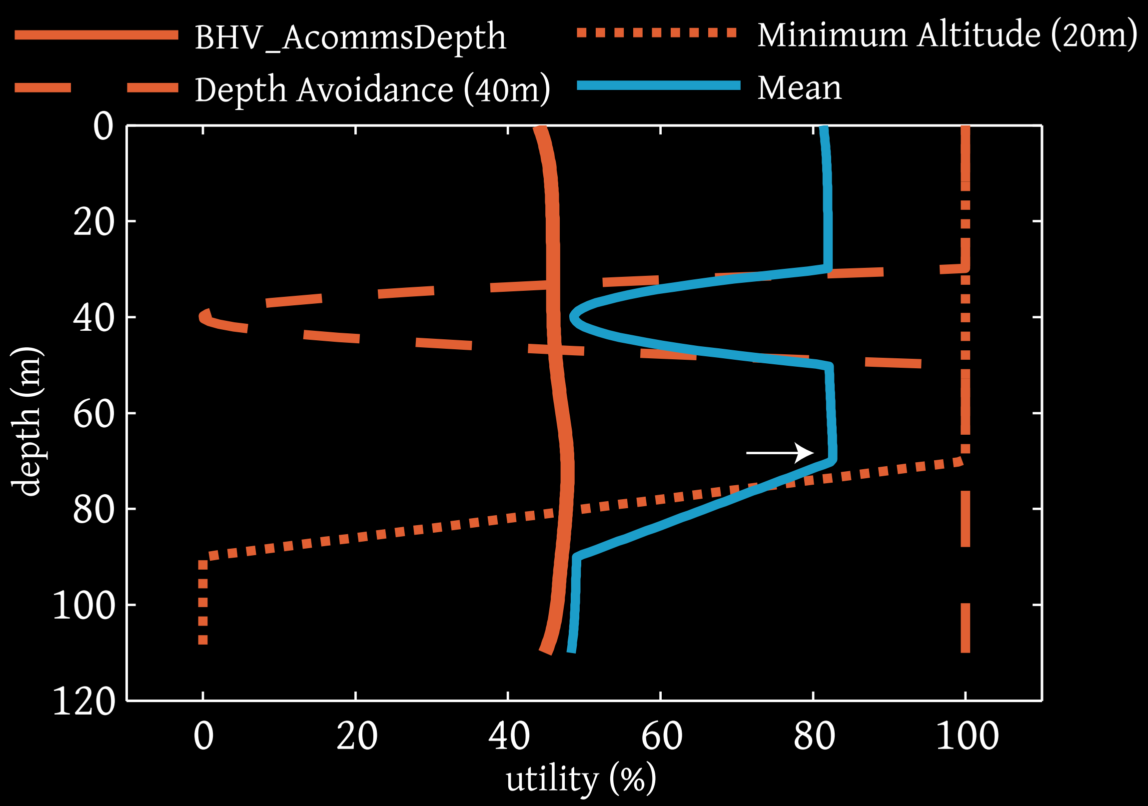


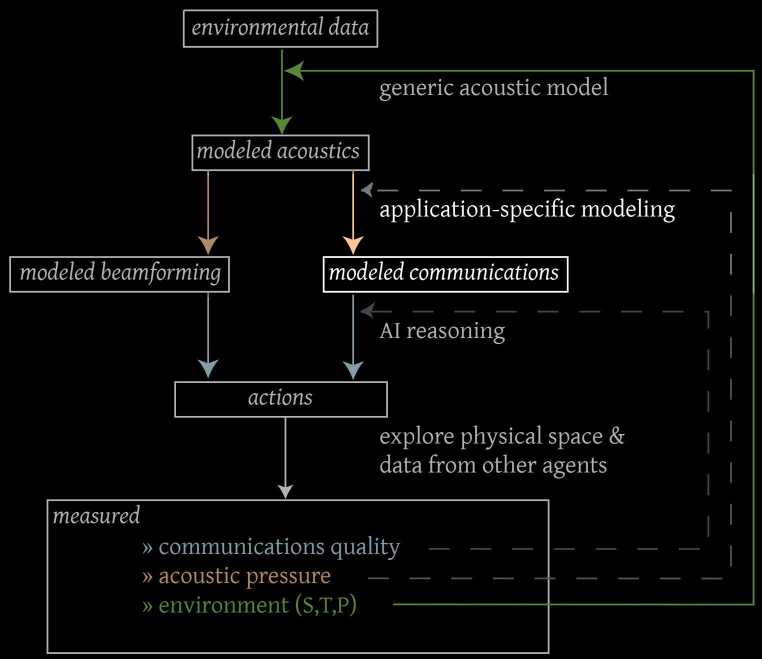
0% utility: TL = 108 dB
(<1% messages received)

100% utility: TL = 0 dB

3. BHV_AcommsDepth Utility Function

Interaction with other behaviors:

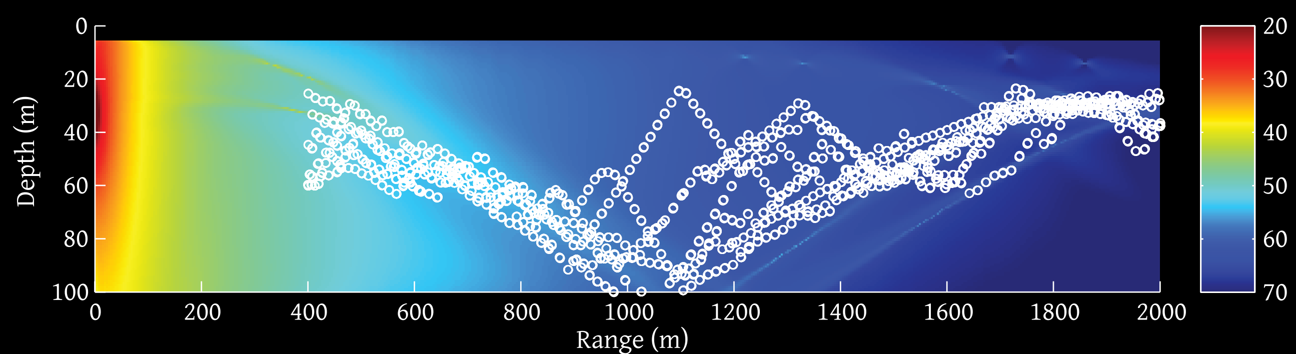


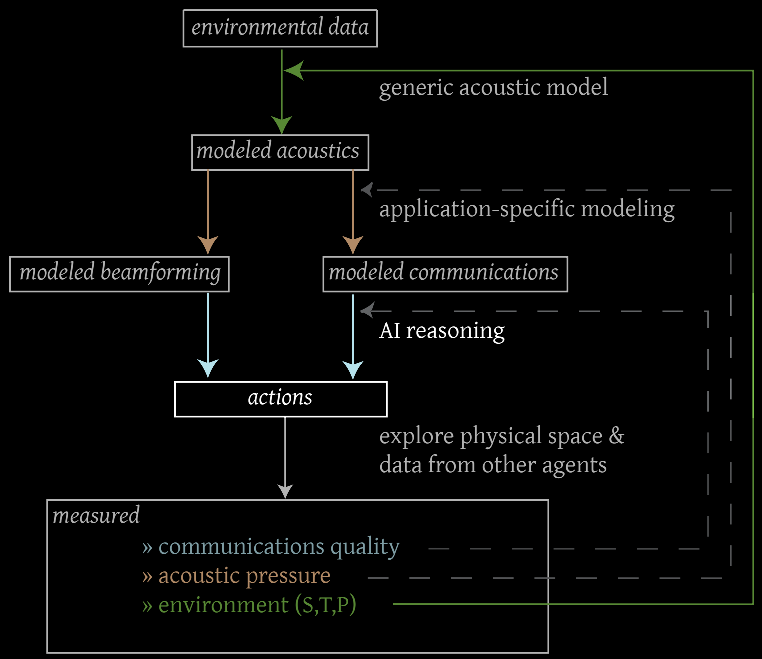


4. Transit

2010-08-08 runs:

- white dots: AUV position
- Buoy: range = 0 m, depth = 30m
- Underlay: TL model from representative SSP.

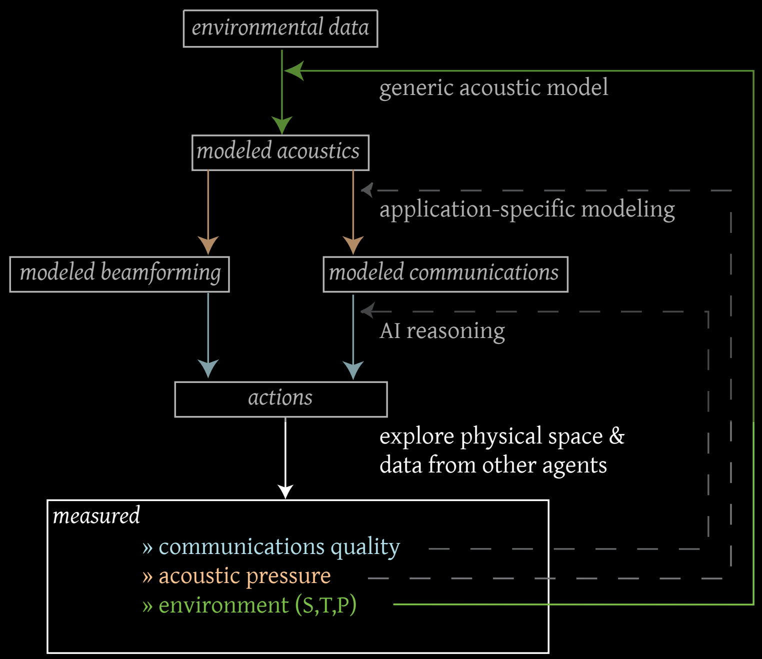


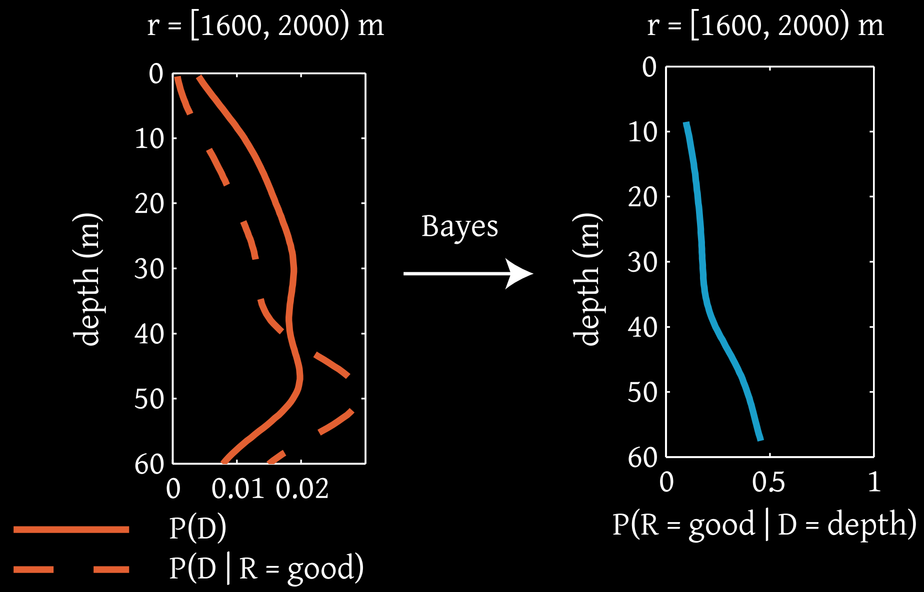


5. Measure data and feedback

Measured data:

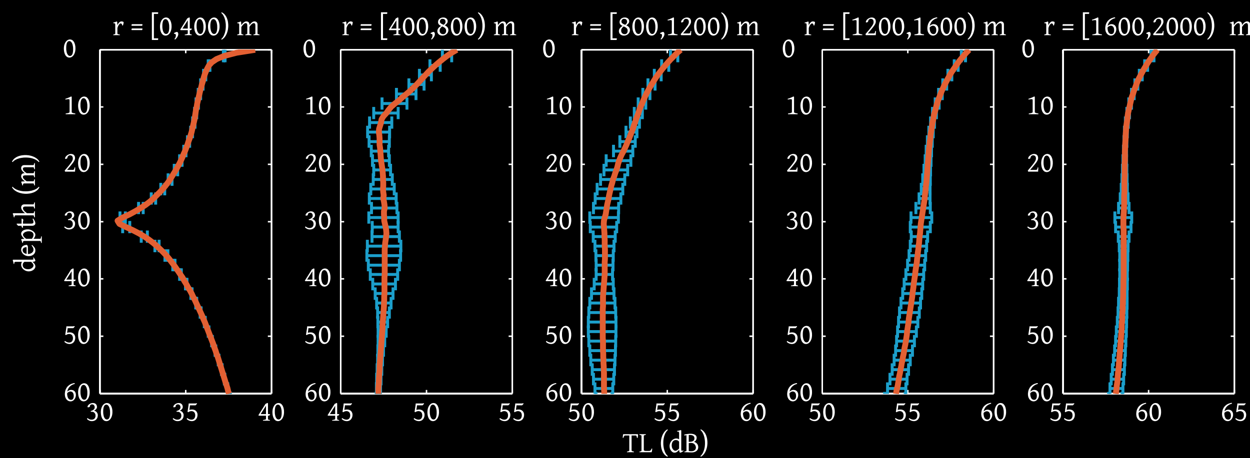
1. Vehicle depth:
   - random variable D
2. Received 32 byte messages (good = passed CRC without errors):
   - Bernoulli random variable R (good / bad)



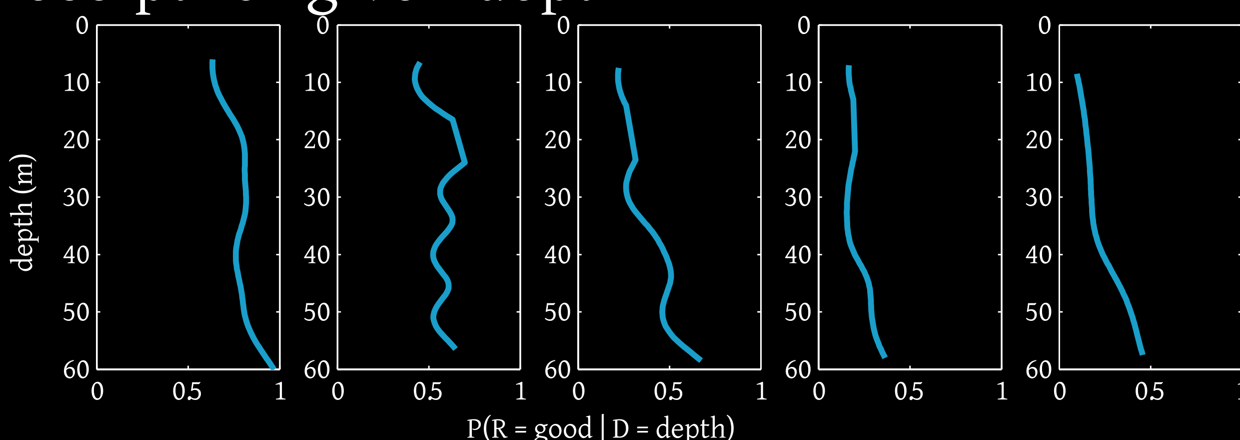


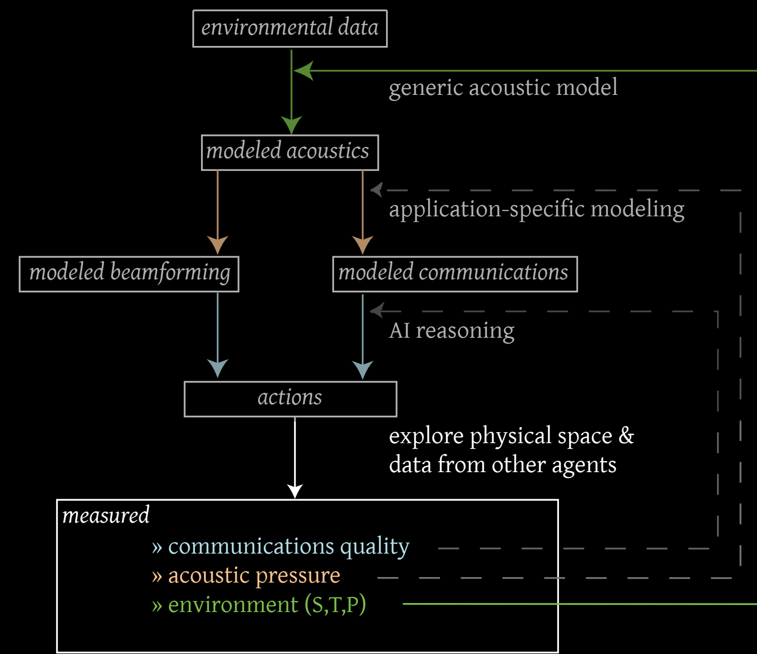
5. Measure data and feedback

μ, σ for modeled TL for 111 measured SSPs



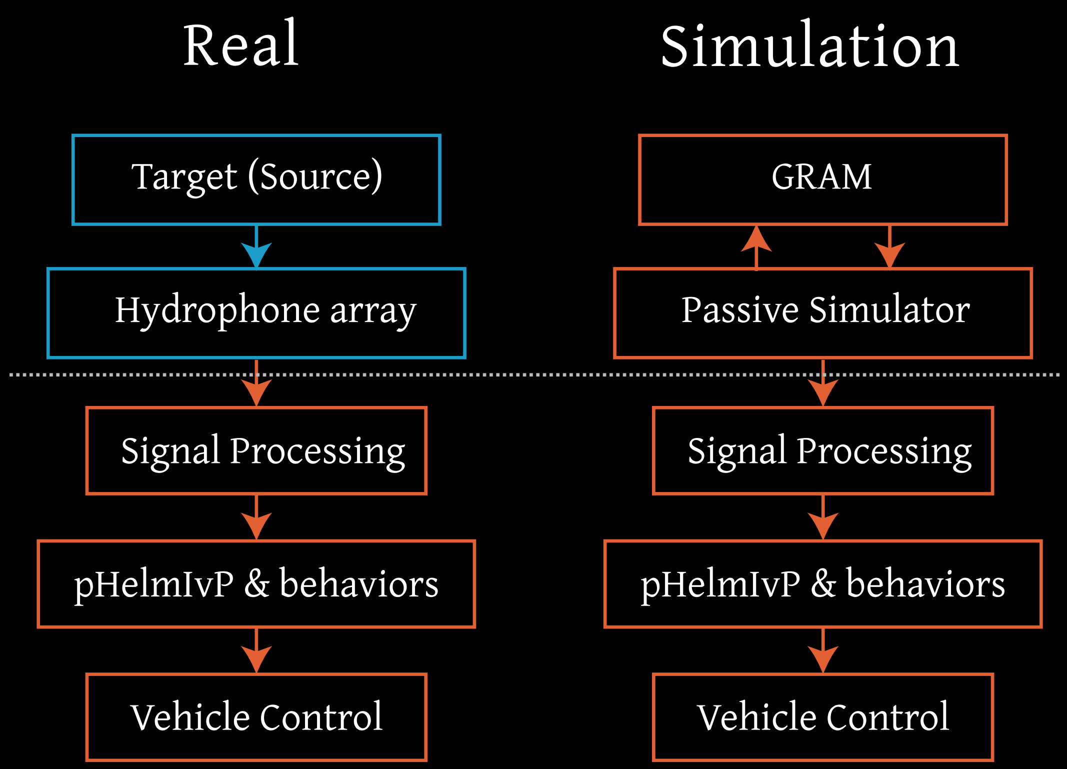
Measured Bayesian probability of message receipt for given depth





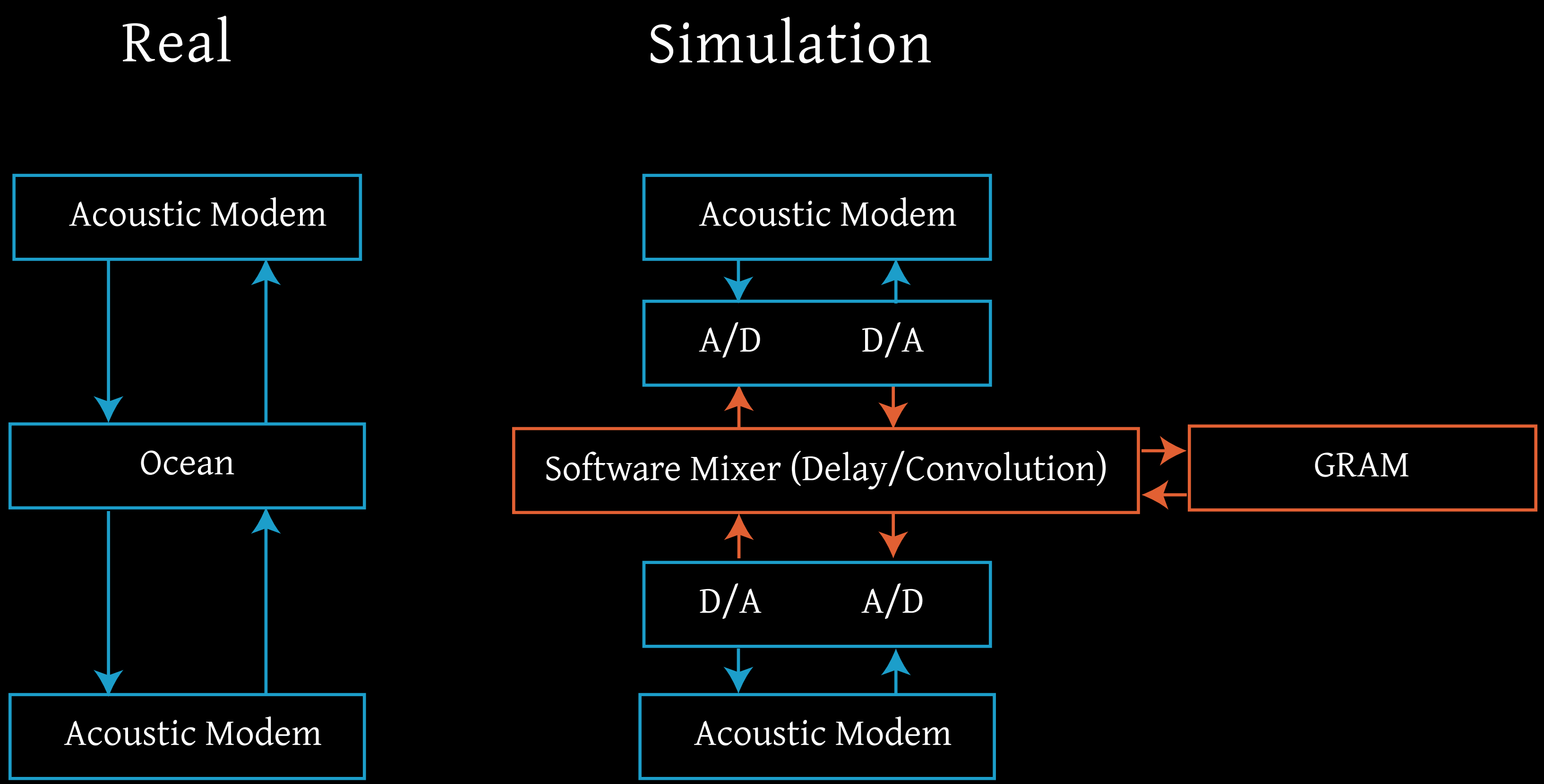
Other uses of GRAM: Simulation

- *In-situ* modeling for predictive adaptation (previous ex.)
- Software-only simulation of actual sonars



Other uses of GRAM: Hardware

- Hardware-in-the-loop testing of modem systems



Summary

- Generic Robotic Acoustic Modeling (GRAM) allows AUVs to use acoustic models addressing:
  - power
  - realtime constraints
- GLINT10: GRAM, BELLHOP, MOOS-IvP for model-predictive improvement of acoustic communications
- Other uses of GRAM
  - full software simulation
  - hardware-in-the-loop testing.

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