PN'07
R/V Wecoma
Accomplishments and Lessons Learned
MIT – NUWC – SAIC - BF

PN'07 Washup Meeting

APL-UW

Oct. 11, 2007

The Seattle Times
Front page Oct. 12, 2007

“Is Sound Transit Reliable”

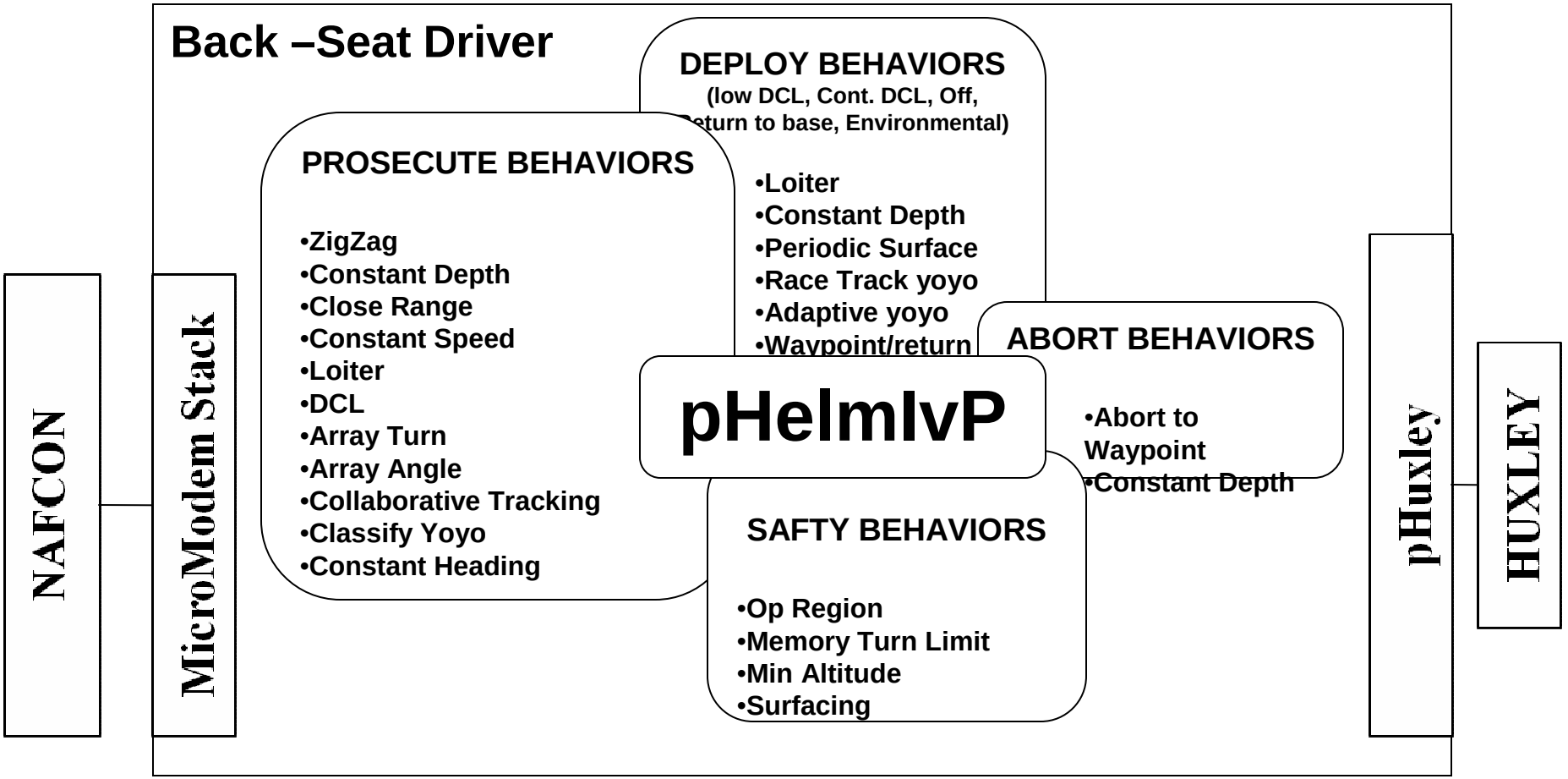
R/V Wecoma
AUV Hardware

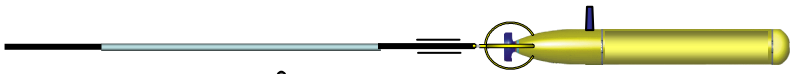
- Vehicle Performance
  - Macrura
    - 28 hours dive time
    - 25 hours VSA data collection
  - Unicorn
    - 32 hours dive time
    - 6 hours DURIP data collection
- Towed arrays
  - VSA robust. NUWC recorder problem
  - DURIP: Failed Oct 6. Replaced by onboard simulations
- Reliability
  - MAC Tailcone failure Oct. 11 pm
  - One Hardware failure induced launch delay (0.5 day)
  - One operator error-induced delay (30 minutes)

R/V Wecoma AUV Software

- Bluefin Low-level Control
  - Huxley/MOOS backseat driver connectivity flawless
  - Issues
    - Dynamic depth control of Macrura/VSA must be improved
    - Pitch abort when backseat driver requests large depth changes
- MIT MOOSIvP Backseat Driver Control
  - All behaviors and vehicle control processes frozen in August operated flawlessly. No issues.
  - Faulty third-party software modified within last weeks created significant delays.
    - Real time data acquisition
    - Micromodem and CCL drivers
- ACOMMS Software
  - Cost 2 days of acoustic connectivity.
  - Not properly tested in virtual experiments. Debugged onboard
- Data Acquisition.
  - Late delivery. Debugged onboard

Back-Seat Driver Paradigm

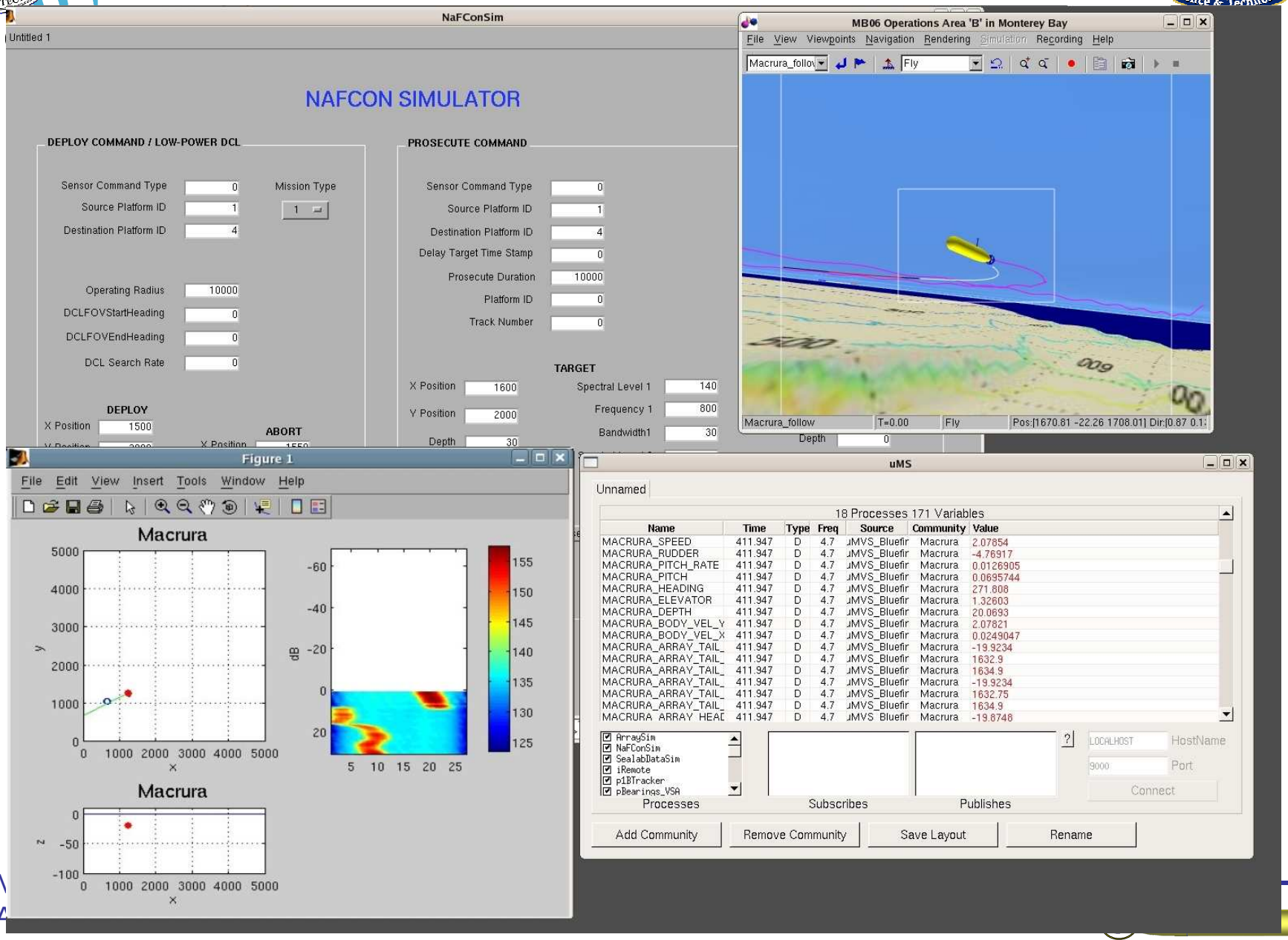




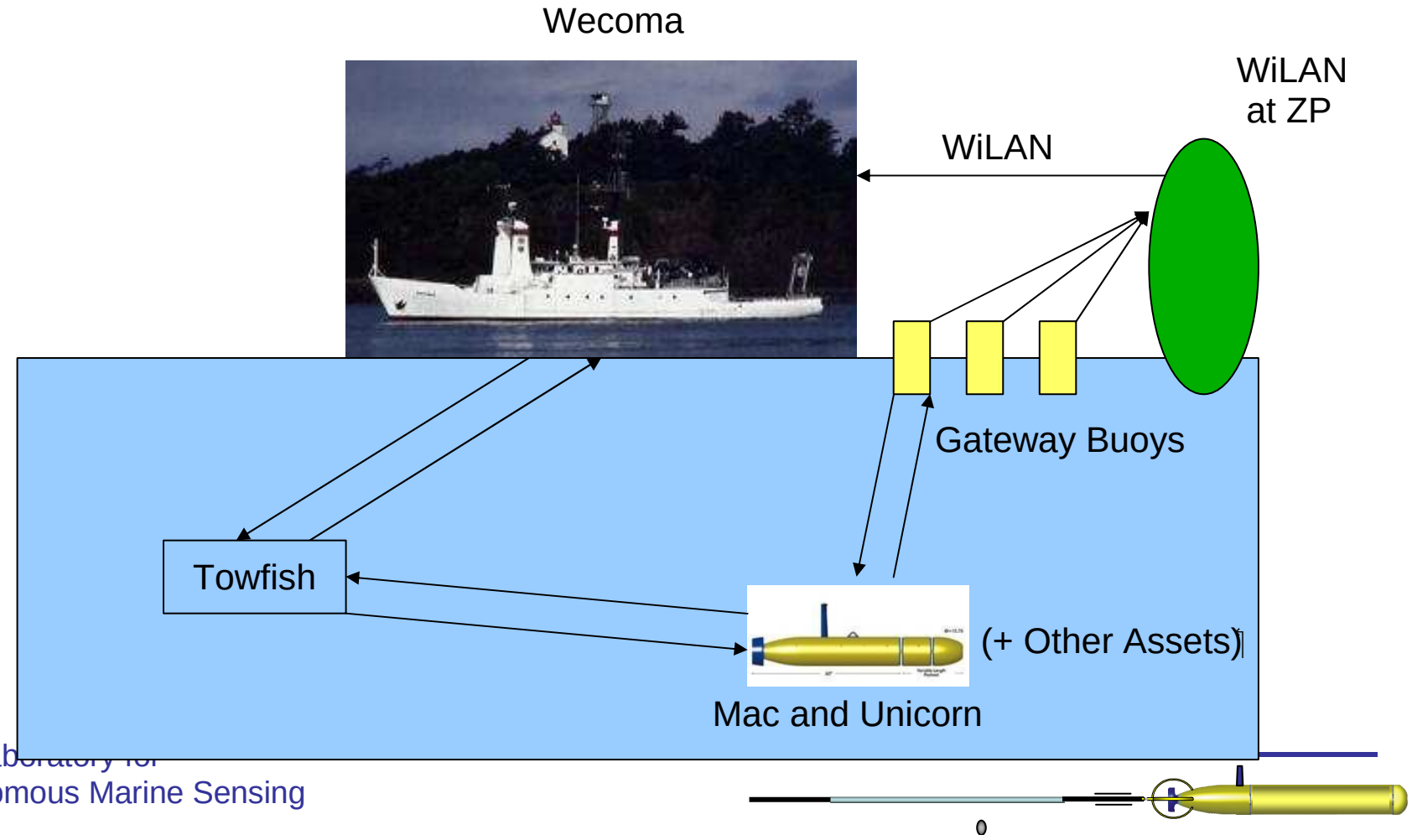
PN07
SIMULATION CAPABILITIES

- MOOS/SEALAB Complete Mission Simulation Environment
  - vehicle and array dynamics
  - acoustic transmissions
  - vehicle ACOMMS
  - NaFCon Simulator
- Exercises extensively in virtual experiments
  - Debugging
  - Code development support
  - CONOPS development
- Daily use of MOOS/SEALAB simulator
  - prepare for next day's missions
  - tune vehicle behaviors / beamforming
  - validate process modifications

SIMULATION ENVIRONMENT

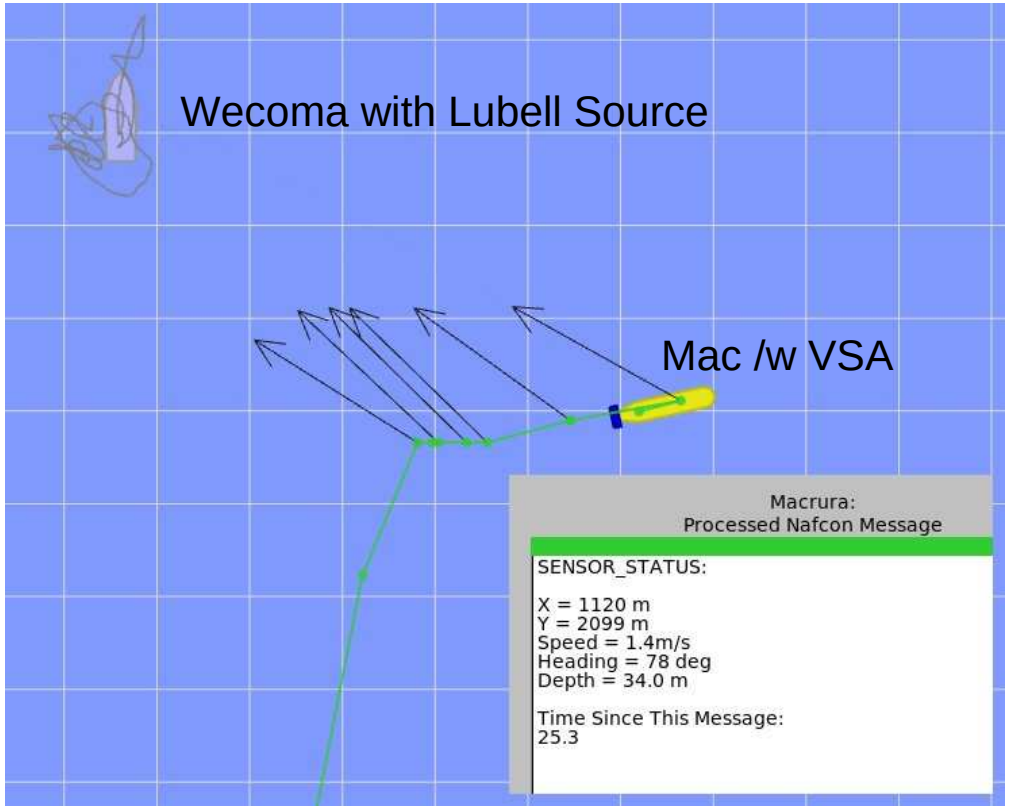


MIT/Wecoma's Top Side Topology



Top Side Display

- Accomplishments
  - Logged directly into 4 WHOI buoys via WiLAN.
  - Merged Wecoma towfish data with WHOI buoy data into one display.
  - Displayed Contact and Track Reports.
  - Use of “NodeSpecificInfo” fields for other information (time to slowdown, collaboration state, etc)



- Issues:
  - Couldn't merge non-NAFCON message data (other ships' locations, OMAS source location, etc.) into local display.
  - Some messages appeared in Penn State NAFCON Display but didn't appear in WHOI buoys.

PN07 Wecoma Completed Events

- A6 Mag, A6 MDL-hex:
  - 3hours hex loiter with Mac/VSA
  - Wecoma Lubell at station 4
  - Defender Lubell along East border
- A6 MDL-line
  - 4 hours racetrack between stations 4 and 6
  - Defender/Lubell at center E-F
  - Wecoma steaming @ 3 kn in A-B second half
- B15 Ambient noise collection
  - 2 km N-S racetrack with field sampling with VSA at 10 depths
- B20 Continuous DCL Loiter
  - Standard deploy mission
  - Contact reports
    - Defender Lubell
    - Wecoma Lubell
    - OMAS
    - Surface assets

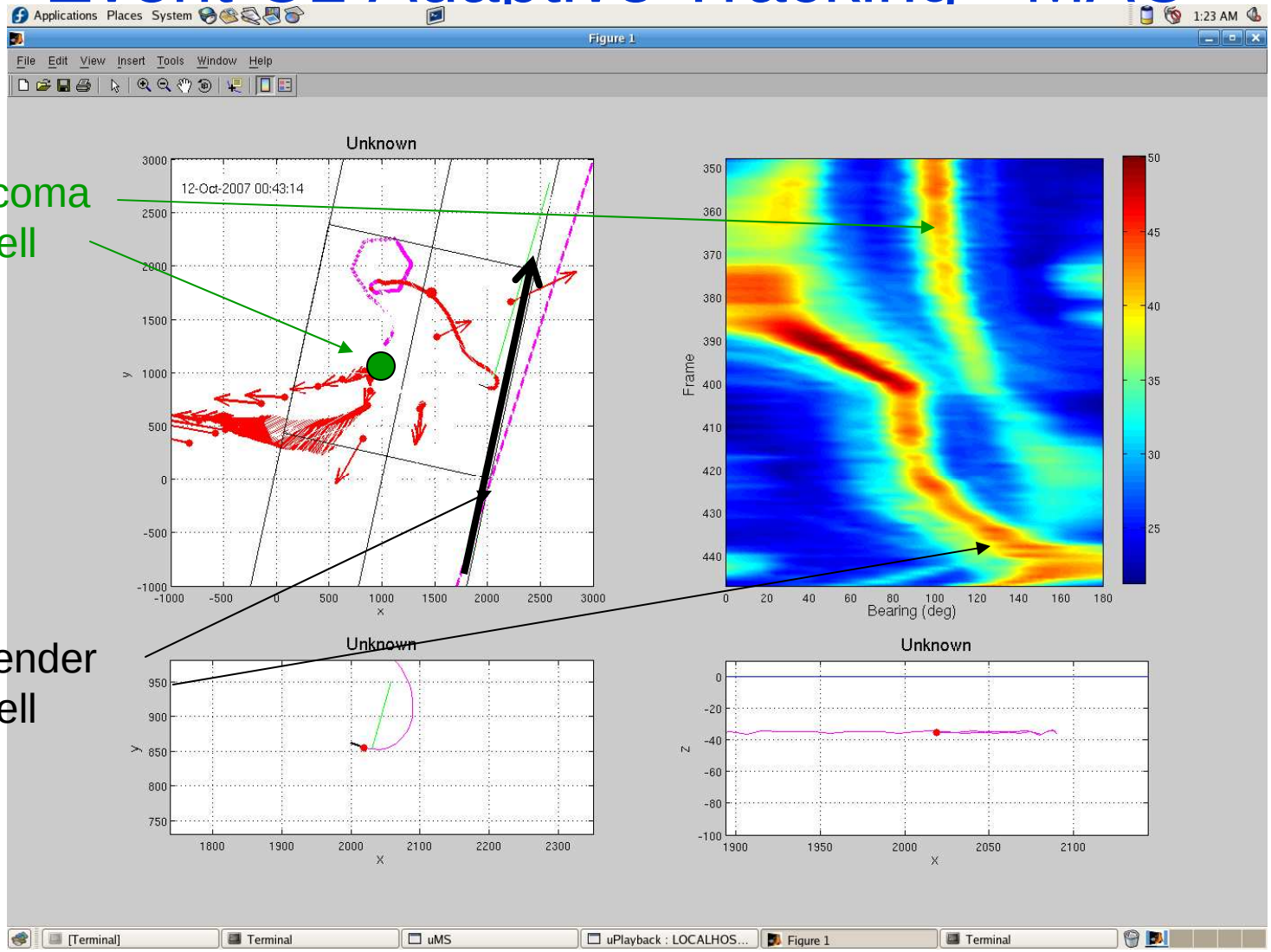
PN07 Wecoma Completed Events

- C1 Adaptive, autonomous DCLT.
  - Lubell on Wecoma
  - Defender Lubell
  - Surface assets
  - Contact and track reports
- C3,C4 Collaborative Adaptive and Non-Adaptive DLT.
  - Macrura VSA and onboard signal processing
  - Unicorn: On-board target bearing simulator
- C6 Vertical adaptive YoYo REA
- C7 ZigZag TMA with both Unicorn and Macrura
- C8 Depth classification yoyo for depth discrimination

Oct. 6
Event C1 Adaptive Tracking - MAC

Wecoma
Lubell

Defender
Lubell



Oct. 6
Event C1 Adaptive Tracking - MAC

PN07 Wecoma
Onboard Acoustic Signal Processing

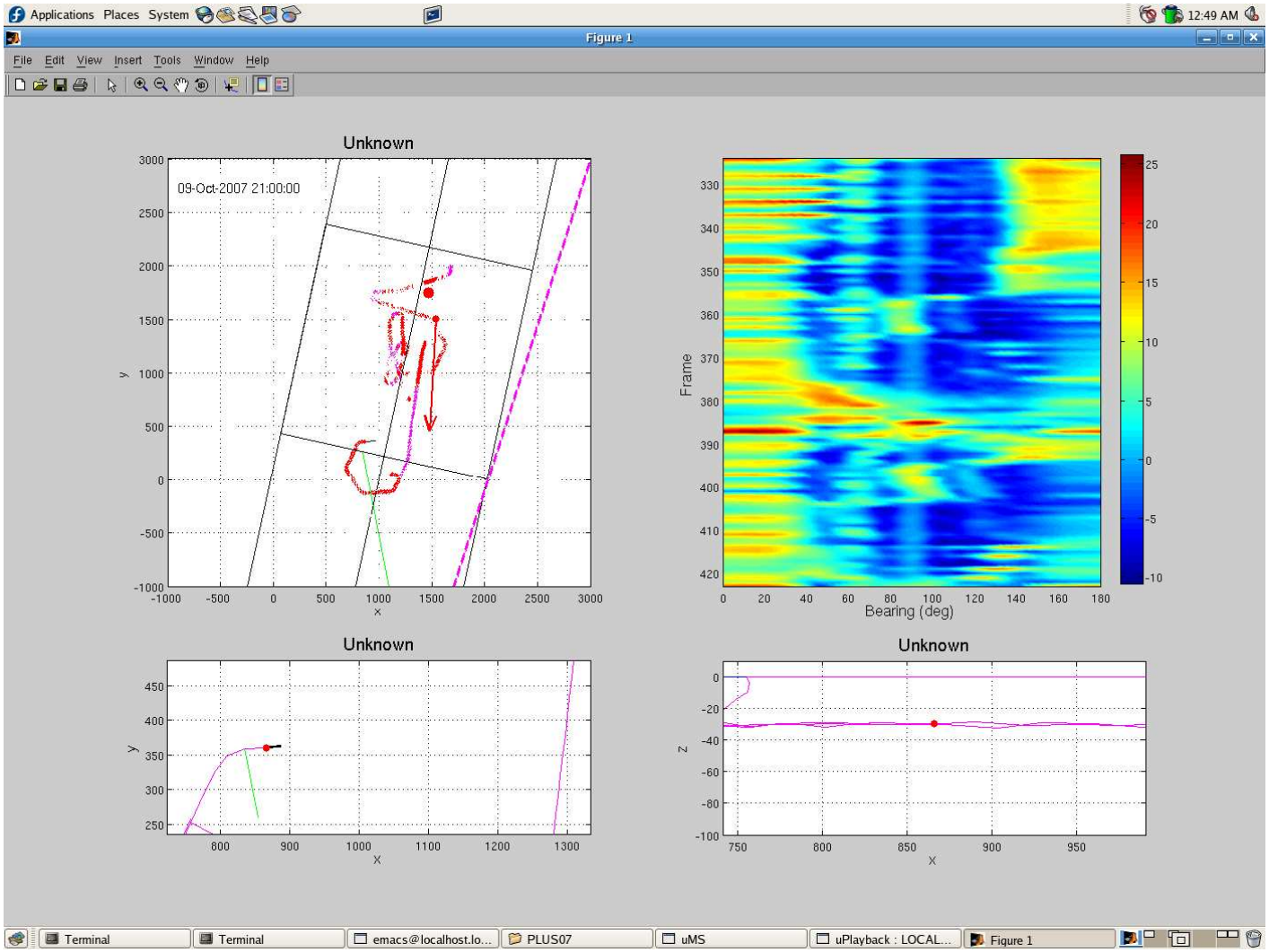
Accomplishments

- Successful implementation of real-time detector, beamformer, beam interpolation, bearing stabilization and tracking algorithms.
- Changed the real-time detector on the Bluefin AUVs in order to be compatible with the signal environment at Dabob Bay.
  - Introduced parameters and supporting code to use any subset of sorted spatial beam powers for ambient noise statistical estimation.
  - Continuously update the statistical noise estimates using exponential averaging.
- Successfully detected and tracked
  - Broadband LUBELL waveform (800-1000 Hz)
  - OMAS by processing only the bins coincident to the 800, 900 and 1000 Hz tones
- Performed quality control analysis of the acoustic data collected, including BTRs, spectrograms, etc.

Issues

- Detector used at MB06 required that the source not be present during noise estimation
  - Changed aboard the Wecoma
- Problems with the non-acoustic data processor

PN07 Wecoma
Event B20,T8 OMAS Tracking



Collaborative Tracking

- Accomplishments
  - Developed a triangulation-based multi-bearing target tracker
    - Tracker accounts for network latency
    - Can work with bearings from any number of fixed and/or mobile nodes
    - Implemented in a MOOS module. Fully simulated in the MIT simulator.
    - Run in-water on Unicorn and Macrura in PN 07
  - Developed a 2-vehicle collaborative tracking behavior
    - Vehicle motion optimized to reduce track estimate uncertainty
    - Implemented in the behavior-based IvP helm. Fully simulated in MIT simulator.
    - Run in-water on Unicorn and Macrura in PN 07
- Issues
  - Macrura and Unicorn received very few contact reports from each other in the water, too few to develop a collaborative tracking solution
    - Possibly due to vehicle self-noise

In-water Target Simulation

- Accomplishments
  - Implemented a target simulator which uses the target information contained in the prosecute message to produce target bearings for the target trackers and contact reports
  - Plug and play compatible with the real acoustic bearing estimators including stimulating the proper l/r ambiguity breaking maneuvers
  - Uncertainty can be added to the bearings
  - The target simulator was run in-water on Unicorn when the DURIP array went TU and it produced numerous contact reports on multiple missions. The bearings were also used to successfully estimate target tracks on multiple missions.

PN07 Wecoma
MLBL data collection

- 2 vehicles
- 2 days, 6 hours of data collection
- 200+ range/position pairs from gateway buoy
  → data will get used to refine **M**oving **L**ong **B**ase**L**ine Algorithm
- Improvements:
  - use of dedicated CAN message
  - reporting position uncertainties

PN07 Wecoma Lessons Learned I

- Nested, autonomous DCLT possible
  - Behavior-based control key to autonomy
  - Demonstrated robustness to lack of network connectivity, with fully autonomous tracking of Lubell and OMAS
- ACOMMS vastly improved, but latency and intermittency issues remain for field control
  - Status and Contact reports received robustly
  - Significant problems commanding vehicles beyond 1 km range
    - Central polling architecture dangerous in poor conditions. Need regular scheduling of node transmissions (“I am here”)
    - Need local polling capability between vehicles for collaborative tracking.
  - CCL command language extreme complex and restrictive. More flexible protocol needed
    - Example Mission Type 4, Environmental Sampling not allowed. A6/MDL missions had to be started from surface
    - Need flexibility in PROSECUTE messages
      - Switch between 4 levels of autonomy had to be done on surface

PN07 Wecoma Lessons Learned II

- Virtual experiments paid off
  - High-Fidelity simulation accurately reproduced at sea behaviors
    - MOOS-IvP Autonomous behavior-based control software
    - SEALAB high-fidelity acoustic simulator
  - All control software tested in virtual experiments worked as intended. No debugging
  - ACOMMS and data acquisition software completed or modified later than “code freeze” had to be debugged onboard

PN07 Wecoma
Lessons Learned III

- MIT-BF AUV Launch and operation procedure developed to perfection
  - Launch procedure very smooth, no incidents.
  - Initial deployment into hex loiter
  - Commands via CCL. Wecoma commanding when NaFCon failed.
  - Last day Macrura and Unicorn launch and dive in 20 minutes
  - Come home missions commanded from Wecoma
  - Recovery smooth and eventless, even VSA.
  - Bluefin operational support and mission execution exceptionally good. Great ops team!
  - Hardware reliability beyond expectation
  - BF Software support exceptional
    - No “secrecy” or “fingerpointing” regarding Huxley issues.

PN07 Wecoma
Lessons Learned IV

- Dabob Bay Ideal setting for network concept development and demonstration
  - Portable range a gift from above. Removed all tensions between ops and science teams
  - Range control did phenomenal job at keeping track of all assets. Close calls due to NaFCon and RV operator errors (and hardware failure)
  - Keyport logistical support exceptional