



NURC - Partnering for Maritime
Innovation



Behavior Development for Anti-Submarine Warfare:

The GLINT09 and GLINT10 Field Trials

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NATO Undersea Research Centre: Underwater acoustics and ASW



1959: SACLANT

NATO maritime and transformational requirements

Seagoing research: Maritime innovation in NATO Nations

- Cooperative ASW
- Autonomous Naval Mine Countermeasures
- Ship and Port Protection
- Marine Mammal Risk Mitigation
- Maritime Situational Awareness
- Environmental Knowledge & Operational Effectiveness





Cooperative Anti-Submarine Warfare



GLINT: Generic Littoral Inter-operable Network Technology

Sensor networks Littoral Surveillance

Distributed processing Distributed intelligence

Behavior sets for autonomous multi-static platforms

Information transfer Concepts of use Interoperability

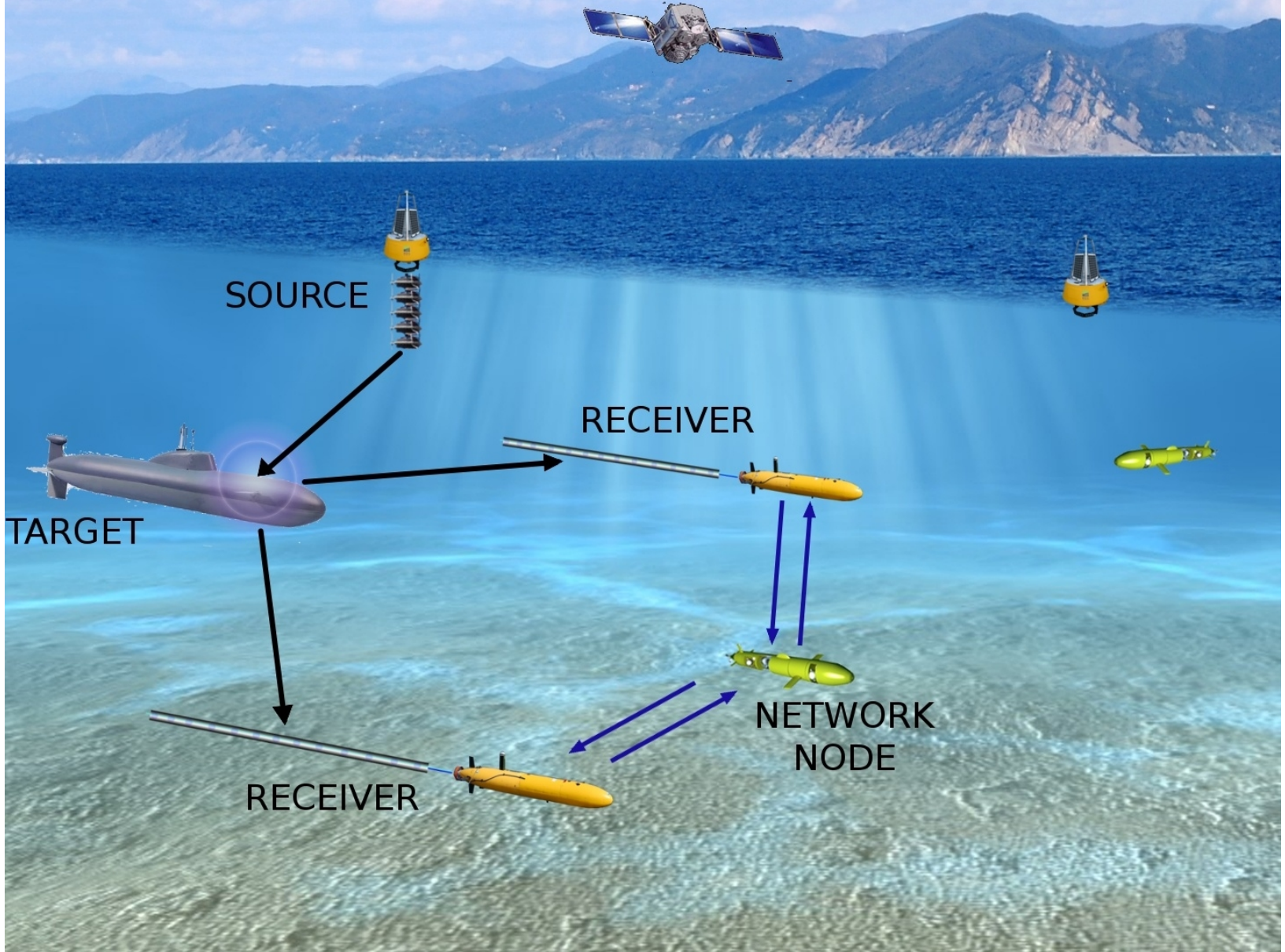
Advanced modeling Decision support

Command, control and integration





Multi-static Active Sonar and Data Fusion





GLINT09: Objectives for autonomy/behaviors



How can an AUV monitor its environment purely with its own sensors, convert the obtained data into information, which can then be used to alter its trajectory to exhibit some form of ASW relevant behavior?

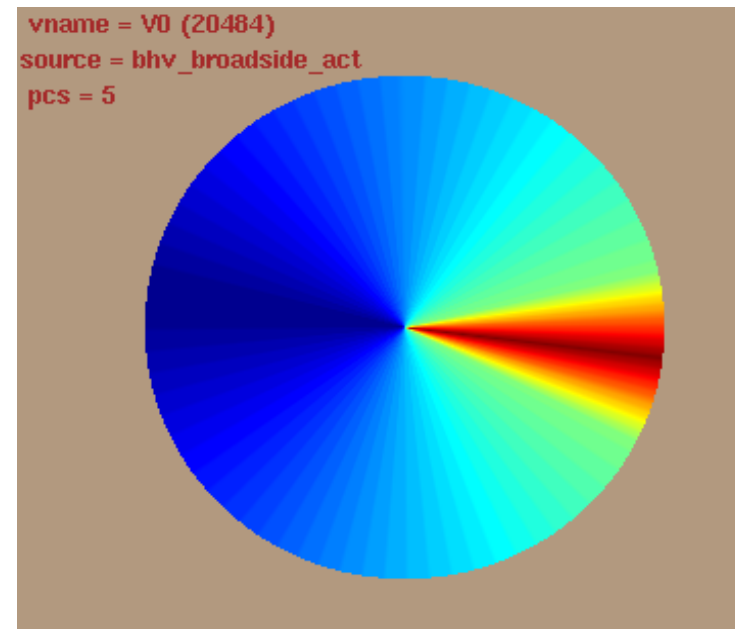
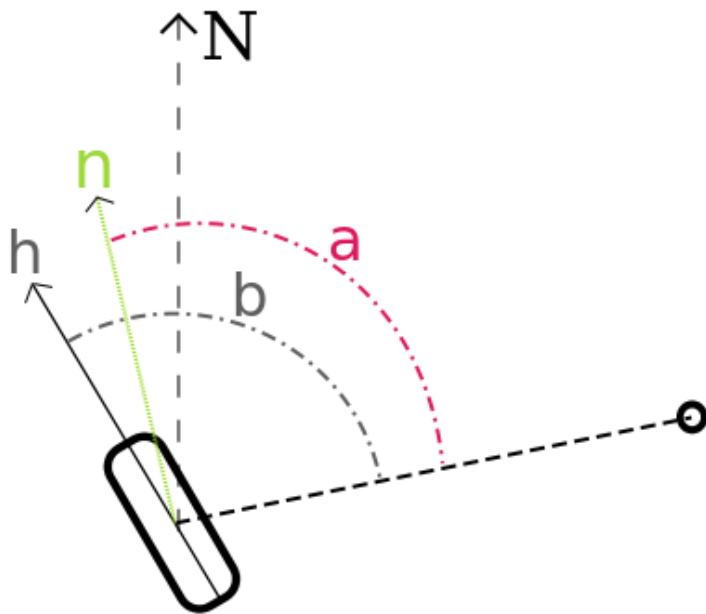
- real-time on-board processing
- adaptive behaviors

- heuristic approach: broadside behavior



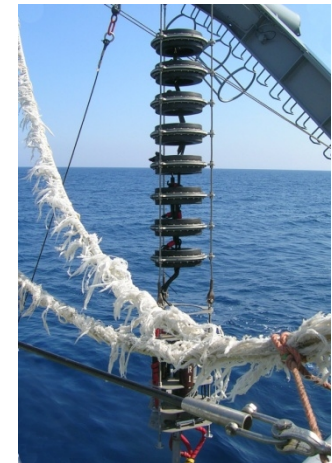
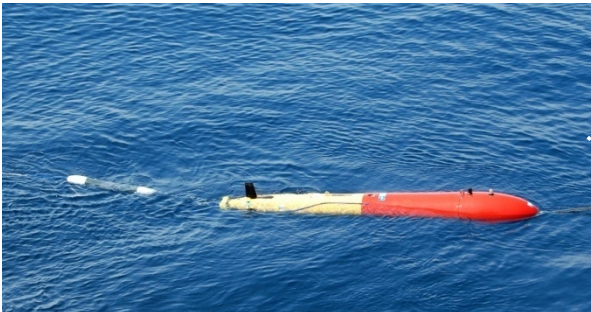
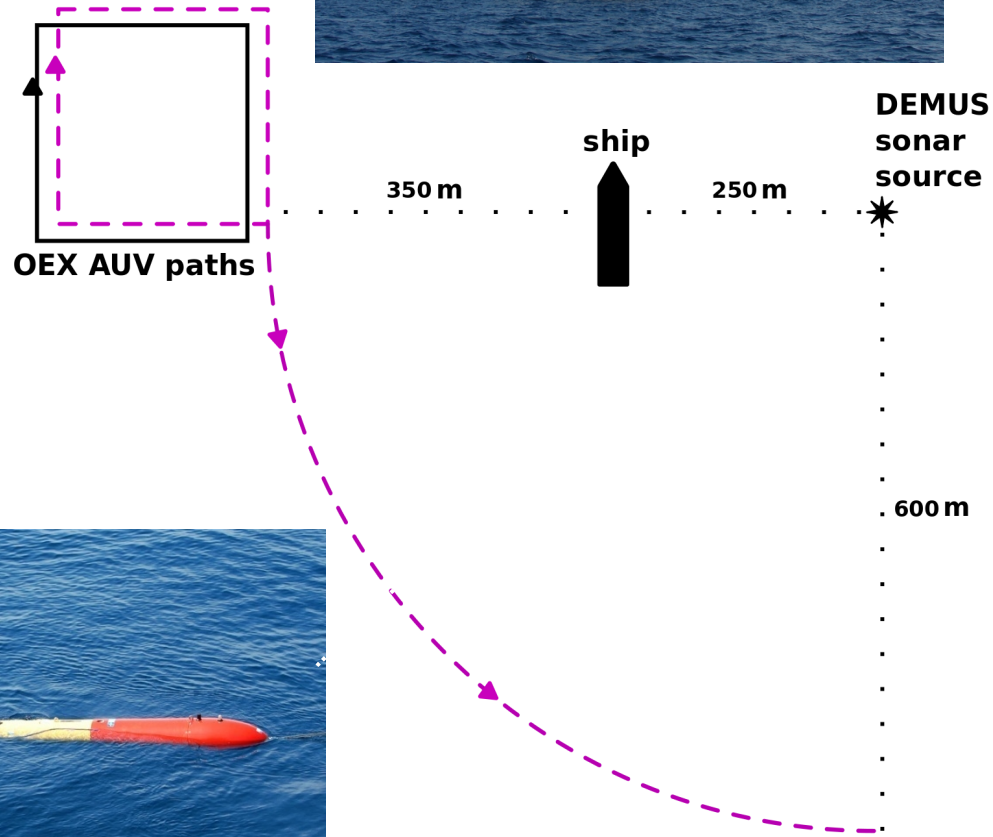
BHV Design: Objective Function

- ZAIC_PEAK function: calculate a new heading to get a contact at 90 degrees to the towed array: $n = h \pm b \mp a$
- domain: course, points: 360, pieces: 5



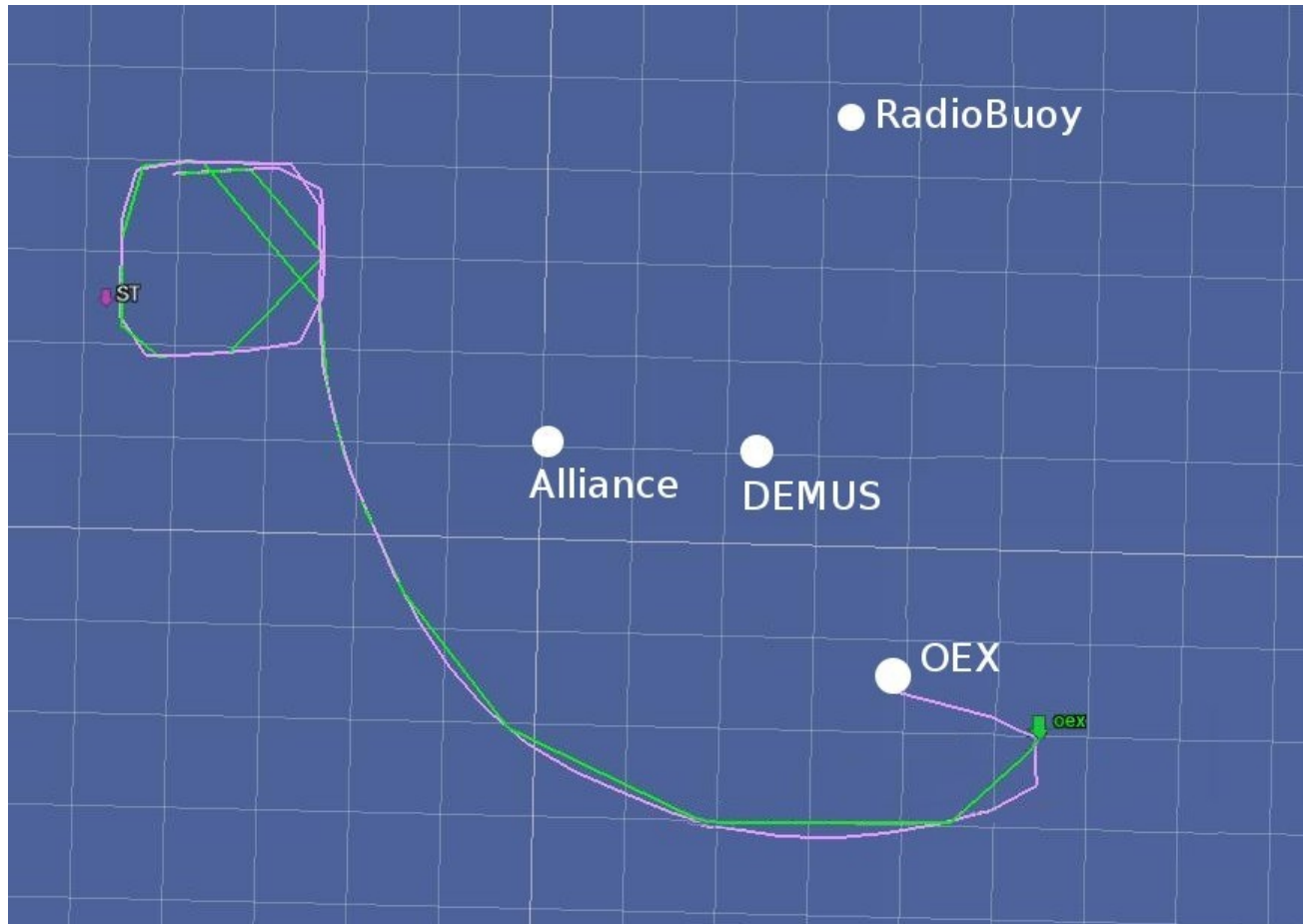


GLINT09: set-up broadside bhv





GLINT09: successful demonstration of real-time on-board signal processing + broadside behaviour



grid:
200m



GLINT09

real-time on-board processing

contacts

highest SNR contact

heuristic:
calculate 'broadside'
heading

one heading →
ZAIC_PEAK

GLINT10

real-time on-board processing

tracks

track evaluator:
score(contact SNR,
track length)

information theoretic:
full bi-static localization
equations

all possible headings →
AOF



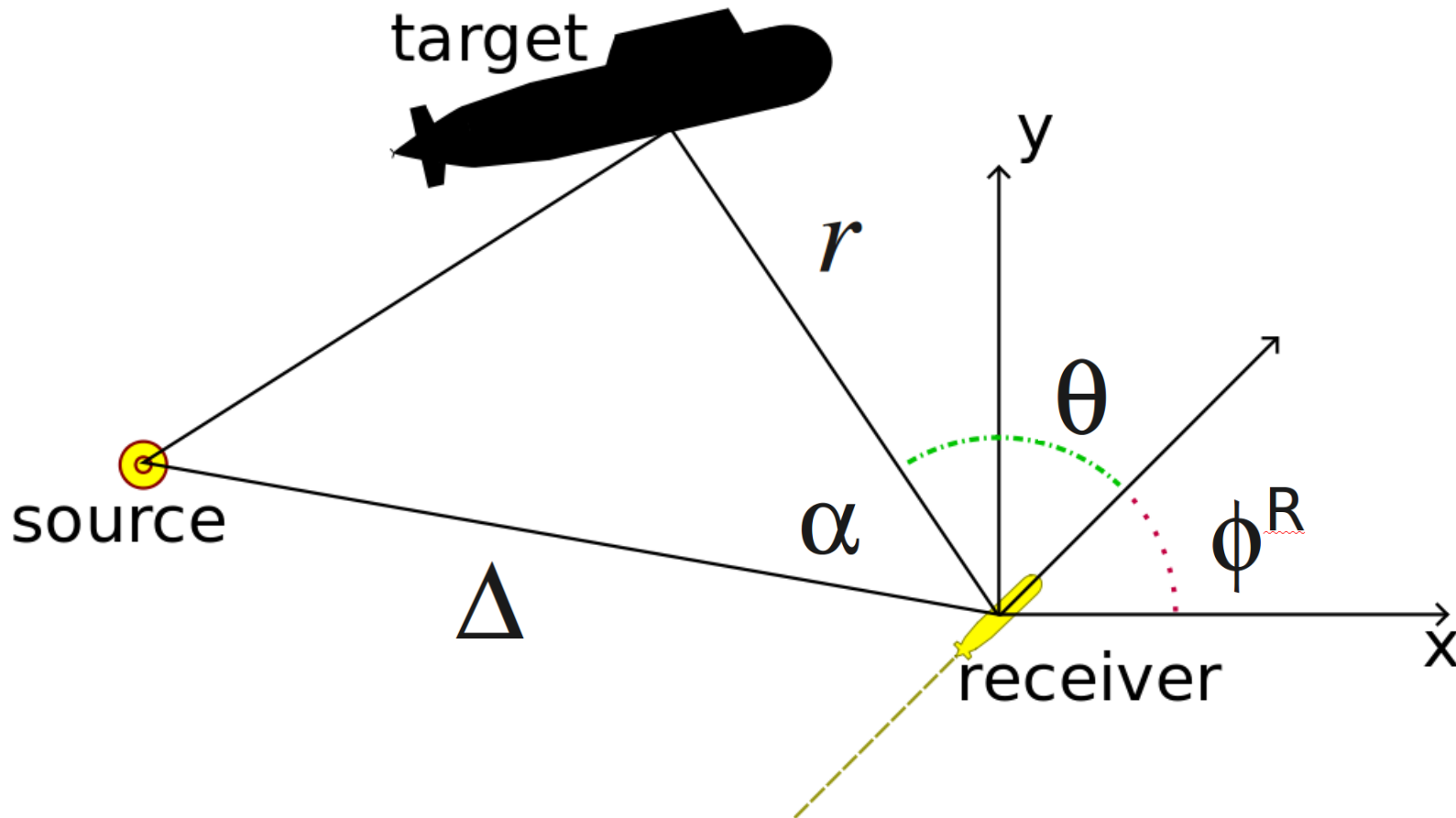
GLINT10: information theoretic approach



- create tracks: real-time on-board processing + NURC's DMHT tracker
- choose a track : score by signal-to-noise ratio associated contact and length of track,
- calculate the error in the localization of the chosen track, for all possible headings one step into the future,
- let IvP pick the heading that minimizes this error.



GLINT10: bi-static localization equations



$$x^T = x^R + r \cos(\theta + \phi^R)$$

$$y^T = y^R + r \sin(\theta + \phi^R)$$



GLINT10: localization error using bi-static localization equations



$$\begin{aligned}\sigma_{x^T}^2 &= \sigma_{x^R}^2 + \cos^2(\theta + \phi^R)\sigma_r^2 + r^2 \sin^2(\theta + \phi^R) \\ &\quad \times \left(\sigma_\theta^2 + \sigma_{\phi^R}^2 \right) + 2 \cos(\theta + \phi^R)\sigma_{x^R r} \\ &\quad - 2r \cos(\theta + \phi^R) \sin(\theta + \phi^R)(\sigma_{\theta r} + \sigma_{\phi^R r})\end{aligned}$$

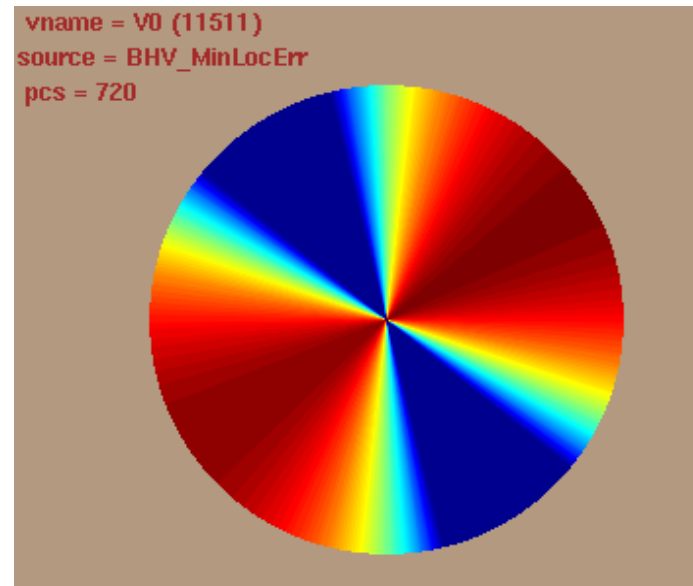
$$\begin{aligned}\sigma_{y^T}^2 &= \sigma_{y^R}^2 + \sin^2(\theta + \phi^R)\sigma_r^2 + r^2 \cos^2(\theta + \phi^R) \\ &\quad \times \left(\sigma_\theta^2 + \sigma_{\phi^R}^2 \right) + 2 \sin(\theta + \phi^R)\sigma_{y^R r} \\ &\quad + 2r \sin(\theta + \phi^R) \cos(\theta + \phi^R)(\sigma_{\theta r} + \sigma_{\phi^R r})\end{aligned}$$



BHV Design: Objective Function

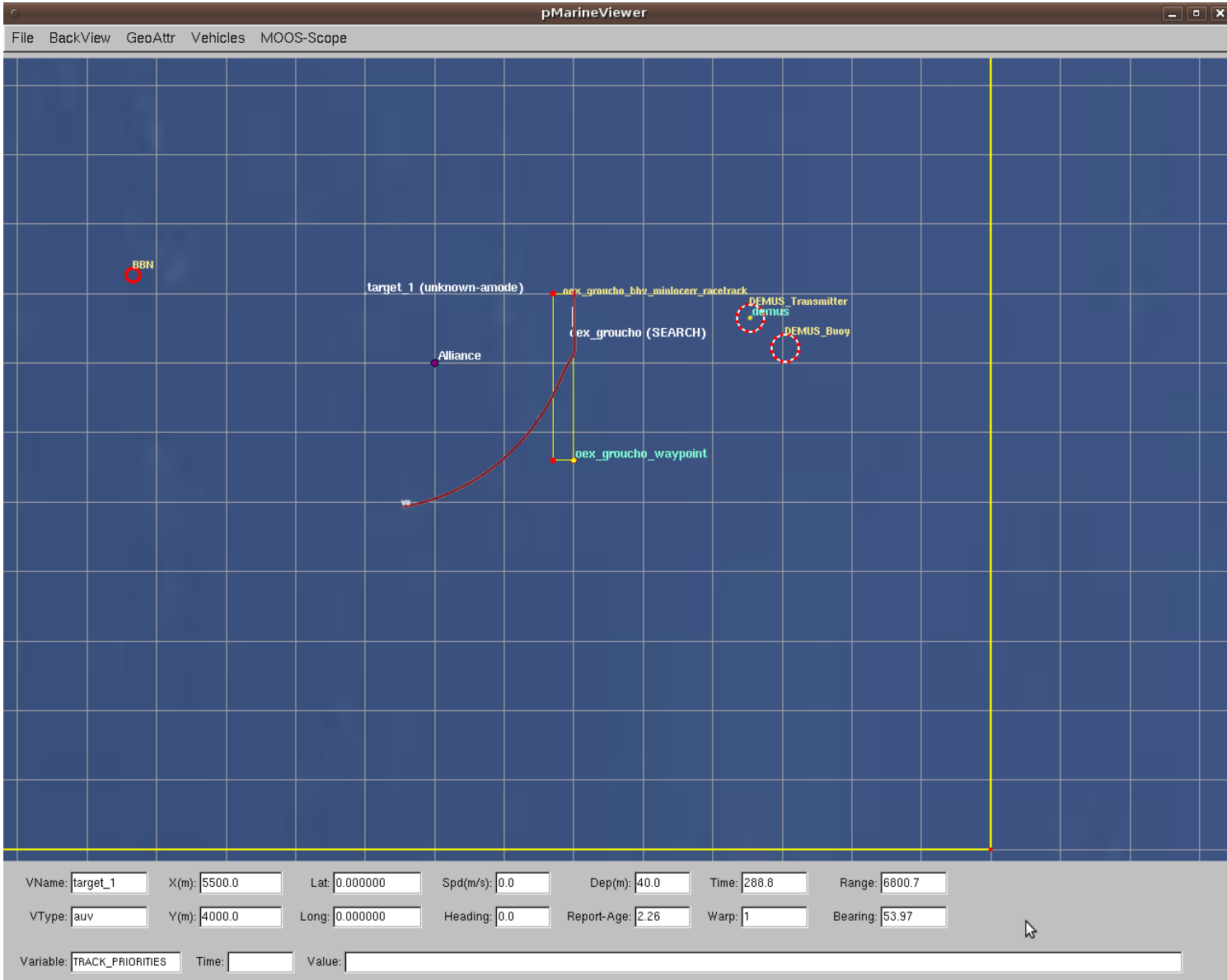


- AOF function: calculate and return the inverse of the trace of the localization error matrix for a chosen track
- domain: course, points: 720, pieces: 720





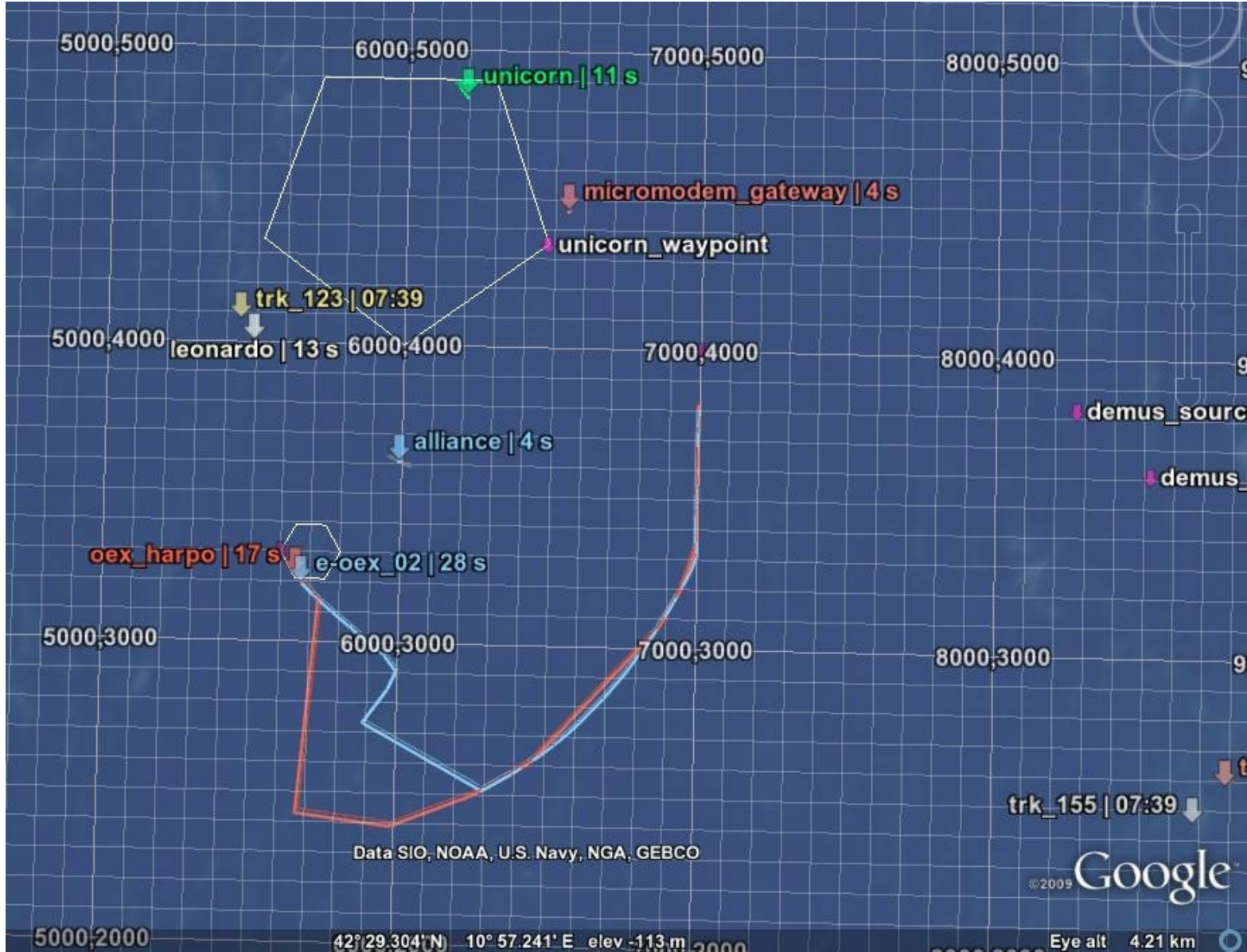
Simulations: one AUV optimizing for a static target



grid:
500m



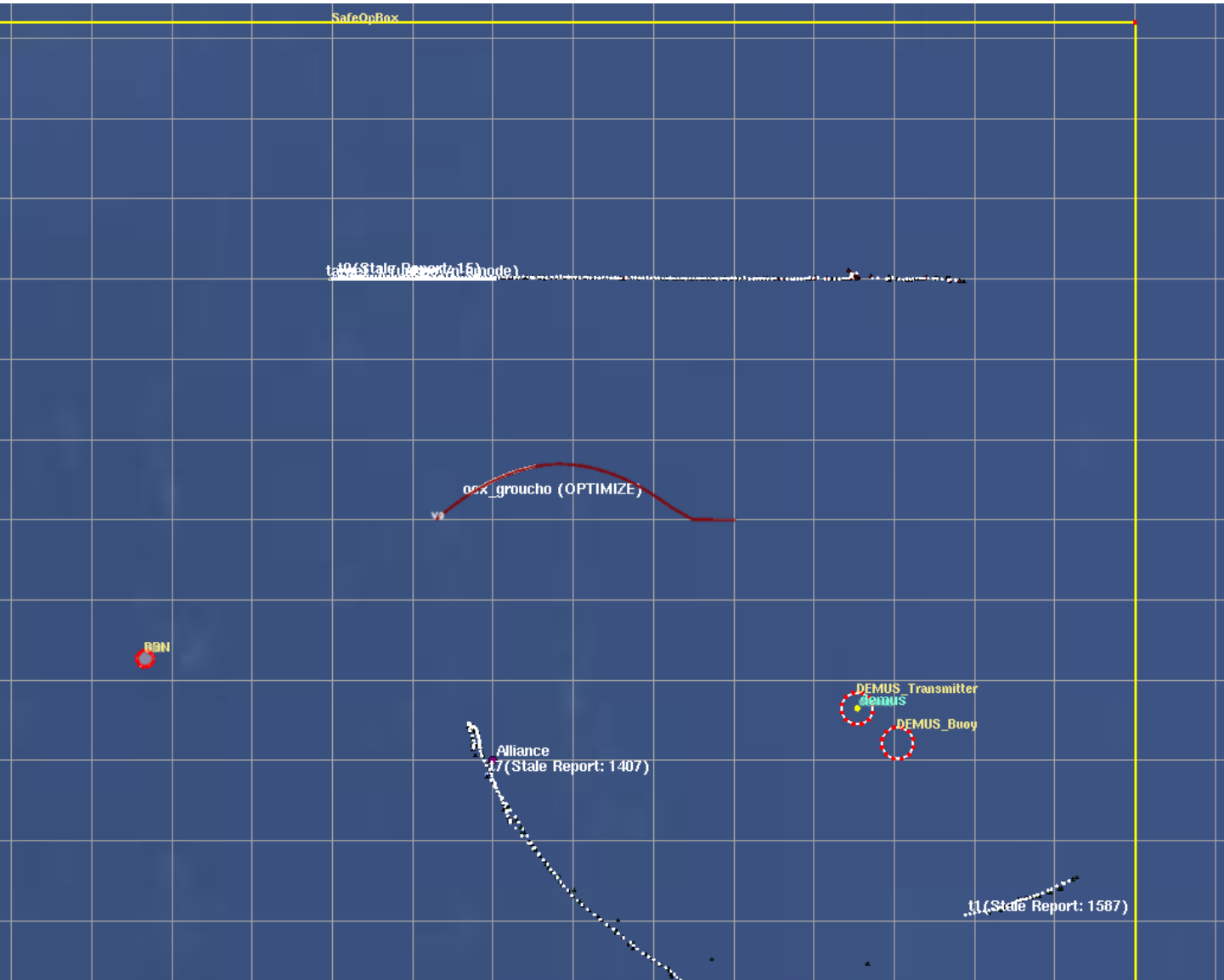
GLINT10: one AUV optimizing for a static target (echo repeater)



grid:
100m



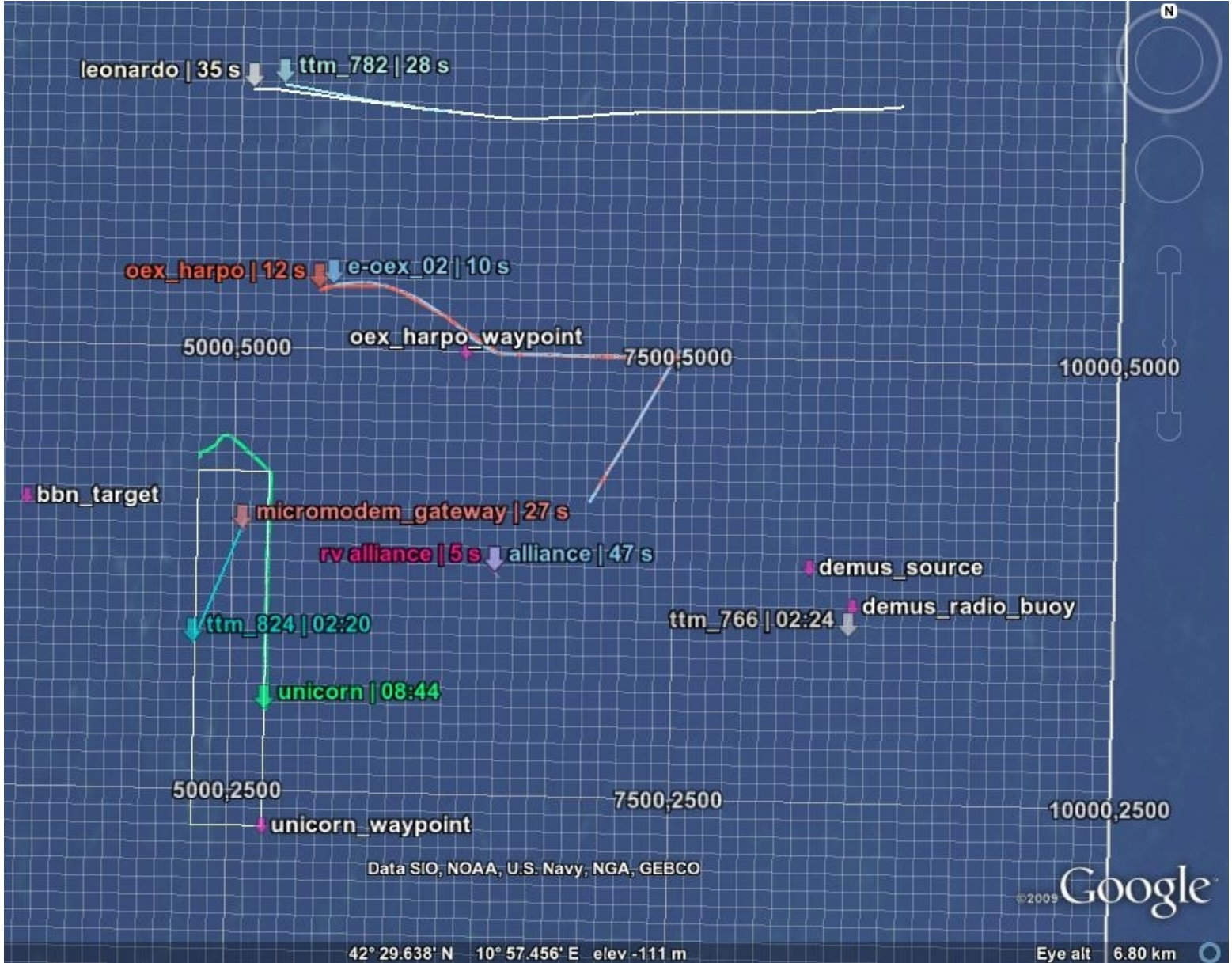
Simulations: one AUV optimizing for a moving target



grid:
500m



GLINT10: one AUV optimizing for a moving target (echo repeater)



grid:
100m

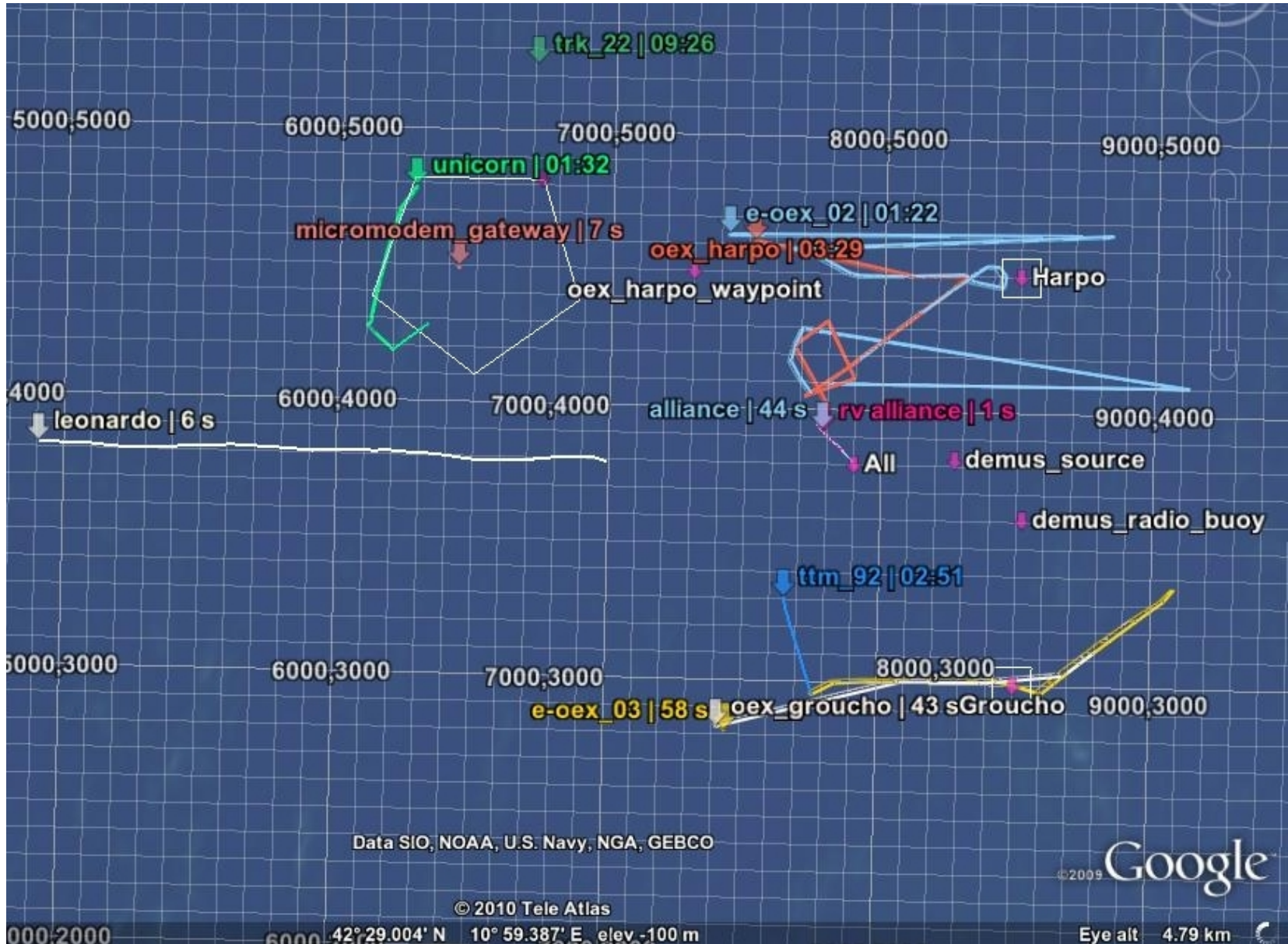


Two AUVs





GLINT10: two AUVs optimizing individually for a moving target





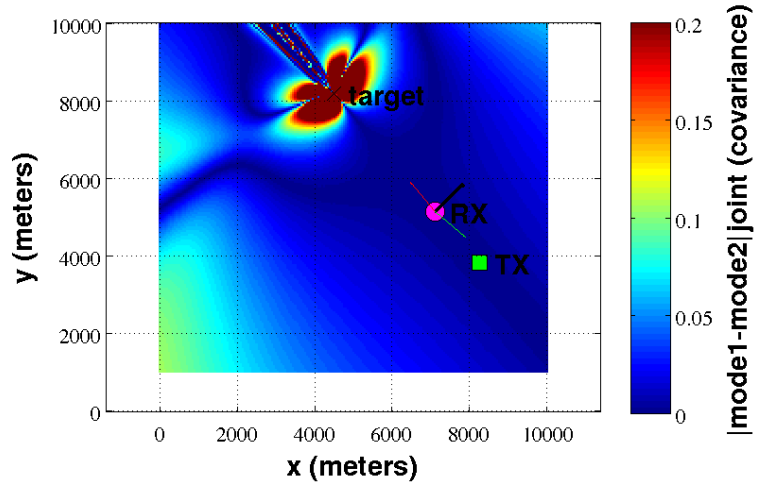
GLINT10: 1 AUV optimizing collaboratively, 1 individually for a moving target



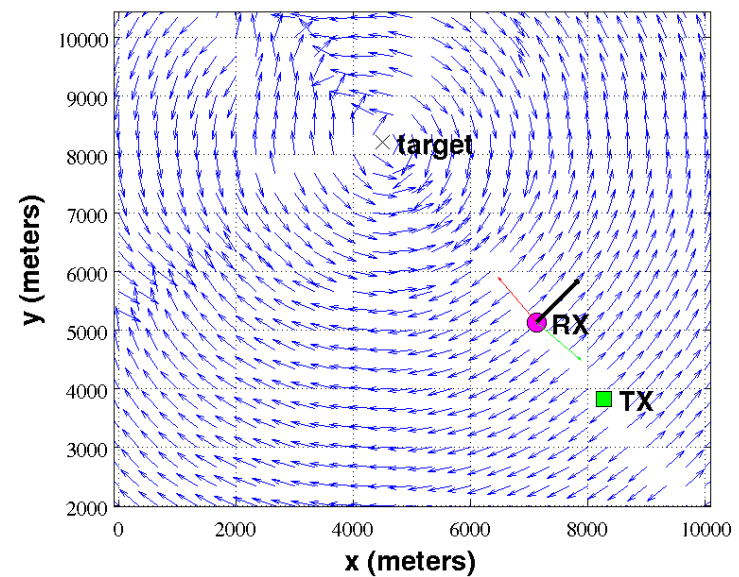
Michael J. Hamilton

Talk-09, August 24th 9.00 - 9.30 : Information theory based multi-vehicle collaboration for multi-static sonar using MOOS-IvP

modal peak difference, joint op, all locations

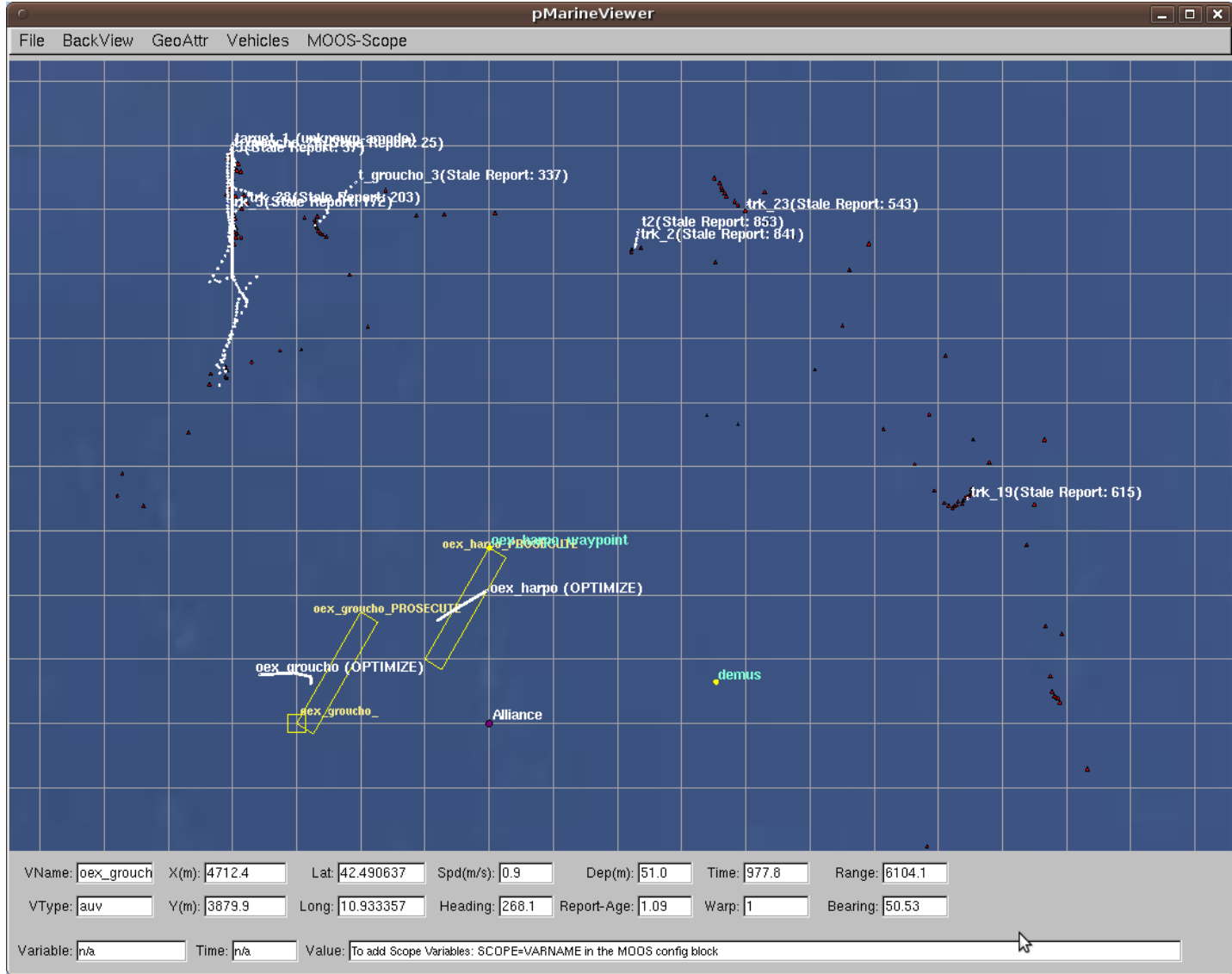


Joint Localization



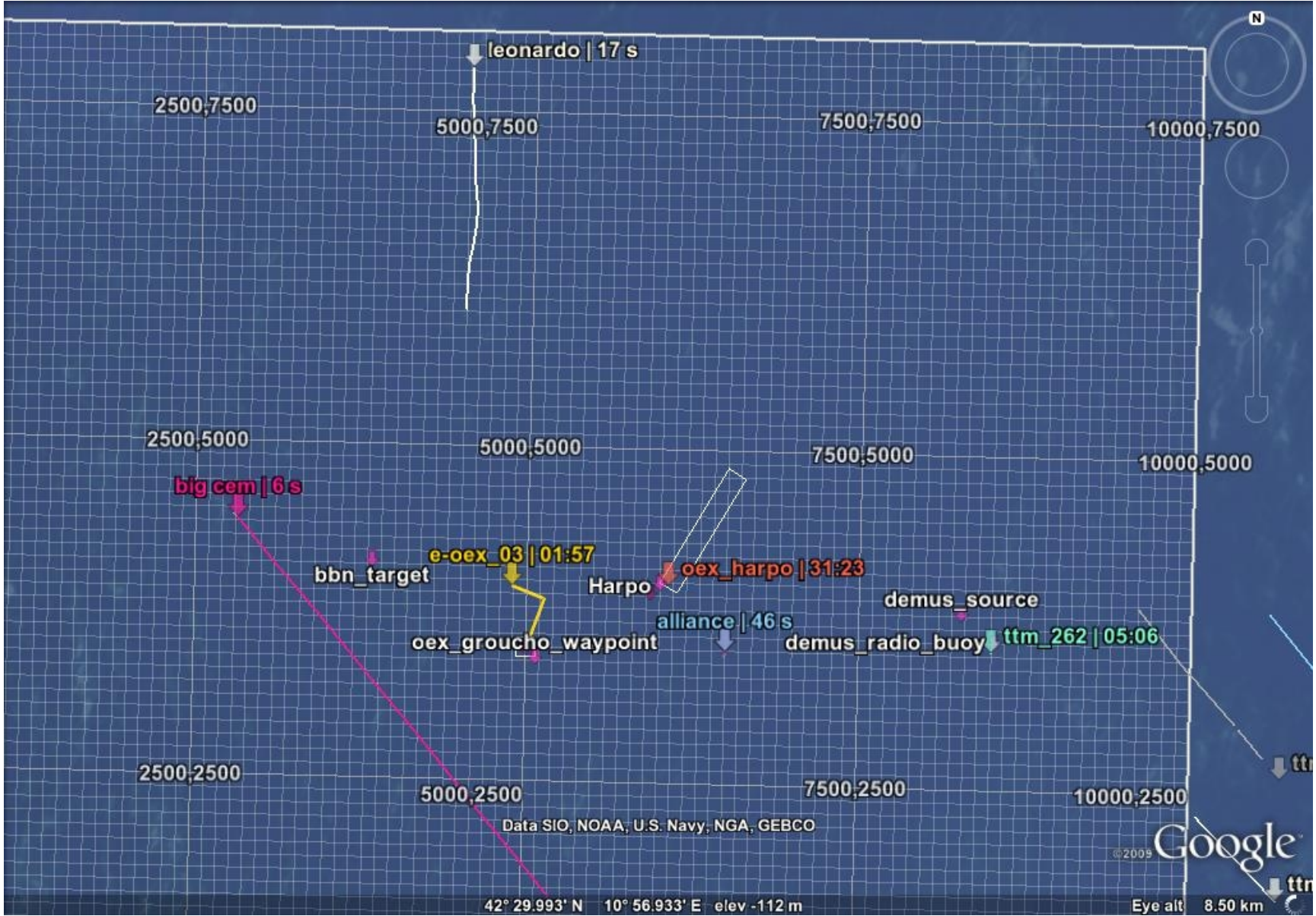


Simulations: 1 AUV optimizing collaboratively, 1 individually for a moving target





GLINT10: 1 AUV optimizing collaboratively, 1 individually





GLINT10 logview: 1 AUV optimizing collaboratively, 1 individually



logview

File BackView GeoAttr Vehicles Replay LogPlots(L) LogPlots(R) HelmPlots IPFPlots(Top) IPFPlots(Bot)

vname = V0 (14162)
source = BHV_MinLocErr
pcs = 720

vname = V0 (14162)
source = BHV_MemoryTurnLimit
pcs = 4

Vehicle: 14162-V0	Mode: OPTIMIZE	Decision: course=81.9, depth=50.9, speed=0.9	Vehicle: 14162-V0	Mode: OPTIMIZE	Decision: course=81.9, depth=50.9, speed=0.9
Active: BHV_MemoryTurnLimit, BHV_MinLocErr, BHV_Broadside_ConstantDepth, BHV_Broadside_ConstantSpeed			Active: BHV_MemoryTurnLimit, BHV_MinLocErr, BHV_Broadside_ConstantDepth, BHV_Broadside_ConstantSpeed		
Running: BHV_OpRegion, BHV_AvoidObstacles_DemosBuoy, BHV_AvoidObstacles_DemosTransmitter, BHV_AvoidObstacles_BBN			Running: BHV_OpRegion, BHV_AvoidObstacles_DemosBuoy, BHV_AvoidObstacles_DemosTransmitter, BHV_AvoidObstacles_BBN		
Idle: BHV_Abort_Waypoint, BHV_Abort_Waypoint_ConstantDepth, BHV_Surface_GoToDepth, BHV_Surface_ConstantSpeed, BHV_Surface_ConstantSpeed, BHV_Surface_ConstantSpeed, BHV_Surface_ConstantSpeed			Idle: BHV_Abort_Waypoint, BHV_Abort_Waypoint_ConstantDepth, BHV_Surface_GoToDepth, BHV_Surface_ConstantSpeed, BHV_Surface_ConstantSpeed, BHV_Surface_ConstantSpeed, BHV_Surface_ConstantSpeed		
Complete: none			Complete: none		

Var: **V0DESIREDDDEPTH** CurrVal: 50.9 Time: 3560.2 IN OUT RESET play-rate: Paused collect: Off CurrVal: 50.9 Var: none

50.9	n/a
-9.569	8352.77
0	n/a

Vehicle: 16563-V0	Mode: OPTIMIZE	Decision: course=288.1, depth=49.6, speed=0.9	Vehicle: 16563-V0	Mode: OPTIMIZE	Decision: course=288.1, depth=49.6, speed=0.9
Active: BHV_MemoryTurnLimit, BHV_JointMinLocErr, BHV_Broadside_ConstantDepth, BHV_Broadside_ConstantSpeed			Active: BHV_MemoryTurnLimit, BHV_JointMinLocErr, BHV_Broadside_ConstantDepth, BHV_Broadside_ConstantSpeed		
Running: BHV_OpRegion, BHV_AvoidObstacles_DemosBuoy, BHV_AvoidObstacles_DemosTransmitter, BHV_AvoidObstacles_BBN			Running: BHV_OpRegion, BHV_AvoidObstacles_DemosBuoy, BHV_AvoidObstacles_DemosTransmitter, BHV_AvoidObstacles_BBN		
Idle: BHV_Abort_Waypoint, BHV_Abort_Waypoint_ConstantDepth, BHV_Surface_GoToDepth, BHV_Surface_ConstantSpeed, BHV_Surface_ConstantSpeed, BHV_Surface_ConstantSpeed, BHV_Surface_ConstantSpeed			Idle: BHV_Abort_Waypoint, BHV_Abort_Waypoint_ConstantDepth, BHV_Surface_GoToDepth, BHV_Surface_ConstantSpeed, BHV_Surface_ConstantSpeed, BHV_Surface_ConstantSpeed, BHV_Surface_ConstantSpeed		
Complete: none			Complete: none		

Var: **V0VEHICLE ID** CurrVal: 13 Time: 4165.6 IN OUT RESET play-rate: Paused collect: Off CurrVal: 13 Var: none

13	n/a
-7.757	8946.01
13	n/a



GLINT10: Other developed behaviors



Kevin D. LePage

- Talk-30, August 25th, 13.30 - 14.00 :
The Design of a MOOS-IvP Behavior Based on Maximizing the SNR of Autonomous Assets Operating within a Multistatic Sonar System: BHV_MaximizeSNR_Active
- BHV_MinimizeTL_Active_Depth:
adapting AUV depth based on a model of transmission loss.



Next:



Information theory & game theory

- Collaborative & cooperative AUVs
- Optimal sensor placement
- Situational Awareness

