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

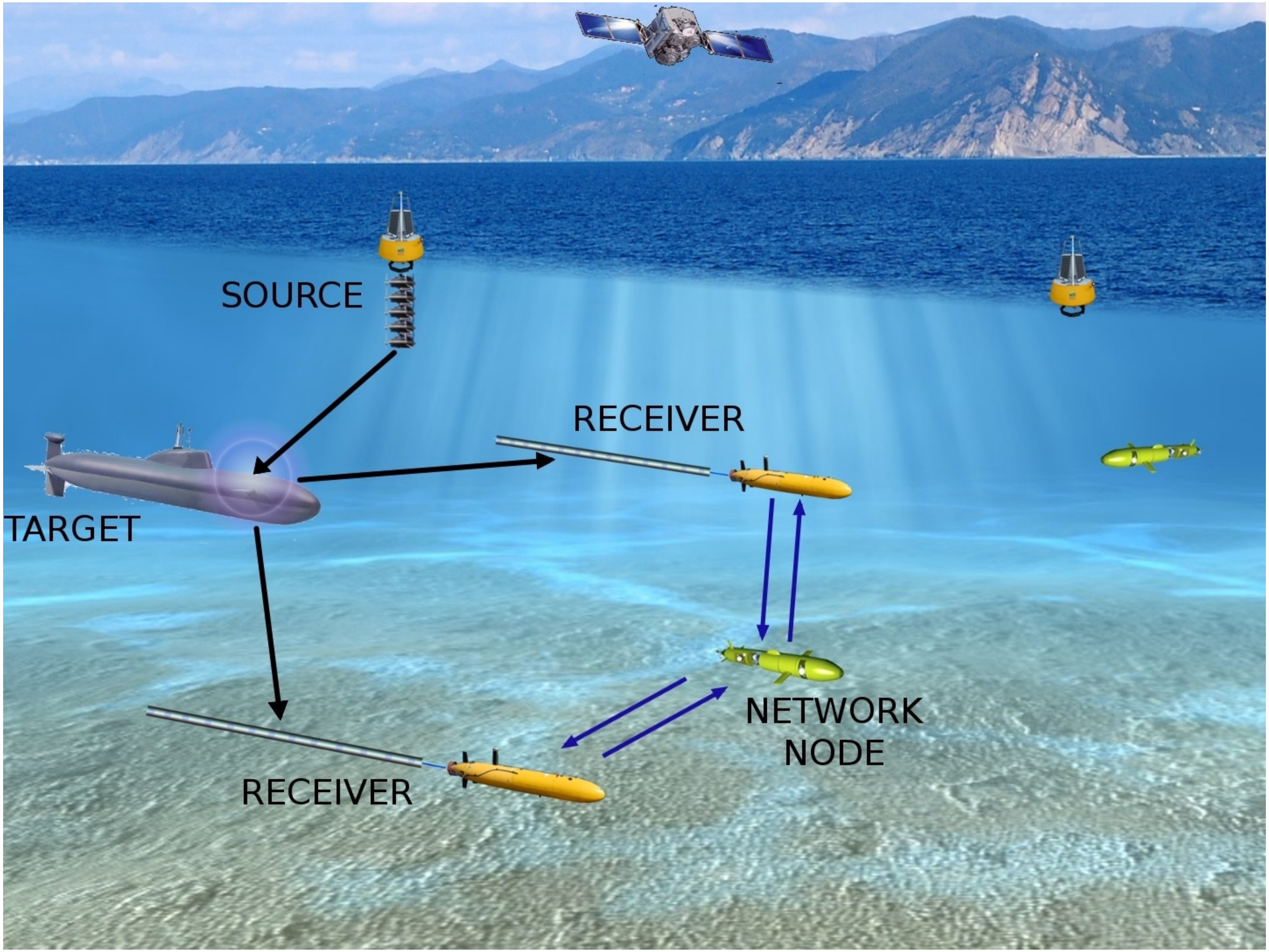
Interoperability

Advanced modeling

Decision support

Command, control and integration

Multi-static Active Sonar and Data Fusion



GLINT09: Objectives for autonomy/behaviors

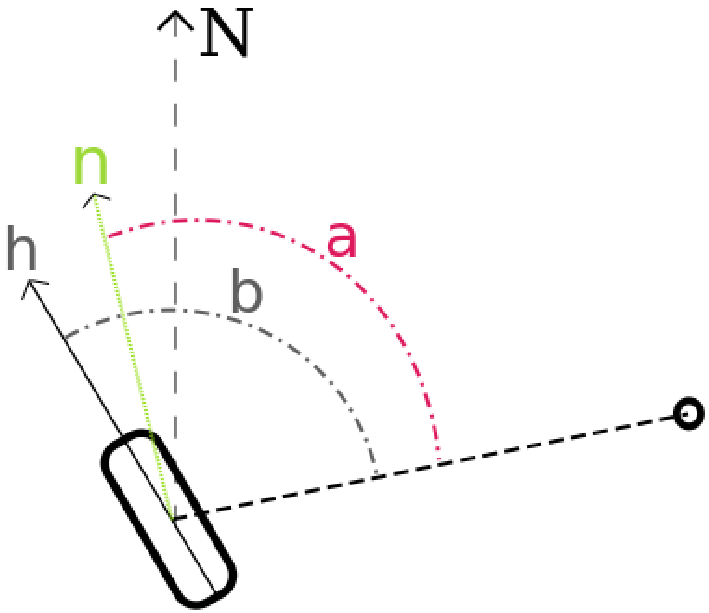
How can an AUV monitor its environment purely with its own sensors, convert the obtained data into information, which can then be used to alter its trajectory to exhibit some form of ASW relevant behavior?

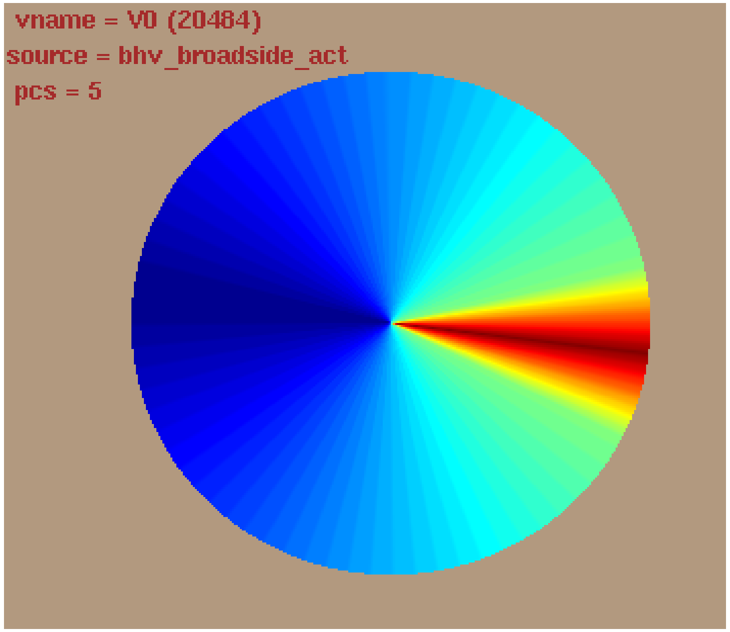
- real-time on-board processing
- adaptive behaviors

- heuristic approach: broadside behavior

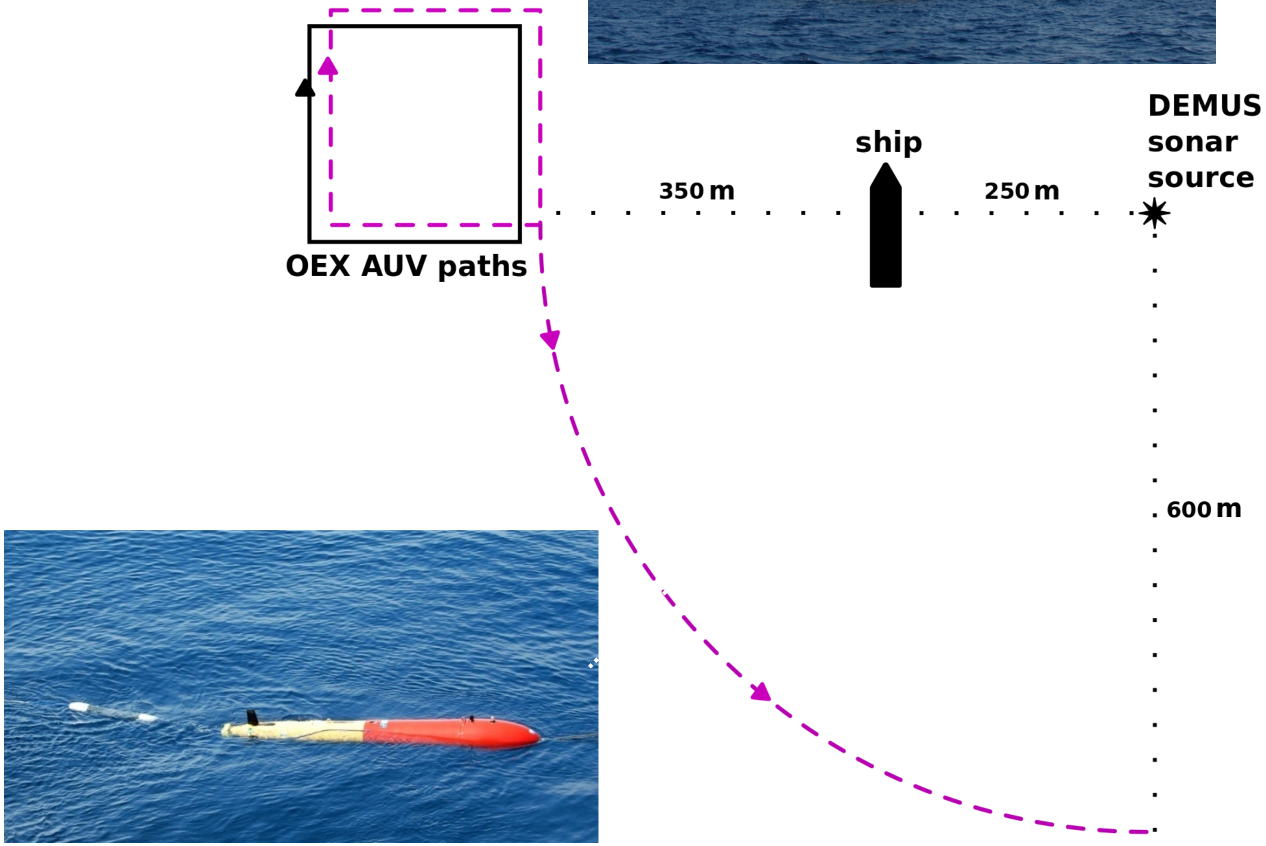
BHV Design: Objective Function

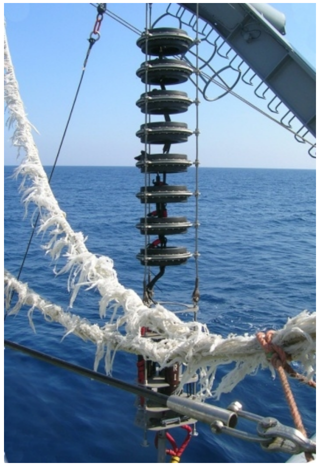
- ZAIC_PEAK function: calculate a new heading to get a contact at 90 degrees to the towed array: $n = h \pm b \mp a$
- domain: course, points: 360, pieces: 5



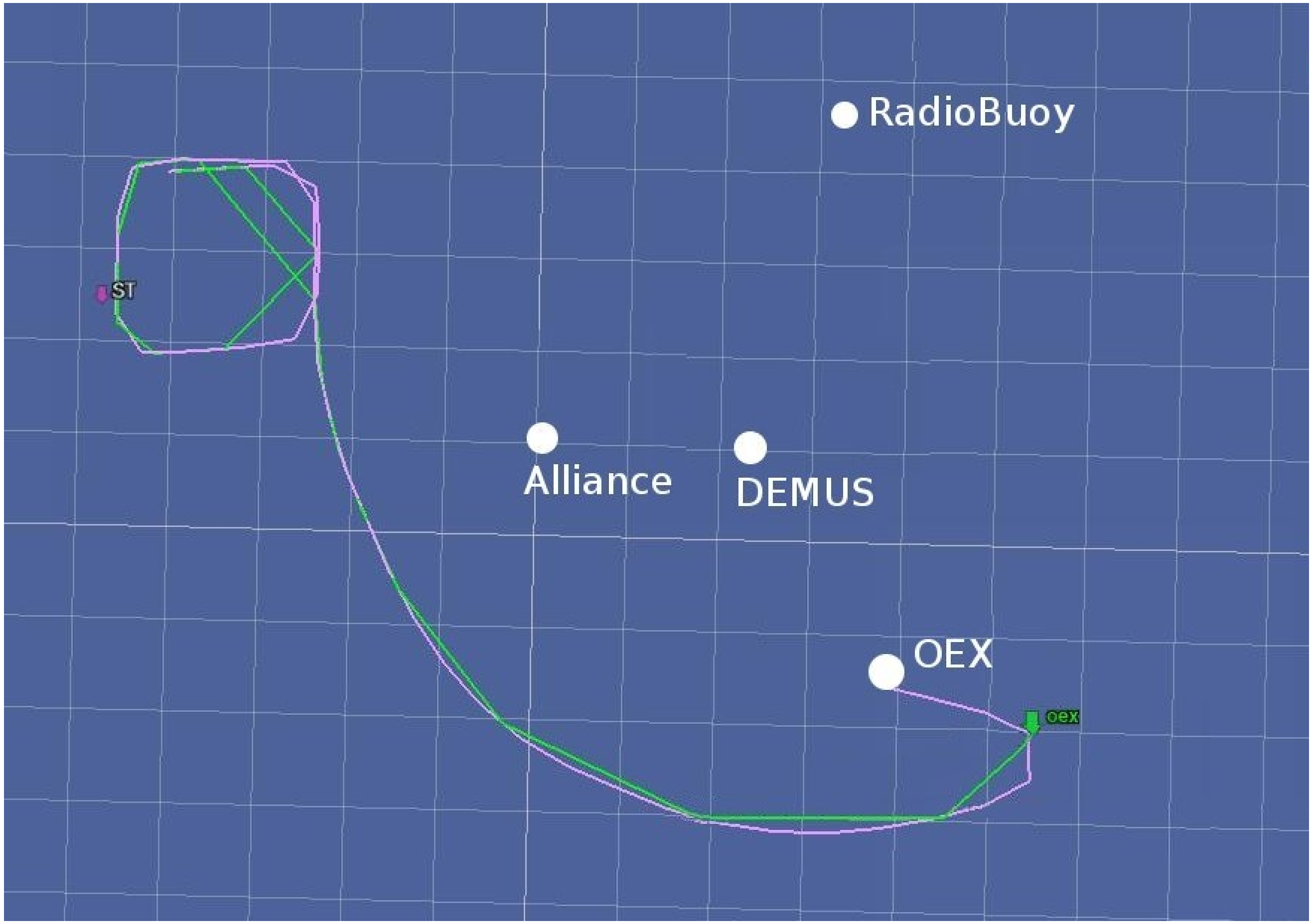


GLINT09: set-up broadside bhv





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



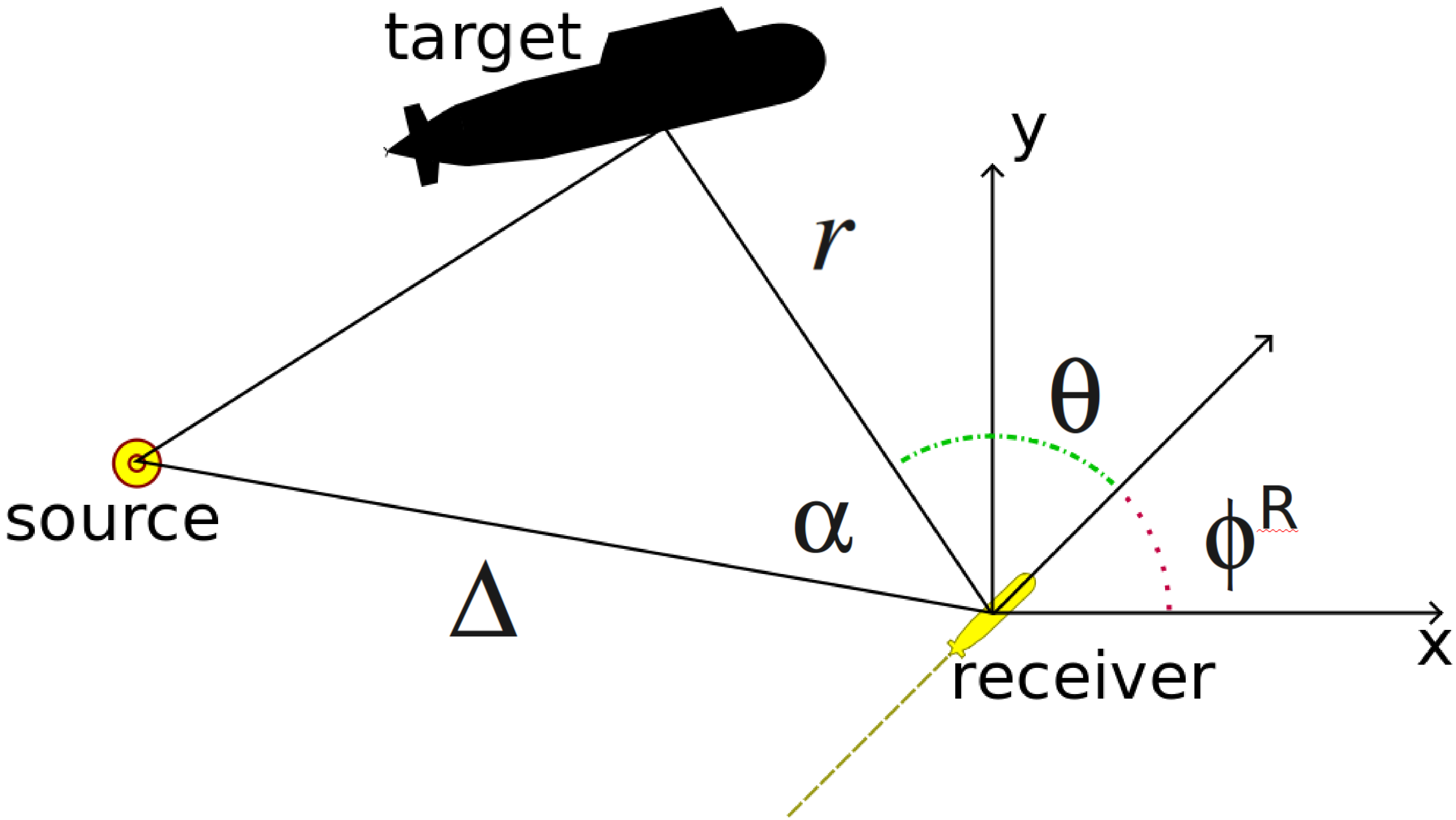
grid:
200m

GLINT09	GLINT10
real-time on-board processing	real-time on-board processing
contacts	tracks
highest SNR contact	track evaluator: score(contact SNR, track length)
heuristic: calculate 'broadside' heading	information theoretic: full bi-static localization equations
one heading → ZAIC_PEAK	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

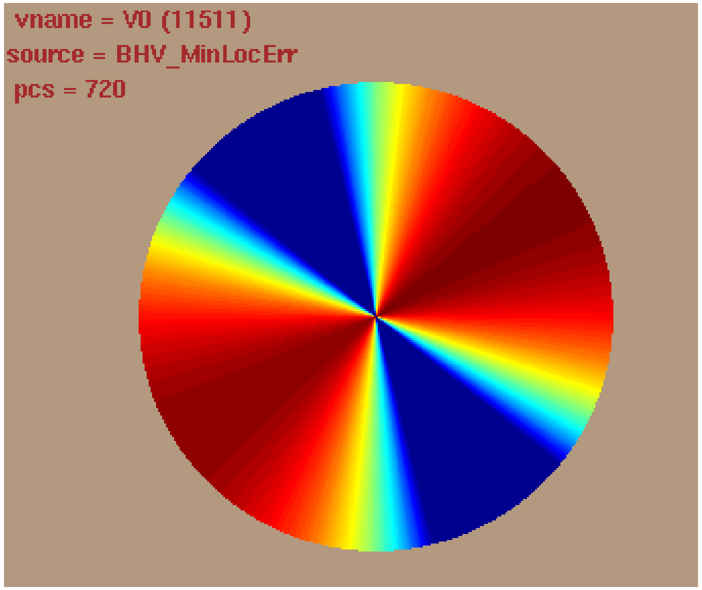
$$
\begin{aligned}
\sigma_{x^T}^2 = \sigma_{x^R}^2 &+ \cos^2(\theta+\phi^R)\sigma_r^2 + r^2\sin^2(\theta+\phi^R) \\
&\times\left(\sigma_\theta^2+\sigma_{\phi^R}^2\right) + 2\cos(\theta+\phi^R)\sigma_{x^R r} \\
&- 2r\cos(\theta+\phi^R)\sin(\theta+\phi^R)(\sigma_{\theta r}+\sigma_{\phi^R r})
\end{aligned}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

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

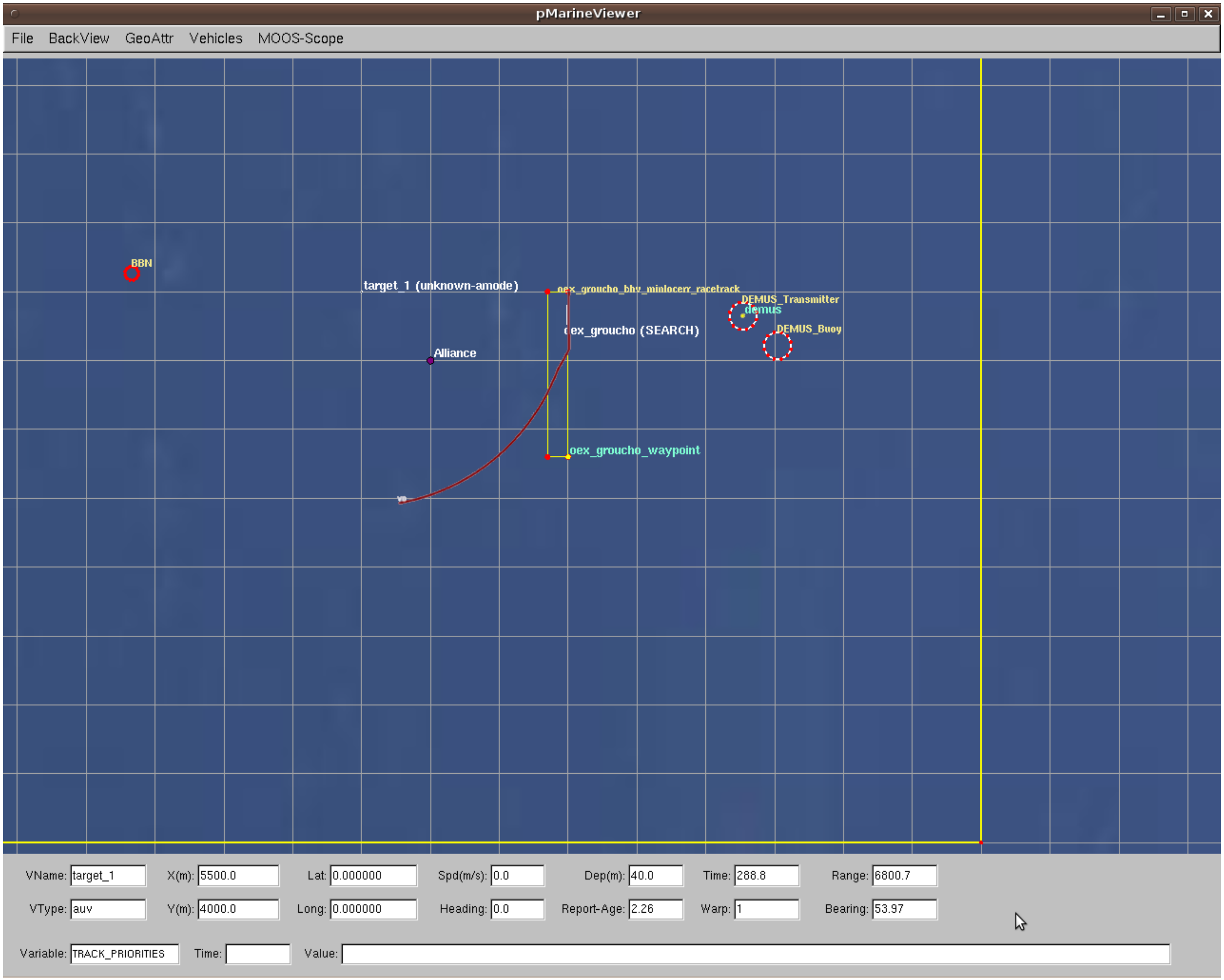
Coraluppi, S. (2006), Multistatic sonar localization, IEEE Journal of Oceanic Engineering 31(4), pp. 964-974

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

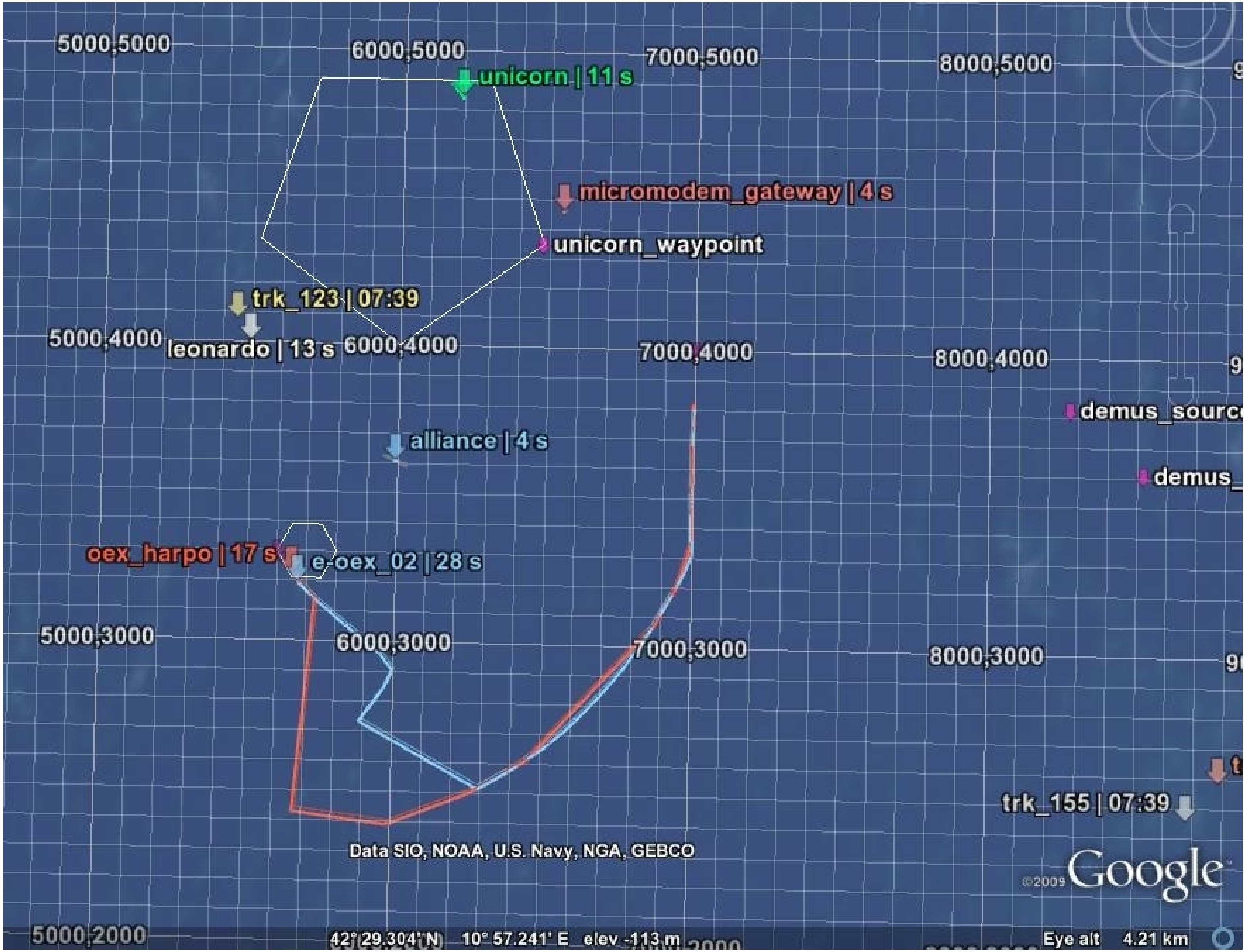


Simulations: one AUV optimizing for a static target



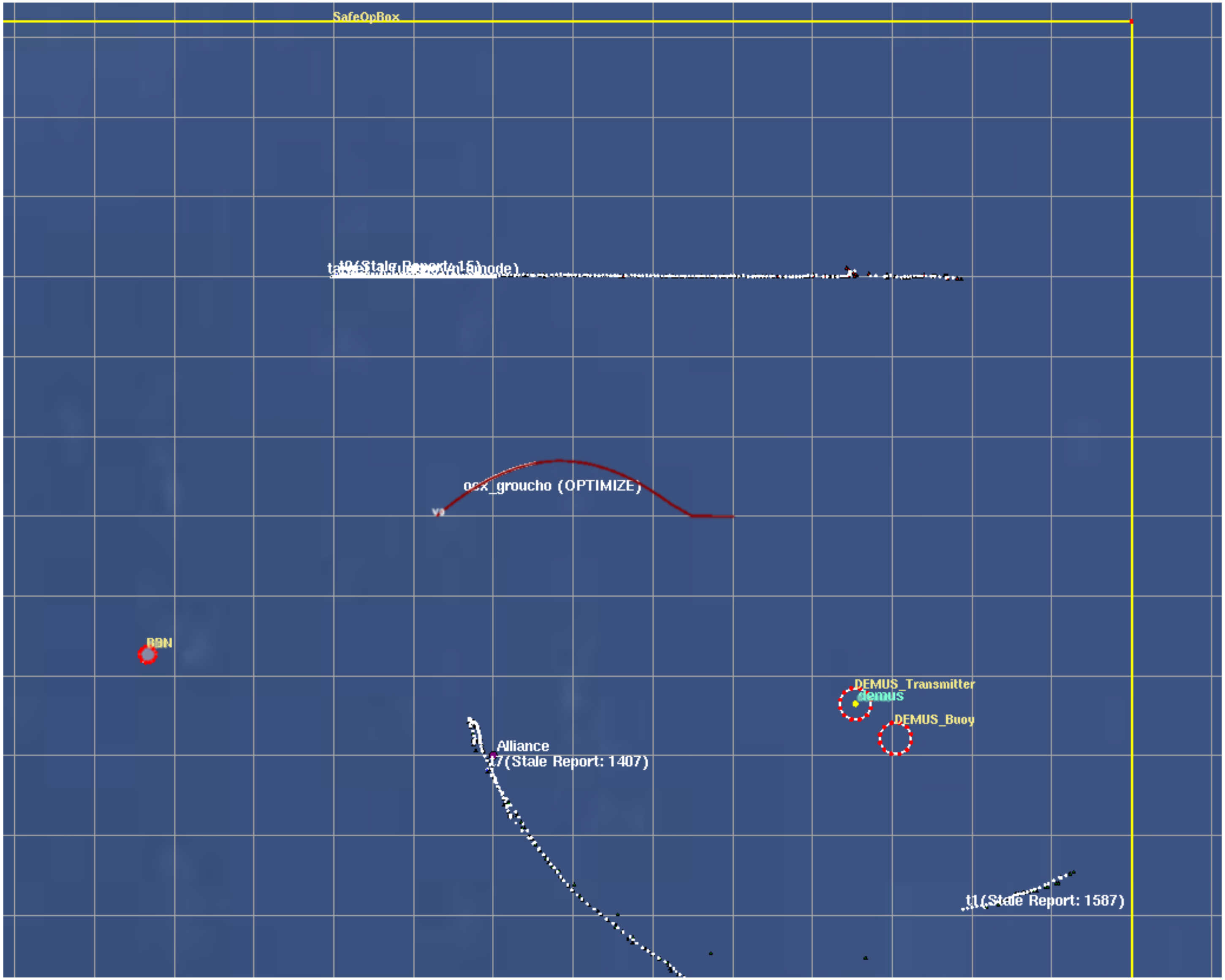
grid: 500m

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



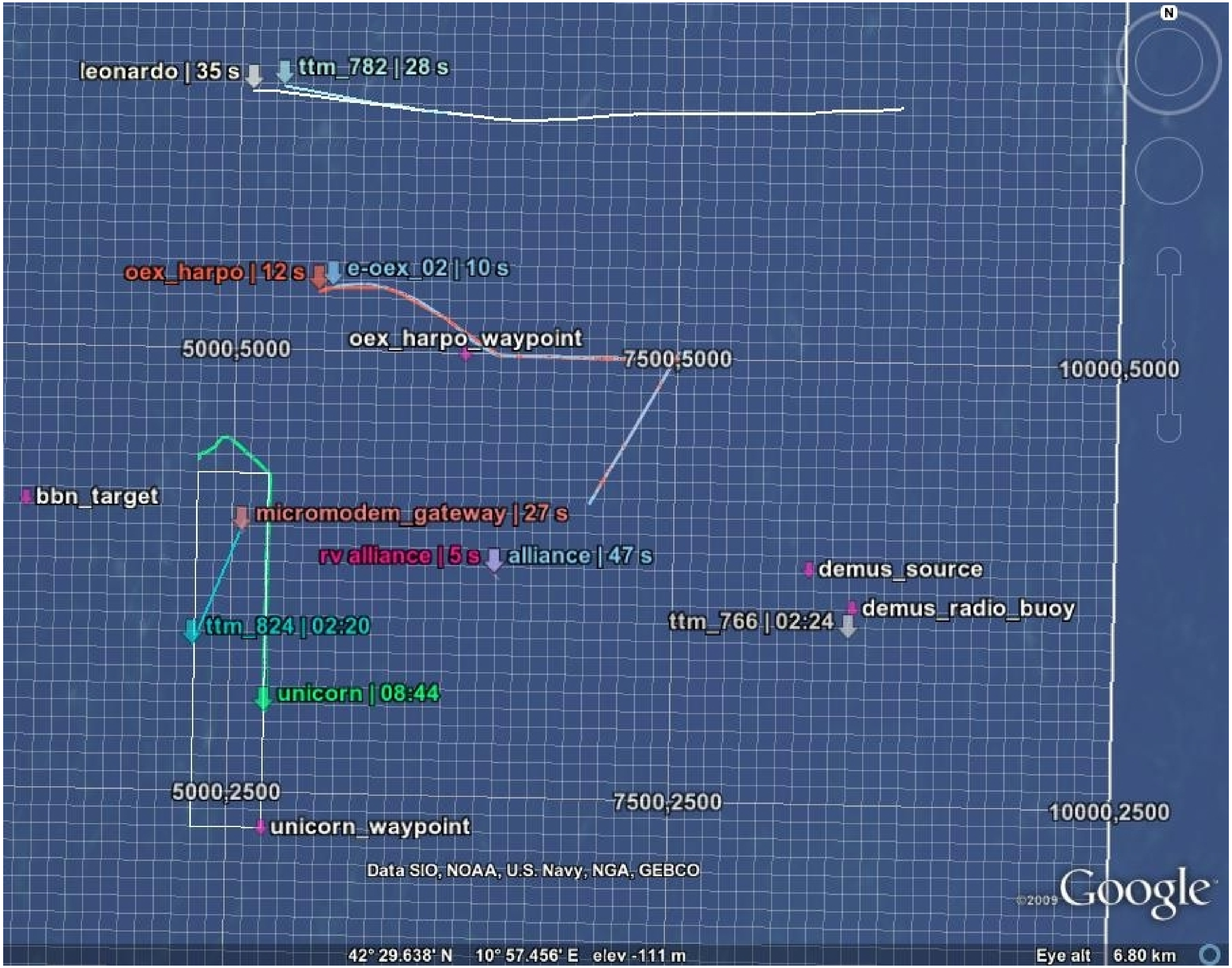
grid: 100m

Simulations: one AUV optimizing for a moving target



grid: 500m

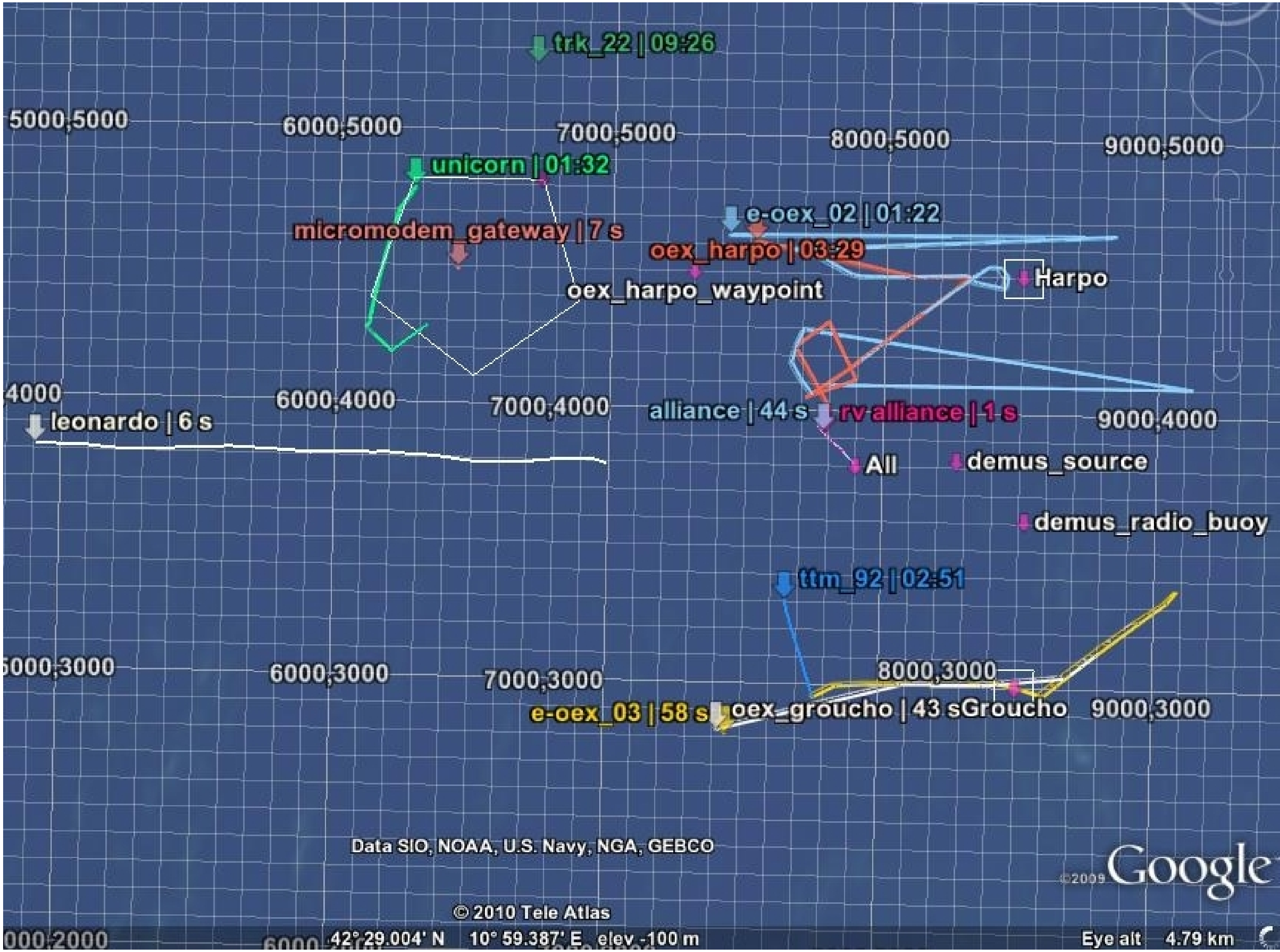
GLINT10: one AUV optimizing for a moving target (echo repeater)



grid: 100m

Two AUVs

GLINT10: two AUVs optimizing individually for a moving target

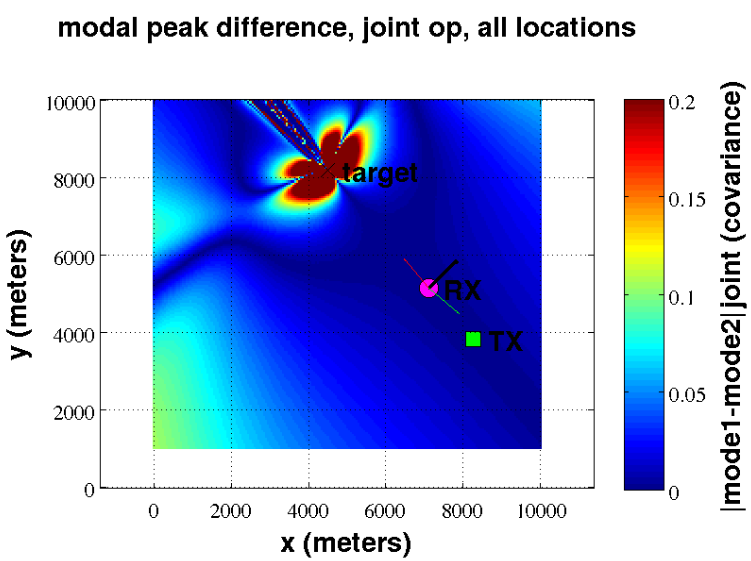


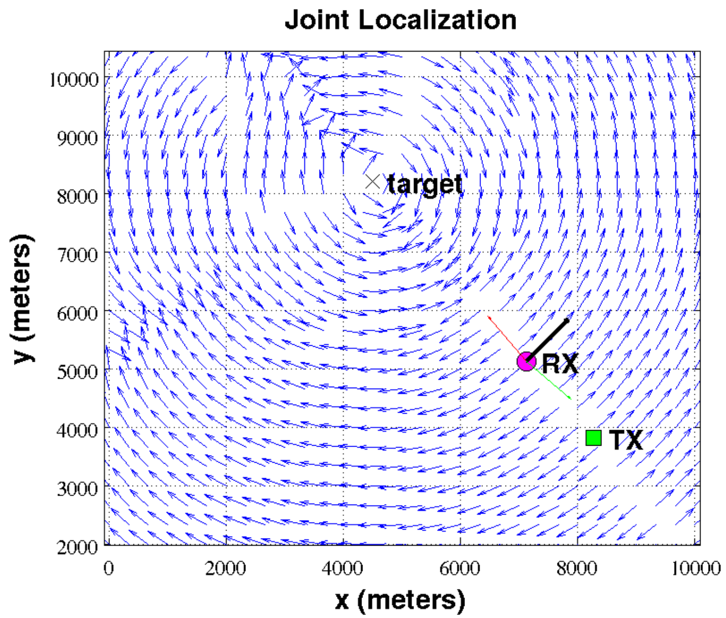
grid: 100m

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

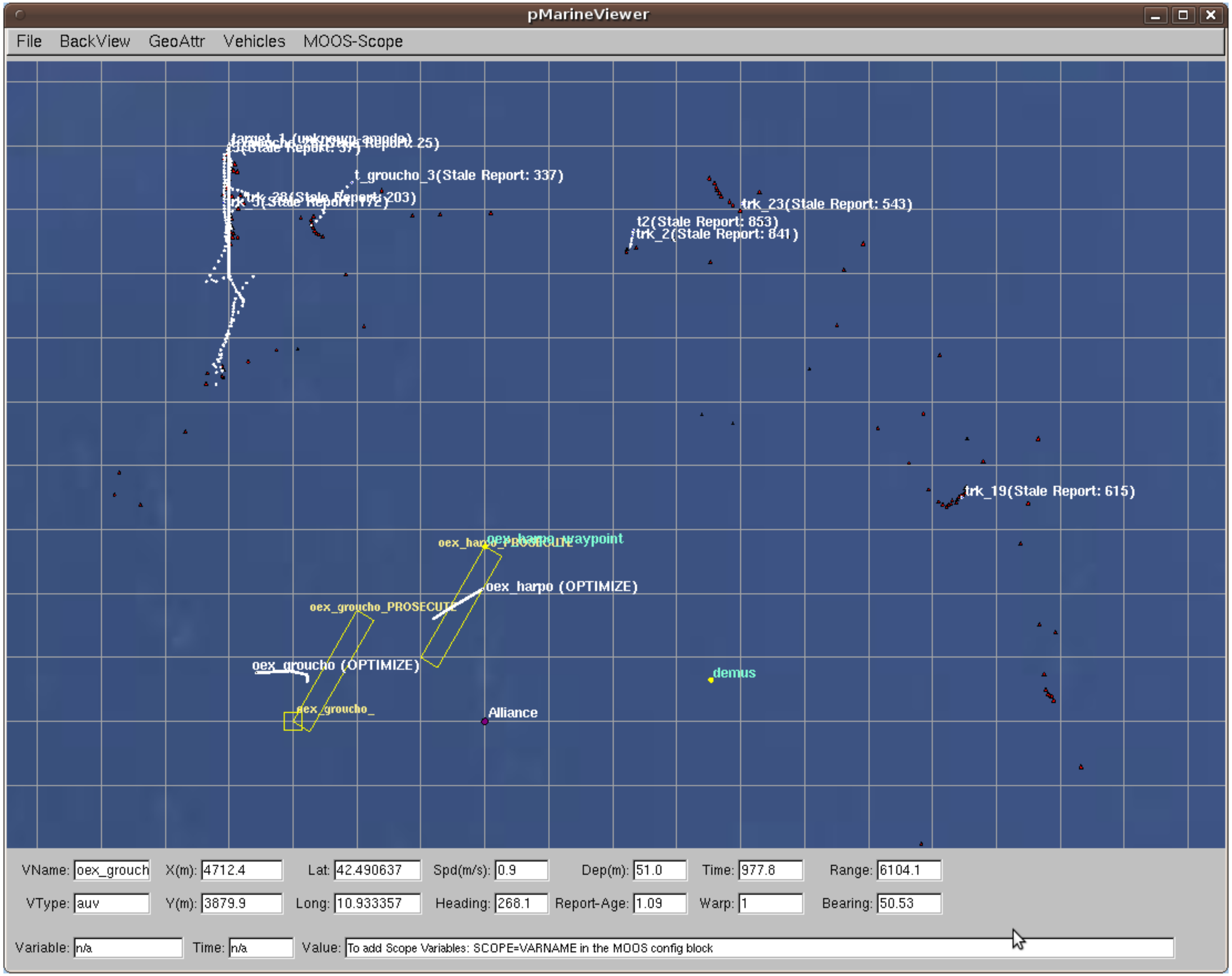
Michael J. Hamilton

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

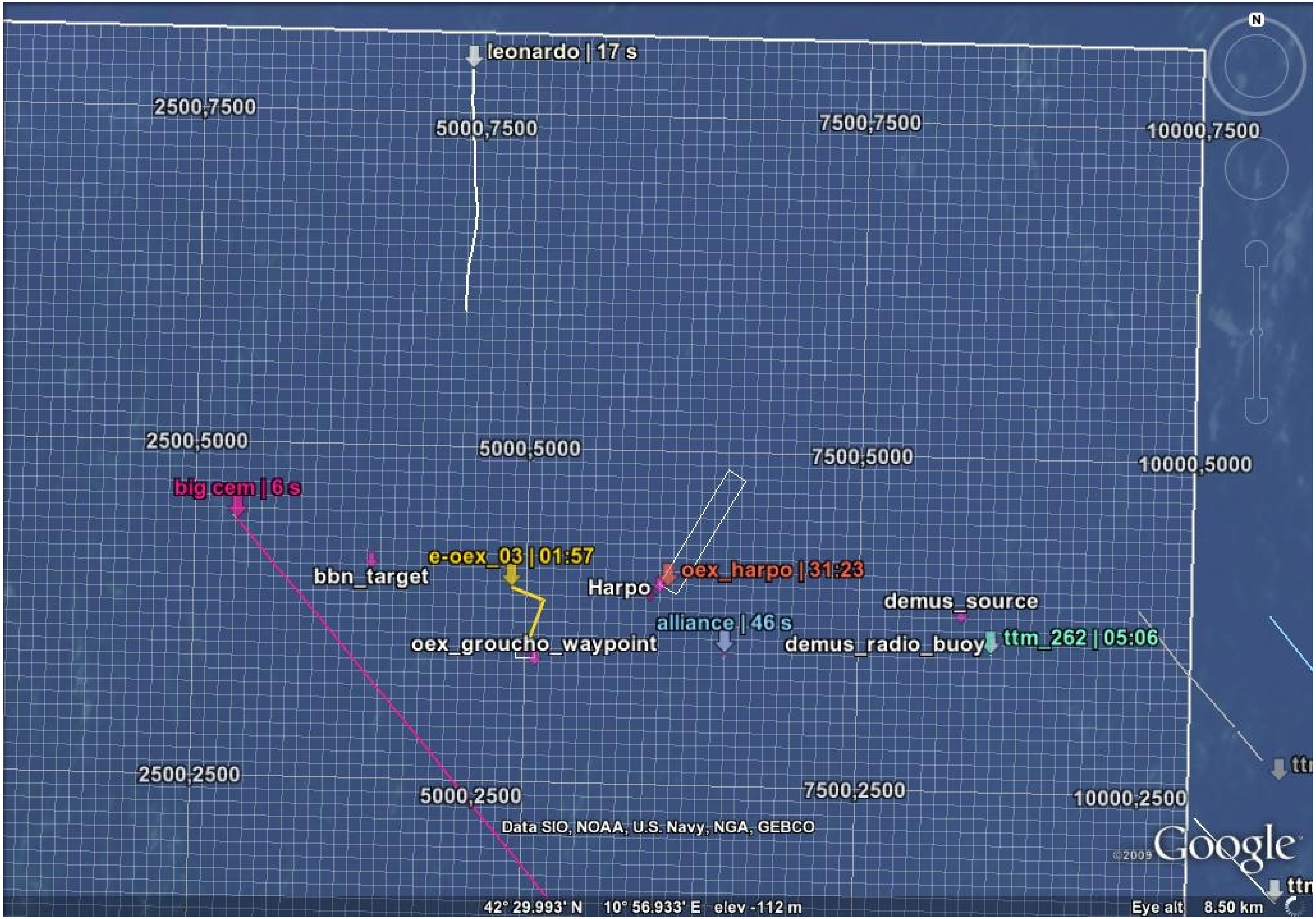




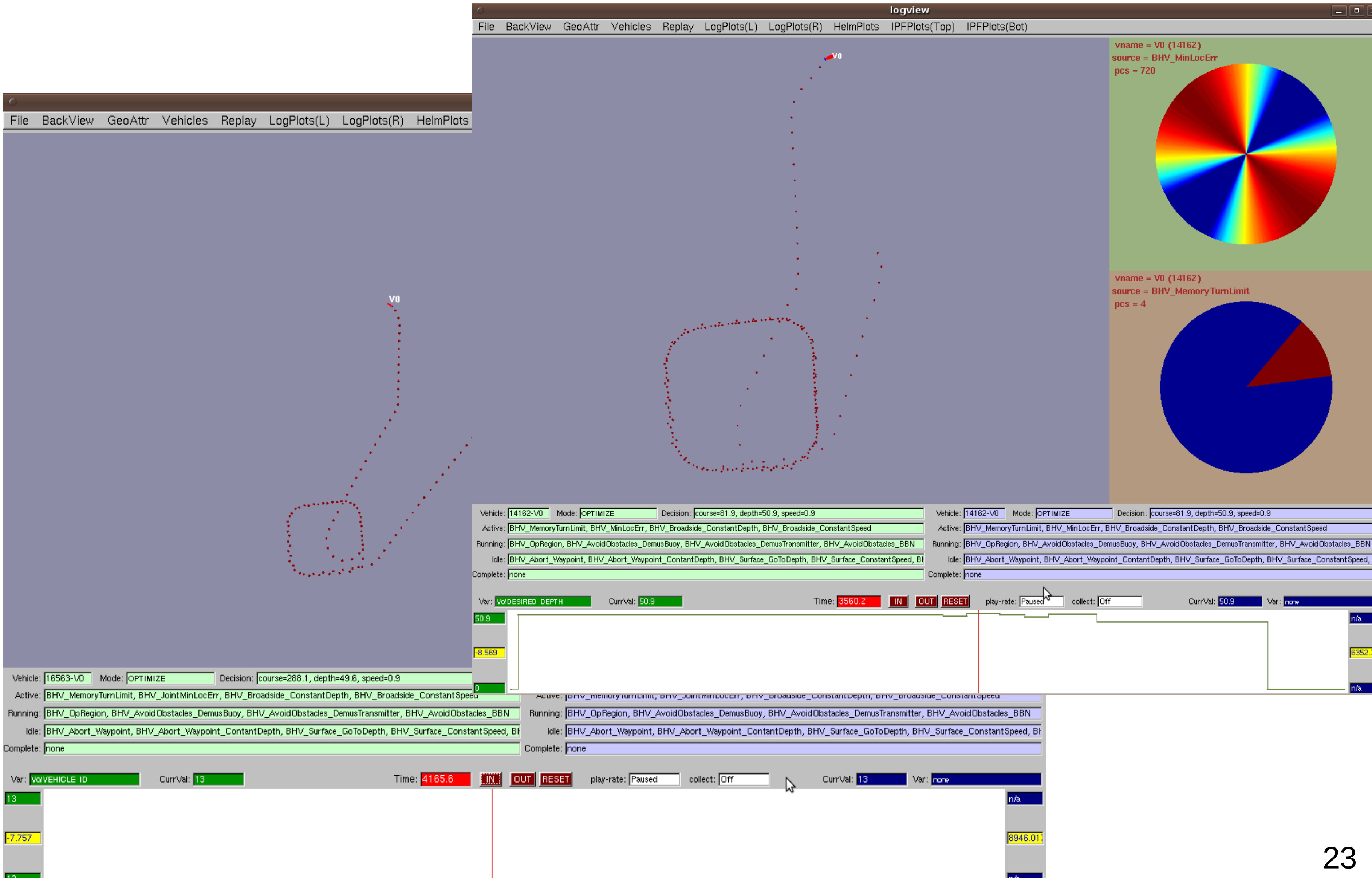
Simulations: 1 AUV optimizing collaboratively, 1 individually for a moving target



GLINT10: 1 AUV optimizing collaboratively, 1 individually



GLINT10 logview: 1 AUV optimizing collaboratively, 1 individually



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