Marine Systems & Robotics
Control Architecture for Multiple Autonomous Unmanned Vehicle Operations

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http://impact.uni-bremen.de/

Vision

- **Multi-AUV** *cooperation* – MCM scenario
- Semantic world modeling
- Communication

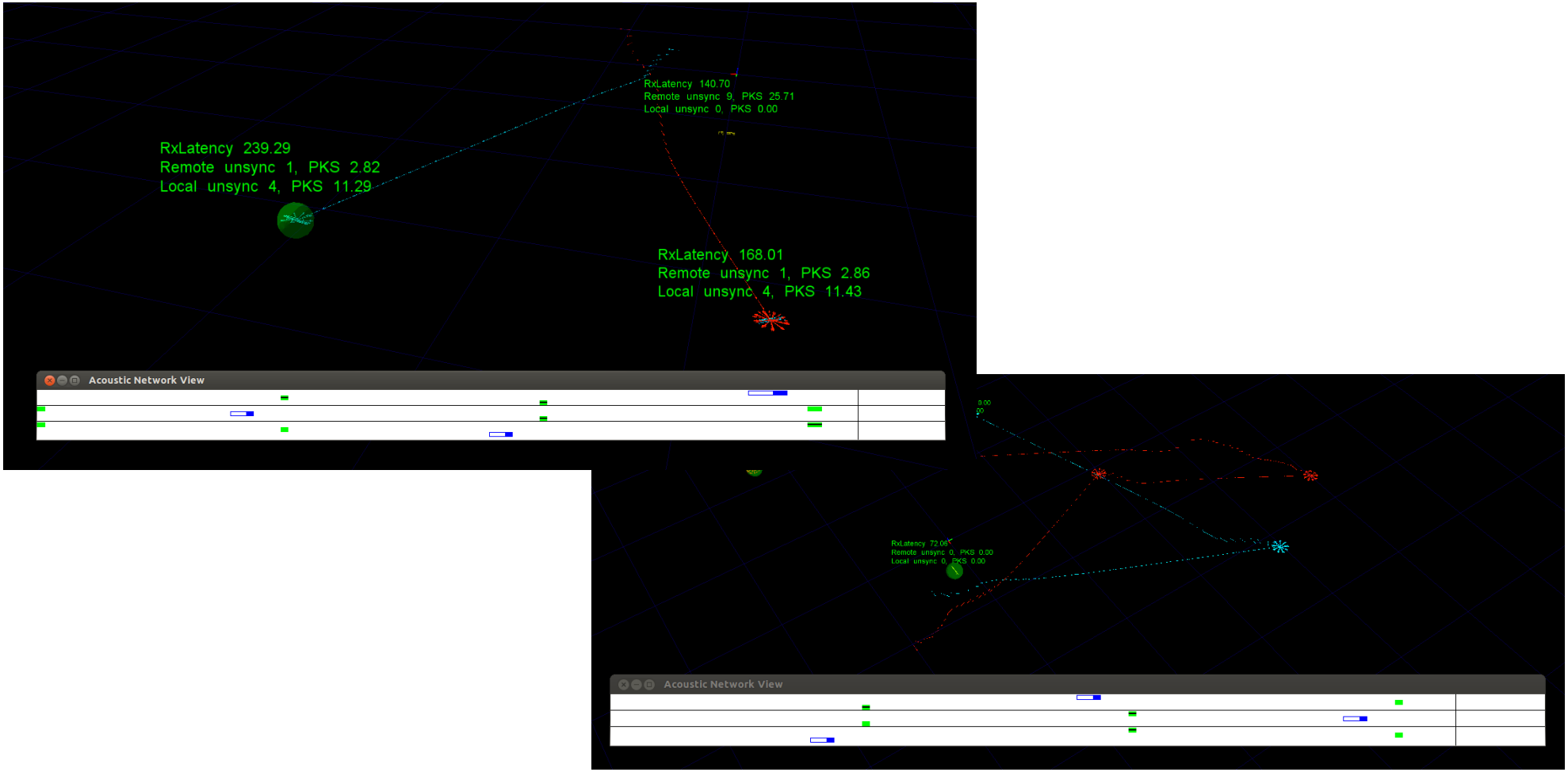
Steps

- **Search:** looking for mine-like objects
- **Identify:** discard false positive
- (**Neutralise)**

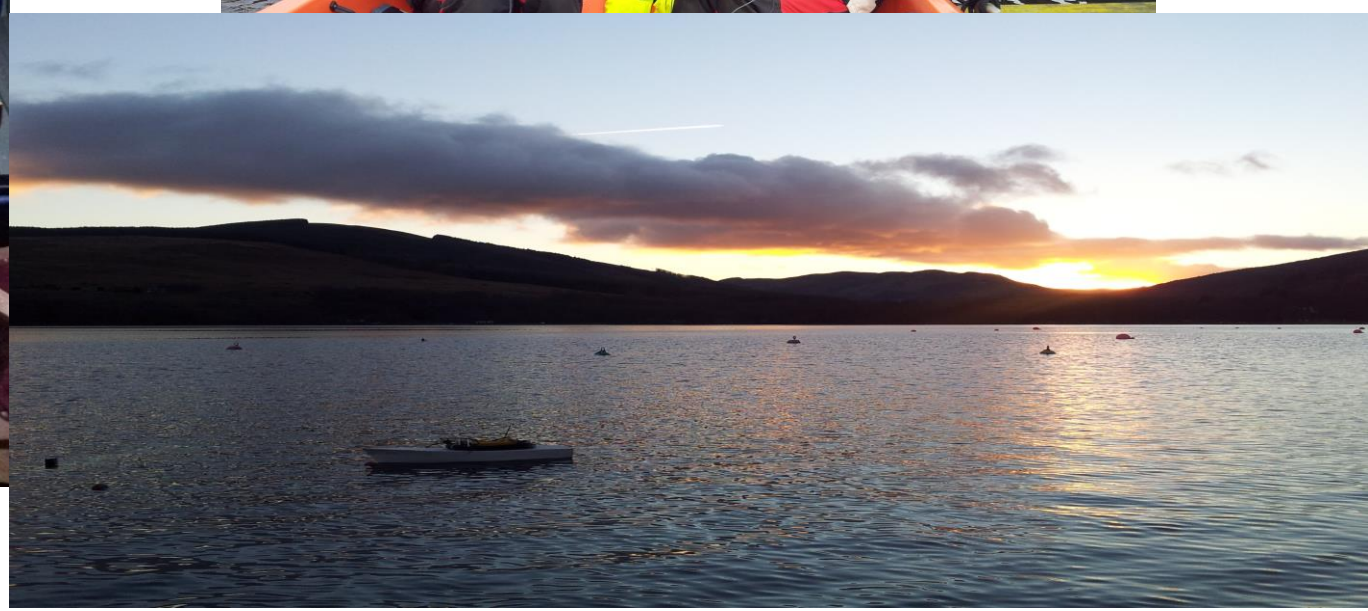
Challenges

- Information exchange at different levels of abstraction
- Selection of information to be shared
- Robust to communication failures
- No central communication point

Simulated Results



@Loch Earn



The system

“ mechanism for reliable, timely information distribution over high latency, low bandwidth, high loss, broadcast communication channels. The approach will use automatic retransmissions and selective peer relaying to provide reliable exchange in the face of partial communications loss and temporary hidden nodes.”

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The system – low bandwidth

Packet type 0 (FSK)	32 bytes
Packet type 1 (PSK)	192 bytes
Packet type 2 (PSK)	192 bytes
Packet type 3 (PSK)	512 bytes

Each timeslot: 23 seconds

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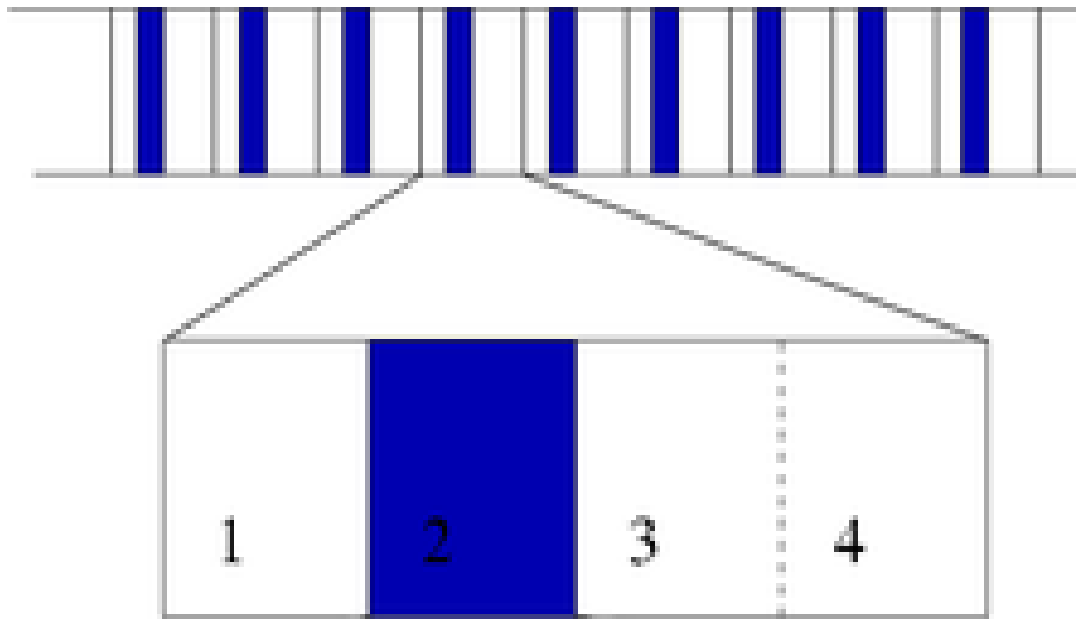
The system – TDMA



Each node sends data in its own slot

Ack Policy 1: standard ack

Each node transmits a *N-1* bit vector, to ack messages received in the previous *N-1* TDMA timeslots

This vector is added to each data packet

0	#1
1	#2
.	.
.	.
1	#N-2
0	#N-1

$$E(T_{delivered}) = \frac{1}{1 - p_{ij}}$$

$$E(T_{acked}) = \frac{1}{(1 - p_{ij})(1 - p_{ji})}$$

Ack Policy 2: matrix ack

Each node transmits a ***NxN* matrix**

→ *increase the probability that an ack is actually delivered*

- Each node stores *N-1* matrixes, received by peers, plus has its own matrix
- Periodic reset needed
- When transmitting, performing an *OR* among matrixes

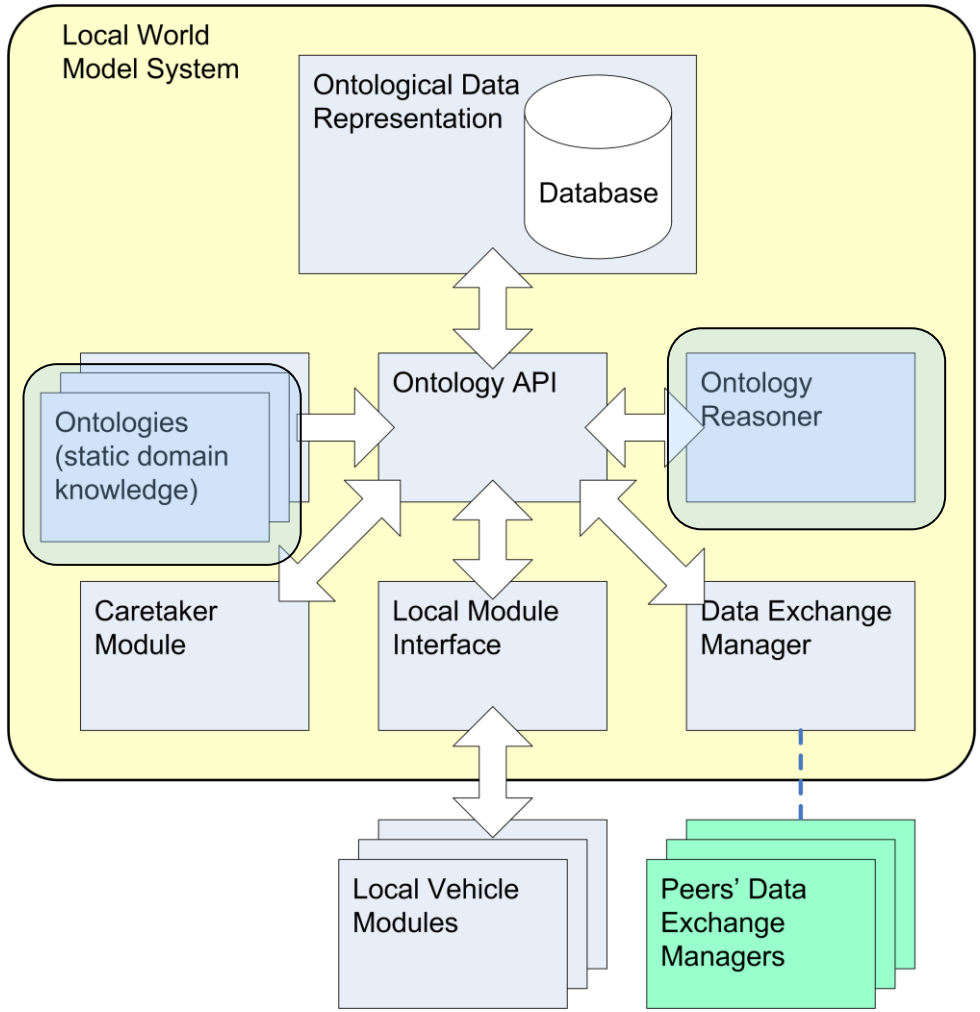
Ack Policy 3: matrix pseudo-ack

- Based on Ack Policy 2
- Checking packet content to determine if a peer has already all the information
- Not possible if information content of packets and existing knowledge of peers is not known

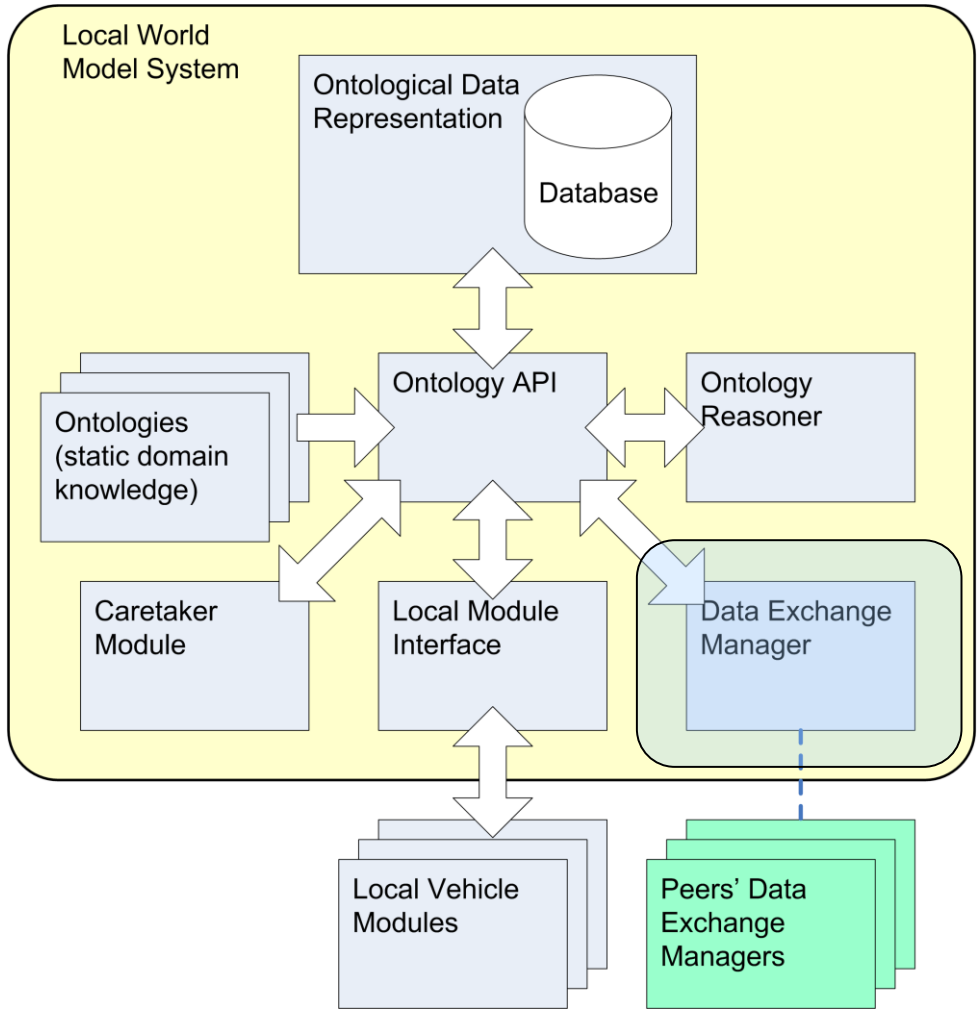
The system

"distributed world model service, that automatically updates local ontology descriptions of the environment and vehicles in an invisible and efficient way"

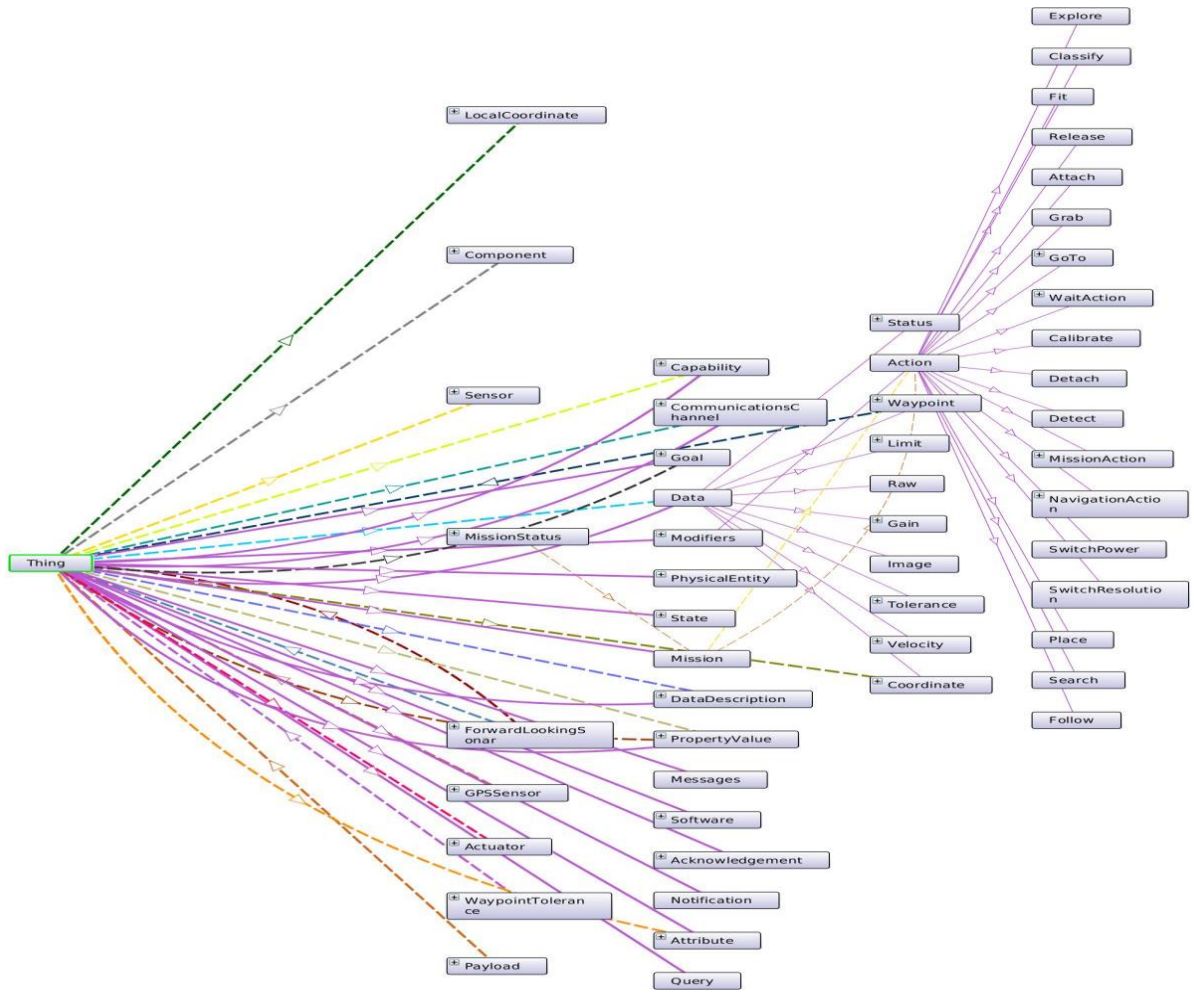
Architecture



Architecture



Ontology


Thing
LocalCoordinate
Component
Sensor
Capability
CommunicationsChannel
Goal
Data
MissionStatus
Modifiers
PhysicalEntity
State
Mission
DataDescription
ForwardLookingSonar
PropertyValue
Messages
GPSSensor
Software
Actuator
Acknowledgement
WaypointTolerance
Notification
Attribute
Payload
Query
Status
Action
Waypoint
Limit
Raw
Gain
Image
Tolerance
Velocity
Coordinate
Explore
Classify
Fit
Release
Attach
Grab
GoTo
WaitAction
Calibrate
Detach
Detect
MissionAction
NavigationAction
SwitchPower
SwitchResolution
Place
Search
Follow

The system

"a mechanism to exchange information on a need to know basis"

Each vehicle *publishes* information about information interest

Selective intelligent *Dropbox* among N platforms

The system

"a mechanism that enables information exchange requirements to be modified on the fly during execution, based on plan focus and events"

On-the fly dynamic publishing of new information triggering events
→ e.g. shore platform able to send new target information, introducing a change in vehicle's behaviour

On-the fly request of new types of information, after the mission started

Metrics and Performances

- Mission time
- Mission cost
- System trust
- Bytes Exchanged vs. Richness of World Model

Scenarios

- Scenario 1: boat with echosounder
- Scenario 2: boat with ROV
- Scenario 3: 1 AUV in standard exploration mission
- Scenario 4: multiple AUVs in standard exploration mission
- Scenario 5: multiple AUVs with re-inspection without cooperation
- Scenario 6: multiple AUVs with re-inspection with cooperation and standard ack
- Scenario 7: multiple AUVs with re-inspection with cooperation and matrix ack

Mission Time

- **Scenario 1: boat with echosounder**
  - Slow (slow speed plus short spacing among lanes)
  - Time of the people involved

- **Scenario 2: boat with ROV**
  - Slower (as ROV needs to swim)
  - Time of the people involved

- **Scenario 3: 1 AUV in standard exploration mission**
  - Optimised time, according to sensor capability
  - No person time while surveying, person time for target detection
  - Need of multiple missions (autonomous exploration, human data analysis, autonomous target re-acquisition)

Mission Time

- **Scenario 4: multiple AUVs in standard mission**
  - Linear according to the number of vehicles + overhead
  - Still human work required for target detection and still time to reacquire the target
- **Scenario 5: multiple AUVs with re-inspection without cooperation**
  - Substantial time reduction
  - AUV needs to finish exploration first to make a reacquisition
- **Scenario 6: multiple AUVs with re-inspection with cooperation and standard ack**
  - Almost as good as Scenario 7

Mission Cost

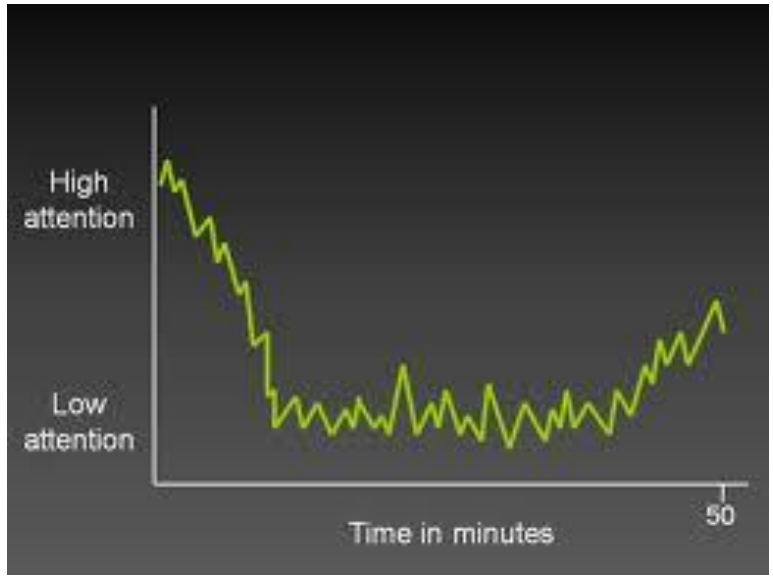
- **Scenario 1: boat with echosounder**
  - Cost of boat and sensor
  - Cost of people involved
- **Scenario 2: boat with ROV**
  - Cost of boat and ROV
  - Time of the people involved
- **Scenario 3: 1 AUV in standard exploration mission**
  - Cost of AUV – no people while AUV running
  - Cost of people analysing the data
  - Cost of AUV for reacquisition

Mission Cost

- **Scenario 4: multiple AUVs in standard mission**
  - Similar to 3 (n times the cost for AUV)
- **Scenario 5: multiple AUVs with re-inspection without cooperation**
  - Saving on target detection by humans
- **Scenario 6: multiple AUVs with re-inspection with cooperation and standard ack**
  - Same as Scenario 7

System Trust

- **Scenario 1: boat with echosounder**
  - Not good resolution for deep-water operations
- **Scenario 2-3-4**
  - Human attention deteriorates
- **Scenario 5-6-7**
  - Same consistent performance



Questions ?