

# **Information Fusion and Situation Awareness using ARTMAP and Partially Observable Markov Decision Processes**

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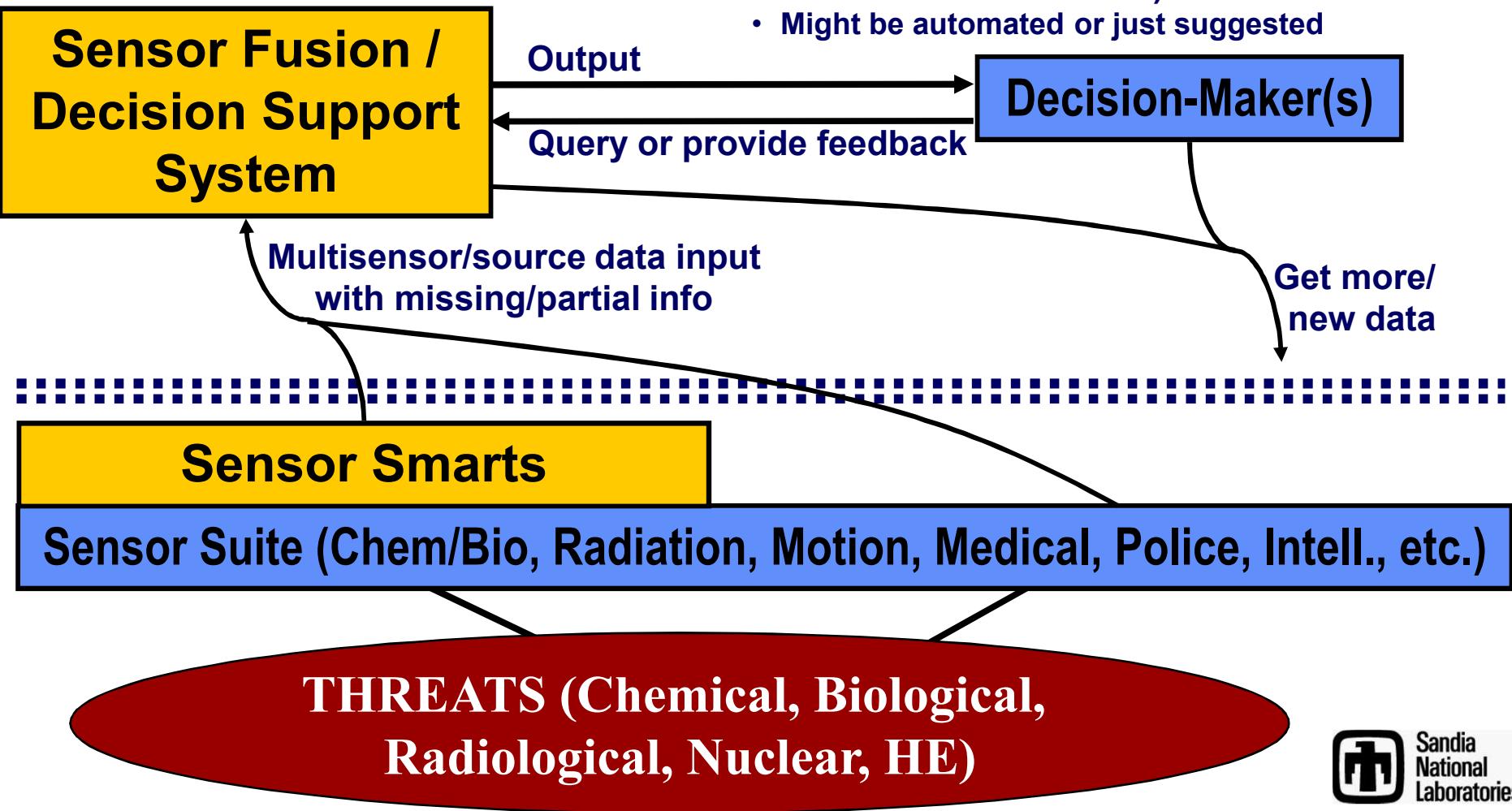
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# The Problem being addressed

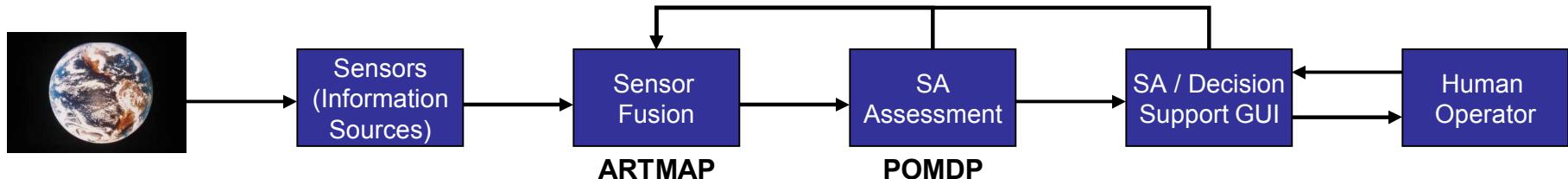
Assumed

Our work



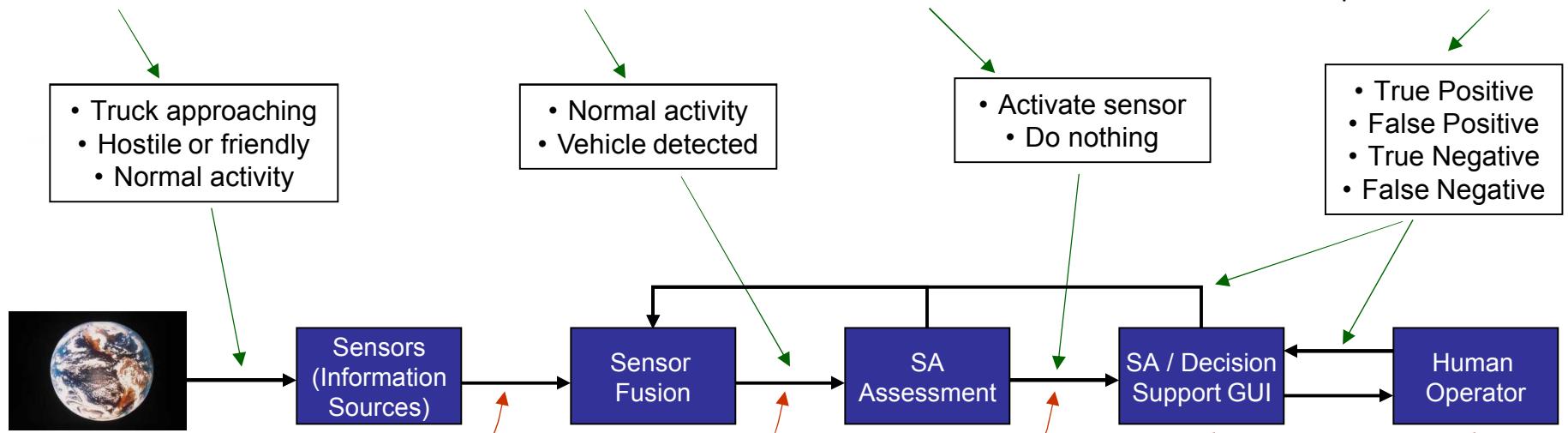


# Sensor Fusion / Situation Awareness (SA)

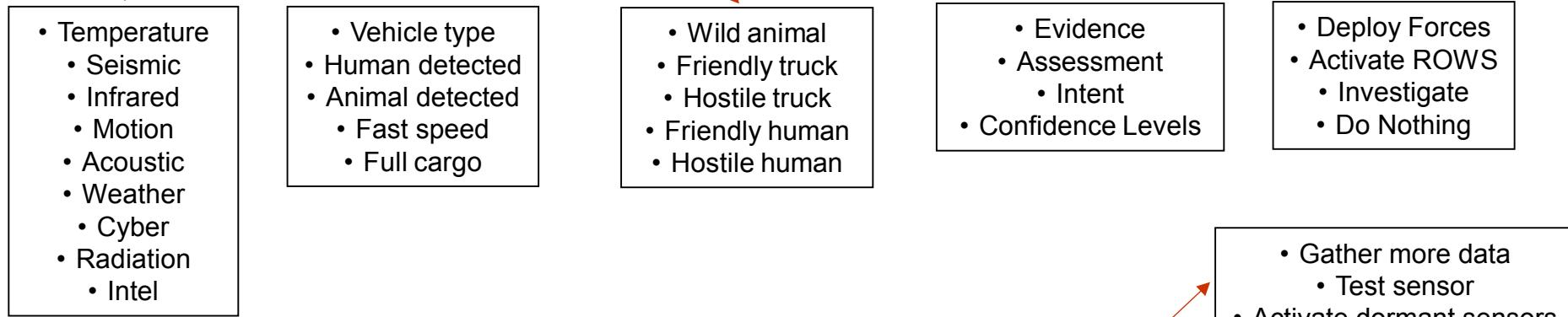


- **Information Sources**
  - **Electronic sensors, Intel, Cyber, etc.**
- **Sensor Fusion via ARTMAP**
  - **Converts sensor data into observations for decision-making**
    - Truck, animal, human intruder
    - **Graceful degradation given partial data**
- **SA Assessment via Approximate Dynamic Programming**
  - **Partially Observable Markov Decision Process**
  - **Provides SA Assessments & Suggests Actions, given (possibly partial) observations**
  - **Outputs probabilities for confidence levels**
- **SA / Decision Support GUI**
  - **Decision-Maker (Human Operator) focused**

The **state** of the environment results in **observations**, which invoke **actions**, whose values are measured to produce **rewards**.



Raw data is filtered into evidence to make an assessment which is displayed on a screen to aid the operator's decision-making.



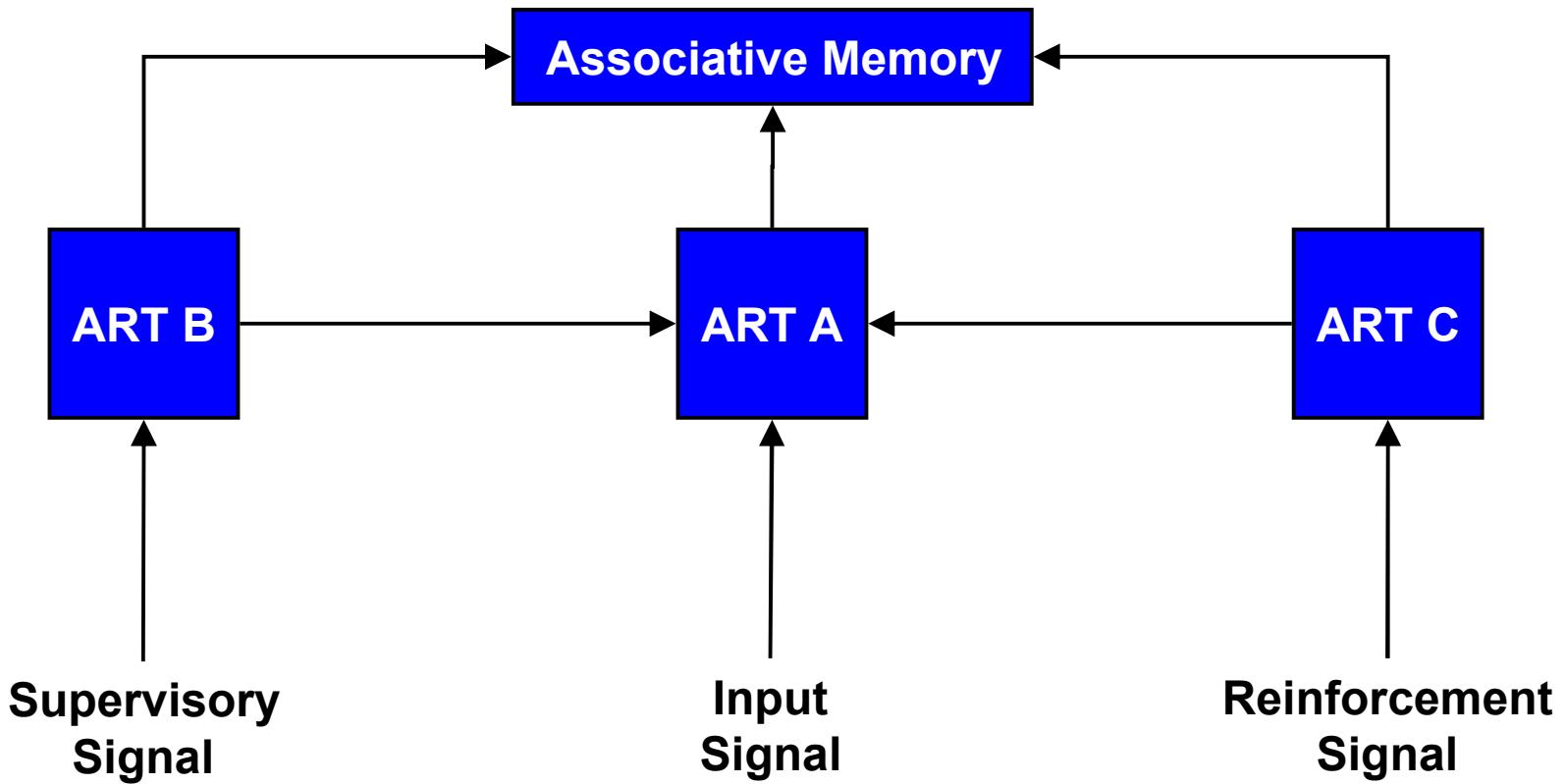
Also, the assessment calculation engine or the human operator can engage **adaptive actions**.



# Machine Learning Mechanisms

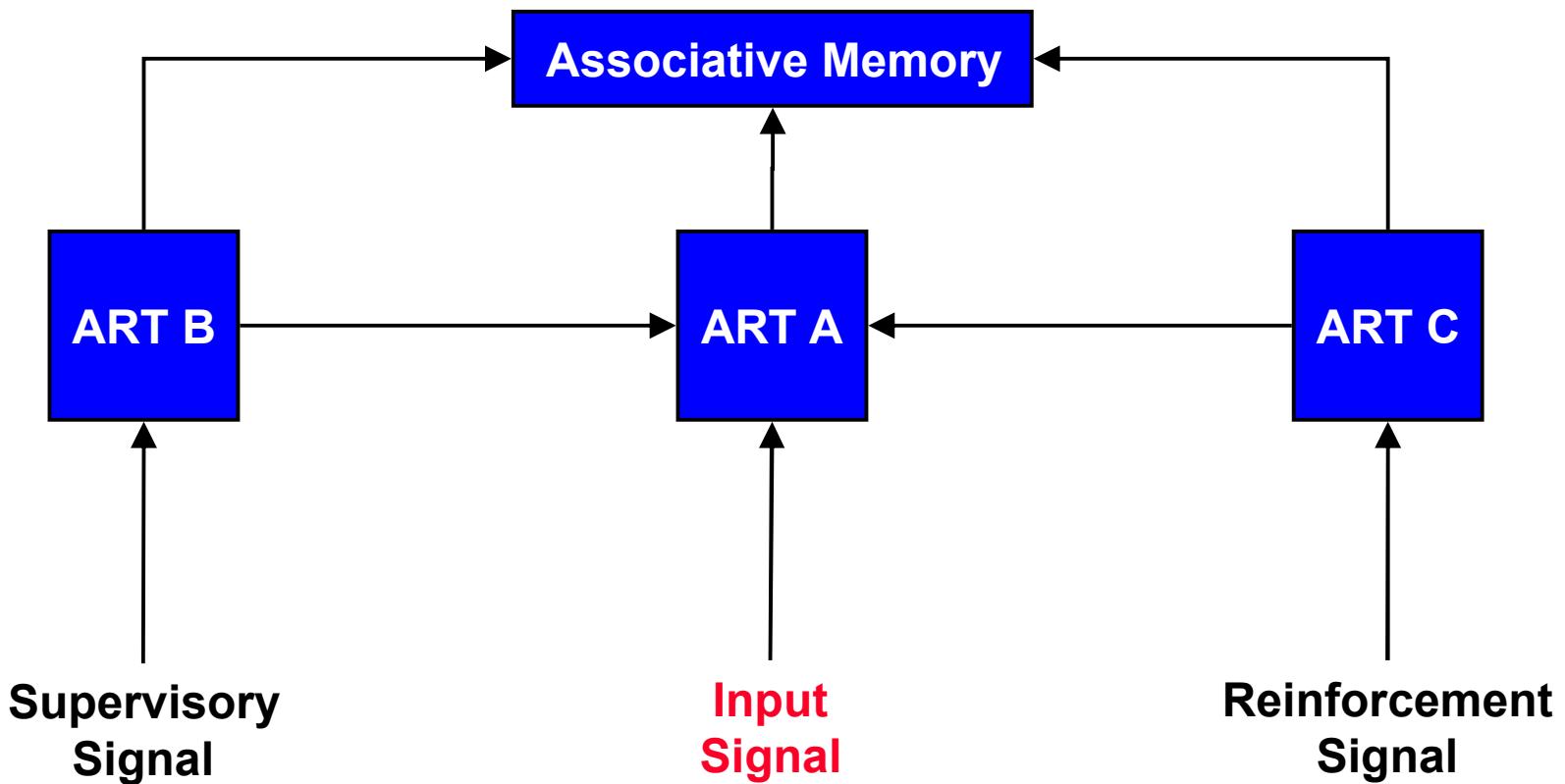
- **Unsupervised Learning** Often too pessimistic
  - Clustering of the input data based on similarities between inputs.
- **Supervised Learning** Often too optimistic
  - Learning with a teacher - says what the output should have been.
    - The correct output pattern is known for every input pattern.
- **Reinforcement Learning** Most realistic for many problems
  - Learning with a critic - gives a value to the system's action (output).
    - One doesn't know the appropriate output pattern for each input, but the system gets criticized with a reward or punishment after completing a series of actions (e.g., at the end of each tic-tac-toe game).
    - Must compare values to other actions to find best action for each input.
    - Interaction with the environment - both input (state) and output (action).

# Coordinated ARTMAP Sensor Fusion Module



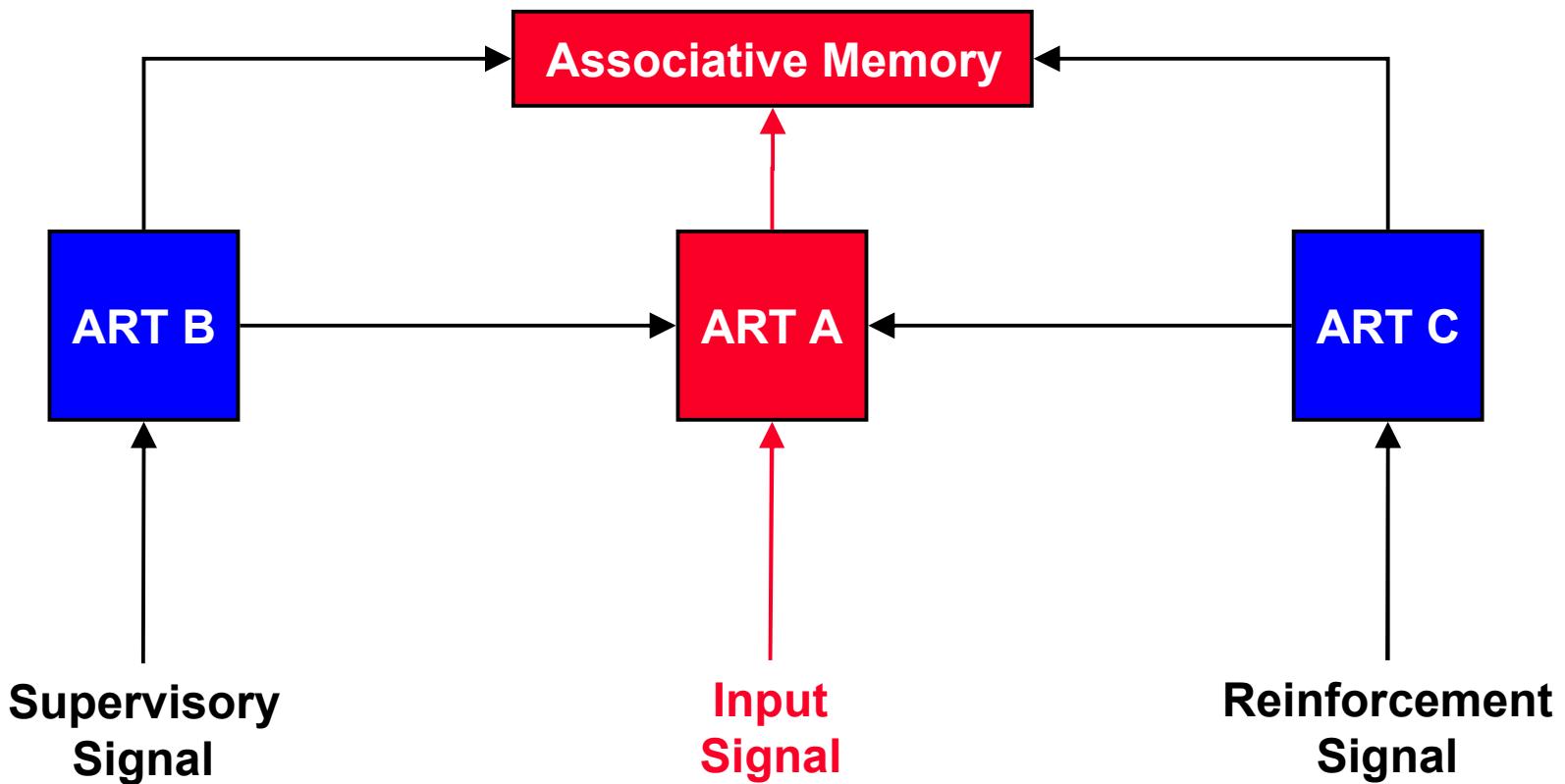


# Unsupervised Learning



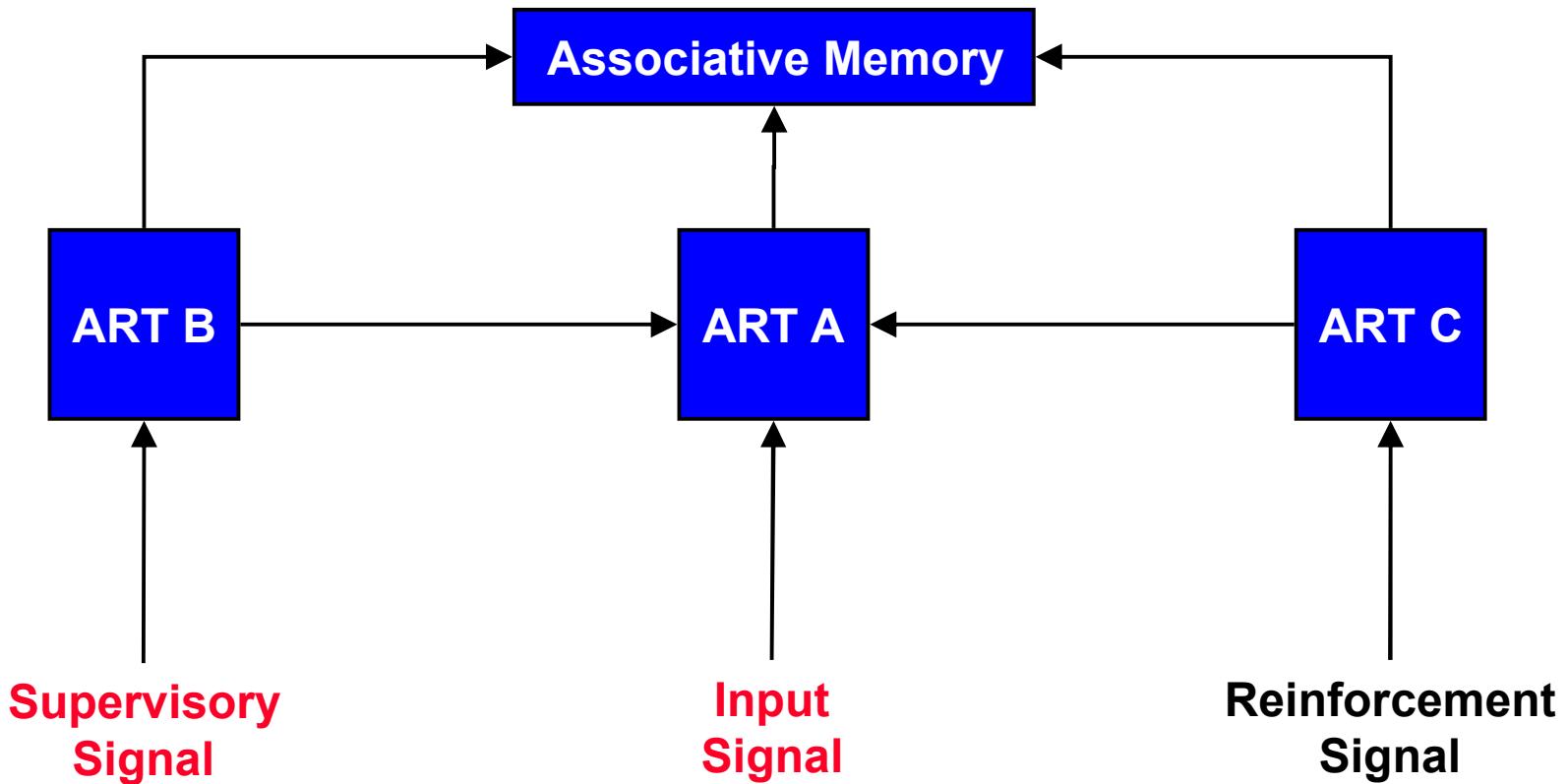


# Unsupervised Learning

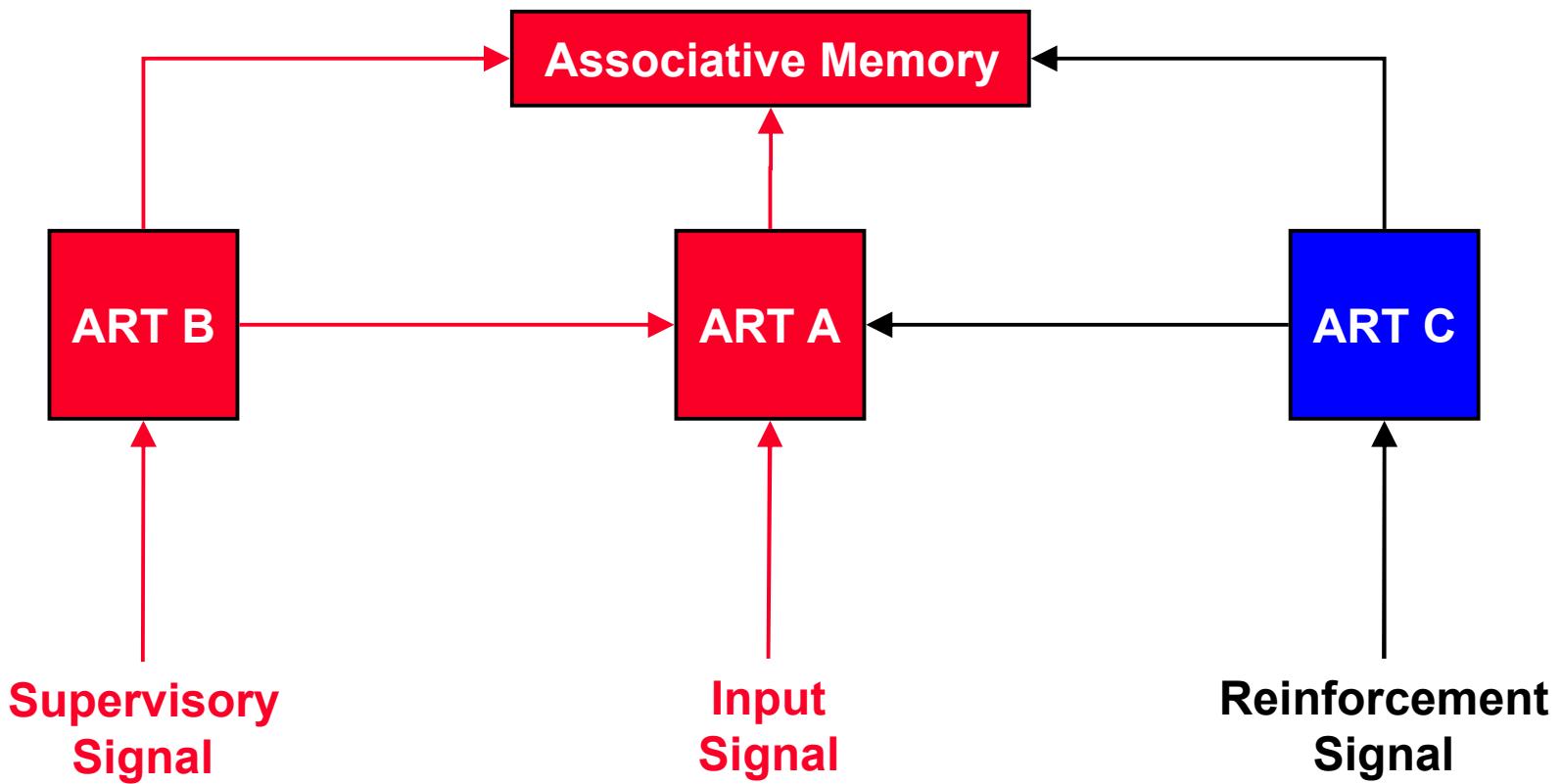




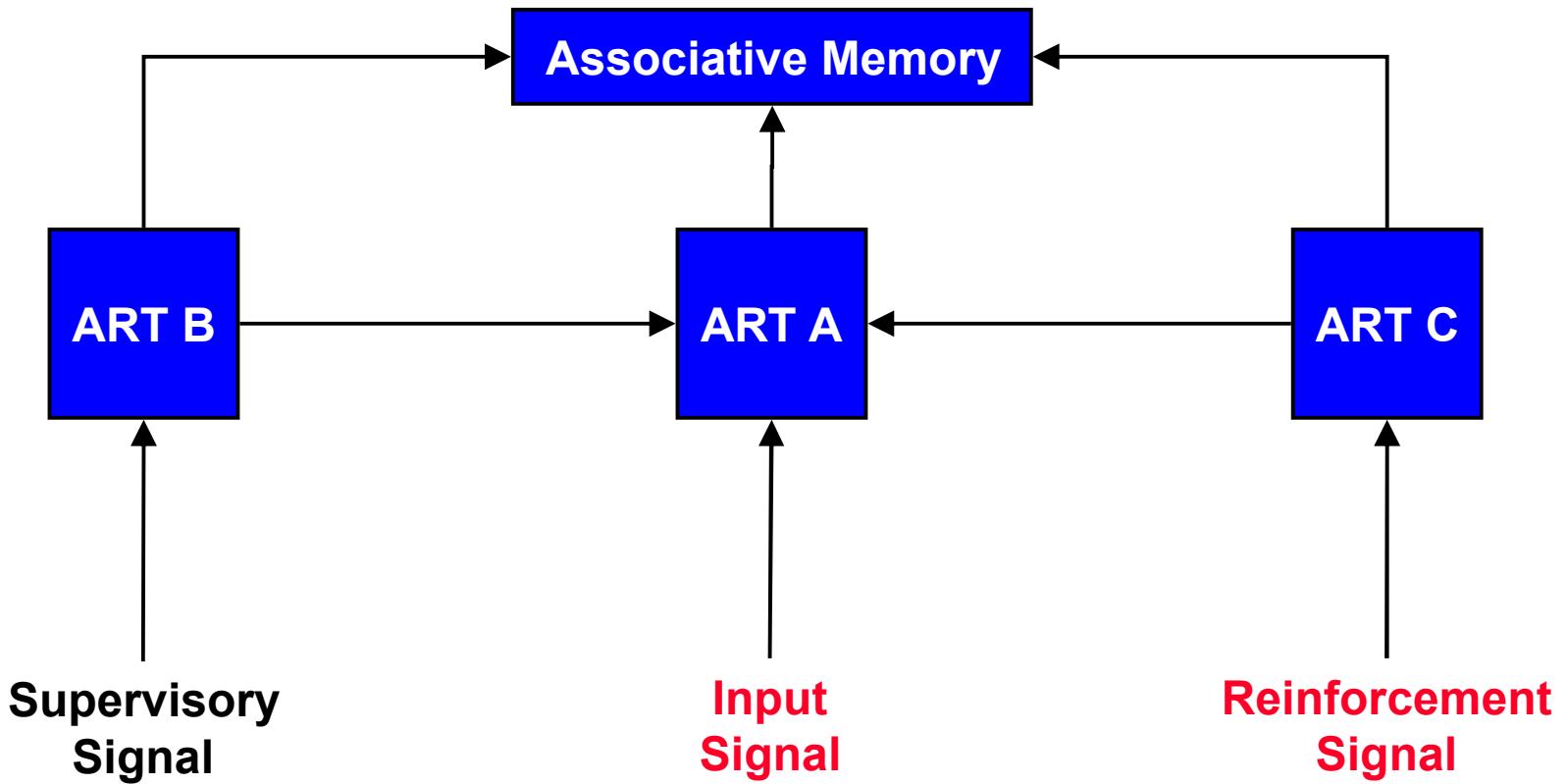
# Supervised Learning



# Supervised Learning

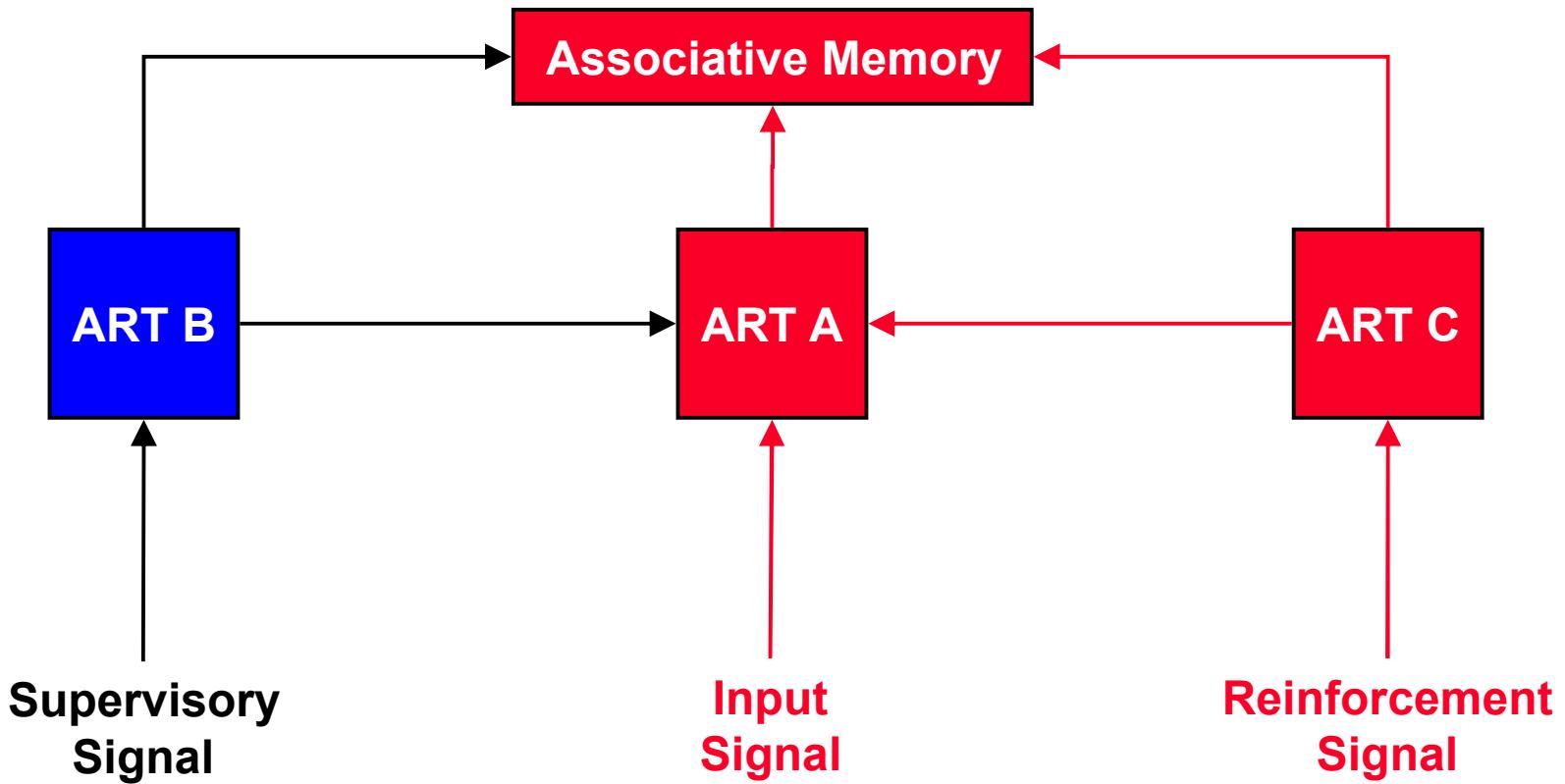


# Reinforcement Learning





# Reinforcement Learning





# Decision Support

- Desired Operator Interface
  - Actionable and Meaningful output
    - SA Assessment
    - Confidence Level
    - Suggested Response
  - Accept Reinforcement
- Issues
  - Amount of multisensor data fusion
    - Too much: No transparency into computational process
    - Too little: Excessive information to manage
  - Engage operator
    - Maintaining vigilance in rare event situations

# Track Detail

## ASSESS Feedback

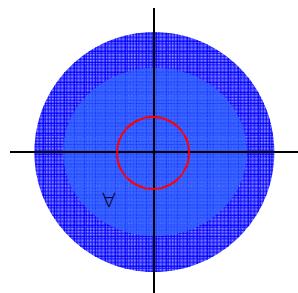
- No Activity
- Friendly Activity
- Threat
- Other ...

Bearing	162 deg
Range	11 nm
course	000 deg
speed	9.2 ft/sec
alt	<50 ft MSL
IFF	Foe

Type

Truck

ASSESS	Threat
Status	Immed
Intent	Assault
Confidence	78%



## BASIS FOR ASSESSMENT

Assess

### Evidence in Support

- Explosives detected
- Vehicle reporting missing
- Near cargo weight capacity

Status

### Evidence against

- Slow speed
- Near cargo weight capacity

Intent

### Possible Assessments

- Surveillance
- Assault
- Lost
- Uncertain

### Assumptions

- Explosives detected
- Vehicle reporting missing
- Near cargo weight capacity

## Threat Ops

Offload force



Dispatch squad

[Activate ROWS](#)

Alert

Det chemical weapon



Alert

Det nuclear weapon



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Drive away



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## BASIS FOR DEFENSE OPS

Activate ROWS

- Ammunition = Full
- Attack could come from more than one direction
- Support dispatched squad
- Favorable field of fire

## TRACK LIST

27 ➤45 Min – Truck – Assault – Offload Force

19 ➤T6 Northbound on Paragon Road



# Events

11

12

13

14

15

16

17

5H 4M      3H 20M  
Net Z Down

6H 20M

T6 Patrol 1A North

2H 40M

11M      Unknown Target 18 Detected  
4B West 3H 20M

5H 2M

T3 Patrol 4B East

2H 40M

{3H Sunset }



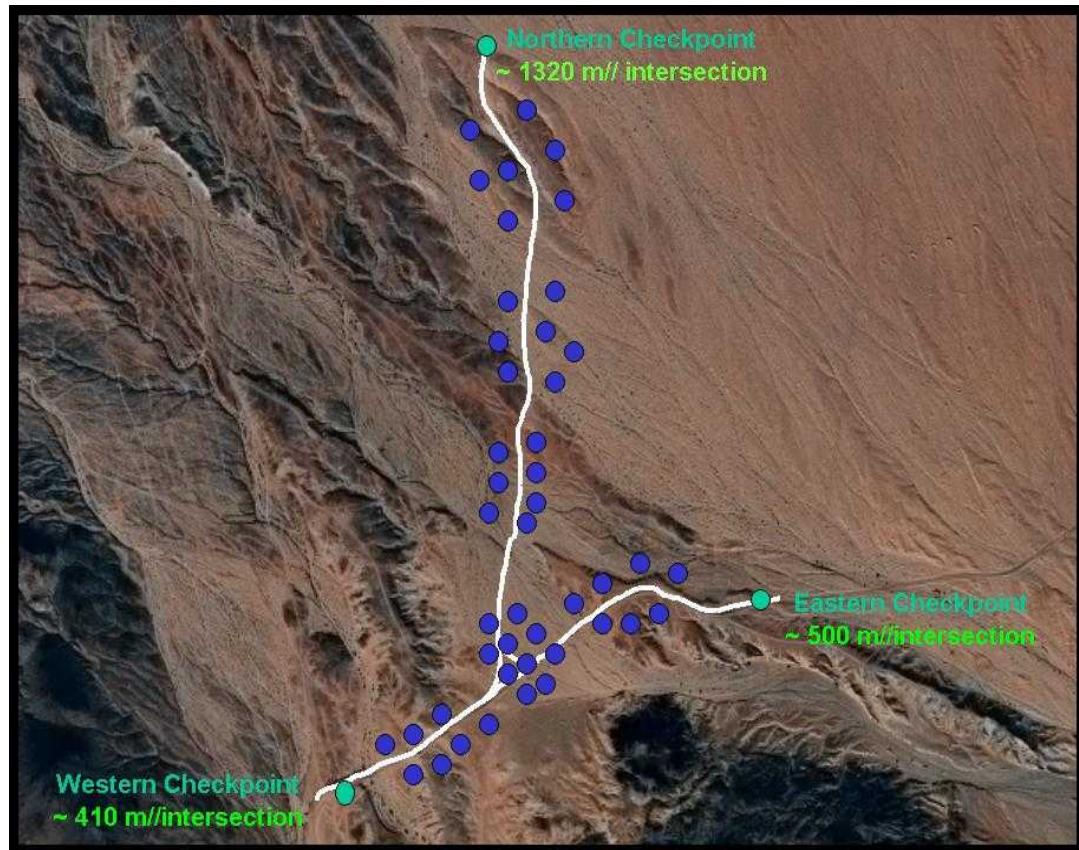
# How is our approach different?

- Adaptive
  - Can discover/take advantage of knowledge unknown to humans
  - Can adapt to varying environments in lifecycle
    - New targets trained in the field by (Unsupervised Learning)
    - Optimized by the Manufacturer (Supervised Learning)
    - System tailored to local environment (Reinforcement Learning)
- Sensor Fusion across Different Sensors AND across Time AND Space
  - Capture the history and build a story of the environment
  - Provide rational for Outputs
  - Allow feedback / inquiries from Decision-Maker(s)
  - Robust to partial / incomplete data
- Decision-Maker focused
  - Transparent
  - Interactive



# Ground Vehicle Tracking Experiments

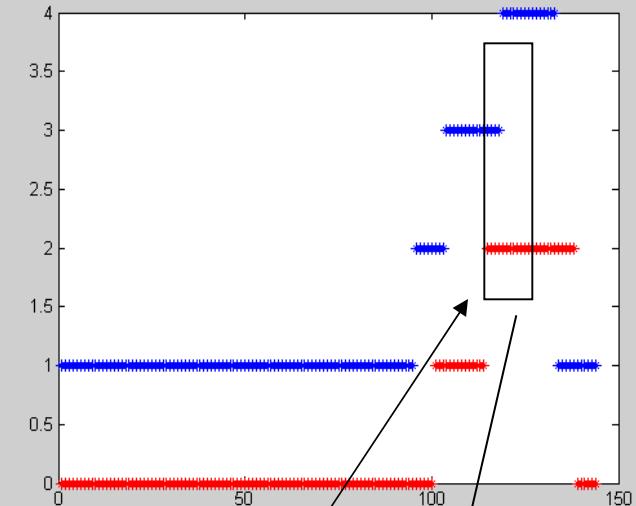
- DARPA SensIT Data
  - University of Wisconsin
  - 23 Sensor Nodes
    - Seismic
    - Acoustic
  - Raw (analog) data
  - Detection (binary) data
- Experiments
  - Going north?
  - Location
  - Speed
  - Heading
  - Vehicle Type
- Test false alarm rate against
  - Removal of key sensors
  - Manipulation of key sensors
  - Non-random noise



# Application of Fuzzy-ART for Ground Vehicle Tracking

## Classification of Observations

Vehicle Type	ART Vigilance	DataSet Selection
<input checked="" type="checkbox"/> AAV <input type="checkbox"/> DW	0.6	<input type="radio"/> All <input type="radio"/> 3 <input type="radio"/> 4 <input checked="" type="radio"/> 5 <input type="radio"/> 6 <input type="radio"/> 7 <input type="radio"/> 8 <input type="radio"/> 9 <input type="radio"/> 10 <input type="radio"/> 11
<b>Classify the Selected DataSet(s)</b>		



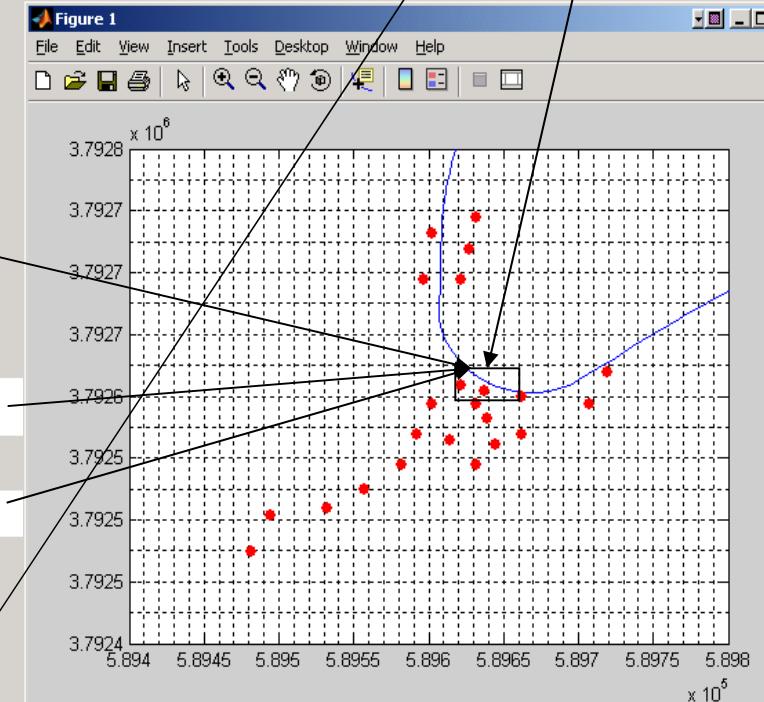
Data Code (1-18)	Time Period (1 - 150)
3	120

Testing Vigilance	Observation(s) that matched with the test data
0.87	5

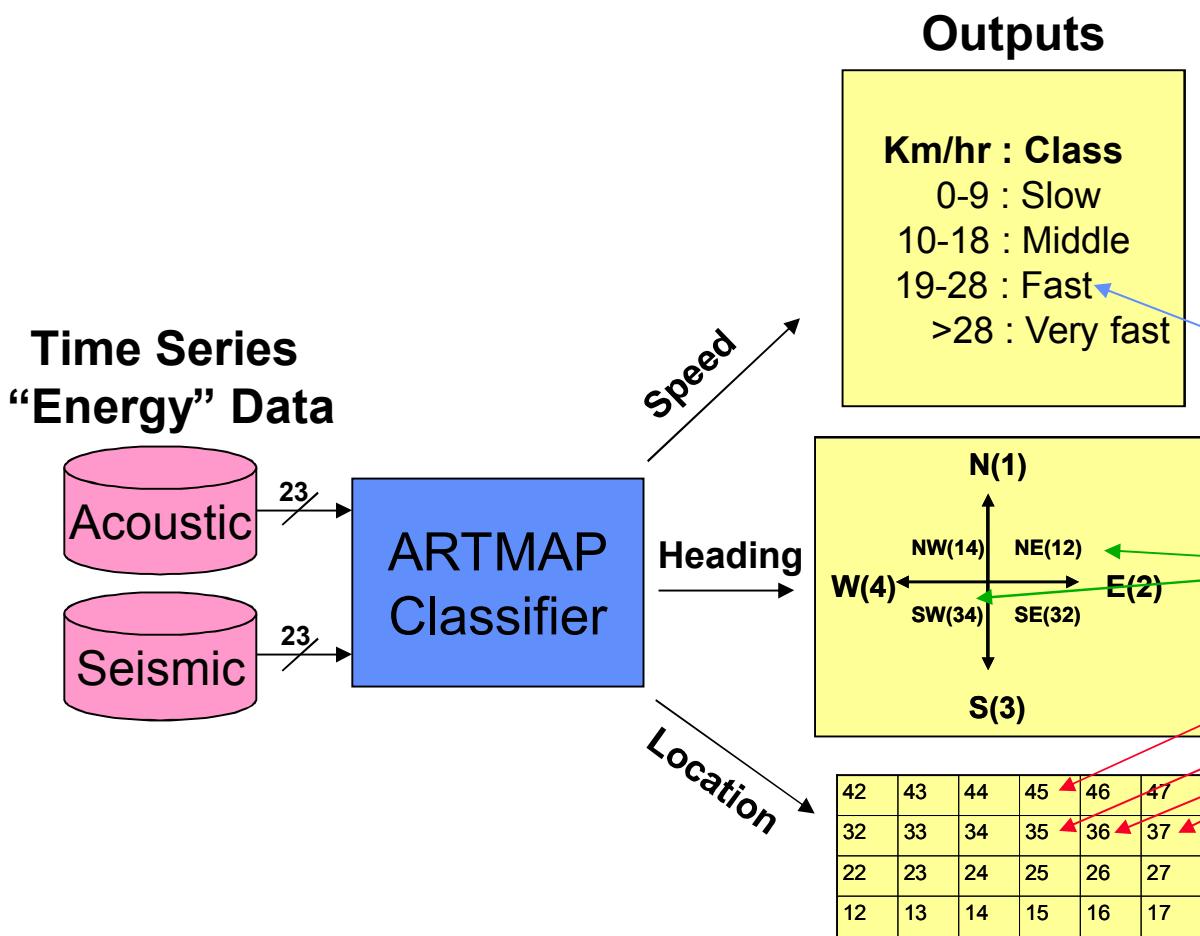
Reports on the test data set

**Generate Report**

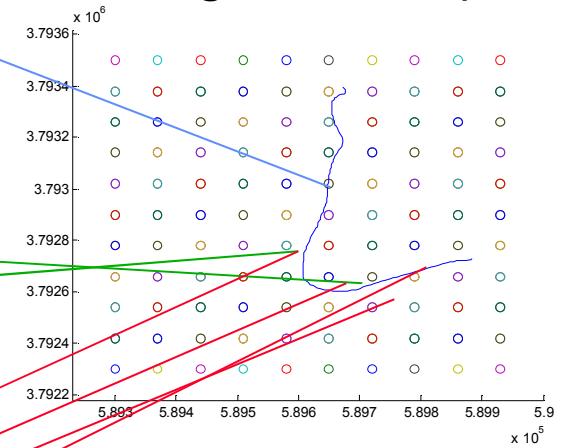
VehicleType	AAV
On Road	3
Speed	20.6
Heading	
SE SE SE SE SE SE SE SE NE NE NE NE NE NE	
Locations	
64 64 64 64 64 64 64 64 64 64 64 74 74 74	
Corresponding to the Class(es)	
3 3 3 3 3 3 3 3 4 4 4 4 4 4	



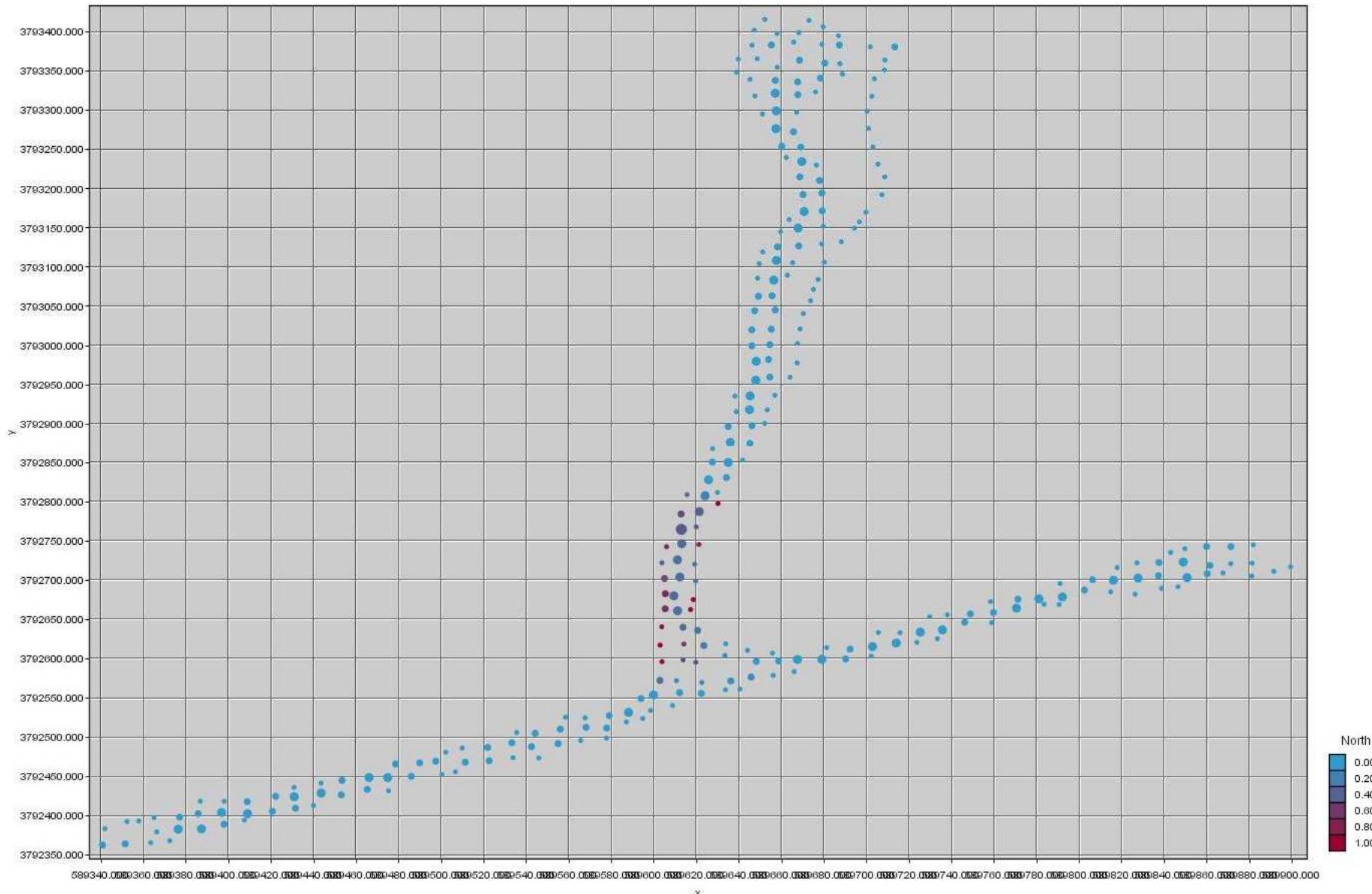
# Fuzzy ARTMAP for Ground Vehicle Tracking



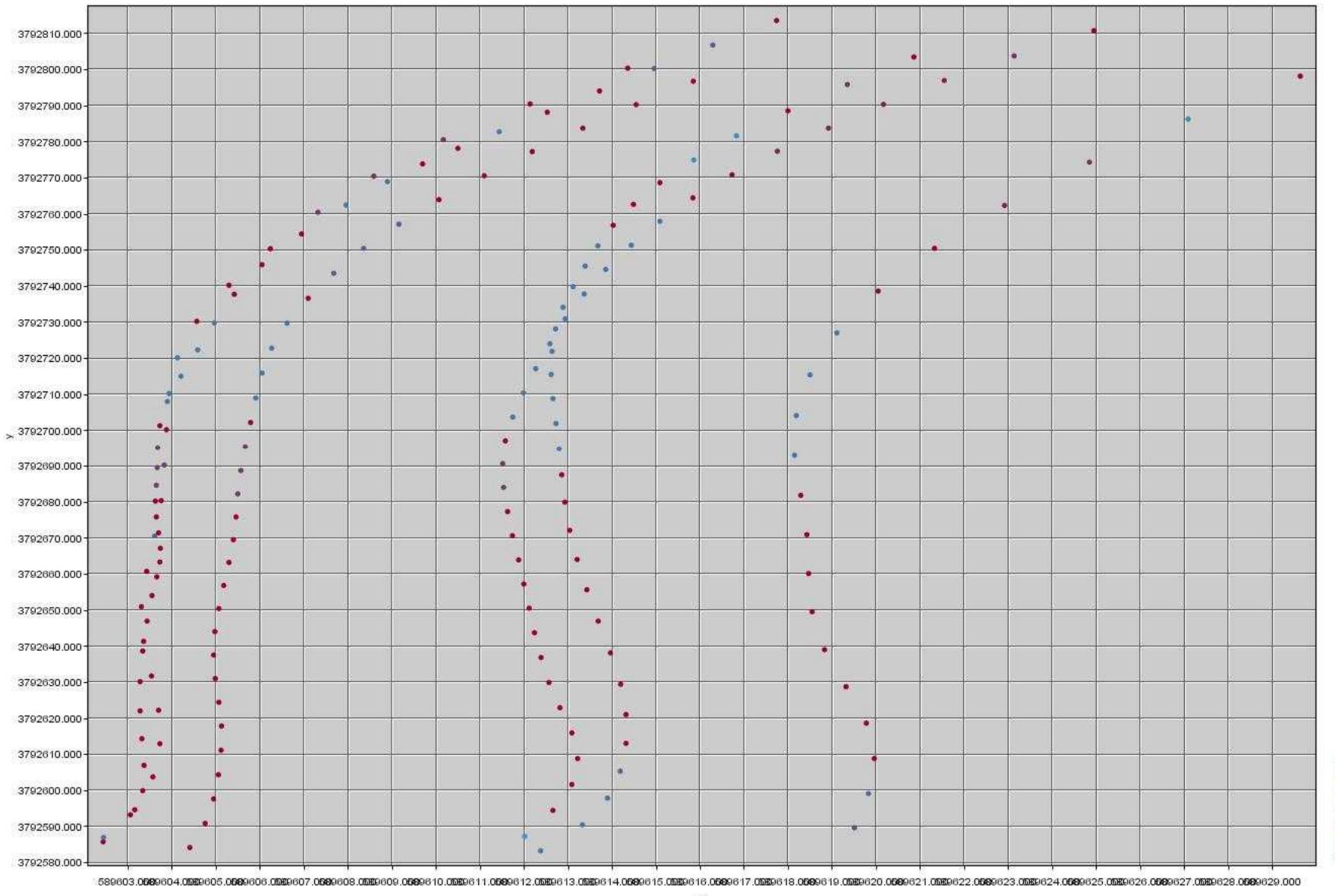
Assault Amphibian Vehicle traveling on route 3 (AAV5)



# Multilayer Perceptron Results



# Multilayer Perceptron Results



# Q & A

