



# Issues to Consider as we go

- What are the unique challenges of the scenario?
  - Is there a way to make the scenario more “fundamental” and focus on the challenge
- What information needs to be combined from multiple nodes, and how often?
- What are some likely queries?
- How would we benchmark success?
- Can this test be implemented as a real world experiment?



# Assumptions

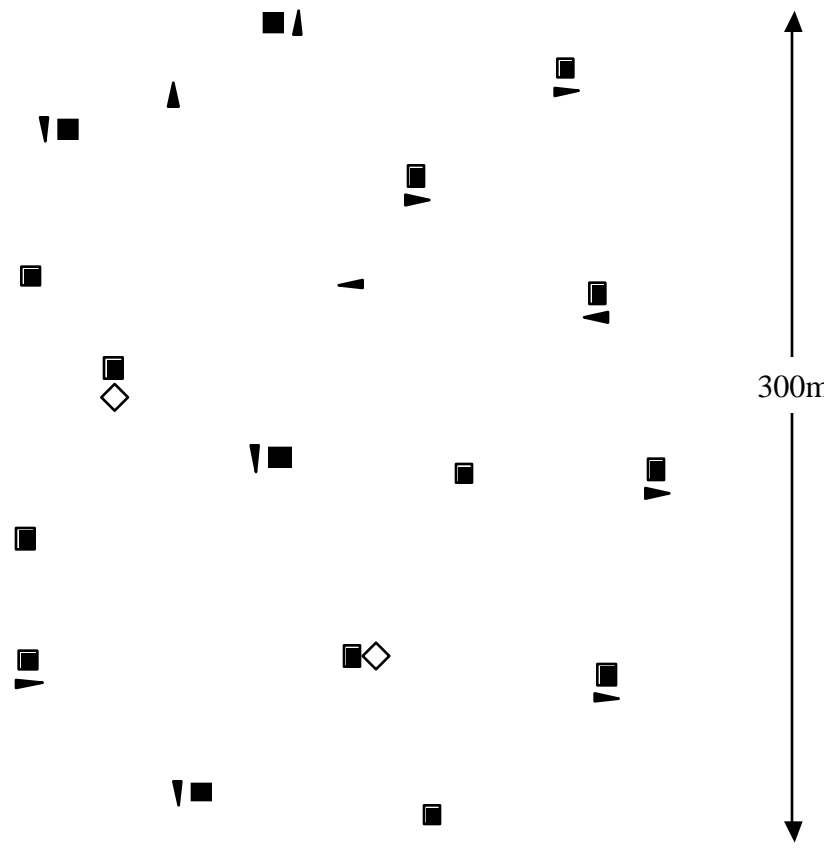
- Single vehicle unless otherwise shown
- Unless otherwise stated, vehicles attempt to maintain constant speed and do not shift gears
- Unless otherwise stated, vehicles start beyond the sensor field and arrive in sequence
- Complications to be handled as we get better:
  - Variation of acoustic signature with aspect
  - Acceleration, braking, and gear shifts
    - Changes the acoustic signals
  - Spatio-temporally varying propagation models
  - Node unreliability





# 2D Array Laydown Example

- Microphone/  
Microphone Array
- ▶ PIR
- ◇ 3-Axis Seismic



Randomly distributed in [X, Y,  $\theta$ ]

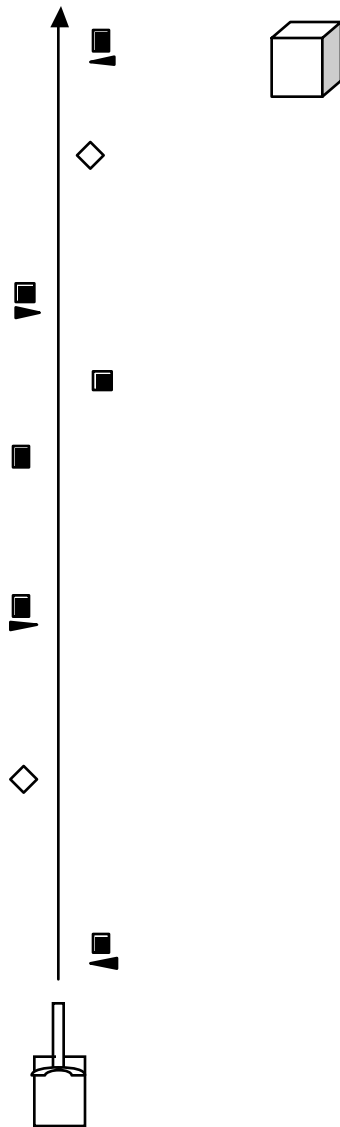


# Benchmarking

- Generic Benchmarks
  - Energy Consumption
    - Total, per node (max, avg)
    - $f(\text{computation, communication})$
  - Detection Accuracy
    - Frequency of false positives, negatives
  - Detection Latency
    - Mean, max vs. query source location
  - Tracking accuracy
    - Mean, max, std.
    - $f(\text{desired output frequency})$
  - Tracking Latency
    - Mean, max vs. query source location
- Task-specific Benchmarks



# 1: Track Single Target



## Task

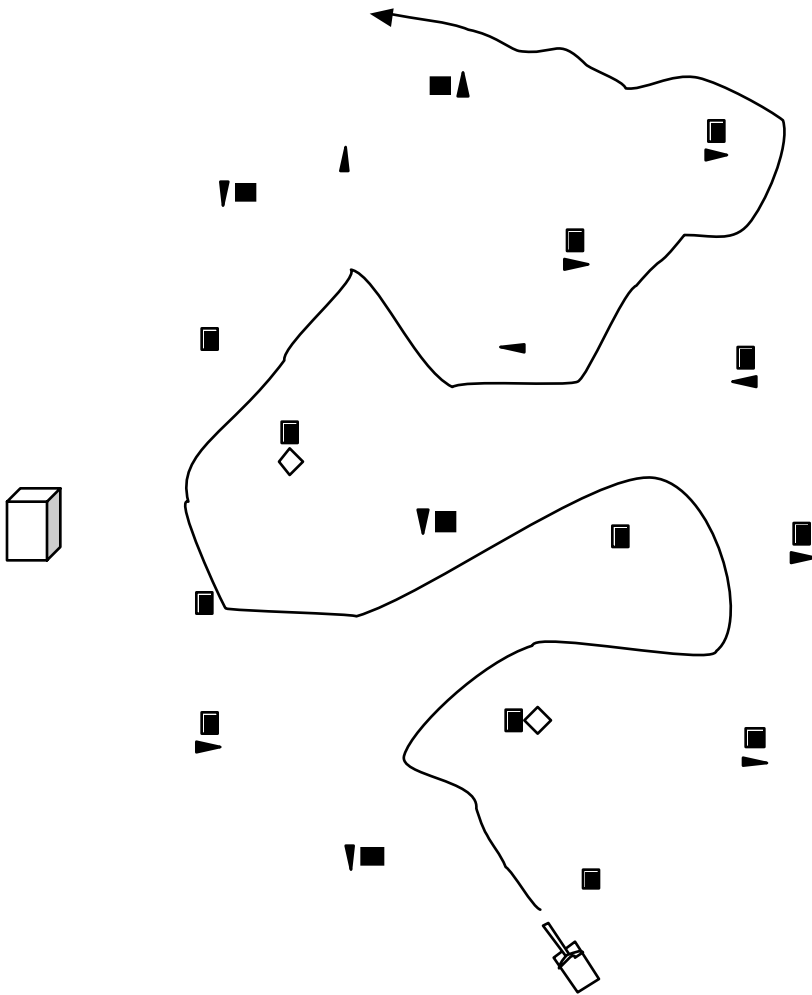
- Estimate target position vs. time

## Challenges

- Localize target
- Maintain accurate estimate in large gaps between sensors
- Fuse data from multiple sensor types



## 2: Track Single Maneuvering Target



### Task

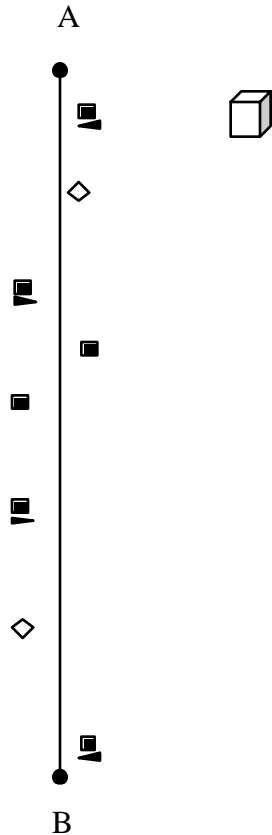
- Estimate target position vs. time

### Challenges

- No road, hence no prior knowledge of vehicle trajectory
- Constant direction dynamics models no longer adequate
- Many sensors making simultaneous observations



# 3: Track Accelerating/Decelerating Target



Task

- Estimate target position vs. time

Challenges

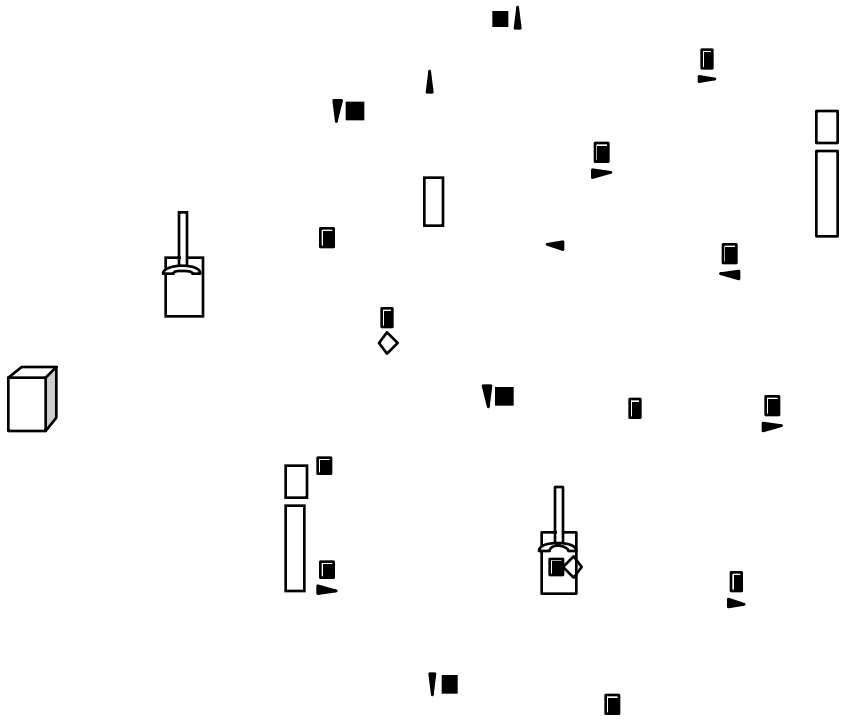
- Vehicle signature time-varying
- Constant velocity dynamics models no longer adequate
- Gear shift requires maintaining internal discrete state (curr. gear)

*Vehicle begins stationary and idling at point “A”  
Accelerates, maintains constant velocity  
Decelerates and stops at point “B”*

*Extra credit: Handle gear shifts*



# 4: Count Stationary (idling) Targets



Task

- Count number of targets
- Locate targets

Challenges

- Multiple vehicles
- Unknown number of vehicles
- Cannot depend on peak-finding (CPA) of acoustic signal

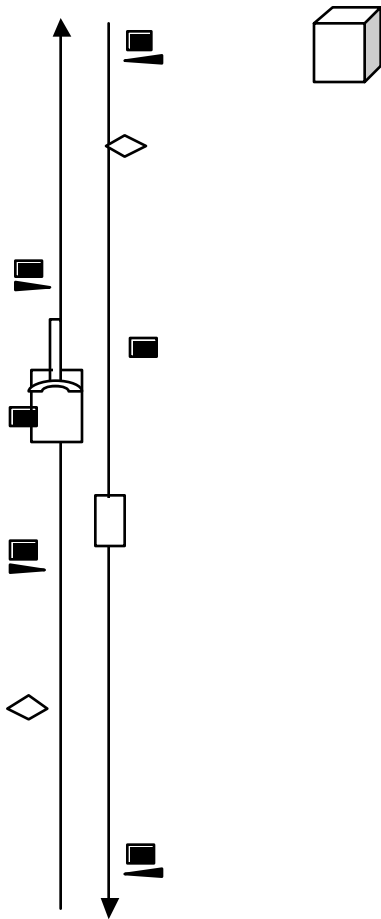
Task-Specific Benchmarks

- Accuracy of count

vs. dynamic range of acoustic outputs from ensemble of vehicles



# 5: Two-way traffic



Task

- Track target positions
- Estimate target crossing time

Challenges

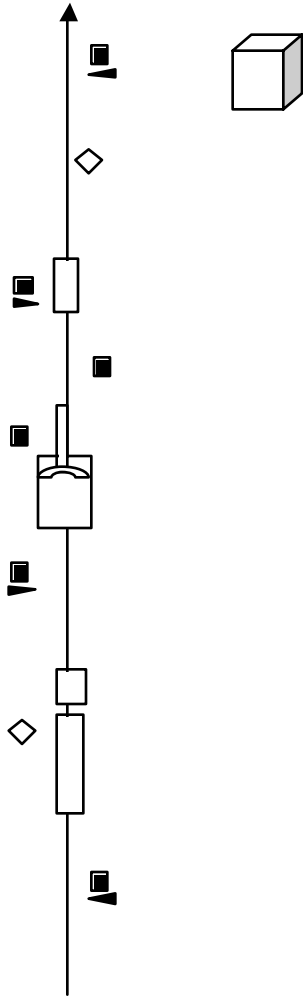
- Vehicles in close proximity, need to use dynamics to keep identities separate

Task-Specific Benchmarks

- Accuracy of crossing time estimate



## 6: Convoy on a Road



*Vary inter-vehicle spacing to vary problem difficulty*

### Task

- Count number of vehicles of each type
- Determine order of vehicles

### Challenges

- Multiple vehicles
- Classification and state information must follow vehicle along full length of road

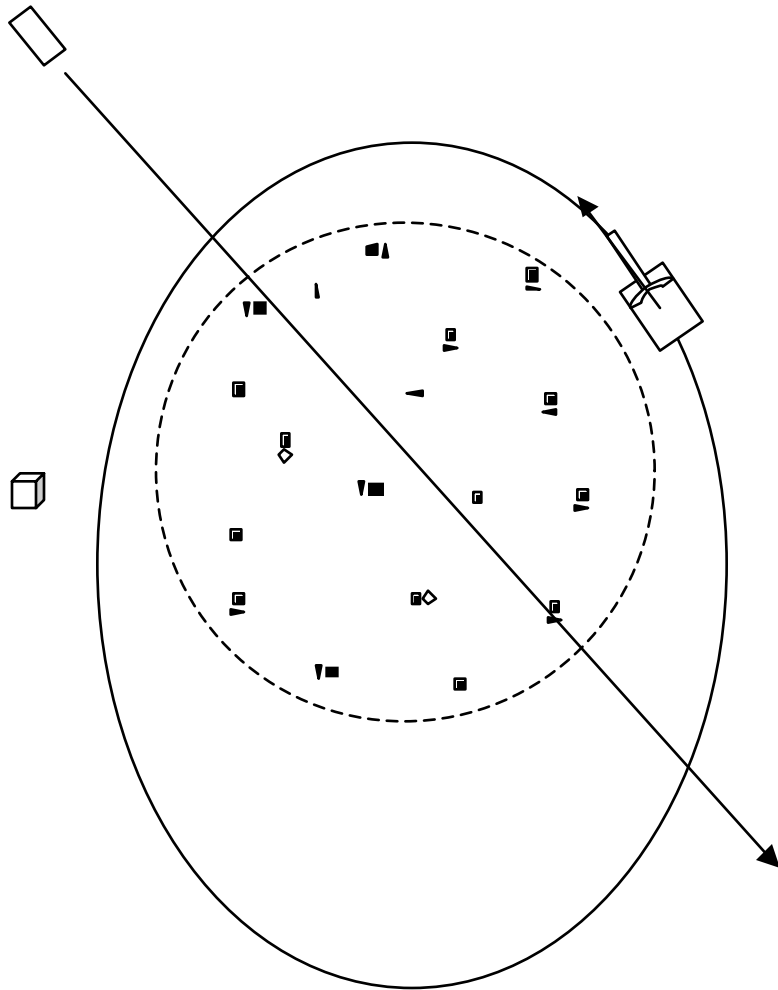
### Task-Specific Benchmarks

- Accuracy of count & order

vs. vehicle spacing & convoy velocity



# 7: Perimeter Violation Sensing



## Task

- Alert on violation of perimeter
- Ignore activity outside of perimeter (distractors)
- Identify violator type and track location

## Challenges

- Filter out distractor
- Respond quickly while minimizing quiescent activity

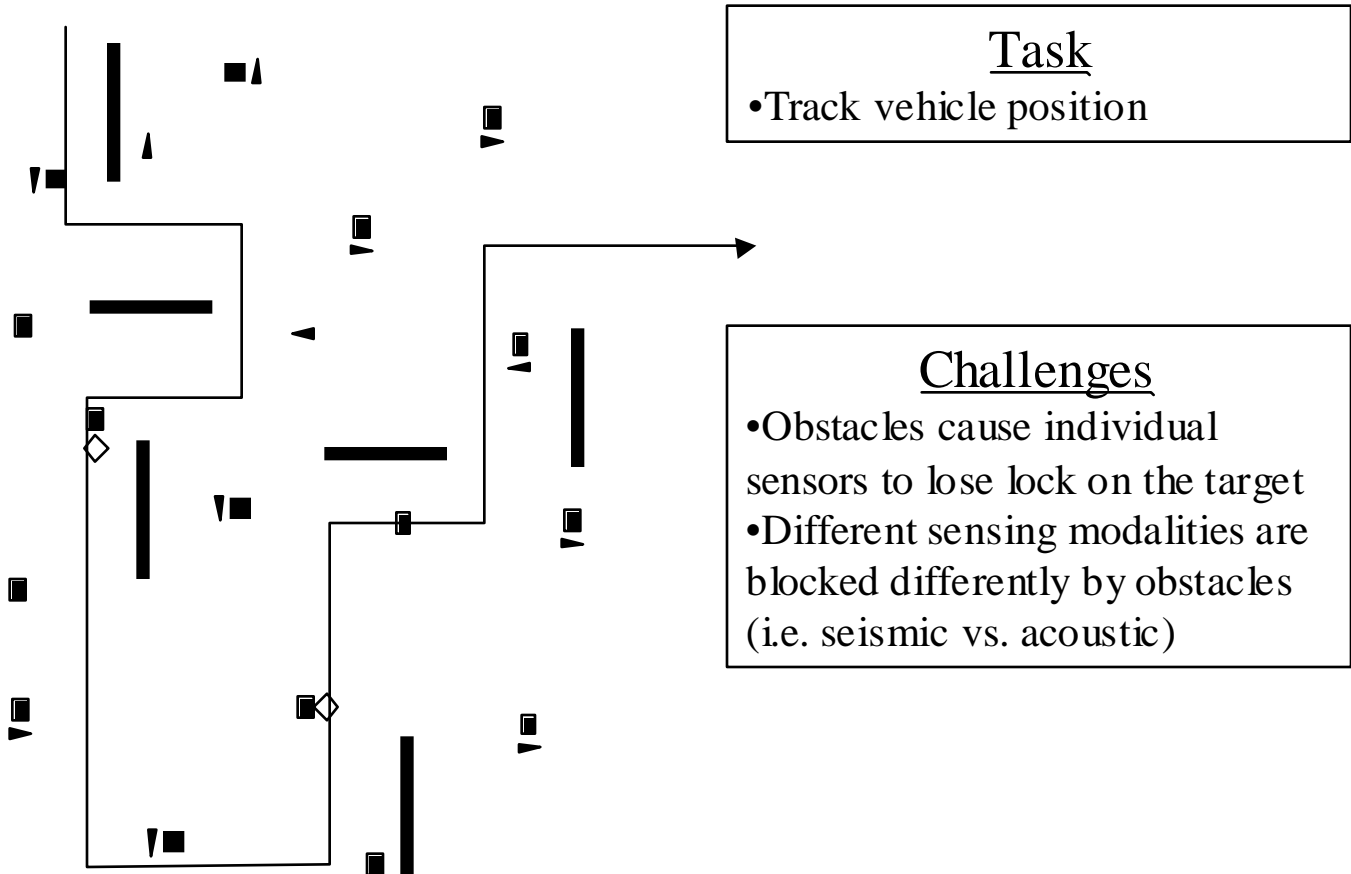
## Task-Specific Benchmarks

- Detection delay
- Power usage during periods of no violation
- Frequency of false positives

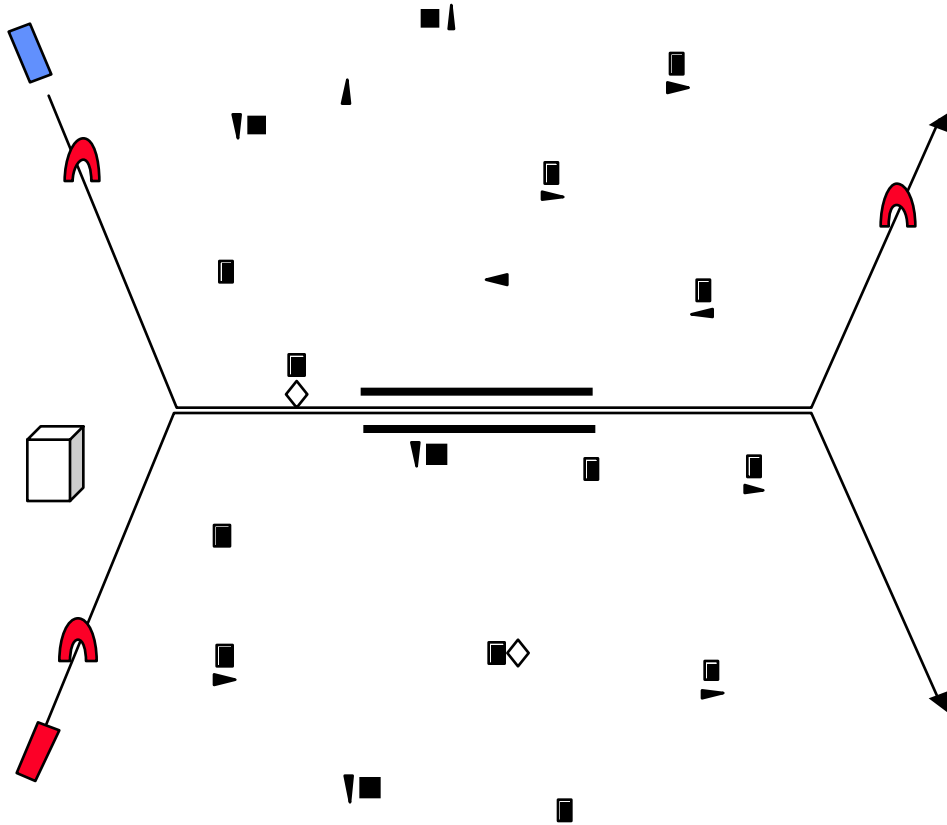
all vs. distractor/violator  
source amplitude ratio



# 8: Tracking in an Obstacle Field



# 9: Road Junction Merge/Split on Localized One-Time Sensor



*Targets can only be distinguished from each other by magnetometers (shown), which give one-time “red/blue” output when the vehicle passes over them.*

## Task

- Track targets
- Maintain target identities
- Re-establish identity of both targets when right-hand magnetometer is crossed

## Challenges

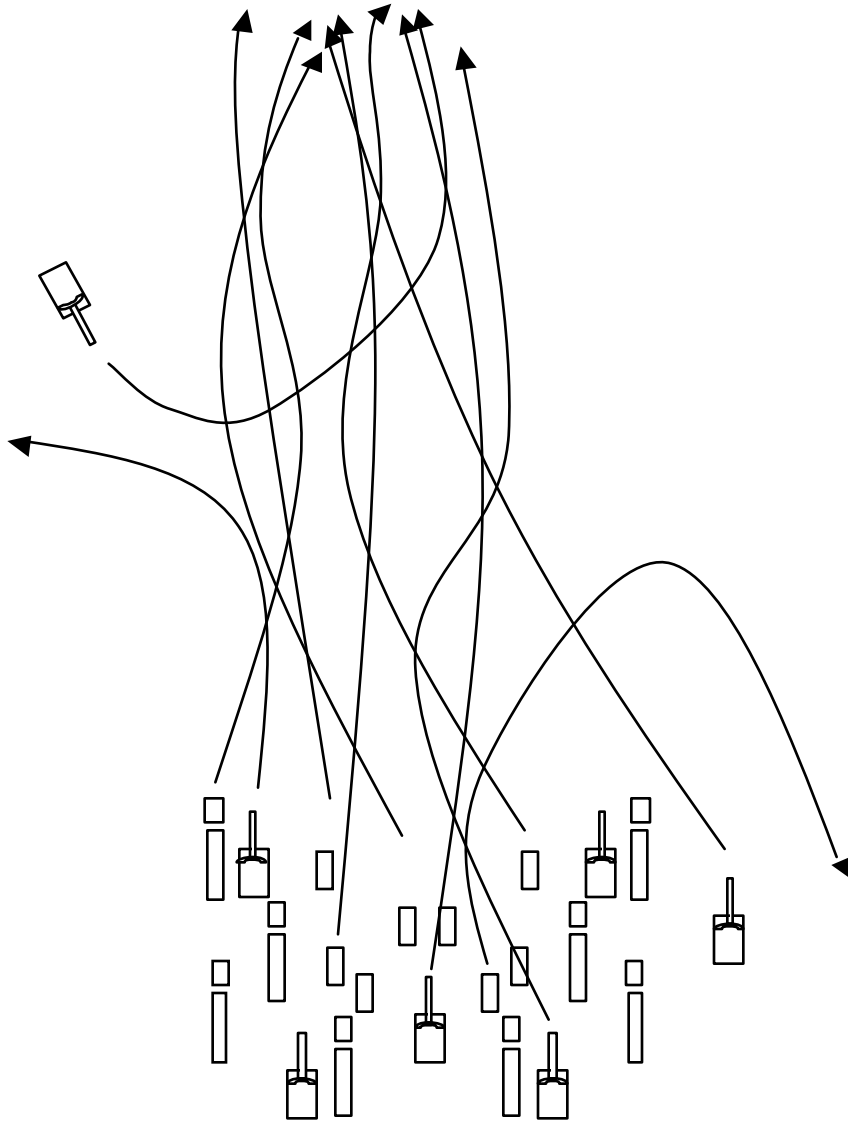
- Need to conserve number and type of targets as they pass through tunnel.
- Need to reason about targets – Seeing blue at top right mag. guarantees red at bottom.

## Task-Specific Benchmarks

- Time to propagate data from RHS magnetometer to red car in the lower RHS



# 10. Cluster Behavior



## Task

- Track cluster centroid
- Keep count of vehicles in cluster adjusting as some leave and join

## Challenges

- Large number of targets
- Coalescing many similar targets, limiting exponential hypothesis blowup
- Measuring global properties of cluster (centroid, count) rather than properties of single target

## Task-Specific Benchmarks

- Maximum number of targets which can be handled simultaneously
- Centroid accuracy