# Flexible Resource Assignment in Sensor Networks: A Hybrid Reasoning Approach

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# Outline

- Introduction
  - Problem and Motivation
- Approach
  - Capability Inference
  - Capability-Asset Matching
- Future work
- Conclusion

# Introduction: Problem

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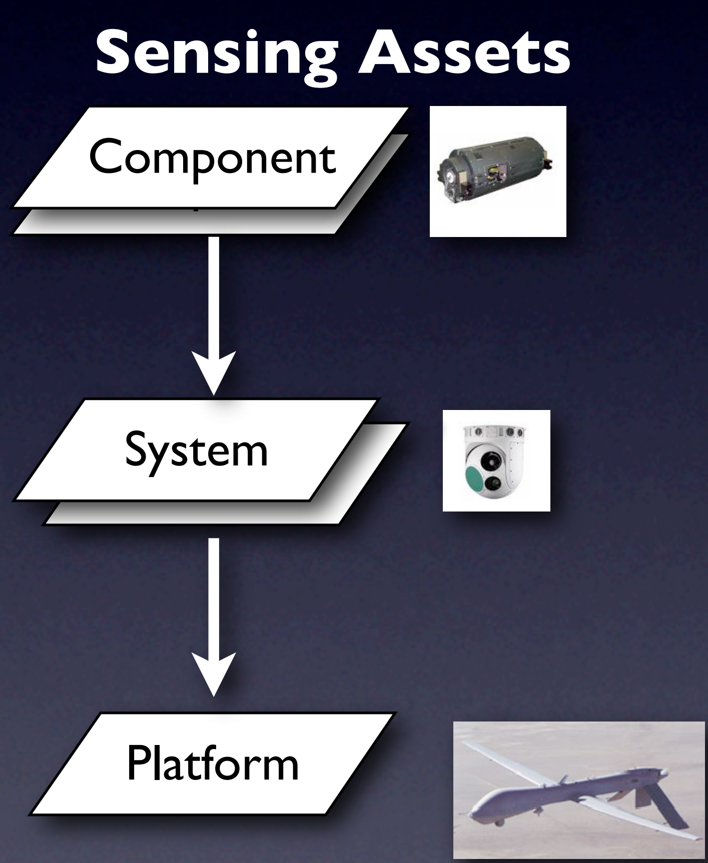

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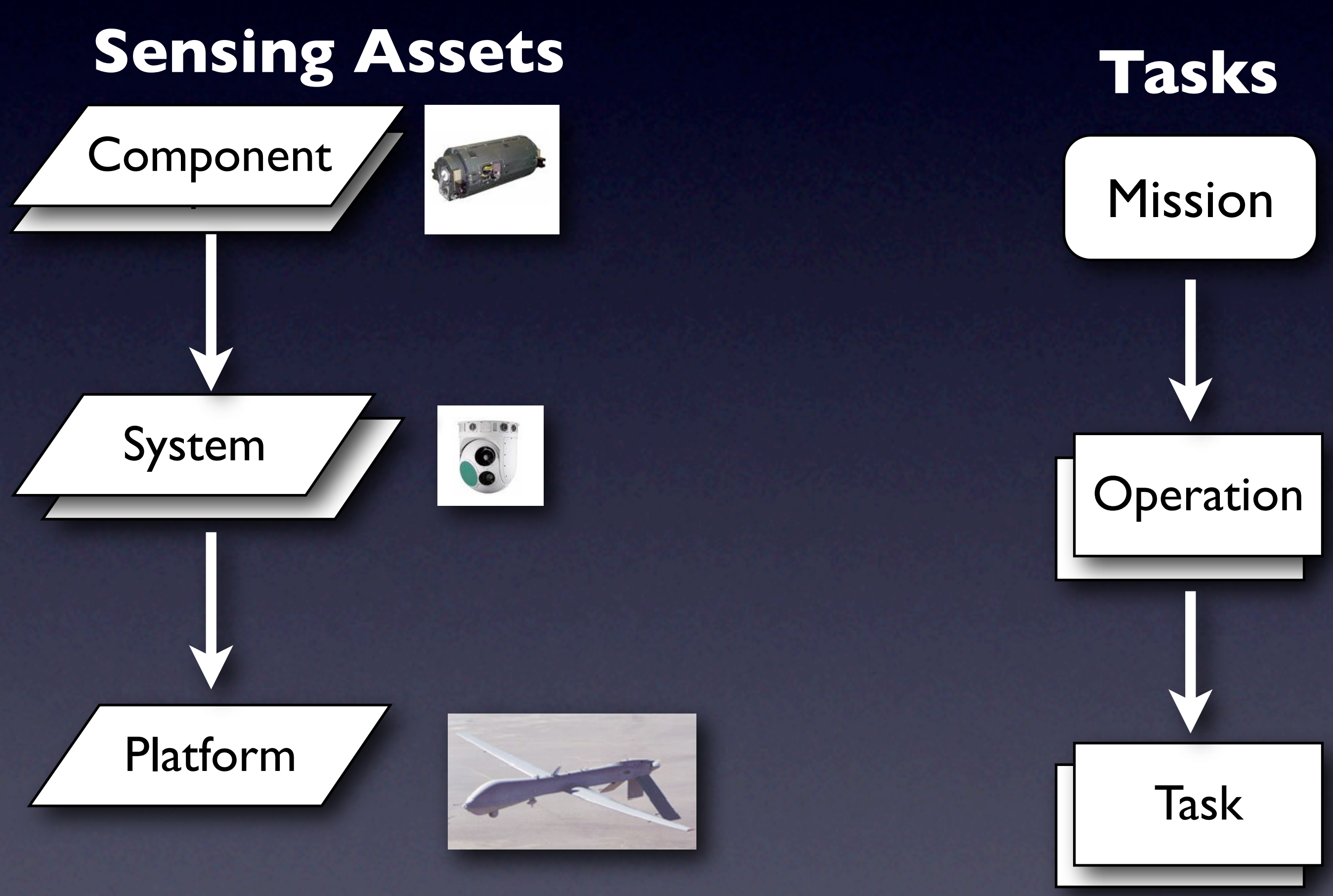

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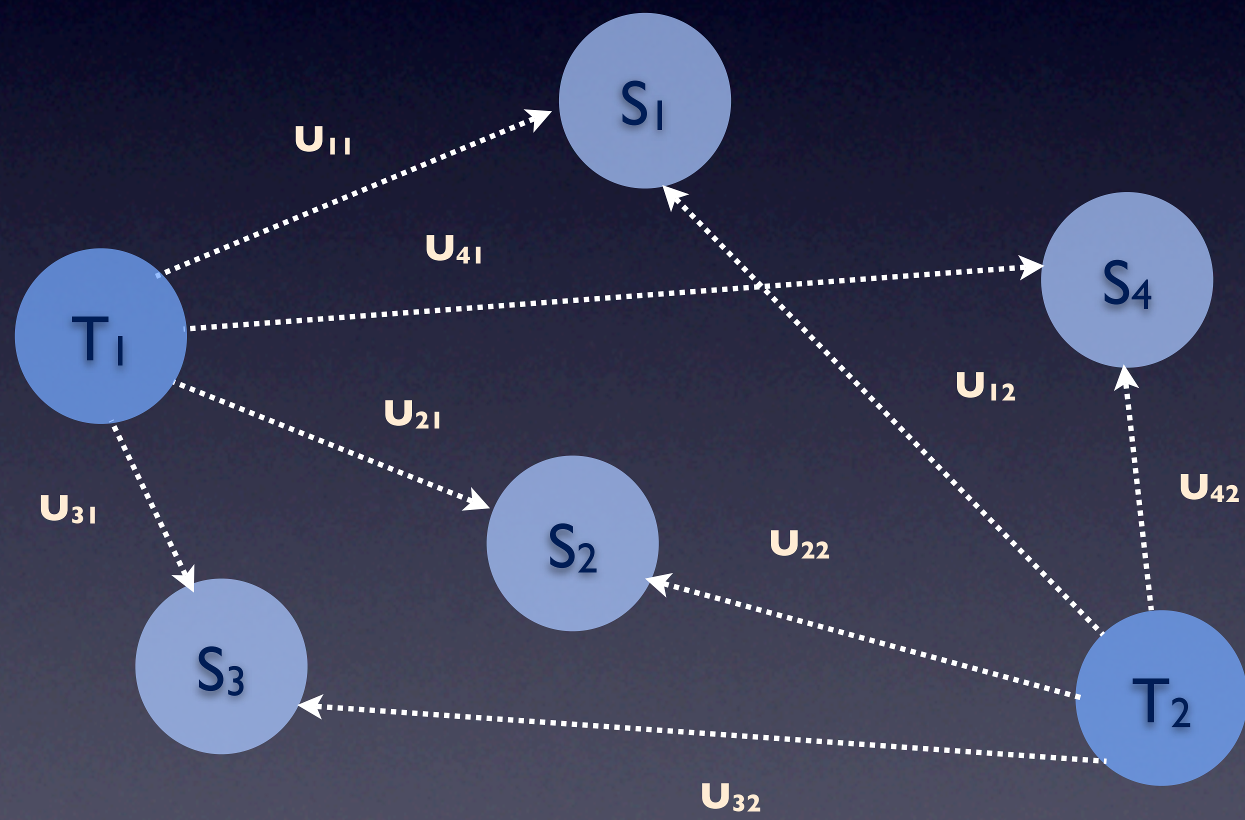

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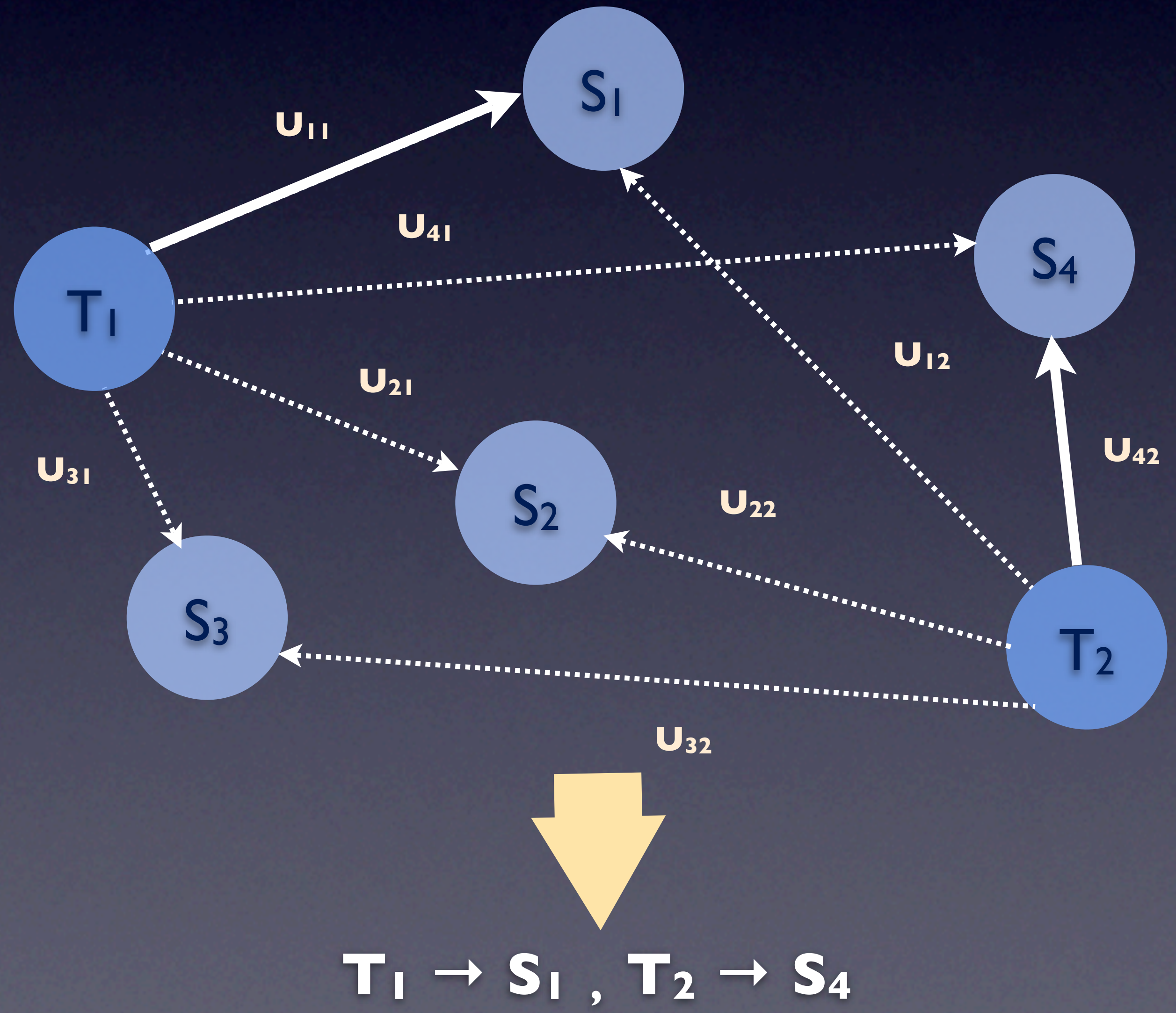

# Introduction: In a Coalition

- Coalitions are formed to achieve collective goals.
- Due to the nature of coalitions  and the environments they operate on asset-task assignment is even more complicated.
    - Different partners
        - Ownership issues, Policy issues etc.
    - Heterogeneity of the sensing assets
        - Quantitative and Qualitative attributes
    - Assets are scarce and high in demand
    - Multiple tasks to accomplish simultaneously
    - Highly dynamic environment (assets failures, situation changes etc)

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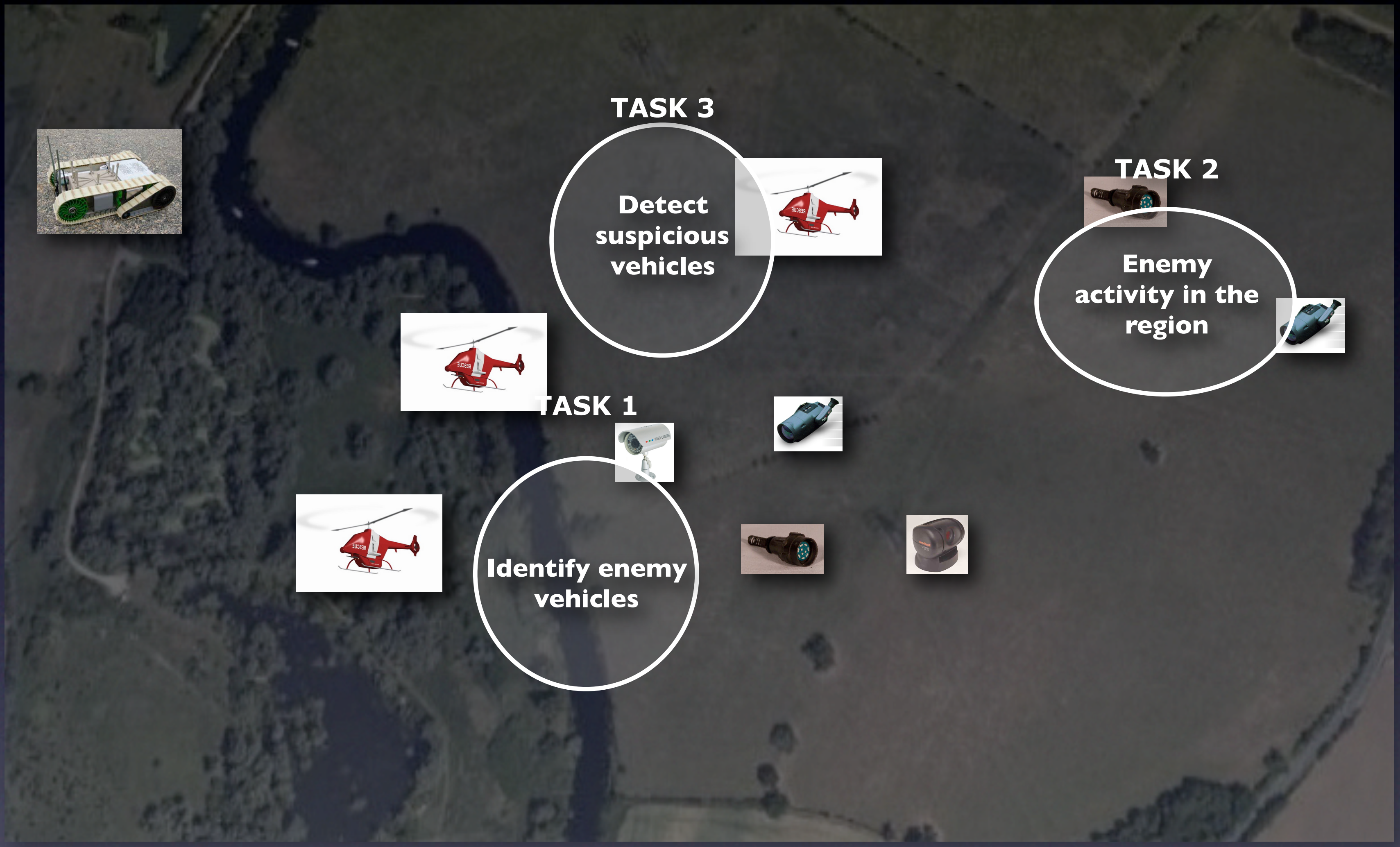

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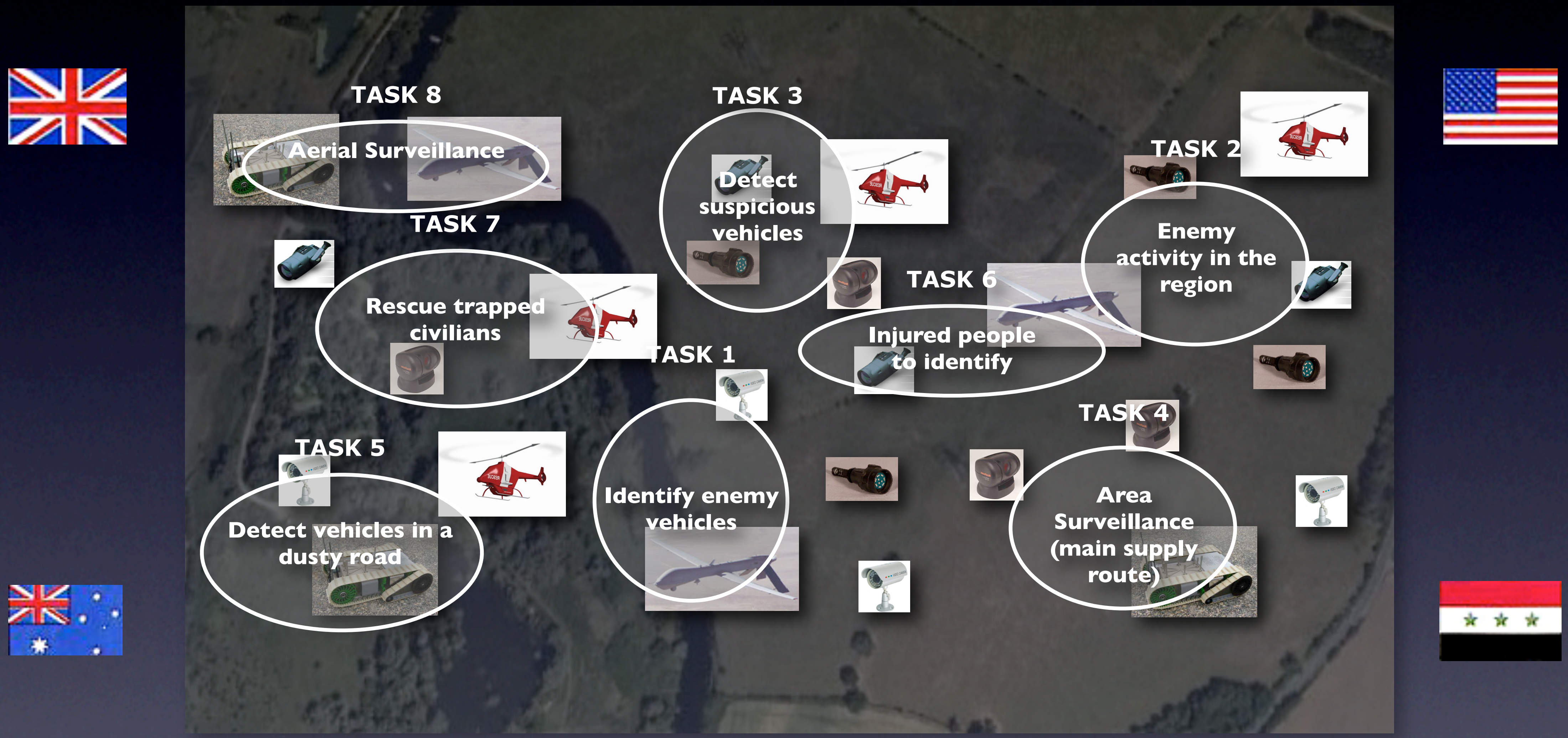


Adopted from EKAW 2008 - Slide credit: Diego Pizzocaro, University of Cardiff

# Introduction: Approach

- Need to infer different capabilities that could be used to satisfy tasks.
  - **Acoustic** or **imagery** data could be used to **detect a vehicle**.
- Need to decide what types of assets are capable of satisfying the information requirements of each task.
  - Logically sounding pairs of assets and tasks. They match in-terms of the requirements advertised by the tasks and the capabilities provided by the assets.
  - If a **radar** is capable of performing the tasks, then a **synthetic aperture Radar** (SAR) is also capable of performing the task.

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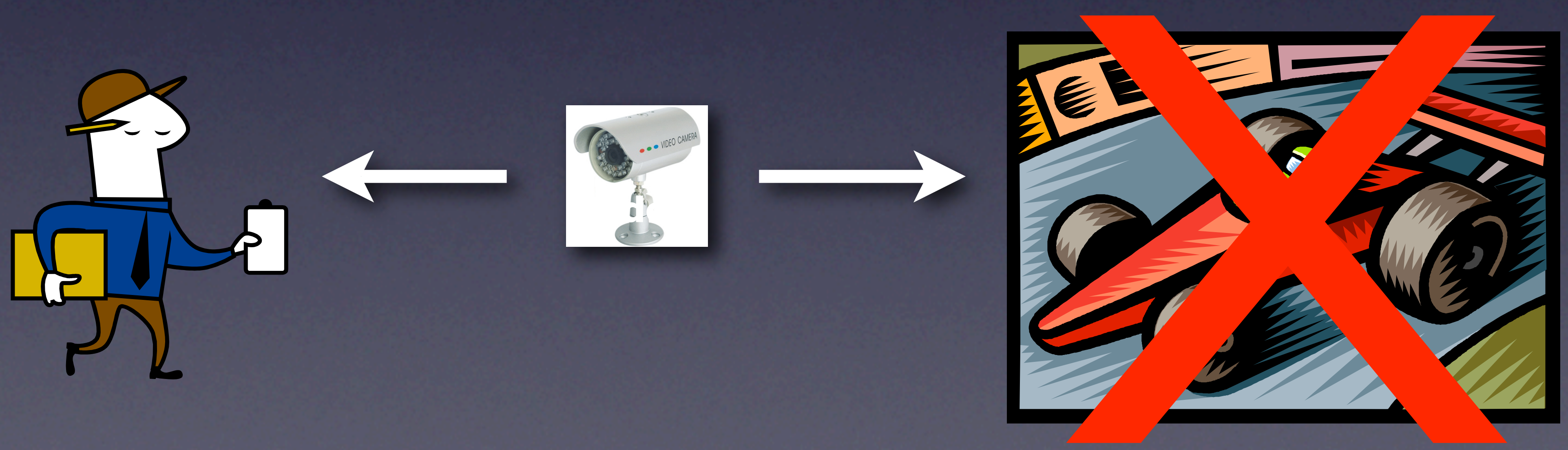

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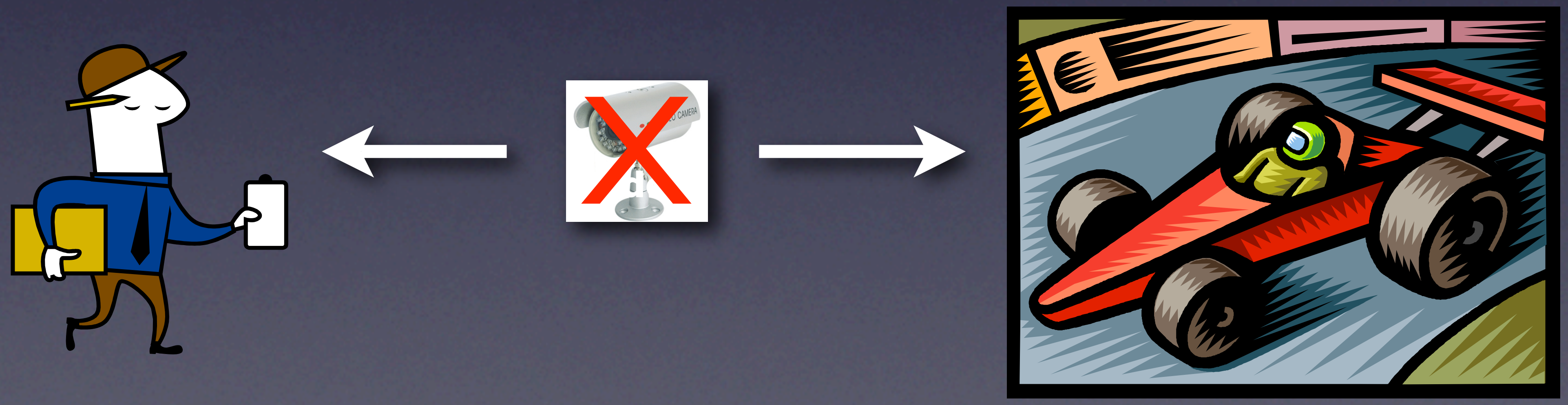

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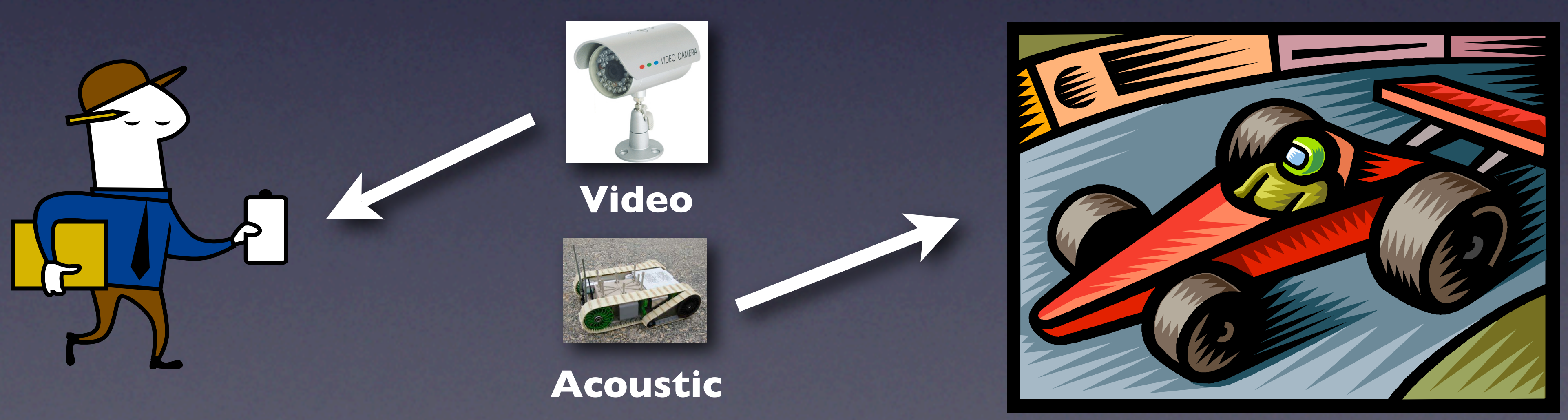

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**National Image Interpretability Rating Scales (NIIRS)**

**NIIRS 1 [over 9.0 m GRD]**

| Visible NIIRS | Radar NIIRS | Infrared NIIRS | Multispectral NIIRS |
|---|---|---|---|
| Detect a medium-sized port facility and/or distinguish between taxi-ways and runways at a large airfield. | Detect the presence of aircraft dispersal parking areas.<br><br>Detect a large cleared swath in a densely wooded area.<br><br>Detect, based on presence of piers and warehouses, a port facility.<br><br>Detect lines of transportation (either road or rail), but do not distinguish between | Distinguish between runways and taxiways on the basis of size, configuration or pattern at a large airfield.<br><br>Detect a large (e.g., greater than I square kilometer) cleared area in dense forest.<br><br>Detect large ocean-going vessels (e.g., aircraft carrier, super-tanker, KIROV) in open water.<br><br>Detect large areas (e.g., greater than I square kilometer) of marsh/swamp. | Distinguish between urban and rural areas.<br><br>Identify a large wetland (greater than 100 acres).<br><br>Detect meander flood plains (characterized by features such as channel scars, oxbow lakes, meander scrolls).<br><br>Delineate coastal shoreline.<br><br>Detect major highway and rail bridges over water (e.g., Golden Gate, Chesapeake Bay).<br><br>Delineate extent of snow or ice cover. |

NIIRS:http://www.fas.org/irp/imint/niirs.htm

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| Multispectral NIIRS |
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- 3 main interpretation task (IT) types

  Detect
  ↑ Distinguish
  ↑ Identify

- Knowledge base created from NIIRS knowledge corpus

**FIT(T,W,F,C,I,V)**

**T** = Type of the interpretation task to perform (detect, distinguish, or identify)

**W** = { $W_i$ } is a set of Detectables that can be observed from the image

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- 3 main interpretation task (IT) types

Detect

Detect, based on presence of piers and warehouses, a port facility
**FIT(detect,[Port],[Pier,Warehouse],[ ],image(Radar),1)**

Detect a large cleared area in dense forest
**FIT(detect,[ClearedArea],[ ],[DenseForest],image(Infrared),1)**

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- Rules to capture the knowledge and forward chaining to find required NIIRS values to perform the tasks.

**$detect(x_j, i_j, v_j) \leftarrow distinguish(x_j, i_j, v_j)$**

**$distinguish(x_j, i_j, v_j) \leftarrow identify(x_j, i_j, v_j)$**

**$detect(x_j, i_j, v_j) \leftarrow FIT(detect, w, f, c, i_j, v_j) \wedge x_j \in w$**

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```
?- detect(largeAirliner,Results).
Results = [(image(infrared),2),(image(radar),2),(image(visible,3))]

?- detect(smallAirliner,Results).
Results = [(image(infrared),3)]

?- distinguish([largeAirliner,smallAirliner],Results).
Results = [(image(infrared),3)]
```

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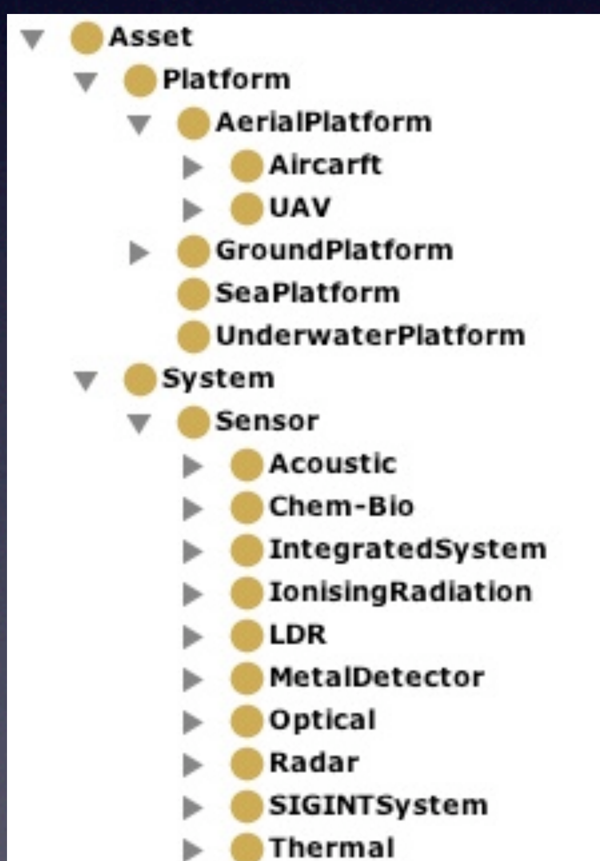
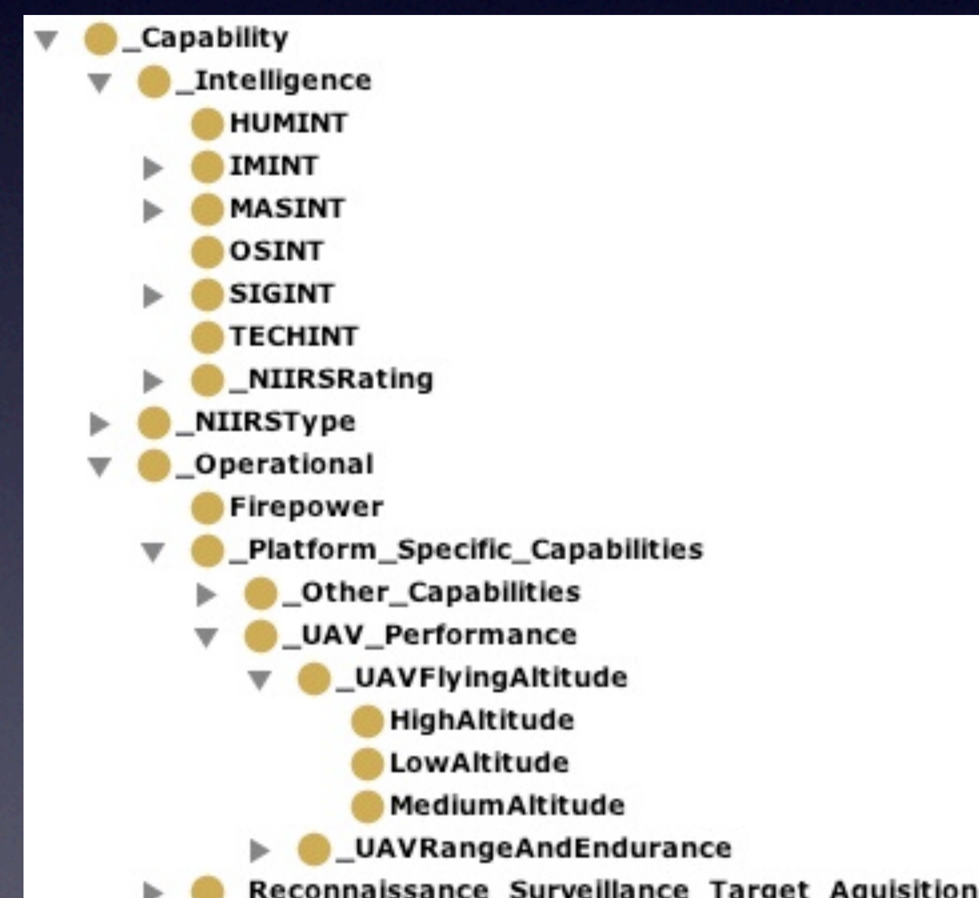
- Knowledge represented via ontologies.
  - Sensors and platforms
  - sensing capabilities provided by assets.
  - Information requirements of tasks







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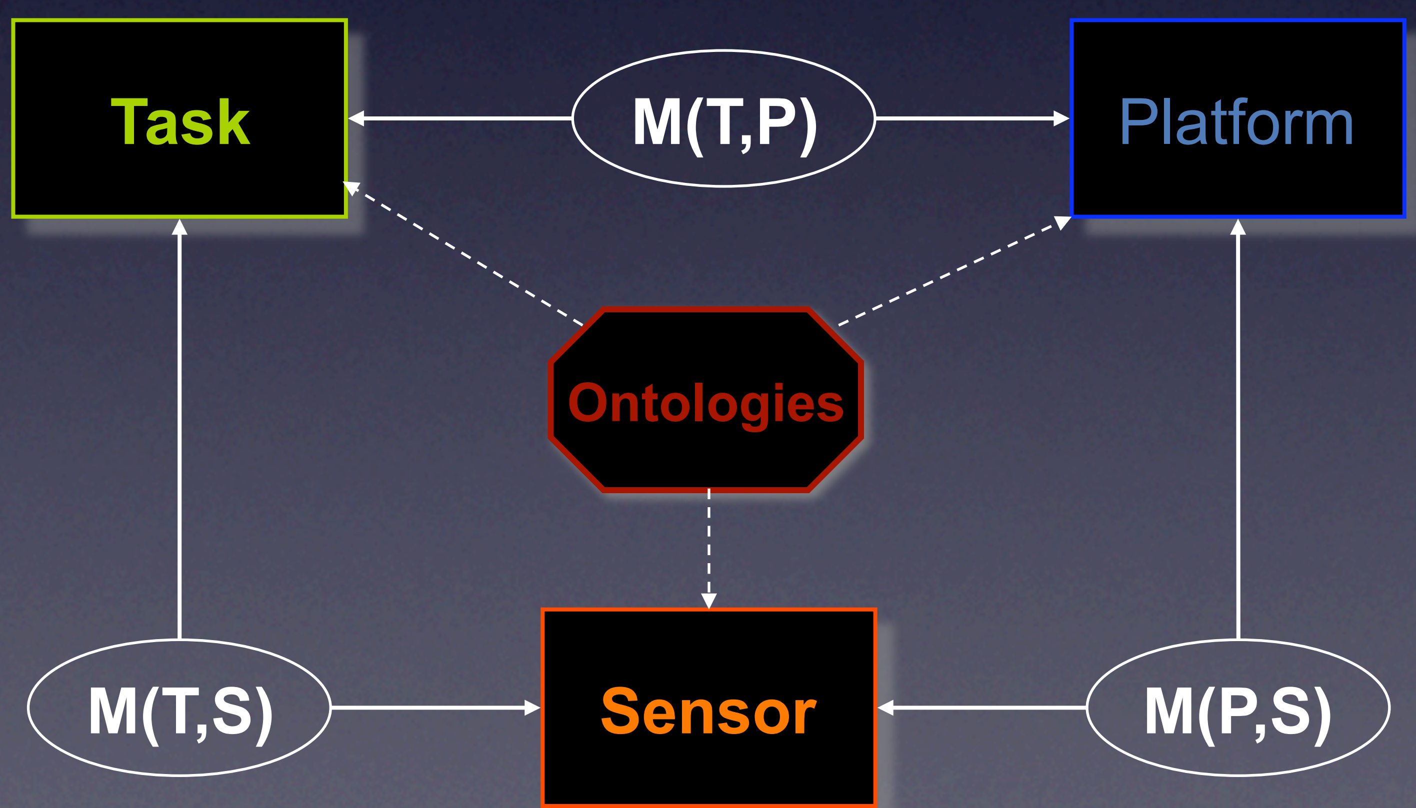
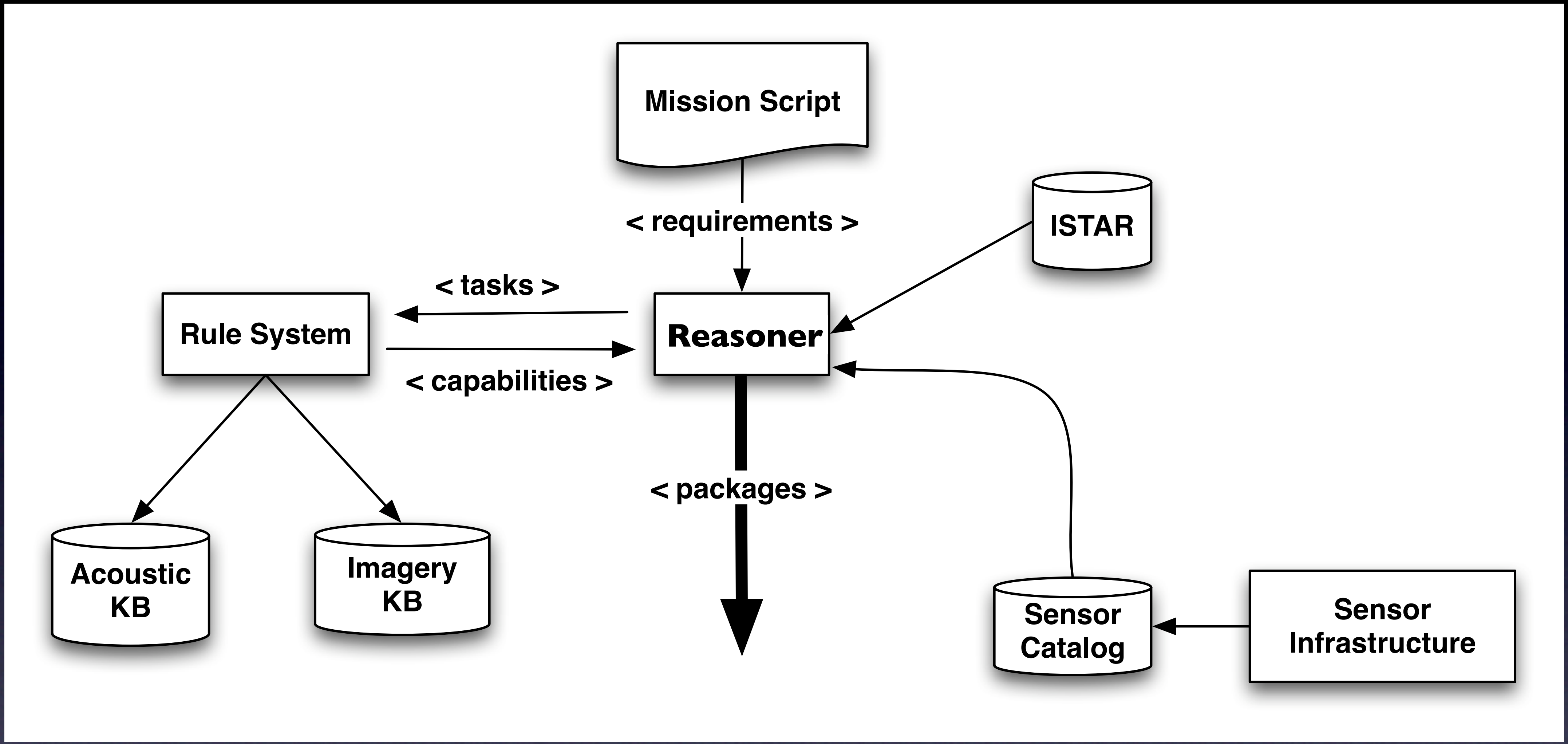


# System Architecture



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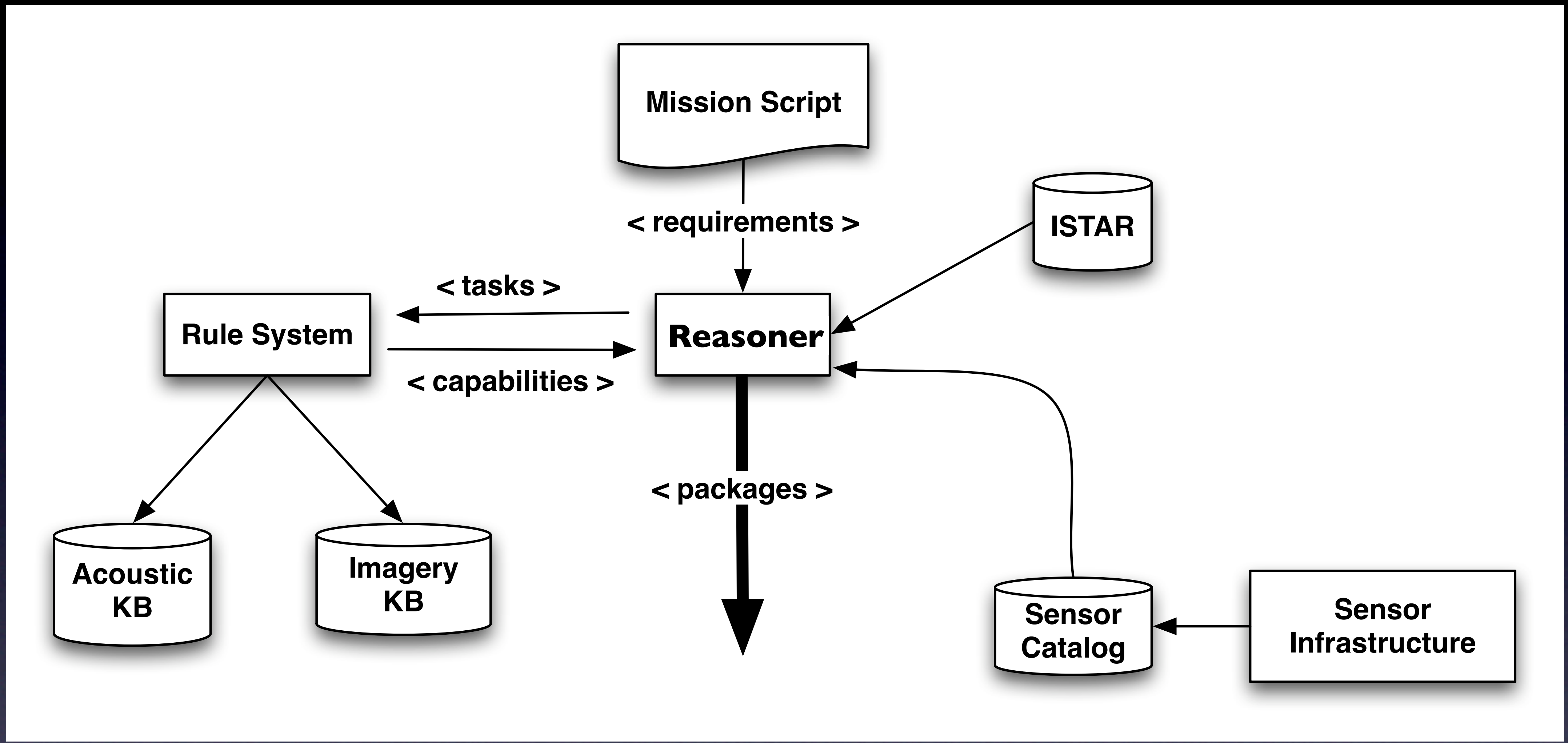
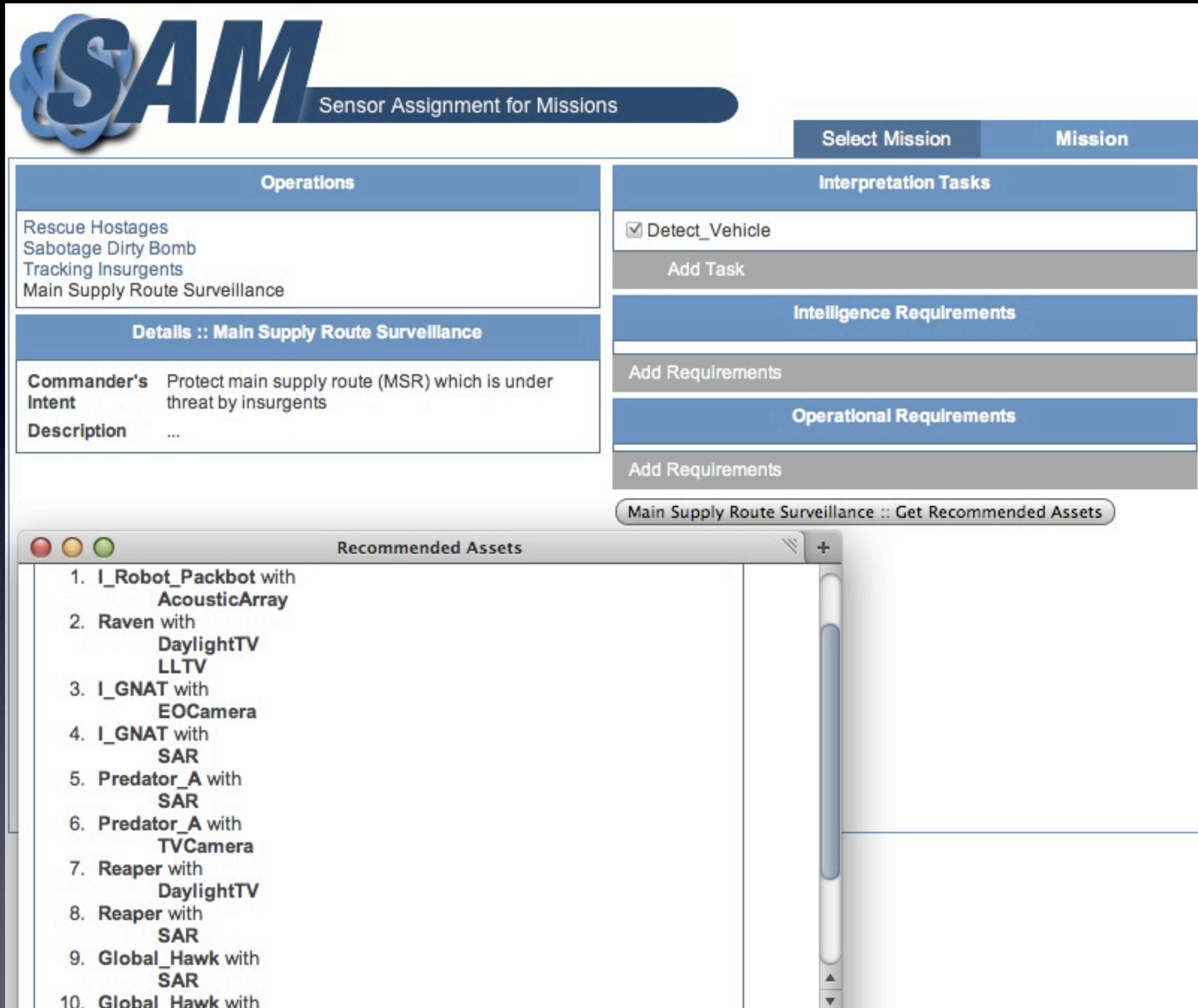



- **Packages**: A collection of all possible assets types that could satisfy tasks.


SAM
Sensor Assignment for Missions
Select Mission
Mission
Operations
Rescue Hostages
Sabotage Dirty Bomb
Tracking Insurgents
Main Supply Route Surveillance
Details :: Main Supply Route Surveillance
Commander's Intent
Protect main supply route (MSR) which is under threat by insurgents
Description
...
Interpretation Tasks
Detect_Vehicle
Add Task
Intelligence Requirements
Add Requirements
Operational Requirements
Add Requirements
Main Supply Route Surveillance :: Get Recommended Assets
Recommended Assets
1. I_Robot_Packbot with
AcousticArray
2. Raven with
DaylightTV
LLTV
3. I_GNAT with
EOCamera
4. I_GNAT with
SAR
5. Predator_A with
SAR
6. Predator_A with
TVCamera
7. Reaper with
DaylightTV
8. Reaper with
SAR
9. Global_Hawk with
SAR
10. Global_Hawk with

# Future work

- More research on the rule-based derivation of capabilities.
  - Applicability of the SWRL for the rule system and performance evaluation.
  - Introduce more knowledge sources.
  - Constraints (weather, terrain, etc.) and policies.
- Explanations
  - Justify recommendations.
  - If there is no feasible solution, suggest constraints that can be removed/weakened to open up possible recommendations.
- Logic-based rule engine for asset-task matching (First-order-logics).

# Conclusion

- Capability inference process is crucial to provide flexibility to the assignment process.
- Ontology centric approach is important to cope with heterogeneity of the sensing assets and of tasks.
- We have implemented prototype versions of the rule system and the first integrated hybrid reasoning systems to identify the fit-for-purpose assets.
- Positive feedback from the UK and US users.

# Acknowledgment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- Dr. Mario Gómez Martínez, Artificial Intelligence research Institute (IIIA), Spain

Thanks for listening.

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