An Ontology-Based Approach to Assigning Sensors to Tasks

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Context: Task-Oriented Deployment of Sensor Data Infrastructures

- ✓ Goal: deliver timely, reliable and actionable information to end-users
- ✓ Technical Summary
  - ✓ Data Orchestration: Given *n* missions, determine, locate, and characterize resources required
  - ✓ Reactive Source Deployment: Re-purpose, move, or re-deploy resources
  - ✓ Push/Pull Data Delivery: Disseminate information
- ✓ Problems Addressed
  - ✓ Optimal use of resources to get the "best" information in a timely manner to the people who need it

Outline

- ✓ Introduction to the problem
- ✓ Technical Approach
  - ✓ Ontologies
  - ✓ Semantic matchmaking
- ✓ Proof of concept
  - ✓ SAM software prototype
  - ✓ Integration with a sensor network infrastructure
- ✓ Future Work

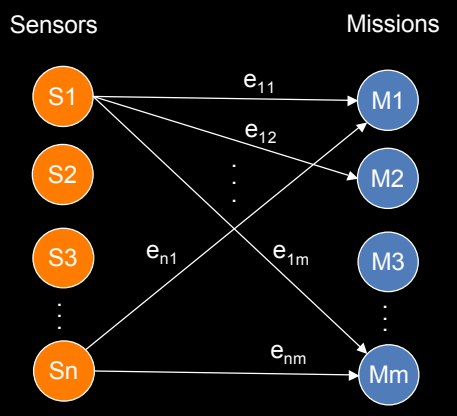
Introduction to the problem

What and Why ?

The Overall Problem

- Given
  - A number of ISR (Intelligence, Surveillance & Reconnaissance) assets (sensors & sensor platforms)
  - A number of missions competing for the same assets
- Goal is
  - To allocate assets in a way that maximizes the global utility

Sensor-Mission Matching



- How to obtain the utility of sensors to missions (e_{ij})?
- How to deal with different types of sensors
- How to represent different mission requirements?

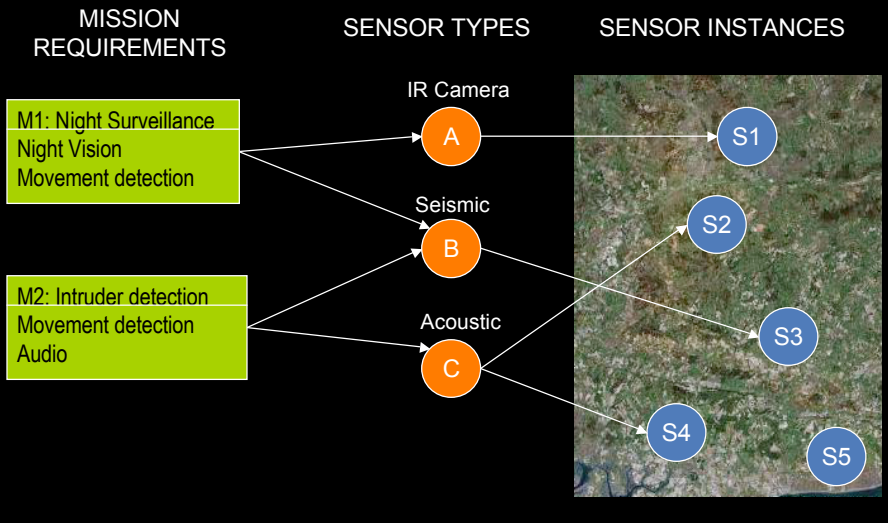
Refocusing the Problem

- Given
  - A mission with specific ISR requirements
  - Alternative means to collect information and produce intelligence
- Goal is
  - To assess the fitness for purpose of alternative means to accomplish a mission
  - Both qualitative & quantitative assessment

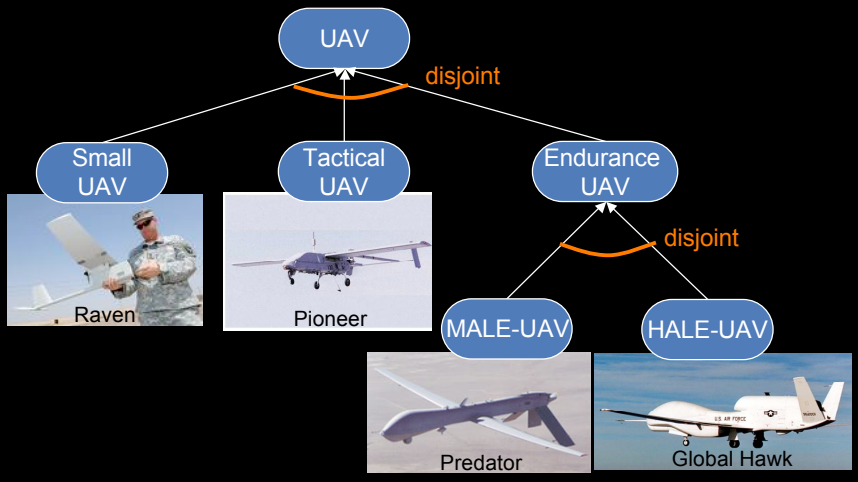
Approach

- Use ontologies to
  - specify the ISR requirements of a mission
  - specify the ISR capabilities provided by different asset types
- Use semantic reasoning
  - to compare mission requirements and capabilities
  - decide if requirements are satisfied (or to what extent)

Capability-based matching



A Simple Example



A Simple Example

- Given a mission that requires Wide Area Surveillance
  - This capability is provided by Endurance-UAV
- Three UAVs are available:
  - UAV1 is-a Tactical-UAV
  - UAV2 is-a MALE-UAV
  - UAV3 is-a HALE-UAV
- From only the concept definitions we know:
  - UAV1 is not an Endurance-UAV
  - UAV2 & UAV3 are types of Endurance-UAV
- So we can use either UAV2 or UAV3

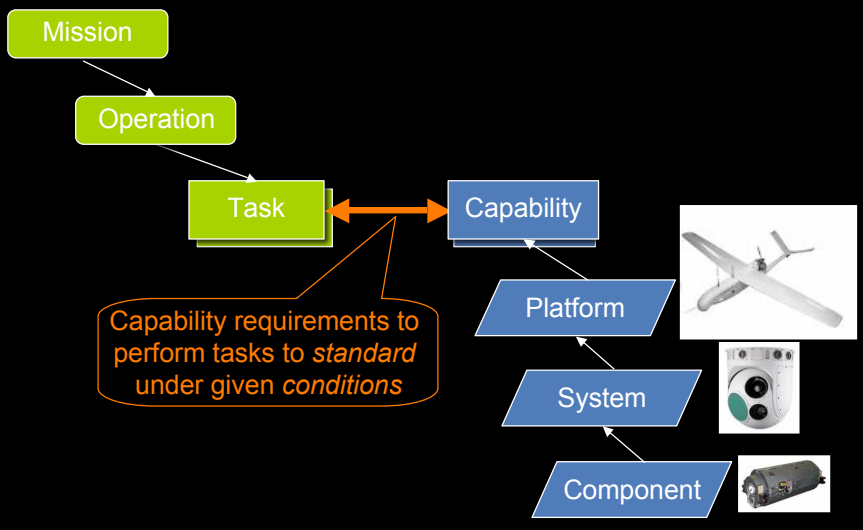
A Simple Example

- Suppose there is bad weather, additional capability is to be able to fly "above the weather"
  - Capability provided by HALE-UAV (high altitude)
- Preferred choice is now UAV3
- Note that:
  - We only state minimum explicit information about the UAVs (e.g. UAV1 is-a Tactical-UAV)
  - Everything else is inferred from the concept definitions (e.g. UAV1 is not a high altitude UAV)

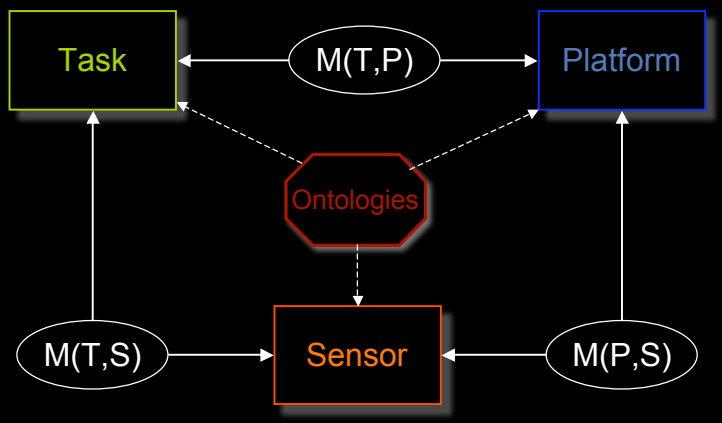
Technical approach

How ?

Missions and Means Framework

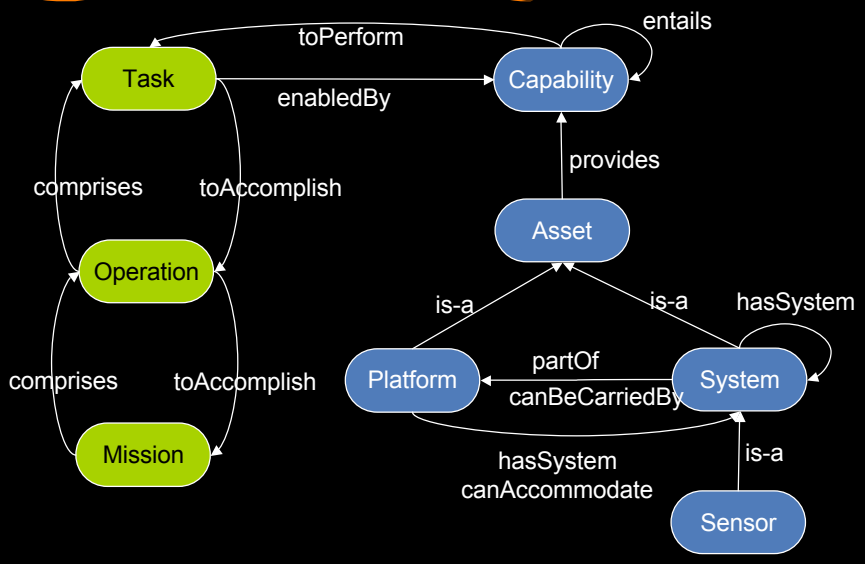


Abstract Architecture

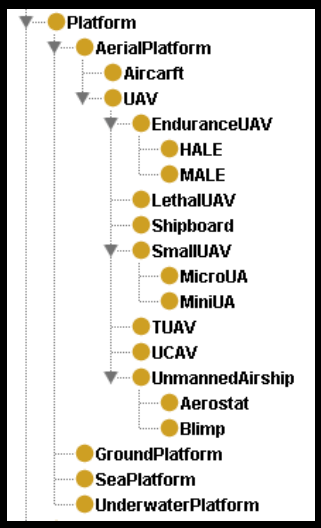


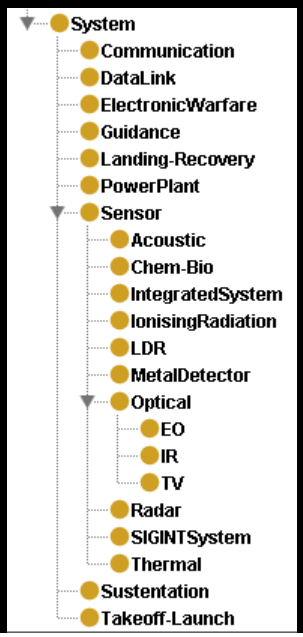
M(X,Y): *matching relation between* X *and* Y

MMF Ontology: Main Concepts

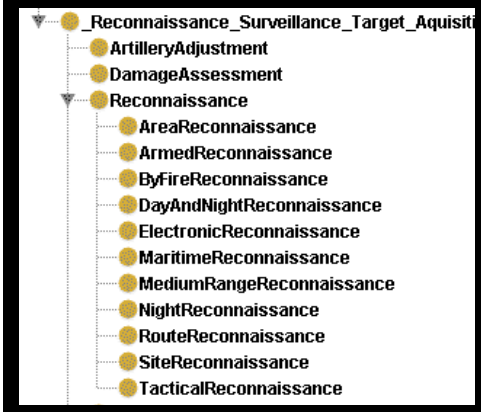


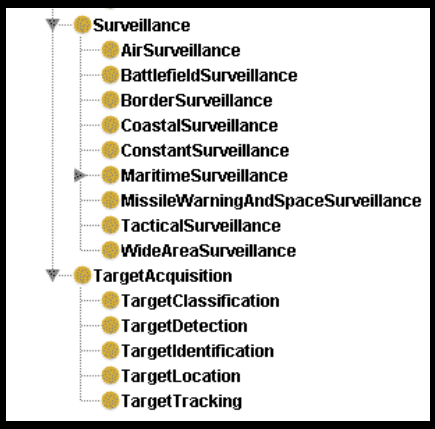
Platforms and Systems



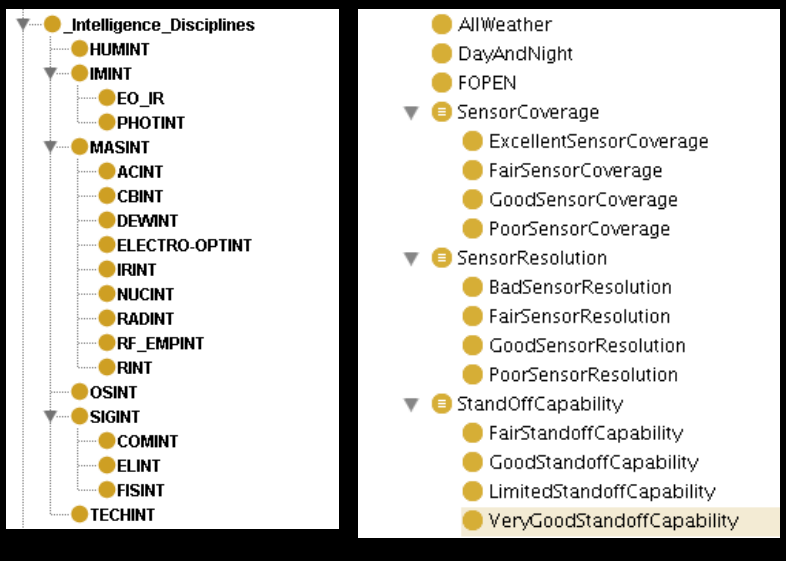


Platform Capabilities

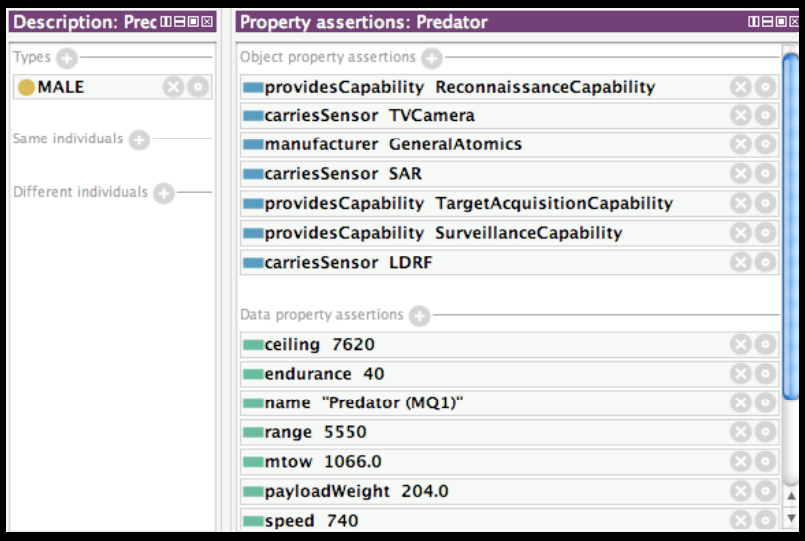




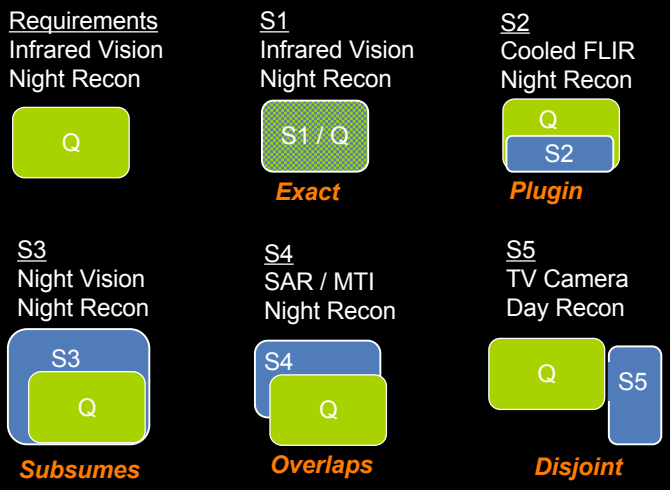
Sensor Capabilities



Platform Specification Example

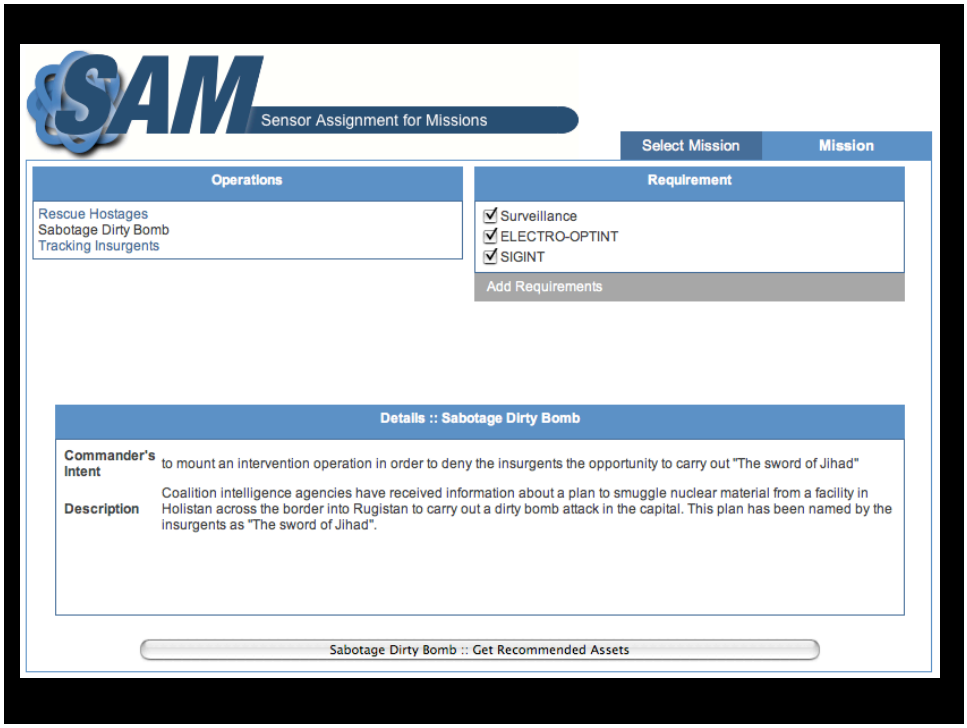


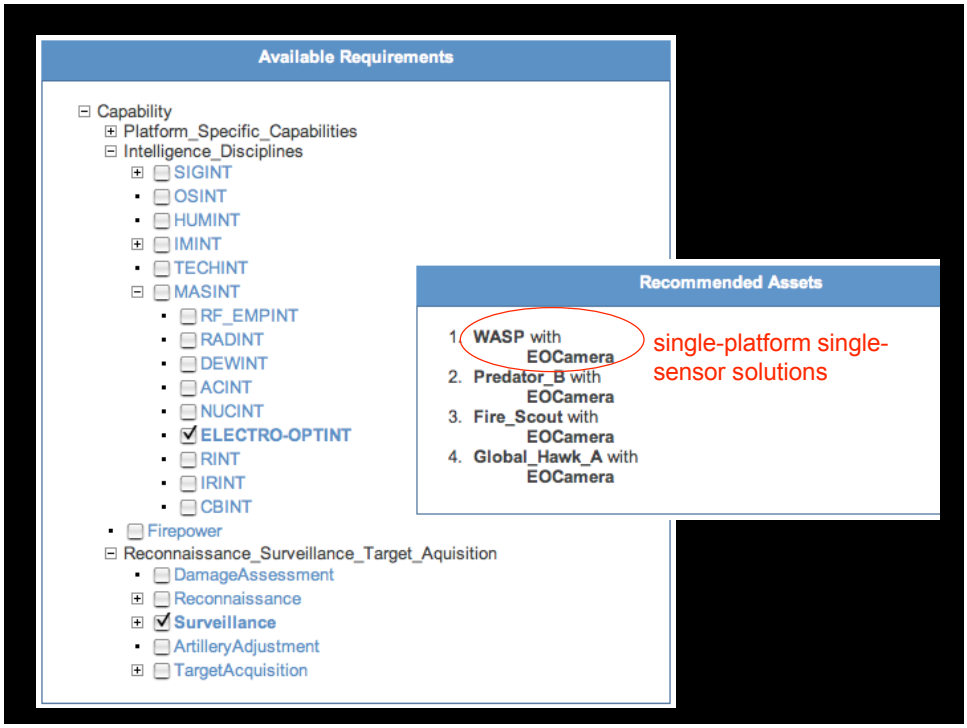
Semantic Matching Relations



S.A.M.
Sensor Allocation and Management

Proof of concept


SAM
Sensor Assignment for Missions
Select Mission
Mission
Operations
Rescue Hostages
Sabotage Dirty Bomb
Tracking Insurgents
Requirement
Surveillance
ELECTRO-OPTINT
SIGINT
Add Requirements
Details :: Sabotage Dirty Bomb
Commander's Intent
to mount an intervention operation in order to deny the insurgents the opportunity to carry out "The sword of Jihad"
Description
Coalition intelligence agencies have received information about a plan to smuggle nuclear material from a facility in Holistan across the border into Rugistan to carry out a dirty bomb attack in the capital. This plan has been named by the insurgents as "The sword of Jihad".
Sabotage Dirty Bomb :: Get Recommended Assets


Available Requirements
Capability
Platform_Specific_Capabilities
Intelligence_Disciplines
SIGINT
OSINT
HUMINT
IMINT
TECHINT
MASINT
RF_EMPINT
RADINT
DEWINT
ACINT
NUCINT
ELECTRO-OPTINT
RINT
IRINT
CBINT
Firepower
Reconnaissance_Surveillance_Target_Aquisition
DamageAssessment
Reconnaissance
Surveillance
ArtilleryAdjustment
TargetAcquisition
Recommended Assets
1. WASP with EOCamera
2. Predator_B with EOCamera
3. Fire_Scout with EOCamera
4. Global_Hawk_A with EOCamera
single-platform single-sensor solutions

Multi-platform multi-sensor solutions ?

Requirements
Surveillance
ELECTRO-OPTINT
SIGINT

Capabilities
ConstantSurveillance
Carries EO Camera

Capabilities
ConstantSurveillance
Carries SIGINT sensor

Available Requirements

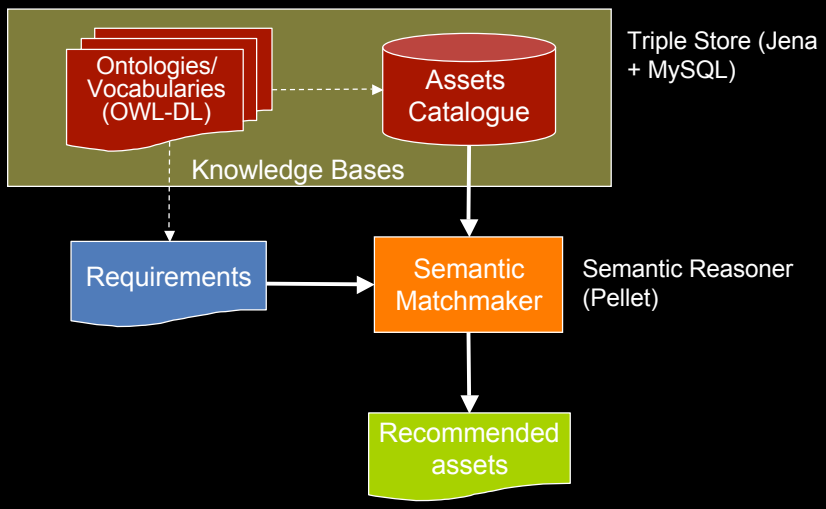
- Capability
  - Platform_Specific_Capabilities
  - Intelligence_Disciplines
    - **SIGINT**
    - OSINT
    - HUMINT
    - IMINT
    - TECHINT
    - MASINT
      - RF_EMPINT
      - RADINT
      - DEWINT
      - ACINT
      - NUCINT
      - **ELECTRO-OPTINT**
      - RINT
      - IRINT
      - CBINT
    - Firepower
  - Reconnaissance_Surveillance_Target
    - DamageAssessment
    - Reconnaissance
    - **Surveillance**
      - MissileWarningAndSpaceSurveillance
      - CoastalSurveillance
      - ConstantSurveillance
      - BorderSurveillance
      - BattlefieldSurveillance
      - WideAreaSurveillance
      - TacticalSurveillance
      - MaritimeSurveillance
      - AirSurveillance
    - ArtilleryAdjustment
    - TargetAcquisition

Recommended Assets

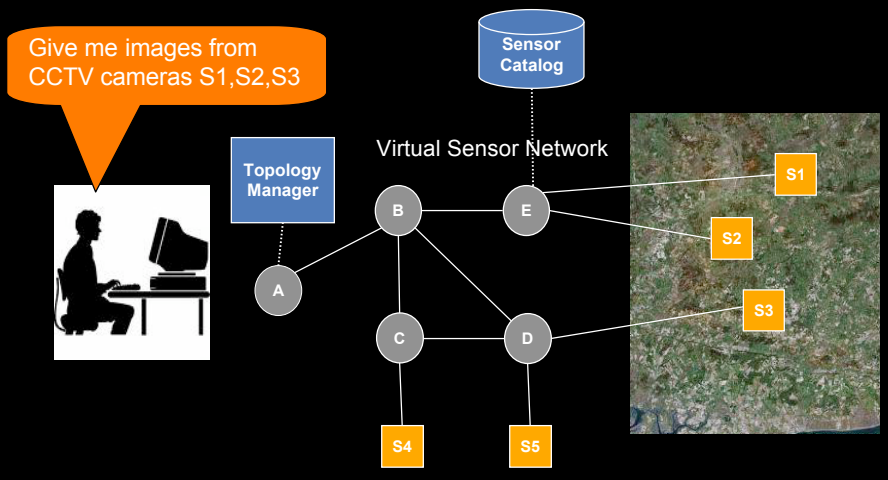
1. **I-GNAT** with **SIGINTSensor**
   WASP with **EOCamera**
2. **Predator_B** with **EOCamera** **SIGINTSensor**
3. **Fire_Scout** with **EOCamera**
   I-GNAT with **SIGINTSensor**
4. **Global_Hawk_A** with **EOCamera**
   I-GNAT with **SIGINTSensor**

multiple-platform
multiple-sensor
solutions

SAM architecture



ITA Sensor Fabric (IBM UK)



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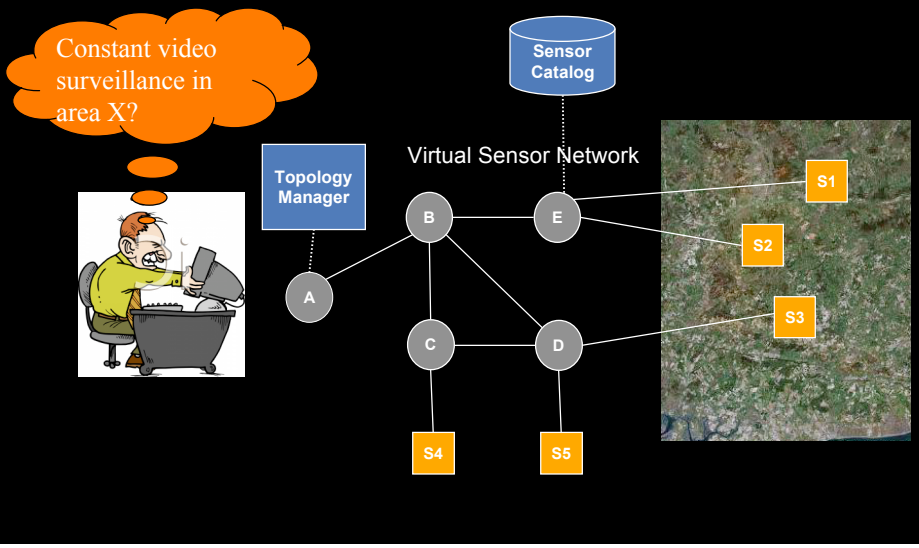
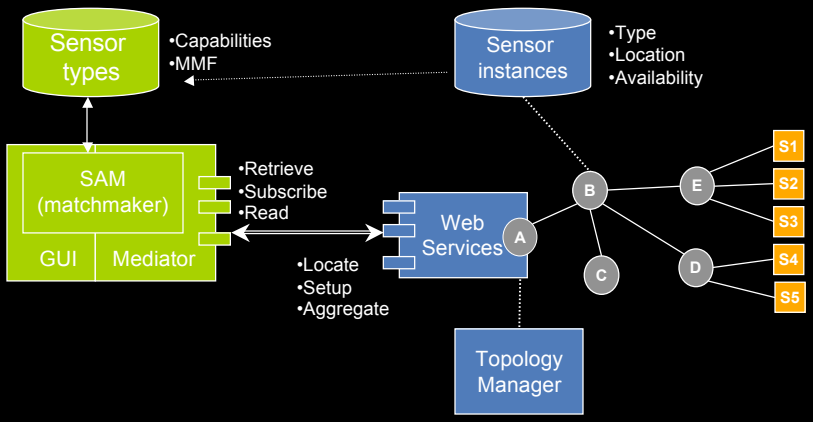
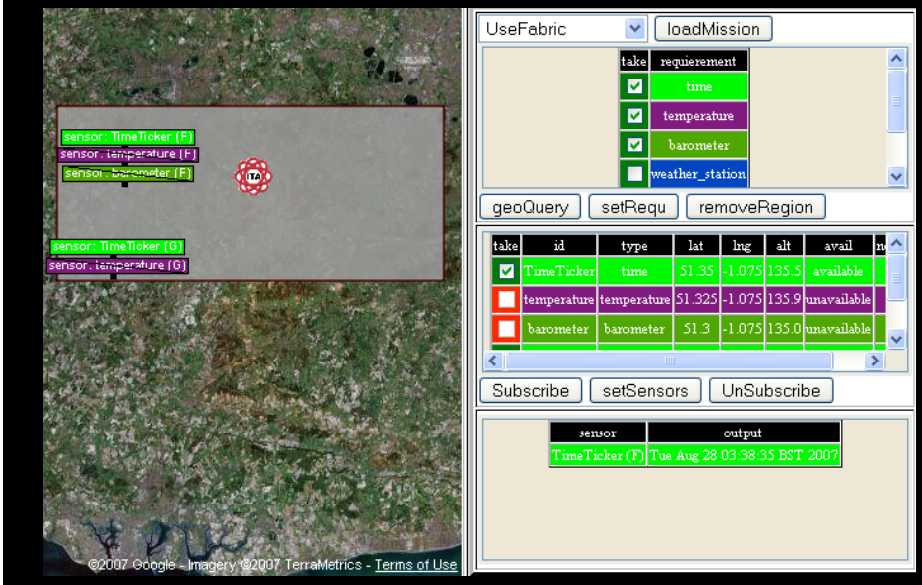


Integrated Architecture: SAM + SF





S.A.M. Evolution

Future Work

Ongoing & Future Work

- Richer model for specifying mission requirements
  - From asset capabilities to information needs (how vs what)
  - Add quantitative requirements: Performance, QoI, etc.
  - Conditions impacting assets performance: weather, terrain, enemy activity…

Ongoing & Future Work

- More sophisticated matchmaking
  - Matching degrees
  - Utility/QoI metrics
- Taking into account operational status
  - Availability / readiness
  - Distinguish between organic / non organic assets

IMINT QoI: NIIRS scales

NIIRS 4 [1.2 - 2.5 m GRD]

Visible NIIRS	Radar NIIRS	Infrared NIIRS	Multispectral NIIRS
Identify all large fighters by type (e.g., FENCER, FOXBAT, F-15, F-14). Detect the presence of large individual radar antennas (e.g., TALL KING). Identify, by general type, tracked vehicles, field artillery, large river crossing equipment, wheeled vehicles when in groups. Detect an open missile silo door.	Distinguish between large rotary-wing and medium fixed-wing aircraft (e.g., HALO helicopter versus CRUSTY transport). Detect recent cable scars between facilities or command posts. Detect individual vehicles in a row at a known motor pool. Distinguish between open and closed sliding roof areas on a single bay garage at a mobile	Identify the wing configuration of small fighter aircraft (e.g., FROGFOOT, F- 16, FISHBED). Detect a small (e.g., 50 meter square) electrical transformer yard in an urban area. Detect large (e.g., greater than 10 meter diameter) environmental domes at an electronics facility. Detect individual thermally active	Detect recently constructed weapon positions (e.g. tank, artillery, self-propelled gun) based on the presence of revetments, berms, and ground scarring in vegetated areas. Distinguish between two-lane improved and unimproved roads. Detect indications of natural surface airstrip maintenance or improvements (e.g., runway extension.

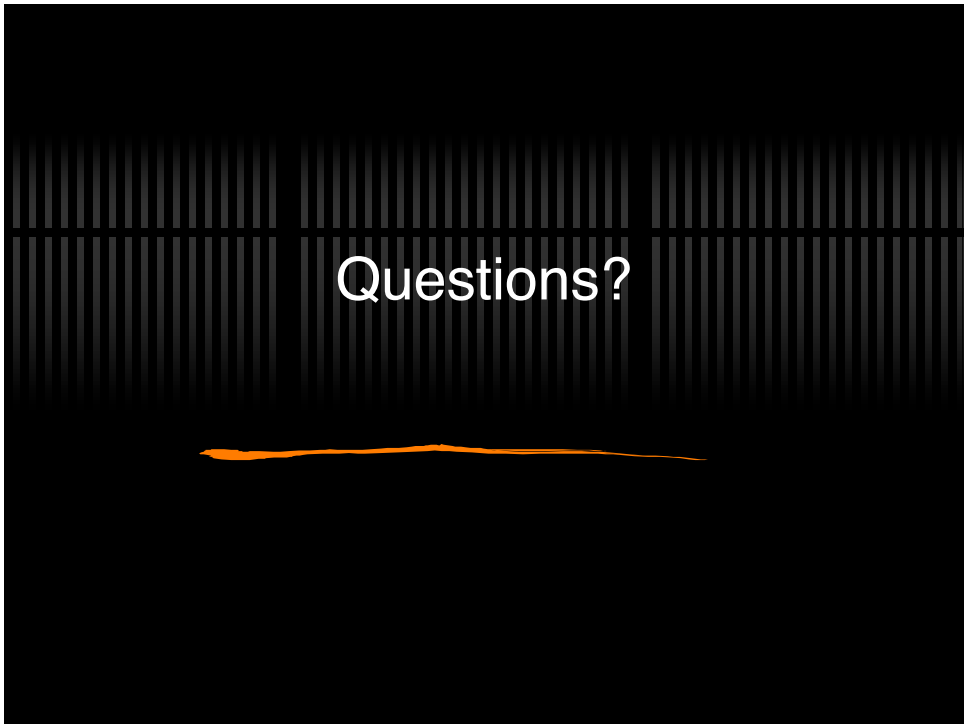
Matching Degrees

Explain Recommendations

- ✓ Justify recommendations: Why some solution is preferable?
- ✓ If there is no feasible solution, why? → Suggest constraints that can be removed/weakened to open up possible recommendations

Collaborative efforts

- ✓ With DSTL/ARL
  - ✓ Specification of intelligence requirements in terms of information needs
- ✓ With IBM UK
  - ✓ Integration with “Sensor fabric”
- ✓ With CUNY/Penn State
  - ✓ SAM provides input to their allocation algorithms


Questions?