Agent Framework For Intelligent Data Processing

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Data Processing and Mining

- Terminology:
  - data processing = data preparation
- Observations:
  - Majority (80%) of the scientist's time is spent preparing the data
  - Remainder (20%) of the time is used for actual analysis and mining
  - There are few data preparation/processing steps are commonly used on many different kinds of data especially imagery data
    - Subsetting, Data Format Translation, Subsampling

Can we automate Science Data Processing?

- Yes, but the current methodology involves using:
  - scripts with explicit domain knowledge
  - local data, services
- Adapt to the changing computational environment
  - Web services
    - Semantic Web
  - Grid Services
    - Semantic Grid
- User specifies a goal instead of steps with detailed information required to achieve the goal
  - The different services with proper details are chained together to execute the users task
  - Example:
    - *Subset temperature fields over Florida from TMI dataset for Summer 2002*

Challenges

- *Specifying a query (Natural Language Processing Research)*
- *Optimal service composition (Planning Research*)

✓ **Metadata**

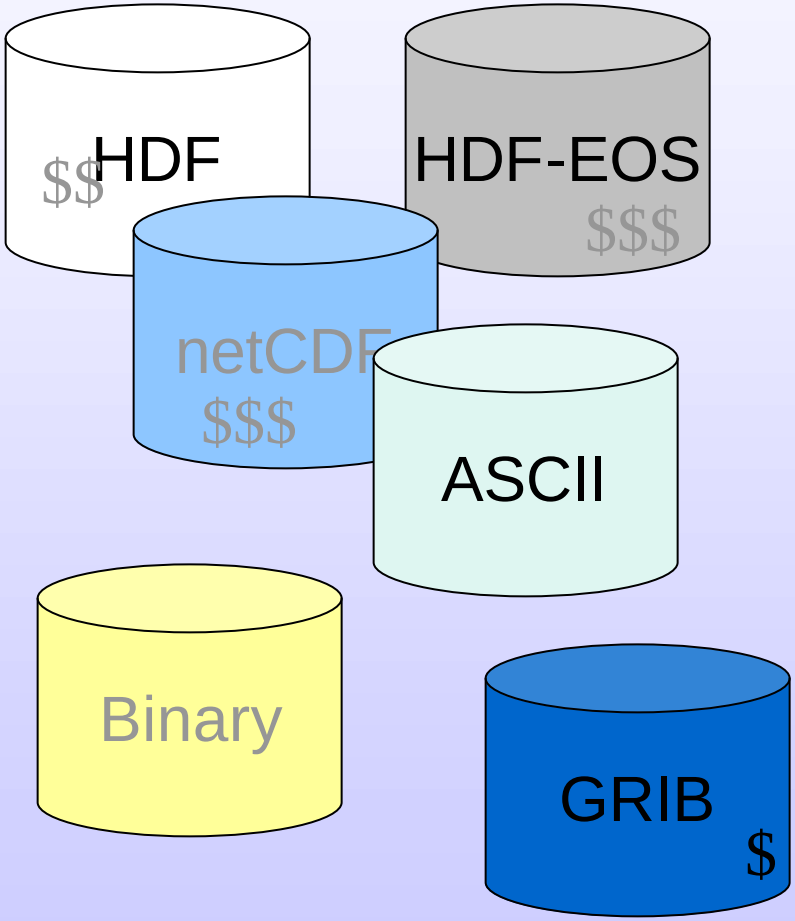
- **Services require a rich set of metadata**
  - **Structural metadata: to provide full description of the data file in bits & bytes, to allow application to read the data**
  - **Semantic metadata: to provide meaning of the data along with a context, to allow application to understand what it has read and how to use it**

✓ **Data Processing Framework**

Project Objectives

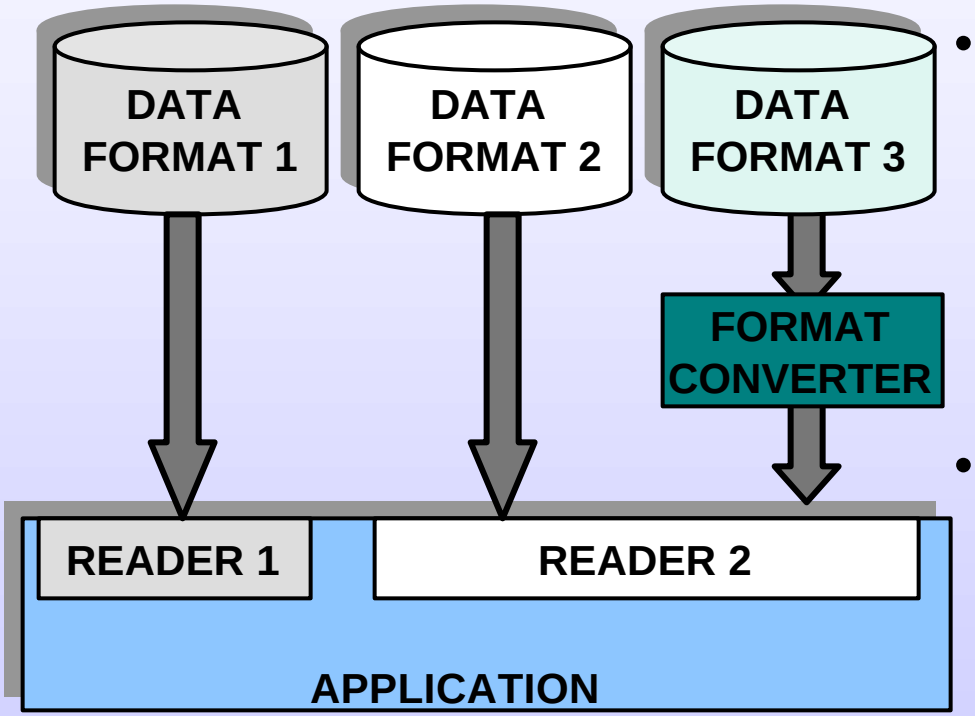
- Design a Metadata Solution
  - Use Earth Science Markup Language (ESML) for structural metadata description
  - Enhance ESML description by providing semantic metadata by leveraging ontologies
- To design and implement a proof of concept Agent Framework (MIDAS) to:
  - leverage the semantic metadata and ontologies for reasoning
  - provide an intelligent, automated processing capabilities for Science data
  - be scalable and adaptable
  - integrate and exploit distributed standalone applications, web services and grid services

Metadata Solution: Background



- **Earth Science Data Characteristics**
  - Different formats, types and structures (18 and counting for Atmospheric Science alone!)
  - Some formats lack metadata where as others are metadata rich ($)
- **Heterogeneity leads to Data usability problem**

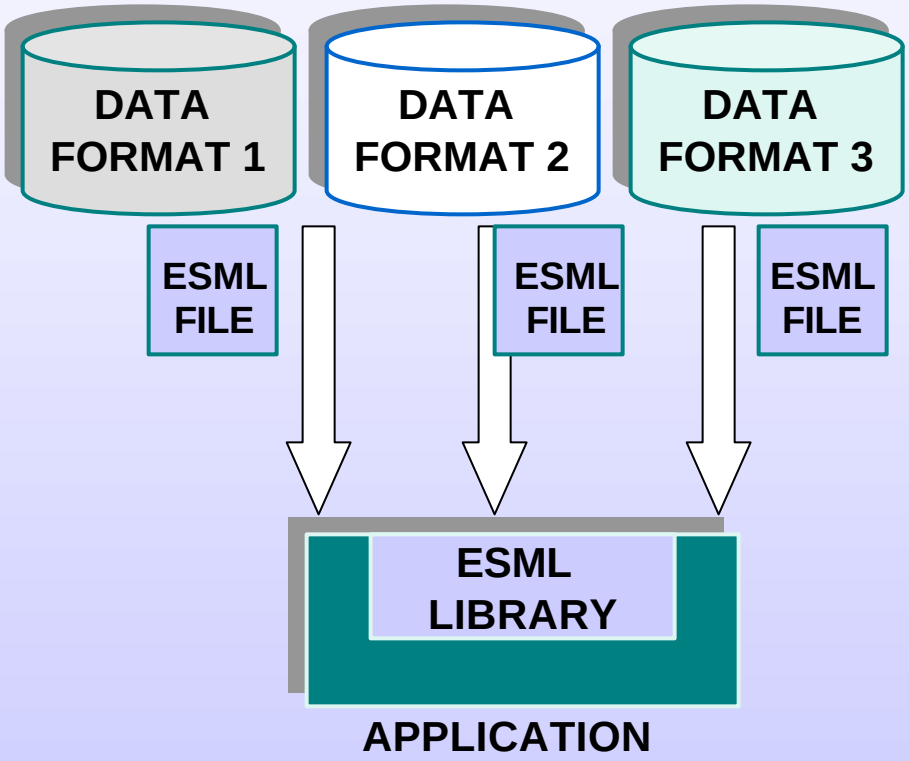
Metadata Solution: Background



Data Usability Problem

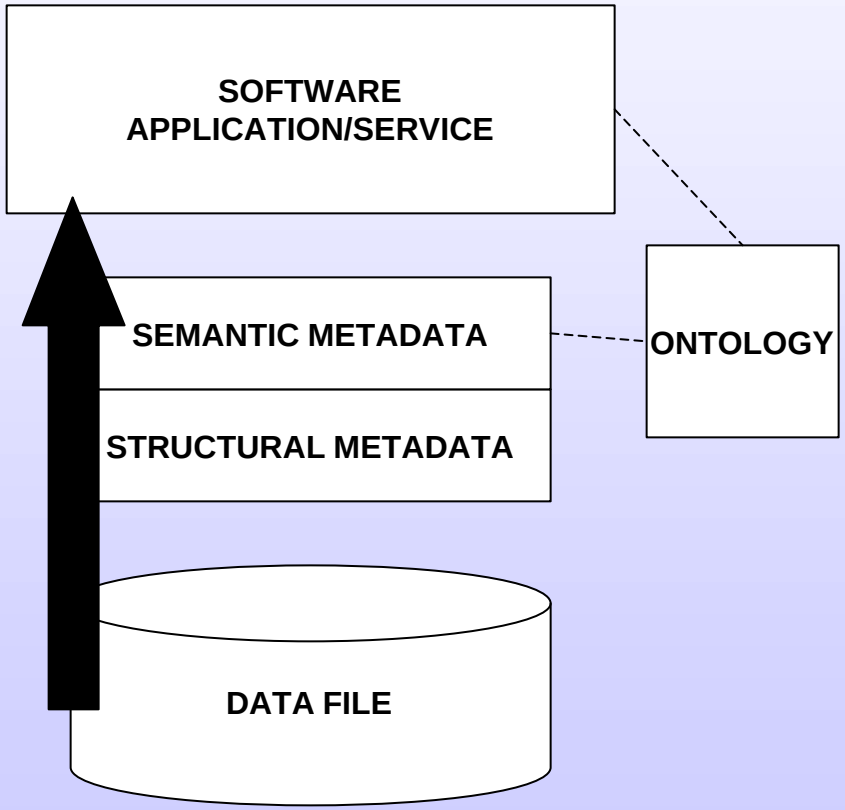
- Requires specialized code for every format
  - Difficult to assimilate new data types
  - Makes applications tightly coupled to data
- One possible solution - enforce a Standard Data Format
  - Not practical for legacy datasets

Metadata Solution:
Earth Science Markup Language (ESML)



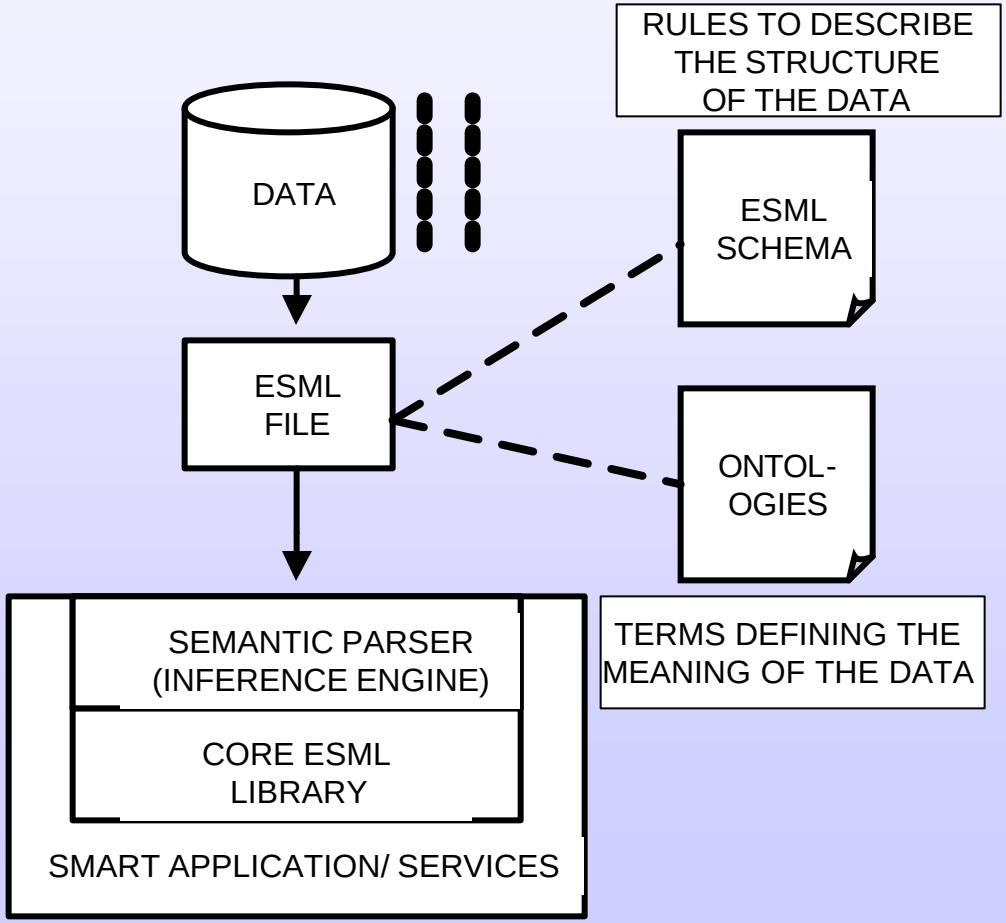
- ESML (external metadata) files containing the structural description of the data format
- Applications utilize these descriptions to figure out how to read the data files resulting in data interoperability for applications

Metadata Solution:
Vertical Metadata Integration via Ontologies



- Horizontal Metadata Integration
  - Mediation services
  - Yellow page services
- Vertical Metadata Integration focuses on semantics for the use of the data by an application
- Both Structural and Semantic metadata are required

Metadata Solution: Extending ESML with Ontologies



- ESML Schema provides structural metadata
- Extend ESML schema by embedding semantic terms in the ESML Description File to provide a complete description of the data
- Allow various science communities can create their own ontologies (for example, SWEET) and use them with ESML Description Files for their data

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Metadata Solution: Example of Embedding Semantics in ESML

```
<<a:ESML xmlns:a="ESML" xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
xsi:schemaLocation="ESML.xsd" >
 <SyntacticMetaData>
  <Binary>
   <Structure instances="1" name="SampleSet">
    <Array occurs="100">
     <Array occurs="100">
      <Field name="UWind" type="Int32" order="LittleEndian"/>
     </Array>
    </Array>
    <Array occurs="100">
     <Array occurs="100">
      <Field name="DimX" type="Int32" order="LittleEndian"/>
     </Array>
    </Array>
    <Array occurs="100">
     <Array occurs="100">
      <Field name="DimY" type="Int32" order="LittleEndian"/>
     </Array>
    </Array>
   </Structure>
  </Binary>
 </SyntacticMetaData>
</a:ESML>
```

Original ESML Description File containing only structural metadata

ESML Description File embedded with Semantic Tags defined in separate ontologies

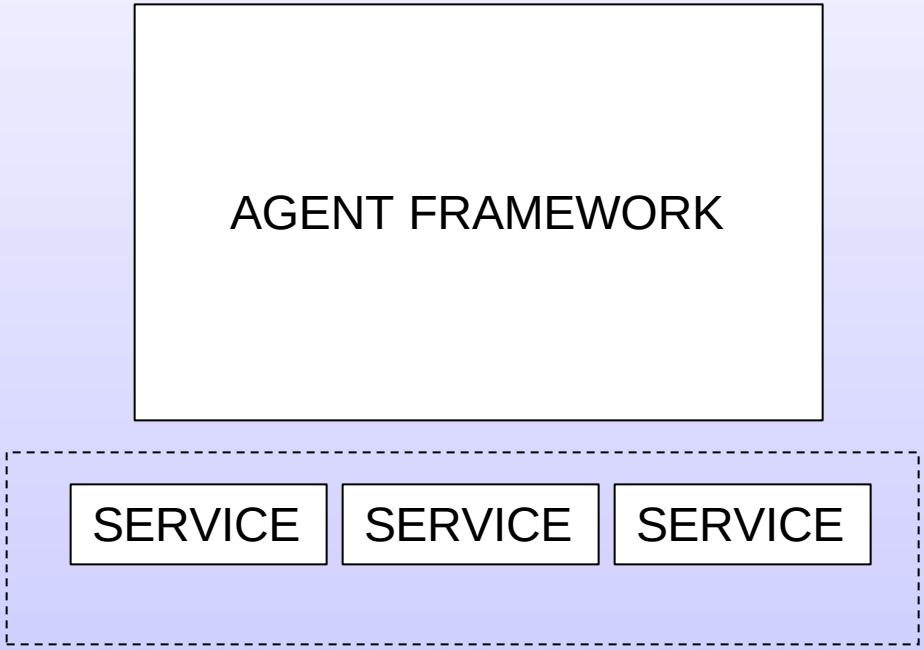
```
<a:ESML xmlns:a="ESML" xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
xsi:schemaLocation="ESML"
xmlns:daml="http://www.daml.org/2001/03/daml+oil#"
xmlns="http://www.itsc.uah.edu/esml-ex#">
   <SemanticMetaData>
        <Latitude rdf:ID="DimX"/>
        <Longitude rdf:ID="DimY"/>
        <DataField rdf:ID="UWind"/>
        <DataSet rdf:ID="SampleSet">
             <hasField rdf:resource="#DimX"/>
             <hasField rdf:resource="#DimY"/>
             <hasField rdf:resource="#UWind"/>
        </DataSet>
   </SemanticMetaData>
   <SyntacticMetaData>
        <Binary>
             <Structure instances="1" name="SampleSet">
             ……................................................
             </Structure>
        </Binary>
   </SyntacticMetaData>
</a:ESML>
```

MIDAS Agent Framework Design: Layer Architecture

- *Infrastructure Layer*: provides the environment that agents can act upon, i.e. services
- *Agent Layer*: contains the agents used to achieve the overall goal of the framework
- *Organization Layer*: defines the organizational structure of the system which is important for agents interaction
- *Coordination Layer*: defines coordination methods required to resolve conflicts and select the next agent
- *Constraint Layer*: verifies whether the system goals are met and interfaces with the users/user interface

MIDAS Agent Framework Design: Infrastructure Layer

- Consists of services domain
  - Search
  - Subsetting
  - Data Format Translation
  - Calibration
  - Navigation
  - Reprojection
  - Visualization
  - Aggregation
  - Fusion
  - Mining



MIDAS Agent Framework Design: Agent Characteristics and Types

- All the agents have the following characteristics:
  - Role
  - Behavior- methods/functions that it can act upon
  - State – store information of itself and the world it perceives
  - Intelligence/Knowledge– to be able to make decisions via ontologies and a reasoning engine or via a machine learning algorithm or via heuristic algorithm
  - Communication protocol – to interact with other agents
- Types of Agents in the Layer
  - Manager Agents
    - Global Manager
    - Domain Manager
  - Worker Agents

MIDAS Agent Framework Design: Agent Description

- **Global Manager Agent:** Given an user input request, distribute the work and collate results
- **Domain Manager Agent:**
  - Keeps a registry of all the Worker agents in its domain
  - All Worker agents advertise their capabilities to the Manager Agent
  - Parses the incoming message and uses an ontology to find the “correct” Worker agent
  - Polls Worker agents for results
  - Fires and Hires Agents
- **Worker Agent**: Uses ESML semantic metadata and ontologies to **map** input message to API requirements of the Service
  - Example:
    - Navigate the data
    - Map Parameter Concept to Field Name(s)
    - Map Spatial Concept to Bounding Box
    - Map Temporal Concepts to Time Range

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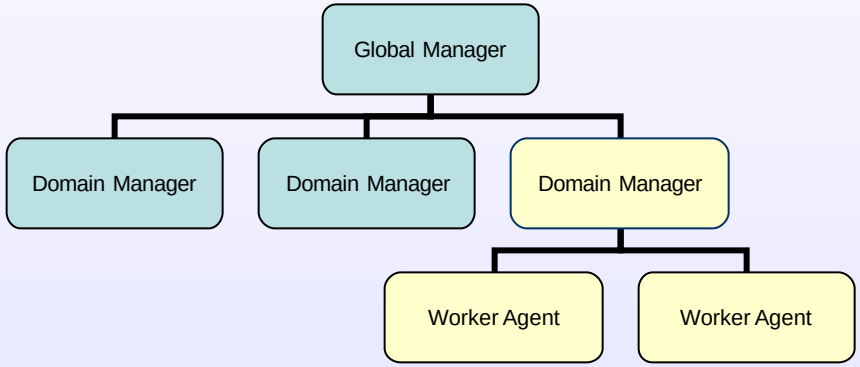
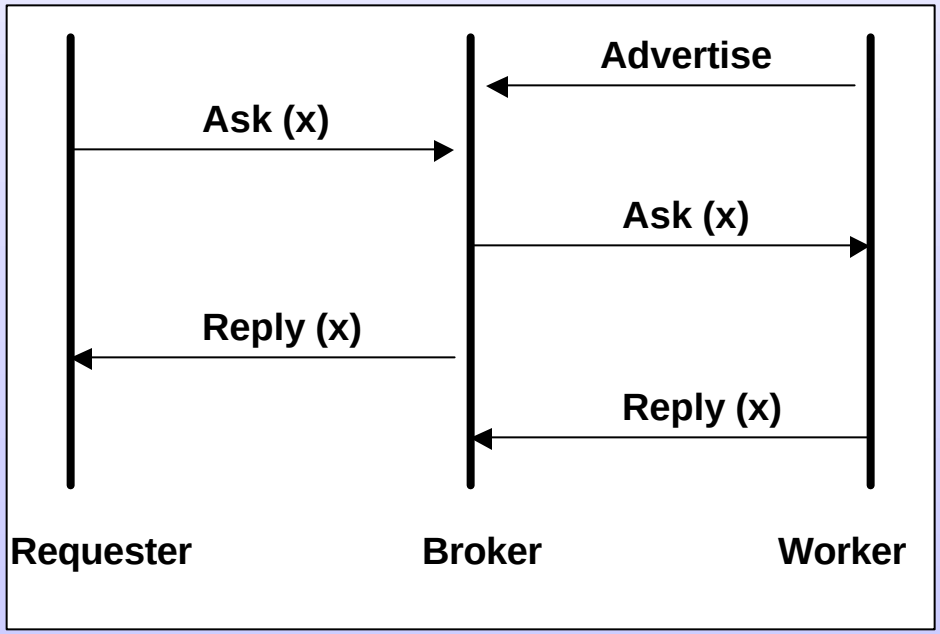
MIDAS Agent Framework Design: Organization and Coordination Layer





Organization Layer

- A simple tree structure with a global manager and number of domains is used.
- Each of the domains contains a Manager agent and Worker agents
- Advantage: scalable design that will allow addition of new domains to the overall framework

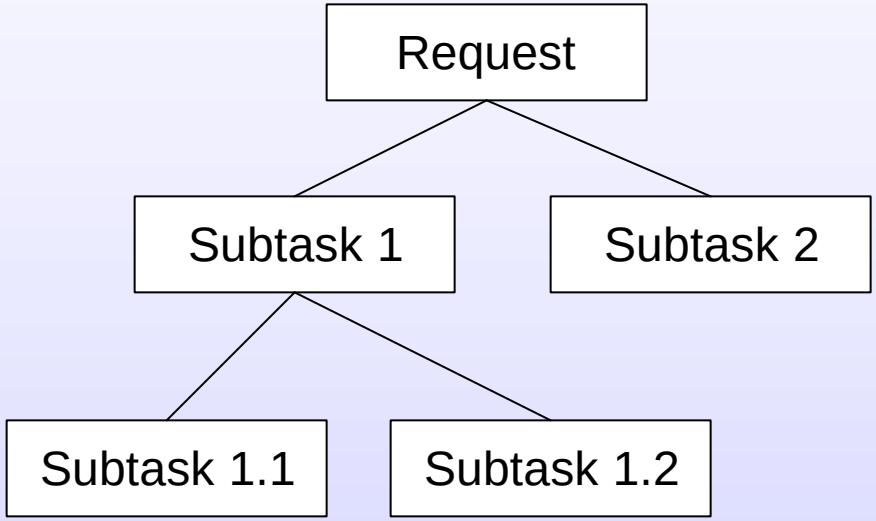
Coordination Layer

- A broker model is used
- Advantage: unlike matchmaker or a contract-net, this model allows the broker to shoulder some responsibility of finding the right agent and returning the result

MIDAS Agent Framework Design: Constraint Layer and Performatives

Constraint Layer

- By using a tree to represents requests, one can check the goal achievement.
- When all the leaf and intermediary nodes are satisfied, resulting in completion of the root node, the task has been accomplished.

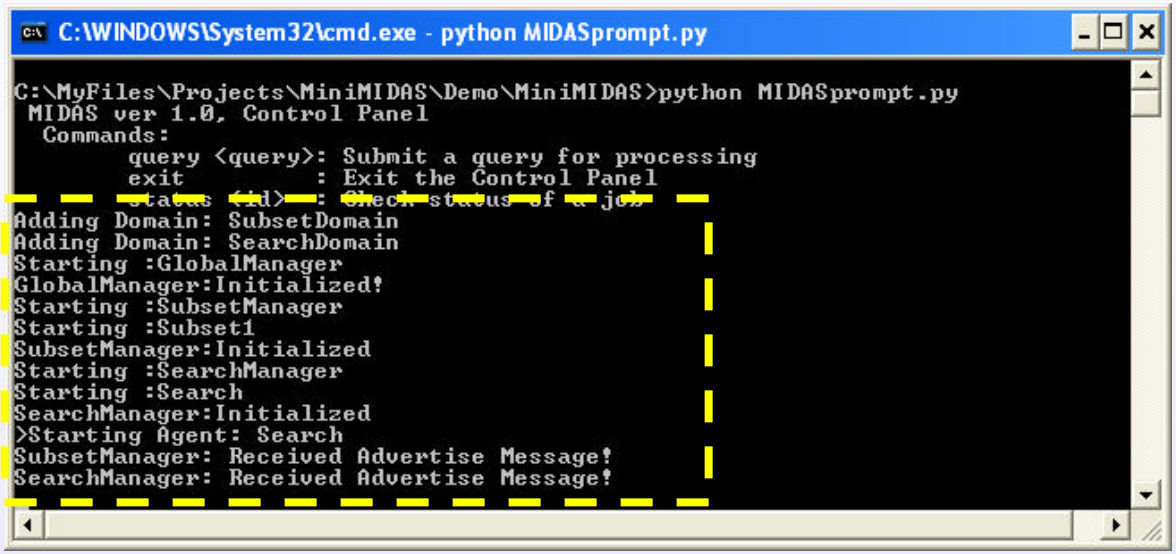


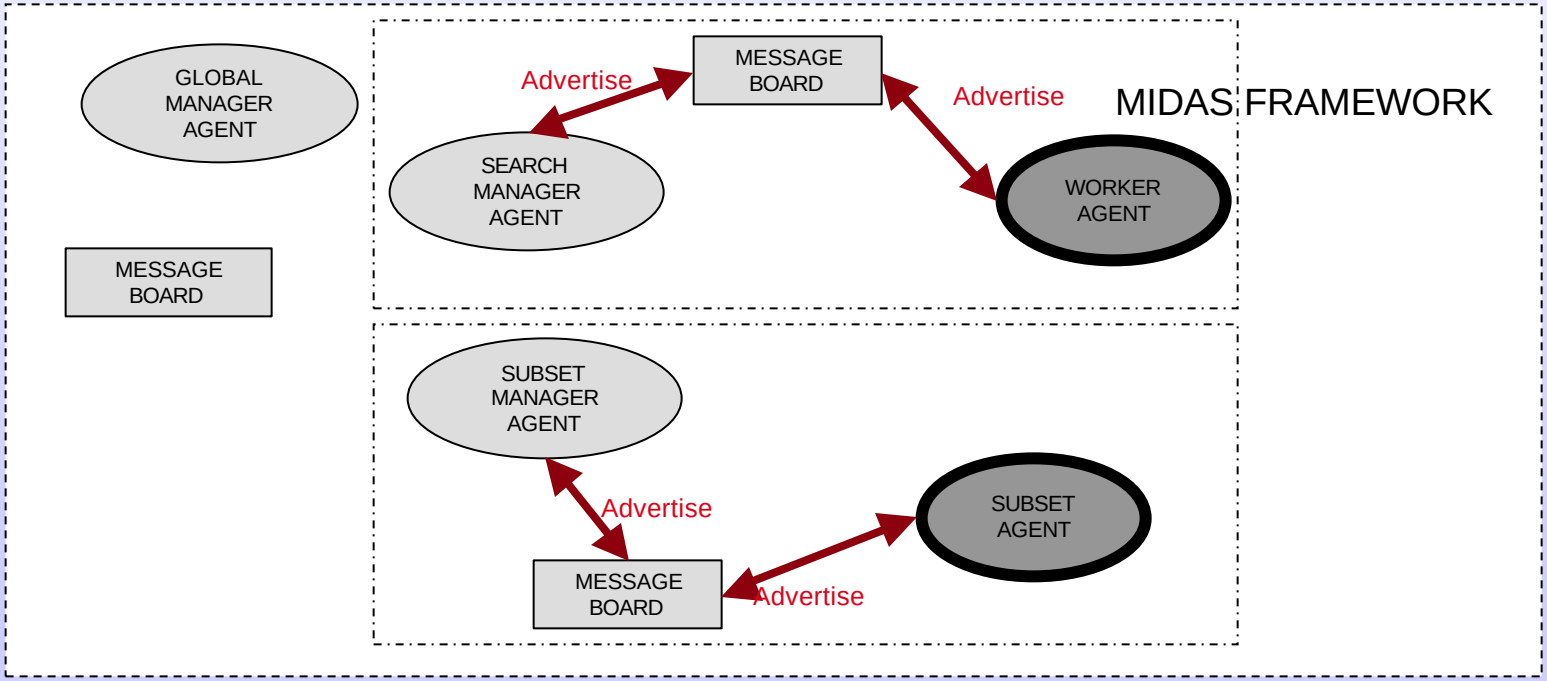
Performatives

- Performatives are the permissible "speech acts" agents use to interact
- Partial set derived from KQML (Knowledge Query and Manipulation Language- UMBC)
- Basic Responses:
  - Error, Sorry
- Query: (Evaluate, AskStatus)
- Capability: (Advertise)

```
advertise
:content <performative>
:language KQML
:ontology <word>
:force <word>
:sender <word>
:receiver <word>
```

MIDAS: Initialization

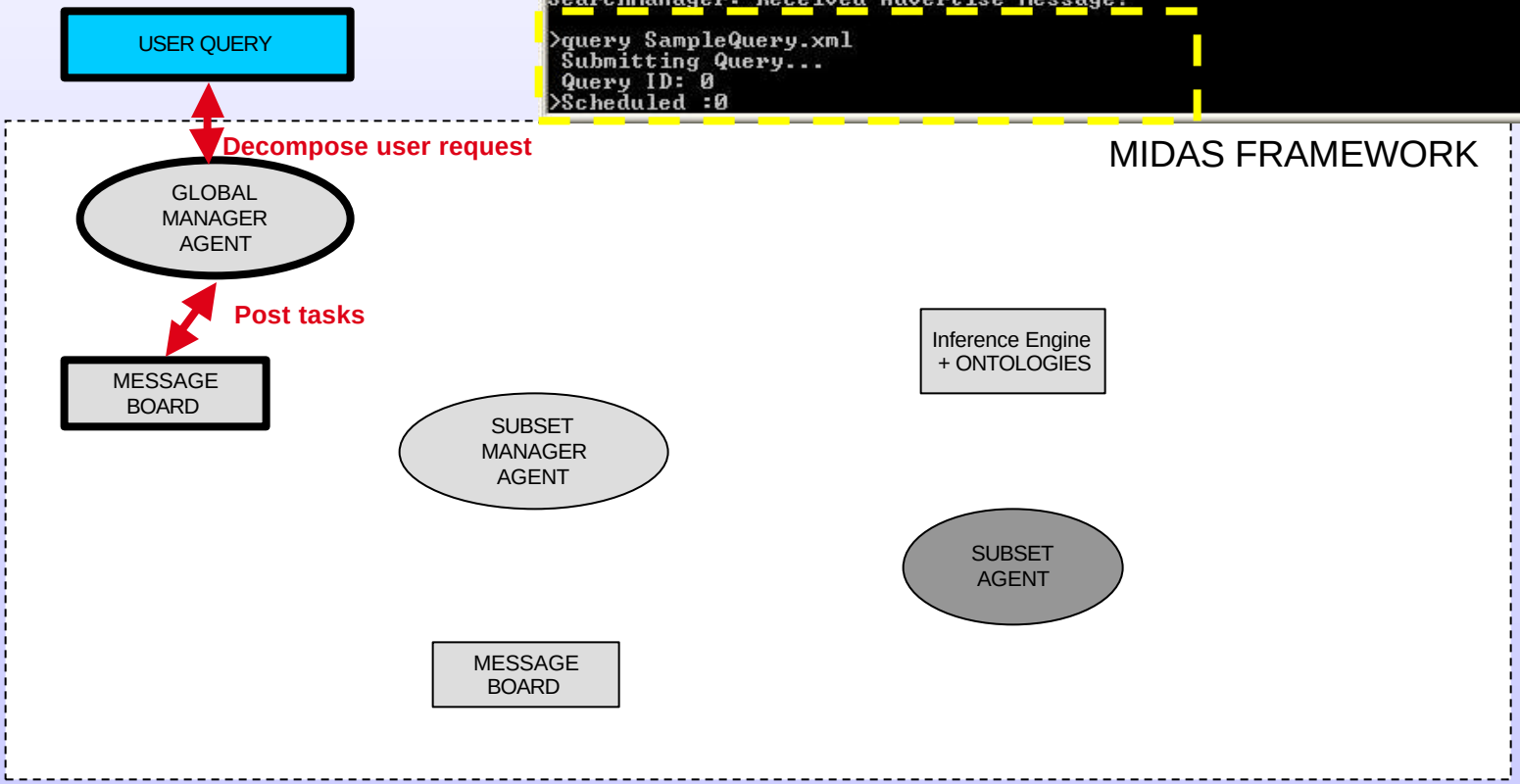




MIDAS : Subset Query

```
C:\WINDOWS\System32\cmd.exe - python MIDASprompt.py
C:\MyFiles\Projects\MiniMIDAS\Demo\MiniMIDAS>python MIDASprompt.py
 MIDAS ver 1.0, Control Panel
  Commands:
        query <query>: Submit a query for processing
        exit         : Exit the Control Panel
        status <id>  : Check status of a job
Adding Domain: SubsetDomain
Adding Domain: SearchDomain
Starting :GlobalManager
GlobalManager:Initialized!
Starting :SubsetManager
Starting :Subset1
SubsetManager:Initialized
Starting :SearchManager
Starting :Search
SearchManager:Initialized
>Starting Agent: Search
SubsetManager: Received Advertise Message!
SearchManager: Received Advertise Message!

>query SampleQuery.xml
 Submitting Query...
 Query ID: 0
>Scheduled :0
```



SUBSETTING SERVICE

ESML DESCRIPTION FILE

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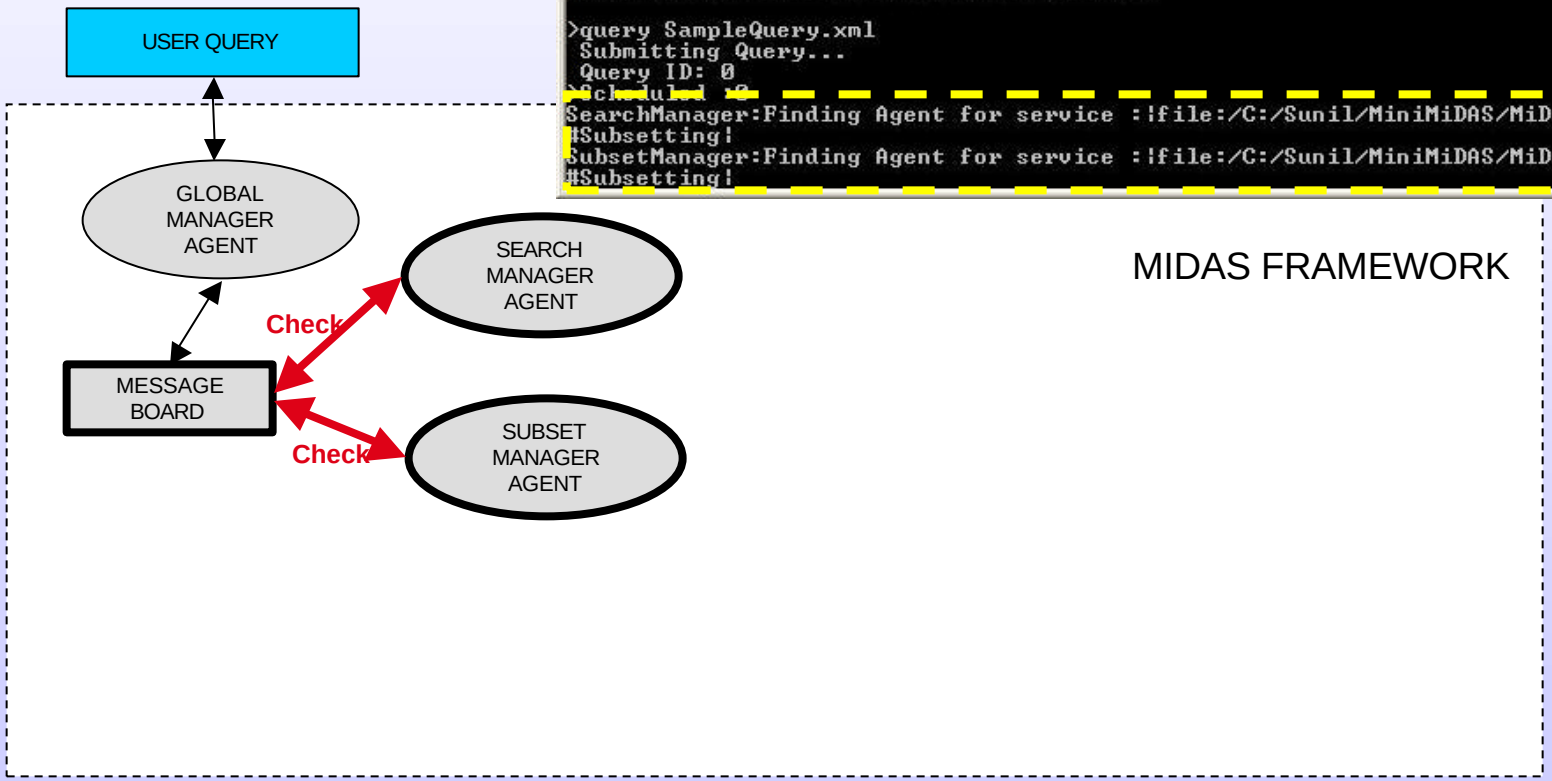
SubsetManager:Initialized
Starting :SearchManager
Starting :Search
SearchManager:Initialized
>Starting Agent: Search
SubsetManager: Received Advertise Message!
SearchManager: Received Advertise Message!

>query SampleQuery.xml
 Submitting Query...
 Query ID: 0
>Scheduled 10
SearchManager:Finding Agent for service :|file:/C:/Sunil/MiniMiDAS/MiDASOntology
#Subsetting|
SubsetManager:Finding Agent for service :|file:/C:/Sunil/MiniMiDAS/MiDASOntology
#Subsetting|
```



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 Submitting Query...
 Query ID: 0
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#Subsetting|
SubsetManager:Finding Agent for service :|file:/C:/Sunil/MiniMiDAS/MiDASOntology
#Subsetting|
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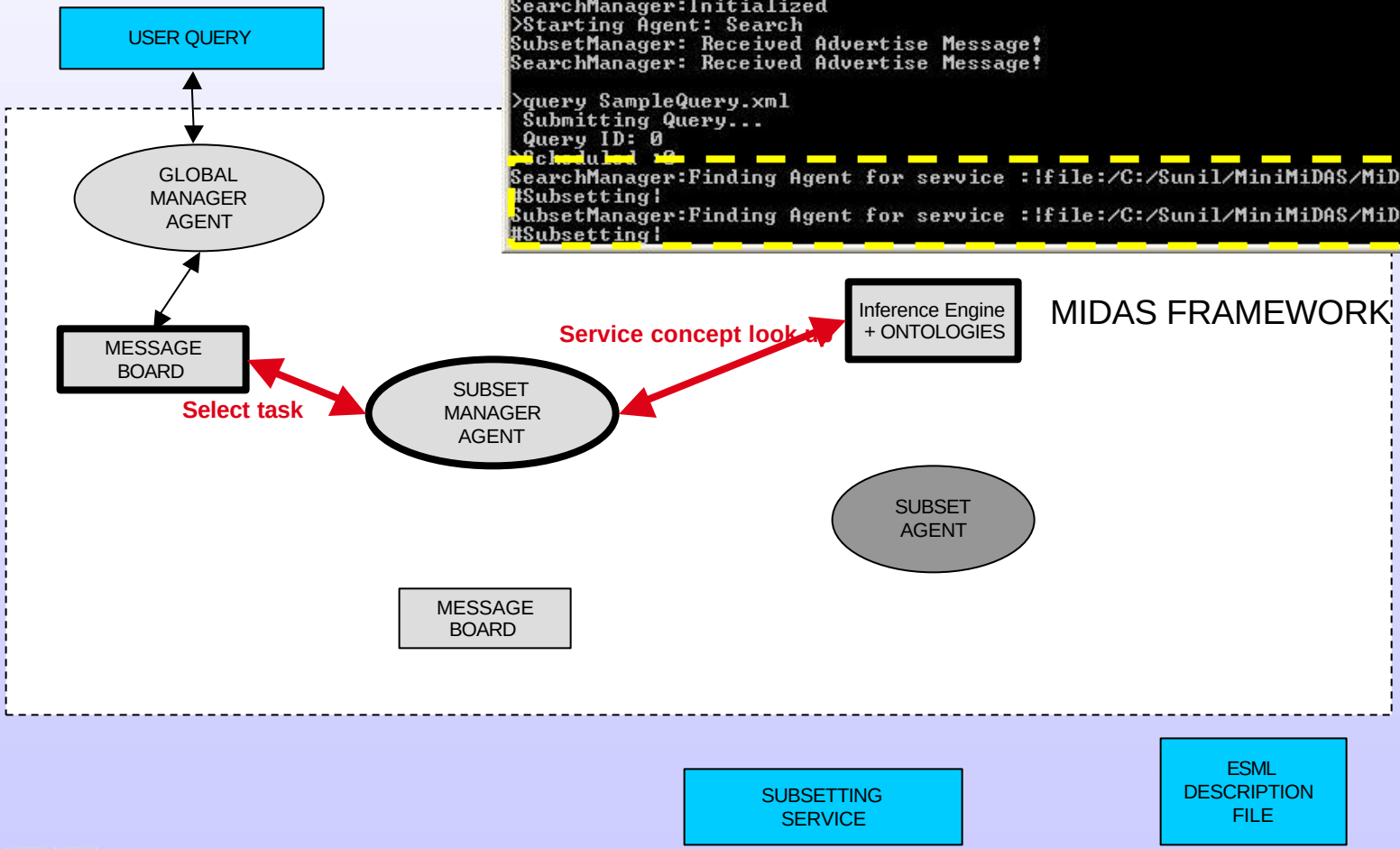

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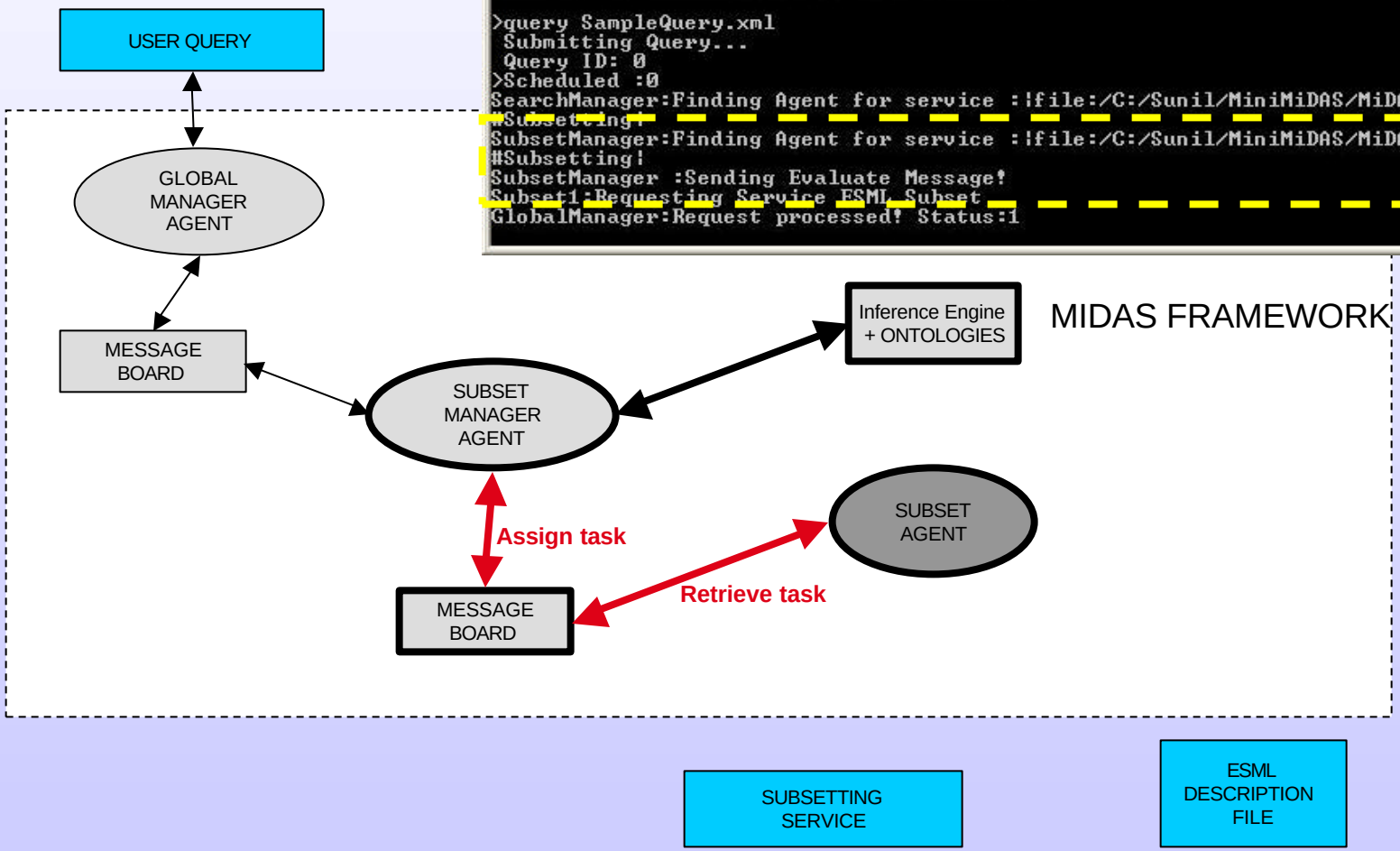
>query SampleQuery.xml
 Submitting Query...
 Query ID: 0
>Scheduled :0
SearchManager:Finding Agent for service :!file:/C:/Sunil/MiniMiDAS/MiDASOntology
#Subsetting!
SubsetManager:Finding Agent for service :!file:/C:/Sunil/MiniMiDAS/MiDASOntology
#Subsetting!
SubsetManager :Sending Evaluate Message!
Subset1:Requesting Service ESML Subset
GlobalManager:Request processed! Status:1
```



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SearchManager:Initialized
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SearchManager: Received Advertise Message!

>query SampleQuery.xml
 Submitting Query...
 Query ID: 0
>Scheduled :0
SearchManager:Finding Agent for service :!file:/C:/Sunil/MiniMiDAS/MiDASOntology
#Subsetting!
SubsetManager:Finding Agent for service :!file:/C:/Sunil/MiniMiDAS/MiDASOntology
#Subsetting!
SubsetManager :Sending Evaluate Message!
Subset1:Requesting Service ESML_Subset
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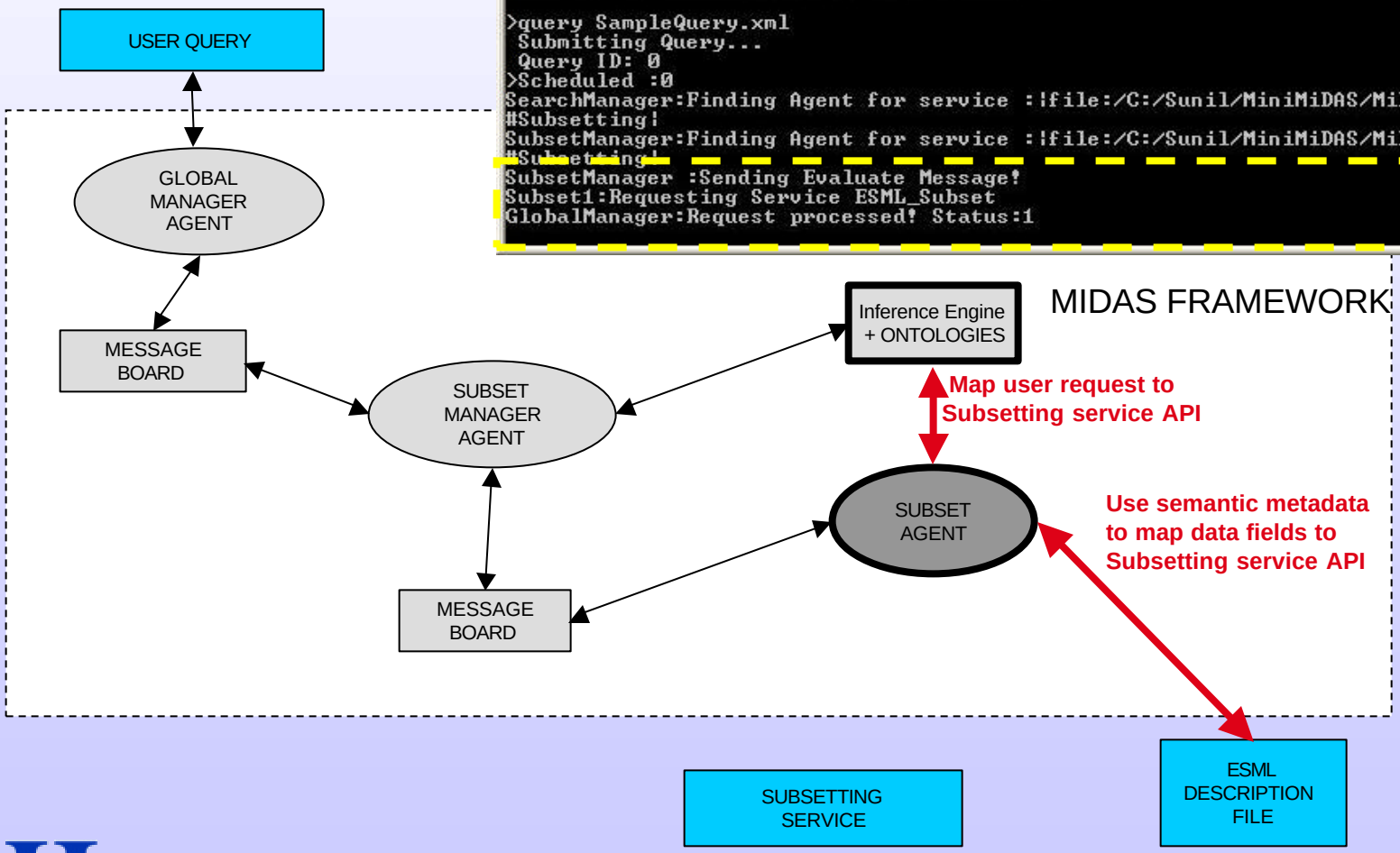

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 Query ID: 0
>Scheduled :0
SearchManager:Finding Agent for service :!file:/C:/Sunil/MiniMiDAS/MiDASOntology
#Subsetting!
SubsetManager:Finding Agent for service :!file:/C:/Sunil/MiniMiDAS/MiDASOntology
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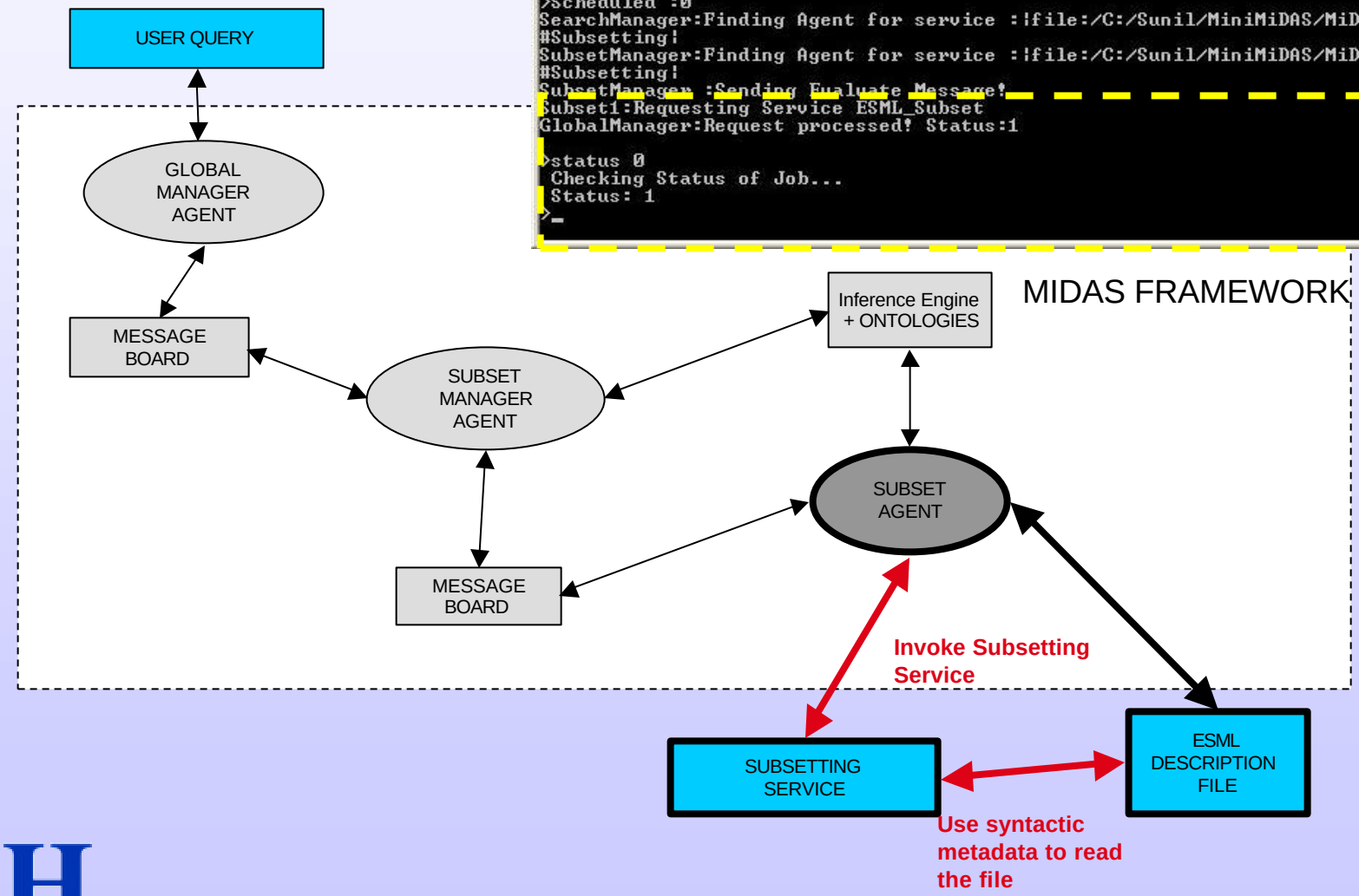
>status 0
 Checking Status of Job...
 Status: 1
>_
```



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MIDAS Summary

- Contains three data preparation/processing domains with services for:
  - Search
  - Data Format Translation
    - Any ESML supported format to Binary
  - Subsetting
- Leverages both Semantic and Structural metadata in ESML
  - Unlike existing hardwired services
- Uses Ontologies and inference engines for reasoning
- Can be adapted for both Web and Grid services

Questions?

Additional ESML Information:
http://esml.itsc.uah.edu

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