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# AI Planning for Grid/Web Services Composition, Policy Analysis & Workflow

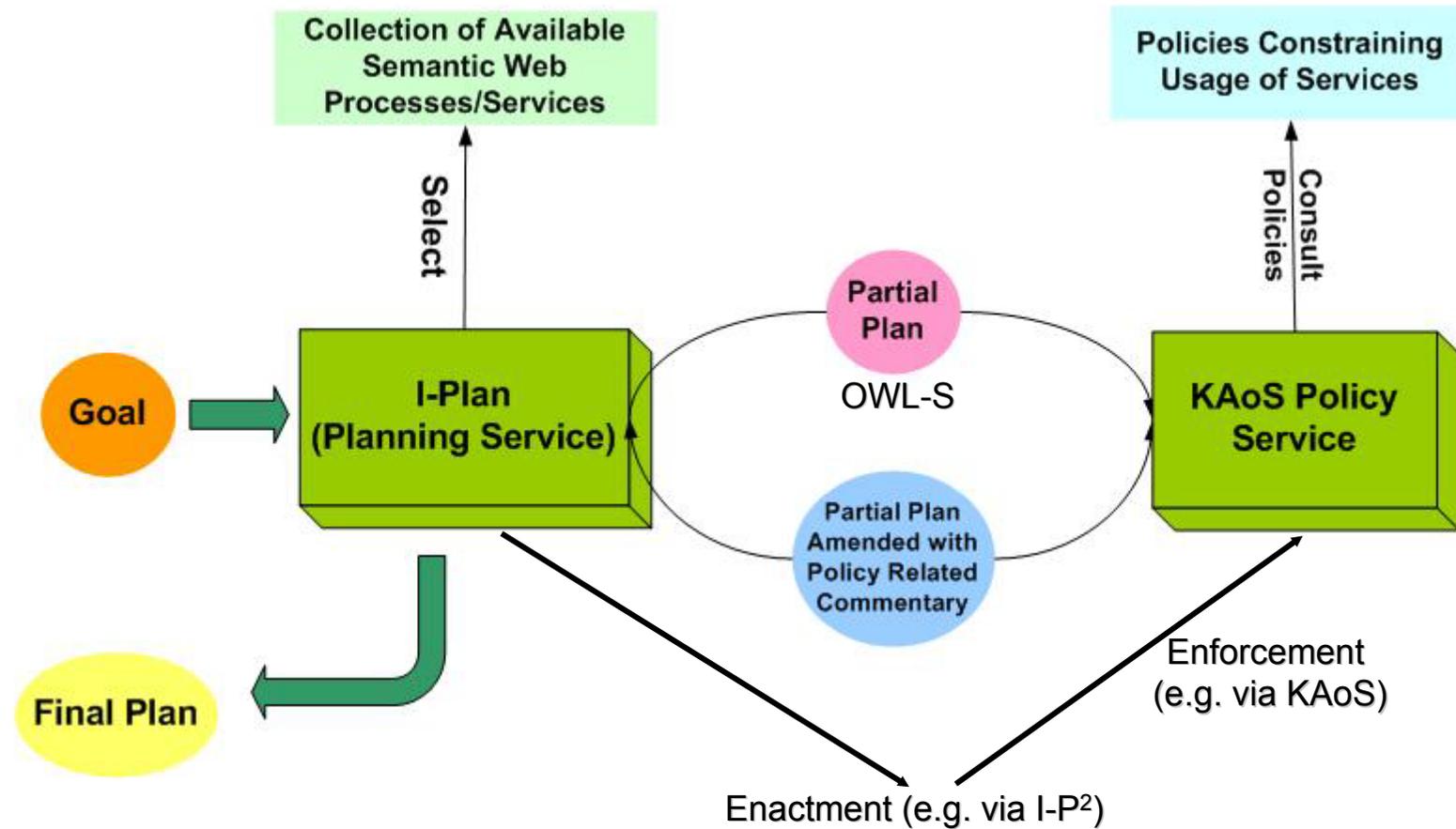
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# I-X/KAoS Composer (& Enactor)



# Previous Relevant AIAI Work

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- ***O-Plan***

- On-line web service exposing API via CGI scripts since 1994
- HTTP interface since 1997
- Simple - single user single-shot plan generator
- Mixed-initiative – multiple options, multiple users with multiple roles, long transactions, collaborative planning, execution and plan repair on failure
- Air Campaign Planning Workflow Aid - people and systems

- ***I-X***

- I-X supports the construction of mixed-initiative agents and systems which are intelligible to their users and to other systems and agents
- Dynamic workflow generation and reactive execution support
- I-Q query adaptor for OWL, OWL-S lookups via CMU Matchmaker, Semantic Web Queries via OWL and RDQL (AKTive Portal)
- I-Plan planning/re-planning tool

- ***CoAX and CoSAR-TS***

- Coalition Command and Control/Search and Rescue Task Support
- Use on CoABS Grid and with KAoS Domain and Policy Services



# Previous Relevant IHMC Work

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- **KAoS**

- Developed domain and policy services compatible with several popular agent (e.g., CoABS Grid, Cougaar, Brahms, SFX) and distributed computing (e.g., CORBA, Grid Computing, Web Services) platforms
- Use of OWL to represent application domain concepts and instances, and policy information
- Analysis and policy disclosure algorithms built on top of Stanford's Java Theorem Prover

- **CoAX and CoSAR-TS**

- Use of KAoS to rapidly specify, deconflict, and enforce policies in coalition agents experiment (CoAX)
- Use of KAoS to define, deconflict, and enforce policies governing access to CMU Semantic Matchmaker information in conjunction with AIAI's I-X tool set (CoSAR-TS)



# FY04 Progress

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1. ***Initial exploration of the research agenda for using AI planners and workflow analysis capabilities as web service composition tools***
2. ***O-Plan Web Service experiments***
  - *Dealing with Inputs & Outputs*
  - *Recovering Dataflow from Plan Goal Structure*
  - *OWL-S Import & Export*
3. ***I-Plan***
  - *As a web service*
  - *As a Java planning tool (stand-alone and embedded)*
4. ***KAoS Policy Analysis of workflows***
  - *Translate instances of OWL-S processes into KAoS Action Classes to allow policies to be written about OWL-S processes*
  - *KAoS Policy Semantics extended for more sophisticated insertion of policy obligations into OWL-S composite processes*
  - *KAoS role-value-map extensions allow generation of richer OWL-S dataflow semantics*



# FY04 Progress

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**5. Use KAoS Policy Analysis during I-Plan plan generation**

**6. Scenarios**

- *Simple examples – e.g. document handling*
- *myGrid biochemistry scenario to identify tool requirements*
- *CoSAR scenario - Emerging web Interactive demo of all the integrated technology on CoSAR-TS scenario*

## **Explorations**

- *KAoS Workflow Policy Analyzer as a Web Service*
- *Link to AKT work on OWL-S manual composition tool (SEdit)*



# I-Plan Web Service – Search & Rescue

The screenshot displays a web browser window with three main panes. The left pane, titled "Web service results", contains information about the O-Plan version (3.3, released 30-Apr-00, built 24-May-00) and I-Plan, I-X version (3.2+, 02-May-04). It also lists "O-Plan Results" with planning statistics: am-cycles = 26, n-alts-chosen = 0, n-alts-remaining = 10, and n-poisons = 0. A list of links is provided for further details, such as "TF problem description", "PostScript graph of the plan", "Plan narrative", "World state when the plan finishes", "Data Flows", and "PostScript data-flow graph". The "I-X Results" section includes links for "LTF problem description", "Initial plan as XML", "Debugging output", "Final plan as XML", and "PostScript graph of the plan".

The middle pane shows the source code for the web service, including refinements for hospital\_lookup, sar\_lookup, hospital\_selection, and hospital\_notifier. The code defines variables, constraints, and annotations for each refinement.

The right pane, titled "Position Demo", features a form for specifying parameters. It includes an "Initial state" section with a dropdown menu for "ion downed\_pilot\_1" set to "sea", and a "Desired state" section.

Two overlapping windows in the foreground show plan graphs. The top window, "web-service-42-ix-plan-graph[1].ps - GSview", displays a complex graph with nodes and edges, representing the search and rescue plan. The bottom window, "web-service-42-ix-plan-graph[1].ps - GSview", shows a simplified graph with four nodes: "NODE-0 ACTION (HOSPITAL\_LOOKUP HOSPITAL TO HOSPITAL\_LIST)", "NODE-1 ACTION (HOSPITAL\_SELECTION HOSPITAL\_LIST TO HOSPITAL)", "NODE-2 ACTION (SAR\_LOOKUP HOSPITAL TO SAR\_RESOURCE\_LIST)", and "NODE-4 ACTION (HOSPITAL\_NOTIFIER HOSPITAL TO)".

# O-Plan/I-Plan OWL-S Importer

<http://ontology.ihmc.us/CoSAR-TS/CoSAR-TS-ServiceOntology.owl>

```
(refinement ArabelleCoastGuardCutter_Service (ArabelleCoastGuardCutter_Service ?hospitalLocation_In ?pickupLocation_In ?countryofHospital_In to ?injuryType_out ?person_out)
(variables ?hospitalLocation_In ?pickupLocation_In ?countryofHospital_In ?injuryType_out ?person_out)
(constraints
(world-state condition (type ?hospitalLocation_In) = Location)
(world-state condition (type ?pickupLocation_In) = Location)
(world-state condition (type ?countryofHospital_In) = Country)
(world-state effect (type ?injuryType_out) = Injury)
(world-state effect (type ?person_out) = Person))
(annotations
(output-objects = ((?injuryType_out Injury) (?person_out Person)))
(input-objects = ((?hospitalLocation_In Location) (?pickupLocation_In Location) (?countryofHospital_In Country))))))

(refinement GaoMarineHelicopter_Service (GaoMarineHelicopter_Service ?hospitalLocation_In ?pickupLocation_In ?countryofHospital_In to ?injuryType_out ?person_out)
(variables ?hospitalLocation_In ?pickupLocation_In ?countryofHospital_In ?injuryType_out ?person_out)
(constraints
(world-state condition (type ?hospitalLocation_In) = Location)
(world-state condition (type ?pickupLocation_In) = Location)
(world-state condition (type ?countryofHospital_In) = Country)
(world-state effect (type ?injuryType_out) = Injury)
(world-state effect (type ?person_out) = Person))
(annotations
(output-objects = ((?injuryType_out Injury) (?person_out Person)))
(input-objects = ((?hospitalLocation_In Location) (?pickupLocation_In Location) (?countryofHospital_In Country))))))

(refinement USArmyHelicopter_Service (USArmyHelicopter_Service ?hospitalLocation_In ?pickupLocation_In ?countryofHospital_In to ?injuryType_out ?person_out)
(variables ?hospitalLocation_In ?pickupLocation_In ?countryofHospital_In ?injuryType_out ?person_out)
(constraints
(world-state condition (type ?hospitalLocation_In) = Location)
(world-state condition (type ?pickupLocation_In) = Location)
(world-state condition (type ?countryofHospital_In) = Country)
(world-state effect (type ?injuryType_out) = Injury)
(world-state effect (type ?person_out) = Person))
(annotations
(output-objects = ((?injuryType_out Injury) (?person_out Person)))
(input-objects = ((?hospitalLocation_In Location) (?pickupLocation_In Location) (?countryofHospital_In Country))))))

(refinement USMarineHelicopter_Service (USMarineHelicopter_Service ?hospitalLocation_In ?pickupLocation_In ?countryofHospital_In to ?injuryType_out ?person_out)
(variables ?hospitalLocation_In ?pickupLocation_In ?countryofHospital_In ?injuryType_out ?person_out)
(constraints
(world-state condition (type ?hospitalLocation_In) = Location)
(world-state condition (type ?pickupLocation_In) = Location)
(world-state condition (type ?countryofHospital_In) = Country)
(world-state effect (type ?injuryType_out) = Injury)
(world-state effect (type ?person_out) = Person))
(annotations
(output-objects = ((?injuryType_out Injury) (?person_out Person)))
(input-objects = ((?hospitalLocation_In Location) (?pickupLocation_In Location) (?countryofHospital_In Country))))))
```

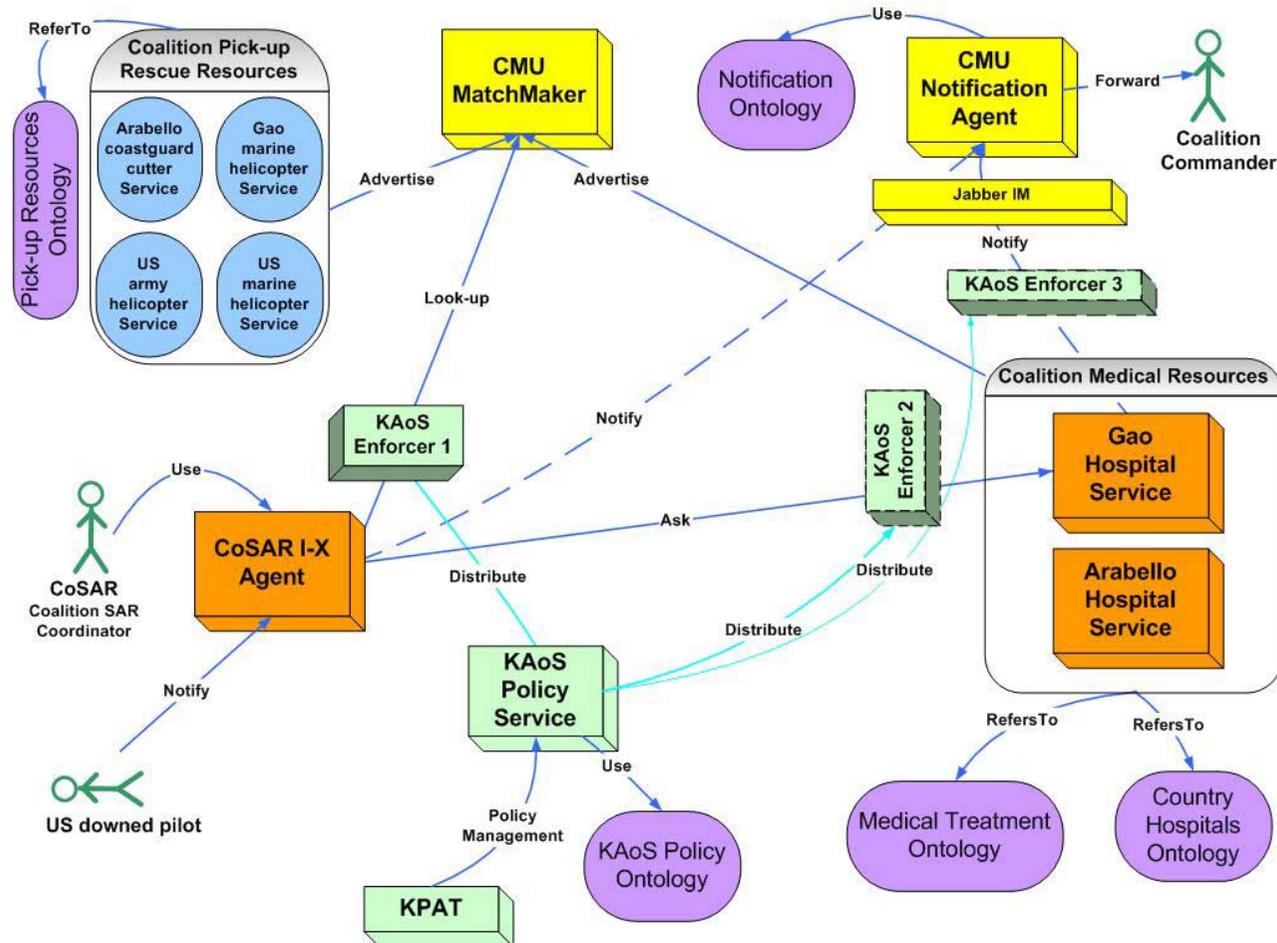
# KAoS Policy about an OWL-S Process

Using vocabulary from CoSAR -TS OWL-S Process ontology policies

The screenshot displays the KPAT (KAoS Policy Administration Tool v2.0) interface. The left sidebar shows a tree view of Actor Classes, with 'Co-SARTS\_Coordinator' selected. The main window is divided into several sections:

- Template Information:** Name: Generic OWL Editor, Description: Generic editor for OWL policies.
- Policy Editor:**
  - Policy id: urn:KAoS#policy-b0f08ea6-00fc-0000-8000-0000deadbeef
  - Policy name: NotificationObligation
  - Description: CoSAR-TS Coordinator is obliged to notify Colaition Commander
  - Priority: 1
  - Role: Co-SARTS\_Coordinator
  - Restriction: is
  - Complement: obligated
  - Value(s): NotificationProcess
  - Properties: with properties:
- When Actor performs PickUpPilot:** A section for defining conditions and actions, with a dropdown menu open showing properties like countryOfHospital\_In, deliveryHospitalLocation\_In, destination\_In, etc.
- Policy Changes:** A section at the bottom for managing changes, with buttons for Add Actor Class, Show Instances, Commit, and Refresh.

# COSAR-TS Web Interactive Demo



[http://ontology.ihmc.us/CoSAR-TS/Demos/CoSAR-TS\\_Demo\\_Concept.htm](http://ontology.ihmc.us/CoSAR-TS/Demos/CoSAR-TS_Demo_Concept.htm)

# I-Plan Tool – CoSAR-TS Search & Rescue

**Coalition Search and Rescue Coordinator**

File New Tools Help Test

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**Issues**

Description	Annotations	Priority	Action

---

**Activities**

Description	Annotations	Priority	Action
example		Normal	No Action
setup-initial-state		Normal	No Action
sea-rescue pilot-A red-sea burns		Normal	No Action
pick-up-and-transport pilot-A red-sea "Gahwad El" burns		Normal	No Action
us-army-helicopter-service gahwad-el-lat-long red-sea Arabelle to burns pi		Normal	No Action
treat-injury pilot-A "Gahwad El" burns		Normal	No Action
arabelle-hospital-service pilot-A burns to string-0		Normal	No Action

---

**State**

Pattern	Value
longitude Southampton	-1.404
maxSpeed USS_Michigan	70Km/h
weapon USS_California	"10 loaded torpedo"
weapons WMD	Biological
maxSpeed USS_California	52Km/h
maxSpeed GaoMarineHelicopter	120Km/h
type red-sea	location
type Heathrow	airport

---

**Annotations**

Key	Value

**Coalition Search and Rescue C...**

File

Planning statistics:  
Steps taken = 15  
Alternatives posted = 1  
Alternatives picked = 0  
Alternatives remaining = 1  
Number of nodes = 7  
Longest node-end path length = 13

**Coalition Search and Rescue C...**

File

```

Executing begin_of Item[Activity[arabelle-hospital-s
Condition: p=v[(type pilot-A)=person]
Condition: p=v[(type burns)=injury]
Executing end_of Item[Activity[arabelle-hospital-ser
Effect: p=v[(type string-0)=string]
Executing end_of Item[Activity[treat-injury pilot-A "Ga
Executing end_of Item[Activity[sea-rescue pilot-A re
Executing end_of Item[Activity[example]]

No problems found.

Final world state:
(latitude AIA) = 55.944
(longitude AIA) = -3.186
(type Arabelle) = country
(latitude ArabelleCoastguardCutter) = 23.45

```

**CoSAR** I-X Process Panels  
Based on I-X Technology



# I-K-C – CoSAR-TS Search & Rescue

**Coalition Search and Rescue Coordinator**

File New Tools Help Test

**Issues**

Description	Annotations	Priority	Action

---

**Activities**

Description	Annotations	Priority	Action
example		Normal	No Action
setup-initial-state		Normal	No Action
sea-rescue pilot-A red-sea burns		Normal	No Action
pick-up-and-transport pilot-A red-sea "Gahwad EI" burns		Normal	No Action
gao-marine-helicopter-service gahwad-el-lat-long red-sea Arabello to burn		Normal	No Action
treat-injury pilot-A "Gahwad EI" burns		Normal	No Action
arabello-hospital-service pilot-A burns to string-0		Normal	No Action

---

**State**

Pattern	Value
longitude Southampton	-1.404
maxSpeed USS_Michigan	70Km/h
weapon USS_California	"10 loaded torpedo"
weapons WMD	Biological
maxSpeed USS_California	52Km/h
maxSpeed GaoMarineHelicopter	120Km/h
type red-sea	location
type Heathrow	airport

---

**Annotations**

Key	Value

**Coalition Search and Rescue C...**

File

Planning statistics:  
Steps taken = 13  
Alternatives posted = 1  
Alternatives picked = 1  
Alternatives remaining = 1  
Number of nodes = 7  
Longest node-end path length = 13

---

**Coalition Search and Rescue C...**

File

Executing begin\_of Item[Activity[sea-rescue pilot-A  
Executing begin\_of Item[Activity[pick-up-and-transp  
Condition: p=v((type "Gahwad EI")=hospital]  
Condition: p=v((country "Gahwad EI")=Arabello)  
Condition: p=v((location "Gahwad EI")=gahwad-el-  
Condition: p=v((type red-sea)=location)  
Executing begin\_of Item[Activity[gao-marine-helicop  
Condition: p=v((type gahwad-el-lat-long)=location)  
Condition: p=v((type red-sea)=location)  
Condition: p=v((type Arabello)=country)  
Executing end\_of Item[Activity[gao-marine-helicopte  
Effect: p=v((type burns)=injury)  
Effect: p=v((type pilot-A)=person)  
Executing end\_of Item[Activity[pick-up-and-transpor  
Executing begin\_of Item[Activity[treat-injury pilot-A "C  
Condition: p=v((country "Gahwad EI")=Arabello)  
Executing begin\_of Item[Activity[arabello-hospital-s

**CoSAR** I-X Process Panels  
Based on I-X Technology



# I-K-C – CoSAR-TS Search & Rescue

**Coalition Search and Rescue Coordinator**

File New Tools Help Test

**Issues**

Description	Annotations	Priority	Action

---

**Activities**

Description	Annotations	Priority	Action
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us-marine-helicopter-service gahwad-el-lat-long red-sea Arabello to burns		Normal	No Action
treat-injury pilot-A "Gahwad EI" burns		Normal	No Action
arabello-hospital-service pilot-A burns to string-0		Normal	No Action

---

**State**

Pattern	Value
longitude Southampton	-1.404
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maxSpeed USS_California	52Km/h
maxSpeed GaoMarineHelicopter	120Km/h
type red-sea	location
type Heathrow	airport

---

**Annotations**

Key	Value

**Coalition Search and Rescue C...**

File

Planning statistics:  
Steps taken = 13  
Alternatives posted = 0

**Message**

No plan was found

OK

Plan    Replan    Check Plan

---

File

No problems found.

Final world state:  
 (latitude AIAI) = 55.944  
 (longitude AIAI) = -3.186  
 (type Arabello) = country  
 (latitude ArabelloCoastguardCutter) = 23.45  
 (longitude ArabelloCoastguardCutter) = 38.55  
 (maxSpeed ArabelloCoastguardCutter) = 35Km/h  
 (type ArabelloCoastguardCutter) = cutter  
 (altitude Bandar\_Airport) = 10  
 (latitude Bandar\_Airport) = 19.25  
 (longitude Bandar\_Airport) = 37.0  
 (type Bandar\_Airport) = airport  
 (latitude Birmingham) = 52.45  
 (longitude Birmingham) = -1.75  
 (route Edinburgh Belfast Dublin London) = //EE.7

Cancel



# Some Features of the Approach

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- 1. Planning using OWL-S Service Model IOPE Core**
- 2. Can easily extend to accommodate richer temporal, resource and performer constraints**
- 3. Policy analysis feedback during planning**
- 4. Should separate plan-time model from run-time enactment environment**
- 5. Single shot plan service with re-plan facility or richer “mixed-initiative” multiple-options mode**
- 6. Exploring links to a graphical web service editor**
- 7. Exploring seeking web service description information at planning or enactment time**
- 8. Can run as separate services or as embedded tools**



# Continuing Issues

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- 1. OWL-S input beyond primitives**
- 2. OWL-S output espec. wrt Preconditions/Effects**
- 3. Two way I-X  $\leftrightarrow$  KAoS rich interchange**
- 4. Widen scope of KAoS policy analysis**
- 5. Discrete vs. continuous analysis of workflows**
- 6. Mixed-initiative planning support, GUI**
- 7. Multiple option exploration, GUI**
- 8. Current service environment vs enactment model**
- 9. When to stop planning – how far to commit**
- 10. LOTS of planning power when we need it**



# OWL-S Semantics Issues

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- ***OWL-S doesn't yet define a way to express preconditions and effects***
  - *The intention is to fix this in SWSL*
- ***It is awkward to express the data-flow in a composite process that invokes the same service more than once***
  - *The intention is to fix this in OWL-S 1.1*
- ***There are partial orders of service invocations and temporal constraints that the OWL-S control structures cannot express***
  - *The intention is to fix this in SWSL*

# OWL-S Workflow Issues

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- ***Current Process Model ontology is more suited to the purpose of defining internal structure of a single service***
- ***Need to attach Profile restrictions to a step of the workflow; used to find a Matchmaker-registered service that meets requirements during enactment***
- ***Composite processes are made up of non-unique instances of processes. We have not been able to find a way to add additional information to a particular step, for instance:***
  - ***Profile restrictions***
  - ***Policy analysis results***



# OWL-S Deployment Issues

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- ***There doesn't seem to be an authoritative document that precisely defines the OWL-S semantics. Many questions aren't answered by the Technical Overview or by the OWL definitions of the OWL-S ontologies***
- ***RDF is awkward to use and difficult to read, and OWL-S doesn't yet have an agreed alternative "surface syntax"***
- ***There is currently no OWL-S editor***
- ***Doing simple things with OWL-S requires lots of software (e.g. Jena2 and all that it requires or the OWL-S API which requires Jena2 and more)***



# Continuing Work

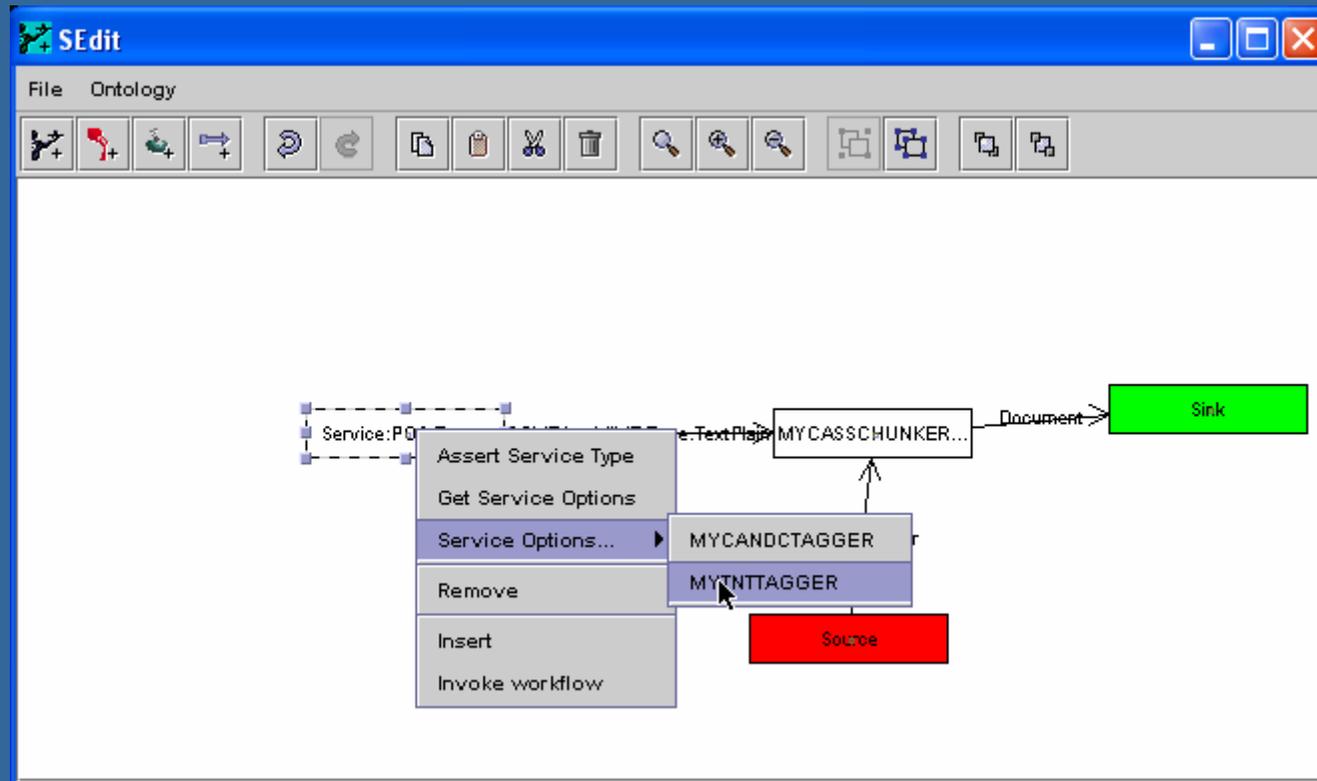
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- ***Complete integration of I-Plan Planner with KAoS policy analysis services***
  - *Also allow the use of WSDL workflow analyses*
- ***Java Web Start version of KPAT to obviate the need for prior installation on user's machine***
- ***Generic KAoS enforcer for OWL-S***
- ***Mixed-initiative planning, integration with AKT project graphical composition tool***
- ***Web-based demonstration integrating I-Plan, I-P<sup>2</sup>, CMU Matchmaker, KAoS and servlets simulating services***



# Semantic Web Service Workflow Composition Editor

AKT Project – Stephen Potter, AIAI



# AIAI Summary Report

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- **2003 Goal**

- Link I-X coordination and task support with KAoS agent, domain and policy services
- Demonstrate in a Search & Rescue scenario in TTCP Binni C2 Domain
- To be shown as AAI-2004 Intelligent Systems Demonstrator  
<http://www.aiai.ed.ac.uk/project/cosar-ts/demo/isd/>

- **2004 Goal**

- Create a web service composition tool based on AI planning technology that can account for execution policy issues, requirements and constraints

- **Release Plans**

- Currently I-X version 3.3 and CoSAR demonstration are available via web for research use
- Open source I-X version 4.0 for research and US government use planned for September 2004. Tool based on this put on SemWebCentral soon after.

- **Plans to end of Project**

- Do our best to package the results (effort mostly used to date)
- Do our best to continue to participate in SWSL and W3C SWS-IG



# IHMC Summary Report

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- **2003 Goal**
  - Provide KAoS domain and policy services to I-X
  - Different from and complementary to CMU Matchmaker Policies and OWL-S security extensions
  - Develop policies and enforcers for Search & Rescue scenario in TTCP Binni C2 Domain
- **2004 Goal**
  - Provide policy analysis capability for OWL-S composite processes (next: WMSO)
- **Release Plans**
  - Web hosting of KAoS and CoSAR demonstrations for research use
  - Distribution of KAoS on SemWebCentral for research and US government use planned for October 2004
- **Plans to end of Project**
  - Enrich policy analyses of OWL-S specified workflow
  - Finish the live Web demonstration of integrated technology and CoSAR scenario by August 2004
  - Collaborate with CMU on Matchmaker improvements and usage
  - Develop generic policy enforcer for OWL-S services



# Further Information

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- <http://www.aiai.ed.ac.uk/project/cosar-ts/>
- <http://ontology.ihmc.us/>
- <http://i-x.info>

