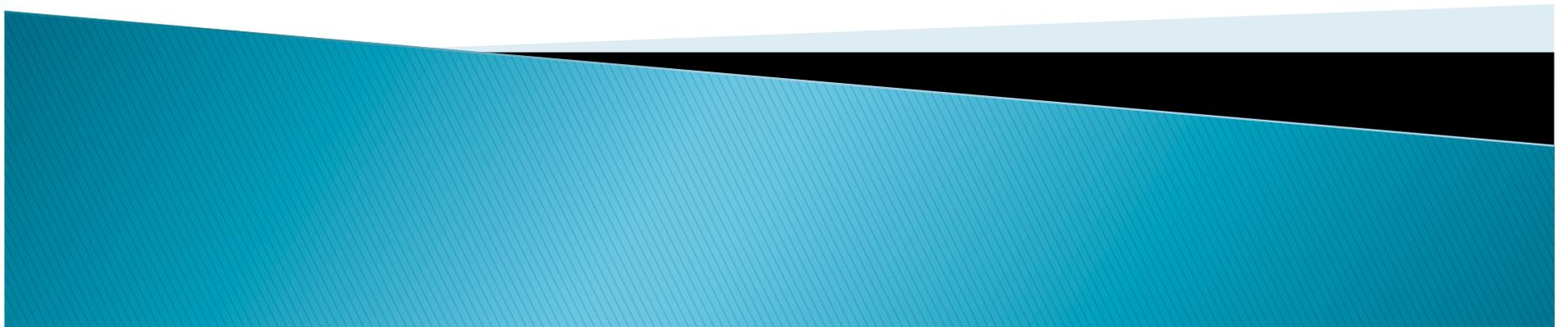


Intelligence Analysis Ontology for Cognitive Assistants

Mihai Boicu, Gheorghe Tecuci, David Schum



Disciple-LTA Overview

Disciple-LTA is a **new type of personal cognitive assistant** that:

- can **rapidly acquire expertise** in intelligence analysis,
 - can **train** new intelligence analysts, and
 - can **help analysts** analyze complex hypotheses
- ▶ through **mixed-initiative reasoning**,
- ▶ allowing a **synergistic integration** of a human's experience and creativity with an agent's knowledge and speed, and
- ▶ facilitating **collaboration** with complementary experts and their agents.

- Rapid and systematic hypothesis analysis
- Assumption-based reasoning
- Evidence retrieval and representation
- Automatic report generation
- Collaboration and information sharing

- Rapid acquisition of analytic expertise
- Learning to analyze based on source's culture
- Tutoring new analysts
- Automatic test generation
- Easy integration with other tools and services

Disciple Approach to Agent Development

Develop learning and problem solving agents that can be taught by subject matter experts to become knowledge-based assistants.

The expert teaches Disciple how to solve problems in a way that resembles how the expert would teach a student, an apprentice or a collaborator.

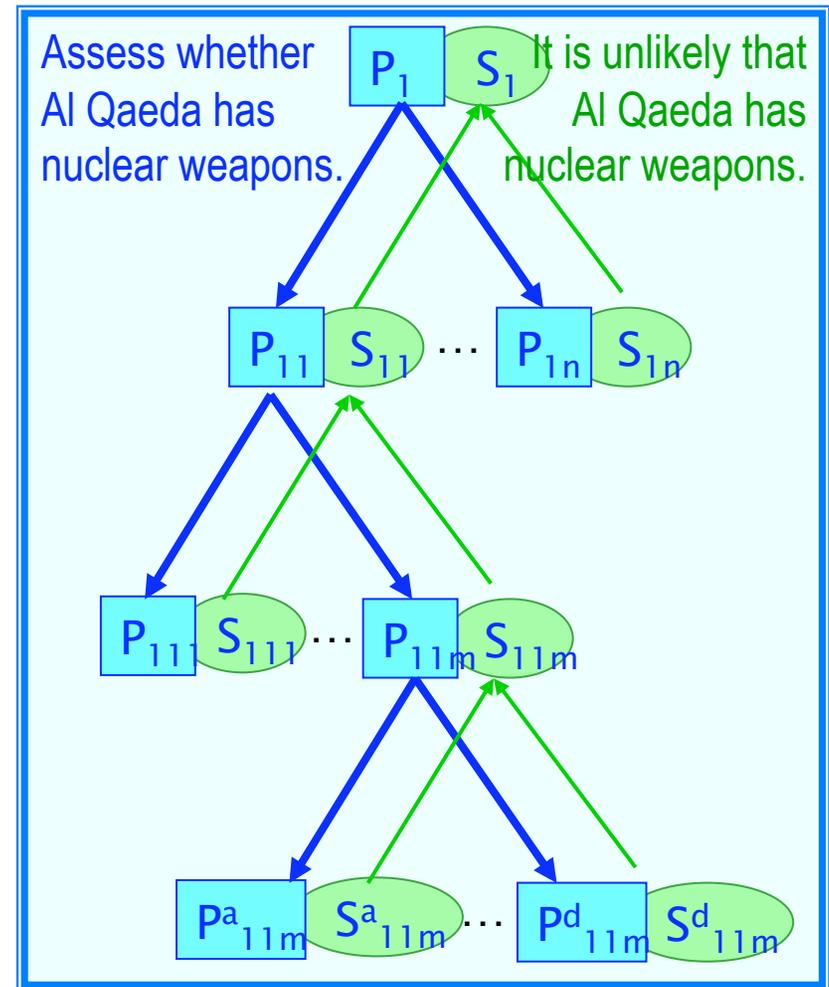


Disciple continuously develops and refines its knowledge base to capture and better represent expert's knowledge and problem solving strategies.

There is no longer a distinction between knowledge base development and its maintenance.

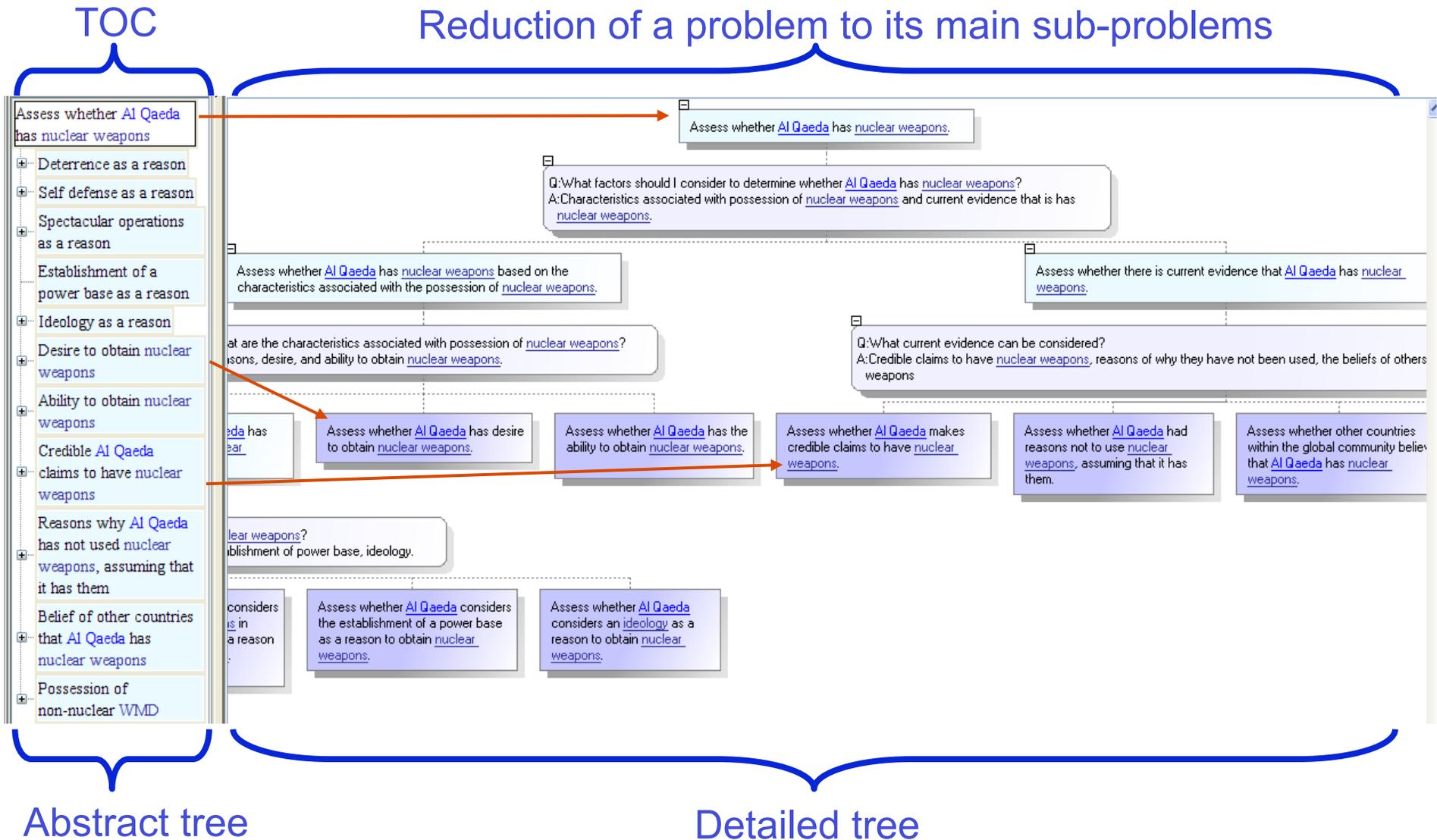
Hypothesis Analysis through Problem Reduction

1. A complex hypothesis analysis problem is successively reduced to simpler problems that either have known solutions or can be solved through evidence analysis.
2. Potentially relevant pieces of evidence for the unsolved problems are identified.
3. The pieces of evidence are analyzed to obtain solutions for the unsolved problems.
4. The solutions of the simplest problems are successively combined to obtain the solution of the initial problem.



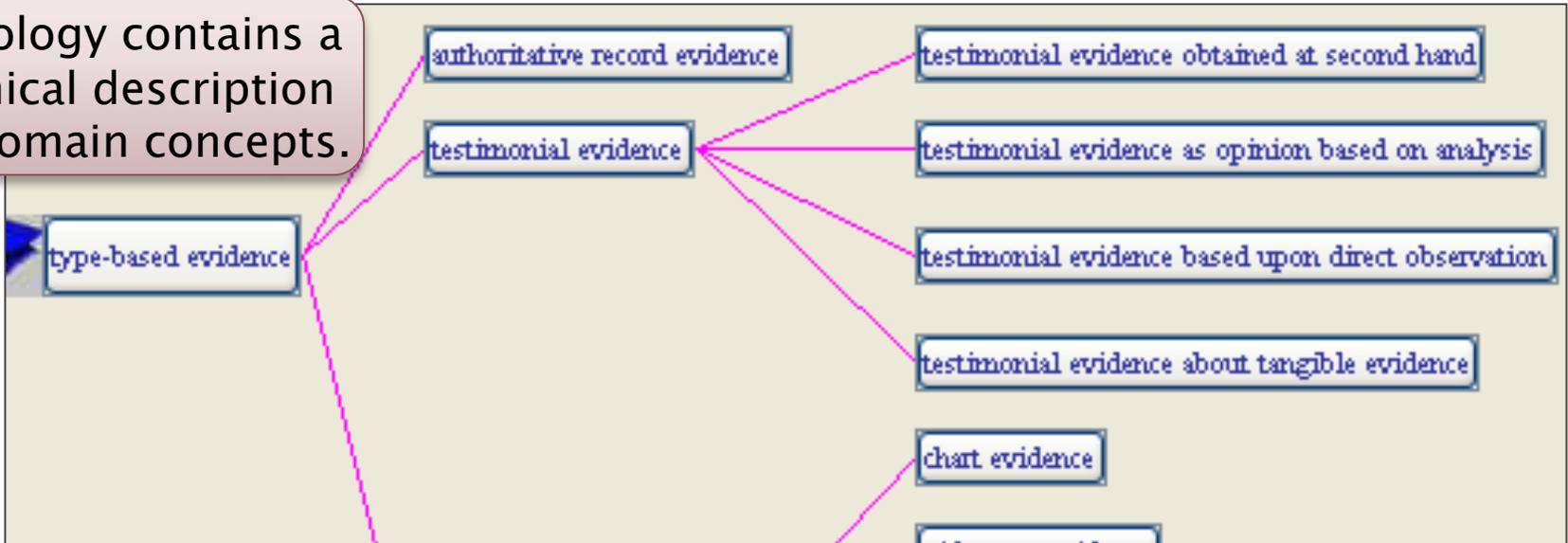
Remote	Unlikely	Even chance	Probably, Likely	Almost certainly
National Intelligence Council's standard estimative language				

Abstract and Concrete Reduction Tree



Knowledge Base = Ontology + Rules

The ontology contains a hierarchical description of the domain concepts.



Representation of EVD-Dawn-Mir01-02c

```

            graph TD
              A["(*)Al Qaeda"] -- instance-of --> B[group]
              A -- has as weapons --> C["(*)chemical weapons 1"]
              A -- has as weapons --> D["(*)nuclear weapons 1"]
              C -- instance-of --> E[chemical weapons]
              D -- instance-of --> F[nuclear weapons]
              A -- uses as deterrent --> C
              A -- uses as deterrent --> D
          
```

Description

We [Al Qaeda] have chemical and nuclear weapons as a deterrent and if America used them against us we reserve the right to use them

Interpretation

Al Qaeda has chemical and nuclear weapons as deterrent

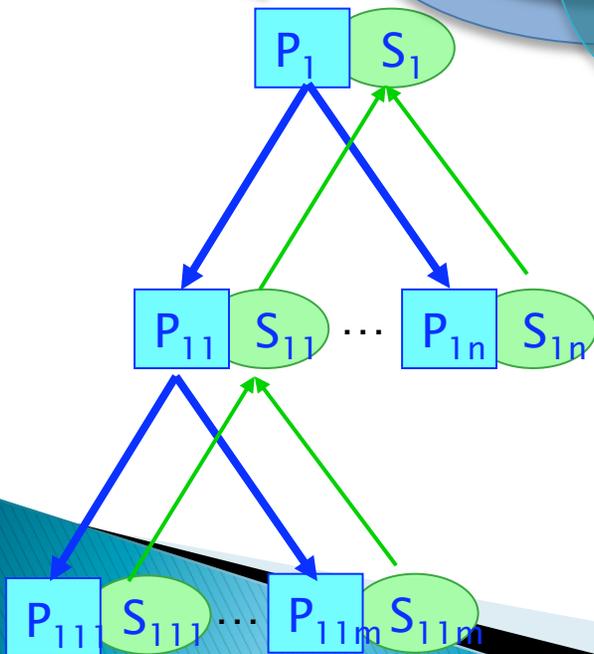
Find New Instance

Interpretation: Al Qaeda has chemical and nuclear weapons as deterrent.

Knowledge Base = Ontology + Rules

The rules specify general reduction or synthesis steps described with the concepts from the ontology.

ANALYSIS TREE



Partially learned rule

IF: Assess whether there are states with nuclear weapons willing to sell nuclear weapons to ?O1.

Q: Which is a nuclear state which is not an enemy of ?O1 and does not oppose the proliferation of nuclear weapons?
 A: ?O2

MAIN CONDITION

Var	Lower Bound	Upper Bound
?O1	(terrorist group)	(actor)
?O2	(nuclear state)	(nuclear state)

EXCEPT WHEN CONDITION 1

Var	Lower Bound	Upper Bound
?O1	(terrorist group)	(actor)
?O2	(superpower, nuclear state)	(actor)

Var	Relationship	Var
?O2	perceives as enemy	?O1

EXCEPT WHEN CONDITION 2

Var	Lower Bound	Upper Bound
?S11	[medium - medium]	[very low - very high]
?O2	(nuclear state)	(actor)

Var	Relationship	Var
?O2	degree of opposition to nuclear weapons proliferation	?S11

THEN: Assess whether ?O2 is willing to sell nuclear weapons to ?O1.

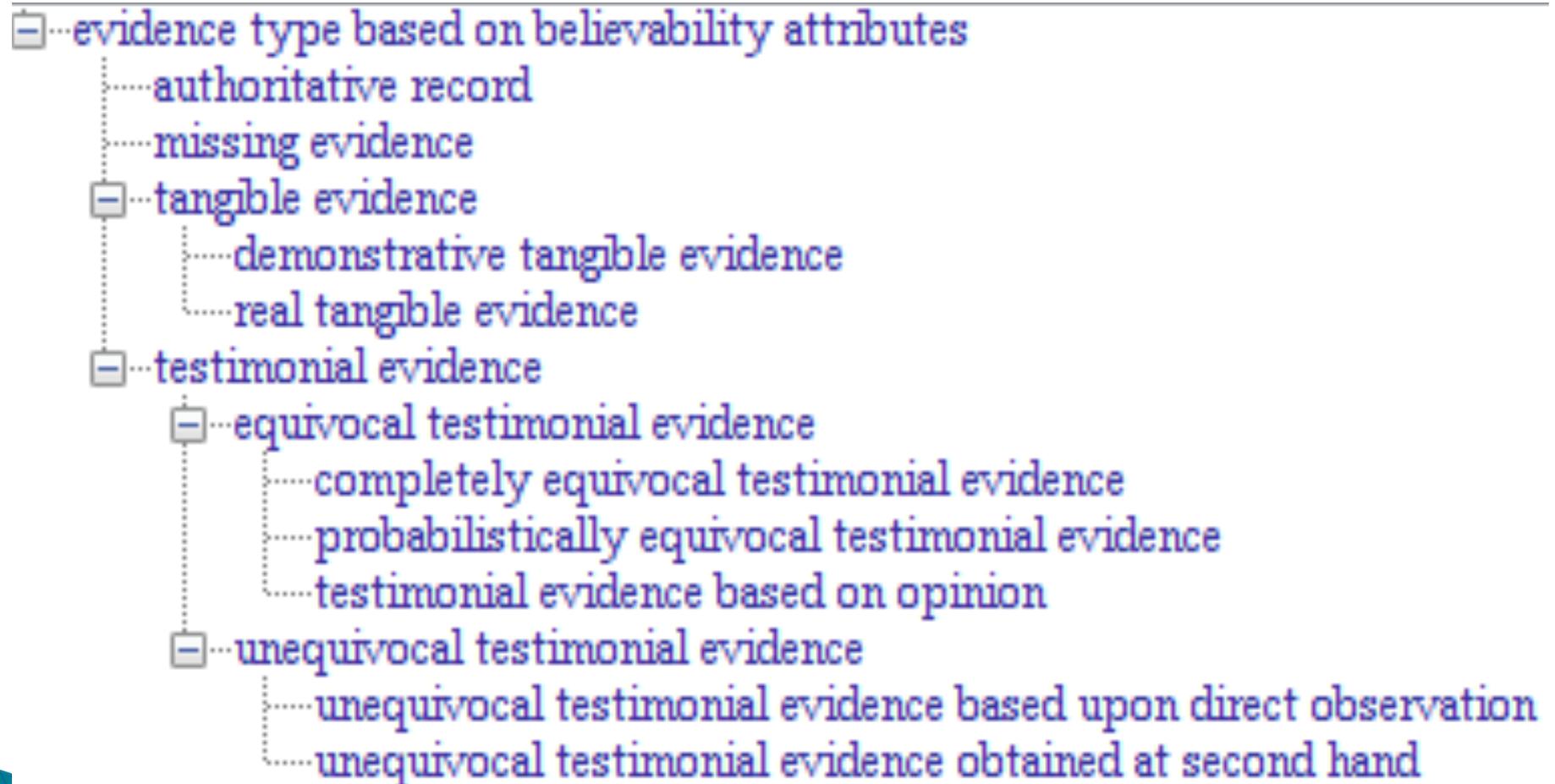
To assess whether there are states that may be willing to sell nuclear weapons to an actor, one has to consider each nuclear state which is not an enemy of that actor and does not oppose the proliferation of nuclear weapons, and determine whether that state may be willing to sell nuclear weapons to that actor.

Multiple Roles of the Ontology

- ▶ knowledge representation
- ▶ user-agent communication
- ▶ problem solving
- ▶ knowledge acquisition and learning



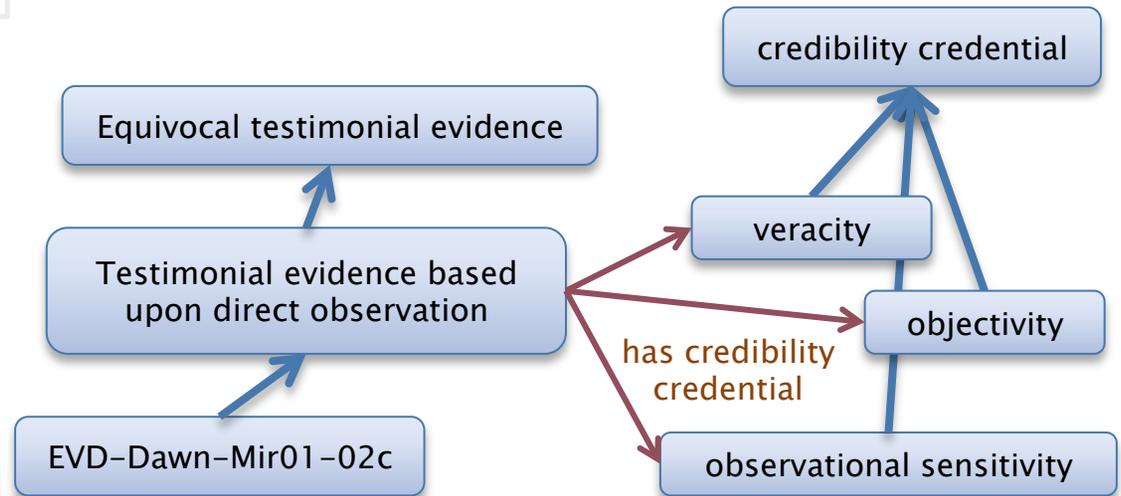
Ontology of Substance Blind Classes of Items of Evidence



Ontology of Believability Credentials

Assess whether *Al Qaeda* has nuclear weapons: *likely*

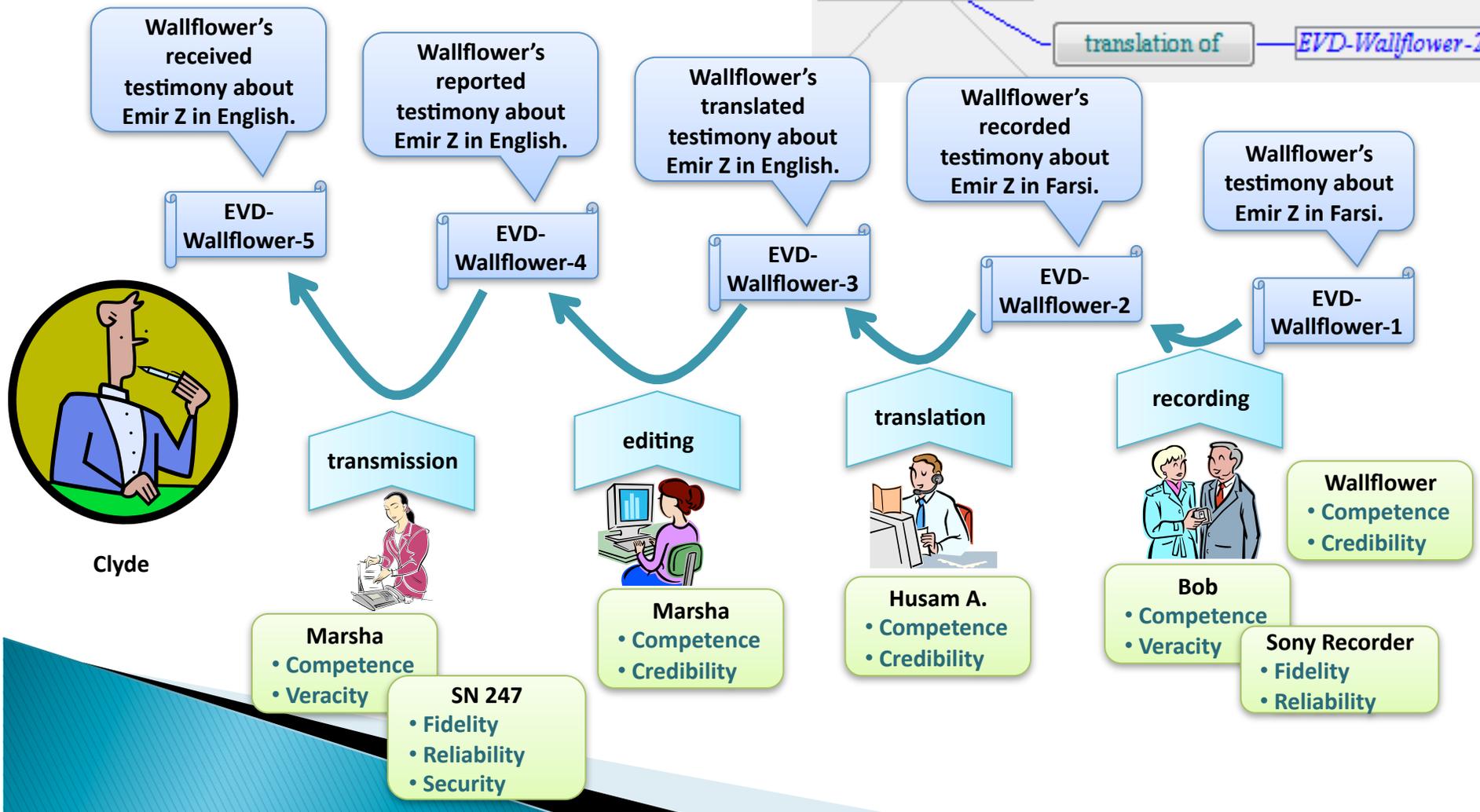
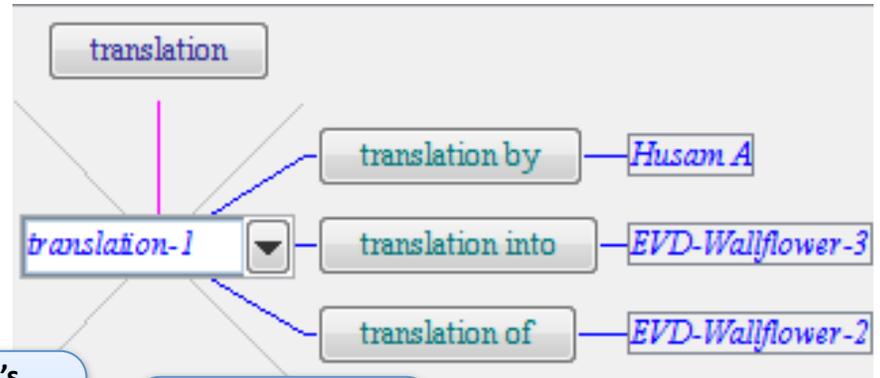
- + Deterrence as a reason: *an even chance*
- Self defense as a reason: *an even chance*
- Favoring evidence: *an even chance*
 - + EVD-Reuters-01-01c: *unlikely*
 - EVD-Dawn-Mir01-01c: *an even chance*
- Relevance: *almost certain*
- Believability: *an even chance*
 - Reporter *Hamid Mir*: *almost certain*
 - + Competence: *almost certain*
 - + Credibility: *almost certain*
 - Source *Osama bin Laden*: *an even chance*
 - + Competence: *almost certain*
 - Credibility: *an even chance*
 - Veracity: *an even chance*
 - Objectivity: *almost certain*
 - Observational sensitivity: *almost certain*
- Disfavoring evidence: *no evidence*



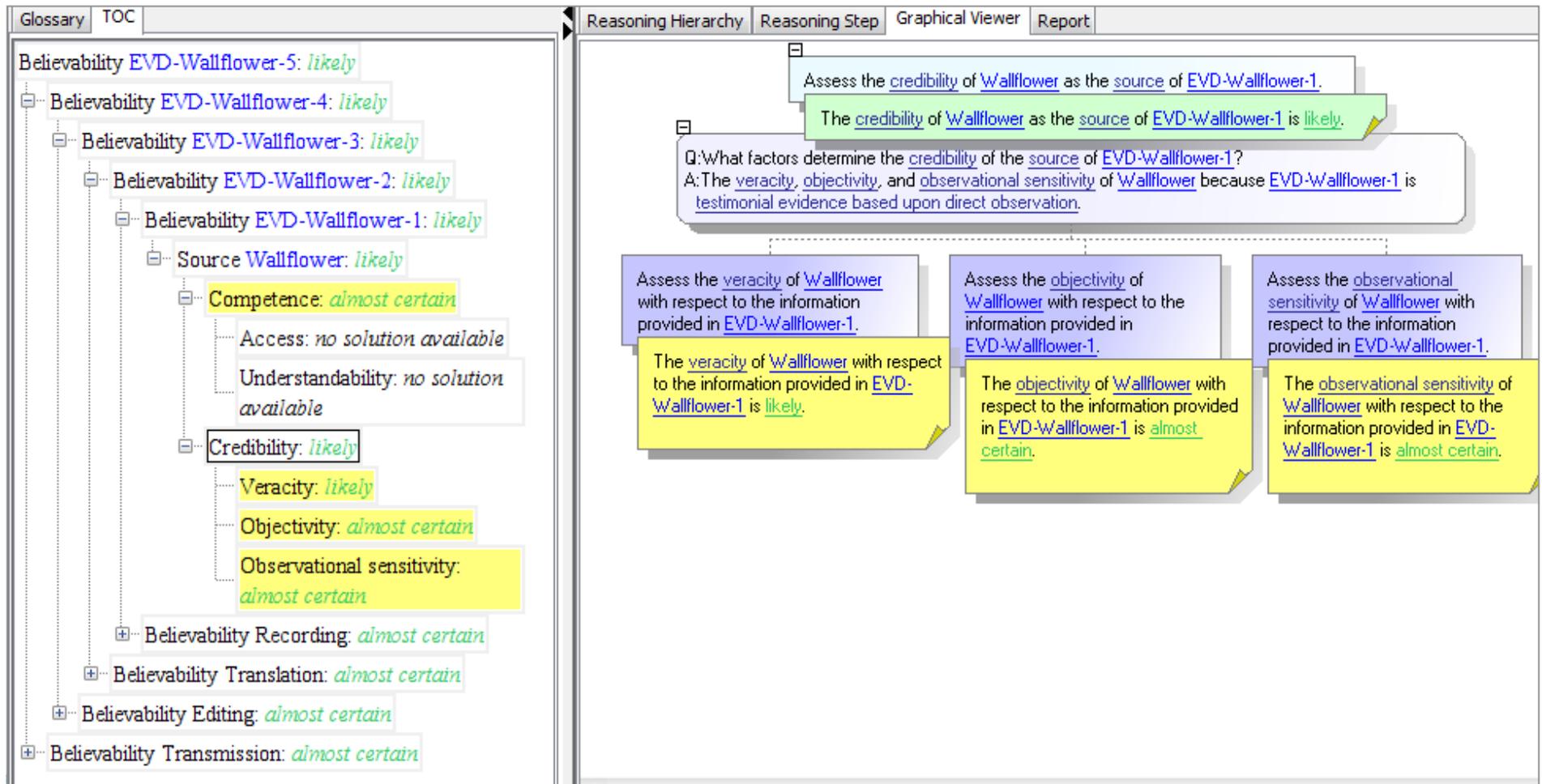
Assess the credibility of Osama bin Laden as the source of EVD-Dawn-Mir01-01c.
 The credibility of Osama bin Laden as the source of EVD-Dawn-Mir01-01c is an even chance.
 Q:What factors?
 A:The veracity, objectivity, and observational sensitivity of Osama bin Laden because EVD-Dawn-Mir01-01c is testimonial evidence based upon direct observation.

<p>Assess the <u>veracity</u> of <u>Osama bin Laden</u> with respect to the information provided in <u>EVD-Dawn-Mir01-01c</u>.</p> <p>The <u>veracity</u> of <u>Osama bin Laden</u> with respect to the information provided in <u>EVD-Dawn-Mir01-01c</u> is <u>an even chance</u>.</p>	<p>Assess the <u>objectivity</u> of <u>Osama bin Laden</u> with respect to the information provided in <u>EVD-Dawn-Mir01-01c</u>.</p> <p>The <u>objectivity</u> of <u>Osama bin Laden</u> with respect to the information provided in <u>EVD-Dawn-Mir01-01c</u> is <u>almost certain</u>.</p>	<p>Assess the <u>observational sensitivity</u> of <u>Osama bin Laden</u> with respect to the information provided in <u>EVD-Dawn-Mir01-01c</u>.</p> <p>The <u>observational sensitivity</u> of <u>Osama bin Laden</u> with respect to the information provided in <u>EVD-Dawn-Mir01-01c</u> is <u>almost certain</u>.</p>
---	---	---

Ontology of Actions for Chains of Custody



Analyzing the Chain of Custody



Assumption-based Reasoning

The screenshot displays the 'Assumption Assistant' software interface, which is divided into several functional areas:

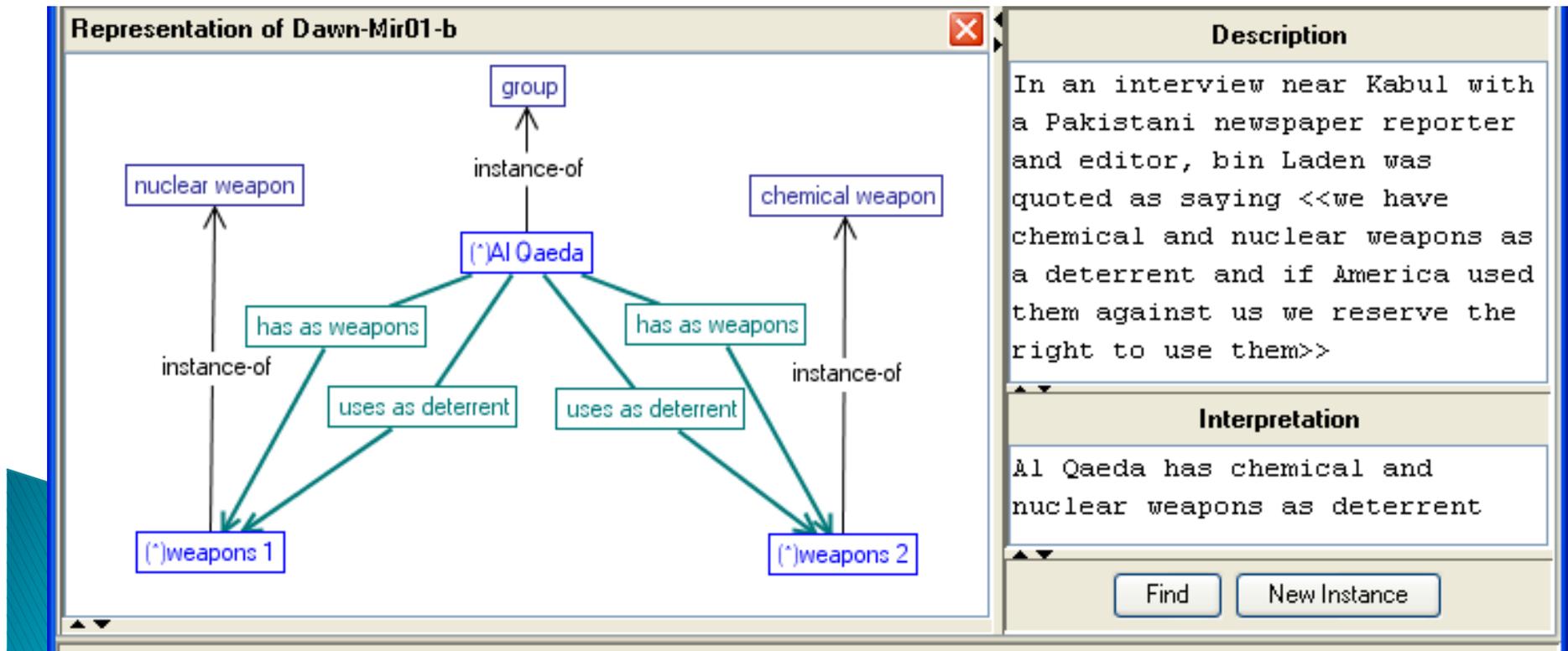
- Reasoning Hierarchy (Left Panel):** A tree view showing the structure of the reasoning process. The root is 'Believability EVD-Wallflower-5: unlikely', which branches into 'Believability EVD-Wallflower-4: unlikely', 'Believability EVD-Wallflower-3: unlikely', 'Believability EVD-Wallflower-2: likely', and 'Believability EVD-Wallflower-1: likely'. Further sub-nodes include 'Source Wallflower: likely', 'Believability Recording: almost certain', 'Believability Translation: unlikely', 'Believability Husam A: unlikely', 'Competence: almost certain', 'Credibility: unlikely', 'Veracity: unlikely', 'Objectivity: almost certain', 'Observational sensitivity: almost certain', 'Believability Editing: almost certain', and 'Believability Transmission: almost certain'.
- Reasoning Step (Middle Panel):** A graphical viewer showing a reasoning step: 'Assess the credibility of Husam A as the reporter of EVD-Wallflower-3'. A green box contains the statement: 'The credibility of Husam A as the reporter of EVD-Wallflower-3 is unlikely.' Below this, a blue box contains the text: 'A: The veracity, objectivity, and observational sensitivity of the'. Two yellow boxes provide supporting information: 'Assess the veracity of Husam A as the reporter of EVD-Wallflower-3. The veracity of Husam A as the reporter of EVD-Wallflower-3 is unlikely.' and 'Assess the objectivity of Husam A as the reporter of EVD-Wallflower-3. The objectivity of Husam A as the reporter of EVD-Wallflower-3 is almost certain.'
- Assumptions (Right Panel):** A list of assumptions with their status and justifications. The first assumption is 'The veracity of Husam A as the reporter of EVD-Wallflower-3 is almost certain.' with an unchecked 'Enabled' checkbox and a justification field 'J:'. The second assumption is 'The veracity of Husam A as the reporter of EVD-Wallflower-3 is unlikely.' with a checked 'Enabled' checkbox and a justification field 'J:'. Buttons for 'Modify', 'Save', and 'New' are visible at the bottom.



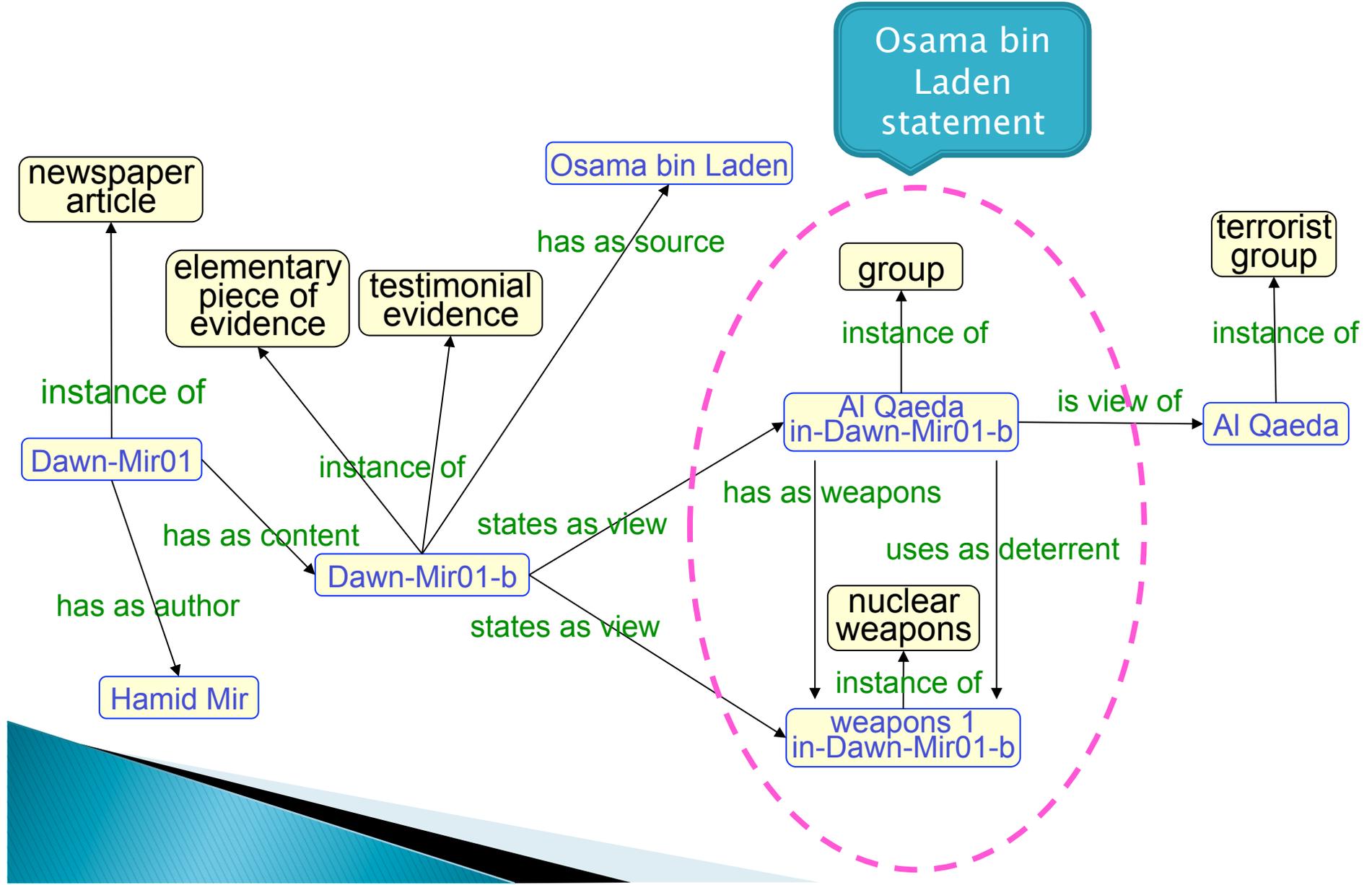
Representing the view of a human source

A statement made by Osama bin Laden

- ▶ represents his view
- ▶ should not interfere with other (maybe contradictory) statements made by other sources, or by the analyst who taught Disciple.



View representation



Tutoring: Lessons and ...



Lesson Fragment: Hypothesis support from a piece of evidence

Lesson: Hypothesis support from [piece of evidence](#).

Assess to what extent the [piece of evidence](#) favors the hypothesis.

The information provided by the [piece of evidence](#) and the extent to which it is believable.

Assess to what extent the [piece of evidence](#) favors the hypothesis, assuming that we believe the information provided by the [piece of evidence](#).

Assess the extent to which the information provided by the [piece of evidence](#) is believable.

The [piece of evidence](#) is [testimonial evidence obtained at second hand](#).

The [piece of evidence](#) is [testimonial evidence about tangible evidence](#).

Assess the [believability](#) the reporter of the [piece of evidence](#).

Assess the [believability](#) the source of the [piece of evidence](#).

Assess the [believability](#) the reporter of the [piece of evidence](#).

Assess the [credibility](#) of the [tangible evidence](#).

Assess the [believability](#) the [source](#) of the [piece of evidence](#).

Abstract reduction strategy

Illustrations: [Previous](#) [Next](#) **Select Example:** [EVD-Dawn-Mir01-02c](#) and [Al Qaeda](#)

Assess to what extent the piece of evidence [EVD-Dawn-Mir01-02c](#) favors the hypothesis that [Al Qaeda](#) considers deterrence as a reason to obtain [nuclear weapons](#).

Q: What factors determine how a piece of evidence favors a hypothesis?
A: The information provided by the piece of evidence and the extent to which it is believable.

Assess to what extent [EVD-Dawn-Mir01-02c](#) favors the hypothesis that [Al Qaeda](#) considers deterrence as a reason to obtain [nuclear weapons](#), assuming that we believe the information provided by [EVD-Dawn-Mir01-02c](#).

Assess the extent to which the information provided by [EVD-Dawn-Mir01-02c](#) is believable.

Q: How was [EVD-Dawn-Mir01-02c](#) obtained?
A: [EVD-Dawn-Mir01-02c](#) was obtained as testimonial evidence of [Osama bin Laden](#) cited in [EVD-Dawn-Mir01-02](#) by [Hamid Mir](#).

Assess the extent to which one can believe [Hamid Mir](#) as the reporter of [EVD-Dawn-Mir01-02](#).

Assess the extent to which one can believe [Osama bin Laden](#) as the source of [EVD-Dawn-Mir01-02c](#).

Automatically generated illustration of the abstract strategy

Tutoring: ... and Stories

Tutoring

Lesson: Hypothesis support from [piece of evidence](#).

Assess to what extent the [piece of evidence](#) favors the hypothesis.

The information provided by the [piece of evidence](#) and the extent to which it is believable.

Assess to what extent the [piece of evidence](#) favors the hypothesis, assuming that we believe the information provided by the [piece of evidence](#).

Assess the extent to which the information provided by the [piece of evidence](#) is believable.

The [piece of evidence](#) is [testimonial evidence obtained at second hand](#).

The [piece of evidence](#) is [testimonial evidence about tangible evidence](#).

The [piece of evidence](#) is [direct testimonial evidence](#).

Assess the [believability](#) the reporter of the [piece of evidence](#).

Assess the [believability](#) the source of the [piece of evidence](#).

Assess the [credibility](#) of the [tangible evidence](#).

Assess the [believability](#) the [source](#) of the [piece of evidence](#).

Veracity

Veracity
by David Schum, George Mason University

Veracity is an attribute of the **credibility** of human sources of **testimonial evidence**. The term veracity is **truthfulness**. Is this human source being truthful in his report? A source is being truthful only if the event(s) he reported did actually occur. That may involve a human source's **credibility**; we will explore these other reasons later. The issue is concerned is whether this source believes what he is reporting to us. This requires us to believe that he has deliberately told us something that was contrary to what he believed. This source was told what to tell us by someone else. In this second case, the source is necessarily lying to us; he is simply relaying to us what others have said he should tell us. In either case, this source is untruthful. In short, untruthfulness and deception go hand in hand.

Here is a **source** who tells us that he observed a certain event to have occurred. Is he necessarily lying to us? The answer is no, for the following reasons. This source is not necessarily lying to us; he is simply relaying to us what others have said he should tell us. In either case, this source is untruthful. In short, untruthfulness and deception go hand in hand.

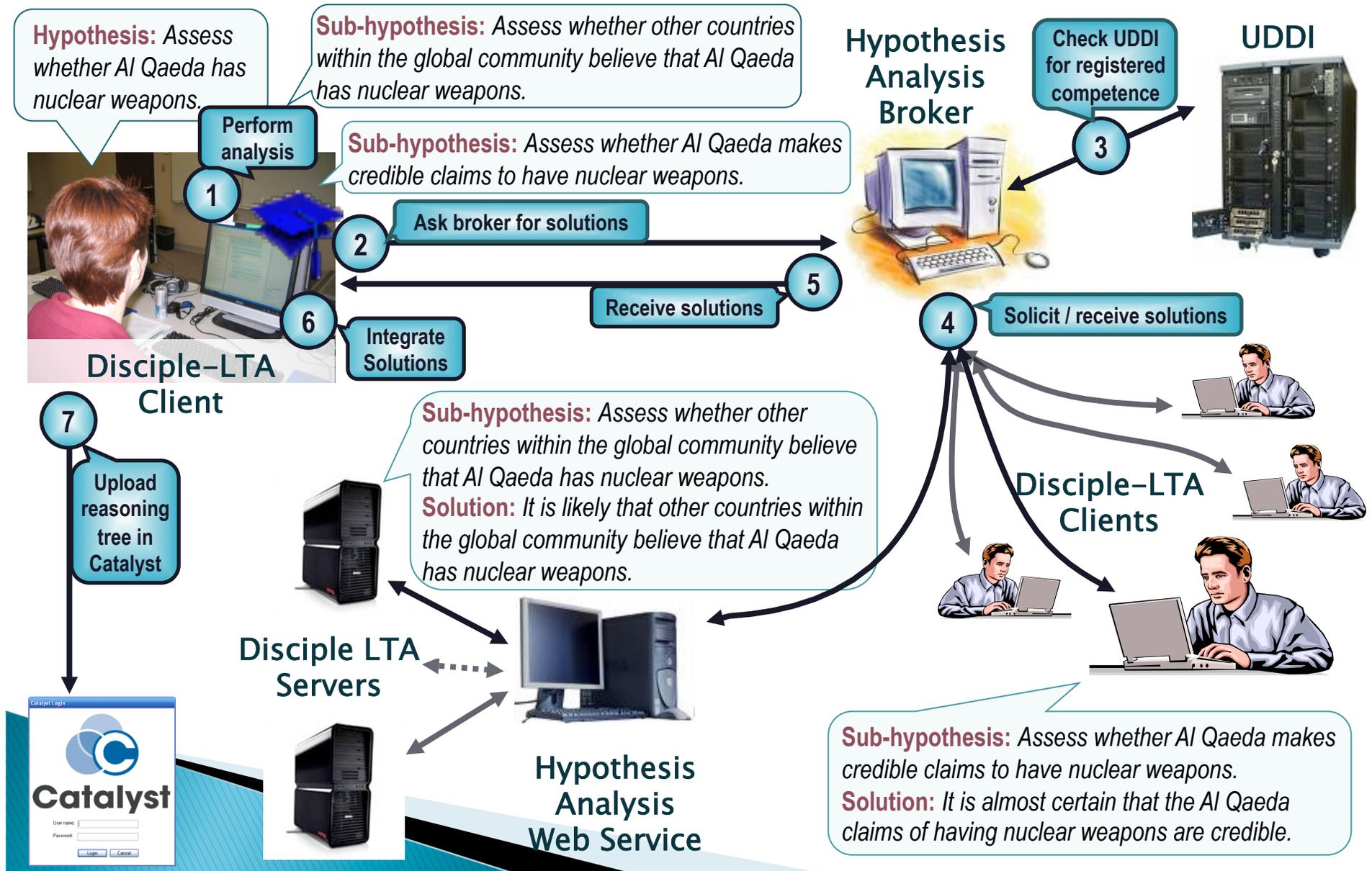
Assess to what extent the [piece of evidence](#) favors the hypothesis that [Al Qaeda](#) considers deterrence as a reason to obtain [nuclear weapons](#), assuming that we believe the information provided by [EVD-Dawn-Mir01-02c](#).

Q: What factors determine how a piece of evidence favors the hypothesis?
A: The information provided by the [piece of evidence](#).

Q: How does the [piece of evidence](#) favor the hypothesis?
A: [EVD-Dawn-Mir01-02c](#).

Assess the extent to which [EVD-Dawn-Mir01-02c](#) favors the hypothesis.

Ontology in Service Oriented Architecture



Support for Learning Expert Analysis



1. The analyst extends the analysis logic

Assess whether there are states with nuclear weapons that may be willing to sell nuclear weapons to Al Qaeda.

Which is a nuclear state?
North Korea

Assess whether North Korea may be willing to sell nuclear weapons to Al Qaeda.

What might be a possible reason for North Korea to sell nuclear weapons to Al Qaeda?
United States is perceived as a common enemy of North Korea and Al Qaeda.

Assess to what extent the perception that United States is a common enemy of North Korea and Al Qaeda might be a good reason for North Korea to sell nuclear weapons to Al Qaeda.

2. Disciple learns reasoning rules



Learned Rule

DECOMPOSITION RULE DDR.0

IF: Assess whether there are states with nuclear weapons that may be willing to sell nuclear weapons to ?O1.

Q:	Which is a nuclear state?	
A:	?O2	

MAIN CONDITION

Var	Lower Bound	Upper Bound
?O1	(terrorist group)	(actor)
?O2	(nuclear state)	(nuclear state)

THEN: Assess whether ?O2 may be willing to sell nuclear weapons to ?O1.

To assess whether there are states that may be willing to sell nuclear weapons to an actor, one has to consider each nuclear state and assess whether that state may be willing to sell nuclear weapons to that actor.

Learned Rule

DECOMPOSITION RULE DDR.1

IF: Assess whether ?O1 may be willing to sell nuclear weapons to ?O2.

Q:	What might be a possible reason for ?O1 to sell nuclear weapons to ?O2?	
A:	?O3 is perceived as a common enemy of ?O1 and ?O2.	

Var	Lower Bound	Upper Bound
?O1	(actor)	(actor)
?O2	(actor)	(actor)
?O3	(superior)	(superior)

Var	Relationship	var
?O1	perceives as enemy	?O3
?O2	perceives as enemy	?O3

THEN: Assess to what extent the perception that ?O3 is a common enemy of ?O1 and ?O2 might be a good reason for ?O1 to sell nuclear weapons to ?O2.

Support for Problem Solving



Reasoning type: Reduction Reasoning mode: Modeling Plausibility: medium

Reasoning Hierarchy Reasoning Step Graphical Viewer Report

Assess whether there are states with nuclear weapons willing to sell nuclear weapons to Al Qaeda.

- Which is a nuclear state?
North Korea
 - Assess whether North Korea is willing to sell nuclear weapons to Al Qaeda.
- Which is a nuclear state?
France
 - Assess whether France is willing to sell nuclear weapons to Al Qaeda.
- Which is a nuclear state?
India
 - Assess whether India is willing to sell nuclear weapons to Al Qaeda.
- Which is a nuclear state?
Iran
 - Assess whether Iran is willing to sell nuclear weapons to Al Qaeda.
- Which is a nuclear state?
Israel
 - Assess whether Israel is willing to sell nuclear weapons to Al Qaeda.
- Which is a nuclear state?
Pakistan
 - Assess whether Pakistan is willing to sell nuclear weapons to Al Qaeda.

Rule Viewer

DECOMPOSITION RULE DDR.00104 FORMAL DESCRIPTION

IF: Assess whether there are states with nuclear weapons that may be willing to sell nuclear weapons to ?O1.

Q:	Which is a nuclear state?
A:	?O2

MAIN CONDITION

Var	Lower Bound	Upper Bound
?O1	(terrorist group)	(actor)
?O2	(nuclear state)	(nuclear state)

THEN: Assess whether ?O2 may be willing to sell nuclear weapons to ?O1.

Support for Refining Expert Analysis



2. The analyst critiques the reasoning

1. Disciple applies the learned rule

3. Disciple-LTA refines the rule with an except-when condition



This is wrong!
France will not sell nuclear weapons to Al Qaeda because it perceives it as an enemy.

Assess whether there are states with nuclear weapons willing to sell nuclear weapons to Al Qaeda.

- Which is a nuclear state?
North Korea
- Assess whether North Korea is willing to sell nuclear weapons to Al Qaeda.
- Which is a nuclear state?
France
- Assess whether France is willing to sell nuclear weapons to Al Qaeda.
- Which is a nuclear state?
India
- Assess whether India is willing to sell nuclear weapons to Al Qaeda.
- Which is a nuclear state?
Iran
- Assess whether Iran is willing to sell nuclear weapons to Al Qaeda.
- Which is a nuclear state?
Israel
- Assess whether Israel is willing to sell nuclear weapons to Al Qaeda.
- Which is a nuclear state?
Pakistan
- Assess whether Pakistan is willing to sell nuclear weapons to Al Qaeda.

To assess whether there are states that may be willing to sell nuclear weapons to an actor, one has to consider each nuclear state and assess whether that state may be willing to sell nuclear weapons to that actor, **except for** the case in which the nuclear state is an enemy of that actor.

Rule Viewer

Refined Rule LE DDR.00205 FORMAL

DESCRIPTION

IF: Assess whether there are states with nuclear weapons willing to sell nuclear weapons to ?O1.

Q:	Which is a nuclear state?
A:	?O2

MAIN CONDITION

Var	Lower Bound	Upper Bound
?O1	(terrorist group)	(actor)
?O2	(nuclear state)	(nuclear state)

EXCEPT WHEN CONDITION 1

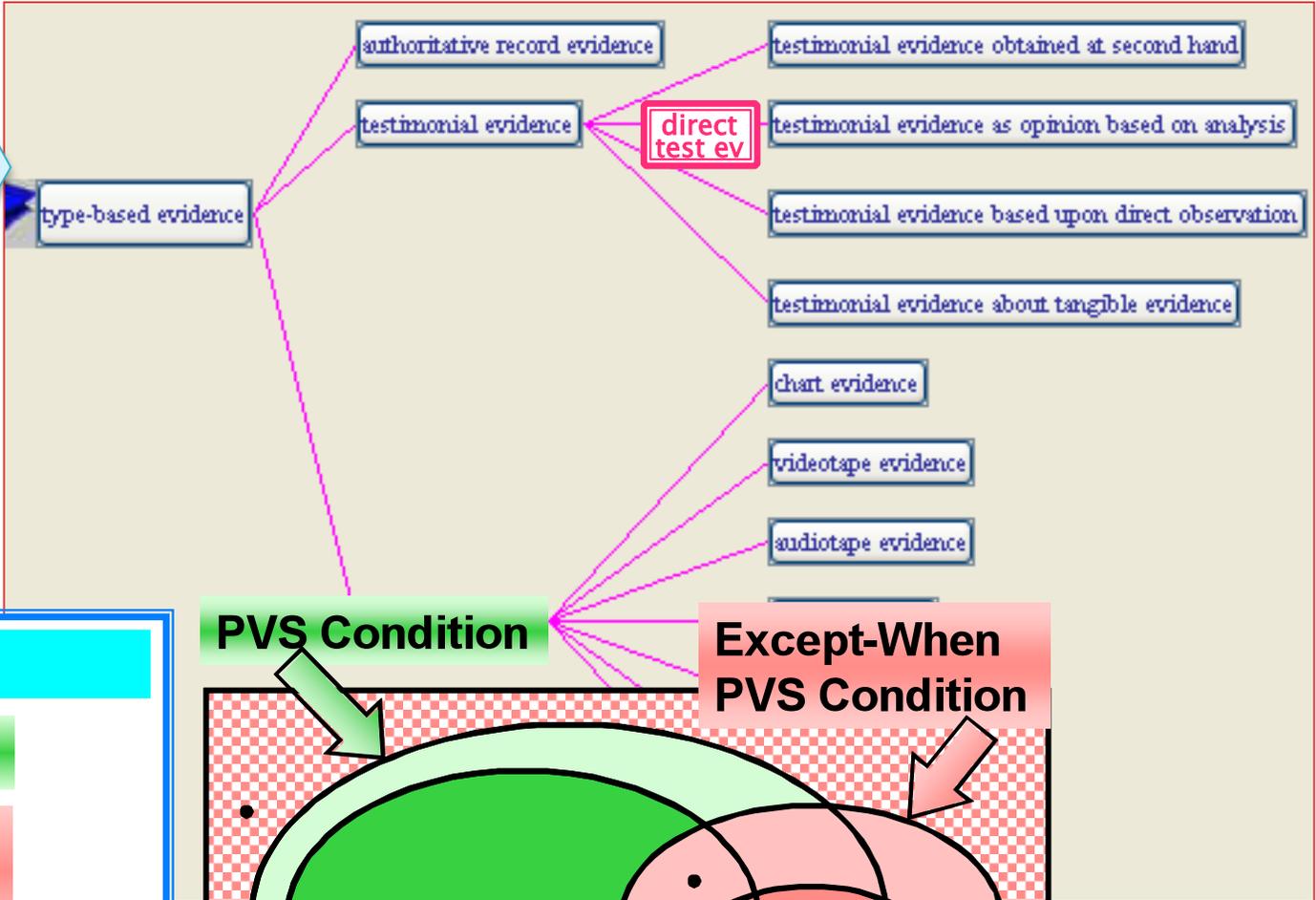
Var	Lower Bound	Upper Bound
?O2	(nuclear state)	(actor)
?O1	(terrorist group)	(actor)

Var	Relationship	Var
?O2	perceives as enemy	?O1

THEN: Assess whether ?O2 is willing to sell nuclear weapons to ?O1.

Evolving representation space

Continuous adaptation of the previously learned rules to the evolution of the ontology.



IF <Problem>

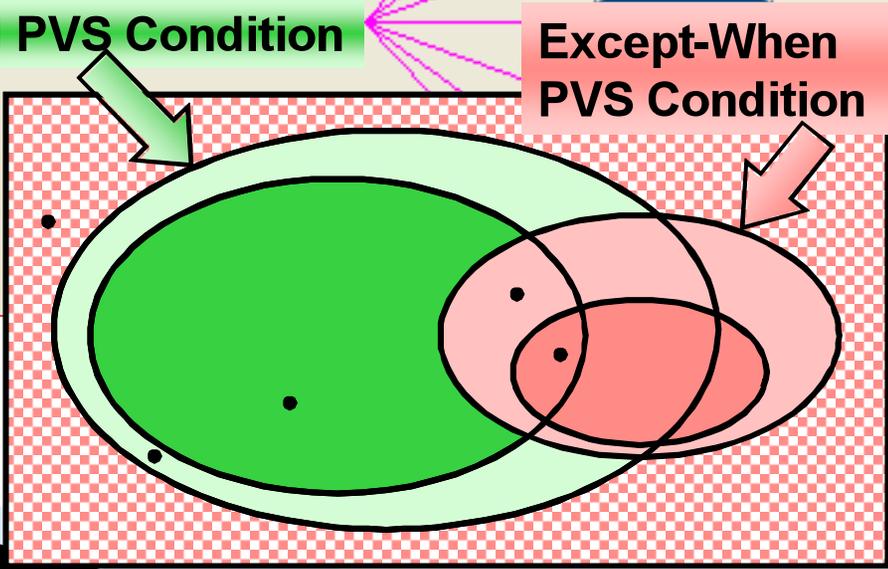
PVS Condition

Except-When PVS Condition

THEN <Subproblem 1>

...

<Subproblem m>



Summary and experimentation remarks

Analytic Assistance

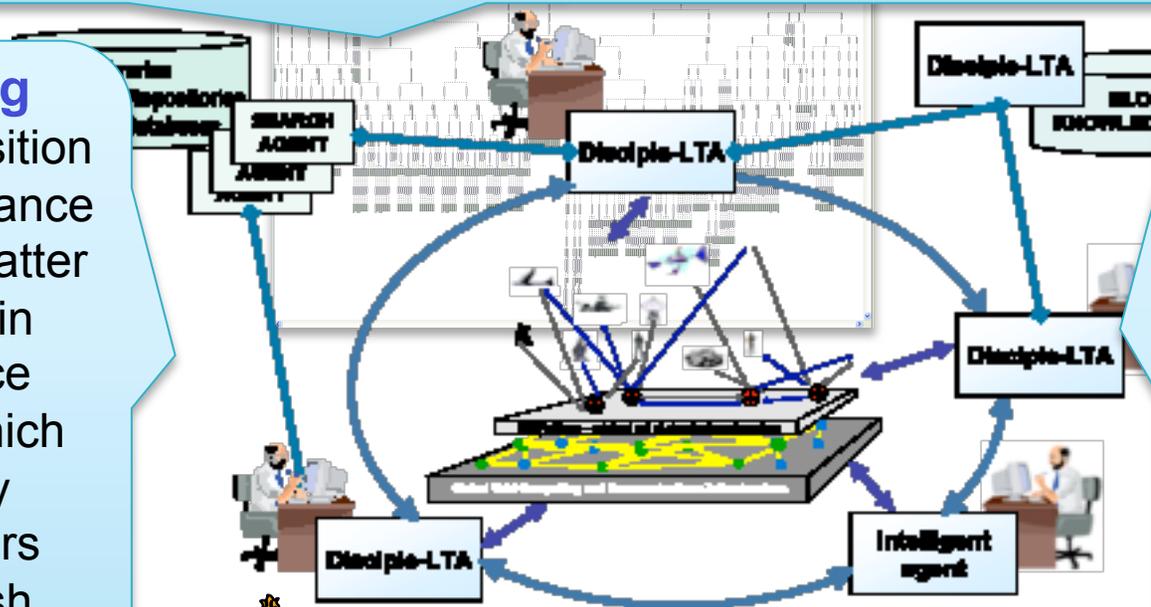
Empowers the analysts through mixed-initiative reasoning for hypotheses analysis, collaboration with other analysts and experts, and sharing of information.

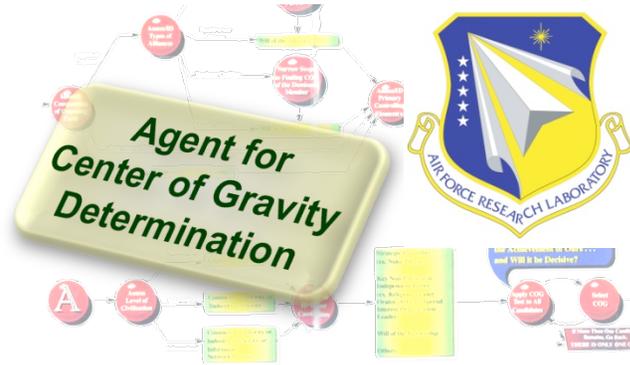
Learning

Rapid acquisition and maintenance of subject matter expertise in intelligence analysis which currently takes years to establish, is lost when experts separate from service, and is costly to replace.

Tutoring

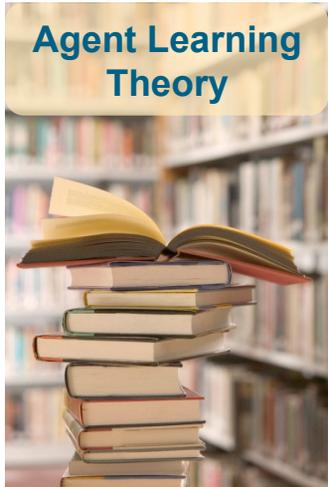
Helps new intelligence analysts learn the reasoning processes involved in making intelligence judgments and solving intelligence analysis problems.



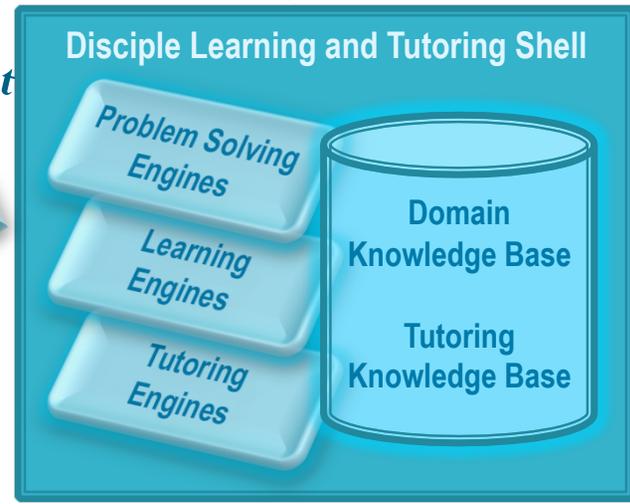


Agent for Hypothesis Analysis

The graphic features a yellow box with the title 'Agent for Hypothesis Analysis' and a radiation symbol. Below the box is a map of the Middle East with a radiation symbol overlaid on it. To the right is the logo of the United States Intelligence Community.



Critical requirement for a new generation of cognitive assistants



- Expertise modeling
- Multistrategy learning
- Mixed-initiative reasoning
- Reasoning with uncertainty

Agent for PhD Advisor Assessment

Agent for Web Believability Assessment

Two yellow boxes with titles are shown over a background image of a classroom with students at desks.

Agent for Financial Regulations

NSF

STTR Phase II

The graphic features a yellow box with the title 'Agent for Financial Regulations' and a radiation symbol. Below it is the NSF logo and the text 'STTR Phase II' over a background of US dollar bills.

