

# Linguistic Ranking of Terrorist Scenarios using Belief and Approximate Reasoning

SAND 2007-XXXXC

Risk Symposium 2007  
**Risk Analysis for Homeland Defense and Security :  
Theory and Application**

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# Acknowledgments

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- **Linguistic Approach**
  - Logic Evolved Decision (LED) Methodology developed at Los Alamos National Laboratory by Terry Bott and Steve Eisenhower
  - Belief/Plausibility measure of uncertainty added
- **Belief/Plausibility Measure of Uncertainty**
  - Work and suggestions from Jon Helton, Arizona State University
- **Belief/Plausibility for Fuzzy Sets**
  - Ronald Yager, Iona College, New Rochelle, NY
- **Advanced Concepts Group at Sandia National Laboratories**
  - LDRD, under direction of John C. Cummings



# Background

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- **Adversary/Defender Model**
  - Each has different goals and different states of knowledge
    - Adversary is the Threat
    - Defender knows Vulnerability and Consequence given a Threat
- Linguistic Model for Selecting Adversary Threat Scenarios
- Numerical Model for Defender for Evaluating Risk from Threat Scenarios
- Darby, J., “Evaluation of Risk from Acts of Terrorism: The Adversary/Defender Model Using Belief and Fuzzy Sets”, SAND2006-5777, Sandia National Laboratories, Albuquerque, NM, Sept., 2006



# Threat

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- Threat Modeled as a **Scenario**
  - Target
  - Desired Consequences
  - Resources
    - Attributes (numbers, equipment, weapons)
    - Knowledge (readily available, reconnaissance, insiders)
- Effectiveness of Security Depends on Scenario
- Which Scenarios?



# Scenario Model

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- **Evaluate and Rank Scenarios based on Risk**
  - Risk a function of:
    - **Threat** (likelihood of scenario and resources for scenario)
    - **Vulnerability** (likelihood security system prevents consequence given the threat scenario)
    - **Consequence** (magnitude of result given security system fails)
- Threat evaluated from perspective of Adversary
- Vulnerability and Consequence evaluated from perspective of Defender



# Uncertainty

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- **Scenarios have considerable epistemic uncertainty**
  - Adversary intentionally selects scenarios, Defender has poor state-of-knowledge of these scenarios
- **Use Belief/Plausibility Measure of Uncertainty**
  - Considers epistemic uncertainty
  - Reduces to Probability as special case



# Linguistic Approach

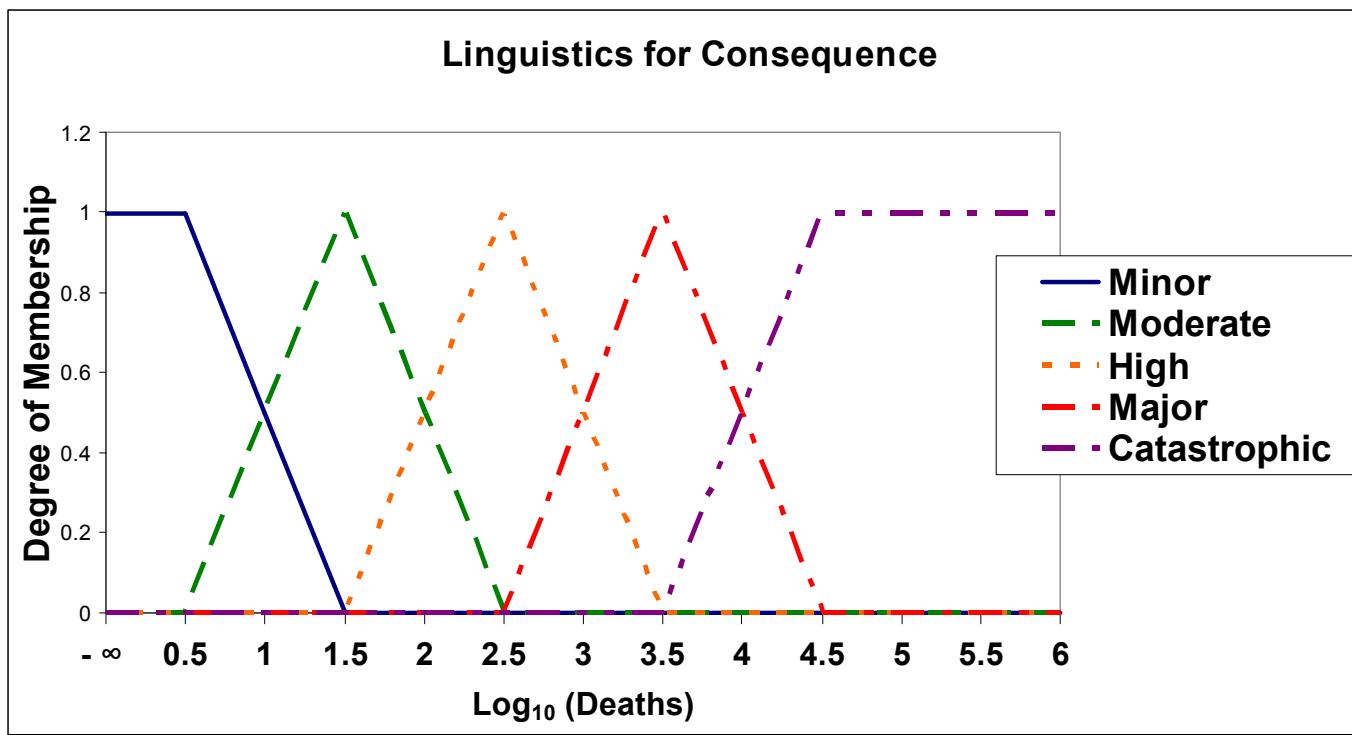
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- Not all variables are numeric
  - Consequences – some numeric, some not numeric
    - Casualties – numeric
    - Economic Loss – numeric
    - Damage to National Security – not numeric
- Each Variable comprised of Fuzzy Sets
  - Fuzzy Sets are linguistics (words)
    - Some numeric
    - Some not
- Variables are combined Linguistically
  - Approximate Reasoning Rule Base for Combining Fuzzy Sets
- Belief/Plausibility for Uncertainty based on Evidence assigned to Fuzzy Sets

# Fuzzy Sets

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- Some Variables are numeric, such as Deaths





# Fuzzy Sets

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- Some Variables are not numeric, such as **Adversary Technical Capability**
  - Low Level
  - Bachelor of Science Level
  - Advanced Level
- Treat All Fuzzy Sets as Linguistic
- Combine Variables with an Approximate Reasoning Rule Base on the Fuzzy Sets
  - Approximate Reasoning specifies the Mathematics for Combining Linguistics



# Implementation

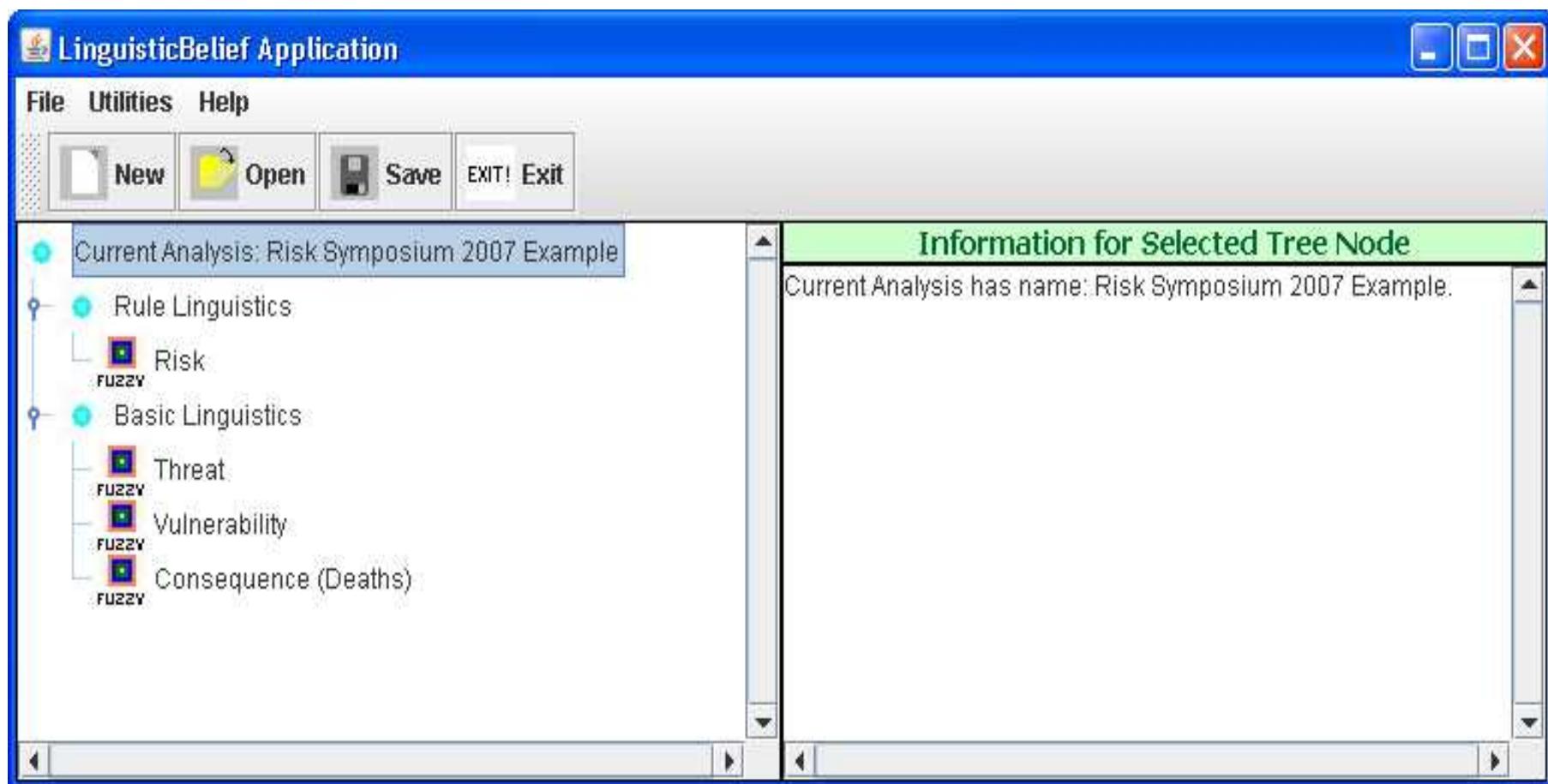
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- **LinguisticBelief Java application**
  - Darby, J., “LinguisticBelief: A Java Application for Linguistic Evaluation using Belief, Fuzzy Sets, and Approximate Reasoning”, SAND2007-XXXX, Sandia National Laboratories, Albuquerque, NM, to be published
  - Not restricted to evaluation of threat scenarios



# Simple Example

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## Modify Basic Linguistic: Consequence (Deaths)

## Fuzzy Sets:

Minor (less than about 100)

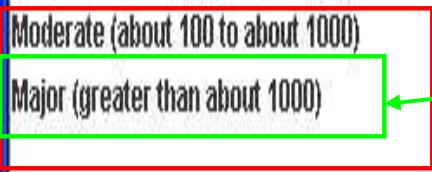
Moderate (about 100 to about 1000)

Major (greater than about 1000)

## Focal Elements:

Moderate (about 100 to about 1000) &amp; Major (greater than about 1000), has evidence 8.000e-01.

Major (greater than about 1000), has evidence 2.000e-01.

A red rectangular box highlights the "Moderate (about 100 to about 1000)" and "Major (greater than about 1000)" entries in the Fuzzy Sets list.  
Rename Selected Fuzzy Set

Delete Selected Fuzzy Set

Delete Selected Focal Element

Cancel

## Rules for selected RuleLinguistic



## Rules for RuleLinguistic: Risk

Fuzzy Set for Input Linguistic: Threat	Fuzzy Set for Input Linguistic: Vulnerability	Fuzzy Set for Input Linguistic: Consequen...	Output Fuzzy Set for Rule (blank if rule not ...)
Unlikely	Very Vulnerable	Minor (less than about 100)	Low
Unlikely	Very Vulnerable	Moderate (about 100 to about 1000)	Low
Unlikely	Very Vulnerable	Major (greater than about 1000)	Medium
Unlikely	Moderately Vulnerable	Minor (less than about 100)	Low
Unlikely	Moderately Vulnerable	Moderate (about 100 to about 1000)	Low
Unlikely	Moderately Vulnerable	Major (greater than about 1000)	Low
Unlikely	Not Very Vulnerable	Minor (less than about 100)	Low
Unlikely	Not Very Vulnerable	Moderate (about 100 to about 1000)	Low
Unlikely	Not Very Vulnerable	Major (greater than about 1000)	Low
Credible	Very Vulnerable	Minor (less than about 100)	Low
Credible	Very Vulnerable	Moderate (about 100 to about 1000)	Medium
Credible	Very Vulnerable	Major (greater than about 1000)	Medium
Credible	Moderately Vulnerable	Minor (less than about 100)	Low
Credible	Moderately Vulnerable	Moderate (about 100 to about 1000)	Low
Credible	Moderately Vulnerable	Major (greater than about 1000)	Medium
Credible	Not Very Vulnerable	Minor (less than about 100)	Low
Credible	Not Very Vulnerable	Moderate (about 100 to about 1000)	Low
Credible	Not Very Vulnerable	Major (greater than about 1000)	Low
Likely	Very Vulnerable	Minor (less than about 100)	Medium
Likely	Very Vulnerable	Moderate (about 100 to about 1000)	Medium
Likely	Very Vulnerable	Major (greater than about 1000)	High
Likely	Moderately Vulnerable	Minor (less than about 100)	Low
Likely	Moderately Vulnerable	Moderate (about 100 to about 1000)	Low
Likely	Moderately Vulnerable	Major (greater than about 1000)	Medium
Likely	Not Very Vulnerable	Minor (less than about 100)	Low
Likely	Not Very Vulnerable	Moderate (about 100 to about 1000)	Low
Likely	Not Very Vulnerable	Major (greater than about 1000)	Low

Specify Output Fuzzy Set for Selected Rule Choices Are: ▾

Accept Rules as Shown

Cancel

## Current Analysis: Risk Symposium 2007 Example. Linguistic: Risk

### BELIEF AND PLAUSIBILITY FOR FUZZY SETS:

Low has [Belief, Plausibility] interval of: [0.000, 1.000]

Medium has [Belief, Plausibility] interval of: [0.000, 1.000]

High has [Belief, Plausibility] interval of: [0.000, 0.300]

### FOCAL ELEMENTS:

Low & Medium & High. Evidence is: 3.000e-01.

Low & Medium. Evidence is: 7.000e-01.

### Select Family of Fuzzy Sets for [Belief, Plausibility] Interval Calculation

Low

Medium

High

Calculate [Belief, Plausibility] interval for Selected Family of Fuzzy Sets

[7.000e-01, 1.000e+00]

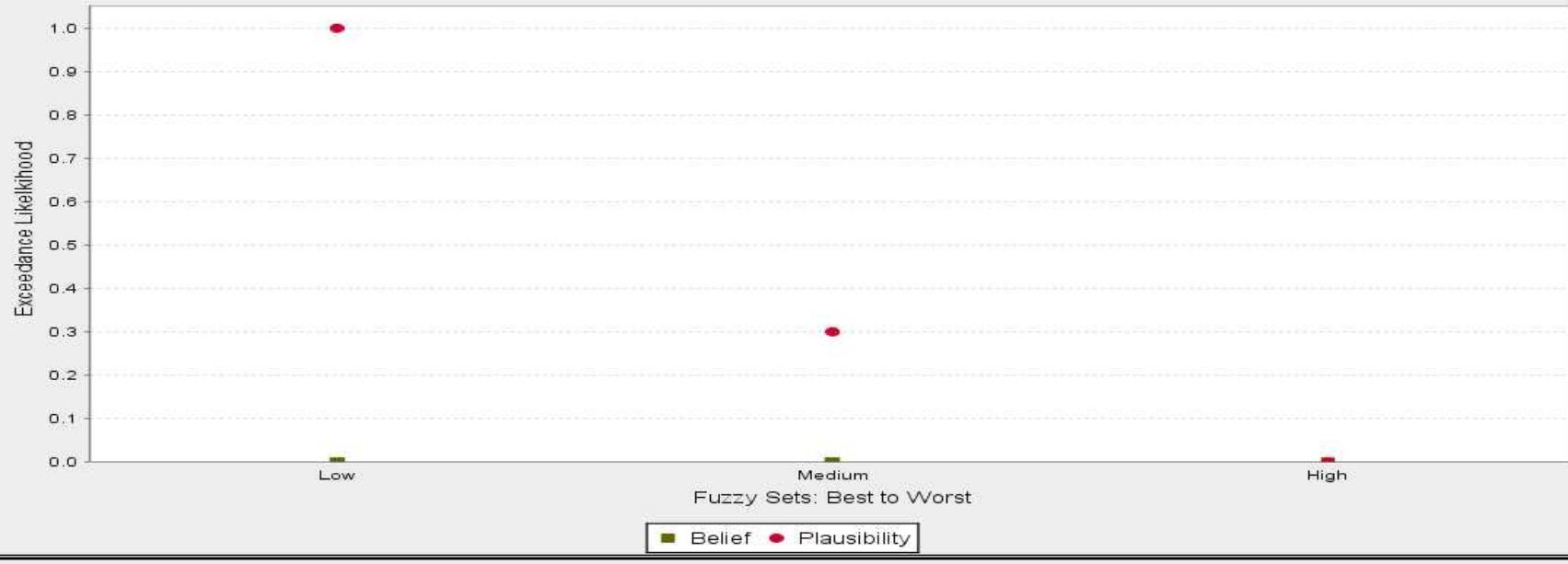
Plot Results

Cancel

### Belief/Plausibility Function



### Complementary Cumulative Belief/Plausibility Function



OK

es

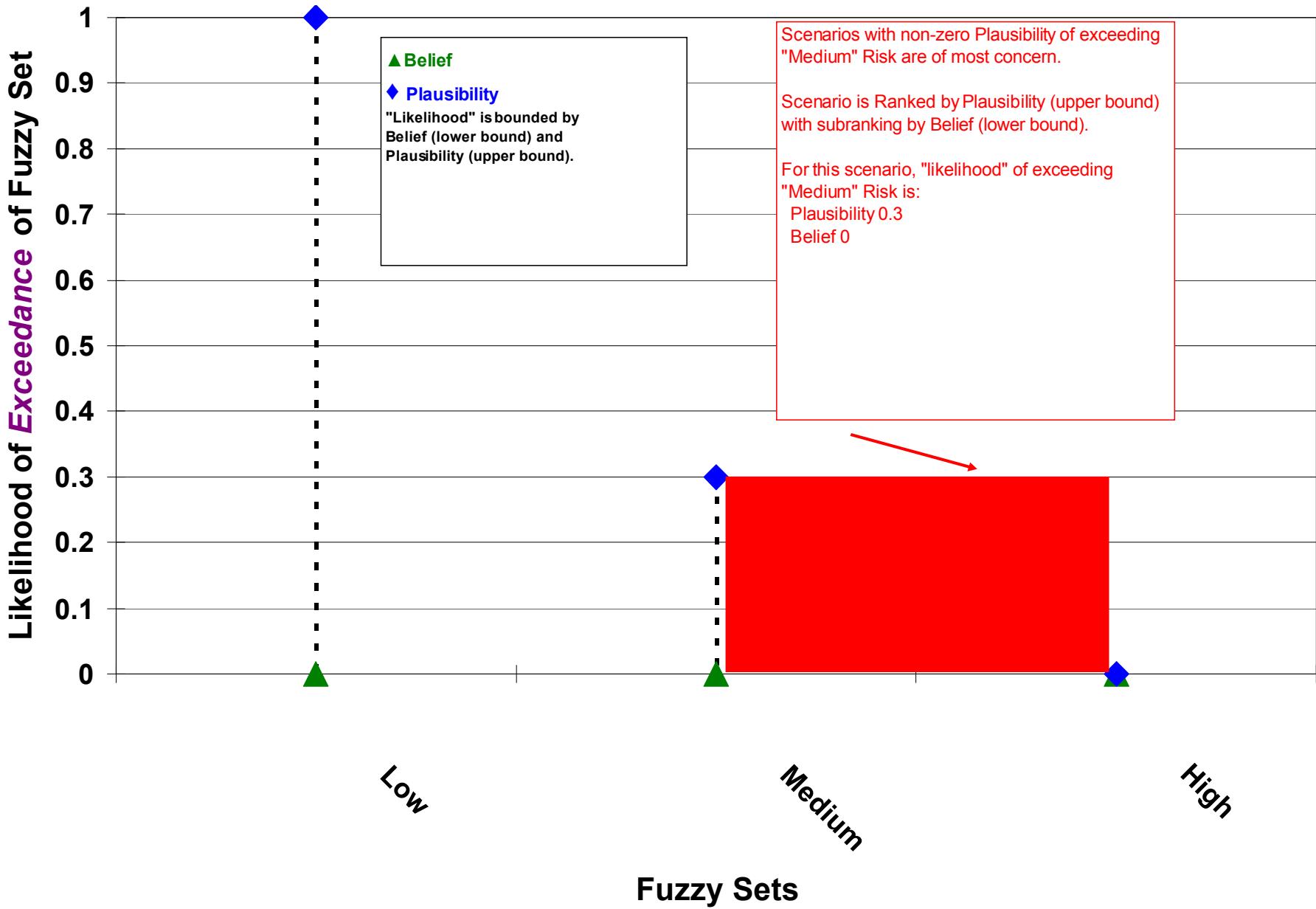


# Ranking Scenarios

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- Rank by Highest Plausibility of Exceeding Worst Fuzzy Set
  - Subrank by Belief if equal Plausibility

# Risk





# Example Application

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- **Risk Evaluation Process, 2005**
  - Manual Process by International team
  - CBRNE: Chemical, Biological, Radionuclide (dispersal), Nuclear, Explosive (conventional)
- **Implemented in LinguisticBelief**
  - Evaluated 5 Scenarios

LinguisticBelief Application

File Utilities Help

New Open Save EXIT! Exit

Current Analysis: CBRNE\_1B

Rule Linguistics

- Potential Impact
- Relative Technical Feasibility
- Vulnerability
- Risk Level

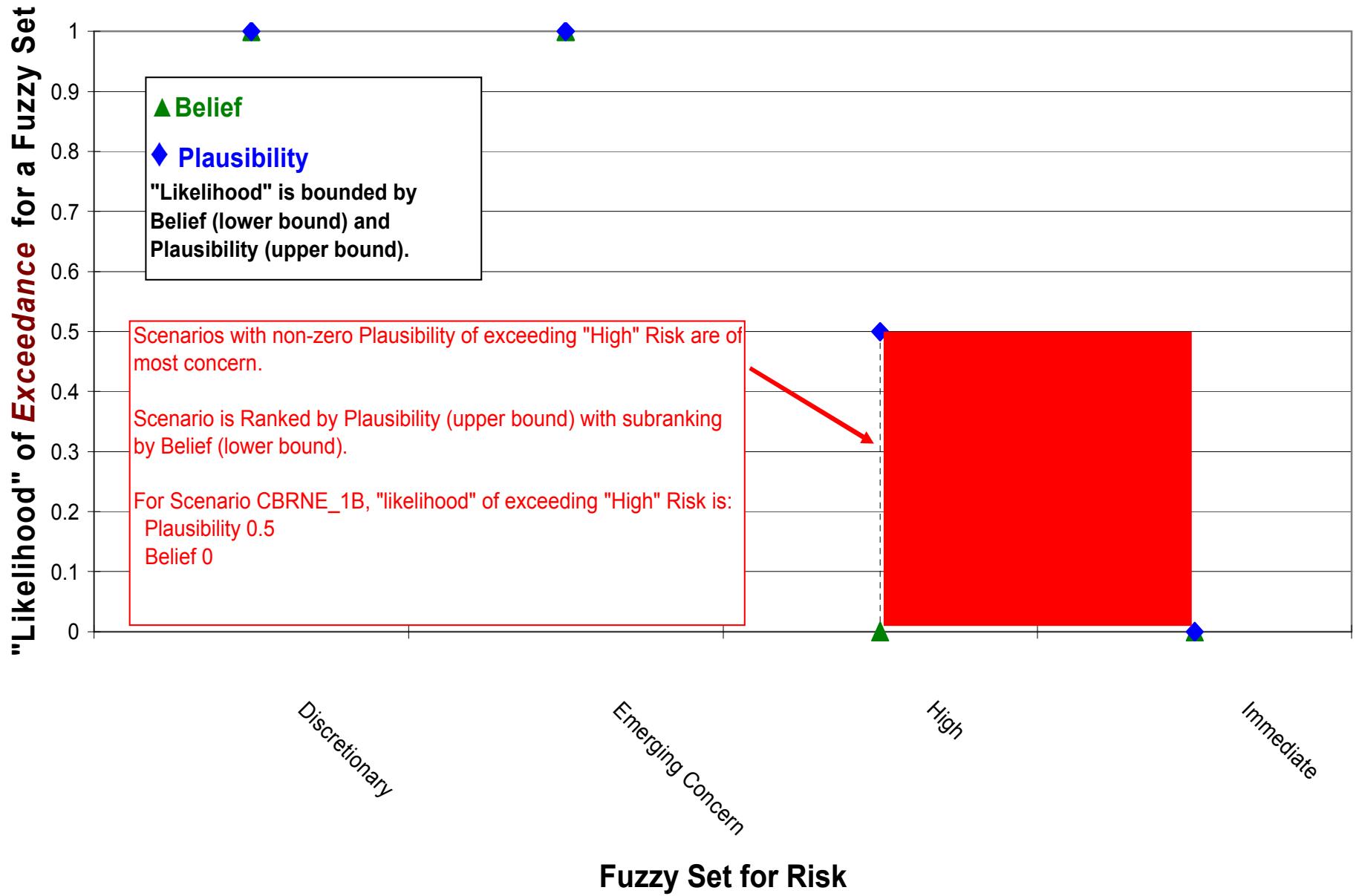
Basic Linguistics

- Material
- Equipment
- Technical Expertise
- Knowledge
- Dead/Injured
- Disruption of Capability/Capacity
- Economic Loss
- Intensity of Response
- Intelligence Judgment

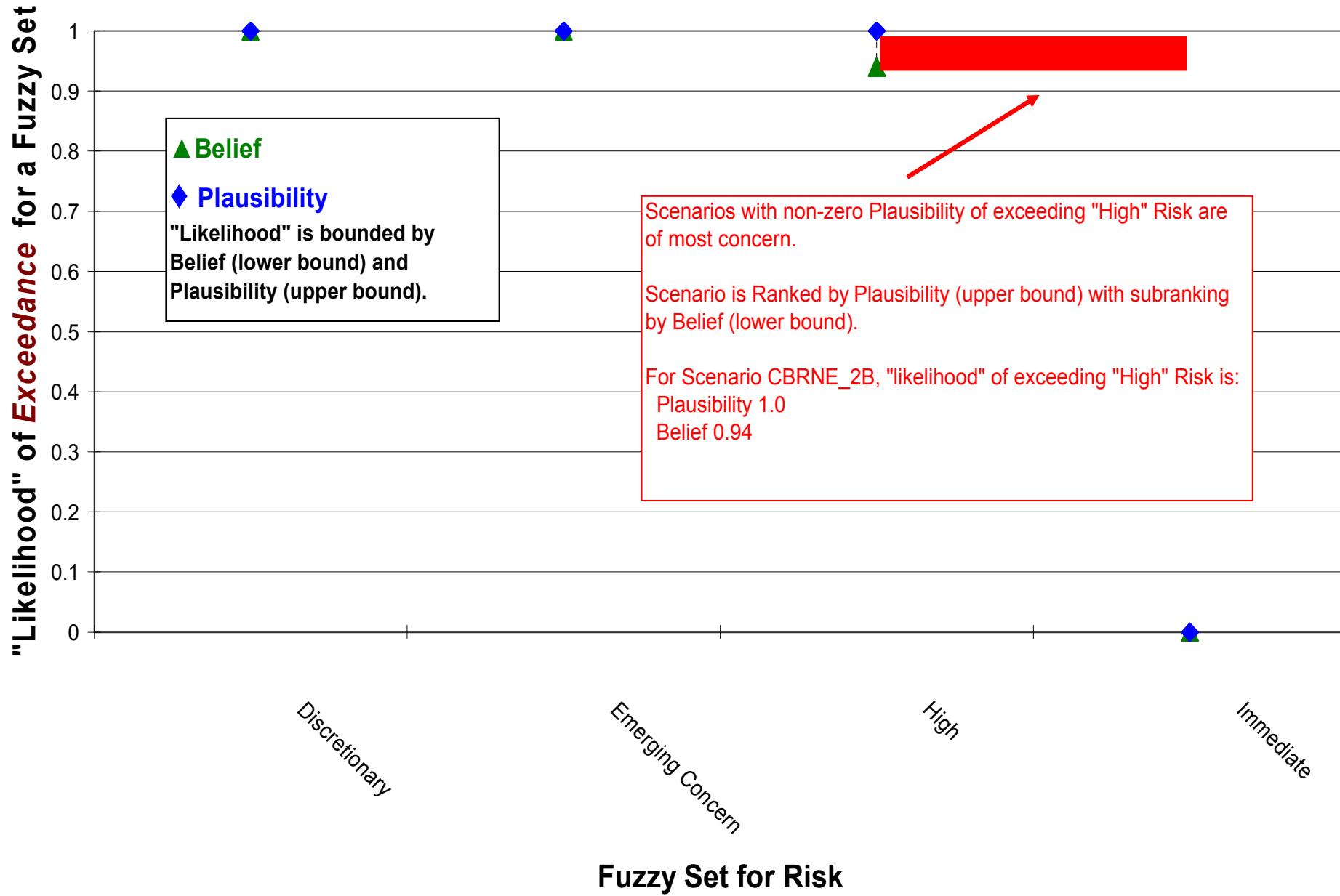
Information for Selected Tree Node

For the Rule Linguistic Risk Level the Fuzzy Sets are as follows: Discretionary, Emerging Concern, High, Immediate, . The input linguistics are as follows: Vulnerability, Intelligence Judgment, . The Rules are as follows: \* Rule input fuzzy sets: Extreme, Likely, -- Rule output fuzzy set: Immediate\*, \* Rule input fuzzy sets: Extreme, Emerging, -- Rule output fuzzy set: Immediate\*, \* Rule input fuzzy sets: Extreme, Possible, -- Rule output fuzzy set: High\*, \* Rule input fuzzy sets: Extreme, Unlikely, -- Rule output fuzzy set: Emerging Concern\*, \* Rule input fuzzy sets: High, Likely, -- Rule output fuzzy set: Immediate\*, \* Rule input fuzzy sets: High, Emerging, -- Rule output fuzzy set: High\*, \* Rule input fuzzy sets: High, Possible, -- Rule output fuzzy set: High\*, \* Rule input fuzzy sets: High, Unlikely, -- Rule output fuzzy set: Discretionary\*, \* Rule input fuzzy sets: Moderate, Likely, -- Rule output fuzzy set: High\*, \* Rule input fuzzy sets: Moderate, Emerging, -- Rule output fuzzy set: Emerging Concern\*, \* Rule input fuzzy sets: Moderate, Possible, -- Rule output fuzzy set: Emerging Concern\*, \* Rule input fuzzy sets: Moderate, Unlikely, -- Rule output fuzzy set: Discretionary\*, \* Rule input fuzzy sets: Low, Likely, -- Rule output fuzzy set: Emerging Concern\*, \* Rule input fuzzy sets: Low, Emerging, -- Rule output fuzzy set: Discretionary\*, \* Rule input fuzzy sets: Low, Possible, -- Rule output fuzzy set: Discretionary\*, \* Rule input fuzzy sets: Low, Unlikely, -- Rule output fuzzy set: Discretionary\*, . [Belief, Plausibility] Intervals for fuzzy sets are as follows : Fuzzy Set: Discretionary [0.000, 0.000], Fuzzy Set: Emerging Concern [0.000, 0.000], Fuzzy Set: High [0.500, 1.000], Fuzzy Set: Immediate [0.000, 0.500], .

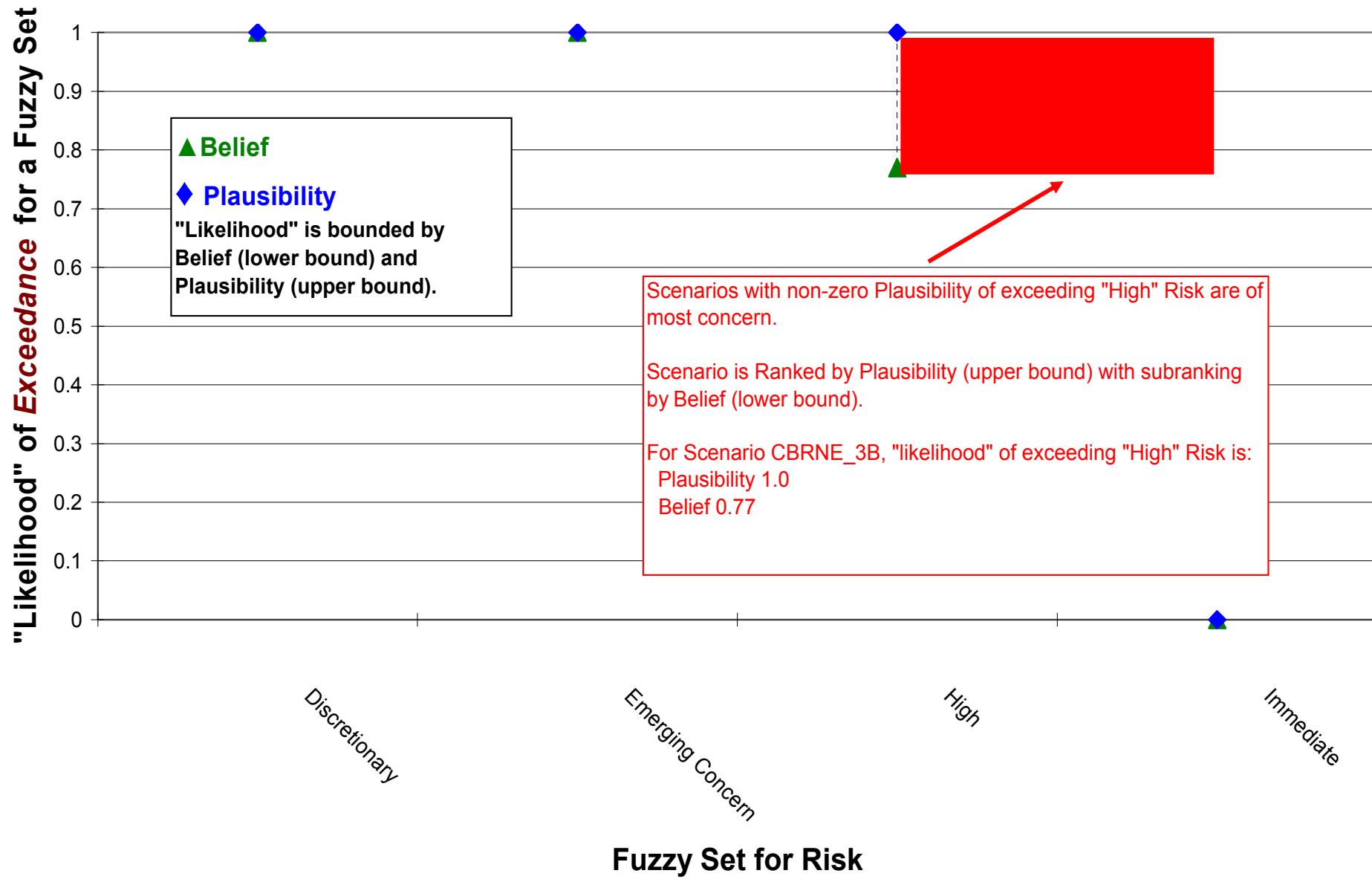
# Risk for Scenario: CBRNE\_1B



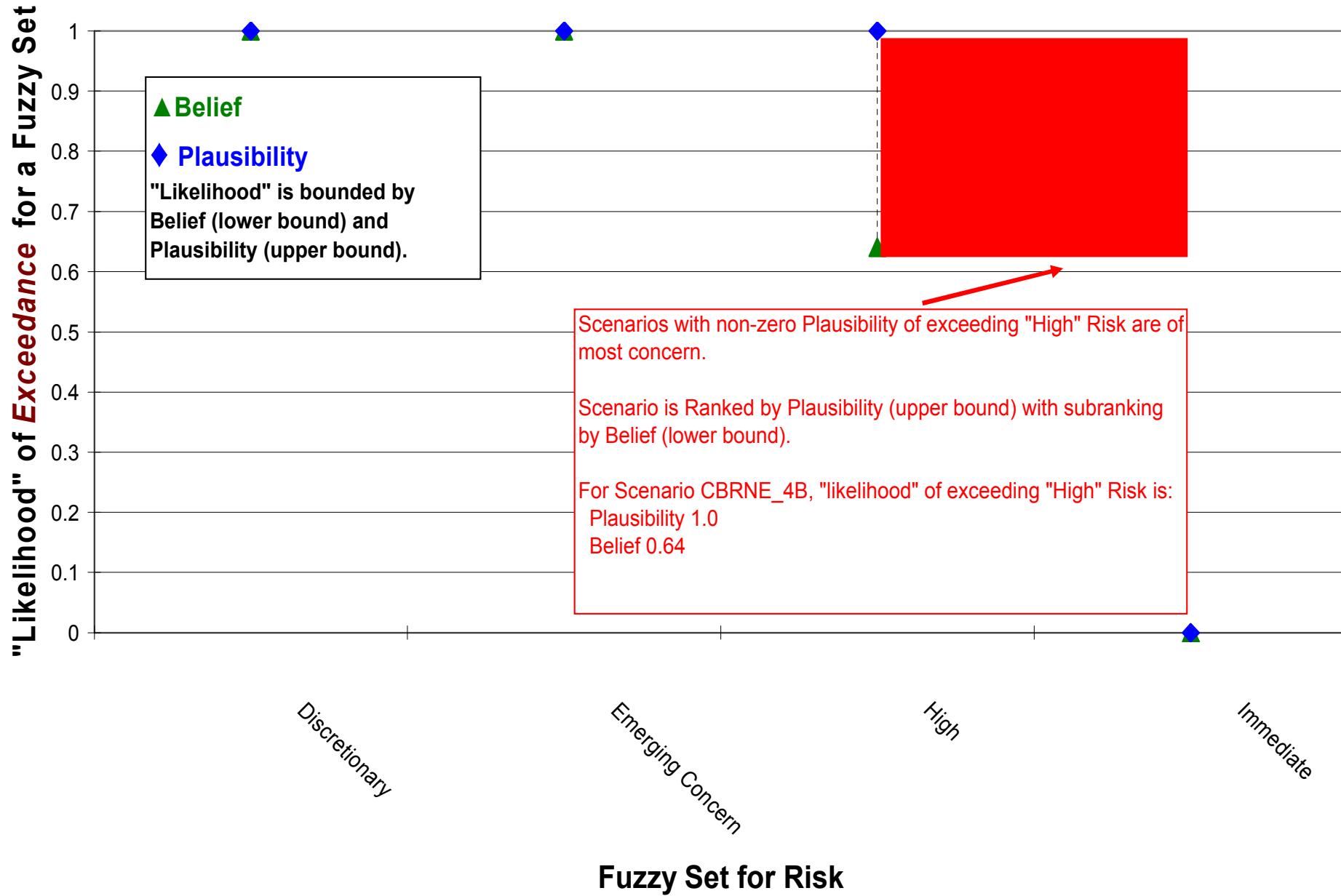
## Risk for Scenario: CBRNE\_2B



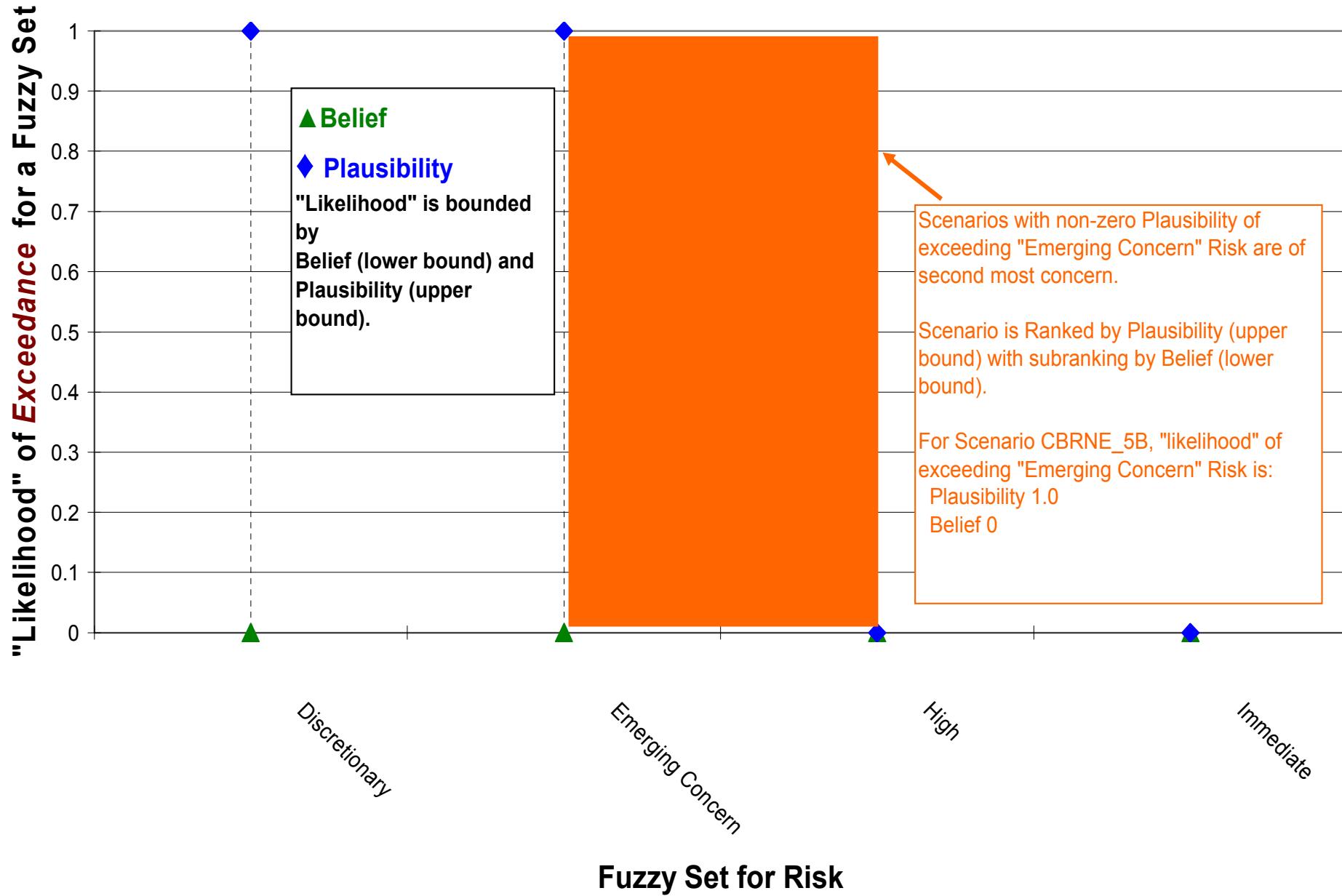
# Risk for Scenario: CBRNE\_3B



# Risk for Scenario: CBRNE\_4B



# Risk for Scenario: CBRNE\_5B





# Ranking for Scenarios

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## RANKING FOR SCENARIOS CBRNE\_1B through CBRNE\_5B

For *Exceeding* Fuzzy Set “High” the Scenarios rank ordered (decreasing) are:

CBRNE\_2B has plausibility of exceedance of 1.0 and belief of exceedance of 0.94

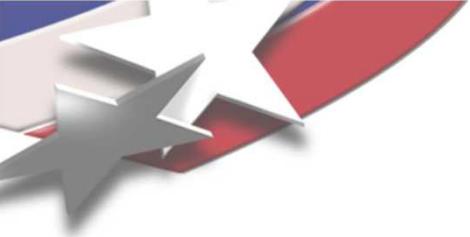
CBRNE\_3B has plausibility of exceedance of 1.0 and belief of exceedance of 0.77

CBRNE\_4B has plausibility of exceedance of 1.0 and belief of exceedance of 0.64

CBRNE\_1B has plausibility of exceedance of 0.5 and belief of exceedance of 0.0

For *Exceeding* Fuzzy Set “Emerging Concern” the Scenarios rank ordered (decreasing) (not already ranked for a worse fuzzy set) are:

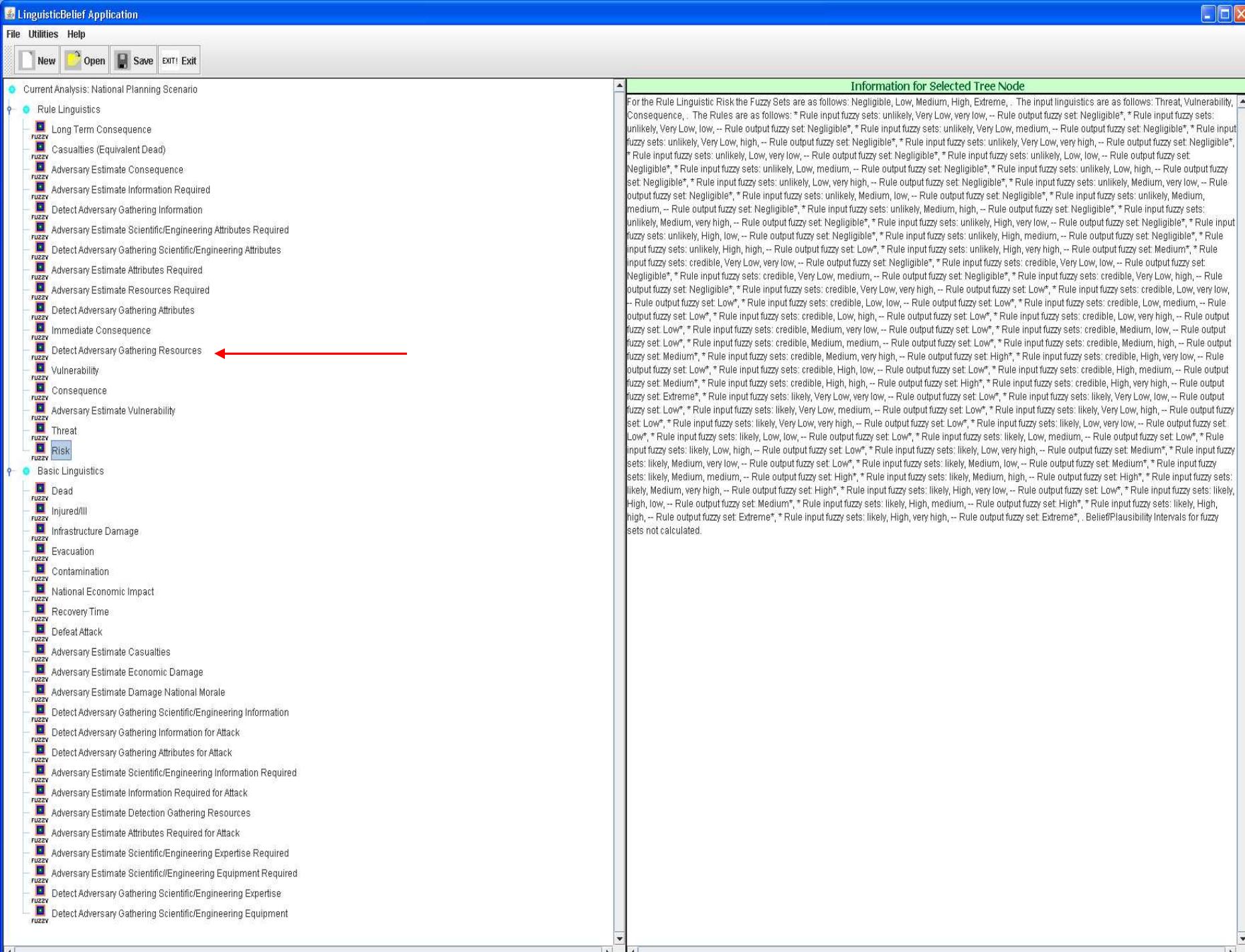
CBRNE\_5B has plausibility of exceedance of 1.0 and belief of exceedance of 0.0



## More Complex Model

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- Evaluate “National Planning Scenarios” (2005)
- Evaluate the 13 that are terrorist attacks
  - Model Complete
  - Expert Elicitation and Evaluation
    - May, 2007
- Include “Detection of Gathering of Resources” by Intelligence Community
  - Scientific /Technical Attributes and Knowledge
  - Attributes and Knowledge to Defeat Security System





# Summary

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- **Developed Tool for Linguistic Evaluations**
  - LinguisticBelief Java Application
    - Fuzzy Sets
    - Approximate Reasoning
    - Belief/Plausibility
- **Applied LinguisticBelief to Evaluation of Terrorist Scenarios**
  - Two DOE Weapons Sites
  - Combined Cyber/Physical Security
  - International Risk Model for CBRNE Scenarios
  - National Planning Scenarios (in process)