Ontologies for Modeling Enterprise Level Security Metrics

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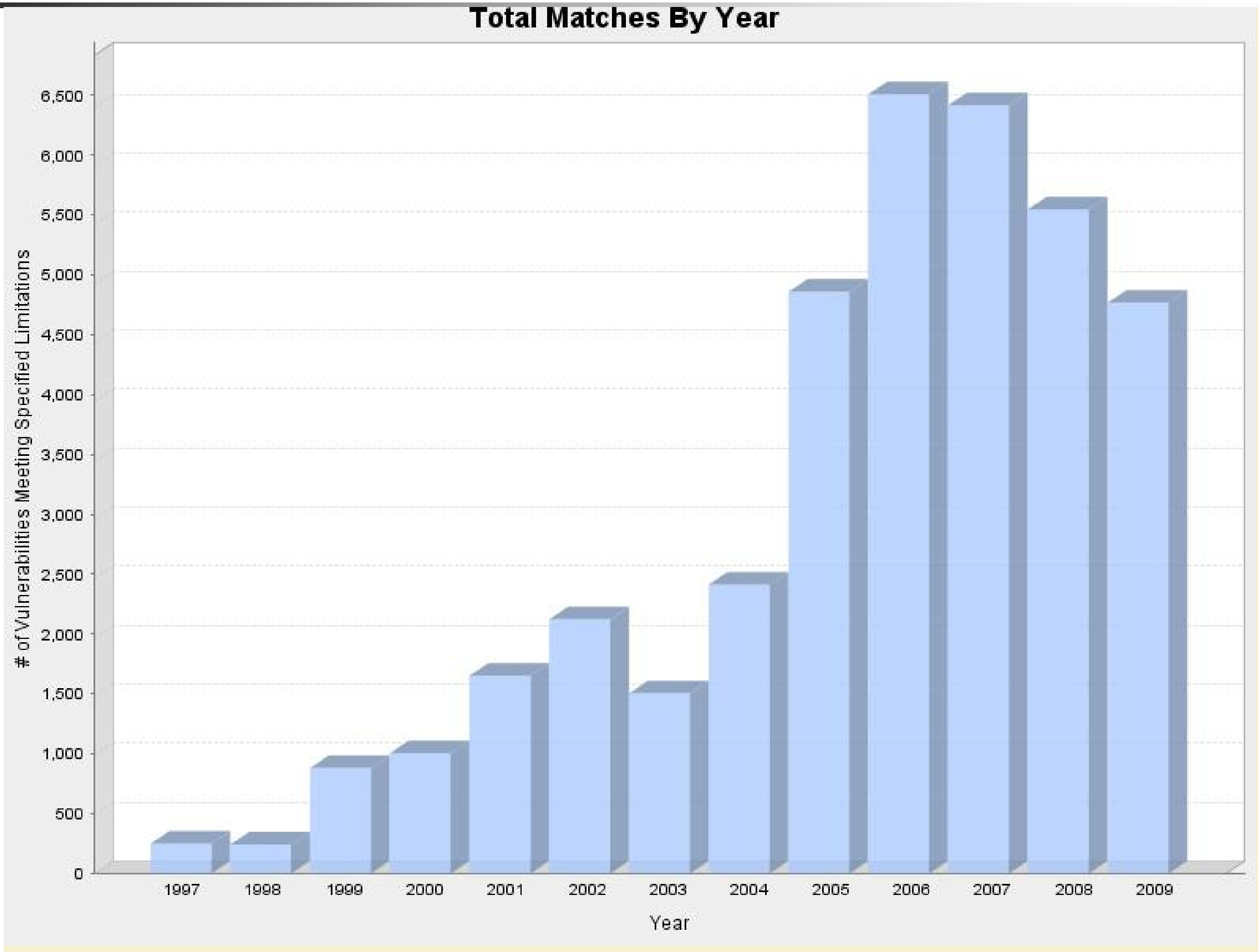
Enterprise Network Security Management

- Networks are getting large and complex
- Vulnerabilities in software are constantly discovered
- Network Security Management is a challenging task
- Even a small network can have numerous attack paths

Trends for Published Vulnerabilities

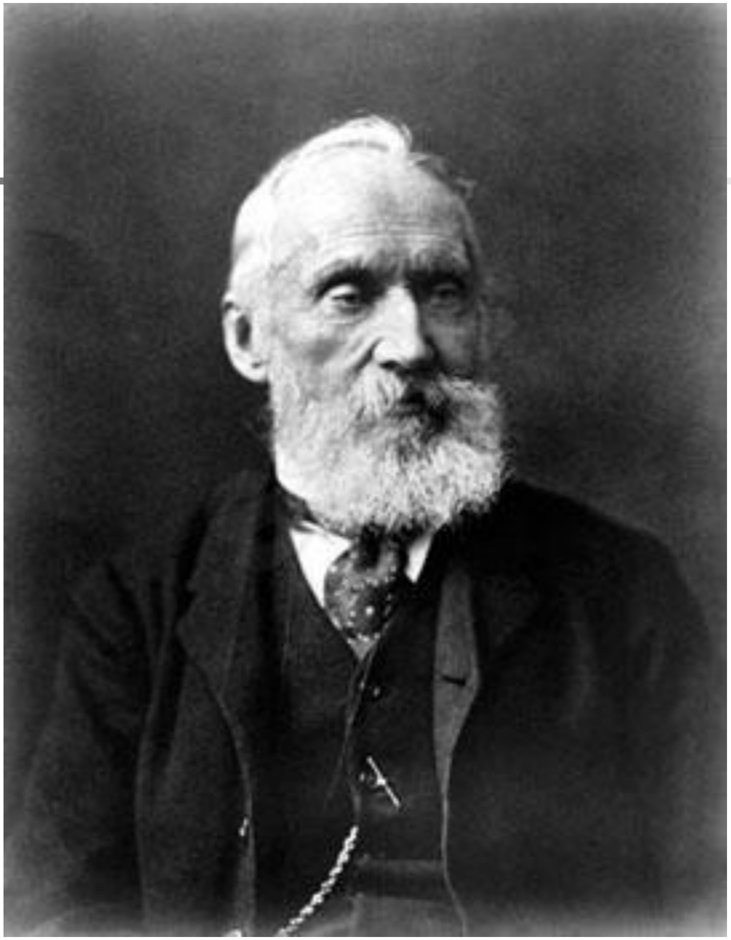


Current Status of Enterprise Network Security Management

- Currently, security management is more of an art and not a science
- System administrators operate by instinct and learned experience
- There is no objective way of measuring the security risk in a network
- “If I change this network configuration setting will my network become more or less secure?”

Why Security Metrics

- Difficult questions to answer:
  - How secure is the database server in a given network configuration?
  - How much security does a new configuration provide?
  - How can I plan on security investments so it provides a certain amount of security?
  - Which countermeasures or controls provide the greatest risk reduction
- For this we need a model or an ontology for Enterprise Level Security



If you cannot measure (or model) it, you cannot improve it.

---Lord Kelvin

Challenges in Security Metrics

- Metric for individual vulnerability exists
  - Impact, exploitability, temporal, environmental, etc.
  - E.g., the Common Vulnerability Scoring System (CVSS) v2 released on June 20, 2007[1]
- However, how to compose individual measures for the overall security of a network?
  - Our work focuses on this issue

[1] Common Vulnerability Scoring System (CVSS-SIG) v2, http://www.first.org/cvss/

What is an Attack Graph

- A model for
  - How an attacker can *combine* vulnerabilities to stage an attack such as a data breach
  - *Dependencies* among vulnerabilities
  - Present *all* possible attack paths in a compact graphical structure

What is an Ontology

- It is a set of entities and relations
- It can be created for any collection of related concepts
- One application of ontology is to organize expert knowledge (e.g. automobiles, electronic items, human diseases and so on)

Ontology for Managing Enterprise Level Security

- Precise definitions of computer security concepts and their relationships
- The ontology should have *knowledge* about threats, assets and security mechanisms
- A secondary goal is to make the ontology portable

What is OWL

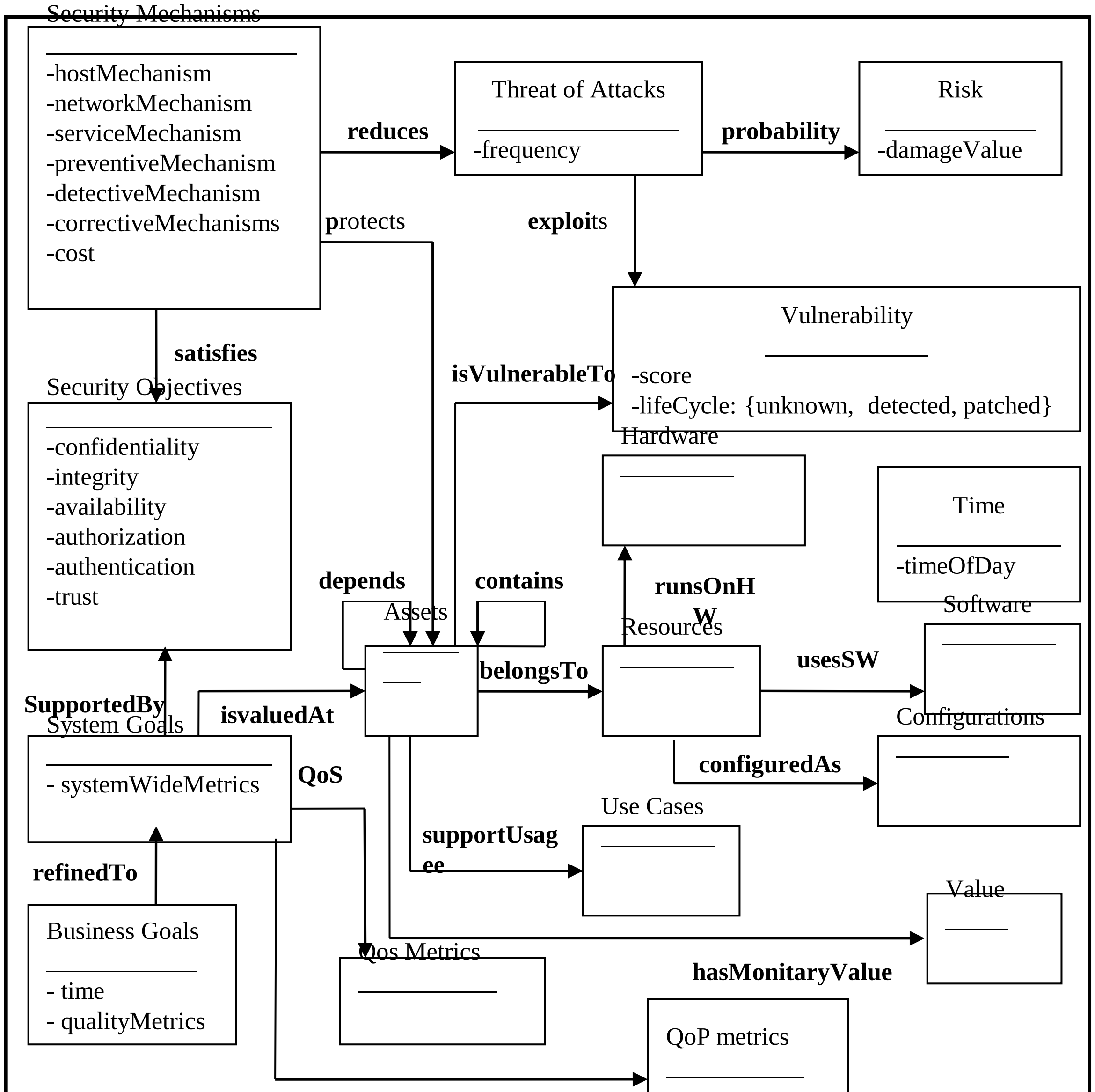
- Web Ontolology Language
- *Classes* describe concepts
- *Sub-classes represent concepts that are more specific*
- *Instances* are members of this class
- *Properties* can define relationships among classes
- *Properties* can also defines different attributes of a class

Example of OWL

- Security Mechanism is a class
- A Detective Mechanism is a sub class
- A Preventive Mechanism is also a sub class
- IDS is an instance of a Detective Mechanism
- A Firewall is an instance of a Preventive Mechanism
- Asset is an example of another class
- A Security Mechanism *protects* an asset
- An asset *has a* value

An Ontology for Security Metrics

- Threat
- Vulnerabilities
- Countermeasures
- Assets
- Risk
- Security Objectives
- Business Goals
- Use Cases



Security Mechanisms

-hostMechanism
-networkMechanism
-serviceMechanism
-preventiveMechanism
-detectiveMechanism
-correctiveMechanisms
-cost

reduces

Threat of Attacks

-frequency

probability

Risk

-damageValue

protects

exploits

Vulnerability

-score
-lifeCycle: {unknown, detected, patched}

satisfies

isVulnerableTo

Security Objectives

-confidentiality
-integrity
-availability
-authorization
-authentication
-trust

Hardware

Time

-timeOfDay

depends

contains

runsOnHW

Assets

Resources

Software

usesSW

belongsTo

SupportedBy

isvaluedAt

System Goals

- systemWideMetrics

QoS

Configurations

configuredAs

Use Cases

supportUsagee

refinedTo

Value

Business Goals

- time
- qualityMetrics

Qos Metrics

hasMonitaryValue

QoP metrics

Properties of the Asset Class

```
<rdf:Property rdf:ID=”value”>
   <rdfs:domain  rdf:resources=”Asset”/>
   <rdfs:range      rdf:resources=&xsd:integer/>
</rdf:Property>
<rdf:Property rdf:ID=”depends”>
   <rdfs:domain  rdf:resources=”Asset”/>
   <rdfs:range      rdf:resources=”Asset”/>
</rdf:Property>
<rdf:Property rdf:ID=”contains”>
   <rdfs:domain  rdf:resources=”Asset”/>
   <rdfs:range      rdf:resources=”Asset”/>
<rdf:Property rdf:ID=”isVulnerableTo”>
   <rdfs:domain  rdf:resources=”Asset”/>
   <rdfs:range      rdf:resources=”Vulnerability”/>
<rdf:Property rdf:ID=”belongsTo”>
   <rdfs:domain  rdf:resources=”Asset”/>
   <rdfs:range      rdf:resources=”Resource”/>
<rdf:Property rdf:ID=”monitaryValue”>
   <rdfs:domain  rdf:resources=”Assets”/>
   <rdfs:range      rdf:resources=”Value”/>
<rdf:Property rdf:ID=”supportUsage”>
   <rdfs:domain  rdf:resources=”Assets”/>
   <rdfs:range      rdf:resources=”Use Cases”/>
</rdf:Property>
```

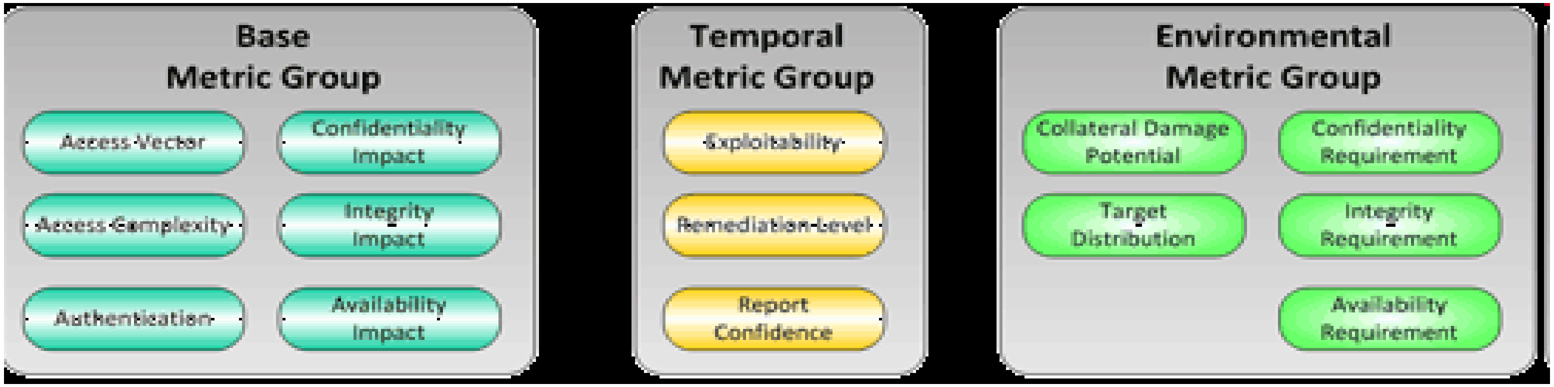
cvss

- Stands for *Common Vulnerability Scoring System*
- An open framework for communicating characteristics and impacts of IT vulnerabilities
- Consists three metric groups: *Base, Temporal,* and *Environmental*

CVSS (Cont'd)

- Base metric : constant over time and with user environments
- Temporal metric : change over time but constant with user environment
- Environmental metric : unique to user environment

CVSS (Cont’d)



CVSS metric groups

- Each metric group has sub-matricies
- Each metric group has a score associated with it
- Score is in the range 0 to 10

Access Vector

This metric measures how the vulnerability is exploited.

- Local
- Adjacent Network
- Network

Access Complexity

This metric measures the complexity of the attack required to exploit the vulnerability

- High: Specialized access conditions exist
- Medium: The access conditions are somewhat specialized
- Low: Specialized access conditions do not exist

Authentication

This metric measures the number of times an attacker must authenticate to a target to exploit a vulnerability

- Multiple: The attacker needs to authenticate two or more times
- Single: One instance of authentication is required
- None: No authentication is required

Confidentiality Impact

This metric measures the impact on confidentiality due to the exploit.

- None: No Impact
- Partial: There is a considerable information disclosure
- Complete: There is total information disclosure

- Similar things for the Integrity Impact and Availability Impact

Base Score

Base Score = Function(Impact, Exploitability)

Impact = 10.41 * (1-(1-ConImp)*(1-IntImp)*(1-AvailImpact))

Exploitability = 20*AccessV*AccessComp*Authentication

Base Score Example CVE-2002-0392

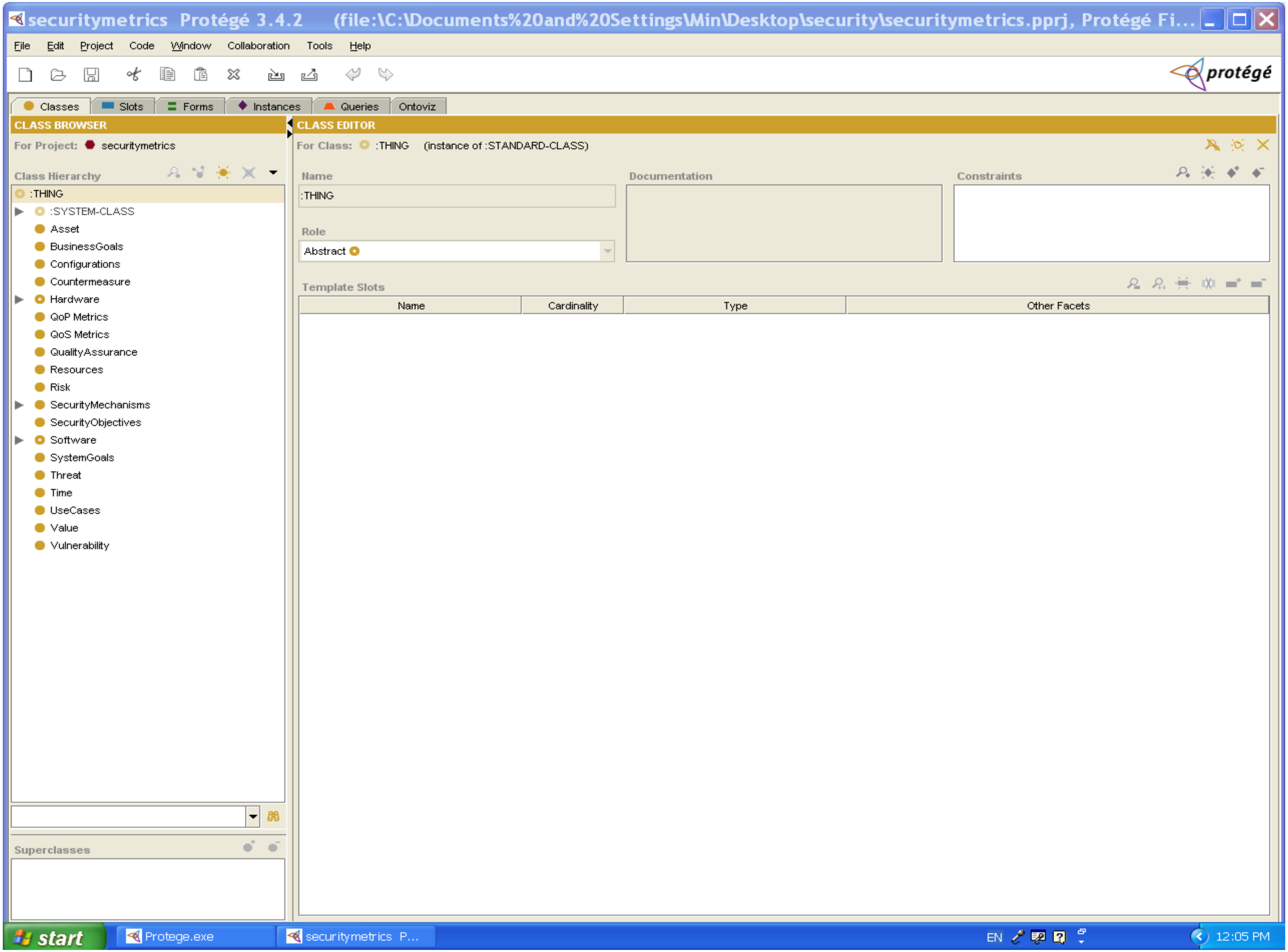
- Apache Chunked Encoding Memory Corruption

BASE METRIC	EVALUATION	SCORE
Access Vector	[Network]	(1.00)
Access Complex.	[Low]	(0.71)
Authentication	[None]	(0.704)
Availability Impact	[Complete]	(0.66)

Impact = 6.9

Exploitability = 10.0

BaseScore = (7.8)



securitymetrics Protégé 3.4.2 (file:\C:\Documents%20and%20Settings\Min\Desktop\security\securitymetrics.pprj, Protégé Fi...

CLASS BROWSER

For Project: ● securitymetrics

Class Hierarchy

- :THING
  - :SYSTEM-CLASS
  - Asset
  - BusinessGoals
  - Configurations
  - Countermeasure
  - Hardware
  - QoP Metrics
  - QoS Metrics
  - QualityAssurance
  - Resources
  - Risk
  - SecurityMechanisms
  - SecurityObjectives
  - Software
  - SystemGoals
  - Threat
  - Time
  - UseCases
  - Value
  - Vulnerability

Superclasses

CLASS EDITOR

For Class: :THING (instance of :STANDARD-CLASS)

Name: :THING

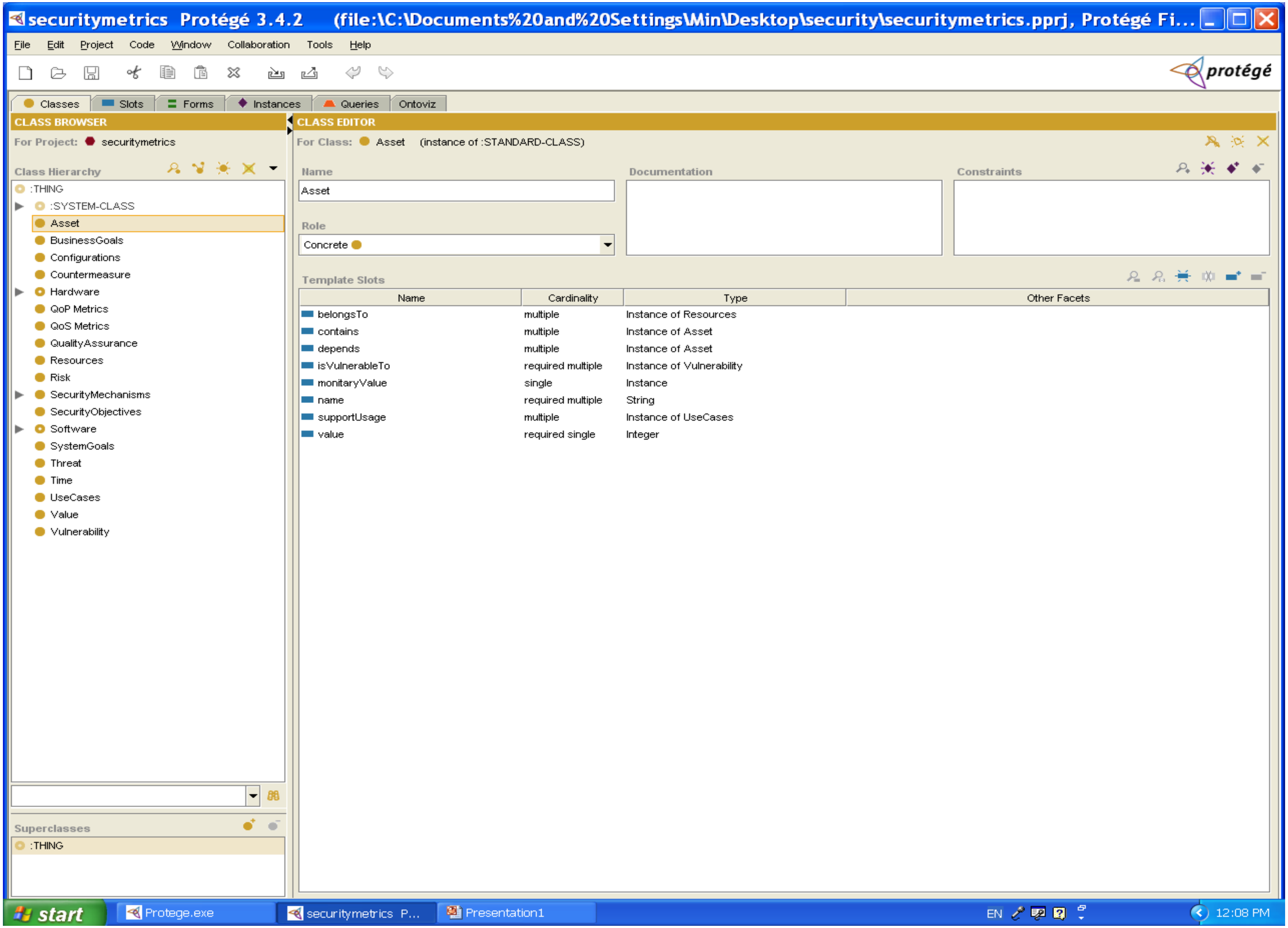
Documentation

Constraints

Role: Abstract

Template Slots

Name	Cardinality	Type	Other Facets



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  - Value
  - Vulnerability

Superclasses

- :THING

CLASS EDITOR

For Class: ● Asset (instance of :STANDARD-CLASS)

Name: Asset

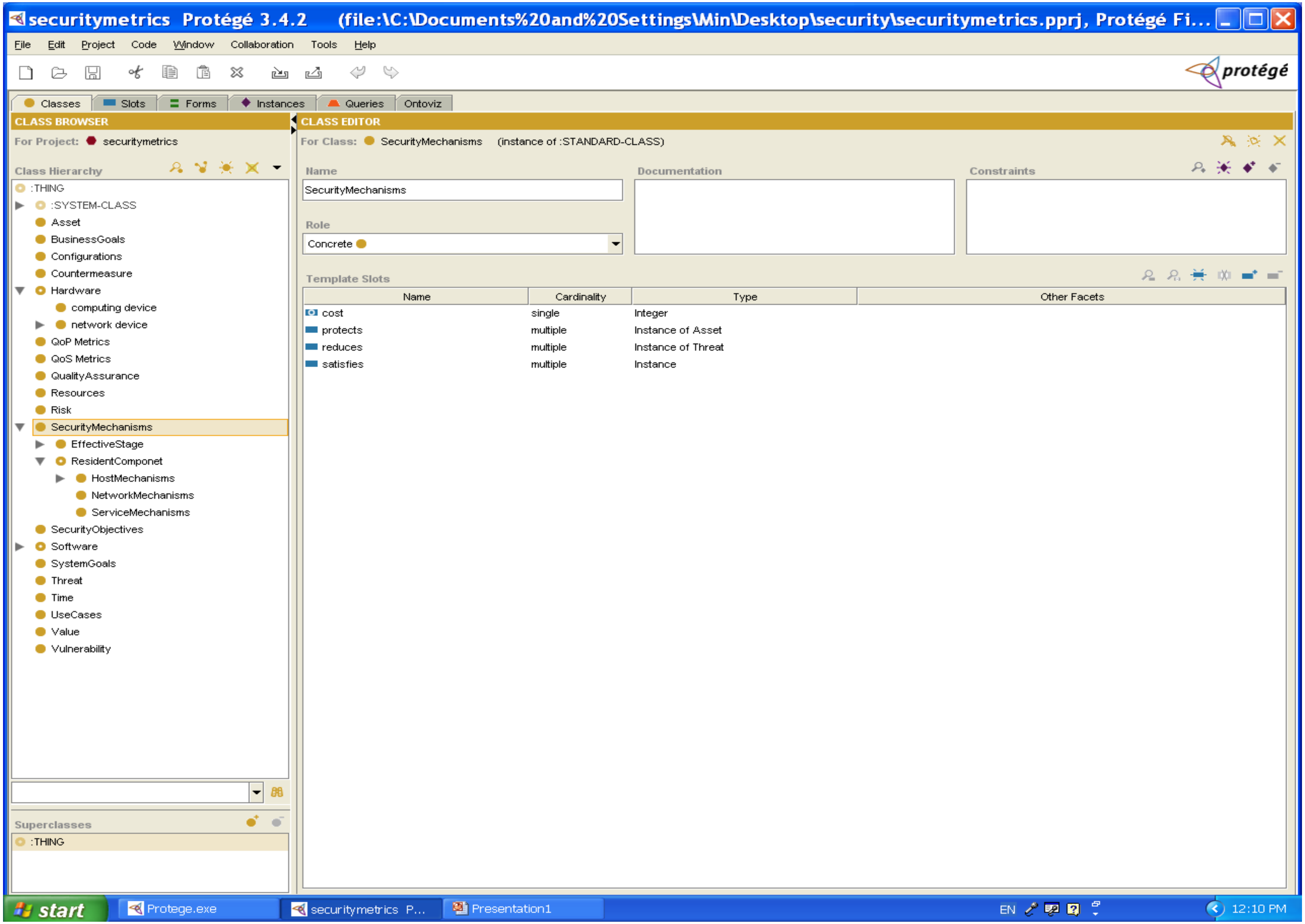
Documentation

Constraints

Role: Concrete ●

Template Slots

Name	Cardinality	Type	Other Facets
belongsTo	multiple	Instance of Resources	
contains	multiple	Instance of Asset	
depends	multiple	Instance of Asset	
isVulnerableTo	required multiple	Instance of Vulnerability	
monitaryValue	single	Instance	
name	required multiple	String	
supportUsage	multiple	Instance of UseCases	
value	required single	Integer	



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CLASS BROWSER

For Project: ● securitymetrics

Class Hierarchy

- :THING
  - :SYSTEM-CLASS
  - Asset
  - BusinessGoals
  - Configurations
  - Countermeasure
  - Hardware
    - computing device
    - network device
  - QoP Metrics
  - QoS Metrics
  - QualityAssurance
  - Resources
  - Risk
  - SecurityMechanisms
    - EffectiveStage
    - ResidentComponet
      - HostMechanisms
      - NetworkMechanisms
      - ServiceMechanisms
  - SecurityObjectives
  - Software
  - SystemGoals
  - Threat
  - Time
  - UseCases
  - Value
  - Vulnerability

Superclasses

:THING

CLASS EDITOR

For Class: ● SecurityMechanisms (instance of :STANDARD-CLASS)

Name: SecurityMechanisms

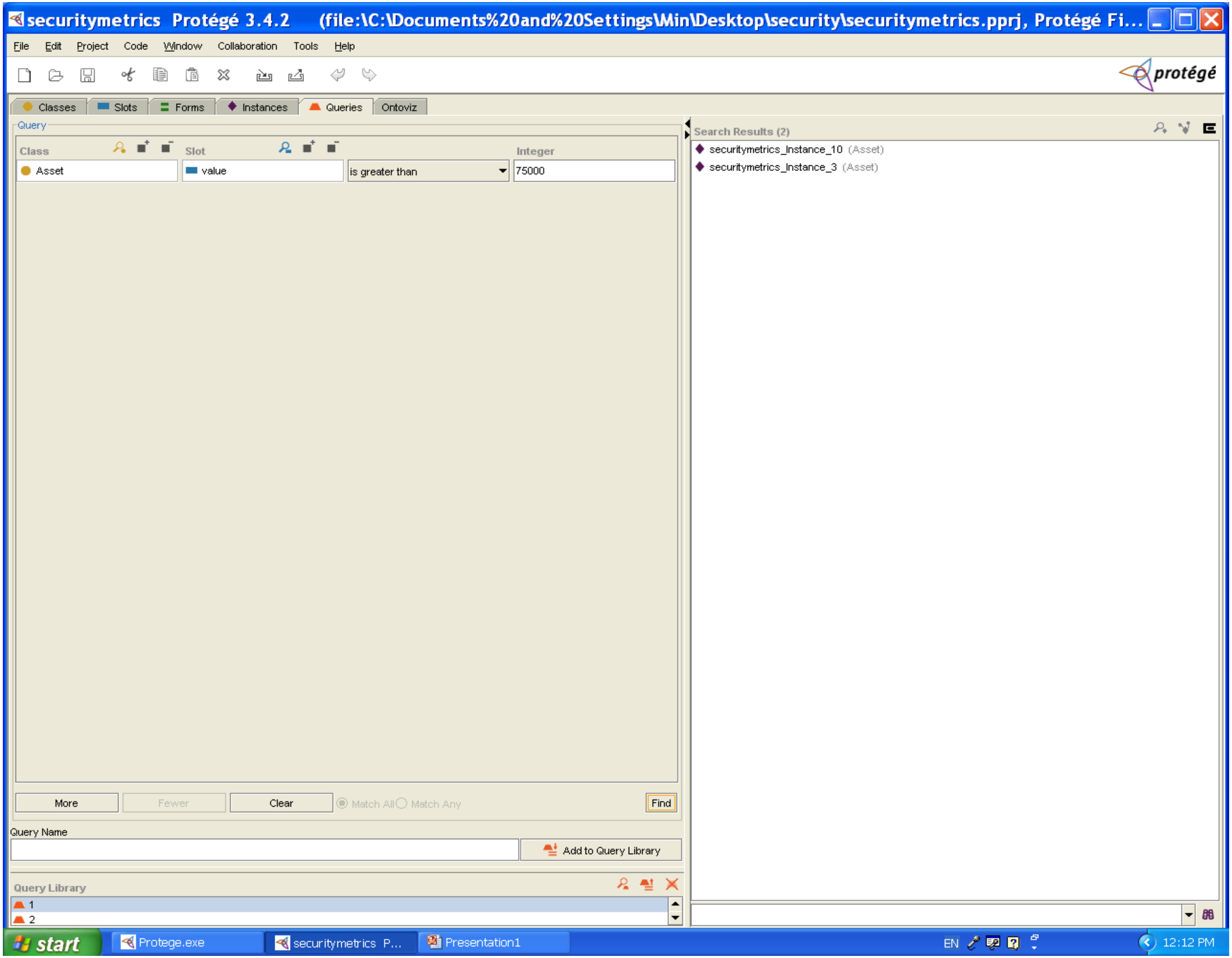
Role: Concrete ●

Documentation

Constraints

Template Slots

Name	Cardinality	Type	Other Facets
cost	single	Integer	
protects	multiple	Instance of Asset	
reduces	multiple	Instance of Threat	
satisfies	multiple	Instance	

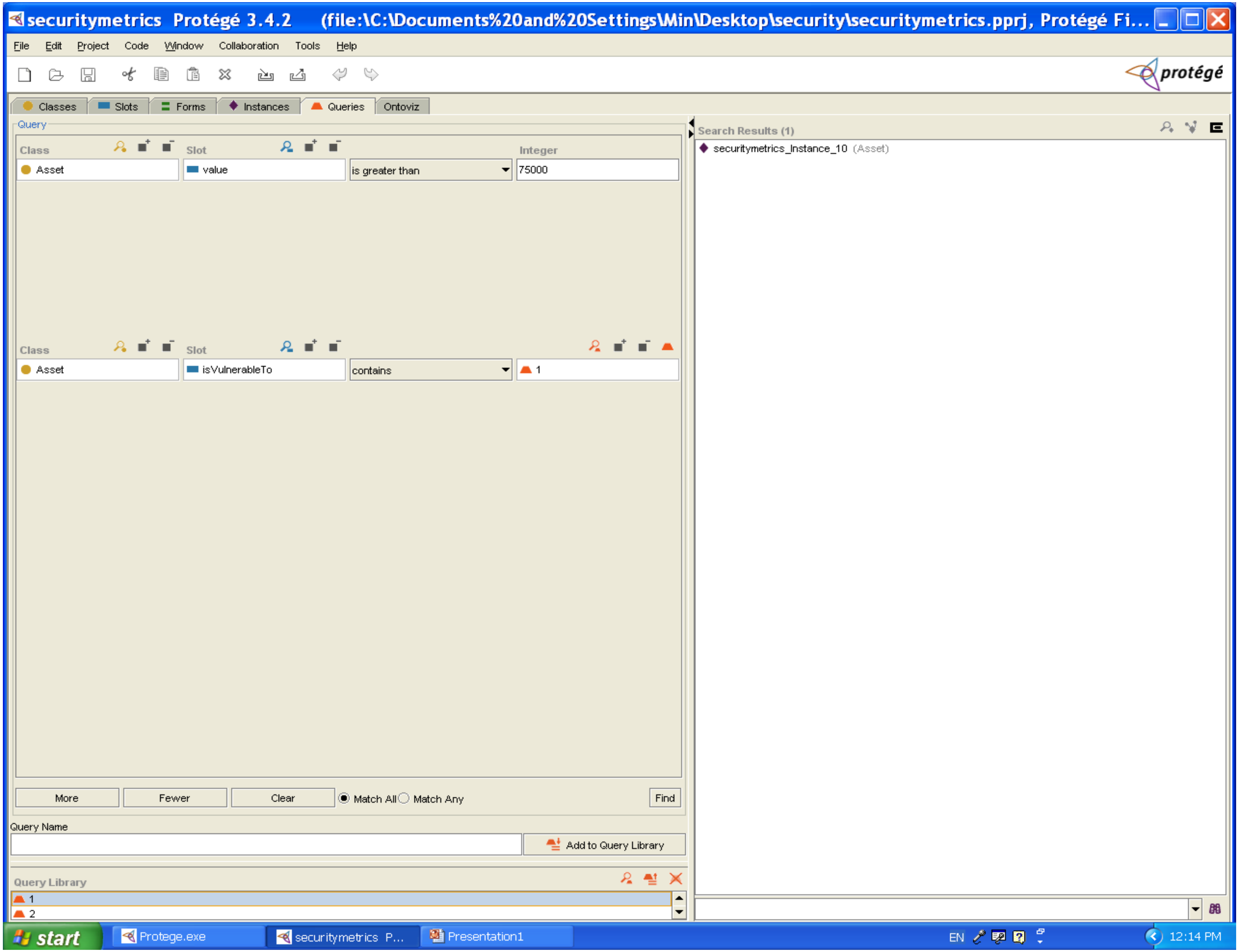


securitymetrics Protégé 3.4.2 (file:\C:\Documents%20and%20Settings\Min\Desktop\security\securitymetrics.pprj, Protégé Fi…

Class	Slot		Integer
Asset	value	is greater than	75000

Query Library:
- 1
- 2

Search Results (2)
- securitymetrics_Instance_10 (Asset)
- securitymetrics_Instance_3 (Asset)



Query

Class	Slot		Integer
Asset	value	is greater than	75000

Class	Slot		
Asset	isVulnerableTo	contains	1

● Match All ○ Match Any

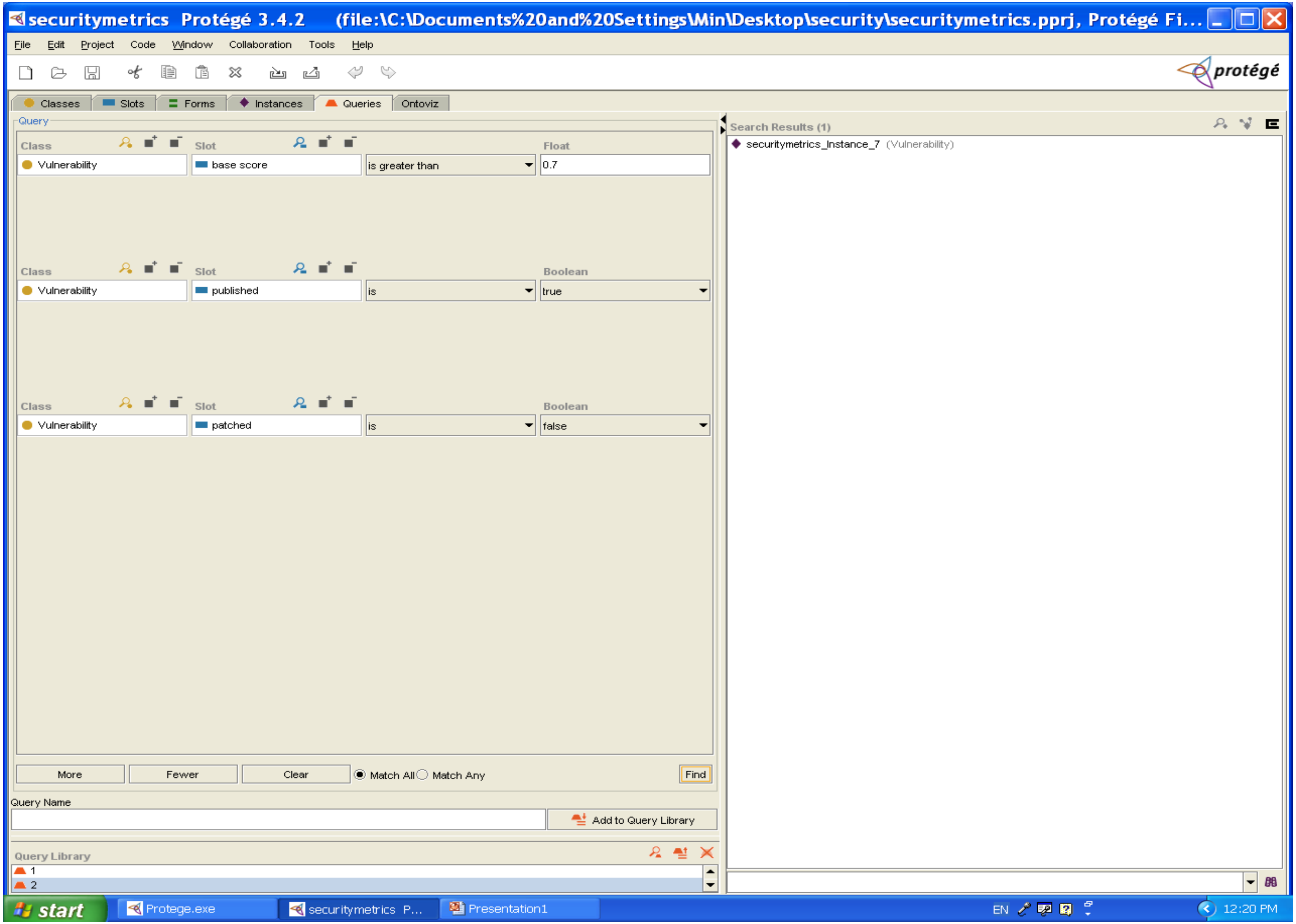
Query Name

Query Library

1
2

Search Results (1)

securitymetrics_Instance_10 (Asset)



securitymetrics Protégé 3.4.2 (file:\C:\Documents%20and%20Settings\Min\Desktop\security\securitymetrics.pprj, Protégé Fi...

Query

Class: Vulnerability — Slot: base score — is greater than — Float: 0.7

Class: Vulnerability — Slot: published — is — Boolean: true

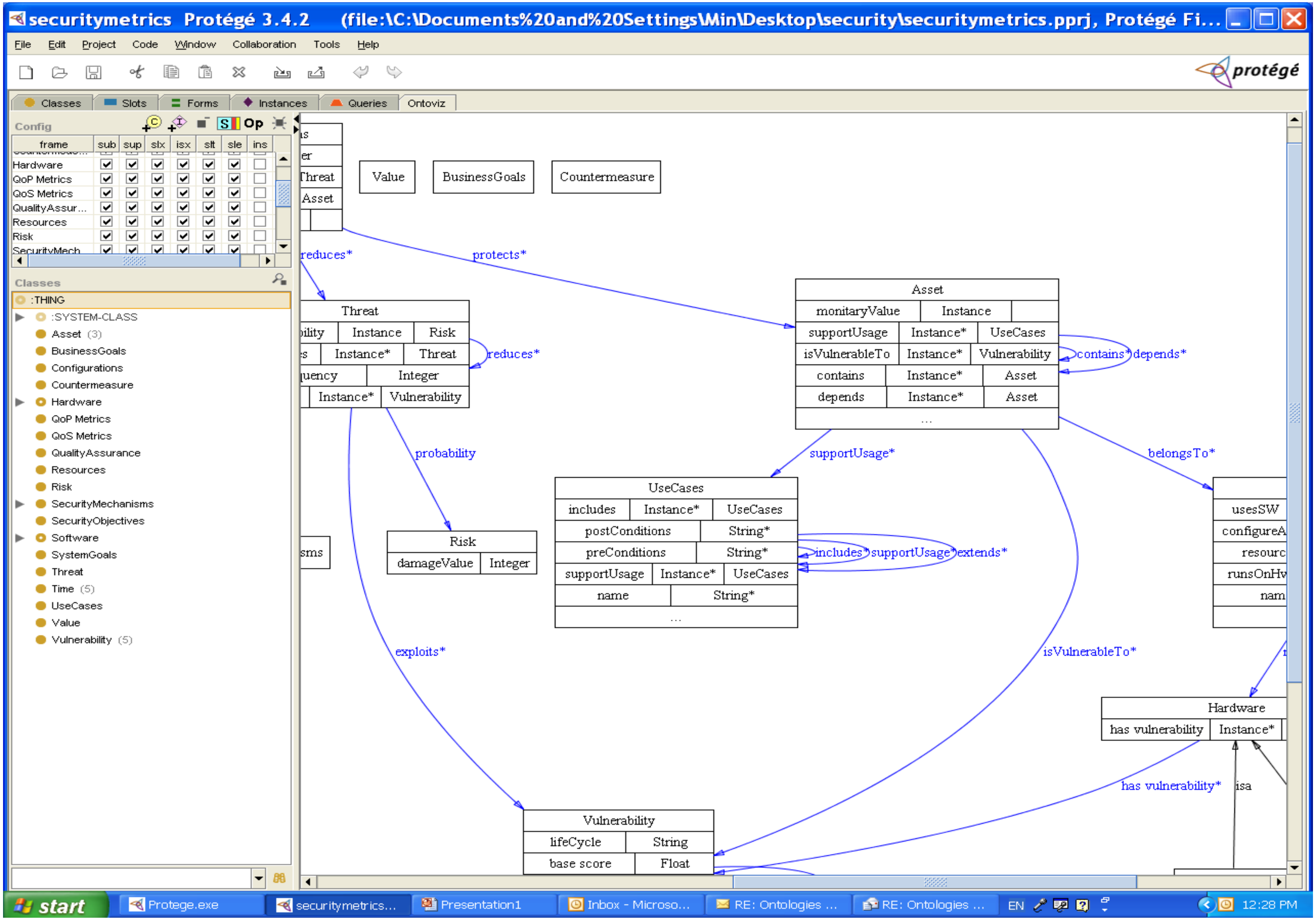
Class: Vulnerability — Slot: patched — is — Boolean: false

● Match All ○ Match Any

Query Name

Query Library
1
2

Search Results (1)
securitymetrics_Instance_7 (Vulnerability)



frame	sub	sup	slx	isx	slt	sle	ins
Hardware	☑	☑	☑	☑	☑	☑	□
QoP Metrics	☑	☑	☑	☑	☑	☑	□
QoS Metrics	☑	☑	☑	☑	☑	☑	□
QualityAssur...	☑	☑	☑	☑	☑	☑	□
Resources	☑	☑	☑	☑	☑	☑	□
Risk	☑	☑	☑	☑	☑	☑	□
SecurityMech	☑	☑	☑	☑	☑	☑	□

- :THING
  - :SYSTEM-CLASS
  - Asset (3)
  - BusinessGoals
  - Configurations
  - Countermeasure
  - Hardware
  - QoP Metrics
  - QoS Metrics
  - QualityAssurance
  - Resources
  - Risk
  - SecurityMechanisms
  - SecurityObjectives
  - Software
  - SystemGoals
  - Threat
  - Time (5)
  - UseCases
  - Value
  - Vulnerability (5)

Asset		
monitaryValue	Instance	
supportUsage	Instance*	UseCases
isVulnerableTo	Instance*	Vulnerability
contains	Instance*	Asset
depends	Instance*	Asset
...		

Threat		
ility	Instance	Risk
s	Instance*	Threat
uency	Integer	
	Instance*	Vulnerability

UseCases		
includes	Instance*	UseCases
postConditions	String*	
preConditions	String*	
supportUsage	Instance*	UseCases
name	String*	
...		

Risk	
damageValue	Integer

Vulnerability	
lifeCycle	String
base score	Float

Hardware	
has vulnerability	Instance*

usesSW
configureA
resourc
runsOnHw
nam

Example Queries

- Find all Assets with value > 100K that have vulnerabilities that are published but not patched
- Which security mechanism will prevent a certain attack and how much does it cost
- Suppose a vulnerability is discovered in a certain version of a shared library, give me all products that use this shared library and are affected by it.

Conclusions

- Presented an Ontology for Modeling Enterprise Level Security
- Implemented it using OWL
- It can be used to generate reports about enterprise level security