SNAPSHOTS OF SYSTEMS ENGINEERING RESEARCH AT UMCP

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Model-Based Systems Engineering Workshop

Goddard Space Flight Center

Greenbelt, Maryland, February 18, 2016

OVERVIEW

Model-Based Systems Engineering at Maryland

- Model-Based Systems Engineering (MBSE) at ISR

Snapshots of Research

- Working with GPM: PaladinRM Software Tool.
- Working with Semantic Web Technologies.
- Integration of NLP with Ontologies and Textual Requirements

Acknowledgements / Co-Workers

- At UMD: Scott Selberg, Natasha Shmunis, Vimal Mayank, Cari Wojcik, John Baras, Reza Ghodssi, Matt Mosteller, Nefretiti Nassar, Parastoo Delgoshaei, Eddie Tseng, and Leonard Petnga.
- At NASA: David Everett, Jessica Knizhnik, Craig Carignan.

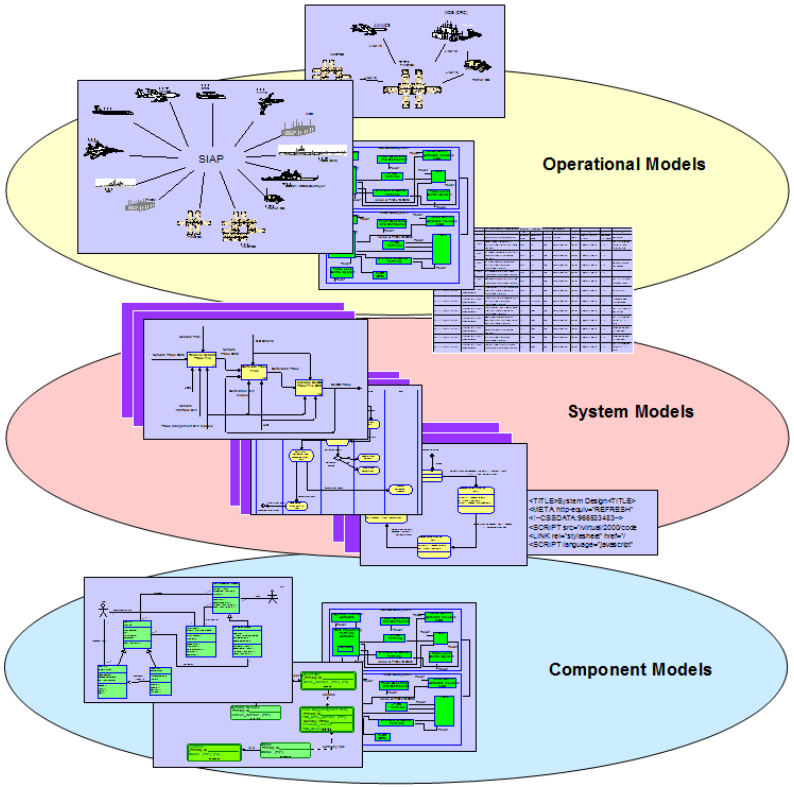
MODEL-BASED SYSTEMS ENGINEERING

Definition and Scope

- Formalizes the development of systems through the use of models.
- Broad in scope, across multiple stages of system development and multiple physics.

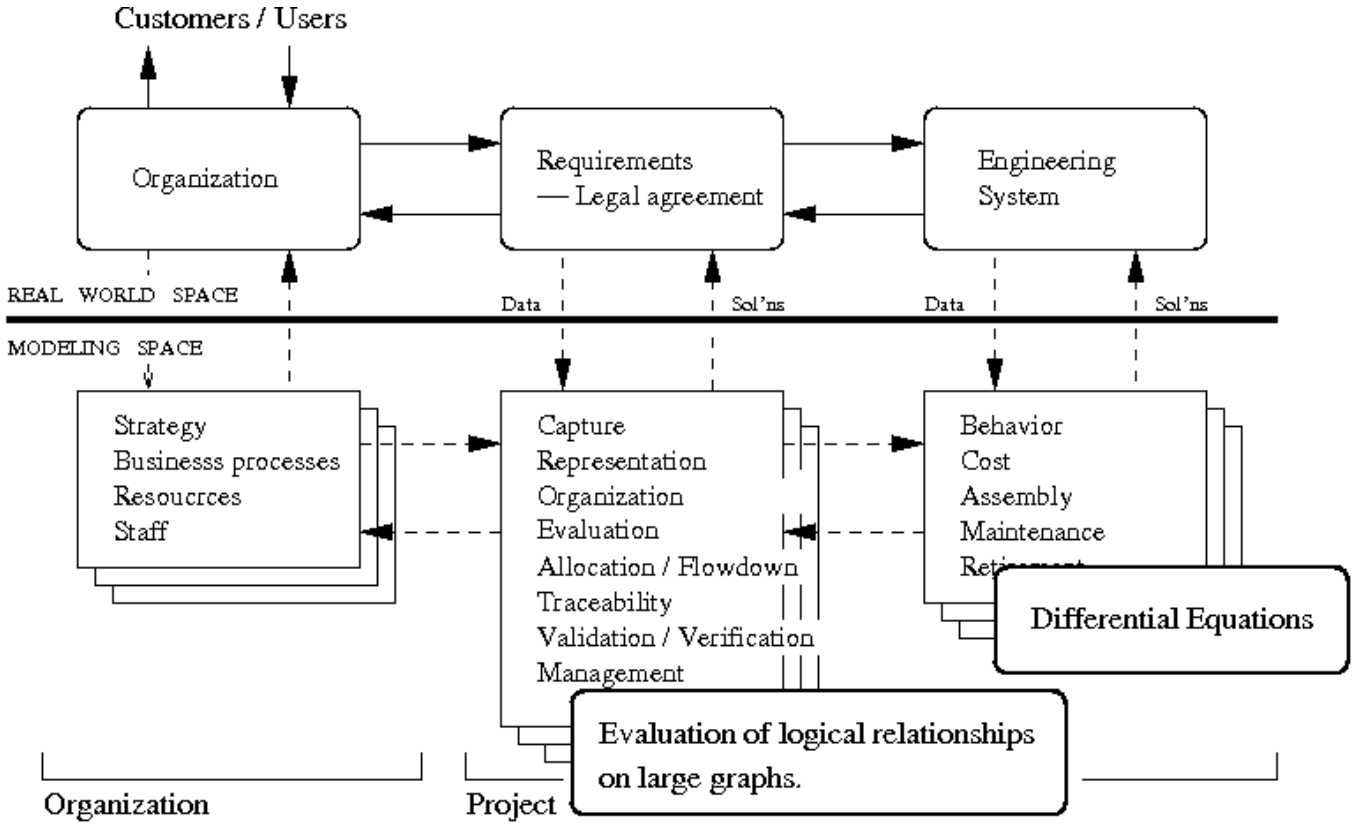
Benefits of MBSE

- Allows for the development of virtual prototypes.
- Facilitates communication among disciplines in team-based development.
- Enables semi-formal and formal approaches to system assessment.
- Management of system complexity.



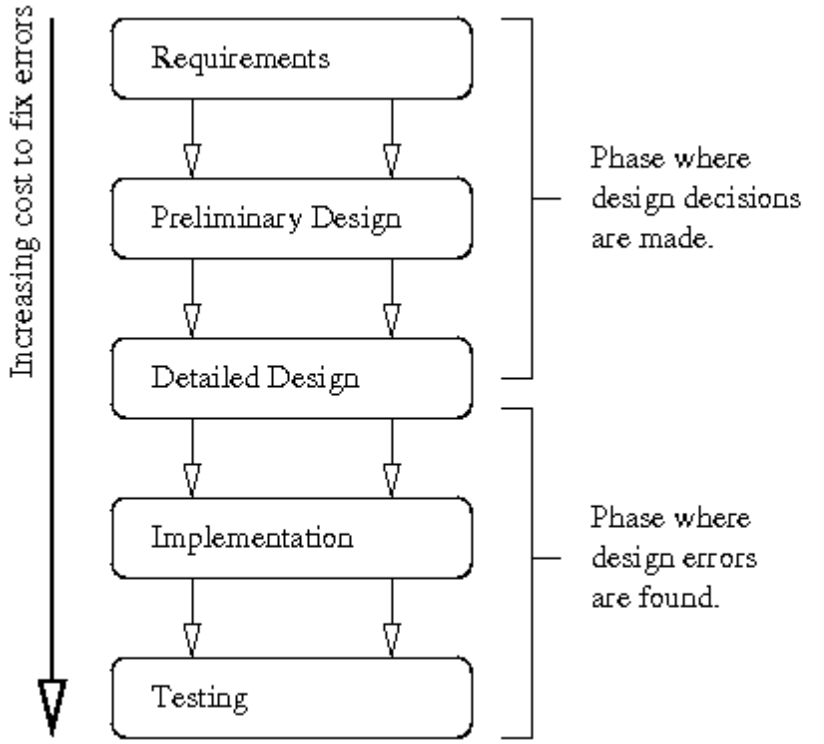
MODEL-BASED SYSTEMS ENGINEERING

Tenet 1: Create Big-Picture View and Emphasize Model-Based Systems Engineering.
The mathematics needed for formal approaches to systems engineering is foreign to many engineers.

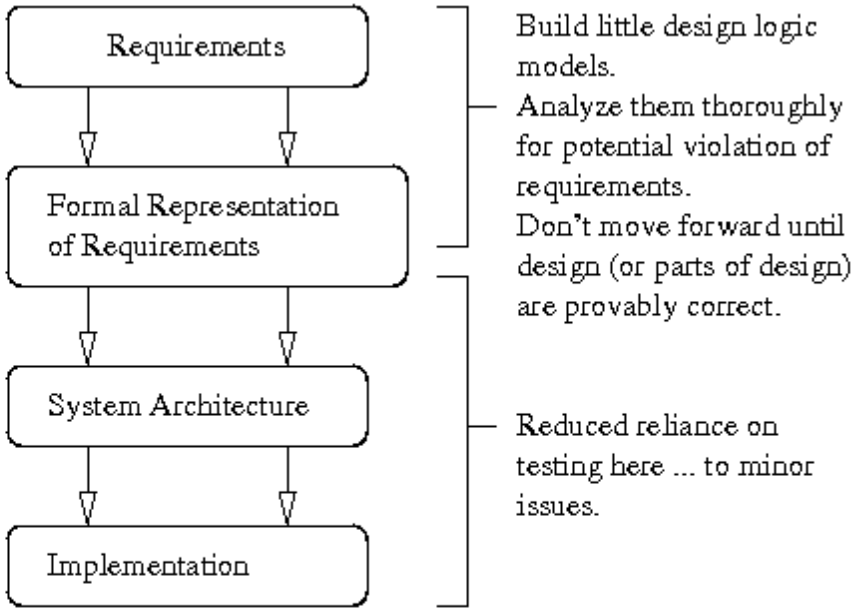


MODEL-BASED SYSTEMS ENGINEERING

Tenet 2: Emphasize Disciplined Approaches to Design. Techniques include decomposition, abstraction, and formal analysis.



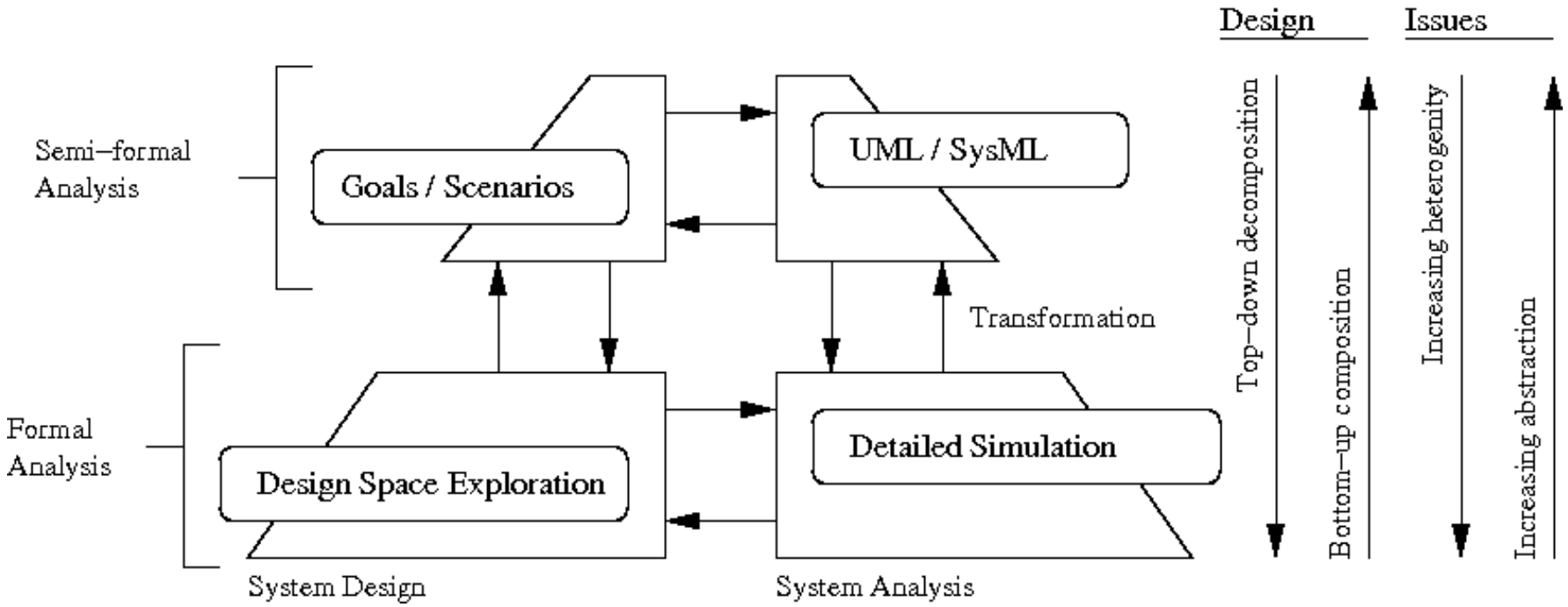
Traditional Approach to Design and Test....



Early detection of errors and "system operation" that is "correct–by–construction"...

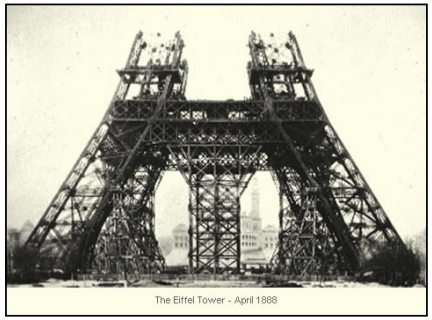
MODEL-BASED SYSTEMS ENGINEERING

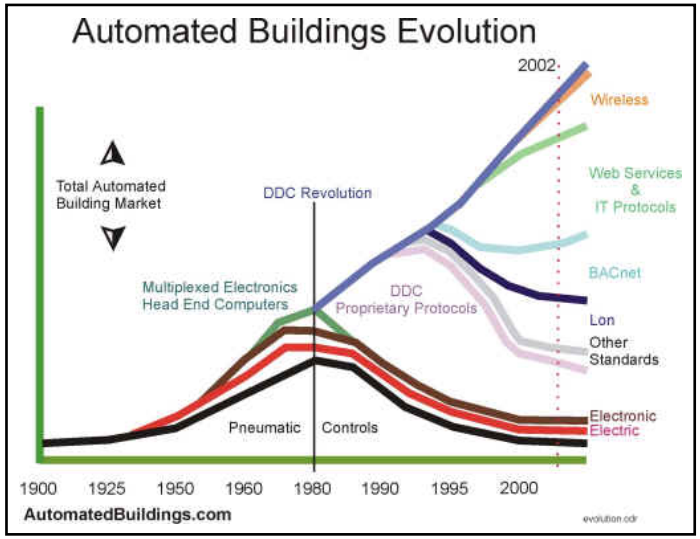
Tenet 3: To keep the complexity of design activities in check, we need to employ mixtures of semi-formal and formal approaches to system development.



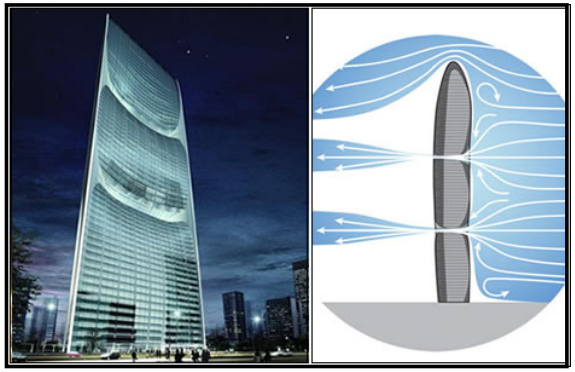
MODEL-BASED SYSTEMS ENGINEERING

Motivating Application Area 1: Buildings!

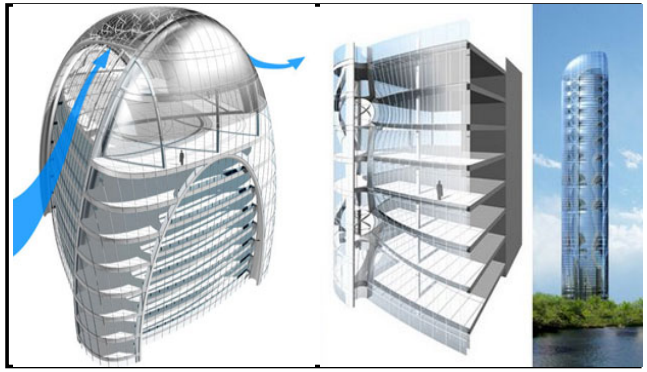




Pearl River Tower Complex

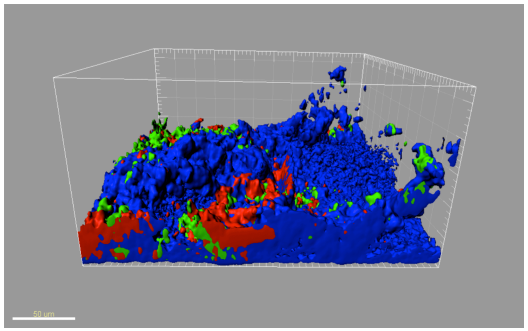


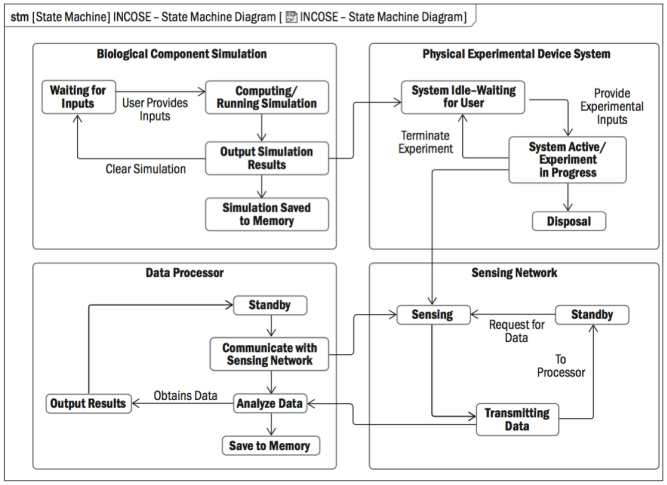
Green Technology Tower –– Architectural Proposal for Chicago

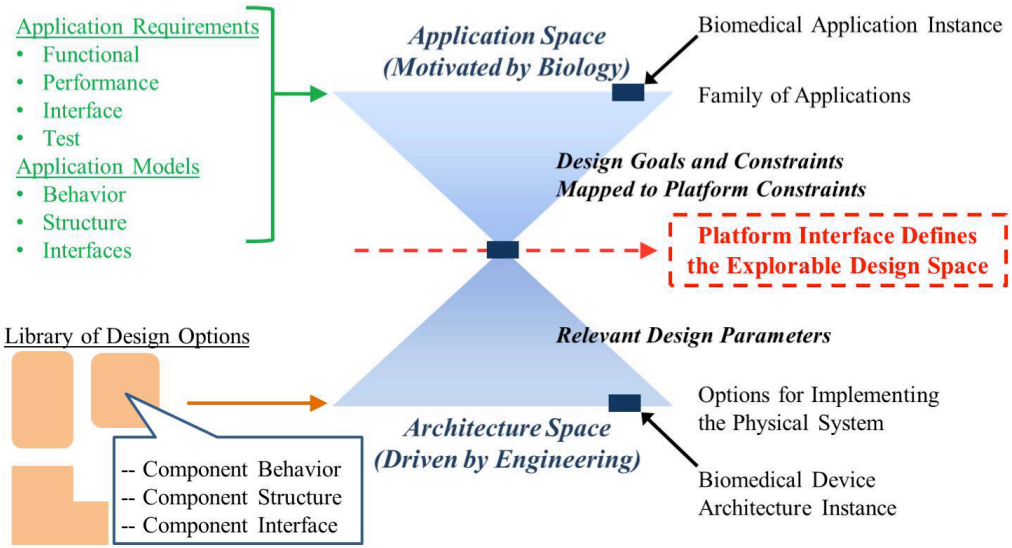


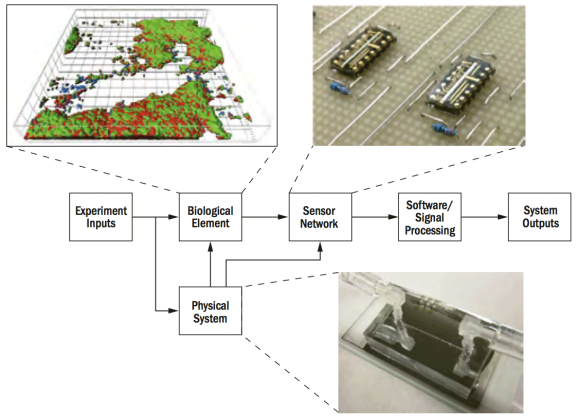
MODEL-BASED SYSTEMS ENGINEEERING

Motivating Application Area 2: Platforms for Biomedical Experimental Research







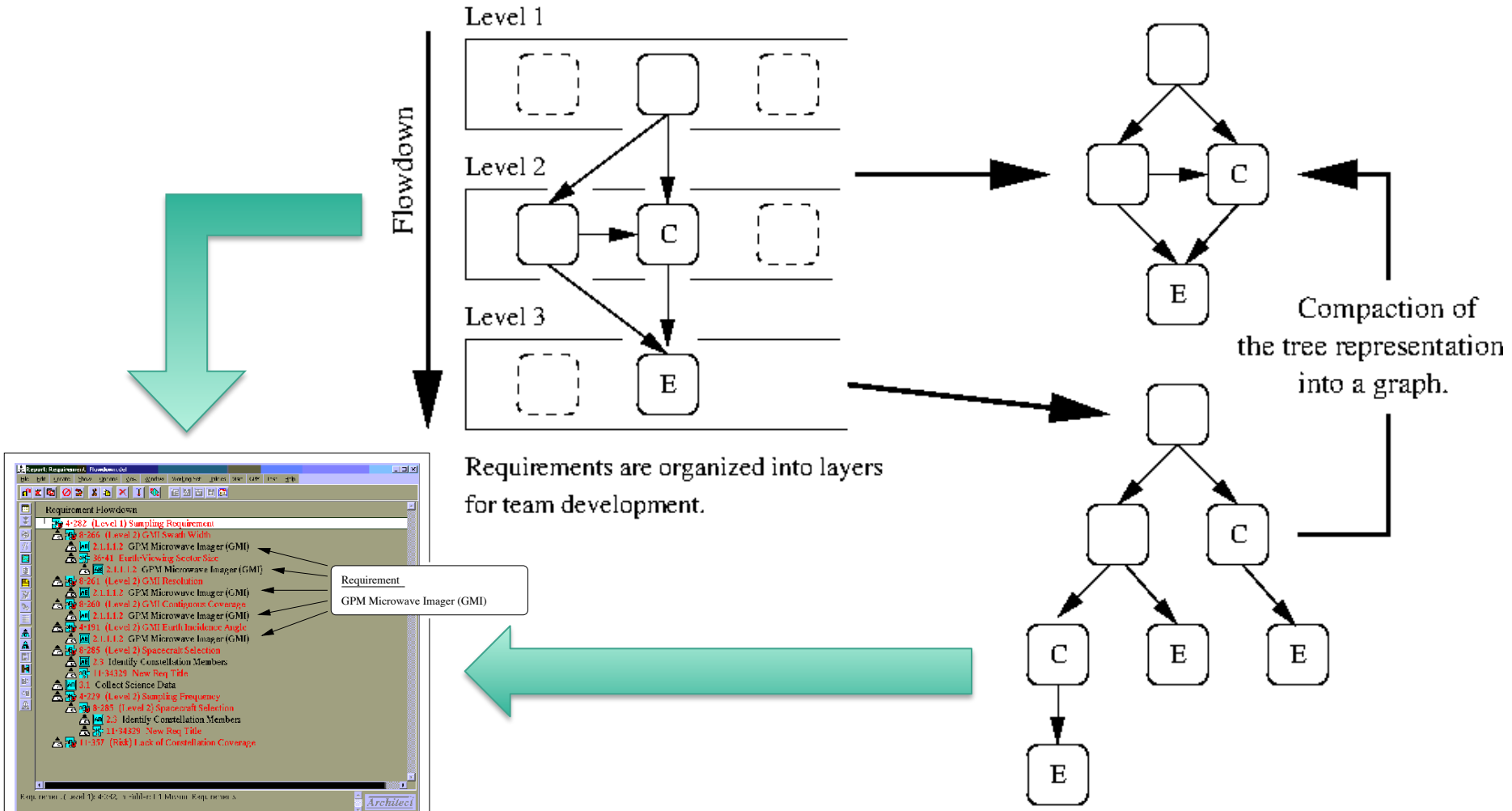


Source: Mosteller et al., 2012

PART 1

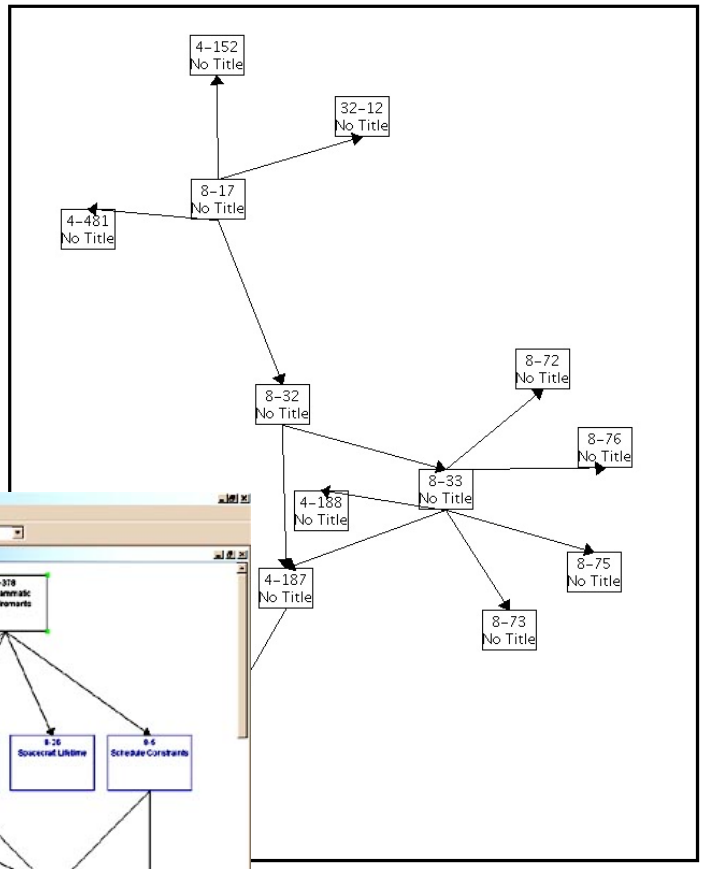
WORKING WITH GPM (2002-2003)

WORKING WITH GPM

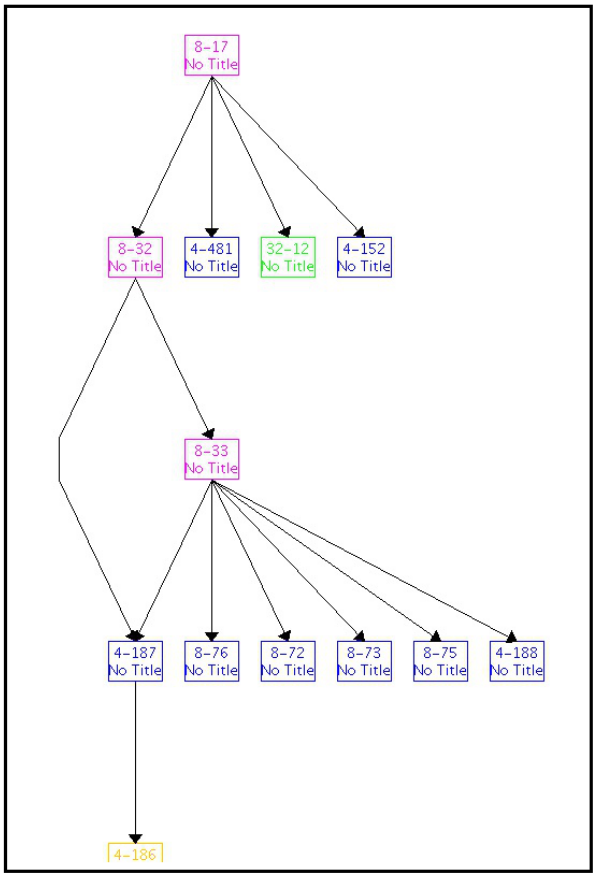


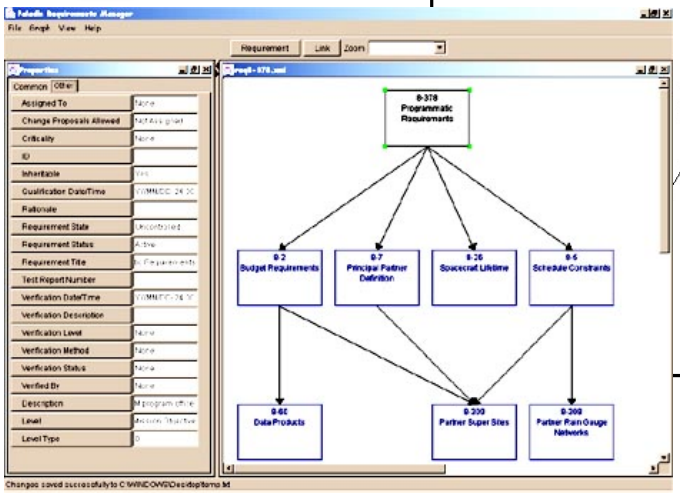
WORKING WITH GPM

SPRING LAYOUT



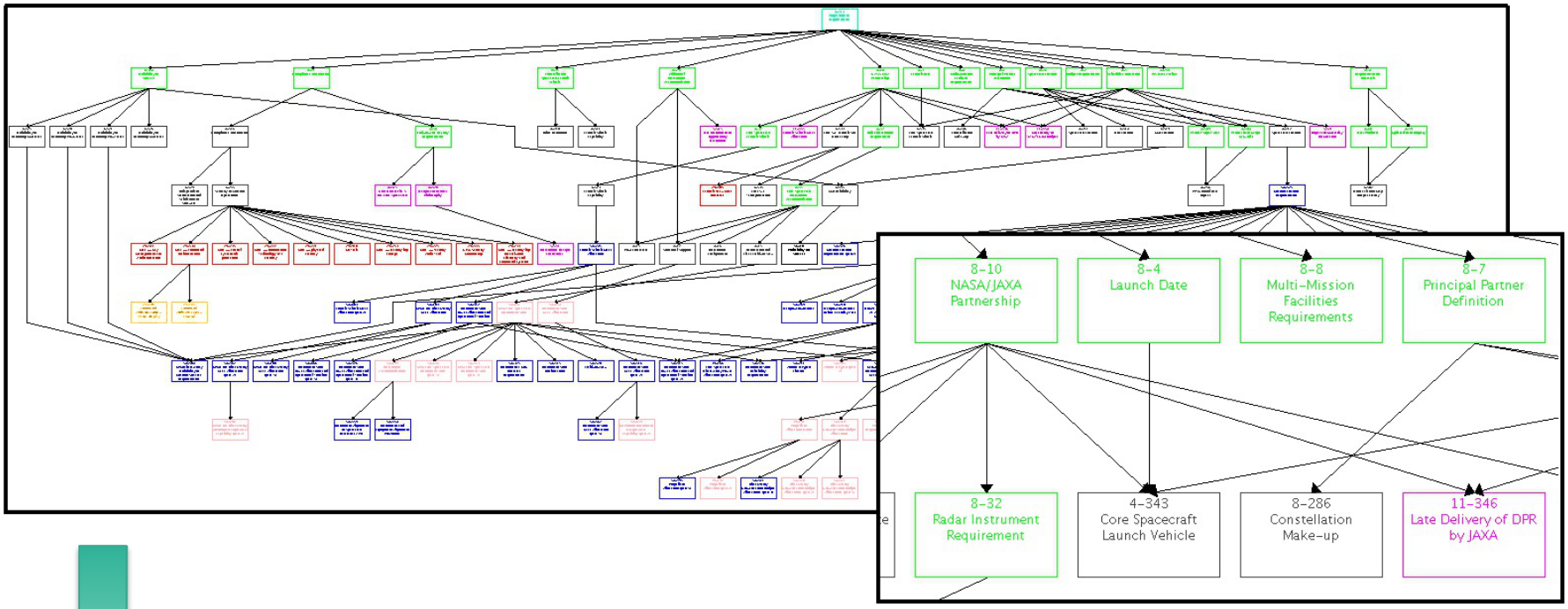
HIERARICHAL LAYOUT





WORKING WITH GPM

Paladin RM Graphical User Interface.



Print hardcopy …

Hardcopy of Requirements …..

PART 2

WORKING WITH SEMANTIC WEB TECHNOLOGIES

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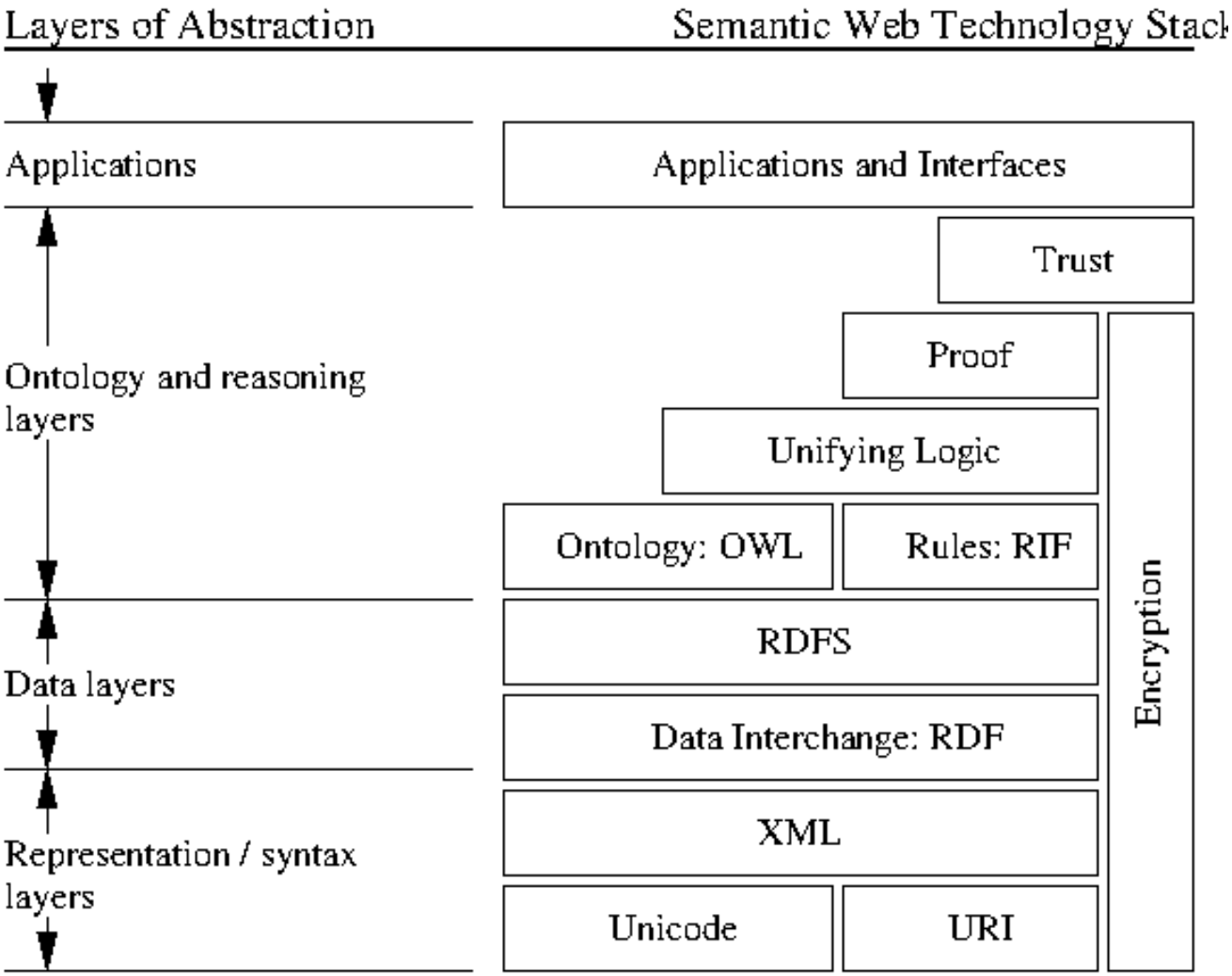
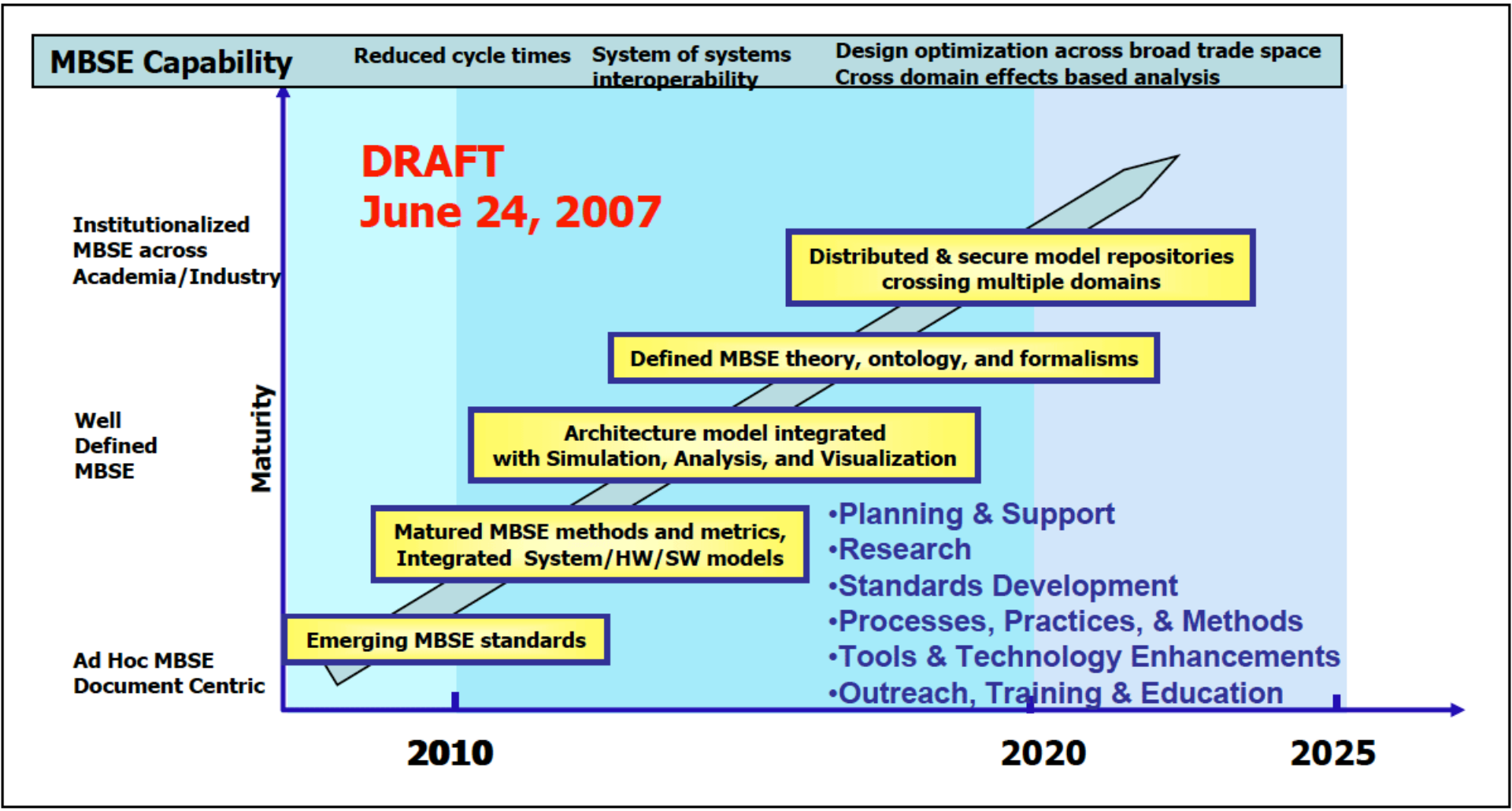


MBSE CAPABILITY 2020 -- 2025



WORKING WITH SEMANTIC WEB TECHNOLOGIES

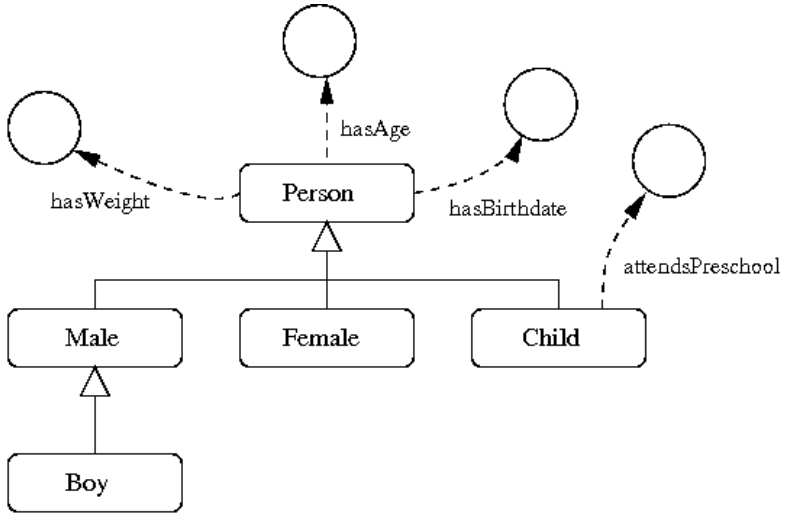
ONTOLOGY MODELING AND RULE-BASED REASONING

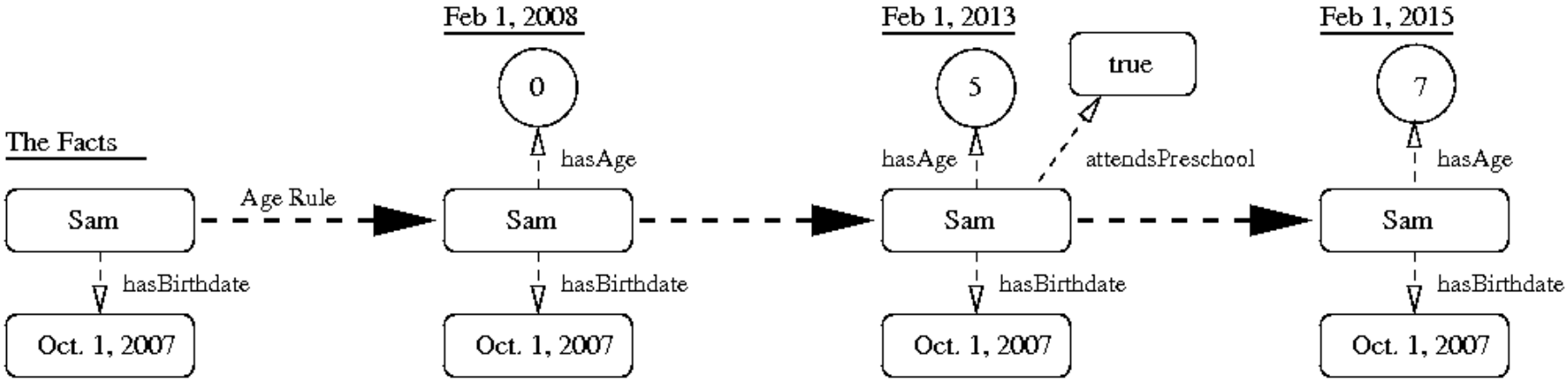
Fact. Sam is a boy. He was born October 1, 2007.

Rule 1: For a given date of birth, a built-in function getAge() computes a person's age.

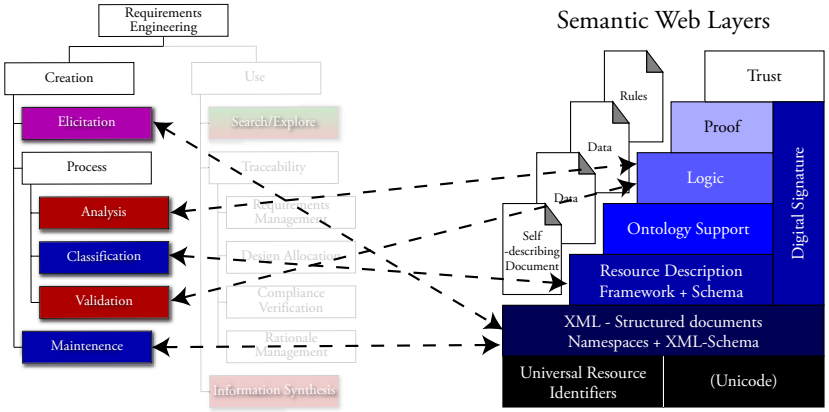
Rule 2: A child is a person with age < 18.

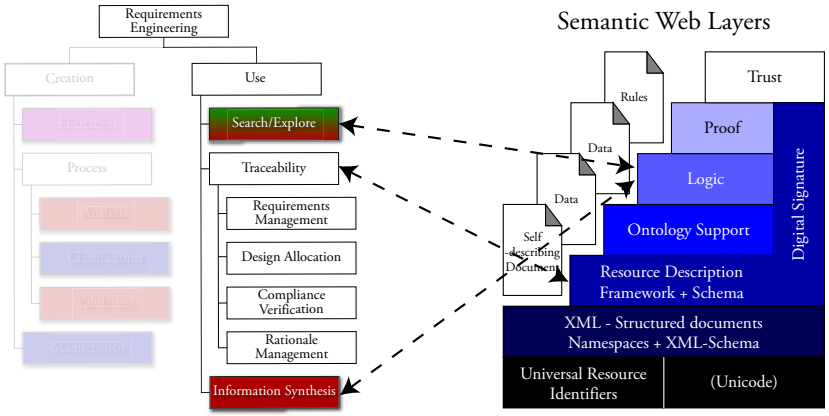
Rule 3: Children who are age 5 attend preschool.

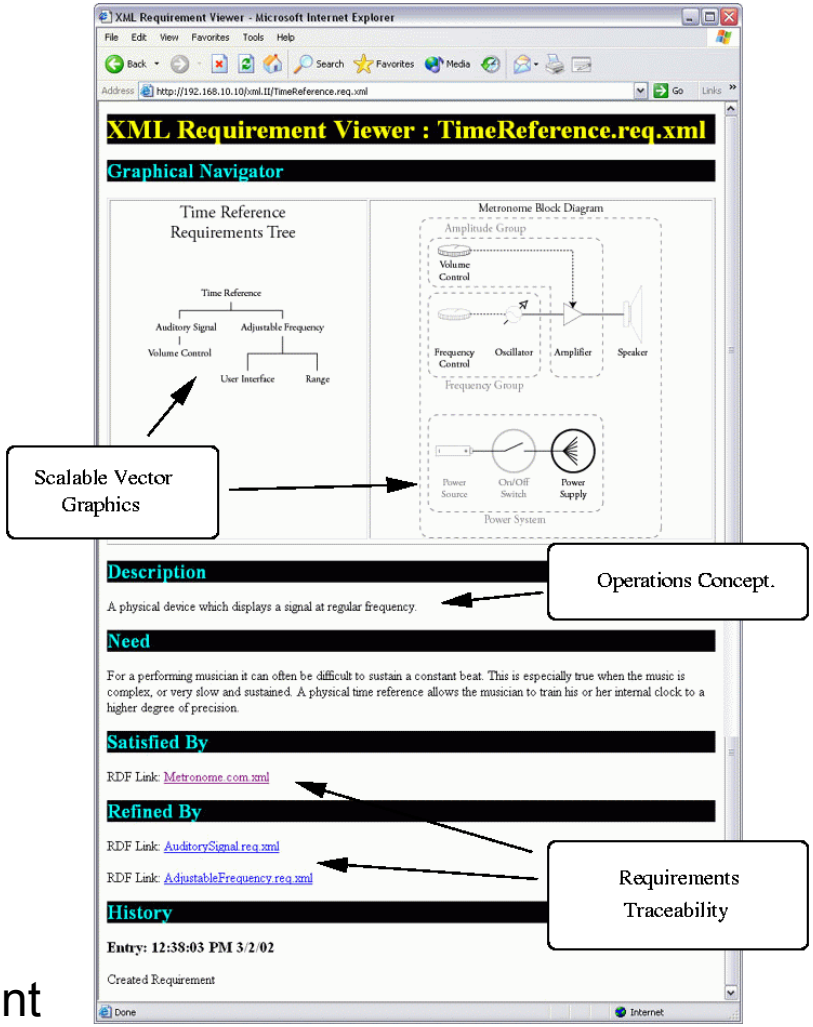




WORKING WITH SEMANTIC WEB TECHNOLOGIES



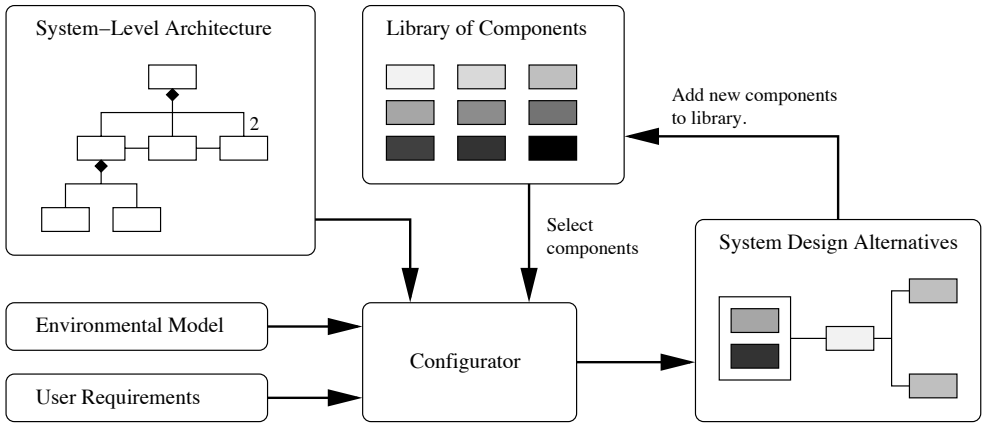


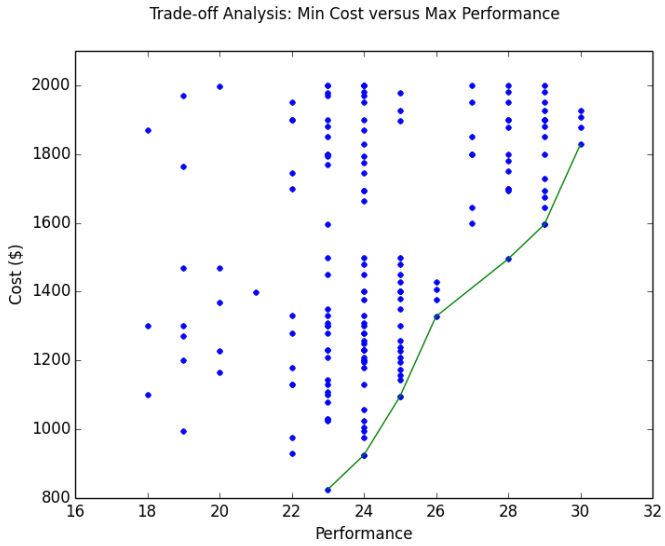


Source: Scott Selberg, MSSE Graduate Student

ENCE 688R / MSSE PROJECT WORK

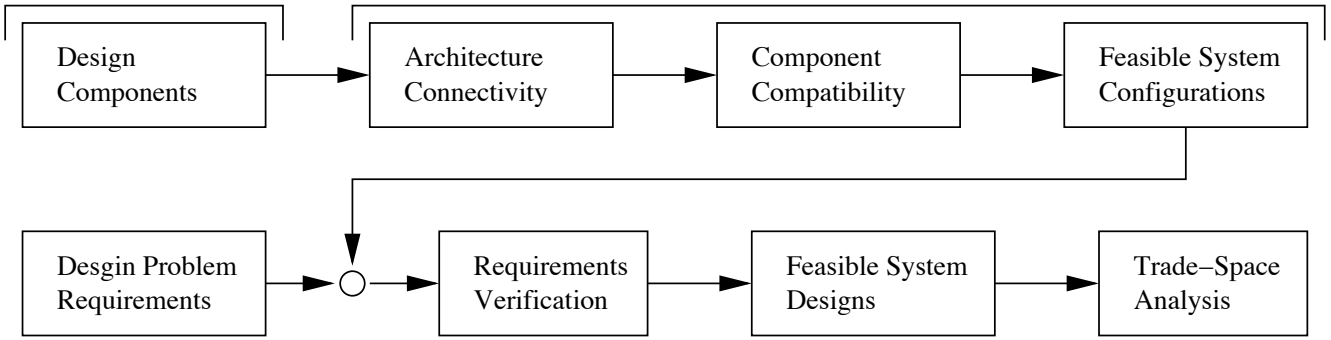
DESIGN AND TRADE-OFF ANALYSIS WITH RDF GRAPHS

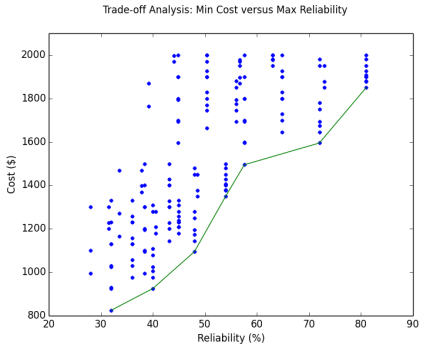




Problem Definition
RDF Graph Models

Inference–Rule Driven Graph Transformations

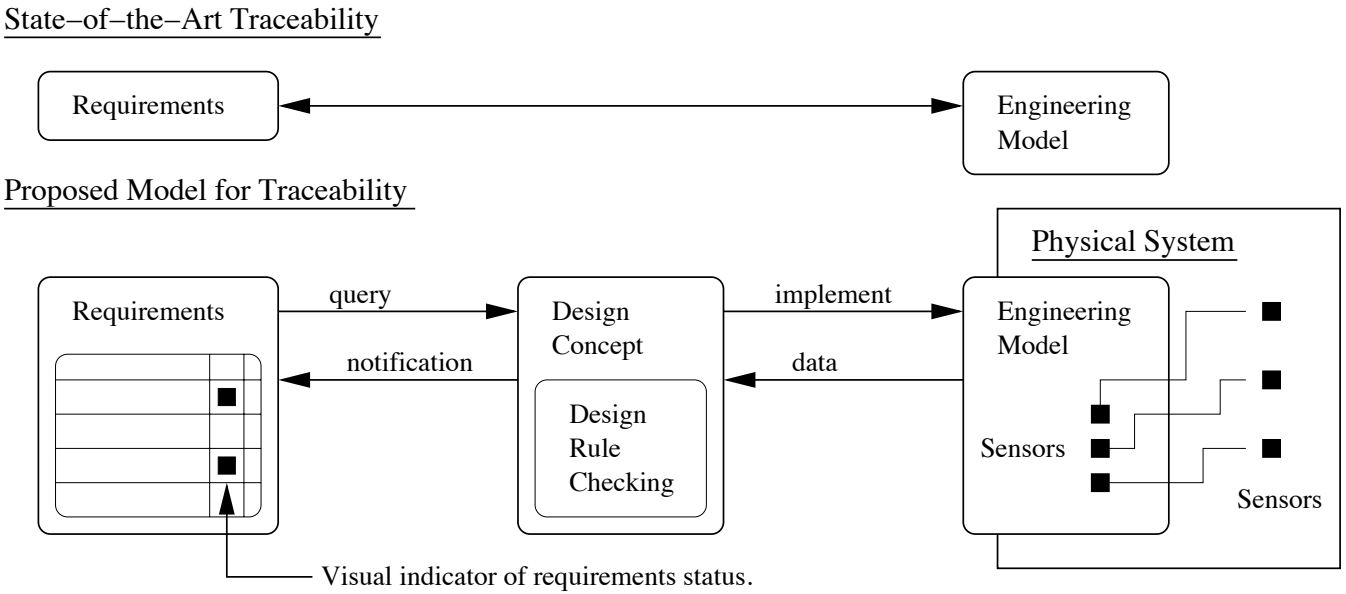




Source: Nefretiti Nassar, MSSE Graduate Student.

WORKING WITH SEMANTIC WEB TECHNOLOGIES

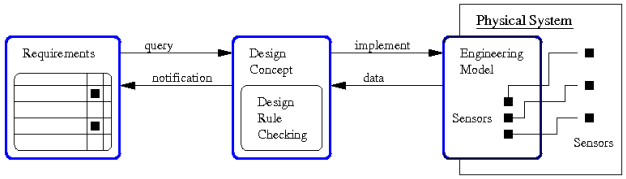
New idea (2005): Ontology-enabled Traceability Mechanisms



Approach: Requirements are satisfied through implementation of design concepts. Now traceability pathways are threaded through design concepts.

Key Benefit: Rule checking can be attached to "design concepts" (ontology), therefore, we have a pathway for early validation.

WORKING WITH SEMANTIC WEB TECHNOLOGIES



Digital Clock View

Time of Day

14:29:22

Time Model

Train Model

Individual Train Behavior(s)

Train Statechart

Service Begins

In Service

Out of Service

Service Ends

User action

Scheduler Statechart View

Scheduler Statechart

Start

Idle

[t==5 am.]

[t==2 am.]

End

Dispatch Train

Stop Train

Stop

Dispatch

Active

Clock Controller

Train Controller

Scheduler Controller

System–Level Behavior of Trains.

Wheaton

Silver Spring

Takoma Park

Fort Totten

U Street

Catholic Univ

Metro Center

Gallery Place

Union Station

Smithsonian

L Enfant Plaza

Eastern Market

Property changed

listeners

listeners

Requirements Controller

Ontology Controller

Metro System Controller

Requirements Model

Req 1.

Req 2.

Req 3.

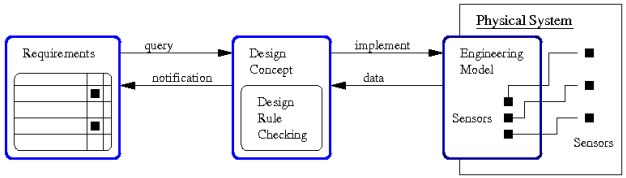
Metro System Ontology Model

Metro System Model

Structure ....

Behavior ....

WORKING WITH SEMANTIC WEB TECHNOLOGIES



Requirement level (textual representation)

The metro system will start working at 5 am.

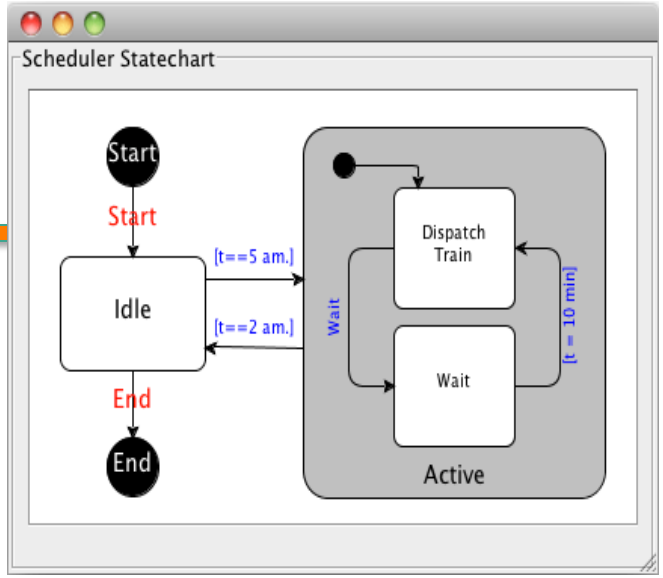
Rule level (SWRL)

scheduler(?s)^ hasTime(?s,?t) ^ swrlb:greaterThan(?t,5) ^ train(?tr)

^ isAvailable(?tr,true)=>sendTrain(?s,?tr)

Guard Statement

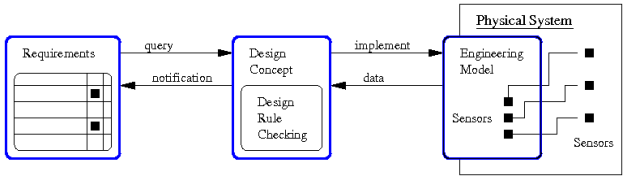
The transition from idle to active is conditional on " [t == 5 am.]" evaluation results.

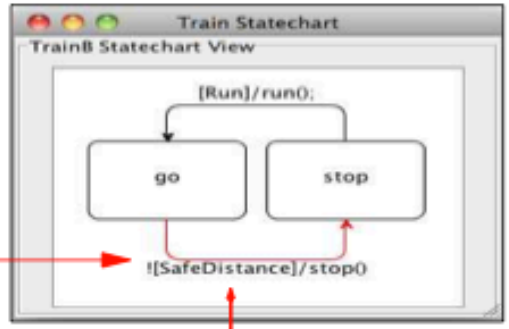


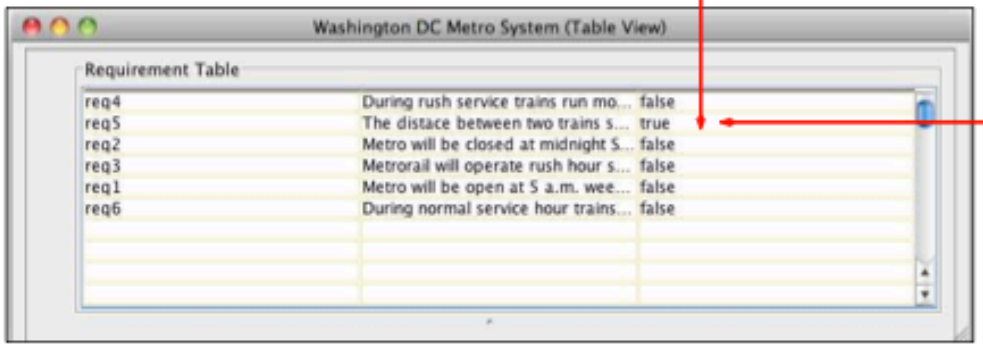
Expected Behavior

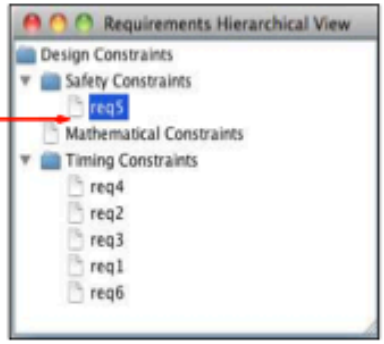
- The scheduler statechart will transition from idle to active at 5:00 am.
- The statechart of at least one train will transition to the "At Station" state.

STATECHART TO REQUIREMENT TRACEABILITY



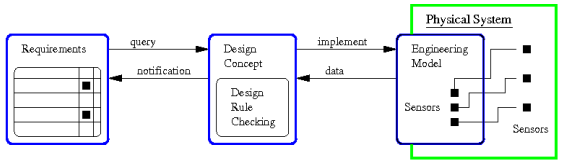


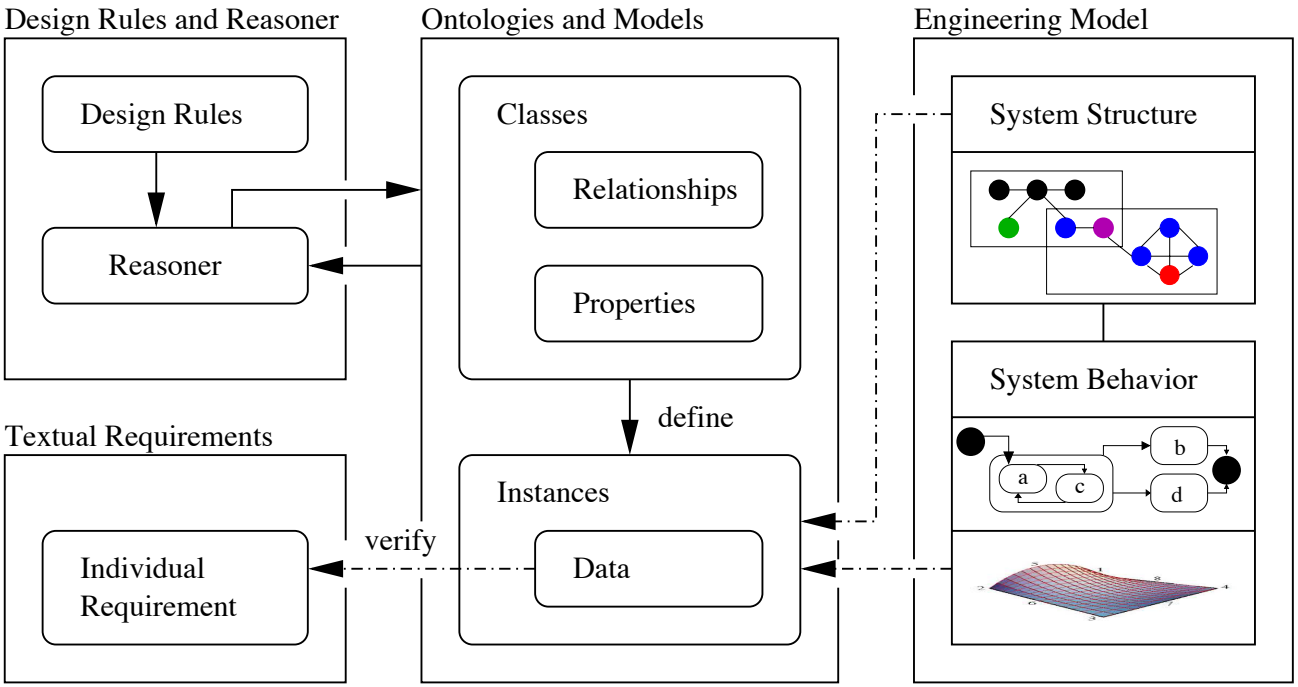




WORKING WITH SEMANTIC WEB TECHNOLOGIES

Parastoo finishes MSSE Degree in Dec. 2012.
Matriculates to Ph.D. in Civil Systems in Jan. 2013.





Remarks

System structures are modeled as networks and composite hierarchies of components.

Behaviors will be associated with components.

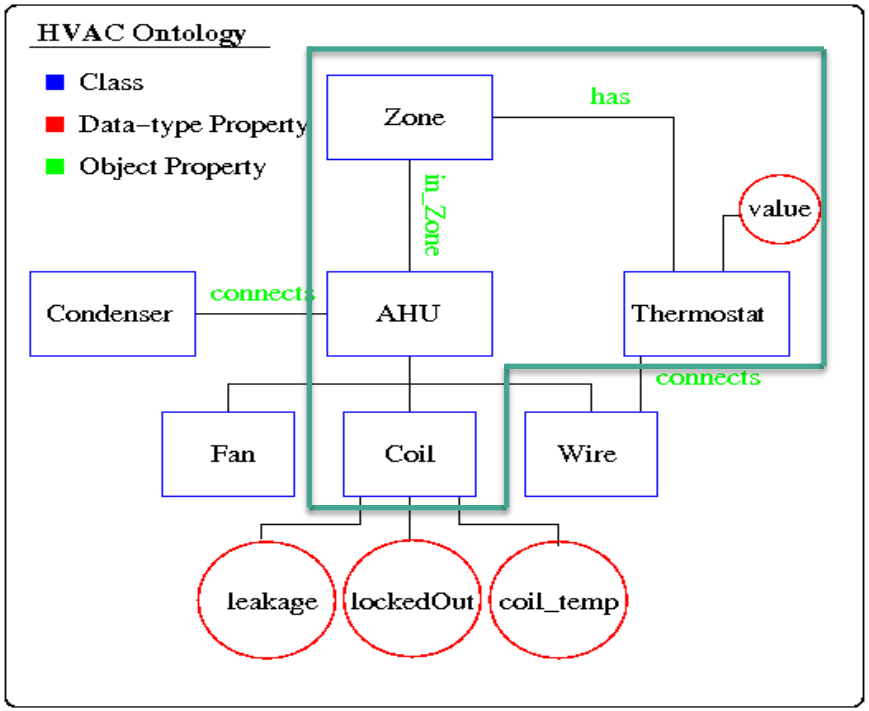
Discrete behavior will be modeled with finite state machines.

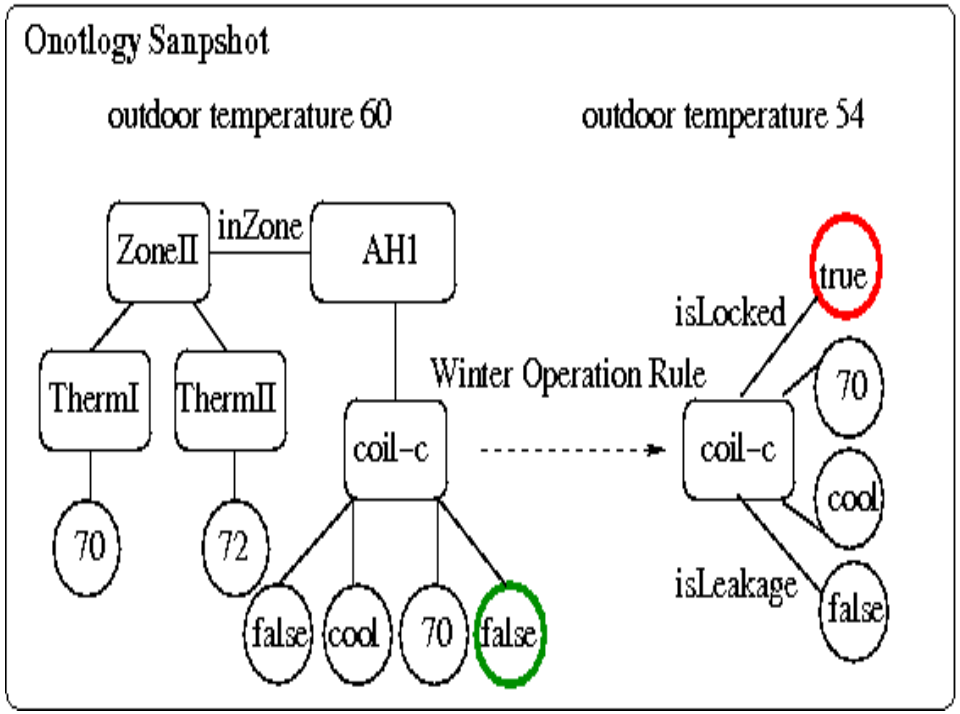
Continuous behavior will be represented by partial differential equations.

WORKING WITH SEMANTIC WEB TECHNOLOGIES

Requirement: Cooling coil will be locked out for winter operation (55 F)

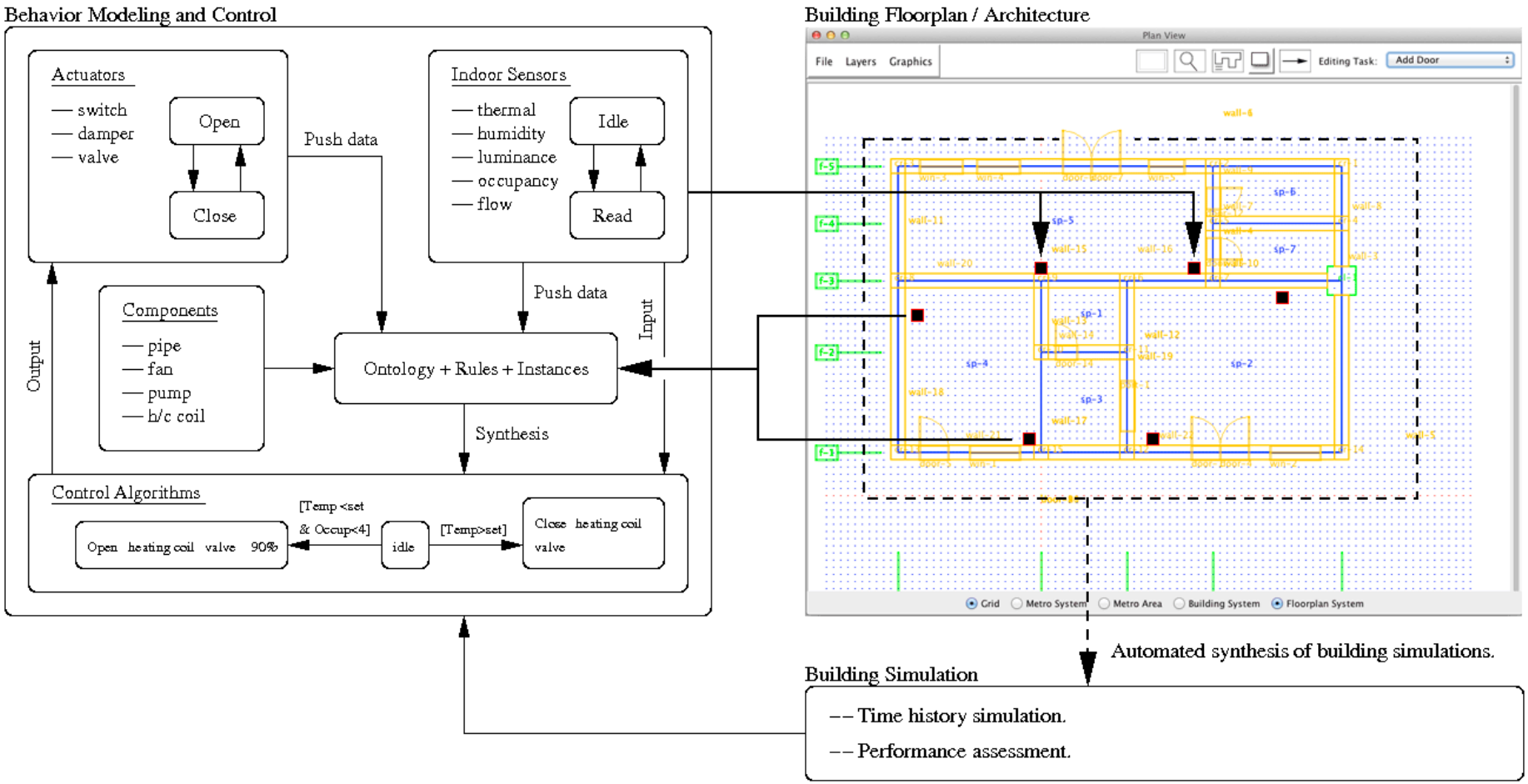
Rule: (?cc RDF:type Cooling) (?cc ont:isLocked? ?l) (?out_temp ont:hasValue ?v) lessThan(?v,55) ->(?l, true)





INFERENCE RULES FOR HVAC ONTOLOGY

WORKING WITH SEMANTIC WEB TECHNOLOGIES

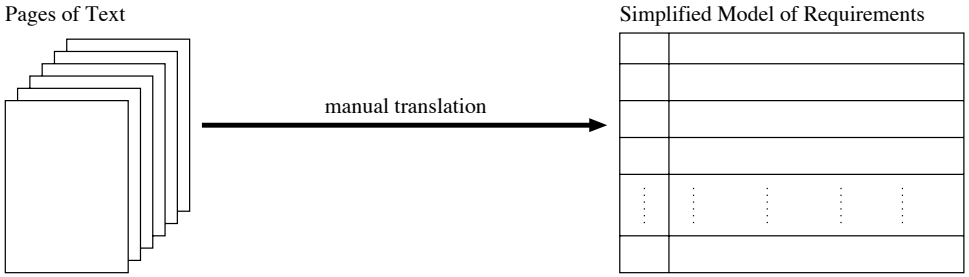


PART 3

INTEGRATION OF NLP WITH ONTOLOGIES AND TEXTUAL REQUIREMENTS

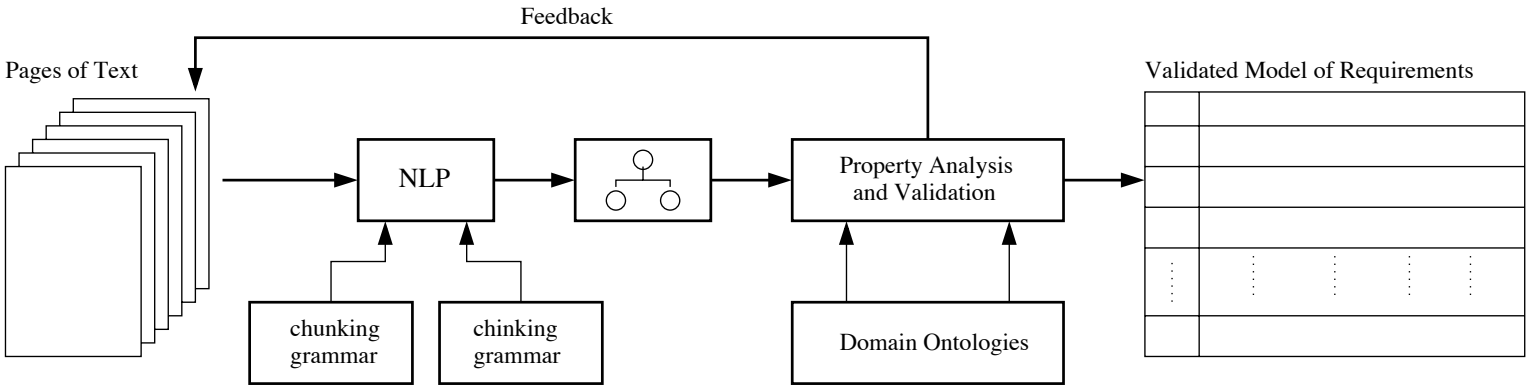
State-of-the-Art Practice / Our Idea

State-of-the-Art Practice: Transforming Textual Requirements into Models

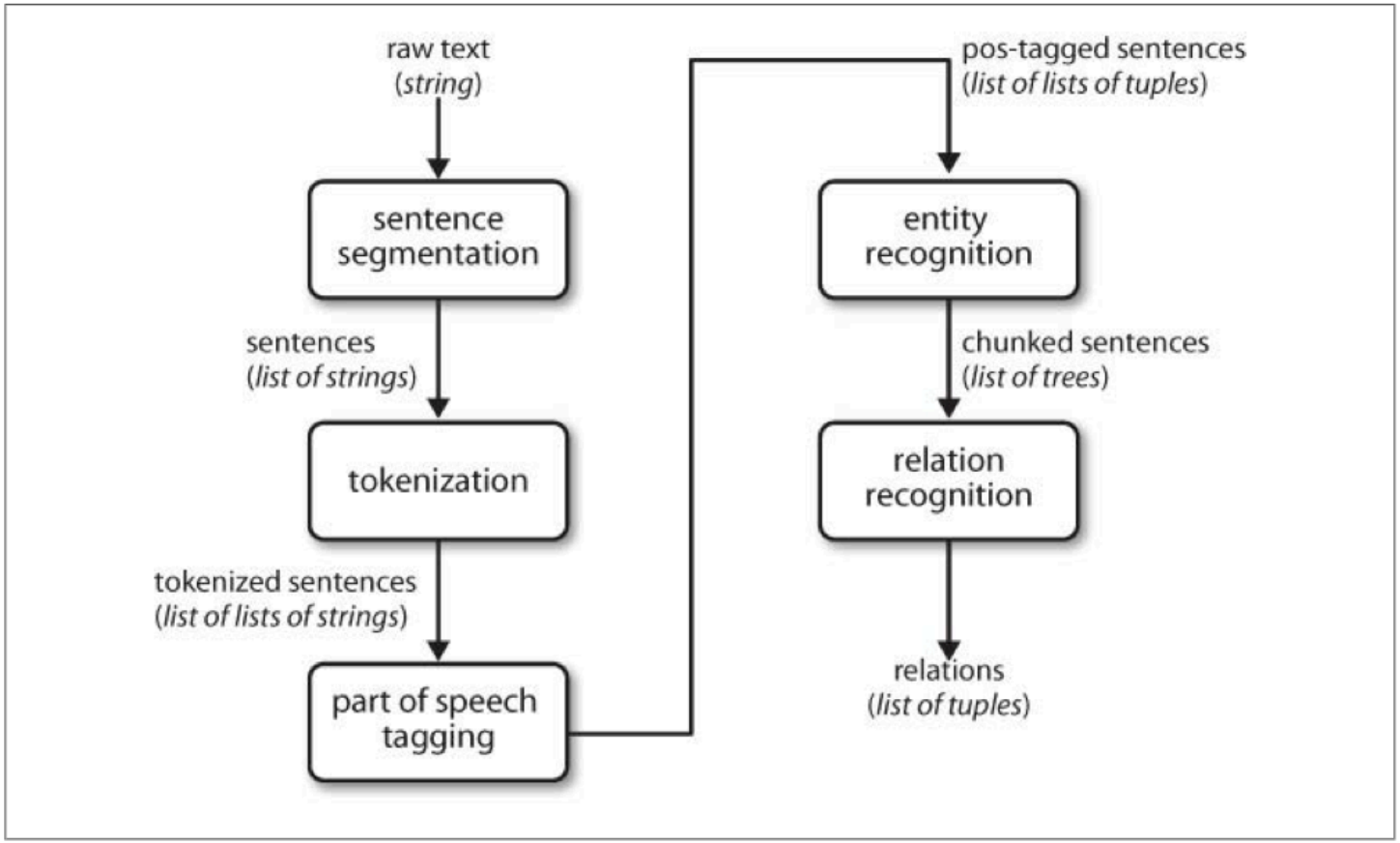


Problem size: 100's – 1000's of pages.
Difficulties: slow, error prone, no support for validation.

Our Idea: Integration of NLP with Ontologies and Textual Requirements



Working with the Natural Language Processing Toolkit (NLTK)



Source: Scholarly Paper, Andres Arellano, 2014.

Working with the Natural Language Processing Toolkit (NLTK)

Tokenization: Identify and provide access to individual words in the text.

```
text = "These prerequisites are known as (computer)
        system requirements and are often used as a
        guideline as opposed to an absolute rule."
tokens = nltk.word_tokenize(my_string)
print tokens
=>
['These', 'prerequisites', 'are', 'known', 'as',
 '(', 'computer', ')', 'system', 'requirements',
 'and', 'are', 'often', 'used', 'as', 'a',
 'guideline', 'as', 'opposed', 'to', 'an',
 'absolute', 'rule', '.']
```

Working with the Natural Language Processing Toolkit (NLTK)

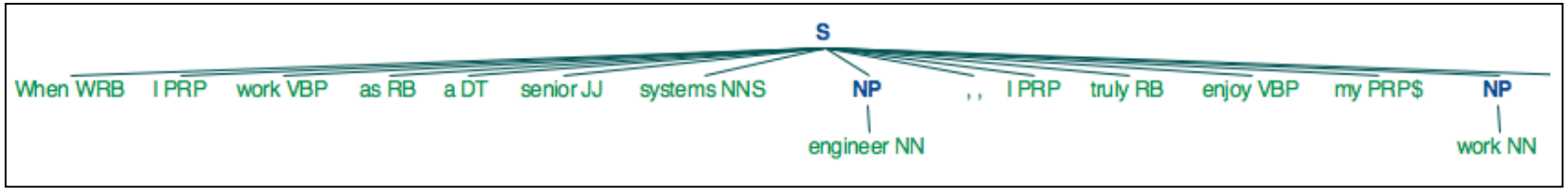
Part of Speech Tagging: Identify the role each word plays in the sentence.

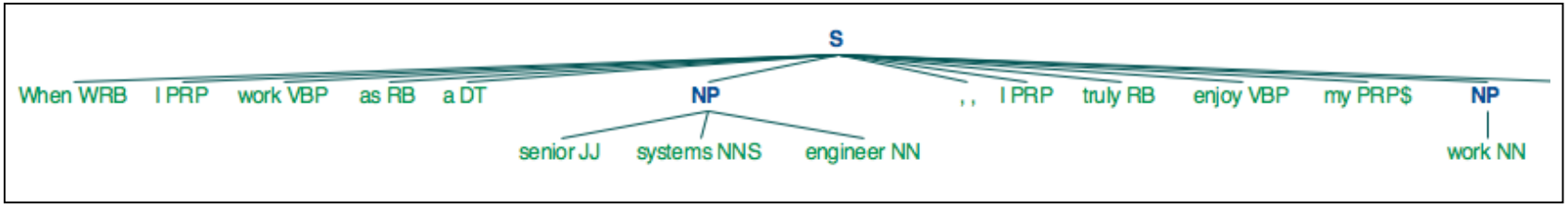
```
my_string = "When I work as a senior systems
              engineer, I truly enjoy my work."
tokens = nltk.word_tokenize(my_string)
print tokens

tagged_tokens = nltk.pos_tag(tokens)
print tagged_tokens
=>
[('When', 'WRB'), ('I', 'PRP'), ('work', 'VBP'),
 ('as', 'RB'), ('a', 'DT'), ('senior', 'JJ'),
 ('systems', 'NNS'), ('engineer', 'NN'), (',', ','),
 ('I', 'PRP'), ('truly', 'RB'), ('enjoy', 'VBP'),
 ('my', 'PRP$'), ('work', 'NN'), ('.', '.')]
```

Legend: WRB = Wh-verb (e.g., How, where, why), PRP = Personal pronoun (e.g., I); RB = Adverb; JJ = Adjective, VBP = Present verb tense, etc.

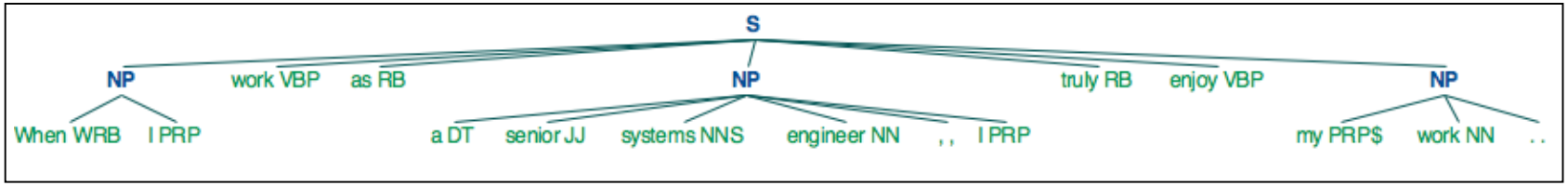
Working with the Natural Language Processing Toolkit (NLTK)

Chunking: These are patterns of part-of-speech tags that define what kinds of words make up a chunk.

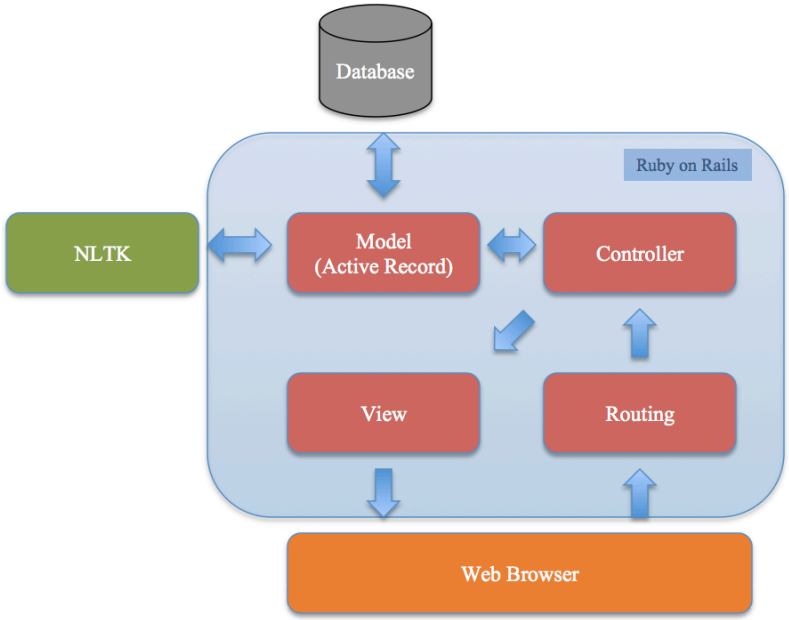




Chinking: Patterns for what kinds of words should be excluded from a chunk.

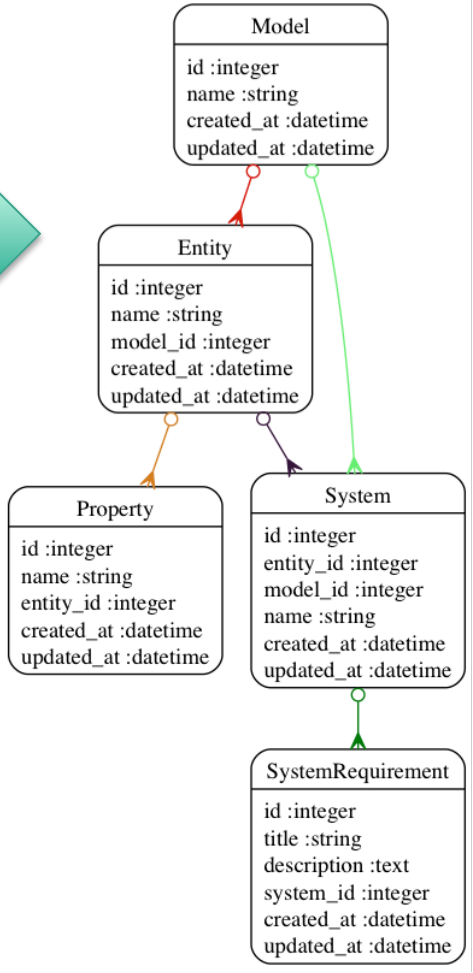


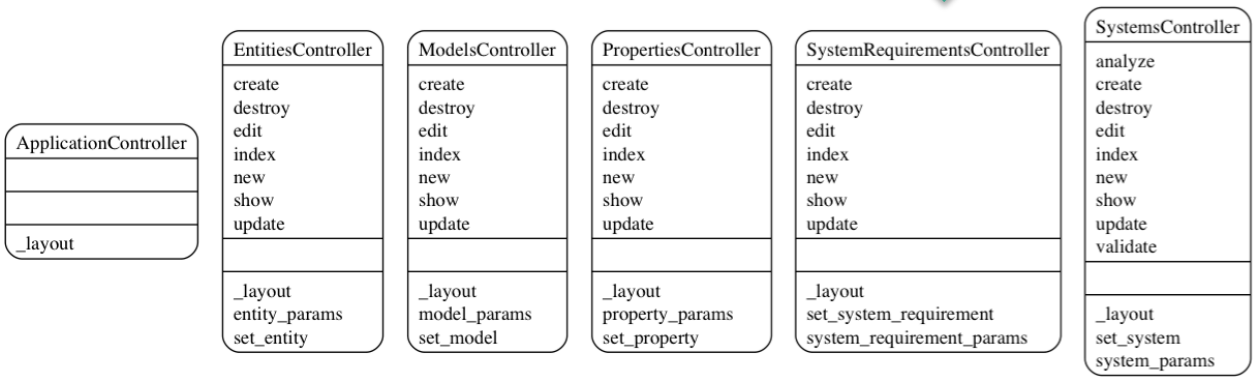
Systems Integration / Prototype Software Implementation



Model Architecture

Controllers





Simple Aircraft Application

Ontology Model

+Model: Transportation
+Entity: Aircraft
+Engines
+Wings
+Slides
+Throttle Levels
+Altitude Indicator
Length: 254 meters
Passengers Capacity

TextReq Validation | Systems | Requirements | Models | Entities | Properties

Model

Name: Transportation
Entities: Track
Station
Rail Line
Train
Route
Aircraft

Back | Edit | Delete

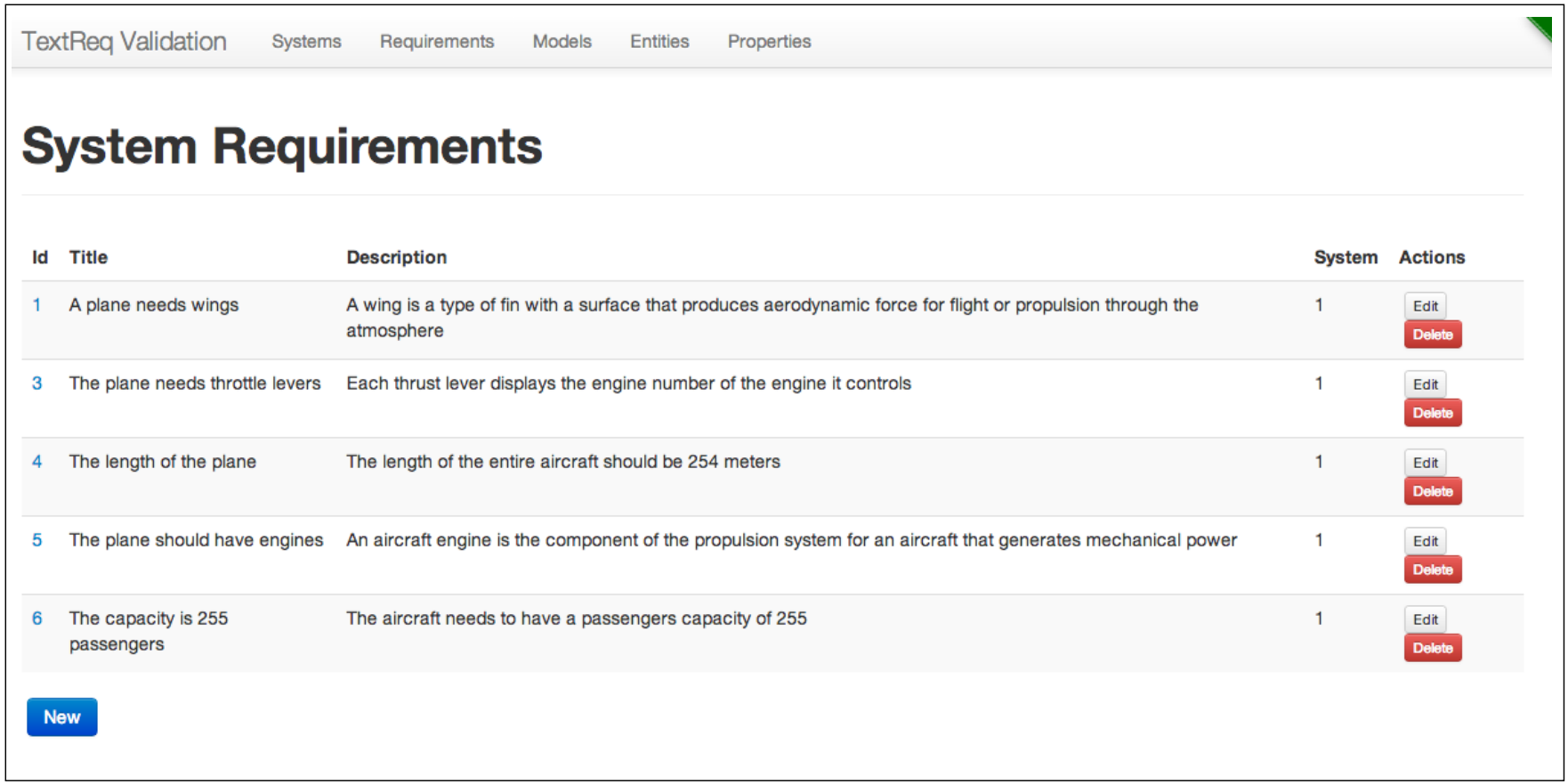
TextReq Validation | Systems | Requirements | Models | Entities | Properties

Entity

Name: Aircraft
Properties: engines
wings
slides
throttle levers
altitude indicator
length
passengers capacity

Back | Edit | Delete

Simple Aircraft Application: Requirements



Simple Aircraft Application: Analysis of Requirements

Basic Properties

Property	Value
Chars	547
Len tokens	94
Sentences	1
Porter stems	94
Lancaster stems	94
Wnl stems	94

Objects

NN	aircraft plane engine capacity length propulsion atmosphere component fin flight force lever number power surface system throttle thrust type
NNS	passengers displays engines generates levers meters wings
NP	aircraft engine engine number generates mechanical power passengers capacity propulsion system throttle levers thrust lever displays

Simple Aircraft Application: System Validation

System Validation

Verified properties	engines, wings, throttle levers, length, passengers capacity
Unverified properties	slides, altitude indicator

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Thank You

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