Concept Map Based Software Engineering

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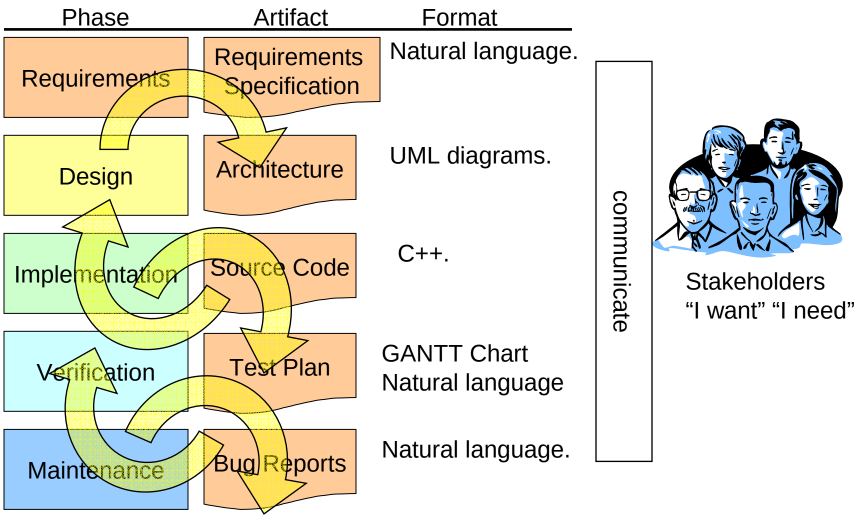
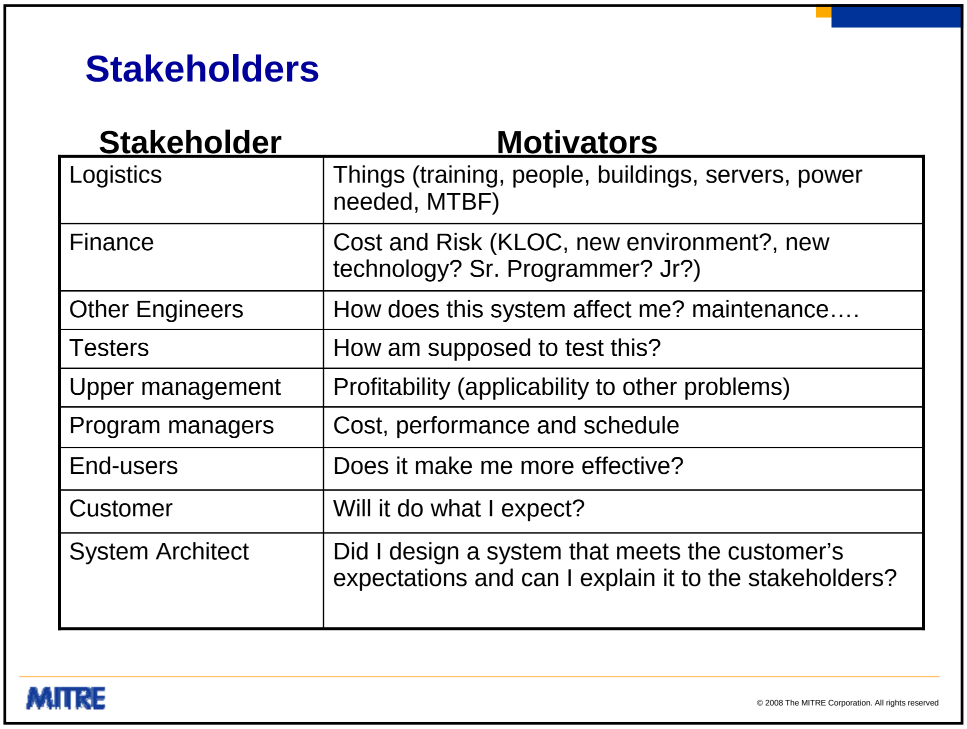
Typical SE Process



Phase	Artifact	Format
Requirements	Requirements Specification	Natural language.
Design	Architecture	UML diagrams.
Implementation	Source Code	C++.
Verification	Test Plan	GANTT Chart Natural language
Maintenance	Bug Reports	Natural language.

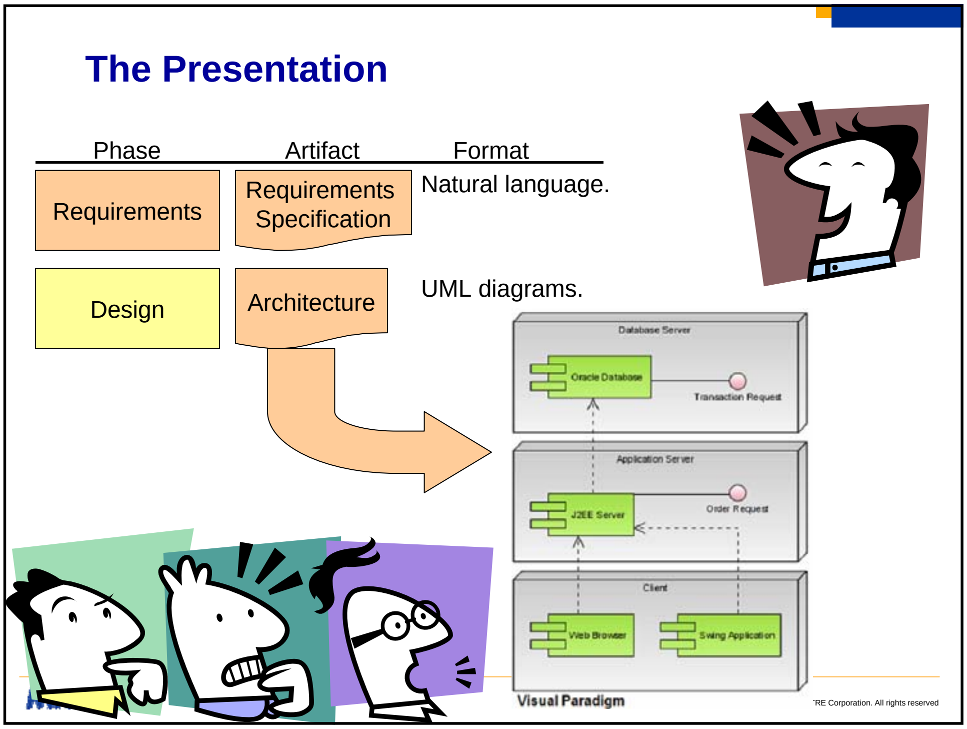
communicate

Stakeholders
“I want” “I need”



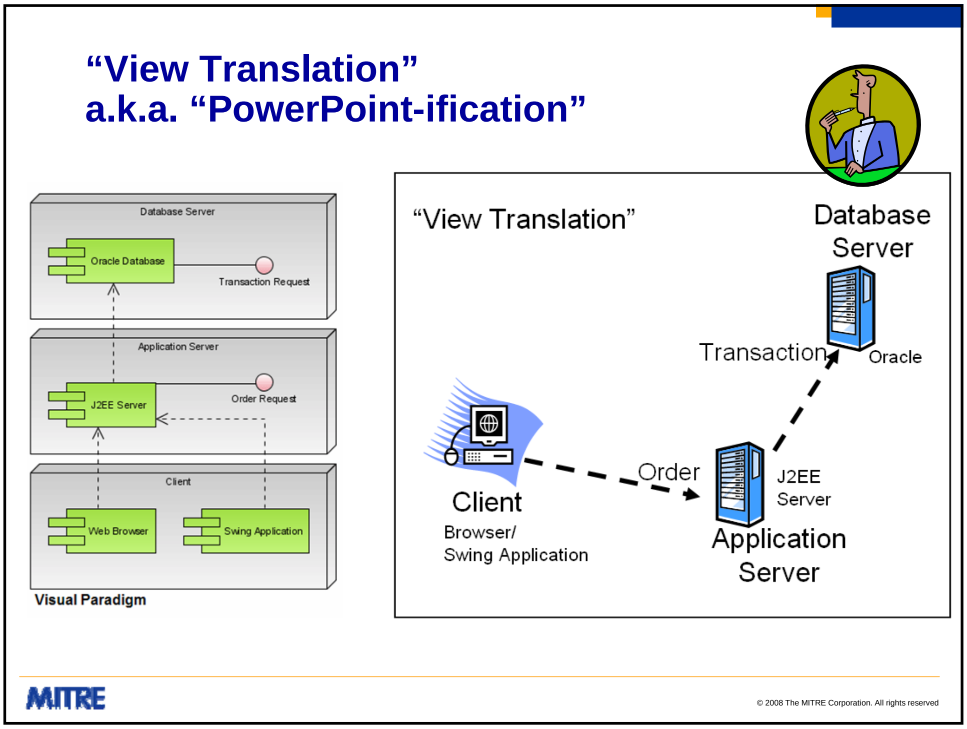
Stakeholders

Stakeholder	Motivators
Logistics	Things (training, people, buildings, servers, power needed, MTBF)
Finance	Cost and Risk (KLOC, new environment?, new technology? Sr. Programmer? Jr?)
Other Engineers	How does this system affect me? maintenance….
Testers	How am supposed to test this?
Upper management	Profitability (applicability to other problems)
Program managers	Cost, performance and schedule
End-users	Does it make me more effective?
Customer	Will it do what I expect?
System Architect	Did I design a system that meets the customer's expectations and can I explain it to the stakeholders?



The Presentation

Phase	Artifact	Format
Requirements	Requirements Specification	Natural language.
Design	Architecture	UML diagrams.



"View Translation"
a.k.a. "PowerPoint-ification"

Database Server

Oracle Database

Transaction Request

Application Server

J2EE Server

Order Request

Client

Web Browser

Swing Application

Visual Paradigm

"View Translation"

Database Server

Transaction

Oracle

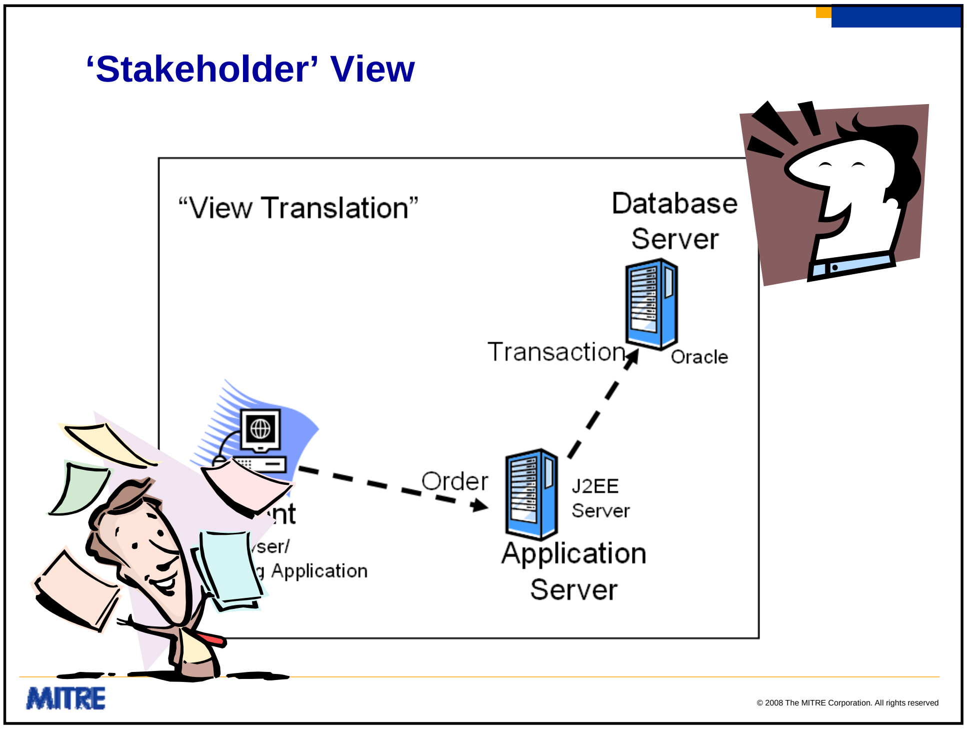
Order

J2EE Server

Client

Browser/ Swing Application

Application Server



'Stakeholder' View

"View Translation"

Database Server

Transaction

Oracle

Order

J2EE Server

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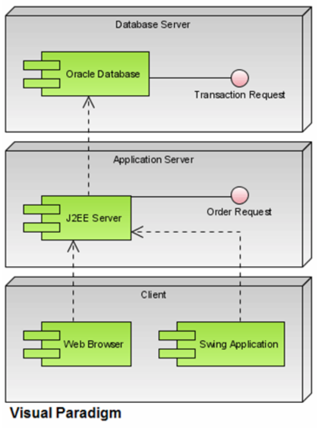
ser/

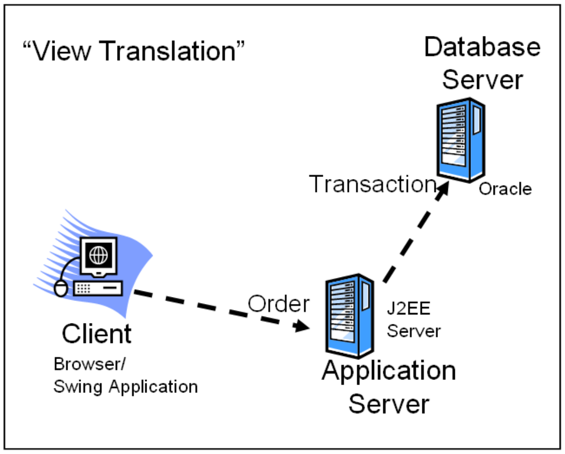
g Application

Application Server

The “pretty picture” is broken.



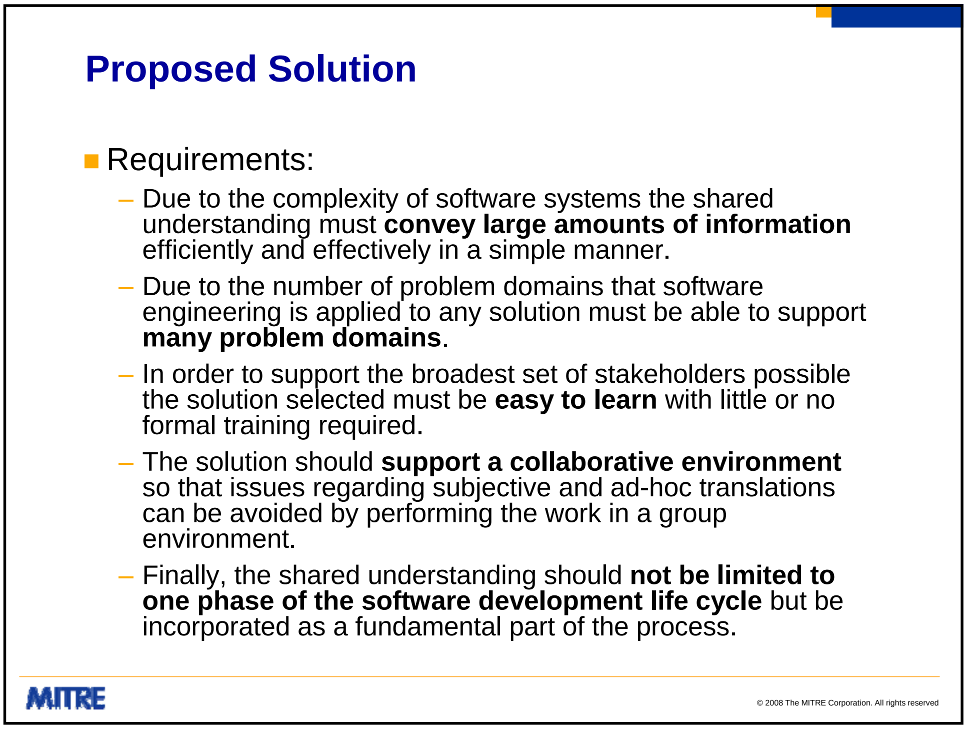
‘Module view + C&C view’



‘Module view + C&C view + Allocation view’

Problem:

- Lack of a common conceptual model that supports a shared understanding of a system.
- Side effect requires that model translations be done.
- Model translations:
  - **inaccurate** due to the subjective nature of the translation
  - **inconsistent** since the translations are done in an ad-hoc manner and therefore vary from presenter to presenter
  - **time consuming** to produce
  - **inaccurate when translated** from a more robust representation of the system
  - **out of date with reality** since work must be done to keep the ‘stakeholder’ model in line with the working model.
- All of these problems result in miscommunications and wasted time and effort.



Proposed Solution

- Requirements:
  - Due to the complexity of software systems the shared understanding must **convey large amounts of information** efficiently and effectively in a simple manner.
  - Due to the number of problem domains that software engineering is applied to any solution must be able to support **many problem domains**.
  - In order to support the broadest set of stakeholders possible the solution selected must be **easy to learn** with little or no formal training required.
  - The solution should **support a collaborative environment** so that issues regarding subjective and ad-hoc translations can be avoided by performing the work in a group environment.
  - Finally, the shared understanding should **not be limited to one phase of the software development life cycle** but be incorporated as a fundamental part of the process.

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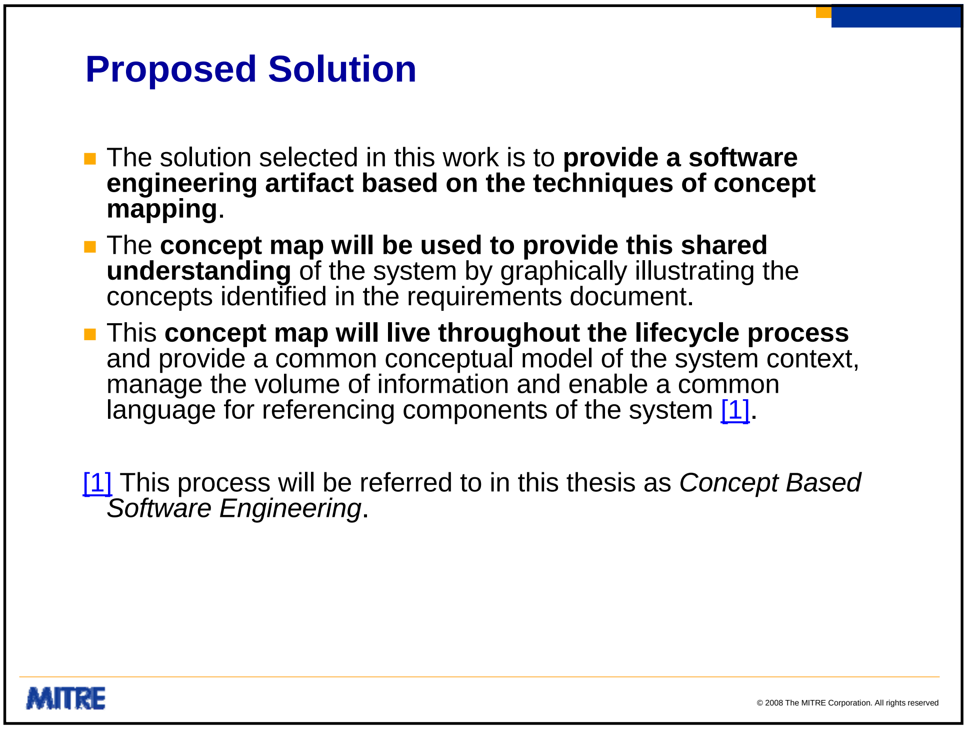

Proposed Solution

- The solution selected in this work is to **provide a software engineering artifact based on the techniques of concept mapping**.
- The **concept map will be used to provide this shared understanding** of the system by graphically illustrating the concepts identified in the requirements document.
- This **concept map will live throughout the lifecycle process** and provide a common conceptual model of the system context, manage the volume of information and enable a common language for referencing components of the system [1].

[1] This process will be referred to in this thesis as *Concept Based Software Engineering*.

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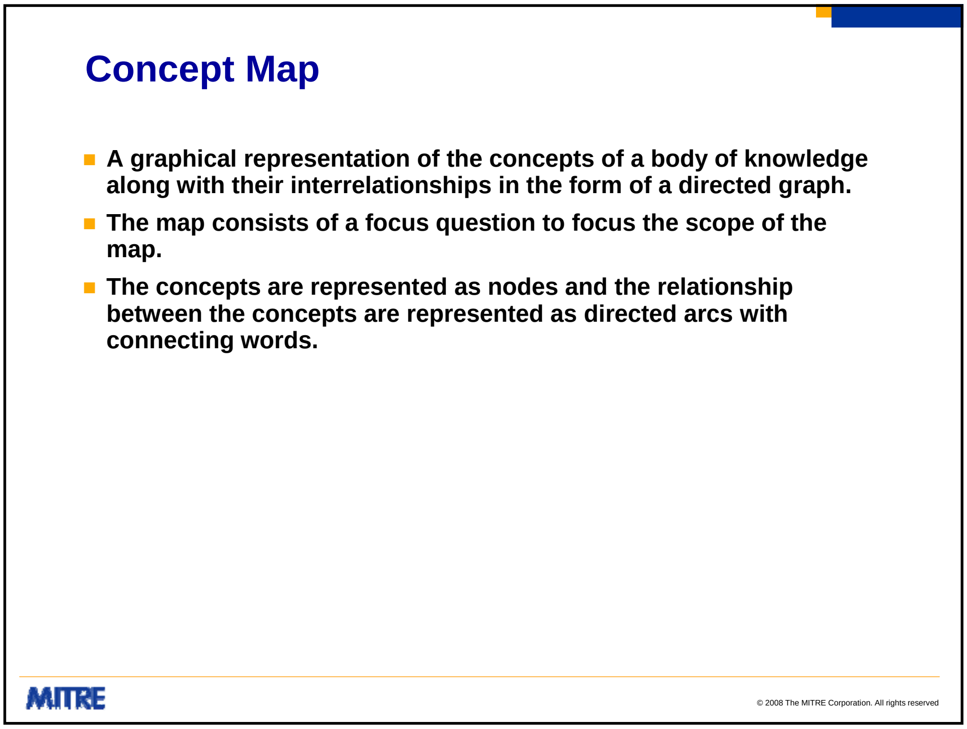
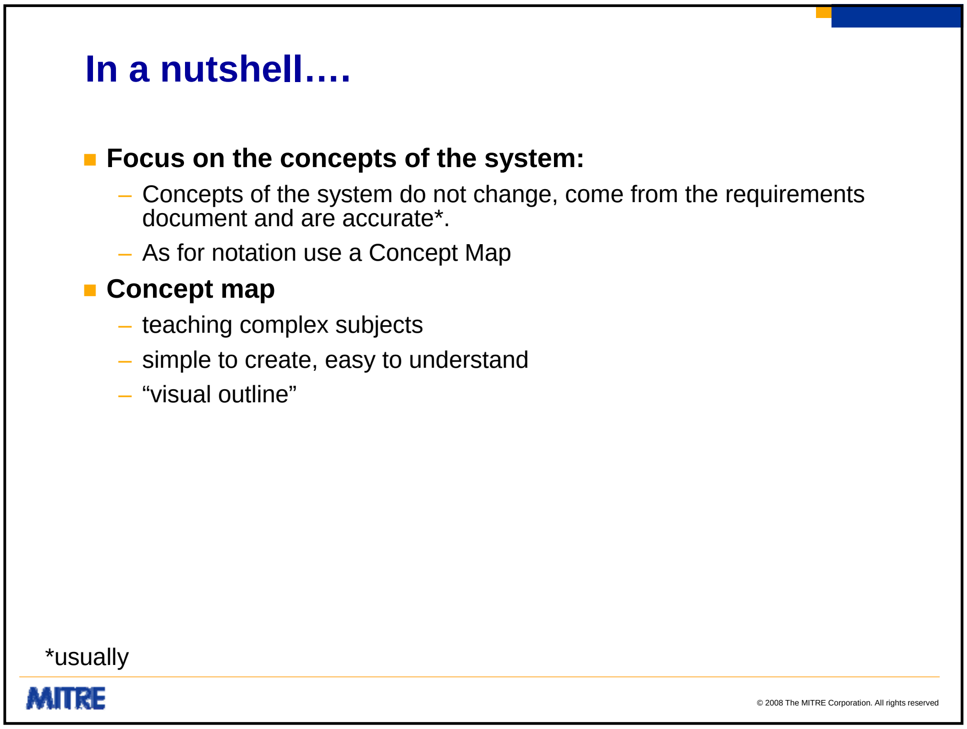


Concept Map

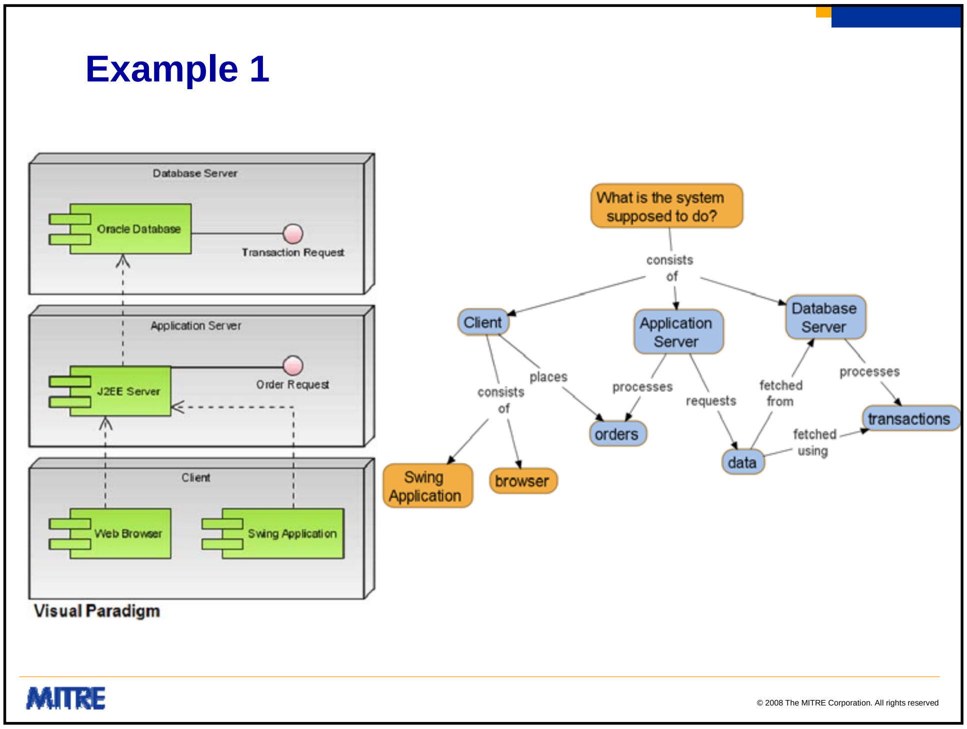
- A graphical representation of the concepts of a body of knowledge along with their interrelationships in the form of a directed graph.
- The map consists of a focus question to focus the scope of the map.
- The concepts are represented as nodes and the relationship between the concepts are represented as directed arcs with connecting words.



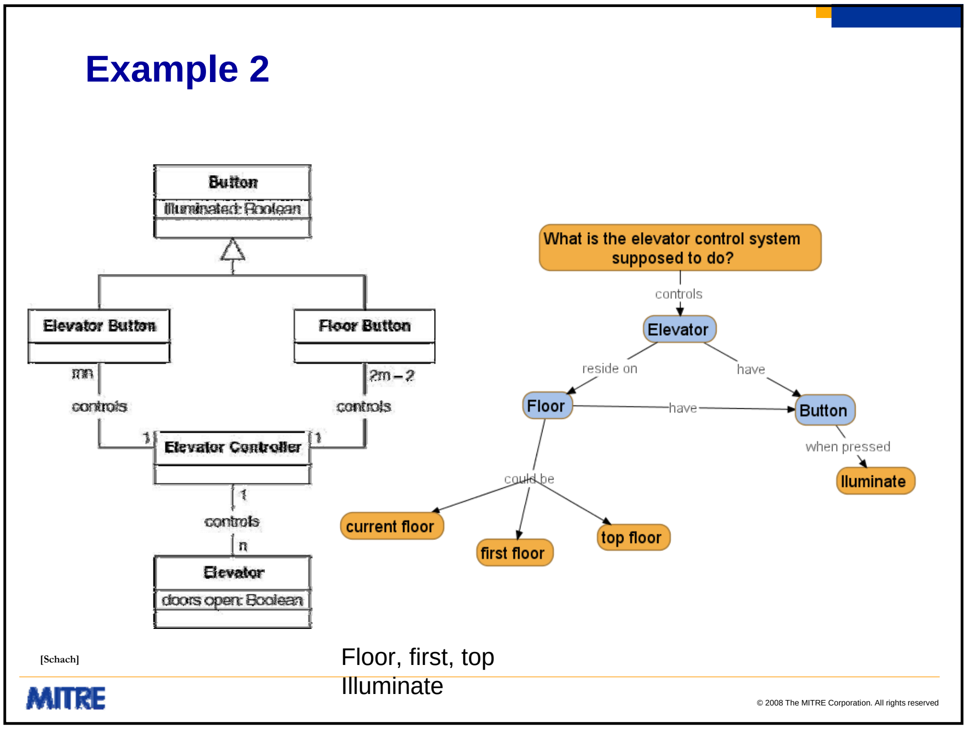
In a nutshell….

- **Focus on the concepts of the system:**
  - Concepts of the system do not change, come from the requirements document and are accurate*.
  - As for notation use a Concept Map
- **Concept map**
  - teaching complex subjects
  - simple to create, easy to understand
  - “visual outline”

*usually



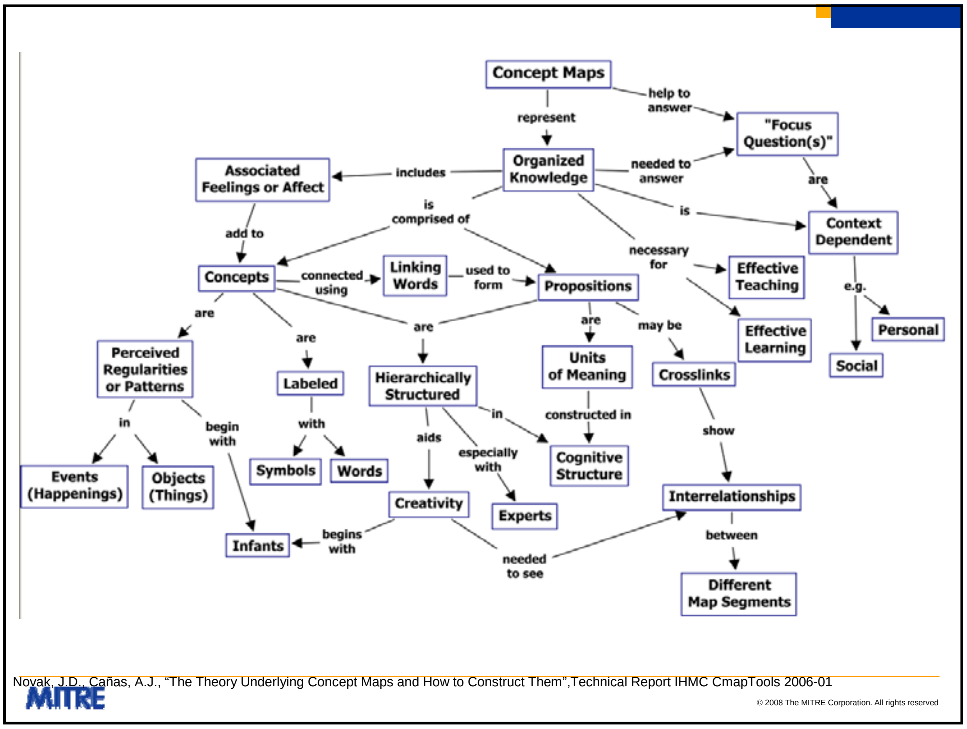
Example 1



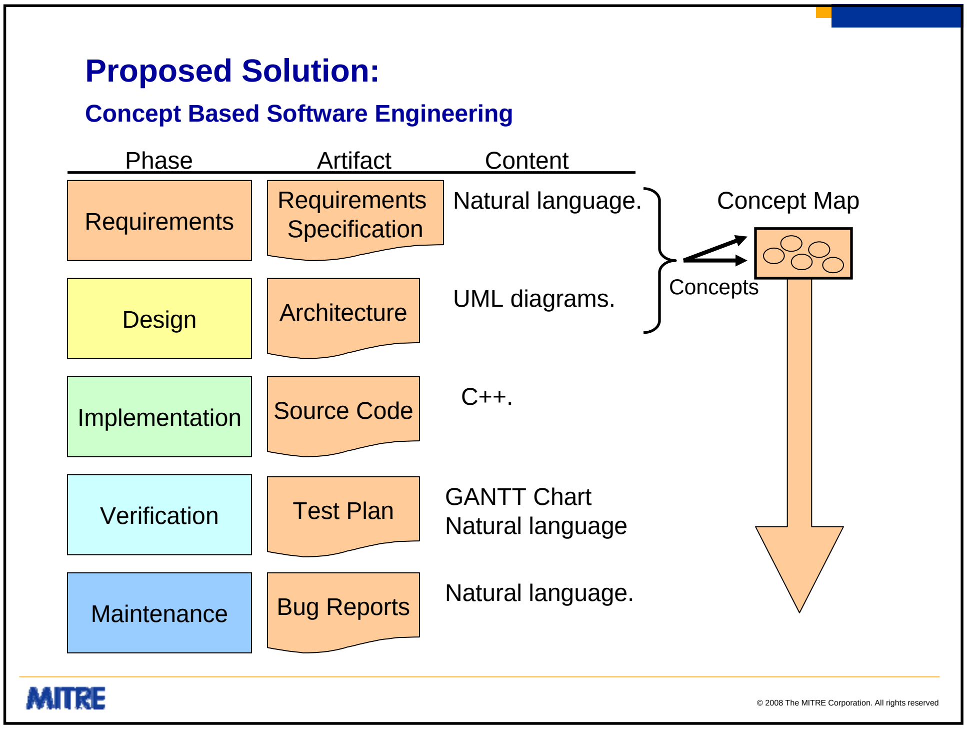
Example 2

[Schach]

Floor, first, top
Illuminate



Novak, J.D., Cañas, A.J., "The Theory Underlying Concept Maps and How to Construct Them",Technical Report IHMC CmapTools 2006-01



Proposed Solution:

Concept Based Software Engineering

Phase	Artifact	Content
Requirements	Requirements Specification	Natural language.
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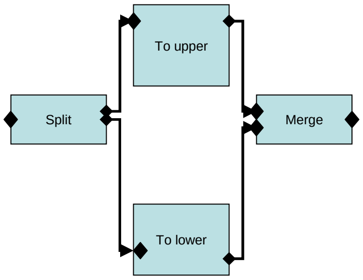
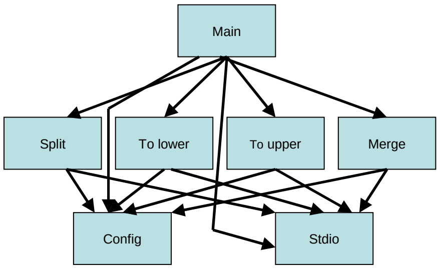
Verification	Test Plan	GANTT Chart Natural language
Maintenance	Bug Reports	Natural language.

Problem: Mapping between views



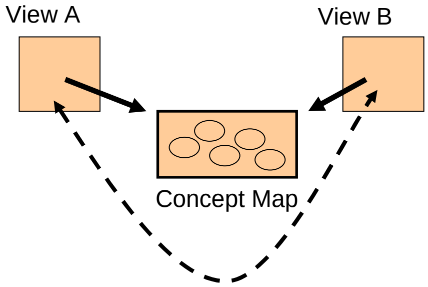
runtime view

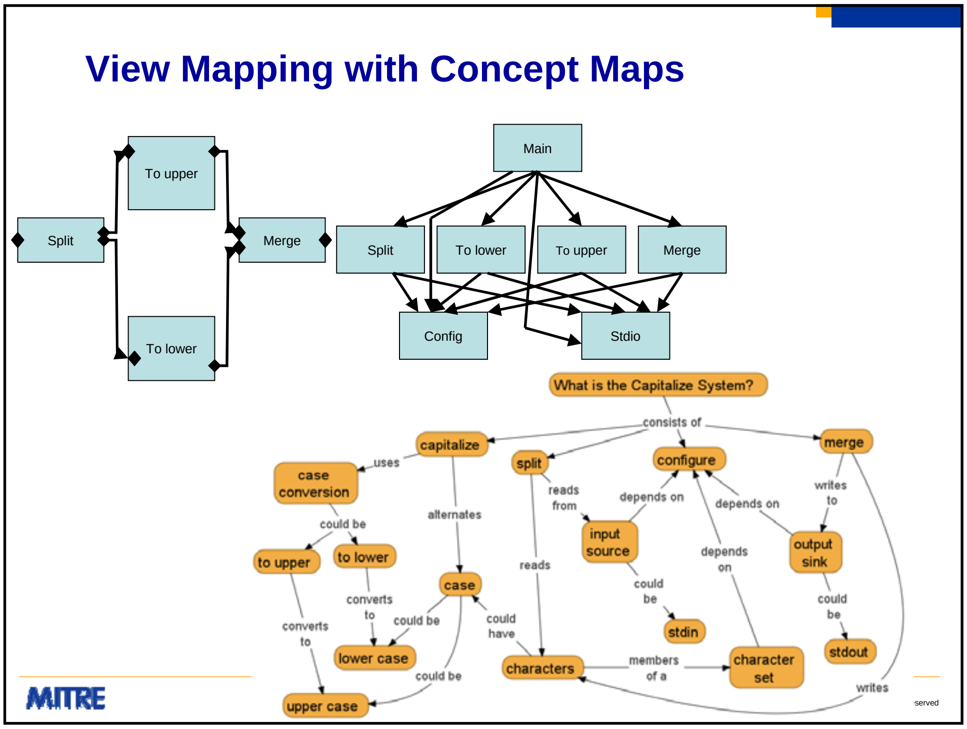


implementation view

Some components in one view not in another.

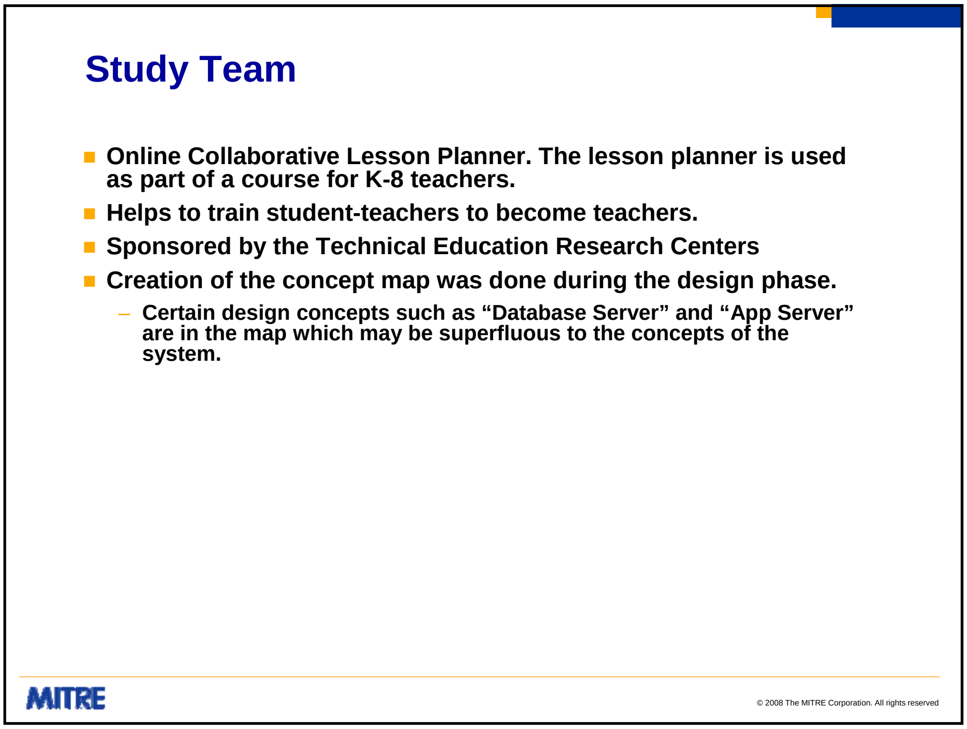
Proposed Solution: View Mapping





View Mapping with Concept Maps

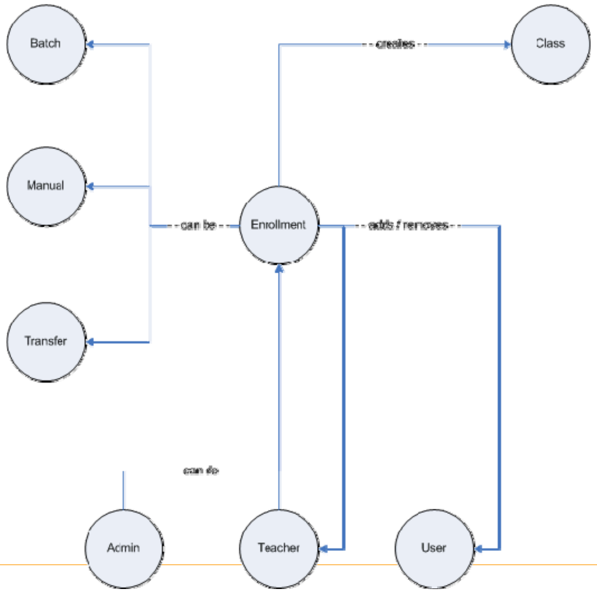
served



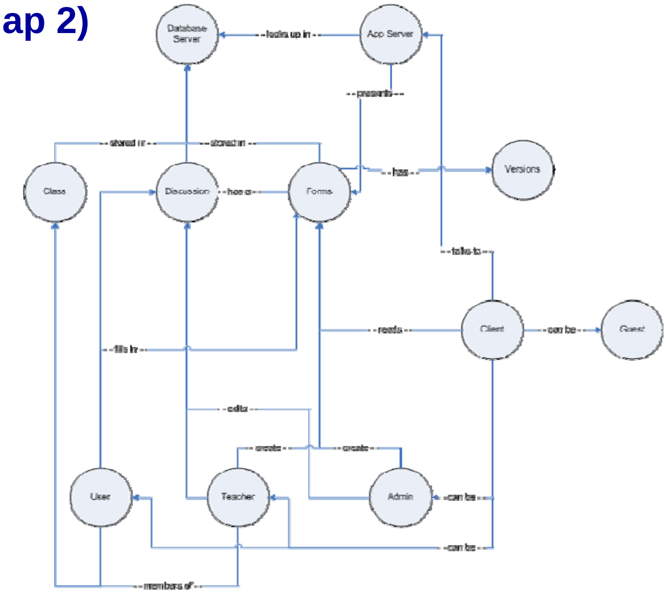
Study Team

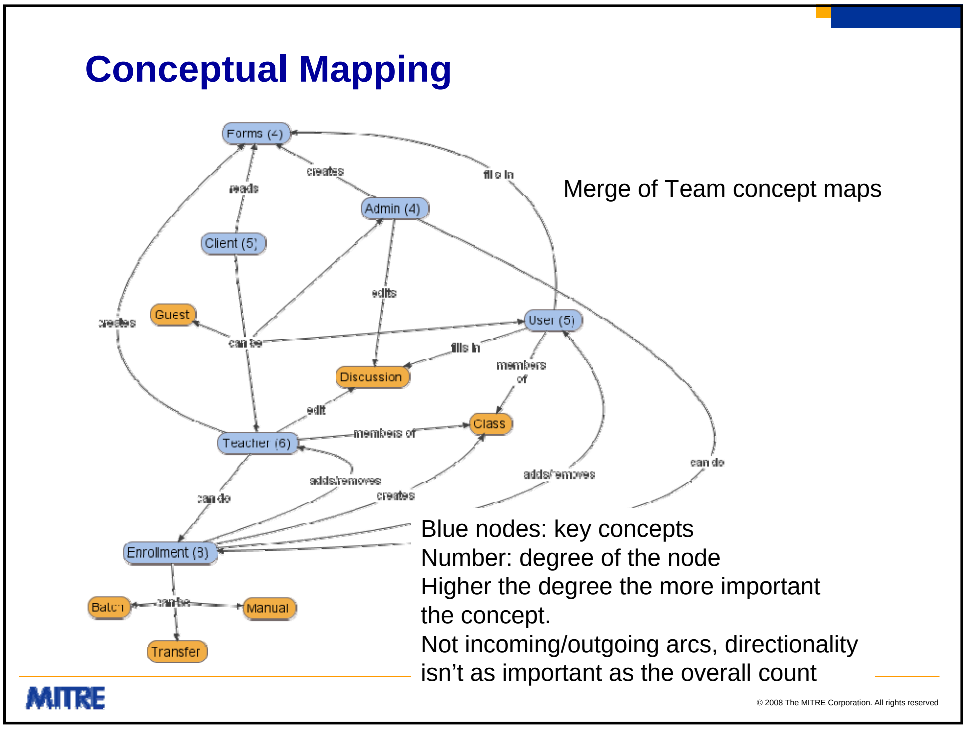
- Online Collaborative Lesson Planner. The lesson planner is used as part of a course for K-8 teachers.
- Helps to train student-teachers to become teachers.
- Sponsored by the Technical Education Research Centers
- Creation of the concept map was done during the design phase.
  - Certain design concepts such as “Database Server” and “App Server” are in the map which may be superfluous to the concepts of the system.

Team (map 1)



Team (map 2)

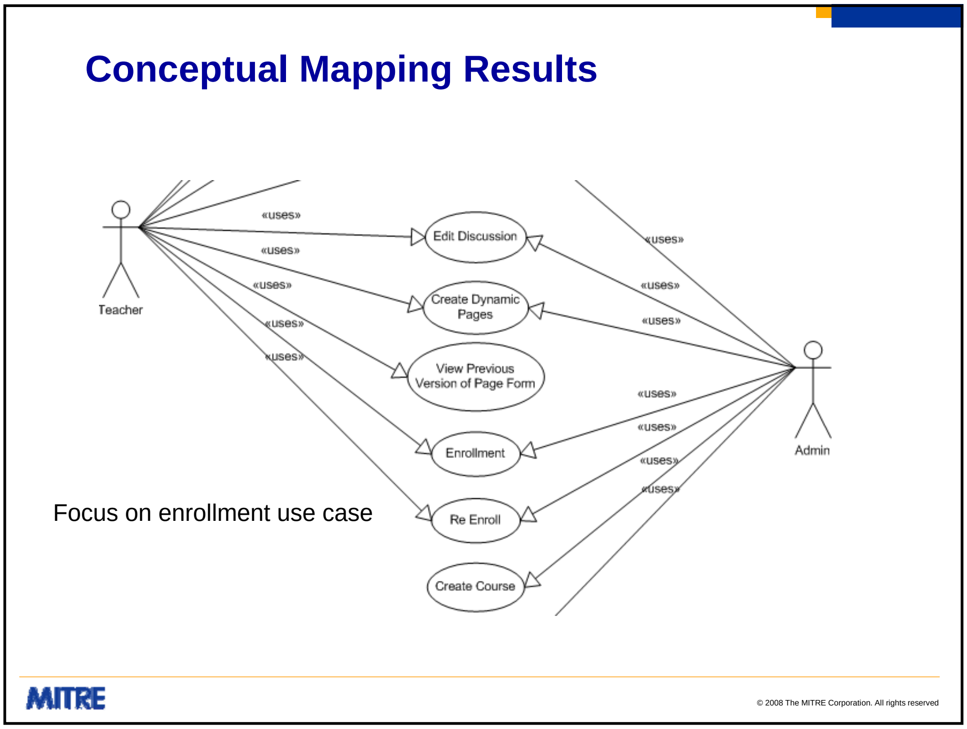




Conceptual Mapping

Merge of Team concept maps

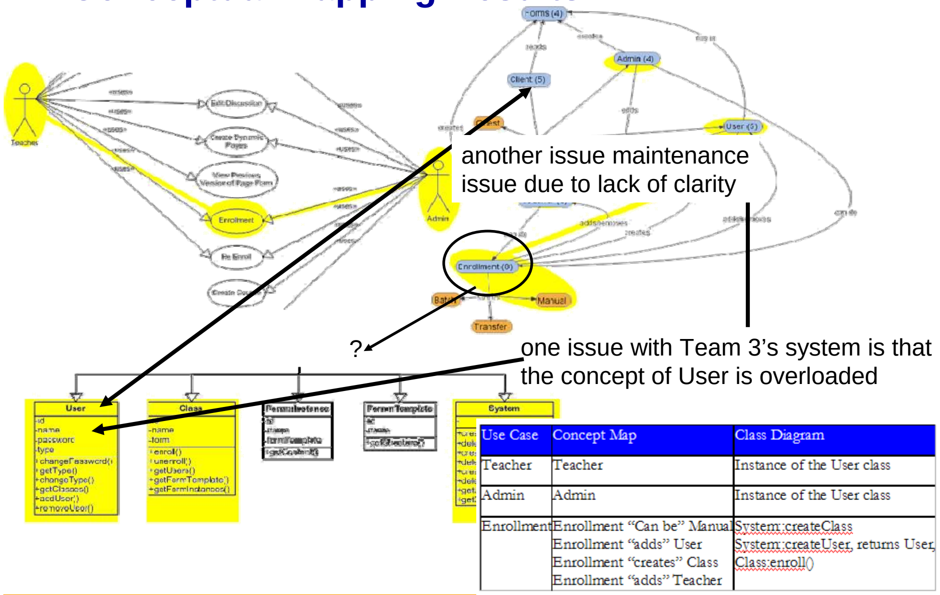
Blue nodes: key concepts
Number: degree of the node
Higher the degree the more important the concept.
Not incoming/outgoing arcs, directionality isn't as important as the overall count



Conceptual Mapping Results

Focus on enrollment use case

Conceptual Mapping Results



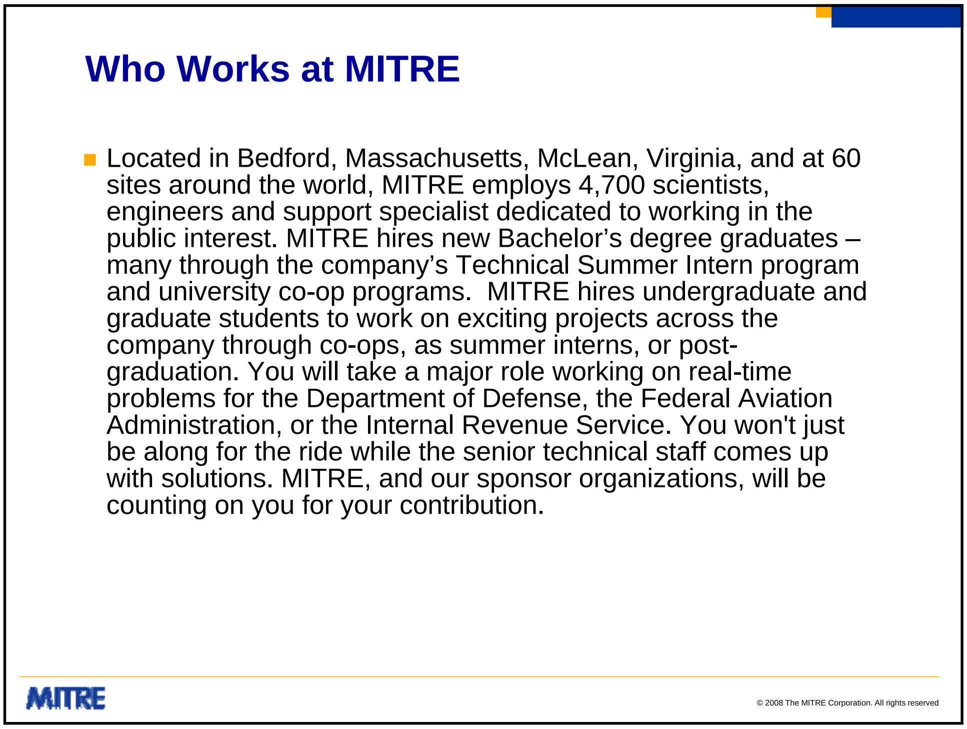
another issue maintenance issue due to lack of clarity

one issue with Team 3's system is that the concept of User is overloaded

Use Case	Concept Map	Class Diagram
Teacher	Teacher	Instance of the User class
Admin	Admin	Instance of the User class
Enrollment	Enrollment "Can be" Manual Enrollment "adds" User Enrollment "creates" Class Enrollment "adds" Teacher	System:createClass System:createUser, returns User, Class:enroll()

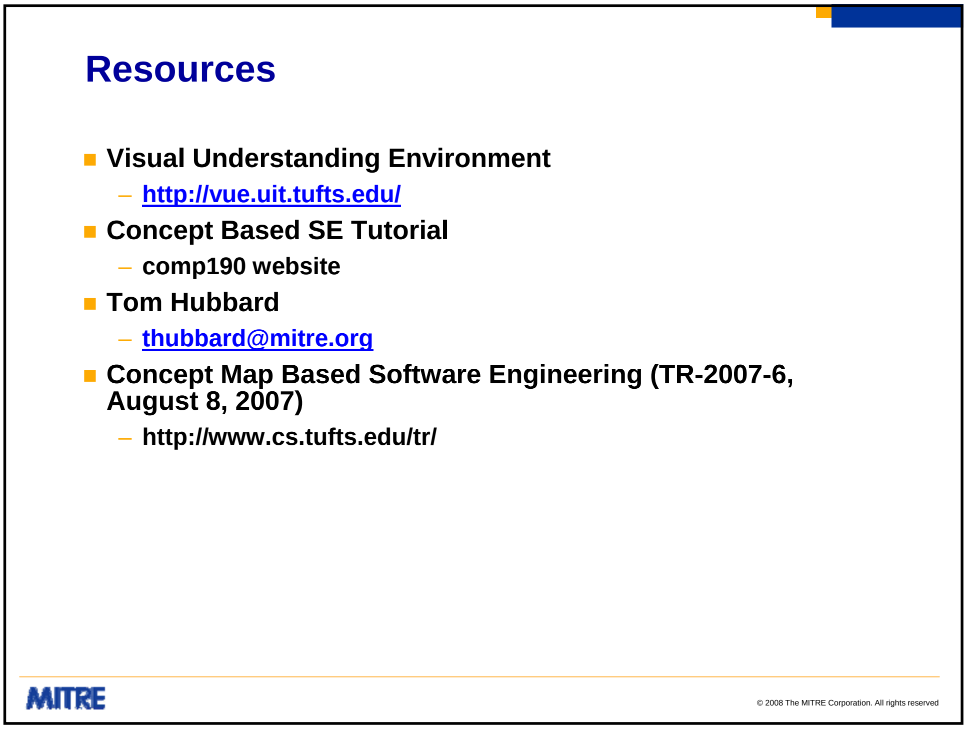
Backup

- Who Works at MITRE
- Resources
- Future Work
- Partial UML to CM Guide
- Full Example



Who Works at MITRE

- Located in Bedford, Massachusetts, McLean, Virginia, and at 60 sites around the world, MITRE employs 4,700 scientists, engineers and support specialist dedicated to working in the public interest. MITRE hires new Bachelor's degree graduates – many through the company's Technical Summer Intern program and university co-op programs. MITRE hires undergraduate and graduate students to work on exciting projects across the company through co-ops, as summer interns, or post-graduation. You will take a major role working on real-time problems for the Department of Defense, the Federal Aviation Administration, or the Internal Revenue Service. You won't just be along for the ride while the senior technical staff comes up with solutions. MITRE, and our sponsor organizations, will be counting on you for your contribution.



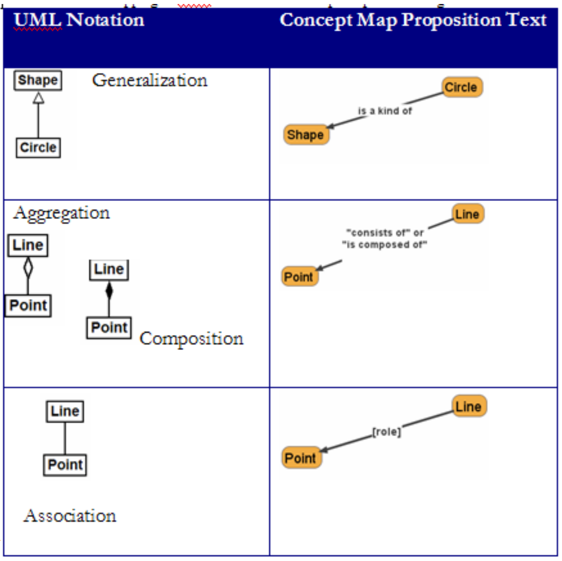
Resources

- **Visual Understanding Environment**
  - **http://vue.uit.tufts.edu/**
- **Concept Based SE Tutorial**
  - **comp190 website**
- **Tom Hubbard**
  - **thubbard@mitre.org**
- **Concept Map Based Software Engineering (TR-2007-6, August 8, 2007)**
  - **http://www.cs.tufts.edu/tr/**

Future Work

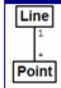
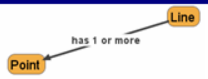
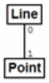
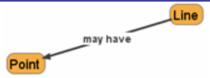
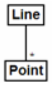
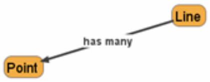
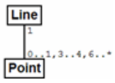
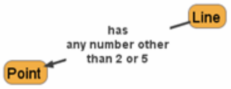
- More work visualizing the actual mapping with more complex systems is needed.
- Also, a mapping using a more complete set of UML conceptual models, Connector and Component views, and Department of Defense Architectural Framework (DoDAF) conceptual model examples is needed particularly with large systems.
- A method to evaluate the effectiveness of using concept maps in software engineering should be researched and developed. One technique that may prove valid is active design reviews [Parnas].
- Future work can build on the UML notation to concept map connecting word mapping. This mapping is needed to leverage the extensive work that has gone into the definition of UML and use the ideas developed there in concept maps.

UML to Concept Map Guide



UML Notation	Concept Map Proposition Text
Shape Circle Generalization	Circle is a kind of Shape
Aggregation Line Point Line Point Composition	Line "consists of" or "is composed of" Point
Line Point Association	Line [role] Point

UML to Concept Map Guide

UML Notation	Concept Map Proposition Text
 Multiplicity	
Multiplicity 	
 Multiplicity	
 Multiplicity	

Full Example

#1 Understand the problem

- **Requirements documents and interviews with the customer**

Elevator Control System

A product is to be installed to control n elevators in a building with m floors. Each elevator has a set of m buttons, one for each floor. These illuminate when pressed and cause one elevator to move to the corresponding floor. Illumination is canceled when corresponding floor is visited by elevator. Each floor, except the first and the top floor, has 2 buttons, one to request an elevator to move up , up a one or more floors and one to request an elevator to move down one or more floors. These buttons illuminate when pressed. The illumination is canceled when an elevator visits the floor, then moves in the desired direction. If an elevator has no requests, it remains at its current floor with its doors closed.

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#2 Discover the concepts

- Create a Focus Question
  - **“***What is the elevator control system supposed to do?”*
- Using the focus question, Identify Relevant Concepts
  - **Noun extraction or use case analysis**
  - **create a list of concepts “parking lot”**

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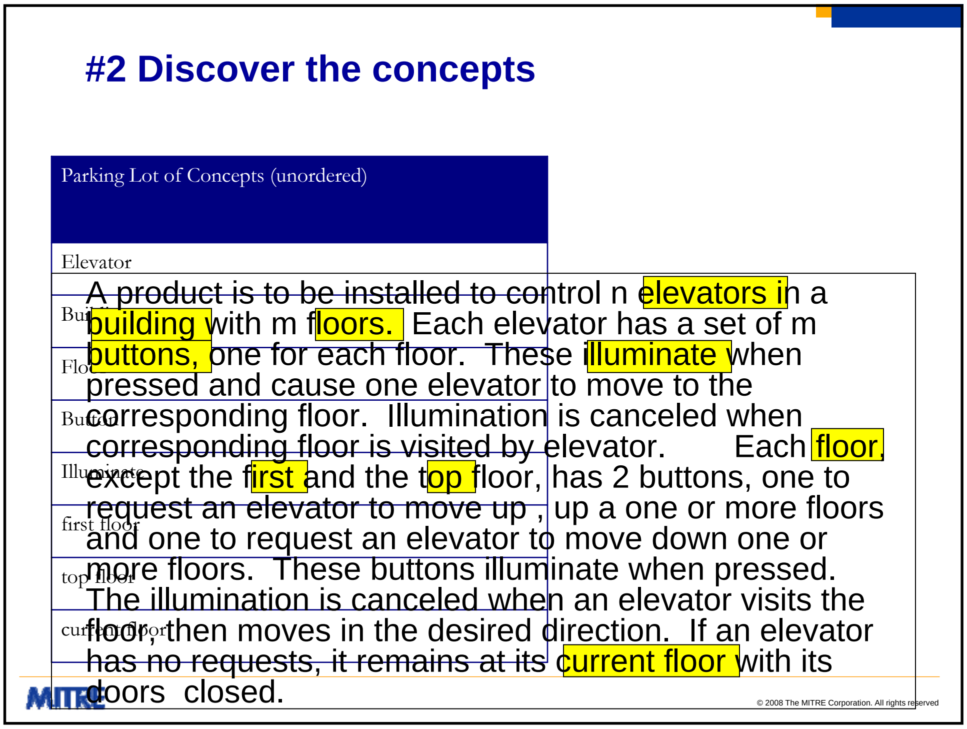

#2 Discover the concepts

Parking Lot of Concepts (unordered)
Elevator
Bui
Flo
Button
Illuminate
first floor
top floor
current floor

A product is to be installed to control n elevators in a building with m floors. Each elevator has a set of m buttons, one for each floor. These illuminate when pressed and cause one elevator to move to the corresponding floor. Illumination is canceled when corresponding floor is visited by elevator. Each floor, except the first and the top floor, has 2 buttons, one to request an elevator to move up , up a one or more floors and one to request an elevator to move down one or more floors. These buttons illuminate when pressed. The illumination is canceled when an elevator visits the floor, then moves in the desired direction. If an elevator has no requests, it remains at its current floor with its doors closed.

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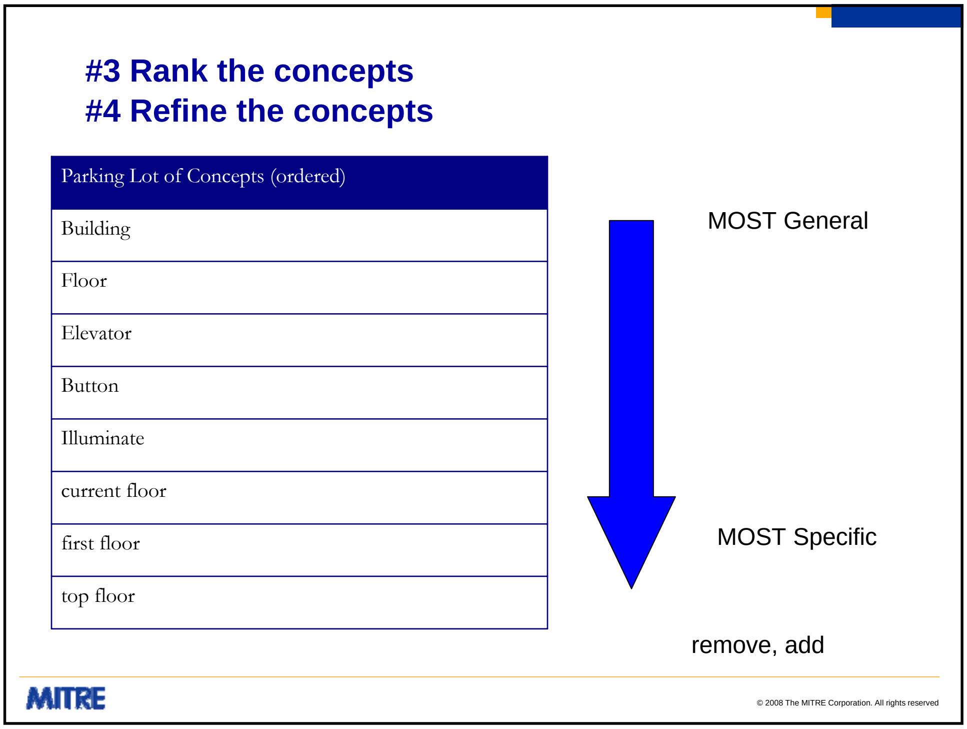

#3 Rank the concepts
#4 Refine the concepts

Parking Lot of Concepts (ordered)
Building
Floor
Elevator
Button
Illuminate
current floor
first floor
top floor

MOST General

MOST Specific

remove, add

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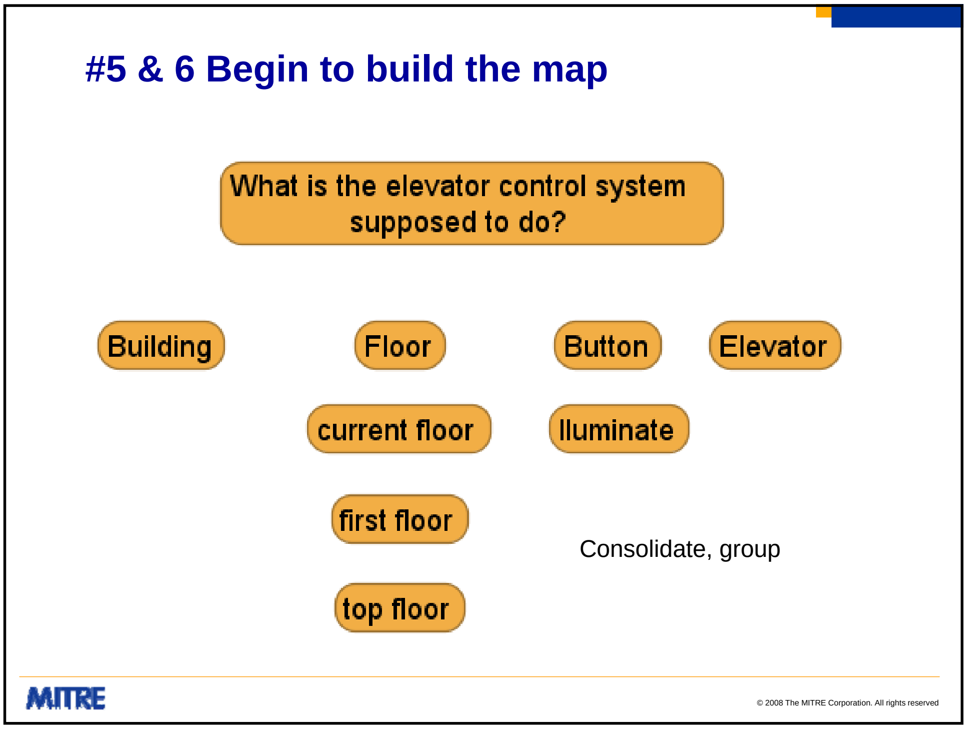

#5 & 6 Begin to build the map

What is the elevator control system supposed to do?

Building

Floor

Button

Elevator

current floor

Iluminate

first floor

top floor

Consolidate, group

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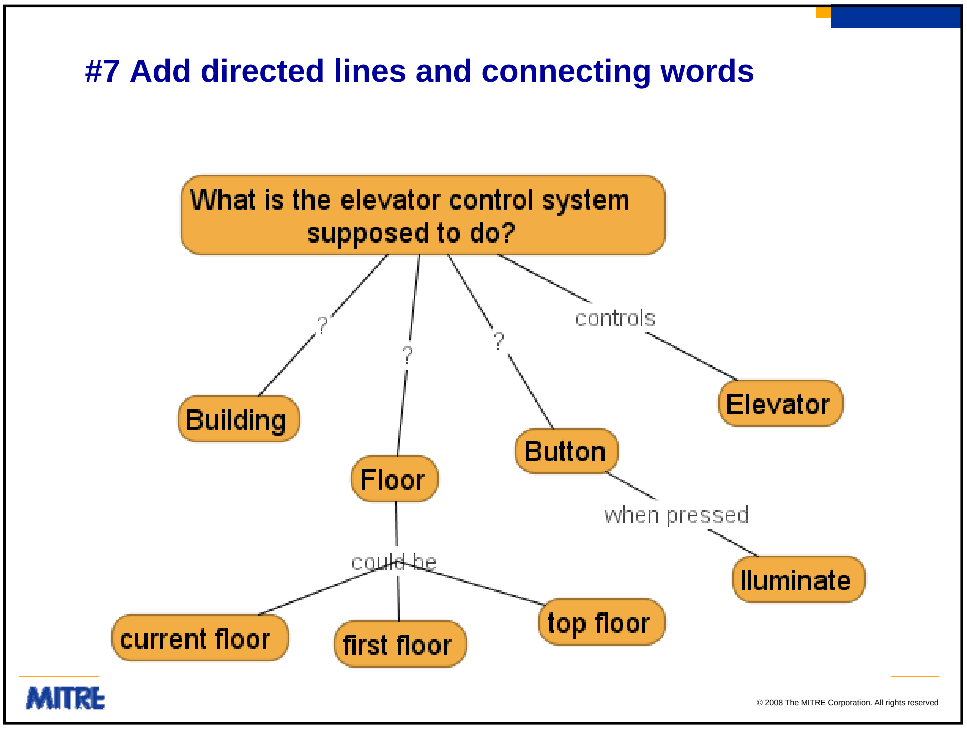

#7 Add directed lines and connecting words

What is the elevator control system supposed to do?

?

Building

?

Floor

could be

current floor

first floor

top floor

?

Button

when pressed

Iluminate

controls

Elevator

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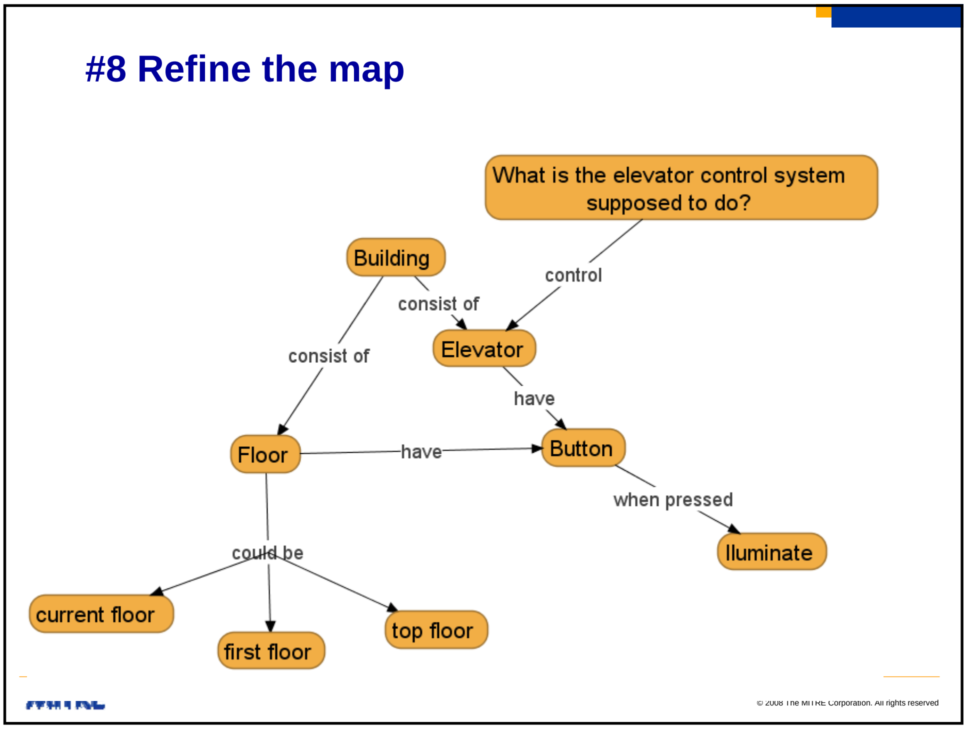
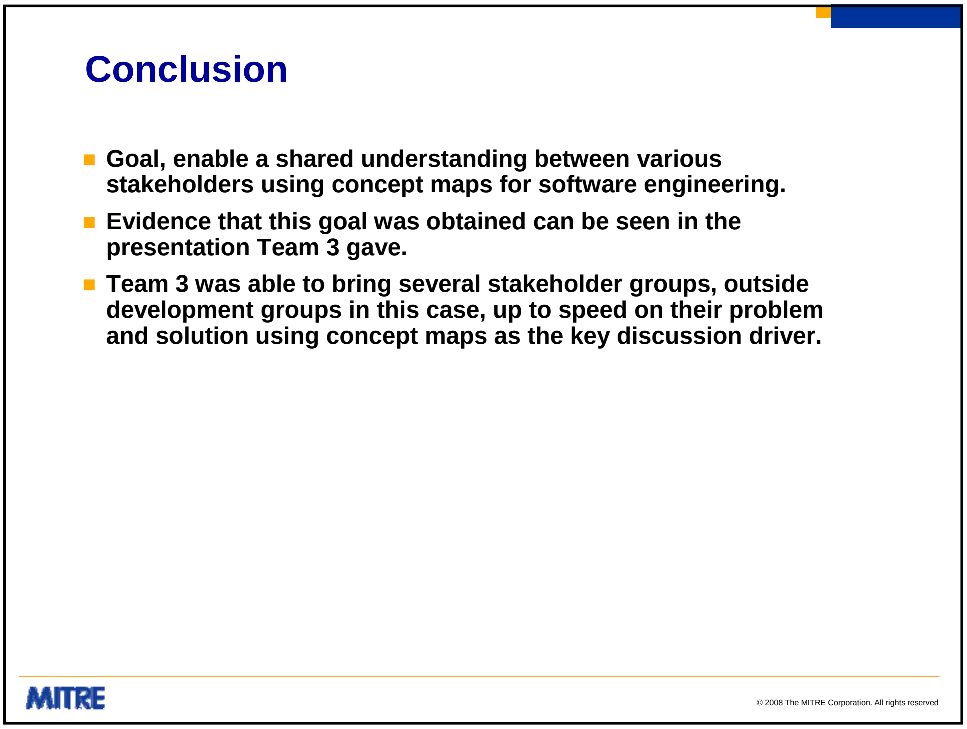
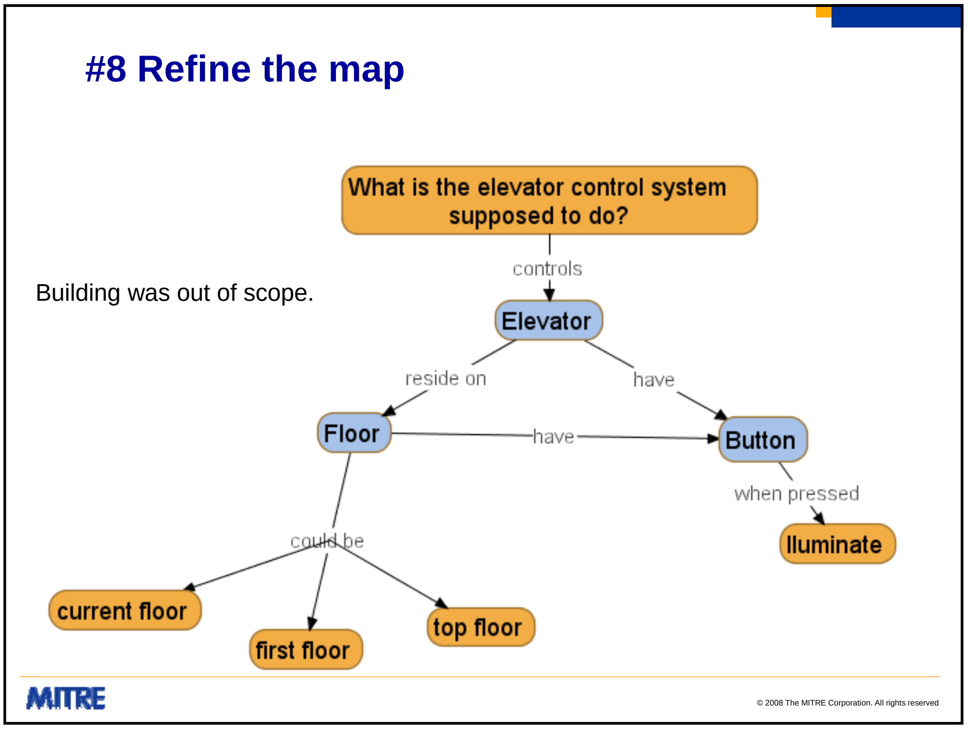


#8 Refine the map



Conclusion

- Goal, enable a shared understanding between various stakeholders using concept maps for software engineering.
- Evidence that this goal was obtained can be seen in the presentation Team 3 gave.
- Team 3 was able to bring several stakeholder groups, outside development groups in this case, up to speed on their problem and solution using concept maps as the key discussion driver.



#8 Refine the map

Building was out of scope.

What is the elevator control system supposed to do?

controls

Elevator

reside on

have

Floor

have

Button

when pressed

Iluminate

could be

current floor

first floor

top floor

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