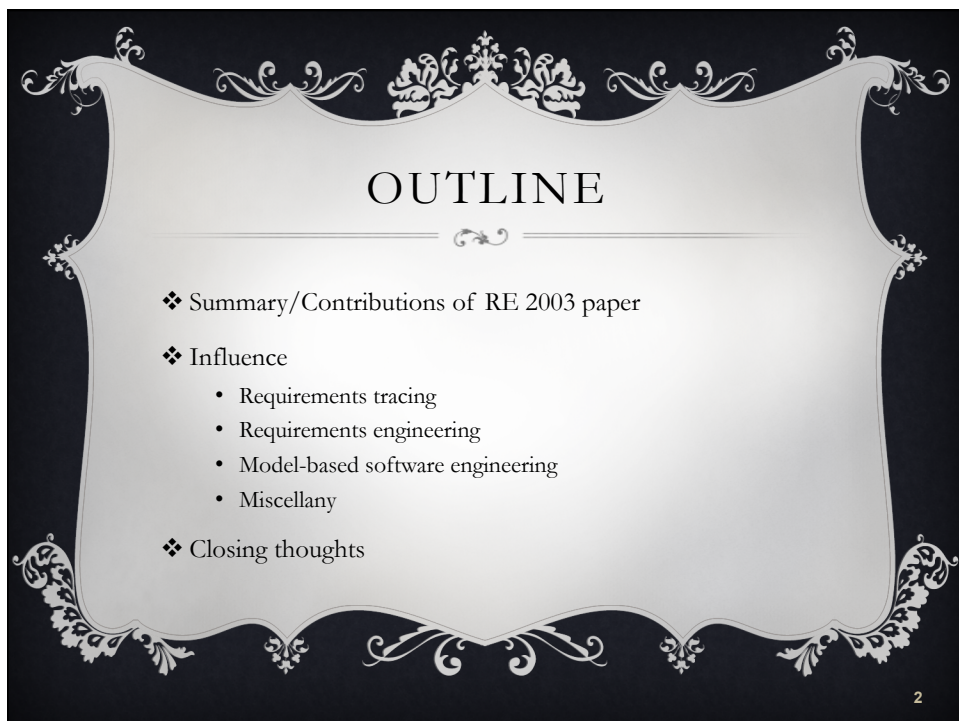





IMPROVING REQUIREMENTS TRACING VIA INFORMATION RETRIEVAL

Jane Huffman Hayes, Alex Dekhtyar, James Osborne

Thanks to Jesse Yannelli for artwork, Jane Huang for some slides



OUTLINE

- ❖ Summary/Contributions of RE 2003 paper
- ❖ Influence
 - Requirements tracing
 - Requirements engineering
 - Model-based software engineering
 - Miscellany
- ❖ Closing thoughts


2




FUN FACTS

Middle of post-Y2K technology slump

Is software industry in the US doomed because of imminent outsourcing?

 is 5 years old, already a verb

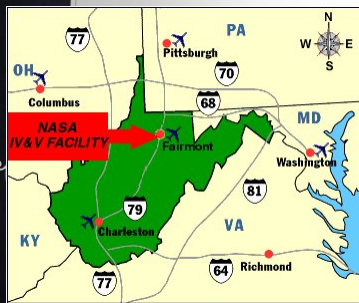
Four more years 'til iPhone



FUN FACTS

... and a NASA IV&V facility in Fairmont, WV
wants researcher help with Software Assurance...

(and gives \$\$!)



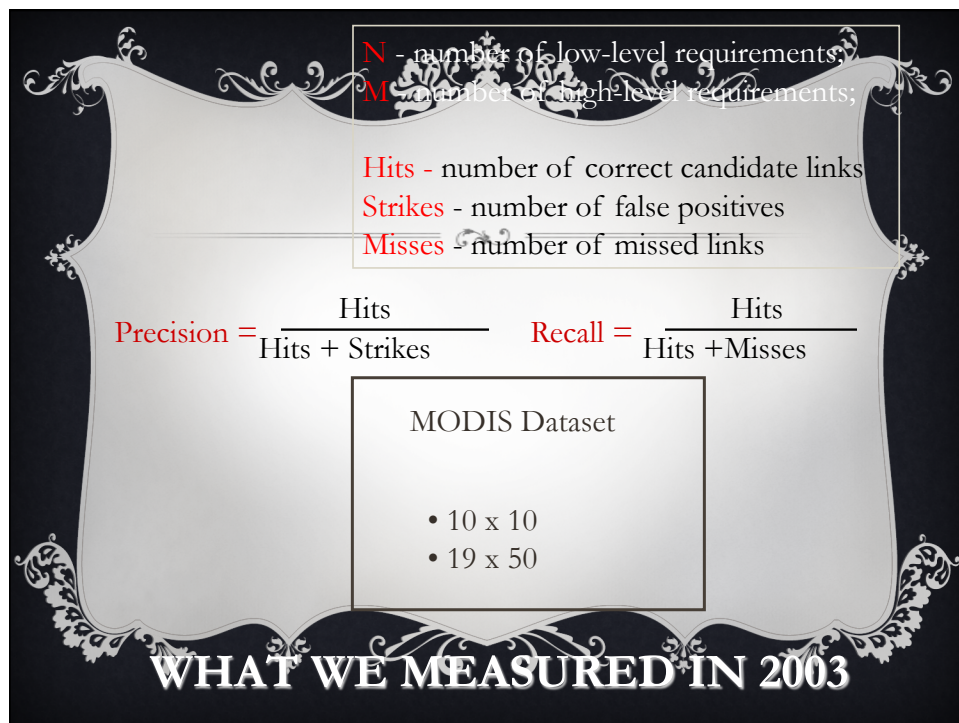
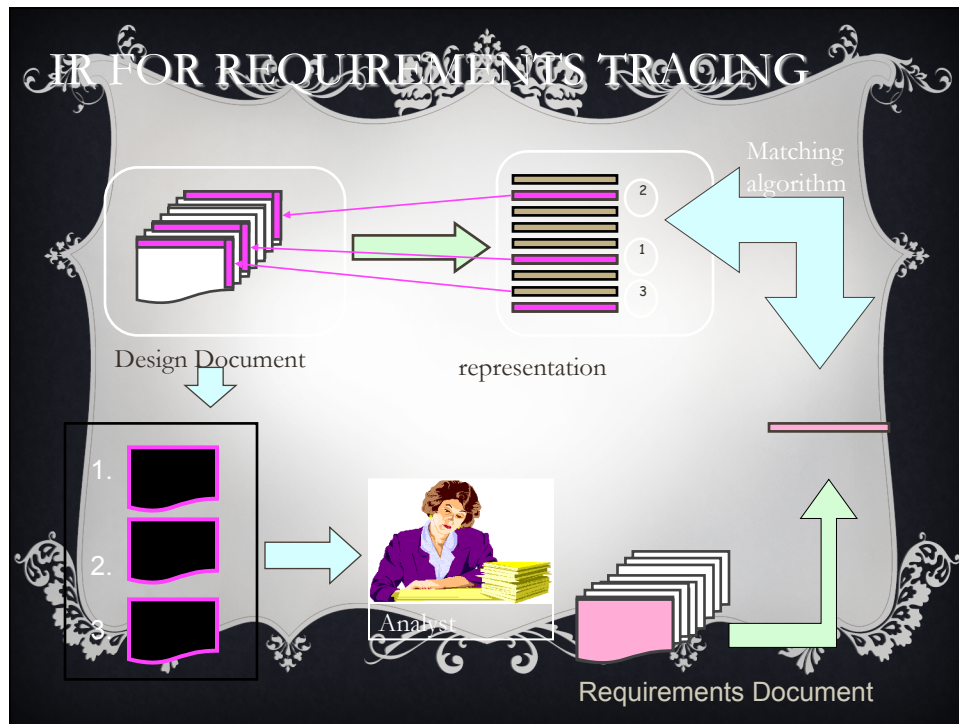
5

CAN SOFTWARE ENGINEERING RESEARCHERS HELP LAUNCH SPACESHIPS?

(i.e.: what is the most annoying thing about IV&V?)







OUR RESULTS SLIDE FROM 2003

• Human analyst vs. Thesaurus retrieval

	SuperTracePlus Tool	Analyst[1]	Retrieval with thesaurus algorithm
Correct links	41	41	41
Correct links found	26	18	35
Total number of answers	67	39	86
Missed requirements[2]	3	6	4
Average recall[3]	69.37%	53.30%	71.69%
Average precision[3]	56.48%	53.55%	32.76%
Overall recall[4]	63.41%	43.90%	85.36%
Overall precision[4]	38.80%	46.15%	40.69%
Performance (hours)	N/A – included in analyst performance	9	Seconds for algorithm, 0.33 for thesaurus building

[1] Analyst was working with the results of SuperTracePlus analysis
 [2] "Missed requirements" refers to high-level requirements with existing links for which the method failed to return a correct match
 [3] Average recall and precision were computed by first computing the recall and precision for each individual requirement and then taking the average over all requirements
 [4] Overall recall and precision were computed by dividing the total number of retrieved links over the number of existing links (recall) and the total number of retrieved links over the total number of candidate links (precision)

WHAT WE LEARNED (2003)

- Languages of documents are different
 - Leads to low recall
- Many keyword matches circumstantial
 - Leads to low precision
- Analysts: high recall but low precision (on small datasets)
- Thesaurus : recall improves significantly
precision improves some



WHAT WE LEARNED (2013)

High Recall, Low Precision

Empirical software engineering: datasets, measures

Human Analysts: **can't live with'em**
can't live without'em

Phenomenal work being done in many guises

This award belongs to our community...



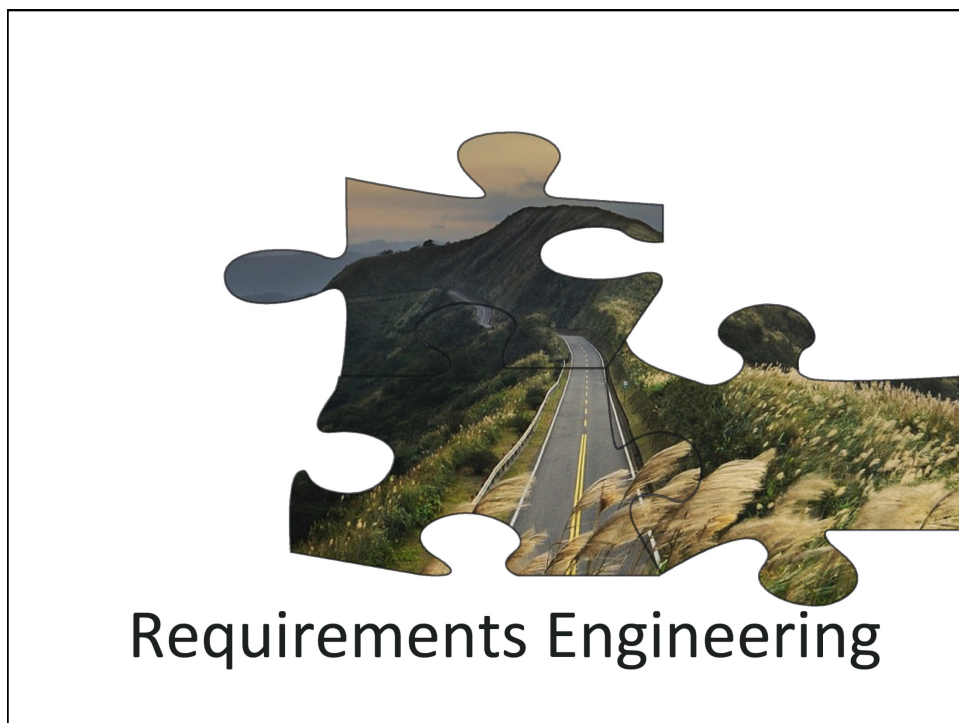
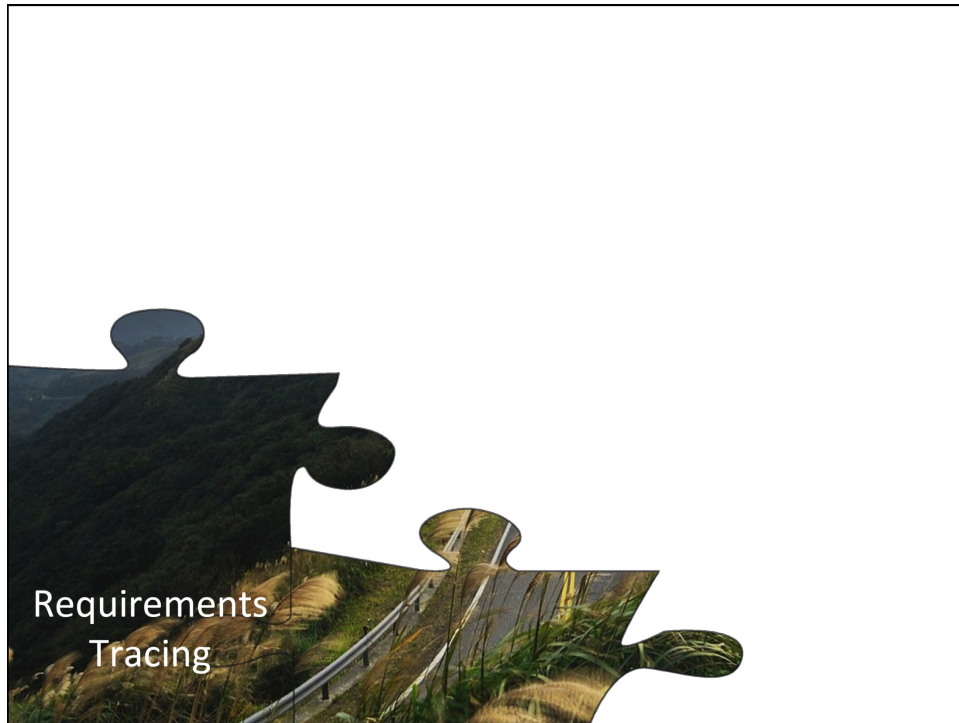
INFLUENCE

Requirements Tracing



REQUIREMENTS TRACING

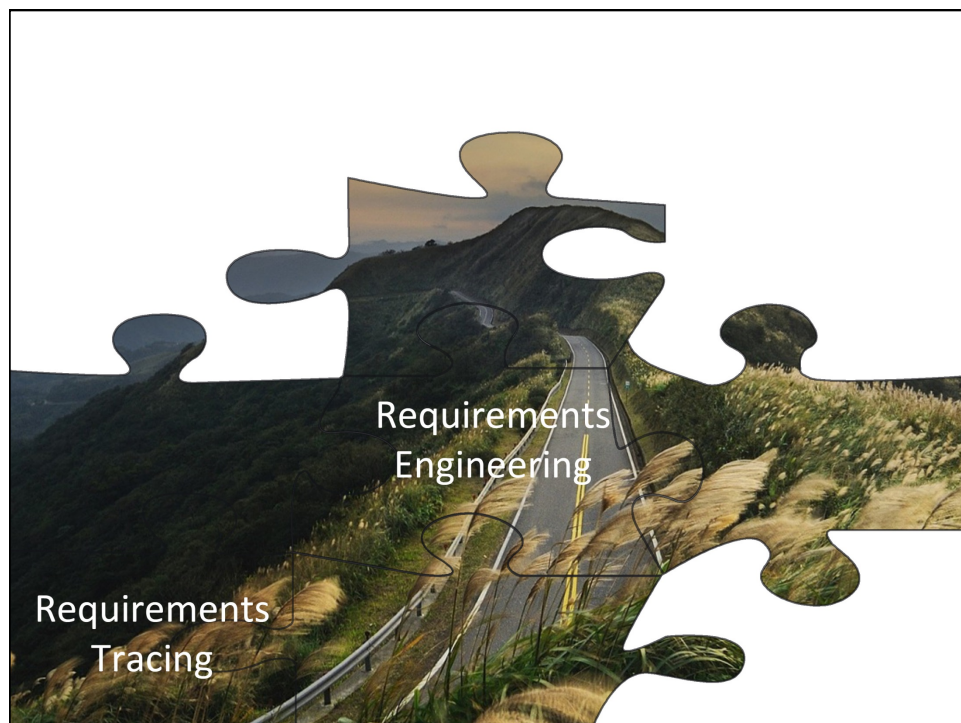
- ❖ Linking documents and source code, 2003, 2005
- ❖ Artifact management, 2007
- ❖ Marcus and Maletic
- ❖ DeLucia, Fasano, Oliveto, Tortora



REQUIREMENTS ENGINEERING

- ❖ Managing non-functional requirements, 2005
- ❖ Consolidation of multiple source requirements, 2012
- ❖ Huang, Settimi, BenKhadra, Berezhanskaya, Christina
- ❖ Wnuk, Host, Regnell

19






A FORWARD-LOOKING IDEA...

- ❖ Idea: Form a Center of Excellence for Software Traceability (CoEST)
- ❖ The first CoEST meeting occurred under the St. Louis Arch at ICSE 2005. It was attended by Jonathan Maletic, Guilio Antoniol, Alex Dekhtyar, Jane Cleland-Huang, Jane Hayes, and several students

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Center of Excellence for Software Traceability

[member login](#)

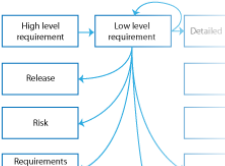
[About CoEST](#)
[Traceability](#)
[TraceLab](#)
[Research Directions](#)
[Resources](#)



Developing automated tools to minimize the cost and effort of traceability.

Center of Excellence for Software Traceability

The vision of the Center of Excellence for Traceability (CoEST) is to provide leadership for traceability research, education, and practice; promoting the pursuit of excellence from research idea to practice, based on a foundation of innovative, ethical, collaborative work.




+ What is Traceability?

+ Grand Challenges

+ For Industry

NEW!

Tracelab now in beta!



Center of Excellence for Software Traceability

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Professor, City University, London

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CalPoly.

Grand Challenges Coordinator:
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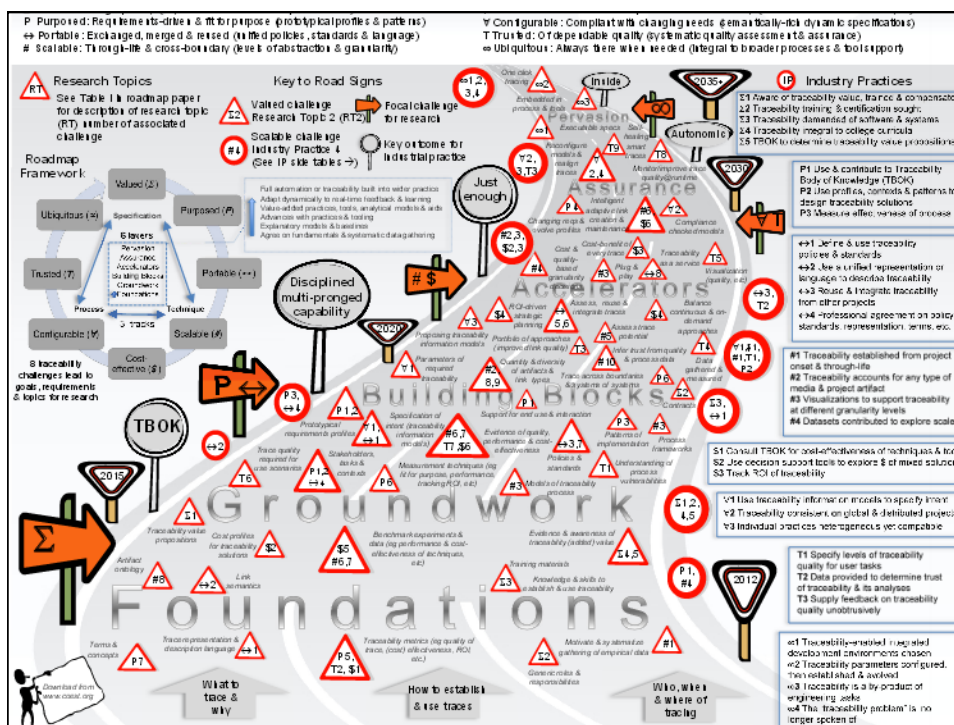
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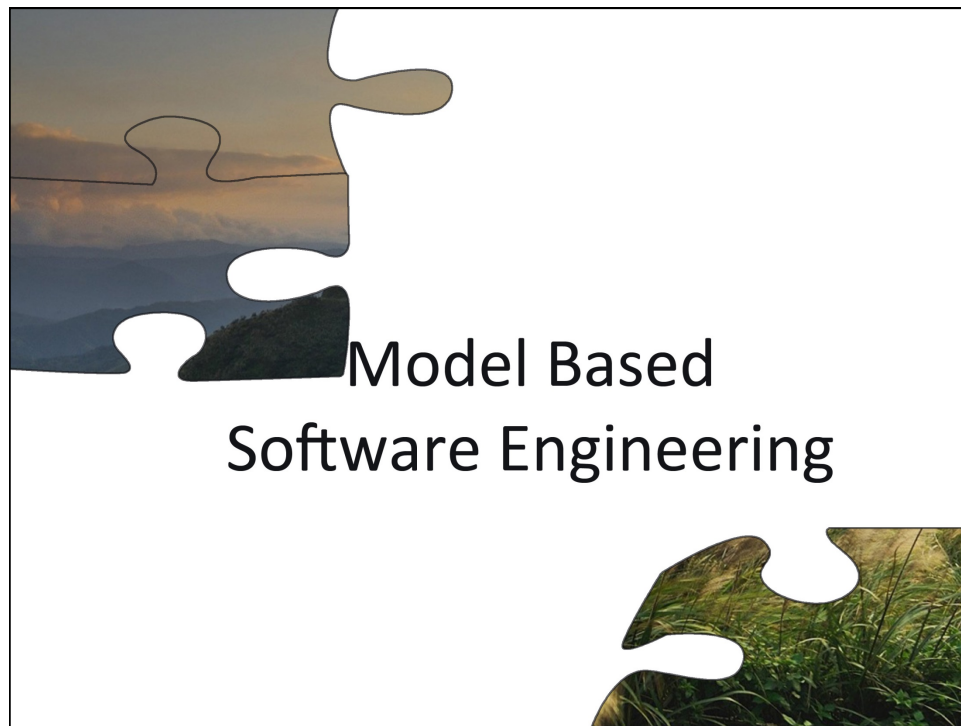
Student Coordinator:
Giulio Antoniol
Ecole Polytechnique Montreal, Canada

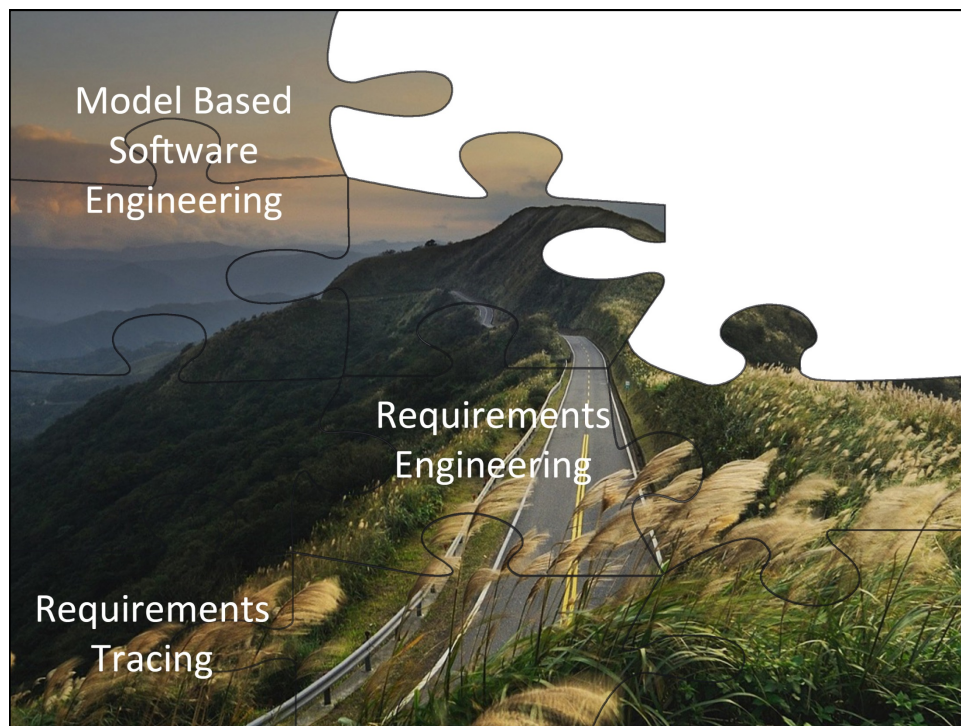
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Search CoEST

NEW BOOK
Software and Systems Traceability
Andrea Zisman
Jane Cleland-Huang
Olly Gotel
Springer Verlag
to be released in **Fall of 2011**





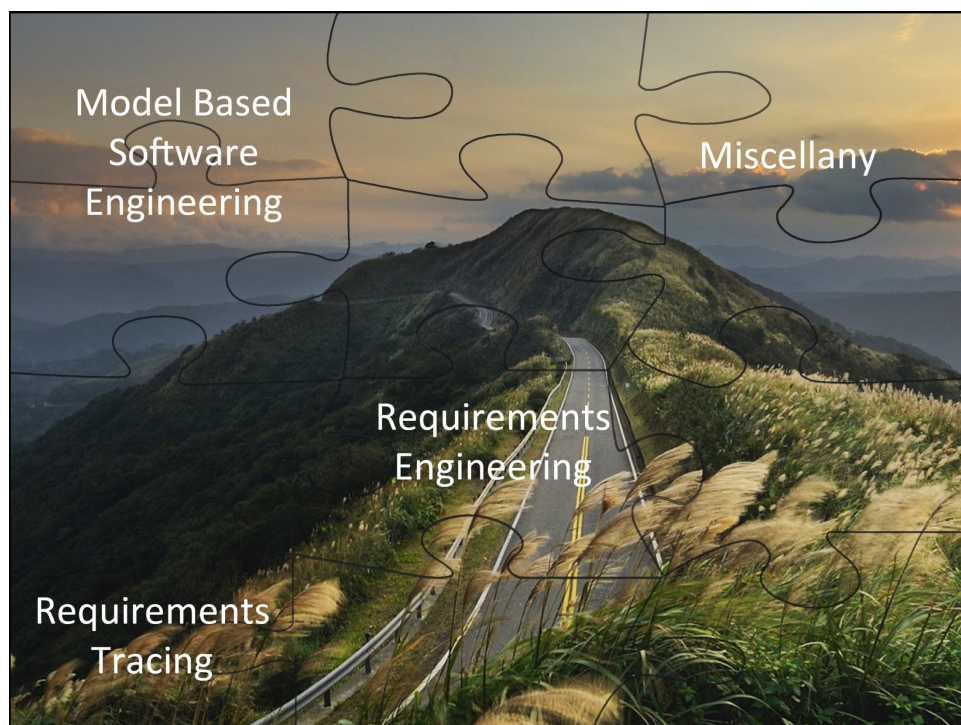


MISCELLANY

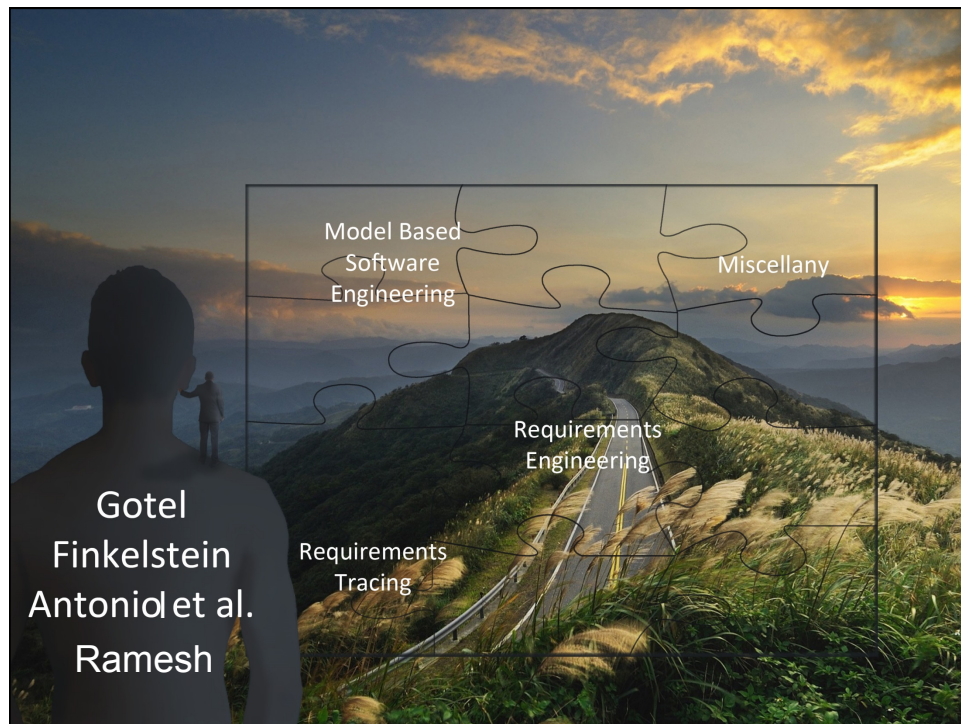
- ❖ Mining textual requirements for architectural design, 2012
- ❖ Matching web service interfaces, 2010

- ❖ A Casamayor, D Godoy, M Campo
- ❖ HR Motahari Nezhad, GY Xu, B Benatallah

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FUTURE DIRECTIONS

- ❖ Ubiquity
- ❖ Assisted methods
- ❖ Application-specific

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TRACEABILITY RESEARCH TIMELINE

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1995 & earlier
Seminal
work in
trace-
ability


Rudimentary
tools

2nd Generation of
Trace features in RM
tools

Technology
transfer
pilots

1995-2010

Numerous researchers work on various traceability
topics receiving funding from NASA, NSF, & Industry


 funded by
NASA &
NSF
2006/7

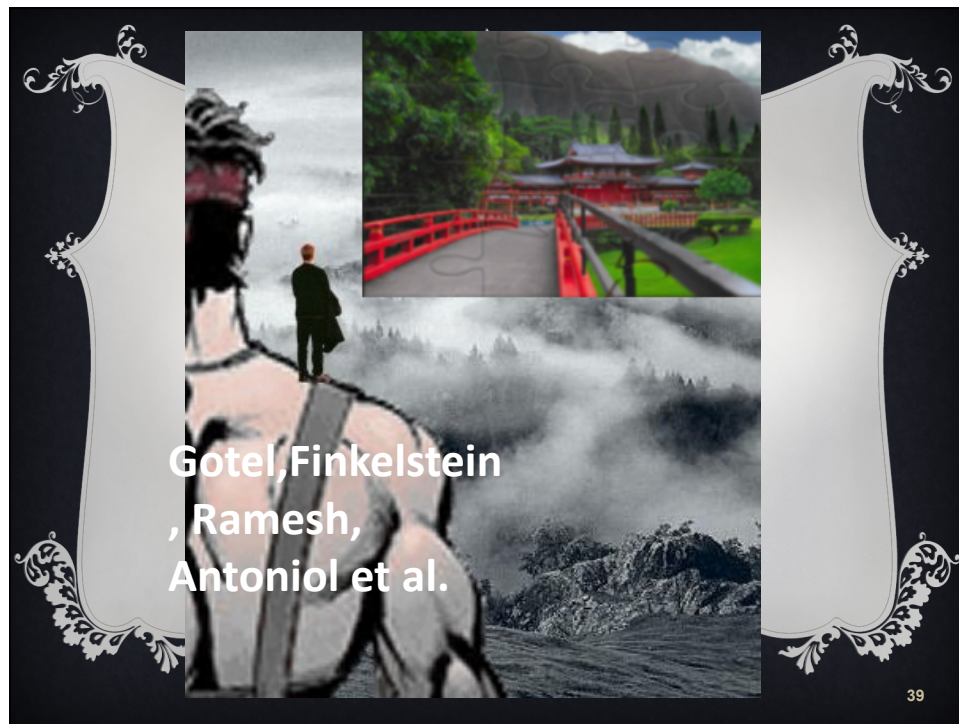
Grand
Challenge
Workshops
held,
GCT 1.0
released

2010: MRI
funded by
NSF for \$2M

 GCT 2.0
released,
Jan. 2011

What next?

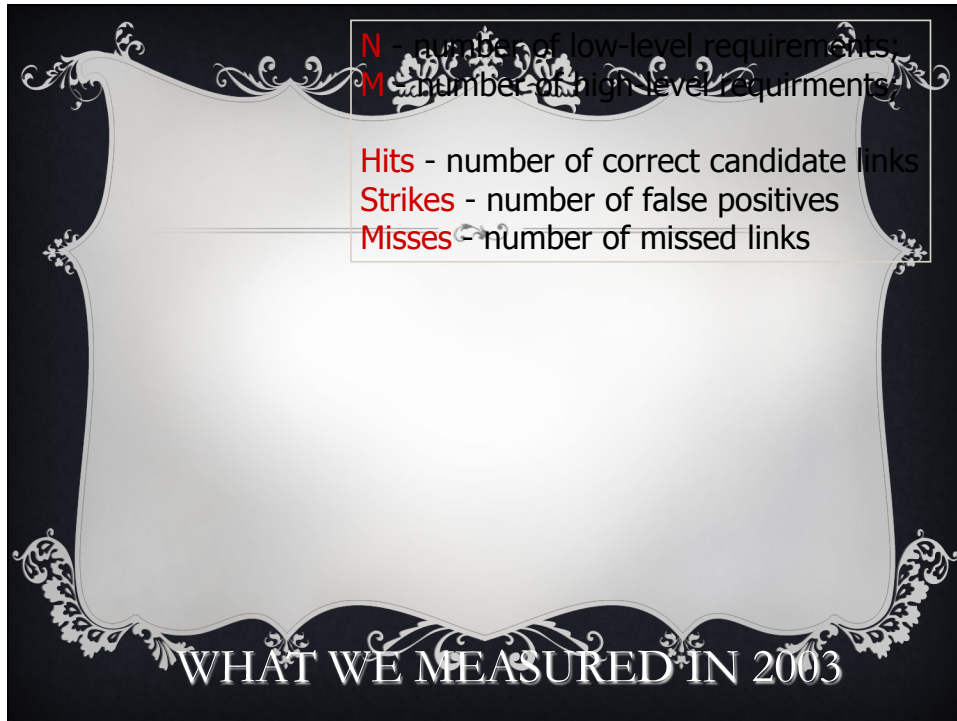
The Grand Challenges provide a roadmap for future research efforts and the mechanism for tracking progress towards our goals



REQUIREMENTS TRACING – BACKUP??

- ❖ Establishing, maintaining relationships of artifacts/elements
- ❖ Supporting s/w eng./IV&V/evolution/etc. tasks

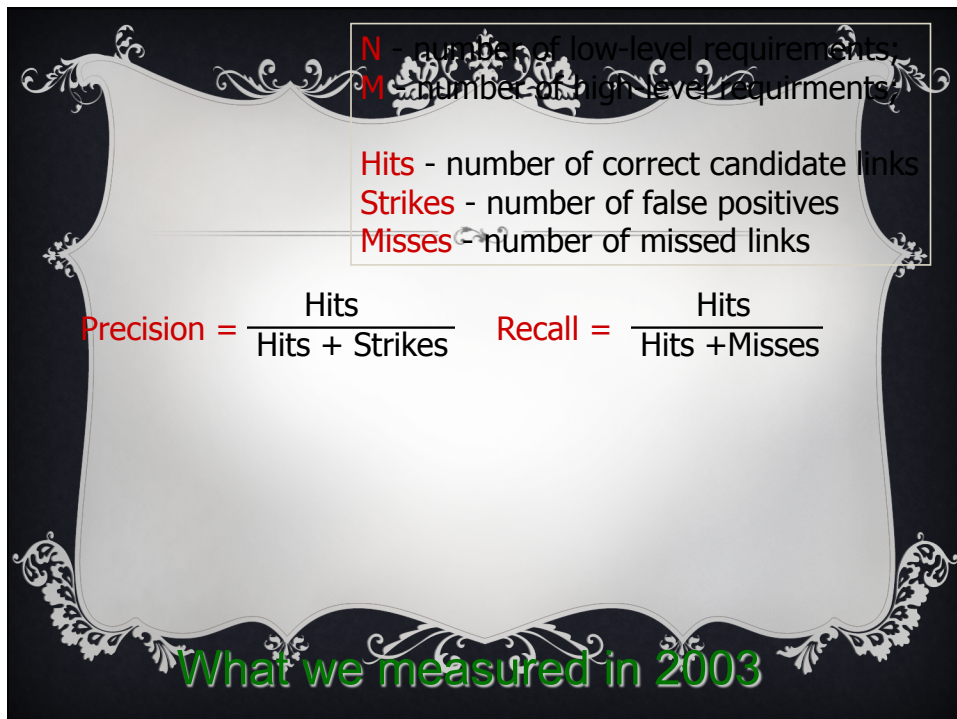
40



N - number of low-level requirements;
M - number of high-level requirements;

Hits - number of correct candidate links
Strikes - number of false positives
Misses - number of missed links

WHAT WE MEASURED IN 2003



N - number of low-level requirements;
M - number of high-level requirements;

Hits - number of correct candidate links
Strikes - number of false positives
Misses - number of missed links

Precision = $\frac{\text{Hits}}{\text{Hits} + \text{Strikes}}$ **Recall** = $\frac{\text{Hits}}{\text{Hits} + \text{Misses}}$

What we measured in 2003

N - number of low-level requirements;
M - number of high-level requirements;

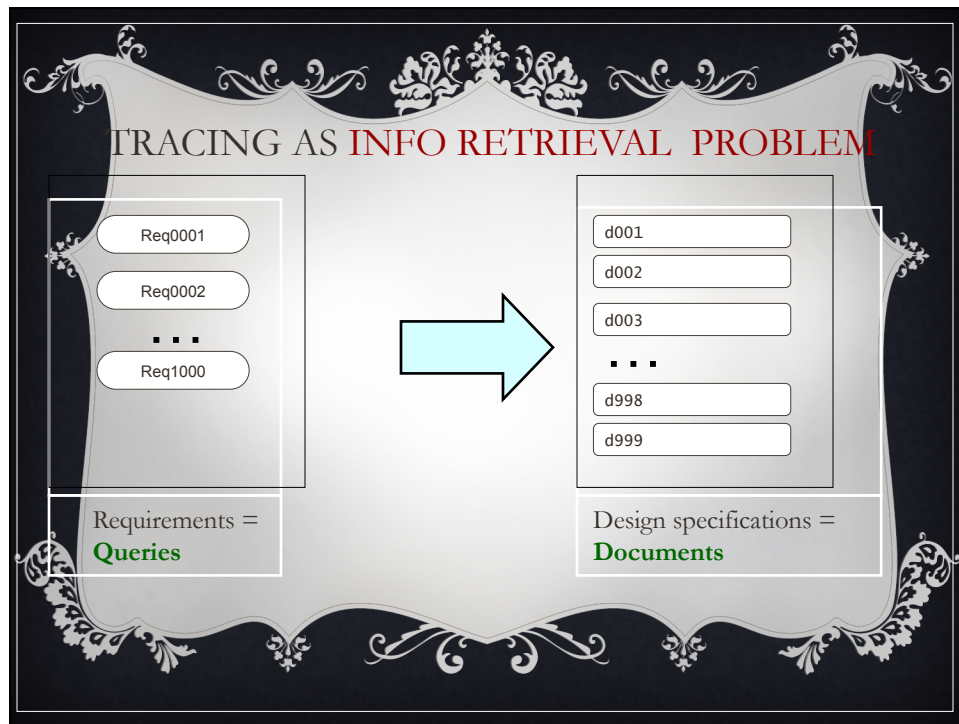
Hits - number of correct candidate links
Strikes - number of false positives
Misses - number of missed links

Precision = $\frac{\text{Hits}}{\text{Hits} + \text{Strikes}}$ **Recall** = $\frac{\text{Hits}}{\text{Hits} + \text{Misses}}$

Selectivity = $\frac{\text{Hits} + \text{Strikes}}{M * N}$

What we measured in 2003





WHAT WE TRIED IN 2003: VECTOR (TF-IDF) MODEL

- Vocabulary of keywords determined $V = \{k_1, \dots, k_n\}$
- Each document (and query) is represented as a vector

$$\mathbf{d} = (w_1, w_2, \dots, w_n)$$

of keyword weights

- Weights:

$$w_i = \text{freq}(k_i, d) \cdot \log\left(\frac{1}{\text{FREQ}(k_i)}\right)$$

Frequency of keyword in document

Inverse frequency of keyword in collection

+ Simple Thesaurus

