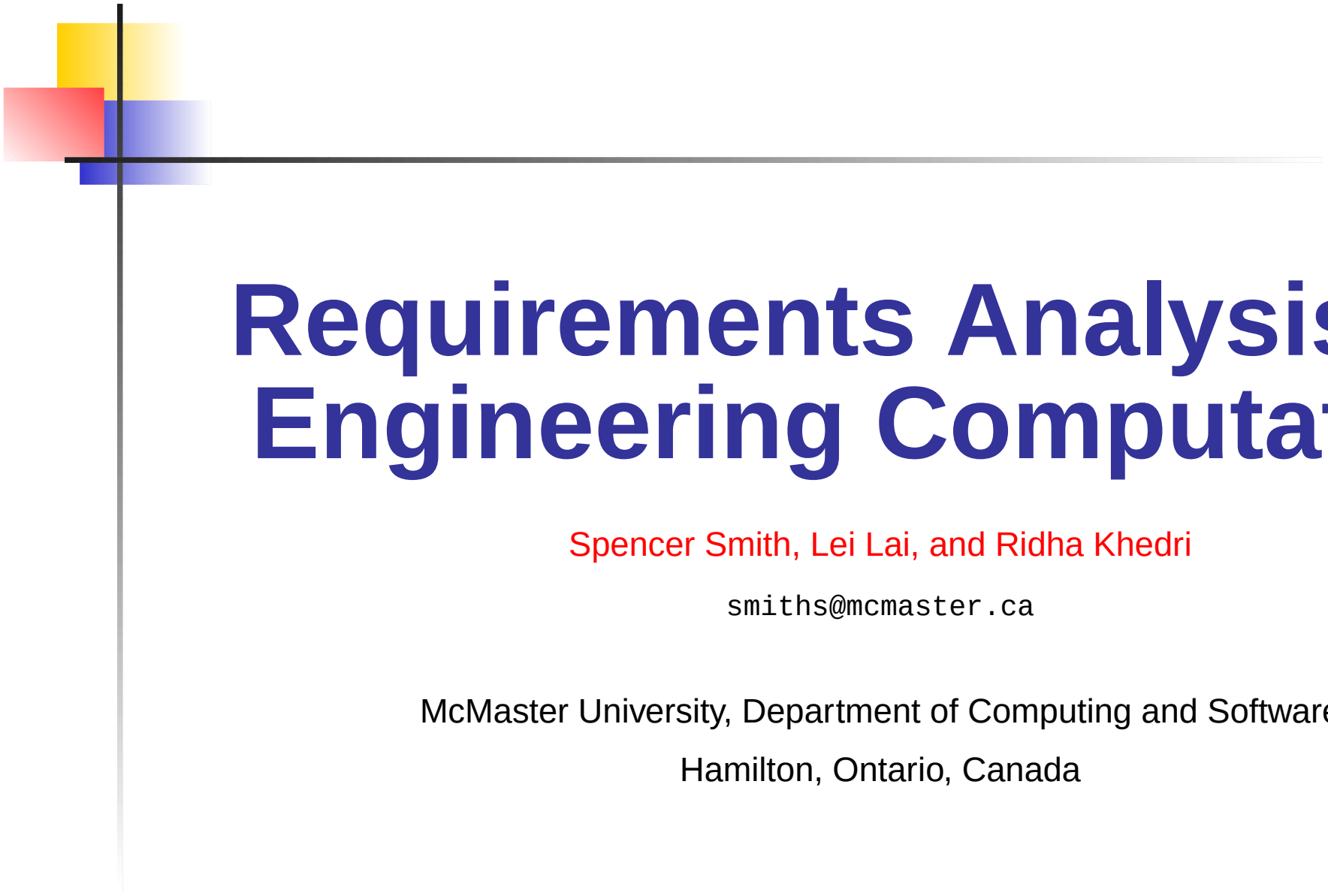

Requirements Analysis for Engineering Computation

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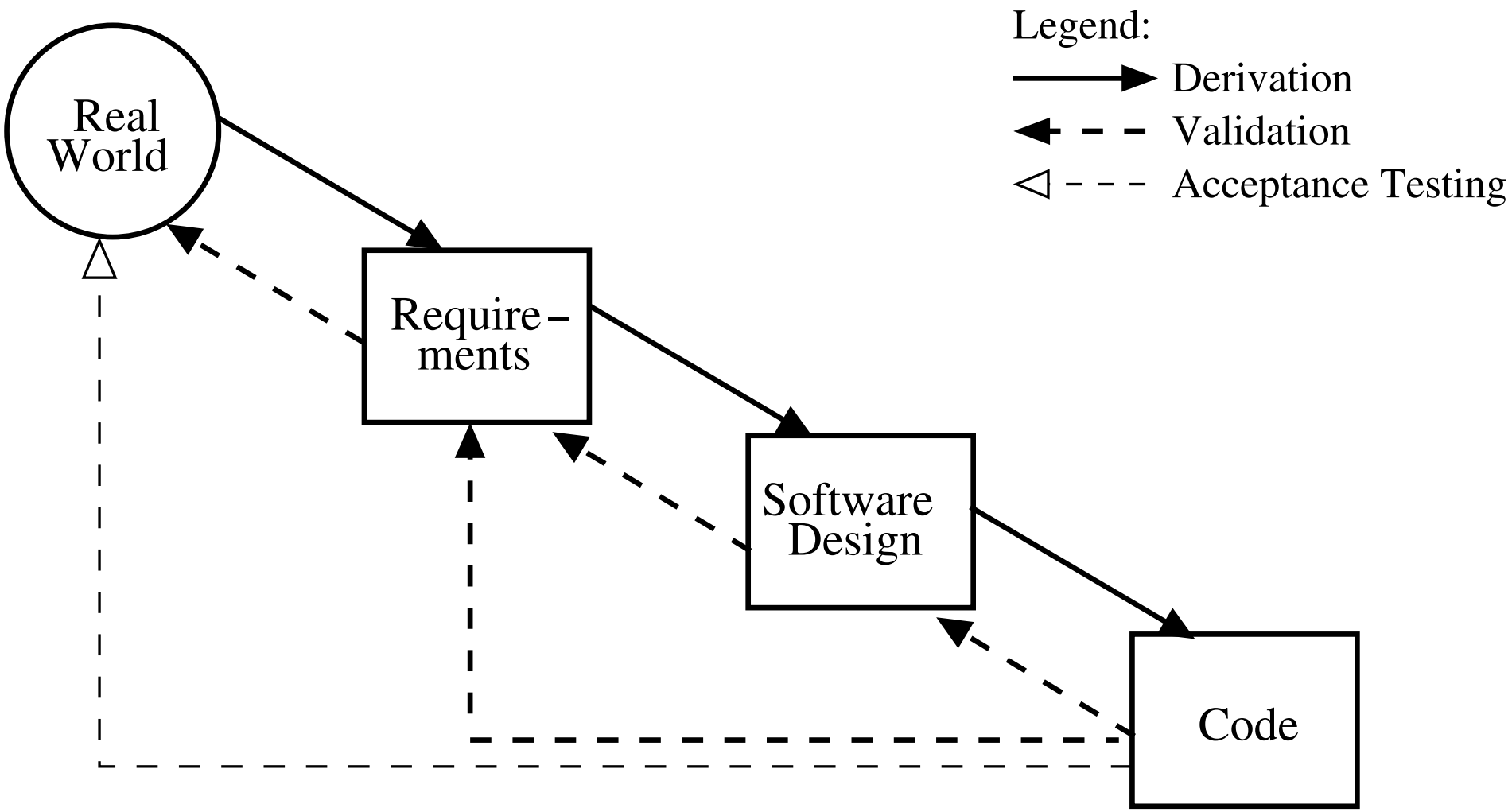
Overview

- Requirements elicitation, analysis and documentation
- Tabular expressions
- Why requirements analysis for engineering computation?
- System Requirements Specification and template for beam analysis software
  - Provides guidelines
  - Eases transition from general to specific
  - Catalyses early consideration of design
  - Reduces ambiguity
  - Identifies range of model applicability
  - Clear documentation of assumptions
- Concluding remarks

Requirements Analysis



Software Requirements Activities

- A software requirement is a description of how the system should behave, or of a system property or attribute
- Requirements should be unambiguous, complete, consistent, modifiable, verifiable and traceable
- Requirements should express “What” not “How”
- Formal versus informal specification
- Functional versus nonfunctional requirements
- Software requirements specification (SRS)
- Requirements template

Tabular Expressions

Composition rule	$\cup_{i=1}^{4} H_2[i] \cap (\cap_{j=1}^{2} H_1[j] \ ; \ G[i,j])$

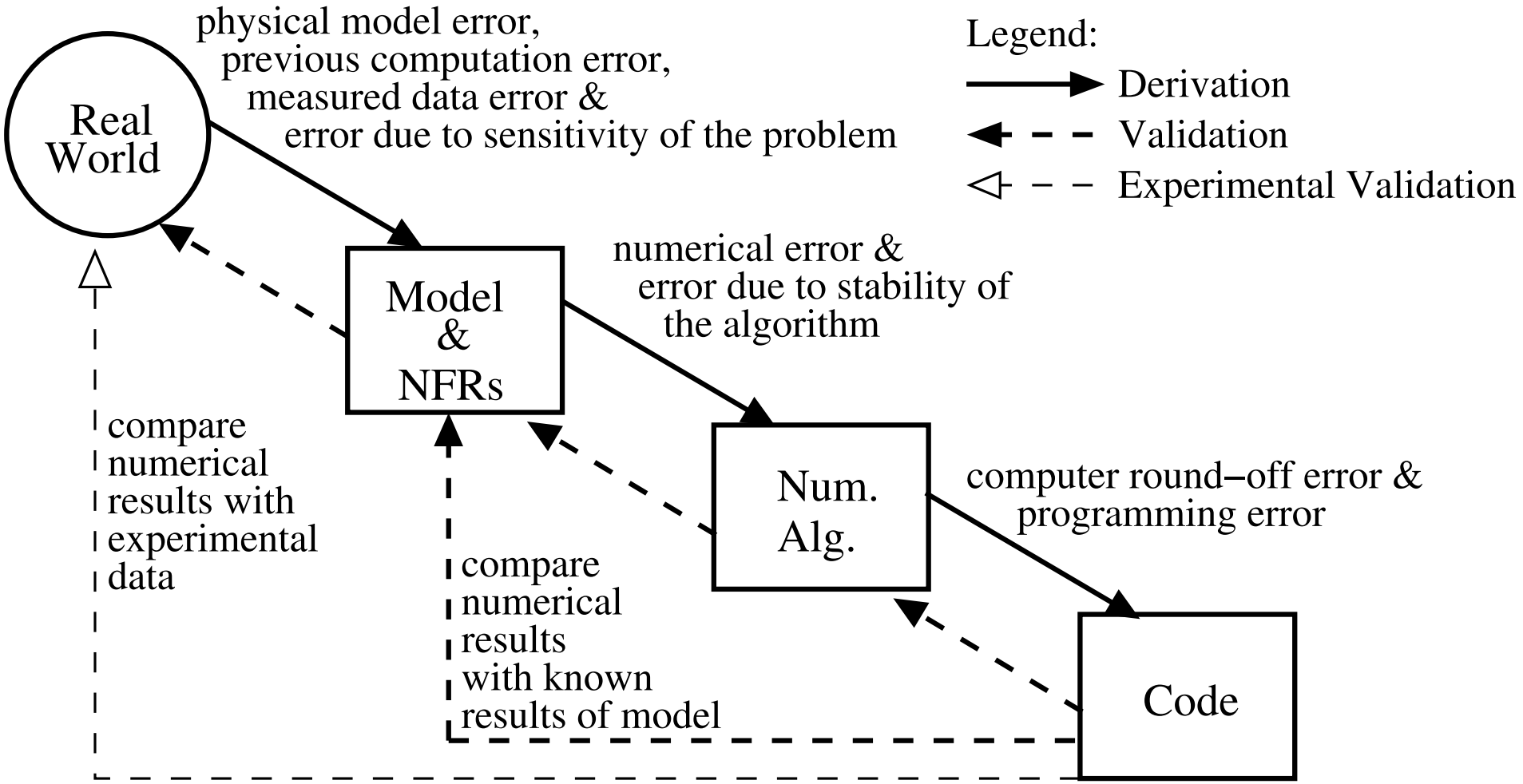
H_1

$S'_{GET} \cup =$	$ErrorMsg' + =$

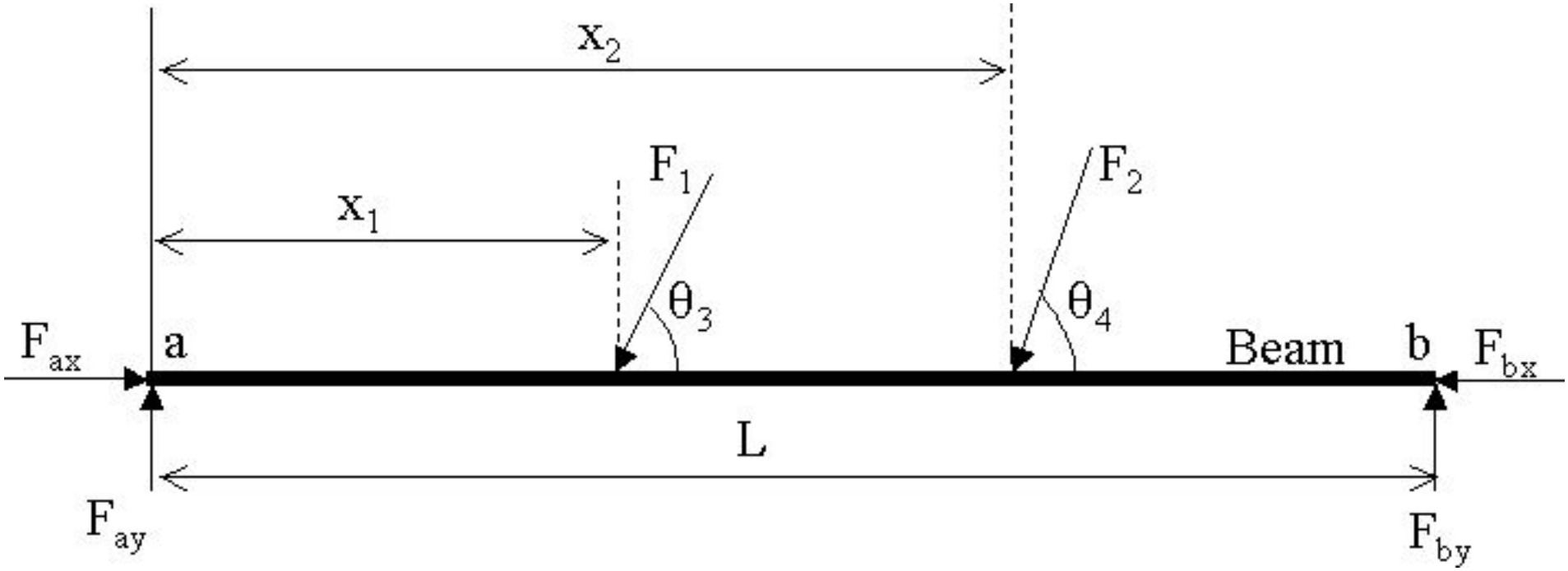
H_2	G
$x_1 < 0$	$\emptyset$ $InvalidInput\_x_1$
$0 \leq x_1 < min_d$	$\emptyset$ $x_1\_TooSmall$
$x_1 > max_d$	$\emptyset$ $x_1\_TooLarge$
$min_d \leq x_1 \leq max_d$	$\{@x_1\}$ $NULL$

$\wedge ChangeOnly(S_{GET}, ErrorMsg)$

Why Requirements Analysis?



Beam Analysis Software



Proposed Template

1. Reference Material: a) Table of Symbols ...
2. Introduction: a) Purpose of the Document; b) Scope of the Software Product; c) Organization of the Document.
3. General System Description: a) System Context; b) User Characteristics; c) System Constraints.
4. Specific System Description:
   (a) Problem Description: i) Background Overview ...
   (b) Solution specification: i) Assumptions; ii) Theoretical Models; ...
   (c) Non-functional Requirements: i) Accuracy of Input Data; ii) Sensitivity ...
5. Traceability Matrix
6. List of Possible Changes in the Requirements
7. Values of Auxiliary Constants

Provides Guidance

- Details will not be overlooked, facilitates multidisciplinary collaboration
- Encourages a systematic process
- Acts as a checklist
- Separation of concerns
  - Discuss purpose separately from organization
  - Functional requirements separate from non-functional
- Labels for cross-referencing
  - Sections, physical system description, goal statements, assumptions, etc.
  - PS1.a “the shape of the beam is long and thin”

Eases Transition from General to Specific

- "Big picture" first followed by details
- Facilitates reuse
- "Introduction" to "General System Description" to "Specific System Description"
- Refinement of abstract goals to theoretical model to instanced model
  - **G1**. Solve for the unknown external forces applied to the beam
  - **T1** $\sum F_{xi} = 0, \sum F_{yi} = 0, \sum M_i = 0$
  - **M1** $F_{ax} - F_1 \cdot \cos\theta_3 - F_2 \cdot \cos\theta_4 - F_{bx} = 0$

Ensures Special Cases are Considered

H_2		H_1	
		$S_{GET} = S_{sym} - S_{unkF}$	$S_{GET} \neq (S_{sym} - S_{unkF})$
$S_{unkF} \notin \mathbb{P}_3$	-	$(ErrorMsg' = InvalidUnknown) \wedge ChangeOnly(ErrorMsg)$	$FALSE$
$S_{unkF} = \{@F_{ax}, @F_{bx}, @F_{ay}\}$	-	$ErrorMsg' = NoSolution \wedge ChangeOnly(ErrorMsg)$	
$S_{unkF} = \{@F_{ax}, @F_{ay}, @F_1\}$	$x_1 \neq 0 \wedge \theta_3 \neq 0 \wedge \theta_3 \neq 180$	$F'_{ax} = \frac{-\cos\theta_3 F_2 x_2 \sin\theta_4 + \cos\theta_3 F_{by} L + F_2 \cos\theta_4 x_1 \sin\theta_3 + F_{bx} x_1 \sin\theta_3}{x_1 \sin\theta_3} \wedge F'_{ay} = -\frac{F_2 x_2 \sin\theta_4 - F_{by} L - F_2 \sin\theta_4 x_1 + F_{by} x_1}{x_1} \wedge F'_1 = \frac{-F_2 x_2 \sin\theta_4 + F_{by} L}{x_1 \sin\theta_3} \wedge ChangeOnly(S_{unkF})$	
	$otherwise$	$(ErrorMsg' = Indeterminant) \wedge ChangeOnly(ErrorMsg)$	

G

Catalyses Early Consideration of Design

- Identification of significant issues early will improve the design
- Section for considering sensitivity
  - Conditioning?
  - Buckling of beam
- Non-functional requirements
  - Tradeoffs in design
  - Speed efficiency versus accuracy
- Tolerance allowed for solution: $|\sum F_{xi}|/\sqrt{\sum {F_{xi}}^2} \leq \epsilon$
- Solution validation strategies
- List of possible changes in requirements

Reduces Ambiguity

- Unambiguous requirements allow communication between experts, requirements review, designers do not have to arbitrary decisions
- Tabular expressions allow automatic verification of completeness
- Table of symbols
- Abbreviations and acronyms
- Scope of software product and system context
- User characteristics
- Terminology definition and data definition
- Ends arguments about the relative merits of different designs

Identifies Range of Model Applicability

- Clear documentation as to when model applies
- Can make the design specific to the problem
- Input data constraints are identified
  - Physically meaningful: $0 \leq x_1 \leq L$
  - Maintain physical description: PS1.a, $0 < h \leq 0.1L$
  - Reasonable requirements: $0 \leq \theta_3 \leq 180$
- The constraints for each variable are documented by tables, which are later composed together
- $(min_f \leq |F_{ax}| \leq max_f) \wedge (|F_{ax}| \neq 0) \Rightarrow$
  $\forall(FF|@FF \in S_F \cdot FF \neq 0 \wedge \frac{max\{|F_{ax}|,|FF|\}}{min\{|F_{ax}|,|FF|\}} \leq 10^{r_f})$

Clear Documentation of Assumptions

Phy. Sys. /Goal	Data /Model	Assumption										Model	
		A1	A2	...	A4	...	A8	A9	A10	...	A14	**M1**	...
G1	**T1**	√		...		...	√	√		...		√	...
G2	**T2**	√		...		...	√	√		...			...
G3	**T3**	√		...		...		√	√	...			...
	M1		√	...		...				...		√	...
PS1.a	L			...		...			√	...		...	...
...	...	...	...	...	...	...	...	...	...	...	...	...	...

A10. The deflection of the beam is caused by bending moment only, the shear does not contribute.

Concluding Remarks

- Motivated, justified and illustrated a method of writing requirements specification for engineering computation to improve reliability
- Also improve quality with respect to usability, verifiability, maintainability, reusability and portability
- Tabular expressions to reduce ambiguity, encourage systematic approach
- Conclusions can be generalized because other computation problems follow the same pattern
- Input then calculate then output
- Benefits of approach should increase as the number of details and the number of people involved increase