2IS55 Software Evolution

Requirements Evolution

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Where innovation starts

Assignment 1: Reminder

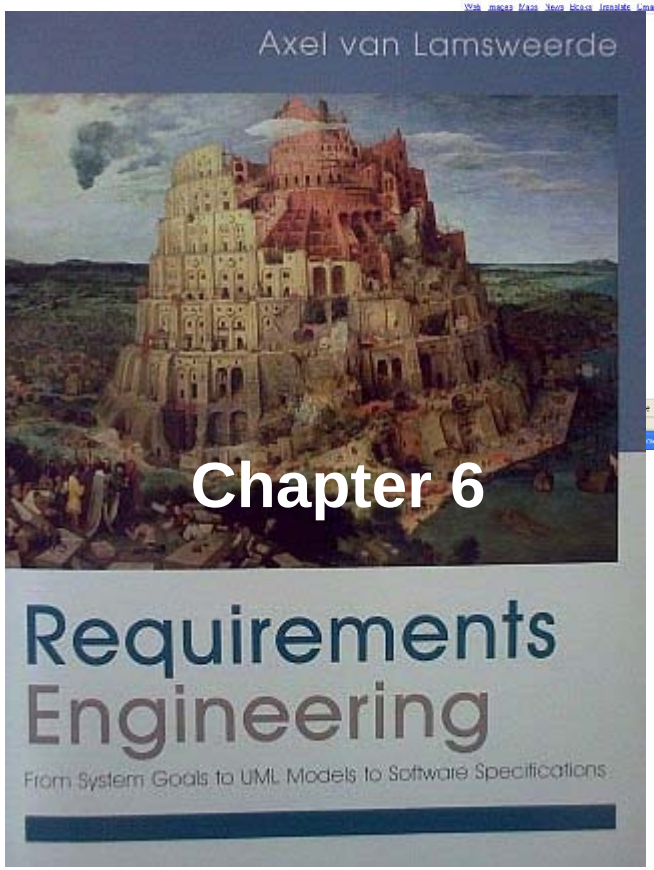
- **Deadline: Today, 23:59**
- **Individual**

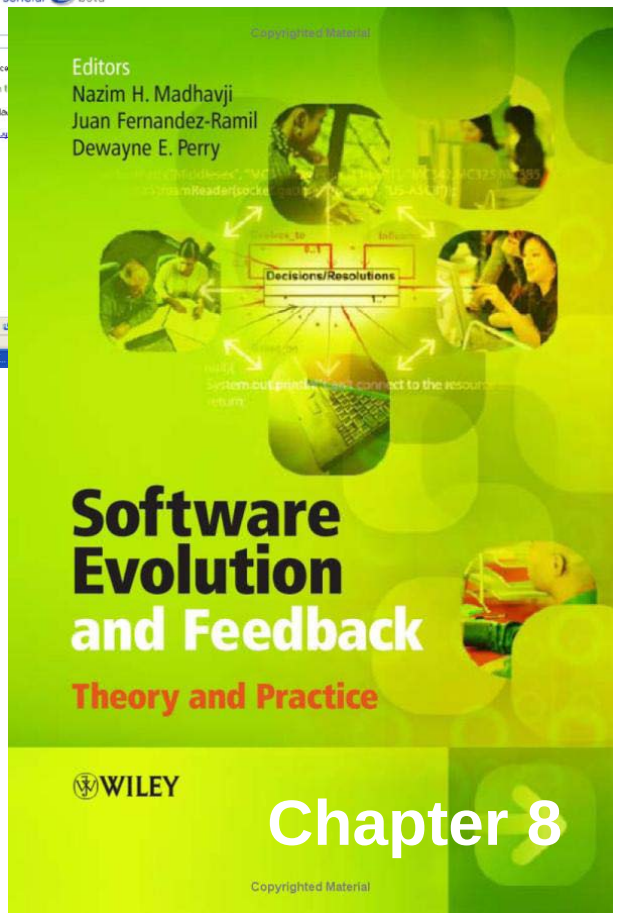
- **Preference: PDF**
- **How to submit: Peach**
  - **http://peach.win.tue.nl/**

- **Assignment 2**
  - **Is already open**
  - **Deadline: February 23, 23:59**
  - **Individual**

Sources


Google Scholar - Mozilla Firefox
Google
scholar beta

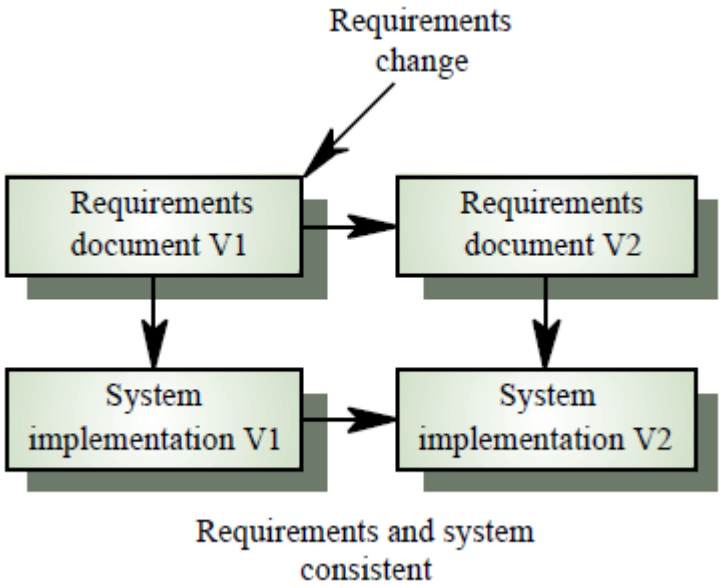

Axel van Lamsweerde
Chapter 6
Requirements Engineering
From System Goals to UML Models to Software Specifications

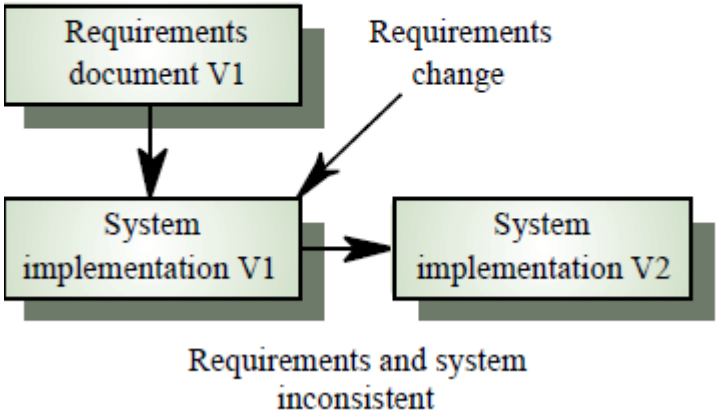

Editors
Nazim H. Madhavji
Juan Fernandez-Ramil
Dewayne E. Perry
Decisions/Resolutions
Software Evolution and Feedback
Theory and Practice
WILEY
Chapter 8

Requirements Evolution

- **Requirements are “just a piece of paper”…**
- **Tend to be forgotten during the evolution**

Sommerville 1996



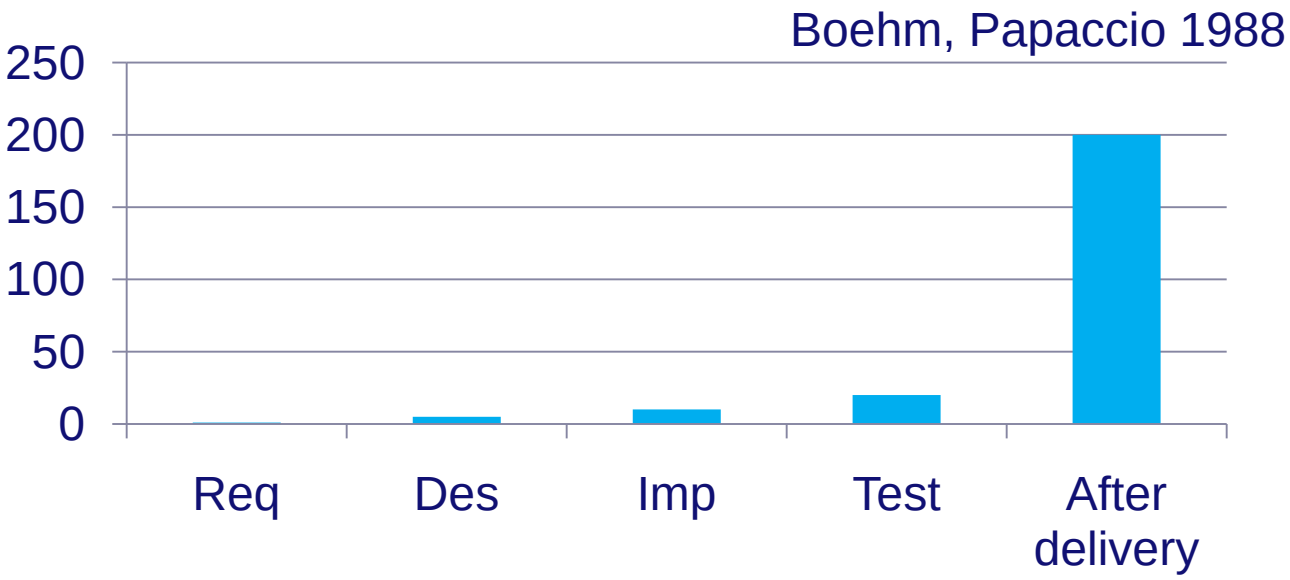


This is how it should be…

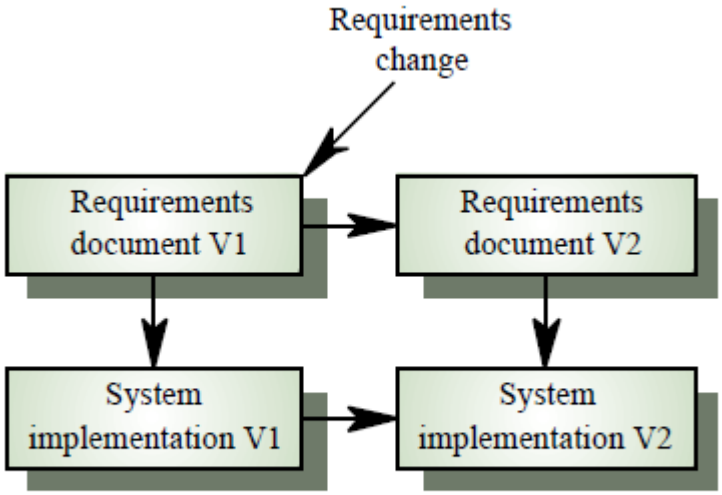
this is how it often is.

Why requirements?

- **Errors in requirements are:**
  - **common:**
    - **25% of all the errors (Jones ‘91)**
    - **1 error per function point (~ 80 LOC Java; Jones ‘95)**
  - **expensive**



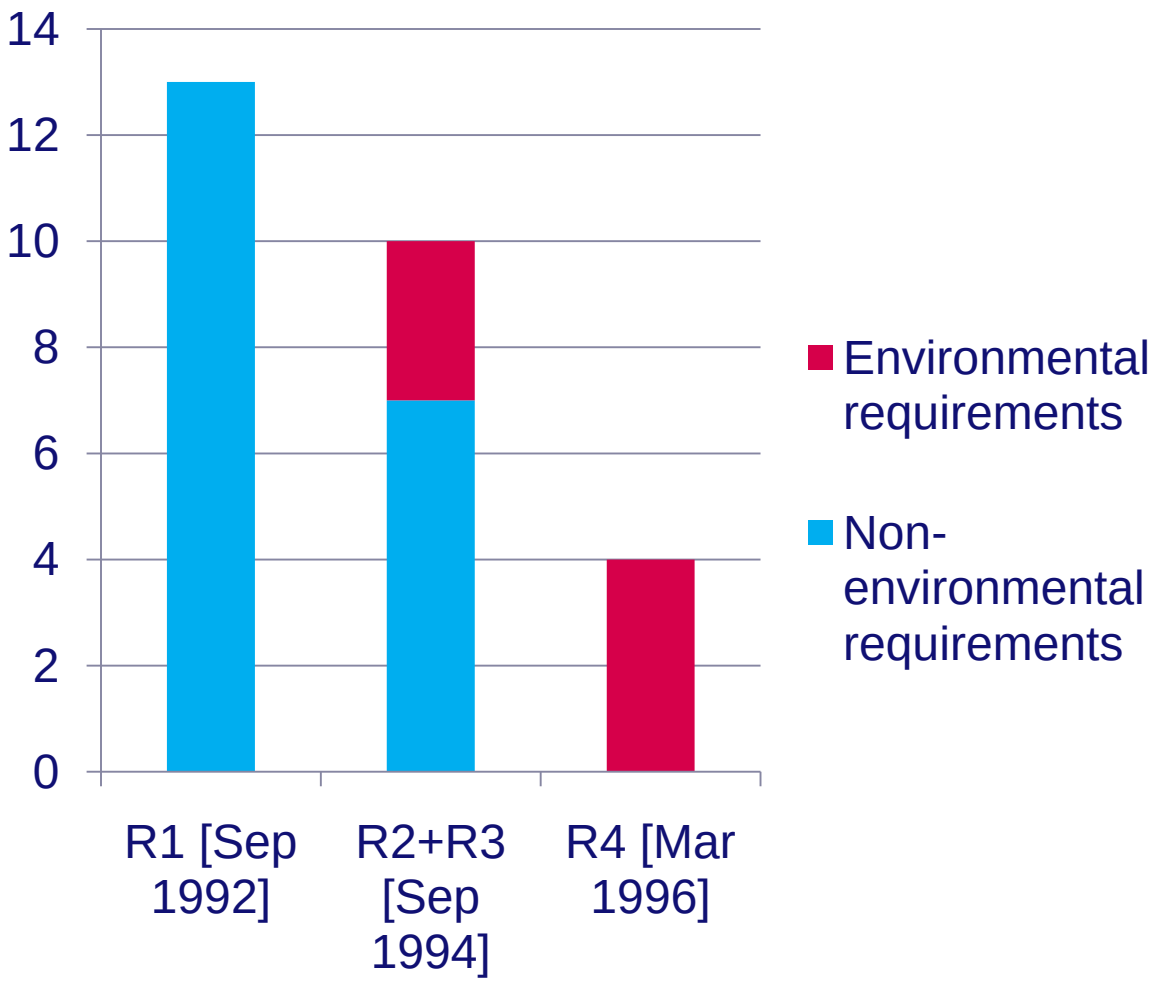
Questions



- **Why do the requirements evolve?**
- **How suited is a given requirements document for evolution?**
- **How do the requirements evolve and co-evolve?**

Why do the requirements evolve?

- **Environment changes**
- **[Nanda, Madhavji]**
  - **Congruence Evaluation System**
  - **Research prototype**



Suitability for evolution

- When is evolution difficult?
  - Per requirement:
    - "Bad requirements": vague, subjective, weak, underspecified, overtly complex, unreadable…
    - Volatile requirements
      - Related to dependencies between the requirements
  - Per requirements document:
    - Missing requirements
    - Inconsistent requirements

Bad requirements: Check lists

- **Industrial approach: guidelines, checklists, templat**
- **Manu**
  - **“Ea los (Eu**
  - **“Ea**
- **Do y**

Specific
Measurable
Attainable, Appropriate, Actionable
Realistic
Time-bound, Traceable

Bad requirements: Check lists

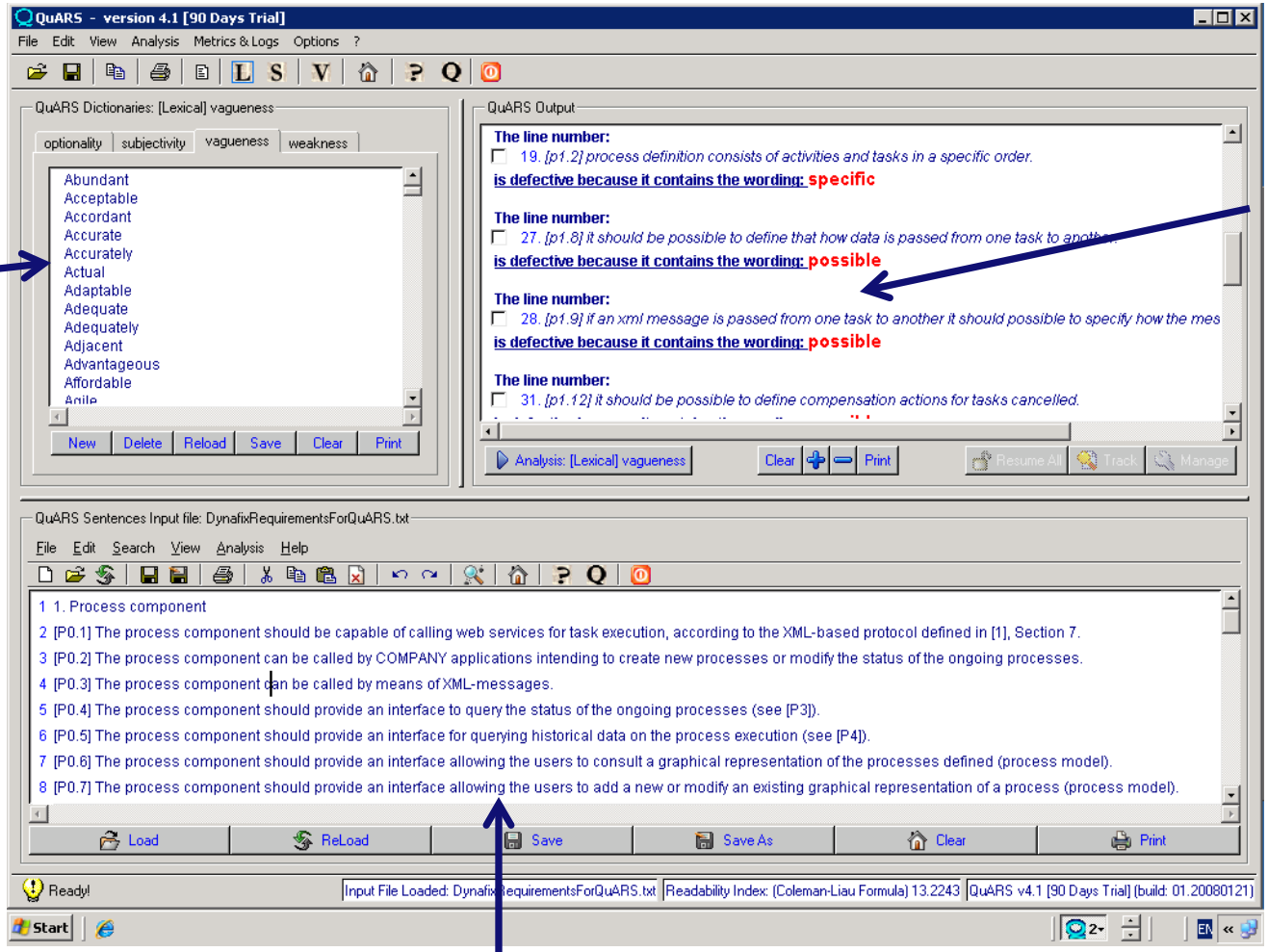
- **Industrial approach: guidelines, checklists, templates**
- **Manual verification**
  - **“Each requirement should state consequences of losses of availability and breaches of security” (European eGovernment program)**
  - **“Each requirement is measurable” (SMART)**
- **Assessment**
  - **is subjective**
  - **requires training and experience**

Bad requirements: More automation?

Problem	Indicators (examples)
Vagueness	clear, significant, useful, adequate, good, bad
Subjectivity	similar, as … as possible, taking … into account
Optionality	possibly, if needed, if appropriate, eventually
Weakness	could, might
Underspecification	(write/read) access, (data/control) flow, “TBD”
Multiplicity	and, or
Implicity	Anaphora (it, these, previous, above)

Fabbrini, Fusani, Gnesi, Lami, 2001.

How to make the requirements better?



Lexical indicators

Defects

Requirements

Readability measurement

- **Requirements from a student project (Horus 2007)**
  A. **An account is an administrator account, a scientist account or an observer account.**
  B. **An administrator shall be able to configure whether multiple experiments may be executed simultaneously on a particular satellite.**
  C. **Experiment data can be retrieved from the system.**

- **Which one is more difficult to read?**
- **Flesch-Kincaid grade level:**
  - **A – 11.2, B – 20.2, C – 8.1**

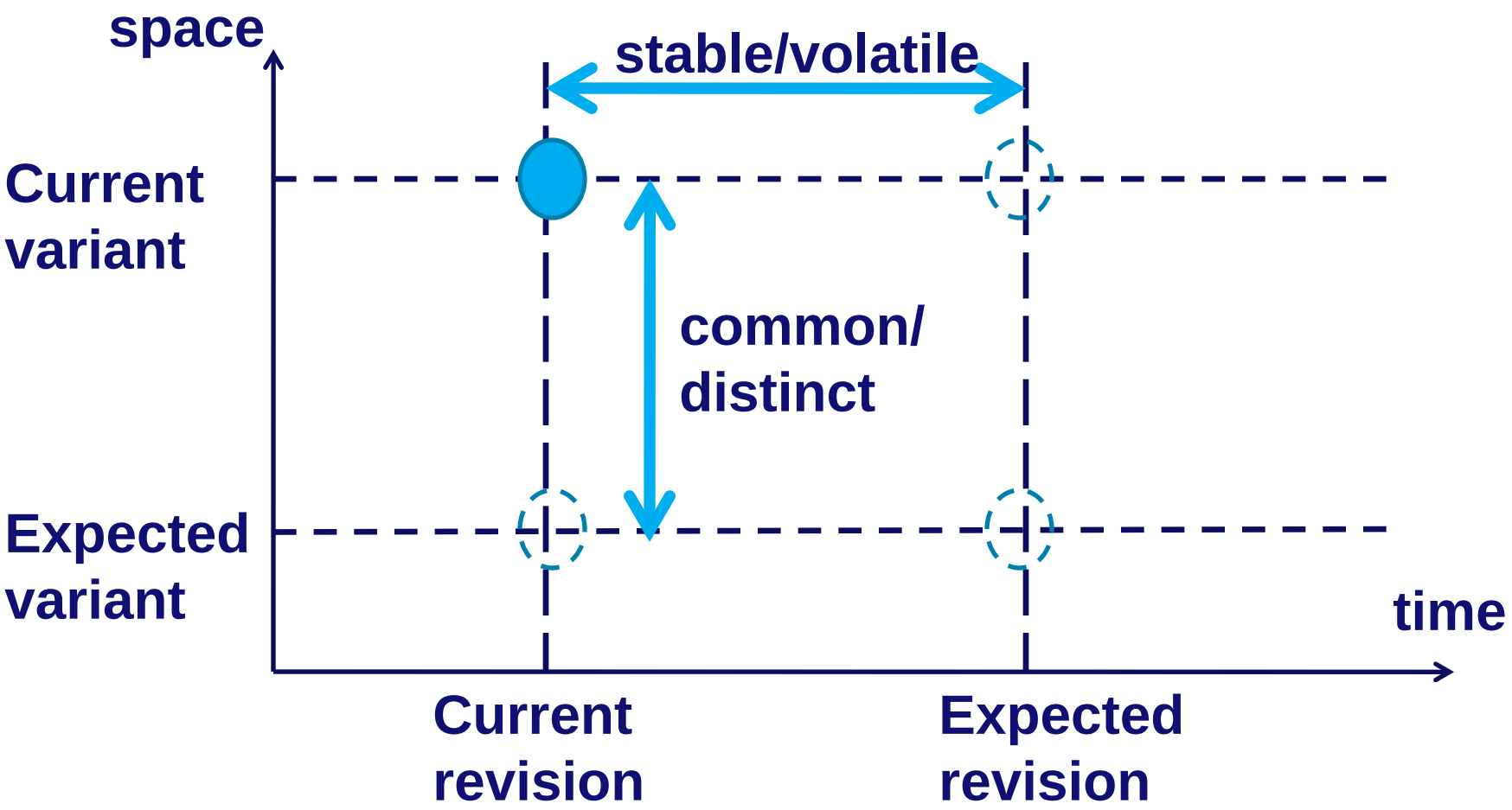
Flesch-Kincaid grade level

- **Number of years of (US) education required to understand the text.**

$$0.39\left(\frac{\text{total words}}{\text{total sentences}}\right)+11.8\left(\frac{\text{total syllables}}{\text{total words}}\right)-15.59$$

- **Might be misleading for smaller texts**
  - **Use for features instead of individual requirements**
  - **Feature = group of related requirements**
- **The NASA study (Wilson,Rosenberg,Hyatt 1997)**
  - **Mean = 10.76, std dev = 1.59**

Second problem: Volatile requirements



- **Variants** – adaptations to different users or environments
- **Revisions** – subsequent versions of one product

How can we identify volatile requirements?

- **Feature = group of related requirements**
  - **Features should separate more and less stable requirements**
  - **Intuition: More stable requirements should not depend on less stable ones**

- **Problems:**
  - **We cannot predict future change**
  - **Analysis of natural language requirements is difficult**

Relative stability

- **“Relative stability” – one requirement is more stable (>) than another one.**

- **Example: meeting schedule system**
- **Notify the participants vs. Notify the participants by SMS**
  - **Intention or concept > operation or fact**
- **Notify the participants vs. Arrange recurrent meetings**
  - **Core (in any variant/revision) > others**
- **Notify the participants vs. The system should have an MS Windows “look and feel”**
  - **Functional > non-functional**
- **NB: Conflicts and choices among different options are usually quite volatile**

How can we address volatility?

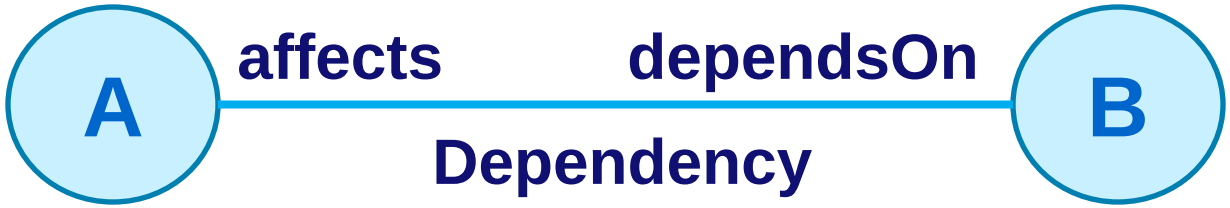
- At requirements engineering time:
  - Try to find a more stable alternative
  - Put special attention to traceability (backwards – rationale, forwards – design, implementation, tests)
  - Anticipate and record responses for future changes

- At design time:
  - Encapsulate volatile requirements in separate modules

Volatility and dependencies

- **“More stable requirements should not depend on less stable ones”**

- **A affects B (B depends on A) if changing A might require changing B.**



Types of dependencies (examples)

- **Use**
  - **A explicitly refers to B**
  - **“IMSETY shall adhere to Table 2.1 for user rights”**
- **Generalization/refinement**
  - **A is a more general case of B**
  - **“Observers shall not be authorized to manipulate experiments.”**

	Users		
Entities	Administrator	Scientist	Observer
Payload	CRUD	R	R
Satellite	CRUD	-	-
User	CRUD	RU	-
Payload command list	CRUD	R	-
Experiment	CRUD	CRUD	R
Observation	RD	R	R
Representation	-	CRD	CRD

Table 2.1: CRUD matrix

Types of dependencies (examples, continued)

- **Temporal**
  - **Satisfaction of A should precede/follow satisfaction of B**
  - **“IMSETY shall require users to be logged in before they can use any of the system’s functionality.”**

- **Satisfiability**
  - **Satisfaction of A implies satisfaction of B**
  - **More general than “generalization/refinement”**
  - **But also**
    - **“The system shall interface with an MCS for communication with satellites.”**
    - **“IMSETY shall log all communications with the MCSes.”**

How can we derive dependency relations?

- **Manually**
- **If requirements are formalized (à la “2IW26 Software validation”) – formal techniques, e.g., using model checking**
- **Using transitivity**

2ID25 Information retrieval

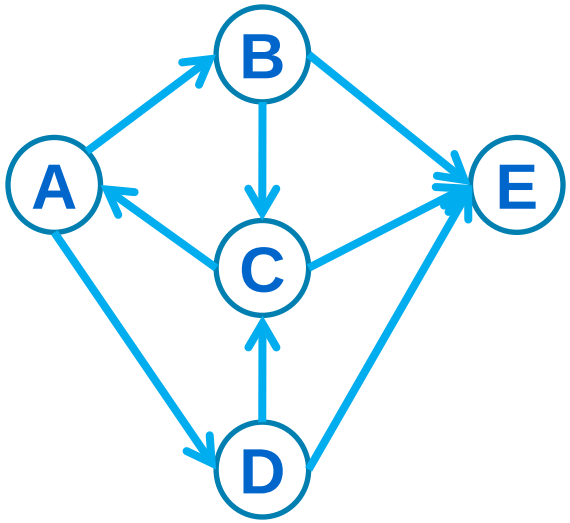
- **Keyword-based [Huffma… …orne 2003]:**
  - **At any moment, only one sc… …compose an experiment on a single payload.**
  - **A scientist shall be able to request the scheduling of the execution of experiments on a predefined moment.**

Problems (and solutions) with keyword-based

- **Terminology vs. regular use**
  - **scientist, experiment vs. moment**
  - **solution: domain dictionary**
- **Synonyms (solution: thesaurus)**
- **Some requirements are more “essential” for the keyword than others.**
- **Lexical correlation vs. dependency**
  - **Which type?**

Dependency analysis

- **Traceability graph**
  - **Vertices: requirements**
  - **Arcs: dependency relations**



- **What do you think about the requirements document right?**
- **What does this mean for evolution?**
- **How would the quality information influence your interpretation?**
- **What are the limitations of the traceability graph approach?**

Inconsistent requirements

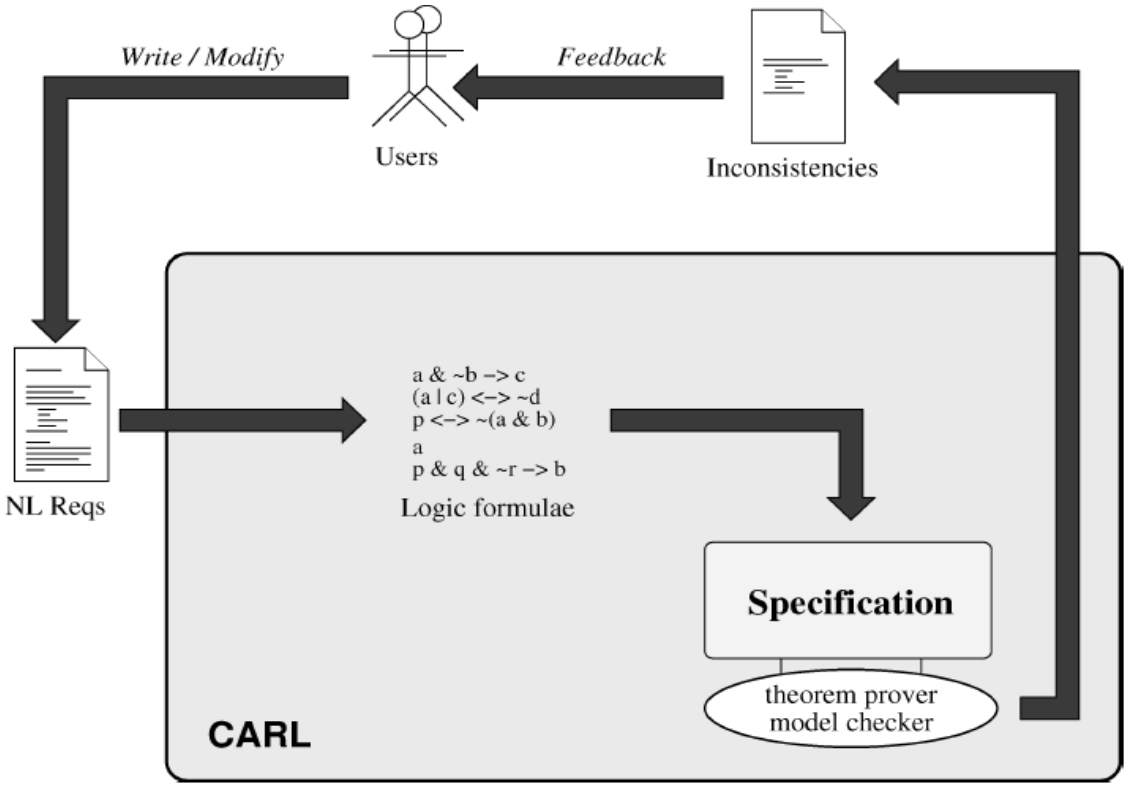
- Different kinds of requirements: use cases, process models, natural language requirements
- Different sources of requirements: multiple documents, multiple stakeholders
- Different types of inconsistencies:
  - Terminological (synonyms, different interpretations of the same term): data dictionary, glossary, ontology
  - Logical (strong) – conjunction of the requirements is *false*
  - Logical (weak) – under some condition conjunction of the requirements is *false*

Logical inconsistencies: Heuristics

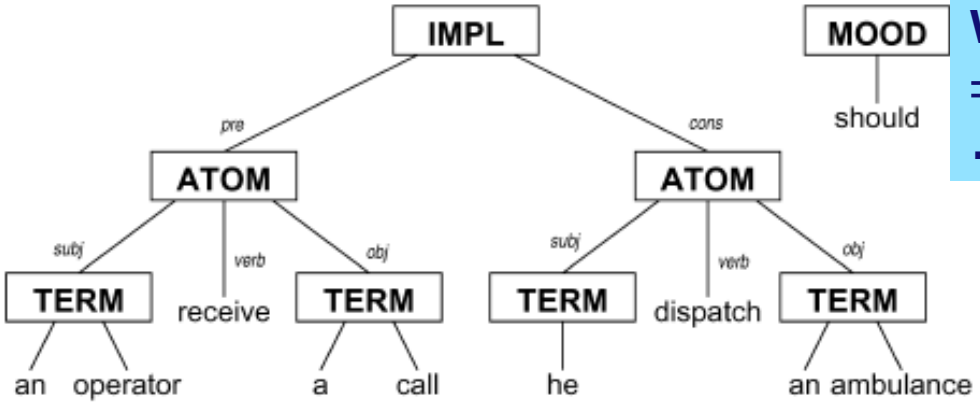
- **Logical inconsistencies [van Lamsweerde]**
  - **Heuristic: scrutinize dependent requirements**
  - **Heuristic: public availability vs. confidentiality**
    - **Grades should be publically available**
    - **Students should not have access to other students' grades**
  - **Heuristic: increases vs. decreases**
    - **Increase access to books and journals**
    - **Reduce operational costs**
  - **Heuristic: security vs. user-friendliness**

Inconsistent requirements: Linguistics+Logics

- **CARL [Gervasi. Zowghi 2005]:**
  - **Translate nat. lang. requirements to logical formulae**
  - **Analyse consistency**



CARL: From text to formula

Original requirement	`When an operator receives a call, he should dispatch an ambulance.`
After morpho-syntactic analysis	`When/CC/WRB an/DT operator/NN receive/VB/Z a/DT call/NN he/PP should/MD dispatch/VB an/DT ambulance/NN`
Parse tree, as produced by the CICO algorithm ($\mathcal{P}$)	
Equivalent logic formula ($\mathcal{T}$)	`receive(operator,call)` → `dispatch(operator,ambulance)` (with priority set to "optional")

WHEN a/SENT b/SENT
⇒ IMP $a $b
…

- **Now CARL can check for (weak) inconsistencies, resolve ambiguities and even "invent" unexpected scenario's.**

CARL: Detect inconsistency

1. A medical emergency is either an illness or an accident.
2. When an operator receives a phone call concerning a medical emergency, (s)he should dispatch a nearby available ambulance.
3. When an operator receives a phone call concerning a nonmedical emergency, the operator should not dispatch an ambulance, and he should transfer the phone call to another service.
4. When an operator receives a phone call, if an ambulance is not nearby or not available, then the operator should not dispatch that ambulance.
5. When an operator receives a phone call, (s)he should dispatch a nearby available ambulance.

How can we address inconsistency?

- **Weaken or drop one of the conflicting statements**
- **Specialize the requirement such that the conflict disappears.**
  - **When an operator receives a phone call *concerning medical emergency*, (s)he should dispatch a nearby available ambulance.**
- **For weak logical inconsistencies: avoid the condition**
  - **Logical (weak): under some condition conjunction of the requirements is *false***
- **Evaluate different options and choose the "best" one**
  - **NB: Source of volatility**

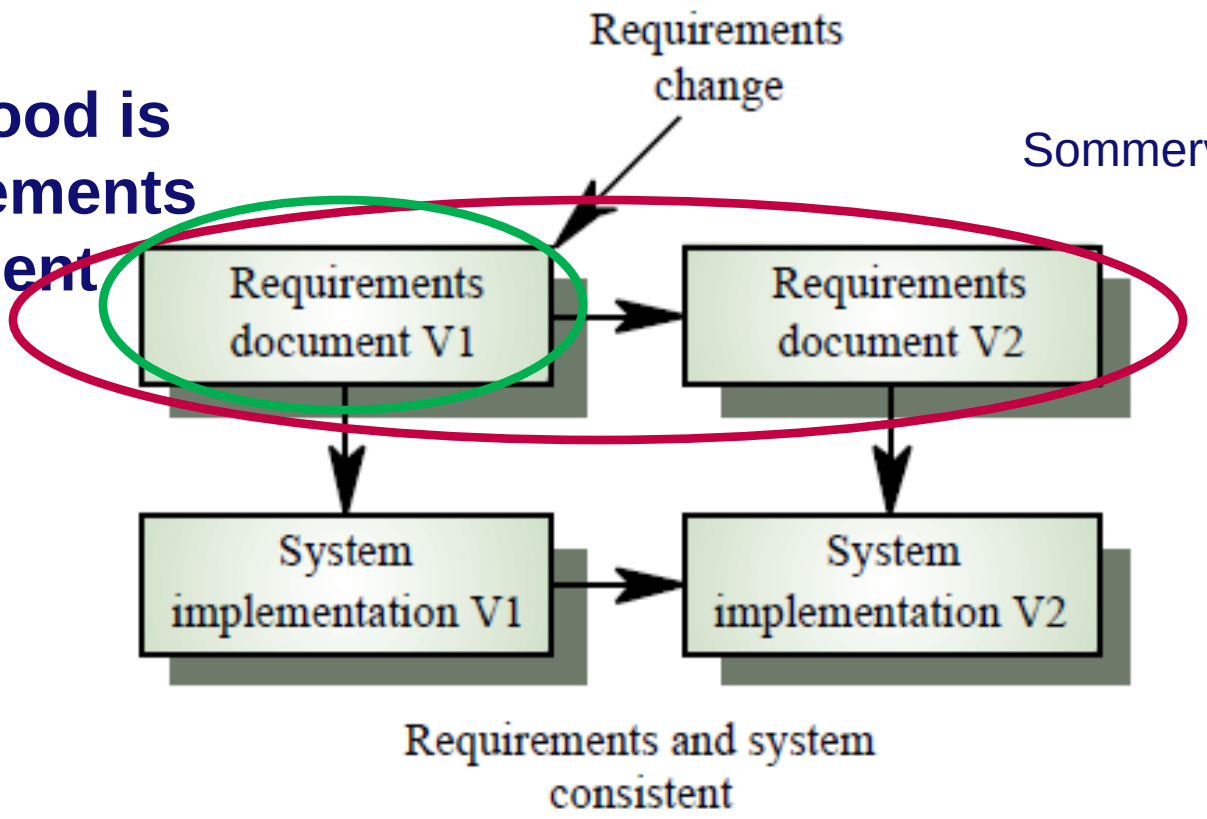
Summary so far…

- **Requirements evolution can be hindered by**
  - **"Bad requirements": vague, subjective, weak, underspecified, overtly complex, unreadable…**
  - **Volatile requirements**
    - **Related to dependencies between the requirements**
  - **Missing requirements**
  - **Inconsistent requirements**

So far…

Next…

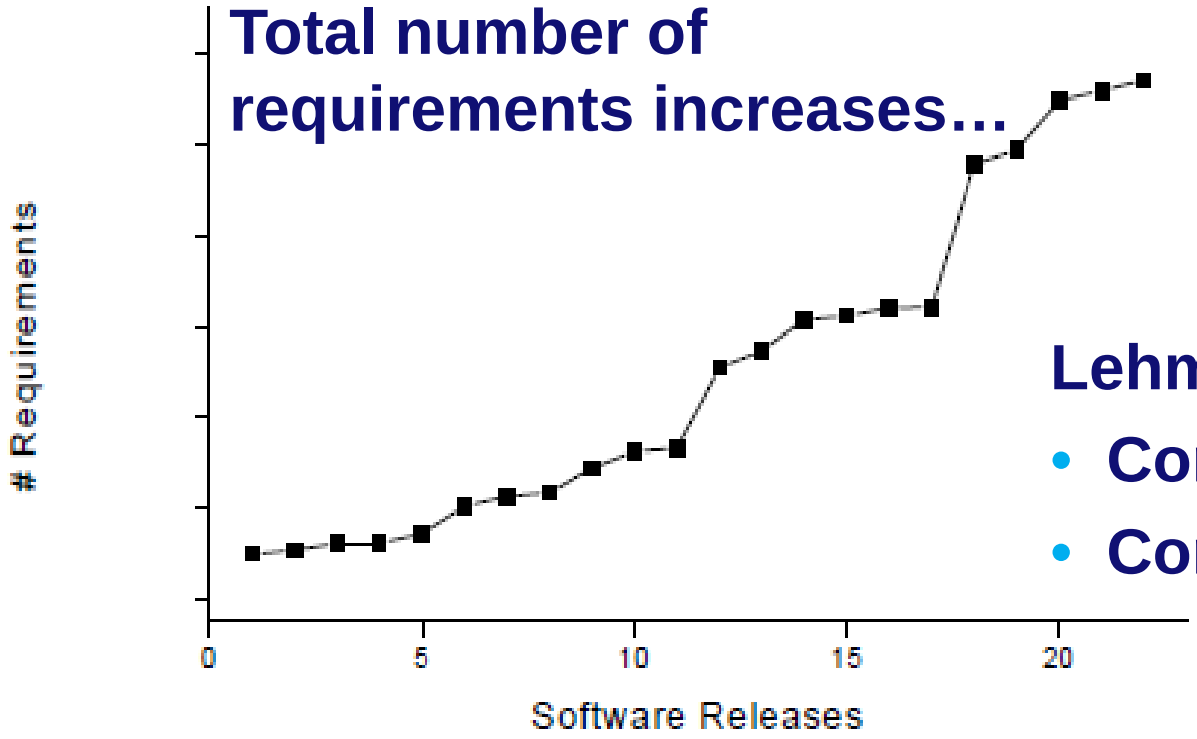
How good is requirements document v1?



Sommerville 1996

How do the requirements evolve?

- **Are Lehman's laws applicable?**
- **[Anderson, Felici 2000]: avionics software**

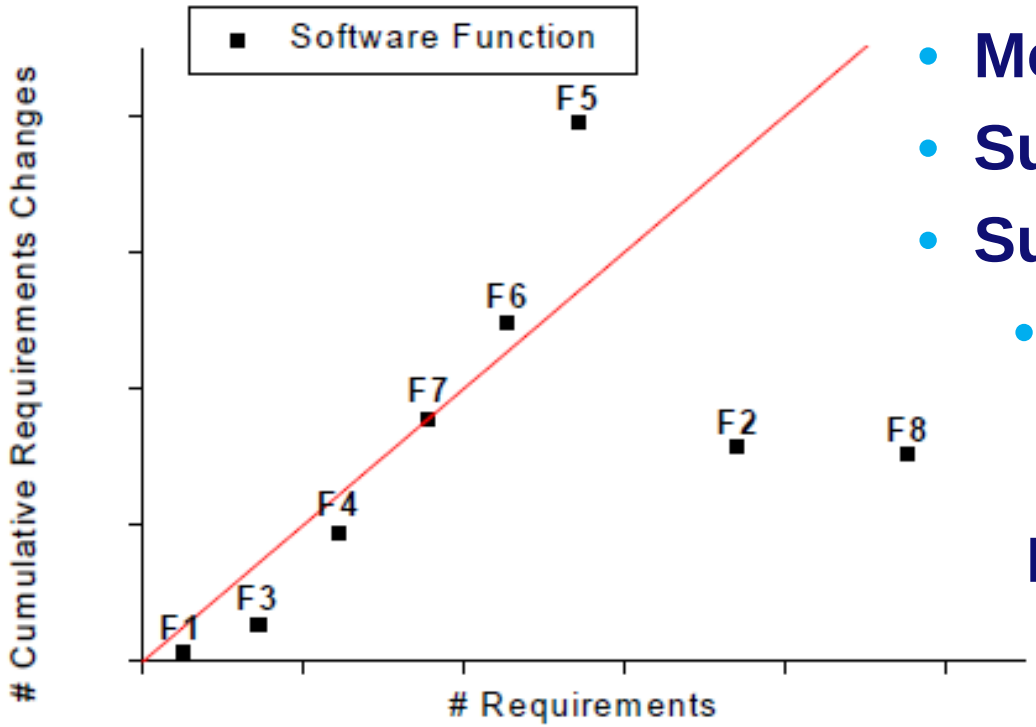


Lehman's laws

- **Continuing change**
- **Continuing growth**

Evolution and volatility

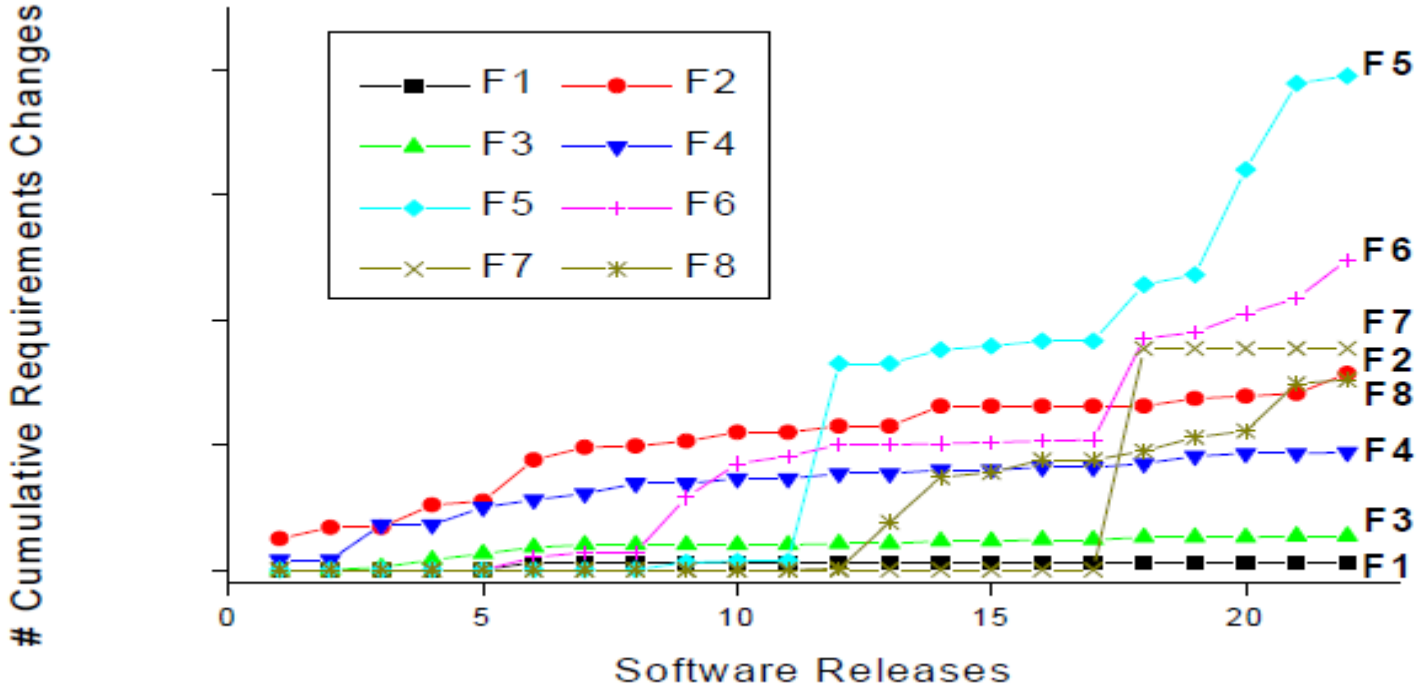
- Volatility = subject to change?
- Eight functions, different documents



- Mostly linear correlation
- Sublinear: F2, F8
- Superlinear: F5
  - Most likely to change

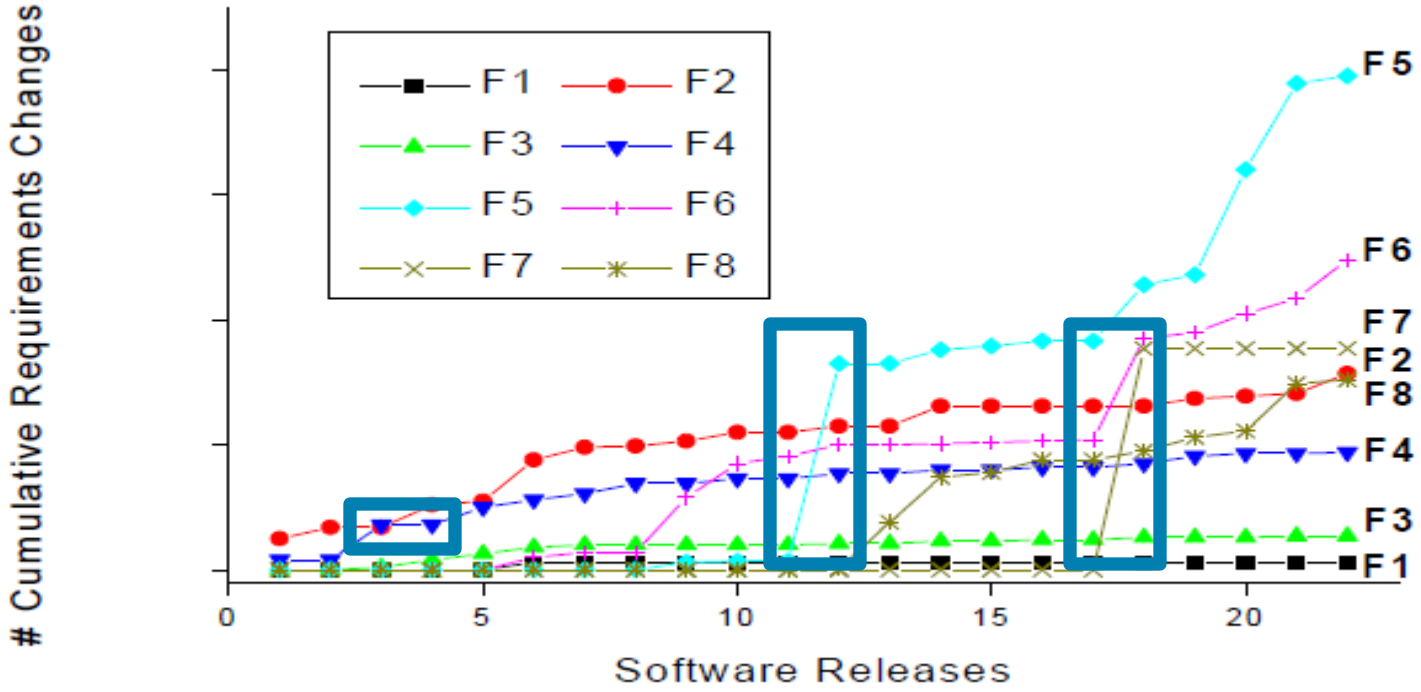
F1 *seems* to be stable

Closer look at the 8 functions (1)



- **F1 is indeed stable.**
- **F1 is about system architecture**
- **Conjecture: system architecture is stable**

Closer look at the 8 functions (2)



- **Different functions are likely to change at different times.**

How do the req. evolve – what have we done?

- **Calculated**
  - **the number of requirements**
  - **the number of changes**
  - **the cumulative number of changes**
- **Studied**
  - **how these values change with time**
- **Last week something similar for size/complexity/…**

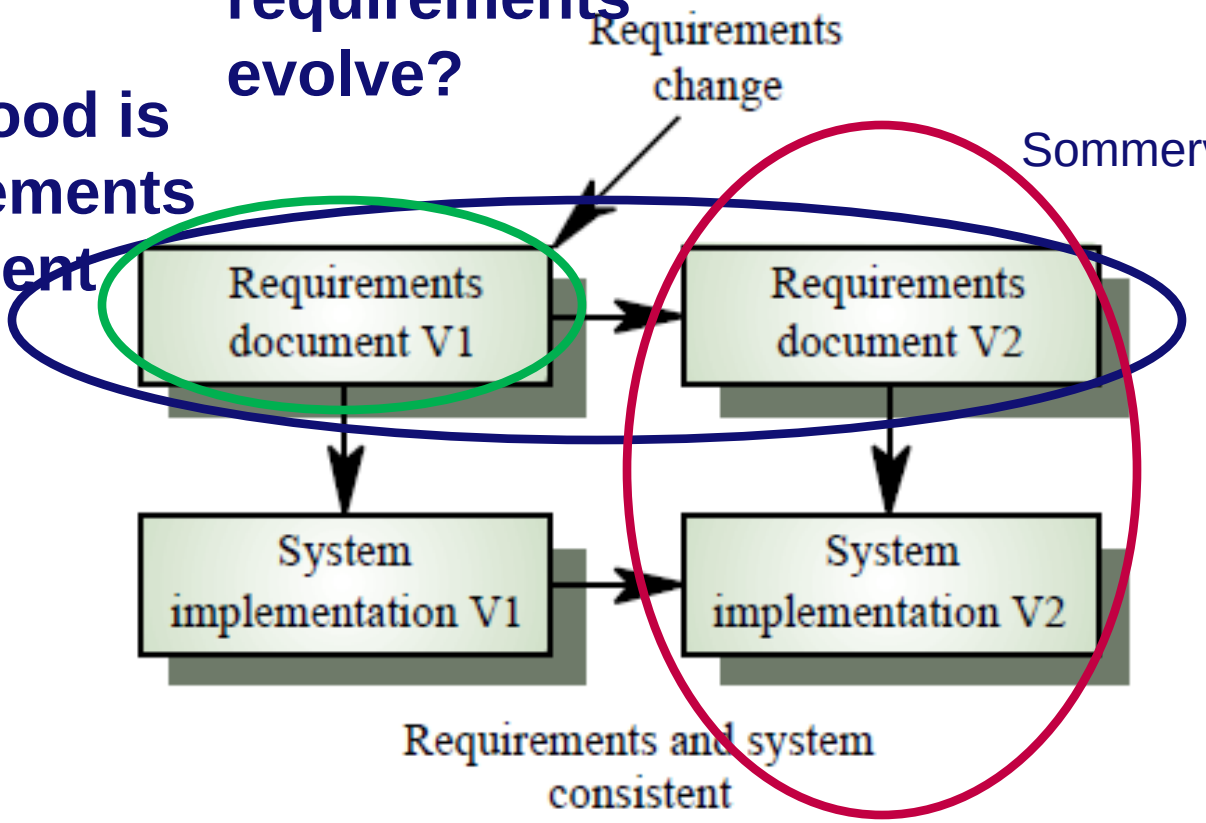
- **Generic approach**
  - **Metrics: function from software artefacts to numbers**
  - **Time series: sequence of measurements at successive times**

So far…

How do the requirements evolve?

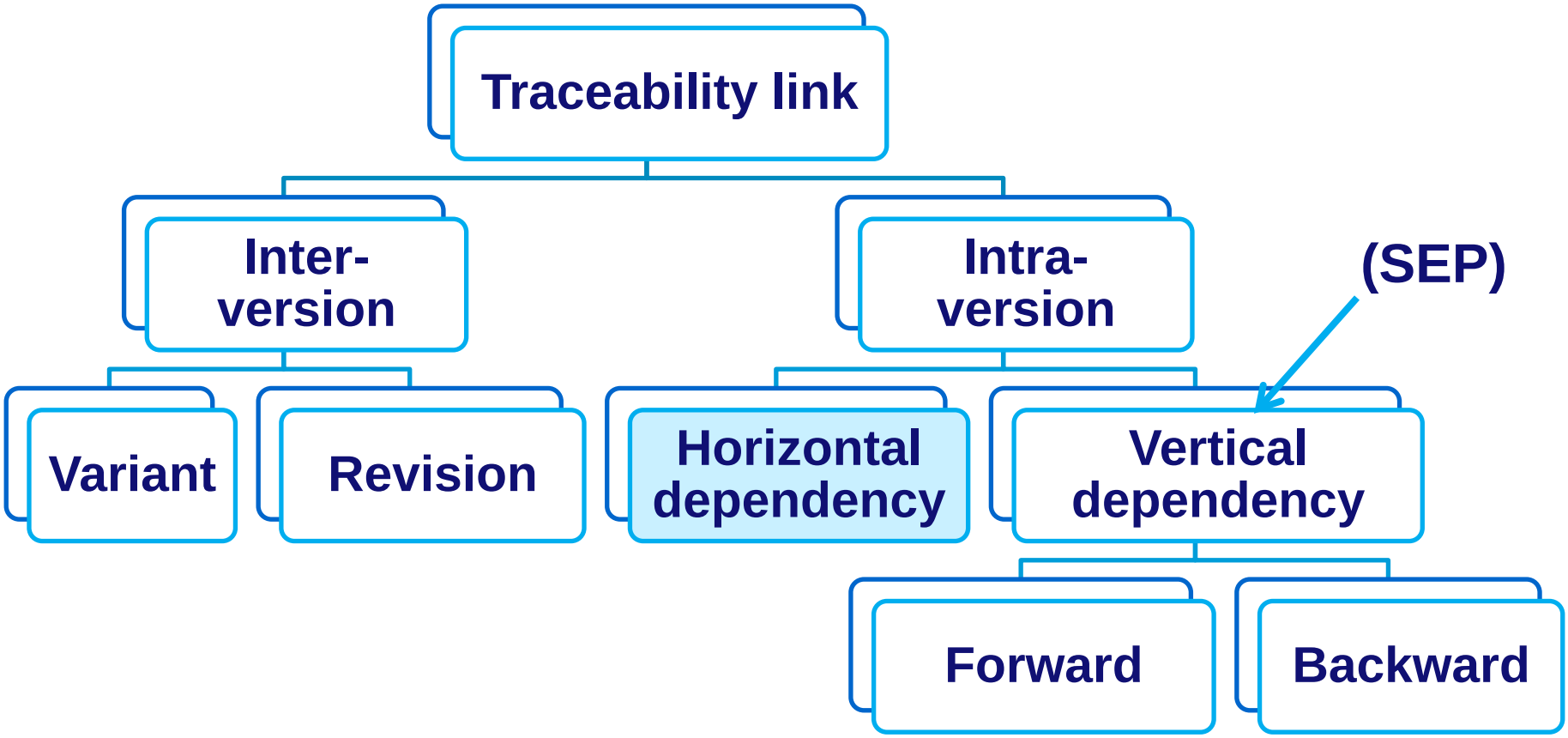
Next…

How good is requirements document v1?



Sommerville 1996

Co-evolution: Traceability links

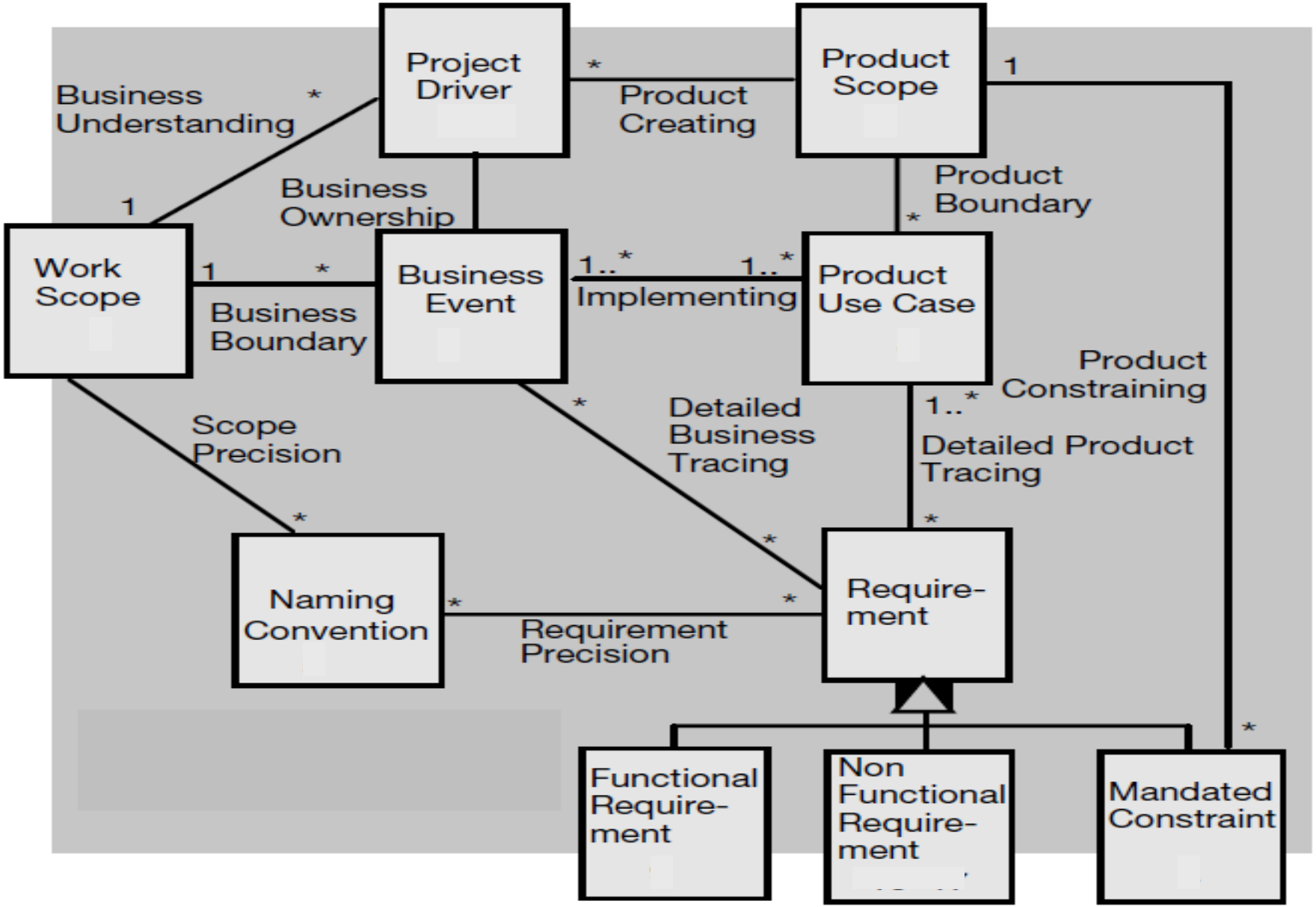


Why do we need traceability?

[Wiegers 2003]

- **(Co-)evolution**
  - **Change impact analysis**
  - **Maintenance**
  - **Reengineering**
- **Certification**
- **Project tracking**
- **Reuse**
- **Risk reduction**
- **Testing**

Backward dependencies [Robertson]



Traceability matrix

- **Means of expressing traceability information**

User req.	SW req.	Design Elem.	Func	Test Case
UC-28	SR-28, SR-15	Class catalog	sort	7, 8
UC-29	SR-44	Class catalog	import check	12, 13

Two popular techniques

User req.	Use Case		
	UC-1	UC-2	UC-3
UR-1	*		
UR-2	*		
UR-3		*	*
UR-4			*

What are their advantages and disadvantages?

We need tools!

- **Large amount of information:**
  - **requirements, components, traceability links**
  - **database technology!**

- **Many commercial/OS tools are available**
  - **OS requirements management tool: http://sourceforge.net/projects/osrmt/**
  - **http://requirements.tigris.org/**

- **You might like to try them!**

Conclusions

- Requirements often evolve due to environmental changes
- Suitability for evolution: quality, volatility, dependencies, inconsistency
- Evolution:
  - Continuous change and growth
  - System architecture is “almost” stable
- Co-evolution
  - Need for backward and forward traceability

Assignment 2

- **Organizational:**
  - **Is already open**
  - **Deadline: February 23, 23:59**
  - **Individual**
  - **Please submit in PDF**

- **Given a real-world set of requirements you'll assess their quality, study dependencies between them and discuss the implications of your findings on the requirements evolution.**