Requirements Engineering

A Methodology for Writing High Quality Requirement Specifications and for Evaluating Existing Ones

Software Assurance Technology Center

NASA Goddard Space Flight Center

http://satc.gsfc.nasa.gov

Dr. Linda Rosenberg

301-286-0087

Linda.Rosenberg@gsfc.nasa.gov

Overview

- Introduction
- Aspects of Requirement Development
- Writing Effective Requirements
  - Requirement Documents
  - Requirement Characteristics
  - Requirement Statements
- Levels of Requirements
- Requirement Management & Repository
- Quality, Traceability, & Linkage Metrics
- Conclusion

Introduction

I SAYS WHAT I MEANS
I MEANS WHAT I SAYS

Project Development - Problem

Generally accepted -

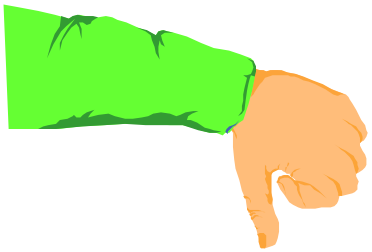
Requirements are basis for task,

verification and validation necessary

At project conclusion -

Some requirements not satisfied

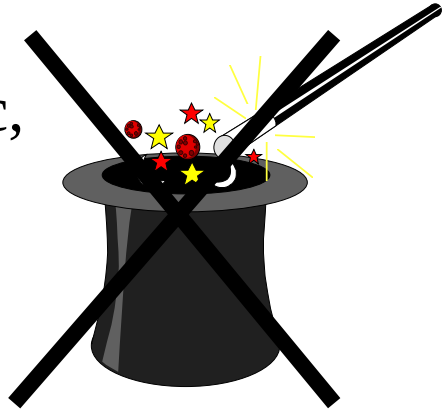
==> Redo project components or accept less than what was specified



Program Development - Solution

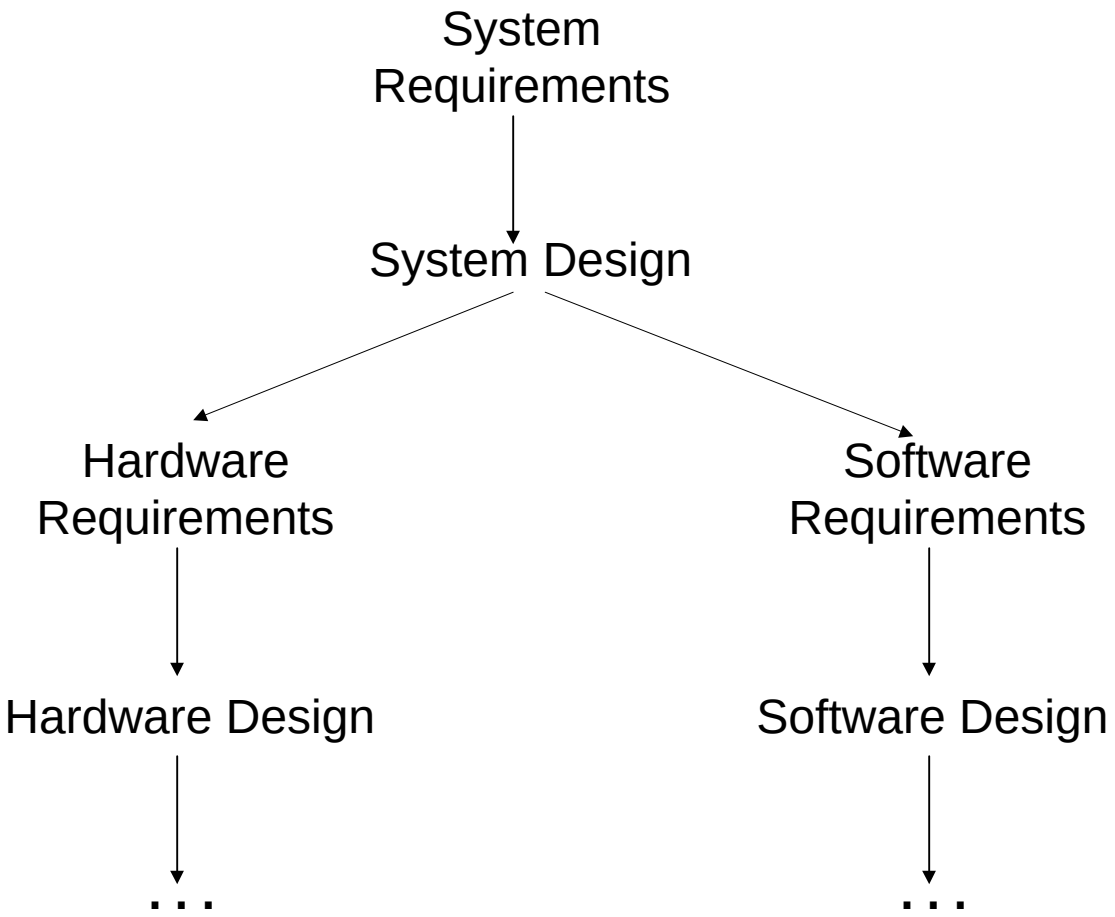
Start at the beginning, get the requirements right

However, cannot get requirements right by magic,
need tools and analysis techniques



==> Do it right the first time and start with the requirements!

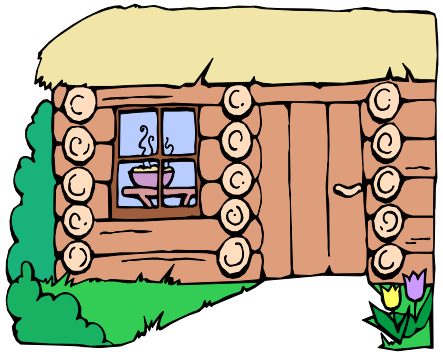
Requirement Development Paths



Requirements & Quality Management

Quality Management ==> Management of all aspects that concern quality assurance, quality assurance planning, and quality metrics, including verification and validation.

Verification - Determination whether the products fulfill the requirements established - “Are we building the system right?”



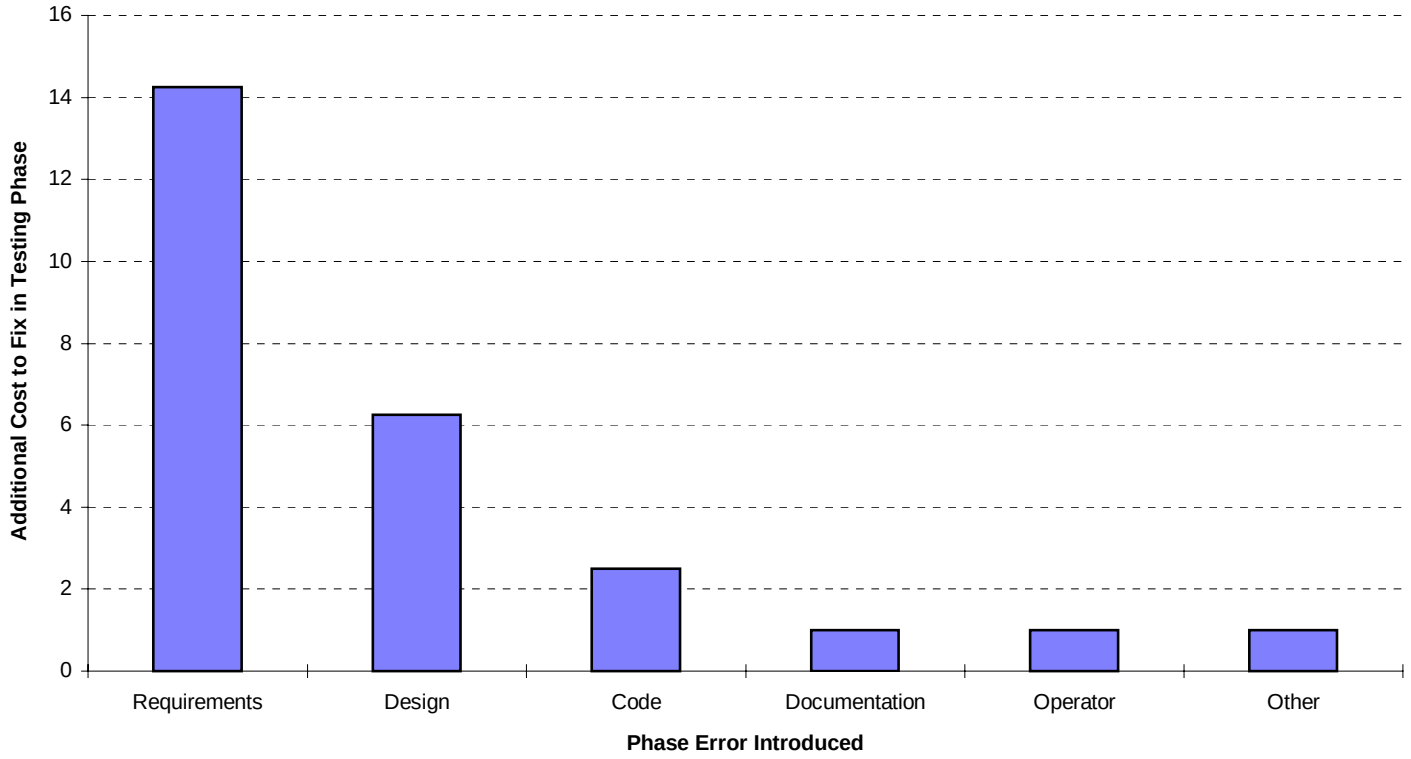
Validation - Determination of the correctness of the final product with respect to the user’s needs and requirements -
“Are we building the right system?”

Requirement Concerns

- Inability to write correct software requirement specifications (SRS)
- Desire to truncate and shorten requirement phase activities
- Lack of customer specification and verification of requirement correctness
- Identification of appropriate tools and methods for requirement specification
- lack of recognition of essentialness of requirement specification
- Lack of experience in writing requirement specifications

Error Detection Cost

Cost to Fix Errors Found
in Testing Phase



∴ Find errors as soon as possible for maximum savings !

Definition Of Terms

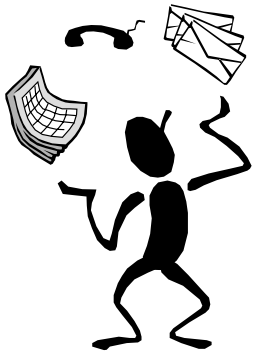
- "Requirements Specification" and "Specification Documents" are terms that refer to the document(s) or the total set of statements that define a mission required (system level) capability and its environments.

- "Requirement(s)" or "specification statement(s)" are terms that refer to individual statements or sets of individual statements, i.e. sentences, that define individual functions or aspects of a capability or an environment.

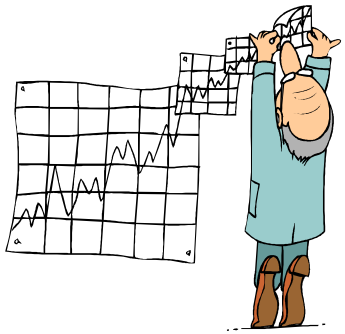
Aspects of Requirement Development

1 - Specification

2 - Verification



3 - Management



4 - Measurement

1 - Requirements Specification

Critical aspects in conveying information about system requirements:

Structure: The organization of the document to convey the appropriate level of detail

Language: The use of imperatives, directives, and the omission of options and ambiguity

2 - Requirement Verification

Issues critical to testing:

Stabilization:

- Is requirement volatility zero?
- Is requirement movement between builds stable?

Traceability:

- Do all requirements trace to higher and lower level documents?
- Are all requirements tested? Do they trace to a test?

Characterization to test program:

- What is the average number of requirements traced to each test?

3 - Requirements Management

Crucial management for successful delivery of a system:

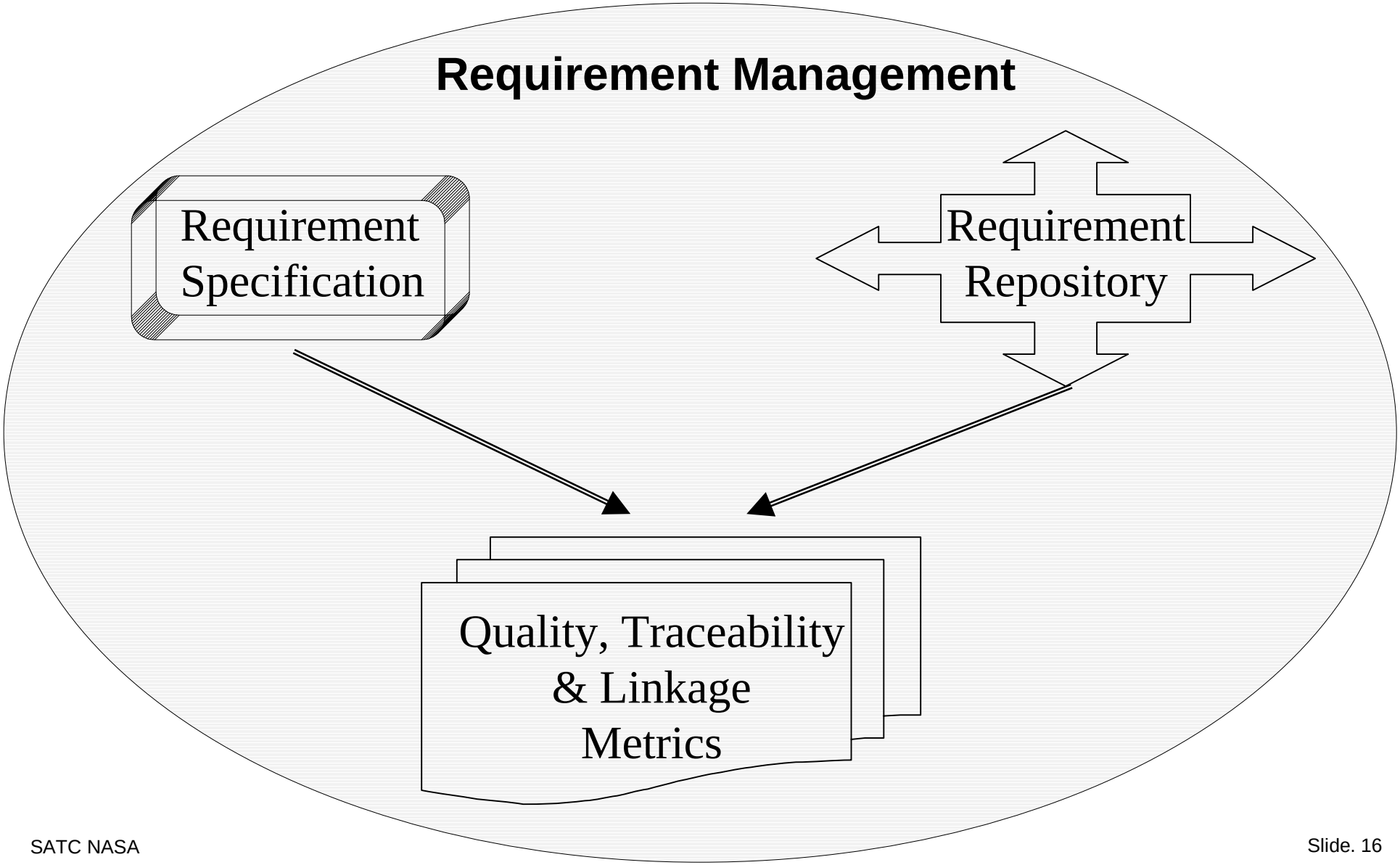
- Manage requirements through the life cycle.
- Use of requirement management tools to provide important insight to the requirements
- Extensive and comprehensive use of metrics to provide information so that management can take effective action.

4 - Requirement Measurement

What can be measured?

- Specification
  - Quality of statements for testability
- Verification
  - Stabilization
  - Trace to test
  - Trace to previous detail level
  - Expansion of requirements to test
- Management
  - Complexity of database links

Requirement Components



Writing Effective Requirements

SATC Requirement Analysis Findings

Problems Common To Most Documents

- → Documentation and style standards not used or misapplied
- → Poor organization of information content
- → Uneven emphasis and levels of detail
- → Inconsistent identification schemes
- → Verbose text
- → Poor sentence structure
- → Poor word selection

Formal Specification Language

Z (ZED)

ADD_Cnode

Δ HYP

cid? : CID

key? : KEY

result! : RESULT

$cid? \notin cused \quad \land$

$cused' = cused \cup \{ cid? \mapsto key? \}$

$result! = ok$

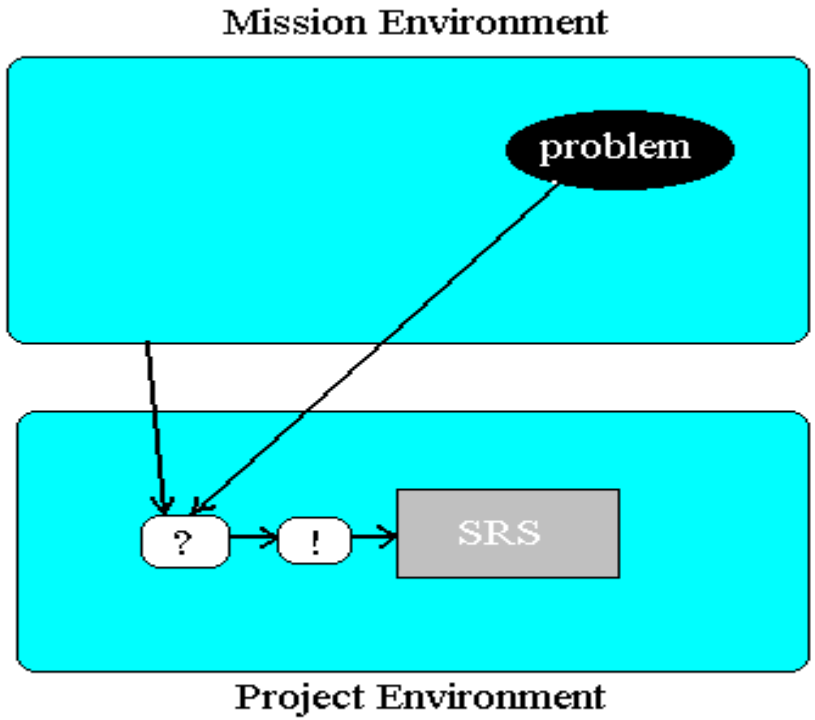
System/Software Requirements Specification (SRS) Objective

The objective of the SRS

is to

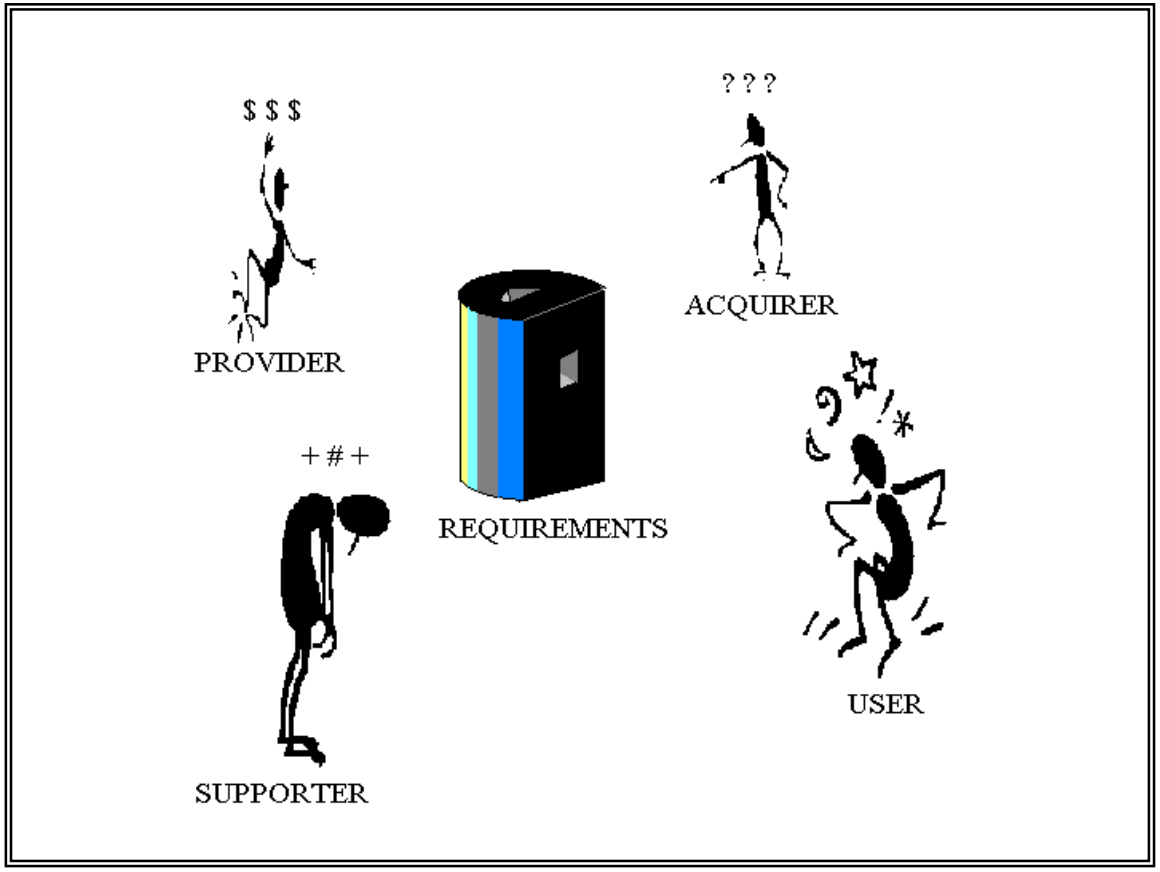
DEFINE CAPABILITIES

that will satisfy a mission need/problem as ….

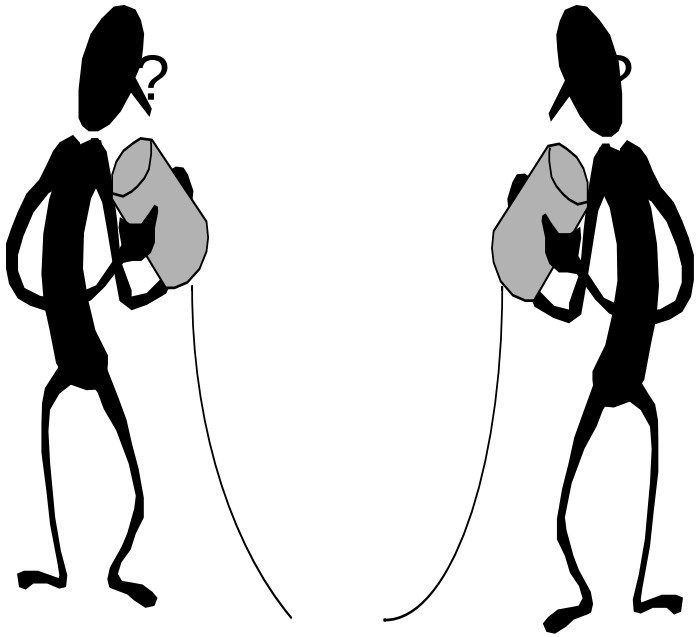


SRS Objective

…. seen by all project participants and stake holders.



Purpose Of SRS



..system shall..

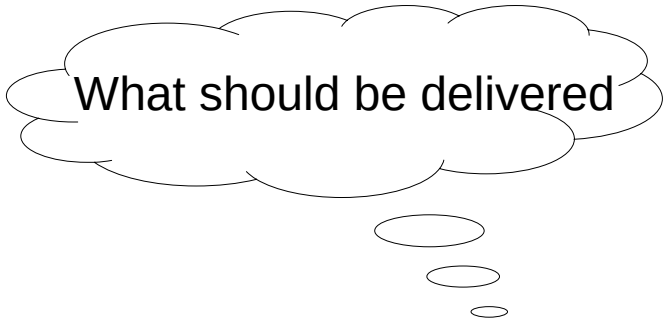
..Λ Ξ = Σ Δ..

- Contract Between Acquirer & Provider Of Capability
  - ◆ Defines what is to be provided
  - ◆ Establishes when and how things are to be provided
- Provides the Basis for:
  - ◆ Assessing proposed engineering changes
  - ◆ Resolution of acquirer/provider disputes
  - ◆ Development of test requirements
  - ◆ Preliminary user's manual
  - ◆ Maintenance & support planning

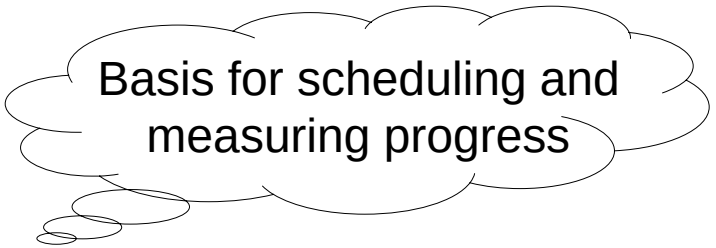
SRS Requirements

- Specify constraints on implementation
- Easy to change / maintain
- Serve as reference tool for maintenance
- Characterize acceptable responses to undesirable events

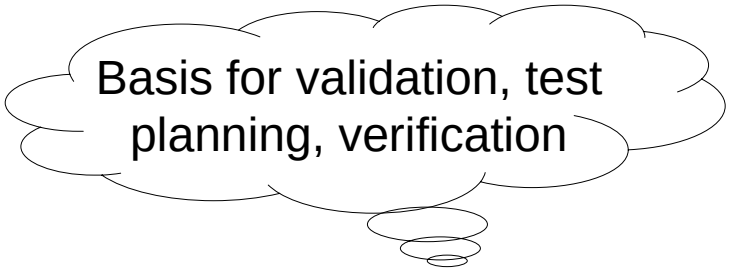
Roles in SRS



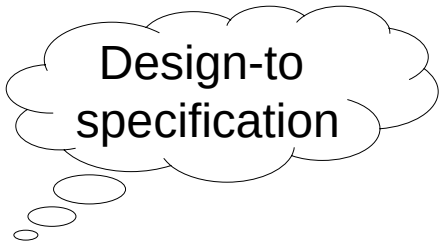
Customer



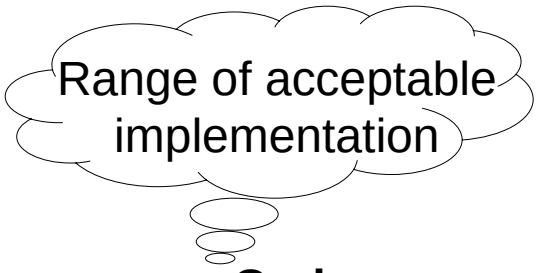
Manager



Quality Assurance



Designer



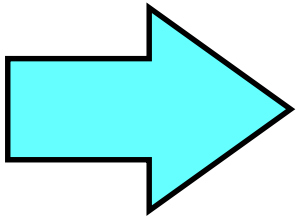
Coders

Scope Of SRS

Descriptive/Prescriptive/Expectation

Current Systems

Capabilities
Organizations
Personnel
Logistics
Maintenance



Future Systems

Capabilities
Organizations
Personnel
Logistics
Maintenance

Change Activities

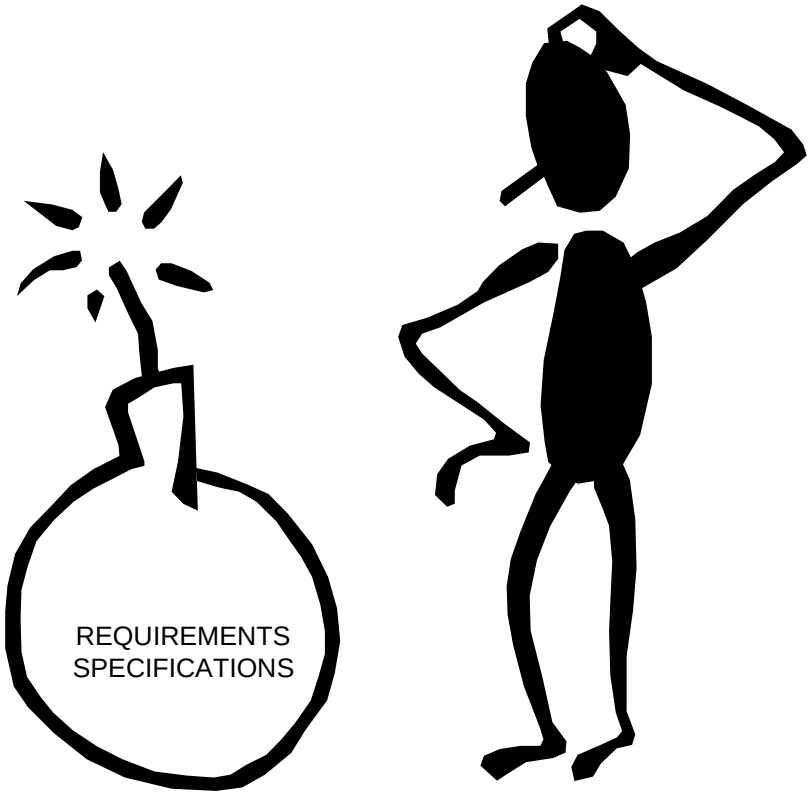
Acquisition
Installation
Transition
Retirement

Scope Of Detail

Required Capability Topics

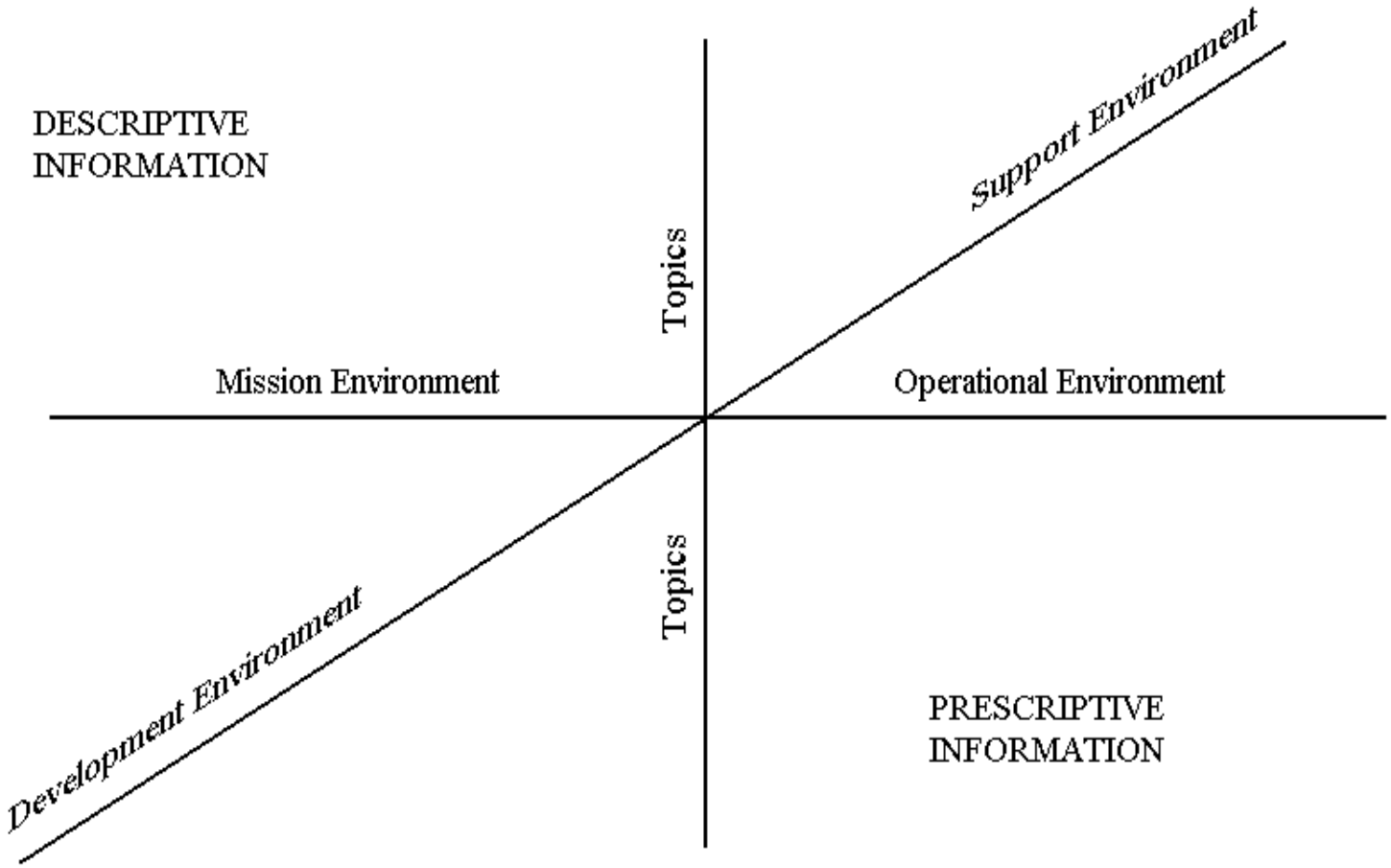
1. Interfaces
2. Functional Capabilities
3. Performance
4. Data Structures/Elements
5. Safety
6. Reliability
7. Security/Privacy
8. Quality
9. Constraints & Limitations

Basic Documentation Problems



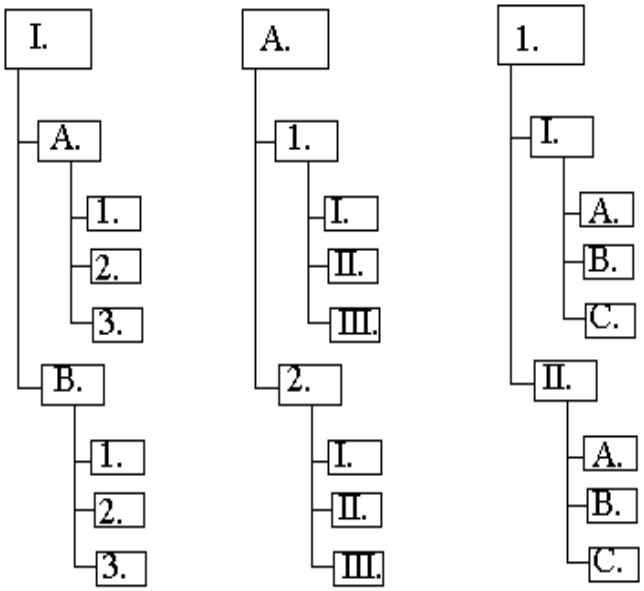
- Structural
  - Organization
  - Relationships
  - Detail
- Natural Language (English)
  - Ambiguity
  - Inaccuracy
  - Inconsistency

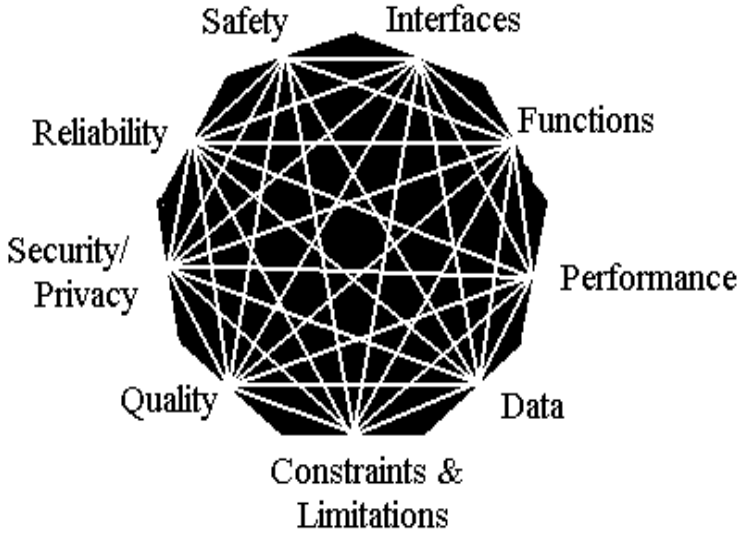
The Structural Dilemma



The Structural Dilemma

Content topics are not isolated subjects.
They have multiple and complex relationships.
This compounds the structural problem.





Documentation Standards And Data Item Descriptions (DIDs)

Documentation standards establish DIDs as generic design solutions for the problem of structuring information.

- A SRS DID is a high level, generic structure for organizing requirements specifications by predefined subjects.
- Generic design structures must be adapted/tailored to satisfy the needs of a particular project.
- Variations: IEEE, DoD, NASA

SRS DID - IEEE

REQUIREMENTS - IEEE DID-830-1993

1.0 Introduction
- 1.1 Purpose
- 1.2 Scope
- 1.3 Definitions, acronyms, and abbreviations
- 1.4 References
- 1.5 Overview

2.0 Overall description
- 2.1 Product perspective
- 2.2 Product functions
- 2.3 User characteristics
- 2.4 Constraints
- 2.5 Assumptions and dependencies

3.0 Specific requirements

Appendices

Index

SRS DID - DoD

SOFTWARE REQUIREMENT SPECIFICATION- DI-IPSC-81433

1. Scope
2. Reference Documents
3. Requirements
    - 3.1 Required states and modes
    - 3.2 CSCI capability requirements
    - 3.3 CSCI external interface requirements
    - 3.4 CSCI internal interface requirements
    - 3.5 CSCI internal data requirements
    - 3.6 Adaptation requirements
    - 3.7 Safety requirements
    - 3.8 Security & privacy requirements
    - 3.9 CSCI environment requirements
    - 3.10 Computer resource requirements
    - 3.11 Software quality factors
    - 3.12 Design and Implementation constraints
    - 3.13 Personnel-related requirements
    - 3.14 Training-related requirements
    - 3.15 Logistics-related requirements
    - 3.16 Other requirements
    - 3.17 Packaging requirements
    - 3.18 Precedence and criticality of requirements
4. Qualification Provisions
5. Requirements Traceability
6. Notes

A. Appendixes

CSCI = Computer software configuration item‘‘

SRS DID - NASA

REQUIREMENTS - NASA DID-P200

1.0	Introduction	
2.0	Related documentation	
3.0	Requirements approach and tradeoffs	
4.0	External interface requirements	
5.0	Requirements specification	
	5.1	Process and data requirements
	5.2	Performance and quality engineering requirements
	5.3	Safety requirements
	5.4	Security and privacy requirements
	5.5	Implementation constraints
	5.6	Site adaptation
	5.7	Design goals
6.0	Traceability to parent's design	
7.0	Partitioning for phased delivery	
8.0	Abbreviations and acronyms	
9.0	Glossary	
10.0	Notes	
11.0	Appendices	

Tailor SRS Design To Satisfy Project Needs

Arbitrary grouping of information makes the document difficult to understand and difficult to maintain.

- Group requirements that are part of a single function.
- Address functions with common inputs and outputs within the same area of the document.
- Address functions connected by output-to-input relationships in that order.
- Tie processes that must be accomplished in the same time frame together.
- Emphasize functional similarities, but ensure that the functional requirements are distinct.

Document Tailoring

Tailoring is adapting the design of the general purpose solution (the Data Item Description) to fit the unique needs of the current documentation problem.

- "Stub" sections that don't apply with "N/A" at highest node and provide or cite reason.
- Add new sections at end of appropriate level branch of the document's structure.
- Don't change the document's basic identification scheme established by the DID.

Tailoring Example

→ **3.8 Security & Privacy -** ***N/A, An open system with no classified or privacy data.***

3.9 Environmental Requirements ……

3.10 Computer Resources Required

3.10.1 Hardware…….type, quantity, etc.

3.10.2 Hardware Utilization ……CPU time, disk capacity, etc.

3.10.3 Software ……OS, DBMS, etc.

3.10.4 Communications ……Networks, Links, Nodes, etc.

→ ***3.10.5 Uninterruptable Power Sources ….. Motor/Generators***

→ 3.11 Software quality factors. ***TBD by 09/30/97, WM Wilson C300.1***

SRS Quality Attributes

A SRS should be:

1. Complete
2. Consistent
3. Correct
4. Modifiable
5. Concise
6. Testable
7. Traceable
8. Unambiguous
9. Understandable
10. Validatable
11. Verifiable
12. Independent
13. Annotated
14. Appropriate Abstraction Level

1 - Complete

A "**COMPLETE**" requirements specification must precisely define:

- **All** the known real world situations that will be encountered by the prescribed capability
- The capability's responses to those situations
- Full labels and references to all figures, tables and diagrams

A "**COMPLETE**" requirements specification must **NOT** include:

- Situations that **will not** be encountered
- Unnecessary capability features.

Incomplete Specification Statement

3.8 Security & Privacy - TBD

3.9 Environmental Requirements - TBD

3.10 Computer Resources Required

3.10.1 Hardware - Not yet selected

3.10.2 Hardware Utilization - TBD

3.10.3 Software ……OS, DBMS, etc.

3.10.4 Communications …Networks, Links, Nodes, etc.

3.11 Software quality factors. - TBD

2 - Consistent

- A "**CONSISTENT"** requirements specification is one where:

- There is no conflict between:
  - Individual statements of required capabilities
  - Individually specified capabilities' behavioral properties
- Constraints do not adversely impact essential behavioral properties.

! Functions and performance levels must be compatible and required quality features (reliability, safety, security, etc..) must not negate the capability's utility.

An Inconsistent Specification

"3.7 Safety Requirements"

. . . .

"3.7.4. 1 In the event of a liquid nitrogen (LN) spill, a 30 dB audible alarm shall be activated and continued until launch tower LN sensors return to a null reading."

. . . . .

"3.13 Personnel Related Requirements"

. . . .

"3.13. 7 Personnel in the area of the launch tower during tanking operations shall wear hearing protective devices that provide a minimum of 35 dB audio attenuation."

3 - Correct

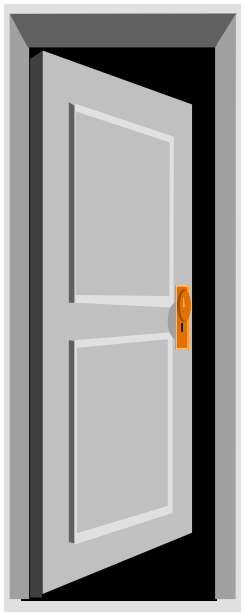
A "**CORRECT**" requirements specification must:

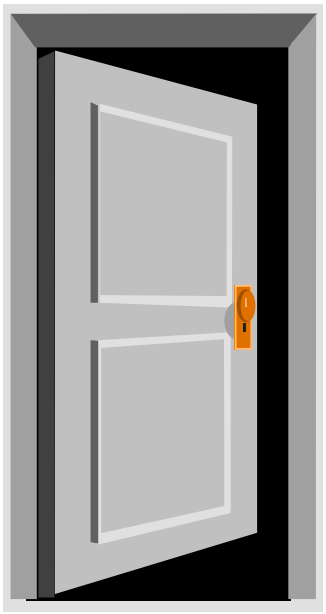
- Accurately and precisely identify the individual conditions and limitations of situations that the desired capability will encounter
- Define the capability's proper response to those situations that will be encountered

Incorrect Specification Statement

3.5.1 The building's entrance shall be a standard 6.8' by 2' 6" doorway.

Should be 3' 8"





4 - Modifiable

A "**MODIFIABLE"** requirements specifications is such that changes can be made easily, completely, and consistently.

- Groups related concerns together
- Separates unrelated concerns
- No redundancy
- Express each requirement separately

! This attribute is exhibited by a logical organization of specifications based on their relationships.

Group Related Concerns, Separate Unrelated Concerns

3.1 The CCS shall ingest and store spacecraft engineering data, both recorded and real-time ….

3.1.1 The CCS shall be able to ingest and store engineering data from new ORU/ORIs.

3.1.2 The CCS shall be able to store converted engineering data received through the common test device interface.

3.1.3 The CCS shall be able to ingest and store onboard computer memory dump data for the life of the mission.

3.1.4 The CCS shall be able to store converted engineering data received from a simulation facility.

3.1 The CCS shall ingest and store spacecraft engineering data, both recorded and real-time ….

3.1.1 The CCS shall be able to ingest and store engineering data from new ORU/ORIs.

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3.1.3 The CCS shall be able to store converted engineering data received from a simulation facility.

3.2 The CCS shall be able to ingest and store onboard computer memory dump data for the life of the mission.

5 - Concise

A **“CONCISE”** requirement specification is a short as possible without adversely affecting any other quality of the SRS.

! Major reductions in SRS size are rarely possible without adversely effecting other qualities.

Baroque Writing

3.1 The check printing function of the payroll system shall provide the capability to validate check amounts.

==> 3.1 The payroll system shall validate check amounts.

Concise and Understandable

6 - Testable

A "**TESTABLE"** requirements specification must state each requirement in such as manner that pass/fail or quantitative assessment criteria can be derived from the specification itself and/or referenced information.

- There must exist a finite cost effective technique to verify each requirement is satisfied by the system.

! If you can't test it, why request it?

Be Specific

3.1 The system shall be user friendly and fast.

Specification is nonspecific due to the use of vague words.
Its implementation cannot be objectively assessed based on the specification.

3.1.1 The system's functions shall be activated and terminated by menu selections.

3.1.1.1 Functions shall be initiated within 500 μ sec. after their selection.

The requirements are specific.
The implementation can be directly tested against the specification.

Cost to Test

8.1.6 In the case of a reactor melt-down, the system shall reduce the deaths of personnel within a 20 mile radius by at least 80%.

Cannot test, not worth the cost.

7 - Traceable

A "**TRACEABLE"** requirement specification uniquely identifies each stated requirement.

- Backward traceability to previous stages of development by explicit reference source in earlier documents
- Forward traceability to all documents spawned by SRS with each requirement having a unique name or reference number.

! Number each requirement hierarchically

! Include only one requirement per paragraph

! Use a convention for individual requirements such as "shall"

Uniquely Identify Each Requirement For Traceability

A Gaggle Of Requirements

"The XYZ system shall provide variance/comparative information that is timely, itemized in sufficient detail so that important individual variances are not hidden because they cancel each other, pinpoints the source of each variance, and indicates the area of investigation that will maximize overall benefits."

Better But Not Good (vague words)

5.1 The XYZ system shall provide variance/comparative information.

5.1.1 Variance/comparative information shall be ***timely***.

5.1.2 Variance/comparative information shall be itemized in ***sufficient*** detail to:

5.1.2.1 Prevent ***important*** individual variances from being hidden.

5.1.2.2 Pinpoints the source of each variance.

5.1.2.3 Indicate the area of investigation that will ***maximize overall*** benefits.

8 - Unambiguous

An "**UNAMBIGUOUS"** requirement statement can only be interpreted one way.

- Natural language is inherently ambiguous. Review by an independent party to identify ambiguities.
- Alternative - requirement specification languages but have long learning curves and few understand.

Say What You Really Mean!

WHAT WAS WRITTEN:

"The system shall ignore anomalies 20 seconds prior to engine shut down."

WHAT WAS IMPLEMENTED:

"The system shall clear all anomaly indicators 20 seconds prior to engine shut down."

WHAT WAS MEANT:

"The system shall ignore any anomaly occurring during the 20 second period immediately prior to engine shut down."

9 - Understandable

An "**UNDERSTANDABLE"** specification's meaning is easily grasped by all of its intended readers with minimum explanation.

- English is the 'common denominator' that is understood by all project participants. Words must be selected with care and the language must be used properly in order for a specification's intent to be correctly comprehended.
- The larger and more complex the problem addressed by the requirements specification, the more difficult is the task to design a document that aids rather than inhibits understanding.

Words And Structure Facilitate Understanding

"Users attempting to access the ABC database shall be reminded by a system message that must be acknowledged and page headings on all reports that the data is sensitive and access is limited by their system privileges."

3.1 *Users attempting to access the ABC database shall be reminded by a system message that data is sensitive and access is limited by their system privileges.*

3.1.1 The system data classification message must be acknowledged by the user before access to the ABC database is permitted."

3.2 *Page headings on all reports shall remind users that the data in the report is sensitive and cannot be distributed to unauthorized individuals.*

10 - Validatable

A "**VALID"** requirements specification is substantiated as being true as stated by each individual and organization having a vested interest in the system solution.

! To validate a requirements specification all the project participants, managers, engineers and customer representatives, must be able to understand, analyze and accept or approve it.

Valid & Invalid Requirements

Operational requirements for the Boeing 747-200B/VC-25A, USAF tail number 29000.

3.3 In the event of an inflight emergency, the aircraft shall land at the nearest US military, NATO or commercial airfield.

3.4 In the event of a national emergency, the aircraft shall ***effect inflight transfer of NCA personnel to the Airborne Command Post.***

11 - Verifiable

A "**VERIFIABLE"** requirement specification is consistent with specifications at higher and lower levels of abstraction.

"Verify: to prove to be true or correct by comparison to a standard or reference to ascertainable facts."

! Ambiguous specifications are not verifiable.

Can You Verify?

- The system shall have a good human interface.
- The program shall never enter an infinite loop.

Output of the program shall be produced within 20s of the event x 60% of the time and shall be produced within 30s of the event x 100% of the the time.

12 - Independent

An **“INDEPENDENT”** specification specifies what is to be accomplished, not how it is done.

! There should be more than one system design and implementation that correctly implements the requirements.

Freedom of Choice !

The requirement database shall store the requirements using a numerical hierarchical numbering schema such as 1, 1.1, 1.1.1 …

The requirement database shall store the requirements in such a manner that an exact count of the number of requirements can be electronically extracted.

13 - Annotated

“ANNOTATED” specifications are easily understood as to the importance (ranked), relative stability, and/or version.

- Accomplished by adding appropriate suffix
- Should be done on all or none of the requirements, not partially completed

Sample Annotations

Importance - *For budgeting or inclusion*

Mandatory	(M)
Desirable	(D)
Optional	(O)

Essential	(E)
Conditional	(C)
Optional	(O)

Stability - *Where to build in flexibility* - *Probability to change*

High	(H)
Medium	(M)
Low	(L)

Version - In database, column for each version, X in column if in version

Priority Ranking
By Order Of Appearance

3.1.4 The XYZ system shall generate reports showing detailed and summary information about the maintenance schedule for:

a. Routine maintenance schedules

b. Non-routine maintenance schedules

c. Upgrade maintenance schedule

Implication may be incorrect, add:

3.1.4.1 Implementation, and operational priority for the schedule reports is in order stated above.

14 - Appropriate Abstraction Level

"**ABSTRACTION LEVEL**" is dependent on the function of the SRS.

It should be specific enough that any system built that satisfies the requirements satisfies all user needs, and abstract enough that all systems that satisfy all user needs also satisfy all requirements

Levels of Abstraction

1 System shall provide communications.

1.1 System shall provide voice communication.

1.1.1 Telephone system shall provide voice communication

1.1.1.1 Telephone system shall provide local calls, long distance calls, call forward …

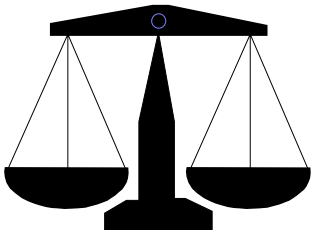
1.1.1.1.1 Telephone shall provide local calls where user hears dial tone within 3 seconds of lifting receiver ...

Not in SRS

- x Cost
- x Delivery Schedule
- x Report Procedures
- x Software Development Methods
- x Quality Assurance
- x Validation and Verification Criteria
- x Acceptance Procedures

Requirement vs. Design Implementation

Needs vs. Implementation



Dangers:

Forcing a design when not intended

Believing all requirements are covered when not

Needs vs. Implementation

Requirement: *"The contractor shall provide a database for requirement management."*

What was meant:

Provide the capability for tracing between requirements.

Provide the ability to add requirement attributes.

Provide the ability to sort requirements.

Problem - May need a requirement management tool, not a database as specified.

Requirement vs. Design Implementation

Solution -

State what is needed not how it is to provided.

Ask **WHY** the requirement is needed.

If this does not lead to “real” requirement, then probably appropriate as stated.

Requirement Characteristics

1 - Type - Identifies the source an contractual applicability

2 - Application - Identifies the object of a requirements

3 - Categorization - Identifies purpose of requirement

4 - Compliance Level - Identifies the depth of compliance mandated for a requirement

5 - Priority - Identifies the relative importance of a requirement in terms of implementation or sequence of testing

1 - Type

Primary - Usually a requirement levied on a contractor / producer under force of contract

"The payload shall be transported into orbit in the payload bay."

Derived - Requirements that are generated apart from the primary requirements; if not primary than is derived.

"The payload shall have a diameter of less than 14 feet."

2 - Application

Product parameter - Requirement that applies the product or service to be developed

"The external surfaces of all equipment shall be white."

- Qualitative - Contains no measurable requirement

  "The mixer shall produce a mixture of homogeneous appearance."

- Quantitative - Measurable requirement

  "The mixer shall produce a mixture of x granularity in five minutes."

2 - Application (cont.)

Program parameter - Requirement that applies to the activities associated with enabling the creation of a product or service.

"The contractor shall develop a concept of operations."

- Task - Identifies an analysis or other effort to be performed

  "Prepare a systems management plan."

- Compliance evaluation - Identifies the methodology for measuring compliance

  "NASA DID P200 shall be used for requirement specification."

- Regulatory - Identifies administrative elements

  "Deliverable data shall be furnished with unlimited rights to the government."

3 - Categorization

Functional - describes system service or function

Non-function - constraint placed on system or development process (response time or language standard)

3 - Categorization (cont.)

Input	*receive EDI data*
Output	*export a particular format*
Reliability	*mean time to failure*
Availability	*expected hours of operation*
Maintainability	*ease with which components can be replaced*
Performance	*response time*
Environmental	*dust levels that must be maintained*
Ergonomic	*colors to minimize eye strain*
Safety	*limits for radiation*
Standards	*conform to ASME codes*

3 - Categorization (cont.)

Security	*authorization of users*
Facility	*temperature requirements*
Transportability	*weight limits*
Training	*number and length of tutorials*
Documentation	*on-line help*
External interfaces	*industry standard communication*
Testing	*remote diagnostics*
Quality provisions	*calibration intervals*
Conversion	*accept data from older system versions*
Growth	*will support an additional number of users*
Installation	*ability to put new system into use*

4 - Compliance Level

Mandatory - Typically contains *"shall"* - mandates conformance

Guidance - Typically a *"will"* statement - accomplishment is desired/preferred

Information - Supporting or giving insight into a measurable requirement; non-binding

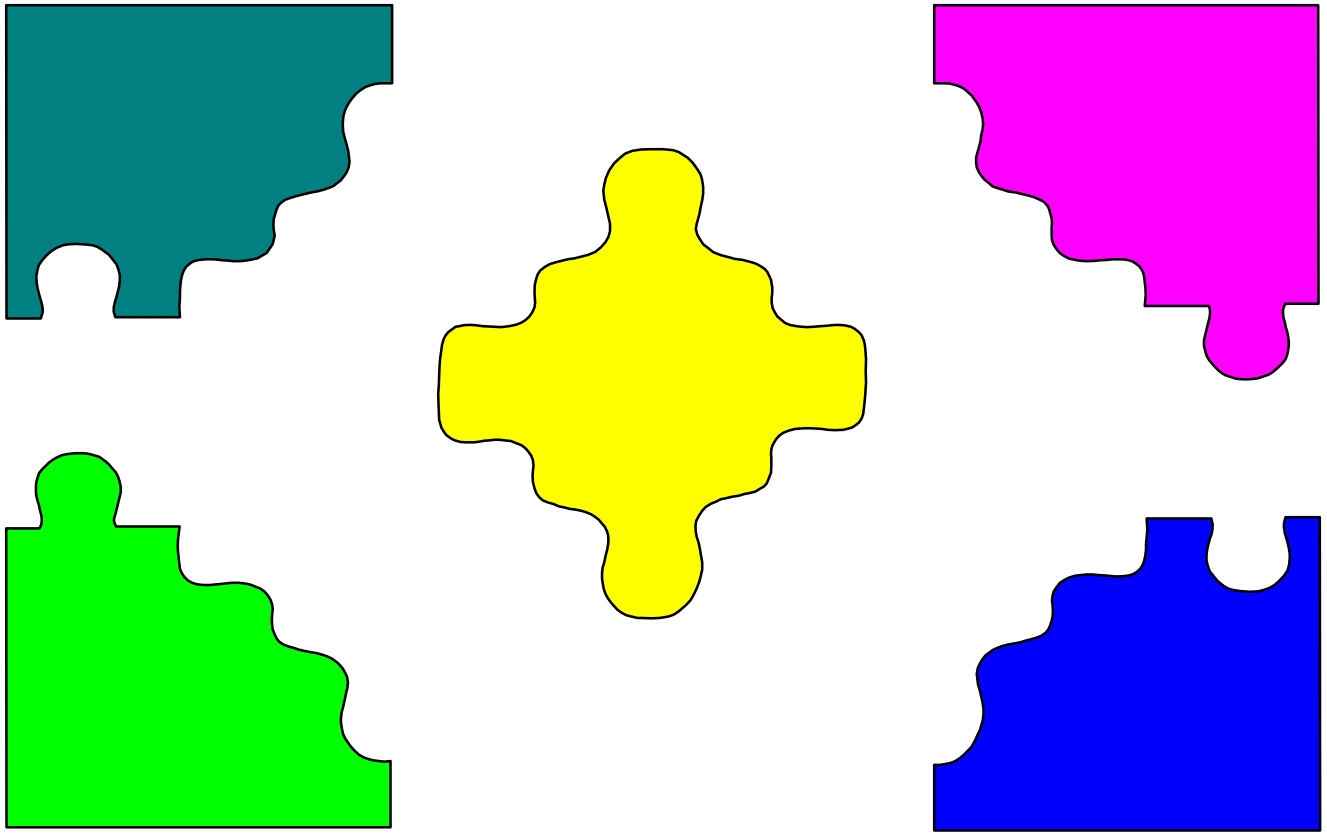
5 - Priority

Values of priority will be dependent on program and company needs

High / Medium / Low

Catastrophic / Critical / Marginal / Negligible

Requirement Specification Statements



Formulating Requirements Specification Statements

1. Perspective And Selection of Imperatives
2. Sentence Structure
3. Words and Phrases To Avoid
4. Use Of Examples And References
5. Use Of Tables And Charts

Specification Statement Elements And Their Use

ELEMENTS of a specification are:

1. Entity
2. Action
3. Event
4. Condition
5. Target
6. Object
7. Constraint
8. Localization

Specification Statement Structure

Specification Structure:

[Localization] [Actor] [Action] [Target] [Constraint]

Example:

7.1 When three or more star trackers lose reference stars, the spacecraft shall immediately align its main axis on the Earth-Sun line unless the optical instrument's cover is open.

Localization: "When three or more star trackers lose reference stars"

Actor: "spacecraft"

Action: "align"

Target: "main axis"

Constraint: "unless the optical instrument's cover is open"

Perspective And Selection of Imperatives

Imperatives are those words and phrases that command that something must be provided.

Shall is usually used to dictate the provision of a functional capability.

Must*/*must not is used to establish performance requirements or constraints.

Are applicable is used to include, by reference, standards or other documentation as an addition to the requirements being specified.

Responsible for is used in requirements documents that are written for systems whose architectures are predefined.

Will is used to cite things that the operational or development environment are to provide to the capability being specified.

Is required to passive voice, ***Should*** is advisory. Neither should be used in requirement specification statements.

Words And Phrases To Avoid

1. Weak Phrases
2. Options
3. Generalities

Weak Phrases

Weak Phrases are clauses that are apt to cause uncertainty and leave room for multiple interpretations.

Phrases such as *"adequate"*, *"as appropriate"* and *"timely"* indicate that what is required is either defined elsewhere or, worse, that the requirement is open to subjective interpretation.

Phrases such as *"but not limited to"*, *"as a minimum"*, and *"TBD"* provide a basis for expanding a requirement or adding future requirements.

Options

Options are words such as "*may*" and "*optionally*", that give the developer latitude in satisfying the specification statements that contain them.

! Options loosen the specification,

! Reduces the acquirer's control over the final product, and

! Establishes a basis for possible cost and schedule risks.

Generalities

Generalities provide gross quantitative or qualitative descriptors that indicate direction of intent but no useful information.

"About"

"Almost"

"Bad"

"Close"

"Good"

"Many"

"Most"

"Timely"

Selection Of Words And Phrases

Use the most simple word appropriate to the intent.

Hide "is to put out of sight"
Obscure "is lacking light or dim"

Circumference "is the line bounding a circular area"
Perimeter "is a line bounding an area of any shape"
Periphery "is the boundary of a solid object"

Using Examples

- Immediately follow what is to be illustrated with the example.

  Attention spans are short and shrinking!

- Repeat an example if it is not located on the same page as its second or later use.

  It's better to be repetitive than to divert the reader's attention!

- Ensure that the example is not mistaken for part of the specification through the use of italics, quotes, or being explicit.

  For example: "This is an example."

References

- Identify all external documents in the SRS section designated for that purpose. For DI-IPSC-81433 and NASA DID-P200, this is Section 2.
- Identify each reference cited with a unique number or identifier, such as “2.14.”
- Cite references by short or common title, full title, version or release designator, date, publisher or source, and document number or other unique document identifier. For example:

  “2.14 NASA Software Management, Assurance, and Engineering Policy, NMI 2410.10, March 26, 1991.”
- Use the unique citation identifier when referencing information in that document. For example: “. . . as defined by Section 3.1 of reference document 2.14, NMI 2410.10.”

Tables And Charts

- Title and identify each table and chart with a unique identifier.
- List each table and chart in the SRS's table of contents by title, unique identifier, and page number.

  Help the reader find it!
- Identify the purpose of the table or chart in the text immediately preceding it.

  No surprises!
- Explain each aspect or element of the table or chart (columns, rows, symbols, blanks, etc.) from right to left then top to bottom.

  No puzzles!

Explain The Chart

3.4.5 Each software module shall be assigned to one of the criticality categories identified by the first column of Table 3-2. The second column identifies the criticality criteria for each category. The third column establishes the level of failure tolerance that shall be provided by each module assigned to each category. Column four establishes the minimum redundancy level requirement for each module assigned to each category.

CRITICALITY CATEGORY	FUNCTIONAL CRITICALITY	FAILURE TOLERANCE	FUNCTIONAL REDUNDANCY
1	Crew safety	2 failures	3 minimum
2	Critical mission support	1 failure	2 minimum
3	Noncritical functions	0 failures	1 minimum

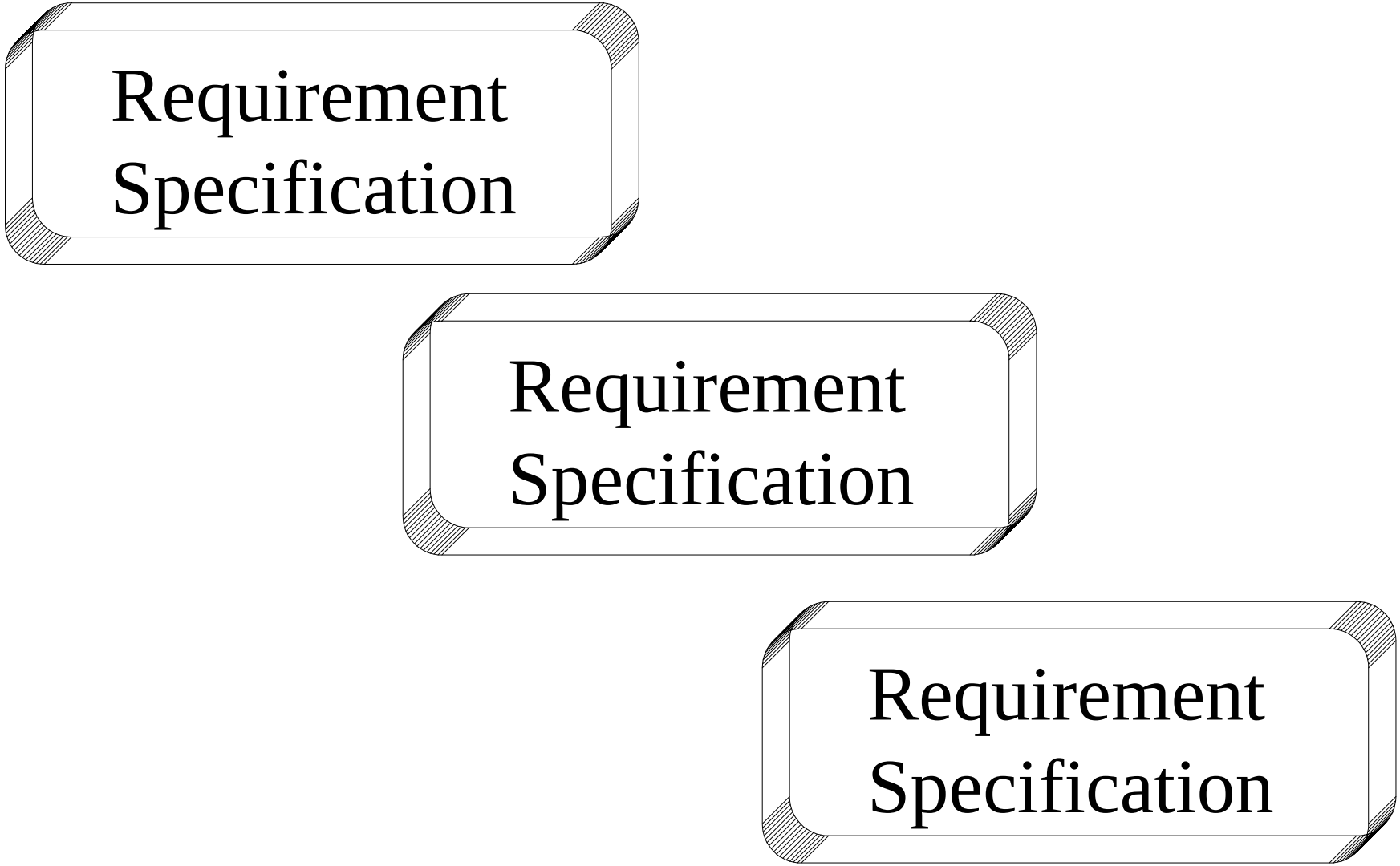
Table 3-2. Functional Redundancy Levels

SRS Summary

The SRS is an item of software. Ensure that:

- Projects requirements for SRS document are defined.
- SRS structure is tailored to satisfy its requirements.
- The document and individual specifications exhibit all desirable documentation quality characteristics.
- All topics are addressed in the SRS.
- Individual specifications:
  - Are logically structured and simply stated.
  - Stated with the imperative, words and phrases that are appropriate to the intended meaning.

Levels of Requirement Specifications



2 - Level Requirements

Level 1 - Requirement Definition

High level abstract description in natural language of what services system is expected to provide, constraints under which it must operate. Use customer provided information.

Level 2 - Requirement Specification

Detailed description of what system must do. Sets out system services in detail; precise. May serve as contract between system buyer and software developer

Example - 2 Level

Requirement Definition:

1. The software must provide a means of representing and accessing external files crated by other tools.

Requirement Specification:

1.1 The user must be provided with facilities to define the type of external files

1.2 Each external file type must have an associated tool which may be applied to the file

1.3 Each external file type must be represented as a specific icon on the user's display.

. . .

NASA's Levels of Requirement Detail

Level 1: Mission-level
Very high level
Rarely, if ever, change.

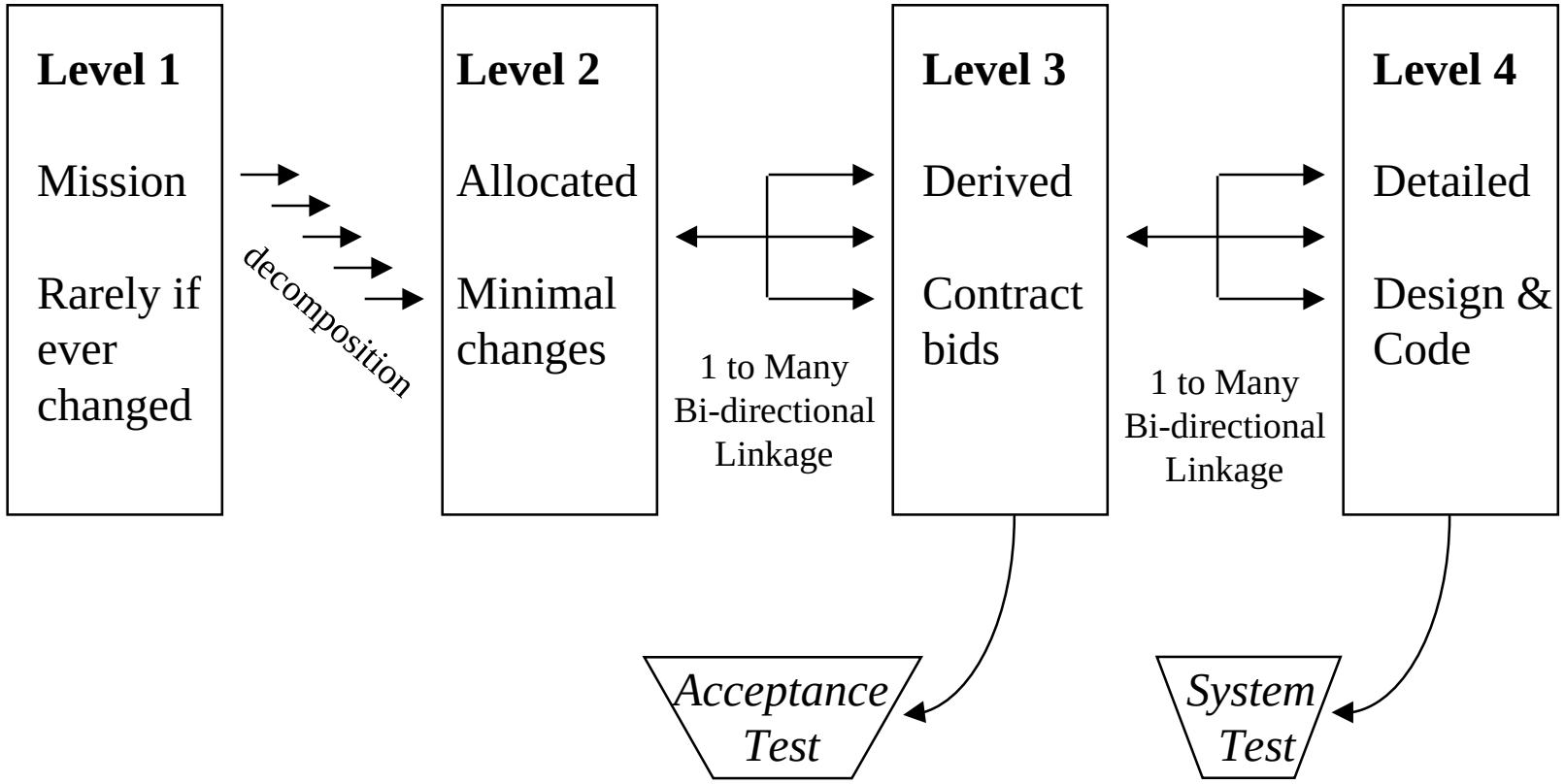
Level 2 : Allocated
Change should be minimal.
Project's development started

Level 3 : Derived
Contracts are bid
Acceptance Tests

Level 4 : Detailed
Used to design and code the system.
System Tests

NASA, *Software Assurance Guidebook*, NASA Goddard Space Flight Center Office of Safety, Reliability, Maintainability, and Quality Assurance, 9/89.

Levels of Requirement Detail



Verification Of Specifications Across Documents

CONCEPT DOCUMENT

3.1.1 Solar power shall be the main source of all subsystems electricity.

3.1.2 When the sun is eclipsed, electricity shall be provided by batteries.

SYSTEM REQUIREMENTS DOCUMENT

3.1.2.3 Combined weight of primary and secondary batteries shall not exceed 500 pounds.

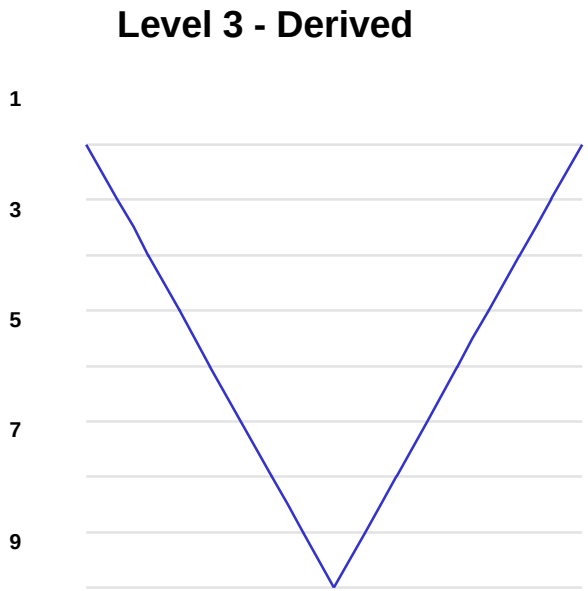
3.1.2.4 Secondary S/C batteries shall be charged in parallel with powered subsystems during S/C daylight.

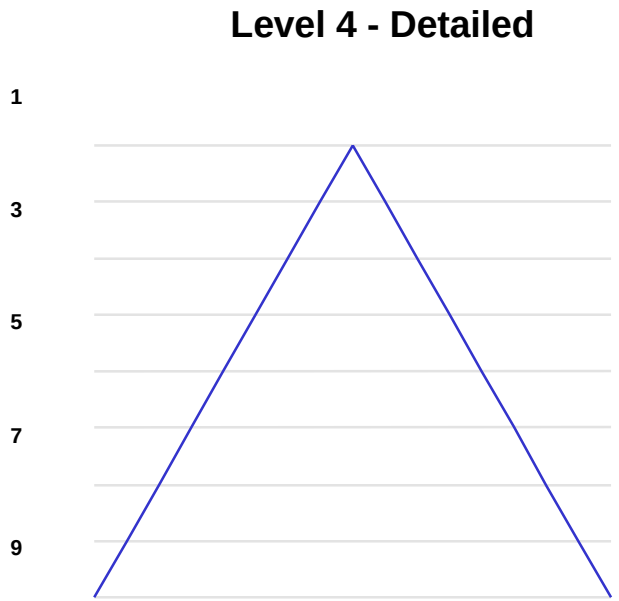
DESIGN DOCUMENT

3.1.2.3.1 Sodium sulfur (NaS) batteries shall be used as the S/C's secondary batteries.

Structure Level at Which Requirement Occurs

Expected





High Level Detail

Lower Levels of Detail

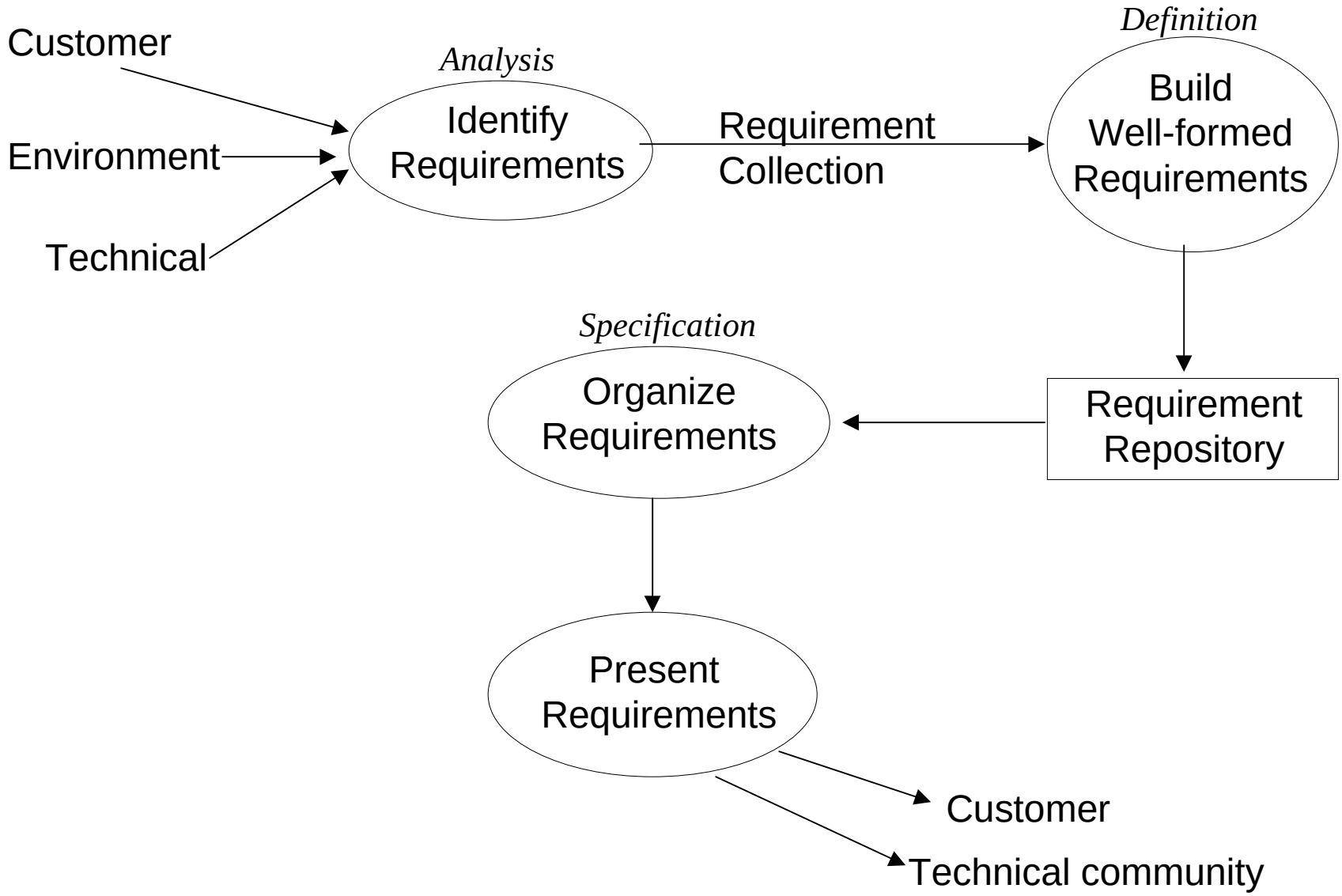
Level ==>
1
1.1
1.1.1 ...

Requirement Management

Requirement Management Process

- The process is goal directed and aimed at the production of a set of requirements
- The system boundaries are defined
- All requirements are solicited, fairly evaluated, and documented
- Requirements are specified as capabilities and that qualifying conditions and bounding constraints are identified distinctly from capabilities
- Requirements are validated, or purged if invalid, from the requirement set
- Consideration is given to consistency when many authors
- The developing set is understood, at the appropriate level of detail, by all individuals

Development Process



Development Activities

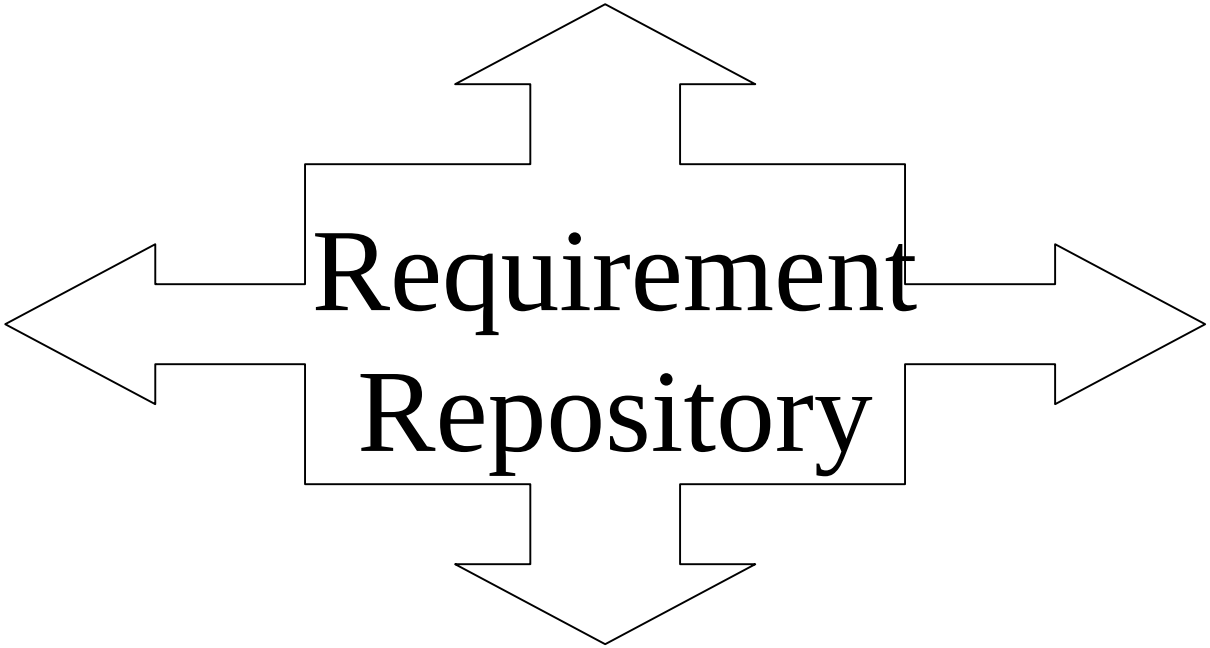
Analysis - Derive system requirement prototypes if necessary

Definition - Translate requirement information into well formed statements to accurately reflect what customer wants. Written so end user and customer can understand.

Specification - Detailed and precise description of system requirements to act as basis for contract between customer and developer

Important Concepts

- Use a requirement management tool or database as a repository to store requirements
- Design the structure of the repository carefully to fit the data not the management structure
- Consider the metrics to be collected in the design of the repository
- Start the metrics program with the initial requirement specification

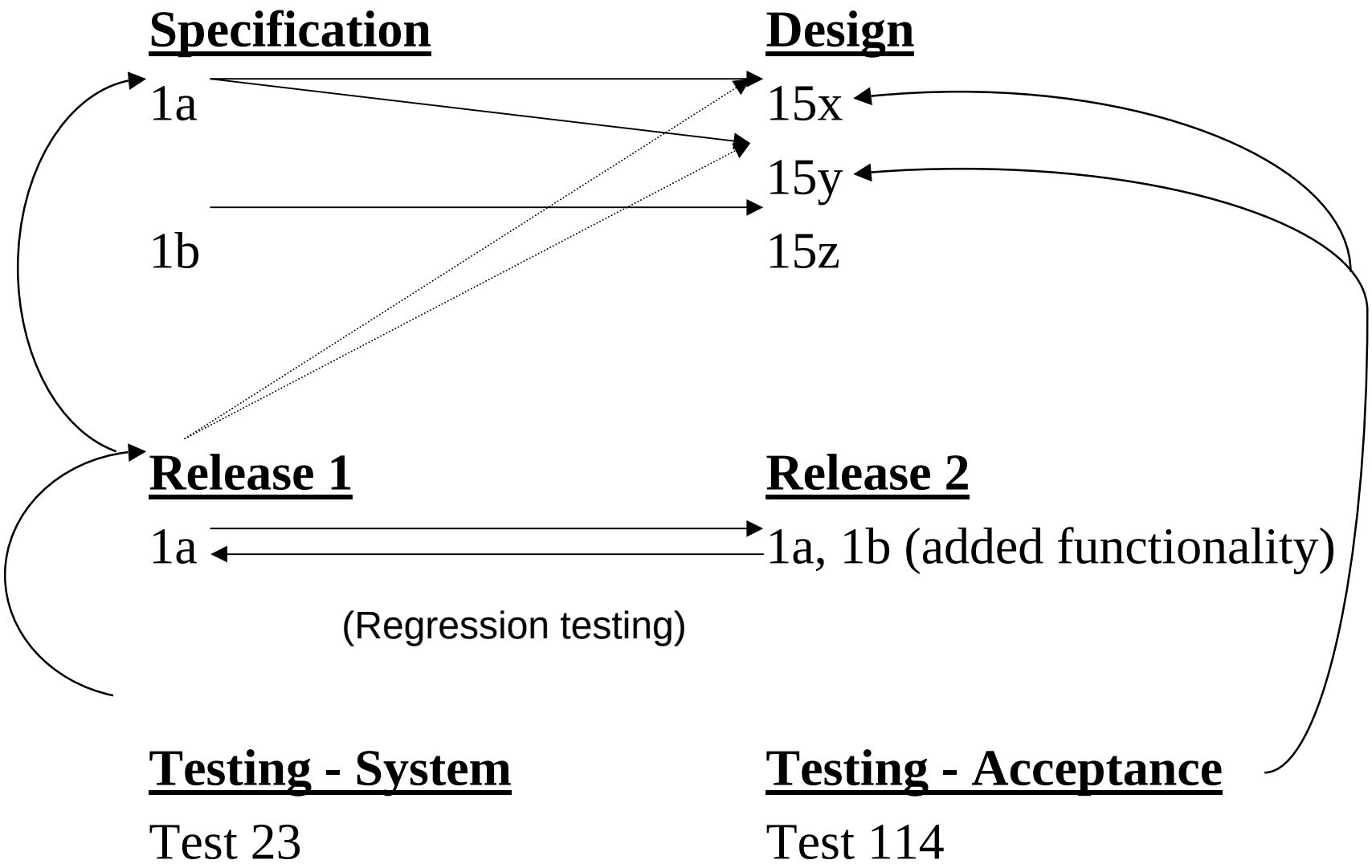

Requirement
Repository

Requirement Repository

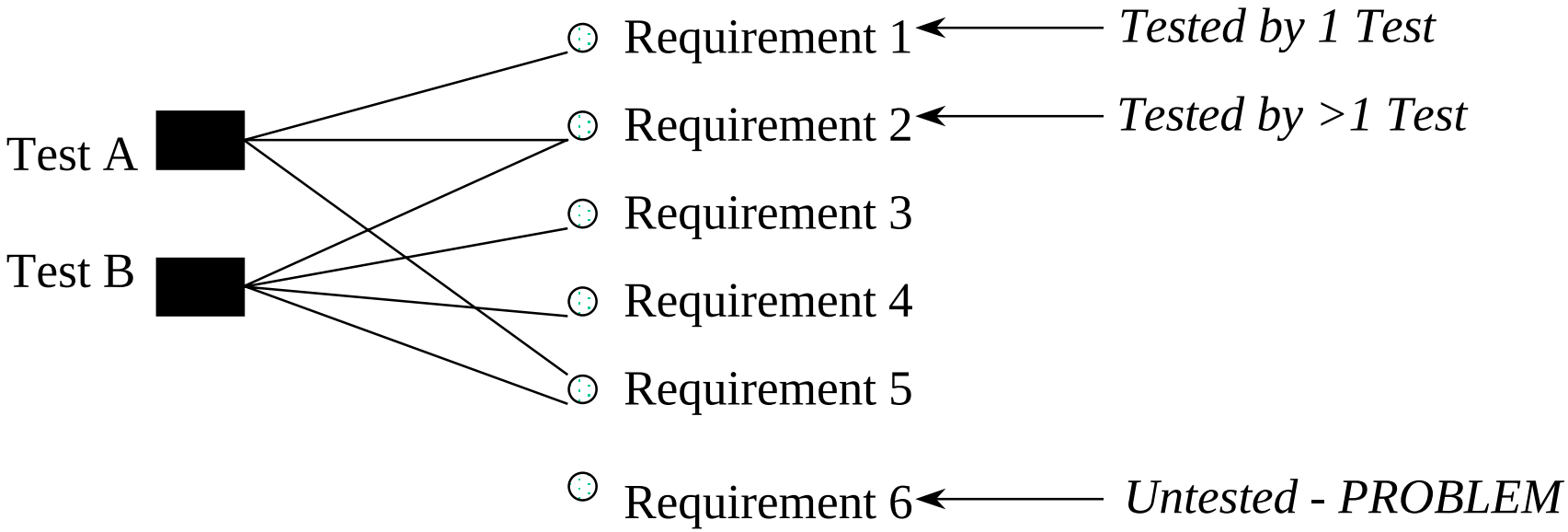
- Chosen prior to start of project
- Purpose - how requirements will be prepared, tracked, traced, measured and tested
- Choice - what capabilities are needed; flexibility, etc.

Word Processor	Spreadsheet	Relational Database	Requirement Tool
Word	Excel	Access	RTM
Word Perfect	Lotus	Dbase	DOORS
	Quattro Pro	Oracle	
		Sybase	

Requirement Allocation & Traceability

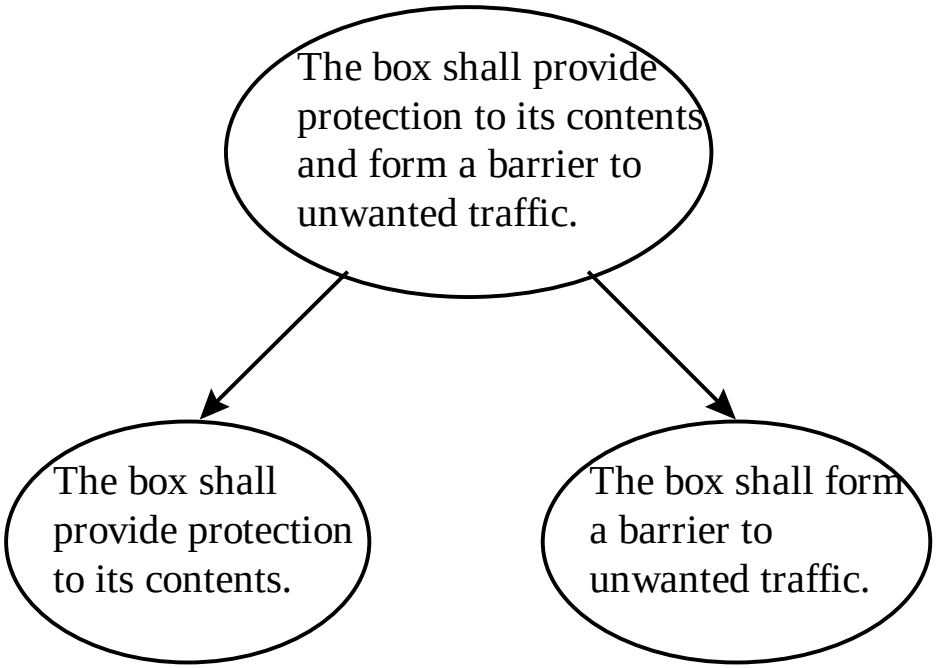


Test Coverage

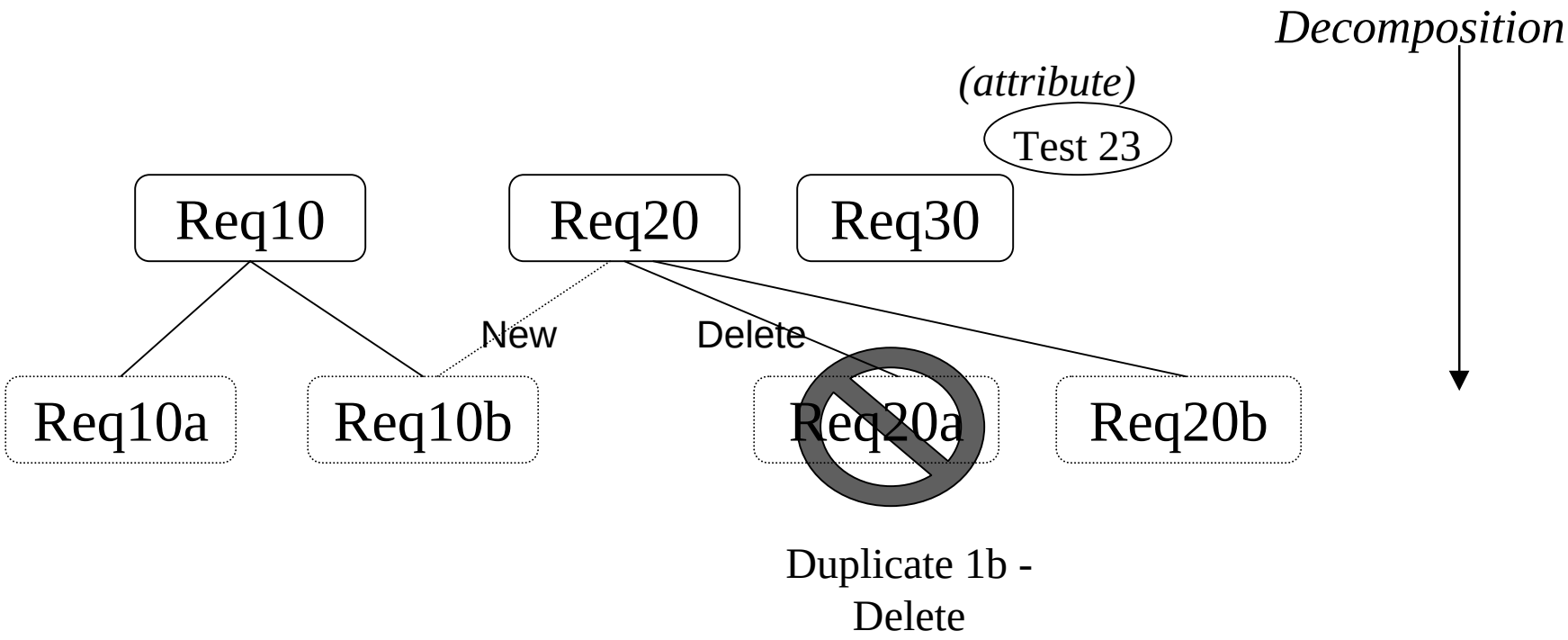


Sample Linkage

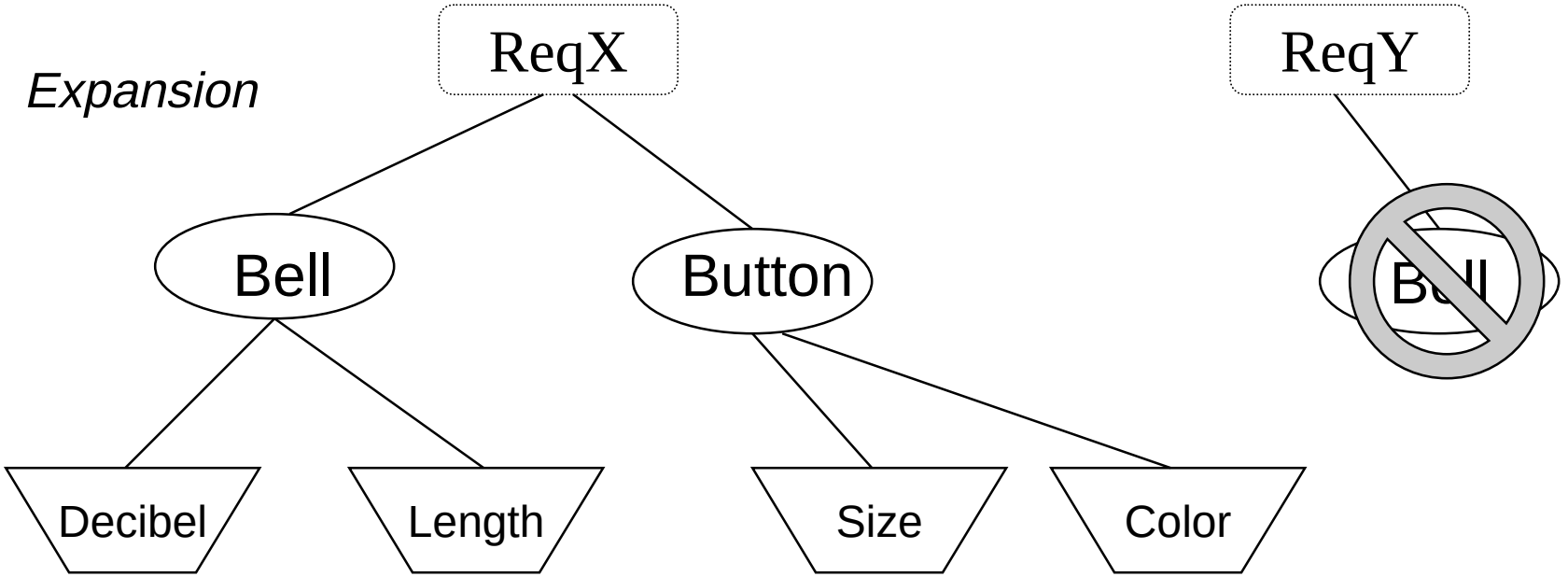
Requirement Simplification



Requirement Decomposition & Simplification



Requirement Expansion & Decomposition



Requirement Repository-Project Requirements

	Word Processor	Spreadsheet	Relational Database	Requirement Tool
Document config. mgt	X		X	X
Document preparation	X			X
Function decomposition			X	X
Metrics			X	X
Report preparation			X	X
Requirement allocation		X	X	X
Requirement config. mgt		X	X	X
Requirement expansion			X	X
Requirement importation				X
Requirement simplification				X
Requirement storage	X	X	X	X
Requirement traceability			X	X
Test coverage/adequacy			X	X

Requirement Repository- Database Capabilities

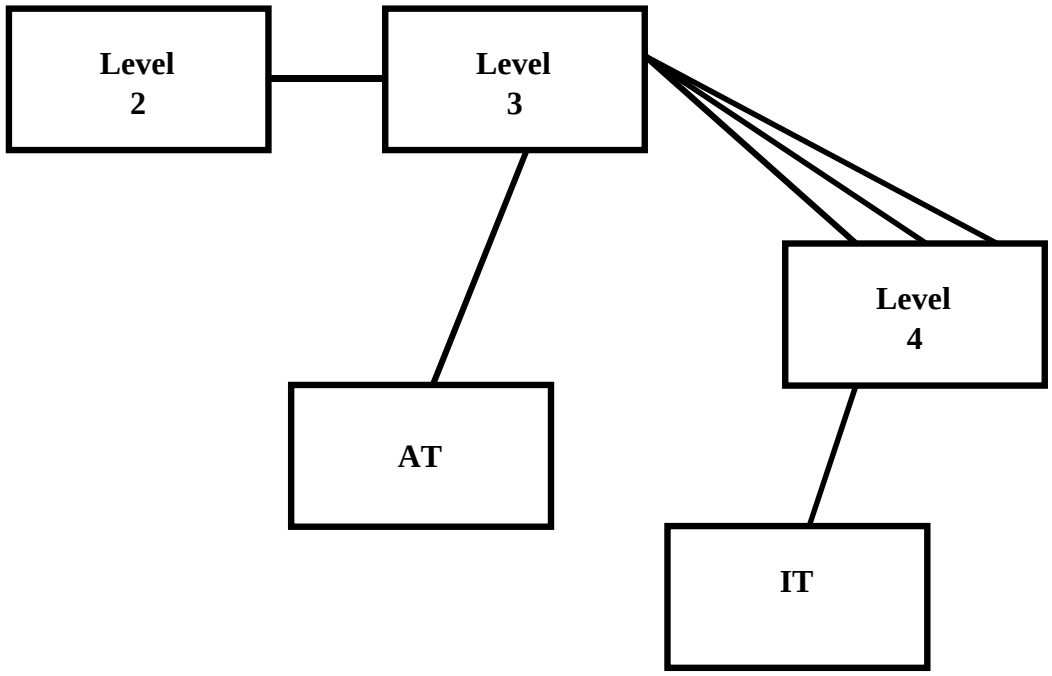
	Word Processor	Spreadsheet	Relational Database	Requirement Tool
Ad Hoc querying			X	X
Classification by attribute			X	X
Classification by linkage			X	X
Decomposition Inheritance				X
Historical comparisons				X

Requirement Repository-Metric Capabilities

	Word Processor	Spreadsheet	Relational Database	Requirement Tool
Document size	X			
Dynamic changes over time				X
Release size	X	X	X	X
Requirement expansion profile			X	X
Requirement types	X	X	X	X
Requirement verification			X	X
Requirement volatility	X	X	X	X
Test coverage			X	X
Test span			X	X
Test types	X	X	X	X

Class Design <==> Link Design

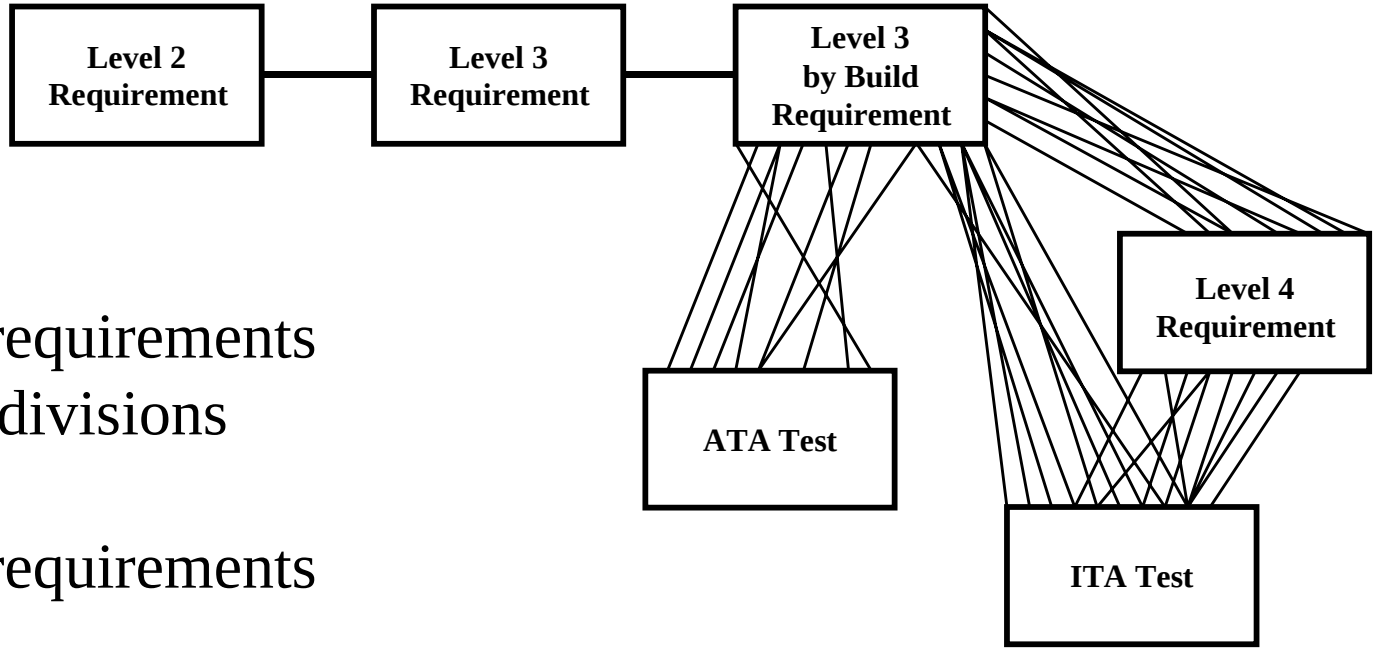
A requirement in Class Level 3 with appropriate decomposition



Minimal Linkage

Class Design <==> Link Design
Project X

A requirement in Class Level 3 with pseudo-decomposition



Level 3: 1,500 requirements
with 6-30 subdivisions

Level 4: 6,000 requirements

==> 19,000 links between
Level 3 and Level 4

Complex Linkage

Requirements Repository Summary

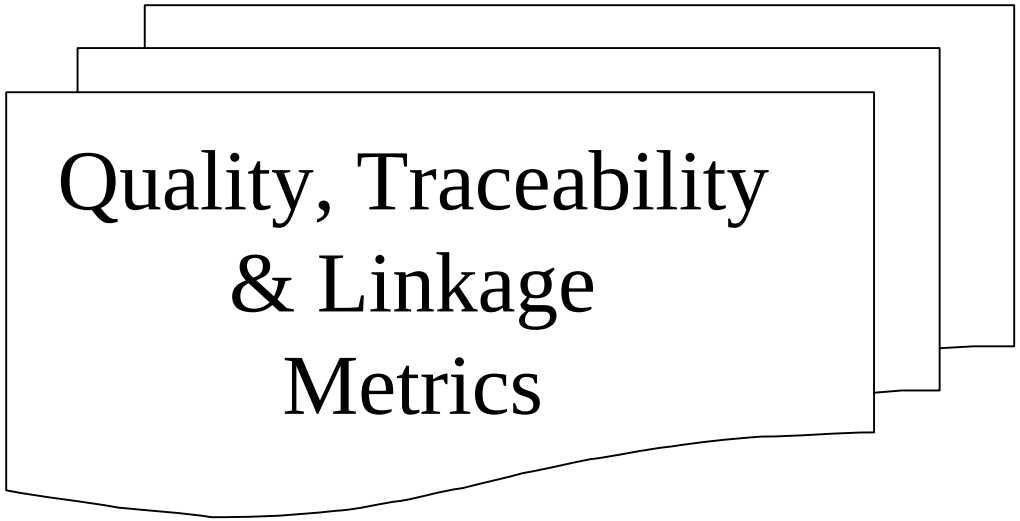
Requirement repository tool needs to be chosen with care based on project requirements

Need effective dialogue between requirement engineers and database engineers

Tools with more capabilities require more resources

Resources needed include training and learning curve, design and set up, and maintenance

Requirement Components



Requirement Quality Attributes

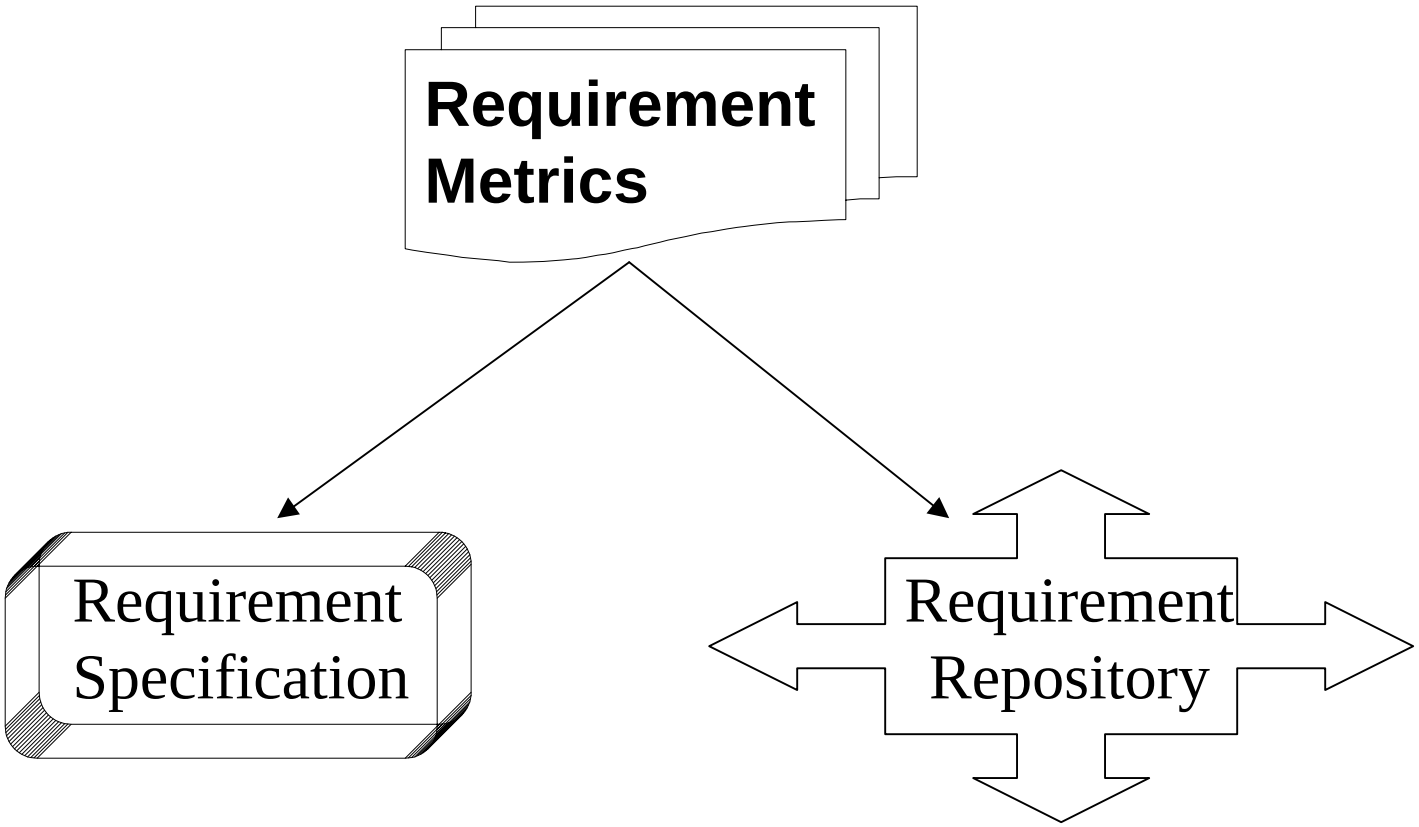
- ***Ambiguity*** - Requirements with potential multiple meanings.
- ***Completeness*** - Items left to be specified
- ***Traceability*** - The traceability of the requirements upward to higher level documents and downward to code and tests.
- ***Understandability*** - the readability of the document.
- ***Requirement Volatility*** - The rate and time within the life cycle changes are made to the requirements.

Requirement Metrics

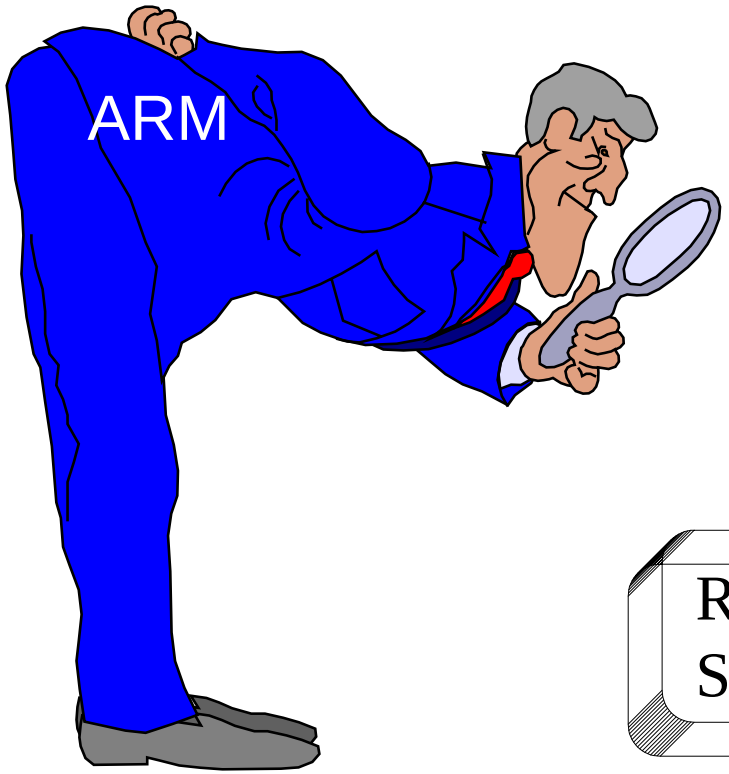
- **Ambiguity** = Weak Phrases (adequate, as appropriate, as applicable, but not limited to, normal, if practical, timely, as a minimum) + Options (can, may, optionally)
- **Completeness** = TBD + TBA + TBS + TBR
- **Understandability** = Numbering Scheme
- **Traceability** = Number of Items traced to tests, between builds, between levels of detail
- **Volatility** = Number of Changes / Number of Requirements

  Number of Requirements: = Imperatives (shall, must, will, required, responsible for, should, are to, are applicable) + Continuances (below:, as follows:, following:, listed:, in particular, support:, :)

Metric Sources



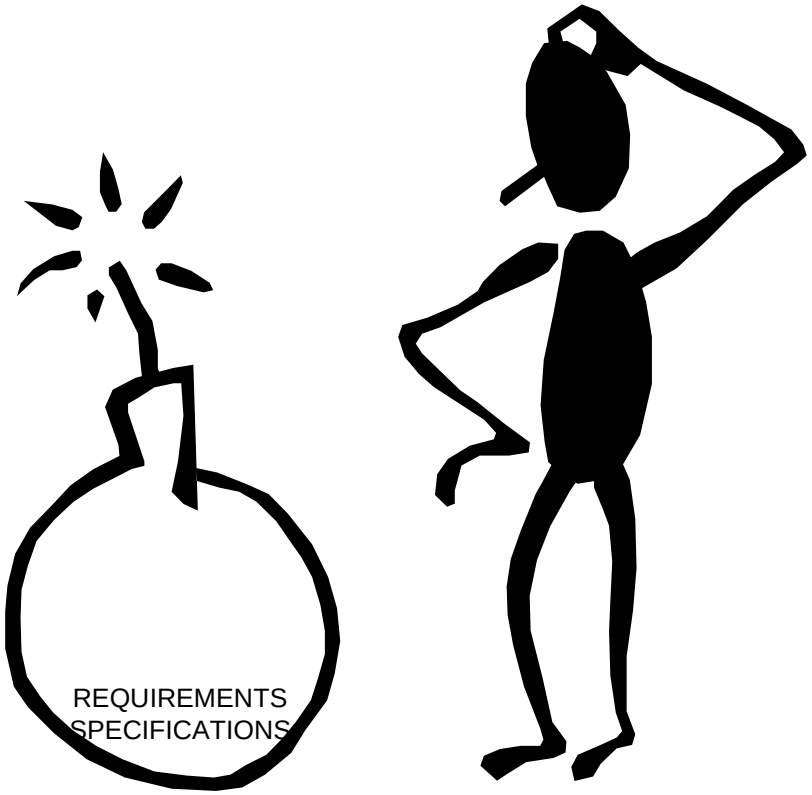
Automated Requirement Measurement Tool (ARM)



Requirement Specification

Available free: http://satc.gsfc.nasa.gov

Basic Underlying Documentation Problems



- Structural
  - Organization
  - Relationships
  - Detail
- Language
  - Ambiguity
  - Inaccuracy
  - Inconsistency
- Careless Prose

Automated Requirement Measurement Tool (ARM)

Objective - Provide measures that can be used to evaluate the quality of a requirements specification document.*

- Available early in the life cycle
- Simple to use
- Easy to understand output
- Identify specific requirement weaknesses (structure and language)
- Indicator of specification areas that can be strengthened
- Basis for estimating required resources

*Not "Did we write the right requirement?" But "Did we write the requirements right?"

ARM Background

Automated Requirements Analysis (ARM)*

- ⇨ Established database containing 46 requirements documents
- ⇨ Developed ARM Tool
  - Full text scan
  - Counts:
    - ◆ Lines of text
    - ◆ Specification statements
    - ◆ Unique specification subjects
    - ◆ Quality Indicators
    - ◆ Levels of document structure
    - ◆ Specifications at each level

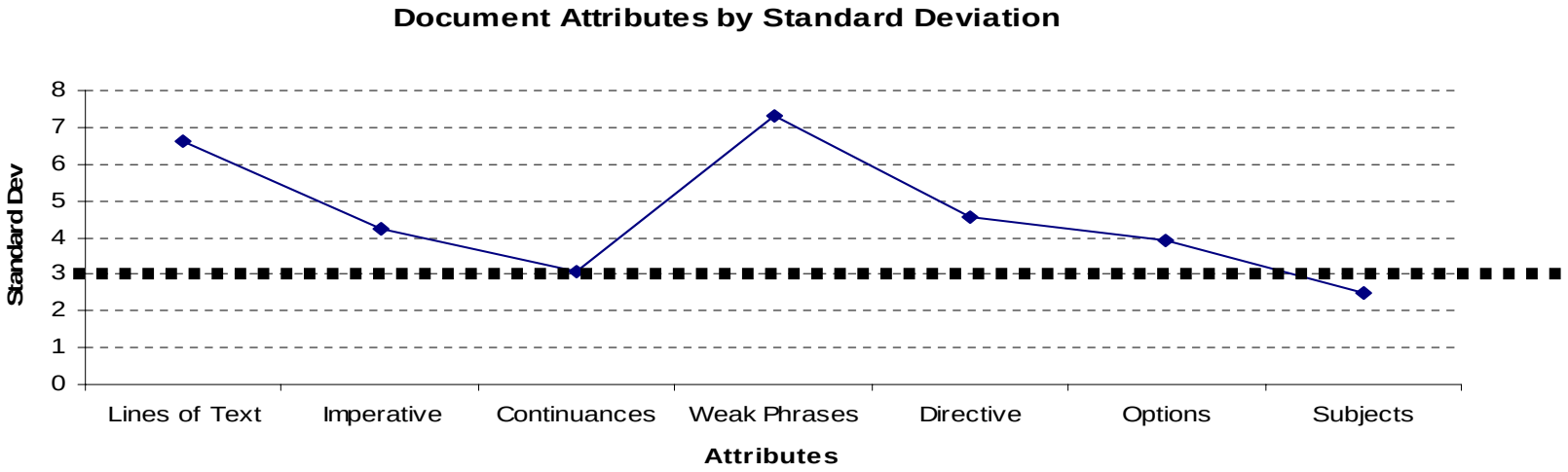
    By finding:
    - ❑ Sentences & Section titles
    - ❑ Sentences with imperatives
    - ❑ Words preceding imperatives
    - ❑ Special words & phrases
    - ❑ Section identifiers
    - ❑ Identifiers & imperatives
  - Produces summary & detail reports
- ⇨ Compare Hand counts to automated counts

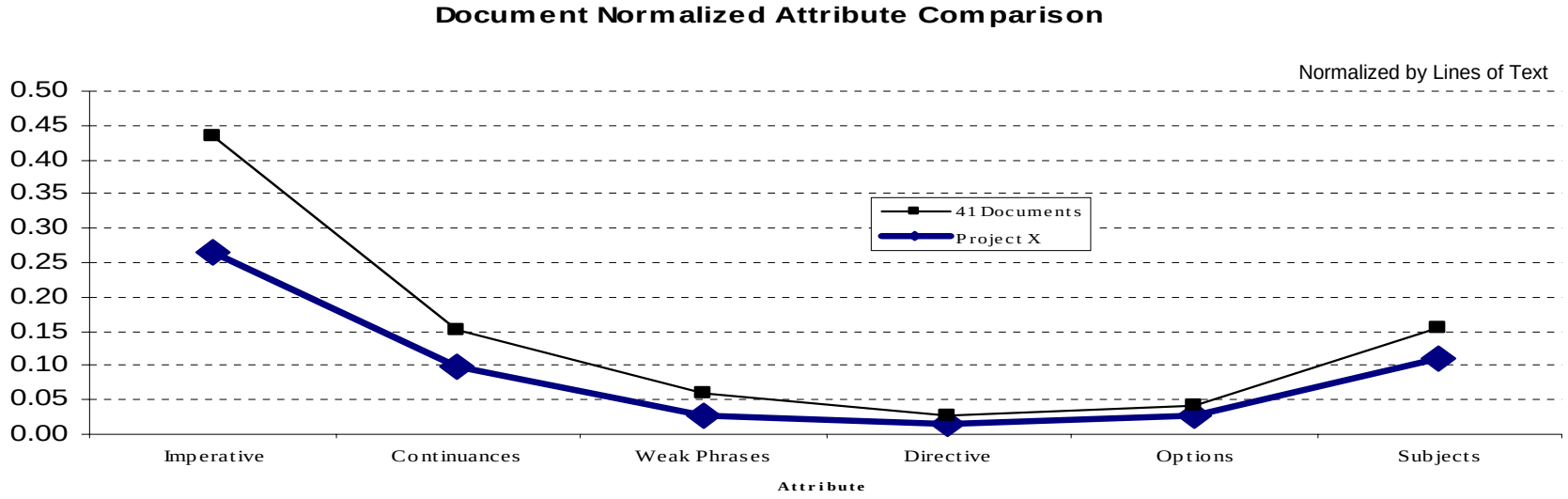
*Available at no cost: http://satc.gsfc.nasa.gov

ARM Analysis of Project X

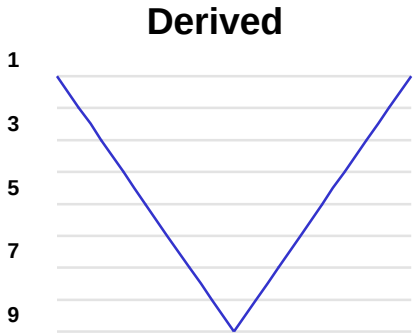
56 DOCUMENT	**Lines of Text** - Count of the physical lines of text	**Imperatives** - shall, must, will, should, is required to, are applicable, responsible for	**Continuances** - as follows, following, listed, inparticular, support	**Directives** - figure, table, for example, note:	**Weak Phrases** - adequate, as applicable, as appropriate, as a minimum, be able to, be capable, easy, effective, not limited to, if practical	**Incomplete** (TBD, TBS)	**Options** - can, may, optionally
Minimum	143	25	15	0	0	0	0
Median	2,265	382	183	21	37	7	27
Average	4,772	682	423	49	70	25	63
Maximum	28,459	3,896	118	224	4	32	130
Stdev	759	156	99	12	21	20	39
Project X	34,664	1,176	714	873	13	480	187

Project X Evaluation

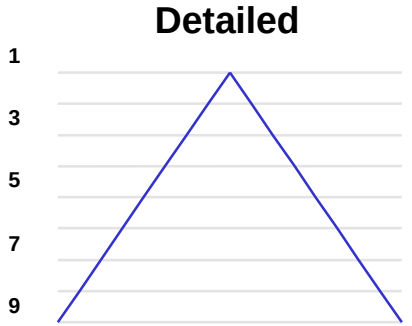


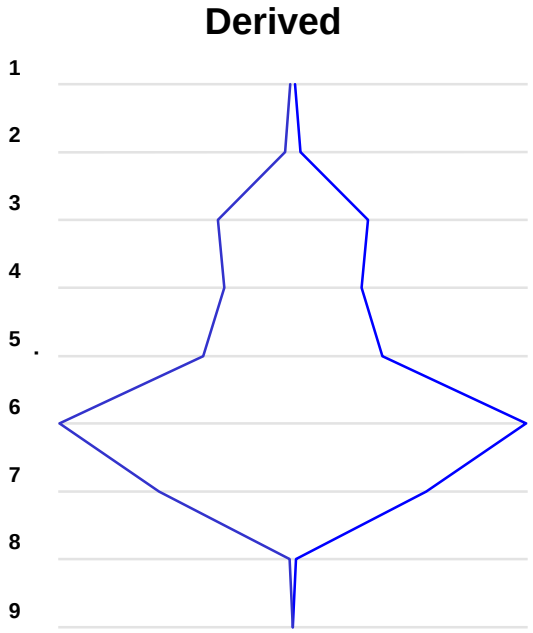


Structure Level at Which Imperative Occurs

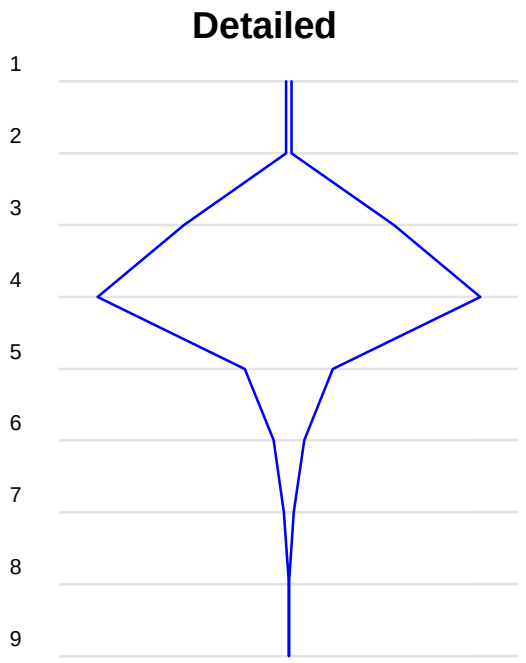


Expected





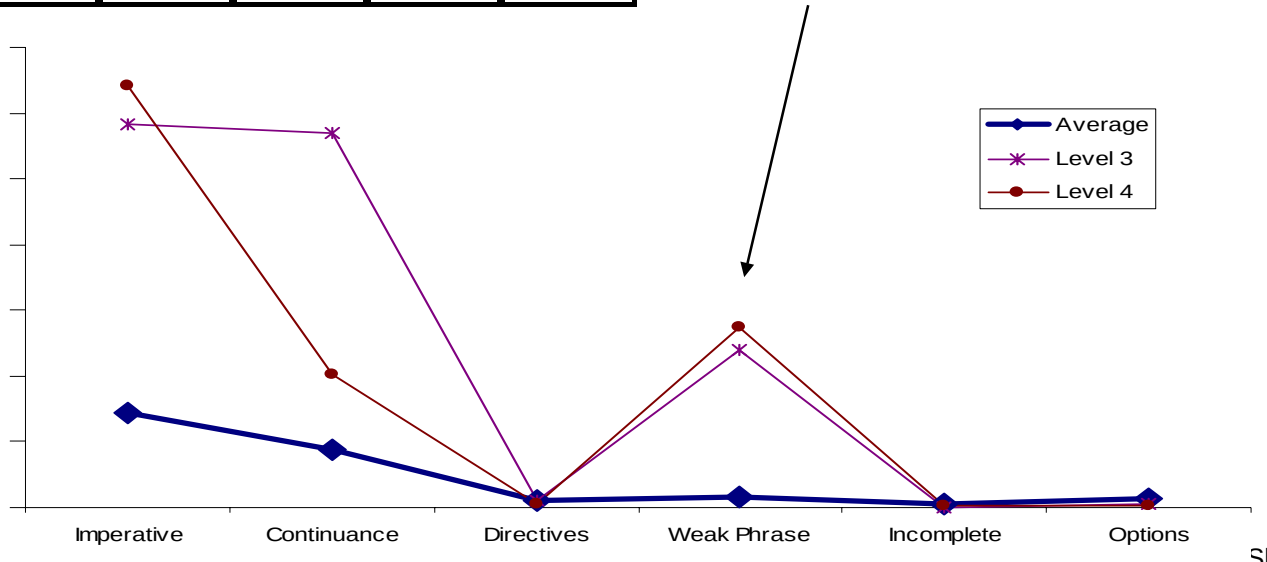
Actual



Project Z - 2 Specification Levels

56 DOCUMENT	**LINES OF TEXT** - Count of the physical lines of text	**Imperatives** - shall, must, will, should, is required to, are applicable, responsible for	**Continuances** - as follows, following, listed, inparticular, support	**Directives** - figure, table, for example, note:	**Weak Phrases** - adequate, as applicable, as appropriate, as a minimum, be able to, be capable, easy, effective, not	**Incomplete** - TBD, TBS, TBR	**Options** - can, may, optionally
Average	4772	682	423	49	70	25	63
Level 3	1011	588	577	10	242	1	5
Level 4	1432	917	289	9	393	2	2

Problem --> Excessive weak phrases - not testable



Sample Output - Project A

ARM INCOMPLETE REPORT FOR FILE .txt

TBD # 1: In Line No. 86, ParNo. a., @ Depth 1

a. CERES: 2 in building 1250, LaRC; 2 in building TBD, LaRC; 1 at SAIC; 1 at building 1300; 1 each at 2 other buildings TBD, LaRC

TBD # 2: In Line No. 86, ParNo. a., @ Depth 1

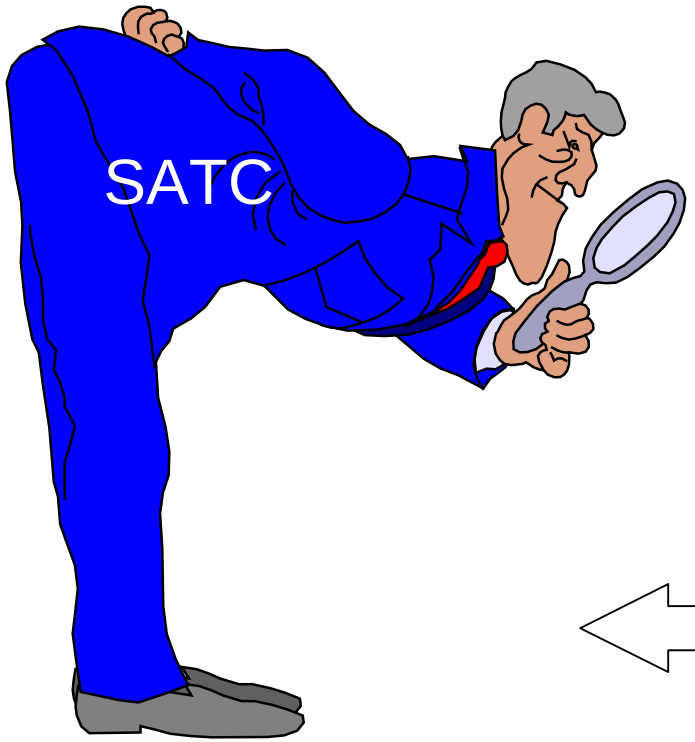
a. CERES: 2 in building 1250, LaRC; 2 in building TBD, LaRC; 1 at SAIC; 1 at building 1300; 1 each at 2 other buildings TBD, LaRC

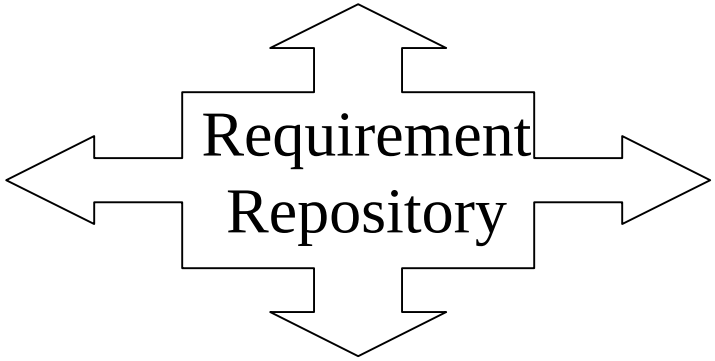
ARM WEAK PHRASE REPORT FOR FILE ProjectA.txt

provide for # 1: In Line No. 65, ParNo. d., @ Depth 1

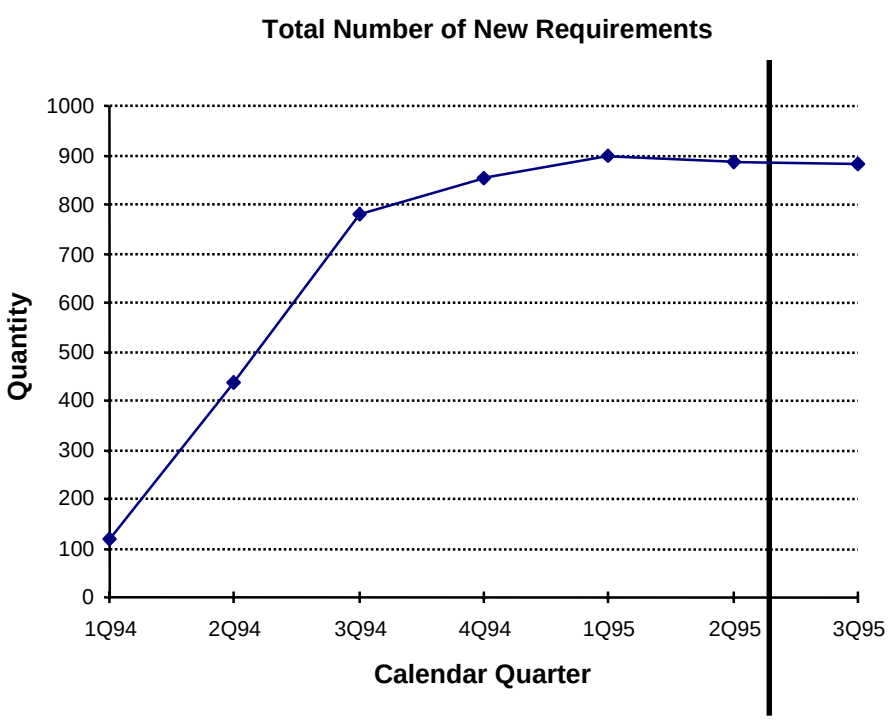
F-FOS-00490 The ProjectA shall PROVIDE FOR security safeguards to cover unscheduled system shutdown (aborts) and subsequent restarts, as well as for scheduled system shutdown and operational startup.

Requirement Metrics

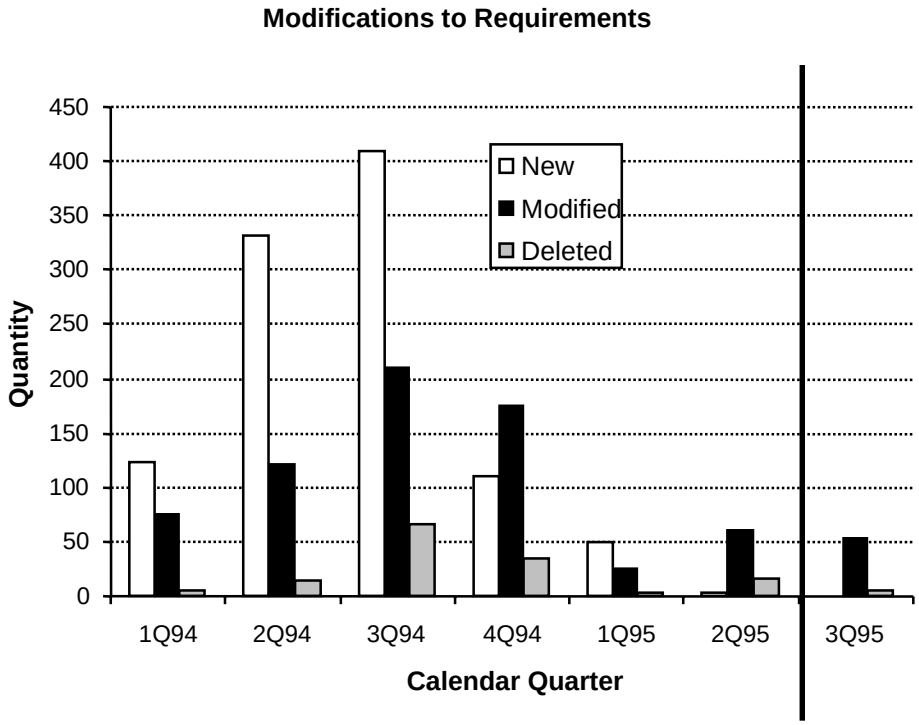




Requirement Volatility



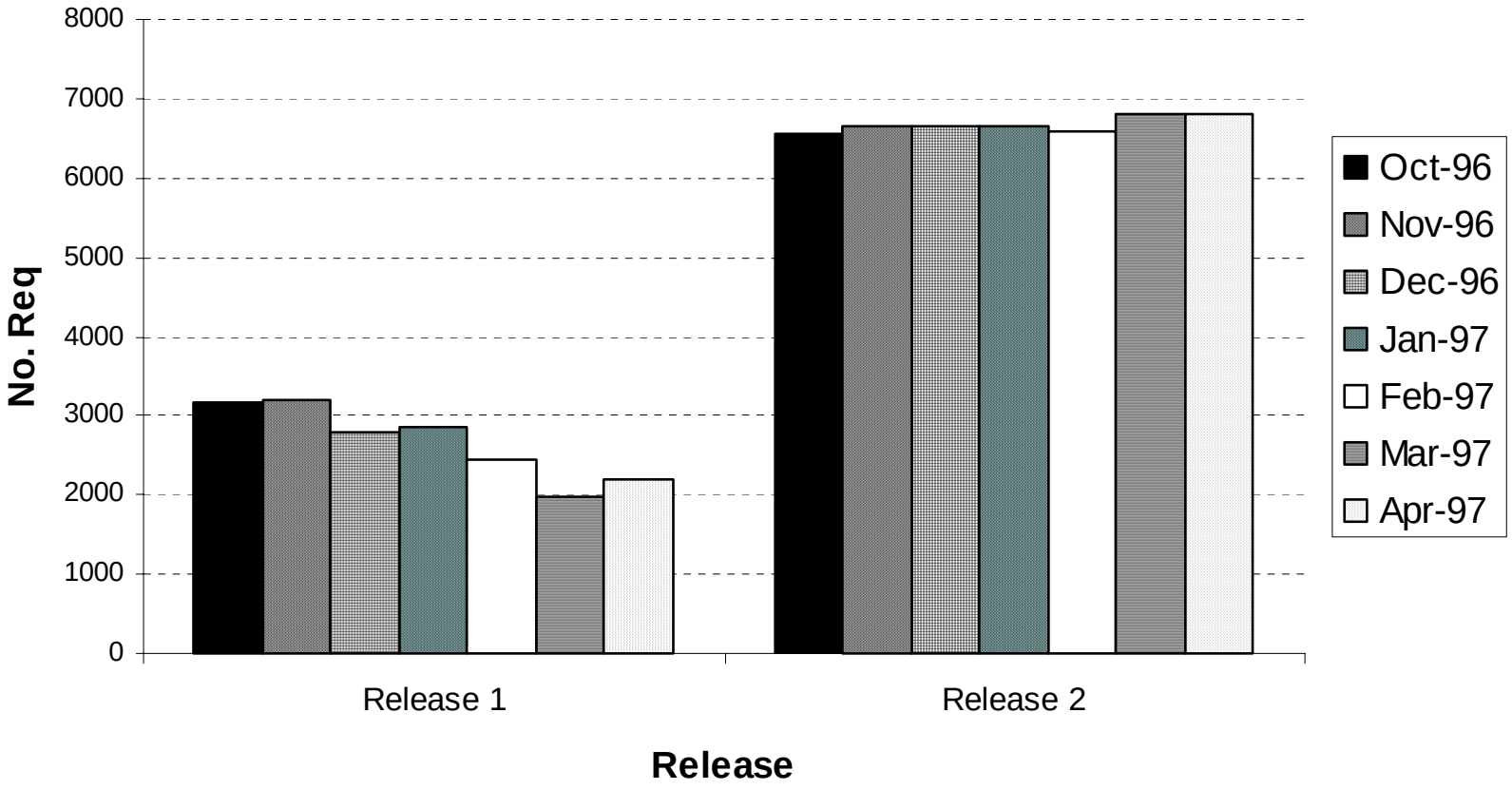
CDR
Looks Good!
(Stable)



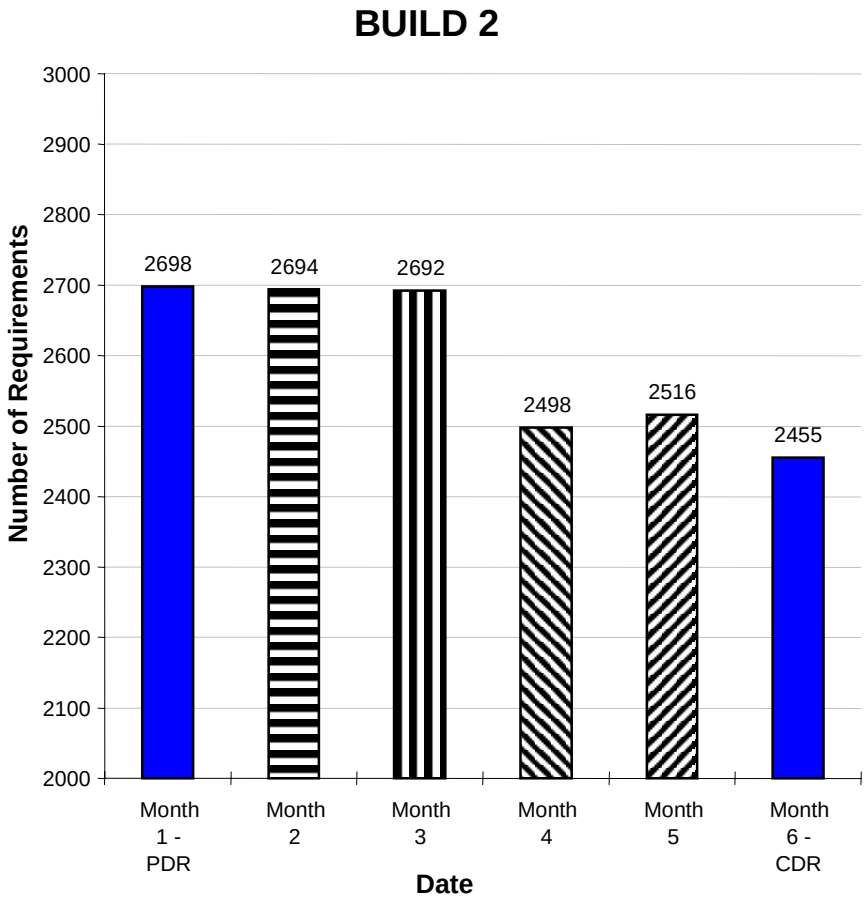
CDR
Excessive Changes!
NOT Stable

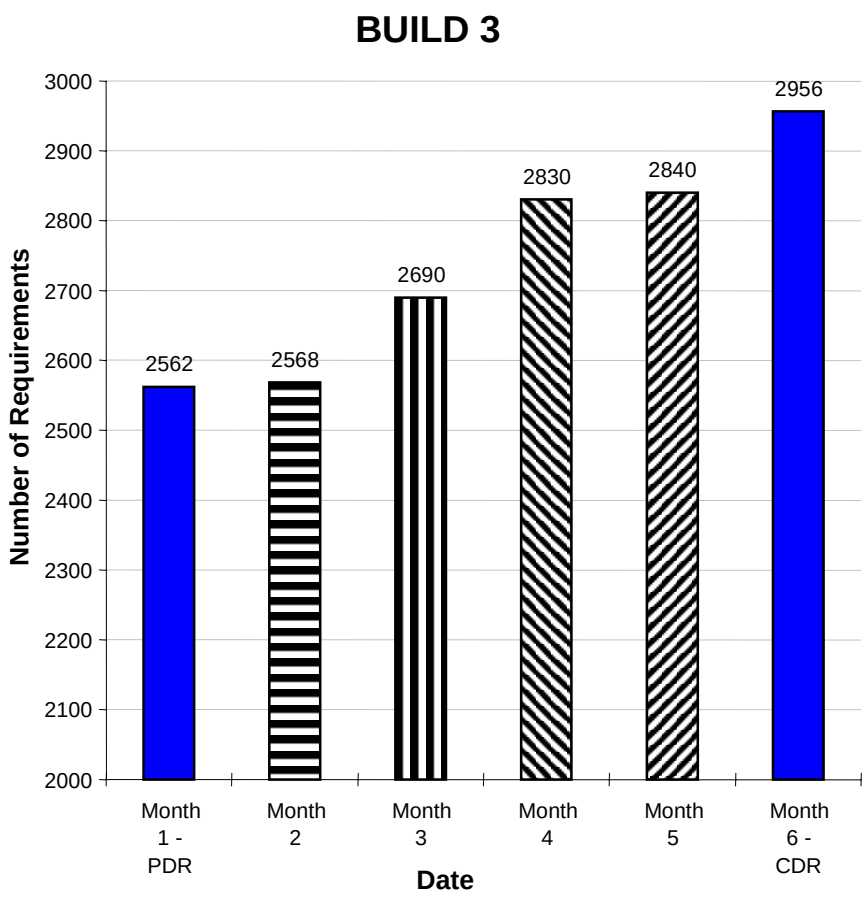
Combination of BOTH views indicate risk area - requirements are NOT YET stable

Requirement Volatility



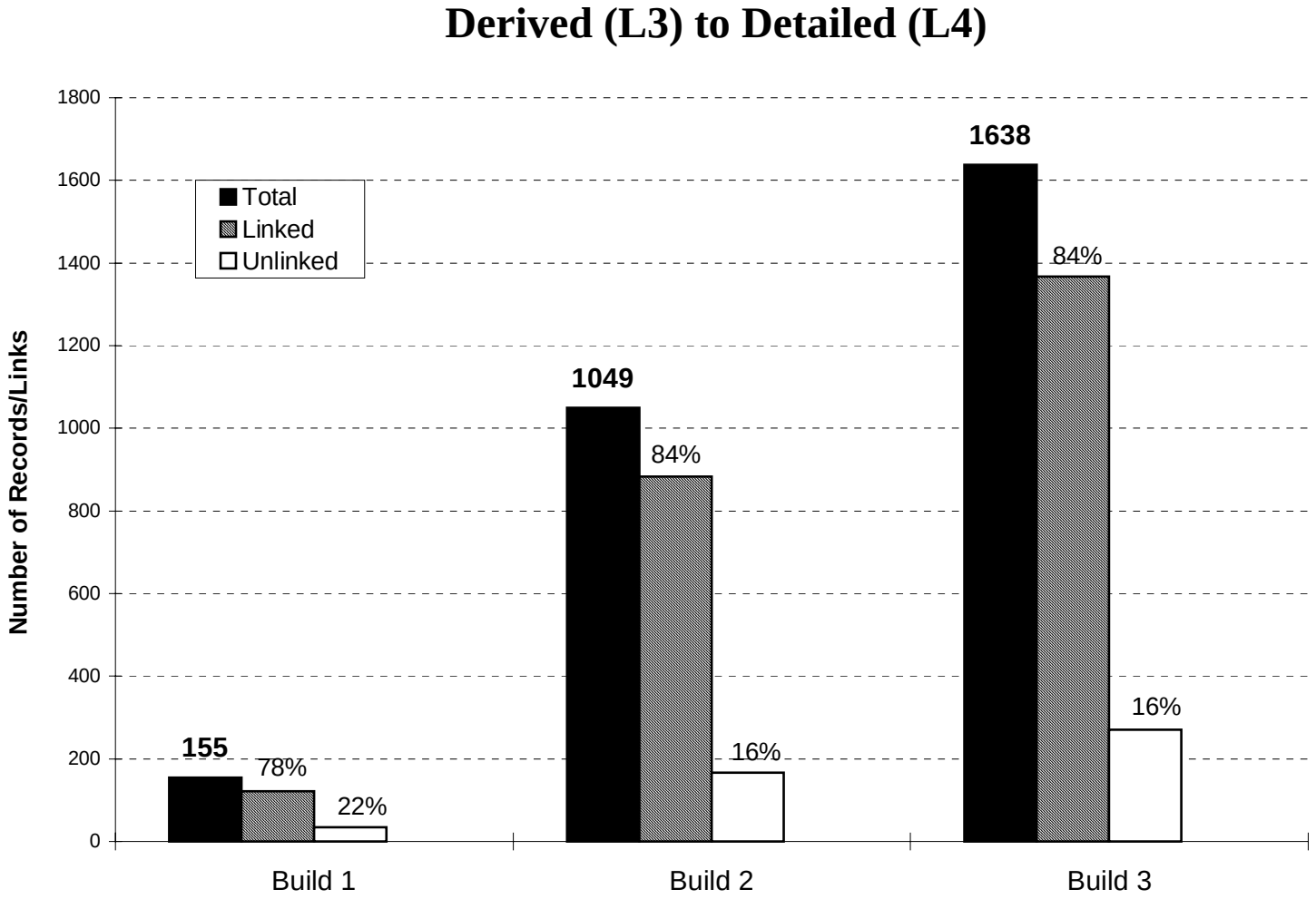
Requirement Stabilization By Build



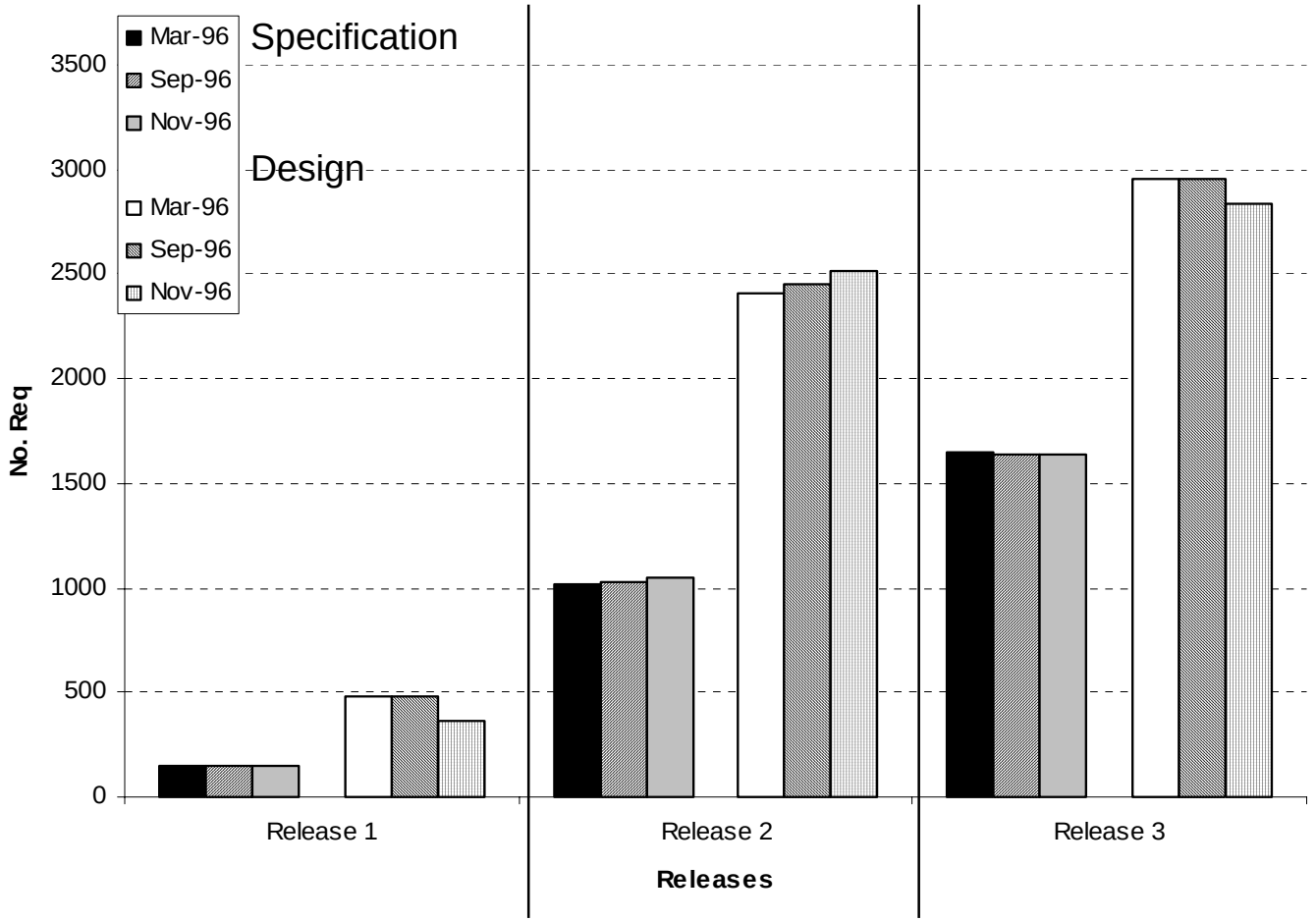


(Detailed L4)

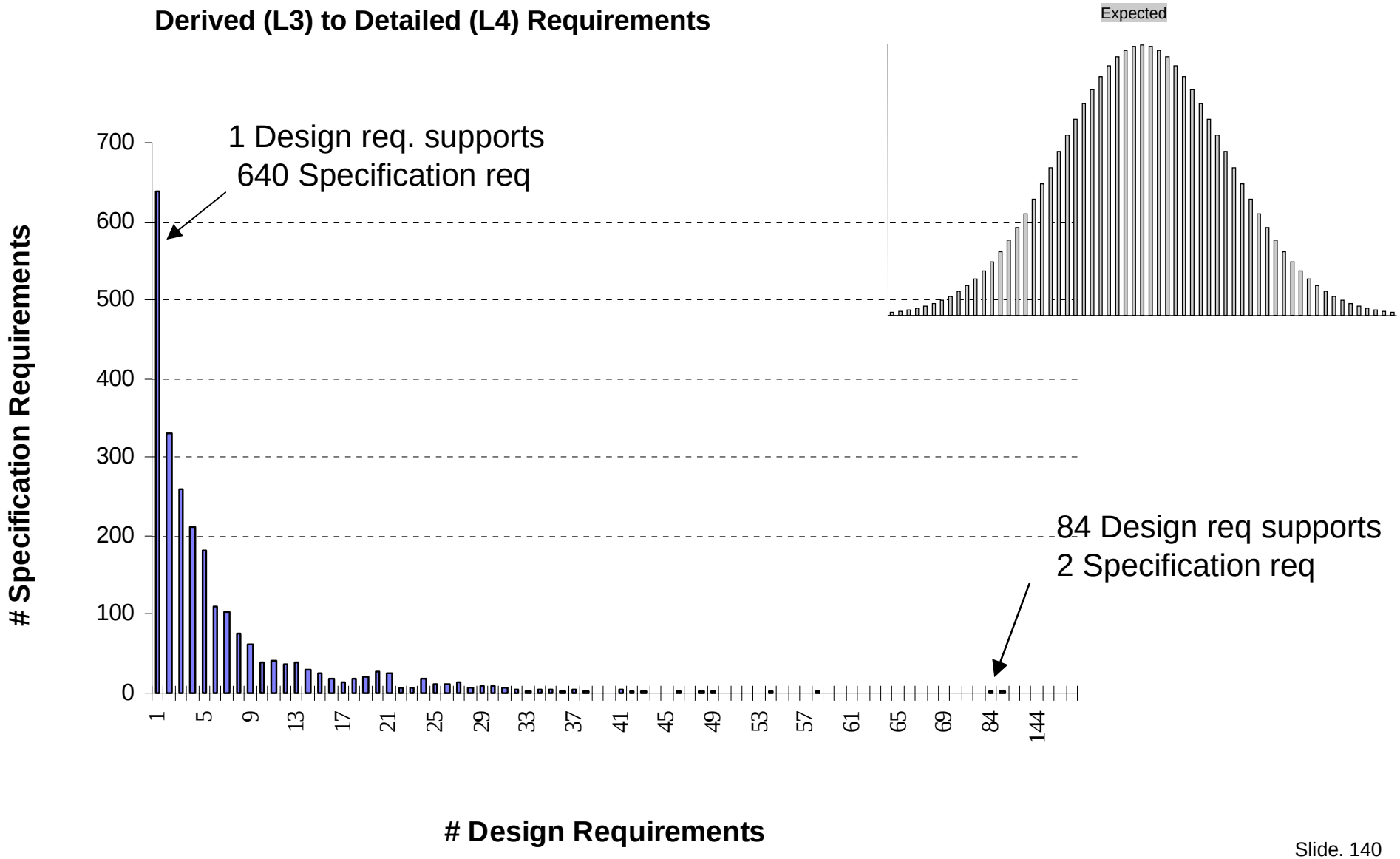
Requirement Traceability



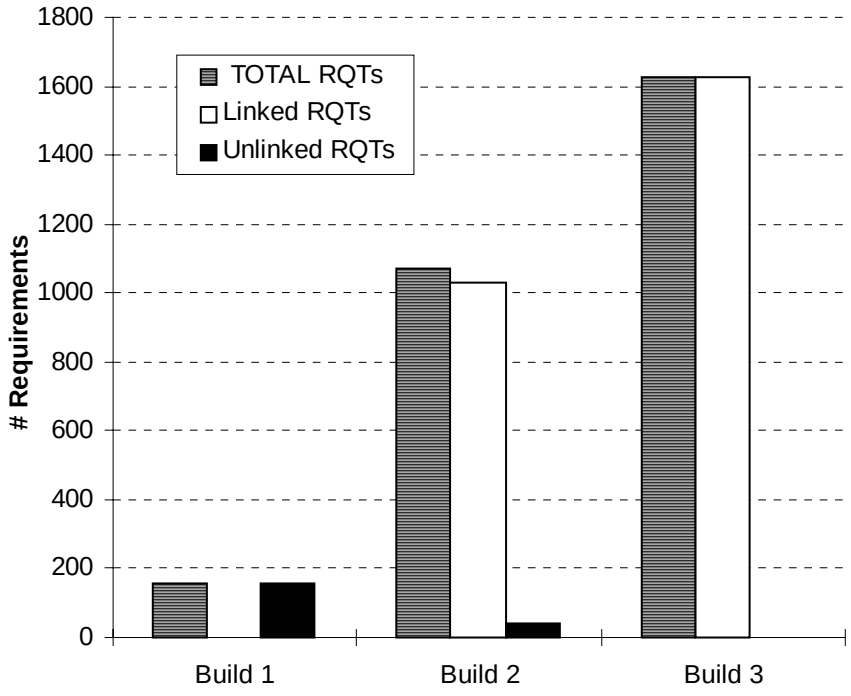
Requirement Expansion



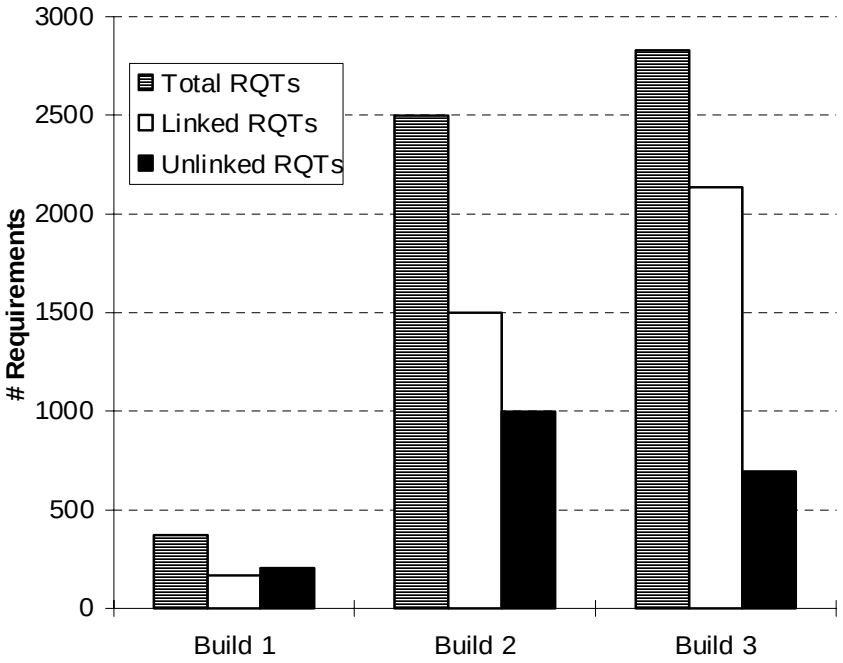
Requirement Decomposition



Requirement Verification - Trace to Test



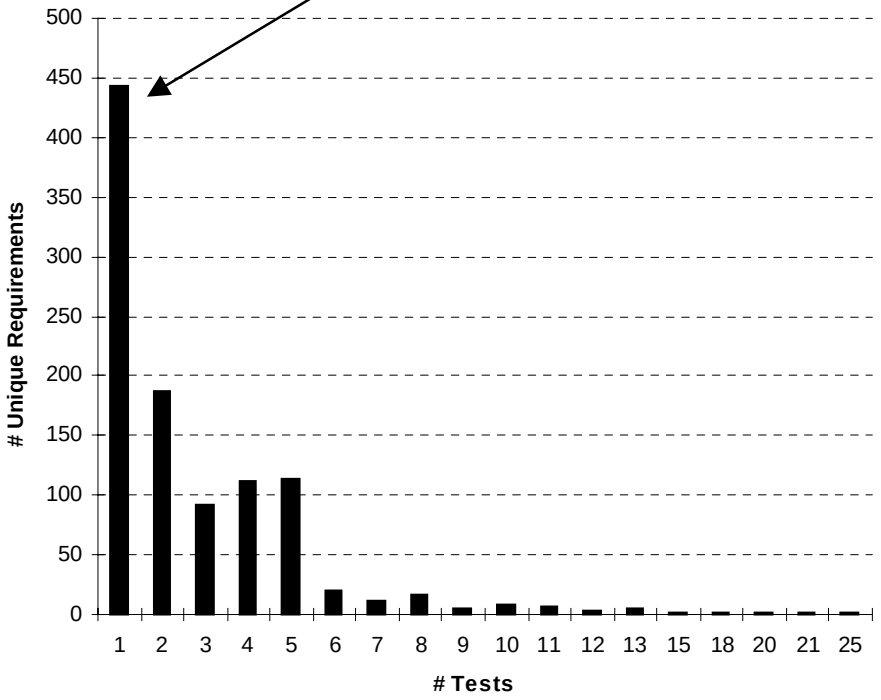
Derived (L3) Requirements



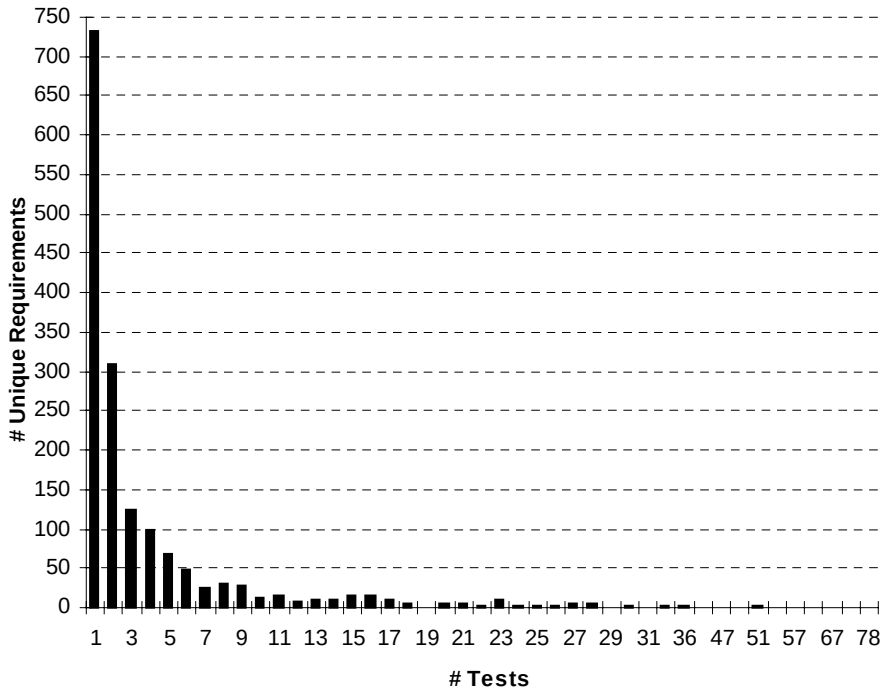
Detailed (L4) Requirements

Test Span
System test Profile (CDR)

445 requirements are each tested by only 1 test

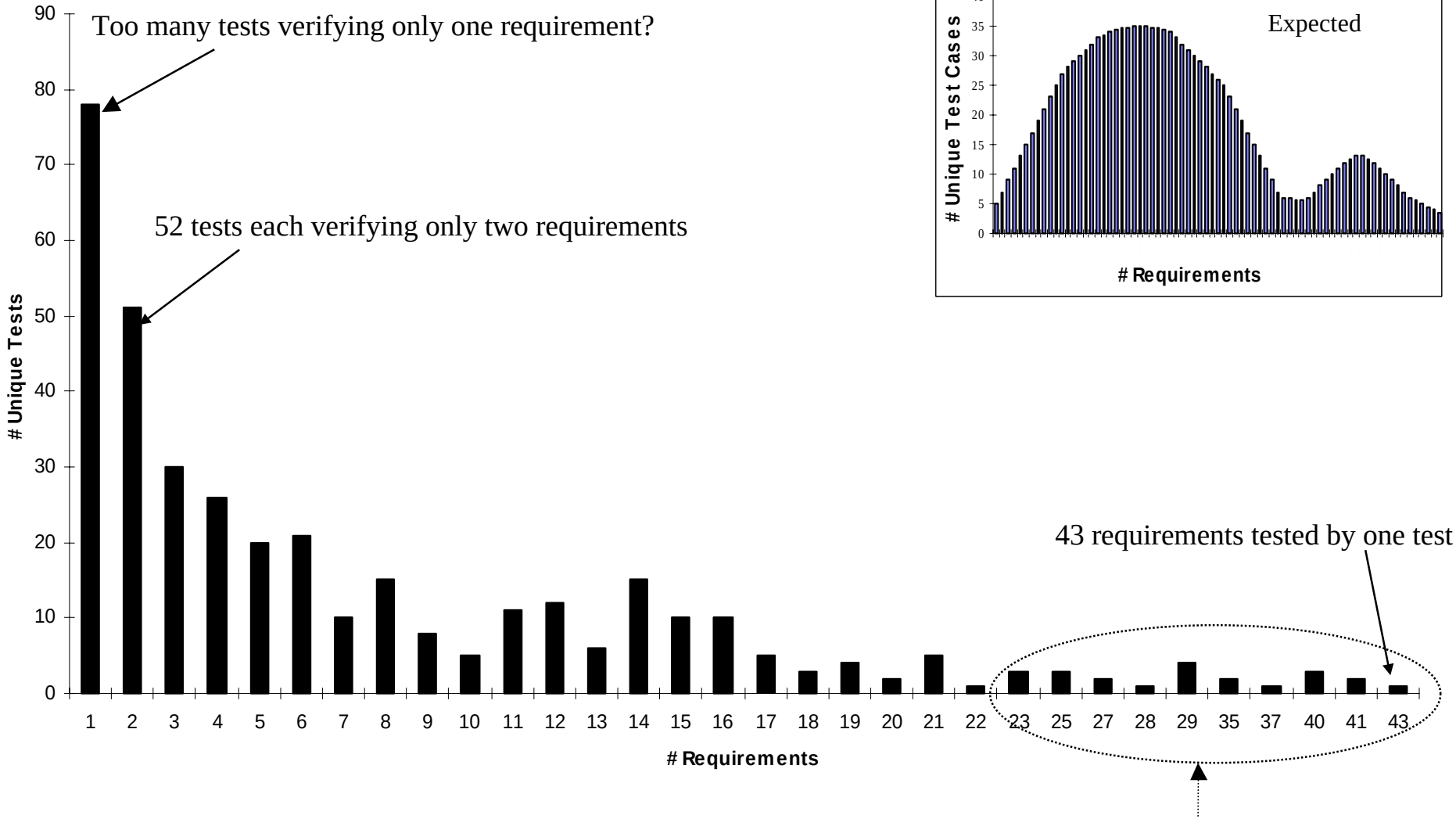


Build 2



Build 3

Test Comprehensiveness



Sufficient Testing?

Metrics Summary

Requirement metrics assist in identifying potential project risks

Multiple metrics are needed for comprehensive evaluation

Evaluation of requirement text can yield risk information very early in the life cycle

Metric collection is cheaper, faster and more reliable with requirement management tools

Detailed design of database schema necessary for effective evaluation

Requirement Conclusions

Use of natural language for requirements may result in problems later - need care, attention and review to language usage and structure.

Repository for requirements can provide benefits in management of project if you use correct tool.

Metrics can be used to track requirements process and give valuable insight into project status and early warning of problems.

References

Davis, A., et. al, “Identifying and Measuring Quality in a Software Requirements Specification” Proc. 1st Int’l Software Metrics Symp, 1993.

IEEE Recommended Practice for Software Requirement Specifications, 830-1993

NASA Software Assurance Guidebook, NASA GSFC, Office of Safety and Mission Assurance, 9/89.

Thayer, R., et al., *Software Requirements Engineering*, 2nd Edition, IEEE Computer Society Press, 1997.