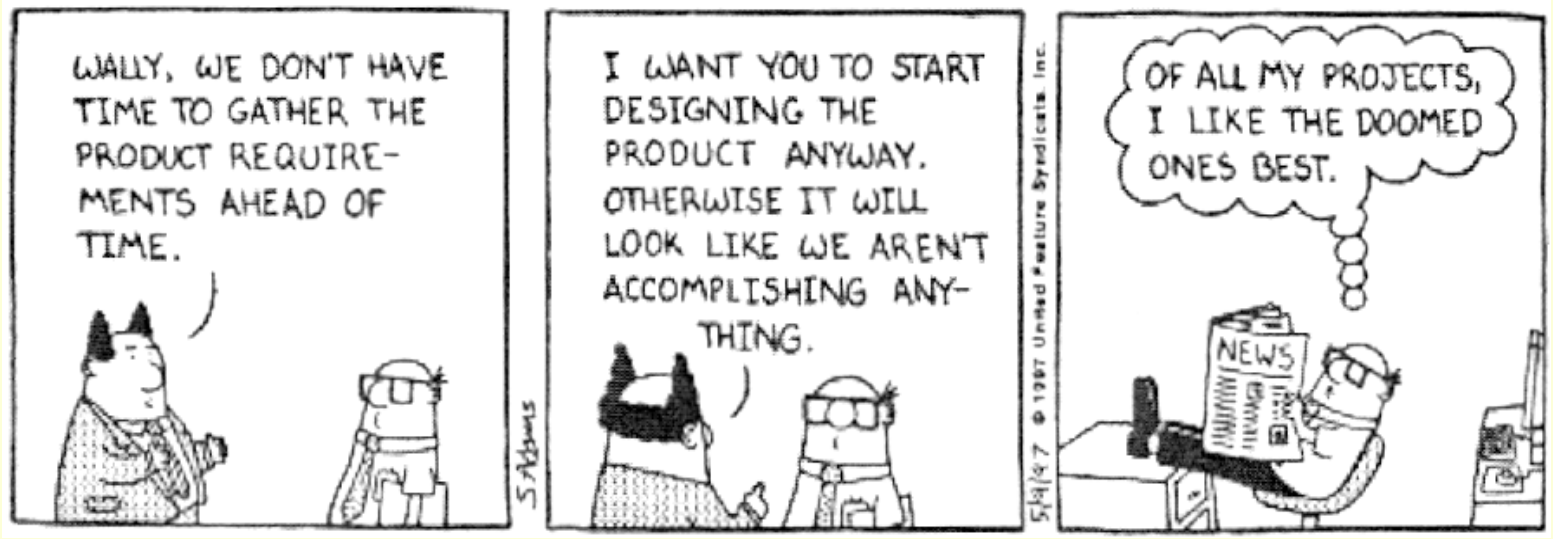
Writing Effective Requirements

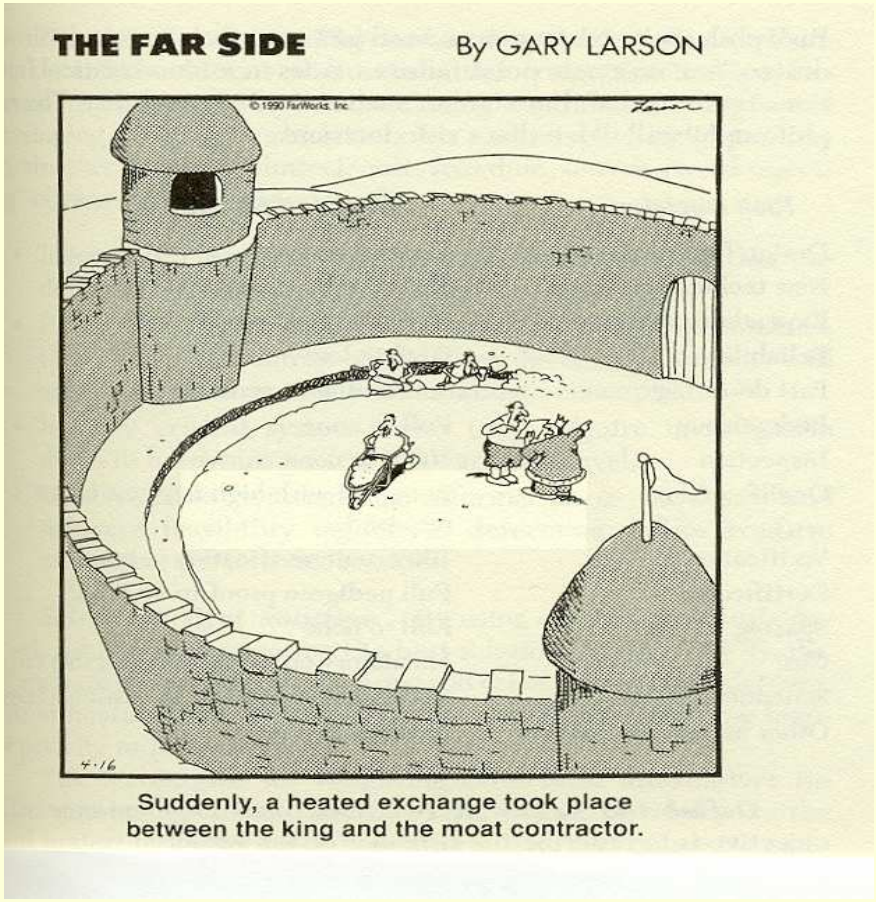
Sound Familiar?

DILBERT / Scott Adams



If so, you're in the wrong place! You need to be in the Fundamentals of Systems Engineering, not Writing Effective Requirements.

How about this then …?



"Lawyer's Delight!"

$$$$$

OK, you're in the right place!

An Effective Requirement Is …

- **Necessary**
  - **A condition or capability needed to solve a problem or achieve an objective**
    - **Mission success cannot be achieved without meeting the requirement.**
    - **Avoid over-specifying (restricts design space, adds cost) – ask "Why is this a requirement?", "What is the need it reflects?"**
    - **Specify the "what," not the "how."**
- **Verifiable**
  - **A requirement must be objectively verifiable (by test, analysis, inspection, or demonstration) to prove compliance; the requirement should be written in a fashion such that the means of verification is clearly understood.**
  - **A desired capability that cannot be objectively verified should be written as a design goal ("should"), not a requirement ("shall").**
- **Achievable**
  - **If it's not achievable, you cannot satisfy your contractual obligations.**
    - **A quality supplier never signs up to something that they cannot deliver.**
  - **To be achievable, a requirement must be technically feasible, affordable, and fit within schedule and other constraints.**

An Effective Requirement Is Also …

- **Simple, concise & easily understood**
  - **Vague and ambiguous requirements**
    - **can be misinterpreted and result in a faulty design solution that fails to satisfy the customers' needs and your contractual obligations.**
    - **cannot form the basis for an objective verification criteria.**
  - **Each requirement must specify one and only one function.**
- **Unique**
  - **Verifying redundant requirements adds unnecessary cost.**
  - **Redundant requirements may result in contradictions.**
- **Traceable**
  - **Relationship with parent requirement(s) is defined and documented.**
  - **Relationship with child requirement(s) is defined and documented.**
  - **Rationale describing allocation is documented.**

Is This An Effective Requirement?

3.2.1.1.3.9 Optical/electronic noise.

Noise patterns in the output video due to optical reflections, electronic processing, microphonics and radiation variations arising in the optical or TV subsystems shall not be evident on a test display at any contrast or brightness level for any illumination input. The test display shall also be free of any significant noise or interference due to the transmission or reception of laser energy, operation of the data link, data processing from the transducers inside the MPS or other sources in the system. The following design areas shall be given special attention to achieve optical electronic noise free video:

a. **Laser energy ghosts will be controlled by optics design**
b. **Laser pump light will be controlled in laser design**
c. **Veiling glare, as defined in MIL-STD-150, shall be less than 1 percent by optical design, which includes metal finishes and coatings of optical finishes and coatings of optical surfaces and lens edges**
d. **A ruggedized TV camera tube that has no mechanical resonance below kilohertz will be used to minimize microphonics**

Of Course It's Not!

What are some of the problems here?

3.2.1.1.3.9 Optical/electronic noise.

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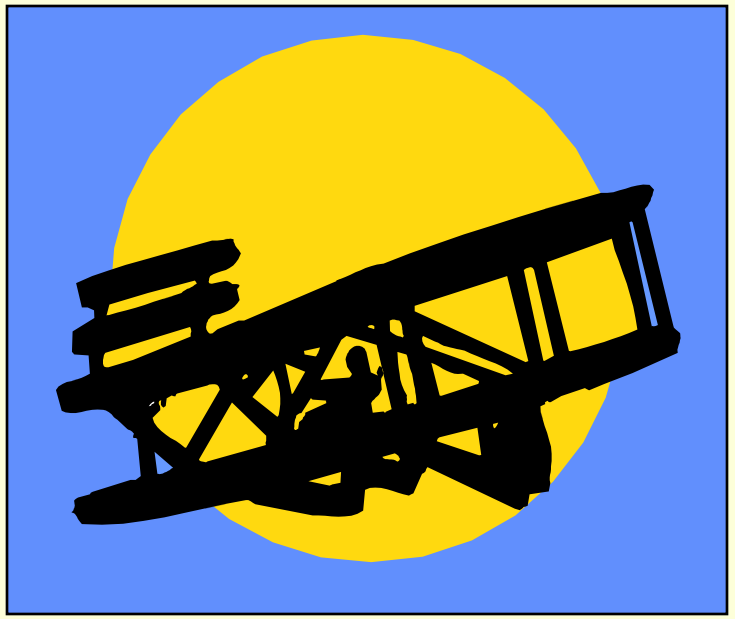
a. **Laser energy ghosts will be controlled by optics design.**
b. **Laser pump light will be controlled in laser design.**
c. **Veiling glare, as defined in MIL-STD-150, shall be less than 1 percent by optical design, which includes metal finishes and coatings of optical finishes and coatings of optical surfaces and lens edges.**
d. **A ruggedized TV camera tube that has no mechanical resonance below 1 kilohertz will be used to minimize microphonics.**

How About This One?

"Advertisement and Specification for a Heavier-Than-Air Flying Machine," U.S. Army Signal Corps Specification No. 486, 1907.

> **"10. It should be sufficiently simple in its construction and operation to permit an intelligent man to become proficient in its use within a reasonable length of time."**



- **How simple is "sufficiently simple"?**
- **How intelligent is "intelligent"?**
- **How proficient is "proficient"?**
- **What is a "reasonable" length of time?**

Common Traps And The Means To Avoid Them

- **Bad or missing information**
  - **Leads to over-specifying requirements or failing to specify needed requirements.**
  - **Remedies**
    - **Identify and involve the stakeholders and subject matter experts in every step of the product lifecycle.**
    - **Develop and validate concepts-of-operations (ConOps), mission scenarios, linkage and flow, constraints (cost, schedule, and technical).**
    - **Employ requirements analysis tools, checklists (comprehensive specification templates are good for this purpose).**
- **Specifying the "how," not the "what."**
  - **Remedy**
    - **Determine the need statement and write the requirement accordingly.**
- **Verbosity**
  - **Extra words mean extra chances to misunderstand!**
  - **Remedies**
    - **Be concise.**
    - **Use simple, common terms whenever possible – avoid using "buzz words" and "project-speak."**

Common Traps And The Means To Avoid Them (cont)

- **Using vague or ambiguous words, phrases, and statements.**
  - **Subject to multiple interpretations.**
  - **Not objectively verifiable.**
  - **Creates an opportunity for the customer to require additional work without additional compensation, or the contractor to demand additional compensation for in-scope work.**
  - **Example words and phrases to avoid**
    - **“Achievable”, “adequate”, “approximately”, “complete”, “damaged”, “degraded”, “efficient”, “effective”, “minimize”, “maximize”, “flexible”, “modular”, “nominal”, “normally”, “optimum”, “survive”, “typically”, “usually”, “generally”, “often”, “easy”, “to the maximum (or minimum) extent”, “as much (or little) as possible”, “user-friendly”, “scalable”, “versatile”, “apprximately”, “and/or”, “shall be designed to”, “shall be capable of”**
  - **Remedies**
    - **Be precise.**
    - **State the real need.**

Vague Requirements Cannot Be Objectively Verified

- **What does the word "survive" mean to you?**
  - **The unit shall survive exposure to the non-operating temperature range of -40°C to +65 °C.**
- **Does it mean ... ?**
  - **The unit shall perform as specified after exposure to the non-operating temperature range of -40°C to +65 °C. Or …**
  - **The unit shall withstand, but be degraded, by exposure to …. Or …**
  - **The unit shall not present a hazard during or after exposure to ….**

The Wrong Way To Specify A Design's Capability

- **Specifying a capability of the design does not ensure that the as delivered unit will perform as desired.**
- **The following examples control the unit's design but not its delivered performance.**
  - **...the unit shall be designed to provide...**
  - **...the unit's design shall be capable..**

A unit that was designed correctly, but improperly assembled or damaged during exposure to its operating environment would technically satisfy the wording of the design requirement, but would likely fail to meet the customer's expectations.

The Proper Method for Specifying a Design's Capability

- **Poor:** The unit's design shall be capable of surviving exposure to the non-operating temperature range of -40°C to +65 °C.

- **Poor:** The unit shall be designed to survive exposure to the non-operating temperature range of -40°C to +65 °C.

- **Better:** The unit shall perform as specified after exposure to the non-operating temperature range of -40°C to +65 °C.

More Common Traps And The Means To Avoid Them

- **Multiple requirements ("shalls") per statement.**
  - **Increases risk that a requirement may be missed in the design.**
  - **May present problems in verification if the requirements have to be verified by different methods, at different times, or at different levels of assembly.**
  - **Remedy**
    - **Only specify a single requirement per statement.**
- **Use of negative or passive sense**
  - **i.e., "The system shall not perform the following maneuver when ...."**
  - **Remedy**
    - **Reword to positive statements; use active verbs.**
- **Misuse of the terms "shall," "will," and "should."**
  - **Requirements use "shall," statements of fact use "will," and goals use "should."**
  - **Terms such as "are," "is," "was," and "must" don't belong in a requirement.**
  - **Remedy**
    - **Stick with the government and industry standard defined above – to deviate from it will only invite confusion.**

More Common Traps And The Means To Avoid Them (cont)

- **Inconsistent use of phrases to reference, specify alternative courses of action, or state limitations.**
  - **Can create confusion for the reader.**
  - **Remedy**
    - **Pick a phrase and be consistent throughout a specification or family of specifications.**
      - **For example, use "as specified in" when referencing external documents, use "as specified herein" or "as specified in x.x.x" when referencing within a document.**
      - **Use "not greater than" or "not less than" when stating limitations.**
      - **Use "on Figure 1" and "in Table 2" when referencing figure and table information.**
- **Being over-stringent on parametric requirements**
  - **It is not possible to verify absolute values. Test instrumentation has finite measurement accuracy.**
  - **Remedy**
    - **Place acceptable tolerances on parameters, e.g., dimensions, weight, voltage.**
    - **Tolerances should be stated as values, not percentages.**

Cross-Referencing Requirements

- **Cross-referencing within a specification is used only to**
  - **Clarify relationship between conditional requirements.**
  - **Avoid inconsistencies and unnecessary repetition.**

- **The proper language for cross-referencing is:**
  - **...as specified herein** — **When referencing to a requirement within the spec that is obvious and easy to find (e.g., requirement is a paragraph title).**
  - **...as specified in n.n.n** — **When the requirement paragraph is not obvious or may be difficult to find.**

Example of Correctly Cross-Referenced Requirements

3.2.1.4.3 Under voltage command inhibit.

The system shall inhibit command execution when exposed to an under voltage condition, as specified herein.

3.2.1.5.1 Input voltage.

The system shall perform as specified when supplied with an input voltage of 28 +/- 6 Vdc.

3.2.1.5.2 Under voltage.

After exposure to an under voltage condition, the system shall perform as specified within 10 seconds of return to the nominal input voltage levels specified in 3.2.1.5.1. Under voltage condition is defined as input voltage less than 22 Vdc.

Example of Unnecessary Cross-Referencing

3.2.1.1.7 Output torque.

The motor's output torque shall be not less than 300 lb-ft when supplied with input voltage as specified in 3.2.1.5.1 and while the operating temperature is as specified in 3.2.5.2.2.

Cross referencing of both the operating temperature and the input voltage is unnecessary because, unless otherwise specified, performance requirements must be met in the presence of all environments. Cross referencing of the input voltage and the operating temperature by paragraph number is unnecessary because the reference input voltage and operating temperature are easy to find in the specification.

3.2.1.5.1 Input voltage.

The motor shall perform as specified herein when supplied with an input voltage of 28±6 V dc.

3.2.5.2.2 Operating temperature.

The motor shall perform as specified over the operating temperature range of -40 ^{o}C to 100 ^{o}C.

Proper Style for Writing Parametric Performance Requirements

- **No** — **The unit output voltage shall be 5 V dc.**
- **No** — **The unit output voltage shall be 5 V dc +/- 10%.**
- **Yes** — **The unit output voltage shall be less than 5.0 V dc.**

Tolerance is stated as an absolute value

- **Yes** — **The unit output voltage shall be 5.0 +/- 0.5 V dc.**

Required resolution
and tolerance are consistent.
(Number of required decimal places are consistent.)

- **Yes** — **The unit output voltage shall be not less than 4.5 Vdc and not greater than 5.5 Vdc.**

Requirements Wording Templates

- **Templates are shown for 4 classes of requirements:**
  - **Behavior/Performance.**
  - **Design Production Capability.**
  - **Design Constraint.**
  - **Process Compliance.**
- **These templates provide:**
  - **guidelines for assessing necessity and sufficiency, or completeness, of the requirement statement components.**
  - **guidance for assessing requirements quality.**

Requirement Wording Template for Behavior /Performance Requirement

The <*System_name*> **shall** <behavior> **if** <conditions>, **where** <quality factor>.

Upon <conditions>, **the** <*System_name*> **shall** <behavior> **where** <quality factor>.

Examples

- **The ATM shall reject withdrawal requests if the amount requested is not divisible by 20.**
- **Upon Operator Request, the system shall disable all audible alarms.**

Requirement Wording Template for Production Capability

The system_name shall produce <output>
for use by <nodes>,
if <conditions>,
using <inputs/outputs>,
where <quality factor>.

Examples

- **The ATM shall produce a receipt for use by bank patrons if a transaction is completed.**
- **The system shall produce a launch alert message for use by the Missile Defense Agency if a launch is detected within the programmed target area within 2 minutes of launch detection.**

Requirement Wording Template for Design Constraints

The <system_name> **shall have** <instance>
with this <feature>,
and/or <constraint>.

Examples

- **The ATM shall have an ACME 12.1-inch TFT active-matrix display.**
- **The Ground Segment Software shall be programmed in ADA.**

Requirement Wording Template for Process Compliance

The *system_name* shall be <programmatic process> in accordance with <document> where <quality factor>.

Example

- **The ATM shall be developed in accordance with ISO9001, Quality System Management Guidelines.**

NOTE:
Process requirements are typically more appropriate when placed in the Statement of Work (or Process Specification), not in a Performance or Design Specification.

Abbreviations Versus Symbols

- **From ANSI/IEEE 260**
  - **Abbreviation**

    A letter or combination of letters which by convention represent a word or a name in a particular language.
  - **Symbol**

    A symbol represents a quantity or unit that is language independent.
- **Example**
  - **Electromotive Force**
    - **Symbol** **E**
    - **Abbreviation in English** **EMF**
    - **Abbreviation in French** **FEM**
- **The US GPO Style Manual contains rules for abbreviations and symbols, along with numerous examples.**

Symbols are preferred over abbreviations – less ambiguous.

Use of Abbreviations & Symbols

- **First use of an abbreviation or symbol in a paragraph.**
  - **Spell it out in full.**
  - **Place it in parentheses after first use.**
- **Plural abbreviations.**
  - **If referring to more than one, you can put a plain "s" at the end as long as the meaning is clear. If the abbreviation is using periods, e.g., M.D., or the plural meaning will not be clear, then use an "'s" or simply spell it out. For example,**
    - **"IMUs" means more than one IMU, e.g., "The three IMUs … ."**
    - **"IMU's" is possessive, e.g., "The IMU's bias performance … ."**
    - **"M.D.'s" can mean more than one M.D., or possessive. Make sure it's clear in context.**
- **Don't:**
  - **use an abbreviation or symbol in a paragraph title if at all possible.**
  - **start a sentence with an abbreviation, symbol, or digit number, e.g., "10 minutes shall elapse … ."**
    - **Can get confused with paragraph numbers or numerically ordered lists.**
    - **Instead use "The elapsed time shall be not greater than 10 minutes … ." or "Not greater than 10 minutes shall elapse … ."**

Numbers Within Text

- **Spell it out at the beginning of a sentence and for quantities under 10.**
  - **No** **16 men were working.**
  - **Yes** **Sixteen men were working.**

  - **No** **There were 3 men working.**
  - **Yes** **There were three men working.**
  - **Yes** **There were 11 men working.**

- **Use Arabic numerals for measurements (vs. spelling it out).**
  - **No** **The nail was three inches long.**
  - **Yes** **The nail was 3 inches long.**
  - **No** **Output voltage shall be not greater than five volts.**
  - **Yes** **Output voltage shall be not greater than 5 volts.**

Exercise Caution When Using Greek Letters or Other Non-Alphabetic Characters as Symbols in Text

- **Be careful when using symbol font to create Greek letters for units, for example, "Ω" for "ohm."**
  - **When porting files between document applications, the text may get corrupted during translation.**
  - **As an example, "Ω" becomes "?" when translating from MS Word to PDF form.**

- **The safest practice is to spell the units out.**

In Summary

- **When writing effective requirements, remember the following basic concepts:**
  - **Make sure each requirement is necessary, verifiable, and achievable.**
  - **Write clearly, simply, concisely and unambiguously.**
  - **Make sure each requirement is unique and traceable.**
  - **Use only one “shall” per statement.**
  - **Specify “what’s required," not "how to do it". Don't specify a design constraint unless it’s necessary to do so.**
  - **Avoid buzz words and project-speak.**
  - **Keep the language active and positive vs. passive and negative.**
  - **Be consistent with your choice of phrasing throughout.**
  - **Don't assume the reader will know what you meant even if that’s not what you wrote.**

Recommended Government and Industry Standards, Writing Style Guides, and Literature on Writing Requirements

- **Standards for system, hardware and software specifications**
  - **MIL-STD-961E w/Change 1, Department of Defense Standard Practice, Defense and Program-Unique Specifications Format and Content.**
  - **IEEE/EIA 12207.0-1996, 12207.1-1997, and 12207.2-1997.**
  - **IEEE/EIA 830-1998 describes quality and content of a Software Requirements Specification (SRS).**
- **Writing standards and style guides**
  - **United States Government Printing Office Style Manual**
  - **"The Elements of Style," Strunk and White, 4th ed., 2000.**
  - **"The Elements of Technical Writing," Blake and Bly, 1993.**
  - **"Harbrace College Handbook," Hodges, Horner, Webb, and Miller, 13th edition, 1999.**
- **Recommended Reading**
  - **"Guide for Managing and Writing Good Requirements," Ivy F. Hooks.**