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Engineering Specification Editing Tools

Final Report

December 1993

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The techniques described are intended to help writers and reviewers of specifications identify weaknesses in their drafts more quickly, thoroughly, and accurately than in the past. There were two parts to the effort that went into their development. The first involved the "knowledge-engineering" needed in order to learn more about what makes specifications good or bad, so that the computer might be programmed to flag significant sources of potential error. The second part was experimentation with software techniques for automating the examination process. It was centered around the development of a small-scale natural language parser intended for parsing sentences that are typical in training systems specifications and statements of work. Surprisingly, for such an important subject as it is, relatively little organized knowledge was found about how to write and edit specifications. Most of the material used was borrowed from other fields.

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EXECUTIVE SUMMARY

PROBLEM

Each year, the Government spends billions of dollars on engineering changes, contract claims, and modifications to recently purchased items. In many cases, these costs could have been avoided if weaknesses in the specifications were found and fixed before entering into contracts.

OBJECTIVE

The techniques developed under this Independent Exploratory Development are intended to help writers and reviewers of specifications identify such weaknesses quickly, thoroughly, and accurately.

APPROACH

There were two parts to the effort on this project. The first involved a continued search for literature that relates to specification writing. It also involved gathering examples of specification errors by examining drafts of specifications. This "knowledge-engineering" was needed in order to learn more about what makes specifications good or bad, so that the computer might be programmed to flag significant sources of potential error.

The other domain was experimentation with software techniques for automating the examination process. It has been centered around the development of a small-scale natural language parser intended for parsing sentences that are typical in training systems specifications and statements of work.

FINDINGS

Surprisingly, for such an important subject as it is, there is relatively little organized knowledge about how to write and edit specifications. Much material was borrowed from other fields, and some of it is more useful to human reviewers than to electronic ones. A great deal of the knowledge gathered consists of the awareness of many linguistic minutiae, any one of which could lead to a serious contract dispute.

We have found that a relatively simple parser yields information on sentence structure sufficient to generate reasonably accurate warning messages about certain error-prone types of syntax. In addition, we have found that data extracted by the parser can be used to facilitate checking the entire document for explicitly conflicting requirements.

CONCLUSIONS

Appendix C of this report sets a standard for elimination of the types of errors commonly encountered in specifications. In doing so, it provides information not furnished by the existing applicable standards, MIL-STD-490A and MIL-STD-961C. Considering the stringency of Appendix C, one may readily conclude that writing high-quality specifications is a task that requires an uncommonly high level of literacy, a great deal of specialized training, and the help of cognitive tools like those developed on this project.

RECOMMENDATIONS

In light of what has been learned on this project, it is recommended that the knowledge-engineering effort regarding specification writing be conducted on a continuing basis. It is further recommended that additional research be conducted to apply emerging technology to the specification quality problem. Finally, it is recommended that the parser software developed under this effort be ported to the Windows environment so that syntactic ambiguity warnings can be made available to users of the Joint Acquisition Management System (JAMS).

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Engineering Specification Editing Tools

I. INTRODUCTION

Problem

The process of purchasing goods and services under contract is lengthy and complicated for many reasons. In the course of going from the need to the delivered goods and services, a great quantity of written matter is produced. All this paperwork serves the purpose of communicating information to a large number of people with a wide variety of responsibilities. Among the most important procurement documents are those that describe in detail the goods and services to be delivered (Richardson, 1990). These are engineering drawings, engineering specifications, and statements-of-work. Specifications and statements-of-work nearly always consist of sparsely illustrated text. They may or may not be accompanied by a set of drawings. For the purposes of this discussion, the text portion of these documents will be referred to collectively as specifications. The specifications discussed here are informal specifications. There is no intention for them to be as complete and rigorous as the formal specifications discussed by computer scientists. They are intended to describe only those features of the end item that bear upon fitness for its intended purpose.

Specifications are like any other work product. They are the result of applying labor to raw materials, producing a new item with added value. They are subject to defects just like other products. Where they differ from most other products is that, in addition to being products themselves, they describe products as well. In the language of the computer scientist, they are "meta-products".

Each defect in specification will result in one of five possible events. These are:

a. The error will go unnoticed or will be gratuitously corrected by the reader, and have no effect on the end item.

b. The error will be embodied in the end item, causing it to be unfit for its intended purpose, though not defective under the terms of the contract.

c. The error will conflict with another portion of the specification, creating a situation known as "impossibility of performance."

d. The error will cause the end item to have an unneeded, but otherwise harmless feature, and be lacking a needed one.

e. The error will be found and formally corrected after contract award.

The final result of all outcomes except the first is cost growth. In practice, the majority of defects lead to the first outcome. This is fortunate, since such defects are far more common than one might expect. In reviewing numerous specifications, it is not unusual to find at least three or four defects per typed page. While this number seems appalling, the author finds it encouraging that so many contractors exercise goodwill in dealing with specification errors rather than using them to financial advantage whenever possible. Usually such errors become problems only when the project is beset by financial or technical difficulties. At such time, their effect is to make the contract virtually unenforceable.

Purpose

The information gathered and techniques developed under this Independent Exploratory Development (IED) project are intended to help writers of engineering specifications identify defects in their work quickly, thoroughly, and accurately, so that they may be corrected as early as possible.

Background

Literature covered on this topic comes under six subject headings:

a. Rhetoric,

b. Technical writing,

c. Legal writing,

d. Engineering specifications,

e. Natural language processing, and

f. Philosophy of science.

There is a large body of widely read literature dealing with the skill of expressing oneself well, both on general rhetoric and on technical writing. Many of the types of errors found in specifications are addressed in it (Bly and Blake, 1982, Strunk

and White, 1979). But the task of drafting specifications requires knowledge beyond that level. Books on legal writing discuss some topics that are very important to specification writers, like the correct use of commas (Block, 1986), but they aim to cover a broader subject than specification writers need, and pay little attention to the many sources of ambiguity in the English language that are of important concern in specifications.

Literature on specifications per se comes from two discourse communities: the construction industry and the systems management community. Despite the fact that a difference between the two is sometimes indicated by authors from both camps, there is no genuine need to make such a distinction. Contracts for civil engineering works are governed by the same principles as contracts for any other kind of engineering. Likewise, civil engineers deal with the same laws of nature and the same economic realities as all other engineers. Consequently, literature from both sources should be regarded equally.

On the whole, they both tend to lean towards discussion of what might be called macrostructure - format, organization, sources of information, types of requirements, mandatory requirements, and other topics not related directly to the words and sentences from which actual documents are built. They usually talk only briefly of microstructure, covering particularly the distinction between the meanings of the words "will" and "shall". A notable exception to this brevity is found in Henry Henkin's book Drafting Engineering Contracts (1988), which devotes about forty pages to microstructure. Some of Henkin's examples illustrate the very same phenomena of the English language that are well-covered in literature on automatic processing of natural language, which was examined initially for information on how to program the parser. Hence the review of literature from that source (e.g. Winograd, 1983) was expanded in search of more examples and better explanations of the sources of ambiguity in the English language.

The pursuit of absolute rigor in the definition of terminology, because of its importance in the natural and social sciences, has been investigated at great length by some of the leading scientists of our times (Hempel, 1966), and published under the subject heading "Philosophy of Science." Certain topics from that work are highly applicable to the specification problem, notably Bridgman's concept of operational definitions.

Organization of this Report

Section II is based on an earlier document that has been updated to reflect the information collected in the course of the project. It provides a description of the types of errors that may be found in specifications, and theorizes about conditions that may contribute to their likelihood. Appendix A contains a more detailed hierarchy of the error types described. Section III is a description of the exploratory software development performed as part of the project, and Section IV discusses some theoretical aspects of specifying that were encountered. Appendix B is a detailed list of words, phrases and syntax that are likely to be associated with specification errors. Appendix C is a guide for specification writers based on the material presented in Section I.

II. TYPES OF ERRORS AND THEIR CAUSES

Developing a nomenclature for errors

Our research on specification defects started out as an effort to develop computer software that would provide some assistance to writers of engineering specifications. The aim was to shorten the time needed to develop a set of specifications while enhancing its quality as well. While much has been accomplished along those lines, it has become evident that there are many factors affecting specification quality that require remedies other than those that can be provided by computer software. The purpose of this report, therefore, is to document what has been learned about specification defects, as well as to discuss computer software that may help editors to recognize and correct some of them.

To design software that would help locate errors in draft specifications, it is first necessary to know what types of errors occur in such text. In an attempt to make such a determination, drafts of engineering specifications from a variety of sources have been examined. From the data gathered, the types of errors likely to be found in specifications seem more or less consistent, regardless of the document's place of origin. Furthermore, the types of errors described below have been found to occur almost as frequently in documents that are already released and in use as they do in drafts. In an effort to document the knowledge gained, a list was made of 26 types of defects commonly found in specifications. These types were grouped into seven major categories. Each of the categories is described briefly in the following paragraphs. A complete list of the 26 types of defects is given in outline form. For each type of defect, a list was made of likely reasons why the development process may produce such a defective result. Many of the reasons apply to more than one type of error. When summarized, the list consists of 22 factors affecting the quality of engineering specifications. Both complete lists are represented jointly in Table I. The information presented in the lists, though more detailed and organized differently, closely parallels the experience documented by McRobb (1989).

Categories of Errors

The sections that follow are brief descriptions of seven general classes into which the 26 commonly found types of defects may be grouped. When considering a specific error observed in practice, it was sometimes difficult to decide how the error should be

categorized, since many observed errors could fall into more than one category. To that extent the grouping is subjective.

a. Organization Errors

Organization errors are defects that would prevent an experienced reader from locating a specific piece of sought-after information in the document. Since nearly all specifications are organized according to a standardized outline like those given in MIL-STD-490A (AFSC, 1985), there are only two ways to make an organization error. They are by stating a given requirement in the wrong place and by numbering the paragraphs incorrectly. Organization errors may not be serious in themselves, but they contribute to the likelihood of inconsistency errors and injure the specifier's credibility. They also create confusion when each person working on the project has access only to the portion of the specifications that are deemed by "higher-ups" to be relevant to his or her part of the job. Such practice is common in industry, and is mandated by security rules on sensitive work.

b. Reference Errors

Reference errors are cases where the text refers to another paragraph, an illustration, table, another document, or an acronym that cannot be readily found by the reader. The referenced item may be inaccessible for a number of reasons. The most common type of reference error occurs when a document cites one of its own paragraphs. The reference starts out being correct, but goes awry when part of the document is moved and renumbered, as so often happens during development. Also in this category are cases where the referenced document does not contain the information cited. A computer program called PARANA (Oriel, 1989) is available to facilitate the location and correction of reference errors.

c. Incorrect Requirements

Several times, requirements have been found that, upon investigation, turned out to be incorrect in substance. They were identified as belonging to four categories:

(1) Text wrong for logical reasons,

(2) Text wrong for practical reasons,

(3) Violations of law or regulations, and

(4) Numbers or units-of-measure wrong.

Incorrect requirements of the first three types may be extreme cases of incorrectly expressed requirements. In these cases, what was inadvertently expressed seems plausible as something the writer might have actually wanted to specify.

d. Incorrectly Expressed Requirements

One of the most common kinds of errors found in the specifications studied was failure to state the requirements clearly, correctly, and concisely. While the project engineers responsible for specifications are usually much better writers than many other types of professionals, skill at clearly describing complex equipment seems to be rare. Furthermore, since most of the text had ostensibly been edited, one may also conclude that the errors were missed by more than one reviewer. Hence it is possible either that the reviewers are not recognizing the defects, or that the text had not been edited as claimed. Most likely, what happened was a combination of both. Editing documents of such a nature as engineering specifications is tedious work, even with the help of state-of-the-art computerized assistance. It requires specialized skills possessed by relatively few engineers, as well as the time and patience to do the job well. Editing specifications may also require the objectivity of a person not encumbered by preconceived ideas about the specified items. One difficulty in employing such persons as editors, however, lies in the fact that such a person is usually intimidated by the technical nature of the text and is reluctant to criticize it.

A major cause of incorrectly expressed requirements is the misuse of certain words and phrases. Considerable progress has been made towards reducing errors in word usage by the use of a specialized personal computer program called SpecTrE. SpecTrE checks the text for strings belonging to a prescribed set of commonly misused words and phrases. Appendix B contains a list of such words and phrases. Enhancing the performance of programs like SpecTrE and finding new methods that they might use was the main aim of this exploratory development project. Figure 1. illustrates the relative frequencies of misuse of some words that are often found in specifications. The frequencies vary considerably from sample to sample, according to the writer's skill level.

Another important source of error along these lines is the manner in which terminology originates. The creation of new

terms and the use of old terms in new ways are a normal part of everyday speech communication, and are habitual unconscious behavior. Relatively few persons seem to have cultivated an awareness of their normal tendency to behave in such a manner, but doing so is essential to becoming a good technical writer. Each term used in technical documents must be traceable to a single authoritative source so that every reader will associate the same meaning with the term. Otherwise, the term may be misunderstood. Even a writer who is aware of the terminology problem may be confounded by the large number of terms present in specifications and may inadvertently use one in a confusing manner. Some progress towards a means of making specification writers aware of such potential misunderstandings is reported under "Remapping of information," in Section III below.

Other ways in which language is often misused in specifications are covered in Section III under "Usefulness of syntactic information."

e. Inconsistencies

Inconsistencies are among the most difficult errors to identify, since doing so in an exhaustive manner would require checking each specification requirement against all the rest for expressed as well as implied conflicts. They usually occur because of the large size of the document, and human inability to remember the entire content. Another cause of inconsistency is the use of inconsistent terminology, called elegant variation, which is taught in the schools as desirable in other forms of writing, but which is unwise in technical and legal writing. Some progress on a method that makes a large class of inconsistencies easier to find is reported in Section III, under "Remapping of information."

f. Poor Business Practices

The use of what are considered poor business practices is one of the simplest of the seven categories to identify in practice. There are four types that are often erroneously used in contracts. These are:

(1) Specifying agreements-to-agree (NAVMAT, 1978),

(2) Warranting suitability of an item for a specific purpose (ASBCA, 1967),

(3) Specifying by vendor and part number (ASBCA, 1967), and

(4) Specifying design when specifying form, fit and function would suffice (Clough, 1975).

g. Omissions

Omissions from the generic sections of specifications are surprisingly easy to catch. An experienced reviewer easily notices that certain routinely required items are missing. On the other hand, missing requirements that are peculiar to the item being specified are very difficult to recognize.

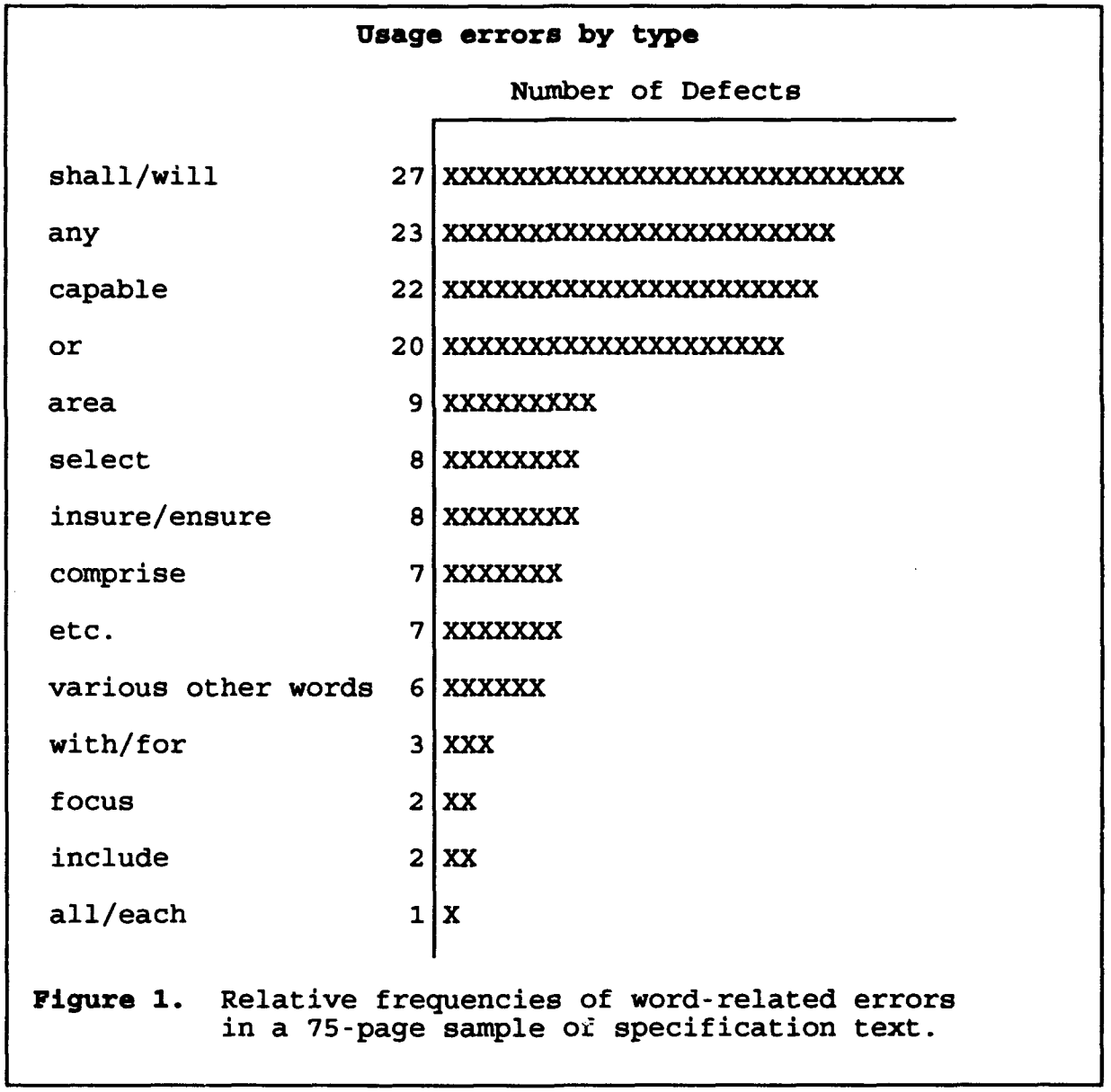

Figure 1. Relative frequencies of word-related errors in a 75-page sample of specification text.

UNDERLYING CAUSES

DEFECT TYPE	1 Piecing documents together from multiple sources	2 Lack of editing	3 Changes made to document, numbers not updated globally	4 Lack of use of available software tools	5 Indiscriminate copying from boilerplate	6 Failure to read the cited document	7 Failure to check revision status of documents	8 Lack of acronym glossary in large document	9 Writer does not know the meaning of the acronym	10 Inadequate front-end analysis	11 Specifier's technical knowledge is inadequate	12 Weak verbal skills	13 Writer does not understand the intended req't	14 Sentence too complex	15 Non-committal attitude	16 Overdependence on automated spelling checker	17 Negative training in verbal skills	18 RDT&E in production contract	19 Inadequate training in contract admin.	20 Paradigms encumber human thought process	21 No standard outline and boilerplate	22 Short schedule
Wrong section	x	x																			x	
Paragraph numbering			x	x																		
Cross-references			x	x																		
External references				x	x		x	x														
Figure references			x		x																	
Undefined acronyms								x	x													
Subject matter wrong					x					x	x											
Logically impossible	x											x	x									
Impossible, other										x												
Numerical requirements	x									x												
Illegal	x					x				x												
Incorrectly stated												x		x						x		
Non-specific words			x							x		x			x							
Nonsense	x											x										
Grammatical errors	x											x		x								
Incorrectly used words	x		x									x										
Ambiguities	x		x									x										
Spelling errors	x		x													x						
Self-contradictory	x	x																				
Synonyms		x															x					
Agreements-to-agree										x								x	x			
Warranting suitability																			x			
Specifying make & model																			x			
Design vice performance												x							x	x		
Missing	x									x											x	
TBD's in text	x																					x

Table I. Types of specification defects related to their underlying causes.

The Underlying Reasons for Defects in Specifications

The 22 reasons described below are suggested for the occurrence of the above-mentioned types of errors. A brief description is given for each. These are correlated with the error types in Table I. While some of them can be verified by simple deduction, many of the reasons listed are based on informal observations made in the course of professional practice, and therefore deserve only the status of untested, but carefully chosen, and probably true, hypotheses.

It is evident from Table I. that the dominant causes of error are lack of editing and weak verbal skills. Upon this basis the search for automated editorial tools is justified.

a. Piecing together documents

Usually, specifications are not written from beginning to end by a single person. Instead, the lead engineer delegates the writing of numerous sections to specialists, who may not be aware of the overall goals of the project, and may have parochial views about certain requirements. The lead engineer is faced with the difficult task of fitting all these pieces together, finding all the places where they may conflict, and adjusting them to be correct and consistent with each other.

b. Lack of editing

Most published matter must undergo several rigorous rounds of editing before it gets into print. Often it is substantially changed by rewrite editors. Such care is not often taken with engineering specifications. In most engineering organizations, comments on the draft are sought from senior engineers and engineering managers. The specifier then rewrites portions of the document in response to the comments. Usually, very little is altered from what was written in the first draft.

We believe that there are several factors at work diminishing the value added by such an engineer-only editing process. First, editing is a special skill, requiring talent and training. While a few engineers may have the talent, even fewer have done anything to cultivate it. Hence it is unusual for an engineer to notice and flag errors in grammar, usage, and consistency that a skilled editor would catch.

One possible explanation for why so few incorrectly stated requirements are caught is that all of the reviewers are persons of very nearly the same mind-set as the specifier.

Their paradigm for what is correct in specifications is the same as that of the writer, and, by virtue of nature's design for the human mind, they are unable to recognize many defects that might be easily seen by a person of different mind-set.

One way of solving this problem would be to use technically trained reviewers who are not familiar with the subject matter of the specification. Such persons must be given sufficient time to acquire the knowledge needed to fully understand the text as a part of the editing job. Doing so would amount to making a trial run on the specification. Such an approach may have a natural limitation in that the reviewers may no longer be effective editors once they acquire a thorough knowledge of the subject matter.

c. Incomplete changes

Often, when a document is in nearly finished form, a change is made in a single location, and the document is not searched for other text that may be affected by the change. A simple example is the case where an entire paragraph is added or deleted, and the resultant renumbering sets askew all of the cross-references that refer to the renumbered paragraphs.

d. Lack of use of available software

Many writers of specifications are not aware that specialized software is available off-the-shelf or can be easily developed to ease their workload and enhance the quality of their product. Many of the commercially available style checking programs, all of which are descendents of CRES (Kincaid et al, 1982) allow users to supplement their inspection and annotation rules. PARANA checks paragraph numbering, cross-references, and references to military specifications and standards. ASSIST (NAEC, 1986) checks the specification tree to the fifth tier for currency. As well as these application-specific tools, there are some little-used features in the available word processors that can eliminate certain types of errors. An example is the automatically updated paragraph cross-references in some of the newer word processing programs.

e. Indiscriminate copying from boilerplate

While the availability of specification boilerplate greatly enhances the writer's productivity and the quality of the work, it may also introduce errors because of the blind trust that may be placed in it. There is a tendency to copy the

boilerplate in its entirety into the document being prepared, and not tailor it to the specific application. All boilerplate must be checked for relevance and for consistency with the rest of the document. McRobb (1989) gives an example in which a boilerplate outline has been applied verbatim, producing a monstrous result.

f. Failure to read the cited document

In order to properly cite a specification or standard, a writer needs to be familiar with its content. A classic error of this sort was often found in citations of DD-G-451D, a general specification for sheet glass products, which was used for many years until it was cancelled in 1986. Many specifications that cited it said merely that the glass had to conform to DD-G-451D. Persons who actually read DD-G-451D found that it was a general specification defining the grades of glass, from the most flawless plate glass for mirrors down to greenhouse-quality glass which needed only to be translucent. So in many cases, unbeknownst to the specifier, contractors had the option of using the very cheapest grade of glass available, greenhouse glass, regardless of the application.

g. Failure to check revision status of documents

Even though the specifier may be familiar with the content of the specifications and standards to be cited, a current index must be checked to determine the status of the document. Doing so is a relatively simple clerical task and may be delegated to non-technical personnel. Failure to check this seemingly minor detail often results in expensive claims from contractors who are unable to meet a stated requirement, but expend a great deal of effort trying to do so. A good example is the case where a contractor spent a great deal of time and incurred delays trying to find a large quantity of an obsolete part that was unwittingly specified.

h. Lack of acronym glossary in large document

The normal practice in preparing documents is to define each acronym the first time it is used in the text. This is done to be sure the reader will not be puzzled about what the acronyms mean. When the document is only a page or two long, it's easy to scan backwards and find the places in the text where the acronyms are defined. In a hundred-paged document, it may take hours to find just one definition. One solution to this problem is to put a glossary of acronyms in the document where

it is easy to find. It is relatively easy to check the text to make sure each acronym appears in the glossary. Specifications of more than about twenty pages should always have an acronym glossary. Such a glossary has been added to this report so that the author cannot be accused of ignoring his own advice.

i. Writer does not know the meaning of the acronym

Often an acronym is so overused that people have seen and heard it enough times to form a concept of its meaning while never having seen it formally defined. They begin to use the acronym in their speech and writing to convey their own concept of its meaning, which is not necessarily the meaning intended by the person who coined the acronym.

How many times in meetings where acronyms are being bandied about have you heard someone interrupt the discussion with the question "Pardon me, but I'm new to this topic. Could someone tell me exactly what XXXX means?" Usually, no one in the meeting is able to give a satisfactory definition of the acronym, and all but one person looks like a fool.

Whenever an acronym is found to be undefined in a draft document, the reviewer is advised to check all usages of the acronym carefully for errors in meaning, because if the drafter knew the meaning of the acronym, in all likelihood, it would have been defined in the text.

j. Inadequate front-end analysis

The message here is simple. It's tough enough to write good specifications when you thoroughly understand what is to be specified. It's impossible when you don't.

k. Specifier's technical knowledge is inadequate

This situation is similar to the case of inadequate front-end analysis. Usually, a technical specialist is available to assist in the writing of specifications in technically difficult domains. When such help is available, the defects are caused by failure to use the available help.

l. Weak verbal skills

Strong verbal skills are absolutely essential for engineering specification writing. The English language is rich in pitfalls of impreciseness and ambiguity. The linguists Katz and Fodor are reported to have said that it is not possible to make an English statement that is totally unambiguous (Obermeier, 1989). To avoid the pitfalls, specification writers need to possess a large inventory of alternatives for expressing their ideas and always choose the one that is least likely to be misunderstood. Unfortunately, the verbal skills of engineers are not cultivated adequately by the education system, and most come out of school with a relatively small bag of writing tricks (Vaughan, 1991). Engineers are usually perceived as people who communicate mainly through graphics, and spend most of their time working with equipment. Often, as students, they look upon English class as a senseless waste of time forced upon them unnecessarily. This may be true for an engineer who wishes to spend an entire career doing detailed design work, but such people are very few in number. While project engineers who prepare specifications rate well above most college graduates in writing skills, there is still a need to raise those skills to even higher levels.

m. Writer does not understand the intended requirement

This is closely allied with poor front-end work and lack of technical expertise, but can happen even though both are excellent. It tends to happen when the front-end work is done by a different person from the one writing the specifications.

n. Sentence too complex

Writers of specifications tend to lose sight of how long their sentences are. They add clause after clause until they've arrived at a sentence that expresses their thoughts exactly. Long before the sentence is finished, it has grown so complex that it's beyond its creator's ability to comprehend (Flesch, 1946). Ignoring for the moment what this does to the reader, a sentence so built often contains syntax and usage errors. This is because it takes too long to read. By the time you get to its end, you've forgotten how it began. Parsing so long a sentence takes a studied effort, and no one but an English professor or a lawyer ever does such a thing. The reader, of course, approaches the text with no prior knowledge of what the writer intended. Losing his or her train of thought in reading a long sentence, the reader starts over and tries again, and keeps doing so until the text is understood. When the sentence

has an error in grammar, the reader probably will not be able to figure out what the writer meant.

o. Non-committal attitude

Reluctance to make binding commitments is fundamental to human nature. It stands to reason that in order to feel confident when making a commitment, you need to take the time to study what the commitment involves. Once you've done so, you're sure you'll be able to live up to your word. Specification writers are likewise inclined to avoid making commitments because they usually don't have the time and information to do the studying. In addition, there are too many reasons beyond their control why they may not be able to live up to their commitments. When they do make a commitment, it is usually accompanied by many qualifications and warnings.

The business of writing engineering specifications runs contrary, then, to our very nature with regard to making commitments. Specifications are necessarily definite and concise. Writing them involves making a large number of binding decisions about the items being purchased.

p. Overdependence on automated spelling checker

When an automatic spelling checker is used to check a document, it does not read the document and understand its content. Hence, when it finds a phrase like "pilot icing" where the writer meant "pitot icing", the error goes unflagged and uncorrected. Such occurrences were found to happen about once in a hundred typed pages. They may be extremely damaging. In one specification paragraph, the word "preclude" was found where "provide" was intended, evidently a typo. The resulting sentence was a clearly stated requirement that the equipment be built so it didn't work properly. It went unnoticed through all the normal reviews.

q. Negative training in verbal skills as taught in the schools

It seems incongruous, but, in our commercial society, the communications skills are being taught from the point of view of people who aspire to write literature. Hence, some writing practices are taught in English class that do not apply to specifications. Such teaching creates a distinctly different situation than that discussed under "Weak verbal skills," above. The possession of certain perfectly good skills for literary writing may interfere with the production of high-

quality specifications. The most outstanding one is avoiding the monotonous repetition of words by using synonyms. Engineers who have had their specifications criticized by a lawyer will attest that keeping the terminology rigidly consistent is far more important than writing lively prose. Another often-taught practice is the use of sentences that vary in structure. Simple declarative statements are the best for specifications.

r. RDT&E in production contract

In recent years, there has been pressure to use fixed-price contracts, with the expectation that fixing the price at contract award will reduce cost growth. This practice has forced many contracts that involve extensive engineering development and testing and the normal accompanying uncertainty to be let as fixed-price type contracts. Once the work is under way, it progresses more-or-less as it would under a cost-plus contract, except that the cost growth occurs in a contentious and uncontrolled manner. Very few engineering managers seem to realize that they are fully able to avert this type of problem by taking a firm stand to the effect that the contract involves RDT&E, and should be funded and managed accordingly.

s. Inadequate training in contract administration

There are a few topics in contract administration that bear on the writing of engineering specifications that, for some reason, aren't being adequately taught to writers of engineering specifications. This lack of training results in the Government's use of widely recognized poor business practices, and consequent waste of money.

t. Human thought process

The engineer's paradigm of the equipment being specified and of the specifications themselves tends to be a limiting factor in his or her ability to perceive specification defects. This is a specific case of a well-known phenomenon of the human mind that is often thought to be caused by the presence of adaptive filters in the human information processing system (Dodd and White, 1980).

The filtering problem affects the writing process as well as the editing process. Engineers tend to think more in terms of the design of hardware and software rather than in terms of its

desired performance. It is very hard for someone who has been trained to think in terms of hardware to practice restraint in telling the designer how to build the system, and confine the specifications to a description of what the equipment has to do. This limitation may arise from the lesser degree of meaningfulness present in the terminology of performance specifications. Further discussion on this topic appears below under "IV. ADDITIONAL FINDINGS."

u. Failure to use standardized outline

There are several standardized specification outlines in use. It is important to choose the one usually used for similar work. Good judgement must be exercised about how to tailor it to the specific application. For training devices, the standard outline is taken from MIL-STD-490A. Boilerplate specification paragraphs save labor and promote uniformity from one purchase to the next. Organizations that are committed to the idea of providing their engineers with good boilerplate specifications have also developed explanatory material to accompany each paragraph of boilerplate.

v. Short schedule

Lack of enough time is the most often used excuse for failure to do a good job. Surprisingly, the research revealed only one type of defect that is directly attributable to short schedule. That was cases where "To Be Determined" or "TBD" was found imbedded in the text of a supposedly finished document. Other defect types may be indirectly attributable to short schedules, but those would be attributed in this scheme to one of the other reasons, like insufficient editing.

III. SOFTWARE DEVELOPMENT

Parsing Sentences

The development done under this project has been similar, with one important difference, to the ongoing work being done by commercial software houses in pursuit of a credible "grammar and style checker" program. Most personal computer users have tried such software, and many have decided that it does not perform especially well. Often, when a commercially available grammar checker generates a comment about syntax, the comment is erroneous (Bates, 1990). The difference between such software and that developed under this project lies in the character of the text being analyzed and the diversity of errors pursued. The grammar and style checkers search for a great number of possible faults in sentences with practically no bounds to their meaning. On the other hand, the specification-tool software seeks relatively few possible faults in text limited to the relatively routine language of specification requirements.

Another difference between the objectives of this project and the mainstream of editorial software developers is best understood by contrasting it with similar exploratory development done by Kieras. Kieras has developed advanced editorial software that incorporates a parser and a set of editorial rules with the aim of helping writers produce text that is easy to comprehend (Kieras, 1990). Our aim has been to help writers produce text that is more difficult to misinterpret, which is not the same, since readers of specifications often consciously seek alternate interpretations in an effort to minimize costs.

After determining that none of the personal computer software packages available at the time permitted users to access the needed syntactic data, a suitable parser was developed. The parser itself is not the topic of primary interest, but since a good deal of effort went into its development, a few words about it are in order.

The parser developed as part of this investigation is best described as an augmented chart parser. The name "chart parser" means that it operates first by building a table of all the well formed substrings (WFST) in the sentence, and then by traversing, one at a time, each possible syntactic tree contained in the WFST. "Augmented" means that, while building the WFST, the grammatical rules are not applied in a simple rote manner. Instead, each time a decision is made to apply a grammatical rule, the parser is given the option of executing a special subroutine that examines numerous aspects of the situation before deciding whether or not the rule should apply. The grammatical

rules, then, are applied in a more comprehensive manner than they would be in a simple context-free parser.

The parsing decisions are based on information drawn from a lexicon, which contains an entry for each recognized word. The lexicon was built from a pre-existing one by incorporating new data regarding the parts of speech that each word may take, as well as a variety of other information of use in the decision process. The lexicon of about 5400 words was originally compiled by reducing several complete sets of specifications to word lists and merging the results. Information on the parts of speech was extracted from a purchased data base, and then reworked manually, using a learner's dictionary as a source for additional information regarding parts of speech, transitivity, and countability.

The grammar was custom built to parse the types of sentences found in specifications. A basic set of rules was first written using some published grammars as examples (Sager, 1981; Mayer and Kieras, 1987). Both the lexicon and the grammar were fine-tuned for specification analysis by exercising them on a large corpus of specification text, and revising each as necessary to enhance the accuracy of results produced.

Each grammar rule, in addition to the rule itself, carries a flag that is used to create a pointer to the central word of each well-formed substring. For example, in a prepositional phrase, the pointer points at the object of the preposition; in a noun phrase, it points at the main noun. This feature was added to permit the software to reduce the sentence to kernels, which were used in one of the experiments described below.

From experience in testing commercially available grammar checkers, it appears that the syntactic parser is performing at least as well as the parsers used in the best of such packages.

The usefulness of syntactic information

The original motivation for implementing the parser was to resolve uncertainties encountered in flagging words that may be used as more than one part of speech. In those cases, data extracted from sentences by the parser provide a more certain determination of the part of speech for each word.

It was somewhat of a disappointment, though, that relatively few cases occur where the data can be actually used productively. They serve to eliminate only a small number of unnecessary comments--a proportion far smaller than what would justify the complexity of the added software.

In the course of reading literature on Natural Language Processing (NLP), which was a prerequisite to programming the parser, discussions were found of syntactic ambiguity that contained more detail than those in any known source on composition. It seems surprising that such knowledge gained in the study of linguistics has not been carried over into rhetoric, but, by all accounts, that does indeed seem to be the case. The appropriate action was to make a list of syntactic forms that might be of concern to specification writers because of the ambiguities they may generate. A set of example sentences was also developed to illustrate each member of the list so it could be understood by the non-grammarian engineers in the intended audience. That list is documented in Appendix B.

Because the list contained types of ambiguous syntax that were not positively identifiable by the computer, it was shortened to the forms that were positively identifiable, and tests for them were implemented in the software. The syntax types removed from the list were: "ellipsis and gapping," which causes the parser to report that it has encountered a sentence fragment, and "adjacent phrases lacking a clear boundary," which the parser erroneously bundles together as a single phrase.

Examining the specification corpus with the help of the new software, many opportunities for ambiguity that formerly escaped notice became evident. The most commonly encountered among the forms that generate ambiguity are the cases where a modifier either may or may not act across a coordinating conjunction. Examples of ambiguity of that type abound in nearly every document examined. Another type, the ambiguous string of prepositional phrases, seems to occur in specifications mainly in conjunction with the phrase "for use..." Therefore, the test for it can be implemented very easily in software like SpecTrE, which has no parser.

Semantics of surrounding text

As mentioned above, an investigation was done to gain some knowledge about whether or not semantic information contained in surrounding text could be used to distinguish relevant flags from irrelevant ones. Early in the development of spec-writers' software, the testing was implemented for nearby words and phrases to reduce the number of erroneous flags. It was found that approximately ten percent of the erroneous flags could be eliminated. Tests in the early software were limited to:

a. the presence of certain words within a few words of, or immediately adjacent to the flagged item, and

b. presence of a certain word somewhere within the sentence being examined.

This investigation involved using the parser to extract the noun phrases from the sentence and the paragraph being examined, and making them available for use in deciding whether or not to print a comment when a sensitive word or phrase was found.

The scheme was conceived with the full expectation that there would be sensitive words and phrases in the existing ruleset that were not sensitive in certain cases because of the topics being discussed in their context. However, once the software was implemented, and the consequent rigorous definition for those cases had been established, the search for actual cases in which the new capability could be used was found to be fruitless. The hypothesis regarding the usefulness of semantic information in surrounding text is untrue in terms of the test applied.

As a result of the ensuant search for explanations as to why the hypothesis was untrue, it was decided that the rules were set up mainly to flag words that had little or no meaning to begin with. Those sensitive words that had definite meaning already had exception rules, and didn't need additional ones. In cases where a "meaningless" word had an exception rule, the exception rule tested for a definite word modifying the meaningless one. For example, "high" alone is meaningless; "Eight inches high" is not. Furthermore, the sensitive words had intentionally been chosen as words that had a high likelihood of being troublesome regardless of where they were encountered in a set of specifications.

This line of reasoning suggests that the problem ought to be approached from the other direction, making a list of topics likely to appear in specifications, and then, under each topic, make a list of words that might be sensitive in that context. The resulting list could then be tested on the corpus to see if any bugs were discovered. Investigation of this possibility remains to be done. One possible problem is forseeable with rules developed in such a manner: they will probably be policy related, and likely will require regular maintenance.

Re-mapping of information

Two other possible uses of the parser in the analysis of text were investigated. The first of these is potentially very useful in checking large specification documents for consistent use of terminology and consistency of requirements. It uses the parser to identify and log each noun-adjective group found as it processes the entire document from beginning to end. Logged along with each noun-adjective group are the paragraph number,

the sequence number of the sentence, and a copy of the entire sentence in which the noun-adjective group appeared.

The resulting file is sorted by the main noun of each noun-adjective group, with subordinate sort keys being the first and second words of the group. The sorted file is both an index to the text and a re-mapped copy of the text that allows the reviewers to examine every occurrence of each term in close proximity to every other occurrence. While it is similar to the familiar Key Word In Context (KWIC) index, there are two significant differences. First, the new index contains entries based only on noun-adjective groups, and second, each entry contains a complete copy of its sentence of origin. With such a listing, a sample of which is shown in Figure 2., it is not necessary for the reviewer to remember what was said about each topic elsewhere in the document.

Since the mapping is one-to-many, a listing of this file may be separated into sections and parcelled out to several editors without sacrificing the completeness of the examination.

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TERM	S. NO.	PARA.	SENTENCE
computer, dafcs	288	3.3.10	The DAFCS Computer shall not be supplied .
computer, digital automatic flight control system	289	3.3.10	However , the Attitude Hold functions normally performed by the Digital Automatic Flight Control System (DAFCS) Computer shall be simulated through the use of trainer peculiar electronics .
computer, iff transponder	74	3.2.1.2.3	In addition , the IFF Transponder Computer shall not normally be installed on the trainer .
computer, iff transponder	75	3.2.1.2.3	However , the trainer shall provide all the cabling and connectors necessary for normal IFF Transponder Computer operation as well as installation of the IFF Transponder Computer Mount .
computer, normal iff transponder	75	3.2.1.2.3	However , the trainer shall provide all the cabling and connectors necessary for normal IFF Transponder Computer operation as well as installation of the IFF Transponder Computer Mount .
conclusions	721	4.3	Analysis may take the form of the technical evaluation of accumulated results and conclusions (design equations , structure analysis , data , charts) , intended to provide proof that verification of requirements has been accomplished .
conditioning, output power	327	3.4.1.1.3	3.4.1.1.3 Output Power Conditioning .
conduction, electrical	687	3.4.15.9	Finish and / or protective coatings shall be applied to all surfaces where required for consideration of appearance , personnel safety , electrical conduction , and protection against corrosion or other deterioration .
cone, a simulated tail	104	3.3.1.1	A simulated Tail Cone shall be added from Station 485 to Station 550 .
cone, actual aircraft tail	105	3.3.1.1	The simulated Tail Cone shall be used to mount all of the antennas and sensors normally located aft of Station 485 on the actual aircraft Tail Cone .
cone, simulated tail	105	3.3.1.1	The simulated Tail Cone shall be used to mount all of the antennas and sensors normally located aft of Station 485 on the actual aircraft Tail Cone .
cone, tail	225	3.3.1.2.5	3.3.1.2.5 Tail Cone .
configuration	260	3.3.3	The WOW functions associated with the External Bypass Panel shall operate identically to the actual aircraft regardless of the configuration of the Flight Simulation Input Panel .
configuration	682	3.4.15.7	The mounting configuration of the trainer peculiar equipments , systems and subsystems shall consider placement based on optimum heat dissipation , maximum interconnection lead arrangement flexibility and proper space utilization .
configuration, pin	533	3.4.4.1	If an equivalent connector does not exist , a connector shall be selected that best duplicates the pin configuration , pin location , pin numbering and symbology that the student would see looking at the actual avionic equipment connector .
configuration, standard base	586	3.4.11.2.5	Plug - in relays with standard base configuration , self - wiping contacts and dust - tight sealing shall be used to the maximum extent possible .
configuration, test	752	4.5.2	Test configuration including expected test equipment list .
conflict	12	1.4	In the event of conflict between the documents referenced herein and the contents of this specification , the contents of this specification shall be considered a superseding requirement .
conforming, meters	588	3.4.11.2.6	Elapsed Time Meters shall be four - digit - time totalizing meters conforming to MIL - M 7793 .
connecters	559	3.4.10	cables , connecters and data bus couplers .
connections	299	3.4.1.1	Both the AC and DC Power systems associated with the HH - 60J systems shall be simulated in the trainer with connections , wiring , cabling , and performance characteristics as defined herein .
connections, electrical	614	3.4.13.1	Soldering and assembly of electrical connections and components shall be in accordance with Section 4 General Requirements of MIL - STD - 2000 .

Figure 2. Sample of the expanded index listing.

Further processing was done on the list mentioned above in search of a means to assist editors in performing a terminology audit. The principle is simple. The sorted file is re-copied, leaving out every line whose key is identical to the one before it or after it. The result is a list similar to the list described above, but containing terms that appear only once in the document.

The significance of being used only once is that such terms must belong to one of three categories:

a. Familiar terms that are readily understood by a broad audience,

b. Terms drawn from a cited document, and

c. Undefined terms.

The editors, of course, are looking for the undefined terms, every one of which presents an opportunity for misunderstanding.

Finding nonsense sentences

The final experiment performed with the use of the parser was to determine its usefulness in locating "nonsense" sentences. Nonsense sentences are those that may seem authoritative to a casual reader, but, upon careful study, are found to say something different from what was intended, and may make no sense whatsoever. They are often a source of unintentional humor.

To perform the experiment, the software was configured to separate from each sentence the main noun of the subject, the main verb, and the object of the verb. The software effort was kept to a minimum. A great deal more could have been done to enhance the number of correctly parsed sentences without a major rework of the parser. The objective was not to parse correctly the largest number of sentences, but rather to generate a sample of kernel sentences that could be examined by an editor in search of errors. The three sentence elements were printed along with a copy of the entire sentence. For example:

> The fuel tank area of the airframe skeleton shall be removed and the airframe skeleton shortened by the fuel tank area length.

reduced to:

> area shall be removed.

The example statement is nonsense because "area" in Standard Written English is a word that represents an abstract concept of measurement. Area cannot be removed. The writer of the example sentence erroneously used the word "area," in an informal manner, evidently for want of a recall vocabulary that contained more appropriate words like "segments" and "sections."

By the way, misuse of the word "area" by engineers is a recurring problem, as may be deduced from Figure 1. One case that was examined made mixed use of "area" to mean both "subject domain" and "geographical region," intermingled several times within the same short paragraph. Mixed usage of that sort is described in books on rhetoric as a tactic used by unethical writers who are intentionally trying to lead their audience to an erroneous conclusion. Fowler (1965) called this tactic "legerdemain of two senses." One should not be surprised, then, that a contractor might become confused when usages are mixed unintentionally.

The "nonsense sentence" experiment involved processing a sample of 285 sentences. Of that sample, 152 yielded kernel sentences in which the subject, main verb, and object were identified accurately by the parser. Of the 152 correctly parsed sentences, review of only the kernel led the editor to 36 errors. The 133 sentences that were parsed incorrectly by the software were found by a human parser to contain eleven kernel-related errors.

Although it affected the kernel-sentence experiment, failure of the parser to correctly locate the main kernel of the sentence does not necessarily make the syntactic data obtained by it useless for other purposes. Smaller pieces like noun phrases, prepositional phrases, and infinitive phrases are nearly always parsed correctly, even though the overall structure of the sentence may be missed. The correctly parsed fragments are made available to further processing steps, so correct comments are often generated by the program even when the parser has failed to recognize the correct structure at higher levels in the tree.

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IV. ADDITIONAL FINDINGS

An information model of acquisition

A significant portion of the time on this project has been devoted to learning more about what constitutes error in specifications, finding examples, and determining how to go about avoiding error. A wide variety of sources has been researched, and the information gathered is being used in the development of doctrine and instructional materials for training courses that will be taught to NAWCTSD engineers.

Part of that doctrine is the information-processing model of the procurement process that was presented in an unpublished paper prepared for the Best IR/IED Paper competition (Oriel, 1992). That model presents the procurement process as a communications system with certain characteristics that are significantly different from most mechanistic models of human communication, but nonetheless familiar to the engineers in the target audience.

Operational definitions in specifications

Further regarding the development of doctrine on specification writing, another part, still under development as this report is being written, is a theoretical treatment of the meaningfulness of specification requirements. Based on the writings of the physicist P.W. Bridgman, the doctrine being developed aims to teach engineers to depend as little as possible on the power of words to describe requirements. Instead, they are to be encouraged to state requirements, when possible, using only terms that are definable as the results of a specific series of "operations." To an engineer, "operations" are the steps performed in the construction of something, or the steps performed in the course of testing. Operations are physical, not verbal. Bridgman's doctrine, called "operationism," has had a profound influence on both the natural and social sciences since its introduction in 1927 (Hempel,1966).

By Bridgman's criteria, design requirements, if sufficiently complete, constitute an operational definition of the product. Popularly, the concept of operational definition is described in terms of the statement: "The operational definition of a cake is its recipe." Contract law, as applied to engineering, would call that recipe a "design specification," which is a method of specifying that is highly compatible with every engineer's way of thinking. A design specification is one that tells how to build the required item.

However, Government engineers who oversee the development of new products are discouraged from stating their requirements in design terms because contract law places a heavy burden of responsibility on parties who do so. Whenever a product thus specified does not perform properly, it is the party who drafted the design specifications that must bear the responsibility for the failure. This is true even when the end-item is specified only partly in design terms. In that case, if the contractor chooses a way to complete the missing parts of the design in such a manner that the design-specified parts are inadequate, the contractor is not likely to be held responsible for any failure that may occur.

The alternative, stating requirements in terms of performance, however, is equally risky. Performance requirements are merely a natural language description of what the equipment is supposed to do. They do not provide an operational definition of the specified item. According to Bridgman's philosophy, they can never be rigorous unless accompanied by a set of testing requirements that are sufficiently complete and detailed to constitute an operational definition of all the terms used in describing the performance requirements.

With its newly required table of Quality Assurance (QA) requirements, the recently circulated draft of MIL-STD-490B, the proposed guiding document on specification practices, has moved nearer to an operationist doctrine than its predecessor, MIL-STD-490A. The format that MIL-STD-490B gives for the table of QA requirements has a column that contains a general statement regarding the test method to be used in verifying each paragraph's requirements. Had it been intended to achieve operationist rigor, that column would have to contain a citation of a detailed test specification. Examples of such test specifications abound in the vast literature published by the engineering standardization community, and the availability of a set of similar procedures for testing specific items to be purchased would be a prerequisite to implementing a rigorous operational approach to specifying them. One category of goods that may presently be specificed in accordance with operational definitions is the semiconductor devices covered by the MIL-S-19500 series of specifications (SPAWARS, 1990).

It is appropriate to point out that operationist doctrine has been very effectively implemented for production contracts by means of the strict rules regarding the use of the first article as a baseline. Language, after first article acceptance, is no longer the basis of the contractual agreement regarding the configuration of the product.

V. CONCLUSIONS AND RECOMMENDATIONS

Conclusions

Appendix C of this report sets a standard for elimination of the types of errors commonly encountered in specifications. In doing so, it fills a gap left by existing standards. Considering the stringency of Appendix C, one may readily conclude that writing high-quality specifications is a task that requires an uncommonly high level of literacy, a great deal of specialized training, and the help of cognitive tools like those developed on this project.

Recommendations

Appendix C has been prepared as an additional step towards training engineers to write high-quality specifications. Appendix C sets a standard for elimination of the types of errors commonly encountered in specifications. In doing so, it fills the gap left by the existing applicable standards, MIL-STD-490A and MIL-STD-961C (DMSSO, 1985). It has intentionally been kept short and to-the-point, and is written using plain language. It also is intentionally written in the first and second person to hold the reader's attention.

In light of what has been learned on this project, it is recommended that the research effort regarding specification writing be conducted on a continuing basis. It is further recommended that additional research be conducted to apply emerging technology to the specification quality problem. Finally, it is recommended that the parser software developed under this effort be ported to the Windows environment so that syntactic ambiguity warnings can be made available to users of Windows-based software, particularly the Joint Acquisition Management System (JAMS).

Coordination and utilization

Numerous organizations were contacted in the course of this exploratory development. Most of them expressed an interest in the work, but no others were found to be conducting directly related efforts. The Government agencies furnishing information that was used in the course of this work were the Army Logistics Management Center, the Naval Sea Systems Command, the Defense Standardization Program Division, and the Los Alamos National Laboratory. Academic institutions doing likewise were the University of Michigan, Texas Tech University, and the University

of California at Los Angeles. Points of contact for all these organizations appear in the distribution list for this report.

Much of what has been learned about specification writing in the course of this research has been carried over into the hypertext articles embedded in the software product called SpecTrE. SpecTrE is presently in use by specification writers at many Navy commands. The content of the text articles in SpecTrE has been coordinated with the departments within NAWCTSD. A Windows-based version of SpecTrE has been prepared and is being used as part of the JAMS program--a joint Army, Navy, Air Force system under development to help facilitate the preparation of acquisition documents. New versions of both the SpecTrE and PARANA programs, along with their documentation, are in preparation, and we expect to make them available via the Defense Technical Information Center in 1994.

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GLOSSARY OF ACRONYMS

ACO	Administrative Contracting Officer
AFSC	Air Force Systems Command
ASBCA	Armed Services Board of Contract Appeals
ASSIST	Automated Specifications and Standards Information System
CDRL	Contract Data Requirements List
CO	Commanding Officer, Contracting Officer
COTR	Contracting Officer's Technical Representative
CRES	Computer Readability Editing System
IED	Independent Exploratory Development
IR	Independent Research
JAMS	Joint Acquisition Management System
KWIC	Key Word In Context
NAEC	Naval Air Engineering Center
NAVMAT	Naval Materiel Command
NAWCTSD	Naval Air Warfare Center Training Systems Division
NLP	Natural Language Processing
PARANA	Paragraph Analyzer -- a computer program.
PCO	Procuring Contracting Officer
QA	Quality Assurance
SOW	Statement Of Work
SPAWARS	Space and Warfare Systems Command
SpecTrE	Specification (writers') Trainer and Editor -- a computer program.
TBD	To Be Determined
WFST	Well-Formed Substring Table

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Appendix A

CATEGORIES OF SPECIFICATION DEFECTS

1. Organization errors
   - 1.1 Requirements stated in the wrong place
   - 1.2 Paragraph numbering errors

2. Reference errors
   - 2.1 Errors in cross-references
   - 2.2 Erroneous references to other documents
   - 2.3 Erroneous references to figures
   - 2.4 Acronyms that are used, but are not defined in the text

3. Incorrect Requirements
   - 3.1 Subject matter is wrong
   - 3.2 Statements clearly impossible for logical reasons
   - 3.3 Statements impossible for practical reasons
   - 3.4 Errors that relate to numerical requirements
   - 3.5 Violations of law or regulations

4. Requirements Incorrectly Expressed
   - 4.1 The reviewer can deduce what the writer meant to say, but the text says something else.
   - 4.2 Meaningless words like "better", "easy", and "as applicable" that leave a requirement subject to the opinion of the reader

4.3 Nonsense - reviewer could make no sense whatsoever of this requirement

4.4 Grammatical errors - syntax, hyphenation, punctuation, verb tense, subject-verb agreement, parallelism and all other grammatical errors

4.5 Incorrectly used words

4.6 Ambiguities

4.6.1 Semantic
4.6.2 Syntactic
4.6.3 Pragmatic

4.7 Spelling errors - may be clearly misspelled or often a misspelling that resulted in an incorrectly applied word - like "pilot ice" vice "pitot ice"

5. Inconsistencies

5.1 The text contradicts itself.

5.2 *Synonyms* used without being clearly defined as synonymous.

6. Poor Business Practices

6.1 Agreements-to-agree

6.2 Warranting suitability of an item for a specific purpose

6.3 Specifying by make and model number

6.4 Specifying design when specifying performance would suffice

7. Omissions

7.1 Anything that the reviewer felt belonged in the text, but was not there

7.2 TBD's (To Be Determined) in text not filled-in

Appendix B

SENSITIVE WORDS, PHRASES, AND STRUCTURES FOR SPECIFICATION WRITERS

MEANINGLESS WORDS

The following words are meaningless in specifications unless accompanied by words that convey additional information. For example, it is unlikely that the meaning of "a long bolt" could ever be agreed upon, but "a seven-inch long bolt" is clear.

about
acceptable
accordingly
accurate
additional
adequate
adjustable
affordable
applicable
appropriate
average
better
careful
convenient
deep
dependable
desirable
easily
easy
economical
efficient
essential
et al.
etc.
excessive
general accordance
good
greater
high
higher
highest grade
highest quality
immediately
improper
instant
insufficient
irrelevant
knowledgeable
less
long
low
lower
major
multiple
neat
necessary
normal
not necessarily
optimum
other
periodically
pleasing
possible
practicable
practical
proper
quick
reasonable
recognized
relevant
reputable
safe
satisfactory
secure
securely
significant
similar
simple
smooth
stable
substantial
sufficient
suitable
temporarily
temporary
the like
timely
typical
uneconomical
unsafe
variable
various
wide
workmanlike
worse
worst

TOTALITY WORDS

Totality is a concept that is very easy to state in words, but very rarely occurs in the real world. Totality statements are abundant in our speech, but we rarely intend for a listener to take them literally. Contractors will take totality statements literally when it is profitable to do so. The following words are a few that are characteristic of totality statements:

all	entire	none
always	identical	simultaneous
continually	never	

IMMEASURABLE WORDS

These words are mostly nouns representing things that are not generally quantified.

achievement	demonstration	realism
best ___ practice	qualification	standard practice
confidence		

PRONOUNS

Pronouns are always risky in specifications, because readers often find a different antecedent for them than the one that the writer intended. Pronouns of the first person are probably less hazardous from the standpoint of their potential to be misunderstood, but are considered improper in specifications.

it	they	we
me	this	you
them	us	your

REQUIREMENTS THAT APPLY TO A THIRD PARTY

The following words are often used in such a way that the specifications, when taken literally, state a requirement that is not binding on the contractor. Instead, they require something of the individuals who use the equipment.

by the instructor	operator shall	trainee shall
instructor shall	skill	

WORDS THAT CAUSE LEGAL DIFFICULTIES

The following five groups relate to legal intricacies of specification writing.

The first involves something called "agreements to agree," which are not considered a good contracting practice. Every contract is supposed to be a meeting of minds. Requirements to reach an agreement at some future date are contrary to the legal concept of a contract, and have no place in a fixed-price contract. The following words are characteristic of "agreements to agree":

agree	concur	to be agreed upon

Public Law 96-511, The Paperwork Reduction Act of 1980, restricts what may be purchased in the way of data items to that which is described in authorized Data Item Descriptions (DIDs). The law forbids the Government from expanding the scope of data items beyond that described in the DID cited. Therefore, writers of specifications and SOWs must be very careful about what they require in connection with data items. In general, it is best to avoid discussing data requirements in specifications and SOWS. Such discussion belongs in block 16 of the form DD1423. The following words and acronyms are characteristic of text describing data items:

CDRL	DI	UDI

The following words often appear in text that erroneously grants a warranty to the contractor regarding information contained in the specifications. When such a warranty is granted, the contractor may rely solely on whatever the Government has said, and may not be responsible for conducting further investigations before proceeding with their design.

assure	guarantee	known
certify	know	knows
		warrant

The following words are often found in text that assigns duties to individuals. Such assignments should not be buried in the details of specifications. They belong, instead, in the body of the contract, and should be drafted by a contracts specialist, not by an engineer.

buyer	contracting officer	COTR
CO	technical representative	PCO
ACO		

The following words often appear in text that obligates the Government incorrectly or unnecessarily:

furnish	loan	waive
Government	Navy	

VERBS AND AUXILLIARIES THAT DO NOT STATE REQUIREMENTS

The only auxilliary verbs authorized for use in specifications are "shall," "will," "should," and "may." Of these, "shall" is the only one that may be used to state a binding requirement. Requirements stated without "shall" are either not binding or are erroneously stated. Each occurrence of the following words and phrases should be checked in specifications to determine whether or not a requirement has been misstated.

are	is to	must
can	may	should
is	might	will

POTENTIAL GENERATORS OF CONFLICTS

The following words and phrases are likely to appear in text that conflicts with other portions of the contract:

contract	SOW	statement of work
the specification	unless specified	herein
price	as specified	as required
commence	on time	
unless otherwise specified		

HAZARDOUS MATERIALS

Hazardous materials are sometimes specified inadvertently. While it is not possible to give an extensive list of them, the following three are listed because they are likely to be found in training device specifications. Also significant in this category, but too numerous to list here are the words associated with Class I Ozone Depleting Substances, as defined in the Clean Air Act.

asbestos	beryllium	cadmium

AMBIGUOUS WORDS

The following three words are often used in a military context with an intended meaning that is different from what is seen in normal usage:

activity	An organization, or the state of being active?
operational	Pertaining to military operations, or merely something that works?
capability	It may be "capable," but not actually do it.

The next three words are technical terms used by lawyers as well as ordinary words.

consideration	This may mean "something given in payment."
construction	This could mean the interpretation of language.
several	This may mean "separate," instead of "more than two."

The following are words in general usage, and are either ambiguous themselves or play a key role in certain frequent syntactic ambiguities:

any	Could mean several or only one.
anywhere	To a contractor, this could mean one place, of his choice.
as well as	Could mean "and" or "equally well."
because	This phrase may introduce either a restrictive or nonrestrictive dependent clause. The difference between the two uses is distinguished by the presence or absence of a comma before "because." If there is a comma, the clause is nonrestrictive. The presence of the comma changes a requirement to a mere observation. Sabin (1985) has compiled an exhaustive list of similar introductory words, and gives examples of their uses in both restrictive and nonrestrictive clauses.

critical	Could mean: important, crucial, analytical, dangerous.
for use	Who does the using and who does the preparing? This phrase often generates an ambiguous series of prepositional phrases.
include	Is this word followed by an exhaustive list of everything to be included, or by only a partial list?
limited	This word is often used by spec writers who want to ask for something, but are unable to state what it is.
inflammable	Use flammable.
noninflammable	Use nonflammable.
or	Contractor may choose one or the other. Expect to get only one option.
problem	Does this mean a failure, a difficulty, or a training exercise?
property	Does this mean real property, personal property, or an attribute of something?
strict	Which "strict": "to the letter," or "exactly as intended"?
uninflammable	Use nonflammable.
up to	More than the minimum is a gift from the contractor.
which	See "because."

LOGIC TRAP WORDS

These words are often found in specifications, and their logic is not immediately obvious:

accept or reject	This allows no option for partial rejection.
approve	It is not wise to say that we hold something in esteem. Try "authorize." It makes less of a commitment.

designed to	It may be "designed" such, but will it be built and installed that way?
either	Be sure you don't really mean "both."
extent possible	Often found after "greatest" or "maximum," this may require an unbounded effort.
maximum, minimum	These two words may denote an unbounded or impossible task. Is the requirement practically attainable?
as a minimum	You will probably not get more. Contractors nearly always do the minimum required.

ENGLISH USAGE ERRORS

These are ordinary English usage errors that are likely to be found in specifications.

affect	Always a verb, usually means "to influence" or "to pretend to have or feel."
call out	Use "cite," "refer to," or "reference."
compliance to	Use "compliance with" or "conformance to."
comprise	This word is usually used incorrectly. Use "consist" instead.
effect	Noun for "result" or "consequence," or verb for "bring about" or "make happen."
ensure, assure	"Ensure" means to make something certain. "Assure" means to remove a person's doubt.
insure	"Insure" should refer only to "indemnity."
irregardless	This word is a double negative, all by itself.
it's, its	"It's" is a contraction for "it is." "Its" is the possessive form of "it."

only	This word is often placed in the sentence incorrectly. Notice how the following sentences each have a different meaning: Only the dog eats dry kibble. The only dog eats dry kibble. The dog only eats dry kibble. The dog eats only dry kibble. The dog eats dry kibble only.
plan	Specifications should not use the word "plan" to mean "drawing."
stationery	This means "writing paper and supplies." "Stationary" means "immobile."

OTHER TROUBLESOME WORDS

The following words fall into categories too small to warrant their own heading. Each of them is nonetheless a potential source of error in specifications.

align, approximate	To state a requirement, these words must be accompanied by an explicit statement of tolerances.
consider	Requirements containing this verb often give no direction regarding action to take.
design, develop	Before requiring design or development, specification writers should determine that no satisfactory product is already available off-the-shelf.
DoD, MIL	Industry standards are preferable to Government standards.
establish	This word should always be accompanied by clear language indicating who is required to do the establishing.
host	When referring to persons, corporations, or institutions, the one referred to by this word is reasonably expected to pay the bill for food and lodging.

note	Notes that writers have left to themselves should be removed from documents before release.
reference	This word sometimes appears when a specific document should have been cited.
respond	When referring to equipment, this word is sometimes indicative of the writer's tendency to personify an inanimate object. Doing so is not conducive to clear thinking, which is essential to specification writing.
select	The context should clearly indicate how the selection is to be made.
standard	This word should refer to a specific standardization document. It cannot stand alone and be meaningful in the context of specifications.
TBD	Never release a document that contains this acronym.
trade off study	This phrase should be accompanied by a description of the study to be done, and what action is to be based on the results.

FAULTY SENTENCE STRUCTURES

Some defects are a result of improper phrase or sentence structure, and may be entirely unrelated to the meanings of the words involved. Those types of syntax are illustrated in the examples given below. Note that the examples given are in no way ungrammatical, but they are defective in the context of specifications because they convey alternative meanings depending upon which structure the reader chooses to recognize.

- The phrase with multiple coordinating conjunctions:

... gluing and clamping or riveting.

Note that there is no fixed order of precedence of logical operators in English as there is in formal languages like Algol. This example is a very simple one. The really serious errors along these lines are to be found in long sentences that have several conjunctions.

- The string of prepositional phrases:

... predictions shall be prepared for use in the preliminary design-review meeting.

Here, the reader may prepare the predictions in the meeting, much to the consternation of the writer, who expected to use the predictions in the meeting. Notice that the meanings of the individual words are exactly the same regardless of which interpretation you prefer. The confusion arises because the reader has no clue as to which word is modified by each of the two prepositional phrases. Strings of prepositional phrases abound in specifications. Most are disambiguated by semantic constraints. Those that remain ambiguous are very difficult to recognize without the help of hints from the computer program.

- The modifier that may or may not act across a conjunction:

... stainless steel nuts and bolts.

Specifications using this phrase require only that the nuts be of stainless steel. Bolts of any material would be acceptable, regardless of whether that is what the specification writer intended. Some linguists classify this as a case of ellipsis since the words "stainless steel" are intended to modify "bolts," but their presence is assumed to be understood by the reader. Errors of this type are the most numerous syntactic ambiguities observed in specification drafts, and they deserve special attention. Formal languages solve this ambiguity problem by having operators that force the logical grouping of conjoined

symbols. An example would be the begin ... end grouping in Algol.

- Adjacent phrases that lack a clear boundary:

The completed assembly shall be designed and constructed to withstand, without damage, permanent deformation, cracking or metal fatigue, stresses incident to movement, handling in transit, hoisting and tiedown aboard transporting vehicles, final installation, and use.

The writer in this case probably intended a semicolon after "fatigue" but did not furnish it. That punctuation would have provided the necessary delimiter. Better form in so complex a situation would be to furnish the second noun phrase as a numbered, indented list. Punctuation often plays an essential role in disambiguating the syntax of sentences in specifications. Commas, hyphens, and semicolons must be used exactly according to the rules. Virgules (slash marks) are taboo.

- Ellipsis and gapping:

The generator shall supply the processor with 10.5 amperes and the batteries 8.5 amperes.

A "shall supply" has been left out, and there is no indication whether it belongs after "and" or after "batteries."

- Ambiguous pronoun referents:

Prior to accepting products from subcontractors, the prime contractor shall evaluate them for compliance with the standards.

Which is to be evaluated, the products or the subcontractors? Flagging these in specifications is very easy. We simply flag every pronoun and direct the reader to make sure there is only one noun that may be attached to the pronoun.

Appendix C

RECOMMENDED STANDARD

FOR THE

PREPARATION OF
ENGINEERING SPECIFICATIONS

1. SCOPE

This document tells engineers and scientists some things they must know to write and edit high-quality procurement specifications. Most of the material covered does not appear explicitly in any other readily available document. We've tried to make it easy reading so you don't get tired of it after a few pages. Its message is too important to go unread. To make it easy reading, we've made the language less formal than a regular standard. Its outline, however, is done in the six-part format of a procurement specification as described in MIL-STD-490A. It defines certain often-misunderstood duties of both specification writers and specification reviewers.

2. APPLICABLE DOCUMENTS

The items listed here are not necessarily cited in the text of this specification. They are all relevant to your work as a specification writer. Your boss should have a copy of each handy for you to read.

2.1 Government Documents

2.1.1 Specifications, standards, and handbooks

MIL-STD-490A - Specification Practices (The "B" version of this standard is in preparation)

MIL-STD-961C - Military Specifications and Associated Documents, Preparation of

MIL-HDBK-245C - Preparation of Statement of Work (SOW)

2.1.2 Other Government documents

Armed Services Board of Contract Appeals. Schaevitz Engineering, Inc. ASBCA No. 11524, 67-2 BCA ¶6678.

Naval Material Command. Defense Contract Management for Technical Personnel. Washington, D. C. , 1978.

Oriel, J. T. User's Guide for SpecTrE. Orlando, Naval Training Systems Center, 1990.

Oriel, J. T. User's Guide for CkList and PARANA. Orlando, Naval Training Systems Center, 1989.

2.2 Non-Government Publications

Bly, R. W. and Blake, G. Technical Writing. New York, McGraw Hill Book Company, 1982.

McRobb, M. Specification Writing and Management. New York: Marcel Dekker, Inc. , 1989.

Sabin, W. A. The Gregg Reference Manual. New York:McGraw-Hill, Inc. 1985.

3. REQUIREMENTS

3.1 Organization. Organize your specifications according to one of the outlines in MIL-STD-490 and MIL-STD-961. Try to follow the outline closely, but don't let the outline become more important than clarity and conciseness. McRobb gives an example of how a 16-page specification was reduced to four pages by reworking the outline to better fit what was being specified rather than by following the prescribed outline (McRobb, 1989).

3.1.1 State the requirements in the right place. Don't put requirements for services in specifications. Requirements for services belong in the Statement of Work. Specifications are for goods, not services. Likewise, don't put things in the specifications that belong in the other sections of a contract. Specification requirements to deliver data are a commonly found violation of this rule. If you mention a data item in the specifications, and expect it to be delivered, you must also have it listed in the Contract Data Requirements List (CDRL). You must also make sure that each specification requirement appears under the correct heading.

3.1.2 Paragraph numbering. Paragraph numbers shall progress upwardly, one at a time, so that there are no gaps in numbering.

3.2 References

3.2.1 Cross-references. When the text of a specification refers to text elsewhere in the specification, the citation shall be correct. Mistakes in cross-references are common because paragraph numbers are often renumbered and the cross-references neglected. Such mistakes are unacceptable in engineering specifications.

3.2.2 References to other documents. When you cite another document, it must be a currently active document. Canceled documents shall not be cited. You may cite obsolete versions of documents only when you are specifying modifications to equipment built under the obsolete version. You should know enough about the document you're citing to cite it correctly. For many specifications, you must know the type, grade, alloy, or other parameters that must be specified along with the number of the document. Well-written MIL-SPECS will have this information tabulated in the section entitled "Ordering Data" or "Acquisition Requirements".

3.2.3 References to figures and tables. Your document shall not have text that refers to the wrong or non-existent illustrations or tables. Likewise, there shall be no illustrations or tables that are not mentioned in the text.

3.2.4 Acronyms. Acronyms shall be defined the first time they appear in the text. For documents over 50 pages long that use acronyms, you shall also include a glossary of acronyms.

3.3 Requirements. No one in the Executive branch of the Government has the authority to specify goods that exceed the Government's minimum requirements. The Government cannot spend public funds to suit the personal preference and prejudice of individuals. You must specify strictly in terms of what the Government really needs.

3.3.1 Correctness of subject matter. Statements made in specifications shall be technically correct. If you must specify something you're not familiar with, seek technical advice from someone who knows the topic and follow the advice.

3.3.2 Logic. Statements that you make in specifications shall be logically correct.

3.3.3 Practicality. Requirements that you state shall be commercially practical to implement. If you don't know a way that something may be built, find an engineer that can advise you on the matter and follow the engineer's advice.

3.3.4 Numerical requirements. When you specify things by number you need to take particular care. See to it that your numbers are right. Take care that the units and their abbreviations are correct and consistent. Use metric units unless you have an important reason to use others.

3.3.5 Precision of language. Readers of your specification will not always know ahead of time what you meant to say. When the specification says something similar to, but not exactly what you meant, the finished product will be something different from what is needed. If someone notices the disparity, fixing it will cost both money and embarrassment. We have seen many cases where the language used in specifications is so poorly written that even an engineer familiar with the type of equipment being described could make no sense of the words used. While such occurrences are OK in drafts, they are unacceptable in released documents.

3.3.6 Specificity. Requirements shall be specific. Don't use words like "better", "easy", and "as applicable" that let the reader decide what they mean.

3.3.7 Grammar. Specifications shall have no errors in grammar. We usually use Sabin (1985) as the authority on grammar.

3.3.8 Usage. Word usage shall be as defined in the "Definitions" section of the document. Words not explicitly defined in the specification may be drawn from another glossary, provided the glossary is cited. Otherwise, words shall be used as defined in your Government-issue desk dictionary. If the dictionary has more than one definition for a given word, then the choice of which definition to use will be made by the contractor, not by the Government.

3.3.9 Clarity. Statements made in specifications shall have only one possible meaning.

3.3.10 Spelling. You shall not misspell words in specifications.

3.3.11 Consistency. The text of specifications shall not contradict itself. Tables and illustrations shall also be consistent with the text.

3.3.12 Terminology. Each person, place, thing and idea mentioned in specifications shall be referred to by a unique name. You shall never use synonyms without clearly defining them in the "Definitions" section as being synonymous.

3.3.12.1 Definitions. Wherever possible, terms shall be defined without dependence on interpretable language. Definitions shall therefore be traceable to words that are defined in terms of an empirical procedure.

3.4 Business Practices

3.4.1 Agreements-to-agree. For fixed-price contracts, make the requirements of specifications complete and specific so that the product is fully defined. There shall be no items specified in such a way that agreements must be reached with the contractor after the contract is awarded.

3.4.2 Warranties. A warranty is an assurance that something is good. When we warrant an item, we are responsible for the costs incurred if it is not as good as expected. You shall not write specifications in such a way as to give the contractor a warranty. Engineers often unknowingly grant a warranty for the correctness of technical information or suitability of an item for a specific purpose. A statement to the effect that something is known, appropriate, suitable, fit, correct, or good in any other way is sufficient for a contractor to take as a warranty. Given such a warranty by the Government's engineer, a contractor may rely on the warranty and prepare a bid with no further investigation of the warranted "fact".

3.4.3 Specifying by make and model number. Specifying by make and model number "or equal" should be done only when you are absolutely certain that there is no way that other aspects of the design can be done in such a way that the specified item will not work. When you specify by make and model, you are warranting the suitability of the item for that purpose, and are responsible for the outcome.

3.4.4 Specifying design. Specifying design when you need only specify performance is foolish. You should concentrate your efforts on describing the needed performance. You will be held responsible if the design details you specify turn out to be incompatible with the design done by the contractor's engineers.

3.5 Completeness

3.5.1 No missing requirements. Specification requirements shall be complete.

3.5.2 TBDs. Specifications shall not contain "TBDs" (To Be Determined) unless the specification is for equipment to be developed under a cost-plus type contract.

4. QUALITY ASSURANCE PROVISIONS

This section tells you how your work will be checked to make sure it meets the requirements. All errors found during the quality assurance inspections shall be corrected before the specifications are finalized.

4.1 Inspection of organization. Check the paragraph titles of the draft specification against the standardized outline. If they don't follow the standard outline exactly, the author must give a practical reason why the deviation was made.

4.1.1 Requirements stated in the right place. Check the document for requirements that properly belong in the SOW, CDRL, and Special Provisions by carefully reading and marking-up a hard copy. Also check for requirements that belong in a different paragraph. All misplaced requirements shall be relocated to where they belong.

4.1.2 Paragraph numbering. Use the program PARANA to check the paragraph numbering for errors. Correct the errors found.

4.2 Inspection of references

4.2.1 Cross-references. Use PARANA to help you do an exhaustive check for erroneous cross references. Correct the errors found.

4.2.2 References to other documents. Use PARANA to check the references to other Government documents. Look up each one to check whether it is current. Correct the erroneous references.

4.2.3 References to figures and tables. Use your word processor to search the document for all occurrences of the word "figure" and check each referenced figure for relevance to the text. Also check that all illustrations are mentioned in the text. Repeat the process for tables. Correct all erroneous references.

4.2.4 Acronyms. Use PARANA to tabulate all uses of each acronym. Check each use for correctness. Correct all the errors in acronym usage.

4.3 Inspection of requirements

4.3.1 Correctness of subject matter. Technical specialists shall review the document for technical correctness. The errors found shall be corrected be[illegible] the document is finalized.

4.3.2 Logic. An experienced editor shall review the document for logical correctness. The errors found shall be corrected before the document is finalized.

4.3.3 Practicality. A systems engineer shall determine whether the equipment described is commercially practical to build and maintain. When it is found that the equipment described is impractical, the specification and all other program documents shall be rewritten so as to correct the problem.

4.3.4 Numerical requirements. Technical specialists shall check to see that the numbers are right. An editor shall check that the units and their abbreviations are correct and consistent. The author shall furnish a practical explanation if other than metric units are used. All numerical errors shall be corrected.

4.3.5 Precision of language. Skilled editors shall review the specifications with the help of computerized editing tools like CkList and SpecTrE to find imprecisely stated requirements. Imprecise language shall be corrected.

4.3.6 Specificity. Computerized editing tools shall be used to find all occurrences of non-specific words. Each case found shall be corrected.

4.3.7 Grammar. Skilled and experienced editors shall find all grammatical errors in the specifications. All grammatical errors found shall be corrected.

4.3.8 Usage. Skilled editors shall review the specifications with the help of computerized editing tools like CkList and SpecTrE to find errors in word usage. Errors in word usage shall be corrected.

4.3.9 Clarity. Statements with more than one possible meaning shall be found by skilled editors. Each one found shall be reworked so that it has only the one meaning intended by its author.

4.3.10 Spelling. Misspelled words in specifications shall be found by using an automated spelling checker. Skilled editors shall review the specifications to find improper words that get by the spelling checker because they are spelled correctly even though they are not used correctly. All spelling errors shall be corrected.

4.3.11 Consistency. Skilled and experienced editors shall find all contradictions and consistency errors in the specifications. All consistency errors found shall be corrected.

4.3.12 Terminology. Skilled and experienced editors shall check to see that there are no inconsistencies in the terminology used in the specification. The editors shall be equipped with software tools to enhance their effectiveness at checking

multiple occurrences of each term used and at checking for the erroneous use of synonyms. Each instance of inconsistent terminology shall be corrected.

4.4 Inspection of Business Practices

4.4.1 Agreements-to-agree. Skilled editors equipped with computerized tools shall inspect the specification text for statements that would require decisions to be made and agreements reached with the contractor after contract award. In the case of specifications to be used with fixed-price contracts, all such occurrences shall be removed. In the case of cost-plus contracts, the agreements shall be listed, and the list presented to the Contracting Officer for concurrence before the specification is finalized.

4.4.2 Warranties. Skilled editors shall examine the specification text for wording that would grant the contractor a warranty. In each case, the wording shall either be corrected so as not to grant the warranty, or the engineer shall present proof that the warranty will not result in an expense to the Government.

4.4.3 Specifying by make and model number. Skilled editors shall examine the text for specification by make and model. In each case, the specification shall either be corrected so as not to grant an implied warranty, or the engineer shall present proof that the warranty will not result in an expense to the Government.

4.4.4 Specifying design. Senior engineers shall examine the text for design specification. When cases are found where design has been specified when specifying form, fit, and function would have sufficed, the text shall be corrected.

4.5 Inspection for completeness

4.5.1 No missing requirements. Specification requirements shall be checked for completeness by senior engineers. Items found missing shall be added to the document.

4.5.2 TBDs. Specifications shall be searched for the strings "TBDs" and "To Be Determined". Unless the specification is for equipment to be developed under a cost-plus type contract all such occurrences found shall be filled in with properly completed text.

5. PREPARATION FOR DELIVERY

This section is not applicable in this case, but is included here to preserve the customary six-part format.

6. NOTES

6.1 Intended use. Documents written to meet this specification are for use in the procurement of goods. Services are described in Statements of Work. Many, but not all of the provisions of this specification are applicable to Statements of Work as well.

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