Providing Proper Emphasis

If you have an important point to make, do not try to be subtle or clever. Use a pile driver. Hit the point once. Then come back and hit it again. Then hit it a third time — a tremendous whack [1].

—Winston Churchill

As mentioned in Lesson 1, several years before the fateful launch of the Space Shuttle Challenger, a NASA engineer had reservations about the O-ring design of the shuttle's solid rocket boosters. These O-rings served as a secondary seal to prevent hot combustion gases from escaping through the joints in the rocket boosters. After hearing those reservations, NASA management requested that the engineer seek opinions about the design from O-ring experts around the country. Given below is the short memo report that the engineer wrote to document the opinions from those experts. For the board investigating the Challenger accident, this memo report was the end of the paper trail for NASA's concern about the O-ring design of the solid rocket booster [2]. As you read this short report, think about why this report did not spawn further discussion among NASA managers about reservations in the O-ring design. Also, think about which details were the most important and how those details were emphasized.

Subject: Visit to Precision Rubber Products Corporation and Parker Seal Company

The purpose of this memorandum is to document the results of a visit to Precision Rubber Products, Lebanon, TN, by Mr. Eudy, EES1, and Mr. Ray, EP25, on February 1, 1979, and also to inform

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you of a visit to Parker Seal Company, Lexington, KY, on February 2, 1979, by Mr. Ray. The purpose of the visits was to present the O-ring manufacturers with data concerning the large O-ring extrusion gaps being experienced on the space shuttle solid rocket motor clevis joints and to seek opinions regarding potential risks involved.

The visit on February 1, 1979, to Precision Rubber Products Corporation by Mr. Eudy and Mr. Ray was very well received. Company officials Mr. Howard Gillette, Vice President for Technical Direction, Mr. John Hoover, Vice President for Engineering, and Mr. Gene Hale attended the meeting and were presented with the SRM clevis joint seal test data by Mr. Eudy and Mr. Ray. After considerable discussion, company representatives declined to make immediate recommendations because of the need for more time to study the data. They did, however, voice concern for the design stating that the SRM extrusion gap was larger than that covered by their experience. They also stated that more tests should be conducted with the present design. Mr. Hoover promised to contact Marshall Space Flight Center (MSFC) within a few days. Mr. Gillette provided Mr. Eudy and Mr. Ray with the names of two consultants who may be able to help. We are indebted to Precision Rubber Products Corporation for the time and effort being expended by their people on this problem, especially since they have no connection with the project.

The visit to the Parker Seal Company on February 2, 1979, by Mr. Ray, EP25, was also well received; Parker Seal supplies the O-rings used in the SRM clevis joint design. Parker representatives Mr. Bill Collins, Vice President for Sales, Mr. W. B. Green, Manager for Technical Services, Mr. J. W. Kosty, Chief Development Engineer for R&D, Mr. D. P. Thalman, Territory Manager, and Mr. Dutch Haddock, Technical Services, met with Mr. Ray, EP 25, and were provided with the identical SRM clevis joint data as was presented to Precision Rubber Products Corporation on February 1, 1979. Reaction to the data by Parker officials was essentially the same as that by Precision: the SRM extrusion gap is larger than they have previously experienced. They also expressed surprise that the seal had performed so well in the present application. Parker experts would make no official statements concerning reliability or potential risk factors associated with the present design; however, their first thought was that the O-ring was being asked to perform beyond its intended design and that a different type of seal should be considered. The need for additional testing of the present design was also discussed, and it was agreed that testing which more closely simulated actual conditions should be done. Parker officials will study in more detail with other company experts and contact MSFC in approximately one week. Parker Seal has shown a serious interest in assisting MSFC with this problem and their efforts are much appreciated.

The opinions expressed by the two O-ring manufacturers confirmed the engineer's concern about the ability of O-rings to provide a secondary seal. However, the report failed to emphasize those opinions. Why? One reason was the wording. For instance, as discussed in Lesson 1, the wording of the title was not effective:

Subject: Visit to Precision Rubber Products Corporation and Parker Seal Company

Not only did this title fail to connect the visit to the secondary seal of the shuttle solid rocket booster, but the title did not even hint that a potential problem existed. Because the managers who received this report likely were busy, many might not have been inclined to read beyond the title. A much stronger title would have been

Subject: Concern by O-ring Manufacturers about the Secondary Seal Design in the Shuttle's Solid Rocket Boosters

A second reason that the report lacked proper emphasis was the lack of repetition of important details in the conclusion. Instead, the report ended abruptly. As mentioned in Lesson 7, the conclusion is an opportunity to restate the most important details. Also, lacking at the end of this report was a future perspective on what the audience should do next. As written, the report suggested that others would handle the problem. However, the problem remained unresolved and no one at NASA followed up.

A third reason that the report lacked proper emphasis was poor placement of important details. The two most important sentences in the report are in the middle of paragraphs. One sentence, which expressed a manufacturer's concern about the gap, occurs in the middle of the long second paragraph. The second sentence, which conveyed another manufacturer's surprise that the seal had performed so well, occurs in the middle of the long third paragraph. If you want to bury a detail in a report, place that detail in the middle sentence of a middle paragraph. Essentially, this report placed the two most important sentences in the report's two least important places.

At the hearings of the Challenger investigation board, the testimony of this author revealed that burying these concerns was *not* his intention [2]. So why did he structure his report this way? My suspicion is that he became caught up in writing a trip report, rather than in using this report to convey the concerns of experts to the intended audience. In other words, the engineer was so focused on the occasion that he neglected the audience and purpose.

Emphasize details with wording

In weak scientific documents, many details float, ungrounded, because the author has not shown why the details were included:

> One of the panels on the north side of the solar receiver will be repainted with Solarcept during the February plant outage.

What is the most important detail here? Is it that the panel is on the north side? Is it that the panel is being repainted with Solarcept? Is it that the repainting will occur during the February plant outage? The problem with this sentence is that you do not know. In this sentence, which was a standalone item of a progress report, all details carried the same weight. Put another way, the author used five prepositional phrases to insert the details. Although prepositional phrases are valuable for incorporating details about time and position, a string of prepositional phrases does not provide emphasis. In other words, all five prepositional phrases in the above sentence carried the same importance.

In strong scientific writing, the writer shows the relative importance the details by giving reasons for their inclusion:

> Because the February plant outage gave us time to repair the north side of the solar receiver, we repainted the panels with Solarcept, a new paint developed to increase absorptivity.

In this revision, readers can see why the details are included. Understanding the *why* allows readers to assign an importance to the details. As mentioned in Lesson 5, one way to convey the *why* is by using infinitive phrases, which are verb phrases that begin with the word *to*:

> ...to repair the north side...to increase absorptivity.

Using infinitive phrases helps show the causal relationship of details, which allows readers to infer the relative importance of those details.

In addition to using infinitive phrases to convey the *why*, professional writers also use dependent clauses introduced by words such as *because* and *although*:

> Because the February plant outage gave us time to repair the north side of the receiver,...

As stated earlier, a myth abounds that the word *because* cannot begin a sentence. No respected book on grammar offers this advice. Moreover, major publications such as *Nature* contain many sentences that begin with *because*. Professional writers begin sentences in this way because these writers want to emphasize important details.

Emphasize details with repetition

Readers do not retain every detail in a document—far from it. However, mentioning a detail two or three times in the document helps to increase the likelihood of retention. For instance, if you have an important result in a report or paper, you should heed Winston Churchill's advice and mention it three times. Where you choose to repeat an important detail is strategic. The organization of most scientific documents allows you to mention the detail naturally in three places: the summary, the document's middle, and the conclusion.

Summaries are important for readers. As Winston Churchill also said, "Please be good enough to put your conclusions and recommendations on one sheet of paper at the very beginning of your report, so that I can even consider reading it [3]." In essence, a summary, often referred to as an abstract in research writing, gives away the results and lets the audience decide whether they want to read the document to learn how the author arrived at those results:

> This report describes a new inertial navigation system that will increase the mapping accuracy of oil wells by a factor of ten. Using three-axis navigation, the new system protects the sensors from high spin rates. The system also processes its information by Kalman filtering (a statistical sampling technique) in an on-site computer. Test results show that the three-dimensional location accuracy is ± 0.1 meters of well depth, an accuracy ten times greater than conventional systems.
>
> Besides mapping accuracy, the inertial navigation system has three other advantages over conventional systems. First, its three-axis navigator requires no cable measurements. Second, probe alignment in the borehole no longer causes an error in displacement. Third, the navigation process is five times faster because the gyroscopes and accelerometers are protected [4].

This summary is tight. It is a sum of the significant points, and only the significant points, of the project—note that every detail written in a summary is either a repetition or condensation of something in the main text of the document. This summary also stands on its own, independent of the report. For instance, the summary defined the unusual term "Kalman filtering."

Although many names exist for summaries in scientific writing, essentially two types exist: informative summaries and descriptive summaries. An informative summary, often called an executive summary when written for management, is the type of summary depicted above. As in the example, informative summaries present a synopsis of the work. For that reason, an informative summary is analogous to a box score in baseball. In a box score, you gather the most important results of the game: how many runs, hits, and errors each team had. You also gather many secondary results such as who the winning and losing pitchers were and who hit home runs.

A descriptive summary, on the other hand, states what *kind* of information will occur in the document; it is a table of contents in paragraph form. A descriptive summary is like the byline to a baseball game, such as the opening game of the 1971 World Series:

Pittsburgh (Ellis, 19-9) versus Baltimore (McNally, 21-5)

From the byline, you know what is going to happen— which teams will play, who will be the pitchers, and what their records are. Descriptive summaries give the same kind of information about the document, namely, what the document will cover:

> **New Chemical Process for Eliminating Nitrogen Oxides From Diesel Engine Exhausts**
>
> This paper introduces a new chemical process for eliminating nitrogen oxides from the exhausts of diesel engines. The process uses isocyanic acid, a nontoxic chemical used to clean swimming pools. In this paper, we show how well the process reduced emissions of nitrogen oxides from a laboratory diesel engine. To explain how the process works, we present a scheme of chemical reactions [5].

Note that the first sentence of this descriptive summary identifies the work for the audience. Do not think that the repetition between the title and summary is redundant. Being redundant is a needless repetition of details. The repetition here is purposeful—you want to clarify any doubts that the audience has about the meaning of the title. Notice also that the second sentence provides secondary details that could not fit into the title. When your title is not able to separate your work from everyone else's work, your summary has to make that separation. The final two sentences of this descriptive summary list chronologically what will occur in the document: a discussion of the experiment followed by discussion of the theory.

Because a descriptive summary does not contain the actual results, it can be written ahead of the actual paper and even ahead of the experiments or computations. In fact, many researchers write descriptive summaries to conference proceedings, even though the work is not yet finished. Another feature of a descriptive summary is conciseness, often only two or three sentences.

In actuality, most summaries are not entirely descriptive or informative. Rather, most summaries are combinations of the two:

New Chemical Process for Eliminating Nitrogen Oxides From Engine and Furnace Exhausts

This paper introduces a new chemical process for eliminating nitrogen oxides from engine and furnace exhausts. Nitrogen oxides are a major ingredient of smog and contribute heavily to acid rain. In our process, isocyanic acid—a nontoxic chemical used to clean swimming pools—converts the nitrogen oxides into steam, nitrogen, and other harmless gases. While other processes to reduce nitrogen oxides are expensive and, at best, only 70 percent effective, our new process is inexpensive and almost 100 percent effective.

In laboratory tests, our process eliminated 99 percent of nitrogen oxides from the exhaust of a small diesel engine. If incorporated into diesel engines and industrial furnaces, this new process could greatly reduce the 21 million tons of nitrogen oxides released each year into the atmosphere of the United States. Besides presenting experimental results, this paper also presents a scheme of chemical reactions to explain how the process works [5].

Most of the sentences in this summary are informative. These sentences present the most important results: what distinguishes the new process and how effective it is at reducing nitrogen oxides from the exhaust of a test engine. The last sentence of the summary, though, is descriptive. Instead of actually presenting the scheme of chemical reactions that explain the process, the summary just states that the reactions will be given. Such a descriptive treatment was necessary because the format did not allow room for a listing of the six chemical reactions.

Many engineers and scientists find the principle of summarizing their work at the beginning difficult to swallow. They do not believe that audiences will read their papers and reports all the way through if the results are stated up front. Truth be told, these engineers and scientists are correct—many readers, after seeing a summary, will not read the entire document. However, the readers who are interested in the details of your work will continue reading. Remember: The goal of scientific writing is not to entice everyone to read to the end of your document, but to inform or persuade the intended audience as efficiently or effectively as possible.

Besides emphasizing the most important details, summaries also make it easier for audiences to read through complex documents. Not being told what is going to happen in a complex document is akin to being forced to hike a difficult trail without a map. On a hike, if you are not sure in which direction you are headed or how far you will travel, you tire more readily, especially when the trail steepens. The same is true for a challenging document. For instance, in a paper with Monte Carlo simulations, you may tire if you do not know what those simulations accomplish. If, however, you know that those simulations shed new light on specific chemical reactions that interest you, then you are more likely to stay with the paper.

Emphasize details with placement

Where text borders white space is where you receive emphasis. Titles and headings, for instance, receive emphasis because they are surrounded by white space. In fact, the higher level the heading, the greater the white space that the artist leaves around that heading. Likewise, the beginnings and endings of sections also receive emphasis because they are bounded, either above or below, by white space. To a lesser degree, the beginnings and endings of paragraphs receive emphasis because of the white space given by the tab at the beginning of paragraphs and by the white space at the end of the paragraph's last line.

In addition, illustrations receive emphasis partly because of the white space around them, but mainly because of their appearance. Although readers might not read every sentence in a document, they almost always look at every illustration. Therefore, if you can place important results in an illustration, do so. For example, Figure 8-1 shows how much radiation the average person in the United States receives from the operation of nuclear power plants as opposed to other sources. These other sources include natural sources, such as solar radiation

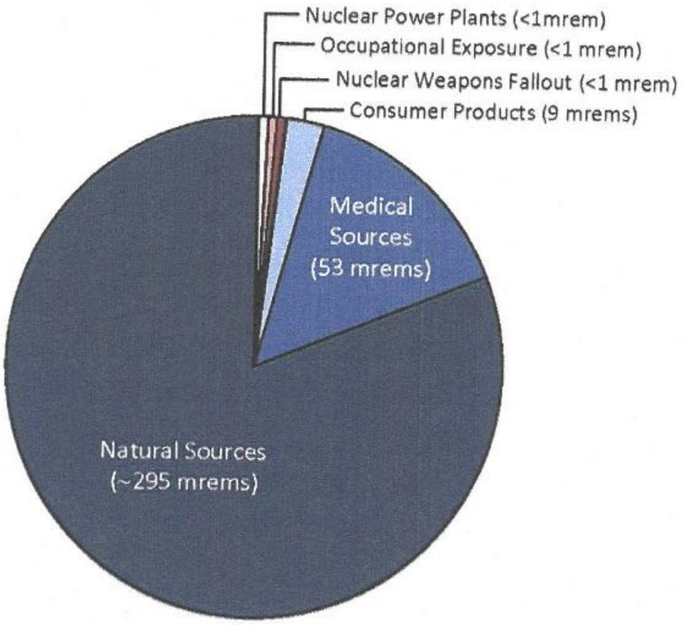

Figure 8-1. The breakdown of annual radiation dosage to the average person in the United States from all sources [6]. Most of the contribution comes from natural sources, such as radon and cosmic radiation.

and radon, and medical sources, such as dental X-rays. Illustrations such as Figure 8-1 stand out in papers and reports. You should realize, though, that a large number of illustrations dilutes the importance given to any one. If Figure 8-1 was one of the ten such pie graphs, it would not receive nearly as much emphasis.

In addition to using illustrations and white space for emphasis, you can also use the lengths of sentences and paragraphs. For example, a short sentence following a long sentence receives emphasis, particularly if that short sentence is the last sentence of the paragraph. Likewise, a short paragraph following a long paragraph receives emphasis. In the following example, notice how the Warren Commission used a combination of short sentences and placement at the end of the second paragraph to emphasize the name of the man in the lunchroom.

> When the shots were fired, a Dallas motorcycle patrolman, Marrion L. Baker, was riding in the motorcade at a point several cars behind the President. He had turned right from Main Street onto Houston Street and was about 200 feet south of Elm Street when he heard a shot. Baker, having recently returned from a week of deer

hunting, was certain the shots came from a high-powered rifle. He looked up and saw pigeons scattering in the air from their perches on the Texas School Book Depository Building. He raced his motorcycle to the building, dismounted, scanned the area to the west and pushed his way through the spectators toward the entrance. There he encountered Roy Truly, the building superintendent, who offered Baker his help. They entered the building, and ran toward two elevators in the rear. Finding that both elevators were on an upper floor, they dashed up the stairs. Not more than 2 minutes had elapsed since the shooting.

When they reached the second-floor landing on their way up to the top of the building, Patrolman Baker thought he caught a glimpse of someone through the small glass window in the door separating the hall area near the stairs from the small vestibule leading into the lunchroom. Gun in hand, he rushed to the door and saw a man about 20 feet away walking toward the end of the lunchroom. The man was empty-handed. At Baker's command, the man turned and approached him. Truly, who had started up the stairs to the third floor ahead of Baker, returned to see what had delayed the patrolman. Baker asked Truly whether he knew the man in the lunchroom. Truly replied that the man worked in the building, whereupon Baker turned from the man and proceeded, with Truly, up the stairs. The man they encountered had started working in the Texas School Book Depository Building on October 16, 1963. His fellow workers described him as very quiet—a "loner." His name was Lee Harvey Oswald [7].

Placement can work in the opposite way: Placing important information in the wrong place can greatly reduce the chances that the audience will remember that information. For instance, many scientists and engineers bury details in long lists:

> This report uses data from both the test and evaluation and power production phases to evaluate the performance of the Solar One receiver. Receiver performance includes such receiver characteristics as point-in-time steady state efficiency, average efficiency, start-up time, operation time, operations during cloud transients, panel mechanical supports, and tube leaks. Each of these characteristics will be covered in some detail in this report.

Now that you have read this paragraph, close your eyes and name as many receiver characteristics as you can that will be covered in the report. Did you remember all seven items? As stated earlier, people remember things in groups of twos, threes, and fours. The list here was too long. Also, a problem was that the list occurred in the middle of the paragraph. A better way to emphasize this information would be to group those characteristics and then place the list in a location, perhaps the end of the paragraph, that receives more emphasis.

> This report uses data from both the test and production phases to evaluate the performance of the Solar One receiver. In this report, we will evaluate performance by studying the receiver's efficiency, operation cycle, and mechanical wear.

You might ask why not format the list vertically down the page. Because of the additional white space, this vertical list would certainly receive more emphasis. The main reason is that although vertical lists serve instructions and résumés, too many vertical lists disrupt the reading of papers and reports. These disruptions in reading occur much in the same way that traffic lights slow the driving through a city. If the list is truly important and one that the readers would search for, such as work tasks in an email or research hypotheses in a thesis, you might format it vertically. However, if you have more than one vertical list for every two or three pages of text, you should reconsider. While frequent vertical lists often serve a resume or set of instructions, too many vertical lists make a paper, report, or proposal appear like an outline.

An alternative to a vertical list is a table. Tables are not just for numbers. Skilled writers also incorporate columns of short, parallel descriptions. One way to view a table is as a matrix of information. While a vertical list gives only one perspective to a topic, a table can give two, three, or more perspectives.

Vertical lists, particularly when they are long, are notorious for burying information. The following was a list of recommendations from Morton Thiokol to NASA on improvements needed for the solid rocket booster of the space shuttle. The list came from a briefing that preceded the Space Shuttle Challenger disaster by over 5 months. Because the list was long, the emphasis given to the first recommendation was diluted [8].

Recommendations

- The lack of a good secondary seal in the field joint is most critical and ways to reduce joint rotation should be incorporated as soon as possible to reduce criticality.
- The flow conditions in the joint areas during ignition and motor operation need to be established through cold flow modeling to eliminate O-ring erosion.
- QM-5 static test should be used to qualify a second source of the only flight certified joint filler material to protect the flight program schedule.
- VLS-1 should use the only flight certified joint filler material in all joints.
- Additional hot and cold subscale tests need to be conducted to improve analytical modeling of O-ring erosion problem.
- Analysis of existing data indicates that it is safe to continue flying existing design as long as all joints are leak checked with a 200 psig stabilization pressure, are free of contamination in seal areas and meet O-ring squeeze requirements.
- Efforts need to continue at an accelerated pace to eliminate SRM seal erosion.

In addition to noting that the list was too long, Richard Feynman pointed out that a contradiction exists between the sixth item and the first [9].

How could the important details of this list be better emphasized? One improvement would have been to make a short list of the two or three most important recommendations followed by a list of the secondary recommendations on a separate page. Another improvement would have been to rework the language. The sentences are full of imprecision and needless complexity. For instance, in the first recommendation, what did the writer mean by the phrase "most critical"? No middle ground exists with the word *critical*. Something is either critical or not. Other problems with the language include wordiness, discontinuities, and needless passive voice.

Finally, the author should rethink the use of bullets. Although bullets are a pet stylistic device for many engineers and scientists, the purpose of bullets is to remove hierarchy. Unfortunately, removing hierarchy also removes emphasis. A better choice is a numbered list, which at least provides an order. Another reason to challenge bullets is that they do not show connections [10], and connections are important for a reader's understanding, especially when the information is complex. Yet a third reason to challenge bullet lists is that they are first-draft thinking. Perhaps many engineers and scientists like bullet lists because they are easy to write, but for an author attempting to persuade or for a reader seeking to understand, bullet lists fail to deliver. Richard Feynman challenged their value in scientific writing [9], and so do I.

Move larger blocks of secondary information into appendices

So far, this lesson has discussed how to increase emphasis. Do occasions exist in which you want to reduce emphasis? The answer is yes. For instance, you typically write reports for two or three types of readers, with each type having a different technical background and reason for reading the report. Given that, how do you write the main text of your report for all these audiences? The answer is that you do not. Instead, you place the primary information for your primary audience in the ***main text*** of the report, and then you use ***appendices*** for secondary types of information.

Note that the length of the information affects your decision whether to create an appendix. In general, you can think of secondary information as a branch that takes readers away from the main trunk of the report. If the branch is long (more one page), placing that information into an appendix generally serves the report. However, if the tangent is only a paragraph or two, then an appendix generally does not serve.

One common type of appendix presents background information to help a less technical audience understand the report. For example, if you had written a report on improving a chemical test for the forensic analysis of blood, you might include an appendix for less technical readers that explains