A GUIDE FOR SYSTEMS ENGINEERING GRADUATE WORK

HOW TO WRITE WELL AND MAKE YOUR CRITICAL THINKING VISIBLE

Version 2.0

Systems Engineering Department
Naval Postgraduate School
Monterey, CA, 2017

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PREFACE

This guide is designed to help students communicate effectively in writing. It is useful for all graduate work and the thesis or capstone project report.

Technical and nontechnical communication is perceived as a lesser component of engineering education. Writing skill receives little attention, even though it is consistently cited by professional societies, employers, and accrediting bodies in the United States—such as the Accreditation Board for Engineering and Technology (ABET)—as vital for a proficient engineer.

The ABET Engineering Accreditation Commission's (EAC) *Criterion for Accrediting Engineering Programs* lists several requirements for the successful engineer:

a. An ability to apply knowledge of mathematics, science, and engineering

b. An ability to design and conduct experiments, as well as to analyze and interpret data

c. An ability to design a system, component, or process to meet desired needs within realistic constraints, such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability

d. An ability to function on multidisciplinary teams

e. An ability to identify, formulate, and solve engineering problems

f. An understanding of professional and ethical responsibility

g. An ability to communicate effectively

h. The broad education necessary to understand the impact of engineering solutions in a global, economic, societal and environmental context

i. A recognition of the need for, and an ability to engage in, lifelong learning

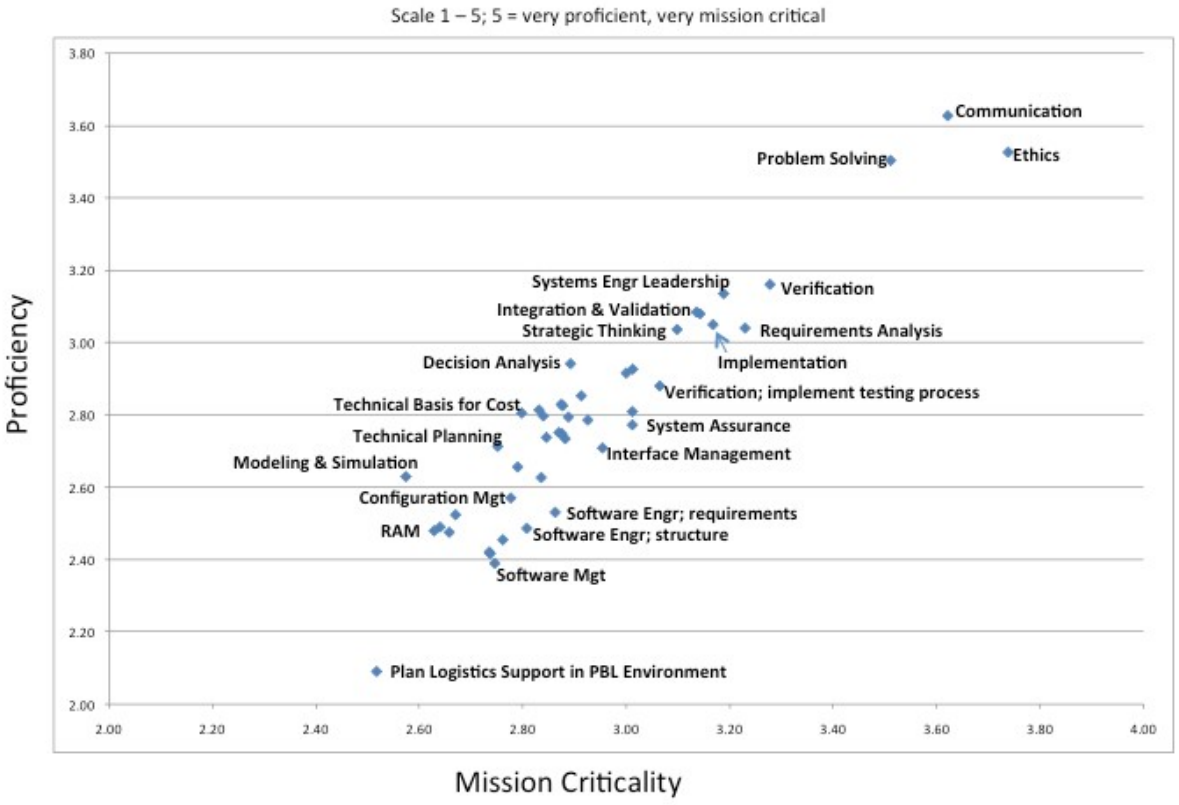
j. A knowledge of contemporary issues

k. An ability to use the techniques, skills, and modern engineering tools necessary for engineering practice. (Accreditation Board for Engineering and Education 2009)

Outcomes (d), (f), and (g) require that an ABET-accredited curricula address developing students' understanding of professional responsibility, how to work on teams, and how to communicate effectively. These are soft skills, and as such receive minimal attention in an already crowded engineering curriculum because such skills are often the

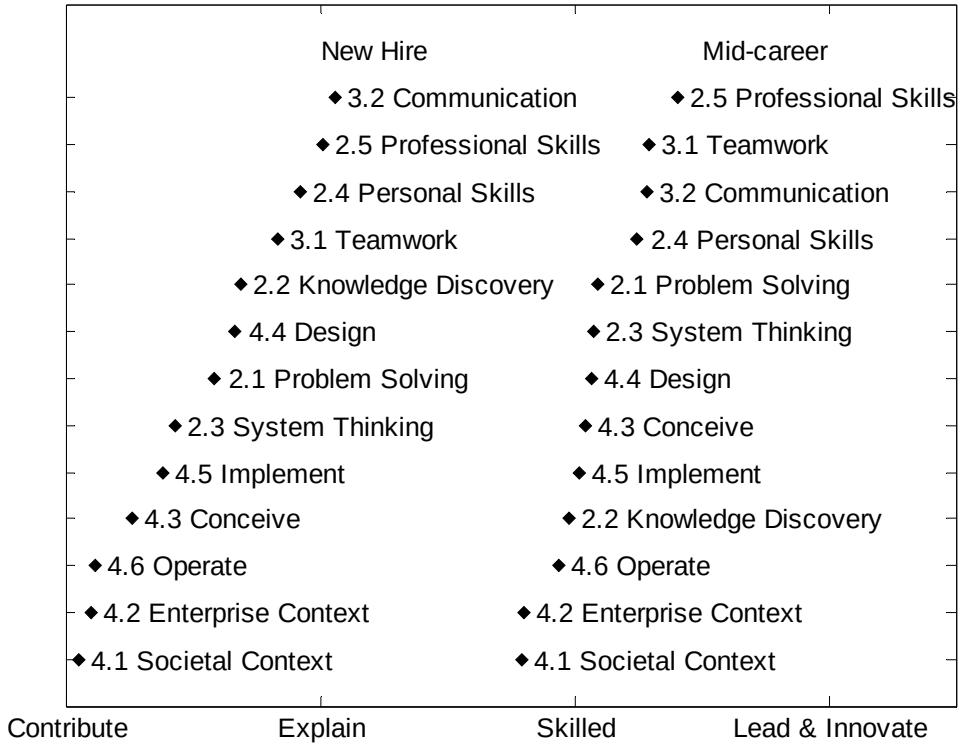
hardest to teach, learn, and assess. Practice in authentic engineering contexts, such as in capstone design projects, teaches soft skills better than classroom lectures do.

Communication rates as one of the most highly desired and important traits of a successful engineer in the U.S. defense workforce. The results of a 2010 survey of engineers from the Department of Defense (DOD) systems engineering 38,000-member workforce are shown in following image. Next to professional ethics, communication simultaneously requires the highest level of proficiency and ranks as the most mission critical of any of the 29 engineering competencies surveyed.



Survey of the Department of Defense Systems Engineering Workforce Skill Proficiencies. Source: Lasley-Hunter, Brooke, and Preston (2011).

To determine levels of proficiency desired in the areas identified by the DOD Systems Engineering Workforce Study, and by the syllabus of goals for engineers from Conceive, Design, Implement and Operate (CDIO), an international consortium of engineering teachers, the CDIO surveyed naval commands. The next image displays the survey results.



Desired Skill Proficiencies of Engineers. Source: Niewoehner (2011).

The survey measured systems engineers' responses to levels of desired proficiency for new hires and mid-career engineers in the categories identified by the DOD study and the CDIO syllabus. Systems engineers were asked, "At what levels of proficiency is it expected that a hired systems engineer perform?" The levels of proficiency ranged from a low of "contribute" to the process up to the ability to "lead and innovate."

Addressing skills not specific to an engineering discipline *per se*—the ability to communicate, to have professional skills (a sense of ethics, fairness, and other attributes), personal skills (productive attitudes, the ability to think and learn), and the ability to work on a team—rates highly for new hires and continues to be among the most important skills for mid-career engineers. By mid-career, engineers should have achieved greater proficiency in all areas.

To align with these aims, the Systems Engineering Department incorporates writing and critical-thinking skills into its curricula. This writing guide sets the standards expected of student work in the department.

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I. OVERVIEW

To help students become successful systems engineering students and proficient systems engineers, this guide provides instruction for writing that explicitly demonstrates critical thinking. The professional engineering community has shown increased interest in technical ability, mastery of engineering science, and effective communication. The NPS Systems Engineering (SE) Department supports effective public speaking, writing, and teamwork skills to prepare for success as a practicing engineer.

The SE Department provides a dedicated faculty member, Barbara Berlitz, to help its students with writing, critical thinking and research. All graduate students may use outside professional writing, editing, and formatting assistance.

The Graduate Writing Center (GWC) is another resource available to SE students seeking to improve their writing and critical-thinking skills. The GWC offers a wealth of handouts, videos, and links on its website at https://my.nps.edu/web/gwc/home. On-campus students also are encouraged to attend resident workshops and online workshops, and presentation videos are available to students who are off campus. Finally, in addition to working with Barbara Berlitz, students are encouraged to tap the center's writing coaches in order to improve their writing mechanics and critical thinking. Writing coaches work one-to-one with students. Coaching is typically arranged through appointments made by the student. For more information, visit:

Online resources:	https://my.nps.edu/web/gwc/resources
Workshops:	https://my.nps.edu/web/gwc/workshops
Presentations:	https://my.nps.edu/web/gwc/quarterly-presentation
Coaching:	https://my.nps.edu/web/gwc/coaching

In addition, the Thesis Processing Office (TPO) provides advice on citations and NPS thesis publishing standards, instructions for using the thesis and capstone templates, and the forms you will need to submit with your thesis or capstone report. Be sure to familiarize yourself with the office's website at https://my.nps.edu/web/thesisprocessing.

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II. ENGINEERING REASONING: A CRITICAL-THINKING PARADIGM

GET TO KNOW THIS BOOK

Engineering Reasoning: Based on Critical Thinking Concepts & Tools

This mini textbook serves as a touchstone for the Systems Engineering Department. It provides students and faculty alike with a common vocabulary for discussing critical thinking and reasoning within engineering.

Elder, Linda, Robert Niewoehner, and Richard Paul. 2013. *Engineering Reasoning: Based on Critical Thinking Concepts & Tools.* 2nd ed. Tomales, CA: Foundation for Critical Thinking.

Engineering Reasoning presents critical thinking as an ability that humans develop by reflecting on their own thinking. Its "A Model of Engineering Reasoning" maps out the critical-thinking process; see Figure 1. At NPS, systems engineering students learn to apply the *standards* of critical thought, such as "accuracy," "precision," "relevance," and "breadth," to *elements* of thought, which combine to produce *traits* of a mature thinker.

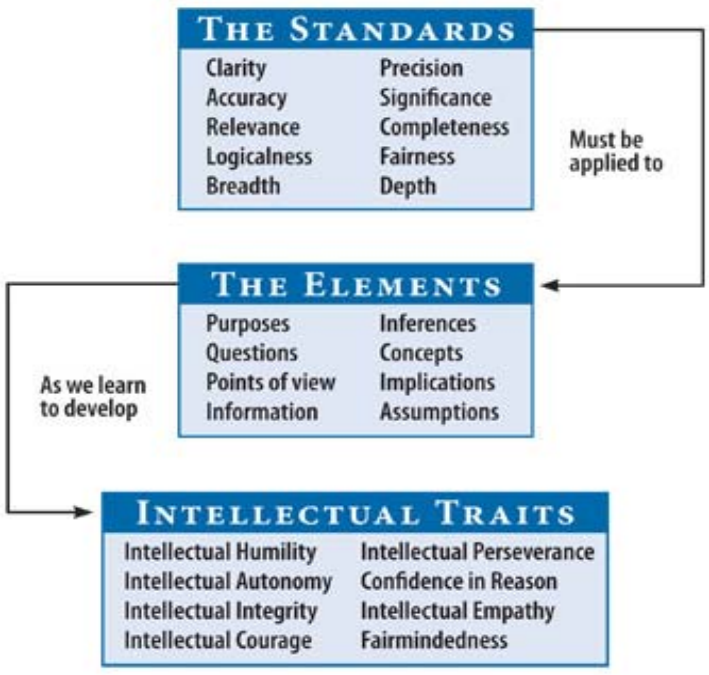

Figure 1. Map of the Critical-Thinking Process. Source: Elder, Niewoehner, and Paul (2013).

SE Department instructors will evaluate student writing based on *Engineering Reasoning's* distinctions between the standards, elements, and traits of critical thought.

In Table 1, see how this use of critical-thinking vocabulary might appear. Column 1 displays a student's claim, and Column 2 displays faculty feedback derived from *Engineering Reasoning*. The feedback prompts the student to demonstrate thinking more explicitly in later iterations.

Table 1. Anonymous Dialogue between a Student Writer and an Instructor Providing Feedback

Student claim in a draft technical argument	**Faculty comment using the vocabulary of *Engineering Reasoning***
"The carbon footprint of the DDG51 should be mitigated."	This claim is not *precise*. What *assumptions* have been made? This is an *incomplete* claim.
"It is important that the carbon footprint of the DDG51 be mitigated."	For whom is the carbon footprint *significant*? What are the *implications* of reducing it? Telling how to accomplish this claim would be more information, and more persuasive.
"The carbon footprint of the DDG51 class of ships would be mitigated by modifying shipboard lighting fixtures to reduce energy consumption."	What *points of view* are involved in this? What is the *purpose* for making these modifications? If the people who are directly interested in this are pointed out, the *significance* of this claim would be clearer

To address the concerns from Table 1, consider the following revision:

> The carbon footprint in DDG51 class ships would be reduced if an off-the-shelf component were used to turn down shipboard lights during times of low usage. Modifying existing systems could be implemented at a lower cost than replacing existing light fixtures because the ship (i.e., replacing existing lights with newer, energy efficient versions) stays the same. Regulating shipboard light use with a timer would bring about the energy reduction in line with Secretary of the Navy Ray Mabus's request for a "greener" fleet by 2012.

The writer states assumptions more precisely (modifications trump replacements), articulates points of view (people interested in the integrity of the ship and/or in cost-effective solutions), and explains more purposefully why these modifications would be positive now. The justification cites Secretary of the Navy Ray Mabus's statement about a "greener" fleet by 2012.

Hint: Notice that there is an "s" after the apostrophe in Mabus.

Section 7.15 of *The Chicago Manual of Style* says, "The possessive of most singular nouns is formed by adding an apostrophe and an s. The possessive of plural nouns (except for a few irregular plurals, like "children," that do not end in s) is formed by adding an apostrophe only.… The general rule extends to proper nouns, including names ending in s, x, or z, in both their singular and plural forms, as well as letters and numbers."

It provides these examples, among others: Kansas's legislature, Jesus's adherents, Berlioz's works, puppies' paws, a bass's stripes, Dickens's novels.

TAKEAWAY: *Engineering Reasoning* prepares students to evaluate reasoning when writing for coursework or a report, whether a thesis or capstone report. Word choice requires precision, accuracy, clarity, and critical thinking; this applies to all communications. A successful SE student must master engineering reasoning to become a proficient engineer. Second, the SE Department and the Thesis Processing Office rely on *The Chicago Manual of Style* for rules on punctuation and grammar. Students can access the entire manual on the SE Department writing page at the Dudley Knox Library: http://libguides.nps.edu/se/writing.

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III. ASSEMBLING ARGUMENTS IN TECHNICAL WRITING

GET TO KNOW THIS BOOK

A Manual for Writers of Research Papers, Theses, and Dissertations

Also known as "the Turabian manual" after its author, Kate L. Turabian, this book helps students augment their knowledge of academic writing and understand what is meant by graduate-level research. It simplifies what is contained in *The Chicago Manual of Style*. In addition to a chapter on assembling arguments (chapter 5), it has two particularly helpful chapters, 18 and 19, explaining how to write using the "author-date references style," which is preferred by the SE Department and required in its theses and capstone reports.

A Manual for Writers forms the basis of the next section of this guide, which outlines the steps in an argument. Turabian describes an argument as something composed of three elements: a claim, reasons for accepting a claim, and the evidence that supports those reasons. Persuasive writing is built out of answers to the following questions:

- What is the claim?
- What reasons support it?
- What evidence supports those reasons?
- How do the author and anticipated reader respond to objections and alternative views?
- How are the reasons relevant to the claims?

Written arguments follow a particular pattern: state a claim ("in a sentence or two"), then support the claim with reasons and evidence. Next, acknowledge and respond to readers' points of view, whether implicitly or explicitly. As *A Manual for Writers* points out, writers must imagine and anticipate objections, such as the evidence is unreliable, out of date, inaccurate, insufficient, not adequately representative of all available evidence, or irrelevant (49–62).

Turabian, Kate L. 2010. *A Manual for Writers of Research Papers, Theses, and Dissertations: Chicago Style for Students and Researchers*, 8th ed. Chicago: University of Chicago Press.

If this mirrors *Engineering Reasoning*, it should. Turabian and the textbook on critical thinking outline basic patterns used by disciplined thinkers. Below is a concrete example to see how technical arguments look in an SE context. Figure 2 contains an abstract from a report submitted to the SE Department. The claims made here are that there is a materiel solution to "increase the survivability of the V-22 Osprey," and that the four systems to do this are (1) a forward looking infrared camera, (2) an infrared countermeasure system, (3) the Joint and Allied Threat Assessment System, and (4) amp and chin-mounted GAU-21s.

This paper describes the development of a materiel solution to increase the survivability of the V-22 Osprey tiltrotor aircraft against man-portable projectile weapons during the vulnerable phases of approach, landing, takeoff, and departure. The project focused on the defensive capability of the V-22 aircraft and the application of a model-based system engineering (MBSE) approach to determine the highest ranking alternative after performance, cost, and risk analyses. The team performed a threat assessment to identify capability gaps in defense during four operational scenarios within urban and rural mission environments. Candidate system functions were chosen based on requirements derived from capability gaps. These functions were decomposed to form a physical architecture based on detection and mitigation components using ViTech© CORE system architecting software. A complex variation of Zwicky's morphological box was created in Microsoft Excel to assess the performance of millions of component combinations based on relative comparisons of 43 quantifiable measures of performance (MOPs). Independent risk and cost analyses were conducted on the top 29 performing alternatives to make a final recommendation. The group of recommended systems included a forward looking infrared (FLIR) camera, an infrared countermeasure (IRCM) system, the Joint and Allied Threat Assessment System (JATAS), and ramp and chin-mounted GAU-21s.

Figure 2. Example of a Technical Argument

Note the pattern: claims, followed by reasons, backed up by evidence, resulting in a conclusion directly related to the initial claim (the desire to improve the survivability of the V-22 Osprey through a particular set of systems suited to the complex SE context under consideration). The authors write persuasively because they used appropriate methods to analyze appropriate data and explained their reasoning fully in specifying what they analyzed, including the methods or tools used.

Hint: Do not use copyright symbols as the excerpt did above, next to "ViTech."

1. An argument explaining a methodology

This next selection from a report shows how the writers chose a process model that would organize their technical approach. The writers carefully explain the reasoning behind a modified Vee model. Not only do they explain it, they *show it* by providing graphics, and they situate the use of a common model in light of what others have done, as well as in relation to their own needs; see Figure 3.

To ensure a rigorous technical approach, a Systems Engineering (SE) process was designed to address the challenge of the MQ-8C development. By identifying a materiel solution before developing detailed requirements, the SE process established a concurrent path that clarified the technical capabilities of the materiel solution. The alternative also quantified and detailed the requirements associated with the JUONS.

The need to compare the capabilities of the materiel solution to the decomposed user requirements traced from the JUONS drove the development of a parallel SE assessment process. This strategy, followed by a gap analysis makes concurrent, independent assessments necessary, while preventing discoveries in one path from affecting, or skewing, the work of the other. The conceptual basis for the approach is shown in Figure 5, which established the working level concept for the Gap Analysis and Feasibility Assessment.

To achieve these goals, the traditional DOD Pre-Milestone, an SE process, and the DOD SE Vee model were modified (Defense Acquisition University 2011). This baseline was adapted to the specific, dual-path approach for this project, depicted in Figure 6. The traditional SE Vee relies on a linear path with concurrent feed-forward and feedback mechanisms to inform verification methodology and task iteration. For the FEU project, the SE process relied on two independent tracks of requirements investigation and capabilities investigation. These tracks converged in an integration activity in which the results of both tracks would be compared, evaluated, and integrated into a common baseline. Disconnects in this baseline would indicate likely gaps and feasibility risks, and these would be investigated and analyzed through the upward, integrated, leg of the Vee.

Figure 3. An Argument Explaining a Methodology (Continued on Next Page)

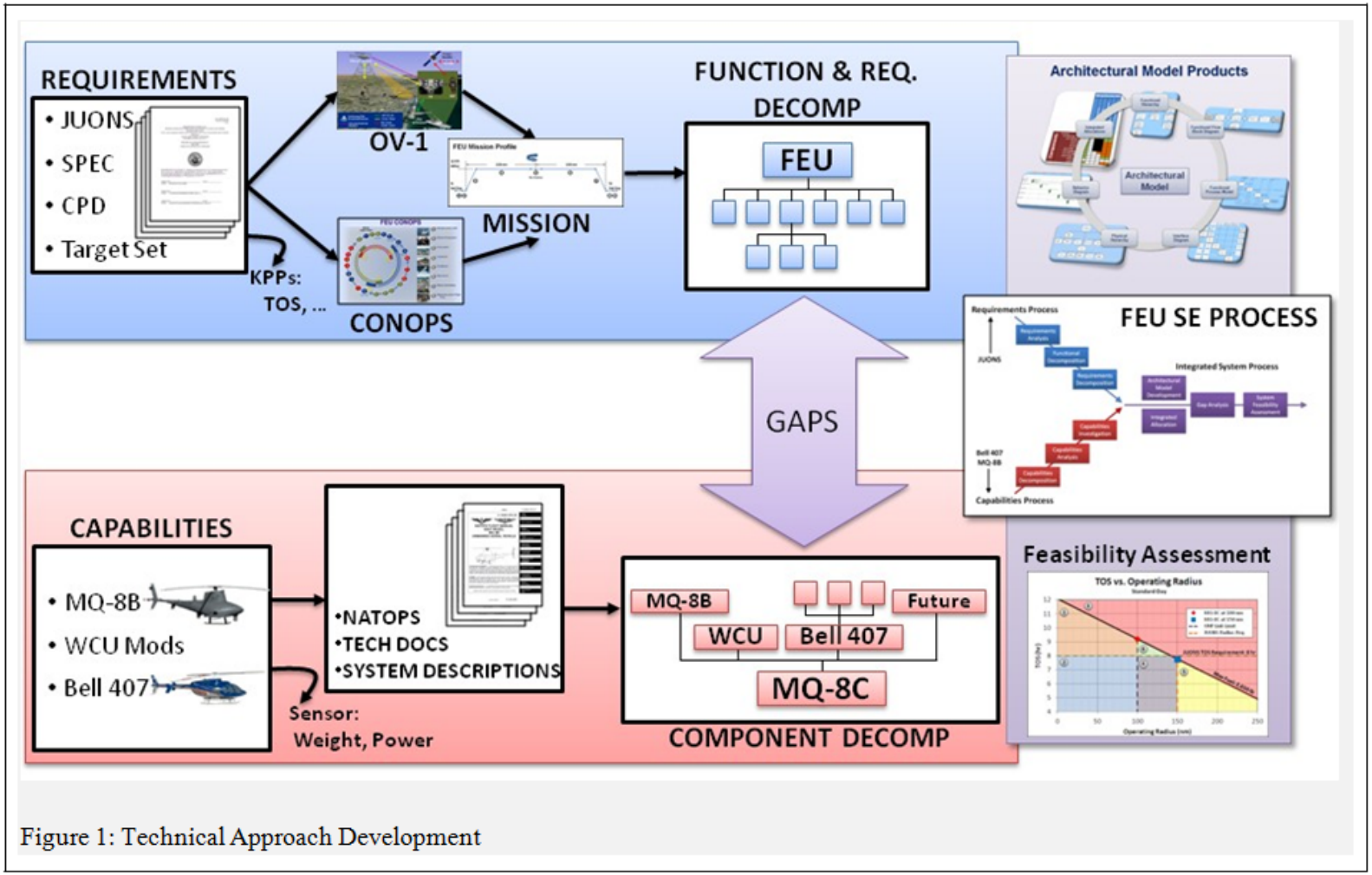

Figure 1: Technical Approach Development

Figure 3 (Continued)

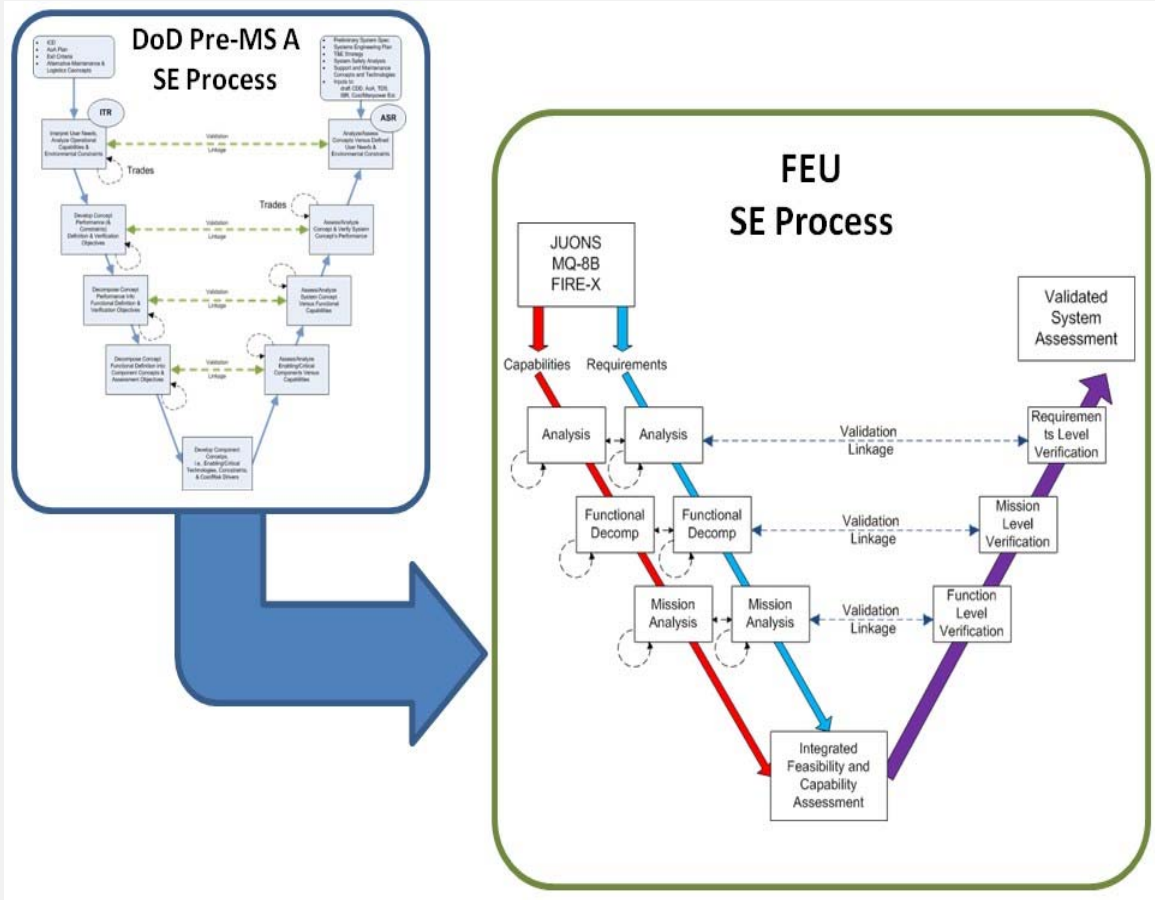

Figure 6. FEU System Engineering Process. Adapted from Defense Acquisition University (2011).

As the project progressed toward the Integrated Feasibility and Capability Assessment, users understood that the model did not adequately represent the tasks necessary to complete the independent and integrated assessments. Additionally, the FEU SE Process Vee model included iteration and feedback links that did not represent the fundamental strategy. To address this shortcoming and refine the process model, the team adapted the FEU SE Process Model Vee to clarify the unique tasks associated with the independent investigations, Figure 6. The updated process diagram specified the tasks associated with the individual process steps and clarified integrated system tasks.

Figure 3 (Continued)

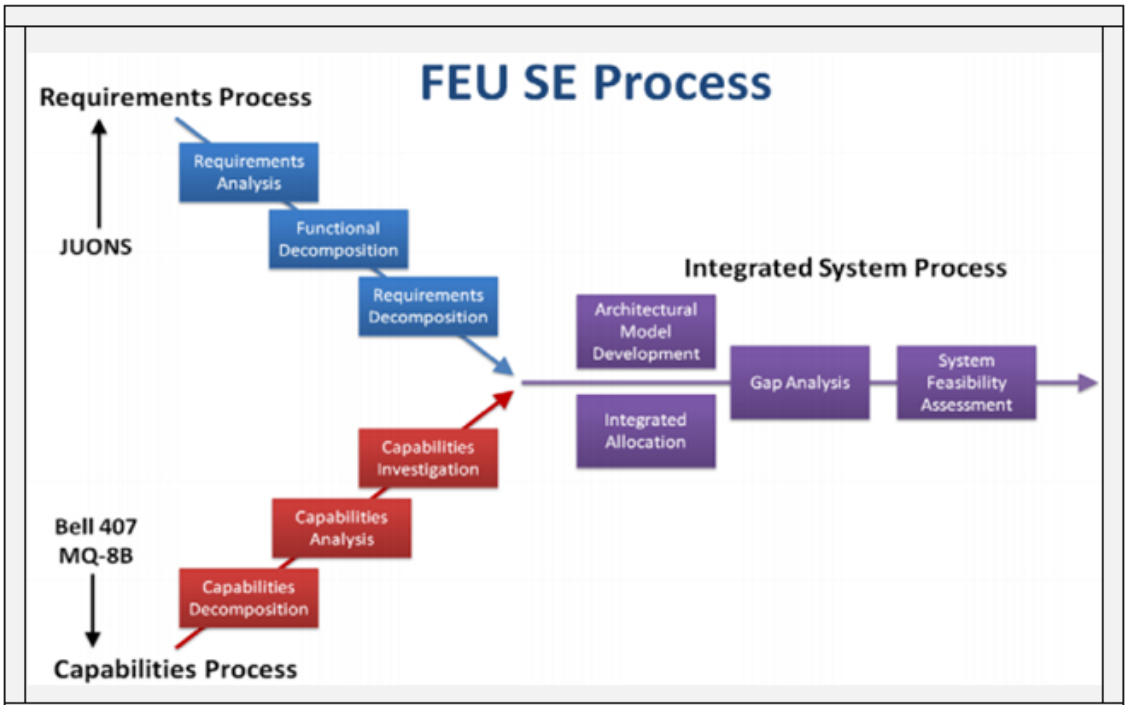

Figure 7: SE Process Flow

Figure 3 (Continued from Previous Page)

Before each figure or table appears, identify each by label and number. Explain how to read the figure and/or the logic behind its construction. Provide a legend. Explain how any lines are obtained, and describe the connections between data points and the color coding used in the graphic.

In Figure 3, the writers explain how the graphics connect to the main point of the section: to show and tell the rationale behind a process model to structure the technical approach. In each figure, the authors include not only a discussion of the figure, but also a technical argument, providing both reasons and evidence.

2. An argument in a data analysis section

Figure 4 comes from a thesis in which the writers present evidence but have not yet arrived at an argument. The instructor's responses (in red) ask for a more complete explanation: as a reader, he indicates the writer's need to provide more guidance on interpreting the meaning of the graphic. In the comments, the SE professor asks for the technical arguments to be developed, for a written explanation, and for the evidence (the graphic itself) to be adequately articulated.

Figure 30, generated by JMP data visualization software, illustrates the correlation of all 28 systems with respect to eight key system attributes. From this chart, relationships can be inferred with respect to the solar irradiance, wind speed, and all eight key system attributes.

Instructor comment 1: Yes, they can be inferred but what did YOU infer from these plots? You must be specific about how these were used to either modify, reinforce, etc., so your reader knows exactly why they are looking at this.

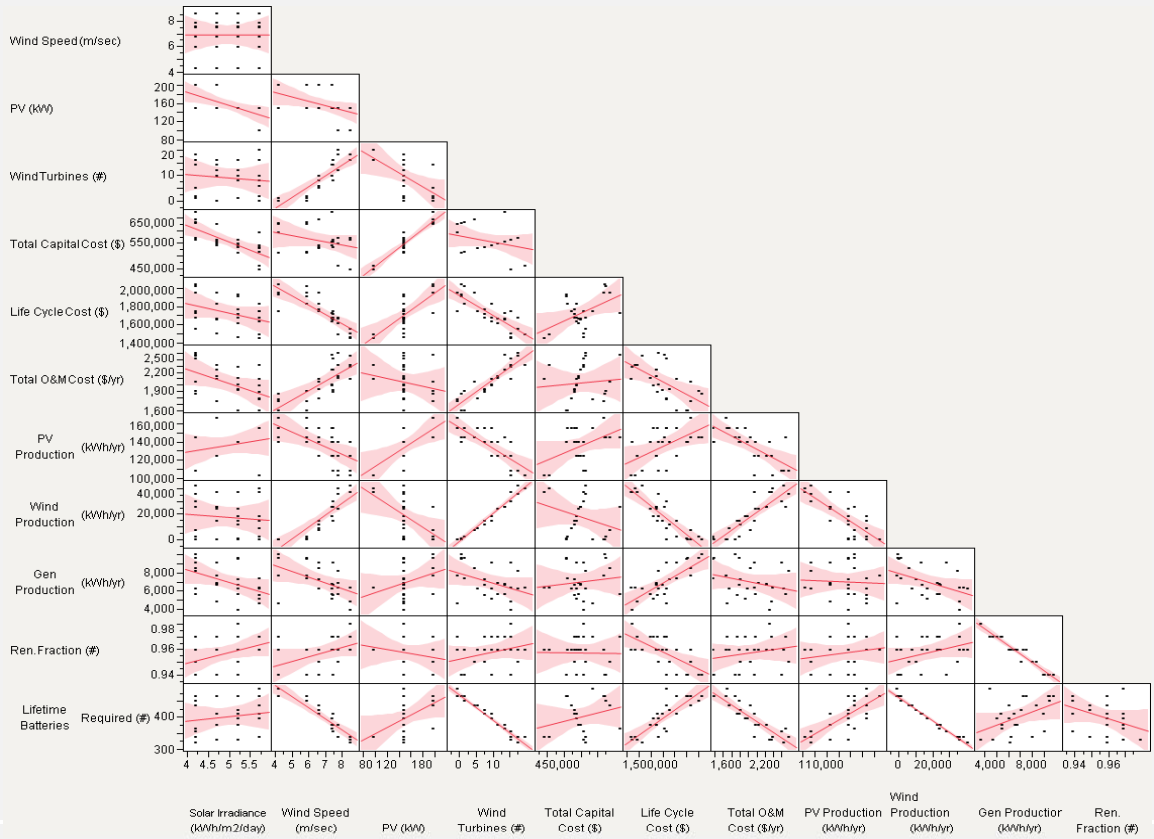

Figure 30. Correlation Table of All 28 Energy Systems and the Eight Key System Attributes

Figure 4. An Argument in a Data Analysis Section in a Thesis
(Continued on Next Page)

Linear trend lines are included to aid in visualizing relationships among the environmental data and attributes. The slope of the lines indicates either positive or negative correlations.

Instructor comment 2: You have not stated anywhere in this section why you show this plot, and specifically, how it relates to the rubric, or anything else you found. Did you use this for any specific purpose—did it confirm or deny any outcomes, how was this useful, etc.?

Thinner lines indicate stronger relationships because the data points follow trends more closely. For example, the total O&M cost negatively correlates with PV energy production and positively correlates to wind production.

Instructor comment 3: It seems to me that many of the correlations have R-squared values that are very low (though some seem high) and that the shaded areas indicate on many that the linear fit can vary quite a bit based on the data and analysis. You should explain this in describing your results here.

Figure 4 (Continued from Previous Page)

Although the writers have explained some of the elements of the correlation table, the instructor commentary indicates a few areas for improvement, pointing out that the students have not connected the observations to a main point. The comments also note how some of the ambiguities in the correlation table have not been adequately explained. As students revise arguments, instructor criticism helps them develop stronger critical thinking.

TAKEAWAY: When preparing a class assignment or a final report, remember this pattern of assembling an argument: claims supported by reasons and borne out by evidence. Technical arguments must present explanations and persuade. They are based on abstract reasons and concrete evidence.

The dialogue between instructor and student is a valuable part of the process. Be sure to address all of your advisor's comments as you work on your thesis or capstone report. Regular meetings with your advisor are vital for this important dialog to help you as you build your work. Regular meetings may prevent lengthy revisions or a change of direction in your research.

IV. CITING

GET TO KNOW THIS BOOK

The Chicago Manual of Style

This 1026-page encyclopedic style manual contains everything you need to know about formatting entries in a list of references and the rules of English usage (grammar, syntax, and punctuation).

When following *The Chicago Manual of Style*, use the "author-date" method of citing your research and compiling a list of references. The author-date method is mandatory for the thesis and capstone project report.

The book in its entirely is available through the Dudley Knox Library, via your NPS credentials, at http://www.chicagomanualofstyle.org.libproxy.nps.edu/home.html. A truncated guide of sources common to NPS theses and capstone reports is at http://libguides.nps.edu/citation/chicagoad/.

University of Chicago Press. 2010. *The Chicago Manual of Style*, 16th ed. Chicago: University of Chicago Press.

This section shows that writing includes research citations, but it does not address the intellectual tasks of model selection or analysis within the SE discipline; advisor(s) will address SE analysis methods and offer model and data suggestions.

The SE Department requires its students to use the author-date citation method of *The Chicago Manual of Style* (not the "notes and bibliography" style) for theses and capstone project reports. This method employs parenthetical citations instead of footnotes.

The only exception to this rule is if the report is in the LaTeX thesis template. Unlike the Word template that SE students typically use for theses and capstone reports, the writer will use IEEE citation style, which is packaged into the LaTeX template. The templates may be downloaded at https://my.nps.edu/web/thesisprocessing/templates-forms.

1. Using citations: Summarizing, paraphrasing and quoting

Scholarly writing involves 1) incorporating the use of other sources by using a summary, paraphrase, or quotation; 2) discussing the importance of these contributions to the research project of the writer; 3) signaling the use of others' work with signal phrases, so that it is clear what constitutes the writer's work and what is drawn from others; and 4) including citations in a complete and consistent way.

2. What needs citing?

All material in a written document is considered to be the author's creation—unless the reader is told otherwise through signal phrases and citations. This means each sentence in the report is original or cited. Citations are used to clarify when someone else's work has been summarized, paraphrased, or quoted.

The following items represent some of the types of sources that may be incorporated into a formal report. In all cases, the original creator must receive credit for his or her written words, spoken words, images, or ideas:

book	government document	proof
computer code	graph	published article
concept	idea	speech
conversation	model	table
dataset	lecture	typology
definition	organizational chart	unpublished article or paper
drawing	photograph	video

The Dudley Knox Library and Thesis Processing provide useful examples of the types of materials that NPS students often cite here: http://libguides.nps.edu/citation/chicagoad.

3. The summary

A summary is a writer's restatement of another's contribution to knowledge. This is indicated by means of a signal phrase, an identification of original context, and an in-text citation.

Summaries often create the context for why a researcher is asking a particular question. A recent article in the journal *Systems Engineering* presents a summary of various documents produced by several organizations that contributed to defining systems engineering:

> The core of systems engineering standards and de facto standards—IEEE 1220 (Institute of Electrical and Electronics Engineers 1998), ANSI/EIA-632-1999 (American National Standards Institute and the Electronic Industries Alliance 1999), ISO/IEC 15288:2002 (International Organization for Standardization and the International Electrotechnical Commission 2002), and CMMI (Carnegie Mellon Software Engineering Institute 2002)—have been around for a decade, which makes the definition of systems engineering somewhat immature. MIL-STD 499A (U.S. Department of Defense 1969), and MIL-STD-490A (U.S. Department of Defense 1985) were the first standards that mentioned systems engineering, but define systems engineering in a much narrower way. (Valerdi and Davidz 2009, 176–177)

In the preceding excerpt, note the following:

- how to use the author-date method of citing sources when the sources cited are not written by single authors, but rather by agencies or institutions
- how to include multiple citations in one paragraph
- how to refer to military standards
- how to format a "block quote" (quotes of five or more lines)—no quotation marks, single-spaced, indented 0.5 inches from the left and right margins, and parenthetical citation located outside of the quoted passage, after the final punctuation of the quote.

A summary like this one from *Systems Engineering* provides the development of a literature review (for a thesis) or the background section explaining the rationale behind the research conducted (for a project report written by a team).

This journal excerpt summarizes several documents to develop a frame of reference for other ideas. Notice how the writers capture key definitions to demonstrate where important ideas are coming from. It also gives a good example of how to cite industry and technical standards and other items used in military writing. Again, use the Dudley Knox Library link at http://libguides.nps.edu/citation/chicagoad for examples typical to NPS reports.

Below is an example from a summary written for the *Journal of Business*, whose purpose is to build context in the field of economics:

> Recent literature has examined long-run price drifts following initial public offerings (Ritter 1991; Loughran and Ritter 1995), stock splits (Ikenberry, Rankine and Stice 1996), seasoned equity offerings (Loughran and Ritter 1995), and equity repurchases (Ikenberry, Lakonishok, and Vermaelen 1995). (Avery and Chevalier 1999, 499)

Observe how to write a sentence that features a summary, and how to write in-text citations for single-, dual-, and multiple-authored works. When the parenthetical citation appears within a *normal* sentence (not in a block quote), citations are placed just before the final mark of punctuation. Since this is an example of a both a block quote and a block quote that contains parenthetical citations, notice that the authors (Avery and Chevalier), year (1999), and page number (499) of the writer appear after the quotation's period, and without any period after the citation. The full citation for this journal article is included in the list of references, alphabetically by the first author's last name.

4. Paraphrasing

To see what paraphrasing looks like, here is a plagiarism example to see *what not to do*—failing to give credit to the original source. Use paraphrase appropriately to avoid violating academic integrity. Failing to credit other researchers or authors, and using their words, phrases,

order of logic, or the order of the presentation of ideas without acknowledgment constitutes plagiarism.

Let us look at an example of how one author was plagiarized by another, presented in a class lecture on November 3, 2010, by Erik Dahl of the National Security Affairs Department. He presented the following passage, which was written by NPS Professor Simson Garfinkel and published in an online journal:

> Causes that employ Leaderless Resistance do not have these links because they are not organizations: they are ideologies. To survive, these ideologies require a constant stream of new violent actions to hold the interest of the adherents, create the impression of visible progress towards a goal, and allow individuals to take part in actions vicariously before they have the initiative to engage in their own direct actions. (Garfinkel 2003)

Compare Garfinkel's paragraph to the following paragraph from Marc Sageman's 2009 book, *Leaderless Jihad: Terror Networks in the Twenty-First Century*. Words and phrases similar to, or copied from, Garfinkel's work have been italicized:

> The leaderless social movement has other limitations. *To survive*, it *requires a constant stream of new violent actions to hold the interest of* potential newcomers to the movement, *create the impression of visible progress toward a goal*, and give potential recruits a *vicarious* experience *before they take the initiative to engage in their own* terrorist activities. (145)

This instance of plagiarism and others has had devastating consequences for Sageman's professional reputation. But plagiarism could have been prevented if Sageman had paraphrased correctly.

Here is what a paraphrase should look like. Use a signal phrase to indicate that someone has been used as a source (i.e., "Garfinkel describes") and/or a citation (i.e., [Garfinkel 2003]) after the (proper) paraphrase appears. Enclose words and phrases borrowed verbatim in quotation marks:

> Garfinkel (2003) describes this concept of "leaderless resistance" movements by saying that they are not organizations, but are ideologies. They need frequent new revolts or rebellions to recruit and sustain followers; this creates the impression that participants have an achievable aim. Further, the "new stream of violent actions" allows adherents to imaginatively take part in the ideological movement, prior to "engage(ing) in their own terrorist activities."

In paraphrasing, represent the other person's main point in different words and vary the order of presentation, syntax, and word choice. Generally, no more than three words in a row should be the same between the original version and paraphrased version. Enclose unique phrases in quotation marks. Use a signal phrase ("Garfinkel describes") to show the reader where the source's contribution begins. Then conclude the paraphrased material with a citation. It is assumed that what comes after the citation are your own analysis and words.

5. Quotations

A quotation is the direct inclusion of someone else's exact wording into a new written work. Quotations require quotation marks, except for block quotes (quotations five lines or more). Block quotes should be indented 0.5 inches on the left and right, with no quotation marks around them.

Introduce quoted material with an attribution or some explanation for its relevance to the context of the report. Thesis processors see many theses and capstone reports with quotes that "appear out of nowhere"—quotes that make up the entire sentence with no attribution or introduction. A parenthetical citation alone is not sufficient; include attribution such as "according to" and the like.

When to include page numbers: A direct quotation must have an in-text citation that includes the page number or other locator to the original quote. Any time you use a graphic, table, chart, or figure created by someone else, you must indicate that the quoted material comes from someone else, provide a citation to locate it, and include a page number or other specific location information if the source material does not have pages.

Complete rules for quoting are found in the Dudley Knox Library's link to *The Chicago Manual of Style*, chapter 13: http://www.chicagomanualofstyle.org.libproxy.nps.edu/home.html.

6. In-text (parenthetical) citations

What follows are examples of how to write using the author-date style to cite sources within the body of a report. These examples are from the chapter "Documentation II: Author-Date References" in *The Chicago Manual of Style*. Remember, the NPS library provides examples of sources frequently used by NPS students, such as government reports, field manuals and directives, at http://libguides.nps.edu/citation/chicagoad.

- **Basic method**

Below is a passage that shows different ways that citations can be incorporated into the text. The two essential pieces of information to include are the author's last name (or organization name, if it is the author or owner of the work) and the publication year:

> As legal observers point out, much dispute resolution transpires outside of the courtroom in the "shadow of the law" **(Mnookin and Kornhauser 1979)**. Here we empirically demonstrate that workers' and regulatory agents' understandings of discrimination and legality emerge not only in the shadows of the law but also, as **Albinston (2005)** suggests, in the "shadow of organizations." (Quoted in University of Chicago Press 2010; emphasis added)

Notice that the first citation, to a dual-authored work, lists both last names and the year—in parentheses—followed by a period *outside* the parentheses. An alternative is to put only the year in parentheses when the writer has already provided the name of the author within the

sentence; see the Albinston citation. Finally, note that the citation for an entire block quote follows the final period in the quote and has no ending punctuation.

- **Special situations**

  - **Direct quotations**
    Include its page number or page range. Use an en dash, not a hyphen, between page numbers (an en dash is longer than a hyphen):

    (Pollan 2006, 99–100)

  - **Source by two authors**
    Write "and" between names:

    (Ward and Burns 2007, 52)

  - **Source by three or more authors**
    Include all author last names in the first instance, and then use "et al." after the first name in subsequent citations:

    First use:
    (Doe, Smith, and Jones 2009)

    Then:
    (Doe et al. 2009) or
    According to the data collected by Doe et al. (2009) …

  - **Clarifying information, in addition to the citation**
    Include additional bits of information inside the parenthesis, after the author's name and date, separated by a semi-colon:

    (Mandolan 2009; *t*-tests are used here)

  - **Author's name woven into sentence**
    When woven into the sentence, do not repeat the author's name inside the citation:

    Tufte's (2001) excellent book on chart design warns against a common error.

  - **Cross referencing other articles**
    To tell readers to consult other articles, write:

    At least three works satisfy the criteria outlined in Smith's (1999) study: see Rowan (2006), Bettelthorp (2004a), and Choi (2008).

  - **Multiple references inside one citation**
    Use a semi-colon to separate them:

    (Armstrong and Malacinski 1989; Beigl 1989; Pickett and White 1985).

- **Using citation management software**

Citation management software will create an in-text citation such as "(Navy 2001)" if a single author cannot be located. The problem with this is that (Navy 2001) could apply to thousands of different documents. Therefore, manually insert the name of the agency within the Navy that published the document: (NAVSEA 2010).

Be sure to edit the corresponding entry in the reference list to match the in-text citation.

Microsoft Word's citation manager does not produce perfect in-text citations or reference lists. **Substantial** hand editing is required in most cases.

Hint: To edit the reference list or citation, convert it to "static text" first. This can usually be done via the drop-down menu on each citation or on the list of references. For help, ask a thesis processor.

- **Multiple citations to one source in one paragraph**

Instead of repeating the same in-text citation after each sentence, which can look awkward to the reader, use a *mix* of in-text citations and signal phrases. Note the mix of citation methods to the 2009 Smith and Jones article in this paragraph:

> Red and yellow are the best colors with which to decorate your restaurant because they induce feelings of hunger (Smith and Jones 2009). Consider popular fast-food chains, which often use red and yellow in their advertising and décor. According to Smith and Jones' study (2009), restaurant customers felt more energized in red and yellow environments, which encouraged them to order more food. The same study indicated that patrons felt relaxed in blue and purple environments, which encouraged them to "spend more time considering the menu options and eat at a slower pace" (29). Although blue décor can give your restaurant a more casual, laid-back feel (Kramer, 1999), Smith and Jones believe it encourages patrons to linger at their tables without ordering additional food or beverages. Accordingly, it is difficult to identify a popular chain restaurant that decorates with calmer hues. (Quoted in Naval Postgraduate School 2017)

- **Informal or unpublished information**

Formal research rarely uses information from private conversations or lectures, so use these types of sources sparingly. Unpublished information prevents readers from tracing a claim to its original source. Furthermore, the reader may want to see the original context or re-create the experiment.

Research involves locating where information comes from and making sure it is available for others. Thus, whenever possible, writers who base a claim in a paper on a lecture should cite

the course textbook so others can find it. When basing a claim on a module in a course, find published readings with the same information in order to make it available to others.

In a formal work like a thesis, informal sources such as newspaper articles and simple web pages, such as "About Us" pages, can be mentioned in the narrative only; a formal citation does not need to be included in the list of references.

- **Unpublished or yet-to-be published academic or government works**

  (Smith, unpublished)
  (Smith, manuscript submitted for publication)

- **Unpublished data**

  Provide the source of information, and explain why it is unavailable to the reader:

  (C. R. Brown and M. B. Brown, unpublished data)

- **A comment made in a lecture**

  Provide the exact date and location:

  An important distinction between design and architecture was made in a lecture on conducting a system upgrade given at the Naval Postgraduate School in Monterey, CA, on December 14, 2011 …

- **A conversation or email**

  To cite a comment from a subject-matter expert or a professor, include the person's title or affiliation in the narrative before providing the in-text citation. Providing detail authenticates the statement and makes the tone of the paper suitable for graduate work:

  William Smith (personal communication 2015), a civil engineer and professor at the Naval Postgraduate School, made this important distinction between architecting and design.

- **Internet sources**

  Wikipedia and Google can provide basic ideas and introduce concepts used in research, but graduate work requires more thoroughly vetted material. When including information from *Wikipedia*, a personal website, or a blog, justify the use of these unscholarly sources. *The SE Department discourages all use of Wikipedia*.

  To refer to websites, identify them by a specific title; by the name of the sponsor, owner of the website or author of a pertinent page; or by a descriptive phrase. In the list of references, be sure to provide a Digital Object Identifier (DOI) or a stable URL for every online source cited. (Do not include this level of detail in the parenthetical citation.) If a publication year is not available, use a last modified date. In the absence of a last modified date, use the access date.

- **Figure and table titles—Include "Source:" or "Adapted from**"

Include a source line when borrowing a figure or table. Place the source line in a new sentence after the figure title or table title.

Figure 23. Figure Title Here. Source: Smith (2017).
Table 17. Table Title Here. Adapted from Jones (2016).

If a figure or table is altered in any way to suit the facts of the report, add the words "Adapted from" before the citation. If it is an exact copy from another source, add the word "Source:" to the citation (note that a colon is used with "Source:" but not with "Adapted from." Provide the author's last name and put only the year in parentheses.

Figures should have a title below them (see Figure 5); tables should have a title above them.

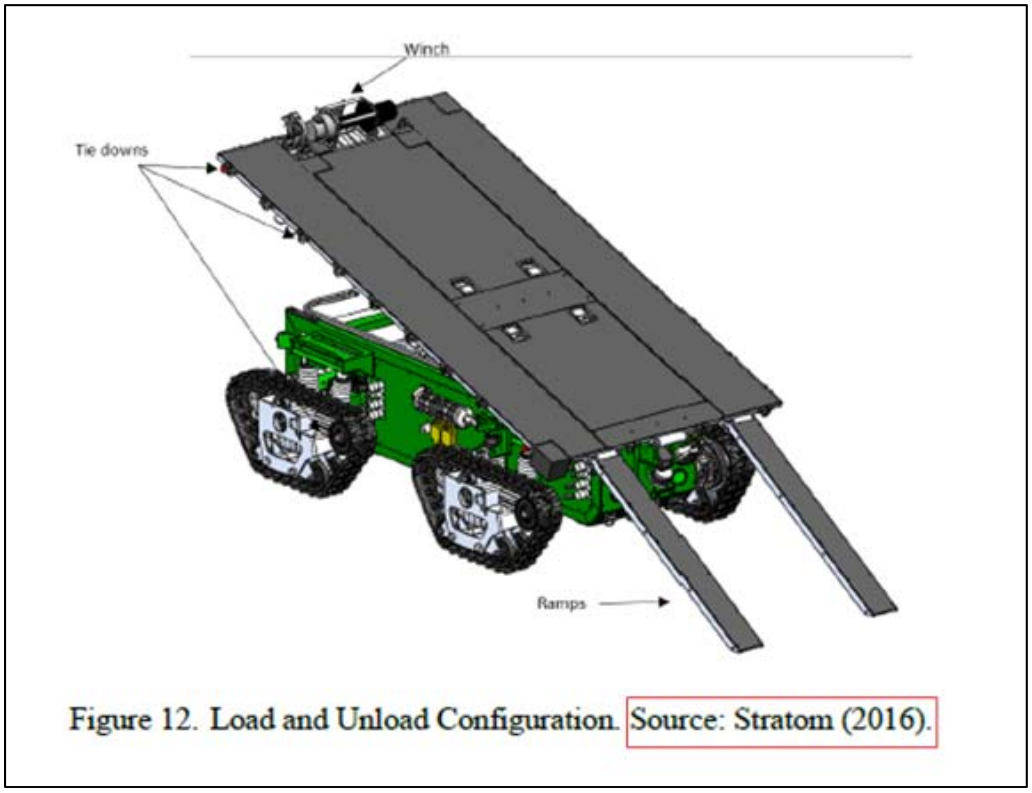

Figure 5. How to Cite a Figure (Red Box for Instructional Purposes Only).
Source: Team ACME (2016).

Hint: The thesis and capstone templates provide both a figure title and an optional figure subcaption for each figure. Every figure must have a title, preferably one line fewer than 15 words. Then, any extra information is placed in a subcaption between the image and title, as in this figure from the 2016 capstone by Team East:

Mobile landing platform (MLP) moored with large, medium-speed roll-on/roll-off (LMSR) (left), auxiliary dry cargo ammunition (T-AKE) (top right), expeditionary fast transport (EPF) (bottom right).

Figure 2. Ships of the Maritime Pre-positioning Force.
Source: USMC CD&I (2015, 12, 15, 17).

TAKEAWAY: Format your citations and reference list entries using the author-date branch of *The Chicago Manual of Style*. Cite information that is not already established or common knowledge.

Do not use footnotes as citations, endnotes, superscripts, or other methods of citing sources. The "notes and bibliography" branch of Chicago style applies to the humanities and social sciences, not to SE technical writing. The only exception to this rule is if the report is in LaTeX; you may use the IEEE citation style packaged inside that template.

Be careful to use signal phrases, quotation marks for special words, and in-text citations to credit the work of others. Avoid plagiarism by 1) using in-text citations (include page numbers for direct quotations) 2) adding "Source:" or "Adapted from" to captions if a figure, table, or other pictorial material is taken from another source, and 3) providing a complete list of sources at the end of the paper.

Each source cited in the body of the paper must have a corresponding entry in the list of references, and vice versa.

V. TECHNICAL WRITING STYLE

GET TO KNOW THIS BOOK

The Naval Institute's Guide to Naval Writing

Robert Shenk's *The Naval Institute's Guide to Naval Writing* tells military and nonmilitary audiences how to write a technical report or an article for a scholarly journal. His book demonstrates the technical writing style appropriate for SE students.

Shenk, Robert. 2008. *The Naval Institute's Guide to Naval Writing.* Annapolis, MD: U.S. Naval Institute.

This section discusses some features of technical writing style, in order to show *how* and *why* technical writing sounds the way it does.

VOICE, PERSON, TENSE, AND TONE

Language choices create the right sound in technical writing. Infrequently and selectively using passive voice, using the correct grammatical person, choosing the proper verb tense and avoiding informality create the right tone for technical writing. Use the active voice as much as possible, but if not possible without using redundant expressions such as "this author" or "the researchers," then use the passive voice. Occasional use of the first person ("I," "we") is acceptable in the SE Department. This is consistent with contemporary, professional SE journals.

Technical writing uses a formal tone to highlight its subject matter, downplay the writer, and focus on the information presented in the report. Treatment of voice, person, tense, and tone contribute to this goal.

1. Passive and active voice

A sentence written so that it does not indicate *who* is doing the action will be using a form of the verb "to be" (such as *was eaten, has gone, is done, are harvested*). This is passive voice. Use the passive voice only when needed to emphasize what is done. Using the passive or active voice is a stylistic decision; neither style is right or wrong. Converting a sentence from passive to active might occasionally require the use of the first person to show who is doing the action. Favor active verbs over passive constructions. Write "this thesis *examines* three case studies" rather than "the following case studies *were examined* in the thesis."

Passive voice creates problems when the actor evades responsibility for taking an action, when an entire paper reflects the passive voice, or when passive and active voices appear in the same sentence.

Use the active voice to enliven writing and to avoid wordiness. A variety of edits might be possible. See Barbara Berlitz for individual assistance. The Writing Center at UNC-Chapel Hill has a useful handout at http://writingcenter.unc.edu/handouts/passive-voice/ for you to use.

2. Verb tense

Technical writing uses tense for specific purposes. Use the present tense to talk about established information (i.e., "the data show") and use past tense to discuss research already completed by others.

3. A formal tone

There are ways to create the formal tone expected for SE writers:

- Do not use contractions or abbreviations. Spell out "it's" or "can't."
- Write "according to" instead of "per."
- Avoid jargon: Instead of "manning," write "personnel requirements."
- Write "versus" instead of "vice."
- Avoid slang. Instead of casual expressions like "by the book" or "24/7," write "according to established procedures," or "continuous surveillance."
- Do not use "etc." Finish the list for the reader or use "such as" or "and the like."

PUNCTUATION AND OTHER SENTENCE-LEVEL CHOICES

Sentence-level choices enable the reader to focus on the message. When writers violate common writing conventions, a reader can be confused and be forced to refocus his or her attention on determining the meaning, which makes reading uncomfortable. Use punctuation correctly and carefully.

1. Commas

Commas separate elements in a sentence and items in a list. They also group ideas or steps in a sequence. Commas are required before the coordinating conjunction in compound sentences (two independent clauses joined by *and*, *but*, *for*, *so*, *nor*, *yet*, *or*).

Although many rules govern comma usage, in SE technical writing, use commas to make a sentence clear. Military and professional writing often leave out commas or use them incorrectly, which creates confusion. To borrow from the title of a well-loved grammar book, saying that *a panda eats shoots and leaves* differs greatly from *a panda eats, shoots, and leaves.* In the first, pandas eat (bamboo) shoots and then move on; in the second, the Panda chows down

dinner, shoots a gun, and moves on. Here are some examples to remember:

- Commas follow introductory words, phrases or clauses in a sentence: "As a careful study will show, the curves prove that Fourier's theory is correct."

- Commas separate two or more adjectives modifying a noun: "The large, reflective white target."

- Commas separate a dependent clause in the middle of a sentence: "The measurement, although in rough agreement with the theory, does not agree perfectly."

Despite the frequent advice to read a passage out loud and insert commas at breathing pauses, this practice, though useful, can encourage the overuse of commas. This practice does work well for determining placement of commas after introductory words, phrases or clauses. Consult *The Chicago Manual of Style* for the rules of comma use. Alternatively, write shorter sentences, making two or three out of one long one.

2. Quotation marks

Not surprisingly, quotation marks denote the use of someone else's thoughts, but other lesser-known uses of quotation marks are useful and important (Table 2). *The Chicago Manual of Style* mandates double quotes, not single quotes, unless one needs to use quotes within a quote.

Table 2. Uses of Quotation Marks and Examples

Use of Quotation Marks	Example
To set off a word that is colloquial but deemed acceptable to use; this is rare	…the dependence on the type of "kill."
To set off a word as special or note a term on first use	…this is an instance of a "system of systems."
To use a word or phrase from another source, when paraphrasing a writer	…the term "autonomous" here is used in contrast to something that is "automatic."
To link words into groups, especially stages in a process	…while the "Perform Localized Tracking" function is being carried out, the function "Fire HEL" is also performed.

3. Capitalization

In military writing, capitalizing words that do not need to be capitalized is the norm. However, in nonmilitary writing, such as in a thesis or capstone report, capital letters signify

proper names, not common nouns. Do not capitalize "government agency," because there are many government agencies. The Federal Drug Administration, however, should be capitalized because only one government agency has that name.

In the next example, capitalization denotes specific things (proper nouns):

> Crystal Ball was used to analyze the variables associated with the HEL and performed a technique known as Monte Carlo simulation to provided forecasts of the entire range estimate of the cost probability to outfit a HEL weapon system onto a naval surface combatant.

The reader knows that Crystal Ball is a particular thing—a proper noun—because it has been capitalized. Although one is unlikely to mistake this Crystal Ball with a gypsy's crystal ball, capitalization performs an important function. Notice that the writers do not capitalize "surface combatant." Why? Numerous surface combatants exist. For these reasons, write "naval surface combatant" or "U.S. Navy surface combatant" or "Navy surface combatant," not "NAVAL SURFACE COMBATANT" or "Naval Surface Combatant."

4. Apostrophes

Apostrophes indicate *possession* and should not be confused with plurality by adding only an "s". Plural acronyms or years *do not* get an apostrophe added: *1970s*, *UAVs*.

For example, if a writer wants to ask whether military police organizations, represented by the acronym MP, can help Army programs with security, he would write: "Can MPs help provide Army programs more security?"

When the possessive noun ends with an "s," place the apostrophe after the s: "Can Army programs' security be enhanced by MPs?"

Hint: For plurals, add an "s" but not an apostrophe: MOPs (not MOP's) and 1990s (not 1990's). When several people possess something, put the apostrophe outside the final s: the three students' books.

---

5. Hyphens

Use hyphens to link multiword phrases. Sometimes the use of two or more words together is required to describe something. Hyphenate those words.

the back-of-the-envelope model	commercial-off-the-shelf solution
man-in-the-loop	land-based aircraft

6. Compound nouns

A single noun made up of two or more words is a compound noun: *twenty-nine*, *cross-reference*. When in doubt, consult *Webster's* dictionary. If not found in *Webster's*, omit the hyphen. You may also consult *The Chicago Manual of Style's* hyphenation table, which provides a plethora of examples.

Hint: Do not confuse hyphens with dashes, which are longer and perform different functions from hyphens. There are two types of dashes: the "en" dash and the "em" dash, which is the longest dash. Use an en dash between a range of numbers; use an em dash to indicate breaks in thought. In the reference list, use three em dashes to replace an author's name a second or more times, if several works by the same author were cited. Both dashes are found in Word's ribbon, under Insert→Symbol→More Symbols→Special Characters (they are the top two choices).

---

7. Bulleted lists

The Chicago Manual of Style sections 6.124 and 6.125 give many examples of proper punctuation of bullet, or vertical, lists. According to section 6.124, lists should be introduced with a full grammatical sentence followed by a colon. Then, if the items in the list are full sentences, the writer should capitalize the first word and add ending punctuation. If the items are numbered, a period follows the numeral and the first word will be capitalized, even if the items are not in sentence form. Bullet items are not capitalized unless they are full sentences. You may need to override Word's automated capitalization.

Here is a link to that section of *The Chicago Manual of Style* through the Dudley Knox Library's SE Research Guide page at http://www.chicagomanualofstyle.org.libproxy.nps.edu/16/contents.html. Go to the section on Punctuation (chapter 6) and then look for "vertical lists." By contrast, the list can be structured as if it were all one sentence; use standard punctuation between elements of the list and end it with a period. (In this case, the lead-in to the vertical list would not be a complete sentence, but form part of a long sentence.) See section 6.125.

8. Other specialized punctuation rules

Here are some other punctuation rules to keep in mind:

- Numerals designate measured distances, figures, percentages: 7 km, 90° F, Figure 4.
- Numbers one through nine are spelled out; use numerals 10 and above in general narrative material.
- Variables or symbols do not begin sentences.
- Leading zeros are used in decimal values. "Point seven five" is written as 0.75.

- Dates may be formatted as May 10, 2009, or 10 May 2009 but not May, 2009 (the middle comma is the error). Choose **one** date format to use consistently.

- A range of numbers uses an "en" dash to separate them, not a hyphen. The en dash is found under Insert→Symbol→More Symbols→Special Characters on Word's ribbon.. Close up the spaces around the en dashes ("1–100" not "1 – 100").

LANGUAGE USE: INTRODUCING SPECIALIZED TERMS

Good technical writing must balance the need to define specialized terms against the need to use shorthand vocabulary common in systems engineering. Although SE writing involves technical language that efficiently communicates among professionals in the field, formal writing customarily provides a brief definition of a specialized term on its first use.

In this example, observe how the SE term "system of systems" is used, briefly defined, not capitalized, and connected to the particular situation described in the report:

> The FCS was envisioned to be the first of its kind; a system designed around an entire unit formation. The term "system of systems" emerged to describe the multiple platforms, supporting products, and peripheral systems that would be necessary to address the vast capabilities FCS would offer. The system was comprised of manned and unmanned systems, as well as a ubiquitous communications network.

Define a technical term the first time it appears. Although the reader may know the meaning of system of systems, a reader new to the field of SE would need a definition. If you expect most of your readers to know SE terminology, the definition can be brief.

Providing a context for a technical argument appears in the following example. It both summarizes one section and provides detail about what will be discussed:

> Maintenance of Naval aircraft occurs around the globe in a complex three-level maintenance (3M) system. Data is recorded tracking the maintenance steps involved from the removal of a component from the aircraft all the way through its repair and reinstallation. Data available in the fleet 3M system for BCMs is closely mirrored by requisition data available in the supply system. Data from the fleet 3M system will be used in this paper for analysis of the research questions posed by this thesis.

A good writer explains not only the material covered, but also *how* the material will be covered, *why*, and *in what order*. As in the passage about aircraft maintenance, the writer presents the topics in the order of presentation in the subsequent chapter.

Hint: The SE Department wants SE model names capitalized, an exception to the general rules the *Chicago* manual. Generally, specialized terms are lowercased.

WORD CHOICE: DISCUSSING THE SUBJECT MATTER

This section examines four kinds of language-use problems that might arise in SE report writing:

- not realizing how words could be interpreted by various audiences
- choosing the wrong word altogether
- not realizing that the word has a specialized use in the SE context
- making one word do the job of another type of speech

1. Not anticipating how a word might be interpreted

If a report proposed a "final solution," the reader might not appreciate its similarity to "the Final Solution" of World War II and Nazi Germany. The writer fails to recognize another potential meaning attached to a word, independent of the author's intended use.

Not understanding multiple meanings of a word occurs mostly with jargon or slang. When describing a system in a remote location by writing "there would be no reach back to CONUS," a person in the military would readily understand the meaning, but few others would know what "reach back" or "CONUS" mean. Instead, write: "There would be no connectivity to the contiguous United States."

2. Selecting the wrong word altogether

Sometimes wrong words are used because of an honest mistake. Perhaps a group of Native Americans might be called "Intuits" not "Inuits," or one might use "material" instead of "materiel." This commonly occurs with homonyms (cite/site, principle/principal, compliment/complement.) These kinds of mistakes require a proofreader to catch them. Word processing software will **not** catch these errors, but good writing manuals will provide extensive lists. Check with the reference librarian for help locating one. Here's one to try: http://www.cooper.com/alan/homonym_list.html.

3. Words that are special in SE contexts

Learning the discipline of SE requires recognizing its specialized words. Use SE's specialized words correctly: *design, architecture, framework, limitations, scope, boundary, decomposition, allocation, measure of performance, measure of effectiveness, verification, validation, process, requirements,* and *shall*. Recognize these specialized SE vocabulary words and their specific uses in the field. Use SEBok to assist you: http://sebokwiki.org/wiki/Category:Glossary_of_Terms.

4. An example of a writer defining terms

This example from a recent SE report demonstrates that the writers mixed up the SE terms “needs” and “requirements” (Figure 6). The red text represents instructor comments in reference to the use of SE terminology.

> Stakeholder requirements development is accomplished by first identifying the stakeholders and their needs. Research is required to identify all those affected by energy system implementation and their respective energy system needs. The next step is to prioritize the relative importance of the stakeholders and their needs. Prioritizing the stakeholders is accomplished through pairwise comparisons and the analytic hierarchy process (AHP) (Satay, 1982). Pairwise comparisons involve comparing each stakeholder against one another and assigning quantitative values indicating their relative importance to each other with respect to energy system implementation. The AHP is used to capture the quantitative values in a matrix, where the values are reduced to vectors of weights that describe the relative importance of each stakeholder. Requirements are then extrapolated by analyzing and categorizing common stakeholder values. Requirements are also assigned weights based on individual stakeholder’s preferences; this step is also accomplished by pairwise comparisons and the AHP. The full analytical criteria method is used to establish the final requirement weightings by taking the product of the individual stakeholder preferences and the stakeholder weights.
>
> ***Instructor comment:*** Stakeholders have needs that systems engineers turn into requirements. JCIDS was created to avoid using the term requirements for just this reason, so engineers could create proper requirements using requirement statements. The raw needs of stakeholders are to be transformed into requirements, so save the term “requirements” for a situation where you have restated primitive needs into the correct format of a requirement.

Figure 6. SE Terms Being Incorrectly Defined in Student Writing

The instructor commentary clarifies the special meanings of “needs” and “requirements,” and further distinguishes between “primitive” and “effective” needs.

Another ambiguity in writing occurs when a student writes: “A systemic concept is proposed.” It means “a concept of a system is proposed.” A systemic concept is one in which a concept is overtaking a system, or is system-wide. This differs greatly from “a concept of a system.” Such a mistake would be egregious because of the weight that the word “system” carries in this context and in systems engineering.

5. Making one word do the job of another part of speech

Another word-choice problem surfaces when writers mix up or blur parts of speech. For example, using nouns as verbs is common in military circles (i.e., "you need to maintenance your telework agreement"). "Maintenance" is a noun, whereas "maintain" is a verb. Or, "you need to evade to neutral territory." Usually, one evades something, not "evade to" something.

Mixing up and transposing word types does not pose a vital threat. "You may need to reference it to locate your position," when you really would be *referring* to it, or say "I inputted it" to mean you entered data, thereby making an input.

However, asking a word to do a job in a sentence that it cannot do creates trouble for the reader. Infamous noun stacks demonstrate this problem. Sometimes writers use too many nouns in a row, which either makes a noun do a verb's job, or asks a noun to act as an adjective or adverb. In the phrase, "The ship is stationary with contact movement radial inbound," does not indicate what is moving. "Contact movement radial inbound" contains no clear verb, only nouns. What is moving "radially?" Is it "inbound" to the ship? Is the "contact movement" what is "radial (ly) inbound"?

Although it is sometimes tempting to use these familiar patterns of speech from one's military career, follow Shenk's (2008) advice in *The Naval Institute's Guide to Naval Writing* to break up noun strings or stacks such as "aircraft carrier crack arrestor applications" and "Commander Navy Region Southwest San Diego Dockside Mail Center" by inserting prepositional phrases such as "crack arrestor applications *in* aircraft carriers," and "the San Diego Dockside Mail Center *of* Commander Navy Region Southwest" (230–231).

To conclude, notice this exemplary example of SE technical writing in a thesis (assume that the acronyms have already been properly introduced). It is formal in tone, avoids jargon even though the writing is about an SE, military-specific topic, and depicts a situation the writer has needed to explain before making an argument.

> Additionally, within the Army, each level of bureaucracy has its own unstable process. Notably, the TRADOC Writing Guide series is re-written with each revision of the JCIDS instruction and undergoes an iterative process as the TRADOC staff grapples with their interpretation of JROC and AROC publications, directives, and guidance. Occasionally, subordinate publications require documents to be written in a manner that is mutually exclusive of higher directives. Inevitably, this leads to delays as documents loop through the review process attempting to please two masters. (Brocht 2010)

6. Making each word count

Make each word necessary, and ruthlessly remove needless words. A sentence should be as long as needed to express an idea. Empty phrases such as "all things considered," "a large number," or "for the most part" create needless clutter and can be replaced with simple words: "considering," "many," and "mostly." Likewise, using fancy words such as "utilization" for "use or "connectivity" for "connect" adds needless complexity. "A falsification has occurred" means

"someone falsified evidence," which is shorter and easier to understand. Since repeating ideas in a sentence can slow down the reader, use passive voice carefully and eliminate repeated words and ideas. Never use a pompous word when a plain one communicates clearly.

7. Parallel structure

Systems engineering reports use many lists. Those lists need to be in parallel structure. What is parallel structure in a list? Each item in the list must begin using the same part of speech. If a verb starts the listed item, all words in that list need to begin with a verb. Failure to write lists in parallel structure is common, especially with in-line lists, which blend in with the narrative: "The engineers wanted the new device to run smoothly, take off quickly, and cheap." This list lacks parallel structure. The word "cheap" is not a verb as are "run" and "take off," so the writer needs to insert "be" in front of "cheap."

TAKEAWAY: Academic writing style is toned down so that the reader hears the message that needs to be communicated—without distraction. Make yourself, as the author, invisible to your reader. Make your thinking visible.

Use words as the types of speech they are; avoid the first person; use commas correctly; use present tense when the information described has been established; and use transitions to move the reader from point to point ("additionally," "occasionally," and "inevitably"). Use metaphors sparingly for maximum impact (i.e., "attempting to please two masters").

Seek a middle course between technical language and normal prose, using enough context to explain the points and the meaning of terms, while avoiding "filler" language. In this way, seek to retain *relevant* information and create *concise* writing, while not over explaining what the reader can easily understand.

VI. THE WRITING PROCESS

Good writing involves stages of production that happen in sequence, and poor writing comes about when these distinct stages blur, or when a stage is omitted entirely (see the stages in Figure 7). Writing entails more than simply writing a final draft, and revision goes beyond correcting the format of a paper, which involves only the appearance and layout expected in a document.

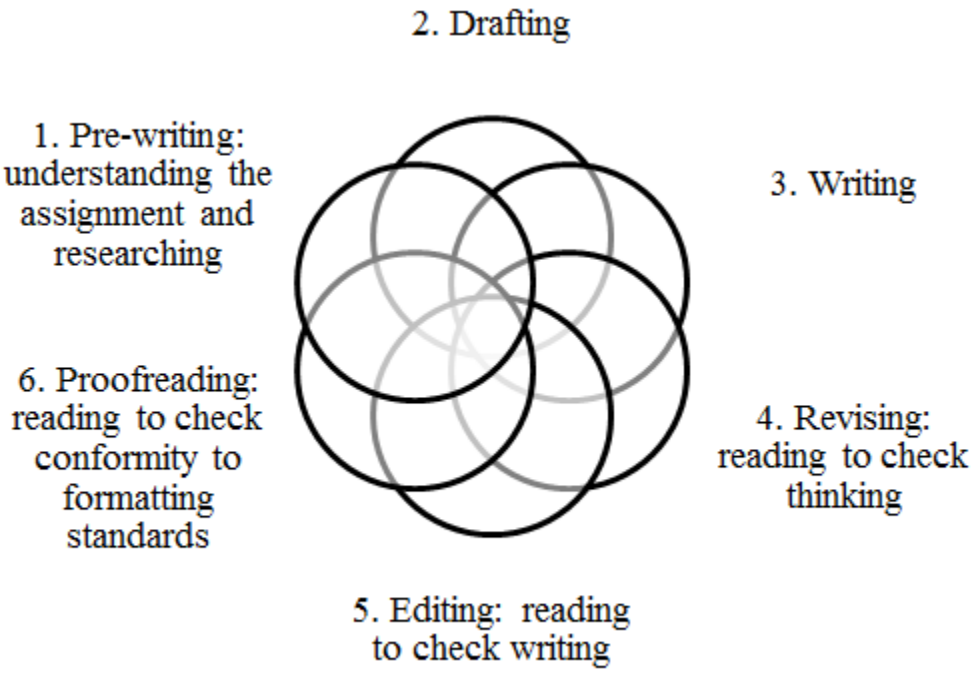

Figure 7. The Steps in the Writing Process. Adapted from Aaron and Fowler (2007).

1. Prewriting: Understanding the assignment and researching

At this stage, ask: "Who is the audience? What purpose is supposed to be achieved? What medium do I have to work with? What is appropriate language use in this context?"

Before tackling a systems engineering writing assignment, see what the instructor intended for the assignment. Read the entire assignment or all the documents affiliated with the task. Then ask: "What is this assignment's purpose from a top-level point of view?"

Remember to include enough in the written submission so that "professional peers of the authors" can "follow, assess, and replicate the experimental findings to test their reliability and validity" (Goldbort 2006, 241).

To check the writing process:

- Show the data and mental models used to draw conclusions.
- Identify assumptions behind actions taken.
- Use citations to link the reader to an external and third-party witness to the information.

Another step before drafting requires the writer to secure background information. This involves 1) reading and evaluating material from internet searches, publications, slides, notes, or articles provided by instructors, 2) researching in a library with the assistance of a librarian, and 3) synthesizing newly discovered research with the writer's previous experience as a professional, independent learner and reader. The writer takes notes while reading other writers' works, drafts of concept, maps, or outlines.

After the prewriting stage, writing a rough draft is the next step, as shown in Figure 7.

2. Drafting

Drafting helps the writer, not the reader. During the drafting stage, the writer creates the product. Ideas appear and fall into a pattern, and notes form sentences and paragraphs.

3. Writing

After a rough draft has been written, the writer turns from getting ideas down in a logical sequence, to evaluating whether clear thinking is taking place. This stage in the writing process is purposeful and with clear goals, ensuring that the writer has presented an argument and provided an assertion backed up by evidence or examples and supported by claims made in a particular context.

4. Revising: Reading to check thinking

The writer examines claims that have been made, evaluates them, evaluates how well reasons or evidence support them, and tries to anticipate how an audience would respond to the claims made in the paper, perhaps by proposing and openly discussing potential counter claims.

5. Editing: Reading to check writing

Only after a document has been drafted and revised can the stage known as "editing" begin. Editing is a secondary check to see whether what is written communicates clearly, so that a reader does not have to work to discover the intended message.

How is editing different from revising? During the revision stage, a writer composes a title for the paper and asks, "Does this title summarize the article, providing sufficient detail to

differentiate the paper from similar ones, but general enough so someone could figure out what *kind* of paper it is?" During the editing stage, the writer checks that the chosen title makes sense or is not confusing.

6. Proofreading: Reading to check conformity to format standards

In proofreading, the writer verifies that the written product follows expected formatting requirements. Also, the student eliminates errors in grammar, punctuation, spelling, or usage. Use the checklist that Thesis Processing offers on its website at http://my.nps.edu/documents/105790666/106471207/Common+Errors.pdf, and for coursework, carefully reread the project assignment.

Ensure that the title follows capitalization standards. Make sure not to use "material" for "materiel." Check to see whether a separate cover page is needed, and whether it is appropriate to use acronyms in a title. Ensure the title is the same in every place it appears (cover page, title page, abstract page, etc.) Copyediting and formatting fall into the proofreading stage, in which the writer scrubs out surface errors (copyediting) and ensures compliance with publication standards (formatting).

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VII. ORGANIZING A TECHNICAL REPORT

Remember the old writing rule: "Tell 'em what you are going to tell 'em, tell 'em and tell 'em what you just told 'em"? This fits in a graduate SE context as well as in a high school English class. Follow this dictum to structure engineering communications.

A report's *introduction* presents a summary of the argument. The *body* of the report uses evidence to back up the validity of the claim by showing evidence and how to interpret it. The *conclusion* shows the reader how the claims are valid, based on the evidence presented.

1. The introduction

In a report, an introduction presents an overview of the report and explains how it is organized. The introduction should have *a thesis statement.* This is a two- to three- sentence synopsis of the argument or main points. Present the information in the order in which they appear in the main body of the report.

2. The abstract

Although an abstract resembles an introduction, it is not. It performs a different function. Researchers often read only the abstract to determine if an article addresses topics aligned with their research goals. Abstracts include keywords—used by search engines—and provide a succinct summary of a report's contents.

Project reports for classes and for the MS degree require an abstract. Although an abstract appears first in a report, write it last, because it briefly summarizes the report. At NPS, the abstract in a thesis or capstone report is a 200-word summary of 1) the problem examined 2) the method used in approaching the problem and 3) the conclusions found through the analysis.

3. The executive summary

An executive summary, on the other hand, serves busy decision makers who prefer to read a complete synopsis rather than a long paper. The executive summary presents recommendations from the research, the results obtained, the methodology used, and the data gathered to support the recommendation. An executive summary of the thesis or capstone report is approximately 3% to 5% of the word count of the main body (usually around three pages). It explains the motivation for the work, discusses the results, and explains their significance. Most readers will carefully read the executive summary, but few will read the entire report. Key points must be presented effectively, and the results should be early in the summary.

Hint: If citations are included in the executive summary of a thesis or capstone report, include a list of references of the items cited at the end of the summary. The rationale is that the executive summary is considered a stand-alone document.

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4. The body

Report writing moves readers from point to point by means of transitions and summaries. Transitions build a bridge from one paragraph to the next, so that the reader understands how each section in the report connects to a previous one. Introductions and conclusions do not include transitions; however, *topic sentences* (the first sentence of a paragraph, which encapsulates the main point of the body of the paragraph), and *concluding sentences* (the final sentence that articulates the end of one set of points and the transition to a new set of ideas) should appear consistently throughout the report, within chapters, and in transitions from chapter to chapter.

5. The conclusion

A conclusion summarizes and restates the most important points of a paper. A conclusion helps the reader revisit the main points. Like the introduction, a conclusion covers the main points, but it also outlines unanswered questions or unresolved ambiguity. Further, a conclusion states any problems that remain to be solved. Reports end with the author(s) offering recommendations that emerge from the report and areas for future researchers to examine.

VIII. CRITICAL-THINKING TASKS

When the abstract, executive summary, and body contain the argument, a formal SE thesis or capstone report progresses according to the following critical-thinking tasks:

1. Define a problem

An SE project's problem definition uses a brief yet formal story to explain and define a complex problem or issue for the reader. It may rely on history and discovered, but-as-yet-unresolved, problems.

2. Define the context

Providing a short explanation of the theory, conceptual framework, model, or a body of knowledge creates a foundation for the work, or interprets the paper's area of inquiry.

For example, describe the context that led to using a modified Vee model to think through the order of steps for an SE process. Explain why a modified Vee model fits the context. Either show someone else using that model, and what it contributed to the analysis, or demonstrate how its use makes sense, given the situation.

3. Present and explain the data

Writers justify the data used in making claims by explaining why it suits the context. When using data attained through statistical analysis software, state why the data presented is the right data for the purpose. Refer to recognized authorities using citations or credible analysis explaining the choice.

4. Analyze the data

Explain why the methodology used fits the data. For discrete events simulation, part of the task of a persuasive writer is to explain why the method best generates the findings, as opposed to another kind of modeling and simulation.

5. Explain the findings

A report arrives at research findings (i.e., a recommendation, a new theory, a model, an important case study, a solution to a problem, or a design for a process). The body of the report communicates the findings, but results must be explained.

6. Use the SE writing self-assessment questionnaire

Answer the following questions to gauge mastery of critical thinking and learning within the SE discipline.

Overall

- Did the project work? Did it apply the SE process across the system's life cycle?
- Did it clearly define terms and symbols?
- Did it include enough important information without extraneous details for the audience?
- Did it communicate succinctly?
- Did it conduct systems analysis, including deterministic and stochastic modeling of systems (including combat simulations and combat modeling)?
- Did it conduct decision analysis, risk analysis and management, economic modeling, or life-cycle supportability analysis, including basic optimization and trade-space management?
- Did it develop a systems engineering plan to manage schedule, cost performance and risk in a project?
- Did it demonstrate the ability to deliver and conduct technical reviews?

Introduction

Does the introduction

- identify and formulate an operational, technical or engineering problem;
- identify and define the techniques, skills, and tools needed to address it;
- identify primary and secondary research questions; and
- provide an explanation of the organization of the report in a thesis statement (a two- to three-sentence synopsis of the report's content and method of organization)?

Literature review or background and context section

Does the literature review or background and research context section

- explain background research, in order to define the problem to be examined;

- define the problem in relation to issues of research, design, development, procurement, operation, maintenance or disposal of systems, and processes for military applications;
- identify key stakeholders, along with their interest in the project;
- describe a tailored systems engineering process, along with its key products, in order to show how it will help solve the problem; and
- look at other views of the questions addressed?

Data analysis sections or body of the report

Compare your final draft against this checklist. Indicate yes/no/not applicable for each. Does the body of the report (as applicable)

- define requirements;
- conduct functional analysis (define functions, decompose functions, show functional sequencing, analyze a functional architecture, generate alternative physical solutions, decompose physical entities, perform functional allocation);
- explain a concept of operations;
- develop scenarios and vignettes;
- define metrics;
- explain hardware, software, and human-factors considerations;
- discuss testing and verification;
- describe a physical solution architecture;
- offer a rationale for a selected concept;
- describe the process to establish an effective need, along with the techniques used to support that process;
- present the results of bounding and scoping the problem;
- present the initial functional and nonfunctional requirements;
- show the connection between mission threads (or similar) to a doctrine (or similar);
- present a value hierarchy (or Measures of Merit or objective hierarchy), and the connection between such measures to the problem statement and an objective alternative-evaluation in terms of solving the problem;

- provide MOEs that clearly follow from MOPs and that are solution independent;
- present functional architectures and commonly accepted modeling tools (such as IDEF0, EFFBD, HPM, UML);
- explain the ideation process behind generating a generic physical architecture;
- offer the results of generating a generic physical architecture, connected to the functional architecture;
- describe the process of feasibility screening, along with life-cycle feasibility constraints;
- present DoDAF products (or appropriate architecture description templates) used to describe the system from a functional, physical, and operational perspective;
- present modeling and analysis efforts, and the connection between data extracted from a model, and the reason behind the value system used to analyze the data;
- provide the model itself, described in words and pictures (with details provided in an appendix), where tables and graphs summarize key results;
- provide information about the model, so that the reader can understand why it was used or so that analysis of alternatives can be conducted;
- offer an explanation of limitations, assumptions, and factors used in analyzing model results;
- generate alternative designs;
- conduct sensitivity analysis;
- offer ways to objectively compare alternatives;
- explain the conversion of data from research and modeling to a decision matrix;
- demonstrate that life-cycle cost was used as a decision variable;
- show a clear connection between a decision matrix and a value hierarchy; and
- provide a solution that meets functional and nonfunctional requirements and objectively and quantitatively offers the best solution to the problem?

The conclusion

Does the conclusion of the report

- revisit research questions or the initial problem statement;
- make recommendation(s) based on the research;
- define areas for further research;
- address significant questions and its conclusions followed from the information laid out in the report;
- present both positive and negative implications of the work;
- explain implications that emerged from the analysis that were unclear at the beginning; and
- explain consequences if recommendations are not followed?

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IX. CONCLUSION

The goal of this writing guide is to demonstrate ways to make your critical thinking more evident, and writer's voice unobtrusive, by following writing conventions. Writing allows an author to discover problems in thinking and to avoid the block to critical thinking that Elder, Niewoehner and Paul identified—thinking egotistically from one's point of view. Transferring ideas from mind to paper prevents this and provides an antidote to the failure to communicate, as depicted in Sydney Harris's cartoon (Figure 8).

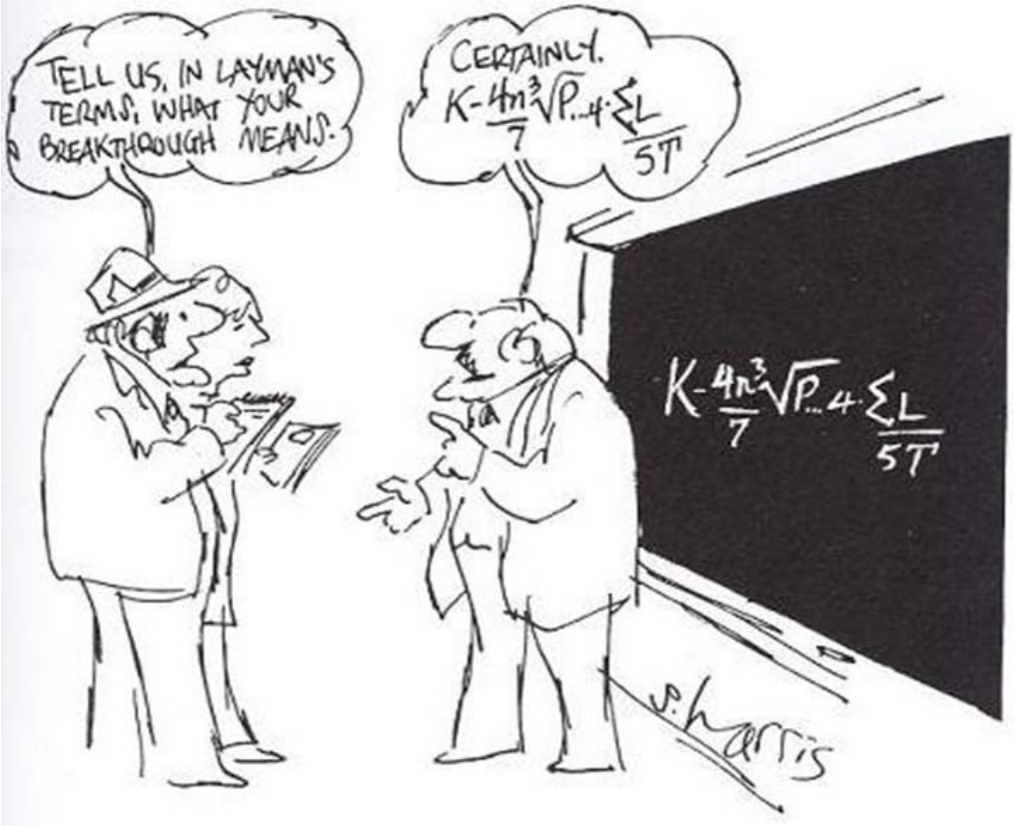

Figure 8. Cartoon by Sidney Harris. Source: Harris (2015).

Figure 8 reminds SE communicators of what to avoid: presenting a solution without an account of the method to get there. Good writers always recognize the reader's needs.

Format checklist

The Thesis Processing Office (TPO) provides NPS publication standards for reports archived in the Dudley Knox Library. Refer to the guidance at its website, which is updated quarterly, for the thesis and capstone report templates, formatting rules, and requirements: http://my.nps.edu/web/thesisprocessing.

Formatting entries in a list of references

Please use the links below for examples of reference formatting. These pages are vetted by TPO and provide examples of materials commonly used by NPS students. See also chapters 18 and 19 of *A Manual for Writers of Research Papers, Theses, and Dissertations.*

In the SE thesis and SE capstone reports, use the *The Chicago Manual of Style's* author-date style. Follow the format shown at http://libguides.nps.edu/citation/chicagoad and http://www.chicagomanualofstyle.org.libproxy.nps.edu/tools_citationguide.html (click on the the "Author-Date" tab.

For the LaTeX template, use the IEEE BibTeX file included with the template: http://libguides.nps.edu/citation/ieee.

Assessment rubrics

Ask your advisor for guidance on the assessment rubrics for theses and capstone project reports.

Two general rubrics are attached here to help students self-assess any written assignment. These rubrics are not aligned with any particular SE course.

The "Intellectual Standards for Engineering Reasoning: An Aid to Authors and Graders of USNTPS Student Deliverables" shows that the standards and elements of critical thinking valued and endorsed by the SE department have been adopted by other professional organizations—in this case, the United States Naval Test Pilot School.

Students should use these rubrics to define tasks in all written and oral presentations created for the master's degree. Individually scored sections of the rubric indicate strengths and weakness, so that students can focus on areas of weakness. Although rubrics provide guidance, they do not identify all strengths and weaknesses.

GENERAL WRITING RUBRIC 1
(FOCUS ON WRITING STYLE)

	1 = Not Attained	3 = Satisfactory	5 = Outstanding
Syntax and Structure	Paragraphs, sentences or whole chapters are missing or undeveloped.	Chapters and paragraphs are adequate.	Well-developed chapters, paragraphs and sentences communicating priorities, relationships of dependence, cause-and-effect relationships, and time sequences.
	Relationships among sentences, paragraphs, or chapters are missing.	Relationships among sentences, paragraphs or chapters are mostly visible but require some extra work by the reader; missing smooth transitions.	Paragraphs flow from one to the other, preparing the reader for what follows and summarizing key ideas before moving on to new ones.
	Sentences are fragmented, confused, circular, incomplete, simplistic or monotonous.	Sentences are clear but lack variety or complexity.	Sentences are of different lengths, with some simple and some complex.
Mechanics	Pervasive copyediting errors distort meaning and make reading difficult.	More than a few sentence-level errors every few pages, annoying but do not affect the message; may have errors such as too many capital letters or quote marks—deliberate but wrong.	The writing is near perfect, with few spelling errors, and conventions for punctuation and capitalization are followed.

	1 = Not Attained	3 = Satisfactory	5 = Outstanding
Tone and Language Use	Frequent use of slang, excessive jargon, or nouns as verbs alienates reader or is confusing; ignorance of proper use of SE terminology (i.e., *design, architecture*, *framework*, *limitations*, *scope*, *boundary*, *decomposition*, *allocation*, *measure of performance*, *measure of effectiveness*, *verification*, *validation*, *process*, *requirements*, *shall*); many problems with homonyms and/or uses first or second person; errors in subject-verb agreement; errors in verb tenses.	Acceptable language use, occasional redundancy, rare if any use of slang, or jargon; uses SE terms adequately (i.e., *design, architecture*, *framework*, *limitations*, *scope*, *boundary*, *decomposition*, *allocation*, *measure of performance*, *measure of effectiveness*, *verification*, *validation*, *process*, *requirements*, *shall*); may have a few errors with homonyms; stays in third person; rare errors in subject-verb agreement, and rare errors in verb tenses.	Highly articulate academic tone employing professional language on an advanced level, using SE terms in sophisticated way (i.e., *design, architecture*, *framework*, *limitations*, *scope*, *boundary*, *decomposition*, *allocation*, *measure of performance*, *measure of effectiveness*, *verification*, *validation*, *process*, *requirements*, *shall*); no errors with homonyms (their/there; principal/principle; affect/effect; its/it's, etc.) Stays in third person; no errors in subject-verb agreement or use of verb tenses.
	Exclusive or misuse of the passive voice.	Some use of the passive, creating wordiness.	Uses the active voice when possible and passive voice when appropriate.

GENERAL WRITING RUBRIC 2
(FOCUS ON WRITING, ORGANIZATION, AND ARGUMENTATION)

	1 = Not Attained	3 = Satisfactory	5 = Outstanding
Introduction	Contains vague or confused perspective on the topic, and goals are not developed or stated.	Contains clear perspective on the topic, and goals are stated.	Contains a new perspective on the topic, where goals are strongly developed and stated.
Literature Review or Background and Context	Content does not review and build on appropriate prior work; unreliable sources used or not cited.	Content reviews and builds on appropriate prior work to a moderate extent; reliable sources are cited.	Content reviews and builds upon appropriate prior work to a significant extent; reliable sources cited correctly.
Explanation of Methodology	Research approach is unsound or inappropriate for the purpose of the paper.	Research approach is basic, appropriate for the purpose of the paper, suited to the perspective (i.e., quantitative, qualitative, mixed).	Research approach is sophisticated, appropriate to the purpose of the paper, suited to the perspective (i.e., quantitative, qualitative, mixed).
Data Analysis	Data collection and assessment results need improvement or do not support the goals of the paper.	Data collection and assessment results are clear and logical, moderately supporting the goals of the paper.	Data collection and assessment results are very clear and logical, strongly supporting the goals of the paper.
Conclusion	Conclusions do not appear to be supported by the data, are unformulated, or do not make a contribution to research.	Conclusions are formulated and are supported by the data, making a contribution to research.	Conclusions are carefully formulated and are strongly supported by the data, making a significant contribution to research.

	1 = Not Attained	3 = Satisfactory	5 = Outstanding
Mechanics	Pervasive copyediting errors distort meaning and make reading difficult.	Sentence-level errors are present, but they do not distort the content.	The writing is near perfect, checked for spelling and other irregularities in punctuation, capitalization, etc.
Language Use	Frequent use of slang, excessive jargon is alienating or confusing; ignorance of proper use of SE terminology. Uses first or second person often. Many problems with homonyms or word choice.	Acceptable language use, occasionally redundant, uses slang, jargon, or SE terms without nuance. Written in the third person. May have a few errors with homonyms or word choice.	Highly articulate academic tone employing professional language on an advanced level, using SE terms in sophisticated way. Written in the third person. No errors with homonyms or word choice.
Voice	Exclusive use or misuse of the passive voice creates confusion.	Use of passive voice creates wordiness or ambiguity.	Uses the active voice when possible and passive voice when appropriate.
Research	Fails to meet research requirements. Sources are not quoted, are given with no discussion, or quotations make up too large a percentage of the paper or seem unreliable.	Incorporates reliable sources of a type suitable to the context and integrates them appropriately.	Meets or exceeds research requirements and integrates sources effectively, applying knowledge gained from research to the new setting of the paper with depth and precision.
Documentation	In-text citations or items in list of references are incomplete. *CMS* author-date method not used or misused.	Cites sources using *CMS* author-date method. Sources cited in the text clearly coordinate with items in list of references.	Cites sources using *CMS* author-date method smoothly: all items cited in the text are aligned with entries in list of references.

USNTPS ASSESSMENT RUBRIC

The rubric for assessing student deliverables for the U.S. Naval Test Pilot School addresses the standards and elements of thought.

Standard	Definition	Questions Targeting the Standard
Clarity	Understandable; the meaning can be grasped *Clarity is a gateway standard. If a statement is unclear, we cannot determine whether it is accurate or relevant. In fact, we cannot tell anything about it because we do not yet know what it is saying.*	• **Could you elaborate further on that point?** • **Could you express that point more clearly in another way?** • **Could you give me an illustration or example?** • **Have the assumptions been clearly stated?** • **Have terms and symbols been clearly defined?** • **Do drawings/graphs/photos and supporting annotations clearly portray important relationships?**
Accuracy	Free from errors or distortions; true *A statement can be clear but not accurate, as in "Most creatures with a spine are over 300 pounds in weight."*	• **Is that really true?** • **How could we check that?** • **What is your confidence in that data?** • **Has the test equipment been calibrated? How or when?** • **How have simulation models been validated?** • **Have assumptions been challenged for legitimacy?** • **Are there hidden or unstated assumptions that should be challenged?** • **What if the environment is other than we had expected (e.g., hotter, colder, dusty, humid)?**

Standard	Definition	Questions Targeting the Standard
Precision	Exact to the necessary level of detail *A statement can be both clear and accurate, but not precise, as in "The solution in the beaker is hot." (We don't know how hot it is.)*	• **Could you give me more details?** • **Could you be more specific?** • **What are acceptable tolerances for diverse pieces of information?** • **What are the error bars or confidence bounds on experimental, handbook, or analytical data?** • **Does the readability of the measurement justify this level of precision?** • **At what threshold do details or additional features no longer add value?**
Relevance	Relating to the matter at hand *A statement can be clear, accurate, and precise, but not relevant to the question at issue. A technical report might mention the time of day and phase of the moon at which the test was conducted. This would be relevant if the system under test were a night vision device. It would be irrelevant if it were a microwave oven.*	• **How is that connected to the question?** • **How does that bear on the issue?** • **Have all relevant factors been weighed?** • **Are there unnecessary details obscuring the dominant factors?** • **Has irrelevant information been included?** • **Have features and capabilities (and hence costs) been included which the customer neither needs nor wants?**

Standard	Definition	Questions Targeting the Standard
Significance	Significant to the matter at hand *Our speech or writing can be clear, accurate, precise, and relevant, yet focus on insignificant conclusions or details rather than the most important features.*	• **Does one detail of many overwhelm the others in importance or influence?** • **Are insignificant details presented that obscure recognition of first-order factors or effects before working down to the more subtle?** • **Is that dealing with the most significant factors?** • **Are insignificant details presented that compromise the overall conclusion?**
Depth	Containing complexities and multiple interrelationships *A statement can be clear, accurate, precise, and relevant, but superficial. For example, the statement, "Radioactive waste from nuclear reactors threatens the environment," is clear, accurate, and relevant. Nevertheless, more details and further reasoning need to be added to transform the initial statement into the beginnings of a deep analysis.*	• **How does your analysis address the complexities in the question?** • **Have important interrelationships been fully identified and studied?** • **How are you taking into account the issues in the question?** • **Does this analytical model have adequate complexity and detail, given its counterpart in reality?**
Breadth	Encompassing multiple viewpoints *A line of reasoning may be clear, accurate, precise, relevant, and deep, but lack breadth (as in an argument from either of two conflicting theories, both consistent with available evidence).*	• **Do we need to consider another point of view?** • **Is there another way to look at this question?** • **What would this look like from the point of view of a conflicting theory, hypothesis, or conceptual scheme?** • **Have the full range of options been explored?** • **Have interactions with other systems been fully considered?**

Standard	Definition	Questions Targeting the Standard
Logic	The parts make sense together, no contradictions *When we think, we bring a variety of thoughts together into some order. The thinking is "logical" when the conclusion follows from the supporting data or propositions. The conclusion is "illogical" when it contradicts proffered evidence, or the arguments fail to cohere.*	• **Does this really make sense?** • **Does that follow from what you said? How does that follow?** • **But earlier you implied this and now you are saying that. I don't see how both can be true.** • **Are the evaluation conclusions supported by logical analysis?**
Fairness	Justifiable, not self-serving or one-sided *Fairness is particularly at play where more than one viewpoint is relevant to understanding and reasoning through an issue (conflicting conceptual systems), or where there are conflicting interests among stakeholders.* *Fairness gives all relevant perspectives a voice, while recognizing that not all perspectives may be equally valuable or important.*	• **Have other points of view been considered (contractor, program office, fleet user, maintenance, public citizens, etc.)?** • **Are vested interests inappropriately influencing the evaluation?** • **Are divergent views within the evaluation team given fair consideration?** • **Have the environmental/safety impacts been appropriately weighed?** • **Have we thought through the ethical implications in this decision?**
Concision	Economy of thought, words, and images enhance clarity by preventing self-generated noise	• **Would fewer words work?** • **Could all related graphs be overlaid or placed on one page to improve the insight into trends and encourage direct comparison?** • **Are relevant visual perspectives efficiently presented?**

Standard	Definition	Questions Targeting the Standard
Suitability	Seeking to be fitting or appropriate by selecting the right tone and presentation for the intended audience	• **Does this convey the appropriate tone?** • **Is the level of detail appropriate for the intended audience?** • **Is the language patronizing or condescending?** • **Is the language overly complex or specialized?** • **Are the elements appropriately placed to maximize communication?**

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