STYLE MANUAL OF THE COLLEGE OF ENGINEERING

Edition 3.5

Embry-Riddle Aeronautical University
Prescott Campus

Angela Beck, Dept. of Humanities/Communications
Patric McElwain, Dept. of Humanities/Communications
Jim Helbling, Dept. of Aerospace Engineering

July 26, 2011
# TABLE OF CONTENTS

List of Tables ................................................................. xi

List of Figures ................................................................. xii

Acknowledgements ............................................................. xvi

Changes to the Current Edition ............................................. xvii

1.0 Statement of Intent ...................................................... 1

2.0 Revision and Editing Checklists ....................................... 3

  2.1 General Revision Guidelines ........................................... 3

  2.2 Content Revision ....................................................... 3

  2.3 Style Revision .......................................................... 4

  2.4 Format Revision ........................................................ 4

  2.5 Graphics Revision ...................................................... 5

  2.6 Grammar/Mechanics Editing .......................................... 5

3.0 General Layout and Presentation Issues ............................. 6

  3.1 Neatness and Legibility ............................................... 6

  3.2 Margins and Page Layout .............................................. 7

    3.2.1 Margins ............................................................ 7

    3.2.2 Spacing ........................................................... 7

    3.2.3 Alignment ........................................................ 9

    3.2.4 Orphans and Widows ............................................ 9

    3.2.5 Footnotes and Endnotes ........................................ 9
3.3 Pagination ………………………………………………………… 10
  3.3.1 Pagination Before the Introduction ………………… 10
  3.3.2 Pagination Beginning with the Introduction ……… 10
  3.3.3 Headers …………………………………………………… 11
  3.3.4 Footers ……………………………………………………… 12
3.4 Font ………………………………………………………………… 12
3.5 Headings and Subheadings …………………………………… 13
  3.5.1 APA-style Headings ……………………………………… 13
  3.5.2 AIAA-style Headings …………………………………… 22
4.0 Organizational Patterns ………………………………………….. 24
  4.1 Process Analysis ……………………………………………… 25
    4.1.1 Stages and Sub-stages ……………………………………… 26
    4.1.2 Indicative Mood and Present Tense …………………… 26
    4.1.3 Passive Voice……………………………………………… 26
    4.1.4 Marking the Stages ………………………………………… 26
    4.1.5 Cause and Effect …………………………………………. 27
  4.2 Instructions ……………………………………………………… 27
    4.2.1 Enumerated Steps ………………………………………… 29
    4.2.2 Imperative Mood …………………………………………. 29
    4.2.3 By + Procedure ………………………………………… 29
  4.3 Procedures……………………………………………………… 30
    4.3.1 Enumerated Steps ………………………………………… 31
    4.3.2 Repeat Statements ……………………………………….. 31
5.2.3 Subjunctive Mood ........................................... 54

5.3 Person and Direct Address ................................. 55
  5.3.1 Person ....................................................... 55
  5.3.2 Direct Address ........................................... 55

6.0 Grammar and Punctuation ........................................... 56
  6.1 Sentence Types ................................................... 56
    6.1.1 Simple Sentences .......................................... 56
    6.1.2 Compound Sentences ...................................... 56
    6.1.3 Complex Sentences ....................................... 57
    6.1.4 Compound/Complex Sentences ............................ 57

  6.2 Fragments, Comma Splices, and Run-ons ......................... 58
    6.2.1 Fragments ..................................................... 58
    6.2.2 Comma Splices .............................................. 58
    6.2.3 Run-ons ....................................................... 59

  6.3 Verb Tenses ....................................................... 59

  6.4 Pronouns: Use of “It,” “This,” and “These” ...................... 61
    6.4.1 Pronouns ..................................................... 61
    6.4.2 Ambiguous “It” .............................................. 61
    6.4.3 Ambiguous “This” and “These” ............................ 62

  6.5 Modifiers: Dangling and Misplaced ............................ 63
    6.5.1 Modifiers ..................................................... 63
    6.5.2 Dangling Modifiers ......................................... 63
    6.5.3 Misplaced Modifiers ....................................... 64
6.6 Colons and Semicolons ........................................... 65
   6.6.1 Colons ...................................................... 65
   6.6.2 Semicolons .................................................. 65
6.7 Hyphens ............................................................ 66
   6.7.1 Hyphen Usage .............................................. 66
   6.7.2 Word Division .............................................. 66
   6.7.3 Compound Term ........................................... 67
   6.7.4 Unit Adjectives ........................................... 67
   6.7.5 Exceptions for Hyphen Usage ............................ 68
   6.7.6 Suspended Hyphens ....................................... 70
7.0 Academic and Technical Language ................................ 71
   7.1 Reportive Verbs ............................................. 71
   7.2 Latinate vs. Germanic Verbs ............................... 73
   7.3 Evaluative Adjectives ....................................... 73
   7.4 Qualification .................................................. 75
      7.4.1 Certainty .................................................. 76
      7.4.2 Distance ................................................. 77
      7.4.3 Generalization .......................................... 78
      7.4.4 Verb Strength ........................................... 79
   7.5 Usage .......................................................... 80
   7.6 Formality ...................................................... 85
8.0 General Guidelines for Graphics and Equations .................. 88
   8.1 Types of Graphics .......................................... 88
9.5.1 Print Sources ........................................... 125
9.5.2 Electronic Sources ..................................... 129
9.5.3 Audiovisual Sources .................................... 131

10.0 Use of Software .............................................. 132

10.1 Drafting a Table of Contents Using Word ..................... 132
10.2 Drafting a List of Figures (or Tables) Using Word .......... 132
10.3 Modifying Headers and Footers (with Page Numbers)
    Using Word ................................................. 133
10.4 Inserting Tables Using Word ................................ 134
10.5 Inserting Tables Using Excel ................................. 134
10.6 Inserting Pictures Using Word ............................... 135
10.7 Inserting Figures Using Excel ............................... 135

11.0 Standardized Outlines for Lab Reports ........................ 136

11.1 Standardized Outline for Informal APA-style Lab Reports
    (i.e., Informal Reports) ..................................... 136
11.2 Standardized Outline for Formal APA-style Lab Reports
    (i.e., Formal Reports) ....................................... 137
    11.2.1 Front Matter ........................................... 137
    11.2.2 Body ................................................... 137
    11.2.3 End Matter ............................................. 137
11.3 Standardized Outline for AIAA-style Lab Reports
    (i.e., AIAA-style Reports) .................................. 138

12.0 Description of Lab Reports by Section ....................... 139

12.1 Description of Informal Reports by Section .................. 139
    12.1.1 Title Page ............................................. 139
12.1.2 Introduction .................................. 141
12.1.3 Procedures .................................. 146
12.1.4 Results and Discussion ......................... 148
12.1.5 Conclusions and Recommendations ............ 151
12.1.6 References .................................. 154
12.1.7 Attributions .................................. 155

12.2 Description of Formal Reports by Section .......... 157

12.2.1 Title Page .................................. 157
12.2.2 Abstract .................................. 159
12.2.3 Table of Contents .............................. 161
12.2.4 List of Tables ................................ 163
12.2.5 List of Figures ................................ 164
12.2.6 List of Graphics ................................ 165
12.2.7 List of Symbols ................................ 166
12.2.8 List of Abbreviations/Acronyms ............... 169
12.2.9 Introduction .................................. 170
12.2.10 Theory .................................. 172
12.2.11 Apparatus and Procedures ..................... 179
12.2.12 Results and Discussion ....................... 184
12.2.13 Conclusions and Recommendations ............ 187
12.2.14 References .................................. 190
12.2.15 Attributions ................................ 191
12.2.16 Appendix I: Sample Calculations ............. 192
12.2.17 Appendix II: Raw Data .................................. 192
12.2.18 Other Appendices ...................................... 193
12.3 Description of AIAA-style Lab Reports .................... 194
  12.3.1 Title/Author Block ................................... 194
  12.3.2 Abstract ............................................... 195
  12.3.3 Nomenclature ......................................... 196
  12.3.4 Introduction ......................................... 197
  12.3.5 Procedures ........................................... 202
  12.3.6 Results and Discussion ................................ 205
  12.3.7 Conclusions and Recommendations ................... 209
  12.3.8 Appendix ............................................. 211
  12.3.9 Acknowledgments .................................... 211
  12.3.10 References .......................................... 212
  12.3.11 Footnotes ........................................... 214
13.0 Systems Engineering ........................................ 215
  13.1 Systems Engineering Processes ........................ 215
  13.2 Systems Engineering Documentation ..................... 218
    13.2.1 Request for Proposal (RFP) ......................... 219
    13.2.2 Statement of Work (SOW) ......................... 220
    13.2.3 Contract Data Requirement List (CDRL) Items .... 225
    13.2.4 Data Item Description (DID) ...................... 226
    13.2.5 Drawing Package .................................... 227
    13.2.6 Product Structure Tree ............................. 228
<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>13.2.7 Requirements Document</td>
<td>229</td>
</tr>
<tr>
<td>13.2.8 Test Plan</td>
<td>231</td>
</tr>
<tr>
<td>13.2.9 Test Results/Verification Document</td>
<td>233</td>
</tr>
<tr>
<td>14.0 Technical Presentations</td>
<td>236</td>
</tr>
<tr>
<td>14.1 Presentation as Story</td>
<td>236</td>
</tr>
<tr>
<td>14.2 Elements of a Strong Presentation</td>
<td>237</td>
</tr>
<tr>
<td>14.3 PowerPoint Slides</td>
<td>238</td>
</tr>
<tr>
<td>15.0 Grading Standards</td>
<td>241</td>
</tr>
<tr>
<td>16.0 Where to Go for More Help</td>
<td>250</td>
</tr>
<tr>
<td>17.0 References</td>
<td>251</td>
</tr>
</tbody>
</table>
# LIST OF TABLES

Table 4.1: Process Analyses, Instructions, and Procedures .................. 24
Table 4.2: Frequently Used Transitions ........................................... 46
Table 6.1: Functions of Present and Past Tense ................................. 60
Table 7.1: Some Useful Reportive Verbs .......................................... 72
Table 7.2: Some Useful Evaluative Adjectives ................................. 75
<table>
<thead>
<tr>
<th>Figure Number</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.1</td>
<td>Simple Headings: Aligned Left and Bolded</td>
<td>16</td>
</tr>
<tr>
<td>3.2</td>
<td>Simple Headings: Indented and Bolded</td>
<td>17</td>
</tr>
<tr>
<td>3.3</td>
<td>Simple Headings: Aligned Left and Underlined</td>
<td>18</td>
</tr>
<tr>
<td>3.4</td>
<td>Simple Headings: Indented and Underlined</td>
<td>19</td>
</tr>
<tr>
<td>3.5</td>
<td>Enumerated Headings: Aligned Left and Bolded</td>
<td>20</td>
</tr>
<tr>
<td>3.6</td>
<td>Enumerated Headings: Indented and Bolded</td>
<td>21</td>
</tr>
<tr>
<td>3.7</td>
<td>AIAA-style Headings for Sections of the Body of a Report</td>
<td>23</td>
</tr>
<tr>
<td>4.1</td>
<td>Sample Process Analysis</td>
<td>25</td>
</tr>
<tr>
<td>4.2</td>
<td>Sample Instructions</td>
<td>28</td>
</tr>
<tr>
<td>4.3</td>
<td>Sample Procedures</td>
<td>30</td>
</tr>
<tr>
<td>4.4</td>
<td>Sample Descriptive Abstract</td>
<td>35</td>
</tr>
<tr>
<td>4.5</td>
<td>Sample Informative Abstract</td>
<td>36</td>
</tr>
<tr>
<td>4.6</td>
<td>Sample Point-by-point Comparison</td>
<td>38</td>
</tr>
<tr>
<td>4.7</td>
<td>Sample Subject-by-subject Comparison</td>
<td>39</td>
</tr>
<tr>
<td>4.8</td>
<td>Sample Point-by-point Contrast</td>
<td>41</td>
</tr>
<tr>
<td>4.9</td>
<td>Sample Subject-by-subject Contrast</td>
<td>42</td>
</tr>
<tr>
<td>4.10</td>
<td>First Sample of Parts of a Whole</td>
<td>43</td>
</tr>
<tr>
<td>4.11</td>
<td>Second Sample of Parts of a Whole</td>
<td>43</td>
</tr>
<tr>
<td>4.12</td>
<td>Three Examples of Technical Definitions</td>
<td>44</td>
</tr>
<tr>
<td>8.1</td>
<td>Types of Graphics: Tables and Figures</td>
<td>89</td>
</tr>
<tr>
<td>8.2</td>
<td>Sample Table</td>
<td>92</td>
</tr>
</tbody>
</table>
Figure 13.5: Sample Data Item Description ........................................ 227

Figure 13.6: Sample Product Structure Tree ................................. 228

Figure 13.17: Sample Requirements Document ............................ 230

Figure 13.18: Sample Test Plan .................................................. 231

Figure 13.19: Sample Test Results/Verification Document .............. 233

Figure 15.1: Sample Grading Rubric 1: Written Submissions ......... 243

Figure 15.2: Sample Grading Rubric 2: Lab Reports ..................... 244

Figure 15.3: Sample Grading Rubric 3: Research Reports .............. 247

Figure 15.4: Sample Grading Rubric 4: Oral Presentations, Individual
Or Group ................................................................. 248

Figure 15.5: Sample Grading Rubric 5: Collaborative Projects and
Group Presentations ...................................................... 249
ACKNOWLEDGEMENTS

We wish to thank the faculty of the College of Engineering (COE) and the Department of Humanities/Communications at Embry-Riddle Aeronautical University (ERAU) for their cooperation, collaboration, and collegiality in this project and in the ongoing process of enriching the professional and communication skills of ERAU students.

We also extend our gratitude to Dean Dr. Ron Madler of the College of Engineering and Dean Dr. Archie Dickey of the College of Arts and Sciences for their unflagging support of this project.

We are particularly grateful to Dr. Julio Benavides, Dr. Ken Bordignon, Prof. Art Draut, Dr. David Lanning, Dr. Wahyu Lestari, Dr. Lance Traub, and Prof. Alvin Ray Yount, all of whom provided material and valuable feedback for this latest edition.
CHANGES TO THE CURRENT EDITION

This edition of the *Style Manual of the College of Engineering* has benefited from thoughtful student and faculty feedback, resulting in approximately 15 pages of additional content, revisions, and improvements throughout. The most pertinent changes made in the hopes of improving the scope, usefulness, and clarity of this manual include the following:

- Addition of a section on Warnings, Cautions, and Notes.
- Revision and expansion of the discussion on headings and subheadings;
- Revision and expansion of the discussion of vertical lists, including updated examples;
- Addition of commentary to various examples to further student understanding;
- Revision of the discussion of certainty, hedging, and qualification, including updated examples;
- Expansion of the formality checklists to include instruction on proper introduction of acronyms and proper notation for quantities;
- Revision of the guidelines for graphics and equations;
- Inclusion of call-outs and units of measure for graphics and equations;
- Guidelines for how often to cite when paraphrasing;
- Addition of several new models for print and electronic sources;
- Reorganization of Citation Standards to improve readability and accessibility;
- Addition of definitions in Systems Engineering;
- Update of References;
- Update and expansion of numerous examples throughout; and
- General reformatting and editing for improved readability.

We wish to express our gratitude to our students and to the faculty of the College of Engineering and the Department of Humanities/Communications for their critical, helpful feedback. Any errors that remain are the sole responsibility of the authors.
1.0 STATEMENT OF INTENT

The difference between fair technical writing and sound technical writing is the difference between information that can be understood and information that cannot be misunderstood. This style manual is designed for the College of Engineering (COE) at Embry-Riddle Aeronautical University (ERAU), Prescott campus, in an effort to help Embry-Riddle students become stronger technical writers. To this end, this style manual has three (3) purposes:

1. To provide students with a guide to the writing of various technical documents, primarily Lab Reports, in accordance with the requirements of the COE;

2. To provide engineering instructors with a reference tool for aid in the creation of technical writing assignments such as Lab Reports and in the creation of grading rubrics for reports and presentations; and

3. To provide technical writing instructors with a teaching tool so that they may help students learn the disciplinary standards for writing in engineering.

To meet these instructional goals, this manual richly describes and exemplifies the content, organization, rhetoric, language, citation, and format typical of three (3) specific types of Lab Reports:

- Informal APA-style Lab Reports (i.e., informal reports),
- Formal APA-style Lab Reports (i.e., formal reports), and
- Formal AIAA-style Lab Reports (i.e., AIAA-style reports).

In addition to these three (3) types of Lab Reports, general academic writing standards (e.g., the proper use of reportive verbs) as well as disciplinary-specific expectations (e.g., the organizational structure of an Apparatus/Procedures section) have been addressed. Students and faculty have suggested details and examples, improving both the quality of content and the ease of use.

This manual overviews academic and technical writing from multiple perspectives (chiefly rhetoric and linguistics) and is motivated by five (5) principle observations:

1) The outcomes of the writing task are shaped by both the purpose(s) of the writer and the expectations of the reader;

2) The expectations of the reader are shaped by the values of the reader’s and writer’s disciplines. For students, learning how to satisfy the reader (i.e., the instructor) often means learning the values and the preferred conventions of the discipline;
3) A discipline’s particular writing conventions are often opaque and are difficult even for practitioners in the field to articulate;

4) Instructors may thus have difficulty teaching students the conventions of their own discipline; and so

5) Students are often required to write for their discipline without understanding the writing conventions of their discipline.

While no manual can reveal all the conventions of a particular discipline nor turn student writers into expert writers in their field, this manual is designed to reveal many of the organizational, rhetorical, linguistic, grammatical, and citational standards valued by the faculty of the COE at ERAU, Prescott campus. The COE, Prescott campus, has adopted both the standards of the American Psychological Association (APA) and of the American Institute of Aeronautics and Astronautics (AIAA) for its technical documentation, and so both of these standards are presented in this revised edition of the Style Manual of the College of Engineering.

This manual is intended as both a textbook and a reference and as such supplements standard undergraduate style guides (e.g., The Little, Brown Handbook). The body of this manual is divided into sixteen (16) well-defined sections containing concise definitions, clear explanations, and multiple examples. Some sections also include helpful checklists. The authors hope that students use this style manual to craft successful academic and technical texts, but students must bear in mind that the templates and suggestions are recommendations.

THE COURSE INSTRUCTOR HAS THE FINAL SAY REGARDING ORGANIZATIONAL DETAILS, CITATION STANDARDS, AND OTHER IMPORTANT ELEMENTS TO BE INCORPORATED INTO LAB REPORTS AND OTHER WRITING ASSIGNMENTS.

IT IS THE STUDENT’S RESPONSIBILITY TO CONFIRM THE INSTRUCTOR’S REQUIREMENTS FOR LAB REPORTS AND OTHER WRITING ASSIGNMENTS.
2.0 REVISION AND EDITING CHECKLISTS

The following checklists are intended to guide revision and editing of academic documents. A checklist for general revision practices is presented, as are checklists for content, style, format, graphics, and grammar/mechanics. (See Section 7.0: Academic and Technical Language for more guidelines.)

2.1 General Revision Guidelines

✓ If possible, allow a “cooling period” before revision. Allow for sufficient distance from the draft so that it can be read with fresh eyes.

✓ Adopt a different state of mind for revising than writing so that the assessment of the draft can be more objective.

✓ Consider the reader first. Someone without expert knowledge of the topic must be able to understand the text.

✓ Always revise using a hard copy of the draft so that changes can be tracked.

✓ Do NOT attempt to do all the revising at once. Revise in stages, concentrating on one set of issues at a time.

✓ If possible, find an outside set of eyes to read the draft and make comments.

2.2 Content Revision

✓ Ensure that the objective/purpose of the document is stated in the introduction.

✓ Ensure all the needs and questions of the audience have been addressed.

✓ Ensure that all essential information has been included. If material that has been requested has been omitted, add it.

✓ Stick to the point. If there is material that has not been requested as part of the document, eliminate this material.

✓ Check the content for accuracy.

✓ Ensure that the technical terminology is appropriate for the audience. Define all terms as necessary.

✓ Do NOT data dump into the text. Explain all examples and assertions.

✓ If numbers are involved, check that they “add up.”
✔ Ensure that all outside material has been documented both internally (in the text) and externally (in the References).

✔ Compare the most recent draft with the previous draft to ensure that all the revisions have made it into the current draft.

2.3 Style Revision

✔ Keep paragraphs short (no more than 12 lines maximum) to increase readability.

✔ Ensure that the sentences are clear.

✔ Be concise: do NOT use three words when one will do.

✔ Avoid second person (unless giving instructions), first person, or direct address in formal writing. Use third person only.

✔ Check for parallelism in the structure of the sentences.

✔ Use passive and active voice as appropriate.

✔ Use vertical lists when the list has a minimum of three (3) or more items. Use bullet points or numbers as appropriate.

✔ Select appropriately formal vocabulary: use Latinate rather than Germanic verbs.

✔ Use evaluative adjectives that are more specific than “good” or “bad.”

✔ Use a variety of reportive verbs other than “says.”

✔ Qualify or hedge statements carefully.

✔ Place adverbs before verbs where possible to increase formality.

✔ Avoid contractions in formal writing.

✔ Place numerical values in parentheses after their spelled-out forms (e.g., six (6) versions of the model).

2.4 Format Revision

✔ If you are following an assigned format (e.g., APA style or AIAA style), check to ensure you have followed this format successfully.

✔ Ensure that the margins are accurate and consistent throughout the draft.
✓ Check the pagination.

✓ Check the spacing within the paragraphs, the spacing between the paragraphs, and the spacing of any block quotes or extended quotes to ensure they match the required format.

✓ Check the headings. Ensure that they follow a clear and consistent hierarchy.

✓ Ensure that all citations are formatted according to the required standard (i.e., APA style or AIAA style).

2.5 Graphics Revision

✓ Ensure that all graphics are sized so as to be clear. Do NOT include fuzzy graphics.

✓ Ensure that all graphics have been introduced, placed as close to the relevant text as possible, and then analyzed and explained—do NOT “data dump.”

✓ Ensure that all graphics have clear axes, labels or call-outs, as needed.

✓ Ensure that all graphics are numbered and titled.

✓ Ensure that graphics have been documented, as needed.

2.6 Grammar/Mechanics Editing

✓ Check your spelling: do NOT rely solely on spell check.

✓ Check each sentence to ensure that all are grammatical.

✓ Check carefully for dangling modifiers.

✓ Ensure that transitions are plentiful, appropriate, and clear.

✓ Check for appropriate usage of commonly misused words such as data/datum.

✓ Check all pronoun references. Ensure that each it is a clear and accurate reference. After each this and these place an appropriate noun to ensure clarity of reference.

✓ Ensure that the names of any persons mentioned in the text are spelled accurately.
3.0 GENERAL LAYOUT AND PRESENTATION ISSUES

As a general note, this entire *Style Manual of the College of Engineering: Edition 3.5* is formatted according to APA standards. As such, the manual itself serves as an example of proper margins, spacing, pagination, headers, footers, font, headings, subheadings for APA-style papers.

3.1 Neatness and Legibility

Papers must be neat and legible. They must be formatted and presented so that they are easy to read and make a strong visual impression.

Papers must also be free of errors, including basic **grammatical errors** (e.g., incomplete sentences or fragments), **usage errors** (e.g., assure/ensure/insure), and **misspelled words** (many of which are not caught by spell-checker programs).

Consider the following presentation issues before turning in a paper:

- The paper looks carefully prepared; it is not crumpled, stained, or printed crookedly on the paper.
- The paper is either bound or, for shorter papers, is cleanly stapled at the top left-hand corner.
- There is either a signed Title Page (for APA-style reports) or a Title/Author Block (for AIAA-style reports), with all the pertinent information clearly visible. (See Section 12.0: Description of Lab Reports by Section.)
- Any error corrections or white-outs are undetectable.
- The pages are laid out carefully and correctly; the prose is centered on the page, is properly spaced, and is within set **margins**.
- The **font** is easy to read and is not too large or too small (at least 12-point Times New Roman, Arial, or similar font).
- The prose is divided into paragraphs.
- The paper has primary and, when appropriate, secondary and tertiary section **headings** (e.g., has A-level, B-level, and C-level headings as appropriate).
- Figures and tables are inserted in the appropriate place on the page, are consecutively numbered, and are labeled.
- The **pagination** (i.e., page numbers) is clear and properly placed.
o There is subject/verb agreement.

o The appropriate verb tenses are used.

o There are no incomplete sentences or fragments.

o There are no comma errors.

o There are no usage errors.

o There are no spelling errors; a spell-checker program was run, but the paper was also reviewed for errors the spell-checker might have missed.

### 3.2 Margins and Page Layout

#### 3.2.1 Margins

Margins should be set to 1.5 in. at the left (to allow space for binding) and 1 in. at the top, bottom, and right margins.

#### 3.2.2 Spacing

There are three (3) standards for spacing: standard essay format, block format, and AIAA format. **Standard essay format** requires double-spacing throughout the paper, including the References section. Each paragraph is indented, and there are no extra spaces between paragraphs. This type of format is typical of humanities and social science papers.

**Block format** is single-spaced throughout the paper, including the References section. There is no indentation at the beginning of paragraphs, but there is one (1) blank line between paragraphs. Block format is preferred for both informal and formal Lab Reports.

**AIAA format** is single-spaced throughout the paper, including the References section. Each paragraph is indented, and there are no extra spaces between paragraphs. This type of format is required for AIAA-style documents.

The following paragraphs are written in **standard essay format**:

The Boundary Waters Canoe Wilderness Area (BWCAW) is in extreme Northern Minnesota and is adjacent to the Canadian-U.S. border. Along with its counterpart, the Quetico Provincial Park in Southern Canada, the BWCAW covers an area of over 2 million
The Boundary Waters Canoe Wilderness Area (BWCAW) is in extreme Northern Minnesota and is adjacent to the Canadian-U.S. border. Along with its counterpart, the Quetico Provincial Park in Southern Canada, the BWCAW covers an area of over 2 million acres. Nearly 1,000 lakes and 1,200 miles of canoe routes add to its uniqueness among American national forests. Its pristine beauty and serene calm make it a jewel of Minnesota and its colorful history makes it all the more impressive (MacDonald, 2002).

One of the first civilizations to inhabit this area was a Native American tribe known as the Laurel. They prospered greatly from the abundance of fish, game, and plants still thriving in the BWCAW today. Furthermore, abundant deposits of copper allowed the Laurel to establish a thriving trade business (Barnard, 1999).

The same paragraphs are written below in **block format**:

The Boundary Waters Canoe Wilderness Area (BWCAW) is in extreme Northern Minnesota and is adjacent to the Canadian-U.S. border. Along with its counterpart, the Quetico Provincial Park in Southern Canada, the BWCAW covers an area of over 2 million acres. Nearly 1,000 lakes and 1,200 miles of canoe routes add to its uniqueness among American national forests. Its pristine beauty and serene calm make it a jewel of Minnesota and its colorful history makes it all the more impressive (MacDonald, 2002).

One of the first civilizations to inhabit this area was a Native American tribe known as the Laurel. They prospered greatly from the abundance of fish, game, and plants still thriving in the BWCAW today. Furthermore, abundant deposits of copper allowed the Laurel to establish a thriving trade business (Barnard, 1999).

And the same paragraphs are written below in **AIAA format**:

The Boundary Waters Canoe Wilderness Area (BWCAW) is in extreme Northern Minnesota and is adjacent to the Canadian-U.S. border. Along with its counterpart, the Quetico Provincial Park in Southern Canada, the BWCAW covers an area of over 2 million acres. Nearly 1,000 lakes and 1,200 miles of canoe routes add to its uniqueness among American national forests. Its pristine beauty and serene calm make it a jewel of Minnesota and its colorful history makes it all the more impressive (MacDonald, 2002).
One of the first civilizations to inhabit this area was a Native American tribe known as the Laurel. They prospered greatly from the abundance of fish, game, and plants still thriving in the BWCAW today. Furthermore, abundant deposits of copper allowed the Laurel to establish a thriving trade business (Barnard, 1999).

As noted, either block format or AIAA format are preferred for Lab Reports, but it is the student’s responsibility to discover the instructor’s preference.

3.2.3 Alignment

The prose should be aligned to the left (ragged right is preferred), with the exception of the information on the Title Page and simple A-level headings, which are centered on the page. (See Section 3.5: Headings and Subheadings.) Lists in the Front Matter are fully justified from left to right. (See Section 1.2.3: Table of Contents, Section 12.2.4: List of Tables, Section 12.2.5: List of Figures, Section 12.2.6: List of Graphics, Section 12.2.7: List of Symbols, and Section 12.2.8: List of Abbreviations/Acronyms.)

3.2.4 Orphans and Widows

An orphan is a single line of prose, usually the first line of a paragraph, which has been left hanging at the bottom of the page. The last paragraph at the end of each page should contain at least two (2) complete lines of prose. Likewise, a heading or sub-heading should not be orphaned at the end of the page without at least two (2) lines of prose beneath it.

A widow is a single word that is left hanging in the last line of prose in a paragraph; the word at the end of the sentence on the following page is a widow:

The last word at the end of this sentence is an example of a widow.

Because widows interfere with the reader’s flow, the last line of a paragraph should ideally be comprised of at least two (2) or three (3) words.

3.2.5 Footnotes and Endnotes

Footnotes fall within the bottom 1-in. margin of the page; they should be numbered consecutively with superscript numerals at the end of the sentence or paragraph. Footnotes are required in AIAA-style formatting for citing the name and contact information of the authors of a report. (See Section 12.3.1: Title/Author Block and Section 12.3.11: Footnotes.) They are also used to note tangential but interesting information.
Alternatively, endnotes may be used to note supplementary information. **Endnotes** are found after the Conclusions and Recommendations section, starting at the top of a new page, before the References. The following sentences exemplify the superscript numerals that mark a footnote/endnote:

The graphic software has been previously tested and is routinely used for such reports\(^1\).

Many have suggested that Tolkien’s work inspired this extensive collection\(^1\).

Neither footnotes nor endnotes should be used needlessly. Footnotes and endnotes should only be used for information that is important but, if included in the prose proper, would distract the reader from the point at hand.

### 3.3 Pagination

**Pagination** refers to the proper formatting of page numbers. Page numbers should be consecutive, and should be the same font type and size as the rest of the paper. They should be placed at the top right-hand corner of the paper for APA-style documents. They should be placed at the bottom center of the page for AIAA-style documents.

#### 3.3.1 Pagination Before the Introduction

The Front Matter of a formal report (i.e., the Abstract, Table of Contents, List of Tables, List of Figures, List of Symbols, and List of Abbreviations/Acronyms) is not considered part of the body of the paper. These sections are paginated, but they use lowercase Roman numerals, beginning with “i” and running consecutively until the Introduction begins. Furthermore, these page numbers are placed at the bottom center of the page throughout the Front Matter. Note that the Title Page is considered to be “page zero” and so is not paginated at all.

#### 3.3.2 Pagination Beginning with the Introduction

Page “1” begins with the Introduction of the paper. Each page thereafter is numbered consecutively, including pages with figures and tables, any endnote pages, and References. The page numbers continue through any Appendices to the end of the paper. Furthermore, these page numbers should be placed either at the top right of the page (APA-style formatting) or in the bottom center of the page (AIAA-style formatting).
3.3.3 Headers

A header provides a brief identification of the author(s) or section title. Headers are placed on all pages of a document, including the Front Matter, except for the Title Page; there are no headers placed on the Title Page.

If a header is desired, it may be placed in one (1) of three (3) places. The first is at the top-right corner of each page. This style of header includes content information (preferably the last name of the author, although the first few words of the title of the paper or the section number and title of the section are acceptable) and the page number:

```
Rabern       7
Non-standard Grommet Design  32
2.0 Theory   3
```

Alternatively, a header may be placed at both the top-left and the top-right corners of each page. In this case, the content information is at the top left and the page number is at the top right of each page:

```
Rabern
Non-standard Grommet Design
2.0 Theory
```

Note that this style manual uses this third style of header. Finally, a header may be placed at the top-left corner, top center, and top-right corner of each page. In this final case, the instructor or author’s last name is at the top-left corner, the content information (e.g., course, section, or title) is at the top center, and the page number is at the top-right corner of each page:

```
Felton AE 420.1 19
Helbling 2.0 Theory 3
Team Angel Non-standard Grommet 32
```

While all three (3) of these headers are technically acceptable, the rule of thumb is the simpler the header, the better. Thus, the first or second styles stated at the very beginning of this subsection are highly recommended.
3.3.4 Footers

A footer provides page numbers, the date of a document, and similar information, if this information is not already included in a header. Footers are placed on all pages of a document, including the Front Matter, except for the Title Page.

If a footer is desired, it may be placed in one (1) of two (2) places. The first position is at the bottom-right corner of each page. This footer only includes the date of the draft and is preferred for Lab Reports:

15 JAN 11

September 9, 2011

Mar. 15, 2011

The second position for a footer is at the center and right of the bottom of the page. This footer places the page number at the bottom center of each page and the date of the draft at the bottom-right corner of each page:

<table>
<thead>
<tr>
<th>Standards</th>
<th>1</th>
<th>09 SEP 05</th>
</tr>
</thead>
<tbody>
<tr>
<td>Record-keeping</td>
<td>2</td>
<td>April 7, 2005</td>
</tr>
<tr>
<td>Flim-flammery</td>
<td>3</td>
<td>31 DEC 05</td>
</tr>
</tbody>
</table>

As with headers, the simpler the footer, the better. In fact, many documents may not require any footer at all, although footers are useful for tracking the most-recent draft of a frequently revised document (such as a Lab Report).

3.4 Font

The preferred font is “Times New Roman,” although “Arial,” “Courier,” or some other easy-to-read font may be used. A sans-serif font may be used for headings and for figures to make them stand out more.

The preferred font size is 12 point. 10-point font or smaller is too hard to read, and 14-point or 16-point font should be reserved for the title on the Title Page and for A-level and B-level headings. (See Section 3.5: Headings and Sub-headings.) Note, however, that professional publications often require other font sizes (e.g., AIAA requires 11-point, 10-point, and even 9-point font be used for different sections of a professional submission; see Section 12.3: Description of AIAA-style Reports). Nonetheless, the academic standard for the College of Engineering, Prescott campus, is **12-point font**.
Bold font, italics, and other specialized fonts should be reserved for headings and to point out special terms (e.g., technical definitions):

**Pagination** is the formatting and placement of consecutive page numbers that are often found in the upper right-hand corner of every page of a document.

The process in which a metal is subjected to elevated temperatures for a period of time to cause structural or electrical changes in its properties is called **annealing**.

These specialized fonts should be used consistently; if one A-level heading is in bold, all A-level headings should be in bold. If one B-level heading is underlined, all B-level headings should be underlined.

3.5 Headings and Sub-headings

There are generally three (3) levels of headings found in Lab Reports and other technical documents: **A-level headings** (i.e., primary headings), **B-level headings** (i.e., secondary headings), and **C-level headings** (i.e., tertiary headings). APA-style and AIAA-style headings differ, as explained in the following sections (i.e., Section 3.5.1: APA-style Headings and Section 3.5.2: AIAA-style Headings).

3.5.1 APA-style Headings

**A-level headings** are used for major section headings (e.g., the Table of Contents, the Introduction, the Results, the References section). A-level headings are in bold type; each letter is capitalized. They are written in 16-point font for increased visibility.

**B-level headings** are used to mark subsections within major sections, e.g., the Procedures subsection within the Apparatus/Procedures section. B-level headings are either in bold type OR underlined; the first letter of each word is capitalized, unless the word is an article, preposition, or conjunction (e.g., a, an, the, in, on, and, or). They are written in 14-point font for increased visibility.

**C-level headings** may be used to mark small but important sections within subsections, such as Phase One within the Procedures subsection within the Apparatus/Procedures section. C-level headings are either in bold type OR underlined; the first letter of each word is capitalized unless the word is an article, preposition, or conjunction (e.g., a, an, the, in, on, and, or). C-level headings are usually written in 12-point font, the same size as the rest of the prose in the report.

APA-style headings may be either simple or enumerated, aligned left or indented, bold font or underlined font. **Simple headings** are illustrated in Figure 3.1:
Simple Headings: Aligned Left and Bolded through Figure 3.4: Enumerated Headings: Indented and Underlined; simple headings have no reference numbers preceding the name of the heading.

Enumerated headings are illustrated in Figure 3.5: Enumerated Headings: Aligned Left and Bolded and Figure 3.6: Enumerated Headings: Indented and Bolded; enumerated headings have reference numbers preceding the name of the heading (e.g., 3.0 Apparatus and Procedures, 3.1 Apparatus, 3.2 Procedures) so that the numbers establish a clear hierarchy (i.e., 3.1 and 3.2 belong to Section 3.0 of the Lab Report). Enumerated headings are consecutively numbered as follows:

- A-level: 1.0, 2.0, 3.0, 4.0, etc.
- B-level: 1.1, 1.2, 1.3, 1.4, etc.
- C-level: 1.1.1, 1.1.2, 1.1.3, 1.1.4, etc.

Left-aligned headings are formatted using the following scheme for both simple and enumerated headings (see Figure 3.1: Simple Headings: Aligned Left and Bolded, Figure 3.3: Simple Headings: Aligned Left and Underlined, and Figure 3.5: Enumerated Headings: Aligned Left and Bolded):

- A-level: flush with the left margin, above the first line of prose
- B-level: flush with the left margin, above the following line of prose
- C-level: flush with the left margin, above the following line of prose.

Indented headings are placed on the page in slightly different manners, depending upon whether simple or enumerated headings are used. For simple headings, the following indentation scheme is used (see Figure 3.2: Simple Headings: Indented and Bolded and Figure 3.4: Simple Headings: Indented and Underlined):

- A-level: centered on the page, above the first line of prose
- B-level: flush with the left margin, above the following line of prose
- C-level: one (1) tab (i.e., five [5] spaces) from left margin, immediately followed by a period and a line of prose.

For enumerated headings, the following indentation scheme is used (see Figure 3.6: Enumerated Headings: Indented and Bolded):
Unless the audience/course instructor states another preference, APA-style headings are the default heading style for the College of Engineering. APA-style headings are typically enumerated, aligned left, and in bold font as shown in Figure 3.5: Enumerated Headings: Aligned Left and Bolded. Note that in this style A-level headings are 16-point font, B-level headings are 14-point font, and C-level headings are 12-point font. Only the A-level heading is all capped.

In placing headings, consistency is the key to clarity. The following six (6) pages contain illustrations of the six (6) different APA-style heading schemes, from Figure 3.1: Simple Headings: Aligned Left and Bolded through Figure 3.6: Enumerated Headings, Indented and Bolded.
A-LEVEL HEADING

B-Level Heading Bolded

C-level Heading Bolded

XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
XXXXXXXXXXXXXXXXXX.

C-level Heading Bolded

XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
XXXXXXXXXXXXXXXXXX.

B-Level Heading Bolded

C-level Heading Bolded

XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
XXXXXXXXXXXXXXXXXX.

C-level Heading Bolded

XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
XXXXXXXXXXXXXXXXXX.

Figure 3.1: Simple Headings: Aligned Left and Bolded
A-LEVEL HEADING

B-Level Heading Bolded

C-level Heading Bolded. XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
A-LEVEL HEADING

B-Level Heading Underlined

C-level Heading Underlined

XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
XXXXXXXXXXXXXX.

C-level Heading Underlined

XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
XXXXXXXXXXXXXX.

B-Level Heading Underlined

C-level Heading Underlined

XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
XXXXXXXXXXXXXX.

C-level Heading Underlined

XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
XXXXXXXXXXXXXX.

Figure 3.3: Simple Headings: Aligned Left and Underlined
A-LEVEL HEADING

B-Level Heading Underlined

C-level Heading Underlined. XXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX

C-level Heading Underlined. XXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX

B-Level Heading Underlined

C-level Heading Underlined. XXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX

C-level Heading Underlined. XXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX

B-Level Heading Underlined

C-level Heading Underlined. XXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX

C-level Heading Underlined. XXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX

Figure 3.4: Simple Headings: Indented and Underlined
1.0 A-LEVEL HEADING

1.1 B-Level Heading Enumerated

1.1.1 C-Level Heading Enumerated

XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX.

1.1.2 C-Level Heading Enumerated

XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX.

1.2 B-Level Heading Enumerated

1.2.1 C-Level Heading Enumerated

XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX.

1.2.2 C-Level Heading Enumerated

XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX.

Figure 3.5: Enumerated Headings: Aligned Left and Bolded
1.0 A-LEVEL HEADING

1.1 B-Level Heading Enumerated

1.1.1 C-level Heading Enumerated

XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX.

1.1.2 C-level Heading Enumerated

XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX.

1.2 B-Level Heading Enumerated

1.2.1 C-level Heading Enumerated

XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX.

1.2.2 C-level Heading Enumerated

XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX.

1.3 B-Level Heading Enumerated

1.3.1 C-level Heading Enumerated

XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX.

1.3.2 C-level Heading Enumerated

XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX.

Figure 3.6: Enumerated Headings: Indented and Bolded
As the preceding six (6) examples show, various schemes can be used to place headers in document to organize prose. The key is to use a clear hierarchy and to be consistent throughout the document.

3.5.2 AIAA-style Headings

**Major Headings** are used for major section headings (e.g., Nomenclature, the Introduction, the Results, and the References section). Major headings are centered on the page. They are written in bold type and in 12-point font, in accordance with COE standards. Only the first letter of each word is capitalized, unless the word is an article, preposition, or conjunction (e.g., a, an, the, in, on, and, or).

Major headings that mark sections of the Body of a report (i.e., Introduction, Theory, Results, Conclusions) are also numbered using upper-case Roman numerals (i.e., I. Introduction; II. Theory; III. Results; IV. Conclusions). Headings that mark other sections of the report (e.g., Nomenclature, Acknowledgments, References) are not numbered. There is one blank line after the Major heading.

**Subheadings** are used to mark subsections within major sections, (e.g., Theoretical Background, Theoretical Predictions). Subheadings are aligned with the left margin. They are written in bold type and, for Lab Reports to be submitted to an instructor, are written 12-point font in accordance with College of Engineering standards. Only the first letter of each word is capitalized, unless the word is an article, preposition, or conjunction (e.g., a, an, the, in, on, and, or).

Subheadings are numbered using capital letters (e.g., A. Theoretical Background; B. Theoretical Predictions). There is no blank line after the Subheading; the prose begins immediately on the following line.

**Sub-subheadings** may be used to mark small but important sections within subsections, such as Phase One within the Procedures subsection within the Apparatus/Procedures section. Sub-subheadings are aligned with the left margin. They are written in italic type and, for Lab Reports to be submitted to an instructor, are written in 12-point font in accordance with College of Engineering standards. Only the first letter of each word is capitalized unless the word is an article, preposition, or conjunction (e.g., a, an, the, in, on, and, or).

Sub-subheadings are numbered using Arabic numerals (e.g., 1. First Phase; 2. Second Phase). There is no blank line after the sub-subheading; the prose begins immediately on the following line.

Figure 3.7: AIAA-style Headings for Sections of the Body of a Report, which follows, illustrates the scheme for AIAA-style headings:
I. Major Heading

A. First Subheading
   XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
   XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
   XXXXXXXXXXXXX.

1. First Sub-subheading
   XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
   XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
   XXXXXXXXXXXXX.

2. Second Sub-subheading
   XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
   XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
   XXXXXXXXXXXXX.

B. Second Subheading
   XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
   XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
   XXXXXXXXXXXXX.

1. First Sub-subheading
   XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
   XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
   XXXXXXXXXXXXX.

2. Second Sub-subheading
   XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
   XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
   XXXXXXXXXXXXX.

Figure 3.7: AIAA-style Headings for Sections of the Body of a Report.

As the preceding figure shows, just as with APA-style headings, the key to AIAA-style headings is to use a clear hierarchy and to be consistent throughout the document.
4.0 ORGANIZATIONAL PATTERNS

Organizational patterns commonly used in Lab Reports and other technical documents include process analyses, instructions procedures, abstracts, compare and contrast, and technical definitions, and vertical lists.

Process analyses, instructions, and procedures are strongly related organizational schemes. They explain how something happens or how something works; there are differences in their functions and attendant grammatical markers, however, as described in Table 4.1: Process Analyses, Instructions, and Procedures:

<table>
<thead>
<tr>
<th>Text Type</th>
<th>Function</th>
<th>Grammatical Markers</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Process Analyses</td>
<td>Explain how a process typically occurs or is usually accomplished</td>
<td>Present Tense, Indicative Mood, Passive Voice, Third Person, Written in Prose</td>
</tr>
<tr>
<td></td>
<td>Example: The parachutists first acknowledge the 5-minute warning from the Jumpmaster.</td>
<td></td>
</tr>
<tr>
<td>2. Instructions</td>
<td>State how a process should be carried out by the reader</td>
<td>Present Tense, Imperative Mood, Active Voice, Second Person, Written in Numbered Steps</td>
</tr>
<tr>
<td></td>
<td>Example: Step 1. Acknowledge the 5-minute warning from the Jumpmaster.</td>
<td></td>
</tr>
<tr>
<td>3. Procedures</td>
<td>Describe how a process was carried out by the experimenter</td>
<td>Past Tense, Indicative Mood, Passive Voice, Third Person, Written in Numbered Steps</td>
</tr>
<tr>
<td></td>
<td>Example: 1.0 The 5-minute warning from the Jumpmaster was acknowledged.</td>
<td></td>
</tr>
</tbody>
</table>
The same sentence about parachuting from a C-130 is exemplified in the preceding table three (3) times: once as part of a process analysis, once as an instruction, and once as a procedure. The differences in tense, mode, voice, person, and numbering should be readily apparent.

Process analyses, instructions, and procedures are more fully exemplified below, along with other organizational schemes. Procedures are also described in more detail throughout Section 12.0: Description of Lab Reports by Sections.

4.1 Process Analysis

Process analyses (also known as process descriptions) are used to explain how a system works; this organizational scheme often includes an explanation of the stages and sub-stages integral to the process or system. Typical process analyses may explain how a microchip functions, how an engine works, or how a weather system develops. For example, Figure 4.1: Sample Process Analysis describes how a structural mockup of an airplane wing is typically created:

Manufacturing the ribs for a structural mockup is typically divided into three (3) phases. The first phase involves the creation of the dies for each section of the ribs. The second phase involves the hammering of aluminum sheets into the shape of the dies, and the third phase involves heat-treating the aluminum ribs according to T3 standards.

The first phase of creating the dies consists of four (4) steps and requires ABS plastic sheet, ½-in. thick plywood, and CATIA templates. First, the plastic sheet is glued along one side of the wood using standard carpenter’s glue. Then, the templates of the rib sections generated by CATIA are cut using a pair of scissors and are glued onto the plastic-covered plywood using standard carpenter’s glue.

Next, once the glue is dry, the rib sections are cut following the templates using a band saw. Finally, two (2) holes of ¼-in. diameter are drilled into each rib section with a drill press, one (1) hole 1 in. from the front of the section and one (1) hole 1 in. from the rear of the section. These two (2) holes serve as placement for the bolts and nuts as described below….

Figure 4.1: Sample Process Analysis
(Source: Adapted from Mobility Aerospace, 2003)

Process analyses are marked by their use of chronological stages and passive voice, as described in the following sections.
4.1.1 Stages and Sub-stages

A process analysis presents each of the stages or sub-stages of the process or system in the same order in which they occur; in the preceding example, the templates are glued onto the plywood and then the plywood sections are cut.

4.1.2 Indicative Mood and Present Tense

The stages of a process analysis are written in the indicative mood, as a series of factual statements (as per Section 5.2: Mood):

Once the glue is dry, the rib sections are cut following the templates using a band saw.

The present tense is used to write process analyses; the present tense thus expresses processes that are generalized or continuous (such as how all combustion engines work, or how weather patterns generally form).

4.1.3 Passive Voice

In a process analysis, as with procedures, the action performed should be the focus, not the agent/doer. Thus, once the agent/doer is established, process analyses are usually written in passive voice (as described in Section 5.1: Voice):

First, the plastic sheet is glued along one side of the wood using standard carpenter’s glue. Then, the templates of the rib sections generated by CATIA are cut using a pair of scissors and are glued onto the plastic-covered plywood using standard carpenter’s glue.

The agent/doer is the lab partner(s) who is responsible for creating the ribs for the structural model of the airplane. Repetitive reference to the lab partner is removed through the use of passive voice, and the prose flows more smoothly.

4.1.4 Marking the Stages

The stages of a process analysis are easier to follow if they are marked by enumerative words (as per Section 4.8: Frequently Used Transitions):

First, the plastic sheet is glued along one side of the wood using standard carpenter’s glue. Then, the templates of the rib sections generated by CATIA are cut using a pair of scissors and are glued onto the plastic-covered plywood using standard carpenter’s glue. Next, once the glue is dry, the rib sections are cut following the templates using a band saw.
saw. Finally, two (2) holes of ¼-in. diameter are drilled into each rib section with a drill press.

In this example, “first,” “then,” “next,” and “finally” clearly mark the typical order this process follows.

4.1.5 Cause and Effect

Many process analyses often explain how certain circumstances lead to particular effects: A causes B that in turn causes C. These cause-and-effect descriptions should be clearly marked so that the reader can easily follow the chain of cause-and-effect:

When the piston is drawn upward, the air below it rises, thereby causing the pressure to fall.

The airfoil creates a difference in air pressure; as a result, lift is generated.

A current is sent through the material so that the electrons become polarized.

On this petri-net, if a token is present on place 5 and place 6, then the transition occurs.

The magma quickly flows into the pores of the rocks; thus, the rocks rupture.

Words and phrases such as “thereby causing,” “as a result,” “so that,” “if…then,” and “thus” are a few of the more useful markers that show how A causes B which in turn causes C.

4.2 Instructions

Instructions are used to teach the reader how to complete a task, step by step. Typical instructions include putting together a bicycle, hooking up a computer, frying a strip of bacon, or toasting a piece of bread. For example, Figure 4.2: Sample Instructions is a partial set of instructions for using a rivet gun:
1.0 Place three (3) drops of air-tool oil in the air hose adaptor on the underside of the gun.

2.0 Connect the air hose to the air hose adaptor by twisting the connecting tubing clockwise until tight.

3.0 Adjust the air pressure through the rivet gun:
   3.1 Place the non-dominant hand on the muzzle of the rivet gun and the dominant hand on the handgrip.
   3.2 Hold the rivet gun against the surface of the metal sheeting, perpendicular to the surface.
   3.3 Squeeze the trigger of the rivet gun once.
   3.4 Adjust the knob to the desired air pressure by twisting the pressure knob clockwise with one hand while holding the trigger down with the other.

   **NOTE:** THE SMALLER THE RIVET, THE LESS THE REQUIRED LEVEL OF AIR PRESSURE.

4.0 Place the non-dominant hand on the muzzle of the rivet gun and the dominant hand on the handgrip.

5.0 Hold the rivet gun perpendicular to the surface of the metal sheet to be riveted with the muzzle of the rivet gun touching the surface.

6.0 Brace the body with the feet and lean as much of the body weight into the rivet gun as is feasible.

7.0 Squeeze the trigger of the rivet gun once.

8.0 Repeat Step 4.0 through Step 7.0 for each similar-sized rivet.

---

**Figure 4.2: Sample Instructions**

As illustrated in the preceding figure, some of the most salient characteristics of instructions are the use of enumerated steps (i.e., numbered steps) and of imperative mood (i.e., commands), as described in the following subsections.
4.2.1 Enumerated Steps

Instructions state the steps of a task in the *chronological* order in which they must occur; to present these steps in the wrong order would cause the reader to fail in their task. For example, in the preceding step of instructions, the air hose was connected to the rivet gun before the trigger was squeezed in a pressure test; if the trigger were squeezed before the air hose were connected, there would have been no pressure and the rivet gun would not have functioned. To be accurate, instructions must be presented in chronological order.

As a reflection of this accurate, chronological order, steps should be *enumerated* (i.e., placed in a clearly numbered list) using the decimal enumeration system. For example, in Figure 4.2: Sample Instructions, primary steps are numbered 1.0, 2.0, 3.0, and so forth while substeps are numbered 1.1, 1.2, 1.3, and so forth.

4.2.2 Imperative Mood

The steps of a set of instructions are written in the *imperative* mood, as a series of commands (as per Section 5.2: Mood):

6.0 *Brace* the body with the feet and *lean* as much of the body weight into the rivet gun as is feasible.

Note that use of the command verbs *brace* and *lean* in the preceding example.

4.2.3 By + Procedure

Instructions often require that a particular procedure be used to complete a step of the task. This requirement is marked with a “by + procedure” phrase:

3.4 Adjust the knob to the desired air pressure *by twisting the pressure knob clockwise with one hand while holding the trigger down with the other*.

In this example *by twisting the pressure knob clockwise with one hand while holding the trigger down with the other* describes the procedure by which the air pressure is adjusted. Here are further examples:

Cock the lancet *by pulling the dark gray sliding barrel on the end of the device*; draw a drop of blood *by placing the lancet against the tip of a finger and pressing the Release button*.

Determine the percentages of hardwood and softwood fiber *by performing the TAPPI test*.

Correct RAM failure at 0000 *by swapping the 86/30*. 
As these examples indicate, the specific procedures by which specific steps or substeps can be accomplished are noted by overt “by+procedure” statements.

4.3 Procedures

Procedures are used to report how an experimental or manufacturing procedure was completed at one particular point in time. Sometimes, a set of procedures is called a “methodology.” For example, Figure 4.3: Sample Procedures is part of a procedures section of a Lab Report:

12.0 The avionics circuit board was cleaned:

12.1 Approximately 10 ml of semi-aqueous cleaner was poured over the top of the board so that the entire top of the board became damp.

12.2 A soft bristle brush was dipped into the bowl of the semi-aqueous cleaner.

12.3 The board was vigorously scrubbed with the wet, soft bristle brush for 10 sec.

12.4 The top of the board was rinsed with 10 ml of isopropyl alcohol to remove all potentially harmful residues.

12.5 The excess isopropyl alcohol was blotted from the board with a lint-free cloth.

13.0 The avionics circuit board was inspected.

13.1 The top of the board was placed under a black light.

13.2 The board was visually inspected for contaminants which fluoresced.

14.0 Steps 12.0 through 13.0 were repeated three (3) more times until no further contaminants were detected.

15.0 The avionics circuit board was set aside for use in steps 26.0 through 29.0.

Figure 4.3: Sample Procedures
Some of the most salient characteristic of a procedures section as illustrated in the preceding figure are the enumerated steps and the use of repeat statements, as discussed in the following sections. (Procedures are further exemplified throughout Section 12.0: Description of Lab Reports by Section.)

### 4.3.1 Enumerated Steps

Procedures state the steps of a completed task (e.g., a lab experiment, a wind tunnel test, a structural test) in the order in which they occurred; these steps are often divided into two (2) or more phases, especially if the project lasted two (2) or more days or included two (2) or more major tasks.

If a set of procedures contains more than one phase, than each phase is identified by a title which describes the type of task undertaken, e.g., *Phase 1: Preparation* and *Phase 2: Execution*.

Steps should be enumerated (i.e., placed in a clearly numbered list). If the procedures are divided into phases, then the steps in each phase are numbered independently, i.e., the first step in each phase is always step 1.0.

Substeps are also enumerated using the decimal enumeration system. Thus, in the preceding example step 12.0 was accomplished in five (5) substeps, which are numbered step 12.1, 12.2, 12.3, 12.4, and 12.5, respectively.

### 4.3.2 Repeat Statements

Lab experiments and various types of tests often require repetitious actions, e.g., taking the same type of measurement several times. In this case, rather than restate the same action over and over, procedures often use *repeat statements*. In the preceding example, steps 12.0 and 13.0 were repeated several times as indicated by Step 14.0:

14.0 Steps 12.0 through 13.0 were repeated three (3) more times until no further contaminants were detected.

Repeat statements such as this example provide brevity while maintaining a complete description of the lab procedures.

### 4.3.3 Indicative Mood and Past Tense

The steps of a procedures section are written in the *indicative* mood, as a series of factual statements (as per *Section 5.2: Mood*):

13.0 The avionics circuit board *was inspected.*
In addition to indicative mood, procedures utilize *past tense*; the past tense indicates that these procedures were used to complete the lab experiment which is now finished.

### 4.3.4 Passive Voice

In a procedures section, the action performed should be the focus, not the agent/doer. Thus, once the agent/doer is established, procedures are usually written in *passive voice* (as described in Section 5.1: Voice):

> 13.1 The top of the board was placed under a black light.

From the context the reader understands that the agent/doer who removed the thermometer was the lab experimenter(s). Repetitive reference to the experimenter is removed through the use of passive voice and the prose flows more smoothly.

### 4.3.5 Graphics

Procedures often include graphics, properly introduced in the prose and enumerated, to illustrate the steps taken to complete the lab experiment or the test, as shown in the following example:

> 7.4 The baseline temperature was taken using the digital thermometer as illustrated in **Figure 3.2: Recording Temperatures**:

![Figure 3.2: Recording Temperatures](image.png)

As shown in **Figure 3.2: Recording Temperatures**, the temperature was recorded to within 0.1-deg. F.

As this example illustrates, graphics must be properly introduced, captioned, and commented upon, not data dumped. (See Section 8.2: Avoidance of Data Dumping for advice on how to include graphics in Lab Reports and other technical documents while avoiding data dumping.)
4.4 Abstracts

An abstract is a type of technical summary, the other major type being the executive summary. Abstracts are written mostly for Lab Reports, formal reports, journal articles, and doctoral dissertations, although other types of technical documents may use them as well. Abstracts are placed at the beginning of the document summarized, although they may also be published separately from the parent document; when the latter occurs, the abstracts are typically published in research indexes, documents used by researchers to review current work being undertaken in a specific field.

Abstracts consist of two (2) types: descriptive and informative. The type selected is dependent on the abstract’s purpose or function; formal APA-style Lab Reports typically include informative abstracts in their Front Matter.

4.4.1 Formatting Checklist for Descriptive and Informative Abstracts

Both descriptive and informative abstracts share the following formatting guidelines:

✓ Abstracts are objective summaries of the documents summarized; if, for example, the abstract is written by someone other than the author of the original document, the abstract writer must objectively summarize the original document and NOT offer editorial comment.

✓ Abstracts are self-contained, stand-alone documents (i.e., are comprehensible by themselves).

✓ Abstracts may NOT introduce information not contained in the original document.

✓ Abstracts may NOT contain quotations.

✓ Abstracts are written in paragraph form.

✓ Abstracts may use horizontal lists, but they may NOT use vertical lists.

✓ Abstracts may NOT contain documentation, citation, or footnotes.

✓ Abstracts may NOT use graphics.

✓ Abstracts may NOT refer to other parts of the document (e.g., “see pages 34-38 for further budget information”).

✓ Abstracts may NOT use headings to distinguish sections.
Abstracts are typically under 250 words; only abstracts for lengthy technical documents approximate a page in length; often, the formatting guidelines will specify a length of fewer than 250 words, but if not, the general rule of thumb is that an abstract must **NOT** exceed approximately 2/3 of a page.

### 4.4.2 Third Person, Indicative Mood, Voice, and Tense

Both types of abstracts use the *third person* and *indicative mood* throughout. Both *passive* and *active voices* are used as needed.

*Tense,* however, varies depending on what is being said. Present tense is typically used for the purpose, scope, results, conclusions, and recommendations sections; past tense is typically used for the methods and textual overview sections.

### 4.4.3 Descriptive Abstracts

A **descriptive abstract** is written when the intent is to guide the reader in deciding whether or not they need/want to read the original document—i.e., in judging if reading the document in its entirety is beneficial. Descriptive abstracts are essentially a listing of the document’s contents, in that they outline the areas covered in the summarized document—they **DO NOT** summarize the document’s content or findings.

The following general areas or organizational structure must be present in a descriptive abstract:

- **Purpose**: What is the topic and function of the document?
- **Scope**: What content areas are covered in the document?
- **Methods**: How were the data used in the document obtained (i.e., obtained through primary research, secondary research, or a combination of the two)?

These areas are illustrated in **Figure 4.4: Sample Descriptive Abstract**.
This project’s objectives were to review the state of the art in on-line transient stability assessment, evaluate promising new technologies, and identify technical and computational requirements for calculating transient stability limits and corrective and preventive control strategies for operating situations that are transiently insecure. [←Purpose and Scope]

Six (6) on-line transient stability package vendors were identified by conducting a literature survey. A detailed questionnaire which addressed several pertinent issues relating to on-line transient stability assessment was prepared. All six (6) vendors responded to the questionnaire. The responses received were carefully analyzed. This analysis provided a detailed overview of the capabilities of available tools, performance metrics, modeling features, and protective and corrective control measures. An elaborate questionnaire was then prepared and sent to all PSERC member companies. This questionnaire addressed specific needs in terms of required features, preferred performance, and control capabilities. [←Methods]

Figure 4.4: Sample Descriptive Abstract
(Source: Adapted from Vittal, 2005)

Note that within the preceding figure, the purpose, scope, and methods contained within the descriptive abstract are identified by bracketed labels.

4.4.4 Informative Abstracts

An informative abstract is written when the intent is to give the reader a succinct but comprehensive overview of the contents and findings of the summarized document so that it literally stands for that document—i.e., by reading the abstract without further reference to the summarized document, the reader may come away with an accurate understanding of that summarized document.

The informative abstract expands the descriptive abstract by adding four (4) additional areas after purpose, scope, and methods. In total, these seven (7) areas are as follows:

- **Purpose**: What is the topic and function of the document?
- **Scope**: What content areas are covered in the document?
- **Methods**: How were the data used in the document obtained (i.e., obtained through primary research, secondary research, or a combination of the two)?
Results: What data were obtained for each content area identified in the scope?

Conclusions: What conclusions were drawn based on the results?

Recommendations: What recommendations were drawn based on the conclusions? (If no recommendations are made, a statement of “No recommendations were made” is appropriate for the purposes of audience clarity.)

Textual overview: What organizational sections are included in the document, especially unexpected, lengthy, or unusual sections?

These areas are illustrated in Figure 4.5: Sample Informative Abstract:

This project’s objectives are to review the state of art in on-line transient stability assessment, evaluate promising new technologies, and identify technical and computational requirements for calculating transient stability limits and corrective and preventive control strategies for operating situations that are transiently insecure. [Purpose and Scope]

Six (6) on-line transient stability package vendors were identified by conducting a literature survey. A detailed questionnaire which addressed several pertinent issues relating to on-line transient stability assessment was prepared. All six (6) vendors responded to the questionnaire. The responses received were carefully analyzed. This analysis provided a detailed overview of the capabilities of available tools, performance metrics, modeling features, and protective and corrective control measures. An elaborate questionnaire was then prepared and sent to all PSERC member companies. This questionnaire addressed specific needs in terms of required features, preferred performance, and control capabilities. [Methods]

A detailed analysis of the responses received provides a clear picture of the desired features and performance specifications of an on-line transient stability assessment tool. [Results] A comparison of the analysis conducted on the vendor responses and the PSERC member company responses identifies areas and topics that need further development and research. [Conclusion] This information is recommended for soliciting new research proposals and providing vendors a guide to the features that need to developed and implemented. [Recommendations]

Figure 4.5: Sample Informative Abstract
(Source: Adapted from Vittal, 2005)
This report contains a literature survey conducted on new analytical developments in on-line transient stability analysis. Based on this review, novel concepts based on quadratized models for power system components are also explored. [↩Textual Overview]

**Figure 4.5: Sample Informative Abstract, cont’d**
(Source: Adapted from Vittal, 2005)

Note that as illustrated in the preceding figure, this 243-word example builds on the descriptive abstract by adding the areas of results, conclusions, recommendations, and textual overview.

### 4.5 Compare and Contrast

#### 4.5.1 Comparison

*Comparison* is a method of development that points out *similarities* between elements in the topic being discussed. Comparison is most effective when a complex or unfamiliar topic is explained by relating it to a less complex or familiar topic.

First, a basis for comparison must be established. For example, in a discussion about film where the horror genre and the science-fiction genre are being compared (i.e., the *topics or subject* of the comparison), one might decide to develop a comparison based on the genres’ intended audience, themes, and history (i.e., the *points* to be made).

Second, a decision must be made as to how the comparisons will be developed. Two (2) patterns of development are available for making comparisons: *point by point* and *subject by subject*. In the point-by-point approach, each point is discussed, first for the first topic, then for the second topic, until all points have been covered. A sample outline for a point-by-point comparison of the horror and science-fiction genres follows:

1.0 Intended audience

1.1 Horror genre
1.2 Science-fiction genre

2.0 Themes

2.1 Horror genre
2.2 Science-fiction genre
3.0 History

3.1 Horror genre
3.2 Science-fiction genre

This outline was used to write the sample comparison essay depicted in Figure 4.6: Sample Point-by-point Comparison:

First, the intended audience of the horror genre is someone who enjoys the adrenaline rush of being moved by terror, suspense, and revulsion. For example, *Drag Me to Hell* (2009) will appeal to someone who enjoys experiencing the emotions involved in watching an innocent girl pursued by forces beyond her control. The intended audience of the science-fiction genre is someone who not only enjoys an adrenaline rush but is fascinated also by the spectacle of the effects that science and technology have on the human condition. For example, *Terminator Salvation* (2009) will appeal to someone interested in experiencing the emotions involved in watching a protagonist trying to save humanity from the technology it has created.

Second, common themes in the horror genre are the exploration of humanity’s relation to the unknown and the struggle between good and evil. For example, both themes can be found in *Darkness* (2005). In addition to the struggle between good and evil, common themes in science fiction are “science gone wrong” and what happens when people fail to take responsibility for their actions. For example, both of these themes can be found in *Frankenstein Unbound* (1990).

Finally, horror films have been popular since the beginning of the film industry. For example, DVD sales of horror films for 2008 reached 250-million dollars. Likewise, science-fiction films have always had an audience and have never gone out of style. For example, DVD sales of science-fiction films for 2008 reached 300-million dollars.

**Figure 4.6: Sample Point-by-point Comparison**

In the point-by-point comparison illustrated in the preceding figure, for each point discussed, the horror genre topic is always discussed first and the science-fiction genre is always discussed last; using a consistent pattern creates clear organization and allows the reader to readily follow the comparison.

In the subject-by-subject approach, the two (2) topics or subjects are discussed separately—first one, then the other. Thus, all the points are covered for the first topic or subject, and then all the points are covered for the second topic or subject.
An outline for a subject-by-subject comparison of the horror and science-fiction genres follows:

1.0 Horror genre
   1.1 Intended audience
   1.2 Themes
   1.3 History

2.0 Science-fiction genre
   2.1 Intended audience
   2.2 Themes
   2.3 History

This outline was used to write the sample comparison essay depicted in Figure 4.7: Sample Subject-by-subject Comparison:

The intended audience of the horror genre is someone who enjoys the adrenaline rush of being moved by terror, suspense, and revulsion. For example, *Drag Me to Hell* (2009) will appeal to someone who enjoys experiencing the emotions involved in watching an innocent girl pursued by forces beyond her control. Common themes in the horror genre are the exploration of humanity’s relation to the unknown and the struggle between good and evil. For example, both themes can be found in *Darkness* (2005). Historically, horror films have been popular since the beginnings of the film industry. For example, DVD sales of horror films for 2008 reached 250-million dollars.

In comparison, the intended audience of the science-fiction genre is not only someone who enjoys an adrenaline rush but also someone who is fascinated by the spectacle of the effects that science and technology have on the human condition. For example, *Terminator Salvation* (2009) will appeal to someone interested in experiencing the emotions involved in watching a protagonist trying to save humanity from the technology it has created. In addition to the struggle between good and evil, common themes in science fiction are “science gone wrong” and what happens when people fail to take responsibility for their actions. For example, both of these themes can be found in *Frankenstein Unbound* (1990). Much like horror films, science-fiction films have always had an audience and have never gone out of style. For example, DVD sales of science-fiction films for 2008 reached 300-million dollars.

Figure 4.7: Sample Subject-by-subject Comparison
In the subject-by-subject comparison illustrated in the preceding figure, the topics are discussed in a consistent pattern, aiding readability.

While both patterns are of use in technical writing, point-by-point comparison is usually considered more sophisticated and thus is more frequently used.

4.5.2 Contrast

Contrast is a method of development that points out differences between elements in the topic being discussed. Contrast is most effective when a complex or unfamiliar topic is explained by relating it to a less complex or familiar topic.

First, a basis for contrast must be established. For example, in a discussion about film where the musical genre and the film-noir genre are being compared, one might decide to develop a contrast based on the genres’ intended audience, structure, and cinematography.

Second, a decision must be made as to how the contrasts will be developed. Two patterns of development are available for making contrasts: point by point and subject by subject. As with comparisons, in the point-by-point approach, each point is discussed, first for the first topic, then for the second topic, until all points have been contrasted. A sample outline for a point-by-point contrast of the musical and film-noir genres follows:

1.0 Intended audience
   1.1 Musical genre
   1.2 Film-noir genre

2.0 Structure
   2.1 Musical genre
   2.2 Film-noir genre

3.0 Cinematography
   3.1 Musical genre
   3.2 Film-noir genre

This outline was used to write the sample contrast essay depicted in Figure 4.8: Sample Point-by-point Contrast:
The intended audience of a musical is someone who enjoys being entertained by music and dance and who can suspend the natural tendency to be bound by a realistic view of life—for normally people do not burst spontaneously into song. For example, *Singing in the Rain* (1952) will appeal to someone with this ability. On the other hand, the intended audience of film noir is someone who has pessimistic perspective on reality and who tends to have a cynical view of the life and especially humanity. For example, *The Last Seduction* (1994) will find an audience with someone with this perspective.

Musicals follow a linear structure with a clear beginning, middle, and end. For example, *Rent* (2005) illustrates this pattern. Film noir, however, often uses complex internal structures even when employing a linear pattern. For example, *Kiss Kiss Bang Bang* (2005) uses this approach.

The cinematography of musicals generally uses a straightforward approach so as to not draw attention to itself and thus take the audience’s attention away from the music. This style can be seen in *Across the Universe* (2007). Cinematography in film noir, on the other hand, relies on sharp visual contrasts, shadows, and odd camera angles that become part of the thematic content. This approach can be seen in *The Ice Harvest* (2006).

**Figure 4.8: Sample Point-by-point Contrast**

In the point-by-point contrast illustrated in the preceding figure, for each point discussed, the musical genre is always discussed first, followed by the film-noir genre; using a consistent pattern helps the reader to readily follow.

In the subject-by-subject approach, the two (2) topics or subjects are discussed separately—first one, then the other. Thus, all the points are contrasted for the first topic or subject, and then all the points are contrasted for the second topic or subject. An outline for a subject-by-subject contrast follows:

1.0 Musical genre
   1.1 Intended audience
   1.2 Structure
   1.3 Cinematography

2.0 Film-noir genre
   2.1 Intended audience
   2.2 Structure
   2.3 Cinematography
This outline was used to write the sample contrast essay depicted in Figure 4.9:
Sample Subject-by-subject Contrast:

The intended audience of a musical is someone who enjoys being entertained by music and dance and who can suspend the natural tendency to be bound by a realistic view of life—for normally people do not burst spontaneously into song. For example, Singing in the Rain (1952) will appeal to someone with this ability. In terms of structure, musicals follow a linear structure with a clear beginning, middle, and end. For example, Rent (2005) illustrates this pattern. The cinematography of musicals generally uses a straightforward approach so as not to draw attention to itself and thus take the audience’s attention away from the music. This style can be seen in Across The Universe (2007).

On the other hand, the intended audience of film noir is someone who has pessimistic perspective on reality and who tends to have a cynical view of the life and especially humanity. For example, The Last Seduction (1994) will find an audience with someone with this perspective. In terms of structure, film noir often uses complex internal structures even when employing a linear pattern. For example, Kiss Kiss Bang Bang (2005) uses this approach. Cinematography in film noir relies on sharp visual contrasts, shadows, and odd camera angles that become part of the thematic content. This approach can be seen in The Ice Harvest (2006).

Figure 4.9: Sample Subject-by-subject Contrast

In the subject-by-subject contrast essay depicted in the preceding figure, the topics are discussed in a consistent pattern, aiding readability.

As with comparisons, point-by-point contrast is usually considered more sophisticated and thus is more frequently used.

4.6 Parts of a Whole

In a parts-of-a-whole description, a complex object is rendered into smaller units. Each unit is then described in detail according to location and/or function. Examples of parts-of-a-whole descriptions are the components of a wing, the components of a sound system, the elements that comprise a rainbow, and the ingredients in four-alarm chili.

In parts of a whole, the writer must indicate how the units are related to each other so that together they form something more complex than the mere sum of the parts: they form not just ribs and skin but a wing that provides lift; not just a collection of wires and amplifiers but a sound system for a home theatre; not just...
light and rain but a meteorological phenomenon; not just beans and meat but four-alarm chili hot enough to make a Texan cry.

In the following example (Figure 4.10: First Sample of Parts of a Whole), the four (4) components of an airplane wing are identified by their location in relationship to the wing as a whole:

In an effort to increase fuel efficiency, scientists at Daimler-Benz and the German Aerospace Research Center are experimenting with an adaptive wing. This new wing has four (4) components: a sensor network which is located at widely differing points under the wing skin, a computer processor which is linked to—but separate from—the flight management computer, an intelligent flap on the wing with a deformable trailing edge, and an adaptable contour region which is midway on the upper surface of the wing.

**Figure 4.10: First Sample of Parts of a Whole**

In the preceding figure, locations are noted in italic font. By giving the locations of each of the components, the writer aids the reader in visualizing the construction of this new invention.

In addition to location, the writer may also wish to describe the function of each component, as in Figure 4.11: Second Sample of Parts of a Whole:

The sensor network continuously collects information about airflow, laminar flow length, possible turbulence, and pressure distribution. The sensor network then feeds this information into the computer processor that in turn calculates the ideal geometry for the wing. The processor transmits the necessary instructions to the intelligent flap and the adjustable contour region. The trailing edge of the intelligent flap changes shape to meet the demands of specific flight conditions while the adjustable contour region adjusts to lie smooth or to bulge according to the computer processor’s directions.

**Figure 4.11: Second Sample of Parts of a Whole**

In the preceding figure, functions are marked in italic font. If the writer were to only identify the location of each part, or to only state the function of each part, then the reader would not acquire a clear picture of how the wing worked as a whole. Both location and function are necessary for a clear, complete description.
4.7 Technical Definitions

Another useful organizational scheme is the technical definition. Technical definitions are typically sentence-length (although paragraph-length and longer definitions are not infrequent) and follow this standardized format: *A (term) is a (category) which (discriminating factors/description)*. Figure 4.12: Three (3) Examples of Technical Definitions provides examples of this format:

1. *Lift* is a force that is generated by a wing and acts perpendicular to the incoming flow, allowing an airplane to climb.

2. *An electron* is a subatomic particle that is negatively charged. It can be free (i.e., not attached to any atom) or bound (i.e., attached to the nucleus of an atom).

3. *C shell* is a command interpreter which was created as an alternative to UNIX’s original shell and which is used by programmers who prefer a syntax similar to that of the C programming language.

Figure 4.12: Three (3) Examples of Technical Definitions

Although it is possible to format technical definitions differently, the standardized format illustrated in the preceding figure is most commonly found in articles published in peer-reviewed technical and academic journals. This format, including the use of italics to note the term being defined, is also the recommended format for Lab Reports.

4.8 Frequently Used Transitions

Transitions are used to help the writer establish clear connections between ideas. A sufficient number of well-chosen transitions prevent confusion of ideas and allow the reader to maintain flow. Transitions may be used in four (4) ways:

- To subordinate ideas,
- To connect sentences,
- To connect paragraphs through enumeration, and
- To connect paragraphs through this + summarization.

First, transitions may be used to subordinate one idea to another:
Although the television series *Lost* is set in contemporary times on an island in the Pacific Ocean, it draws upon many elements of film noir.

*Whereas* Warren Zevon’s music has been called “song noir,” Zevon always viewed himself as a folk singer.

Second, transitions may be used to connect sentences:

The link between Hollywood stardom and substance abuse is well established; *however*, a disturbing trend among young actors and actresses to drink and drive has manifested lately in the media.

Many scientists enjoy reading science fiction. *In fact*, some point out that what once was science fiction is now science fact. *For example*, cell phones and video conferencing were staples of science fiction stories in the 1960’s.

Third, transitions may provide a clear roadmap between paragraphs or sections through **enumeration** (i.e., numbering):

When you select a movie for a Friday night date, *first* check local listings on Hollywood.com to see what is playing at the local theatre. *Second*, scan the Internet Movie Database (imdb.com) or a similar website for reviews of the movie. *Third*, strike any movies that receive a poor review off your list of possibilities. *Fourth*, ask your date to identify his/her preference from your shortened list.

The *initial* phase involved the preparation of the materials.... The *next* phase required their heating....The *final* phase included a cooling sequence....

Fourth, transitions provide a roadmap between paragraphs or sections through a “**this + summary word**” strategy. Here, the sample sentences begin with the word *this* followed by a word or noun phrase that summarizes preceding information:

*This film*, no doubt, seemed like a sound financial decision at the time when the studio gave it the green light.

*This career move* was an excellent way of running up credit card debt and getting into trouble with the IRS.

**Table 4.2: Frequently Used Transitions** categorizes transitions by function:
### Table 4.2: Frequently Used Transitions

<table>
<thead>
<tr>
<th>Type of Transition</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Additive</td>
<td>additionally, also, further, furthermore, in addition, moreover, and, as well as</td>
</tr>
<tr>
<td>Adversative</td>
<td>although, despite, despite the fact that, even if, even though, however, in spite of, nevertheless, nonetheless, and yet, yet</td>
</tr>
<tr>
<td>Causative</td>
<td>as a result, because, consequently, due to, hence, since, thereby, therefore, thus</td>
</tr>
<tr>
<td>Clarifying</td>
<td>i.e., in other words, that is</td>
</tr>
<tr>
<td>Contrastive</td>
<td>conversely, however, in contrast, on the other hand, unlike, whereas, while</td>
</tr>
<tr>
<td>Enumerative/Numbering</td>
<td>finally, first, fourth, next, primary, second, secondary, tertiary, the following, then, third</td>
</tr>
<tr>
<td>Illustrative</td>
<td>e.g., for example, for instance</td>
</tr>
<tr>
<td>Intensifying</td>
<td>as a matter of fact, in fact, indeed, on the contrary</td>
</tr>
<tr>
<td>Summative</td>
<td>this + summary word, this idea, this problem, these results, these possible solutions</td>
</tr>
</tbody>
</table>

As Table 4.2: Frequently Used Transitions demonstrates, there are a variety of transitions available. However, be wary of enumerating or numbering a single string of ideas with different enumeration styles, confusing the reader. When enumerating or numbering, be consistent: use one of the following styles to avoid confusing the reader:

- `first, second, third, fourth` OR `first, then, next, the following, finally` OR `the primary objective, the secondary objective, the tertiary objective, the final objective` |

When enumerating or numbering, consistency is key.

July 26, 2011
4.9 Vertical Lists

Vertical lists are a formatting strategy that increases the visual readability of the text and aids the reader’s ability to apprehend the material presented. A minimum of **three (3) items** is required before a vertical list may be created.

Vertical lists are indented five (5) spaces (i.e., 1 tab) from the left margin in order to indicate subordination to the text. Items in the list are typically stated as phrases, although they may be full sentences or even short paragraphs. If the items being listed can be counted (e.g., two (2) graham cracker squares and one (1) toasted marshmallow) or measured, (e.g., 2 oz. of semi-sweet chocolate), then the quantities or measurements are stated at the beginning of each item or phrase, as follows:

The recipe for the perfect s’more requires the following ingredients and tools:

1. Two (2) graham cracker squares,
2. One (1) toasted marshmallow,
3. 2 oz. of semi-sweet chocolate,
4. Toasting stick, and
5. Campfire reduced to warm coals.

The marshmallow should be lightly toasted with the toasting stick over the campfire coals, but it should not be burned, and it should still warm from the campfire before assembly of the s’more begins.

In the preceding example, the quantities are noted by first spelling the quantity word then placing the quantity number in parentheses (e.g., Two (2)), whereas measurements are noted by stating the value and the unit of measure (e.g., 2 oz.). General items that are not counted or measured (e.g., toasting stick, campfire coals) can be included in the same vertical list as items which must be counted or measured. The order in which the items are introduced depends upon the type of vertical list employed, as discussed next.

Three (3) types of vertical lists may be employed:

- Numbered lists,
- Bulleted lists, and
- Checklists.
Numbered lists are employed when there is a hierarchy within the items—i.e., when the first item listed is the most important or has the ranking priority and the last item listed is the least important or has the lesser priority:

According to movieweb.com (2011), by the end of July 2011, the five (5) highest grossing films of all time in the United States were as follows:

6. *Avatar*

7. *Titanic*

8. *The Dark Knight*

9. *Star Wars: Episode IV—A New Hope*

10. *Shrek 2*.

Despite *Avatar’s* strong showing, critics expected that *Harry Potter and the Deathly Hallows Part II* would surpass its box office receipts by the end of August, 2011.

In this example, a ranking is established and the reader understands that *Avatar* grossed more than did the other films in the list. Also in this example, a brief commentary follows the numbered list so as to prevent data dumping (as noted in Section 8.2: Avoidance of Data Dumping.)

Bulleted lists are used when there is no ranking priority within the items listed and all are essentially of equal significance:

Director Ed Wood, Jr. made a number of films that film critics have deemed among the worst films of all time, some of which follow:

- *Plan 9 From Outer Space*
- *Bride of the Monster*
- *Jail Bait*
- *Glen or Glenda.*

Despite the negative reception from critics, Wood has a following that celebrates his films as being so “bad” that they are “good”:
In this example, no ranking is being stated or implied. Again, the vertical list is commented upon at the end of the list to avoid data dumping.

Checklists state a series of tasks that must be completed in the order presented. Thus, as with numbered lists, a hierarchy of priority is established:

In order to find information on a film, complete the following:

- Log on to your computer.
- Go to the Google search engine.
- Search for the Internet Movie Data Base (i.e., IMDb at www.IMDb.com).
- Click on the Google link to open the IMDb home page.
- Locate the Search window at the top of the IMDb home page.
- Type the name of the film in the Search window.
- Hit “Go” to access the page that provides information on the selected film.
- Access the information on the page as needed and click on additional links if required.

An alternative to the IMDb is movieweb.com.

In this example, the tasks listed must be completed in the order listed.

Regardless of which form of vertical list is selected, lists must be punctuated. There are four (4) punctuation patterns to choose from: three (3) patterns are used when the listed items are phrases and one (1) pattern is used when the listed items are sentences.

If the listed items are phrases, they may be punctuated in one of the following (3) ways. First, the items may be punctuated as running text; that is, the list is punctuated as if it were horizontal text (i.e., a sentence) that is listed vertically:

Four (4) of Warren Zevon’s best records are as follows:

- Warren Zevon (1976),
- Excitable Boy (1978),
- *Transverse City* (1989), and

Of course, these records do not include the compilations that were released after his death.

In this example, commas and the word “and” are placed as if the vertical list were instead a horizontal text or items listed in a sentence. Second, the list may be punctuated by placing a period at the end of each phrase listed:

**Four (4) of Warren Zevon’s best records are as follows:**

Of course, these records do not include the compilations that were released after his death.

In this example, periods are used to mark the end of each item in the list, even though they are phrases and not full sentences.

Third, the list may be punctuated by omitting all punctuation except for a period at the end of the last phrase listed:

**Four (4) of Warren Zevon’s best records are as follows:**
- *Warren Zevon* (1976)
- *Excitable Boy* (1978)
- *Transverse City* (1989)

Of course, these records do not include the compilations that were released after his death.

In this example, the final period is a visual marker that the list is complete.
Regardless of which pattern is selected, the first word of each item listed must be capitalized. Furthermore, once a pattern is selected, that pattern is consistently used throughout the text.

If the items listed are sentences, then the items may be punctuated as one would a sentence in horizontal text (i.e., each item in the list must end with a period):

Several documentary films released in the last five (5) years are significant because of the important information they contain, information that affects life in contemporary American society:

- *In Debt We Trust* (2006) reveals the effect credit-card debt is having on our culture and the political and corporate influences that have colluded to deregulate the lending industry, thus ensuring credit-card dependency.

- *Why We Fight* (2005) offers a nonpartisan study of the forces—political, economic, and ideological—that have driven the U.S. to fight in the 20\textsuperscript{th} and 21\textsuperscript{st} centuries.

- *Waiting for Superman* (2010) examines the public education system in America, tracking the progress (or lack thereof) of a handful of children through “drop-out factories” and “academic sinkholes” in an effort to more fully understand this problem and its impact on this generation of schoolchildren.

Of course, this list is not comprehensive, contemporary American society is further documented in films such as *Supersize Me!* (2004) and *Jesus Camp* (2008).

As the previous examples demonstrate, when it comes to the punctuation of lists, consistency within the document is critical. Do NOT mix phrases and sentences within the same list: the list must contain either all phrases or all sentences. Furthermore, only one (1) pattern for lists using phrases must be used within the document, e.g., all phrases must be noun phrases, or all phrases must be present tense verb phrases, or all phrases must be gerund phrases: do NOT mix patterns.

### 4.10 Warnings, Cautions, and Notes

Warnings, cautions, and notes are typically included in technical instructions. **Warnings** provide the reader with critical information that could prevent harm to the reader or to those around them; **cautions** provide critical information that could prevent damage to equipment or the surroundings; and **notes** provide supplementary information such as technical definitions, troubleshooting information, or links to helpful sources.
Warnings, cautions, and notes are specially formatted. They are typically set apart from the rest of the prose by one blank line. The first word in the warning, caution, or note should be either **WARNING**, **CAUTION**, or **NOTE** typed in all caps, bolded, and underlined so that there is little chance that the reader could miss it. This first word is followed by a colon and then by a line or two of prose.

The prose for warnings and cautions are typically “do not” commands followed by an if/then recommendation for what to do if the warning is ignored and then injury or damage occurs. The following template is often used: **DO NOT ____; DOING SO MAY RESULT IN _____. IF ____ DOES OCCUR, THEN IMMEDIATELY _____.** Note that the prose is typically in all caps and bolded, but not underlined.

The following are examples of warnings, cautions, and notes taken from a set of technical instruction on how to pack a box for international shipping using, among other tools, a pair of a shipping label, duct tape, and scissors:

**WARNING: DO NOT RUN WITH THE SCISSORS. DOING SO MAY RESULT IN SEVERE INJURY. IF INJURY OCCURS, SEEK IMMEDIATE MEDICAL ATTENTION.**

**CAUTION: DO NOT DROP THE SCISSORS ONTO THE WORK SURFACE. DOING SO MAY IRREVERSIBLY SCRATCH OR CHIP THE WORK SURFACE. IF SCRATCHING OR CHIPPING OCCURS, IMMEDIATELY CONTACT A FURNITURE REPAIR SHOP.**

**NOTE: OVERLAPPING THE SHIPPING LABEL WITH THE DUCT TAPE IS ACCEPTABLE BUT NOT DESIRED. ATTEMPT TO MINIMIZE ANY OVERLAP BETWEEN THE TWO MATERIALS.**

As this example shows, first listed are typically warnings, followed by cautions, and finally by notes. There may be numerous warnings, cautions, or notes in a set of technical instructions or other document, and they may be accompanied by photos, warning logos, or other symbols.
5.0 RHETORICAL CONCERNS

5.1 Voice

Voice indicates the relationship of the subject to the verb’s action. English has both active and passive voice.

5.1.1 Active Voice

Active voice emphasizes the performer of the action while not emphasizing the action performed:

Amy Winehouse fled the scene of the accident.

Amy Winehouse claims that the drugs the police found in her purse were not hers.

In these examples, Amy Winehouse, as the subject performing an action, is emphasized by her placement at the beginning of the respective sentences; thus, the subject’s actions (i.e., fled the scene and claims the drugs) are not the focus of these sentences.

5.1.2 Passive Voice

Passive voice emphasizes the action performed by the subject, while either not emphasizing the subject or eliminating reference to the subject altogether:

I Know Who Killed Me (2007) was universally panned by film critics everywhere.

Lindsay Lohan’s film career was killed by her film I Know Who Killed Me (2007).

The scene was fled by the starlet.

The scene was fled.

In all four (4) of the preceding sentences, the action performed by the subject is placed first in the sentences and is thus emphasized. In the fourth and final sentence, any reference to the subject is eliminated entirely.

While active and passive voice can be used to express the exact same meaning, the difference between them is twofold. First, what active and passive voices emphasize is different. Second, active voice is often less wordy than passive voice as passive voice uses a helping verb in addition to the main verb and an additional preposition if the action’s doer is also identified (e.g., [active] “Officials
encourage evaluations” vs. [passive] “Evaluations are encouraged by officials.”); because active voice is often less wordy, it is often stylistically preferred to passive voice.

However, be aware that there are times when passive voice is preferred over active voice, e.g., if one wants to focus on the action alone, as in process analysis or an Apparatus and Procedures section, or if one wants to describe an action without attaching a specific agent/doer to that action, especially if the agent/doer is already well established (e.g., “A series of mistakes were made in the process” vs. “The research team made a series of mistakes”).

5.2 Mood

Mood indicates how the speaker views a statement. Three (3) moods exist in English: indicative, imperative, and subjunctive.

5.2.1 Indicative Mood

The indicative mood states a fact, opinion, or question:

The temperature is currently 67 degrees F. [Fact]

Professor Phil Jones seems to be a great mentor. [Opinion]

Will the meeting take place as scheduled? [Question]

5.2.2 Imperative Mood

The imperative mood expresses a command or direction. In the imperative mood, the subject you is implied, not stated:

Avoid Lindsay Lohan’s film I Know Who Killed Me at all costs.

Go see the latest adaptation of Jack Finney’s Invasion of the Body Snatchers—Nicole Kidman’s Invasion (2007)—as soon as possible.

5.2.3 Subjunctive Mood

The subjunctive mood expresses a notion or statement that is contrary to fact or is hypothetical:

The film would have been a tolerable if it had had a coherent script, a competent director, decent editing, professional acting, and a better catering service.
The popcorn at the movie *would have been* tempting if I had not seen the mouse run by the concession stand.

5.3 Person and Direct Address

5.3.1 Person

*Person* refers to the *personal pronouns* that indicate whether the pronoun refers to the speaker, the person spoken to, or the person(s) or object(s) spoken about. Three (3) persons exist in English:

- **First person**: I, Me, My, We, Ours, Us [the speaker]
- **Second person**: You, Your [person(s) spoken to]
- **Third person**: He, She, It, Him, His, Its, They, Them, Their [person(s) or object(s) spoken about].

As a general rule, the *formal style* uses third person; the *semiformal style* uses first, second, and third person; and the *informal style* uses first and second persons. Most technical documents such as Lab Reports require use of the formal style and avoid the use of all first person and second person pronouns (i.e., they completely avoid I, me, my, we, ours, us, you, and your).

5.3.2 Direct Address

*Direct address* involves use of a word or phrase that indicates the person or group spoken to; use a comma to set off words of direct address:

Hortense, thanks for your help formatting the document.

Engineers, we must plan for the future.

Direct address is to be avoided in most formal technical documents, e.g., Lab Reports or Memos.
6.0 GRAMMAR AND PUNCTUATION

The following sections discuss sentence structure, verb tense, pronoun usage, modifiers, and the use of colons, semi-colons, and hyphens. Common errors (e.g., fragments, run-ons, dangling modifiers, and ambiguity) are also discussed.

6.1 Sentence Types

Four (4) types of sentences exist in English:

- Simple sentences,
- Compound sentences,
- Complex sentences, and
- Compound/complex sentences.

The number of clauses and type of clause each sentence contains determines sentence type as described in the following sections.

6.1.1 Simple Sentences

A simple sentence contains one (1) independent clause. An independent clause can stand alone as a sentence:

Buffy went to the store.

The simplest form of a simple sentence would be “Buffy went.”

6.1.2 Compound Sentences

Compound sentences unite two (2) or more independent clauses of equal importance. Three (3) methods can be used to unite these clauses:

- **Coordinating Conjunctions** (and, but, or, nor, for, so, yet): Veronica Mars believed the Dean was lying about his whereabouts, but she could not be certain without further investigation into the matter.

- **Semicolon**: Veronica planted the listening device in the Sheriff’s office; Wallace waited for her outside in the car.

- **Colon**: Buffy made one thing clear: she wasn’t going to take the situation lying down.
Whichever of the three (3) methods is used, the writer must ensure that the punctuation is used correctly, especially as regards colons and semicolons (as noted in Section 6.6: Colons and Semicolons).

6.1.3 Complex Sentences

Complex sentences contain one (1) independent clause and one (1) or more dependent clauses. A dependent clause cannot stand alone as a complete sentence; it is similar to a main clause, but it begins with a subordinating word. For example, in the following clause,

when the shadows fell across the lake.

*When* is the subordinating word.

The main idea of the complex sentence must be placed in the independent clause and not the dependent clause, because the idea in the independent clause is the one that becomes emphasized. Complex sentences allow writers to place several ideas in relationship to each other by subordinating them to the main idea in the independent clause as follows:

When a grammatical error occurs in professional writing, the credibility of the writer is damaged.

In the preceding sentence, the idea that is emphasized is the one in the independent clause, i.e., the idea regarding writer credibility. This primary idea is then linked to the subordinate idea in the dependent clause, i.e., the idea regarding grammatical errors.

6.1.4 Compound/Complex Sentences

Compound/Complex sentences contain two (2) or more independent clauses and at least one (1) dependent clause. Due to its complicated nature, the compound/complex sentence is the most attention-demanding sentence type for readers. Overuse of this type can fatigue readers. The following sentence is an example of a compound/complex sentence:

When protocol is not followed, mistakes will occur, and these errors will have drastic ramifications.

The independent clauses are *mistakes will occur* and *these errors will have drastic ramifications*, and these independent clauses are linked to the dependent clause *when protocol is not followed.*
6.2 Fragments, Comma Splices, and Run-Ons

Three (3) common grammatical errors (i.e., fragments, comma splices, and run-ons) are described in the following sections. All such errors should be avoided in Lab Reports and other technical documents.

6.2.1 Fragments

A fragment is a group of words that appears to be a simple sentence or a group of words that is punctuated as a sentence but in either case does not express a complete thought:

- Decisions made by the department chair.
- When the details arrive.

Fragments make no sense by themselves and leave out crucial information. A fragment is a major grammatical error and may be corrected by revising the fragment into a full thought, i.e., an independent clause, thus making a simple sentence (as described in Section 6.1: Sentence Types):

- Decisions made by the department chair are open for discussion.
- The decision will be made when the details arrive.

The preceding examples demonstrate how fragments may be revised into complete and correct simple sentences.

6.2.2 Comma Splices

A comma splice occurs when two (2) sentences (i.e., two (2) independent clauses) are joined with a comma:

- The board voted on the measure, it was passed by a slim majority.

A comma splice is a major grammatical error and may be corrected by one (1) of three (3) basic strategies.

- By replacing the comma with a period and capitalizing the first word of the second sentence, thus separating the comma splice into two (2) separate sentences;
- By replacing the comma with a semicolon, thus creating a compound sentence (as discussed in Section 6.1: Sentence Types); or
By adding an appropriate coordinating conjunction after the comma, thus creating a compound sentence (as discussed in Section 6.1: Sentence Types).

These three (3) strategies are illustrated below, in the same order in which they were listed above:

The board voted on the measure. It was passed by a slim majority.

The board voted on the measure; it was passed by a slim majority.

The board voted on the measure, and it was passed by a slim majority.

Careful editing can be implemented to correct fragments as noted above.

6.2.3 Run-Ons

A run-on occurs when two (2) sentences are linked together without punctuation. A run-on is also sometimes referred to as a fused sentence:

The timing of the decision was remarkably poor this situation created a number of complications.

The timing of the decision was remarkably poor and this situation created a number of complications.

Run-ons may be corrected by adding appropriate punctuation, typically a semicolon or a comma, thus making a compound sentence (as discussed in Section 6.1: Sentence Types):

The timing of the decision was remarkably poor; this situation created a number of complications.

The timing of the decision was remarkably poor, and this situation created a number of complications.

Again, careful editing can be utilized to catch run-ons and other grammatical and punctuation errors.

6.3 Verb Tenses

There are three (3) verb tenses in English:

- **Past tense** denotes an action that has been completed or a state of being that is no longer in existence:
The parts were fabricated using ABS plastic.

- **Present tense** denotes an action or state of being in the present time or in continuous existence, a habitual action, or a general truth:

  The use of ABS plastic to fabricate parts is required.

- **Future tense** denotes an action or state of being which is yet to occur:

  ABS plastic will be ordered for fabrication of parts.

The two (2) verb tenses most commonly used in Lab Reports and other technical documents are past tense and present tense. The purpose of the author dictates which tense is most useful for a particular section of a document, but these tenses are typically used as described in Table 6.1: Functions of Present and Past Tense:

### Table 6.1: Functions of Present and Past Tense

<table>
<thead>
<tr>
<th>Tense</th>
<th>Typically Used To…</th>
<th>Found In…</th>
</tr>
</thead>
<tbody>
<tr>
<td>Present Tense</td>
<td>State the purpose of a report</td>
<td>Introduction</td>
</tr>
<tr>
<td></td>
<td>Outline or overview a text and its contents</td>
<td>Introduction</td>
</tr>
<tr>
<td></td>
<td>Summarize current scientific theory or arguments</td>
<td>Theory</td>
</tr>
<tr>
<td></td>
<td>Summarize data from other sources</td>
<td>Theory</td>
</tr>
<tr>
<td></td>
<td>Make generalized statements</td>
<td>Theory, Results</td>
</tr>
<tr>
<td></td>
<td>Present and evaluate results, findings, data</td>
<td>Results, Conclusion</td>
</tr>
<tr>
<td>Past Tense</td>
<td>Summarize previous work accomplished</td>
<td>Theory</td>
</tr>
<tr>
<td></td>
<td>State experimental methods</td>
<td>Procedures</td>
</tr>
<tr>
<td></td>
<td>Summarize work completed</td>
<td>Conclusions</td>
</tr>
<tr>
<td></td>
<td>Offer Recommendations</td>
<td>Conclusions</td>
</tr>
</tbody>
</table>

As illustrated in the previous table, present tense is typically reserved for Introductions, Theory, Results, and Conclusions sections of a Lab Report; past tense is typically reserved for Theory, Procedures, and Conclusions sections.
6.4 Pronouns: Use of “It,” “This,” and “These”

6.4.1 Pronouns

Pronouns substitute for nouns and function as nouns do. Consider the following example:

Because Lindsay Lohan has been charged with two DUI’s, as well as driving on a suspended driver’s license and cocaine possession, under California law she will be sentenced to serve time in jail; the only question that remains is how much time in jail she will serve.

Here, the pronoun she references Lindsay Lohan. Care must be taken that, when pronouns are used, they have a clear, unambiguous reference:

Actresses Lindy Booth and Lindsay Lohan are both actresses and redheads, but she has proven acting ability.

In this example, to whom does the pronoun she refer—Lindy Booth or Lindsay Lohan? As the reference is open to interpretation, ambiguity is the result. This situation must be avoided at all costs.

6.4.2 Ambiguous “It”

In technical writing, avoidance of ambiguity is crucial; thus, technical writing is unlike many other writing genres, such as poetry, where ambiguity is not only allowed but is encouraged. Do NOT use the pronoun it without ensuring that there is a clear reference.

It is often used as an expletive. An expletive is a word that fills the position of another word (i.e., a phatic or empty word), the most common expletives being it and these. Generally, an expletive serves as a “place holder” in that the expletive is used in place of the subject of the sentence:

It is clear that Lindsay Lohan’s film I Know Who Killed Me bombed at the box office for a number of reasons.

Here, the expletive it takes the position of the subject of the sentence in place of the real subject: Lindsay Lohan’s film I Know Who Killed Me bombed at the box office. The sentence must be revised accordingly to avoid the expletive:

Lindsay Lohan’s film I Know Who Killed Me bombed at the box office for a number of clear reasons.

The avoidance of the expletive it makes the preceding sentence more concise.
Use of expletives may be at times necessary to avoid awkwardness; thus, care must be taken when using them in technical writing: employ them only when ambiguity will be avoided. However, as a general rule, never begin a sentence with *it* unless the pronoun has a clear reference in the previous sentence or within the sentence itself:

It was found that the film *I Know Who Killed Me* contained at least 955 mistakes involving plot coherence and logical contradictions.

Here, *it* has no clear reference. Therefore, the sentence must be revived for clarity:

*I Know Who Killed Me* contained at least 955 mistakes involving plot coherence and logical contradictions.

Again, the avoidance of the expletive *it* makes the sentence more concise.

### 6.4.3 Ambiguous “This” and “These”

The pronoun *this* is often used incorrectly to refer to a condition or a number of activities rather than a specific reference, thus creating ambiguity. To avoid this situation, place a noun after the word *this*:

*In Debt We Trust* (2006) is a documentary film that investigates America’s growing debt crisis. The film discovers that credit-card companies, lobbyists, and the Bush administration have worked to deregulate the lending industry. The result has been a culture of credit-card dependency. *This* has created a potential threat to America’s economic stability.

In the previous example, what does “this” refer to: the investigation, the discovery, or the result? The reader cannot be sure. Therefore, an identifying noun must be placed after “this” to clarify the intended meaning and avoid ambiguity:

*In Debt We Trust* (2006) is a documentary film that investigates America's growing debt crisis. The film discovers that credit-card companies, lobbyists, and the Bush administration have worked to deregulate the lending industry. The result has been a culture of credit-card dependency. *This result* has created a potential threat to America’s economic stability.

A similar situation occurs with the word *these*. Therefore, a noun should always be placed after the word “these” in order to clarify the intended meaning and avoid ambiguity:

*In Debt We Trust* (2006) is a documentary film that investigates America’s growing debt crisis. The film discovers that credit-card
companies, lobbyists, and the Bush administration have worked to
deregulate the lending industry. The result has been a culture of
credit-card dependency. These factors have created in a potential
threat to America’s economic stability.

As these examples show, the use of “this/these + noun phrase” helps clarify the
author’s intended reference, prevents ambiguity, and helps the reader clearly
decipher the author’s meaning.

6.5 Modifiers: Dangling and Misplaced

6.5.1 Modifiers

Modifiers are words, phrases, or clauses that modify. Modifiers that are
adjectives modify nouns and pronouns. Modifiers that are adverbs modify verbs,
adverbs, or other adverbs:

*The Bourne Ultimatum* (2007) is a complex film whose action
sequences were carefully developed. (*Complex* is an adjective
modifying the noun *film*; *carefully* is an adverb modifying the verb
*developed.*)

The film’s producer requested a budget update that described the
film’s status because she needed to know the facts. (The adverbial
clause beginning with the word “because” modifies the noun phrase
*budget update.*)

The camera under the tree must not be touched without permission
of the director. (Again, adverbial phrases modify the noun *camera*
and the verb phrase *must not be touched.*)

The first example demonstrates how adverb are often placed before the verb they
modify in order to increase formality (i.e., *carefully developed* is perceived as
being more formal than *developed carefully* as noted in Section 7.6: Formality).

6.5.2 Dangling Modifiers

The dangling modifier is one of the most common errors in technical writing. A
dangling modifier is a modifier that typically is an introductory phrase at the
beginning of a sentence that does not clearly or logically explain the noun or
pronoun appearing after that phrase:

While rehearsing the scene, a lunch break was called by
the director.
This sentence is confusing because the implication is that “a lunch break” was rehearsing the scene. To correct a dangling modifier, the appropriate subject is added to either the main/independent clause or to the modifying clause:

While we were rehearsing the scene, a lunch break was called by the director.

While rehearsing the scene, we took a lunch break called by the director.

In the first example, the subject has been added to the modifying clause, while in the second example, the subject has been added to the main/independent clause.

6.5.3 Misplaced Modifiers

A modifier is misplaced when it modifies the wrong word or phrase, thus causing ambiguity:

While working in the prison cafeteria, Lindsay Lohan served stir-fried gerbils to the inmates on paper plates.

This sentence is confusing because it implies the inmates are standing on paper plates while being served stir-fried gerbils. A similar confusion is created in the following sentence:

I knew a gerbil with a wooden leg named Paris.

This sentence is confusing because it is unclear if Paris is the name of the gerbil or the wooden leg.

The confusion created by misplaced modifiers can be corrected by placing the modifiers as close as possible to the words they are meant to modify:

While working in the prison cafeteria, Lindsay Lohan served stir-fried gerbils on paper plates to the inmates.

I knew a gerbil named Paris with a wooden leg.

These two examples are less ambiguous because the modifiers are placed adjacent to the phrases that they are modifying.
6.6 **Colons and Semicolons**

6.6.1 **Colons**

Colons may be used in three (3) ways. First, a colon is used in time notation to separate the hour from the minutes:

8:30

Second, a colon is used in the salutation of professional correspondence:

Dear Dr. Parker:

The *comma* is used in a salutation only when the correspondence is personal or nonprofessional. Use of the colon *always* indicates the correspondence is neither personal nor nonprofessional, i.e., is professional.

Third, a colon is used to introduce a list when the introduction is stated as a complete sentence:

The SciFi Channel ran marathons of three (3) popular television shows this summer: *Star Trek: Enterprise, Stargate: SG-1*, and *Tru Calling*.

As this example shows, the introduction is a complete sentence; the introduction is followed by a colon which in turn is followed by a list of items. In this third usage, the colon indicates a close connection between the statement that precedes the colon and the list of items (which might be as short as a single item or statement) that follows it.

Also, colons always appear *outside* quotation marks:

*We all knew what he meant when he said “We must tighten the budget”: downsizing was about to commence.*

This sentence is an example of a single item list as well as an example of a colon being located outside of quotation marks.

6.6.2 **Semicolons**

A *semicolon* indicates a pause that is stronger than a comma but not as strong as a period. Semicolons have two (2) uses.

First, semicolons may be used to link two (2) independent clauses that are closely related in content:
The veracity of the report’s conclusions is unclear; they must be verified or disproved at once.

In this example, both independent clauses are focused on the topic of “the report’s conclusions” and are thus closely linked.

Second, a semicolon may be used to separate items in a list where at least one (1) element in the list has an internal comma:

The following cities and states experienced drought conditions in the last year: Virgin, Utah; Truth or Consequences, New Mexico; and Intercourse, Pennsylvania.

Furthermore, semicolons always appear outside quotation marks:

The doctor said, “You must take your medication as directed”; the patient replied “I will.”

As this example indicates, the two (2) independent clauses are closely related to each other and are thus joined by a semi-colon which is placed outside of the quotation marks.

6.7 Hyphens

Hyphen usage can be mildly confusing, especially as the conventions for hyphen usage differ from discipline to discipline. Hyphen usage for unit adjectives (e.g., wind tunnel test plan) can be particularly confounding. (See Section 6.7.5: Exceptions for Hyphen Usage.)

There are times when hyphens MUST be used to reduce ambiguity; nonetheless, the COE, Prescott campus, has adopted conventions that require minimal hyphen usage. This convention is aligned with the standards articulated by both AIAA and the IEEE. The following section explains hyphen usage as adopted by the COE, Prescott campus.

6.7.1 Hyphen Usage

Hyphens have four (4) uses. First, they are used to indicate end-of-line word division. Second, they are used to link certain compound terms. Third, they are used to link unit adjectives. Fourth, they are used to join whole numbers and fractions. Each of these uses is discussed in this section.

6.7.2 Word Division

Hyphens are used to indicate end-of-line word division in printed materials. This function is straightforward, and any dictionary will indicate where the hyphen
must be used to divide a word at the end of a line of printed text. However, common sense must be used. A dictionary may indicate that *analogy* is divided *anal-o-gy*, but if it is divided in the document as *anal-ogy*, readers may become confused, to say the least.

### 6.7.3 Compound Term

A **compound term** expresses a single idea in more than one (1) word. For clarity and coherence, these words are then linked together with hyphens:

- cross-contamination
- time-sharing
- mother-in-law

Note that some compound words in English are not hyphenated but are instead spelled as one (1) word (e.g., *surfboard* as opposed to *surf-board* or *online* as opposed to *on-line*). To determine whether a compound word is hyphenated or not, the strategic use of a dictionary is required.

### 6.7.4 Unit Adjectives

When two (2) or more words modify a third, the modifiers must—with certain exceptions—be linked with hyphens for the sake of clarity:

Willow pronounced Gunther P. Fadoogan's treatise on magic to be a third-rate book.

Here, *third* and *rate* function as a unit in modifying *book*, and, therefore, must be hyphenated. The hyphen functions to clarify the meaning of the phrase: the meaning is not that it is Fadoogan’s “third book” (it could be his first), nor is it a “rate book.” To clarify this situation further, consider the following phrase:

imported gerbil dealer

Is the dealer dealing in imported gerbils, or is the gerbil dealer himself/herself imported? Only a hyphen can clarify this question.

If the intended meaning is that the dealer trades in imported gerbils, then this meaning would be indicated as follows:

imported-gerbil dealer

If the intended meaning is that the gerbil dealer himself/herself is imported, then this meaning would be indicated as follows:
imported gerbil-dealer

Following this line of thought, consider the following phrase:

three foot long supports

As written, this phrase is ambiguous, as the phrase can be interpreted in two (2) ways. Does the phrase indicate an unidentified number of supports that are each three (3) feet long? Or does the phrase indicate three (3) supports that are one (1) foot long each? If the first meaning is intended, then hyphens would be placed as follows:

three-foot-long supports

If the second meaning is intended, then a hyphen would be used as follows:

three foot-long supports

Hyphens are also used in unit adjectives in cases where numbers are used as one of the adjectives, i.e., hyphens are used to join a value and a unit of measure if a noun phrase follows:

10-in. diameter

40-foot-long cable

Four (4) exceptions to these primary rules of hyphen usage can be found in the following section.

6.7.5 Exceptions for Hyphen Usage

There are four (4) notable exceptions to the use of hyphens with unit adjectives. First, adjectives have three (3) forms: positive, comparative, and superlative. While hyphens are used with the positive form, they are not with either the comparative form or the superlative form. For example, consider the following:

Positive: high

Comparative: higher

Superlative: highest

Then consider the following:
In all three (3) cases, the first two (2) adjectives act as unit adjectives, but only “high-ranking” is hyphenated. Why? Because in the case of the comparative and superlative forms, -er/-est indicate that they modify “official,” making a hyphen connecting them redundant.

Second, when the first adjective in a unit adjective ends in -ly, the unit adjective is not hyphenated:

   early warning system

Why? Again, because the -ly indicates it modifies “warning.” Thus, a connecting hyphen would be redundant.

Third, hyphens cannot be used to connect proper nouns when the proper nouns as a unit modify a third word:

   Neither Buffy nor Willow attended the Star Trek convention when it was held in Sunnydale.

Here, although Star Trek modifies convention, the words are not hyphenated, as they are proper nouns.

Fourth, hyphens are optional in commonly used phrases within a discipline where no ambiguity is possible, such as in the following examples:

   system control design
   distributed parameter system
   finite element analysis
   flight test article
   structural test plan
   wind tunnel test
   wind tunnel model
   wind tunnel laboratory
Knowledge of disciplinary values and conventions is necessary to determine whether or not a phrase fits this disciplinary-specific convention.

### 6.7.6 Suspended Hyphens

A suspended unit adjective occurs when a noun has two (2) or more unit modifiers linking a basic element:

long- and short-term goals

This example of a suspended hyphen could be written as follows:

long-term and short-term goals

but the repetition of the word “term” is avoided by use of the suspended hyphen and thus the entire phrase is more concise.
7.0 ACADEMIC AND TECHNICAL LANGUAGE

7.1 Reportive Verbs

A wide range of verbs is available to academic writers. **Reportive verbs** are used to present summaries and add formality to prose; they may take the place of the more informal *says* or *believes*:

While Dawdle *claims* that the speed limit on Willow Creek Road should remain 35 mph, Racer *argues* that it should be increased to 45 mph.

Some reportive verbs are neutral, but many evaluate the material being summarized or reported. Compare the following:

- In *The Baroque Cycle*, Neal Stephenson *states* that Sir Isaac Newton suffered from mercury poisoning.
- In *The Baroque Cycle*, Neal Stephenson *reveals* that Sir Isaac Newton suffered from mercury poisoning.
- In *The Baroque Cycle*, Neal Stephenson *alleges* that Sir Isaac Newton suffered from mercury poisoning.

In the first sentence, *states* is a neutral verb; the writer objectively presents Stephenson’s claim without any evaluation. In the second sentence, *reveals* is not neutral; rather it presents Stephenson’s claim as factual. Moreover, it implies that the information had been secreted away until he bravely uncovered it. In the third sentence, *alleges* is also not neutral; it implies that Stephenson has very little evidence to back his claim.

Reportive verbs are usually found in the **present tense**. (See Section 6.3: Verb Tenses.) In this case, both the source and the information summarized are equally important, as shown in the following examples:

- Gaijin (2003) *suggests* that most Americans cannot find Japan on a political map of the world.
- Yokel (2003) *maintains* that more Americans can name the judges of *American Idol* than can name the current Speaker of the House of Representatives.
- Poon (2008) *claims* that the primary cause of sloth is extreme laziness.
Garth (2009) *presents* findings that are generally flawed due to insufficient data.

Beavis (2002) *offers* a solution that involves the unlikely combination of a bottle of cola, a dozen goldfish, and a house full of fraternity brothers.

Table 7.1: Some Useful Reportive Verbs lists a minute sample of the many reportive verbs in technical and academic English:

**Table 7.1: Some Useful Reportive Verbs**

<table>
<thead>
<tr>
<th>Paired with <em>that</em></th>
<th>Not Paired with <em>that</em></th>
</tr>
</thead>
<tbody>
<tr>
<td>Affirms</td>
<td>Addresses</td>
</tr>
<tr>
<td>Alleges</td>
<td>Cautions</td>
</tr>
<tr>
<td>Argues</td>
<td>Delineates</td>
</tr>
<tr>
<td>Ascertains</td>
<td>Describes</td>
</tr>
<tr>
<td>Asserts</td>
<td>Discusses</td>
</tr>
<tr>
<td>Assumes</td>
<td>Enumerates</td>
</tr>
<tr>
<td>Believes</td>
<td>Establishes</td>
</tr>
<tr>
<td>Claims</td>
<td>Examines</td>
</tr>
<tr>
<td>Contends</td>
<td>Gives</td>
</tr>
<tr>
<td>Dictates</td>
<td>Illuminates</td>
</tr>
<tr>
<td>Explains</td>
<td>Notes</td>
</tr>
<tr>
<td>Finds</td>
<td>Offers</td>
</tr>
<tr>
<td>Hypothesizes</td>
<td>Presents</td>
</tr>
<tr>
<td>Implies</td>
<td>Produces</td>
</tr>
<tr>
<td>Indicates</td>
<td>Refutes</td>
</tr>
<tr>
<td>Maintains</td>
<td>Scrutinizes</td>
</tr>
<tr>
<td>Notices</td>
<td>Summarizes</td>
</tr>
<tr>
<td>Presumes</td>
<td>Synthesizes</td>
</tr>
<tr>
<td>Proclaims</td>
<td></td>
</tr>
<tr>
<td>Proposes</td>
<td></td>
</tr>
<tr>
<td>Reveals</td>
<td></td>
</tr>
<tr>
<td>Says</td>
<td></td>
</tr>
<tr>
<td>States</td>
<td></td>
</tr>
<tr>
<td>Suggests</td>
<td></td>
</tr>
<tr>
<td>Theorizes</td>
<td></td>
</tr>
</tbody>
</table>

As Table 7.1 Some Useful Reportive Verbs indicates, many reportive verbs are paired with the word *that*, but not all. Also note that the word *says* is **NOT** generally considered to be an academically appropriate reportive verb **UNLESS** a spoken conversation (e.g., an interview or a radio broadcast) is being reported.
7.2 Latinate vs. Germanic Verbs

Many English verbs are descended from Western Germanic languages. These Germanic verbs typically require a preposition of some kind. They are thus two (2) or three (3) words in length and are sometimes called phrasal verbs:

She found out that he had lied: he was not a millionaire, but a construction worker in disguise.

They talked about this and that over several chocolate-covered pretzels.

The researchers looked at the flaws in the system and then set up an alternative.

This medication will not get rid of fleas and ticks, but will cut down on the number of bites experienced by the patient.

These Germanic verbs are commonly used in casual speech, but are often too informal for academic texts such as Lab Reports. They can be replaced by more formal verbs, ones which descend from Latin or Romance languages. These Latinate verbs are single words and require no prepositions:

She discovered that he had lied: he was not a millionaire, but a construction worker in disguise.

They discussed this and that over several chocolate-covered pretzels.

The researchers examined the flaws in the system and then created an alternative.

This medication will not eliminate fleas and ticks, but will reduce the number of bites experienced by the patient.

Notice that both the Germanic and the Latinate verbs in these examples are virtually identical in meaning. However, the Latinate verbs are more formal and therefore more desirable in a technical report. Replacing Germanic verbs with Latinate verbs, then, is one of the easiest ways to improve a report’s academic style (and its chances of success).

7.3 Evaluative Adjectives

Adjectives have two (2) primary functions in English: they may modify nouns or act as complements to a verb:
Glenn Beck seems like such a nice man.

What a shame his shows are controversial.

In the first example, nice is an evaluative adjective that modifies man. In the second example, controversial is an evaluative adjective that complements the verb are.

**Evaluative adjectives** typically indicate a positive or negative evaluation of the subject at hand; these evaluative adjectives are particularly useful for marking weaknesses in research findings:

These unsatisfactory results call for further research.

The results are inconclusive.

In these examples, unsatisfactory and inconclusive are negative evaluations of the research being reported. In some cases, however, evaluative adjectives may be context-dependent. That is, the context determines whether these adjectives indicate positive or negative evaluations:

A complex experiment (which may be undesirable)

A complex mechanism (which may be desirable)

In these examples, complex may be either positive or negative, depending upon the author’s and the reader’s values, needs, and understandings of the problem (i.e., the experiment or the mechanism).

Two (2) of the most familiar evaluative adjectives are the words good and bad. While there is nothing wrong with these words in daily speech, they are too vague and informal for use in technical English. Writers should instead consider using some of the alternative adjectives listed in Table 7.2: Some Useful Evaluative Adjectives which appears on the following page. Note how substituting alternatives for good and bad radically improves both the specificity and the formality of the following sentences:

The results were good. [informal]

The results were satisfactory. [formal]

His argument was bad. [informal]

His argument was biased. [formal]
Care must be taken, however, not to misuse (or abuse) evaluative adjectives. Using an evaluative adjective that is too positive or too strongly negative damages the writer’s credibility. The writer must therefore balance objectivity, fairness, and specificity when choosing the appropriate evaluative adjective.

Representative evaluative adjectives are listed here in Table 7.2: Some Useful Evaluative Adjectives:

Table 7.2: Some Useful Evaluative Adjectives

<table>
<thead>
<tr>
<th>Positive</th>
<th>Context-dependent</th>
<th>Negative</th>
</tr>
</thead>
<tbody>
<tr>
<td>Accurate</td>
<td>Adequate</td>
<td>Biased</td>
</tr>
<tr>
<td>Brief</td>
<td>Complex</td>
<td>Deficient</td>
</tr>
<tr>
<td>Compelling</td>
<td>Controversial</td>
<td>Erroneous</td>
</tr>
<tr>
<td>Concise</td>
<td>Expected</td>
<td>Incoherent</td>
</tr>
<tr>
<td>Convincing</td>
<td>Exploratory</td>
<td>Incomplete</td>
</tr>
<tr>
<td>Dynamic</td>
<td>Non-standard</td>
<td>Inconclusive</td>
</tr>
<tr>
<td>Effective</td>
<td>Preliminary</td>
<td>Incongruous</td>
</tr>
<tr>
<td>Efficient</td>
<td>Restricted</td>
<td>Limited</td>
</tr>
<tr>
<td>Groundbreaking</td>
<td>Standard</td>
<td>Long-neglected</td>
</tr>
<tr>
<td>Original</td>
<td>Unexpected</td>
<td>Meager</td>
</tr>
<tr>
<td>Reasonable</td>
<td>Unique</td>
<td>Misguided</td>
</tr>
<tr>
<td>Rich</td>
<td></td>
<td>Misleading</td>
</tr>
<tr>
<td>Rigorous</td>
<td></td>
<td>Obscure</td>
</tr>
<tr>
<td>Satisfactory</td>
<td></td>
<td>Poor</td>
</tr>
<tr>
<td>Scholarly</td>
<td></td>
<td>Problematic</td>
</tr>
<tr>
<td>Significant</td>
<td></td>
<td>Questionable</td>
</tr>
<tr>
<td>Solid</td>
<td></td>
<td>Unconvincing</td>
</tr>
<tr>
<td>Superior</td>
<td></td>
<td>Unfounded</td>
</tr>
<tr>
<td>Thorough</td>
<td></td>
<td>Unsatisfactory</td>
</tr>
</tbody>
</table>

As Table 7.2: Some Useful Evaluative Adjectives indicates, there are a wide variety of adjectives which are appropriate for use in Lab Reports and other formal technical documents. The key is to choose an adjective which is *descriptive, specific, and formal*.

7.4 Qualification

Academic writers often need to **qualify** the statements they make; that is, they need to indicate just how certain (or uncertain) they are of the claims they make. There are four (4) types of qualification (also known as *hedging*):
Writers may use a single type of qualification, or they may choose to combine several different types together in an attempt to defend their statement. Each of these four (4) types of qualification is described in this section.

### 7.4.1 Certainty

The first type of qualification is the use of **certainty**. While certainty or confidence levels may be expressed mathematically in technical documents, they should also be marked verbally. The correct use of terms that mark certainty prevents the writer from making absolute statements or overstatements by indicating just how much confidence the writer has in the statement. Certainty can be expressed through a modal auxiliary as in the following examples:

- Blomstrom claims that raising the speed limit *will* result in more traffic accidents.
- Blomstrom claims that raising the speed limit *may* result in more traffic accidents.
- Blomstrom claims that raising the speed limit *might/could* result in more traffic accidents.

Changing the modal auxiliary from *will* to *may* indicates a lowered confidence in the results of raising the speed limit. Increased or decreased certainty may also be expressed through adjectives or adverbs as in the following list of examples:

- That *The King’s Speech* will garner more Oscars this year is *certain*.
- That *The King’s Speech* will garner more Oscars this year is *almost certain*.
- That *The King’s Speech* will garner more Oscars this year is *a strong possibility*.
- That *The King’s Speech* will garner more Oscars this year is *very likely/probable*.
That *The King’s Speech* will garner more Oscars this year is *likely/probable*.

That *The King’s Speech* will garner more Oscars this year is *a definite possibility*.

That *The King’s Speech* will garner more Oscars this year is *a good possibility*.

That *The King’s Speech* will garner more Oscars this year is *possible*.

That *The King’s Speech* will garner more Oscars this year is *unlikely*.

That *The King’s Speech* will garner more Oscars this year is *a slight possibility*.

That *The King’s Speech* will garner more Oscars this year is *highly unlikely/improbable*.

That *The King’s Speech* will garner more Oscars this year is *a remote possibility*.

As this list progresses, the strength of the claim weakens; the writer is at first highly confident, but ends up highly doubtful that their prediction will indeed occur. Marking the strength of one’s claim by signaling the correct level of certainty is critical for accurate technical writing.

### 7.4.2 Distance

The second type of qualification is **distance**. Writers must distance themselves from potentially incorrect claims or overly strong statements. Again, modal auxiliaries or auxiliary verbs may help to create distance:

Consumers *have* confidence that the stock market will recover.

Consumers *seem to have/appear to have* confidence that the stock market will recover.

By correctly using *seem* or *appear* in the preceding example, the writer cannot be held at fault if consumers were found to lack confidence in the stock market—after all, they *appeared* to be confident, but appearances can deceive even the most observant financial analyst.
A second way for writers to create distance is to preface their claim with the source of the claim—*author-prominent internal citation*, as noted in Section 9.2.1: Author-prominent Citation. This strategy allows any mistakes to be laid at the feet of the data, or the source, or other experts, rather than the writer:

According to this committee’s findings, ....

Based upon his recommendations, ....

In Johnson’s (2007) view, ....

These phrases, and others like them, not only allow the writer to distance themselves from the claim but also provides credit where credit is due, i.e., allows for proper citation of the source material.

### 7.4.3 Generalization

The third type of qualification is generalization. By using one (1) of three (3) strategies, a statement that would otherwise be dismissed as an unsupported or absolute claim becomes more defensible. First, the verb *tend* may be used:

Modern science fiction novels *focus* on the human condition rather than on the future of humankind in space.

Modern science fiction novels *tend to focus* on the human condition rather than on the future of humankind in space.

Second, qualifiers such as *a few, some, many, most*, and *the majority* may be used:

Today’s sports heroes use illegal steroids.

*Some of* today’s sports heroes use illegal steroids.

*Many of* today’s sports heroes use illegal steroids.

*The majority of* today’s sports heroes use illegal steroids.

Third, exceptions to the generalization may be added:

U.S. airlines will incur heavy financial losses over the next quarter.

*Except for regional commuters*, U.S. airlines will incur heavy financial losses over the next quarter.
With the exception of regional commuters, U.S. airlines will incur heavy financial losses over the next quarter.

Apart from regional commuters, U.S. airlines will incur heavy financial losses over the next quarter.

The use of any of these three (3) strategies prevents the writer from making an absolute statement, thus making the statement more accurate and more acceptable to technical readers.

7.4.4 Verb Strength

The fourth type of qualification is the use of **weaker verbs**. Many strong verbs (e.g., *caused*) have weaker counterparts (e.g., *contributed*). The correct use of weaker verbs both increases the accuracy of the statement and prevents the overstatement of a claim:

The consumption of too much chocolate *causes* acne.

The consumption of too much chocolate *contributes to* acne.

The following informal list pairs commonly used strong verbs with their weaker (and highly useful) counterparts:

- Creates/suggests a foundation for…
- Establishes/indicates a link between…
- Fails/neglects to take into consideration…
- Proves/supports the theory…
- Requires/benefits from…
- Shows/suggests that the results…
- Undermines/questions the validity of…
- Validates/supports the hypothesis…

As this list suggests, there are a variety of weaker verbs that can be used to more accurately express technical concepts. Strong verbs such as *cause* and *prove* should only be used with extreme care and in specific circumstances (e.g., one can *prove* a mathematical theorem but it is much more difficult to *prove* whether a design will function adequately without significant levels of analysis and testing).
7.5 Usage

Usage relates to the choices a writer makes regarding the words selected. Understanding the meanings of the words used and using the correct word for the correct task is crucial both for clarity of meaning and for the writer’s credibility. Misusing words will undermine both. What follows is a list of pairs of words that are often misused accompanied by descriptions of their proper uses as well as clarifying examples:

Affect/Effect: Affect is a verb meaning “to influence.” Effect can be used as both a noun and a verb. As a verb it means “to bring about change.” As a noun it means “result.”

- The results of the research affected the way the computer-development team preceded.
- The effect of the decision was long term.
- The use of data processing software effected the results.

Alternatively/Alternately: Alternatively is an adverb that denotes a second possibility. Alternately should only be used in reference to something that alternates or changes periodically.

- At this stage, the blue dye is used to mark the material; alternatively, the red dye may be used.
- The president and vice-president alternately vacationed at Camp David.

Amount/Number: Amount refers to items that cannot be counted. Number refers to items that can be counted.

- In the last year, the amount of computer paper consumed by the department was up 10 percent from the previous year.
- In the last year, the number of boxes of computer paper the department has ordered has significantly increased from the previous year.

And/Or: This expression is awkward and can lead to confusion and ambiguity. Instead, replace the and/or structure by writing “A, B, or both.”

- The committee decided that the person selected for the position would need work experience, appropriate academic credentials, or both.
Assure/Ensure/Insure: Assure means “to promise,” and may only be used in reference to people. Ensure means “to make certain.” Insure is often used as a synonym for ensure; however, reserve insure only for the context of insurance.

Prof. Kurt Meyer assured the review board that the budget figures were correct.

To ensure that the mistake did not happen again, Hortence made extensive notes on what went wrong.

To ensure against any future financial loss, Sarah Michelle insured her home against fire and theft.

Because/Since: Because establishes a cause/effect relationship, whereas since should be reserved to relate to time.

Sarah Michelle decided to take the job in Blythe because she wanted to live in the Southwest.

Since her last performance review, Sarah Michelle has received both a promotion and a raise.

Center On/Revolve Around: To use these phrases correctly, think about their literal meanings: it is illogical to say “the committee’s position centered around the budget,” as nothing can center around something. However, a committee’s position could “revolve around” the budget.

The discussion centered on the proposal’s approval.

Several recent projects revolved around the implementation of the system.

Complement/Compliment: A complement is either of two parts that, when combined, complete or perfect each other. A compliment is an expression of praise or admiration.

When summed with its complement, the angle measured 90 deg.

When given such a compliment, she blushed red.
**Continuous/Continual**: *Continuous* means *uninterrupted*, whereas *continual* means *intermittent*.

The rain was *continuous* from 10 a.m. to 2 p.m.

*We continually* checked the weather report to obtain the most-current update.

**Criteria/Criterion**: The word *criteria* is plural, while the word *criterion* is singular. Both indicate a standard or rule for selection.

The most important *criterion* for job success is communication skills.

Many *criteria* must be satisfied to obtain success in one’s chosen profession.

**Data/Datum**: The word *data* is plural, while the word *datum* is singular.

The *data* reflect the trend predicted by the theoretical analysis.

This particular *datum* indicates that the theory was correct.

**Discreet/Discrete**: To be *discreet* is to be prudent, modest, or restrained in one’s behavior. To be *discrete* is to consist of a separate, unconnected part.

He was *discreet* is showing his affections for his colleague.

Only *discrete* values may be used in this statistical distribution.

**Each other/One another**: *Each other* indicates only two (2) people, while *one another* indicates three (3) or more people.

Michael Wittman and Arthur Phelps worked closely with *each other* on the proposal.

All seven committee members debated with *one another* over the proposed budget.

**e.g./i.e.,**: The abbreviation *e.g.*, means “for example”; the abbreviation *i.e.*, means “that is” or “in other words.” These abbreviations should be very carefully punctuated, as shown in the following examples:
Sarah Michelle attended conferences in several numerous cities, e.g., New York, Dallas, Los Angeles, and Phoenix.

Several options were discussed and option A was selected, i.e., that a formal request for the hiring of additional personnel be made.

Fewer/Less: The word fewer indicates items that can be counted; the word less indicates quantities that cannot be counted.

Fewer benefits were offered employees this year than last.

Less water is needed to irrigate the land than we anticipated.

Good/Well: Good is used as an adjective; well is used as an adverb.

It was a good presentation.

The presentation was well done.

Imply/Infer: To imply is to indicate by suggestion, association, or indirect statement rather than through direct statement. To infer is to draw a conclusion based upon stated facts, data, or premises.

Are you implying that I have been using my I-phone to cheat?

From the lipstick on his collar and smell of perfume on his clothes, my sister inferred that her boyfriend had been cheating.

Inset/Insert: Inset is a noun and refers to a graphic within a graphic. Insert may also be a noun but refers to a physical item that is inserted into a cavity.

The results of the post-hoc analysis are presented in the inset.

The 0.75-in. rod was inserted into the hole.

Oral/Verbal: Oral refers to language that is spoken, while verbal refers to either written or spoken language but does not include nonverbal communication, such as body language. Do not use verbal as a substitute for oral.

The oral [not verbal] agreement we made with the firm last week was followed by the written [not verbal] contact we received today.
Principal/Principle: Principal refers to someone or something that is highest in rank, achievement, worth, or degree (including the principal of a high school). Principle refers to a basic truth, rule, law, assumption, or standard.

The principal investigator argued that the scientific principle in question could be best answered using the research methodology stated in their research grant proposal.

Problem/Issue: A problem is a question that has a scientific answer. Problems are addressed through controlled research and data collection. An issue is a point in a larger controversy or debate. Issues are argued, sometimes in court. Problems are to be solved; issues are to be debated.

A null hypothesis was articulated for the problem.

The captain of the debate team summarized the issue at hand.

Than/Then: Than is a conjunction and is used to compare things; then is an adverb and is used to mark chronological order or a logical consequence.

This manual is much better than my old manual.

First I sold back my old textbooks then I bought new ones.

Whereas/While: Whereas is used to indicated contradictions, comparisons, or opposition; while is most typically used to indicate simultaneous events.

My history teacher grades on a curve whereas my chemistry teacher does not.

My history teacher is hosting a formal debate while my chemistry teacher is proctoring an exam.

Which/That: Which is used to introduce nonrestrictive clauses. A nonrestrictive clause is not essential to the meaning of the sentence and requires a comma before the which. That is used to introduce restrictive clauses. A restrictive clause is essential to the meaning of the sentence and does not use a comma before that.

The engineering program, which is currently being expanded, offers excellent career options.

The engineering program that is offered at ERAU Prescott offers excellent career options.

Who/Whom: Who can only be used as the subject of a clause; whom can only be used as a direct object or other non-subject noun form of a sentence.
The person who [subject of the verb called] called yesterday did not leave a message.

The person whom [direct object of the verb called] I called yesterday did not return my call today.

This list is by no means comprehensive or inclusive but is meant to serve as a guide for further research.

7.6 Formality

A formal writing style or formal tone is expected in academic, professional, and technical writing. Avoidance of contractions, the selection of appropriate person and voice, and attention to proper word choice can help the writer avoid an informal or improper tone. The following checklist can be used to increase the formal tone of most texts. (Additional guidance is provided in Section 2.0: Revision and Editing Checklists.)

✓ Do NOT use contractions such as don’t, can’t, we’ll, you’ll, she’d, haven’t, I’ll; spell words out completely:

NOT: The figures didn’t match the expected results.

BUT: The figures did not match the expected results.

NOT: They’ll have to provide the specifications for the electrical systems soon or they won’t be able to start the project on time.

BUT: They will have to provide the specifications for the electrical systems soon or they will not be able to start the project on time.

✓ Avoid first person when possible; use passive voice instead as discussed in Section 5.3: Person and Direct Address:

NOT: I gathered, collocated and statistically analyzed the results.

BUT: The results were gathered, collated, and statistically analyzed.

✓ Avoid direct address when possible; use third person or passive voice instead as discussed in Section 5.3: Person and Direct Address:
NOT: This paper recommends that *the reader undertake* similar experiments.

BUT: This paper recommends that *similar experiments be undertaken by other members of the scientific community.*

✓ Do **NOT** use *says* excessively; use a variety of **reportive verbs** such as *claims, states, argues*; a useful list of commonly used reportive verbs is provided in **Section 7.1: Reportive Verbs**:

NOT: Lanning (2007) *says that* that in recent trials the newly-developed anti-plagiarism software correctly identified 95% of offenders.

BUT: Lanning (2007) *claims that* in recent trials the newly-developed anti-plagiarism software correctly identified 95% of offenders.

✓ Do **NOT** use two-word **Germanic** verbs such as *point out*; use one-word **Latinate** verbs instead such as *indicate* as directed in **Section 7.2: Latinate vs. Germanic Verbs**:

NOT: A recent study by Gally (2007) *points out* that students who work on proto-types as early as their sophomore year perform better in their senior design courses.

BUT: A recent study by Gally (2007) *indicates* that students who work on proto-types as early as their sophomore year perform better in their senior design courses.

✓ Do **NOT** use *good or bad*; use richer, more specific **evaluative adjectives** instead such as *limited, sufficient, critical*; **Section 7.3: Evaluative Adjectives** contains a list of some useful evaluative adjectives:

NOT: Although this study had a *bad* sample size, the results are *good* and support the hypothesis.

BUT: Although this study had a *limited* sample size, the results are *favorable* and support the hypothesis.

✓ Place adverbs before the verb whenever possible:

NOT: The studies were *controlled carefully*.

BUT: The studies were *carefully controlled*. 
 ✓ Place numerical values in parentheses after their spelled-out forms:

   NOT: In the penultimate stage, the six components were assembled using ¾-in. diameter dowels and wood glue.

   BUT: In the penultimate stage, the six (6) components were assembled using ¾-in. diameter dowels and wood glue.

 ✓ Place acronyms in parentheses after their spelled-out forms:

   NOT: JPL (Jet Propulsion Laboratories) is offering a grant to fund undergraduate student research in several disciplines, including chemistry, physics, and mathematics.

   BUT: Jet Propulsion Laboratories (JPL) is offering a grant to fund undergraduate student research in several disciplines, including chemistry, physics, and mathematics.

 ✓ Replace informal conjunctions such as also with more formal conjunctions such as moreover, furthermore, additionally:

   NOT: The wind tunnel test results were compared to theoretical predictions. Also, the results were used to refine the design of the canard.

   BUT: The wind tunnel test results were compared to theoretical predictions. Furthermore, the results were used to refine the design of the canard.
8.0 GENERAL GUIDELINES FOR GRAPHICS AND EQUATIONS

8.1 Types of Graphics

There are only two (2) types of graphics: tables and figures. **Tables** are either formal or informal. **Informal tables** typically are two (2) columns of three (3) or more rows; they are not labeled or numbered but must still be introduced as noted in the following example:

The following design tasks were completed by members of Swift Aerospace (2010):

<table>
<thead>
<tr>
<th>Design Review</th>
<th>Chris Miller</th>
</tr>
</thead>
<tbody>
<tr>
<td>Loads Analysis</td>
<td>David Skidmore</td>
</tr>
<tr>
<td>Materials Analysis</td>
<td>Colin Anderson</td>
</tr>
<tr>
<td>Component Definition</td>
<td>Scott Sobieralski</td>
</tr>
<tr>
<td>Test Procedures &amp; Data</td>
<td>Ramon Perez</td>
</tr>
<tr>
<td>Wind Tunnel Results</td>
<td>Thomas Nix</td>
</tr>
<tr>
<td>Recommendations</td>
<td>Ben Wilking</td>
</tr>
</tbody>
</table>

These tasks reflect work completed in the first half of AE 421: Aircraft Detail Design as reported in the Mid-semester Briefing (Swift Aerospace, 2010).

As this example shows, the tabulated information is not placed in a grid; instead, the information is formatted so as to provide a clear visual indication of each column and row (i.e., the columns are tabbed in and vertically aligned and the rows are double spaced for readability). Moreover, there is no caption preceding the informal table.

In contrast, **formal tables** are presented in a grid and are labeled with a numbered caption, as discussed in the next section. **Figures** are also labeled with a numbered caption, and include photos, charts, graphs, and any other image that is not defined as a formal table. **Figure 8.1: Types of Graphics: Tables and Figures** visually categorizes the various types of graphics found in academic, professional, and technical writing:
Figure 8.1: Types of Graphics: Tables and Figures

As the preceding figure notes, all tables and figures are types of graphics, but there are many more types of figures than there are types of tables.
8.2 Avoidance of Data Dumping

All types of graphics, whether tables or figures, must be carefully introduced and commented upon in the prose of a report. Never engage in “data dumping” (i.e., placing a graphic into the text without introduction or data commentary); refer to the graphic first, and comment upon it immediately afterwards. There are five (5) steps to avoid data dumping:

1. **Introduce** the graphic,
2. **Place** it,
3. **Label** it,
4. **Caption** it, and
5. **Comment** upon it.

The following discussion more thoroughly examines the proper introduction, placement, labeling, captioning, and commenting of tables and figures.

8.2.1 Introduction of Graphics

Introduce every graphic with a *complete sentence*. End the introductory sentence with a *colon* regardless of whether the graphic follows on the same page as the introductory sentence or on the top of the next page:

*Table 3* outlines the budget for Jan.-Mar. 2003:

*Figure 2.1: Temperature vs. Number of Bounces* illustrates the expected trend:

It is not necessary to inform the reader of the specific location of the graphic if it appears on the next page, especially if one is submitting the report for publication. The publisher has the prerogative (not the writer) to decide where to place the graphic in the final printing, and the writer will not know where the graphic will eventually be placed in relationship to the introductory prose.

On the other hand, if the graphic does not appear on the following page but is instead in an appendix or elsewhere in the document, then it is necessary to use the introductory sentence to inform the reader of the graphic’s specific location:

As previously noted, the deployers are depicted in *Figure 4.4: Structure Subsystem and Deployers* in Section 4.1.3: Deployer Platform Analysis.
This example indicates that the figure does not immediately follow this introductory sentence, and, in fact, that the figure has already been shown in a previous section of the document; the sentence then refers the reader to the specific figure and the specific section. This strategy, however, is rarely used as graphics are almost always placed immediately after they are introduced, as noted in the following section.

8.2.2 Placement of Graphics

Place a graphic as close as possible to its discussion in the text. The most desirable placement is immediately after the introductory sentence. This placement avoids confusing the reader or forcing the reader to flip pages in order to locate the graphic, which is disruptive to the reading process.

Place graphics **horizontally** in the text if possible. If horizontal placement is not possible, place the graphic vertically in the text with the top placed along the inside of the page. **Vertical** graphics must take up the full page, not a portion of it.

*Center* graphics horizontally on the page, equidistant from both the left and right margins. **Scale** graphics sufficiently large so that details are clearly visible but sufficiently small so that the focus is crisp and sharp (i.e., do not include fuzzy photos in technical documents).

Use adequate white space within and around a graphic to ensure an aesthetic balance and readability. Too much white space creates the effect that the graphic is “floating”; too little creates an effect of claustrophobia.

8.2.3 Labeling of Graphics

Clearly label all graphics. For formal tables, clearly label all **column headings** including the **units of measure**. Units of measure (e.g., ft, nm, kts, ft/min) belong in the headings if possible rather than being stated and re-stated, *ad nauseum*, throughout the table. Alternatively, they may be placed in the pertinent cells of the left-most column, again to allow for improved concision and readability.

Moreover, format a table’s column headings in **bold font** so that they stand out from the rest of the entries in the table, as shown in the headings of the sample table in Figure 8.2: Sample Table:
Table 2.1: Predicted Performance Characteristics of the VSR-1

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Requirements</th>
<th>Predicted Values</th>
<th>Predicted to Meet or Exceed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Take-off Distance (ft)</td>
<td>3,000</td>
<td>324</td>
<td>Yes</td>
</tr>
<tr>
<td>Landing Distance (ft)</td>
<td>3,000</td>
<td>662</td>
<td>Yes</td>
</tr>
<tr>
<td>$V_{\text{max}}$ S/L (kts)</td>
<td>100</td>
<td>124</td>
<td>Yes</td>
</tr>
<tr>
<td>$V_{\text{min}}$ S/L (kts)</td>
<td>30</td>
<td>27.3</td>
<td>Yes</td>
</tr>
<tr>
<td>Endurance (hr)</td>
<td>8</td>
<td>8</td>
<td>Yes</td>
</tr>
<tr>
<td>Ceiling (ft)</td>
<td>30,000</td>
<td>32,000</td>
<td>Yes</td>
</tr>
<tr>
<td>ROC&lt;sub&gt;avg&lt;/sub&gt; (ft/min)</td>
<td>≥ 300</td>
<td>1,280</td>
<td>Yes</td>
</tr>
<tr>
<td>Sea Level Maneuver (g)</td>
<td>3</td>
<td>3</td>
<td>Yes</td>
</tr>
<tr>
<td>Max T-O Weight (lb)</td>
<td>-</td>
<td>404</td>
<td>-</td>
</tr>
</tbody>
</table>

Figure 8.2: Sample Table  
(Source: Adapted from Aero-Endurance, 2009)

In the preceding example, each column has a clear, descriptive heading, and column and row headings are in bold font. Moreover, the units of measure are placed in the cells of the left-most column to avoid the clutter that would have been created if the units were repeated over and over in every cell of the table.

For graphs and charts, clearly label all axes. Additionally, clearly state the units of measure on the graphic as shown in Figure 8.3: Sample Figure:

Figure 3.1: Preference by Gender: Chocolate vs. Vanilla

Figure 8.3: Sample Figure
As Figure 8.2: Sample Table and Figure 8.3: Sample Figure show, the units of measure are clearly indicated on each graphic; in these specific examples, the units of measure are located in the left column of the table and along the vertical axis of the figure.

A figure which has *multiple pieces of overlapping information* (e.g., multiple lines or bars on a graph) should have different colors, dashes, or textures assigned to each piece of information (e.g., blue, black, and red bars, or solid, dashed, and bubbled lines). Differentiate information using one of these strategies to increase the reader’s comprehension.

**Call-outs** are text-boxes, often accompanied by arrows, which are used to draw the reader’s attention to certain aspects of a graphic, e.g., to draw attention to a subcomponent featured in a photo, as indicated in Figure 8.4: Sample Call-outs:

---

![Figure 2.1: Face of a Guitar Body](image)

**Figure 2.1: Face of a Guitar Body**

---

**Figure 8.4: Sample Call-outs**  
*(Adapted from Kedare, 2010)*

In Figure 8.4: Sample Call-outs demonstrates, the single call-out is clearly indicated through the use of a white text box and white arrow that clearly contrast with the darker graphic upon which the call-out is superimposed. The font style and size are the same style as found in the graphics’ caption. Call-outs should be used cautiously: strategic use of call-outs can increase readability, but excessive use of call-outs merely clutters a graphic.
8.2.4 Captioning of Graphics

Caption graphics with four (4) pieces of identifying information: the type of graphic (i.e., Figure or Table), the number, the title, and the source (if the graphic is not generated by the author or the author’s lab partners). In keeping with new formatting guidelines, there is no period placed at the end of the caption. The following examples follow this basic pattern:

Table 3.1: First-year Students by Discipline
(Source: ERAU/Prescott, 2007)

Figure 1: Overhead View of Phoenix Sky Harbor Airport
(Source: City of Phoenix 2007)

The first example is the caption for a table. All information except the source is placed on the first line, and the source is placed on the second line. The first line is aligned with the left margin, and the second line (i.e., the source line) is aligned with the first letter in the title of the graphic (i.e., the open parenthesis is placed directly under the “F” in “First”).

The second example is the caption for a figure. All information except for the source is placed on the first line, and the source is placed on the second line. Both lines are centered on the page.

Number graphics sequentially according to type (i.e., Figure 1, Figure 2, Table 1, Table 2). Only use a decimal notation system (e.g., 3.1, 3.2, 3.3, 3.4) for numbering graphics when the document containing the graphics is divided into numbered chapters or segments. The chapter number appears first, followed by the decimal point, followed by the number of the graphic within the chapter. For example, Table 3.1 indicates that the table is in chapter three and is also the first table within chapter three.

Write the title of the caption as a descriptive noun phrase, heavily weighted with descriptive adjectives as necessary, but no longer than necessary for the reader to understand the contents of the graphic.

If a graphic or information contained in a graphic is not original—i.e., not the creation of the author—document the source of the graphic to avoid plagiarism. This internal citation is done in the caption. Place the source on a separate line from the rest of the caption’s information. Place the source in parentheses after the graphic’s type, number, and title, as shown in the preceding examples. Only the author and date need to be cited; do NOT cite an entire URL as the “author”.

July 26, 2011
In formatting captions, consider the following stylistic rules:

- **Single space** all captions.
- Underline all captions or place them in bold font so that they stand out. Use either underlining or bold font consistently for all captions for all graphics in a document. Bold font is the preferred style of the COE.
- Place table captions above the table and at flush left margin as demonstrated in Figure 8.2: Sample Table on p. 92.
- Place figure captions below the figure and centered on the page as demonstrated in Figure 8.3: Sample Figure on p. 92.
- If a lengthy table runs onto the next page, duplicate the caption at the top of the next page and add the phrase “cont’d” at the end of it (e.g., Table 2.1: Expected Conductivities of Container Materials, cont’d).
- If a lengthy table runs onto the next page, duplicate all column headings on the second page of the table so that the reader is clearly reminded of what type of information can be found in each column.

The last two (2) stylistic rules should be followed to prevent a “broken table”, i.e., a partial table with no caption or column headings to inform the reader of the type of information being tabulated.

### 8.2.5 Commenting on Graphics

Comment upon the information found in the graphic. A figure or table might be perfectly introduced, placed, labeled, and captioned, but if there is no data commentary immediately following the graphic, then the author has not interpreted the graphic for the reader and is thus guilty of **data dumping**.

At the beginning of the data commentary, in the very first sentence of the paragraph that follows the graphic, *refer* to the graphic in one of three (3) ways:

1. Use a generic referential phrase:

   As the preceding figure indicates, a significant number of fractures occur in the first sample but not in the second.

2. Use the full type, number, and name of the graphic, all of which is underlined, which is preferred in APA-style reports:

   As shown in Figure 2.3: Seating Configuration, the design includes room for a fifth seat.
3. Use the type and number of the graphic, all of which is bolded, and which is preferred in AIAA-style reports:

As indicated in Fig. 2, the data are a good fit with the theoretical predictions articulated in the preceding section.

While any of the preceding three (3) strategies are acceptable, select one style and maintain it throughout the document.

Consistency in referencing graphics is important, but even more critical is the type of data commentary that follows the initial reference. In writing the data commentary paragraph(s), call the reader’s attention to the most interesting or surprising or unexpected aspects of the data found in the graphic. This information might include one or more of the following:

- An obvious trend,
- Changes in a trend,
- High points or values,
- Low points or values,
- Significant values,
- Important elements of a structure,
- Similarities between samples,
- Differences between samples,
- Unexpected results, and/or
- Undesirable results.

One or more of these types of data commentary can be used to inform the reader of the significance of the data found in the graphic rather than letting the reader try to puzzle it out for themselves (i.e., rather than data dumping).

Figure 8.5: Properly Formatted Graphic illustrates a graphic that is properly introduced, placed, labeled, captioned, and commented upon:
In an effort to validate previous experiments, this lab will attempt to replicate the results of previous tests of similar samples as summarized in Table 2.1:

**Expected Conductivities of Container Materials:**

<table>
<thead>
<tr>
<th>Material</th>
<th>Conductivity [W/m°C]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plastic</td>
<td>0.05 – 0.20</td>
</tr>
<tr>
<td>Styrofoam</td>
<td>0.14</td>
</tr>
<tr>
<td>Paper</td>
<td>0.23</td>
</tr>
<tr>
<td>Stainless Steel</td>
<td>22-66</td>
</tr>
</tbody>
</table>

As indicated in Table 2.1: Expected Conductivities of Container Materials, plastic and Styrofoam have the lowest levels of conductivity, while stainless steel has the highest. The higher the conductivity of a material, the higher the rate of heat loss experienced by a container fabricated from that particular material. For this lab, then, the liquid contained in the stainless steel container is expected to cool most quickly, while the liquid contained in the plastic and the Styrofoam containers is expected to cool most slowly.

---

**Figure 8.5: Properly Formatted Graphic**

As this example indicates, proper introduction, placement, labeling, captioning, and commenting upon graphics allow for clear communication of visual information and more effective Lab Reports (and other technical documents). In any event, data dumping is to be avoided at all costs.

### 8.3 Guidelines for Equations

As with graphics, equations must also be properly introduced, placed, captioned, and commented upon; furthermore, terms must be defined the first time they appear as part of the equation’s data commentary. Moreover, equations are numbered in order of presentation for clear reference. There are two (2) styles for stating equations: APA style and AIAA style, both of which are discussed in the following subsections.

#### 8.3.1 APA-style Equations

When introducing an equation using APA style, name and number the equation (e.g., Equation 1, Equation 2, Equation 3) in a brief introductory sentence before
The aircraft mass ratio, \( \mu_g \), was used in the calculation of the gust alleviation factor and was determined using Equation 3.8 (FAA, 2009):

\[
\text{Equation 3.8}
\]

where \( W/S \) is the wing loading in units of lb/ft\(^2\), \( \rho \) is the cruise altitude density in units of slug/ft\(^3\), \( c \) is the mean geometric chord in units of ft, \( g \) is the acceleration due to gravity for earth in units of ft/s\(^2\), and \( \kappa \) is the lift curve slope in units of per radian. The density for a cruise altitude of 30,000 ft. was used because the gust is based upon 1-g flight occurring during the cruise phase of the flight. Using Equation 3.8, the calculated \( \mu_g \) for the VSR-1 is 28.8.

Figure 8.6: Properly Formatted Equation, APA Style
(Source: Adapted from Aero-Endurance, 2009)

In the preceding example, Equation 3.6 is properly introduced immediately before the equation is presented. Number all equations sequentially; the chapter number containing the equation appears first, followed by a decimal point, followed by the number of the equation within the chapter (e.g., Equation 2.1, Equation 2.2, Equation 2.3 indicate the first, second, and third equations stated in chapter 2 of the document).

If the equation was taken from a source, that source must be cited at the end of the introductory sentence using APA-style citation (i.e., author, date). End the introductory sentence with a colon, even if the equation itself is located on the following page.

After the introductory sentence, leave one (1) blank line. Then, place the equation on the following line, indented at least one (1) tab. Align the caption to the right of the equation, on the same line as the equation, flush with the right-hand margin. The equation caption should include the name and number of the equation (i.e., Equation 3.8 in the preceding example), and should be in bold font.

After the equation, leave one (1) blank line. Then, as a data commentary define all terms in the same order in which they are presented in the equation, reading from left to right, from top to bottom. Each definition should include the term’s unit of measure as appropriate. In the preceding example, “\( W/S \)” is measured in lb/ft\(^2\). Terms which have previously been defined generally do not need to be re-defined. Commonly used set phrases to refer the reader back to previously
defined terms are “...and all other terms are as previously defined” and “All terms have been previously defined.” However, if more than five (5) pages have passed since a term was defined, refer the reader to the pertinent equation or re-define the term as a courtesy so that the reader does not need to search through the document to refresh their memory.

After all terms are defined, if any particular input values were used, state the values and explain their origin. Finally, state the resulting value.

8.3.2 AIAA-style Equations

When introducing an equation using AIAA style, name the equation in a brief introductory sentence before stating the equation. Use the abbreviation “Eq.” for the word “equation.” Do not underline or bold the equation name. A sample equation follows in Figure 8.7: Properly Formatted Equation, AIAA Style:

The gust lines are a function of velocity and wing loading. The gust lines were generated using Eq. (17)⁹:

\[
(17)
\]

In Eq. (17), \(K_g\) is the gust alleviation factor, \(U_{de}\) is the gust velocity for each gust line in KEAS, \(V_e\) is the flight velocity in KEAS, and \(C_{L\alpha}\) is the lift curve slope in per radian. The value of 498 accounts for the sea level density as well as the conversion of \(V_e\) from KEAS to ft/s. The gust alleviation factor is defined by FAR regulations and is calculated utilizing Eq. (18)¹⁰.

\[
(18)
\]

Where \(K_g\) is a function of the mass parameter, \(\mu_g\), and is defined in Eq. (19)¹¹:

\[
(19)
\]

In Eq. (19), \(\rho\) is the density in slugs/ft.³ at the cruise altitude of 30,000 ft., the mean geometric chord of the wing is \(\bar{c}\) in ft., and the acceleration due to gravity is \(g\) in ft/s.

Figure 8.7: Properly Formatted Equation, AIAA Style
(Source: Adapted from Aero-Endurance, 2009)
In the previous example, all equations are numbered sequentially. A decimal system is typically not used for numbering; instead, equations are simply numbered beginning with the number “1”; all numbers are placed in parentheses, like this: Eq. (1).

If the equation was taken from a source, cite the source at the end of the introductory sentence using AIAA-style citation (i.e., superscripted reference numbers). End the introductory sentence with a colon.

After the introductory sentence, leave one (1) blank line. Then, place the equation on the following line, indented at least one (1) tab. Place the caption at the right-hand margin, on the same line as the equation. The equation caption should state the equation number in parentheses and should be in regular (not bolded) font.

After the equation, leave one (1) blank line. Then, define all terms (including the units of measure). Define terms in the order of appearance in the equation, from left to right, from top to bottom.Italicize all symbols used in the definition. Terms which have previously been defined generally do not need to be re-defined; however, if more than five (5) pages have passed since the term was defined, refer the reader to the pertinent equation or re-define the term as a courtesy.

After all terms are defined, if any particular input values were used, state the values and explain their origin. Finally, state the resulting value.
9.0 CITATION STANDARDS

9.1 A Justification for Citation/Documentation

There are two (2) types of citation: internal and external. **Internal citation** is the documentation of sources within the body of a text, usually as part of the prose, although footnotes are considered internal citation as well. Internal citation is also called *in-text citation*. **External citation** is the documentation of sources outside of the body of the text within the References section (sometimes called the Works Cited or the Bibliography section).

Proper citation gives credit to the authors of both primary and secondary sources; it is mandatory in all academic texts including Lab Reports.

All sources must be cited *both* internally and externally. Lack of citation is akin to stealing another’s ideas and claiming them for one’s own; lack of citation is thus considered a form of academic dishonesty (i.e., plagiarism), even if it is committed unintentionally.

All students are expected to uphold ERAU’s high standards of academic integrity. **No form of academic dishonesty or plagiarism will be tolerated.** Please refer to the most current publication of the *Undergraduate Catalog* for a further discussion of academic integrity.

There are two (2) citation styles adopted by the COE: APA-style citation and AIAA-style citation, each of which is discussed in this section. Note that most of the examples of citation that are presented in this section are fabricated and are for illustrative purposes only.

9.2 Internal Citation

**Internal citation** is the citation of sources within the body of a text. Internal citation is required when a writer directly quotes from a source; it is also required when a writer paraphrases a source:

- **Quotation** is borrowing a phrase, clause, sentence, paragraph, or larger chunk of text from a source and copying it directly into one’s text; quoting includes copying tables and figures.

- **Paraphrase** is taking a source’s ideas or claims and re-phrasing them in one’s own words; paraphrasing includes lengthy examples that one summarizes or minor details to which one makes passing reference.

How this information is presented depends upon whether the writer wants to call attention to the author/source (i.e., **author-prominent citation**) or whether they
want to call attention to the information itself (i.e., information-prominent citation), as discussed in the following sections.

9.2.1 Author-prominent Citation

Sometimes it is important that the author be named at the beginning of the sentence. There are several reasons for this type of author-prominent citation:

- The author is well-respected or famous in the field.
- The student writer wishes to contrast this author with another.
- The student writer wishes to distance themselves from the claims of the author, usually because there are flaws in those claims.

For author-prominent citation of a quotation in APA-style documents, the following formula is used:

Author’s last name (year of publication) + reportive verb + “quotation” + (page number).

Sagan (1997) claimed that “I never said ‘billions and billions.’ For one thing, it’s too imprecise” (3).

In the preceding example, the page number appears by itself at the end of the sentence and there is no use of “p.” or “pp.” or “page.”

For author-prominent citation of a quotation in AIAA-style documents, the following formula is used:

Author’s last name + reportive verb + “quotation” + superscripted reference number/footnote.

Sagan claimed that “I never said ‘billions and billions.’ For one thing, it’s too imprecise.”

In the preceding example, a reference number referring to a footnote is written in superscripted font at the very end of the quotation.

For author-prominent citation of a paraphrase in APA-style documents, the following formula is used:

Author’s last name (year of publication) + reportive verb + (that) + paraphrase.
Hoffiz (2011) supports the formation of a cultural studies club on the ERAU campus.

In the preceding example, the year of publication is placed in parentheses.

For author-prominent citation of a paraphrase in AIAA-style documents, the following formula is used:

Author’s last name + reportive verb + (that) + paraphrase + superscripted reference number/footnote.

Hoffiz supports the formation of a cultural studies club on the ERAU campus.9

In the preceding example, the reference number is placed outside the period.

9.2.2 Information-prominent Citation

Sometimes the information being presented is more important than the information’s source and so information-prominent citation is used. In this case, the information comes at the beginning of the sentence and the citation or footnote is relegated to the end of the sentence. There are two (2) types of information-prominent citation: quotations and paraphrases.

For information-prominent citation of a quotation in APA-style documents, the following formula is used:

Optional intro + “quote” (Author(s)’ last name + year of publication: page).

Haiku poems often meditate on the “impermanence of the seemingly permanent” (Stryk and Ikemoto 1973:10).

In the previous example, a colon precedes the page number and there is no “p.” or “pp.” or “page” found in the citation.

For information-prominent citation of a quotation in AIAA-style documents, the following formula is used:

Optional intro + “quote” + superscripted reference number/footnote.

Haiku poems often meditate on the “impermanence of the seemingly permanent.”19

July 26, 2011
In the previous example, the period is inside the closing quotation mark and the superscripted reference number is outside the closing quotation mark.

Information may also be paraphrased. In information-prominent paraphrases, there are three (3) different lengths of paraphrase to consider:

- Sentence-length paraphrases,
- Paragraph-length paraphrases, and
- Extended paraphrases which cover two (2) or more paragraphs.

For sentence-length paraphrases, place the citation at the end of the sentence. For paragraph-length paraphrases, rather than citing the same source over and over at the end of every sentence, cite the source once, and only once, at the end of the paragraph.

For extended paraphrases, i.e., for paraphrases over several paragraphs in length (a very rare occurrence), cite the source at the end of every paragraph. Whether the paraphrase is a sentence, or paragraph, or several paragraphs in length, the same format for information-prominent citation is used as discussed below.

For information-prominent citation of a paraphrase in APA-style documents, whether sentence-length, paragraph-length, or extended paraphrase, the following formula is used:

Paraphrase + (Author(s)’ last name(s) + year of publication).

Japanese poems known as waka are similar to Chinese poetry of the same era in subject matter but not in structure or presentation (Chen 2010).

In the preceding example, there is no page number included in the citation, only the year of publication. APA-style citation of paraphrases differs from MLA-style citation in that page numbers are not required for paraphrases, only for quotations.

For information-prominent citation of a paraphrase in AIAA-style documents, the following formula is used:

Paraphrase + superscripted reference number/footnote

Japanese poems known as waka are similar to Chinese poetry of the same era in subject matter but not in structure or presentation.\(^\text{21}\)
In the preceding example, there is no space between the period and the superscripted reference number/footnote.

If a paraphrased idea is found in more than one source, then each of these sources must be listed at the end of the sentence; in APA-style documents, all sources are listed alphabetically and are divided by semi-colons:

Over the next five (5) years there will be an increased demand for fluent speakers of Chinese as well as for speakers of Arabic; furthermore, there will remain a steady demand for speakers of Spanish (Stringfield 2010; Yeng 2008; Zhou, 2009).

In the preceding example, Stringfield, Yeng, and Zhou appear alphabetically in the citation at the end of the sentence.

In AIAA-style documents, all sources are cited using footnotes. If two (2) sources are cited, a comma is used to separate the two footnotes; if three (3) or more sources are cited, a dash is used to show range:

Over the next five (5) years there will be an increased demand for fluent speakers of Chinese as well as for speakers of Arabic; furthermore, there will remain a steady demand for speakers of Spanish.

In the preceding example, the dashed footnote indicates that information from source number 3, number 4, and number 5 in the References list has been used for this paraphrase.

9.2.3 Block Quotes

Quotes that are longer than 40 words or 3 lines of prose require a special citation style, the block quote (i.e., the extended quote). A block quote follows the following format guidelines for both APA and AIAA styles:

✓ The quotation must be visually separated from the rest of the text by being indented 0.5 in. (or one tab) all along the left AND right margins of the quoted material.

✓ The quotation must be fully justified (rather than aligned flush left).

✓ The quotation must have NO quotation marks around it; the visual format replaces the quotation marks.
The quotation must be separated from the preceding and following text by one blank line on either side (APA style) or by no blank lines on either side (AIAA style).

The quotation must be introduced by a sentence that ends in a colon or by a phrase that ends in no punctuation at all.

The quotation must be followed by data commentary. That is, it must be followed by at least one (1) sentence (preferably a paragraph) that explains or expands upon the information presented in the block quote.

As the last checkmark notes, a block quote cannot simply be data dumped into the report. Guidelines for avoiding data dumping are noted in Section 8.2: Avoidance of Data Dumping. Figure 9.1: Sample of APA-style Block Quote follows these format and organization rules for a block quote:

Several theorists contend that extreme positions will only hurt educational progress. As Dewey (1938) argues

Mankind likes to think in terms of extreme opposites. It is given to formulating its beliefs in terms of Either-Ors, between which it recognizes no intermediate possibilities. When forced to recognize that the extremes cannot be acted upon, it is still inclined to hold that they are all right in theory, but that when it comes to practical matters, circumstances compel us to compromise. (162)

As this argument dictates, taking sides in this matter is impractical at best and damaging at worst. Therefore, a compromise position seems the most reasonable course of action….

Figure 9.1: Sample of APA-style Block Quote

This same quotation has been re-formatted from APA-style citation standards into AIAA-style citation standards and is presented in Figure 9.2: Sample of AIAA-style Block Quote:
Several theorists contend that extreme positions will only hurt educational progress. As Dewey argues:

Mankind likes to think in terms of extreme opposites. It is given to formulating its beliefs in terms of Either-Ors, between which it recognizes no intermediate possibilities. When forced to recognize that the extremes cannot be acted upon, it is still inclined to hold that they are all right in theory, but that when it comes to practical matters, circumstances compel us to compromise.\(^32\)

As this argument dictates, taking sides in this matter is impractical at best and damaging at worst. Therefore, a compromise position seems the most reasonable course of action….

Figure 9.2: Sample of AIAA-style Block Quote

In both of these examples, the block quote has been properly introduced, properly formatted, properly cited, and properly commented upon.

9.3 External Citation/References

External citation is the documentation of sources outside of the body of the text within the References section (i.e., in the Bibliography or Works Cited section). References should be as complete and accurate as possible so that the reader can identify and retrieve each source. The following sections provide general guidelines for formatting APA-style and AIAA-style References sections. Sample citations for various genres (e.g., books, articles, interviews, websites) are presented in Section 9.4: APA Standards and Section 9.5: AIAA Standards.

9.3.1 Guidelines for Formatting APA-style References

The following guidelines assume APA style in the construction of a References section:

- References are considered a continuation of the document and are paginated accordingly; if the last page of the Conclusion was numbered 72, the first page of the References would be numbered 73.

- If the body of the document is in standard essay format (i.e., double-spaced throughout), then the References should simply be double-spaced throughout; if the body of the document is in block format (i.e., single-spaced throughout), then each entry in the References should be single-spaced with a double space between entries.
Each entry should be formatted in using a *hanging indent* style. To create a hanging indent, the first line of each entry should be aligned with the left margin and each succeeding line should be indented ½ in. from the left margin:


In the previous example the second and third lines of the citation are indented one (1) tab from the left margin.

The first piece of information in an entry should be the last name and first initial of each author OR the full name of the institution that authored the source (e.g., Boeing); see the following comments for unknown or Anonymous authors.

Commonly-used acronyms for institutional authors should be placed in parentheses immediately after the institutional author’s name:

American Institute of Aeronautics and Astronautics (AIAA).

Jet Propulsion Laboratories (JPL).

As these examples show, the proper name of the institution is presented first.

All entries should be listed *alphabetically by author* (if the author is known) or *by title* (if the author is unknown). “Anonymous” should only be used as the author’s name if the source itself was signed “Anonymous”; if the author is unknown, then simply do not state an author and begin the entry with the date of publication:


(2007). *Documentation for Engineers* ....


In the preceding list, the last entry is the name of an institution, i.e., an institutional author. There are a number of sources which are authored by institutions and not by individuals. In particular, websites are commonly authored by institutions. For a website, the name of the institutional author is typically indicated in the URL or web address for the website in question (e.g., www.asee.org is the website authored by the American Society for Engineering Education).

Multiple entries that are written by the same author should be listed by year of publication, the earliest first:


In this example, the earliest publication is listed first.

Entries written by the same author and published in the same year are alphabetized by title and then distinguished with a lower-case letter added to the date of publication; these sources should be listed alphabetically according to the order of these lower-case letters:


In this example, the 2009a source is the first in the alphabetized list. When this source is cited internally (i.e., in the body of the document), “2009a” would be used in the citation, not “2009” because there are multiple 2009 documents and the reader needs to be able to identify the specific source.

The year of publication of an entry should be placed within parentheses after the author(s) and before the title of the source; if there is no known author, the year of publication should be placed first in the entry:


In the preceding example, the date is placed in parentheses or, in the case of the last two (2) entries, the date/lower-case letter is placed in parentheses.

For periodical sources, the year and month of publication should be placed after the year of publication, within the parentheses; if the specific date of publication is known (such as for newspapers), it should also be placed within the parentheses:


The previous examples all assume that the year of publication is known. If the year of publication is unknown (which is a common problem with some website sources), then (n.d.) should be used in place of a year of publication:


As previously noted, the year of publication should include lower-case letters in order to distinguish works published in the same year by the same author:


In this example, all three publications are alphabetized and then assigned lower-case letters for identification.

- The first letter of all titles and subtitles in an entry should be capitalized, with the exception of articles (a, an, the), prepositions (in, on, of, for, with, through), and conjunctions (and, but, or) which are NOT the first word of the title or subtitle:
Lab Report 8: Corrosion Tests.

Pass the Popcorn: A Year in the Life of a Film Critic.

The Washington Post.

As illustrated by the second item in this list, titles should be separated from subtitles by colons, and both should be italicized:


The exception to the rule in the preceding bullet is the title of a smaller work (e.g., an article, chapter, or webpage) found within a larger work (e.g., a newspaper, journal, book, or website); in this case, the title of the smaller work is stated first and is not italicized; the title of the larger work is stated second and is italicized:


In this example, the non-italicized titles indicate chapters within a larger work, and the italicized titles are the names of those larger works.

- For edited works, the last name and first initial of the editor should be followed by “(Ed.)” in order to distinguish the editor(s) from the author(s).

- For non-periodical sources, the city and state of publication (or city and country for international publications) should be stated and separated from the name of the publisher by a colon:

  ...New York: McGraw Hill...

  ...San Diego: Academic Press...

As demonstrated in the previous examples, if the city of publication is readily recognizable and internationally famous (e.g., London, Los Angeles, Tokyo,
Berlin), then state only the name of the city, not the city and state (or city and country in the case of international publications).

- For periodical sources, the volume and edition should be *italicized* with the edition placed in parentheses; the page numbers of the chapter or article follow the edition and are not italicized:

  ...73(4), 101-104.

  ...9(1), 20-42.

  In the first entry of this example, “73(4)” refers to the fourth edition of the 73rd volume, and “101-104” refers to the article’s page numbers.

- For chapters within books or edited volumes, the page numbers of the chapter or article should be included within parentheses following a “pp.” notation.


  In this example, the chapter runs from page 190 through page 204.

- For internet sources, the date on which the source was retrieved and the full internet address should be stated using the phrasing “Retrieved (date), from (URL)” as follows:


  As the first example shows, web addresses can be very lengthy, but they must nonetheless be accurately and fully cited in the References page.

**9.3.2 Guidelines for Formatting AIAA-style References**

The following guidelines assume AIAA style in the construction of a References section:

- References are considered a subsection of the document and follow immediately after the Conclusions of the document. (If there is an appendix or acknowledgments, then the References follow immediately after these sections.) There is one blank line before the References begin, as noted in Section 12.3: Description of AIAA-style Lab Reports.
The References should be single-spaced with no blank lines between entries.

Each entry should be indented ½ in. from the left margin (i.e., one tab):


The indentation shown in the preceding example indicates that a new entry is being cited. Unlike APA-style citation, AIAA-style citation does not utilize hanging indents in References.

The first piece of information in an entry should be the superscripted reference number/footnote for the cited entry. There is no blank space after the number and before the first letter of the author’s name.


In the preceding example, the superscripted 2 refers to the second source listed in the References.

The second piece of information in an entry should be the last name and first initial of each author OR the full name of the institution that authored the source (e.g., Boeing); see the following comments for unknown or Anonymous authors.

Commonly-used acronyms for institutional authors should be placed in parentheses immediately after the institutional author’s name:

3American Institute of Aeronautics and Astronautics (AIAA),

4Jet Propulsion Laboratories (JPL),

As these examples show, both APA and AIAA identify acronyms using an identical method.

All entries should be listed *in the order of appearance in the document*:

1Beck, M. A.,

2Zhan, H.,

3Malnar, A.,

4Blomstrom, S.,
In this example, even though “Blomstrom” comes before “Malnar” in the alphabet, because the reference to Blomstrom’s work follows the reference to Malnar’s work in the document, Blomstrom follows Malnar in the References.

- The first letter of all titles and subtitles in an entry should be capitalized, with the exception of articles (a, an, the), prepositions (in, on, of, for, with, through), and conjunctions (and, but, or) which are NOT the first word of the title or subtitle:

  \[ Lab \text{ Report 8: Corrosion Tests. } \]

  \[ Pass \text{ the Popcorn: A Year in the Life of a Film Critic. } \]

\[ The \text{ Washington Post. } \]

In additional to this capitalization standard, titles should be separated from subtitles by colons, and both should be italicized:

\[ ^{12} \text{ Fraher, A. and Kuper, M., Center for International Programs and Services (CIPS) Proposal….} \]

The exception to the rule in the preceding bullet is the title of a smaller work (e.g., an article, chapter, or webpage) found within a larger work (e.g., a newspaper, journal, book, or website). In this case, the title of the smaller work is placed in quotation marks and the title of the larger work is italicized:

\[ ^{13} \text{ Beatty, J. and Nordbrock, A., “The Development of an Intercultural Communications Program,” Writing Program Administration: University Program Development and Refinement….} \]

\[ ^{14} \text{ Rabern, D., “The Gauntlet,” Aerospace, Electrical, and Mechanical Engineering….} \]

\[ ^{15} \text{ Gally, T., “What Every Engineering Student Should Know: Survival Strategies for the AE Graduate,” Ethics and the Engineer….} \]

In the second entry of this list, “The Gauntlet” is the name of a chapter found in a larger work, \[ Aerospace, \text{ Electrical and Mechanical Engineering.} \]

- For edited works, the last name and first initial of the editor should be followed by “(Ed.)” in order to distinguish the editor(s) from the author(s).

- For periodical sources, the volume and number of the entry should be stated using the abbreviations “Vol.” and “No.”:
Vol. 24, No. 11,

Vol. 145, No. 24,

In the first entry on this list, the source is the eleventh edition in the 24th volume.

- For non-periodical sources, the name of the publisher should be separated from the place of publication by a comma:
  
  McGraw Hill, New York,
  
  Springer-Verlag, New York,
  
  Academic Press, San Diego,

As with APA-style citation, if the city of publication is well known, the state and/or country name need not be stated.

- The year of publication of a source should be placed near the very end of the entry. For periodical sources, the date, month, and year of publication should all be noted if known:

  4 July 2009,

  19 Dec. 1996,

  Aug. 2008,

As the last entry in this list indicates, if only the month is known, then the month should be stated.

- For print sources, page numbers/chapter numbers should be the last element of the entry; page numbers are stated following a “pp.” notation:


The last entry of this list indicates that the article in question is printed on pages 117 through 134.
For internet sources, the URL is fully stated at the end of the entry, as is the date of retrieval; the latter is stated in square brackets:

URL: http://www.cp/umist.ac.uk/134 [cited 7 April 2008].

URL: http://www.erau.edu [cited 31 Aug. 2007].

Unlike APA-style citation, when referring to the date on which a website was retrieved, for AIAA-style citation the term “cited” is stated followed by the date, the month, and the year, all of which are in square brackets.
9.4 APA Standards

The following are examples of individual entries that could be found in a References section using APA-style citation. These examples are presented by type of source (i.e., print sources, electronic sources, and audiovisual and interview sources) and follow current APA standards; that is, they are all formatted according to the bulleted guidelines presented in Section 9.3.1: Guidelines for Formatting APA-style References. Notice that APA uses an author + year of publication system, regardless of the type of source being documented.

These examples are intended to be used as templates or models and as such represent a wide range of sources. Many more examples are available in the most recent edition of The Publication Manual of the American Psychological Association (2009b) and Concise Rules of APA Style (2009a) and at www.apa.org. The Landmark Project citation machine at http://www.citationmachine.net/ can also be used to help format entries in a References section.

9.4.1 Print Sources

Abstract, Dissertation or Thesis


Abstract, Print Periodical


Abstract, Technical Report


Book, Edited Volume

Book, Eight (8) or More Authors


Book, Government Agency as Author and Publisher


Book, No Author or Editor


Book, One (1) Author


Book, Three to Seven (3 – 7) Authors


Book, Two (2) Authors


Brochure, Corporate Author

Chapter in a Textbook


Chapter in an Edited Volume


Daily Newspaper Article


Daily Newspaper Article, No Author


Dissertation or Thesis, Unpublished


Encyclopedia Entry


Journal Article, Eight (8) or More Authors


Journal Article, One (1) Author


**Journal Article, Three to Seven (3 – 7) Authors**


**Journal Article, Two (2) Authors**


**Magazine Article, Two (2) or More Authors**


**Magazine Article, No Author**


**Magazine Article, One (1) Author**


**Newsletter Article**


**Paper Presented at a Conference/Symposium, Published**

Paper Presented at a Conference/Symposium, Unpublished


Technical Report, Educational Resources Information Center (ERIC)


Technical Report, Other Sources


Technical Report, University, Published


Technical Report, University, Unpublished

9.4.2 Electronic Sources

Internet Abstract, Technical Report


Internet Article, Duplicate of Print Version


Internet Article, Internet-only Journal


Internet Article, Internet-only Newsletter


Website, Document Linked from Home Page

Website, Home Page, No Date


Website, No Author, No Date


Website, Technical Report, Government


Website, Technical Report, University


9.4.3 Audiovisual and Interview Sources

Interview, Telephone Call, or Email Correspondence


Motion Picture


Music Recording

**Television Broadcast or Special**


**Television Series**

9.5 AIAA Standards

The following are examples of individual entries that could be found in a References section using AIAA-style citation. They are presented by type of source (i.e., print sources, electronic sources, and audiovisual sources) and follow current AIAA standards; that is, they are all formatted according to the bulleted guidelines presented in Section 9.3.2: Guidelines for Formatting AIAA-style References. Notice that AIAA uses a footnoting system, as previously discussed.

These examples are intended to be used as templates or models and as such represent a wide range of sources. More examples can be found in the current AIAA Style Guide, AIAA Style (2009), available from www.aiaa.org.

Note that personal communications such as interviews or email messages are typically NOT cited in the References section in AIAA style; instead, such personal communications are mentioned as footnotes inside the body of the document itself.

9.5.1 Print Sources

Abstract, Dissertation or Thesis


Abstract, Print Periodical


Abstract, Technical Report


Book, Edited Volume

Book, Government Agency as Author and Publisher


Book, No Author or Editor


Book, One (1) Author


Book, Six (6) or More Authors


Book, Three to Five (3 – 5) Authors


Book, Two (2) Authors


Brochure, Corporate Author

Chapter in a Textbook


Chapter in an Edited Volume


Daily Newspaper Article


Daily Newspaper Article, No Author


Dissertation or Thesis, Unpublished


Encyclopedia Entry


Journal Article, One (1) Author


Journal Article, Three (3) or More Authors

19Waysbort, D., Manisterski, E., Leader, H., Minsterski, B., and Ashani, Y., “Laboratory Setup for Long-term Monitoring of the

**Journal Article, Two (2) Authors**


**Magazine Article, Two (2) or More Authors**


**Magazine Article, No Author**


**Magazine Article, One (1) Author**


**Newsletter Article**


**Paper Presented at a Conference/Symposium, Published**


**Paper Presented at a Conference/Symposium, Unpublished**


Internet Article, Internet-only Journal


Internet Article, Internet-only Newsletter


Website, Document Linked from Home Page


Website, Home Page, No Date


Website, No Author, No Date


Website, Technical Report, Government

Website, Technical Report, University


9.5.3 Audiovisual Sources

Motion Picture

41 Carter, C. (Producer) and Bowman, R. (Director), *The X-Files: Fight the Future* [Motion picture], Twentieth Century Fox, United States, 1998.

Music Recording

42 Zevon, W., “The Indifference of Heaven,” *I’ll Sleep When I’m Dead: An Anthology* [CD], Electra Entertainment Group, Los Angeles, 1996.

Television Broadcast or Special


Television Series

10.0 USE OF SOFTWARE

The following sections provide guidance in the use of software in preparing technical documents. Microsoft Word 2007 and Excel 2007 are the primary software tools used at ERAU, Prescott campus, when creating reports. Therefore, the following guidelines apply to Microsoft Word 2007 and Microsoft Excel 2007.

10.1 Drafting a Table of Contents using Word

1. All sections to be included in the Table of Contents should be separated by a header that describes the contents of the section. See Section 12.0: Description of Lab Reports by Section for the sections that should typically be included in the report.

2. Before typing the report, set the heading styles for the section headers by right-clicking on the Heading 1 under the Home tab. Select Modify, and then Format then Font, and change the font type, size and color as appropriate. Click OK (twice).

3. Repeat this process for Heading 2, Heading 3, and so forth as appropriate. (Note that selecting Heading 2 will make Heading 3 available.) Each heading represents a different level section heading (i.e., an A-level heading would be Heading 1, a B-level heading would be Heading 2, and a C-level heading would be Heading 3). (See Section 3.5: Headings and Subheadings for a discussion of the types of headings.)

4. Select the down arrow to the right of the existing Heading options and select Save Selection as a New Quick Style to customize heading names and formats. A new name can be entered (e.g., “Front Matter,” “Figures,” or “Tables”) and the font can be adjusted using the process described in Step 2 above. The customized headers can be used to capture front matter headings and for creating Lists of Figures and Tables as discussed in the following section.

5. Before typing each section header, select the appropriate Heading type.

6. Once the report is complete, insert the Table of Contents at the beginning of the document by selecting the Table of Contents tool under the References tab. Select Insert Table of Contents from the list. Under General, change the number of levels as appropriate. Click OK.
7. After the Table of Contents is inserted, highlight the entire table and change the font type and size under the Home tab. The indents and tabs can also be adjusted using the ruler at the top of the window.

10.2 Drafting a List of Figures (or Tables) using Word

1. Before creating a List of Figures (or Tables), select the appropriate header type (defined as described in Step 4 of the previous section), then type the title of each figure or table included in the report.

2. Once the report is complete, insert the List of Figures (or Tables) after the Table of Contents by selecting the Insert Table of Figures tool under the References tab. Select Options and then select the box next to Style. Choose the appropriate heading type using the pull-down arrow to the right. Click OK (twice).

3. After the List of Figures (or Tables) is inserted, highlight the entire table and change the font type and size under the Home tab. The tabs can also be adjusted using the ruler at the top of the window.

10.3 Modifying Headers and Footers (with Page Numbers) using Word

1. Headers and Footers can be inserted using the Header or Footer tool under the Insert tab. Choose the Blank option and then type in the desired text. The location of the text can be modified using the alignment tools under the Home tab (i.e. center or right justify) or using the ruler at the top of the window. The text will appear on every page of the document, unless a Section Break is added as described in Steps 4 and 5, below. Select the Close Header and Footer button when finished.

2. Page numbers can be added using the Page Number tool under the Insert tab. Select the Format Page Numbers option and use the pull-down arrow next to Number Format to specify lower-case roman numerals or numbers. Section numbers may be included in the page number by selecting the Include chapter number option and defining the appropriate separator. Numbering can also be initialized for new sections (defined in Steps 4 and 5) by selecting the Start At: option under Page Numbering. Click OK when finished.

3. Reselect the Page Number tool and select either the bottom-center or top-right corner option depending on the requirements of the document. (Note: Front matter should always be numbered with lower-case roman numerals using the bottom-center option). Select the Close Header and Footer button when finished.

4. To differentiate between the front matter and the main body of the report, add a section break after the front matter by selecting the Breaks tool under the
Page Layout tab, and selecting Next Page under Section Breaks. Use the Page Number tool as described in Step 2 to change the page numbers from lower-case roman numerals to numbers and implementing the Start At: option. The location may be changed to the upper right corner as described in Step 3; to do so select the Link to Previous option under the Header & Footer Tools. Selecting this option will allow the header, the footer, or both to be reformatted for the new section with the appropriate page number format (and any desired text). Select the Close Header and Footer button when finished.

5. Headers and/or footers for new sections can be added to define new report sections by following the process defined in Step 4 and implementing the appropriate options under the Page Number and Header & Footer tools.

10.4 Inserting Tables Using Word

Creating tables can be accomplished two (2) different ways: with the Table pull-down menu in Microsoft Word 2007 or with Microsoft Excel 2007. Creating tables using the Table tool in Microsoft Word 2007 can be accomplished as follows:

1. Select the Table tool under the Insert tab and select the Insert Table option. Set the appropriate number of columns and rows, define the column width options, and then click OK.

2. Type in the column headers in each of the cells on the top row and then fill in the remaining cells with the remainder of the tabular data.

3. With the table highlighted, place it in the appropriate location using the alignment options under the Home tab or using the ruler on the top of the window.

10.5 Inserting Tables Using Excel

Creating tables using Microsoft Excel 2007 can be accomplished as follows:

1. Create a table using spreadsheet options.

2. Highlight the entire table and set the font type and size to match those existing in the report using the Font and Font Size boxes at the top of the screen. (Note: Font type and size may also be changed after the table has been inserted into the Word document.)

3. Use the Borders tool as appropriate to place borders around the cells of the table.

4. Use the alignment options to appropriately justify the table information.
5. Select the **Copy** icon (with the table still highlighted) and return to **Word**.

6. Select the **Paste** icon to place the table at the appropriate location.

7. Resize if necessary by ‘grabbing’ one corner and dragging the corner to create the proper size.

8. With the table highlighted, place it in the appropriate location using the alignment options under the Home tab or using the ruler on the top of the window.

### 10.6 Inserting Pictures Using Word

Inserting pictures as figures using **Microsoft Word 2007** can be accomplished as follows:

1. Select **Picture** under the Insert tab.

2. Select the file location where the picture exists under **Look in**.

3. Select the appropriate picture file.

4. Select **Insert**.

5. Resize the picture if necessary by ‘grabbing’ one corner and dragging the corner to create the proper size.

6. With the picture highlighted, place it in the appropriate location using the alignment options under the Home tab or using the ruler on the top of the window.

### 10.7 Inserting Figures Using Excel

**Microsoft Excel 2007** can also be used to create plots from numerical data as described below:

1. Highlight the data to be used in creating the plot. Place the data to be plotted along the x-axis (i.e., horizontal axis) in the first row or column.
2. Under the Insert tab, select **XY (Scatter)**. Select the appropriate plot type from those shown.

3. Add the appropriate title and labels using the options available under the Layout tab.

4. With the plot highlighted, select the **Copy** icon and return to **Word**.

5. Select the **Paste** icon to place the table at the appropriate location.

6. Resize the plot if necessary by ‘grabbing’ one corner and dragging the corner to create the proper size.

7. With the plot highlighted, place it in the appropriate location using the alignment options under the Home tab or using the ruler on the top of the window.
11.0 STANDARDIZED OUTLINES FOR LAB REPORTS

This section provides outlines for three (3) types of reports:

1. Informal APA-style Lab Reports (i.e., informal reports);
2. Formal APA-style Lab Reports (i.e., formal reports); and
3. Formal AIAA-style Lab Reports (i.e., AIAA-style reports).

Informal reports provide highly concise overviews of an experiment, using a narrative style for Procedures. Formal reports differ from their shorter, informal counterparts in great part due to their extensive Front Matter and End Matter, but also due to the presence of a separate Theory section and a non-narrative Procedures section.

AIAA-style Lab Reports are similar to both APA-style reports in content and organization (e.g., they all have Introduction, Results, and Reference sections); however, they differ from APA-style reports in how the documents are formatted. Moreover, in the College of Engineering, APA-style reports are typically assigned for courses in the Aero track, whereas AIAA-style documents are typically assigned for courses in the Astro track.

The following lists outline each of the sections to be included in the informal report, the formal report, and the AIAA-style Lab Report. Each section is listed in the order in which it appears in the final draft of the report. (See Section 12.0: Description of Lab Reports by Section for more guidelines.)

The authors of the report are responsible for discovering what type of report the lab instructor requires and what variations (if any) are required. For example, the lab instructor might prefer that the Procedures section be written in narrative style even for a formal report.

11.1 STANDARDIZED OUTLINE FOR INFORMAL APA-STYLE LAB REPORTS (i.e., INFORMAL REPORTS)

- Title Page
- 1.0 Introduction (in six [6] parts)
- 2.0 Procedures, in narrative style (in three [3] parts)
- 3.0 Results and Discussion (in four [4] parts)
- 4.0 Conclusions and Recommendations (in six [6] parts)
11.2 STANDARDIZED OUTLINE FOR FORMAL APA-STYLE LAB REPORTS (i.e., FORMAL REPORTS)

11.2.1 Front Matter

- Title Page
- Abstract
- Table of Contents
- List of Tables
- List of Figures (NOTE: The List of Tables and the List of Figures may be combined into a single List of Graphics as discussed in Section 12.2.6: List of Graphics.)
- List of Symbols
- List of Abbreviations/Acronyms

11.2.2 Body

- 1.0 Introduction (in six [6] parts)
- 2.0 Theory (in five [5] parts)
- 4.0 Results and Discussion (in four [4] parts)
- 5.0 Conclusions and Recommendations (in six [6] parts)

11.2.3 End Matter

- 6.0 References
- 7.0 Attributions
- 8.0 Appendix I: Sample Calculations
11.3 STANDARDIZED OUTLINE FOR AIAA-STYLE LAB REPORTS (i.e., AIAA-STYLE REPORTS)

- Title/Author Block (in two [2] parts)
- Abstract
- Nomenclature
- II. Procedures, in narrative style (in three [3] parts)
- III. Results and Discussion (in four [4] parts)
- Appendix (optional)
- Acknowledgements (optional)
- References
- Footnotes
12.0 DESCRIPTION OF LAB REPORTS BY SECTION

This section presents guidelines for the rhetorical, linguistic, and grammatical elements of each section of the three (3) types of Lab Reports included in this manual: informal reports, formal reports, and AIAA-style reports. Refer to Section 11.0: Standardized Outlines for Lab Reports for an overview of the sections required for each type of Lab Report. Note that a Lab Report format may be altered slightly if it represents the work of a group rather than an individual, or at the lab instructor’s direction.

12.1 Description of Informal Reports by Section

12.1.1 Title Page

- Provides the following information (as illustrated in Figure 12.1: Sample Title Page, Single Author on the next page and in Figure 12.8: Sample Title Page, Multiple Authors in Section 12.2.1: Title Page):
  - Lab number and title;
  - Date of lab and date of submission;
  - Author’s signature, name, and email address;
  - Submission Information (i.e., lab instructor’s name, department, and college);
  - Course number, course name, and current semester; and
  - University name and campus name.

- Centers all information on the page.

- Presents the lab number and title in bold, 18-point font, in capital letters.

- Presents all other information in non-bold, 12-point font, in capital and lower-case letters.

- Uses Times New Roman, Arial, or similar font throughout.

- Includes the name, signature, and contact information of each co-author (if more than one author is responsible for the document), with the author’s names listed alphabetically by last name.

Figure 12.1: Sample Title Page, Single Author exemplifies a title page layout commonly used at Embry-Riddle Aeronautical University, Prescott campus:
LAB REPORT 1:
IMPACT AND FRACTURE TESTS

Date of Lab Experiment:  September 1, 2011
Date of Submission: September 6, 2011

by

Mary Patricia James
Jamesmp1@erau.edu

Submitted to Dr. David Lanning
Department of Aeronautical Engineering
College of Engineering
In Partial Fulfillment
Of the Requirements
Of
ES 321
Engineering Materials Science Lab
Fall 2011

Embry-Riddle Aeronautical University
Prescott, Arizona

Figure 12.1: Sample Title Page, Single Author
As shown in the preceding figure, the title of the Title Page is differentiated from the rest of the information by bold, 18-point font that is in all caps.

12.1.2 Introduction

- Identifies the central research problem of the lab experiment and contextualizes this problem by citing relevant theoretical principles, equations, and published values or findings, as demonstrated in Figure 12.2: Sample Introduction for Informal Reports:

1.0 INTRODUCTION

When steel undergoes a phase transformation through the application of a heat treatment process, the resulting microstructure that is formed within the material contributes to the strength of the steel due to the presence of multiple phases within an alloy (Askeland, 2006).

Because most steels consist of more than one phase and because the boundary between the different phases impedes slip, the strength of steel can be modified depending upon the type of phases that are formed as a result of different heat treatment processes (Askeland, 2006). For this lab experiment, three steel specimens (i.e., 1018, 1045, and W1 tool steel) were examined.

Of these three specimens, 1018 steel has the lowest carbon content. That is, 1018 steel contains approximately 0.18 percent-weight carbon whereas 1045 and W1 tool steel contain approximately 0.45 and 1.1 percent-weight carbon, respectively (MatWeb, 2009). Because the carbon atoms within the iron matrix of the steels act as interstitial defects and because such defects impede slip, the resistance of these steels to plastic deformation (i.e., hardness) is increased with increasing concentrations of carbon (Callister, 2003).

The hardness of the steel is also dependent upon the amount of martensite that is present within the steel. Martensite is a metastable microstructure that is formed when steel is rapidly quenched in water from a temperature exceeding 1333 °F (i.e., the eutectoid transition temperature) to room temperature (Brooks, 1979). Because of the rapid nature of the cooling process, the carbon present within the steel alloy does not have a sufficient amount of time to diffuse into the iron matrix to produce pearlite, bainite, or spheroidite microstructures. As such, the martensite itself appears to be a form of ferrite that is supersaturated with

*Figure 12.2: Sample Introduction for Informal Reports*
(Source: Adapted from Akerson, 2009)
carbon. As the carbon concentration increases, so does the amount of martensite that will form within steels that have been subjected to a rapid cooling process (Brooks, 1979). Then, as the amount of martensite present within the steel increases, so does the hardness of the material (Brooks, 1979)....

However, steels containing large amounts of martensite are typically extremely brittle, thereby making such steels undesirable for most building applications. As such, steels containing large quantities of martensite are tempered to produce tempered martensite, which is less hard but also less brittle (Metallurgy, 2009). A plot of hardness versus carbon content for these steels is shown in Figure 1.1: Martensite Hardness vs. Carbon Content:

![Figure 1.1: Martensite Hardness vs. Carbon Content.](image)

(Source: Callister, 2003).

As is shown in the preceding figure, the hardness of steels containing tempered martensite is significantly lower than that of steels containing regular martensite. In addition, this figure also indicates that hardness of steels containing tempered martensite or regular martensite is higher than steels that contain pearlite.
Steels are typically subjected to five (5) types of heat treatments in materials labs:

1. Heated to 1800 °F for 35 minutes, then quenched in water;
2. Heated to 1800 °F for 35 minutes, quenched in water, reheated to 750 °F for 35 minutes, then quenched in water again;
3. Heated to 1800 °F for 35 minutes, then air-cooled in a ceramic cup;
4. Heated to 1280 °F for 18 hours, then oven-cooled to room temperature; and
5. Heated to 1800 °F for 35 minutes, then oven-cooled to room temperature.

Based upon previously published findings (Callister, 2003), the predicted microstructure of 1018, 1045, and W1 tool steel after undergoing each of these five (5) types of heat treatments varies, as summarized in Table 1.1: Predicted Microstructure for Steels:

<table>
<thead>
<tr>
<th>Heat Treatments</th>
<th>1018 Steel</th>
<th>1045 Steel</th>
<th>W1 Tool Steel</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type 1</td>
<td>Martensite</td>
<td>Martensite</td>
<td>Martensite</td>
</tr>
<tr>
<td>Type 2</td>
<td>Tempered Martensite</td>
<td>Tempered Martensite</td>
<td>Tempered Martensite</td>
</tr>
<tr>
<td>Type 3</td>
<td>Fine Pearlite</td>
<td>Pearlite and Bainite</td>
<td>Bainite</td>
</tr>
<tr>
<td>Type 4</td>
<td>Spheroidite</td>
<td>Spheroidite</td>
<td>Spheroidite</td>
</tr>
<tr>
<td>Type 5</td>
<td>Coarse Pearlite</td>
<td>Pearlite</td>
<td>Pearlite</td>
</tr>
</tbody>
</table>

Although the predicted microstructures listed in the preceding table are similar for steels subjected to the same heat treatment, the amount of microstructure that is formed will vary because of the microstructure’s dependence on the amount of available carbon present within each of the steels.

Figure 12.2: Sample Introduction for Informal Reports, cont’d
(Source: Adapted from Akerson, 2009)
Because steels containing martensite, tempered martensite, pearlite, or bainite tend to increase in hardness with increasing carbon content, the hardness of W1 tool steel should be higher than the hardness of and 1018 and 1045 steel when subjected to the same type of heat treatment. However, an examination of the microstructure and hardness of steels that have been subjected to different heat treatments is required in order to draw a correlation between microstructure, carbon content, and hardness and to test this prediction. Thus, the purpose of this lab experiment was to examine the microstructure and material properties associated with three (3) steels (i.e., 1018, 1045, and W1 tool steel) after the steels had been subjected to two (2) types of heat treatment: type 1 (i.e., heated to 1800 °F for 35 minutes, then quenched in water) and type 4 (i.e., heated to 1280 °F for 18 hours, then oven-cooled to room temperature).

In this report, the hardness and the observed microstructure of the steels that were subjected to these heat treatments are noted and data trends are identified and discussed.

**Figure 12.2: Sample Introduction for Informal Reports, cont’d**
(Source: Adapted from Akerson, 2009)

As demonstrated in the preceding figure, the Introduction offers a clear but concise theoretical context for the lab experiment so that the reader can readily identify key terminology, important concepts, previously published findings, and the purpose for undertaking the lab experiment.

While the Introduction to a formal report separates the Introduction (background and research question) from the Theory (important concepts and previously published findings), the Introduction to an informal report combines this information into a single section in as concise a manner as possible; this style of introduction is similar to that used in AIAA-style reports. Section 12.3.4: Introduction and Figure 12.27: Sample Introduction for AIAA-style Reports offer additional examples of this type of introduction.

- Has an *A-level heading* that is centered at the top of a new page, is aligned with the left margin, and is in bold, 16-point font, in all capital letters. The heading is enumerated (i.e., 1.0 Introduction), followed by one (1) blank line.

- Is written in *block format*, i.e., single-spaced with no indentations at the beginnings of paragraphs and with one extra space/blank line between paragraphs. 12-point Times New Roman or similar font is used. (See Section 3.2.2: Spacing.)
Cites relevant studies or publications using standard APA-style citation (e.g., “...as shown in previously published studies (Johns & Herferd, 2008)...”), with each citation referring to an entry in the References section (as per Section 12.1.6: References).

Uses APA standards for captioning and formatting equations (i.e., Equation 2.1 in the prose and Equation 1.0 in the caption line). Equation editor is used to write equations, and all terms are defined in the paragraph immediately following the equation. (See Section 8.3: Guidelines for Equations.)

Includes graphics as required (e.g., tables of previously published values), properly introduced in the prose, labeled, captioned, and commented upon. (See Section 8.0: General Guidelines for Graphics and Equations.)

Contains six (6) organizational sections: statement of the research topic, background information or theoretical context, justification, research problem or “gap,” purpose statement, and textual overview. These sections are not numbered, nor do they take subheadings; instead, they are written as a cohesive set of paragraphs (i.e., in prose).

Introduces the research topic—the scope of the report, or a technical definition of the object or concept being studied (as per Section 4.7: Technical Definitions).

Presents background information or theoretical context—what is known, which may include any and all of the following sub-elements:

- Technical definitions (as shown in Section 4.7: Technical Definitions) of key theoretical concepts and notions,
- Explanations of relevant theoretical principles,
- Expected results, typically stated as previously established or published values, and
- Data-reduction equations, consecutively numbered and followed by clearly defined variables as per Section 8.3: Guidelines for Equations.

Offers a justification—an explanation of why this research is central, crucial, or important:

States the research problem or “gap”—what is unknown or what needs to be tested. The gap is typically introduced with an adversative transition (e.g., “however” as per Section 4.8: Frequently Used Transitions):
Offers a **purpose statement** for the lab—the research question or hypothesis:

Provides a **textual overview**—including an outline of organizational scheme or comments on anything unusual or unexpected in the report in order to orient the reader to the organization of the Lab Report:

Is generally written in the *present* tense, although the *past* tense may be used when providing background information or historical context. (See Section 6.3: Verb Tenses.)

Optionally identifies the *location and date of the lab experiment*.

Optionally **acknowledges** anyone outside of the professor and fellow students who participated in the lab or offered their aid.

Provides a **transition** to the following section, the Procedures section, which begins on a new page.

### 12.1.3 Procedures

Summarizes the lab procedures using a narrative style. There are two (2) styles for writing Procedures sections: narrative and non-narrative. The latter is reserved for formal reports; however, **it is up to the author of the Lab Report to discover which style the lab instructor requires.**

**Narrative-style procedures** used in informal reports summarize the lab procedures in prose paragraphs, much like a story, clearly integrating the apparatus used into the narrative prose, as demonstrated in **Figure 12.3: Sample Narrative Procedures for Informal Reports:**
2.0 Procedures

The experiment was conducted on October 30, 2009. The set-up required a number of measurements and preparations. First, the mass of a metal projectile ball, measuring 1.5 cm in diameter, was measured using a metric scale and the mass was recorded in a lab journal. Second, the pendulum latch was lifted to ensure that it would not interfere with the experiment, and the projectile ball was properly seated on the frontal position of the mechanism by placing the ball, hole-end first, onto the rod-like mechanism. Third, the mechanism wascocked and placed in the locked position. Fourth, the perpendicular distance from the ball to the floor was measured using a metric tape measure and the distance was recorded in the lab journal.

Then, the experiment was conducted. For the preliminary trial, the trigger was pulled on the ballistic pendulum, which fired the projectile ball. When the ball was fired, the point of impact was visually noted, and the horizontal distance from the pendulum was measured using the measuring tape and noted in the lab journal. Then, an 8-in. by 11-in. sheet of carbon paper was placed, face down, at the point of impact and affixed to the floor with masking tape.

Next, the first experimental trial was undertaken; the ball was retrieved and reloaded into the pendulum, the mechanism was againcocked and locked, and the ball was fired using the trigger. The procedure was repeated and 10 total trials were undertaken. During each trail, the impact of the projectile ball left a carbon mark on the floor at the point of impact.…

Figure 12.3: Sample Narrative Procedures for Informal Reports

As demonstrated in the preceding figure, only critical apparatus are noted and are integrated into the procedures in flowing, coherent prose. Furthermore, the lab procedures are recounted in clear, chronological order with enumerative transitions to mark the order of the actions taken (e.g., first, second, third, then, next).

- Has an A-level heading that is centered at the top of a new page, is aligned with the left margin, and is in bold, 16-point font, in all capital letters. The heading is enumerated (i.e., 2.0 Procedures), followed by one (1) blank line.

- Is written in block format, i.e., single-spaced with no indentations at the beginnings of paragraphs and with one extra space/blank line between paragraphs. 12-point Times New Roman or similar font is used. (See Section 3.2.2: Spacing.)
Includes **graphics** as required (e.g., set-up, key apparatus, procedural details), properly introduced in the prose, labeled, captioned, and commented upon. (See Section 8.0: General Guidelines for Graphics and Equations.)

Contains three (3) organizational sections: set-up, experimental procedures and apparatus, and data collection and reduction. These sections are not numbered, nor do they take subheadings; instead, they are written as a cohesive set of paragraphs (i.e., in *prose*). (See Figure 12.3: Sample Narrative Procedures for Informal Reports on the preceding page.)

- Begins with the **set-up** of the lab experiment, including graphics as required, properly introduced in the prose and enumerated.

- Continues with a rich description of the **procedures** that were followed for completing the lab experiment, stated in chronological order. The procedures are integrated with detailed descriptions of **equipment and instrumentation**, including the material comprising the specimen to be studied, the dimensions of the specimen, and the locations of sensors or actuators.

- Ends with the procedures for **data collection and reduction**. This segment provides the data-reduction equations, introducing them in prose, defining their variables, and numbering them consecutively.

- Is written in the author’s own words, even if a set of instructions has been given for the experiment.

- Is written in **chronological order**, using enumerative or numbering transitions such as “first, second, third” or “first, next, then, finally” to mark procedural order. (See Section 4.8: Frequently Used Transitions.)

- Is written in **passive voice, indicative mood**, and **past tense**. (See Section 5.1: Voice, Section 5.2: Mood, and Section 6.3: Verb Tenses.)

- Provides a **transition** to the following section, the Results and Discussion section, which begins on a new page.

**12.1.4 Results and Discussion**

- Presents the key findings, compares the findings to published values, and identifies trends, as demonstrated in Figure 12.4: Sample Results and Discussion for Informal Reports.
3.0 Results and Discussion

Table 3.4: Vickers Hardness Results of Spheroidite and Martensite Microstructures indicates how the hardness data as achieved by this lab experiment compare with the predicted hardness as described in Section 1.0: Introduction:

Table 3.4: Vickers Hardness Results of Spheroidite and Martensite Microstructures.

<table>
<thead>
<tr>
<th>Steel Type / Microstructure</th>
<th>Estimated Spheroidite Hardness Range (HV)</th>
<th>Experimental Spheroidite Hardness (0.5HV)</th>
<th>Estimated Martensite Hardness Range (HV)</th>
<th>Experimental Martensite Hardness (HV)</th>
<th>Comparison (Spheroidite / Martensite)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1018 (Theoretical 1019)</td>
<td>150 - 213</td>
<td>105</td>
<td>238 - 412</td>
<td>327</td>
<td>30% within lower limit / Within Range</td>
</tr>
<tr>
<td>1045</td>
<td>230 - 238</td>
<td>136</td>
<td>513 - 697</td>
<td>469</td>
<td>41% within lower limit / 9.0% within lower limit</td>
</tr>
<tr>
<td>W1</td>
<td>274 - 279</td>
<td>159</td>
<td>746 - 832</td>
<td>523</td>
<td>42% within lower limit / 30% within lower limit</td>
</tr>
</tbody>
</table>

The last column of the preceding table comments on whether the experimentally achieved values of hardness fall within the predicted range or, if not, what the percentage difference between the nearest range limit and the experimental hardness value is. The following trends are apparent:

1. Most theoretical hardness data ranges do not encompass the experimental data. The percentage differences show moderate to poor agreement between the experimental and predicted results.

Figure 12.4: Sample Results and Discussion for Informal Reports
(Source: Adapted from Iyer, 2009)
2. Spheroidite steels are affirmed to have very low hardness values, i.e., they have a “soft” structure as predicted in noted in the review of theoretical principles stated in Section 1.0: Introduction. Similarly, martensite steel exhibit very large values of hardness.

3. A consistent increase in hardness (theoretical and experimental) is apparent with an increase in the steel’s carbon content for both the spheroidite and martensite microconstituents. For example, the hardness of W1 (1.01% C) steel’s hardness is greater than that of 1045 (0.45% C) steel, which in turn is greater than that of 1018 (0.18% C) steel for both the spheroidite and martensite categories. This trend is in compliance with the theoretical prediction that an increase in the carbon content in steel contributes to the steel’s hardness.

4. The hardness of steel with the martensite microconstituent is greater than that for the steel comprised of the spheroidite microconstituent for all three types of steel (1018, 1045 and W1). This finding matches the theoretical prediction as described in Section 1.0: Introduction and reaffirms trend 2 described above.

An examination of Table 3.4: Vickers Hardness Results of Spheroidite and Martensite Microstructures indicates that the experimental value for martensite for 1045 steel is only with 9% of the theoretically established lower limit. There are several possible explanations for this unexpected result. First, there is the possibility of a mismatch between the steels selected for the historical experiments and for the experiment undertaken as part of this materials lab. Second, the tempering process for the 1045 steel may have been slightly faulty as a new set of lab partners who were not practiced at tempering joined the lab team during the tempering of the 1045 steel….

---

**Figure 12.4: Sample Results and Discussion for Informal Reports, cont’d**

(Source: Adapted from Iyer, 2009)

As demonstrated in the preceding figure, results are presented in graphic form and through data commentary; unexpected findings are identified and rationales or explanations are offered.

- Has an *A-level heading* that is centered at the top of a new page, is aligned with the left margin, and is in bold, 16-point font, in all capital letters. The heading is enumerated (i.e., 3.0 Results and Discussion), followed by one (1) blank line.
o Is written in block format, i.e., single-spaced with no indentations at the beginnings of paragraphs and with one extra space/blank line between paragraphs. 12-point Times New Roman or similar font is used. (See Section 3.2.2: Spacing.)

o Includes graphics as required (e.g., data charts or data tables), properly introduced in the prose, labeled, captioned, and commented upon. (See Section 8.0: General Guidelines for Graphics and Equations.)

o Contains four (4) organizational sections: presentation of data in graphic form, data commentary comparing achieved to expected results, identification of trends, and explanation of any unexpected results.

  o Presents data in graphic form; these results are properly introduced with a paragraph or two of prose and are properly placed, captioned, and commented upon. (See Section 8.0: General Guidelines for Graphics and Equations.)

  o Follows data presentation with data commentary that evaluates or compares the achieved results or acquired data to the expected results as had been stated in the background of the Introduction section (i.e., Section 1.0 of the Lab Report).

  o Identifies trends in the data and interprets their meaning in the context of the lab experiment; the achieved results are shown to be evidence of a key principle or concept or behavior.

  o Explains any unexpected results; moreover, possible reasons for any discrepancy between the achieved results and the expected results (including error analysis as applicable) are discussed.

o Avoids data dumping (i.e., tables or figures that are not followed by prose that discusses the important information presented in the tables and figures). (See Section 8.2: Avoidance of Data Dumping for advice.)

o Is written in the present tense. (See Section 6.3: Verb Tenses.)

o Uses adequate qualifying/hedging words and phrases throughout so as to not make an overly strong claim. (See Section 7.4: Qualification.)

o Provides a transition to the following section, the Conclusions and Recommendations section, which begins on a new page.

12.1.5 Conclusions and Recommendations

  o Summarizes the purpose and findings of the lab, as demonstrated in Figure 12.5: Sample Conclusions and Recommendations for Informal Reports:
4.0 CONCLUSIONS AND RECOMMENDATIONS

This experiment was conducted to determine how two (2) different heat treatments affect the microscopy results and hardness values for three (3) types of steel: 1018, 1045, and W1 tool steel. Also investigated was the change in the characteristics of these types of steel based upon the resulting changes in carbon content after tempering.

This investigation used two (2) types of heat treatments: heating and then water-quenching, and heating and then oven-cooling. After treatment, samples of each type of steel were then mounted, polished, and observed under a metallographic microscope. Finally, the hardness of the steel specimens was determined using a Vickers hardness tester.

Results of the microscopy indicate the formation of dense areas of needles in the tempered martensite’s microscopy and of spheres in the spheroidite’s microscopy. Results of the Vickers hardness test indicate that the tempered steel specimens are harder than the spheroidite steel specimens, due to the different heat treatments that each specimen received. The achieved values for these two (2) types of specimens match the theoretical values. These theoretical values, however, are drawn from older sources and lack accuracy, as noted in Section 3.0: Results. In conclusion, this lab has demonstrated that as the carbon content of steel increases so does its hardness, as theoretically predicted.

As in most experiments, there were limitations to this heat treatment experiment. As previously stated, the accuracy of the hardness values drawn from published sources is low. The accuracy would be improved if more recently published values were used. Additionally, the process of etching the specimens was challenging, and sometimes produced an unfavorable specimen for microscopy.

More favorable specimens would be achieved more frequently if less abrasive chemicals were to be used that take longer to etch the specimen, allowing the conductor more reaction time before the specimen is over-etched. Finally, the time between the removal of a steel specimen from the oven and its quenching was sometimes excessive, and production of the proper microstructure could not be produced. This time would be significantly reduced if an elaborate oven that drops the specimen straight in water through a door in the bottom of the oven were to be designed and fabricated.

Figure 12.5: Sample Conclusions and Recommendations for Informal Reports
(Source: Adapted from Rodriguez, 2009)
As illustrated in the preceding figure, limitations and recommendations are also presented in this section, as noted in following bullets.

- Has an *A-level heading* that is centered at the top of a new page, is aligned with the left margin, and is in bold, 16-point font, in all capital letters. The heading is enumerated (i.e., 4.0 Conclusions and Recommendations), followed by one (1) blank line.

- Is written in *block format*, i.e., single-spaced with no indentations at the beginnings of paragraphs and with one extra space/blank line between paragraphs. 12-point Times New Roman or similar font is used. (See Section 3.2.2: Spacing.)

- Includes *graphics* as required (e.g., summary tables or error analysis graphs), properly introduced in the prose, labeled, captioned, and commented upon. (See Section 8.0: General Guidelines for Graphics and Equations.)

- Includes six (6) elements: a restatement of the *purpose* of the lab, a very brief summary of the Procedures section, a summary of the Results section, a statement of the primary conclusions which can be drawn from the Results, the *limitations* of the lab/ problems encountered during the lab Procedures, and recommendations for overcoming each of the flaws.

- Provides no new results; all results, including data commentary, trends, and unexpected results, have been previously stated in the Results section.

- Provides a critique of the lab experiment through a statement of limitations and recommendations:
  
  - Offers one or two limitations of the experiment, typically in terms of the resources available or the procedures followed. Limitations must be specific in scope and reasonable in tone. Pointing out a restriction that cannot be addressed is of little value; stating problems that can be feasibly and reasonably addressed are of greater value.

  - Pairs each limitation with at least one recommendation for improving the lab experiment. Each recommendation must directly address the limitation it is paired with. Recommendations must be specific, feasible, and stated using an *unreal conditional* of the grammatical form “AA would have been BB if XX had been YY.”

  - Each limitation must be stated BEFORE its recommendation, so that each limitation statement and recommendation statement forms a matched pair; thus, if there are multiple limitations/recommendations, the order of presentation is as follows:
Even if only one (1) limitation and recommendation pairing is offered, the limitation must still be stated before the recommendation.

- Uses adequate *qualifying/hedging* words and phrases so as to not make overly strong claims. (See Section 7.4: Qualification.)

- Is written in the *present* tense. (See Section 6.3: Verb Tenses.)

**12.1.6 References**

- Lists sources that were cited in the body of the paper, as demonstrated in Figure 12.6: Sample References for All APA-style Lab Reports:

---

**5.0 REFERENCES**


---

**Figure 12.6: Sample References for All APA-style Lab Reports**
As demonstrated in the preceding figure, cited sources may include unpublished documents, class documents, and personal communications.

- Has an *A-level heading* that is centered at the top of a new page, is aligned with the left margin, and is in bold, 16-point font, in all capital letters. The heading is enumerated (i.e., 5.0 References), followed by one (1) blank line.

- Single-spaces each citation, with a *hanging indent*, and double-spaces between citations. 12-point Times New Roman or similar font is used. (See Section 9.4: APA Standards.)

- Is formatted according to standard APA citation rules (i.e., author, date of publication, title, place of publication, publisher’s name). (See Section 9.3.1: Guidelines for Formatting APA-style References and Section 9.4: APA Standards.)

- Lists all sources in alphabetical order.

### 12.1.7 Attributions

- Identifies which individual members of a group or team are responsible for different tasks, as shown in Figure 12.7: Sample Attributions for All APA-style Lab Reports:

#### 6.0 ATTRIBUTIONS

<table>
<thead>
<tr>
<th>Task</th>
<th>Participant</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tempering of all steel specimens</td>
<td>Mary Patricia James</td>
</tr>
<tr>
<td>Grinding, polishing, and mounting of specimens</td>
<td>T.S. Keynes</td>
</tr>
<tr>
<td>Conducting Vickers hardness tests</td>
<td>Scott Wells</td>
</tr>
<tr>
<td>Metallography</td>
<td>Logan Runner</td>
</tr>
</tbody>
</table>

**Figure 12.7: Sample Attributions for All APA-style Lab Reports**

As shown in the preceding figure, the individual members of the group or team are listed in a two-column form besides the tasks that they accomplished.
- Has an *A-level heading* that is centered at the top of a new page, is aligned with the left margin, and is in bold, 16-point font, in all capital letters. The heading is enumerated (i.e., 6.0 Attributions), followed by one (1) blank line.

- Lists team members and their assigned tasks in a formal two-column table.
12.2 Description of Formal Reports by Section

12.2.1 Title Page

- Provides the following information (as illustrated in Figure 12.8: Sample Title Page, Multiple Authors on the next page and in Figure 12.1: Sample Title Page, Single Author in Section 12.1.1: Title Page):
  - Lab number and title;
  - Date of lab and date of submission;
  - Author’s signature, name, and email address;
  - Submission Information (i.e., lab instructor’s name, department, and college);
  - Course number, course name, and current semester; and
  - University name and campus name.
- Centers all information on the page.
- Presents the lab number and title in bold, 18-point font, in capital letters.
- Presents all other information in non-bold, 12-point font, in capital and lower-case letters.
- Uses Times New Roman, Arial, or similar font throughout.
- Includes the name, signature, and contact information of each co-author (if more than one author is responsible for the document), with the author’s names listed alphabetically by last name.

Figure 12.8: Sample Title Page, Multiple Authors is presented on the following page:
LAB REPORT 2:
EXPERIMENTAL AERODYNAMICS

Date of Lab Experiment: October 10, 2011
Date of Submission: October 15, 2011

by

Mary Patricia James
Jamesmp1@erau.edu

John Mann
Mann123@erau.edu

Jane Wyman
Wymanj@erau.edu

Submitted to Dr. Lance Traub
Department of Aeronautical Engineering
College of Engineering
In Partial Fulfillment
Of the Requirements
Of
AE 315
Experimental Aerodynamics Lab
Fall 2011

Embry-Riddle Aeronautical University
Prescott, Arizona

Figure 12.8: Sample Title Page, Multiple Authors
Of note in the preceding figure are the multiple authors listed vertically and alphabetized by last name; each author has his/her own signature line. If there are six (6) or more authors, authors and their signature lines may be listed in a two-column format to conserve space; if there are ten (10) or more authors, authors and their signature lines may be listed on a separate signature page that immediately follows the Title Page.

This signature page is identical in format to the Title Page and contains the following information:

- Date of lab and date of submission;
- Authors’ signatures, names, and email addresses;
- Course number, course name, and current semester; and
- University name and campus name.

Separate signature pages are more commonly used in capstone courses than in lab courses, but they are an option.

**12.2.2 Abstract**

- Condenses the Introduction, the Procedures, the Results, and the Conclusions and Recommendations sections and also provides a textual overview (see Section 4.4.4: Informative Abstracts); that is, it delineates the purpose and scope of the lab, reports on the methods used, discusses the lab results, and notes limitations and recommendations before outlining the structure of the report, as shown in Figure 12.9: Sample Abstract for Formal Reports:
ABSTRACT

The purpose of this experiment was to establish a correlation between the hardness of heat-treated steels, the microconstituents of the steels, and the carbon content of the steels.

Three (3) different steel alloys, i.e., 1018, 1045, and W1 were chosen for this study. Specimens for each of these types of steel were divided into two (2) groups, and each group was subjected to a different type of heat treatment. The first group of each type of steel was subject to heating to above the eutectoid temperature.

This heating phase was followed by rapid quenching in water followed by another phase of tempering heat treatment. The second group of each type of steel was subject to slow oven-heating to a temperature just below the eutectoid temperature. This phase was followed by gradual oven-cooling.

The different steel specimens were then cast into molds of a phenolic substance, ground, polished and etched to facilitate metallographic imaging. The molds were viewed under the metallographic microscope and the microstructure was noted. Vickers hardness tests were also performed on each individual specimen with a 0.5-kg load over a time period of fifteen seconds.

It was found that the martensite microconstituent showed smaller grain size and larger hardness values when compared to the spheroidite microstructure. It was further noted that the alloys with higher carbon content had generally higher values of hardness when compared to those of lower carbon content.

While the achieved values matched the theoretically predicted values, the match was less accurate than desirable. The accuracy would be improved if more recently published theoretical data were to be used for baseline predictions.

This report summarizes relevant theoretical concepts and tabulates findings from published sources. The lab methodology is articulated, achieved results are compared to theoretical values, and trends are identified. Finally, limitations are noted and recommendations offered for improving future iterations of the lab.

Figure 12.9: Sample Abstract for Formal Reports
(Source: Adapted from Iyer, 2009)

As the previous figure illustrates, an Abstract clearly and concisely summarizes all work accomplished and reports the achieved results. All sections from the body of the Lab Report are represented in a balanced
manner so that no one section is over-represented or under-represented. (See Section 4.4: Abstracts.)

- Has an A-level heading that is centered at the top of a new page and is typed in bold, 16-point font, in all capital letters. The heading is not numbered and is followed by one (1) blank line.

- Is written in block format, i.e., single-spaced with no indentations at the beginnings of paragraphs and with one extra space/blank line between paragraphs. 12-point Times New Roman or similar font is used. (See Section 3.2.2: Spacing.)

- Is typically no longer than 250 words or 2/3 of a page.

- Is an informative Abstract rather than a descriptive Abstract; as such, it contains a broader scope of information and a greater amount of detail than a descriptive Abstract. (See Section 4.4.4: Informative Abstracts.)

- Ends with a textual overview, i.e., an outline of the organizational structure of the Lab Report, telling the reader what type of information to expect in the forthcoming text (e.g., a lengthy theory section or multiple hypotheses). The textual overview often reads like a Table of Contents in sentence format.

- Has sentences which summarize the work done (i.e., Apparatus/Procedures) written in past tense.

- Has all other sentences written in the present tense. (See Section 6.3: Verb Tenses.)

**12.2.3 Table of Contents**

- Has an A-level heading that is centered at the top of a new page and is typed in bold, 16-point font, in all capital letters. The heading is not numbered and is followed by one (1) blank line, as shown in Figure 12.10: Sample Table of Contents for Formal Reports.
# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abstract</td>
<td>i</td>
</tr>
<tr>
<td>List of Tables</td>
<td>ii</td>
</tr>
<tr>
<td>List of Figures</td>
<td>iii</td>
</tr>
<tr>
<td>List of Symbols</td>
<td>iv</td>
</tr>
<tr>
<td>List of Abbreviations/Acronyms</td>
<td>v</td>
</tr>
<tr>
<td>1.0 Introduction</td>
<td>1</td>
</tr>
<tr>
<td>2.0 Theory</td>
<td>2</td>
</tr>
<tr>
<td>3.0 Apparatus and Procedures</td>
<td>6</td>
</tr>
<tr>
<td>3.1 Apparatus</td>
<td>6</td>
</tr>
<tr>
<td>3.2 Procedures</td>
<td>6</td>
</tr>
<tr>
<td>3.2.1 Phase 1</td>
<td>6</td>
</tr>
<tr>
<td>3.2.2 Phase 2</td>
<td>7</td>
</tr>
<tr>
<td>4.0 Results and Discussion</td>
<td>8</td>
</tr>
<tr>
<td>5.0 Conclusions and Recommendations</td>
<td>10</td>
</tr>
<tr>
<td>6.0 References</td>
<td>11</td>
</tr>
<tr>
<td>7.0 Appendix I: Sample Calculations</td>
<td>12</td>
</tr>
<tr>
<td>8.0 Appendix II: Raw Data</td>
<td>13</td>
</tr>
</tbody>
</table>

---

**Figure 12.10: Sample Table of Contents for Formal Reports**

As shown in the preceding figure, the Table of Contents does NOT list the Table of Contents itself. This type of tables can be automatically formatted as per the instructions stated in **Section 10.0: Use of Software**.
o Lists all sections and subsections which have A-level (primary), B-level (secondary), or C-level (tertiary) headings, including front matter and appendices. (See Figure 12.10: Sample Table of Contents for Formal Reports and Section 3.5: Headings and Sub-headings.)

o Lists each of these sections in order with their corresponding page number.

o Includes the section number (e.g., 3.0) of each section and subsection.

o Is single-spaced within entries and is double-spaced between entries.

o Visually demarcates the subsections (B-level headings) with tabs or indents. For example, in Figure 12.10: Sample Table of Contents for Formal Reports, Section 3.0 is flush with the left margin while Section 3.1 is indented one tab (five spaces) and Section 3.1.1 is indented two tabs (ten spaces).

o Capitalizes each word in the titles and subtitles of each section and subsection, except for conjunctions and prepositions (e.g., “and” or “in”).

o Places the page numbers in perfect vertical alignment.

o Introduces each entry in the same order in which it appears in the Lab Report.

12.2.4 List of Tables

o Has an A-level heading that is centered at the top of a new page and is typed in bold, 16-point font, in all capital letters. The heading is not numbered and is followed by one (1) blank line, as shown in Figure 12.11: Sample List of Tables for Formal Reports:

<table>
<thead>
<tr>
<th>LIST OF TABLES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Table 2.1: Specimen Hardness Data</td>
</tr>
<tr>
<td>Table 2.2: Specimen Impact Energy Data</td>
</tr>
<tr>
<td>Table 4.1: Impact Energy vs. Temperature</td>
</tr>
</tbody>
</table>

Figure 12.11: Sample List of Tables for Formal Reports
As with a Table of Contents, a List of Tables such as the one illustrated in the preceding figure can be automatically formatted; see the instructions stated in Section 10.0: Use of Software.

- Contains a minimum of three (3) tables in the List. Note that if there are fewer than three tables, then tables may be combined with figures into a List of Graphics as described in Section 3.2.6: List of Graphics.
- Lists each table in order with their corresponding page number.
- Is single-spaced within entries and is double-spaced between entries.
- Includes the number of each table (e.g., Table 3.2, which refers to the second table in the third section of the Lab Report).
- Includes descriptive titles for each of the tables.
- Capitalizes each word in the names of the tables, except for conjunctions and prepositions (e.g., “and” or “in”).
- Places the page numbers in perfect vertical alignment along the right margin.
- Introduces each entry in the same order in which it appears in the Lab Report.

12.2.5 List of Figures

- Has an A-level heading that is centered at the top of a new page and is typed in bold, 16-point font, in all capital letters. The heading is not numbered and is followed by one (1) blank line, as shown in Figure 12.12: Sample List of Figures for Formal Reports:

```
LIST OF FIGURES

Figure 2.1 Sample Impact Energy vs. Temperature Plot ........ 13
Figure 3.1 Rockwell Hardness Tester ........................................... 26
Figure 3.2 Stereomicroscope ....................................................... 27
```

Figure 12.12: Sample List of Figures for Formal Reports
As with a Table of Contents and a List of Tables, a List of Figures can be automatically formatted; see the instructions stated in Section 10.0: Use of Software.

- Contains a minimum of three (3) figures in the List. Note that if there are fewer than three (3) figures, then the figures may be combined with the tables into a List of Graphics, as discussed in Section 3.2.6: List of Graphics.
- Lists each figure in order with their corresponding page number.
- Is single-spaced within entries and is double-spaced between entries.
- Includes the number of each figure (e.g., Figure 4.1, which refers to the first figure in the fourth section of the Lab Report).
- Includes descriptive titles for each of the figures.
- Capitalizes each word in the titles of the figures/graphics, except for conjunctions and prepositions (e.g., “and” or “in”).
- Places the page numbers in perfect vertical alignment.
- Introduces each entry in the same order in which it appears in the Lab Report.

12.2.6 List of Graphics

- Combines a List of Tables and a List of figures when there are fewer than three (3) tables and/or three (3) figures; as such, it replaces a List of Tables and List of Figures in a lab report, as shown in Figure 12.13: Sample List of Graphics for Formal Reports:

---

**LIST OF GRAPHICS**

<table>
<thead>
<tr>
<th>Table/Figure</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Table 2.1: Specimen Hardness Data</td>
<td>……………………………</td>
<td>14</td>
</tr>
<tr>
<td>Figure 3.1 Drawing of a Test Specimen</td>
<td>……………………………</td>
<td>24</td>
</tr>
<tr>
<td>Figure 3.2 Charpy Impact Tester</td>
<td>……………………………</td>
<td>24</td>
</tr>
<tr>
<td>Figure 3.3 Rockwell Hardness Tester</td>
<td>……………………………</td>
<td>26</td>
</tr>
<tr>
<td>Table 4.1: Impact Energy vs. Temperature</td>
<td>…………………………</td>
<td>35</td>
</tr>
</tbody>
</table>

---

*Figure 12.13: Sample List of Graphics for Formal Reports*
In Figure 12.13: Sample List of Graphics, only two (2) tables are present in this sample, which is insufficient for a separate List of Tables, and so the tables and figures have been combined into a List of Graphics.

- Has an A-level heading that is centered at the top of a new page and is typed in bold, 16-point font, in all capital letters. The heading is not numbered and is followed by one (1) blank line, as shown in the preceding figure.

- As with other lists, a List of Graphics can be automatically formatted; see the instructions stated in Section 10.0: Use of Software.

- Contains a minimum of three (3) total figures and/or tables in the List. Note that if there is a total of fewer than three (3) figures and/or tables in the lab report, then NO LIST is included in the front matter of a formal report.

- Lists each figure or table in order with their corresponding page number.

- Is single-spaced within entries and is double-spaced between entries.

- Includes the number of each figure and table (e.g., Figure 4.4, which refers to the fourth figure in the fourth section of the Lab Report).

- Includes descriptive titles for each of the figures and tables.

- Capitalizes each word in the titles of the figures and tables, except for conjunctions and prepositions (e.g., “and” or “in”).

- Places the page numbers in perfect vertical alignment.

- Introduces each entry in the same order in which it appears in the Lab Report.

12.2.7 List of Symbols

- Has an A-level heading that is centered at the top of a new page and is typed in bold, 16-point font, in all capital letters. The heading is not numbered and is followed by one (1) blank line, as shown in the Figure 12.14: Sample List of Symbols for Formal Reports:
# LIST OF SYMBOLS

## Primary Symbols

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>AR</td>
<td>Aspect Ratio</td>
</tr>
<tr>
<td>C</td>
<td>Coefficient</td>
</tr>
<tr>
<td>D</td>
<td>Drag Force</td>
</tr>
<tr>
<td>E</td>
<td>Young’s Modulus</td>
</tr>
<tr>
<td>F</td>
<td>Stress</td>
</tr>
<tr>
<td>G</td>
<td>Shear Modulus</td>
</tr>
<tr>
<td>S</td>
<td>Planform Area</td>
</tr>
<tr>
<td>V</td>
<td>Shear Force</td>
</tr>
<tr>
<td>ds</td>
<td>Length Along the Centerline Between Spars</td>
</tr>
<tr>
<td>dθ/dZ</td>
<td>Rate of Twist</td>
</tr>
<tr>
<td>e</td>
<td>Oswald’s Efficiency Factor</td>
</tr>
<tr>
<td>n</td>
<td>Load Factor</td>
</tr>
<tr>
<td>q</td>
<td>Dynamic Pressure</td>
</tr>
<tr>
<td>q</td>
<td>Shear Flow</td>
</tr>
<tr>
<td>α</td>
<td>Angle of Attack</td>
</tr>
<tr>
<td>β</td>
<td>Milling Machine Head-angle</td>
</tr>
<tr>
<td>ε</td>
<td>Strain</td>
</tr>
<tr>
<td>σ</td>
<td>Axial Stress</td>
</tr>
<tr>
<td>ι</td>
<td>Shear Stress</td>
</tr>
</tbody>
</table>

## Subscript Symbols

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Maneuvering</td>
</tr>
<tr>
<td>C</td>
<td>Minimum Cruise</td>
</tr>
<tr>
<td>CL</td>
<td>Coefficient of Lift</td>
</tr>
<tr>
<td>D</td>
<td>Drag</td>
</tr>
<tr>
<td>L</td>
<td>Lift</td>
</tr>
<tr>
<td>SU</td>
<td>Ultimate Stress</td>
</tr>
<tr>
<td>TU</td>
<td>Ultimate Tensile Stress</td>
</tr>
<tr>
<td>b</td>
<td>Bending</td>
</tr>
<tr>
<td>cc</td>
<td>Critical Crippling Stress</td>
</tr>
<tr>
<td>cr</td>
<td>Critical Buckling Stress</td>
</tr>
<tr>
<td>o</td>
<td>Airfoil Lift Curve Slope</td>
</tr>
</tbody>
</table>

---

Figure 12.14: Sample List of Symbols for Formal Reports  
(Source: Adapted from Celerity, 2005)
As shown in the preceding figure, a List of Symbols is organized with primary symbols grouped together first, then subscripts, then superscripts (if there are any). Within these groups the symbols are alphabetized according to the scheme described in the following bullets:

- Has three (3) columns:
  - A list of symbols,
  - A list of the names or definition of each symbol, and
  - A list of the units by which each is measured. Symbols that do not require units of measure have “n/a” or a dash in this third column.

- Includes up to three (3) sub-sections as needed:
  - Primary symbols, alphabetized by
    - English upper case first, then
    - English lower case, then
    - Greek upper case, and finally
    - Greek lower case.
  - Subscript symbols (as needed), alphabetized by
    - English upper case first, then
    - English lower case, then
    - Greek upper case, and finally
    - Greek lower case.
  - Superscript symbols (as needed), alphabetized by
    - English upper case first, then
    - English lower case, then
    - Greek upper case, and finally
    - Greek lower case.

July 26, 2011
**12.2.8 List of Abbreviations/Acronyms**

- Has an *A-level heading* that is centered at the top of a new page and is typed in bold, 16-point font, in all capital letters. The heading is not numbered and is followed by one (1) blank line, as shown in **Figure 12.15: Sample List of Abbreviations/Acronyms for Formal Reports**:

**LIST OF ABBREVIATIONS/ACRONYMS**

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>AAA</td>
<td>Anti-Air Artillery</td>
</tr>
<tr>
<td>BFL</td>
<td>Balance Field Length (ft)</td>
</tr>
<tr>
<td>CDRL</td>
<td>Contract Data Requirement List</td>
</tr>
<tr>
<td>FEM</td>
<td>Finite Element Method</td>
</tr>
<tr>
<td>MANPADS</td>
<td>Man-Portable Air Defense System</td>
</tr>
<tr>
<td>RFP</td>
<td>Request for Proposal</td>
</tr>
<tr>
<td>(W_{TOMAX})</td>
<td>Maximum Take-off Weight (lb)</td>
</tr>
</tbody>
</table>

**Figure 12.15: Sample List of Abbreviations/Acronyms for Formal Reports**

As the preceding figure indicates, a List of Abbreviations/Acronyms does **NOT** include standard abbreviations (e.g., USAF, in., ft).

- Lists non-standard abbreviations along with the spelled-out names or phrases that they represent.

- Places the abbreviations flush with the left margin.

- Places the spelled-out names or phrases center on the page.

- Is single-spaced between all entries.

- Capitalizes each word of the spelled-out names or phrases for each abbreviation except for prepositions (e.g., in, of, for).

- Includes the units of measure in a third column, flush with the right margin, as necessary, as shown in the preceding figure. Note that if none of the abbreviations take units of measure, then no third column is necessary.
12.2.9 Introduction

- Identifies the central research problem of the lab experiment and contextualizes this problem by citing relevant theoretical principles, equations, and published values or findings, as demonstrated in Figure 12.16: Sample Introduction for Formal Reports:

1.0 INTRODUCTION

A “bug” is a coding error in a computer program that causes the program to malfunction. Software programmers frequently refer to “bugs in the equipment” or “working the bugs out.” Such terms were in use as early as Edison’s time. Since then, the “bug” has morphed into the dreaded computer virus. As many as 600 new viruses arose last year (Jacobs, 2003), many that were tailored by hackers to be slipped through anti-virus programs.

The loss to American businesses due to downloaded viruses last year alone has been estimated in the billions of dollar (Zeister, 2003). In response, many companies are creating new anti-virus software. However, few anti-virus programs are capable of screening out one of the most dangerous viruses, the “worm.” The purpose of this lab, then, is to test the first version of an anti-worm program jointly developed by faculty and staff of the College of Engineering at Embry-Riddle Aeronautical University. This anti-worm program has been dubbed “Fishhook.”

In this report, the development of the Fishhook program is recounted, results of the alpha and beta testing of Fishhook are summarized, and the resultant program changes are identified. The potential market for this program is also discussed in the Conclusions and Recommendations section.

Figure 12.16: Sample Introduction for Formal Reports

While the Introduction sections for both informal and formal reports cover critical concepts such as background, research question, and previously published findings into a single section, the Introduction to a formal report separates this information into two (2) sections, the Introduction and the Theory, allowing for a longer discussion of key concepts and a richer exploration of the problem than is typically desired in an informal report. (See Section 12.2.10: Theory.)

- Has an A-level heading that is located at the top of a new page, is aligned with the left margin, and is typed in bold, 16-point font, in all capital letters. The
heading is numbered (i.e., 1.0 Introduction) and is followed by one (1) blank line.

- Is written in *block format*, i.e., single-spaced with no indentations at the beginnings of paragraphs and with one extra space/blank line between paragraphs. 12-point Times New Roman or similar font is used. (See Section 3.2.2: Spacing.)

- Rarely includes any *graphics*; any graphics that are included must be properly introduced in the prose, labeled, captioned, and commented upon. (See Section 8.0: General Guidelines for Graphics and Equations.)

- Contains six (6) organizational sections: statement of the research topic, background information, justification, research problem or “gap,” purpose statement, and textual overview. These sections are not numbered, nor do they take subheadings; instead, they are written as a cohesive set of paragraphs (i.e., in prose). The overarching goal is to identify the research problem, i.e., to state the objective of the lab experiment.

  - Introduces the **research topic**—the scope of the report, or a technical definition of the object or concept being studied (as per Section 4.7: Technical Definitions).

  - Presents **background information** or context—what is known, which in informal lab reports includes previously established or **published values**.

  - Offers a **justification**—an explanation of why this research is central, crucial, or important.

  - States the **research problem** or “gap”—what is unknown or what needs to be tested. The gap is typically introduced with an adverative transition (e.g., “however” as per Section 4.8: Frequently Used Transitions).

  - Offers a **purpose statement** for the lab—the research question or hypothesis.

  - Provides a **textual overview**—including an outline of organizational scheme or comments on anything unusual or unexpected in the report in order to orient the reader to the organization of the Lab Report.

These organizational sections are commonly in a wide variety of technical introductions, not only in Lab Reports, and as such are a very useful way to begin almost any technical document.
Occasionally moves the justification until after the purpose statement, or sometimes until after the textual overview, depending upon where the justification seems to fit most logically and where it provides the Introduction with the greatest amount of coherence or flow.

Optionally identifies the location and date of the lab experiment.

Optionally acknowledges anyone outside of the professor and fellow students who participated in the lab or offered their aid.

Is generally written in the present tense, although the past tense may be used when providing background information or historical context. (See Section 6.3 Verb Tenses.)

Provides a transition to the following section, the Theory section, which begins on a new page.

12.2.10 Theory

Provides a rich exploration of the background of the research problem, defining terms, identifying equations, and noting previously published research projects, findings, and values, as noted in Figure 12.17: Sample Theory for Formal Reports:
2.0 THEORY

The hardness and tensile strength of steel is largely determined by the amount of carbon formed in the steel. However, increasing the carbon content can also cause the steel to lose ductility (Furness, 2009). Figure 2.1: Effects of Carbon Content on Steel illustrates the change in the properties of steel as the amount of carbon is increased:

![Figure 2.1: Effects of Carbon Content on Steel](source: AoZ Materials, 2009)

As seen in the preceding figure, the tensile strength of the steel is increased as more carbon is formed in the steel. Also apparent is the reduction in % elongation and impact energy, which indicates that the steel becomes more brittle as more carbon is added. One very important note is that the tensile strength of the steel does have a peak, indicating that any increase in carbon content beyond approximately 0.8% will actually reduce the strength and hardness of the steel.

Changing the carbon content of the steel not only affects its properties, but also affects the steel's microstructure. Figure 2.2: Fe-Fe₃C Phase Diagram illustrates which microstructure is expected in the steel at certain levels of carbon content:

![Figure 2.2: Fe-Fe₃C Phase Diagram](source: Adapted from Akerson, 2009; Iyer, 2009)
As seen in Figure 2.2: Fe-Fe$_3$C Phase Diagram, the steel region is split into two (2) microstructures. In the low and medium carbon steels, the constituents that make up the steels microstructure are pearlite and ferrite. As the steel is cooled from a high temperature it passes through the $\alpha+\gamma$ region where the ferrite ($\alpha$) begins to form as the proeutectoid microconstituent in the austenite ($\gamma$). Then as the steel is cooled further, below 1333°F, the remaining austenite becomes pearlite, which is a lamellar mixture of ferrite and cementite (Fe$_3$C).

The presence of pearlite gives the low carbon steel its strength, but the continuous ferrite allows for ductility in the steel (Askeland & Phule, 2006). When these hard microconstituents are constant through the steel, the steel becomes more brittle (Askeland & Phule, 2006). Heat treating is an effective way to regain some of the ductility in the steel while maintaining its strength.
There are many different methods for heat treating steel, and each method produces a different microstructure with different properties. The process of heat treating steel is accomplished by heating a steel specimen into austenite form and then cooling it at different rates. Figure 2.3: Time-Temperature Transformation Diagram for Steel follows:

**Figure 2.3: Time-Temperature Transformation Diagram for Steel**  
(Source: AMC, 2007)

The first structure that can be produced by heat-treating steel is pearlite, as seen at the top of the preceding figure. Pearlite is formed by slowly cooling the steel once it has been heated to the austenite region, as previously mentioned. This cooling can be accomplished either by leaving the steel in the oven after heating or by allowing the steel to air-cool after removal from the oven. The first method creates a coarse pearlite and is often referred to as annealing; this method causes the steel to have low strength but good ductility. The second method creates fine pearlite and is known as normalizing. Steel that is heat-treated this way becomes stronger than coarse pearlite steel (Askeland & Phule, 2006).

**Figure 12.17: Sample Theory for Formal Reports, cont’d**  
(Source: Adapted from Akerson, 2009; Iyer, 2009)
Martensite is the result of a third type of heat treatment that is obtained by rapidly cooling the steel once it has been heated to the austenite region. Martensite is identified in Figure 2.3: Time-Temperature Transformation Diagram for Steel. This new steel is extremely hard but very brittle, making it impractical for regular steel uses. In order to improve the steel’s durability, a process known as tempering is performed on the martensite steel to regain some of the steel’s ductility with minimal loss to strength and hardness. This loss of hardness can be seen in Figure 2.4: Rockwell Hardness of Tempered Martensite at various temperatures over time:

![Figure 2.4: Rockwell Hardness of Tempered Martensite](Source: Hale, 2000)

As can be seen in the preceding figure, the longer the martensite is kept at the tempering temperature, the greater the reduction in its hardness. Also, the higher the temperature to which the martensite is raised, the greater the reduction in its hardness. Both of these outcomes are caused by the growth of the cementite particle (Hale, 2000). As the time and temperature of the tempering process for martensite is increased, its microstructure becomes more and more sphere-like. At this point, the steel is approaching a different type of heat-treatment transformation, known as spheroidite. Spheroidite steel is extremely ductile but very soft (Askeland & Phule, 2006).
Based upon the published results, then, it is expected that the hardness of a specimen of steel will increase as it approaches martensite. Specifically, the effects of two (2) types of heat treatment on the microstructures of three (3) types of steel were examined. The types of heat treatment are as follows:

1. Heating to 1800 deg. F for 35 minutes then quenching in water.

2. Heating to 1280 deg. F for 18 hours, then oven-cooling to room temperature.

The three (3) types of steel that were used as specimens for heat treatment were 1019, 1045, and W1 tool steel. The estimated hardness ranges for the spheroidite and martensite microstructures that resulted from the heat treatments were first taken from published data and were then converted to a Vickers Hardness scale and are summarized in **Table 2.1: Vickers Hardness Estimates for 1019, 1045, and W1 Steel Samples**.

**Table 2.1: Vickers Hardness Estimates for 1019, 1045, and W1 Steel Samples**

<table>
<thead>
<tr>
<th>Steel Type / Microstructure</th>
<th>Spheroidite Hardness Range (HV)</th>
<th>Martensite Hardness (HV)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1019</td>
<td>150 - 213</td>
<td>238 - 412</td>
</tr>
<tr>
<td>1045</td>
<td>230 - 238</td>
<td>513 - 697</td>
</tr>
<tr>
<td>W1</td>
<td>746 - 832</td>
<td>272 - 279</td>
</tr>
</tbody>
</table>

The estimated hardness ranges shown in the preceding table were calculated using conversion tables so as to convert the final values from the Rockwell B Hardness Scale to the Vickers Hardness Scale (carbidedepot.com, 2009). The calculations were made assuming a 1/6-in. ball weighted with a 100-kg load for the Rockwell B hardness test and a 136 Vickers hardness test using a diamond pyramid head. Since the lab experiment as reported here used a 0.5-kg load during the Vickers hardness tests, the predicted estimates listed in **Table 2.1: Vickers Hardness Estimates for 1019, 1045, and W1 Steel Samples** may disagree with the achieved experimental results.

Figure 12.17: Sample Theory for Formal Reports, cont’d
(Source: Adapted from Akerson, 2009; Iyer, 2009)

As this extended example demonstrates, while the Introduction sections for informal and formal reports both cover critical concepts such as background, research question, and previously published findings into a single section, the
Introduction to a formal report *separates* this information into two (2) sections, the Introduction and the Theory, allowing for a longer discussion of key concepts and a richer exploration of the problem. (See Section 12.2.9: *Introduction.* A richly detailed Theory section is typically 1/3 to 1/2 the length of the total body of the Lab Report.

- Has an *A-level heading* that is located at the top of a new page, is aligned with the left margin, and is typed in bold, 16-point font, in all capital letters. The heading is numbered (i.e., 2.0 Theory) and is followed by one (1) blank line.

- Is written in *block format,* i.e., single-spaced with no indentations at the beginnings of paragraphs and with one extra space/blank line between paragraphs. 12-point Times New Roman or similar font is used. (See Section 3.2.2: *Spacing.*)

- Cites relevant studies or publications using standard APA-style citation (e.g., “…as shown in previously published studies (Johns & Herferd, 2008)…”), with each citation referring to an entry in the References section (as per Section 12.2.14: *References*).

- Uses APA standards for captioning and formatting equations (i.e., *Equation 2.1* in the prose and *Equation 1.0* in the caption line). Equation editor is used to write equations, and all terms are defined in the paragraph immediately following the equation. (See Section 8.3: *Guidelines for Equations.*)

- Includes *graphics* as required (e.g., tables of previously published values), properly introduced in the prose, labeled, captioned, and commented upon. (See Section 8.0: *General Guidelines for Graphics and Equations.*)

- Contains five (5) organizational sections: technical definitions, theoretical principles, expected results or published values, data-reduction equations, and justification. These sections are not numbered, nor do they take subheadings; instead, they are written as a cohesive set of paragraphs (i.e., in prose).

  - Provides *technical definitions* of important concepts (as shown in Section 4.7: *Technical Definitions*).

  - Outlines the *theoretical principles* and experimental assumptions that are most relevant to the lab. Tables and figures are often presented to provide baseline data and illustration/clarification. These theoretical principles may be taken from published sources that must be cited using APA formatting (as per Section 9.0: *Citation Standards*).

  - States the *expected results* based upon the published data; these results may include previously established or *published values.*
Provides the **data-reduction equations** (as necessary), introducing them in prose, defining their variables, and numbering them consecutively, (as per Section 8.3: Guidelines for Equations).

Gives a **justification** for the lab research by drawing connections between theory and application (i.e., by explaining how engineers might use these theoretical findings in everyday practice).

Does **not** include sample calculations. (They belong in Appendix I.)

Is written in the **present** tense. (See Section 6.3: Verb Tenses.)

Provides a **transition** to the following section, the Apparatus and Procedures section, which begins on a new page.

**12.2.11 Apparatus and Procedures**

Is written in **non-narrative style**, which lists all of the apparatus used in one subsection, then states the procedures in a series of numbered steps in a second subsection. The non-narrative style is most typical of formal reports; narrative style is reserved for informal APA-style (see Section 12.1.3: Procedures) and AIAA-style reports (see Section 12.3.5: Procedures); however, **it is up to the author of the Lab Report to discover which style the lab instructor requires.**

Has an **A-level heading** that is located at the top of a new page, is aligned with the left margin, and is typed in bold, 16-point font, in all capital letters. The heading is numbered (i.e., 3.0 Procedures) and is followed by one (1) blank line.

Is divided into two (2) subsections or subchapters, with the appropriate numbered subheadings, i.e., “3.1: Apparatus” and “3.2: Procedures”.

Is written in the author’s own words, even if instructions have been given for the experiment.

**Apparatus Subsection**

Provides a complete **bulleted list** of all equipment and instrumentation used in the lab as shown in Figure 12.18: Sample Apparatus Section for Formal Reports:

July 26, 2011
3.1 APPARATUS

The following equipment was used during the lab experiment:

- One (1) projectile ball, made of metal, with a diameter of 1.5 cm, for use with the ballistic pendulum;
- One (1) metric scale for measuring the mass of the projectile ball;
- One (1) lab journal for recording all measurements;
- One (1) pen for recording all measurements;
- One (1) ballistic pendulum used to project a ball horizontally off of a table thus allowing gravity to pull the ball downward until it impacts the ground;
- One (1) 10-meter-long measuring tape for measuring the height of the pendulum ball once set in the ballistic pendulum;
- One (1) 8-in. by 11-in. sheet of carbon paper for marking the projectile ball’s points of impact; and
- One (1) roll of masking tape for firmly adhering the carbon paper to the floor of the lab.

Figure 12.18: Sample Apparatus Section for Formal Reports

As the previous figure indicates, the Apparatus subsection lists both critical and more mundane items used during the lab experiment. These items are listed a series of descriptive noun phrases.

- Has a B-level heading that is aligned with the left margin and is typed in bold, 14-point font, in all capital letters. The heading is numbered (i.e., 3.1 Apparatus) and is followed by one (1) blank line.
- Introduces the list with a single, simple sentence.
- Places the apparatus in a bulleted list.
- Lists the apparatus in the order in which they were used in the lab experiment.
Single-spaces within entries, double-spaces between entries.

Quantifies each piece of equipment that was used in both words and Arabic numbers (e.g., “One (1) C-clamp”).

Provides detailed description of equipment and instrumentation, including whether they are metric or standard, their sizes, and even serial numbers where necessary.

States the purpose of each item in the list (e.g., “in order to constrain the sample”).

Includes graphics of the more complex or critical equipment, properly introduced in the prose, labeled, captioned, and commented upon. (See Section 8.0: General Guidelines for Graphics and Equations.)

Ends each entry in the list with a semi-colon, except for the final entry in the list which is ended with a period.

Provides a transition to the following subsection, the Procedures subsection, which begins on a new page.

**Procedures Subsection**

Describes, in the author’s own words, the steps taken to complete the lab, as illustrated in Figure 12.19: Sample Non-Narrative Procedures for Formal Reports:

### 3.2 PROCEDURES

#### 3.2.1 Phase One

The following procedures were used to set up the experiment that was conducted on October 30, 2009:

1.0 The mass of the projectile ball was measured using the metric scale.

2.0 The mass of the projective ball was recorded in the lab journal.

3.0 The pendulum latch was lifted to ensure it would not interfere with the experiment.

---

**Figure 12.19: Sample Non-Narrative Procedures for Formal Reports**
4.0 The projectile ball was seated in the pendulum:

4.1 The ball was placed on the frontal position of the mechanism by placing the ball, hole end first, onto the rod-like mechanism.

4.2 The mechanism was cocked by applying force to the pendulum arm.

4.3 Once fully cocked, the mechanism was locked into the ready position.

5.0 The perpendicular distance from the ball to the floor was measured using a metric tape measure.

6.0 The trigger was pulled on the ballistic pendulum, which fired the projectile ball.

7.0 The point of impact was visually noted.

8.0 The distance from the pendulum to the point of impact was measured using the measuring tape.

9.0 The distance measured in Step 8.0 was recorded in the lab journal.

10.0 A sheet of carbon paper was placed, face down, at the point of impact noted in Step 7.

11.0 The carbon paper was taped down at the point of impact using masking tape.

3.2.2 Phase Two

The following procedures were used to conduct a total of ten (10) experimental trials:

1.0 The projectile ball was seated in the pendulum:

1.1 The ball was placed on the frontal position of the mechanism by placing the ball, hole end first, onto the rod-like mechanism.

Figure 12.19: Sample Non-Narrative Procedures for Formal Reports, cont’d
1.2 The mechanism was cocked by applying force to the pendulum arm.

1.3 Once fully cocked, the mechanism was locked into the ready position.

2.0 The trigger was pulled on the ballistic pendulum, which fired the projectile ball.

3.0 The ball impacted the carbon paper, leaving an imprint at the point of impact.

4.0 Steps 1.0 through 3.0 were repeated nine times for a total of ten (10) experimental trials.

Figure 12.19: Sample Non-Narrative Procedures for Formal Reports, cont’d

As the previous figure indicates, the Procedures section is richly detailed so as to allow a reader to repeat the lab experiment and obtain similar results without the author’s assistance.

- Has a B-level heading that is located at the top of a new page, is aligned with the left margin, and is typed in bold, 14-point font, in all capital letters. The heading is numbered (i.e., 3.2 Procedures) and is followed by one (1) blank line.

- Is written in block format, i.e., single-spaced with no indentations at the beginnings of paragraphs and with one extra space/blank line between paragraphs. 12-point Times New Roman or similar font is used. (See Section 3.2.2: Spacing.)

- Is separated into two or more phases if necessary (e.g., Set-up, Procedures, Data Collection and Reduction), each with its own enumerated subheading (i.e., a C-level heading that is aligned with the left margin and is typed in bold, 12-point font, in all capital letters).

- Lists the steps required to complete the lab in chronological order.

- Is enumerated (e.g., 1.0, 2.0, 3.0) so that the reader can easily follow the steps; if there are two or more phases, each phase begins with step 1.0.
o Includes, where necessary, two or more enumerated substeps (e.g., 1.1, 1.2, 1.3, 1.4) so that more complex procedures are clearly broken down into simpler procedures with no missing or extraneous steps.

o Indicates steps that are repeated, where necessary.

o Includes graphics as required (e.g., illustrations of detailed procedures), properly introduced in the prose, labeled, captioned, and commented upon. (See Section 8.0: General Guidelines for Graphics and Equations.)

o Includes the steps for data collection and reduction, as a phase or set of substeps if necessary.

o Refers back to the equations previously stated in the Theory section, as needed. (See Section 8.3: Guidelines for Equations.)

o Is written in passive voice, indicative mood, and past tense. (See Section 5.1: Voice, Section 5.2: Mood, and Section 6.3: Verb Tenses.)

o Provides a transition to the following section, the Results and Discussion section, which begins on a new page.

12.2.12 Results and Discussion

o Presents the key findings, compares the findings to published values, and identifies trends, as demonstrated in Figure 12.20: Sample Results and Discussion for Formal Reports:
4.0 RESULTS

The data obtained from the tensile test experiment on the unidirectional carbon composite were converted into stress and strain values using the equations stated in Section 2.0: Theory; the values were then plotted as shown in Figure 4.1: Stress/Strain Curve for Unidirectional Carbon:

![Stress/Strain Curve for Unidirectional Carbon Composite](image)

The curve depicted in the preceding figure has the typical stress/strain shape of composites as discussed in Section 2.0: Theory. An analysis of the stress/strain curve yielded important results. The slope of the curve (i.e., Young’s modulus) was determined to be $7.0 \times 10^6$ lb/in.$^2$. The ultimate tensile strength of the carbon composite was calculated to be 60,000 lb/in.$^2$. These experimentally achieved values were then compared to the theoretical values previously stated in Section 2.0: Theory; this comparison is presented in Table 4.1: Theoretical vs. Experimental Values for Young’s Modulus for Unidirectional Carbon Composite:

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Theoretical Young’s Modulus</td>
<td>$7.0 \times 10^6$ lb/in.$^2$</td>
</tr>
<tr>
<td>Experimental Young’s Modulus</td>
<td>$32.0 \times 10^6$ lb/in.$^2$</td>
</tr>
<tr>
<td>Difference</td>
<td>78%</td>
</tr>
</tbody>
</table>

Figure 12.20: Sample Results and Discussion for Formal Reports
(Source: Adapted from Menon, 2006)
As noted in the preceding table, the percent difference between the theoretical and the experimental results is 78%. These findings indicate due to a lower-than-expected modulus, the composite samples have a low tensile elasticity and would tend to plastically deform before expected, which is undesirable. The percentile difference of 78% is significant; such a significant difference can perhaps be attributed to improper application of epoxy during testing, resulting in a weaker composite.

Of note, however, there appears to be a discontinuity apparent in Figure 4.1: Stress/Strain Curve for Unidirectional Carbon Composite at a strain location of approximately 0.035 in. There are two (2) possible explanations for this discontinuity. First, the tensile tester may have slipped or lost its grip during testing, introducing error into the data. Second, the presence of nonlinearities or deformities in the composite may also have been a cause of error. As noted in the preceding table, the percent difference between the theoretical and the experimental results is 78%. Nevertheless, this lab is successful in that a tensile test was successfully conducted on a sample of carbon composite and the Young’s Modulus was calculated using standard methods.

Figure 12.20: Sample Results and Discussion for Formal Reports, cont’d
(Source: Adapted from Menon, 2006)

As demonstrated in the preceding figure, results are presented in graphic form and through data commentary; unexpected findings are identified and rationales or explanations are offered.

- Has an A-level heading that is located at the top of a new page, is aligned with the left margin, and is typed in bold, 16-point font, in all capital letters. The heading is numbered (i.e., 4.0 Results and Discussion) and is followed by one (1) blank line.
- Is written in block format, i.e., single-spaced with no indentations at the beginnings of paragraphs and with one extra space/blank line between paragraphs. 12-point Times New Roman or similar font is used. (See Section 3.2.2: Spacing.)
- Includes graphics as required (e.g., data charts and data tables), properly introduced in the prose, labeled, captioned, and commented upon. (See Section 8.0: General Guidelines for Graphics and Equations.)
- Contains four (4) organizational sections: presentation of data in graphic form, data commentary comparing achieved to expected results, identification of trends, and explanation of any unexpected results.
o **Presents data** in graphic form; these results are properly introduced with a paragraph or two of prose and are properly placed, captioned, and commented upon. (See Section 8.0: General Guidelines for Graphics.)

o Follows data presentation with **data commentary** that evaluates or compares the achieved results or acquired data to the expected results as had been stated in the background of the Introduction section (i.e., Section 1.0 of the Lab Report).

o Identifies **trends** in the data and interprets their meaning in the context of the lab experiment; the achieved results are shown to be evidence of a key principle or concept or behavior.

o Explains any **unexpected results**; moreover, possible reasons for any discrepancy between the achieved results and the expected results (including error analysis as applicable) are discussed.

o Avoids **data dumping** (i.e., tables or figures that are not followed by prose that discusses the important information presented in the tables and figures). (See Section 8.2: Avoidance of Data Dumping for advice.)

o Is written in the **present** tense. (See Section 6.3: Verb Tenses.)

o Uses adequate **qualifying/hedging words** and phrases throughout so as to not make an overly strong claim. (See Section 7.4: Qualification.)

o Provides a **transition** to the following section, the Conclusions and Recommendations section, which begins on a new page.

**12.2.13 Conclusions and Recommendations**

o Summarizes the purpose of the lab and key findings, as demonstrated in Figure 12.21: Sample Conclusions and Recommendations for Formal Reports:
5.0 CONCLUSIONS AND RECOMMENDATIONS

This lab was designed to test the properties of various materials, most specifically their ability to retard the natural process of heat exchange. As mentioned in Section 4.0: Results, the materials of less density performed better during the experiment then those of heavier density due to their resilience for heat exchange. The performance of each material was as expected according to the first law of thermodynamics. This study suggests that the laws of thermodynamics can be used by engineers to help predict the behavior of virtually any material.

Nonetheless, as with most labs, there were limitations. First, during set-up, the thermometers were not calibrated at the same temperature; this inconsistent calibration could have contributed to error. The accuracy of the results would have been improved if the thermometers had all been calibrated at the initial liquid temperature, rather than some thermometers being calibrated at room temperature. Second, the experiment was performed only once, which may be insufficient to fully justify the conclusions drawn. The results would have been more reliable if the experiment were repeated....

Figure 12.21: Sample Conclusions and Recommendations for Formal Reports

Limitations and recommendations are also presented in this section, as illustrated in the preceding figure and as noted in following bullets.

- Has an A-level heading that is located at the top of a new page, is aligned with the left margin, and is typed in bold, 16-point font, in all capital letters. The heading is numbered (i.e., 5.0. Conclusions and Recommendations) and is followed by one (1) blank line.

- Is written in block format, i.e., single-spaced with no indentations at the beginnings of paragraphs and with one extra space/blank line between paragraphs. 12-point Times New Roman or similar font is used. (See Section 3.2.2: Spacing.)

- Includes graphics as required (e.g., summary tables or error analysis graphs), properly introduced in the prose, labeled, captioned, and commented upon. (See Section 8.0: General Guidelines for Graphics and Equations.)

- Includes six (6) elements: a restatement of the purpose of the lab, a very brief summary of the Procedures section, a summary of the Results section, a statement of the primary conclusions which can be drawn from the Results,
the **limitations** of the lab/ problems encountered during the lab Procedures, and **recommendations** for overcoming each of the flaws.

- Provides no new results; all results, including data commentary, trends, and unexpected results, have been previously stated in the Results section.

- Provides a critique of the lab experiment through a statement of limitations and recommendations:
  
  - Offers one (1) or two (2) limitations of the experiment, typically in terms of the resources available or the procedures followed. Limitations must be specific in scope and reasonable in tone. Pointing out a restriction that cannot be addressed is of little value; stating problems that can be feasibly and reasonably addressed is of greater value.

  - Pairs each limitation with at least one (1) recommendation for improving the lab experiment. Each recommendation must directly address the limitation with which it is paired. Recommendations must be specific, feasible, and stated using an **unreal conditional** of the grammatical form “*AA would have been BB if XX had been YY,*” e.g., “The results would have been more accurate if tare data had been gathered.”

  - Each limitation must be stated BEFORE its recommendation, so that each limitation statement and recommendation statement forms a matched pair; thus, if there are multiple limitations/recommendations, the order of presentation is as follows:
    
    - Limitation 1
    - Recommendation 1
    - Limitation 2
    - Recommendation 2
    - Limitation 3
    - Recommendation 3

No matter how many limitations are presented, each must be paired with a recommendation following the order illustrated in the preceding list.
Uses adequate qualifying/hedging words and phrases so as to not make overly strong claims. (See Section 7.4: Qualification.)

Is written in the present tense. (See Section 6.3: Verb Tenses.)

12.2.14 References

Lists sources that were cited in the body of the paper, as demonstrated in Figure 12.22: Another Sample References for All APA-style Lab Reports:

6.0 REFERENCES


Figure 12.22: Another Sample References for All APA-style Lab Reports
Figure 12.22: Another Sample References for All APA-style Lab Reports, cont’d

As demonstrated in the preceding figure, cited sources may include unpublished papers and interviews or personal communications.

- Has an A-level heading that is located at the top of a new page, is aligned with the left margin, and is typed in bold, 16-point font, in all capital letters. The heading is enumerated (i.e., 5.0 References), followed by one (1) blank line.

- Single-spaces each citation, with a hanging indent, and double-spaces between citations. 12-point Times New Roman or similar font is used. (See Section 9.4: APA Standards.)

- Is formatted according to standard APA citation rules (i.e., author, date of publication, title, place of publication, publisher’s name). (See Section 9.3.1: Guidelines for Formatting APA-style References and Section 9.4: APA Standards.)

- Lists all sources in alphabetical order.

12.2.15 Attributions

- Identifies which individual members of a group or team are responsible for different tasks, as shown in Figure 12.23: Another Sample Attributions for All APA-style Lab Reports:


7.0 ATTRIBUTIONS

<table>
<thead>
<tr>
<th>Tasks</th>
<th>Participant</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lay-up, Preparation, Test, Clean-up, Team Lead</td>
<td>W. Lestari</td>
</tr>
<tr>
<td>Lay-up, Preparation, Test, Clean-up</td>
<td>J. Ashworth</td>
</tr>
<tr>
<td>Lay-up, Preparation, Test, Clean-up</td>
<td>K. Bordignon</td>
</tr>
<tr>
<td>Lay-up, Preparation, Test, Clean-up</td>
<td>M. Kim</td>
</tr>
<tr>
<td>Lay-up, Preparation, Test, Clean-up</td>
<td>R. Madler</td>
</tr>
<tr>
<td>Lay-up, Preparation, Test, Clean-up</td>
<td>K. Siebold</td>
</tr>
</tbody>
</table>

Figure 12.23: Another Sample Attributions for All APA-style Lab Reports

As shown in the preceding figure, the individual members of the group or team are listed in a two-column form besides the tasks that they accomplished.

- Has an *A-level heading* that is located at the top of the page, is aligned with the left margin, and is typed in bold, 16-point font, in all capital letters. The heading is numbered (i.e., 6.0 Attributions), followed by one (1) blank line.

- Lists team members and their assigned tasks in a clear two-column table.

12.2.16 Appendix I: Sample Calculations

- Has an *A-level heading* that is located at the top of the page, is aligned with the left margin, and is typed in bold, 16-point font, in all capital letters. The heading is numbered (i.e., 8.0 Appendix I: Sample Calculations) and is followed by one (1) blank line.

- Shows representative samples of all calculations.

- Shows progression from raw data to final results.

- May include source code and program output if sanity-check hand calculations are also included.

12.2.17 Appendix II: Raw Data

- Provides all data used in calculations.

- Has an *A-level heading* that is located at the top of a new page, is aligned with the left margin, and is typed in bold, 16-point font, in all capital letters. The
heading is numbered (i.e., 9.0 Appendix II: Raw Data) and is followed by one (1) blank line.

- Is burned onto a CD if there are more than five (5) pages of raw data. This data CD is then placed in a paper sleeve that is in turn attached to the page bearing the heading “Appendix II: Raw Data” and is then submitted with the Lab Report.

### 12.2.18 Other Appendices

- Are optional.

- May contain information not included in the body of the report but which provides additional understanding of the lab.

- May include photographs and detailed descriptions of apparatus for labs which require numerous or complex equipment.

- Are formatted in the same manner as Appendix I and Appendix II, with consecutively numbered A-level headings.
12.3 Description of AIAA-style Lab Reports

12.3.1 Title/Author Block

- Contains two (2) organizational sections: the title block and the list of author(s). These sections are not numbered and are presented together at the top of the first page of the report, as noted in Figure 12.24: Sample Title/Author Block for AIAA-style Reports:

---

**Lab Report #4: Plasticity**

First Student Author¹  
*ES 320: Engineering Materials Science*

Second Student Scribe²  
*ES 320: Engineering Materials Science*

Third Student Writer³  
*ES 320: Engineering Materials Science*

---

*Figure 12.24: Sample Title/Author Block for AIAA-style Reports*

The preceding figure exemplifies a report title followed by a list of three (3) authors, in alphabetical order. The following bullets provide details regarding the proper way to format a Title/Author Block.

- Centers the **title** of the report at the top of the page in bold, 18-point font, using capital and lower-case letters.

- Has two (2) blank lines between the title of the report and the list of author(s).

- Centers the **list of authors** in non-bold, 12-point font; Times New Roman, Arial, or similar font is used. (Note that papers submitted for publication using AIAA standards are typically written in 10-point, not 12-point font; 12-point font, however, is the educational standard adopted by the COE and ERAU, Prescott campus and for papers submitted to professors, this 12-point standard supersedes AIAA standards.)

- Lists authors in **alphabetical order**. (Note that for works submitted for publication rather than for classroom purposes, the authors typically negotiate...
which author receives the prestigious “first authorship”, i.e., the name which is listed first.

- Identifies each author in the list on two (2) consecutive lines: the author’s name on the first line followed by the author’s affiliation (e.g., class name, research team name, or degree program) on the second line. The author’s affiliation is written in *italics*.

- Follows each author’s name with a *superscript* that refers to a *footnote*; these footnotes contain each author’s contact information (e.g., email address and/or box number).

- Has one (1) blank line after the line stating an author’s affiliation and before the line identifying the next author on the list.

- Has two (2) blank lines before the next section, the Abstract.

**12.3.2 Abstract**

- Includes a brief and clear summary of the reason for the work (i.e., justification), the methods used, and the results achieved in a single paragraph (see Section 4.4.3: Descriptive Abstracts) as noted in [Figure 12.25: Sample Abstract for AIAA-style Reports](#).

---

Rapid estimation of a wing’s drag polar accounting for the combined effects of planform and profile drag represents a significant challenge, but is of necessity for preliminary analysis and design. In this paper, methodology is presented culminating in simple expressions allowing the combination of these drag components. Input included knowledge of the wing’s sectional characteristics as well as the planform’s lift-curve slope and inviscid span efficiency factor. Airfoil profile drag is interpreted as a loss of leading-edge suction, and the effects of camber are explicitly accounted for. This method lends itself to be used as a design tool in which camber and suction may be optimized to minimize drag, depending on the operating conditions. Comparisons of the method with the experimental data show encouraging agreement.

---

**Figure 12.25: Sample Abstract for AIAA-style Reports**
*(Source: Traub, 2009)*

As this figure illustrates, an Abstract contains all critical details found in the reports; there are no references or footnotes. The following bullets provide further details on the style typical of an AIAA-style Abstract.
o Does **NOT** have a heading or sub-heading.

o Is presented using a particular format as specified by AIAA:
  
  o Is indented 0.5 in. from the left and right margins of the report.

  o Has an extra 0.5-in. indentation (for a total of 1.0 in.) for the very first line of the paragraph.

  o Is stated in single-spaced, bold, 12-point font; Times New Roman, Arial, or similar font is used. (Note that papers submitted for publication typically have Abstract written in 10-point font, but 12-point font is the standard of the COE and of ERAU, Prescott campus and is preferred.)

  o Is restricted in length to one (1) paragraph.

  o Is a descriptive Abstract rather than an informative Abstract (see Section 4.4.3: Descriptive Abstracts); that is, it focuses on the justification for the experiment, the methods, and the results; there is no textual overview.

  o Has sentences which summarize the work accomplished (i.e., Apparatus/Procedures) written in *past tense*. (See Section 6.3: Verb Tenses.)

  o Has all other sentences written in the *present tense*.

  o Has two (2) blank lines before the following section, the Nomenclature list.

12.3.3 **Nomenclature**

  o Is a list of symbols or terms that are used in the Lab Report alongside the terms’ corresponding definitions, as shown in Figure 12.26: Sample Nomenclature List for AIAA-style Reports:

<table>
<thead>
<tr>
<th>Nomenclature</th>
</tr>
</thead>
<tbody>
<tr>
<td>( A ) = amplitude of oscillation</td>
</tr>
<tr>
<td>( a ) = cylinder diameter</td>
</tr>
<tr>
<td>( C_x ) = force coefficient in the ( x ) direction</td>
</tr>
<tr>
<td>( C_y ) = force coefficient in the ( y ) direction</td>
</tr>
<tr>
<td>( \alpha ) = angle of attack</td>
</tr>
<tr>
<td>( \eta ) = attainable leading-edge suction parameter</td>
</tr>
</tbody>
</table>

**Figure 12.26: Sample Nomenclature List for AIAA-style Reports**
As shown in the preceding figure, the Nomenclature list is presented in two (2) columns: the first column lists the symbols that are used in the remainder of the report, and the second column names/defines each term.

- Has an A-level heading that is centered, bold, 12-point font, using capital and lower-case letters; Times New Roman, Arial, or similar font is used. The heading is not numbered and is followed by one (1) blank line, as noted in Figure 12.26: Sample Nomenclature List for AIAA-style Reports:

- Is stated in single-spaced, 12-point font; the font used is Times New Roman, Arial, or similar.

- Lists each symbol in alphabetical order in the first column, with Greek symbols at the end of the list.

- *Italicizes* symbols (but not units, which may be included in the list).

- Has an equal sign (i.e., = ) preceding the names/definitions that are found in the second column.

- Does not capitalize any of the term’s names or definitions with the exception of proper names (e.g., Young’s modulus).

- Has one (1) blank line before the following section, the Introduction.

### 12.3.4 Introduction

- Clearly articulates the research topic, provides a background or theoretical principles that underlie the experiment, justifies the research, states the research problem or “gap,” states the purpose of the research, and offers a textual overview, as shown in Figure 12.27: Sample Introduction for AIAA-style Reports:

---

**I. Introduction**

Accurate and economical estimates of the variation of drag coefficient with lift coefficient, the drag polar, are vital for aircraft conceptual and preliminary design studies. Such estimates are also necessary in a research environment for approximation and experimental validation. Rapid estimates of inviscid planform drag (so-called vortex or induced drag) can be made reliably using lifting-line theory, vortex-lattice, or panel methods, depending on the planform under study².

---

**Figure 12.27: Sample Introduction for AIAA-style Reports**  
(Source: Adapted from Traub, 2009)
Additionally, sectional viscous drag (profile drag) may be estimated with reasonable accuracy using freely available computational tools such as X-foil\(^3\). However, incorporation of the sectional profile drag into the total wing drag can be problematic. Frequently, drag comparisons using theoretical computation of the vortex drag in conjunction with use of the experimental zero-lift drag-coefficient yield drag estimates that are always too low compared with the experiment, due to the lack of modeling of the wing profile’s pressure drag.

The sectional profile drag is typically decomposed into two (2) components: a skin-friction component due to shear and a pressure drag component due to flow separation as well as alteration of the effective airfoil shape by the boundary-layer displacement thickness. The skin-friction component is generally assumed to be constant, although it does show a weak variation with lift coefficient. The pressure-drag component typically has a parabolic lift-coefficient dependency. Airfoils that exhibit a drag bucket are designed to have a lift-coefficient range over which extensive laminar flow is maintained; this design enables the maintenance of thin boundary layers with a small displacement thickness. Consequently, the resultant pressure distribution is close to the inviscid case, limiting the pressure-drag rise within the bucket region. The variation of pressure drag may be interpreted as a loss of leading-edge suction (as the streamwise forward-acting axial-force and rearward normal-force components no longer exactly cancel). An analysis based on such an approach (wing leading-edge suction) has the benefit of allowing performance estimates for wings with partial or zero leading-edge suction (i.e., sharp leading edges).

Methods to combine sectional and planform drag exist\(^4\), although the approach is numerical. A study by DeLaurier\(^5\) on drag-coefficient estimation for wings with partial leading-edge suction provided a simple expression to estimate the drag of finite wings with camber and partial suction. However, camber contributions were accounted for using the assumption of a circular-arc section in conjunction with the vorticity distribution solution of Schlichting and Truckenbrodt\(^6\). The method also provided no insight into how to estimate the attainable leading-edge suction or viscous wing efficiency. A significant benefit of the approach was its ability to aid in the design of wings for low-Reynolds-number operation, in which sharp leading edges are often employed to promote transition, with the concomitant penalty of suction loss mitigated by the avoidance of laminar separation.

In the following theoretical exploration, drag-coefficient relations incorporating the effect of partial leading-edge suction as well as camber will be developed for airfoils as well as wings. In the derivation, expressions are

---

**Figure 12.27**: Sample Introduction for AIAA-style Reports, cont’d
(Source: Adapted from Traub, 2009)
developed to allow identification of the axial-force constituents: that is, leading-edge suction and camber thrust. Following the methods previously noted\(^5\), viscous flow effects are then applied to the identified leading-edge suction term.

A. Two-dimensional Airfoils

Development of a sectional relation for the drag coefficient of an airfoil with partial leading-edge suction and camber can be obtained by consideration of the normal and axial forces acting on the profile. Using small-angle approximations of \(\sin(\alpha) \approx \alpha\) and \(\cos(\alpha) \approx 1\) yields Eq. (1):

\[
C_{dl} = C_n \sin(\alpha) - C_a \cos(\alpha) \approx C_n \alpha - C_a
\]  

(1)

Where \(C_{dl}\) is the sectional lift-dependent draft coefficient, \(C_n\) is the sectional normal-force coefficient, \(\alpha\) is the angle of attack, and \(C_a\) is the sectional axial-force coefficient. In addition, it may be assumed that \(C_n \approx C_l\). The effect of camber may be interpreted as shifting the zero-lift angle of attack....

B. Three-dimensional Wings

The drag polar for a symmetrical untwisted finite wing is often written using the form shown in Eq. (2):

\[
C_D = C_{Do} + k_{p+i} C_L^2
\]

(2)

Where \(C_D\) is the finite wing draft coefficient. \(C_{Do}\) is the drag coefficient at zero lift and is usually attributed to skin-friction drag, although a small pressure-drag component may also be present. \(k_{p+i} C_L^2\) represents the contribution of both sectional-pressure- and planform-dependent induced (or vortex) drag (\(k_{p+i} C_L^2\)) For wings, both the pressure component of the profile drag coefficient (\(k_{p} C_L^2\)) and the planform-dependent induced drag coefficient (\(k_i C_L^2\)) vary with the square of the lift coefficient....

As demonstrated in this section, a simple method to combine both sectional and planform drag coefficients for incompressible untwisted finite wings using an explicit analytic equation set would be of use for all forms of preliminary design. In addition, such a method would be a valuable design tool for estimating the effects of camber and airfoil sections on the total wing drag. In this paper, a method is developed to combine profile and planform drag with explicit treatment of the effects of camber. Relations presented allow both drag estimates as well as that of wing efficiency. Comparisons of the method with the experimental data are presented. The following section recounts the methodology used.

---

Figure 12.27: Sample Introduction for AIAA-style Reports, cont’d
(Source: Adapted from Traub, 2009)
As demonstrated in the preceding example, while the Introduction to a formal APA-style report separates the Introduction (background and research question) from the Theory (important concepts and previously published findings), the Introduction to an AIAA-style report combines this information into a single section in as concise a manner as possible. In this respect, the Introduction of an AIAA-style report is similar to that of an informal report. (See Section 12.1.2: Introduction and Figure 12.2: Sample Introduction for Informal Reports for further discussion.)

- Has an A-level heading that is centered, bold, 12-point font, using capital and lower-case letters. The heading is numbered using Roman numerals (i.e., I. Introduction) and is followed by one (1) blank line.

- May be logically divided into subsections as necessary. Each subsection is preceded by a B-level heading that is aligned with the left margin and is in bold, 12-point font, in all capital and lower-case letters. The heading is numbered with capital letters (e.g., A. Theoretical Assumptions, B. Theoretical Predictions). The line before the B-level heading is blank, but the line after the B-level heading is not (i.e., the line after the B-level heading is the first line of the first sentence of the following paragraph).

- Is written in AIAA format. All prose/paragraphs are single-spaced with no extra lines between paragraphs. Each paragraph is indented; 12-point Times New Roman, Arial, or similar font is used. Note that this AIAA-required format is neither standard essay format nor standard block format. (See Section 3.2.2: Spacing for further exemplification of AIAA-style paragraph formatting.)

- Cites relevant studies or publications using standard AIAA-style citation (i.e., using superscripted footnotes), with each footnote referring to an entry in the References section (as per Section 12.1.6: References).

- Uses AIAA standards for captioning and formatting equations (i.e., Eq. (1) in the prose and (1) in the caption line). Equation editor is used to write equations, and all terms are defined in the paragraph immediately following the equation. (See Section 8.3: Guidelines for Equations.)

- Includes graphics as required (e.g., tables of previously published values), properly introduced in the prose, labeled, captioned, and commented upon. (See Section 8.0: General Guidelines for Graphics and Equations.)

- Contains six (6) organizational sections: statement of the research topic, background information or theoretical context, justification, research problem or “gap,” purpose statement, and textual overview. These sections are written as a cohesive set of paragraphs (i.e., in prose), although the Introduction may be logically divided into subsections as the author desires:
Introduces the **research topic**—the scope of the report, or a technical definition of the object or concept being studied (as per Section 6.4: Technical Definitions).

Presents **background information or theoretical context**—what is known, which may include any and all of the following sub-elements:

- **Technical definitions** (as shown in Section 4.7: Technical Definitions) of key theoretical concepts and notions,
- Explanations of relevant **theoretical principles**,
- Expected results, typically stated as previously established or **published values**, and
- **Data-reduction equations** (as necessary), introducing them in prose, defining their variables, and numbering them consecutively (as per Section 8.3: Guidelines for Equations).

Offers a **justification**—an explanation of why this research is central, crucial, or important:

States the **research problem or “gap”**—what is unknown or what needs to be tested. The gap is typically introduced with an adversative transition (e.g., “however” as per Section 4.8: Frequently Used Transitions):

Offers a **purpose statement** for the lab—the research question or hypothesis:

Provides a **textual overview**—including an outline of organizational scheme or comments on anything unusual or unexpected in the report in order to orient the reader to the organization of the Lab Report:

These organizational units are widely used in a variety of Introductions in multiple types of technical documents, not just in Lab Reports. As such this organizational scheme is highly useful in writing Introductions.

Optionally identifies the **location and date of the lab experiment**.

Optionally **acknowledges** anyone outside of the professor and fellow students who participated in the lab or offered their aid.

Is generally written in the **present** tense, although the **past** tense may be used when providing background information or historical context. (See Section 6.3: Verb Tenses.)
The following procedures for the preparation and heat-treatment of three (3) types of steel (i.e., 1018, 1045, and W1 tool steel) were conducted on March 3, 2009, at the Materials Lab at ERAU, Prescott campus.

**A. Preparation and Heat Treatment**

First, a sample of 1018 steel was clamped to a 6-ft by 10-ft worktable using a standard table clamp; the specimen was then cut in half using a hand saw to reduce its size for mounting. One (1) of the halves was notched with the hand saw to differentiate it from the other half. The same methods were used on the remaining samples of 1045 and W1 tool steel so that both notched and unnotched samples were prepared for each type of steel.

Then, the unnotched sample of the 1018 steel underwent the type of first heat treatment (i.e., a water-quenching treatment). Three (3) ovens were pre-heated: the first one to 1800°F, the second one to 750°F, and the third one to 1285°F. One of these ovens is depicted in Fig. 2.1:

![Figure 2.1. Shop Oven](image)

Figure 12.28: Sample Narrative Procedures for AIAA-style Reports
(Source: Adapted from Rodriguez, 2009)
The three (3) ovens such depicted in Fig. 2.1 were used to heat the specimens to the austenite region. Once the ovens were pre-heated, the unnotched specimen was placed in the first oven (which had been heated to 1800°F) and heated for 40 min. The specimen was then removed from the oven and immediately quenched in a bucket of room-temperature water. Upon quenching, the specimen was then placed in the second oven (which had been heated to 750°F) and heated for an additional 40 minutes. The specimen was removed from the second oven and once again was immediately quenched in a bucket of room-temperature water. The unnotched specimens of the 1045 and W1 tool steel underwent this same type of heat treatment (i.e., water-quenching).

Then, the notched sample of the 1018 steel underwent the type of second heat treatment (i.e., an air-cooling treatment). The notched specimen was placed in the third oven (which had been heated to 1285°F) and heated for 18 hours. After 18 hours had passed, the oven was turned off and the specimen was left in the oven to slowly cool to room temperature; the oven doors remained closed for the entire cooling period. Once room temperature had been achieved, the oven was opened and the specimen was removed. The notched specimens of the 1045 and W1 tool steel underwent this second type of heat treatment (i.e., air-cooling); once all specimens had undergone heat treatment, they were ready to be mounted and polished as described in the following section.

B. Mounting and Polishing of Metallographic Mount

After all specimens had undergone either the first or second type of heat treatment (i.e., water-quenching or air-cooling), they were mounted using a Simplimet specimen mounter, shown in Fig. 2.2:

![Figure 2.2. Simplimet specimen mounter](image)

Figure 2.2. Simplimet specimen mounter

Figure 12.28: Sample Narrative Procedures for AIAA-style Reports, cont’d
(Source: Adapted from Rodriguez, 2009)
First, the needle valve on the bottom on the specimen mounter, shown in Fig. 2.2, was closed and the lever the right side of the mounter was utilized to jack up the mounter's piston.... The results of this experiment are presented in the following section.

Figure 12.28: Sample Narrative Procedures for AIAA-style Reports, cont’d
(Source: Adapted from Rodriguez, 2009)

As shown in the preceding paragraph, narrative-style procedures report the lab procedures in prose paragraphs, much like a story, integrating the key apparatus using graphics. As noted, non-narrative style is reserved for formal APA-style reports, as described in Section 12.2.11: Apparatus and Procedures.

- Has an A-level heading that is centered, bold, 12-point font, using capital and lower-case letters; Times New Roman, Arial, or similar font is used. The heading is numbered using Roman numerals (i.e., II. Procedures) and is followed by one (1) blank line.

- May be logically divided into subsections as necessary. Each subsection is preceded by a B-level heading that is aligned with the left margin and is in bold, 12-point font, in all capital and lower-case letters. The heading is numbered with capital letters (e.g., A. Phase 1, B. Phase 2). The line before the B-level heading is blank, but the line after the B-level heading is not (i.e., the line after the B-level heading is the first line of the first sentence of the following paragraph).

- Is written in AIAA format. All prose/paragraphs are single-spaced with no extra lines between paragraphs. Each paragraph is indented; 12-point font is used. Note that this AIAA-required format is neither standard essay format nor standard block format. (See Section 3.2.2: Spacing for further exemplification of AIAA-style paragraph formatting.)

- Cites relevant studies or publications using standard AIAA-style citation (i.e., using superscripted footnotes), with each footnote referring to an entry in the References section (as per Section 12.3:10: References).

- Includes graphics as required (e.g., key apparatus or detailed procedures), properly introduced in the prose, labeled, captioned, and commented upon. (See Section 8.0: General Guidelines for Graphics and Equations.)

- Contains three (3) organizational sections: set-up, experimental procedures and apparatus, and data collection and reduction. These sections are not
numbered, nor do they take subheadings; instead, they are written as a cohesive set of paragraphs (i.e., in prose).

- Begins with the set-up of the lab experiment, including graphics as required, properly introduced into the prose and commented upon.

- Continues with a rich description of the procedures that were followed for completing the lab experiment, stated in chronological order. The procedures are integrated with detailed descriptions of **equipment and instrumentation**, including the material comprising the specimen to be studied, the dimensions of the specimen, and the locations of sensors or actuators.

- Ends with the procedures for **data collection and reduction**. This segment provides the data-reduction equations, introducing them in prose, defining their variables, and numbering them consecutively.

- Is written in the author’s own words, even if a set of instructions has been given for the experiment.

- Is written in **chronological order**, using enumerative or numbering transitions such as “first, second, third” or “first, next, then, finally” to mark procedural order. (See Section 4.8: Frequently Used Transitions.)

- Is written in **passive voice, indicative mood, and past tense**. (See Section 5.1: Voice, Section 5.2: Mood, and Section 6.3: Verb Tenses.)

- Provides a *transition* to the following section.

- Has one (1) blank line before the following section, the Results and Discussion.

**12.3.6 Results and Discussion**

- Presents the key findings, compares the findings to published values, and identifies trends, as demonstrated in Figure 12.29: Sample Results and Discussion for AIAA-style Reports:
III. Results and Discussion

In this section, the experimental data are compared with predictions using the two equations developed in this paper, i.e., Eqs. (20) and (28), to test the three methods reviewed earlier. Figure 2 presents the sectional drag polar, the calculated attainable suction parameter, and the linearized polar; these results were required for input into Eq. (10)…. 

![Figure 2. Experimental Sectional Characteristics for NACA 65-210](image)

As shown in Fig. 2, the theoretical full suction is representative of a drag estimate that may be determined using a numerical method (e.g., a vortex-lattice code) to estimate $\epsilon_i$ in conjunction with the experimental value for $C_{D_{\text{min}}}$. A significant underprediction of drag is clearly evident due to the exclusion of the profile’s pressure-drag constituent:

Figure 12.29: Sample Results and Discussion for AIAA-style Reports
(Source: Adapted from Traub, 2009)
As shown, all three methods using the variable attainable suction concept show excellent accord with the experiment. The estimate using Eq. (20) appears to show the most encouraging agreement. The estimate clearly shows that the wing’s efficiency is not a constant, but shows a significant reduction in the initial drag-rise region of the polar \( (C_L \approx 0.37) \) as previously seen in Fig. 2.

As part of this project, the theoretical effect of camber and attainable suction on the test wing was explored. The predictions indicate that camber has a far more significant effect in reducing drag when leading-edge suction levels are low. As the attained suction tends toward 100%, camber’s effect diminishes to zero. As mentioned previously, camber reduces drag for a given lift coefficient by reducing the required geometric angle of attack of the wing. For a wing with a sharp leading edge (as may be used at low Reynolds numbers), the attainable suction is zero.

However, camber may be used to achieve drag coefficients comparable with those with full suction over a moderate \( C_L \) range. Increasing the zero-lift angle of attack (effect of camber) moves the minimum-drag-coefficient region to higher \( C_L \)'s, a well-known effect of camber. At higher loading conditions \( C_L > 0.6 \), significant camber (large \( \alpha_{2L} \)) is required to minimize drag. The results clearly indicate that for operation of a sharp-edged profile, a wing with variable camber (potential morphing application) would be necessary to achieve efficient flight operation over a significant extent of the flight envelope.

Unfortunately, the agreement between the two theoretical expressions is poor for the three displayed cases. Numerical evaluation shows improving agreement between the equations with increasing attainable suction \( \eta \). However, it may be seen that Eq. (24) predicts drag coefficients below that with full suction as \( \alpha_{2L} \) increases. This prediction is not reflective of a physical reality and may be an issue with the underlying assumptions in the derivation of Eq. (24). As previously mentioned, Eq. (24) may have limited applicability for airfoil profiles that are not circular arcs. Nonetheless, the results in this study indicate that Eq. (24), although not showing the same level of predictive accuracy as Eq. (20), still provides good estimates and is a slightly simpler expression, as summarized in the next section.

---

**Figure 12.29: Sample Results and Discussion for AIAA-style Reports, cont’d**

(Source: Adapted from Traub, 2009)

As demonstrated in the preceding figure, results are presented in graphic form and through data commentary; unexpected findings are identified and rationales or explanations are offered.

- Has an A-level heading that is centered, bold, 12-point font, using capital and lower-case letters. The heading is numbered using Roman numerals (i.e., III. Results and Discussion) and is followed by one (1) blank line.
o Is written in AIAA format. All prose/paragraphs are single-spaced with no extra lines between paragraphs. Each paragraph is indented; 12-point Times New Roman, Arial, or similar font is used. Note that this AIAA-required format is neither standard essay format nor standard block format. (See Section 3.2.2: Spacing for further exemplification of AIAA-style paragraph formatting.)

o Cites relevant studies previously mentioned in the Introduction section using standard AIAA-style citation (i.e., using superscripted footnotes), with each footnote referring to an entry in the References section (as per Section 12.3.10: References).

o Includes graphics as required (e.g., data tables and data charts), properly introduced in the prose, labeled, captioned, and commented upon. (See Section 8.0: General Guidelines for Graphics and Equations.)

o Contains four (4) organizational sections: presentation of data in graphic form, data commentary comparing achieved to expected results, identification of trends, and explanation of any unexpected results.

  o Presents data in graphic form; these results are properly introduced with a paragraph or two of prose and are properly placed, captioned, and commented upon. (See Section 8.2: Avoidance of Data Dumping.)

  o Follows data presentation with data commentary that evaluates or compares the achieved results or acquired data to the expected results as had been stated in the background of the Introduction section.

  o Identifies trends in the data and interprets their meaning in the context of the lab experiment; the achieved results are shown to be evidence of a key principle or concept or behavior.

  o Explains any unexpected results; moreover, possible reasons for any discrepancy between the achieved results and the expected results (including error analysis as applicable) are discussed.

  o Avoids data dumping (i.e., tables or figures that are not followed by prose that discusses the important information presented in the tables and figures). (See Section 8.2: Avoidance of Data Dumping for advice.)

  o Is written in the present tense. (See Section 6.3: Verb Tenses.)

  o Uses adequate qualifying/hedging words and phrases throughout so as to not make an overly strong claim. (See Section 7.4: Qualification.)
12.3.7 Conclusions and Recommendations

o Summarizes the purpose of the lab and key findings, as demonstrated in Figure 12.30: Sample Conclusions and Recommendations for AIAA-Style Reports:

IV. Conclusions and Recommendations

This lab was designed to examine the microstructure and mechanical properties of three (3) types of steel that were subjected to two (2) types of heat treatments. The predicted microstructures and hardness of each specimen were in agreement, with exception to the 1018 steel that underwent the water-quenching heat treatment. The hardness of this sample of steel after treatment was higher than predicted; it is likely that the difference in the amount of martensite that resulted in this sample motivated the difference in hardness between the predicted and measured values.

The average diameter of the cementite grains that were formed within the spheroidite microstructures tended to increase in number and size with increasing carbon content. A similar trend in the number, length, and thickness of needle-like structures formed within the martensite microstructures was also observed to increase with increasing carbon concentration. Moreover, the hardness associated with steels containing martensite was higher than the hardness of steel containing spheroidite.

A limitation of this lab is the limited resolution of the microscope images, which made identification of the microstructures difficult. Determination of the number of grains of a particular phase would be easier if a scanning electron microscope were purchased and made available for future labs.

Figure 12.30: Sample Conclusions and Recommendations for AIAA-style Reports
(Source: Adapted from Akerson, 2009)

Limitations and recommendations are also presented in this section, as illustrated in the preceding figure and as noted in following bullets.

o Has an A-level heading that is centered, bold, 12-point font, using capital and lower-case letters. The heading is numbered using Roman numerals (i.e., IV. Conclusions and Recommendations) and is followed by one (1) blank line.
○ Is written in AIAA format. All prose/paragraphs are single-spaced with no extra lines between paragraphs. Each paragraph is indented; 12-point Times New Roman, Arial, or similar font is used. Note that this AIAA-required format is neither standard essay format nor standard block format. (See Section 3.2.2: Spacing for further exemplification of AIAA-style paragraph formatting.)

○ Includes graphics as required (e.g., summary data tables), properly introduced in the prose, labeled, captioned, and commented upon. (See Section 8.0: General Guidelines for Graphics and Equations.)

○ Includes six (6) elements: a restatement of the purpose of the lab, a very brief summary of the Procedures section, a summary of the Results section, a statement of the primary conclusions which can be drawn from the Results, the limitations of the lab/problems encountered during the lab Procedures, and recommendations for overcoming each of the flaws.

○ Provides no new results; all results, including data commentary, trends, and unexpected results, have been previously stated in the Results section.

○ Provides a critique of the lab experiment through a statement of limitations and recommendations:

  ○ Offers one or two limitations of the experiment, typically in terms of the resources available or the procedures followed. Limitations must be specific in scope and reasonable in tone. Pointing out a restriction that cannot be addressed is of little value; stating problems that can be feasibly and reasonably addressed is of greater value.

  ○ Pairs each limitation with at least one recommendation for improving the lab experiment. Each recommendation must directly address the limitation it is paired with. Recommendations must be specific, feasible, and stated using an unreal conditional of the grammatical form “AA would have been BB if XX had been YY.”

  ○ Each limitation must be stated BEFORE its recommendation, so that each limitation statement and recommendation statement forms a matched pair; thus, if there are multiple limitations/recommendations, the order of presentation is as follows:

    ○ Limitation 1

    ○ Recommendation 1
Regardless of the number of limitations/recommendations pairs included in a Lab Report, the limitation must always be stated before its matching recommendation.

- Uses adequate *qualifying/hedging* words and phrases so as to not make overly strong claims. (See Section 7.4: Qualification.)

- Is written in the *present* tense. (See Section 6.3: Verb Tenses.)

- Has one (1) blank line before the following section, which is either the Appendix, Acknowledgments, or References.

### 12.3.8 Appendix

- Is an optional section that contains only critical, additional information. As such, it should be used sparingly.

- Has an A-level heading that is centered, bold, 12-point font, using capital and lower-case letters. The heading is not numbered and is followed by one (1) blank line.

- Is written in *AIAA format*. All prose/paragraphs are single-spaced with no extra lines between paragraphs. Each paragraph is indented; 12-point Times New Roman, Arial, or similar font is used. Note that this AIAA-required format is neither standard essay format nor standard block format. (See Section 3.2.2: Spacing for further exemplification of AIAA-style paragraph formatting.)

- States any additional information as concisely as possible.

- Has one (1) blank line before the following section, either the Acknowledgments or the References.

### 12.3.9 Acknowledgments

- Briefly acknowledges support, including sponsor and financial support, as shown in Figure 12.31: Sample Acknowledgments for AIAA-style Reports:
Acknowledgments

Team Harrier thanks the staff and faculty of the Department of Aeronautical Engineering for helping to make this project possible, especially Dr. Ron Madler, Dr. Julio Benavides, and Dr. Brad Wall. Thanks are also due to Mr. Patrick David and Mr. Chris Smith.

Figure 12.31: Sample Acknowledgments for AIAA-style Reports

- Has an A-level heading that is centered, bold, 12-point font, using capital and lower-case letters. The heading is not numbered and is followed by one (1) blank line.

- Is written in AIAA format. All prose/paragraphs are single-spaced with no extra lines between paragraphs. Each paragraph is indented; 12-point Times New Roman, Arial, or similar font is used. Note that this AIAA-required format is neither standard essay format nor standard block format. (See Section 3.2.2: Spacing for further exemplification of AIAA-style paragraph formatting.)

- Has one (1) blank line before the following section, the References.

12.3.10 References

- Lists all sources in their order of appearance, NOT in alphabetical order, as shown in Figure 12.32: Sample References for AIAA-style Reports:
References


Figure 12.32: Sample References for AIAA-style Reports
(Source: Adapted from Traub, 2009)

As shown in the preceding figure, the sources are listed in the order of appearance in the text. Each superscripted reference number refers to its corresponding in-text reference. Reference numbers do not have a space after them; they are immediately followed by the first letter of the following word (which is typically an author’s last name).

- Has an A-level heading that is centered, bold, 12-point font, using capital and lower-case letters; Times New Roman, Arial, or similar font is used. The heading is not numbered and is followed by one (1) blank line.
Is written in *AIAA format*. All entries are single-spaced with no extra lines between entries. Each entry is indented; 12-point font is used. (Note that papers submitted for publication using AIAA standards typically write References in 9-point font, not 12-point font; 12-point font, however, is the educational standard adopted by the COE and ERAU, Prescott campus and in this case supersedes AIAA standards.)

Is formatted according to standard **AIAA citation** rules (i.e., author, title, volume number or edition, publisher’s name, place of publication, date of publication, page number). (See *Section 9.3.2: Guidelines for Formatting AIAA-style References* and *Section 9.5: AIAA Standards*.)

Lists all authors’ names, unless a source has six (6) or more authors, in which case “et al.” is used.

Does **NOT** contain personal communications or interviews; these sources are listed as footnotes in the text.

**12.3.11 Footnotes**

Are linked to their corresponding reference number in the text using superscript font.

Are consecutively numbered.

List the author’s (or authors’) affiliation and contact information in the very first set of footnotes.

Include references to personal communications or interviews (which then do **NOT** appear in the References section).

Separate the multiple reference numbers with a comma (i.e., 4, 5).

Indicate a range of reference numbers with a long dash (i.e., 6–9).
13.0 SYSTEMS ENGINEERING

This section provides a very brief overview of systems engineering as it is practiced in several courses offered by the COE, in industry, and in government agencies (e.g., NASA). General concepts and generic processes and techniques are described, with a focus on the types of required documentation.

It should be stressed that this brief discussion is intended to provide some guidance in the practices and documentation of systems engineering as practiced in the COE; COE faculty can provide a much richer description of “best practices” in systems engineering than is available in this brief primer.

13.1 Systems Engineering Processes

Systems engineering is an interdisciplinary process that ensures that a customer's needs are satisfied throughout a system's entire life cycle; to accomplish this goal, seven (7) tasks must be accomplished:

1. Define the problem; identify customer needs, requirements, and system functions.

2. Investigate alternative solutions to the problem; undertake performance, cost, and risk assessments for multiple design alternatives.

3. Model the system; create both computer and physical models, test the models’ performance, and compare to theoretical predictions.

4. Integrate the system; design interfaces between subsystems, create both computer and physical models, test the model’s performance, and compare to theoretical predictions for the entire integrated system.

5. Launch the system; manufacture the system and run it as intended.

6. Assess performance; measure according to set criteria, modify as necessary to meet customer needs and requirements.

7. Re-evaluate; continually and iteratively refine the design. (Adapted from Bahill & Gissing, 1998).

As is evident from the process outlined above, systems engineering is a complicated process that requires numerous units to work closely and to communicate frequently. Systems engineering requires engineers, technicians, contracts managers, suppliers, machinists, software developers, and specialists of various kinds to work together with the client to meet the client’s requirements.
The interdisciplinary nature of systems engineering is clearly articulated in the *NASA Systems Engineering Handbook*,

**Systems engineering** is the art and science of developing an operable system capable of meeting requirements within often opposed constraints. Systems engineering is a holistic, integrative discipline, wherein the contributions of structural engineers, electrical engineers, mechanism designers, power engineers, human factors engineers, and many more disciplines are evaluated and balanced, one against another, to produce a coherent whole that is not dominated by the perspective of a single discipline. (NASA, 2007: 3)

Systems engineering relies upon *practices or processes* that are intended to be systematically and recursively applied to the design, development, operation, maintenance and closeout phases of a project’s life cycle (NASA, 2007). By applying these practices or processes in a *disciplined and iterative fashion*, technical decisions can be made that

- Satisfy top-level requirements,
- Satisfy systems-level requirements,
- Optimize the overall design, and
- Meet given parameters, tolerances, or constraints.

Some of the practices or processes undertaken by systems engineers include system design, product realization, and technical management as depicted in *Figure 13.1: Systems Engineering Practices/Processes*.
As illustrated in the preceding figure, systems engineering entails the technical aspects of a project; budgetary, staffing, and other aspects are typically managed by other segments of project management.

As depicted in Figure 13.1: Systems Engineering Practices/Processes, system engineering begins with system design practices. System design practices define the expectations of the client and other stakeholders, generate technical requirements (both systems/component-level and top-level requirements), and create a design that meets the technical requirements. Iterative application of these
system design practices typically result in a preliminary design that meets all expectations and requirements—at least on paper.

System engineering then moves to product realization practices. Product realization practices fabricate or manufacture parts, components, systems, assemblies, and final products that meet the technical requirements of the design as developed through the system design practices. These practices include materials testing and trade studies, component testing, and integration testing for systems/components as well as the final product. Iterative application of these product realization practices typically result in a detail design that meets all expectations and requirements—a physical product that satisfies the needs of the client and all other stakeholders.

Finally, system engineering requires technical management practices. Technical management practices include communication between personnel, writing of requirements documents and test plans, risk management, configuration management, data management, assessment of test results, and assessment of the success of the overall project at every point in its development. Iterative application of these technical management practices typically result in the revision of the preliminary design or the detail design so as to better meet the client’s expectations and the project requirements.

These systems engineering practices are typically adopted from industry and become part of the various capstone courses offered by the COE. These practices are reflected in various forms of documentation required in the capstone courses, also adopted from industry, some of which are described in the following section.

### 13.2 Systems Engineering Documentation

During the systems engineering process in both industry and in engineering capstone courses, several types of documents are created, some by the client (or the course instructor), some by the design team (or the student). These documents may include the following:

- Request for Proposal (RFP),
- Statement of Work (SOW),
- Contract Data Requirement List (CDRL) items,
- Data Item Description (DID),
- Drawing Package,
- Product Structure Tree,
- Requirements Document,
This bulleted list is representative of most of the key documents associated with different systems engineering processes. Of course, not every project requires every type of document; furthermore, some documents are required only by specific procuring agencies (e.g., CDRL’s are required primarily for military contracts), while others may be favored only by particular contractors (e.g., Product Structure Trees are preferred by Honeywell).

In the remainder of this section, each of these documents is discussed and, where possible, exemplified using authentic examples provided by the faculty and students of the College of Engineering, Prescott campus.

### 13.2.1 Request for Proposal (RFP)

A request for proposal (i.e., RFP) is a document that a client/organization posts to elicit bids from potential vendors/design teams for a product or service. The specifications for the product or service should be stated as clearly and in as much detail as possible in the RFP, as should deadlines, cost limitations, and other requirements set by client/organization. A sample RFP is presented in Figure 13.2: Sample Request for Proposal:

---

This Request for Proposal addresses the development of a surveillance/reconnaissance vehicle in AE 420: Aircraft Preliminary Design and AE 421: Aircraft Detail Design in Fall 2008 and Spring 2009.

**Mission Statement:**

Two (2) prototype vehicles, one (1) from each of two (2) competitive bidders, will enter wind-tunnel verification testing in February, 2009. One (1) vehicle will be selected by a team of experts as best fulfilling the mission elements stated below; a scaled wing component of the selected vehicle will be structurally tested, and a scaled flight prototype of the vehicle will be flight-tested in April, 2009.

The selected vehicle design will begin further proof of concept demonstrations in May 2009 with operational test and evaluation (OT&E) to follow.

---

**Figure 13.2: Sample Request for Proposal**
(Source: Adapted from Ashworth, 2008)
The required mission elements include the following:

- Assembly from transport container,
- Weight and balance determination,
- System checkout,
- Launch and climb to altitude,
- High-altitude surveillance or low-altitude reconnaissance, and
- Recovery and dismantle or re-launch.

Vehicle Design Specifications/Requirements:

The selected vehicle design must meet the following design specifications:

- Be transported in a 6-ft by 6-ft by 4-ft container;
- Be assembled and ready to launch in less than two (2) hours;
- Be launched from a hard surface or gravel road in less than 3,000 feet;
- Have a currently available propulsion system; propulsion system is not otherwise specified;
- Fly to an altitude of 30,000 feet and remain on station for at least 8 hours;
- Be capable of excursions at low altitude (sea level) and low airspeed (30 knots) that will decrease the 8-hour on-station time;
- Achieve airspeeds of over 100 knots and 3-G forces (sea-level conditions) for tactical operations;
- Be remotely piloted (i.e., pilot flying using on-board camera data);
- Transmit both real-time video and infrared data;
- Recover on the take-off runway; and
- Be cost effective to allow a 30-unit purchase.

Figure 13.2: Sample Request for Proposal, cont’d
(Source: Adapted from Ashworth, 2008)

As shown in the preceding figure, an RFP defines the expectations of the client and generates top-level (and sometimes system/component-level) technical requirements; specifications are quantified where possible.

13.2.2 Statement of Work (SOW)

A statement of work (i.e., SOW) is a document that is typically produced by the vendor/design team project manager to define the tasking required to successfully respond to an RFP. The SOW states the assumptions of the engineering task (including assumptions regarding testing and analysis), lists specific engineering
tasks to be undertaken, and defines any documentation to be provided by the vendor to the client, as illustrated in Figure 13.3: Sample Statement of Work:

The information provided below delineates the anticipated effort required of Aero-Endurance in performing detailed design of the exposed right and left wing sections of their surveillance/reconnaissance UAV design.

1.0 Assumptions

1.1 The surveillance/reconnaissance UAV’s designed by Aero-Con and Endurance Engineering during the preliminary design phase completed December 2008 are of sufficient fidelity to allow detailed design to progress without major modification to the aircraft configuration.

1.2 The entire exposed wing section of a 1:4 scale structural model will be considered for the detail design portion of this effort. However, due to symmetry, only the right wing section will be designed, with the resulting configuration applied to the left wing section as well. A structural test article will be manufactured to include both the right and left wing panels and the fuselage section to which they are attached. In addition, an entire flyable 1:4 scale flight test article will be manufactured with the intent of being flown from a model air field.

1.3 Wind tunnel models will be constructed to be representative of the entire aircraft of each teams’ design. Model construction may initiate only after approval by the course instructor of a written model construction proposal, which will be incorporated into the Wind Tunnel Test Plan (CDRL A001). Likewise, proposed methods for instrumentation, data collection and data reduction will be documented in the Wind Tunnel Test Plan, which will require approval by the course instructor prior to the initiation of testing.

1.4 Although design trade studies will be performed to identify the best materials to be utilized in the construction of the aircraft model for the purposes of structural test, actual construction will be accomplished using materials which are deemed cost effective by the course instructor. Every effort should be made to procure materials consisting of similar material properties to those identified as a result of the trade studies.

Figure 13.3: Sample Statement of Work
(Source: Adapted from Helbling, 2009)
A structural proof test to 80% of the predicted maximum design limit wing load will be performed on the final assembly of the structural test article to verify analytical predictions of strain and displacement within the wing section. Testing will not commence until a Structural Test Plan detailing the test procedure has been approved by the course instructor (CDRL A002).

2.0 Engineering Tasks

2.1 Loads Computation. All loads predicted to act on the wing section will be evaluated based on analytical predictions. Load conditions will be determined to represent the worst case loading introduced into the wing section. The applicable load requirements identified in Federal Aviation Regulations, Part 23 will be observed for this program (see Applicable Documents, Section 4.0). The results of this analysis will be documented in the Mid-Semester and Final Reports (CDRL’s A004, and A005).

2.2 Wing Section Structural Configuration. The initial composition of the wing structural assembly will be identified through comparisons to wing sections of existing aircraft. Structural loading, manufacturability, and cost considerations will be observed in determining the final configuration. The results of this study will be documented in the Mid-Semester and Final Reports (CDRL’s A004, and A005).

2.3 Material Selection. A trade study will be performed to identify the materials which would best satisfy the design requirements for the wing section assembly. These requirements will include safe operation while resisting the worst case loading determined via 2.1, manufacturability, and cost. The results of this analysis will be documented in the Mid-Semester and Final Reports (CDRL’s A004, and A005).

2.4 Structural Analysis. Structural analysis will be performed on the sub-components comprising the wing section and all primary load bearing components of the test article assembly using a combination of ‘hand’ calculations and ANSYS finite element analysis. Initial sizing of each component will result from the ‘hand’ computations. ANSYS results will be utilized for final sizing which will be used for defining material quantities for the structural test article. ANSYS will also be utilized for modeling the test.
article as it is actually loaded during the proof test and used for comparison to test results. The results of these analyses will be documented in the Final Report (CDRL A005).

2.5 Wind Tunnel Testing

2.5.1 A wind tunnel model will be fabricated to represent the entire aircraft. The methods proposed for model construction, instrumentation, data collection and data reduction will be documented in the Wind Tunnel Test Plan (CDRL A001).

2.5.2 A wind tunnel test will be performed for the purpose of collecting aerodynamic data to be used in defining performance and stability characteristics of the aircraft and in refining predicted loading on the wing section. Flow visualization techniques will also be employed for evaluation of flow fields around the proposed configuration. The results of the testing will be documented in the Mid-Semester and Final Reports (CDRL's A004, and A005).

2.6 Design Refinement. The structural configuration of the test article will be re-evaluated based on wind tunnel measurements and any revisions to the predicted loading will be defined. Any revision to the original configuration resulting from this evaluation will be documented in the Final Report (CDRL A005).

2.7 Drawing Package. A drawing package will be generated including detail drawings of individual components comprising the test article, as well as assembly drawings and a parts list (CDRL A003). The detail drawings will include all dimensions and text notes required to allow fabrication of the components that make up the assembly. The assembly drawing will identify how the components are to be assembled. The drawing package will be circulated among all team members and the course instructor for their concurrence prior to commencement of manufacturing.

2.8 Component Fabrication. Individual components will be manufactured in accordance with the detail drawings developed in 2.7. The manufacturing process will be documented in the Final Report (CDRL A005).

Figure 13.3: Sample Statement of Work, cont’d
(Source: Adapted from Helbling, 2009)
2.9 **Structural Testing**

2.9.1 A structural test plan will be developed identifying the procedure to be followed in performing the structural proof test of the wing section assembly. A single load condition will be applied to the finished assembly as a part of this test. This test plan will be submitted for approval prior to the commencement of testing (CDRL A002).

2.9.2 Structural tests will be performed in accordance with the test plan described in 2.9.1. All results and recorded measurements will be documented in the Final Report (CDRL A005). Measured stress and deflection values will be compared to values predicted by ANSYS and any differences noted.

2.10 **Final Design Evaluation.** The wing section design will be evaluated based on the structural test results and any recommendations for further refinement will be documented in the Final Report (CDRL A005).

3.0 **Required Documents**

The documents listed in Table 1: Contract Data Requirements List are required to be submitted no later than the due date posted in the table:

<table>
<thead>
<tr>
<th>CDRL No.</th>
<th>Description</th>
<th>Due Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>A001</td>
<td>Wind Tunnel Test Plan</td>
<td>1/22/09</td>
</tr>
<tr>
<td>A002</td>
<td>Structural Test Plan</td>
<td>3/12/09</td>
</tr>
<tr>
<td>A003</td>
<td>Drawing Package</td>
<td>4/24/09²</td>
</tr>
<tr>
<td>A004</td>
<td>Mid-Semester Report</td>
<td>2/26/09</td>
</tr>
<tr>
<td>A005</td>
<td>Final Report</td>
<td>4/24/09</td>
</tr>
</tbody>
</table>

¹ Report section requirements defined in Data Item Description documents resident under Course Documents on the AE421 Blackboard website.

² Individual drawings must be ‘released’ prior to fabrication of parts.

---

*Figure 13.3: Sample Statement of Work, cont’d*
*(Source: Adapted from Helbling, 2009)*
4.0 Applicable Documents

- AE421 Detail Aircraft Design Spring 2009 Syllabus, available via Blackboard
- Federal Aviation Regulations, Part 23, available via the web. Applicable sections:
  - Loads
  - Factor of Safety
  - Strength and Deformation
  - Symmetrical Flight Conditions
  - Flight Envelope
  - Design Airspeeds
  - Limit Maneuvering Load Factors
  - Gust Load Factors
  - Loads Parallel to Hinge Line
  - Maneuvering Loads
  - Gust Loads
  - Ailerons
  - Any other section deemed applicable by the design team
- Niu, "Airframe Structural Design"
- Bruhn, "Analysis and Design of Flight Vehicle Structures"
- ANSYS Tutorials (on AE Resources folder within T drive)
- CATIA V5 Workbook (Release 17)
- Advanced CATIA V5 Workbook (Releases 16 & 17)
- Northrop Structural Design Manual, Vol.'s I, II, and III

---

**Figure 13.3: Sample Statement of Work, cont’d**
(Source: Adapted from Helbling, 2009)

As the preceding figure illustrates, the SOW includes criteria for measuring task success or failure of the project. It also refers to further documentation (e.g., a drawing package) and posts deadlines.

13.2.3 Contract Data Requirement List (CDRL) Items

A contract data requirement list (i.e., **CDRL**) item is a document that the vendor/design team produces in accordance with the SOW in response to specific requirements listed in an RFP. The CDRL is a list of documentation that the vendor/design team is expected to submit over the course of the project, as illustrated in **Figure 13.4: Sample Contract Data Requirement List**:  

---
Table 1: Contract Data Requirements List

<table>
<thead>
<tr>
<th>CDRL No.</th>
<th>Description</th>
<th>Due Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>A001</td>
<td>Wind Tunnel Test Plan</td>
<td>1/22/09</td>
</tr>
<tr>
<td>A002</td>
<td>Structural Test Plan</td>
<td>3/12/09</td>
</tr>
<tr>
<td>A003</td>
<td>Drawing Package</td>
<td>4/24/09</td>
</tr>
<tr>
<td>A004</td>
<td>Mid-Semester Report</td>
<td>2/26/09</td>
</tr>
<tr>
<td>A005</td>
<td>Final Report</td>
<td>4/24/09</td>
</tr>
</tbody>
</table>

1 Report section requirements defined in Data Item Description documents resident under Course Documents on the AE421 Blackboard website.

2 Individual drawings must be ‘released’ prior to fabrication of parts.

Figure 13.4: Sample Contract Data Requirement List
(Source: Adapted from Helbling, 2009)

Of note in the preceding figure are the identification numbers for each document to be submitted; these identifying numbers are written on the documents in question (e.g., “CDRL A002: Structural Test Plan”). Each document listed is also described in richer detail in a further document, a Data Item Description.

13.2.4 Data Item Description (DID)

A Data Item Description (i.e., DID) is a document released by the procuring agency to provide a description of the expected contents and organization of a specific CDRL item (e.g., a Wind Tunnel Test Plan), usually in outline form. Some DID’s include descriptions of the expected language and formatting as well. A DID is illustrated in Figure 13.5: Sample Data Item Description, which follows:
Sections to be included in *CDRL A001: Wind Tunnel Test Plan* are as follows:

1.0 Introduction

2.0 Model Construction
   
   2.1 CAD Model Development*
   
   2.2 3-D Printer Fabrication*

3.0 Model Structural Integrity Verification*

4.0 Testing Procedure*

5.0 Data Collection and Reduction Procedure*

6.0 References

* Section to include technical content.

The format to be followed in creating this report is defined in the *Style Manual of the COE* available at the ERAU, Prescott campus Bookstore.

---

**Figure 13.5: Sample Data Item Description**
(Source: Adapted from Helbling & Beck, 2009)

The sample DID illustrated in the preceding figure provides a very basic outline of the document in question, i.e., of a specific type of test plan. Both the expected content sections and the expected organization are clearly stated and should be carefully followed by the vendor/design team.

13.2.5 Drawing Package

A **Drawing Package** is a collection of technical drawings drafted by the vendor/design team that accurately represents the technical specifications of each part, component, assembly, and final integrated product so as to allow machinists and manufacturers to accurately fabricate and assemble the product.

Each technical drawing in a Drawing Package is a clear rendering of the part, component, assembly, or final integrated product. Careful attention is paid to scale, orientation, geometry, dimensions, units of measure, tolerances, connections, and fit. *Three-view drawings* of the final assembled product (aircraft or spacecraft design) must be included in the Drawing Package.
Each drawing in a Drawing Package is “red-lined” during the systems engineering process, providing feedback in the form of corrections and suggestions to improve the design itself as well as improve the accuracy of the drawings. These changes are then incorporated into the final drawing package submitted to the customer at the conclusion of the project.

### 13.2.6 Product Structure Tree

A **Product Structure Tree** is a chart that represents all the systems that comprise a product as well as their attendant parts, components, and assemblies. The chart provides a hierarchical overview of the product so that the relationships between parts, components, and systems are readily apparent. Systems engineering documents associated with each component, assembly, or system are also noted, as indicated in **Figure 13.6: Sample Product Structure Tree**:

![Figure 13.6: Sample Product Structure Tree](Source: Adapted from Siebold, 2008)

As seen in the preceding figure, each component, assembly, or system is readily identified, and the hierarchical relationship between each is clear. For example, the “satellite” and “ground station” components are part of the “communication” sub-subsystem, which is in turn part of the “attitude hardware” subsystem, which is in turn part of the “attitude” system.
In addition, the systems engineering documents (e.g., Requirements Documents or Test Plans) that are associated with each component, assembly, or system are clearly identified using a 9-digit document numbering system. The first three digits in the document number indicate the document type (e.g., Bill of Materials, Assembly Instructions), the next four digits indicate the project number or system number, and the last two digits indicate a variation or revision. The following list exemplifies a few documents commonly found in a Product Structure Tree and their associated document numbers:

<table>
<thead>
<tr>
<th>Document Type</th>
<th>Document Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Final Product Structure Tree</td>
<td>065-0041-10</td>
</tr>
<tr>
<td>Final Assembly Bill of Materials</td>
<td>066-0041-10</td>
</tr>
<tr>
<td>Final Product Assembly Instructions</td>
<td>366-0041-10</td>
</tr>
<tr>
<td>Final Product Requirements</td>
<td>003-0041-10</td>
</tr>
<tr>
<td>Final Product Test Plan</td>
<td>005-0041-10</td>
</tr>
<tr>
<td>Computer Integration Subsystem Bill of Materials</td>
<td>200-0140-10</td>
</tr>
<tr>
<td>Computer Integration Subsystem Assembly Instructions</td>
<td>300-0140-10</td>
</tr>
<tr>
<td>Computer Integration Subsystem Requirements</td>
<td>203-0140-10</td>
</tr>
<tr>
<td>Computer Integration Subsystem Test Plan</td>
<td>205-0140-10</td>
</tr>
</tbody>
</table>

Thus, document number 005-0041-10 refers to the Test Plan for the final product (005) for the tenth version (10) of the forty-first project (0041).

Finally, the personnel in charge of a specific part, component, assembly, subsystem, or system might be identified on the Product Structure Tree, along with their contact information. Care has to be taken, however, to provide a complete overview of a project without overcrowding the Product Structure Tree.

13.2.7 Requirements Document

A Requirements Document is a document created by a client/organization, often in conjunction with the vendor/design team; a Requirements Document states how each element of a design (e.g., subsystem 1, subsystem 2, the integrated design) shall function so as to meet certain criteria (e.g., measurements, tolerances, standards). A Requirements Document is exemplified in Figure 13.7: Sample Requirements Document:
All requirements shall be tested in accordance with Test Plan 205-0041-00:

1. Based on expected disturbance torques (inaccuracy of CM location) the Altitude Determination and Control System (ADCS) shall undergo a data acquisition and attitude correction cycle a minimum of every 0.01 seconds.

2. The ADCS shall achieve a sample time of no more than 0.01 seconds.

3. Based on analysis undertaken in AE 427: Spacecraft Preliminary Design, throughout descent, the ADCS shall achieve a pointing accuracy in all three (3) axes of no greater than 1 deg.

4. Throughout descent, the ADCS shall control the spacecraft such that it maintains angular velocities in all three (3) axes of less than 1 deg./s.

5. Upon touchdown, the ADCS shall achieve a pointing accuracy in all three (3) axes of no greater than 1 deg.

6. Upon touchdown, the ADCS shall control the spacecraft such that it has an impact velocity of no greater than 1 m/s.

---

**Figure 13.7: Sample Requirements Document**
(Source: Adapted from Moonshine Aerospace, 2008a)

As exemplified in the preceding figure, each requirement begins with the *agent* (who or what is responsible for meeting the requirement), followed by an *appropriate verb* (e.g., perform, provide, achieve, control, weigh, measure) and a *description* of what is to be performed (NASA, 2007). The description must include specific measurements, tolerances, criteria, or other specific performance values. TBD values are kept to an absolute minimum.

All requirements are based upon logical assumptions and analysis; *justifications* for each requirement should be included when possible. For example, requirement #1 in the preceding example, “Based on expected disturbance torques,” is a brief justification for the requirement.

Grammatically, each requirement is stated as a *simple sentence*, in *indicative mode*, in *active voice*; use of the word *shall* is mandatory. Linguistically, terms have been defined and are used consistently.

All specifications and performance values must be *measurable or verifiable*. These measurements or verifications are articulated in a Test Plan so that each and every requirement is accounted for in the Test Plan. The *document number*
for the associated Test Plan is thus included in the Requirements Document for ease of reference.

13.2.8 Test Plan

A Test Plan is a document created by a vendor/design in order to provide the instructions for testing each requirement listed in a Requirements Document. Expected outcomes, required apparatus, test instructions, and pass/fail checklists with signature lines are all standard elements of a Test Plan, as illustrated in Figure 13.8: Sample Test Plan:

1.0 Expected Outcomes

The Ground Station shall transmit test data to and receive test data from the Onboard Computer, in accordance with Requirements Document 203-0143-10.

2.0 Apparatus

The following items are required for testing:

- One (1) NETGEAR Wireless Router,
- One (1) power adaptor,
- One (1) Cat 5 Cable with RJ45 connectors,
- One (1) desktop computer, designated the Ground Station, and
- One (1) laptop computer, designated the Onboard Computer.

Instructions for using these items in the testing of the Ground Station and the Onboard Computer are presented in the following section.

3.0 Instructions

1. Power up the router by plugging the power adapter in to the wall power outlet.

2. Connect the router to the Ground Station using the Cat 5 cable.

Figure 13.8: Sample Test Plan
(Source: Adapted from Moonshine Aerospace, 2008b)
3. Using the computer interface on the Ground Station, open the Command prompt by clicking on the “Start" menu.

4. From the “Start" menu, go to the “Programs/Accessories/Command" prompt.

5. At the Command prompt, type “ping 24.218.156.183,” and press enter. If the ground station computer is able to connect to the laptop it will reply as seen in Figure 3.1: Command Prompt....

### 4.0 Pass/Fail Checklists

<table>
<thead>
<tr>
<th>Pass</th>
<th>Fail</th>
</tr>
</thead>
</table>

- The Ground Station successfully pings the Onboard Computer.
- The Ground Station successfully transmits data to the Onboard computer
- The Onboard computer successfully transmits data to the Ground Station.

- Did any of the above tests fail? If so, the overall test receives a failure.

Technicians/Testers:

<table>
<thead>
<tr>
<th>Printed Name</th>
<th>Signature</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

---

Figure 13.8: Sample Test Plan, cont’d
(Source: Adapted from Moonshine Aerospace, 2008b)

As previously mentioned, all specifications and performance values stated in a Requirements Document are to be measured, demonstrated, inspected, or analyzed in the associated Test Plan, and so, as illustrated in Figure 13.8: Sample Test Plan, the document number of the relevant Requirement Document is stated in the Test Plan, preferably in the expected outcomes. Note that the expected
outcomes are a summation of the requirements being tested and so include the word “shall”.

Also of note, the instructions are written as such and not as a set of procedures. (See Section 6.2: Instructions for advice on drafting well-crafted instructions.) The last entry on the pass/fail checklist states the criteria necessary for the test to earn an overall pass. Typically, a single failure on any part of the test denotes a failure of the test as a whole. Finally, the signature lines identify the names of the technicians performing the tests and verify the date the test was completed.

13.2.9 Test Results/Verification Document

Test Results (also known as a Verification Document) are documents created by a vendor/design summarizing the outcomes of any tests performed on any parts, components, assemblies, subsystems, systems, or products. As such, Test Results are generated after the completion of all tests in accordance with the relevant Test Plan. Test Results often resemble the Results sections of Lab Reports (as described in Section 12.0: Description of Lab Reports by Section); they cover approximately the same content and are organized in approximately the same fashion as a Lab Report, as illustrated in Figure 13.9: Sample Test Results/Verification Document:

---

Single-Axis Control Tests

In order to verify the one-dimensional optimal control derived from Bryson, ADCS tests were conducted using the simulation described in the ADCS test plan document (205-0143-10). If the control theory is accurate, results should show that the system can be critically damped for any known conditions of control torque, disturbance torque, and inertial body properties.

The results for a single-axis control test with an initial deflection of positive 5 deg. and initial rate of positive 3 deg./s on the roll axis generated the initial values summarized in Table 1: Initial Conditions:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial Angular Rate</td>
<td>[3*pi/180 0 0] rad/s</td>
</tr>
<tr>
<td>Initial Quaternion</td>
<td>[5*pi/180 0 0 1]</td>
</tr>
<tr>
<td>Control Quaternion</td>
<td>[0 0 0 1]</td>
</tr>
</tbody>
</table>

Figure 13.9: Sample Test Results/Verification Document
(Source: Adapted from Moonshine Aerospace, 2008c)
Using the initial values reported in the preceding table, the control system had a 5-deg. deadband condition for angular position and a 0.1-degree/s deadband condition for angular rate.

Upon inspection, test results indicate that the system made two (2) control torque state changes to reach the deadband condition. From the initial position the controller commanded a negative torque about the roll axis, which was maintained until the state of the system passed the switching curve. Once the system passed the switching curve, the controller commanded a positive control torque and the system closely paralleled the switching curve until reaching a state that was within the specified deadband conditions. Analysis of the raw data shows that the first torque switch occurred less than 5 seconds after the test began and the deadband condition was achieved less than 7.5 seconds after the test began. Thus, the test criteria were met, as verified by the test technicians.

Therefore, it can be concluded that the new controller designed for the Architeuthis test bed is able to achieve the attitude conditions specified, including required deadbands, settling times, and system stability lifetime, for a linear, single-axis case. For these conditions the controller can bring the system to a critically damped solution due to the approximations made in the controller and attitude subsystems in the Simulink model. However, the system control frequency has an effect on the accuracy of the system. The state of the system in the above test did not exactly follow the accuracy of the system. The state of the system in the above test did not exactly follow the specified switching curve. The state overshot the switching curve before paralleling for the rest of the settling time. Therefore, if the system were allowed to reach the x-axis in the state space plot, the angular position would be slightly negative, rather than zero. As the control frequency becomes larger, the overshoot of the system will be reduced and more closely approximate the theoretical critically damped solution.

**Multi-Axis Control Tests**

Subsequently, post-hoc tests on the ACDS were conducted with initial conditions on all three (3) control axes. By observing the system performance under such simulated conditions, it could be determined to what extent the coupled motion of the axes affects the optimal control theory developed under the assumption of decoupled motion.

As with the single-axis test described above, analysis of these results shows that the settling time to the deadband condition was once again less than 7.5

---

**Figure 13.9: Sample Test Results/Verification Document, cont’d**
*(Source: Adapted from Moonshine Aerospace, 2008c)*
seconds. However, once the system had drifted to the 5-deg. deadband limit for deflection, they system was not able to stop within the deadband once a control torque was applied. Similar results were observed on both the Pitch and Yaw axes. Therefore, the conclusion was drawn that the coupling of the axes, and thus the motion of the body rotation vector due to motion in all three (3) axes, causes the system to leave the deadband condition at certain points during a test. The system remains under stable attitude control during these conditions and within the angular position deadband requirement.

In summary, the controller designed for use aboard the Architeuthis test structure is capable of controlling the attitude of the structure for the known current parameters of the system. Because of the assumption of decoupled control that was made to simplify the problem, under a multi-axis attitude test, the 180-sec. requirement cannot be met under most conditions. However, the system can demonstrate control for these tests and will remain in a stable attitude position. In fact, despite the error in angular rate deadband maintenance, if this controller is employed on a spacecraft during controlled terminal lunar descent, based on the analysis conducted in Spacecraft Preliminary Design, the spacecraft should survive touchdown.

The effect of coupled motion on this controller is still not fully understood; therefore, a more complete understanding can be gained if a Monte Carlo simulation were to be run for multi-axis control at a distribution of initial conditions (within an allowable maximum).

Figure 13.9: Sample Test Results/Verification Document, cont’d
(Source: Adapted from Moonshine Aerospace, 2008c)

As illustrated in the preceding figure, Test Results include the document number of any related Test Plan. The purpose of the testing, key procedures, and expected outcomes are summarized. The test results are then reported along with illustrative graphics and rich data commentary. Data dumping is avoided. (See Section 8.2: Avoidance of Data Dumping for guidance.) Special attention paid to whether or not any segment of the testing failed to meet the criteria stated in the Test Plan, and any failed tests or unexpected findings are explained or justified. After a summary of key findings, a statement of limitations and recommendations is offered. Often, additional testing is recommended, but since additional testing requires additional time, staff, materials, and budget, any such recommendations must be fully justified.
14.0 TECHNICAL PRESENTATIONS

Engineers make many technical presentations, both singly and in groups. In fact, the ability to craft and execute a strong group presentation is a valuable skill and one that the COE hopes to foster in its students. To this end, students are expected to give a number of technical presentations before they matriculate, particularly during their senior year in their “capstone” courses. Students also may give presentations in their lab courses, sharing their lab results with their instructor and peers.

14.1 Presentation as Story

What are the elements of a strong technical presentation? First, a presentation is not simply the re-telling of a string of facts or opinions associated with a research or other project. It is a narrative, a story, told in summary form:

- The “cast of characters”: Who are the presenters? What is the name of the presenters’ team, if any? What is the name of the project? What will the presenters be discussing today (i.e., a brief overview)?

- The “setting”: What is the problem that the presenters are addressing? What is the history of the problem? Why is it important to solve (i.e., the justification for taking up the audience’s time)? What tools will the presenters use to address the problem?

- The “plot”: How did the presenters explore or address or attempt to solve the problem? What kind of work was accomplished? What were the methods or procedures? (Note: Chronological order is most commonly used to organize the “plot”, but topical order or some other logical sequence may also be used.)

- The “climax”: How did the presenters solve the problem? What happened?

- The “resolution”: What is the current status of the project? Are there any loose ends or an opportunity for follow-up work or research? What do the presenters recommend? What types of actions can the audience take now that they have heard the story?

In giving a technical presentation, i.e., in telling the story, props such as handouts or PowerPoint slides are often used. However, the props are merely supplements – albeit important supplements – and they cannot take the place of a skilled oration.

To help refine students’ presentation skills, elements of a strong presentation are overviewed in the following section, and suggestions for crafting strong PowerPoint slides are presented in the section subsequent to that.
14.2 Elements of a Strong Presentation

Becoming a skilled presenter takes practice, a deep knowledge of one’s subject, and attention to the following details:

- First impressions: Is the presenter professionally dressed and groomed? Do they introduce themselves (and their fellow presenters, if any)?

- Body language: Does the presenter stand upright? Does the presenter avoid putting their hands in their pockets? Does the presenter avoid fidgeting with their hands or shifting from foot to foot (i.e., “doing the bathroom dance”)?

- Eye contact: Does the presenter make eye contact with the audience? Do they “sweep” the audience to include everyone? Do they avoid fixating on the handout in their hand or the screen behind them?

- Verbal skills: Does the presenter speak with sufficient volume? Do they clearly articulate/pronounce their words? Do they pace their speech so as to be clearly understood, not too fast, not too slow? Do they avoid fillers such as “um” and “uh”?

- Engagement: Does the presenter speak with enthusiasm about their topic? Do they appear knowledgeable and confident?

- Use of props: Does the presenter call the audience’s attention to a specific section of the handout? Does the presenter stand to the side of the video screen rather than in front of it? Do they use an appropriate pointing device (i.e., laser pointer) rather than their finger? Do they reference a physical model or prop when possible?

- Question and answer: Does the presenter offer the audience an opportunity to ask questions? Do they answer them clearly but briefly? If they cannot directly answer the question, rather than stammering, do they have a stock answered prepare (e.g., “I don’t know, but I will find out and get back to you”)? Do they follow up as promised?

- Timing: Does the presenter remain within the set time limit? Do they avoid droning on and on? Do they avoid rushing at the end to meet the time limit?

With practice, the engineering student (and later, the engineering professional) can acquire the ability to make a strong technical presentation that impresses the audience and serves the presenter’s goals.
Note that a grading rubric that is widely used at ERAU/Prescott rates students according to criteria that correlate to the items bulleted above. This rubric is illustrated in Figure 15.4: Sample Grading Rubric 4: Oral Presentations, Individual or Group found in Section 15.0: Grading Standards.

14.3 PowerPoint Slides

Although PowerPoint can be a useful tool for creating presentations, slides must be properly crafted so that the information on the slide is easy to see and understand. Slides with too much information, too little information, too small a font, lack of headings or labels, poor color choice, or spelling or punctuation errors confuse the audience and damage the presenter’s credibility.

Graphics are an integral component of presentations. For an overview of guidelines governing the use of graphics, see Section 8.0: General Guidelines for Graphics and Equations. The same guidelines that rule graphics in a document also rule graphics on a PowerPoint slide.

The following items are intended to be used as a checklist to ensure that the order in which information is presented and the way that information is placed on the slides are audience friendly:

✓ Begin with a slide that introduces the presenter(s).

✓ Include a slide that outlines or overviews the presentation. Give the audience a script to follow the structure of the presentation or the “story.”

✓ Include slides that introduce subsections of the presentation (e.g., “Research Methodology”) if the presentation exceeds 10 minutes in length. This use of subsection slides keeps the audience on track with the structure of the presentation.

✓ Include slides that contain information critical to the presentation. Do NOT include every minute detail – these details can be filled in orally during the presentation. Instead, craft slides that serve to summarize the presentation.

✓ Include a slide near the end that acknowledges all those who assisted in the project (e.g., professors, lab managers, grant authors, machinists, regional clubs or support groups).

✓ Conclude the presentation with a slide asking the audience for questions and comments.

✓ Include backup slides in case they are needed to support the question-and-answer session following the formal presentation.
✓ Do NOT visually overload slides with information. There should be no more than two (2) pieces/categories of information in each slide.

✓ Do NOT distract the audience with inappropriate background graphics. If a graphic is being used as a background (e.g., a picture of an aircraft), it may overwhelm any text placed over it; thus, avoid all use of such background graphics. Team logos and other such background graphics should be relegated to the header of the slide, if used at all.

✓ Do NOT use blue or white font on a dark-colored background. Plain black font on a plain white background is preferable as this combination provides the sharpest contrast and is easiest to see (and to process).

✓ Do NOT crowd information on the left-hand side of the screen. All information should be roughly centered on the slide.

✓ Ensure sufficient white space. Place no more than one (1) graphic or 5-7 lines of prose on each slide, preserving the white space.

✓ Avoid excessive white space. Place at least three (3) bulleted items in a list or five (5) lines of prose on each slide.

✓ Use clauses or phrases to list information. This avoidance of complete sentences conserves slide space and is easier for the audience to scan.

✓ List bulleted elements in parallel structure. Verb phrases should not be mixed with noun phrases, and all verbs should be in the same tense.

✓ Give each slide its own heading. Headings should consist of a descriptive noun phrase, should be in a 16- or 18-point font, and should be in bold font to be visually separate from the rest of the prose.

✓ Ensure that font size is sufficiently large so as to be visible. Font size of 18-point to 20-point is typical, but the font size should be tested by projecting the slide onto a screen.

✓ Coordinate font size, colors, and graphics to ensure readability. Avoid fancy bullets or fonts, and use a consistent bullet style on each slide.

✓ Label graphics clearly on each axis. For increased comprehension, various styles and colors of lines and bars should be used, and legends should be incorporated into the graphic.

✓ Remove any spelling, punctuation, or grammar errors. Each slide should be meticulously proofread and edited.
Ensure each slide appears as intended when projected. Some color choices, especially dark backgrounds or pale-colored lines, look fine on a computer screen but are very difficult to distinguish when projected.

As with all documents, PowerPoint slides should be crafted to meet audience expectations. Students are responsible for meeting audience expectations (which in public presentations goes well beyond merely discovering and meeting minimal course requirements).
15.0 GRADING STANDARDS

Grades are an important aspect of any educational system. Traditionally, grades have been used both to weed out students who lack potential for success in a field and to reward students for meeting a specific set of educational goals. Grades serve several purposes: to rank the merit of work submitted, to communicate the teacher’s judgment of a student’s progress, and to improve the student’s ability to self-evaluate their work or progress (Davis, 1999).

Final course grades often include such factors as participation, attendance, professional behavior, and the ability to work well in a team or group. While these factors are all important aspects of grading, this section will focus on grading standards for written submissions and for oral presentations.

Grading standards are often formalized in a clearly defined set of criteria called a rubric. All rubrics for written submissions and oral presentations should meet the following criteria:

- They should be multi-faceted; that is, they should have multiple discriminators, parameters, or criteria that measure multiple aspects of a student submission or performance;
- They should be specific; that is, they should unambiguously state the particular characteristics a student submission or performance is expected to exhibit;
- They should be adequately descriptive; that is, they should provide sufficient feedback for the task at hand, no more, no less;
- They should be efficient; that is, both the instructor and the student should be able to quickly use the rubric; and
- They should be transparent; that is, they should be documented and made available to the students, either online, or on a handout, or in the syllabus.

Rubrics may be pass/fail, but most are typically designed using a “ranking” scheme in which each criterion that is being measured is given a relative score (e.g., poor, fair, good, excellent, outstanding). Scores are typically tallied, averaged, and converted to a percentage or letter grade.

The remainder of this section consists of multiple examples of grading rubrics that use both pass/fail and ranking schemes. Rubrics for both written work and oral presentations have been included. The inclusion of these rubrics serves three (3) purposes:
1. To engender a frank discussion about grading standards between students and instructors so that both have a clear understanding as to the students’ goals and responsibilities and the instructors’ expectations;

2. To provide new instructors with rubrics used by various faculty in both the COE and in the Department of Humanities/Communications that these new instructors may wish to adopt and adapt for their own class; and

3. To provide students with a clear idea of the high quality instructors at ERAU expect from student work.

The examples that follow include three (3) rubrics for grading written submissions and two (2) rubrics for grading oral presentations:

- A generalized grading rubric for both technical and non-technical written submissions (see Figure 15.1: Sample Grading Rubric 1: Written Submissions);

- A more specific grading rubric for engineering lab reports (see Figure 15.2: Sample Grading Rubric 2: Lab Reports);

- A generalized grading rubric for research reports that can be used for both written and oral reports (see Figure 15.3: Sample Grading Rubric 3: Research Reports);

- A grading rubric for oral presentations currently used by the COE and the Dept. of Humanities/Communications for rating both individual and group oral reports (see Figure 15.4: Sample Grading Rubric 4: Oral Presentations, Individual or Group); and

- A grading rubric for group oral reports that focuses on teamwork skills (see Figure 15.5: Sample Grading Rubric 5: Collaborative Projects and Group Presentations).

THE COURSE INSTRUCTOR HAS THE FINAL SAY REGARDING GRADING STANDARDS FOR BOTH WRITTEN WORK AND ORAL PRESENTATIONS. IT IS THE STUDENT'S RESPONSIBILITY TO CONFIRM THE INSTRUCTOR'S REQUIREMENTS FOR EACH ASSIGNMENT, WRITTEN OR ORAL.
The **content** of the paper is rich and technically accurate, with clear themes and abundant amounts of evidence and detail; the content is logically organized; there is no irrelevant information.

The paper is **on-task** and does not drift off task; all requirements of the assignment are met.

The **purpose** of the paper is clear; no conflicting purposes are evident; no conflicting claims are evident.

The **reader's reaction** is anticipated; the reader’s needs and expectations are properly met with the correct type and amount of information; the reader is addressed appropriately.

The **organization** of the paper includes all the sections and structural elements typical of that type of paper, in the proper order; the paper is structurally sound; there is no missing information or sections.

The **language** of the paper is appropriate to the purpose of the text, the writer’s role, and the reader’s needs; grammar and vocabulary choices are carefully made; definitions, reportive verbs, and other academic features are present; the paper is concise; there are no redundant or empty phrases.

The paper synthesizes information smoothly; references to common experiences, people and events, and other texts form **connections**; all texts are properly introduced and cited; graphs, tables, and other illustrations are supported by textual description.

The paper’s **presentation** is neat and attractive; the paper is properly formatted, including title page, page numbers, headings, font size, and font type; there are no grammatical errors (including fragments and run-ons); there are no spelling errors.

The paper is highly readable and easy to access; the proper organization, language and presentation allow it to **flow**.

<table>
<thead>
<tr>
<th>Always</th>
<th>Often</th>
<th>Rarely</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Figure 15.1: Sample Grading Rubric 1: Written Submissions**
I. Abstract presents a clear and concise version of the report, summarizing what happened and the results of the experiment. (Abstract should not exceed 250 words –15 percent.)

4- The abstract contains the most important details of the report, including the objectives of the experiment, the method and the results.
3- The abstract contains some of the important details of the report, but either leaves out or incompletely mentions the objectives, method, or results.
2- The abstract contains many irrelevant details and tells the reader little about the experiment or its results.
1- The abstract tells little if anything about the experiment or its results.

II. Report demonstrates that the student understands the purpose and objectives of the experiment. (10 percent)

4- The report clearly states the purpose and objectives of the experiment. Furthermore, the entire report shows a comprehensive understanding of them, and is concluded by referring back to the experimental purpose and objectives.
3- The purpose and objectives are clearly stated, but the report shows an incomplete understanding of them.
2- The purpose and objectives are stated, but the rest of the report does not refer to them.
1- The purpose and objectives are either incorrectly stated or not at all. Little or no understanding of them is shown in the report.

III. Report explains the theory and its application to the experiment. (20 percent)

4- The report gives a comprehensive explanation of the theory involved and shows clearly how it relates to the experimental procedure.
3- The explanation of the theory is adequate, but lacks some details. The connection between the theory and the experiment is not totally clear.
2- The explanation is missing key details necessary to understanding the theory. The report shows little or no attempt to connect the theory to the experimental procedure.
1- There is almost no explanation of the theory at all and the report makes no attempt to connect the theory to the experiment.

Figure 15.2: Sample Grading Rubric 2: Lab Reports
(Source: University of Illinois at Chicago, 2001)
IV. **Report contains a description of the experimental setup and procedure.** (10 percent)

4- The experimental setup and procedure are explained in comprehensive detail along with appropriate diagrams of the setup.
3- The experimental setup and procedure are explained in sufficient detail. No diagrams are present.
2- Student apparently copied procedure from lab manual, little or no description of experimental setup present.
1- Incomplete or inaccurate explanation of experimental setup and procedure.

V. **Report presents data and results appropriately and accurately.** (15 percent)

4- The data and results are accurately presented. Tables and plots are labeled appropriately.
3- The data and results are accurate but presented inadequately. Important results are obscured by data more appropriate for an appendix. Graphics are not always well labeled or helpful.
2- The data and results are only partially accurate and presented poorly. Charts full of unexplained data are given rather than carefully chosen graphics illustrating key details.
1- The data and results are mostly inaccurate and are poorly presented.

VI. **Report analyzes results and discusses the extent to which the results meet the objectives of the experiment.** (20 percent)

4- The results are well analyzed, both explaining what happened in the experiment and any possible deviations from the expected outcomes due to the equipment, procedure, and assumptions. Results refer back to the plots and tables and present a comparison with the theory.
3- The results are adequately analyzed but the discussion too often summarizes what happened rather than why. Only a partial explanation of possible experimental deviation and comparison with theory.
2- The results are poorly analyzed if at all. It is almost totally a summary of what happened in the experiment. Deviations are either not acknowledged at all or mentioned but not explained. No comparison with theory is given and the discussion does not refer to the figures and tables presented.
1- No analysis is present. The report basically summarizes the experimental procedure. There is little or no interpretation of data or results.

---

*Figure 15.2: Sample Grading Rubric 2: Lab Reports, cont’d*

*(Source: University of Illinois at Chicago, 2001)*

---

*July 26, 2011*
VII. Report exhibits consistent design and appropriate language usage. (10 percent)

4- The report is consistent in design looking like a professional report with all sections matching and well presented. There are few grammar and spelling mistakes.

3- Some sections of the report differ in style from the rest (either in font or page layout). There are many spelling and grammar mistakes.

2- Consistency in the report is poor, so much so that it looks like several reports put together rather than one professional document. There are an abundance of grammar and spelling mistakes.

1- There is no consistency to the report. Some sections are even handwritten (possibly experiment notes). The grammar and spelling mistakes are so numerous that the report is hard to read.

Figure 15.2: Sample Grading Rubric 2: Lab Reports, cont’d
(Source: University of Illinois at Chicago, 2001)
<table>
<thead>
<tr>
<th></th>
<th>Minimal</th>
<th>Adequate</th>
<th>Excellent</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Problem Statement</strong></td>
<td>One brief sentence on the topic.</td>
<td>Several sentences that include possible benefits and improvements.</td>
<td>Well-focused, concise statement.</td>
</tr>
<tr>
<td></td>
<td>Lacking detail.</td>
<td>Broader coverage of the topic.</td>
<td>Clearly outlines who benefits, how they benefit, how you will accomplish it.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Writing needs focus.</td>
<td></td>
</tr>
<tr>
<td><strong>Analysis</strong></td>
<td>One analysis method used (usually a process chart).</td>
<td>One method done well.</td>
<td>Use several analysis techniques.</td>
</tr>
<tr>
<td></td>
<td>No support.</td>
<td>Some supplemental analysis.</td>
<td>Several improvements shown.</td>
</tr>
<tr>
<td></td>
<td>Disorganized.</td>
<td>Some improvements shown.</td>
<td>Clear how improvements are achieved.</td>
</tr>
<tr>
<td></td>
<td>Few improvements shown.</td>
<td></td>
<td>Illustrates analysis process.</td>
</tr>
<tr>
<td><strong>Discussion</strong></td>
<td>Identifies problems.</td>
<td>Application of techniques.</td>
<td>Thorough analysis.</td>
</tr>
<tr>
<td></td>
<td>Shows understanding of techniques.</td>
<td>Includes some evaluation, but no creative or innovation displayed.</td>
<td>Evaluation of techniques and improvements.</td>
</tr>
<tr>
<td></td>
<td>No evaluation of techniques.</td>
<td></td>
<td>Design of new process.</td>
</tr>
<tr>
<td><strong>Recommendations</strong></td>
<td>Simple summary and recommendations for correcting problems.</td>
<td>Some extension of work, but still limited.</td>
<td>Broader application of learning to other areas.</td>
</tr>
<tr>
<td></td>
<td>“Here’s what I did.”</td>
<td></td>
<td>Thoughts for further research and evaluation.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>“Here’s what I did, but here’s where it could go.”</td>
</tr>
</tbody>
</table>

Figure 15.3: Sample Grading Rubric 3: Research Reports (Source: Northeastern University, 2003)
Presentation Score Sheet

Presenter's Name: ____________________  Rater: ____________________

Date: ____________________

Scoring system: Check the appropriate box ranging from “1” (very poor) to “4” (very good).

<table>
<thead>
<tr>
<th>THE PRESENTER…</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>Notes/Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Is professionally dressed and groomed.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. Introduces colleagues formally.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Speaks with sufficient but not excessive volume.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. Speaks with appropriate pacing and speed.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. Avoids fillers such as “um”.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6. Makes clear eye contact.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7. Uses an enthusiastic tone, portrays a sense of calm, avoiding fidgeting.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8. Has good posture and remains steady on their feet, not pacing or shifting feet excessively.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9. Uses an appropriate pointing device or strategy.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10. References a physical model or prop when possible.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>11. Offers rich details and compelling evidence to back claims and conclusions, demonstrating command of content.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>12. Uses Powerpoint slides that illustrate the point at hand and are technically accurate.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>13. Uses Powerpoint slides that are appropriately formatted, legible, clean, and contain audience-friendly color schemes.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>14. Waits for leader to pass questions unless directly addressed and tactfully interrupts teammates if needed.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>15. Answers questions authoritatively but is willing to admit a knowledge gap as necessary.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Figure 15.4: Sample Grading Rubric 4: Oral Presentations, Individual or Group
<table>
<thead>
<tr>
<th>Contribution</th>
<th>Beginning 1</th>
<th>Developing 2</th>
<th>Accomplished 3</th>
<th>Exemplary 4</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Research &amp; Gather Information</td>
<td>Does not collect any information that relates to the topic.</td>
<td>Collects very little information--some relates to the topic.</td>
<td>Collects some basic information--most relates to the topic.</td>
<td>Collects a great deal of information--all relates to the topic.</td>
<td></td>
</tr>
<tr>
<td>Share Information</td>
<td>Does not relay any information to teammates.</td>
<td>Relays very little information--some relates to the topic.</td>
<td>Relays some basic information--most relates to the topic.</td>
<td>Relays a great deal of information--all relates to the topic.</td>
<td></td>
</tr>
<tr>
<td>Take Responsibility</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fulfill Team Role's Duties</td>
<td>Does not perform any duties of assigned team role.</td>
<td>Performs very little duties.</td>
<td>Performs nearly all duties.</td>
<td>Performs all duties of assigned team role.</td>
<td></td>
</tr>
<tr>
<td>Participate in Presentation</td>
<td>Does not speak during the science conference.</td>
<td>Either gives too little information or information which is irrelevant to topic.</td>
<td>Offers some information--most is relevant.</td>
<td>Offers a fair amount of important information--all is relevant.</td>
<td></td>
</tr>
<tr>
<td>Share Equally</td>
<td>Always relies on others to do the work.</td>
<td>Rarely does the assigned work--often needs reminding.</td>
<td>Usually does the assigned work--rarely needs reminding.</td>
<td>Always does the assigned work without having to be reminded.</td>
<td></td>
</tr>
<tr>
<td>Value Others' Viewpoints</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Listen to Other Teammates</td>
<td>Is always talking--never allows anyone else to speak.</td>
<td>Usually doing most of the talking--rarely allows others to speak.</td>
<td>Listens, but sometimes talks too much.</td>
<td>Listens and speaks a fair amount.</td>
<td></td>
</tr>
<tr>
<td>Make Fair Decisions</td>
<td>Usually wants to have things their way.</td>
<td>Often sides with friends instead of considering all views.</td>
<td>Usually considers all views.</td>
<td>Always helps team to reach a fair decision.</td>
<td></td>
</tr>
</tbody>
</table>

**Figure 15.5: Sample Grading Rubric 5: Collaborative Projects and Group Presentations. (Source: San Diego State University, 1997)**
16.0 WHERE TO GO FOR MORE HELP

There are many resources for students who want more help with their writing. The professor assigning the Lab Report or other technical document should have open office hours or, upon request, may make an appointment to discuss the assignment. If given sufficient lead time, the professor may even be willing to help with a rough draft.

The faculty at the Writing Center offer writing instruction and tutoring for any student working on any writing project at ERAU, from freshmen essays to Lab Reports to senior theses to graduate school applications to resumes. While they will not merely proof-read or edit student work, they will teach students how to edit their own work. In addition to providing help with rough drafts, they also teach strategies for developing, organizing, and properly formatting material. Writing Center faculty welcome both drop-ins and scheduled appointments. For instructors’ names and Writing Center hours contact the Chair of the Department of Humanities/Communications (Bldg #74, Academic Complex 1, third floor). Names and times are also posted on the Humanities/Communications bulletin board on the third floor of Bldg #74 and elsewhere around campus.

For help with preparing, rehearsing, and fine-tuning oral presentations, visit any of the Speech instructors at the Department of Humanities/Communications. For instructors’ names and office hours, contact the Chair of the Department of Humanities/Communications (Bldg #74, Academic Complex 1, third floor). While you may drop by during office hours, consider making an appointment during busier times of the school term.
17.0 REFERENCES


