RESEARCH GUIDANCE TO M.S. STUDENTS

CLASS 20-M

James E. Bevins, Major, USAF

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AIR FORCE INSTITUTE OF TECHNOLOGY

Wright-Patterson Air Force Base, Ohio

Acknowledgements

Like all good research, this build upon great work by those who came before me, and I must thank them, and those who inspired them, for doing the heavy lifting. I've adopted this guidance from a previous iteration developed by LTC McHale and detailed and thoughtful guidance developed by Dr. Slaybaugh.

This is a living document as each student continues to teach me new things. I've prepared this document based upon my experiences as an M.S. and Ph.D. student at the Air Force Institute of Technology (AFIT) and University of California - Berkeley (UCB), respectively, as well as teaching, and advising, and mentoring AFIT and UCB graduate and undergraduate students. Thus, I owe much gratitude to my thesis and dissertation committees and every student that I taught, advised, or served as a research committee member.

James E. Bevins

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RESEARCH GUIDANCE TO M.S. STUDENTS

1. Introduction

This document outlines my guidance and expectations for M.S. students who work with me as their research advisor. Your first assignment is to read the entire document *twice* and prepare any questions; complete this by our scheduled meeting mid way through the Winter Quarter. It is not my intent to use the text as a binding contract, nor should you view the document as a rigid checklist of instructions and precise rules. Rather, I want the advice and requirements contained within to provide a clear road map for our shared success in the research process. Moreover, I hope my advice aids in your personal and professional growth, yet helps avoid major pitfalls within AFIT's unique, time-constrained graduate education environment. Therefore, you should refer to this document regularly, and it should be the first place you look when you have questions about expectations or standards. I've learned that people perform best when they receive some guidance, understand their responsibilities, and obtain constructive and quantifiable feedback about their work.

The master's thesis must demonstrate your ability to conduct independent research. The research does not need to be original, like a Ph.D. dissertation, which *must* make a unique, meaningful contribution to a field. Although original research is not a requirement for the thesis, your work may produce results which, like a dissertation, contribute to a scientific conference, journal manuscript, or sponsor inquiry; this should be *our* goal. In short, the master's thesis demonstrates your application of the scientific research method, which I describe as shown in Table 1.

The remainder of this document describes the major deliverables of your thesis

Table 1. The scientific research method and correlation to major written requirements.

Task	**Prospectus**	**Thesis**
Pose a research question (hypothesis)	1	1
Outline why the research question is important (motivation)	1	1
Conduct initial research and analysis of your question via review of theory and current and past work related to your topic	2	2
Create environments (experimental, computational) and a plan to address your research question	3	3
Verify and validate your environment(s) Verify: Am I getting the right outputs? Validate: Am I getting the right outputs right?		3
Quantify the expected uncertainties and propagations of error for the created environments		3
Apply your environments to collect data		4
Discuss your data (results) and analyze the results as they relate to theoretical predictions, prior work of other researchers, and your research question		4
State conclusions as they pertain to your research question and recommend future work		5

research. I consider us a team in this effort. Specifically, my primary responsibility is to provide guidance and direct resources as you develop and implement your research. However, it is your responsibility to plan and execute the research. Thus, this is a guided research effort in which you and I will meet regularly to discuss progress and strategies to overcome obstacles, but I will not manage your daily activities. I also encourage you to meet with and discuss your work with other members of your committee and faculty whose knowledge exceeds yours, and mine, in their areas of expertise. Lastly, you are free to accomplish the deliverables in a manner that best suits your work habits and personal schedule, and I will assess a portion of the final grade for your thesis upon the punctuality and quality of completion of these tasks. These deliverables and their approximate suspenses are listed in Table 2.

Table 2. Major deliverables of thesis research.

Task	**Suspense**
Selection of research topic	Week 5 Winter (year 1)
Initial review of theory and literature	Spring (year 1)
Initial development of research methodology	Summer (year 1)
Written prospectus to advisor	Week 9 Summer
Prospectus briefing to committee	Week 10 Summer
Research update to advisor	As needed in Winter & Spring (yr 1)
Research update to advisor	Bi-weekly in Summer
Research update to advisor	Weekly in Fall & Winter (yr 2)
Conference or journal identified for submission	Week 1 Fall
Research update to committee	Week 4-5 Fall
One complete thesis chapter to advisor for review	Week 8 Fall
Research update to committee	Week 9-10 Fall
Complete thesis to advisor for review	Week 11 Fall
Grading copy of thesis to committee	Week 2 (Mon) Winter
Thesis defense complete	Week 5 (Fri) Winter
Administrative thesis paperwork submitted to advisor (PA release/document distribution statement; SF 298 form)	Week 6 (Fri) Winter
Administrative thesis paperwork submitted to Department Head	Week 6 (Fri) Winter
All final thesis documents due to the Thesis Processing Center (TPC)	Week 7 (Fri) Winter
Conference or journal submission complete	Week 9 Winter

Finally, please note, up front, an important rule for reproduction of previously-published figures. The copyright to published work is typically owned by the publisher, who must grant permission to re-use the material. Many publishers have electronic request forms available on their web sites, and the process is usually cost-free and not time-consuming. When the publisher approves your request(s) for reproduction, save the approval documentation and email a copy to me. In my experience, most re-uses occur in the review of prior work (literature review) sections of the prospectus and thesis documents.

2. Expectations

This document outlines my guidance and expectations throughout, but this chapter serves as a general high level overview - a (mostly) one stop shop if you will.

2.1 Interactions and Meetings

Students are expected to meet with me on a regular basis during their research (typically weekly or bi-weekly but more frequently as needed) to discuss research progress, course work, and graduate student life in general. Students are also expected to attend all research group meetings. To facilitate efficient interaction, student should:

- Host notes for one-on-one meetings, code projects, and LaTeX documents on GitHub, Bitbucket, or equivalent.
- Include deadlines in the subject lines of emails to me when I need to do something by a specific date.
- Check my availability via my Outlook calendar and send a calendar invite to schedule a meeting.

2.2 Miscellaneous

Students are expected to do their best to follow reproducible practices. More details can be found here.

Students are expected to be effective communicators. This will be accomplished through formal and informal oral presentations and by writing manuscripts involving their research. Students will share their research findings with their advisor and the rest of the research group on a regular basis, including group meetings. It is my goal

to have you to be able to effectively communicate your research to both an expert in your area of research *and* the policy wonk or program manager funding it.

Effective communication also means *seeking help* when one encounters difficulties! Running into snags is a normal, functional part of doing research. However, if after a reasonable effort you can not find a solution to a problem that you face, please do not continue in isolation hoping that you can work the problem through. Advisors, the research group, and other students are a tremendous resource, and you are expected to seek them out if you need help.

Students are expected to be informed members of the scientific community. This includes successfully completing course work, attending seminars and external scientific meetings (with my approval), and staying current in publications relevant to your research topic. Some journals of interest to our research group include:

- Nuclear Science and Engineering, Nuclear Engineering and Design, Nuclear Technology
- Transactions on Nuclear Science
- Nuclear Instruments and Methods
- Journal of Radiation Effects, Research, and Engineering

Other potential Journals and Conferences of interest are highlighted on GitHub.

Students are expected to be collaborative members of the scientific community. Students are expected to be supportive and helpful to others working at AFIT. In addition, students should seek to collaborate with colleagues and others as appropriate.

Students are expected to be proactive members of the scientific community. This includes proactively seeking additional or new directions for their research that enhances the quality and/or significance of the overall program.

Students will abide by all line items outlined in the American Nuclear Society (ANS) Code of Ethics.

2.3 Useful Skills

Not all of these skills are required for research, but most will benefit your research in most cases.

- the shell and *nix environment
- Python/iPython and another language such as C++ or Fortran
- GitHub
- LaTeX
- Radiation transport codes such as MCNP, GEANT, SCALE, or Serpent

2.4 What You Can Expect From Me

Students will receive training and experiences that will prepare them for successful careers in the DoD, industry, government, or academia. In many cases, AFIT students are already on the path to a successful career, and my goal is to aid in any way possible.

Students can expect a supportive environment that rewards creativity, passion, collaboration, and hard work.

Students can expect and ask for discussions on performance, research plans for the year ahead, opportunities for publications and presentations at scientific meetings, and career interests.

Students can expect assistance in establishing a network of scientific and military contacts and mentors both from within their chosen research area and assignment and outside (as opportunities arise).

Students can expect to receive mid-term feedback (mid-Fall quarter of second year) and feedback at any point they request it.

3. The Prospectus

The purpose of the written prospectus and briefing is to show your thesis committee that you understand the motivation for your research question, have a detailed and reasonably well-scoped plan to address your testable hypothesis, and, if applicable, can explain and analyze preliminary results of your research. The written prospectus should be approximately 30-40 pages, formatted consistent with the *Style Guide for AFIT Dissertations, Theses, and Graduate Research Papers*, and represent a draft of the first three chapters of your thesis. The briefing should include 15-20 slides, presented in about 30 minutes to the committee. An outline and descriptions of the contents of the written prospectus are shown below. You are not required to adhere strictly to the format, but your prospectus should address the listed topics.

1. Introduction. The introduction explains what your research will address and the relevance of your topic.

    1.1 Motivation. Grab the attention of the reader by stating why your research topic is relevant to you and the Department of Defense. You might include a pertinent historical or recent anecdote, but avoid excessive story-telling.

    1.2 Background. Summarize the significant research related to your topic, based upon your literature review; cite references. Your synopsis should explain the broad problem, address the major contributions of prior researchers, and mention areas where questions remain; the last item provides a transition to the next section of the chapter. NOTE: This should focus on the problem, not all of the science behind it; that comes in Chapter 2.

    1.3 Problem. State the problem that your research will address, which should be related to an unanswered question from the background discussion.

    1.3.1 Research Objectives. State your research objectives and the approach taken to solving each.

    1.3.2 Assumptions and Limitations. Discuss assumptions that affect how and where your research can be applied, and how your results are limited.

    1.4 Novel Research Contributions. State the unique contributions that you made to the current state-of-the-art, how you improved the knowledge or capability of a given process or system, and/or how you research impacts the community (or world). Briefly summarize the major components of your research approach.

By the end of your introduction, a reader should have a broad understanding of what you will do, why you will do it, how you plan to do it, and how it is useful.

2. Theory. The theory chapter reviews the pertinent theoretical background and prior work of researchers in your field. The review should expand upon the background summary of Section 1.2 above. I don't like to give a target number of references, but 10 or less indicates that you didn't do enough lit review and 150 or more probably means everything is derivative. Theory should be presented thoroughly, yet concisely, and organized into appropriate major and minor topic areas, which can be difficult to do well. There are two main goals with this chapter: a)out-line the current state of the art in relation to your research (so it is clear where you are taking it) and b) provide the reader with the necessary background to understand and evaluate your work.

   For the prospectus, conduct an extensive review of the literature, as you are unlikely to know what you'll discover during the course of your research. For this reason, it is better to be exposed to information that you won't need, versus being uninformed as you move forward in your research. I relate the review of theory and literature to the familiar term of mission analysis, in Army-speak. Like mission analysis, the literature review is the most time-consuming, yet crucial, early step in the research process.

3. Methodology. This chapter explains the details of your research plan, whether it be experimental, computational, or a combination of methods. Be thorough and transparent as you develop, describe, and present your plan. In this way, you and your committee will feel confident with your approach, and you will almost certainly reduce the number of unanticipated issues that arise as you proceed with your research.

   3.1 Experimental or Computational Setup.

   - For experimental work, show a schematic and/or photos of the equipment to be used.
   - For computational work, you might show a block diagram of the required computational tasks.
   - **Regardless of the type of work, a reader should have a clear understanding of what you plan to do**.

   3.2 Research Approach.

   - Describe why you plan to apply your methodology. For example, prior researchers may have implemented similar methods. On the other hand, if your methods depart from standard practices or improve commonly used methods, you should state so.
   - Describe how you plan to implement your methodology.

  - For experimental work, you might discuss how you plan to evaluate your equipment and procedures.
  - Computational work should include a discussion of methods that were developed by others, but that you'll implement, as well as the development of code that you plan to write.
- **Regardless of the type of work, a reader should have a clear understanding of why you're doing it and how you plan to do it**.

4. Research Schedule. This chapter describes how you will allocate your time and resources for the duration of your research, from the beginning of your research quarter through graduation.

   - Calendars are the best format to display the information and should have resolution down to the weekly level.
   - Incorporate the deliverables listed in Table 2.
   - Identify equipment or resources, as required.

5. Results (if applicable). If you have preliminary results, present them clearly and concisely. Your objective is to convince your committee that you can successfully collect, analyze, and present data. Consider the following general format for presentation of data:

   - Display a result (typically a figure)
   - **For oral presentations**: Explain what's displayed (axes titles, scales, units) and the key take-away of the graphic. This gives you, and your audience, a moment to get oriented and highlights why they should care. *Don't leave the audience to draw their own conclusions; they will often not draw the ones you want.*
   - Discuss the data quantitatively. For example, "This figure shows that _____ increases sharply as a function of _____ and then decreases gradually when _____. In the region from _____ to _____, several oscillations are present."
   - Explain the results *in terms of underlying theory and/or empirical evidence*. For example, "This behavior is expected based upon _____ theory. Additionally, researchers such as _____ have achieved similar results, as published in the reference. This portion of my data, however, is unexpected."
   - State conclusions that can be made from your observations and analysis.
   - If you observe unexpected results, you could offer possible explanations. However, your explanations should based in *theory*, not feelings. In other words, avoid speculation that you cannot support or substantiate. Possible

explanations should be testable, so that you can either confirm or deny their validity. If you have a plan to test the validity of an explanation, state it.

- Avoid gross speculation. It is better to present an unexpected result, state the measures you took isolate the behavior, and conclude that the cause has not yet been determined than it is to manufacture an exotic, mysterious, and unproven claim that you cannot confirm or deny.
- Avoid gross over-speculation.
- Avoid grossly over-speculating.

4. Research Quarter Deliverables

4.1 Research Updates

We will meet at least weekly during the research quarter. The nominal plan will be bi-weekly group meetings, bi-weekly one-on-one meetings in between, and a committee update every 4-6 weeks. However, these meetings can be more frequent, depending on your progress. In short, I'm available as often as you need to discuss your progress or challenges, and I expect you to reach out if you've hit a road block instead of waiting until the next regularly scheduled meeting.

In these meetings, you should talk about your accomplishments of the current week, results, challenges and attempted solutions, and your plan for the next week. These meetings are informal, but the products you prepare for our discussions may be usable in your thesis document. Therefore, I recommend that you spend an hour or two before each meeting gathering your thoughts and producing a few meaningful figures. Having concrete results o review and discuss will a) make the meeting more productive, b) improve the quality of your product, and c) save frantic rework when you present your results for the first time in your thesis document/defense.

Some key milestones to consider for the research quarter (timing varies):

4.2 Conference or Journal Submission

Submission to a scientific conference or peer-reviewed journal should be a goal for all M.S. students. The results of many thesis projects have been submitted to conferences such as the Hardened Electronics and Radiation Technologies (HEART) and the Institute of Electrical and Electronics Engineers (IEEE) Nuclear Science Symposium (IEEE NSS) and journals like the *Journal of Radiation Effects, Research and Engineering* (JRERE) and *IEEE Transactions on Nuclear Science*, as a few examples.

A great place to identify the right conference/journal is from journals and conference proceedings that appear often in your literature review. Many conferences require abstracts or research summaries to be submitted months in advance of the conference date. In these cases, it is common to submit a summary of proposed research in advance, and present the research results at the conference and proceedings. We will look to identify the right avenues as early as the Spring conference and prepare submissions in this time frame.

4.3 Update to Research Committee

Schedule a update to the research committee to inform all members about the progress and execution of your research, as well as any modifications to your original prospectus. Plan for a 20-30 minute presentation with 15-20 minutes of discussions and questions. The prospectus briefing format is a good starting point. Focus on updates from previous meetings and present results and analysis of work completed to date and your plan for thesis completion.

4.4 Submission of Complete Thesis Chapter (Week 8)

During week 8, submit all prefatory pages (see style guide) and a complete Chapter 1 to me. In the prefatory material, leave the abstract and acknowledgments blank, and any items listed as optional in the Style Guide may be omitted.

This is not the "grading copy", but it should also be your very best effort. The goal of this is to get feedback to you on the overall writing style and mechanics that should then be propagated forward as you start to finalize your remaining thesis. There are several items that I consider distracting, and sometimes aggravating, when reading student theses. Therefore, do your best to either adhere to or avoid the following items (some of these extend beyond what would be expected for your single

chapter turn-in but are included for completeness):

- Quantity $\neq$ Quality. Seek to make your writing clear, correct, concise, comprehensible, and consistent. Unnecessary words can confuse explanations or, worse, render an explanation incorrect. In short, ensure that your writing says what it means, and means what it says. There is no grading criteria for length of the thesis. Some of the best theses are remarkably short.

- Organize your chapters into appropriately-numbered sections, subsections, etc. Specifically, if you have a numbered Section 3.1, then you need, at the very least, Section 3.2.

- Use introduction and transition paragraphs and/or sentences to smoothly present and move between topics.

- Present physical and mathematical relationships using equations, with all symbols defined, instead of verbiage. In other words, don't use 100 words to explain something that can be described using a single, well-presented equation.

- Comparative adjectives such as more, less, better, and worse are useless without a point of reference. For example, statements like, "Subsequent measurements were more accurate" open the door for scrutinizing questions like, "More accurate than what?" and "How are you defining accuracy?"

- Use the IEEE citation style to cite references. The style places single or multiple citation numbers in square brackets [1] or [1–3] within the text, and citations in the reference list or bibliography are numbered in the order that they appear in the text.

- Avoid using quotation marks, as they can lead a reader to believe that a statement is less than transparent. For example, consider whether or not you would eat at a restaurant that advertised "cheese" burgers or "fresh" lobster.

- Standardize the presentation of your figures; see Figure 1 as an example. Also, inserting a graphic (figure or table) into your text requires you to mention the graphic in your text; mention any graphic before its insertion.

- Don't (sic) use contractions.

- Treat equations as a natural extension of the English language. If an equation is part of a sentence and at the end, then end the sentence with punctuation. If it is in the middle, use a comma as appropriate and continue the sentence.

- Use appendices for information that is not required to support the thesis but was a major undertaking that may be helpful to others. Do NOT include code. Use Github or Bitbucket to store and version control all code and reference the repo in your thesis. No future student wants to use your (outdated) printed

code from the Appendix; they'd rather have access to the (updated) actual files. Use tags to identify which versions were used in the production of published results.

- PROOF READ YOUR WORK AND/OR HAVE SOMEONE ELSE PROOF IT BEFORE YOU GIVE IT TO ME OR ANY COMMITTEE MEMBERS.

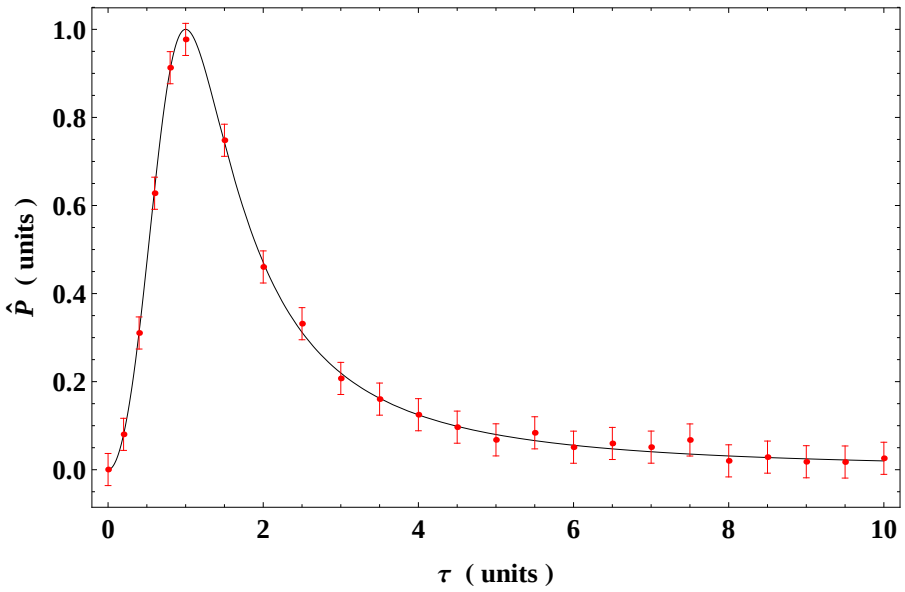

Figure 1. Figures should provide a clear visual representation of your data. Display your figures as shown here and as uniformly as possible throughout the thesis. The font size for the axes and labels should be approximately the size of the figure caption. The caption should be sufficiently complete to accurately describe the figure, but not be a discussion or analysis of the data.

In addition to the items of emphasis mentioned above, I will review your submission carefully for both technical content and formatting. As I read for content, I will focus on the validity of the presented physics and math, the logic of your arguments, and the organization of your document. My format review will concentrate on writing style and attention to detail in spelling, grammar, and consistency. I will complete my review within one week and trust that you'll implement the corrections and recommendations for your submitted chapter and the rest of your document.

In my opinion, this first chapter review produces higher quality final theses.

5. The Thesis

5.1 The Grading Copy

Submission of the grading copy of your thesis to your research committee will represent the near-culmination of more than twelve months of time and effort. You should strive to make this submission as near-perfect as possible with regard to both content and format, with the goal that your draft is thoroughly researched, technically correct, and signature ready. In addition to these technical criteria, you will have to carefully edit your document to ensure that the formatting, style, and organization are high-quality. The written presentation of your document should be clear, correct, concise, comprehensible, and consistent. In short, ensure that your writing says what it means, and means what it says.

An outline and descriptions of the contents of the written thesis are shown below. As with the prospectus, you are not required to adhere strictly to the format, but your thesis should address the listed topics.

0. Abstract. Write this last, when the work is complete. This is the detailed, yet concise, summary of your thesis. Good abstracts answer the questions: What did you do?; How did you do it?; What did you find? Follow this rule.

1. Introduction. The introduction explains what your research addressed and the relevance of your topic. This chapter will be the same as the in prospectus, with required modifications.

2. Theory. The theory chapter reviews the pertinent theoretical background and prior work of researchers in your field. Review the prospectus theory chapter in light of your completed work and edit the chapter as required. Specifically, keep portions of the theory chapter that are used to develop your methodology and analyze the results of your research; remove portions that are not used anywhere in the thesis; add portions that you uncovered after the prospectus and are needed to support your methodology or analyze the results of your thesis. A theory chapter that reads like a 30-page book report is acceptable for a prospectus but unacceptable for a thesis. The theory should be concise and educate the reader on the key concepts required to understand your research.

Do not recreate derivations in the theory if they are not your own or do not add appreciably to the results. Just refer to the source. For example, it should not start with $E = mc^2$ and go downhill from there.

3. Methodology. This chapter explains the details of your research plan, whether it be experimental, computational, or a combination of methods. Be thorough and transparent as you develop, describe, present, and validate your methods. This chapter will be the same as the prospectus, with modifications as needed, and the following *required additions*:

   3.X Validation. A reader should be convinced that your methods produce approximately correct answers. Comparison of your results to benchmarks found in literature is an accepted method of validation. The following two examples of validation are (1) in need of improvement, (2) acceptable (3) good.

   (1) Poor: The reproduction of this figure of computational results is very accurate because it looks very much like Figure X from literature [cite reference].

   (2) Acceptable: Visual inspection of Figure X.X from [literature reference] shows that a ground target at scaled horizontal and vertical distances of 500 m and 400 m, respectively, from the burst will experience an overpressure of approximately 50 psi. The developed numerical overpressure model calculated an overpressure of 49.7 psi for the same distances. Overpressures for eight other combinations of horizontal and vertical distances, representative of the range of overpressures depicted in Figure X.X, were also calculated using the overpressure model, and all were found to agree within 3% of visually interpolated values from the figure. Thus, the computational methodology for ground targets is considered valid.

   (3) Good: Use appropriate statistical tests to validate the model and/or results against a known gold standard.

   3.Y Uncertainty and Error Propagation.

   (1) Natural questions that follow reported results are, "How accurate is your answer?," or "How certain are you of your results?" Thus, the significant results that you report in the thesis should include uncertainty. I prefer that you describe your methods for calculating uncertainty in your methodology chapter, instead of your results chapter. I find that the latter method of presentation distracts from results and analysis.

   (2) Quantify uncertainties and propagations of error for your reported results. Taylor's text [4] is a useful and easy-to-follow reference. The book assumes no prior knowledge and uses various pertinent examples

from physics and engineering to illustrate topics like random uncertainties, propagation of uncertainties, rejection of data, least-squares fitting, and distributions.

Bottom line: A reader who follows your methodology should be able to reproduce results that are similar to yours.

4. Results and Analysis. This chapter presents the findings of your research clearly and concisely, in comparison to theory, empirical evidence, and your research hypothesis or question(s). Consider the following general format for presentation of data:

   - Display a result (typically a figure)
   - **For oral presentations**: Explain what's displayed (axes titles, scales, units). This gives you, and your audience, a moment to get oriented before you discuss your result in detail.
   - Discuss the data quantitatively. For example, "This figure shows that _____ increases sharply as a function of _____ and then decreases gradually when _____. In the region from _____ to _____, several oscillations are present."
   - Explain and analyze the results *in terms of underlying theory and/or empirical evidence*. For example, "This behavior is expected based upon _____ theory. Additionally, researchers such as _____ have achieved similar results, as published in the reference. This portion of my data, however, is unexpected."
   - State conclusions that can be made from your observations and analysis *and in light of your thesis topic*.
   - If you observe unexpected results, you could offer possible explanations. However, your explanations should based in *theory*, not feelings. In other words, avoid speculation that you cannot support or substantiate. Possible explanations should be testable, so that you can either confirm or deny their validity. If you have a plan to test the validity of an explanation, state it.
   - Avoid gross speculation. It is better to present an unexpected result, state the measures you took isolate the behavior, and conclude that the cause has not yet been determined than it is to manufacture an exotic, mysterious, and unproven claim that you cannot confirm or deny. *Avoid gross speculation.* ***Avoid gross speculation***.

5. Conclusions.

   - Summarize the major conclusions from your results and analysis.
   - Recommend future work.

- Often, the conclusions chapter can easily be condensed into an abstract; do not include future work in the abstract.

6. Appendices. Include items such as supplemental figures, algorithm code, derivations, or anything that belongs outside the main body of the document.
7. Bibliography. Include citations for all references, in the order that they appear in the document.

5.2 The Thesis Defense

The defense briefing to your committee should include 25-35 slides, presented in about 40-45 minutes with 15-20 minutes of questions. The presentation should emphasize your results, analysis, and conclusions, since your committee will be familiar with your research. However, also present the background and relevance for your research, theoretical basis, and research methodology, keeping in mind that both committee members and other attendees will be present.

After your presentation, questions from the general audience are addressed, followed by questions from your committee members. At the conclusion of the defense, your committee will let you know whether or not you successfully defended your thesis, i.e., passed. Occasionally, students are required to repeat a thesis defense, but this is uncommon. *I will not schedule a defense until I think you're ready.*

The committee will recommend or require changes to your written document, which they'll provide verbally at your defense and in writing when they review your thesis document. Making these revisions to the satisfaction of all committee members should be your *main focus following the defense.*

5.3 Thesis Grading Expectations

The thesis grade is recorded in 12 credit hours of TENP 799, which you will register for during your graduation quarter. The 20-24 credits of NENG 799 that

you completed as independent research will not have an associated letter grade. Each committee member will complete a thesis grading sheet at your thesis defense, and I will let you know your grade range following the defense. However, your TENP 799 grade will be determined by me after your final thesis document is complete, based upon the following evaluation criteria:

- Your performance during summer NENG 799 research
- The quality of your written prospectus and briefing
- Your performance during the fall research quarter
- The quality of the grading copy of your thesis
- The quality of your thesis defense
- The quality of your final thesis
- Your effort to contribute to your field of research through a conference or journal submission

I will use the listed criteria to assign a grade of A-F or I (incomplete). Some expectations for these grades are listed below, and a copy of the official grading form is worth reviewing.

- **OUTSTANDING (A, A-)** grades are earned for *true excellence* in all areas of research, distinguished by the following:
  - The student receives initial direction and guidance from the committee, and then assumes control of the research by producing initial results with little direct supervision. The student analyzes, suggests, and implements subsequent steps in the process, which are viewed to be the most logical and favorable by the committee.
  - The student achieves meaningful results during the summer quarter.
  - The written prospectus and presentation are thorough.
  - The draft copy of the thesis is clear, correct, concise, comprehensible, and consistent.
  - The student's levels of effort and knowledge are outstanding.
  - The results are significant and publishable, and may be noted by the sponsor as meaningful contributions to their endeavors.

- **SATISFACTORY (B+, B)** grades are earned for *very good work* in all areas of research, distinguished by the following:
  - The student receives initial direction and guidance from the committee, and then provides some creative contribution by proposing some subsequent steps in the process.
  - The student produces an acceptable prospectus during the summer quarter and some usable results.
  - The student produces experimental and/or computational results and analyses that are either consistently correct or require minor modification to be correct.
  - The draft copy of the thesis is comprehensible and reports the research correctly. Minor modifications are required for style and organization.
  - The student's level of effort throughout is solid. I estimate that a solid thesis requires at least 50-60 hours per week.
  - The results may be publishable.
- **MARGINAL (B-, C+, C)** grades are earned for theses which, considered independently from the coursework, would not merit the award of the Master of Science Degree. These grades are infrequent and characterized by the following:
  - The student requires significant and frequent guidance to proceed and has difficulty executing research and/or analyzing results.
  - The student produces a marginal prospectus during the summer quarter.
  - The student has difficulty obtaining results and/or interpreting their significance.
  - The draft copy of the thesis is poorly organized, and/or contains incorrect results, ambiguous language
  - The student's level of effort throughout is inadequate (40 hours or less per week).
- **FAILING (D, F)** grades are earned for unacceptable independent study. These grades are rare and characterized by the following:
  - The student's levels of effort and understanding are marginal at best.
  - The student failed to submit an acceptable prospectus or thesis, or failed to make corrections required by the thesis committee.
- **INCOMPLETE (I)** grades are also rare. An incomplete grade may be assigned when circumstances outside the control of the student prevent them from completing their independent research. Examples include illness, family emergency, and non-delivery or non-availability of experimental or computational

resources. In these situations, we would pursue a one-quarter extension to allow you to complete your thesis. Historically, students who depart AFIT before submitting a thesis require significantly more time than one quarter to complete their research; unfortunately, many of these students never complete a thesis.

6. Graduation Quarter Deliverables

Table 2, shown earlier, listed several important deadlines during the graduation quarter; some of the corresponding dates for the winter 2021 quarter are shown below. Keep in mind that these dates may be modified as graduation approaches, so check the calendar on the AFIT Office of the Registrar web page at http://www.afit.edu/ENER/calendars.cfm, and comply with any additional directives sent by the AFIT Thesis Processing Center (TPC) or the ENP front office.

My modified deadlines tend to look like this:

- **11 January 2021**: Grading copy of thesis due to committee
- **29 January 2021**: Thesis defense complete
- **5 February 2021**: Final thesis submitted to committee for signature
- **12 February 2021**: Final signed thesis and Administrative thesis paperwork submitted to advisor (PA release/document distribution statement; SF 298 form)
- **19 February 2021**: Conference or journal submission complete

The three areas that tend to attract the most attention during the administrative review are: (1) completeness of the entries in your bibliography; (2) page count on the SF 298, which must be the total number of all pages in the document with any type of printed material, from the cover page to the SF 298; (3) The abstract, specifically the naming of individuals outside the US government.

7. Final Thoughts

All students and research projects are unique. Accordingly, some students complete a large quantity of work while others accomplish less. Regardless of the quantity of work you produce, *ensure the quality of the work is your very best effort.* In my opinion, it is better to complete three tasks very well than to produce marginal results for ten. However, balance that thought with the caveat, "perfection is the enemy of good enough." Make these statements your credos, if you have to have a credo.

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