Research Assistant Handbook

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1. Overview

My research group employs undergraduate research assistants, graduate students in the MS and PhD programs, and postdoctoral research associates to work on a variety of research projects in electromagnetics, biomedical devices, computational modeling and optimization, antenna design, phased arrays, signal processing, and wireless communications. In addition to student research assistants, visiting scientists from Europe, Asia, and other countries around the world visit my lab to collaborate on state-of-the-art research. These projects lead to new algorithms, antenna technologies, and other breakthroughs reported each year in many conference presentations and journal publications.

Research projects in my group are supported by millions of dollars in grants from the National Science Foundation, Department of Defense, NASA, and companies like L-3, Raytheon, and man others. This funding provides for student salary, supplies, equipment, hardware fabrication, travel, and experimental campaigns aimed at creating new knowledge in the field of electrical and computer engineering. Some students also receive financial support for their research from internal grants from BYU and prestigious national graduate research fellowships from NASA, NSF, DoD, and other organizations.

The goals of a research experience are to apply principles learned in the classroom, be a part of a stimulating and fast moving team of experts working on a challenging problem, produce results that benefit the funding agencies or companies that sponsor research projects, obtain a graduate degree, and provide a foundation for excellence throughout your career after leaving the university. The objectives of the MS and PhD programs in Electrical and Computer Engineering are to enable graduates to:

1. Apply knowledge in service to community and family and engage in lifelong learning through personal study and education.
2. Obtain employment that utilizes PhD level training, including positions such as academic faculty appointment, post-doctoral research, researcher within industrial or government laboratories, and other principal positions of technical creativity, leadership, and management.
3. Play a leading role in making significant contributions to engineering and technology.
4. Be examples of faith, character, and high professional ethics.

This document outlines basic expectations and guidelines for undergraduate and graduate research assistants in my research group.

2. Student Roles

Students in the research group typically have two roles. The first is to participate in a research experience as an advisee, and the second is a university employee with a research assistant position as part of a funded research project. While synonymous in many instances, these roles are intrinsically different as described in the following sections.

Advisees
Advisees are students who pursue academic endeavors in order to enhance the undergraduate experience or to receive a graduate degree. For students who are also employees, successfully completing a degree may take more hours than the university allows employees to work. You will have to work more than 20-40 hours in order to successfully complete a graduate degree. Receiving a graduate degree requires more than a "work for hire" mentality. Having a stipend while you are in school is a wonderful thing, but the graduate degree requires going above and beyond the expectations of a part time job.

Employees
Employees are students who receive financial compensation for their time on a research project, within university limits. These students are obligated to promptly complete tasks that I may assign them, even those above and beyond the tasks immediately associated with any academic program requirements, including but not limited to theses and dissertations. All time billed to a project must be spent on productive work for the project. Time spent on errands, outside reading, homework, etc. may not be clocked for pay (see below for more detail). An employee who fails to satisfactorily comply with the expectations given in this document may be subject to termination of employment, regardless of his or her academic standing in the department or status as an undergraduate or graduate student. Termination may also occur if research funds are not available for the student's continuing employment or if the student's assistance is no longer needed. Students can be terminated at any time, although this typically only happens in extreme cases, such as the end of a funded research project or misconduct. Termination of employment of a graduate student does not in and of itself constitute termination of the student's graduate program.

3. Academic Issues

This section provides instructions regarding academic credentials, programs, and scheduling:

1. Maintain a minimum 3.0 GPA at all times. If you are an undergraduate student expecting to attend graduate school, you may not be admitted with a lower GPA. If you are a graduate student, receiving a C grade or lower results in an unsatisfactory rating and possible termination from the program.

2. Take personal responsibility for learning the university deadlines associated with your degree program. Do not rely on faculty members, secretaries, or other students to remind you.
3. If you are a graduate student, submit your technical report, paper, thesis, or dissertation for peer review by fellow students in addition to submitting it to me. For a thesis or dissertation, resubmit the manuscript to me after you have addressed the comments provided by your peers, no later than three months before your planned defense date.
4. If you are a graduate student, provide complete copies of your thesis to the committee members and to the department secretary with sufficient time for the thesis to be reviewed by the committee before your thesis defense is officially scheduled.
5. Please provide me with at least two weeks of advance notice when requesting letters of recommendation for graduate school, scholarship, or employment applications. Be sure to let me know the deadline for the letter of recommendation, since the electronic notification usually does not include it.

4. Research

This section provides instructions regarding various aspects of conducting research:

1. Provide me with your CAEDM user name so that I can grant you access to research folders or project wikis.
2. Be organized. Keep research notes in a lab notebook. Keep your work bench and desk areas neat and orderly. Label all parts and containers.
3. Identify the primary and secondary research projects, if applicable, that you will be working on and record contact information for the sponsors of those projects, and the other students who you will work with on the project.
4. Prepare and follow a critical path delineating specific tasks for your research projects.
5. If you need help, come to me to get it rather than letting the project go unfinished. Your graduate degree research is primarily your responsibility, since you are getting the value of a graduate degree. The commitment and effort required to obtain a graduate degree goes beyond the stipend you receive for working on a given project.
6. Follow principles of scientific integrity and maintain total honesty in all research activities and in presenting research results. Best observed results should not be represented as typical results. Error bars and uncertainty estimates are important.
7. Understand that I consider each of you to be my colleague and therefore expect you to make intellectual contributions to our projects. Ponder and pray over your responsibilities as you seek new ideas, approaches, and explanations.
8. Label all data and plots clearly, including units for all axis labels, in every document you create. Include a title or caption that has the date, identifies what was being measured, and clearly describes where the data came from. Use a large font size so that text is legible when the plot is published in a thesis or paper.

9. Keep your data files, codes, and other documents in a folder under your name, so other students know which files are yours, and to avoid lost files floating on computer drives.
10. Label files that are part of batches beginning with the date in this format: YYYY-MM-DD, followed by a consistent project abbreviation, a descriptive but concise name, and indicators that distinguish the particular details of the simulation or measurement.
11. Save all of your project files in their proper places in our group folders or servers and keep the folders updated and organized. Design the folder structure(s) to reflect natural divisions in the data and to facilitate easy retrieval of files. Move out old file versions into a subdirectory so that the latest file versions can be easily located.
12. Back up electronic data in three places, two of which should be in different physical locations.
13. If you are involved in hardware design, once a design is finalized and fabricated, the design files, simulation results, and measurement results should be carefully archived in a clearly labeled directory. That directory should be separate from your work in progress designs, and should be included in the file archive that you provide to me when you graduate.
14. Data from major experiments, particularly those involving expensive, time-consuming off campus campaigns, should be carefully archived, documented, catalogued, backed up on a research group server. Processing codes used to handle experimental data should be included in the archive and easily accessible and usable by other students.
15. Complete all assignments in a timely manner and promptly report back to me when each assignment is finished.
16. Maintain a lab notebook log of activities to document your work toward achieving the milestones specified in your critical path and to support your time card submissions, as applicable.
17. Complete peer reviews of others' writing and research as needed.
18. Writing is critical to a successful graduate program. Graduate students should write a few sentences or paragraphs daily. Research results should be written up initially in a technical report format, followed by conference papers, journal paper, and thesis or dissertation. MS and PhD students ideally attend one or more technical conferences to present research to the technical community. Seek out and apply for university travel grants or external funding to support the travel costs.
19. At the conclusion of your research, provide me with a file archive containing all of your final documents, codes, powerpoint slides, design files, simulation model files, and any other needed source files (see below for instructions for graduating students).

5. Communication and Meetings

This section provides instructions regarding communication and meetings in the research group:

1. Provide your cell phone number and e-mail address for the research group directory.

2. Check your e-mail daily on week days and respond to requests from me within 48 hours if possible.
3. Send copies of critical business-related e-mail communication to me so that I can remain informed about your activities.
4. Provide me with a verbal update in group meetings (or an e-mail update when that is not possible) on your research progress each week. In your update, include a list of accomplishments and a description of your progress relative to the milestones specified in your critical path.
5. Prepare written progress reports and slides for distribution to our research sponsors as required for quarterly or annual reports. Determine the deadlines well in advance and prepare the reports in time to obtain and respond to peer reviews of your work.
6. Upload documentation and critical design files to the project wiki.
7. E-mail is generally the best way to reach me. When a longer conversation is needed, call my cell phone or office number. For routine matters, please leave a message rather than calling back repeatedly.
8. Attend seminars, research group meetings and socials whenever possible.
9. Bring a pad of paper and a pen or pencil or a device with which to take notes during meetings with me or other research assistants.
10. Participate in research-related university functions as requested.
11. Schedule vacations or other absences from campus with me in advance of your departure.
12. Maintain a professional demeanor at all times. Your spoken and written communication and gestures should reflect self-respect, respect for others, and a commitment to excellence and the standards of this university, the church, and the gospel of Jesus Christ.

6. Funding and Compensation

This section provides instructions regarding funding, compensation, and billing:

1. Work within time and budget limitations as required for your research project.
2. Record your billable time to the nearest minute as per university policy.
3. Adhere to the billing guidelines I have established for our research group.
4. Follow university rules for clocking time and correct all mistakes immediately.
5. Identify and apply for scholarships and travel grants available through the BYU Office of Research and Creative Activities (ORCA) and other organizations.
6. All time billed should represent efforts that lead to results and progress towards the goals of the research project.

The following billing guidelines are not intended to be comprehensive in every respect but are given to provide you with a clear understanding of the types of activities that I consider billable and those that I do not consider to be directly supporting the research as funded by our sponsors. If you are unsure about whether billing for a particular activity is appropriate, please ask me.

You should bill hours in the following instances:

1. Completion of university-mandated safety training
2. Design, testing, and other direct research activities
3. Preparation of thesis or journal paper outlines
4. Completion of literature reviews, including studying selected articles
5. Completion of laboratory research and off-site experiments
6. Analyses of collected data
7. Writing research progress updates for your advisor
8. Writing of progress reports to give to sponsors
9. Completion of peer reviews of others' work
10. Completion of telephone calls made to obtain research information or coordinate work
11. Meetings with me to discuss research questions and progress

You should not bill hours in the following instances:

1. Time spent in class or completing homework assignments
2. Participation in practice student presentations, guest presentations, or department seminars
3. Participation in research socials
4. Participation in conferences and seminars, including travel time
5. Review of magazines and other literature I circulate unless they directly pertain to your research
6. Preparation of ORCA proposals, scholarship applications, or employment applications
7. Development or maintenance of your resume
8. Completion of tasks associated with class research projects that are not directly required by the research sponsor
9. Organization and cleaning of your office desk and student office appliances
10. Review of time card errors
11. Breaks associated with meals on research trips
12. Waiting in line to visit with faculty members, secretaries, or other research assistants
13. Preparation of your thesis or project defense and coordinating scheduling with the committee members
14. Completion of final revisions and formatting of your thesis after its submission to the committee members
15. Completion of continuing research after your departure from BYU, regardless of the status of your thesis or project

7. Safety and Security

This section provides instructions regarding safety and security, with primary emphasis on the student office and laboratory:

1. Contact me to get a desk in the graduate lab. Desks are assigned first to graduate students, and if there are extra desks, they can be used by undergraduates. If you are assigned to a desk with a computer, arrange a meeting with the department computer service representative to set up an account.
2. With my permission, obtain laboratory door codes as needed for your research activities. Follow department rules regarding building security and safe-keeping of access codes.
3. Obtain authorization for after-hours building access through the department secretary.
4. Maintain laboratory safety, security, and cleanliness by keeping doors closed where possible; equipment, supplies, and materials put away in their proper locations; and bench tops and floors clean.
5. Participate in required university safety training.
6. Follow all safety rules when working on the roof or in any other hazardous location. Do not work closer than six feet to the edge of the roof without a safety harness. Report violations of safety rules to the laboratory supervisor or me immediately.
7. Identify fire escape routes from the student office, laboratory spaces, and other areas in which you regularly work.
8. For projects involving topics subject to International Traffic in Arms Regulations (ITAR), follow all export controls and information access restrictions provided by your advisor or the project sponsor.
9. Remain alert at all times to potential safety and security problems.

8. Intellectual Property

The Brigham Young University policy on intellectual property (IP) is that all technical works prepared by university personnel are owned by the university. Technical developments from student research projects with commercial potential can be patented and licensed through the BYU Technology Transfer Office to outside companies for commercialization.

IP protection. Students should be in regular contact with the advisor to determine if and when a research development should be submitted to the Technology Transfer Office for IP protection. The normal path is to prepare a white paper or a publication on the development, which can then be filed as a provisional patent application. This triggers a one year period, before the end of which a full patent application must be prepared. Normally, the inventors on the patent application are the student and the advisor. Others who contribute substantially to the development can also be listed.

Confidentiality of IP. Patentable IP should not be disclosed in a public setting before the IP is protected. Research group discussions are generally not considered to be public. Conferences and journal papers do constitute public disclosure, as well as conversations with companies or other organizations and individuals not affiliated with the university. One exception is the project sponsor. Research project sponsors are normally under a nondisclosure agreement with the university, and can participate in discussions on research developments for the project they are sponsoring without creating a public disclosure. Students should not publish, discuss, disclose, or

distribute documents containing details of research developments outside the research group and the project sponsor's technical point of contact without permission from the advisor.

Software. In-house software codes developed as part of research projects fall under the same confidentiality limitations. Codes used in research projects should not be distributed or used outside the research project or the university without permission from the advisor.

Employment. One of the purposes of a university education is to give students knowledge and skills that are useful to a future employer. Graduates should not be unduly limited after leaving the university by IP issues related to research projects they are involved in as students. When students are involved in developing technologies that have commercial potential, however, specific details of the technology that are not yet protected should not be discussed during job interviews or employment. In such cases, students should consult with the advisor to determine how to handle IP issues.

9. Student Office

This section provides instructions regarding the student offices in the Clyde Building:

1. Do not permit students without desk assignments to use the computers in the room or work on class or other projects at the table in the computer center. Do not use computers assigned to specific students without advance authorization. If the lab is empty, doors must be closed and securely locked.
2. Maintain the office so that it is presentable to guests at any time. Organize your personal belongings in such a way that the office appears clean and neat at all times.
3. Use the bookshelves in the room only for holding books, journals, manuals, and other references provided by the department, not for storing personal items. Store department equipment in a physical laboratory elsewhere in the building.
4. Keep the lab clean at all times. Ensure that dishes you bring do not spill and use adequate covers during heating.
5. Display professionalism and respect in your language and behavior at all times and strive to facilitate a feeling of cooperation within the office. Speak quietly and respectfully in the office to ensure that the environment is conducive to productive learning and completion of research activities. While in the office, silence your cell phone to minimize disruptions to others. Take personal cell phone calls out of the office.
6. If you are a teaching assistant for an undergraduate class, avoid holding office hours in the room when possible. Instead, arrange to meet students at other locations in the building, such as in the space just outside the door of the office, in a student lounge, or in a college or department computer laboratory.
7. Understand that a desk assignment is a privilege that comes with responsibilities and that those who fail to follow the office policies will be dismissed from the room.

10. Working in the BYU Microwave Laboratory (505 CB)

The BYU Microwave Lab is a Brigham Young University graduate research facility. At any given time, the lab supports 10-12 ongoing world-class research projects funded by the National Science Foundation and the Department of Defense in wireless communications, antenna systems, synthetic aperture radar, remote sensing, and signal processing. Lab resources include manufacturing facilities, work stations, and test and measurement equipment.

Rules for Lab Use

Lab access: The Microwave Lab is a closed facility. Students are only allowed in the lab with permission from a faculty lab director (Jensen, Long, Warnick, Jeffs, Mazzeo, Bangerter). Lab equipment is not available for general student use and may only be used by permission.

Borrowing components and hardware: Do not take components, cables, parts, or equipment from another lab bench without specific permission from the faculty project director.

Food in the lab: Food and drink are generally not allowed in the lab without faculty supervision, and should never be stored or consumed near test equipment.

Test Equipment: Most test equipment in the lab is owned by specific research projects and can only be used for other purposes by permission from the faculty project director. A few instruments are shared resources, including spectrum analyzers, some of the microwave sources, power supplies, and network analyzers. Shared test equipment should be used carefully to avoid damage. Do not remove any shared equipment from the lab without permission from Dr. Jensen. Removing equipment from the building requires approval from the Dean's office (see the department secretary for the form).

Network Analyzers: Network analyzers are expensive and sensitive instruments. Be sure to follow the guidelines given below for use of all network analyzers.

Undergraduates: The Microwave Lab is primarily a graduate research facility, and undergraduates are only allowed to enter the lab when authorized by a faculty director. Undergraduates may not bring food or drink into the lab.

Cleanliness: Work stations, lab benches, and test equipment benches must be kept clean. The center aisle in the north lab should be kept clear of obstructions.

10.1. Network Analyzer Guidelines

1. Prevent electrostatic discharge - ground yourself using wrist strap when making connections. Use a grounded, conductive mat in front of the analyzer. Short the center conductors of the test cable and device under test before making a connection to dissipate charges on the device under test.

2. Be careful with the probe leads. Damage affects measurement accuracy and they are expensive to replace. Use connector saver adapters if available.

3. Be careful not to infect the network analyzer with viruses or inadvertently change Windows or network analyzer software configuration settings.

4. For wet experiments or chemicals, use long cable lengths to locate the wet items several feet from the network analyzer to avoid spills on the conductive mat or on the analyzer. As much as possible of the wet work should be done using one of the older network analyzers.

5. If you store output files on the network analyzer hard drive, create a directory d:\users\[CAEDM username] for the files.

6. This network analyzer normally should not be moved (contact Dr. Jensen for questions).

11. Graduate Student Evaluations

Faculty advisors are required by the Office of Graduate Studies to complete a formal evaluation of each graduate student twice a year, usually during fall and winter semesters. The evaluation is applicable to all graduate students. The result of each evaluation will be "satisfactory," "marginal," or "unsatisfactory" and will be posted to your university student record. By policy, if your performance is considered "marginal" in one evaluation, the next evaluation must be either "satisfactory" or "unsatisfactory." If the second rating is "unsatisfactory," or if you receive two consecutive "unsatisfactory" ratings, then your graduate program is automatically placed on hold, and you cannot register for classes or progress in your program in any way. Similarly, an "unsatisfactory" rating followed by a "marginal" rating will automatically initiate a hold on your program. The hold can only be removed by a department petition to the Office of Graduate Studies. If the department is unable to support a petition, your graduate program will be terminated by the department. The following descriptions will be used as a guide to evaluate your performance as a graduate student.

Satisfactory
Your GPA for courses listed in your degree plan is above 3.0 each semester. You have prepared and obtained my approval of a critical path for your research. Your research is on or ahead of schedule relative to the milestones specified in your critical path. If your research is behind schedule, the reason for delay is clearly beyond your control. You strictly adhere to research protocols established for our group and competently, punctually, and professionally complete assignments related to your academic program.

Marginal
Your GPA for courses listed in your degree plan is below 3.0 during one semester, but your cumulative GPA is still above 3.0. For reasons not associated with delays beyond your control, your research is behind schedule relative to the milestones specified in your critical path, but it is not so far behind that you cannot meet the final deadline specified for your research. You have consulted with me in developing a plan to accelerate your work or modify your critical path as necessary. You neglect some aspects of the research protocols established for our group but commit to address the deficiencies on a time period acceptable to me. Your work on research assignments related to your academic program is sometimes characterized by incompetence, lack of punctuality, and/or lack of professionalism.

Unsatisfactory
Your GPA for courses listed in your degree plan is below 3.0 during one or more semesters, and your cumulative GPA is also below 3.0. For reasons not associated with delays beyond your

control, you have failed to prepare a critical path, or your research is so far behind schedule relative to the milestones specified in your critical path that you will not be able to meet the final deadline(s) specified for your research. You generally ignore the research protocols established for our group, and your negligence has resulted in data loss or other undesirable outcomes. Your work on research assignments related to your academic program is generally characterized by incompetence, lack of punctuality, and/or lack of professionalism.

EXPECTATIONS FOR DOCTORAL STUDENTS

Students pursuing doctoral degrees in the research group are subject to a unique set of expectations. The desirable characteristics, behaviors, and products of these students are detailed in the following sections.

Characteristics

Successful doctoral students are exceedingly passionate about research and discovery, highly self-motivated, independent thinkers, creative problem-solvers, and eager to learn. They are not puppets of their advisors, nor are they minimalists merely working to get through school or get a paycheck as a research assistant. They have or are actively working to develop exceptional communication skills, including writing and speaking talents, and are able to confidently access and synthesize information in the literature. They generally desire careers in industrial research & development, academia, government research laboratories, or high-level consulting firms and strive to achieve credentials that will garner respect within the scholarly community. They remain focused on achieving this objective and are not distracted by competing interests.

Behaviors

The characteristics of doctoral students are manifest in specific behaviors. They prioritize their research activity above their class work and other academic requirements, recognizing that their courses are appropriately selected to support their research tasks and that most externally funded contracts do not readily accommodate a strict focus on course work alone. During semesters in which they are enrolled full-time, they spend at least 20 hours per week devoted to their research, and they work full-time on their research projects when not enrolled in school. Realizing that their dissertation work may require 2,000 to 3,000 hours, not including time spent on other research projects, they deliberately schedule time for their research, not waiting for a "convenient" time to proceed with their tasks, and they do not need external deadlines or frequent reminders to be productive. They select classes that will specifically prepare them to meet their research objectives, and they do not hesitate to complete more than the minimum number of classes required for the doctoral program. They especially value interdisciplinary work and seek expertise in at least one secondary topic related to their primary interest(s). Because they are immersed in their research, they often develop new ideas, approaches, and solutions to implement without needing to solicit suggestions from their advisors. Indeed, they do not expect their advisors to be able to answer all of their questions, as they are investigating new territory. While anxious to fully exploit the resources available to them in the learning process, they consistently meet deadlines and reliably work within budgetary and other constraints. They are also willing mentors and team players.

Products

Doctoral students recognize that developing scholarly products is their preeminent goal. They enthusiastically seek opportunities to present their work at professional conferences and publish their research findings in peer-reviewed venues; publishing one article per year is a minimum goal. Given that the average duration of doctoral programs completed by students in the department is about four years, a doctoral student should have at least four peer-reviewed publications, on average, at the time of program completion. They find value in reviewing others' work and request appointments on professional committees that will provide them greater exposure to their research areas and more frequent opportunities to contribute and collaborate. They are eager to assist with writing proposals, research reports, technical papers, and other documents that define the body of knowledge on their selected topics. They regularly write down new research ideas and consider innovative ways of accomplishing "extra" work to facilitate additional learning and more frequent and/or more complex publications.

12. Guidelines for Technical Writing

With few exceptions, students in the group will be given opportunities to describe their research findings in writing. Mentoring in technical writing is one of the most important benefits of a graduate degree, and can be more beneficial in the long run than the actual research experience itself. This section addresses various issues associated with technical writing in the research group. Writing during a research project progresses through several key stages:

1. **Technical report.** Documentation of key derivations, simulations, measurements, and other results.
2. **Conference abstracts and papers.** One page abstract or 2-4 page paper with an update on recent research for submission to an annual technical conference such as the IEEE International Symposium on Antennas and Propagation.
3. **Journal papers.** Longer (4+ page) paper with complete documentation of a major research development for publication in an academic journal.
4. **Thesis or dissertation.** Final written document used to satisfy university MS or PhD graduation requirements.

12.1. Technical Report

As you begin a research project, derivations, simulations, and results should be documented in your lab notebook and transferred to a technical report written in LaTeX (pronounced "luh tek"). The technical report includes figures with captions, diagrams, equations, derivations, along with written explanations, experimental descriptions, and interpretations of results. This technical report may be informal and rough at first, but should become increasingly like a thesis chapter or research paper as the work matures. Eventually, the technical report becomes the basis for a conference paper or journal paper.

12.2. Conference Abstracts and Papers

Most graduate students travel to one or more technical conferences to present their work. Technical conference presentations require either one page abstracts or longer 2-4 page papers. Conference papers must be submitted by a deadline that is typically 4-6 months before the conference. If your abstract or paper is accepted, you will then be able to travel to the meeting to

make a 20 minute presentation on your work to other experts from around the world. The paper submission deadline for the IEEE International Symposium on Antennas and Propagation is in January and the meeting takes place the following June or July.

12.3. Journal Papers

Papers published in scholarly journals are the primary mode for communicating scientific and technical advances. Papers are generally 4-20 pages long. A paper motivates the problem of interest, reviews previous work on related problems, then describes the proposed result or solution, including theory, simulations, and/or experiments.

The structure of a technical manuscript usually includes the following elements: title, author list, contact information, abstract, key words or index terms, introduction, results, conclusion, references, and sometimes an appendix. Many authors prefer to write the results sections first and the introduction, background, and conclusion last. Writing in reverse order is valuable because, by first analyzing the data and establishing the conclusions, the author knows in advance the types of supporting information that should be included in the introduction and background sections. The abstract is usually written last.

The abstract should be a concise summary of the purpose and scope of the work, experimental methodology, and important results. The abstract should not include tables, figures, or references and should not require reference to the full manuscript to be understood. The abstract should not have more than 1-2 sentences of motivation for the problem, but should focus on a summary of the key results including quantitative statements of performance improvements and other numerical measures of the value of the work described in the paper.

The introduction should clearly define the problem statement or purpose of the work and enable the reader to recognize the contribution and value of the research to the industry. The introduction should provide the reader with a clear perspective of the usefulness of the research. Establishing the need for the research is often accomplished through a brief review of previously published work on the same topic and clear identification of deficiencies or constraints in that research. The introduction should then describe the scope of the proposed work and how it goes beyond previous work.

Derivations should include enough detail that the results can be reproduced by the reader, but without including every step. Equations should be created in LaTeX or using an equation editor, numbered in parentheses at the right margin, and introduced in the text prior to their appearance on the page. Each variable should be described with units. The experimental description section should describe in detail the experimental methodology. Including photographs to illustrate the setup may be especially useful.

The results section should include calculated values or other results of data analyses, usually presented in tables and figures. As with equations, tables and figures should be referenced by name in the text before their appearance in the paper. Table and figure titles should be formatted following the guidelines published by the journal to which the paper will be submitted. In order of priority, a table or figure should appear after its first mention in the text, be placed in the same section in which it is introduced, and be situated at the top or bottom of a page if possible; it should be referred to by number, not by spatial location within the document. The text should not duplicate, but supplement, the tables and figures in order to highlight or explain specific results.

The conclusion should summarize the problem statement, scope, and experimental methodology; restate important findings; offer recommendations for implementation of research results within a larger context; and point out possible directions for further study. Findings should not appear for the first time in the conclusion section; they should be originally developed in the results section.

References should be prepared following IEEE guidelines or other formats as required by the intended publisher of the document.

An appendix may also be included to document the original data collected during the study, give instructions for using software written by the student, particularly difficult derivations that do not fit well within the body of the paper, or other additional material. The appendix should be referred to in the text and should be appropriately organized into subsections if needed.

Unless otherwise stated, Times New Roman font of 12-point size should be used consistently throughout the text of the report, including in tables and figures, and labels for *x*- and *y*-axes in figures and for rows and columns in tables should include units where applicable. Metric units should be utilized and abbreviated correctly and consistently. All measurements should be given as numerals, as well as numbers of 10 or larger. Whole numbers between one and nine that do not represent measurements and any numeral that begins a sentence should be written as a word. Acronyms and abbreviations should be introduced with their first use in the report, and the acronym or abbreviation should then be used consistently thereafter. A single line of a paragraph or section should not be left on a page by itself. Upcoming subsections should be introduced in the last paragraph of the preceding section.

Review Process

Journal papers are peer reviewed before publication. After a paper is submitted, the journal editor sends the paper to 2-5 reviewers, who read the paper, make comments, and recommend whether or not the paper is suitable for publication. When the reviews come back, the authors revise the paper to satisfy the concerns and recommendations of the reviewers and resubmit the paper with changes. If the paper is accepted, it is published in the journal. Most journals accept one in three or one in two papers, but some journals are more or less selective.

An example of the structure of a research paper is given below.

Structure of a Research Paper

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Abstract. The abstract should state the problem, describe your theoretical approach and/or experimental setup, and summarize the main new results.

1. Introduction

The introduction should tell the reader what the problem is, what has been done by others, and what you are going to do. Since many readers will not read further or only skim the body, it is the most important part of the paper. The basic parts are:

First paragraph - Identify the problem and its importance.
Next paragraphs - Describe previous work and cite relevant papers from the literature.
(For a new graduate student, this is almost always the hardest section to write.)
Be clear about what others have done.
Concluding paragraphs - Outline your approach and summarize main results.

2. Body

The body of a paper presents background, derivations, description of experiments, and results. It consists of several sections, organized by how the material fits into the structure of the paper. Common sections in order of appearance are

Definitions (optional as a separate heading)
Include just enough to fix your notation and help the reader follow later sections.
Development of Design, Model, or Theoretical Results
Strike a balance between detail and conciseness – complexity is easy; clarity is difficult.
Cite as much as possible to avoid duplication; relate your approach to common principles.
Find a simpler way to present the results than your original derivation.
Experimental Description
Numerical/Experimental Results

2.1 Subsections. Top level section headings communicate the basic outline of the paper. The simpler and clearer the structure, the better. Use subsection headings to break up major topics within a section.

2.2 Figures. Figures stand out in a paper. Take advantage of this by using each figure to communicate a clear point. If possible, put that point in the figure caption after describing what the figure shows. Write the captions so that the figures tell your story by themselves.

3. Conclusions

The concluding section of a paper summarizes the main results of the paper (perhaps with more detail than in the abstract and introduction), makes recommendations for action in a larger context, and gives suggestions for further work.

4. References

[1] K. F. Warnick and W. C. Chew, "Numerical simulation methods for rough surface scattering", *Waves Rand. Media*, Vol. 11, No. 1, pp. R1-R30, 2001.

Be sure to cite all ideas, results, sentences, and even phrases from other authors. Using the work of others without attribution is plagiarism. Copyright may also be an issue when using figures or larger chunks of text.

12.4. Writing and Research

After a topic has been selected, the student should meet with his or her advisor to discuss the nature and scope of the work and identify key words and phrases needed for the student to begin a formal literature review on the subject. The literature review should primarily focus on research reports and peer-reviewed articles published in well-known journals, although magazine articles and various internet sites may also be consulted for relevant information. Conducting a

comprehensive literature review should be the first main task of the research and will allow the student to confidently determine areas in which additional research work is needed.

During the extensive reading associated with the literature review, the student should carefully document all pertinent ideas. The student may choose to simply write the ideas and sources in a lab notebook at first, but he or she may achieve greater efficiency by daily typing the information into a LaTeX document that could be utilized in preparation of a first draft of the manuscript at a later date. When the literature review is substantially completed, the student should discuss his or her findings with the advisor and plan the remaining work to ensure that the results will be a unique contribution to the existing knowledge base.

The advisor and the student should then finalize the objectives and scope of the research. The scope should clearly describe the extent of the expected project activities. The advisor and student should then list specific needs, including supplies, equipment, and other support. The availability of laboratory space should also be considered.

Once the objectives, scope of work, and testing needs are delineated, the student should prepare a critical path, or schedule, showing the anticipated starting date and duration of each task. The critical path should reflect all scheduling constraints on the project and include reasonable amounts of time for each proposed activity. Extra time should be given to tasks characterized by comparatively high levels of uncertainty so that unexpected events do not cause undue concern. Beyond simply displaying data collection activities, the critical path should include writing, peer reviews, advisor reviews, revisions, committee reviews, thesis defense, departmental and college reviews, final corrections, and manuscript submission as required. The critical path should indicate the dates by which all critical milestones should be achieved in order for the student to finish before any deadlines associated with his or her project. The critical path should be submitted to the advisor for review and approval early in the research project.

For any model or design files, simulation results, or measured data, the student should design a structured system of folders for efficient data management within the student's research folder. The folder should be the primary repository for all electronic data and should be frequently backed up. As the research proceeds, the student should document all decisions, observations, procedures, and results in a lab notebook. As noted above, filenames in batches should begin with the date in the format YYYY-MM-DD, followed by a consistent project abbreviation, a descriptive but concise name, and indicators that distinguish the particular details of the simulation or measurement.

12.5. Writing Process

In a typical writing process, authors should follow these steps: daily writing, document planning, drafting, revising, and editing.

Daily writing: Graduate students should write a few sentences or paragraphs about their research each day or at least weekly, including figures, plots, diagrams, and research results. This can use an informal style or a journal entry format.

Document planning entails development of the problem statement and supporting data and determination of the structure of a conference paper, journal paper, or thesis. A detailed outline is often the product of this step.

Drafting: is the creation of a first draft of the manuscript, usually using material written at the daily writing phase, a text that embodies all of the ideas and information delineated in the outline.

Revising early draft versions of the document should deal mainly with changes to the big picture, logical structure, and overall content. Revising can be done on a daily basis, working through the document from beginning to end a few paragraphs each day.

Editing: Finally, careful editing of the revised text involves correcting spelling, punctuation, grammar, usage, and mechanical errors and polishing the document in preparation to submit it for review by the intended audience. While each stage of the writing process is important, skilled authors focus most of their efforts on planning and revising, while inexperienced writers spend the majority of their time drafting and editing.

12.6. Writing Rules

Several texts providing comprehensive rules for writing are available for review during the writing process; a particularly useful guide is *A Pocket Style Manual* by Diana Hacker or *Style* by Joseph Williams. Well-written documents should comply with all basic writing rules, as well as these specific guidelines:

- Paragraphs should focus on one main idea, and the main idea should be found in the first or last sentence of the paragraph.
- The first few words of each of the sentences in a paragraph should have some logical relationship or connection.
- Sentences should begin with familiar information and end with what is new.
- Technical writing is usually done in the passive voice to avoid distraction and to focus on results, but first person voice can also be used.
- Theses can be written in a journal style or temporally ordered format if desired or appropriate, but journal papers should focus on results.
- Jargon, clichés, slang, sexist language, contractions, and comparatively generic and informal words such as “get,” “done,” and “thing” should be avoided.
- Sentences should not begin with unspecified “it” or “this” or with “there are” or “there is.”
- When used at the beginning of a nonrestrictive element, the word “which” should be preceded by a comma.
- Dangling modifiers, which are usually introductory phrases that suggest but do not name an actor, should be avoided.
- Sentences should not end with prepositions.
- A comma should be placed just before a conjunction used to connect two noun-verb phrases.
- A semicolon should be used to connect two complete, closely related sentences or to separate items in a list in which at least one item includes commas.

- A leading zero should be presented with numerals less than one.
- Possessive case should be used only for people, not objects.
- Subjects and verbs should always agree; if a compound subject is connected by “or” or “nor,” the verb should agree with the part of the subject nearer to the verb.

12.7. Thesis Outline

A typical thesis or dissertation has the following outline:

Chapter 1: Introduction. Motivation of problem, complete literature review of previous work, and a list of key research contributions of the thesis. A research contribution is different from a research activity. A research activity is what you did during the research, such as building hardware, creating a model, or deriving a result. A contribution is new knowledge that you have contributed to the academic community. Avoid listing research activities, and focus on contributions.

Chapter 2: Background (Optional). Theory and other relevant material that is from the work of others but is needed to understand the thesis.

Chapters 3,4,5, etc.: Technical chapters. These chapters contain technical details of your research, and are often based on conference papers or journal publications.

Chapter 7: Conclusions. This chapter briefly summarizes the work and gives ideas for future work in the area.

Appendices: Instructions for using hardware systems, manuals for software you have created for use by other students in the research group, code listings, or figures for cases where many plots are required to cover a large parameter space.

Bibliography: Complete listing of papers cited in the thesis. Be sure to include a complete overview of all relevant work leading up to your research, including papers by groups both outside BYU and our own research group. Use the IEEE Transactions format.

A common weakness of a thesis is to have a description of a hardware system that was designed and built, but no detail on the insight that was gained in the design or testing processes. A thesis needs to include a creative contribution to understanding as well as a description of a system or component. The underlying logic behind major design decisions should be clearly explained, and the implications of simulated and measured results should be explored.

13. Ethics in Scientific Publication

Published papers are the way we exchange cutting edge knowledge in the scientific and technical communities. Researchers can be very protective of the priority of their ideas, and like any creator, want to be recognized as the originator of their best work. The community also expects that reported results are true and correct and not biased by fraud or conflict of interest.

The basic principles of ethics in scientific work and publication are:

- Be honesty in reporting research. Results should not be fabricated, nor should the best results or the results that appear to support a particular conclusion be selectively included

while excluding other results. Altering data, selectively reporting data, or making up data are unethical.

- Cite and adequately attribute all phrases, sentences, figures, diagrams, designs, results, etc. that are the work of others. When a result is closely based on the work of others, that should be clearly indicated.
- Even with a citation, copyright could be an issue when reusing the work of others. Including material that has appeared in copyrighted works requires either copyright permission or verification that the material is available under the fair use doctrine. This even applies when the work is your own but a publisher holds copyright to the published work. Fair use does tend to be quite generous for reuse of small parts of technical work in low-revenue publishing markets.
- Avoid conflicts of interest by not skewing results or conclusions based on political pressure to meet the preferences of a research funding agency or company.
- Include names of all authors who contribute to the work reported in a paper, and avoid including "honorary" authors who do not contribute materially to the work.
- Other areas of ethical concern are research involving human subjects, preferential citation of work by certain authors or self-citation only, redundant publication of the same work in multiple articles, or undeclared potential conflicts of interest with patrons or funding organizations.

It is the student's responsibility to ensure that work conforms to these and other relevant ethical requirements. If you are in doubt, contact your advisor to discuss the matter. Ethics violations can have serious, career-influencing consequences for you and your coauthors.

14. Scheduling Thesis and Dissertation Defenses

Writing the thesis or dissertation. As detailed above, all graduate students should write about their research on a weekly basis throughout the graduate program. Work should be assembled into a technical report in LaTeX format, including figures, diagrams, captions, and text discussion. Over time, the technical report becomes a part of conference papers, journal papers, and eventually a thesis or dissertation. This is a much easier and better path than writing the thesis all at once a few months before graduating.

Completing the thesis or dissertation. The first step is to turn in drafts of chapters or the entire thesis to the advisor for review and editing. Early drafts should focus on revision (content and organization) and later drafts on editing (detailed grammar and writing quality). Implement all changes marked by the advisor, and *read the thesis on your own and make edits and improvements beyond the advisor's comments.* Have other students or family members help with editing as well.

Literature review and list of contributions. One critical part of a thesis is the literature review. Relevant journal papers from recent years on similar work should be cited. Explain the contribution of each paper, and then explain how your work goes beyond what has already been done. When there is prior work for which a journal paper is not available, conference papers, technical reports, or theses and dissertations can also be included in the literature review. The literature review can be in the introduction (Chapter 1), or it can be included at the beginning of each later chapter if your research involves topics that are in different application areas. The

introduction should also include a list of contributions. This is very important. It is not a list of activities (i.e., what you did), but a list of what new insights, innovations, or results your work contributes.

Submitting the thesis or dissertation to the committee. The thesis *must* be approved by your advisor before submitting to the committee. The thesis must be essentially complete. Experimental results or other additional material can be added between the time the thesis is submitted and the defense, but the thesis cannot be submitted with major gaps or holes.

Scheduling the defense. The university has strict rules that specify (1) the time period between submitting the thesis to your committee and formally scheduling the defense and (2) the time period between formally scheduling and the defense itself. Check with the department graduate secretary for specific details on timing and deadlines, as these can change from year to year. Do not ask to shorten the time period between submitting the thesis and the defense. Faculty schedules are busy, so finding a time when the entire committee can meet in person can be difficult.

The basic procedure is to:

(1) Obtain approval from the advisor to submit the thesis, submit the thesis to the committee in paper or electronic form depending on the wishes of each committee member. Contact the committee to choose a date and time for the defense informally.
(2) After the specified time period between submitting the thesis and formally scheduling the defense (two weeks), if the committee members agree that the thesis is adequate, have the official university form signed by the committee to formally schedule the defense. Submit the signed form and a hard copy of the thesis or dissertation to the department graduate advisor.
(3) A week or two before the defense, give the committee a final copy of the thesis, so that they can read and edit the latest version including any changes you have made between giving out the initial draft in step (1) and the defense.
(4) After the specified time period between formally scheduling the defense and the defense (two weeks), the thesis or dissertation defense takes place.

It is the student's responsibility to read the graduate handbook, consult information available from the graduate studies office, and meet with the department graduate advisor to understand all deadlines and rules regarding the graduate program.

Preparing for the defense. The defense consists of a 20-30 minute presentation followed by questions from the audience and committee. Prepare no more than 20-40 slides (fewer for MS, more for PhD) that cover the motivation for your work, list key new contributions, list publications on your work, and give an overview of each of your major research directions. The slides must be edited and approved by the advisor well before the defense. Do not wait until the last minute to prepare the presentation. Students should also be well prepared to answer questions about the value and relevance of the research and to demonstrate solid understanding of all topics studied in graduate coursework.

15. Graduating Students

Graduating students should leave a legacy that allows newer students to build on their work in moving the research project toward its goals. To accomplish this, in the last 3-5 weeks before leaving, graduating students must do each of the following:

Transition. Meet with other students to explain your research methods, show them how to use codes and models, give them a guided tour of your work area, show them the components and systems you have built or worked on, and show them your files on research group computers and servers.

Clean workspace and inventory parts and equipment. If your project involved hardware fabrication, clean up your work area, organize and label all parts, components, boards, etc. Make sure that new students can easily locate needed parts and equipment.

Documentation. Provide documentation for any hardware and software produced as part of the project. Include the location of the software or hardware, usage instructions, details on the method or design, and list future design changes or updates that are needed. Documentation should be included in a file archive given to your advisor and uploaded to the project wiki.

File archive. ***This is critical*.** All model files, MATLAB scripts, LaTeX files, documents, papers, presentations, slides, and other source files must be organized, cleaned up, documented, copied into an archive, and given to your advisor BEFORE leaving the university. This is an absolute must and is required in order to graduate from the program.

Journal papers and conference presentations. Make arrangements to complete conference presentations and papers that are in review at the time of graduation and require attention after you leave the university.

Finally, graduating students should keep in touch! A few months or a year after graduation, let your advisor know where you are, what projects you have worked on, and stop in or make contact from time to time with your advisor and fellow students.

16. Summary of Initial Assignments for New Students

- Read this entire document and ask me any questions you may have about it.
- Request after-hours access to the Clyde Building.
- Obtain a desk assignment in the student office.
- Obtain the student office door code.
- Obtain the laboratory door code.
- Review fire escape plans for the student office and laboratory.
- Meet with the department computer service representative to set up a computer account as needed.
- Provide me with your CAEDM user name.
- Ask me where you should store your project files.

- Provide me with your cell phone number.
- Purchase a bound volume to use as a lab notebook
- Complete mandatory college safety training.
- Meet with me to discuss your research project(s).