

# Nichol Group Lab Manual

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## 2. About the lab

### 2.1. Mission statement

*To conduct cutting-edge quantum science research in a dynamic, respectful, and inclusive team environment.*

### 2.2. Core values

- **Scientific excellence:** We strive to explore and harness the mysteries of nature in the most precise, clever, interesting, and useful ways possible. This value is the foundation of the group, and it is the goal that motivates us to persevere in the face of challenges.
- **Teamwork:** The work of the research group takes place in teams, or groups of people working together to achieve a common goal. We **respect** each other, and we **communicate** clearly and honestly with each other in an **inclusive** environment that values **diversity**.
- **Integrity:** We conduct our work with honesty and transparency. We do our best to avoid mistakes, but when they happen, we admit to them and fix them.
- **Growth:** Learning and teaching are essential elements of science. Research in an academic environment also involves professional development and career advancement.
- **Commitment:** We achieve scientific excellence because we are committed to it, not the other way around. We recognize that achieving our mission and maintaining our core values requires constant discipline, effort, and dedication.

### 2.3. How the lab works

The group consists of different people and resources working together to achieve our mission and maintain our core values. The PI (**principal investigator**) is John Nichol (me), Associate Professor of Physics. Feel free to address me as John. The PI has responsibility for setting the research directions, managing personnel, and securing funding.

Multiple **graduate students** in the lab carry out much of the work. Graduate students have earned their bachelor's degree and are working toward earning their PhD. The experience and capabilities of graduate students can vary widely depending on many factors. **Postdoctoral associates** (postdocs) have already earned their PhD and are pursuing additional years of training, often with the goal of securing a faculty position. **Undergraduate researchers** work on smaller projects, generally under the supervision of one or more graduate students or postdoctoral associates.

The lab consists of several sub-groups, or teams, each working on a specific project. Each team may involve several graduate students, undergraduate students, and postdocs.

My managing style involves close supervision of graduate students and postdocs. I function best as a scientist and advisor when I understand the details of experiments. When I am in town, I try to see most students every day. Unless I tell you otherwise, I am not trying to apply pressure during these meetings. Usually, I am just interested to hear about how your work is going and to help by offering advice or feedback if possible. Please be aware that I also tailor my supervision style according to your experience. For example, I might explicitly tell a new student how to achieve a certain goal, but I will usually give a more senior student some freedom in how to achieve the same goal. I do this both so that you can learn how to be an effective scientist, and because it is the best use of my time. If you sense that my supervision process changes with time, there is usually a reason for it, but please feel free to discuss it with me.

## 3. Expectations

The list of expectations here was inspired by (Noor, 2012).

### 3.1. General expectations

- Your **safety** is paramount. Follow all rules and protocols, wear appropriate PPE, and complete all safety trainings. Hazards to watch out for in our lab include chemicals, cryogenic liquids, compressed gasses, and magnetic fields. If you observe unsafe behavior, notify the individuals involved immediately.
- **If you are sick with anything more than a mild cold, do not come to the lab.** Stay home, get well, and do not risk the health of others. Right now, we follow CDC guidelines about covid exposure and isolation.
- **Open communication** is critical in the lab, both between you and me, and between you and your teammates. I expect you to update me regularly, clearly, and honestly about your scientific progress. In particular, if we discuss something, and you tell me that you understand something, I expect that you will actually understand it. If you do not, please keep asking me. I also expect you to communicate to me any personal concerns that will impact your scientific ability.
- I expect you to conduct your work with **integrity**.
- Any scientific enterprise involves a seemingly endless list of goals to accomplish. Ultimately, it is up to you to achieve your goals in a precise, yet expeditious manner. However, if you must err on one side of this continuum, you should usually decide to be careful and precise rather than overly expeditious. **It is always much better to do something right the first time than to have to do it twice.**
- Some **shared pieces of equipment** are essential for our lab operation and are very expensive, including the scanning electron microscope, dilution refrigerators, turbo pump station, leak checker, wirebonder, evaporator, etc. Please do your best not to break these items. If these items break, research progress will halt for everyone. Use these items only when you have been trained, and when in doubt, ask. If you discover any problems, fix them immediately (see Appendix 2) and notify me.
- **If you have a question about something in the lab** and you don't know what to do, follow the flowchart in Appendix 1: What to do if you have a question.
- **If you discover that something is broken**, and you don't know what to do, follow the flowchart in Appendix 2: What to do if something is broken.
- **Help me propagate a lab culture of leaving equipment in better condition than when you found it.** Good examples of this include: if you see that the acetone wash bottle in the hood is running low, fill it up. If you notice that we are running low on an evaporation source, tell the person whose job it is to order more. If you see we are running low on printer paper, order more. If something in the cleanroom is out of order, tell the cleanroom staff.
- If you discover something that you think the group should know, or that someone might possibly want to know in the future (e.g., how to operate or fix a special widget), **write a word document about it, and store it in a logical place in Nichol Group/Docs (or another logical place). At minimum, the document should have a title, a list of search terms (starting with "search terms:..." ), and then content.** If the document contains a procedure, instructions, or troubleshooting information for a widget the filename should be something like "widget\_procedure," "widget\_instructions," or "widget\_troubleshooting." After you have made this document, make

sure that Slack has properly indexed the file. Adjust your search terms if needed. If you find a document that someone else wrote, please fix any errors in the document if you find them.

- **Document** all of your research activities.
- I expect you to attend all **group meetings**.
- I expect you to find and read appropriate **background material** for your research project.

### 3.2. Undergraduate students

- All of the general expectations.
- **If you are new to the group, I will assign you a one-semester “training project.”** The training project will give you experience with how research works, and it will also let me evaluate your research potential. If you do well in the training project, we can move on to a research project. The training project will generally be structured as an independent study (PHY 391), and my group will host office hours for you to discuss your progress or questions with us if you wish. You can also contact us at any time via email or slack. The criteria for the final grade for this independent study will generally involve progress toward a specific project goal. Average performance toward those goals will result in a B grade. I define average with respect to the other undergraduates at UR who have conducted research in the group.
- **Once you move on to a research project, I prefer to structure this as a paid student work experience.** As long as you are making progress and your research output is worth the money I spend, I am happy for you to continue working in the group. Usually, this means you should be spending at least 10 hours per week on the project.
- **Ramping up new students on a research project usually takes one or two semesters.** I always hope that students will continue to do research in the group for more than one semester.
- **During the summers, undergraduate research positions are generally reserved for students outside UR through the NSF REU program.** (The reason is that summer research positions are in part a recruiting opportunity for the group, and UR undergraduates typically do not go on to graduate school at UR.) However, I am always happy to discuss summer research with you.
- Once you start on a project, I will assign you a research subgroup, and you should plan to attend the weekly subgroup meetings for that group. You must present at least one slide about what you did in the past week, and at least one slide on what your goals for the next week are.
- If you cannot make the subgroup meetings, please send me electronic updates on your work.
- I recommend that you meet at least once per week with one of the students or postdocs in your subgroup.

### 3.3. Graduate students

- All of the general expectations.
- The first 6-12 months of your experience as a graduate student in the group should be a considered a **trial period**. You may decide that the group or research is not a good fit for you. Conversely, I may decide that you are not a good fit for the group. I always hope that new students will be a good fit, and I do my best to select promising students. However, it happens sometimes that a new student is not a good fit.

- A PhD takes a long time. Expect to spend approximately **6 years earning your PhD**, although the exact length of time will depend on several factors. Together, we will decide on an appropriate timeline as you near completion. See below for more details on graduation.
- **Realize that a successful PhD experience requires you to derive personal meaning and satisfaction from your scientific work.** For better or worse, this is how the modern scientific enterprise is structured. You supervisor and all faculty members derive significant meaning from their work, and nearly everyone you are competing against at other institutions feels the same way. It is possible to think about a PhD as “just a job,” but it will likely be an unsuccessful experience.
- **Realize also that a PhD experience is in many ways similar to an apprenticeship for research.** This means that training happens “on-the-job,” and that it is preparation for a highly-skilled career.
- **Expect to devote at least 40 hours per week on research, including time on weekends.** My working hours are typically 8:30am-5:30pm. I often work evenings, and I try to work at least one afternoon per weekend, either at home or in the lab. Unlike other jobs, graduate students, postdocs, and professors have some flexibility in their working hours. It is important for new graduate students to hold normal working hours so they can learn most efficiently from other students or me. For advanced students, as long as you are making good progress on your project, you can have some flexibility in your hours. Your default operating mode should be to come to the lab.
- You may take up to **4 weeks of vacation every year**, i.e., 20 business days. This includes but is not limited to federal holidays, university holidays, or scheduled university recesses, such as winter break, spring break, etc. **Please inform your teammates and me** in advance of days you will be gone. I understand that emergencies will arise. In this case, please notify me as soon as possible. Updating your status on Slack is a good way to let your teammates know if you cannot come to the lab.
- **Near the start of each year, we will discuss your progress toward your research and professional goals as part of a formal evaluation process.**
- When you start a project, I will assign you a subgroup, and that subgroup will meet together each week to discuss progress and decide on goals for the next week. I will try to meet with you several times in between these meetings. If I don’t manage to do this, **please inform me of any significant changes from the weekly plan that we established in the subgroup meeting.**
- **If you genuinely need something for your research, buy it.** Ask my permission for orders over \$500. Make sure you have the correct account number. There is a spreadsheet on Box with current default account number for all lab members. If you are buying equipment that will be used for a large system, we can often use a fabricated account number to save on overhead. If you see a pink slip in my mailbox, feel free to pick up the package, and place it in the designated spot in the lab.
- If you are running an experiment with a dilution refrigerator, **you must check on the fridge at least once per day** to make sure it is ok. If you are away, there must be someone around the lab whom you can contact in the unlikely event of a problem.
- **If you assemble a printed circuit board, you must completely verify that it works before mounting a device on it.**

- ***I expect you to present the results of your research at national meetings.*** In general, I will attempt to support travel if you are presenting a poster or talk.
- ***You may decide to take at most one internship during your PhD.*** An internship requires official approval from me, so we should discuss it first, well in advance of the internship. Based on my experience so far, a major potential outcome of an internship is a job offer. Thus:
  - The ideal time to take an internship is during your final year when or immediately before you write your thesis. This allows for a minimal disruption to your research.
  - If you would like to take an internship before you are writing your thesis, we will negotiate what research tasks you should finish before you graduate after returning.
 Keep the following additional points in mind:
  - The internship should pay your stipend, unless there is a direct and substantial benefit to the group.
  - Only one person from the group can be away on an internship at one time.
  - Your research will probably stop during your absence. Sometimes, someone else may work on the project.
  - The ramp up time back into research when you return generally takes a few months.
- ***Before you graduate, the following criteria should be satisfied.*** In general, this will take approximately 6 years.
  - You have conducted a substantial amount of independent research. Here, “independent” means that you were a primary driver of the research.
  - This research has been published in a substantial number of papers.
  - You have participated in training the next generation of students.
  - See the [U of R thesis manual](#) for more information about writing your thesis, including how to include a statement about contributors, like other students. If you wish to take a semester to write your thesis and not conduct research, I will arrange for you to be a TA during that time. Usually, it takes about 3 months to write a thesis. Most of the material will be adapted from papers you have already written.

### 3.4. Postdoctoral associates

- All of the general expectations, and most of the expectations for graduate students, except those having to do with internships or thesis writing.
- ***An effective postdoc takes about three years.*** The first year will usually be spent ramping up, and the third year will usually be spent applying for and interviewing for jobs.
- ***Postdocs should think of themselves as role models*** for the rest of the group. I depend on effective postdocs to help achieve our mission and maintain our core values.

### 3.5. PI

- I will always make time to talk with you about your research and/or your academic training. At a bare minimum, I will always be available for at least 30 minutes once a week with notice. (As of 2021, I typically see most students every day, if only for a few minutes.)
- I will communicate honestly and clearly with you.
- I will advise you on how to proceed on the career path that you select.

- I will read and comment on any manuscripts, grant applications, or other written materials you give me within two weeks (excluding theses or dissertations). If I am actively revising or rewriting something, it may take longer.
- I will provide you with resources for your research if they are available to me and the expense is reasonable given the laboratory priorities.
- I will update you on my assessment of your progress, both in research and in your overall training upon request. At the beginning of each year, we will go through an evaluation process, and I will provide you with feedback about your performance in the past year.
- I will introduce you to others in the field and help you make contacts that will be useful throughout your career.
- I will treat you with respect and dignity.

#### 4. Mentoring students

A major part of learning to be a scientist involves learning how to teach others to be scientists, and it is also essential for the continuity of research in the group. Unfortunately, very few of us innately have the skills to be effective mentors or teachers. Thus, like everything else we do in the lab, this is something that requires consistent practice.

My training philosophy is summarized here:

- Successfully training someone new requires 100% effort and commitment from both the trainer and trainee. I have never successfully trained anyone without buy-in from both trainer and trainee. The strategy is difficult, and it takes a lot of time and effort, especially from the trainer, at first. I find it helpful to take the attitude that one is making an investment in the future.
- The trainer should imagine that they are walking together with the trainee on a path, not waiting at the finish line.
- Telling a new student how to do a task and then expecting that they will do it properly is usually a mistake. You should continuously check on the student to make sure they are working properly.
- It is helpful to take a “trust but verify” approach. You should assume that the student will successfully complete the task after you assign it to them, but then you should verify that it is correctly done.
- Learning how to assign appropriate goals for a new student is essential. The newest students must be told what their objective is and how to achieve it. As the student becomes more experienced, you can start to give them some freedom in deciding how to achieve their goals. The most advanced students can decide on their objectives and approaches.
- Realize that different students have different communication styles and learning styles. In particular, the student you are training may have a different learning or communication style than you do. For example, you might enjoy a vigorous back and forth debate about a scientific issue, but your student might feel offended if you excitedly interrupt them during a conversation. In another example, you might learn best if you watch someone doing something, but your student might learn best reading instructions. Training a new student who has a similar learning and communication style to you is generally relatively easy, but training a new student who has a different learning and communication style can be profoundly challenging. The problem is even more difficult because most new students are not fully aware of their communication and learning



preferences. However, learning how to teach and work with people who are different than you is one of the most important skills I can teach you. The best advice I can give you about communication is to always try to understand the non-verbal cues from your student. Although subtle, these cues will often help you understand the student's preferred method of communication. Discerning a new student's learning style often requires trying something (e.g., showing them how to do a task) and then seeing how it works (e.g., observing how well they can repeat the task). Although your first approach may not work, it will often point you in the right direction for how to change your teaching approach.

- Learning how to provide effective feedback is also critical. In general, try to provide more positive feedback than negative. When providing negative feedback, focus on the behavior of the student and its implications for the project. Make sure the student understands the implications of their behavior and understands and agrees on the path forward.

#### 4.1. Mentoring undergraduate students

There are three primary reasons that we mentor undergraduate students in our research group:

- It is an important educational opportunity for undergraduate students
- It is a recruiting opportunity for the group
- Mentoring undergraduate students is a good way for graduate students and postdocs to learn the art of mentoring.

In addition to teaching undergraduates how to conduct research, it is essential to provide them with a structured experience and to make sure they are integrated within the group. With these in mind, the following tasks should be completed before the project begins. The person who should complete the task is indicated in parentheses.

- (PI) Identify the project they will work on.
  - This requires knowledge of their skill level, lab experience, etc. Hopefully this is provided at least a week or two in advance. In general, it is usually safest to expect minimal knowledge, but good work ethics and interest. It also seems generally safe to expect they have some level of coding experience.
  - It can be beneficial to identify more than one project which they can work on and let them have a say as to which one sounds more exciting. This is by no means required and can in fact be counterproductive because it will likely force the student to choose between two projects without sufficient knowledge of either, which can cause them to feel as if they are expected to know both project subjects beforehand. What can be useful, is to do this at a high level. For example, having two different projects, one that is mostly software/coding based, and another that is more hands on/electronics based. You can pitch the projects to them like that – they don't need to know all the details.
  - Ideally, projects are important in that we (the lab) truly care that they get done, but not mission critical or overly time sensitive. This can be a hard balance to strike. Students will absolutely be able to tell if they are working on something that is not important to you or the lab.
  - (PI) Order anything required for the projects so that it is here prior to their start date.
- (PI) Determine project timeline/outline.

- (PI) Notify everyone in the group when the student will be starting, and, if known, what they will be working on.

Once the project starts:

- (PI) Meet with all participating members of the project (John, the student, any supervising graduate students, or postdocs).
  - Outline time expectations. Students should have a set schedule (they are obviously free to work more if they desire, but don't even imply that they should).
  - Outline expectations for what the student should present at group meetings.
  - Provide project goals. Set expectations regarding deliverables and progress updates.
  - Provide relevant background reading material. Keep in mind that they are coming in with very little expertise and will only be here a short time. Reading material should therefore be introductory, short, and critical to the project moving forward. Throughout the summer, they should come across (either themselves or via their mentor) additional reading material when it is relevant/needed.
  - Highlight exactly how/why their project is important to the main goals of the group. E.g., if they are making DACs, explain that all our experiments rely on low-noise and well-calibrated voltage sources, which are expensive and difficult to acquire. Being able to build our own opens up the possibilities for what types of experiments we can even do and allows us to design and test larger qubit arrays.
  - Highlight the importance of documentation. The undergrad student should document everything and do so with care.
  - Go over any relevant safety concerns.
- (PI) Get them set up in the lab.
  - Get them on Slack.
  - Teach them how Box works if needed. They don't need to install Box on their personal laptop, but likely will need to know how to store/access files.
- (Mentor) Train the student on relevant skills needed. This is the upfront time cost from the mentor. Do a good and thorough job here, and you'll be saving time later.
- (Mentor) Introduce the student to everyone in the lab as soon as possible. Have each person give a brief overview of what they are working on. Even better, set up scheduled meetings (they can be as short as 10 minutes) between the student and everyone in the lab so they can introduce themselves and explain what they work on. By the end of the second week, they should know everyone.

As the project continues:

- (Mentor) Arrange a time to meet with the student at least once per week in person. If the student is around the lab a lot, it can be informal (i.e., not scheduled), and doesn't need to be more than 5 minutes. These check-ins are crucial. Not only can you help encourage progress, answer questions, etc., but they convey that you are interested in the project they are working on. Again, students can easily tell when they are working on something no one cares about.
- (Mentor) If the student is not around the lab very much, check in with them over slack several times per week.
- (Mentor) Make sure the student knows that you are available when they have questions.

- Students should attend whichever weekly subgroup meeting to which their project most pertains.
- (Mentor) Try to gradually transition your student from being dependent to independent. Your job is mostly to teach them the initial skills they need to get started, and then to guide their project based on what arises throughout. Try to challenge them to learn new skills, and tackle problems themselves and creatively.
- (Mentor) Remind them to document everything they are doing. This is mandatory and needs to be done with care.

#### 4.2. Mentoring REU students

Mentoring summer REU students follows a similar plan, with the following additional tasks.

Once the project starts:

- (Mentor) plan a social event for the group right away.

As the project continues:

- (Mentor) meet or check-in with the student daily.

As the project concludes:

- (Mentor) Help them put together their final presentation.
  - Plan the outline of their talk together. Explain to them that good talks: are understandable, clearly highlight the motivation and application of the work, clearly explain the steps taken, and concisely summarize results (and possibly future/remaining work).
  - You will likely need to explain to them the context for their work (why they are doing this in the first place), even if you did in the beginning of the REU and throughout.
  - Go through at least one dry-run with them so they can practice. Give them real and thorough feedback. This is immensely helpful, and you can use this as your one and only opportunity to really teach them how to give a good scientific talk.
- (Mentor) Organize a send-off event, ideally at the end of their last day.

Some good resources on mentoring undergraduate students include the following:

<https://reu.eecs.wsu.edu/docs/REU-Mentor-Guidelines.pdf>

[https://www.rise.hs.iastate.edu/News-](https://www.rise.hs.iastate.edu/News-Items/Key%20actions%20of%20successful%20summer%20research%20mentors.pdf)

<Items/Key%20actions%20of%20successful%20summer%20research%20mentors.pdf>

<https://www.herl.pitt.edu/education/undergrad/aspire/mentor-resources>

#### 4.3. Mentoring junior graduate students

Many of the same principles discussed above for mentoring undergraduates apply for mentoring junior graduate students. Projects for junior students will likely be less well-defined, and there will be less structure than projects for undergraduates. Nevertheless, the concepts of intentionally providing structure and integrating students into the group are essential.

## 5. Ethics

### 5.1. Background

At its core, science is a discipline about finding out the truth of the world. We must therefore hold ourselves to the highest standard of honesty in our work. Moreover, as experimental scientists, we must preserve the trust the scientific community has in our data and presentation. Without this, our work is meaningless. Finally, although students and postdocs come and go, the research of the group is my life's work. I will not allow this to lose its worth. Because of these reasons, we have the following rules for our group.

### 5.2. The code rule

Every group member now and in the future should be able to reconstruct the analysis for a paper.

***Analysis code for figures in papers, posters, presentations, etc. must be in the appropriate manuscript folder. It must be self-contained, i.e., any additional scripts or functions must also be in that folder.***

- There should be a single file that generates all figures for each paper. There should be one cell for each figure.
- The code should be traceable back to original data files. Avoid as much as possible copying special-measure data files to other locations or repackaging data. This can lead to errors. As much as possible, your analysis scripts should refer to original files in the original folders. If you must copy files, make a script that does the copying for you.
- The code should be as clean as possible. Write it with others in mind. This will require extra time.
- Do not hardcode data parameters in analysis functions. Use `plsinfo`, `configchans`, etc.
- Put frequently-used analysis routines in functions. This allows you to debug and maximizes consistency.
- As much as possible, use functions in group folders. Do not use functions in your personal folder.
- Do not copy any but the simplest local functions from one script to another. If you find yourself doing this, write an actual function.
- Separate analysis from plotting. Your analysis routines should output data, parameters, fits, etc. Store these as variables and plot them with separate lines of code.
- Your Matlab code must reproduce the data and analysis portions of published figures as accurately as possible. I realize creating code to generate figures is a pain, but it minimizes the chance for error.

### 5.3. The double-check rule

We all make typos when writing papers. The same is true when we are calculating, and it is especially true when we are coding. The purpose of the double-check rule is to eliminate such typos and other more serious errors

***No figures, analysis, simulations, calculations, etc. will be submitted or posted online unless at least two people have agreed that the work is correct. This can mean the following:***

- One person did the work and another person read through every line of the code or calculation.
- Two people independently performed the work.

The double-check rule applies without exception to papers. It also applies to presentations and posters, depending on the context.

#### 5.4. The plagiarism rule

Plagiarism is never acceptable.

- Plagiarism means copying someone else's work (words, pictures, thoughts, etc.) without providing credit.
- When you cite a reference, that means you are quoting the ideas of the reference. It does not mean that you are directly quoting words from the reference.
- If you must copy text, use quotation marks.
- Plagiarism applies to figures.

***Do not plagiarize.***

#### 5.5. The lthenticate rule

Plagiarism can also occur inadvertently. In order to protect ourselves from this, the ***I will run all papers to be submitted through lthenticate prior to submission.***

#### 5.6. Violations

I understand that accidents will happen. In accordance with our core value of honesty, please let me know of any mistakes that have happened immediately, and we will attempt to fix them. Fixing such mistakes becomes progressively harder the farther along a paper is in the publication process, so it is much better to fix them early.

If I discover violations of the rules listed above, in addition to other unethical or dishonest behavior, including but not limited to fabricating or altering data, we will have a very serious discussion. I may dismiss you from the group.

#### 5.7. Data Sharing

The basic premise of our data-sharing policy is that data and analysis code should be made available once a paper is published. There are different ways to do this.

- The Matlab figures associated with a paper can be shared. In practice, this has been the easiest way for us to share our data.
- Even better, the raw data files and analysis code can be shared.

Prior to publication, data can be shared in certain circumstances. Let us consider the following types of people:

- Non-collaborator: Someone not involved in the data taking or analysis
- Experiment collaborator: Someone who is actively involved in the data taking and analysis
- Analysis collaborator: Someone whom we give data to for further analysis. They may ask for additional data sets, but they will not be actively involved in the data taking.

If a non-collaborator asks for data, the data can only be made available to them after it has been part of a published paper.

If an analysis collaborator asks for data, most of the time, the data should only be made available to them after it has been part of a published paper. In rare circumstances, the data can be shared before

publication, once vetted, provided they agree to the rules below. The data and analysis code must be vetted in the same way as for a paper.

- The data are confidential and not to be shared without the Nichol's permission until published.
- Before publication, the Nichol reserves the right to deny permission to use the data in any publications.
- If any Nichol Group members are co-authors, all publications must be submitted to Nichol with at least one month for approval.
- All students involved in the data-collection and analysis should be co-authors.

An experiment collaborator should effectively be treated as a member of the group. This means that the integrity rules above should be followed with respect to any shared data, and that all members involved in the data acquisition need to be consulted about any papers or other distribution of the data.

## 6. Software, Data, and Coding

### 6.1. Programs

We use a variety of programs in the lab, including the following:

- **Box** is the file storage software we use. Box is available through the University of Rochester. Appendix 3: Important directories in Nichol Group lists some important places in our directory.
- We keep records of experiments, device fabrication, and equipment in **OneNote**. In general, any document that need to be frequently changed and/or accessed by multiple people in the group should be kept in OneNote. You can think of OneNote as that RAM for the lab, and Box as the hard drive.
- **Matlab** is the primary measurement and analysis software in the lab, and it is available through the University of Rochester. We use the Special Measure framework for managing data acquisition. The [Special Measure wiki](#) is useful in getting started. An index of our Matlab code is in Nichol Group/Docs/Matlab/index.html. It is generated using Nichol Group/matlab/m2html/createDocs.m. The Matlab function [lookfor](#) is also useful if you are looking for code.
- **Comsol Multiphysics** is the primary finite-element-analysis software we use. We have many different packages for Comsol and frequently use it. We have a license for Comsol, and it can be used on the lab workstation and Bluehive.
- We write most papers in **Latex**, using **Overleaf**. I have a paid Overleaf subscription.
- Figures for papers are refined in **Adobe Illustrator**.
- **Autodesk Inventor** is the 3D computer-aided-design (CAD) program we use for designing parts that need to be machined. You can get a free educational license for all Autodesk products.
- **Autodesk Autocad** is the 2D CAD program we use most for designing devices.
- **Autodesk Eagle** is the program we use for designing circuit boards.
- **Github** is the version control software we use to manage **urpec**, our proximity-effect-correction software for electron beam lithography.
- The lab schedule is on **Google Calendar**.
- We communicate on **Slack**. The group has a paid slack subscription. Slack also serves as our primary way to search Box.
- We use **Google Remote Desktop** to remotely login to our computers.

## 6.2. Resources

I will provide each student with a desktop computer for the office. In addition to these computers, we have computers associated with each measurement setup. We also have a computer dedicated to Matlab and Comsol use in B15Y.

We have a node on Bluehive (“booster”), with 56 cores and 512 GB RAM, for resource-intensive calculations.

## 6.3. Lab notebooks

**All notes necessary to replicate experiments, device fabrication, or equipment maintenance must be recorded in OneNote in the appropriate location.** In particular:

- On shared lab computers, you should ideally use the online version of OneNote. You should ideally log in and log out after each use.
- By the time you start testing a device, all device fabrication steps must be recorded in a new page in the relevant section of NG Fab. Link this page to the relevant index page in that section. The reason for this requirement is that we can more effectively troubleshoot devices if all the steps are recorded.
- If you mount a device on a PCB, make a note in NG Fab/PCB. All PCBs should either have their name written with a marker or a diamond scribe.
- If you buy a new wafer, make an entry in NG Fab/Wafer Index
- If you are testing a device in the Blue Horse, make a new page in NG Data/Tester with the name of the device. If you are testing a device in a dilution refrigerator, make a new folder in Nichol Group/Data that follows the naming convention, i.e., 2022\_09\_10\_JMN01\_D11. Then, make a section in NG Data with that same name. The idea is to have the OneNote structure mimic the folder structure in Box. You should make a note of every data file you take that is potentially useful. (Remember that when you run `smnext()`, that places the filename in the clipboard, so you can automatically paste it in OneNote.) You should also paste analysis figures into the OneNote page.
- The overall structure of NG Data should mirror the structure of Box/Nichol Group/Data as much as possible.
- The intended reader of your notes is not you at the present time. The intended audience is either me or you several years in the future once you have forgotten the details of your experiment. Write your notes with this in mind.
- In general, the contents of lab notebooks, like fabrication recipes, etc., should be treated as confidential. You should not share the contents of lab notebooks with other groups without discussing with me first.

## 6.4. Documentation

Fab recipes are documented in Box/Nichol Group/Fab/Procedures. Fridge instructions are documented in Box/Nichol Group/Fridge. Most other items of documentation are in Box/Nichol Group/Docs. If you want to create an item of documentation, first make sure that it does not already exist. **Duplicate documentation, especially for fab recipes, creates major problems for us. There should only ever be one document for a given topic.** Second, browse the folder structure on Box and find the best place for it.

## 6.5. Data format

**All data files should be acquired with *smrun* and stored in the *special-measure* format.** The only possible exception to this rule involves preliminary data sets used to create drivers. The reason for this rule is that I and other group members may need to be able to access the data after a specific student or postdoc leaves the lab. If the data is in a non-standard format, it will be difficult to access it properly.

## 6.6. Coding

Many functions are used by all members of the lab. Currently, we do not use github to manage our Matlab software for data acquisition and analysis (this may change in the future). Thus, when you make a change to some code do the following.

- Alert group members that you are making a change.
- Make sure any changes you make are non-breaking. Test your code, and try to break it.
- Leave the code in better shape than when you started. This means adding documentation to describe your changes at a minimum. Even better, you can clean up the existing documentation. You can also clean up the existing code, although you should make sure any changes you make are non-breaking.
- If you make a new function or script, document it properly. Understand and use an [H1 comment line](#) in your functions.
- Try to adhere to the [Matlab style guide](#). There is no consistent coding style in the group, but try to make your changes as clean as possible.
- Before you write a new function, make sure it doesn't already exist! We already have many functions to plot data, analyze oscillations, and take power spectra, for example.

## 6.7. Computer disposal

- If you need to dispose of or otherwise retire a computer, please do the following.
  - Confirm that the computer really is dead. If the computer is a laptop, check that the power adapter is still working, for example.
  - Remove and the hard drive, and store it in B15Y.
  - Take the computer to the technology disposal room on the fourth floor of B&L.

# 7. Communication

## 7.1. Slack, email

Slack is the primary means of communication in the group. All graduate students and postdocs should install Slack on their desktops, laptops, and/or phones. Occasionally, I will email you, but I generally prefer Slack.

Box is integrated with Slack. The best way to search for something on box is to enable the Box app and then type `"/box search [search term]"` (see Appendix 1 and Appendix 2).

## 7.2. Meetings

Currently, we have group meetings every week. During these meetings, one student will present a short talk about their research or a paper. The main goals of the group meeting are to provide students and



postdocs a chance to practice public speaking, and for each of the students to teach the rest of the group about some aspect of their work.

## 8. Writing papers

### 8.1. Process

Writing a paper is an integral part of the scientific process. It may seem that writing a paper is something one does after finishing the data acquisition or analysis. In fact, however, writing a paper helps to develop the argument, and writing a manuscript often prompts more measurements and further analysis.

There are many ways to approach writing a paper. I tend to favor the following. Some people prefer to make figures first, but I find that making figures without a clear sense for the overall text is difficult. The more experienced I get, the more I realize that the [process](#) outlined in (Whitesides, 2004) is a great way to write papers.

- Writing an outline and sketching out figures
- Making the figures
- Writing the text

I have heard it said before that a good paper is like an onion. There are many layers to an onion, but each layer contains the full essence of the onion. In the context of a paper, this means no matter how one reads the paper (e.g., title alone, figures alone, introduction and conclusion alone, the whole thing, etc.) one should come away with the main message of the paper.

Write your papers in latex using overleaf. Once the primary author has finished a draft, we typically take turns reading the paper and making or suggesting edits. The process of having coauthors read the paper and make edits is time consuming. It is the first author's responsibility to make sure this process keeps going and runs smoothly.

### 8.2. Authorship

Generally, the student or postdoc who made the largest contribution to a piece of work will be the first author. Multiple students and postdocs can be co-first authors, though there is usually still a "first co-first" author. If most of the supervision and responsibility for the project rests with me, I will be the last author and corresponding author. (Any questions about the paper should be directed to me, since such questions may arrive long after you have left.) Other authors on the paper should have made a substantial contribution to the work, such as fabricating the device, or performing a theoretical calculation. If a group member's only contribution was fabricating the device that was used for an experiment, that group member will be an author on the first paper using the device. Subsequent experiments papers do not need to include that person as an author but can include them in the acknowledgments.

All lab members should write papers before leaving the lab (Barker, 2010) If a paper is submitted before a lab member leaves and it comes back requiring revisions, the first author or someone previously designated should make those changes and resubmit. If a paper is submitted before a lab member leaves but is then rejected, the person who rewrites the paper will become the first author (ideally this

is the original first author). If a paper is left unfinished when a lab member leaves, the person who writes the paper and submits it becomes the first author.

### 8.3. Correcting errors

Errors can be corrected relatively easily during the peer-review process. However, once this process finishes and the paper advances to production or is published, it is difficult to correct any errors. Thus, do your best to find and correct any errors before this. This is part of the reason we have the double check rule, discussed above. Nevertheless, mistakes will happen. If you discover something, let me know as soon as possible, and we will take appropriate action.

### 8.4. Use of AI

[APS](#), [NSF](#), and [NIH](#) all have guidelines about appropriate use of AI in writing papers. The primary concerns are the following.

- An AI cannot be held responsible for any errors. As such, it cannot be credited with authorship. This means that any errors introduced through the use of AI, such as plagiarism or incorrect calculations or citations, are the responsibility of the human authors.
- Any information you upload to an AI is effectively in the public domain. At a minimum, it means you cannot upload confidential documents like papers or proposals that you are reviewing, for example. However, it also means that the draft of the paper you just uploaded for editing is no longer confidential.

My current guidance is the following:

- Substantial parts of papers should not be uploaded to an AI before publication.
- If you use an AI for any part of the writing process, please let me know.
- Violations of these rules leading to unintentional errors or plagiarism will be treated as discussed in Section 5 above.

## 9. Presentations and conferences

### 9.1. Presentations

A vital component of science is the verbal presentation of your work in a talk, seminar, or conference. Just like writing a paper, giving a good talk is something that takes a lot of practice.

- The main purpose of a presentation is to teach the audience about a topic. The main point is not, for example, to show off. Even when you give a “job talk,” you should teach the audience something.
- A good talk is like a story. Good stories have a beginning, middle, and an end.
- All the excellent talks you have heard have at least one thing in common: you understood them. Conversely, many of the bad talks you have heard were probably difficult to follow.
- You should understand everything on your slides. If you duplicate a graph from a paper for example, you should understand everything about that figure.
- All plots should have axes labelled, and all quantities should have units, without exception.
- If you duplicate some content on your slides from somewhere else, like a paper, or the internet, cite it.

- Practice, practice, practice.

## 9.2. Conferences

If you have something to present at a conference, like a talk or poster, I will do my best to pay for your travel. Exceptions to this policy include program reviews, in which all students involved in the project are generally expected to attend. Conferences are a valuable opportunity to network, stay up to date, and present your work. As such, they are a key part of your professional development.

It costs about \$1,000-\$2,000 to send someone to a conference. All students and postdocs should share lodging with someone else. Possible exceptions to this rule can be made, but only if you consult with me first.

## 10. Lab space and equipment

The main research labs consist of Bausch and Lomb B15Y, B5, B4, B14b. B15Y contains the cryogenic measurements systems, B14b contains fabrication equipment, B4 contains soldering equipment and probe stations. Student offices are in Bausch and Lomb B3 and B9. My office is Bausch and Lomb 158. The URnano cleanroom is in Goergen Hall, and the electron beam lithography system is in Bausch and Lomb B10.

## 11. Joining the group

### 11.1. Administrative objectives

- Everyone
  - Join NG Box. Sign up for a Box account (if you don't have one, request one from Tanner Degeknkolb) and ask me to share our folder with you.
  - Join NG Slack. Ask me to add you to our channel.
  - Obtain a UR email address
  - Complete safety training
- For grad students and postdocs
  - Join NG OneNote. Ask me to share out notebooks with you.
  - Order supplies (fab tools, PC if one is not available, etc.) – orders go through PASFinance.
  - URnano training – contact URnano staff about obtaining clean room access and relevant trainings

### 11.2. URnano equipment

Equipment is roughly in order of priority. Trainings up to and including the Elionix should be completed ASAP so one can at least begin working in the CR in some capacity. To get started, fill out the "Access form for individual users," and send it to Greg Medejski or Sean O'Neil.

- General clean room access
- Photolithography and spinners/mask aligner
- Laser writer
- Wet bench
- SEM

- Elionix S50-Ex
- ALD
- RIE
- PVD (thermal and ebeam)
- Tube Furnace
- Filmetrics F40
- Profiler

### 11.3. Nichol Group equipment

- Harrick Plasma cleaner – any grad student or higher can train new users.
- Culver Evaporator (<https://www.youtube.com/watch?v=qblrhBSV26w>, <https://www.youtube.com/watch?v=LmA-z4e36Y4>, <https://www.youtube.com/watch?v=h4Xk4iVloAg>) – at time of writing, most group members can train new users.
- Rothberg Evaporator ([https://www.youtube.com/watch?v=blwF\\_epifM0](https://www.youtube.com/watch?v=blwF_epifM0)) – at time of writing, Yaad trains new users
- AJA UHV ebema evaporator—at time of writing Suraj trains new users.
- EBL using SEM (<https://www.youtube.com/watch?v=sOG8aYGe2FI&t=583s>) – at time of writing, there is no designated trainer. Most graduate students and up can likely train new users.

### 11.4. Fab equipment to obtain

Consider purchasing some of these personal fab tools. It's not a bad idea to take a look at what others have to get an idea of what new users need.

- Carbon fiber tweezers – Ted Pella (ESD Safe, Carbofib, Replaceable Tip Tweezers, Style 2A, rounded tip, 130mm long)
- Toolbox - McMaster
- Metal tweezers for peeling back off tape (2A) – McMaster
- Scissors for cutting tape - McMaster
- Glassware (3 100mL Nalgene beakers and about 2 40mL glass beakers)
- Scribe (Diamond tip) – Ted Pella
- Clean room notebook (we sometimes keep these on hand) – McMaster
- Double sided Kapton tape ¼" wide (we tend to keep this stocked also)
- Acid tweezers – McMaster

### 11.5. Other useful info

- Measurements are made using MATLAB + Special Measure. The Special measure wiki is pretty useful in getting started (<https://github.com/yacoby/lab/special-measure/wiki>).
- Help yourself to an espresso whenever you wish. Don't be shy.
- Good topics for background reading include
  - Quantum dots
  - Cryogenics

- Vacuum systems
- Microwave engineering
- Lockin amplifiers
- Thermal/electron beam evaporation
- Electron beam lithography

## 12. Leaving the group

- In general, please ask me for permission to share anything from our group that has not been published. This includes things that the group has produced, like fabrication recipes or tricks, special measure code, etc. This excludes things that only you have produced, like your private code folder, presentations, etc. (i.e., you can use or share these things as you see fit).
- If you are going to work at a company, I do not expect that you would make such a request. I would also be hesitant to grant such a request for students moving on to big companies.
- I will disable your software accounts (box, slack, OneNote, etc.) shortly after your last day.
- Please delete all nicholgroupur and urqdots chrome profiles on your personal computers, and do not log in to any of the shared google accounts after you leave.
- Make sure all lab notebooks (especially fab notebooks) and fab tools are in the lab before you leave.
- Turn in your keys to the keys drawer before you leave.
- If possible, please provide an email address that we can use to contact you in case questions arise.

## 13. Safety

There are some items in the lab that can be hazardous if not handled properly.

- Please consult all relevant safety data sheets (SDSs) before using any **chemicals** and wear appropriate personal protective equipment (PPE) when using them. Dispose of all chemicals properly. When in doubt, ask the lab safety officer (currently Johnson).
- Wear cryogenic gloves when handling **liquid nitrogen or helium**. A primary concern with liquid cryogenics is that a rapid warmup can create a large volume of gas in the room, displacing the oxygen. We have an oxygen sensor in B&L B15Y. Another concern with cryogenics is that water and air can freeze on contact with them. The resulting layer of ice can block the vent and lead to a dangerous buildup of pressure. Any cryogenic vessels should always be kept at a slight overpressure with respect to ambient conditions, and they should always exhausted through an overpressure valve. **Do not leave any cryogenic vessels open to air**. Finally, there must always be a relief valve for cryogenic gasses. If the gas that boils off has nowhere to go, it will build up a large pressure inside. If you encounter a cryogenic vessel that has an ice block, find a senior lab member or me immediately.
- Always transport **compressed gas cylinders** on an appropriate cart, and always ensure that they are strapped to a wall when not on a cart. Remove the regular and install the cover before moving it. A primary danger is that the cylinder can fall, which might release the valve. As the gas exits the cylinder, the cylinder will become a dangerous projectile.
- Use **ladders** only when properly set up on level ground. Maintain three limbs (i.e., two legs and an arm) on the ladder, and always climb facing the ladder.

- The thermal evaporators and electron-beam evaporator feature **high voltages and currents**. When working on these tools, ensure that all power is off, and cooling water is off, and connect the tools to ground.
- When using the **hoist and trolley** in the lab, use only straps and hardware that are rated for lifting. Inspect the hoist, and make sure that you do not exceed the weight limit.
- Occasionally, we **lift heavy things**, like vacuum pumps. Lift with your legs, not your back. If you need any help, do not hesitate to ask.
- Most of the dilution refrigerators have **superconducting magnets**. If you are running an experiment with a magnetic field, please make sure members of the lab are aware. When magnets are energized, the field outside the frame is usually small, but stay outside of the frame, and do not bring magnetic materials or credit cards inside the frame.

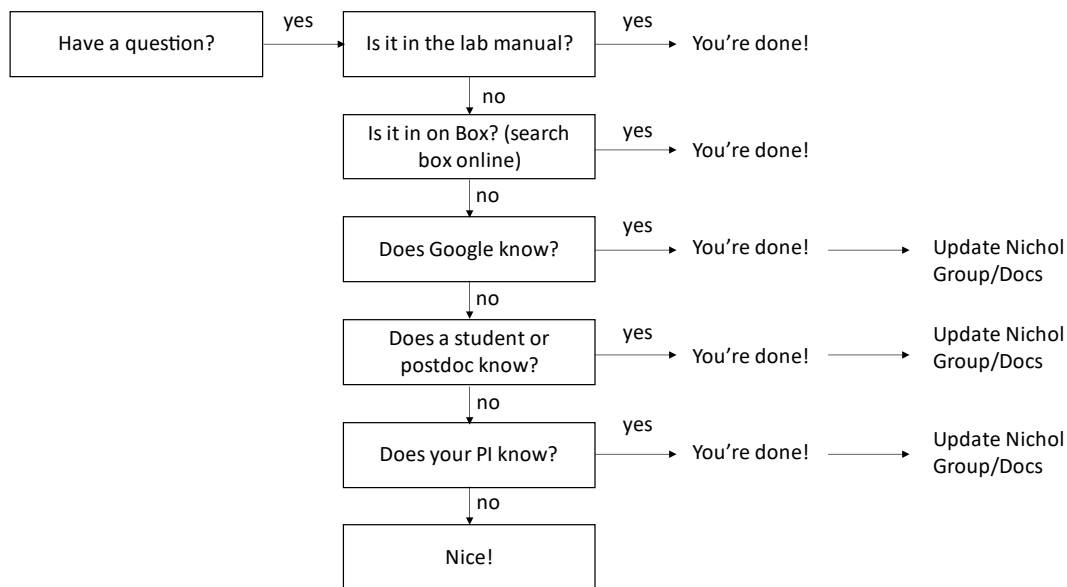
## 14. Letters of recommendation

At some point, you will likely ask me to write a letter of recommendation as you transition to your next position. I am happy to do this, because it is essential for your career development, and it is part of my job. Please follow the guidelines below. (If you do not, I will probably still write you a letter, but I will be grumpy about it, which is not something you want in your letter writer.)

- Required
  - Ask me for the letter at least one month before the due date.
  - Provide me with a list of places and deadlines in a document. A checklist is very helpful. The emails I receive from the schools you are applying to get lost instantly in my inbox.
  - If you want me to read some of your application material, please send me your material at least two weeks before the deadline.
- Optional, but helpful
  - Provide reminders 2 weeks, 1 week, and 1 day before the deadline.
  - If you feel industrious, you can provide me with a draft of the recommendation letter.

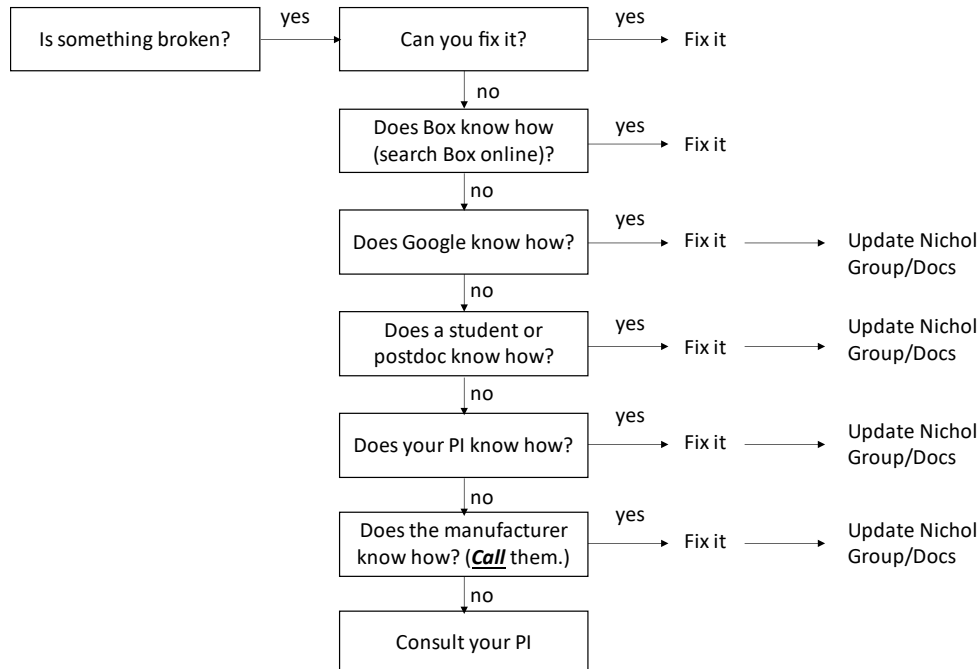
## 15. Appendix 1: What to do if you have a question

This following figure is adapted from (Peelle, 2020).



## 16. Appendix 2: What to do if something is broken

This following figure is adapted from (Peelle, 2020).



## 17. Appendix 3: Important directories in Nichol Group

- Nichol Group/Docs/ is our knowledge repository
- Nichol Group/matlab/Docs/index.html is an index of our matlab code.

- Nichol Group/Fab/Procedures/ contains information about fabrication recipes
- Nichol Group/Fab/SEM images/ contains our SEM images.
- Nichol Group/Fridge/ contains information and logs about operating the dilution refrigerators and cryostats
- Nichol Group/Data/ contains data folders for all major experiments
- Nichol Group/Matab/ contains all of our shared Matlab code.

## 18. Bibliography

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