NSERC POSTGRADUATE SCHOLARSHIPS – DOCTORAL PROGRAM (PGS-D)

TIPS AND TRICKS FOR WRITING A SUCCESSFUL APPLICATION

WATERLOO ENGINEERING, SEPTEMBER 2020

These notes offer tips on how draft an NSERC PGS-D application. The intended audience is someone new to writing competitive grant proposals, unsure of what style to adopt.

Proposal writing is often a difficult balancing act. Too technical, or not scientific enough? Too modest, or too boastful? Too ambitious, or not innovative enough?

We can't make it easy, but we can offer some general tips on the application drafting process, and some specific tips on proposal writing dos and don'ts.

We are also including some real examples from successful proposals. You can see – section by section – how some previous Engineering applicants have tackled these challenges, and get a sense for where the bar might be set.

Every applicant will have a different background, different research to propose, different strengths to highlight and different weaknesses to paper over, so not every tip will be relevant. Take what you can use, but if in doubt trust your own judgement.

These notes are not a step-by-step guide to drafting an NSERC PGS-D. It's important to follow the instructions closely, so you should be sure to consult the official guidelines:

> https://www.nserc-crsng.gc.ca/students-etudiants/pg-cs/bellandpostgrad-belletsuperieures_eng.asp
> https://www.nserc-crsng.gc.ca/OnlineServices-ServicesEnLigne/instructions/201/pgs-pdf_eng.asp

GSPA have also made a number of resources available, including template proposals.

PROCESS TIPS

- **Start working early**.

Ideally, you'd give yourself time to plan, write, breathe, reconsider, rewrite, consult, breathe twice and rewrite again. First drafts can always be substantially improved, but most of us need time to relax and take a step back from what we've written. The process can't be compressed into a day or two.

In the same vein, give your subconscious a chance to help you out – if you spend a few hours consciously working on what you're going to say, and how you're going to say it, your subconscious will keep working in the background while you move onto other things. A better framing for your proposal might occur to you while you're in the shower, or you might wake up one morning with a new idea.

- **Request referees early, and give them 'Cliff's Notes' on your strengths**

Most academics are overworked, especially around the start of the Fall term. Asking for reference letters early is not only polite – it's essential. Make it easy for your referees to write about you – give them bullet points on what you've done, and what your research ideas are. Give them the highlights of your CV. They'll appreciate the help, and you'll get a stronger, more personal reference letter because of it. (You shouldn't worry about seeming immodest, but if you do, just tell them that we told you to do it.)

- **Get feedback on what you write**

Once you have a draft, share it with others and ask for their honest opinion. In particular, ask for their first impressions. Your real reviewers won't have a lot of time to go over your proposal, so first impressions are vital.

Get feedback from people who work in your research area, but also from people who don't. The latter are probably closer to the mindset of the average reviewer – weigh their opinions accordingly. If someone seems to miss the point of what you've written, be aware that reviewers can miss the point too – could you have expressed yourself more clearly?

- **Offer to provide feedback on what others write**

Helping others is tremendously valuable for your own writing. You'll see how others approach the challenge of selling themselves. You'll get a sense of what works, and what doesn't. You'll see how high the bar can be set, and be encouraged to jump higher. Like nothing else, actually reading and critiquing others' proposals will put you in the mindset of a reviewer – which is exactly where you need to be to write a strong proposal.

If you want to start now, take a look at the sample applications at the end of this document. Review them critically. Which of the tips did they follow, and which did they ignore? What were the main selling points, and were they presented in a clear and compelling way? Was the writing interesting? Would you buy what they're selling?

- **Sex, gender and diversity considerations in research**

Please skim NSERC's guidelines on equity, diversity and inclusion. They won't all be relevant to you – you're not building a research team, or hiring your own students after all. But do decide whether sex, gender and diversity considerations are important to your research (page 5 onwards). If so, consider incorporating GBA+ principles, or something similar, into your proposal design.

- **Follow the instructions**

Last but not least, do follow the instructions closely! Assigning scores to proposals is an uncomfortably subjective process for reviewers. If they spot an objective reason to mark someone up or down, however trivial, it can tip the balance one way or another. Make sure all the trivial details – even font size and section titles – are pushing your score up.

WRITING TIPS

PREPARATION

- **Make a plan**

Take a little time to plan what you're going to write in each section. Know what your key selling points are – the few ideas that you want foremost in the reviewers' minds. Then plan how to express these ideas, paragraph by paragraph. Keep your paragraphs short and easy to read – give each paragraph a single clearly defined job.

- **But don't stick to your plan**

This said, accept that your plan will adapt and change as you write. Writing is a thought process. As you write you will change your mind about how best to communicate your ideas. That's fine. Start writing with a plan, and then write so that you can find a better plan.

- **Read something well written before you start typing**

We're conditioned to write in the style of what we read. If all we read is technical journals and tweets, that's how we'll write. Try to read some quality prose for a non-technical audience – be it top-notch science journalism, or even just a good novel – in the week before you start typing.

STYLE

- **Act natural**

The style you adopt is important. By ~~successfully pretending~~ showing that you're familiar with proposal writing, you will demonstrate your confidence as an academic. You'll look and sound like you belong in academia. That, more than anything else, is what your reviewers are looking for.

Fortunately, proposals are best written in a rather natural style – nothing too complicated or formulaic. The text should be easy to read. Try not to write like a journal article – write like a journalist instead.

- **Be concise**

Don't assume complex sentences will impress reviewers and make you seem more 'academic'. The opposite is true – it takes intelligence to communicate complex ideas in a simple way. Use fewer words to express your ideas, and avoid complex sentences with many subordinate clauses.

Be on the lookout for verbose prose acting as filler. Instead of saying "The intended purpose of the research outlined in this proposal is to…", say "This research will…".

If you use sentences that have a large number of subordinate clauses, with the clauses being dependent on one another, and if these clauses are joined by conjunctions, so that they all need to be remembered at once in order for the sentence's meaning to be fully understood, and particularly if the primary meaning of the sentence is postponed until the end rather than stated up front, then your readers will begin to suspect that you're wasting their time, and that they could have communicated the same ideas in a much quicker fashion, and they will get frustrated.

Concise sentences are punchier. They're more memorable and fun to read. Remember – your reviewers might be on their thirtieth proposal of the evening, and their second glass of wine.

- **Be confident**

This form of writing is all about selling yourself and your research plans. Don't be too modest. Don't use the passive voice to describe your own accomplishments.

Don't say "In paper one, it was discovered that soy beans cause rabies, which had previously not been reported in the literature."

Say “In paper one, my co-authors and I showed for the first time that soy beans cause rabies.”

Do use the first person – *I, we, my co-authors and I, my supervisor and I*…

Use the future tense to describe your successful future research. *I will…, we will uncover…, we will develop…, I will design…, our prototype will…, our model will provide the first explanation of…*

When discussing your accomplishments, be prepared to explain why something you’ve done is impressive. Reviewers from outside your field might not know that the Journal of Potato Research is the world’s leading academic vegetable periodical. You have to tell them – back it up with an impact factor if you can. If you’ve spoken at a highly selective conference, tell them that it’s prestigious. And so on.

PITCH

- **Keep it straightforward**

Don’t overuse jargon, or get bogged down in technicalities. Your reviewers will not be specialists in your research field. If your best ideas are encrypted in language they don’t understand, it’ll do you no good.

This is a balancing act, of course. You do need to show reviewers that you have a working professional knowledge of your field, and have interesting and valuable insight to contribute. You need to confidently cite the relevant literature, and outline a plan in sufficient detail that it seems feasible and impressive... to a non-specialist. But try to do so with a light touch. Don’t devote paragraph after paragraph of text to dense technical explanations.

Where the ideas and the research description must get a little technical, it’s often a good idea to begin with a sentence of clear, non-technical motivation, explaining what’s going on (or why) for a lay audience. The trick is to make sure the first sentence of each paragraph clearly communicates what the point of the paragraph is. That way reviewers can follow your reasoning paragraph-by-paragraph, even if they skim the jargon.

- **Make sure your key selling points are prominent**

Don’t hide your best material in the middle of a long, dense paragraph, or at the end of a section. Put it up front – at the start of a paragraph, at the start of a section. Will you be the first person in the world to study the link between soy beans and rabies, and is that your best selling point? Say so right up front (and God help you).

Imagine you’re a corporate lawyer, trying to hide the key point in the small print in the middle of a document. Do the opposite of that!

- **Make the reviewer care about your research**

Research proposals are competitive. Most of us would love every proposal to get funded, but NSERC has a limited budget. When so many people are being told “no”, why should your proposal be different?

This is about more than the technical merits. How will you make a real difference? Are you going to make the world a better place? Improve human health? Build a better mousetrap? Are you going to discover new truths about our universe?

You don’t need to cure cancer to get a scholarship. Any contribution can be important – a marginal improvement in an important process, or an opportunity to evaluate a new clinical tool, or an attempt to develop a new model for a poorly understood phenomenon… But you should make sure the reviewers see that you’re passionate about your research, and why the rest of us should be passionate about it too – whether it’s for the sake of science, for Canada, for humanity, for the planet, or for the design of new milk carton.

TRICKS

- **Include a very clear 'hypothesis statement' or goal in your research proposal**

When outlining your research proposal, include a clear 'hypothesis statement' or goal – a one sentence soundbite that captures what your PhD is trying to design, build, prove, show or demonstrate. Some reviewers think of research in rather formulaic terms, and can be obsessive about wanting to see a clear "hypothesis statement"

- **Acknowledge your collaborators**

Research is usually a team sport. Don't be shy about your own role, but don't be afraid to acknowledge others too. It will show you know how research works, demonstrate generosity of spirit, and radiate confidence about your own contributions. Say "my co-authors and I were able to prove that…" or "With my supervisor, I showed that…"

Where relevant – and if there's space – you can provide some detail about the nature of your contributions. Were you in charge of gathering the data? Did you run the simulation, or build the model? Did you write a section or all of the paper yourself? You can say so.

- **Format your text attractively**

Appearances matter. Space out your paragraphs. Use clear, bold section and subsection titles. Use shorter paragraphs. In moderation, use bullet points, lists, or figures to communicate key ideas. Avoid presenting reviewers with a dense 'wall of text'.

You have limited space, but less is more – quality over quantity. Squeezing in two additional sentences isn't going to matter. Having a visually neat and attractive proposal might make all the difference.

- **Don't worry too much about your first language**

For all this talk of the importance of writing style, you may be thinking that first-language English speakers have a big advantage. In fairness, they do have a small advantage on average. But the reassuring truth is many of them are lousy, lazy writers with terrible grammar and no sense of style (yes first-language English speakers, I'm talking about us – I've read a lot of our grants!). And of course, many people without English as a first language are excellent communicators. Ideas, confidence, communication skills, empathy with the reader – these are the things that really count. That said…

- **Get someone to proofread your prose**

Regardless of your language skills or lack thereof, get your text proofread by someone whose writing you admire. No-one can proofread their own writing – your brain will deceive you and see only what you meant to say, not the unfortunate sequence of characters that you actually typed. Microsoft Word is not a substitute for a human. Typos and ungrammatical sentences will distract from your message, and make you seem less smart and more careless than you would like.

ABOVE ALL - PUT YOURSELF IN THE MINDSET OF THE REVIEWER

Write as though you're reading your own material for the first time. Empathise with the reviewer – someone smart who has spent their life in academia, but who perhaps doesn't know your subject area very well. Someone who is diligently trying to review a pile of 50 proposals over one weekend, while their spouse tries their best to distract the kids.

Make their job as easy as you can – keep it simple, clear and concise. Follow the instructions, and put your key messages front and centre. Make them care about the research you want to do. Make them confident that you're the one to do it.

SAMPLE APPLICATIONS, SECTION BY SECTION

Many, many thanks to the students who granted us permission to share these sections from their successful PGS-D proposals!

We're providing a few quick comments on what they've written – favourable, and not so favourable. First impressions only, but first impressions count.

If you want to practise reviewing proposals – and there's no better way to get better at writing them – you can start here.

SUMMARY OF THESIS MOST RECENTLY COMPLETED OR IN PROGRESS (1)

My research for my MASc. degree was focused on blast head injury caused by proximity to explosive events. Specifically, I was interested in modelling the response of the human head and brain to incident primary blast pressure waves. The goal of this research was to investigate injury mechanisms relevant to mild Traumatic Brain Injury (mTBI), which is an important clinical outcome.

I developed finite element models of the human head, that could be embedded in an air mesh, and subjected to pressure shock loading. I built upon existing work that was done previously in our research group, that had looked predominantly at blast loading to the lungs and thorax, and extended those techniques to the head and brain. The finite element models were of sufficient mesh density to achieve convergence, and accurately capture the complex wave reflections that occur in the tissues during blast loading. This is a critical aspect of finite element modelling that was missing in the literature. The models were planar, in that they modelled the sagittal and transverse planes of the head separately. This was necessary because the mesh density required (~1mm characteristic element size) made 3D models infeasible. Relevant material properties and constitutive models were chosen for each of the tissues of head, the primary ones being skin, muscle, skull, brain, and cerebro-spinal fluid. A considerable amount of effort was undertaken to justify and validate the constitutive equations and boundary conditions of the models. I verified the planar modelling assumption by comparing my model response with a simplified 3D ellipsoid model of the head. I validated the head accelerations and intracranial pressures predicted by my models, by comparing to published experimental data on both cadavers and surrogate headforms.

I used these head models to investigate various helmet geometries and materials, using a parametric study that compared predicted head accelerations, intracranial pressures, and intracranial deformations. This work provided additional information about wave reflection phenomena that occur around the head during a blast wave impact, and quantified the effects of some phenomena that had been identified previously in the literature, but not yet sufficiently characterised. Additionally, my work provided some conclusions about what type of helmet configurations and materials are more effective in mitigating blast loads. For example, the models predicted that a strap system to hold the helmet onto the head, rather than a foam lining, was more effective in mitigating the transmission of stresses to the brain during blast. This information can be used to design more effective protective equipment. The models were provided to our sponsors at the end of the project, so that they could be used during their design process.

Commented [R1]: Good - always good to start with a bang!

Importantly, this paragraph sets the stage nicely for a non-specialist audience. It's short – just three sentences. It *sounds* knowledgeable – mTBI, primary blast pressure waves, important clinical outcomes. But the core message is very easy to understand, and the potential importance of the research is clear.

The first paragraph is always the most important.

(To nit-pick, the first nine words are a little slow. "My MASc research modelled blast head injury…" would get us to the action quicker.)

Commented [R2]: Good - confident use of the first person, clearly focusing on their own contributions, but acknowledging the contributions of others

Commented [R3]: Good - take time to explain the significance of your results.

Commented [R4]: This paragraph is getting rather long – a break might have been preferable.

Commented [R5]: Good to explain the scientific importance of the work.

Commented [R6]: This is very important information – explaining to the reviewer why the research is important, beyond the science.

However, this should have been placed at the front of it's own paragraph – it would have been a strong conclusion – better helmets, injuries prevented, live saved... Instead, it's been hidden in the middle of the last paragraph, and loses its impact somewhat.

SUMMARY OF THESIS MOST RECENTLY COMPLETED OR IN PROGRESS (2)

The goal of this thesis was to develop a deeper understanding of the interactions between the various coupled processes occurring in enhanced geothermal well installations and their effects on well performance. Geothermal energy is a renewable resource accessed by harvesting the heat within the Earth's crust. In an enhanced geothermal well, hydraulic fracturing is used to enhance the conductivity of a hot rock mass with low natural permeability. The fractures create a network through which cool fluid is allowed to flow, extracting heat from the surrounding reservoir. New technologies have increased viability of deep geothermal wells, which are capable of extracting enough heat that they can be used to generate power.

As heat is extracted from the reservoir, the cooling causes the rock mass to contract. This contraction increases the fracture aperture, creating a path of low resistance that redirects flow towards the cooled area. As more fluid is channeled into the cooled fractures, the amount of heat extracted from the reservoir decreases. This phenomena, called flow channeling, decreases the temperature at the production well over time and reduces the well's ability to generate power. It is a complex phenomena that only emerges when considering the coupled thermo-hydro-mechanical processes occurring within the well.

The work done to date on this thesis has included a comprehensive review of existing enhanced geothermal system literature, and the development of a fully-coupled thermo-hydro-mechanical numerical model. This model has been implemented and verified as a two-dimensional reservoir with a one-dimensional planar crack, and also as a three-dimensional reservoir with a two-dimensional crack plane.

Other work during the first year of this thesis has included a presentation at the VI International Conference on Computational Modeling of Fracture and Failure of Materials and Structures, and the submission of two papers to peer-reviewed journals. The topic of the conference presentation was a validation of the eXtended Finite Element Method (XFEM) with experimental mixed mode fracture propagation in PMMA. Following the conference, I first-authored an expanded version of the validation based on comments and critiques. The expanded validation, entitled "Validation of XFEM for Mixed Mode Fracture", has been submitted to the ISI journal Engineering Fracture Mechanics. This validation lead to the discovery of an error in the code for the paper "Dynamic Hydraulic Stimulation and Fracturing of a Wellbore Using Pressure Pulsing" and lead to corrections in the paper which earned me the status of second author. This second paper has been submitted to the Journal of Applied Mechanics, which is also an ISI journal. These works helped to establish the foundational knowledge required to develop and build the enhanced geothermal well model.

Commented [R7]: Somehow, this opening paragraph doesn't say a single thing about what the applicant actually did. The applicant is not mentioned at all, in fact. No research results are mentioned. Not recommended – lead with your strong points!

That said, it does some other things right. It uses simple, natural language to explain to a non-specialist reviewer what's going on. The sentences are short and easy to read. And it hints, from the start, at the importance of the research.

Commented [R8]: Always get someone to proofread your text.

Commented [R9]: It took us three paragraphs to get to the actual research. And then we choose to lead with… a literature review? The model we developed is secondary?

Commented [R10]: This is good – publishing and presenting are, of course, the bread and butter of academia. You're trying to persuade your reviewer that you'll fit right in with their colleagues. If your thesis has led to publications and conference presentations, you might as well say so.

Remember – the reviewer is working fast. They're not going to cross reference with your CV, or look you up on Google Scholar. Include everything you want them to know in the text they're reading.

Commented [R11]: Good.

Commented [R12]: Proofread!

Commented [R13]: Seriously. Proofread! There's no wiggly red line, but that doesn't mean you're safe.

Commented [R14]: Good to explain the scientific importance of the work.

PROPOSAL (1)

Autonomous vehicle technology has evolved from simple driver assistance, such as lane keeping and cruise control, to what is fast approaching full autonomy – vehicles capable of navigating our complex environment with no human assistance. The promise of improved safety, better use of personal time, and more efficient use of limited road resources is on the horizon [1]. But even with all the advancements, many challenges remain. One important challenge is autonomous navigation in real-world occluded environments.

Real world intersections and roadways are messy things. Stationary objects such as parked cars and dustbins can block the sensors of an autonomous car and prevent it from perceiving other vehicles and pedestrians on the road. A human driver would recognize the dangers represented by these obstacles and adjust the car's path to gain a better vantage point and enable a safer maneuver. They would then creep forward and and attempt to peek, seeking more information before taking an action. I plan to study the effectiveness of implementing this behaviour in autonomous vehicles, both geometrically and through the application of Deep Reinforcement Learning.

Related Material: Machine learning has driven much of the development of autonomous vehicles, from vision systems for steering [2, 3] to full end-to-end decision making using deep convolutional neural networks [4]. Deep Reinforcement Learning (DRL), famously used by DeepMind to develop an agent capable of playing Go at a super-human level [5], has only started to find application in autonomous vehicles [6, 7]. Variations of DRL have been applied to autonomous vehicles [8, 9, 10], but these applications have focused primarily on end-to-end operation of the vehicle instead of on maximizing the car's view.

Existing heuristic methods for navigating intersections such as Time-To-Collision (TTC) [11] have proven unable to cope with occlusions if a creep mechanism is not available [12]. After the addition of a creep mechanism, Time-To-Collision is still unable to cope with more complicated scenarios, frequently choosing to remain stationary instead. An agent trained with Deep Reinforcement Learning [12] showed a definite overall improvement in the success rate when navigating intersections, but that success came at the cost of increased collisions.

Other researchers have approached the problem of occlusions by analysing the risks they may contain and modifying the behaviour of the autonomous vehicle, implementing a form of passive safety [13], i.e., if the autonomous vehicle is in a collision, that vehicle will be at rest. If the current path of the autonomous vehicle passes through the reachable spaces of a possible hidden agent, then the path is either adjusted [14] proactively, or the car is slowed and possibly brought to a full stop [15]. Probabilistic methods [16, 17] have been used to predict the risks related to occluded areas and enlarge the available safe space [18, 19, 20], as an alternative to avoiding all of the possible collision areas. While effective, these approaches can result in unnecessary delays and may even cause the car to be stuck because here is no free space available.

Research Objectives: In the Related Material above, the possibility of modifying the vehicle path to minimize future occlusions is rarely mentioned. This is the basic premise I intend to explore: is there an opportunity to improve both the performance and the safety of an autonomous vehicle by optimizing its path such that the maximum amount of information about the environment is collected?

The key questions that I will answer in the course of my PhD research are:

- Is there a geometric method that can be applied to analyse potential paths in real-time?

Commented [R15]: A good, fast-paced introduction. Short, clear sentences. An ambitious vision of the future. Clear real world relevance for the research. And a clear statement of the problem to be studied.

Commented [R16]: Proofread!

Commented [R17]: Good statement of intent. Nice namecheck of a buzzword-compliant technique (deep learning, reinforcement learning).

It could be phrased a little more boldly, though. What about "I will rigorously evaluate…" in place of "I plan to study…"?

Commented [R18]: Use bold text to break up the proposal into clear sections, and provide some structure. A title line for each section might be better, but perhaps space was tight.

Commented [R19]: This is very well written for a lay audience. The citations lend it authority, but the text itself is very easy to follow.

Commented [R20]: Very good – a clear "hypothesis statement".

Some reviewers are borderline obsessive about wanting to see a clear "hypothesis statement" for a research project.

Commented [R21]: Nice use of bullet points to make the key ideas stand out on the page.

- Can I improve upon the geometric method's performance by training a Deep Reinforcement Learning (DRL) agent, while maintaining or improving occupant safety?

Plan of Approach: I will implement the geometric method by applying some of the same computational geometry techniques that I used in the course of my MASc research. By extending a series of rays from the estimated vehicle position, a representation of the view can be constructed, in either two or three dimensions. The final estimate of the view, and thus the total information gained for a given path, is the union of each of the estimated views. I expect that the geometric method, with the necessity of calculating all of the free space for each motion primitive, will be computationally expensive both in time and processor cycles/power. In order to control for this cost, the vehicle's possible paths will be limited to a set of motion primitives (using lattice based planning [21]). Motion primitives are a set of defined curves that, when followed by the autonomous vehicle, allow for complete coverage (to a required resolution) of the available space while maintaining a computationally tractable solution. Motion primitives also ensure that the planner takes passenger comfort into account since the only maneuvers allowed are those that respect the necessary limits on acceleration and the rate of change of acceleration. Further, it is possible to increase or decrease the computational complexity of the problem by altering the density of the lattice and view sampling rate. Finding an appropriate trade-off between the processing cycles required and the accuracy of the constructed view is an important component of the geometric solution.

The DRL agent will also make use of the motion primitives in training and evaluation, in order to maintain a basis for comparison. The input to the DRL agent is expected to be the autonomous vehicle's view and the vehicle parameters, with appropriate pre-processing as required to reduce the dimensionality of the problem. The neural network will be extensively trained on simulation data taken from industry standard simulators, first using a 2D simulator such as SUMO [22] to prove the concept. The DRL agent will then be adapted to use the CARLA [23] simulator, which is based on the Unreal Engine for increased realism. There is also the possibility of testing and validating against real world data provided by industry Partners.

I am initially planning to evaluate the geometric and DRL methods against two common traffic scenarios: making a right or left turn in an intersection, and passing a truck on a two lane highway. In the first scenario, the vehicle must contend with potential obstacles/obstructions on the corners which may interrupt the view of traffic coming from the right or the left. In the second, the truck is essentially a static object relative to the autonomous vehicle. The goal is to find a path that allows the autonomous vehicle to safely collect enough information about oncoming traffic to plan and execute a passing maneuver. I will also evaluate the ability of the DRL network to generalize to new scenarios. The ability to transfer functionality/knowledge to new scenarios is an important quality of any solution.

Conclusion: During my twenty plus year career in the software industry, I thrived on tackling challenging problems. My passion for discovering solutions is what led me back to graduate school two years ago. I will continue my research at the University of Waterloo, supervised by Dr. XXX, holder of a Research Chair in XXX. The University of Waterloo and its state of the art robotics facility, the RoboHub, provides the perfect mix of expertise and resources required to undertake this research. By developing a method to evaluate viewpoints from multiple paths and positions, I hope to enable a more human-like approach for autonomous vehicles operating in real-world occluded environments— a meaningful contribution to the development of safer, friendlier and more efficient autonomous vehicles.

Commented [R22]: It's fine to use one or two acronyms. Make sure you define them on first use. But you don't need to define them twice.

Commented [R23]: Connecting your proposal to your previous experience is a good way to give reviewers confidence that you know what you're doing.

Commented [R24]: Partners (industry, public sector, non profit) are good to mention, even if only in passing – it hints that there are people out in the 'real world' who consider your research important.

(Also, proofread?)

Commented [R25]: Again, could be a bit bolder. "I will begin by…"?

Commented [R26]: This is good – you want the proposal to radiate enthusiasm for the research.

Commented [R27]: This is also good – feel free to boast about the facilities and equipment available at Waterloo that will make your project feasible and successful. (Though perhaps they could also have mentioned WatCAR, the Moose, AVRIL, etc… ☺.)

Commented [R28]: And this is a nice note on which to finish – a valuable counterpoint to a proposal focused on technology, autonomy and deep learning.

Get humans back into the frame – and reassure the reviewer that it's all about ~~Skynet~~ making the world a better place for people.

PROPOSAL (2)

Human body modelling is rapidly becoming an integral part of the design process in applications where impact related injuries are common, such as sports and automotive safety. As one of the three critical organs for sustaining life, accompanying the brain and heart, the lungs present a high priority injury/fatality risk. Lung injuries such as pulmonary contusion, laceration, edema, and collapse have been identified as critical metrics in lung models in automotive crash[1,2], blunt impacts[3], behind armour blunt trauma[4], and blast exposures[5,6]. My research is a multi-scale modelling effort, using finite element (FE) methods and analysis of the lungs at the micro- and macro- scales, to improve the state of lung injury prediction, and ultimately to provide engineers with a better tool to prevent or mitigate human lung injury.

Background: In recent years, FE human body modelling has made considerable progress, enabled in part by improved computational resources. In fact, governmental agencies in automotive safety regulation are adopting certification standards that use human FE models in conjunction with physical crash tests[7-9], because FE models can be used to easily assess a wide range of crash configurations which is not feasible in physical testing. So, there is a strong and sustained interest in industry for good quality models that are biofidelic and can predict injury outcomes. In addition to impact-related applications, FE models are also used to investigate stress and strain mechanics in tissues subjected to mechanical loads independent of external impacts, such as in physiological respiration[10-15]. The objectives of these investigations is often to inform biomechanical understanding, surgical techniques, or prosthesis/implant design.

The lungs are a complex and heterogeneous tissue, comprised of a network of about 500 million alveoli (~200 µm diameter), somewhat analogous to an open-celled foam[16]. The mechanical response of lung tissue is primarily governed by a combination of tissue elasticity and surface tension forces[17]. However, current FE models of lung tissue are often oversimplified (with simple elastic or hyperelastic models), or use non-representative material properties[18-20]. The most widely used constitutive model for lung tissue that incorporates tissue and surface tension forces is known as the Vawter lung model[21]. This model was developed in the late 1970s, to predict stresses in the lungs over the physiological range of motion through respiration, with the tissue data and physiological understanding available at that time. At present, this constitutive model is widely used in impact simulations where the tissue deformations are well beyond its range of validity. Furthermore, there have since been many significant new developments in lung tissue imaging and published material properties. Among these are: the non-linearity of the bulk modulus of lungs[22], the interdependence of tissue and surface tension forces[23,24], experimental techniques to more accurately measure the nature and effects of the lung surface film[25,26], the presence of interalveolar pores[27], and the importance of boundary conditions particularly between the lungs and the chest wall[28]. Each of these presents both a need and opportunity to enhance constitutive models for lung tissue and improve injury prediction, which my research will address.

Approach: The primary methodological approach for this research is finite element analysis, and continuum mechanics. I have over 8 years of experience using LS-DYNA, which is the predominant finite element analysis program for human body modelling. My research group is one of the leading centres of human body modelling in the world, with experts in constitutive modelling, crashworthiness, soft tissue characterization, and FE methods. My supervisor, Prof. XXX, is an internationally recognized leader in impact biomechanics, and my previous experience as a MASc candidate and researcher in this field, makes me well suited to be successful in this research. My main approach is to use multi-scale FE modelling, which models the same tissue separately at different length scales. This is well suited to lung tissue because of the microscopic nature of lung alveoli, which cannot feasibly be modelled discretely

Commented [R29]: This is a strong start – it's immediately clear to the reviewer that this research is going to be important – a matter of life and death.

Commented [R30]: Good – a clear, early statement of the research goal, right in the first paragraph, and confidently in the first person. "*My* research *is*…"

Commented [R31]: This section title needs to be clearer. Bold text, underline, its own line… somehow it needs to stand out.

Commented [R32]: Proofread?

Commented [R33]: Good – clear indication of end-users of the research.

Commented [R34]: This reads well, but it's taking up a lot of valuable space – is it really helping to persuade the reviewer? Was anyone convinced that the applicant knew their stuff by the eighth sentence, who wasn't already convinced by the sixth? Could a shorter background review do the same job, leaving more room for other things (or for better formatting)?

Commented [R35]: Good – show your relevant experience.

Commented [R36]: OK… this might be a step too far. Be bold, be confident, yes… but maybe don't take ownership of your supervisor's research group.

The rest of this sentence is great, though. Flaunt it if you've got it.

Commented [R37]: A bit repetitive – haven't you already said this above, in a more convincing way?

Commented [R38]: Again – you said this bit already. The content is excellent, but the structure could use a little editing, which a proofread might catch.

Also, we need a paragraph break here. There's a clear change of topic – from "My research group rocks and I have all the experience" to "FE modelling and the microscopic nature of lung tissue"

Shorter paragraphs are much more fun for reviewers to read.

within a full organ model. My approach is to model a cluster of alveoli at the microscopic scale (alveolar model), to capture the geometric detail and connectivity of individual alveoli. In parallel, I will model lung tissue at the organ scale, using elements sized to correspond to alveolar clusters. This method provides a link between the two length scales, with the entire alveolar model being representative of a single element within the organ scale model. The organ-scale lung model will be used as a test bed for developing an improved strain energy function (constitutive model) for lung tissue. I have access through my research group to several human body models that incorporate the lung at the organ scale, including a unique blast lung injury model[29], a detailed thorax model[30], and a state-of-the-art full human body model[31,32], which allows me to exercise the organ-scale lung model across a range of loadings.

The multi-scale modelling approach offers two main benefits. Firstly, it allows for boundary conditions to be related between the alveolar and organ scale models. For example, an impact event can be simulated at the organ scale, which generates deformations in the elements. These deformations can then be applied to the alveolar model to investigate stress and strain behaviour in the alveoli. This relation between organ level impacts and alveolar stresses/strains, enables the second benefit, the investigation of injury mechanisms. Specifically, it allows me to use alveolar mechanics to inform about potential for injury in organ-level impacts. The prediction of injury outcomes is a primary goal of most human body models, so this is a critical benefit. The alveolar cluster model requires modeling the alveolar wall tissue and surface film discretely. Although the data on material properties at this scale is scarce, there are relevant studies that inform on suitable properties[33-36]. The main limitation of this data, and in fact most data on lung tissue, is the disconnect between excised tissue sample response, and the response of the lungs in vivo. Unique to my research, I have identified in vivo pressure-volume response of lungs, which is measured extensively in respiratory physiology[37-39], as a good supplementary data set to compare excised tissue sample data to. My approach is to combine these two data sets (excised tissue sample properties and in vivo pressure-volume response) to inform material properties for my models[40].

Objectives: The primary objectives of my research are (1) to develop an alveolar scale model of lung tissue to investigate alveolar stresses/deformations, (2) to develop an improved continuum level constitutive model for lung tissue relevant to impacts, and (3) to determine an improved lung injury criterion or set of criteria for FE models to more effectively prevent and mitigate injury.

Significance: The primary significance of my research is in the field of engineering impact biomechanics. An improved lung tissue constitutive model and injury criteria, which my research will achieve, directly correspond to improved modelling utility and injury outcomes across a broad range of industries. This research also has potential significance to the medical fields of respiratory physiology and pulmonary mechanics. The alveolar scale modelling efforts proposed in my research will provide new insights into stresses and deformations of alveoli during physiological and external loads, and can potentially be useful in lung tissue epidemiology.

Regarding considerations of sex/gender, the consensus among human body modellers is that there is no demonstrable difference in the tissue stress-strain properties between the sexes, and that differences in gross responses are due to geometry or stature[41]. Uniquely, I have access to state-of-the-art full human body models of a 50% percentile male[31] and a 5% percentile female[32], allowing me to assess effects of both sex and stature for lung tissue response at the organ level.

Commented [R39]: This is the third time you've 'approached' in this paragraph alone. Try not to be overly repetitive in your choice of phrasing.

(I'm looking warily ahead, at the word 'model'.)

Commented [R40]: This is good – the whole proposal is written in this simple, confident and straightforward first-person style.

Commented [R41]: Very nice – make sure you claim originality and novelty when you can.

Commented [R42]: We're coming towards the end of the proposal. Usually, the objectives would come towards the beginning. I would move this section in front of the approach/methodology.

Commented [R43]: These objectives would stand out more clearly if they were formatted into a list.

Commented [R44]: This is important – when your research topic could potentially impact different genders (or other groups) differently, you need to demonstrate that you are aware of these potential complications and are taking them into account. Don't let unconscious biases seep into your research and limit its relevance (e.g., by studying human gait, but only using male subjects), unless you have a very clear justification.
Look up GBA+ for more information if you think this might be relevant to you.

MOST SIGNIFICANT CONTRIBUTIONS TO RESEARCH AND DEVELOPMENT

1. Journal article: "Multi-scale modeling of head kinematics and brain tissue response to blast exposure" in Annals of Biomedical Engineering 2019.

This article is an extension of work that I did during my MASc on blast head modelling, where I used my detailed head models in conjunction with a full body kinematics model, to link local and global aspects of blast loads and injury. I contributed the majority of the modelling efforts, analysis, and writing, with guidance from my supervisor XXX. This article is published in a special issue of the Annals of Biomedical Engineering, which is one of the highest impact journals in biomechanics. Importantly, this work demonstrates the utility of multi-scale modelling, which is a critical aspect of my current research.

2. Conference paper/presentation: "Micro-model to evaluate alveolar wall mechanical properties from pressure-volume response" in IRCOBI 2017.

This peer-reviewed conference publication and presentation, to which I contributed all of the writing and modelling efforts, is on preliminary work on my alveolar scale lung model. IRCOBI is currently the largest annual biomechanics conference in the world, and this contribution is important to demonstrate a proof-of-concept of micro scale lung tissue modelling, and how it can be used to inform material properties of the tissue.

3. Journal article: "Head and brain response to blast using sagittal and transverse finite element models" in Int J Numer Meth Biomed Engng 2014.

This article is my first published work, on the blast head models that I developed during my MASc. It was submitted to the International Journal for Numerical Methods in Biomedical Engineering, which is specifically suited to the subject matter. I contributed all of the modelling efforts and analysis, and most of the writing, with guidance from my supervisor.

Additional considerations:

Has your work been cited yet? If so, by whom, to do what? This might help you show the impact of your work.

Outside academia, what's the importance of your work? Any one contribution is going to be a tiny piece of a big puzzle, but why should someone outside your field be glad you did this work? What good things might it lead to?

Commented [R45]: Good – clearly outline your contributions, but also show generosity towards the contributions of others (especially your reviewers' peers).

Commented [R46]: Very good – your reviewer won't know this unless you tell them.

Commented [R47]: Good – outline your contributions.

Commented [R48]: Very good – your reviewer won't know this unless you tell them.

APPLICANT'S STATEMENT

Research experience

My research experience has provided me with the ability to work through adversity, communicate and analyze findings, search and synthesize ideas from the literature, and seek collaborations where my knowledge/skills are deficient. In addition, I have gained most of the technical skills (e.g., device fabrication, ceramic and organometallic synthesis approaches, conducting electrochemical and physical characterization, and using data analysis software) required for the proposed field of study.

Relevant activities

As of December 2018, I serve as XX in the Waterloo XXX Engineering Graduate Student Association. In this role, I help coordinate social and academic events, one of which we are planning involves an inaugural institutional research conference, which aims to provide students with an opportunity to present their work (poster or oral) and encourage collaboration among peers. Since January 2018, I have volunteered for the Let's Talk Science outreach program, which has improved my ability to communicate scientific concepts at various age groups (Kindergarten to University students) in different platforms (school visits, workshops, and fairs). In current and past research involvement, I have trained new students in fundamental lab protocols and safety. I also help maintain safety by conducting weekly inspections of the lab spaces. During my undergraduate studies, I was the Communications Chair on a student-run conference (iSci Synthesis Symposium), where I promoted the event by creating videos, posters, and social media posts. In addition, I organized a workshop aimed to introduce undergraduate students to fundamental skills in Epidemiology and Biostatistics research (search strategies, critical appraisals, and statistical inference). My contributions involved inviting professors and graduate students as guest lecturers, writing the grant application to fund the event, coordinating catering, and hosting the sessions.

Commented [R49]: Good – evidence of leadership.

Commented [R50]: Proofread!

Commented [R51]: Excellent – evidence of leadership, initiative, and communication skills.

Commented [R52]: This is a very strong leadership section. Few of us are able to reel off accomplishments like this. But make sure you use all the ammunition you have. With so many strong research proposals to choose between, 'leadership' can be a key differentiator.

Succeeding in a PhD isn't all about being smart, or racking up impressive volunteer positions – it's also about endurance, resilience, perseverance and overcoming adversity. If you can speak to experiences that demonstrate these qualities, reviewers will place more trust in your ability to stay the course and thrive.

For example: did you work to pay your own way through school, in part or in full? Maybe you can tell reviewers what it taught you that you can bring to your PhD.