

NSF CAREER Proposal Writing Tips

Edited by

ZJ Pei

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Contributors

Daniel Attinger, Columbia University, 2005 CAREER awardee

Jian Cao, Northwestern University, former NSF program director, 1997 CAREER awardee

Shaochen Chen, University of Texas at Austin, 2001 CAREER awardee

Gary J. Cheng, University of Houston, 2006 CAREER awardee

Mario Richard Eden, Auburn University, 2006 CAREER awardee

George A. Hazelrigg, program director, National Science Foundation

Wei Li, University of Washington, 2004 CAREER Awardee

Ana Muriel, University of Massachusetts Amherst, 2002 CAREER awardee

Gracious Ngaile, North Carolina State University, 2005 CAREER Awardee

O. Burak Ozdoganlar, Carnegie Mellon University, 2006 CAREER awardee

Tony L. Schmitz, University of Florida, 2003 CAREER awardee

Timothy W. Simpson, Pennsylvania State University, 2002 CAREER awardee

James E. Smay, Oklahoma State University, 2005 CAREER Awardee

Jan Twomey, Wichita State University, former NSF program director, 1997 CAREER awardee

Henry J. White, Stony Brook University, 2003 CAREER awardee

Maria C. Yang, University of Southern California, 2006 CAREER awardee

Preface

The main purpose of this book is to provide some tips to the assistant professors who plan to write their NSF CAREER proposals.

The idea of editing this book originated during a conversation with Dr. George Hazelrigg (program director at National Science Foundation) when I visited him late November 2006. He encouraged me to proceed. His support is greatly appreciated.

During the first week of December 2006, I sent out invitations to the potential contributors, requesting them to send me their contributions by the end of the month. They responded with enthusiasm. I would like to thank all the contributors for their dedicated work in writing these articles with such a short notice.

I have read all the articles in this book and learned a lot. I wish that I could have had a book like this when I prepared my CAREER proposals several years ago. I am confident that the readers will find the articles in this book beneficial.

Please note that any opinions and recommendations in this book are those of the individual contributors. They do not necessarily reflect the views of the National Science Foundation.

ZJ Pei
Kansas State University

January 17, 2007

Honing Your Proposal Writing Skills

George A. Hazelrigg
National Science Foundation

To young faculty starting their academic careers, that first big grant is very important. To the more senior faculty, that next big grant may be the lifeblood of some graduate students. And a key source of these grants are federal funding agencies such as the National Science Foundation. NSF specializes in the funding of fundamental research and education. So it's a good place to go for support for research that can lead to masters and PhD theses. But NSF is highly competitive, and winning an NSF award can be quite challenging.

On the one hand, there are many courses and references available to help faculty learn how to write a good proposal. And surely they have good tips. But, on the other hand, few get to the core of the problem: why do so many proposals, centered around basically good ideas, get such poor ratings? Having been involved in the review of several thousand proposals, I have some observations to report. Typical problems with proposals include:

1. Failure to follow submission guidelines—NSF, for example, will return without review proposals that do not follow guidelines published in their Grant Proposal Guide. If you're going to take a month or two of your life to write a proposal, I strongly advise that you take an hour to read the GPG. If you are submitting to another agency, read their proposal guidelines carefully.
2. Use of small fonts and illegible materials—It makes no sense whatever to submit a proposal in a format that cannot be read. Yet people do it. As many as half the proposals received at NSF include totally illegible materials, particularly figures and tables, where fonts have been compressed to micron sized grey blobs. I strongly recommend 12-point Times Roman fonts and nothing smaller, including tables and figures. Smaller is not readable, and it only aggravates the reviewers. Use smaller fonts only if you want a lower rating.
3. Misspellings and poor grammar are commonplace—I find that about one in thirty proposals (give or take) has a misspelling in the title. This is a degree of sloppiness that does not impress reviewers. Bad grammar simply makes the proposal difficult to read. NSF does not use grammar as a review criteria, but I'm here to tell you that it counts. It really doesn't matter how good your idea is if the reviewers can't understand it.

These things are so obvious that you may be wondering why I bother to note them. Well, I note them because upwards of two-thirds of the proposals I see have substantial problems in at least one of these three areas. But these aren't the worst thing people do to hurt their chances. The biggest problem I am seeing is that fewer than one in ten investigators frames their research in a way that is to their advantage.

It should be totally obvious that the most important thing a reviewer wants to know when he or she picks up a proposal is what it's about. Ergo, for NSF, the first sentence of paragraph one, page one should begin, "The research objective of this proposal is..." In my experience, any other sentence used to start the proposal results in a lower rating. Every inch from the top of the first

page that I have to go down in the proposal to find this sentence, in my experience, lowers the rating by about one percentage point. At nine inches of text per page, the chance of an award goes to zero if this statement doesn't appear before page 12, or if it doesn't appear at all (and that's not all that infrequent).

The second thing that should be obvious is, given that NSF funds fundamental research, the research objective of the proposed project should be research. There are many words that, to reviewers, mean "not research." These include "develop," "design," "optimize," "control," "manage," and so on. If your statement of your research objective includes one of these words, for example, "The research objective of this proposal is to develop....," you have just told the reviewers that your objective is not research, and your rating will be lower. Count on it. This is how your peers think. Indeed, it is exactly how you will react when you review your colleagues proposals.

So, what is the right way to frame an engineering research proposal objective? First, you have to understand what is research. I define research as the process of finding out something that we (society) don't already know (this excludes library research). Note that research is a process, and it is exactly this process that your proposal is about. The objective of your proposal is precisely what you intend to find out that we don't already know.

Of course NSF doesn't fund all kinds of research, it funds scientific research. Scientific research has three properties that may distinguish it from other forms of research. First, it is methodical. That is, in advance of doing the project, you can lay out a methodology by which you will conduct your research, and that methodology leads knowledgeable reviewers to be able to assess the likelihood of success at achieving your stated objective. Second, it is repeatable. That is to say that, if reasonably competent persons repeat your methodology reasonably well in disparate locations at different times, they will get essentially the same results. Third, it is verifiable. You can show that the results you have obtained are the results you claim.

To illustrate this last point, consider my project to be proving the existence of ghosts. My methodology is to take my camera with me into the elevator late at night. I push the basement button. When the door opens, I see the ghost, and take its picture with my camera. When the ghost's image does not appear in the picture, I have proven that it was a ghost. Well, sorry to tell you, I have seen proposals that read pretty much like this.

Some scientists are taught how to frame research projects. Few engineers are, even PhD engineers. So let's first try to understand the difference between science research and engineering research. To me, the difference is quite clear. The scientist seeks to understand nature at its core, to get to the fundamental essence. To do this, the scientist typically strips away extraneous effects and dives deeply into a very narrow element of nature. And from this look comes what we refer to as the laws of nature: energy and mass are the same thing, for every action there is an equal and opposite reaction, and so on. There are lots of laws of nature, and they apply everywhere all the time.

Engineers live with the laws of nature. They have no choice. Their goal is to design things that work within what nature allows. To do this, they have to be able to predict the behavior of

systems. So a big question for engineers is, how do we understand and predict the behavior of systems in which all the laws of nature apply everywhere all the time. This is an issue of integration, and it is every bit as difficult as finding the laws in the first place. To account for all the laws of nature everywhere all the time is an impossible task. So the engineer must find ways of determining which laws are important and which can be neglected, and how to approximate those laws that are important over space and time.

Engineers do more than merely predict the future. They make decisions based in part on their predictions in the knowledge that their predictions cannot be both precise and certain. Understanding and applying the mathematics of this is also important. This includes the application of probability theory, decision theory, game theory, optimization, control theory, and other such mathematics in the engineering decision making context. This also is a legitimate area of research for engineering.

Understanding what comprises engineering research, you can begin to formulate your research project. I know of only four ways to state a research objective. If you can think of another, please let me know. The four I know are these:

1. “The research objective of this proposal is to test the hypothesis H.”
2. “The research objective of this proposal is to measure parameter P with accuracy A.”
3. “The research objective of this proposal is to prove the conjecture C.”
4. “The research objective of this proposal is to apply method M from disciplinary area D to solve problem P in disciplinary area E.” This research integrates knowledge from one disciplinary area into another. To do this often involves the resolution of inconsistencies across the disciplines.

The very statement of your research objective should lead you directly to your methodology. If it does not, you don't have a clear statement of research objective. I frequently hear statements that are essentially, “The research objective of my proposal is to learn how to make anti-gravity boots.” The problem with this statement is that it leaves one clueless as to what direction the research might take. It provides no insight whatever regarding the methodology.

Not only will a clear, crisp statement of your research objective help you write a better research approach section in your proposal, it will, by itself, raise your rating. Put your research objective right up top in your proposal, and remember the three tips I started with, and you are a long way toward writing a better proposal that will review well.

In the end, you have to remember, you are writing a proposal. A proposal is not a technical paper, in which you take the first three pages for background and credits to those who have come before you. Nor is it a murder mystery, where you find out what it's about on page 15 (that's all NSF allows). No, it's a proposal, where it pays to say what it's about right up top, and to say it in a way that is consistent with the goals of the agency from which you are seeking funding.

CAREER Proposal: Listen to George!

Jian Cao
Department of Mechanical Engineering
Northwestern University
jcao@northwestern.edu

I am not kidding, listen to George! Who's George? George is Dr. George Hazelrigg, who has probably served the most number of years in proposal evaluation at NSF. If you have attended our CAREER Proposal Writing Workshops or DMI Proposal Preparation Sessions at the DMI grantee conference, you have done yourself a good service. Your time was well spent. If you haven't had a chance to listen to George Hazelrigg's talk on how to prepare a proposal, you should at least get a set of his slides, find out where he is going to talk next and attend that meeting.

I am speaking of this recommendation from my own experience as someone who has been on both sides of CAREER, an awardee and a program director who recommended CAREER proposals, including one PECASE winner. I attended George's proposal preparation session at the DMI grantee conference in my last year of graduate study. This certainly helped me in preparing my first, and my only, CAREER proposal. Even though I have done this proposal writing workshop with George at least 3 times since, I still feel refreshed each time listening to his remarks.

With the above message out, in the rest of this article, I am assuming that you have already had access to George's presentation slides and have studied those slides carefully. Let me gather my thoughts and try not to repeat what has already been presented there. If I do repeat, it is because the point is really worthwhile for a second mention.

1. Find a mentor outside of your department or your school

How many times did you tell your secrets to your best friends, but not to your parents when you were young? Same situation here. You definitely need a mentor in your own department who can present your case well for your tenure and promotion. In addition, having a pair of fresh eyes and a clear mind from outside is also extremely valuable. A mentor is someone who is experienced; and someone who you can trust such that you won't be afraid of sharing your worries or failure or ideas with that person.

2. Communicate with your program director (if you choose to do so, then do it BEFORE your submission)

I have seen many times that a well-prepared proposal was being passed among various programs and nobody claimed a total ownership of that proposal. Why? Because it doesn't fit in 'my' program. Really? Yes or no. Each research program has its specific goals, and each program director has his/her view about how the program should be run and what research ideas are worth pursuing. Therefore, if your research proposal turns out to be the one which

could fit with many programs, it could also mean that it doesn't belong to any specific one and could become an orphan. In such a case, talking to program directors before your submission is critical. Don't try to force a program director to accept your definition about his/her program. An effective way is to show the connection and the differences between your proposal and previously funded ones. In the case, particularly in a panel review case, it will also be helpful to suggest who is doing similar work or who has knowledge in reviewing this kind of proposal. If you do suggest names, consider a spread between well established ones and those who are still in the rising curve since established ones may not be able to make the panel.

3. State clearly what is unique about you and your plan

Why NSF should fund you but not the others? What are the unique contributions that you can make with this award? It is probably not that difficult to address this uniqueness in the research part of the proposal, however, it is pretty challenge for the education part. Find where your heart is and what you really care is the first step. Then explore your surroundings, schools, communities or your past connections. I believe that you can find this uniqueness in all situations. Try different combinations or analogues, like we do in a typical brainstorming process.

4. Balance

Balance between excitements and fundamentals, balance between breadths and depth, balance between research and education, balance between ambitions and realistic endeavors, balance since this is a CAREER proposal. In very rare cases, a proposal heavily focused on one aspect gets funded, in which case that particular aspect has to be extraordinary strong.

5. Show evidence

Don't assume that reviewers will read every word in your proposal. Reveal your best parts in the text as well as in your 2-page cv. This applies to both research and educational parts of the proposal. In my own case, I proposed a new metal forming process in the CAREER proposal. Since I was fresh out of a Ph.D., to back up the feasibility of this concept, I had letters of support from industry to show that I did understand industrial problems and had the right connection to carry out the work.

In summary, each proposal is unique. One poorly written proposal has zero probability of success. Believe in yourself, have a good idea, then articulate it. Wish you the best!

There's No Formula, but Read This Anyway

Jan Twomey
CAREER Award 1998
Former NSF Program Officer

Associate Professor
Industrial and Manufacturing Engineering Department
Wichita State University

This is difficult to admit, but there is one aspect about my self that is so much like my mother; that is- giving unsolicited advice on any topic, whether I know something about it or not. In this case you can feel confident that I do know something about the topic. My advice for faculty intending to submit CAREER proposals comes from two perspectives; one having written a successful proposal in 1998, and two – from having been an NSF Program Officer in the Engineering Directorate for three years. I have been a part of a number of CAREER proposal writing workshops as Program Officer and former Program Officer. The advice I offer and the advice given though out this book are recommendations and suggestions. There are no silver bullets, or guarantees that if you follow each and every point given here that your proposal will result in an award. Remember that there is a finite source of funding and therefore not all good proposals will get funded. With that said, here are a few general and some very specific suggestions for preparing a better proposal. I start with the assumption that you have read the CAREER proposal guidelines and that you know NSF's criteria for proposal review - *intellectual merit and broader impacts*.

Have a good understanding of what the CAREER Award is all about. The Award funds your career as an academic – research, and education. It is intended as a springboard, not an end in itself. Therefore before you begin writing you ought to think about who you want to be as an academic over the next 10 years. What contributions will you make as a researcher and an educator? As an academic they are hard to separate. Your contributions should be those you have a passion for and that passion and energy should be conveyed in your writing. Because the CAREER Award is all about your career as an academic and because you have a limited number of opportunities to submit a proposal, it is my opinion that faculty should not submit in their first year of their academic appointments.

The idea must be worthy of research. Therefore it must be important and it must be original (*intellectual merit*). NSF does NOT support development. The idea is the crux of the proposal, all else flows from there including education and outreach activities. Present your research objectives and contributions for the CAREER Award (5 years) in the context of what you want to achieve over the next 10 years. Proposals will not be funded if they are lacking in intellectual merit, no mater how significant the broader impacts. In my experience the majority of CAREER proposals fail because the contribution to the field is incremental. Other reasons include a scope of work that is either too broadly or too narrowly defined and unawareness of seminal work in the area (key literature is missing).

Develop your of educational goals related to your 10 year vision and broader impacts statement that is believable. Educational goals that typically do not review well are those which all tenure track faculty have responsibility for; e.g. working with graduate students, including research results in course material. A broader impacts statement that repeats NSF's list of possible topics is not believable. It shows no real insight and very often will also get low reviews. My recommendation is again to start with who you see yourself as an academic in the next 10 years. This will set your vision for education. You will not accomplish this vision in 5 years. You simply want to make progress in attaining it. My advice has always been to simplify your educational goals by tying them at least in part to your research objectives and if possible to some already established related activities. I recall a PI whose research was in operations research. Her goal was to increase the number of Hispanics in science and engineering. One of her activities was to work with a summer program already established on campus for minorities. The activity called for her graduate students to design short modules to demonstrate how operations research was used to solve real world problems. Her activity exposed minority students to operations research and it gave her graduate students practice in explaining complicated material in a simple fashion.

I will end my suggestions for writing a better CAREER proposal with some specific points.

1. Find a home (NSF Program) for your proposal before you begin writing.
2. The Summary page is the most important page. Typically NSF determines which panel will review your proposal based upon the summary.
3. Be sure that the proposal reads clearly (clearly stated objectives, logical progression of ideas) without grammatical or spelling errors. Think about what its like to read your students papers that are not well written.
4. Don't give NSF a reason not to review your proposal. Adhere to NSF's Grant Proposal Guidelines for proposal preparation. NSF gets a lot of proposals and will return a proposal with out review if you don't adhere to things like page limits.
5. Submit your proposal early. I know you're thinking something like "with my schedule, no chance". So remember this story. As a program officer I worked with a faculty member 2 months before the deadline on making sure he had the right materials together and the right program to submit his proposal to. As many of you will, he put numerous hours into his proposal and submitted it on the deadline. Days later when the proposal was processed it was found to be missing key information. The proposal was returned without review. In the rush to submit it not all information was included. If it were submitted earlier, NSF could have notified the faculty member and had him resubmit with all of the information.
6. Volunteer to be a reviewer. It's the best way to get to know the review process.

Good luck. --Jan

An Open Letter to New Faculty: Writing Your CAREER Proposal

Tony L. Schmitz
Machine Tool Research Center
University of Florida
Gainesville, FL

1. Welcome

Congratulations on your selection of an academic career! Faculty positions offer tremendous opportunities to perform high quality, relevant research, train students, and effect undergraduate and graduate education in a positive way. In fact, your near term plan for how to accomplish these lofty goals is exactly the information you'll want to include in your National Science Foundation CAREER proposal.

In the following sections, I'll first highlight some of the key ingredients that, in my opinion, are necessary for a successful CAREER proposal. Then, I'll describe some of my own experiences in preparing this proposal.

2. Key ingredients

Naturally, you'll want to begin by reviewing the CAREER submission requirements and the Grant Proposal Guide. Aside from this basic information, however, you have full creative license to 'tell your story'. In my view, this is exactly the way to approach your proposal: your job is to tell a compelling story to the reviewers. In order to tell a strong story, it is important to identify your vision. Your vision should answer the following questions:

- a. Why am I going to carry out this research?
- b. How will my research results be applied?
- c. What makes my research objectives unique?

In the end, you want to remember that this is not a research proposal only; it is a career jump-start. The National Science Foundation is investing in your future.

As a reviewer, it soon becomes apparent if the author does not have a clear vision. In the simplest terms, this typically means that reading the proposal does not generate much excitement. It is your job to convince the reviewers that if you complete your work the world will be a better place! To tell an exciting story you'll need to do more than just 'report the facts'. You need to provide compelling justification for why your selected research area is important (e.g., can you provide a sound economic justification for your plans?). To justify your research, you must do your homework. This includes evaluating alternatives to your approach and understanding prior related efforts. You should also talk to people in the industry (more on collaborators later).

Another important task is ensuring that those not familiar with your research area can follow your story. Don't immediately launch into 'tech-speak' and equations. If the reviewers don't know why you are proposing this work, they probably won't spend much time trying to trudge through your equations.

In the final analysis, your goal should be a proposal that prompts the reviewers to say "Gee, I wish I thought of that!" Here are some strategies to help get this response. First, be brave. Even though it can be difficult to describe research that you're not exactly sure how to complete, you must avoid being incremental. Rather, you should propose significant jumps in the state-of-the-art. Clearly, it is possible to propose anything. However, don't attempt to trick the reviewers. To demonstrate to reviewers that you are capable of completing your research, you can use the following strategies:

- a. Establish a logical, chronological plan of activities that will lead you to your research objectives. You might separate your proposed research into stages that correspond to particular years of the five year plan.
- b. Identify clear success metrics. Let the reviewers know how you will decide if your research is on the right track, if you are successful.
- c. Identify major questions that must be answered. Don't be afraid to say "What if x happens?" However, make sure to provide a plan of action if x does occur.
- d. Lend credibility to your proposal by identifying appropriate collaborators.

Finding collaborators is not an easy task. This requires more than just getting warm and fuzzy letters from friends in industry. To find substantive collaborators, identify relevant organizations, get the right person on the phone (or find the person at a conference, etc.), and make your pitch. If you can't convince him/her that they should get on board your research train, then you might want to rethink your story. You probably won't convince reviewers either.

Perhaps the most challenging aspect of wooing collaborators is getting them to invest financially in your research. However, this speaks volumes to reviewers. It is clear that a meaningful collaboration has been established when the collaborating organization is willing to supply equipment, materials and supplies, and/or engineering time to further your research agenda.

Finally, do not leave your education plan as an afterthought. If you do, you will not get funded. It is not sufficient to offer a new graduate course, teach undergraduate courses x , y , and z , and/or participate in undergraduate engineering societies. These are too easy and obvious. You must make your education plan part of your vision. To make sure you have a seamless research/education plan, you should answer the questions: What interests me? What are my talents? How can I apply them to innovative education?

3. My experience

My proposal adventure started prior to arriving at the University of Florida. At the time, I was a mechanical engineer at the National Institute of Standards and Technology (NIST), Gaithersburg, MD. My first step was to start a 'journal' where I collected thoughts about what I wanted to say in my proposal. I recorded every idea, good and bad, and started trying to weave

them together into a cohesive story. Next, I contacted a friend in academia who had previously won a CAREER award to learn about his approach. My next task was to begin contacting potential collaborators. Once I felt that I had enough ammunition, I started drafting my project description. I spent many long evenings and late nights on that first draft.

Once I completed ‘version 1’, I asked a NIST colleague to read the proposal and provide feedback. His frank response was “There is nothing exciting in your education plan. You will not get funded.” Naturally, this critique was not fun to hear, but it did get me to think critically about how to better integrate my research and education plans. I asked myself the question “What do I like?” My answers were: football and engineering (pretty much in that order!). This led to the *Pigskin Professor* video concept¹. My objective was to present engineering concepts in the language of football. I wanted to use the same forum Dr. Tim Gay at the University of Nebraska-Lincoln had used for a similar series: the football stadium Jumbotron. My next task was to convince the assistant athletic director at the University of Florida who was in charge of the Jumbotron content during home football games that this was a good idea. Luckily, he agreed (eventually).

The same NIST colleague also suggested that I serve on a review panel. He even contacted a program manager to help arrange it. The timing of the next unsolicited panel review worked in my favor and I was able to review proposals within the month. This was an invaluable experience. I got to see how the panels were operated. I also saw, firsthand, what made certain proposals stand out.

After these experiences, I sent ‘version 2’ to future colleagues at the University of Florida and professors at other universities to get their impressions. I didn’t follow every suggestion, but I did find out that as more people commented on my proposal, I learned more about what worked and what did not. Finally, I was ready for submission and the rest is history.

4. Parting thoughts

Remember that reviewers must evaluate your proposal based on two main criteria: intellectual merit and broader impacts. You must decide what these criteria mean. In addition, there are particular questions the CAREER reviewer is instructed to ask. For example, reviewers are requested to:

evaluate the scientific quality and importance of the proposed research and education activities, the objectives and significance of these activities, and the capability of the applicant to make an integrative contribution in both education and research.

Don’t make the reviewers search for answers to these questions. Tell them specifically why you meet (and exceed) these criteria in your proposal.

My final two suggestions are to: 1) Proofread! Eliminate grammatical, style, and formatting errors. Use a professional editor to identify these errors; your small investment could yield big dividends. 2) Include relevant, quality graphics. Use these figures to support your story.

¹ The videos are available for viewing at <http://highspeedmachining.mae.ufl.edu>.

In summary, your job is to sell the reviewers on you as a whole package. This includes your research plan, education plan, and prior experience/future potential. They are trying to predict your chances for future success and your ability to make an impact in your field. Give them the ammunition they need to support your proposal. Good luck!

Making Your CAREER Competitive: Tips for Rebounding When Your CAREER is Rejected

Timothy W. Simpson
Professor of Mechanical and Industrial Engineering and Engineering Design
The Pennsylvania State University, University Park PA 16802 USA
Email: tw8@psu.edu; Phone/fax: (814) 863-7136/4745

1. Dealing with Rejection

As an academic, there is perhaps nothing worse than having your CAREER rejected. I am referring to your NSF CAREER proposal, of course, and you cannot overlook the irony that your detailed research and teaching plans for the next five years did not merit enough consideration for funding. I am not sure what the success rate of first-time CAREER Proposals is, but it is not very high based on conversations that I have had with others. The worst case was a colleague of mine who received four Excellent ratings and one Very Good rating on his first submission, yet he did not get funding. Luckily he kept at it and was successful on his third try.

NSF CAREER Awards are one of the few single PI awards that NSF still funds, making them all the more prestigious and all the more competitive. In Engineering Design, only 1 in about 20 proposals – a hit rate of 5% or less mind you – was being funded during my three attempts, and while that has since increased to 2-3 funded each year, the success rate still hovers around 10%, with some programs being as high as 15-20% in a good funding year. Consequently, I urge you to approach the development of your CAREER proposal as a multi-year process where you will probably face rejection once, most likely twice, but hopefully not three times.

To help you make the most of this difficult, yet ultimately rewarding, experience, I highlight some of the subtle, and not so subtle, tips that I have learned and garnered from colleagues over the years in the next section. I then share my own experiences with preparing a winning CAREER Proposal in Section 3, and in Section 4, I offer some parting advice in hopes of making your NSF CAREER Proposal worthy of “Primary Consideration” for funding.

2. Tips and Suggestions

The following tips and suggestions for preparing a competitive CAREER Proposal assume that you (a) have a novel idea that is unique and/or innovative and sets your work apart from others, (b) know how to formulate research questions and objectives, and (c) are familiar with NSF’s Grant Proposal Guidelines and the process of submitting proposals on Fastlane. If not, then you should start reading and talking to colleagues to understand how to do all this. I also assume that you know to which NSF Program you are submitting your proposal. If not, then you need to either get on the phone to start talking to Program Directors or make a trip to NSF to meet them face-to-face. An even better option is to attend a NSF Grantees Conference, if the Division and/or Program you are targeting has one – this is a great opportunity to not only meet multiple Program Directors at once but also learn about the types of research that each Program is funding. It is also a great way to meet colleagues in your field and learn about their work, which can help you verify that your novel idea is as unique or innovative as you think it is.

One-Page Project Summary:

- As with any proposal to NSF, the one-page Project Summary is extremely critical: it sets the stage for the proposal and is what most everyone will read. Only the reviewers assigned to your proposal will review the proposal in depth and discuss it during the CAREER Review Panel. If other panelists want to follow along, they will most likely only read the one-page Summary and flip through the proposal to look at figures and tables, if that.
- Make sure that the research and educational objectives that you have proposed are repeated word for word in the Project Summary. Rewording them even slightly to avoid repetition can cause unnecessary confusion amongst the reviewers. The same goes for your research questions, hypotheses, tasks, etc. that may be stated more than once in the proposal. Do not treat the Project Summary like an abstract that needs new wording.
- Finally, make sure that you clearly address the Intellectual Merit and the Broader Impacts of the work you have proposed in the Project Summary. You should also address your “integrative contributions in education and research”, which is specific to CAREER Awards.

Research & Educational Plans in the Project Description:

- You need to strike a good balance between your research objectives and your educational objectives (about 2/3 and 1/3 of the length of the proposal, respectively), and make sure that one or more aspects of the educational plan integrates research, and vice versa. Spending too much time on the research and not enough time on the educational plan undermines the “integrative” nature of CAREER Proposals.
- Your research plan should be ambitious yet believable. Many new faculty try to propose too much, thinking the more, the better, but this is rarely the case. Reviewers frown upon research plans that can not be reasonably accomplished within the given time frame.
- Along these same lines, make sure that you include a realistic timeline for your research (and educational) tasks, and clearly indicate which students are going to work on which aspects of the project. This helps demonstrate that you have reasonable expectations when it comes to managing the workload and effort that you are proposing.
- Your educational initiatives need to be more than just developing a new graduate course or creating some learning “modules”. This has become an expectation these days, and now you have to go out of your way to be really unique. For instance, a colleague of mine found himself in a position to help develop several episodes of a new engineering-focused educational program on his local public broadcasting station, which he parlayed into the educational portion of his CAREER proposal. Of course, not everyone is going to be able to create television specials based on their research, but if you have a unique opportunity on which to capitalize, then this is a great place to do it.
- Pilot studies and preliminary results for your proposed research and your educational initiatives can significantly strengthen your proposal, but you need time to plan them. This is another area that makes latter proposal submissions stronger as you have more time to demonstrate and “think through” your ideas before proposing what you will do for your CAREER Award. Such results can also be used to convince the reviewers that the scope of the work is realistic.
- Finally, make sure that you “close the loop” on both your research and educational plans, and by this I mean: testing, validation, and assessment. How do you know that the research results or the proposed methods are going to be as good as you say they are? Reviewers are going to want to know how you will test this. This is perhaps most important for your

educational initiatives: how will you assess the effectiveness and test the pedagogical impact of what you are proposing to do? This is where classroom assessment becomes important, and partnering with a local assessment expert, a college-wide learning center, or a colleague from your university's education department, can lend credence to what you propose to do.

Other Sections of Importance:

- In the Intellectual Merit section, make sure to address contributions to your field, your discipline, and any related disciplines. Tying your proposed research to large-scale initiatives or Grand Challenges can be very convincing. Reports published by the National Academies are often a good place to start looking for these (National Academies Press now offers free PDFs of many of their reports online at: <<http://www.nap.edu/>>).
- In terms of Broader Impacts, you do not have to promise to do everything (e.g., K-12, outreach, REUs, RETs, technology transfer, work with under-represented groups, etc.). I strongly suggest that you focus on two or three things and do them well. Proposing to do it all is overly ambitious and therefore unmanageable: strive for depth, not breadth here.
- Be sure to include a section that addresses your long-term career goals (e.g., 5 and 10 years from now, what do you plan to be doing?). This is perhaps most effectively displayed in a table showing how the research *and educational* initiatives outlined in your proposal will provide the foundation for a long and productive career.

	Short-term (5 year) Career Goals	Long-term (10 year) Career Goals
Research	<ul style="list-style-type: none"> • These should be very close to, if not the same as, those outlined in your CAREER Proposal • Emphasize the deliverables that will result at the end of this five years 	<ul style="list-style-type: none"> • Give 2-4 bullets that convince the reviewers that you have thought about how your CAREER proposal supports your long-term research objectives
Education	<ul style="list-style-type: none"> • These should be very close to, if not the same as, those outlined in your CAREER Proposal • Emphasize teaching contributions that will result from this in five years 	<ul style="list-style-type: none"> • Give 2-4 bullets that convince the reviewers that you have thought about how your CAREER proposal supports your long-term educational objectives and teaching goals

- Finally, if you have other NSF funding, make sure to mention it in the section, “Results from Previous NSF Support”, as well as list it on your Current & Pending Support Form, which includes your CAREER Proposal as “Pending”. This section can help explain how any ongoing NSF funding you have will complement the work proposed for your CAREER Award. A CAREER Award is intended to serve as a foundation for your career in academia; so, any ongoing projects should support – in theory – what you are proposing for your CAREER Award. Moreover, if the title of your ongoing NSF grant and your CAREER Proposal are similar and you do not mention the ongoing grant, then reviewers are going to question this, asking why you are trying to get funding for the same project twice. This will not bode well for your CAREER Proposal.

Supplemental Documents:

- It is very helpful to get letters of support from industry even if they cannot offer direct support (i.e., money). In-kind support, equipment donations, and support of class projects all indicate collaboration, and industry collaboration is good for two things: (1) verification and validation with “real world” case studies, and (2) technology transfer, which expands the

Broader Impacts of your work. Getting strong letter of support does not happen over night, and this is another place where you need to think of building a multi-year relationship.

- Do not forget to include a letter from your Department Head, making sure that it adheres to the specifications for the current year's CAREER Proposals as they tend to change from year to year. If your Department Head is busy, as most are, then you may want to give him/her talking points to help with the letter or even offer to draft text for the letter yourself, provided the specifications allow more than just the statement, "I have read this proposal and support the candidate's work", from your Department Head.

Some Other Obvious – Yet Often Overlooked – Suggestions:

- Provided there is enough time, have others proofread your proposal. Winning CAREER Proposals tend to be very "polished", i.e., they have very few editorial mistakes. This includes checking all of the text in your figures and tables as well as section headings.
- Depending on the level of expertise of the proofreader (e.g., a colleague in your field), you may want to ask for comments on the content as well: is it understandable? are objectives and tasks clearly stated? does it seem like too much work (or not enough)? does it integrate your research and teaching plans? etc.
- If your proposal is rejected and you plan to resubmit it, make sure to carefully read the feedback provided by the reviewers and the Review Panel. Even though the people on the Review Panel will be different next year, many of the suggestions and comments will still be applicable; so, make sure to take them into account when revising your proposal. The last thing you want to do is ignore someone's comment only to have him/her review your proposal again next year and raise the same criticisms during the Panel.
- Make sure that the Project Summary is one page and that the Project Description is 15 pages (or less) as you do not want to exceed the page limits. I know someone who did, and while his proposal was being considered for funding, someone pointed out that his proposal was 16 pages long, not 15, which disqualified him. It was an honest mistake on his part, and unfortunately also his third, and final, attempt.
- I would strongly encourage you to stick with 12 pt font and 1" margins. If you cannot say things effectively within 15 pages within these constraints, then you are trying to say too much; the same goes for your one-page Summary. Do not give in to the easy solution of reducing the font size – using 10 pt font may negatively bias your reviewers, which will not help your proposal no matter how much you cram into it. Use this opportunity to learn how to write succinctly and avoid repetition, two things that will improve your writing.
- Finally, it also goes without saying that you should read copies of winning proposals: CAREER Awards as well as regular NSF Grants. Funded NSF proposals are "public domain", and copies can be requested from NSF. It usually takes awhile to acquire them from NSF; therefore, do not be afraid to contact previous CAREER Awardees and Grantees yourself: they are usually happy to share their winning proposals with you.

While most of these tips and suggestions are specific to CAREER Proposals, many of them apply equally well to regular NSF Proposals. With time and practice, most of these suggestions become ingrained in your writing, allowing you to focus on the most important aspect of the proposal, namely, the content itself.

3. My Personal Experience

As they say, “The third time is a charm”. As with most other CAREER Awardees that I know, it took me three tries before receiving my CAREER Award. Here is how it happened.

Despite setting aside nearly a month in the summer to work on my first proposal, I finished it with about one hour to spare before the deadline, which allowed little time for proofreading and getting feedback from others. Needless to say, it did not fair well. My second proposal also took about a month to prepare, but was so drastically different from my first – I was amazed at how much my thinking about my research had changed in just a year – that I did not have a complete first draft ready until one day before it was due. I had a colleague read it that night while I continued to revise it, but I did not allow any time to accommodate any substantive feedback. This proposal faired much better, but it too was not funded. After reading the Panel’s comments, I decided to meet with my cognizant Program Director at NSF, Dr. George Hazelrigg. We met for almost three hours where he walked me through several aspects of my proposal as he recalled the Panel’s concerns and criticisms. This was extremely valuable, and I hope that other Program Directors are as helpful and giving of their time. I also had two colleagues and three previous Awardees review my second proposal. Combined, they offered me enough suggestions to fill perhaps 30 pages, which made revisions all the more difficult: I did not want to remove material that reviewed well, yet I had to address everyone’s concerns and “fill the holes” in the proposal. I also refused to reduce the font size as I had heard that this ensured overly critical reviews. In the end, it still took me about a month to make it all fit within the 15-page limit. At this point, I was somewhat relieved because win or lose, I would at least not spend an entire month the next summer working on my CAREER Proposal.

When I first started this process, I read four winning CAREER Proposal: two funded by the program to which I was applying, which gave insight into the sorts of ideas that were being funded, and two funded by other programs, which allowed me to identify trends in winning proposal. I also read several funded regular NSF grants to get ideas for presenting my ideas and organizing my proposal effectively. Finally, I also sought out mentors, senior colleagues, and previous CAREER Awardees who were willing to review and provide feedback on my proposal, but I was not able to use them effectively until I was preparing the third version of my proposal. Having now been through the process and having served as a reviewer on several Panels, including a CAREER Panel, I now try and play this role for my junior colleagues.

To strengthen my proposal, I included letters of support from industry, adding one new company each year so that by my third submission, I had three solid letters. I built these collaborations through projects in my graduate course, which generated new research ideas while also providing opportunities for new educational initiatives that I proposed as part of my CAREER Proposal. This strategy worked well for me, as it enabled me to offer to have a group of 4-5 students work on a project as part of my graduate course for a new industry collaborator free of charge (except for any material costs). If they liked the output, then we would continue working together and strengthen our relationship. If not, then at least the students were exposed to “real world” problems as part of their course project. I have also used course projects to “kick start” research projects, which have turned into graduate student theses and dissertations and subsequently into peer-reviewed conference and journal publications – an excellent opportunity to integrate research and teaching, which is a critical component of a competitive CAREER Proposal.

Finally, in an effort to make my proposal even more competitive, I negotiated for “in-kind” support from my Department Heads (I have a joint appointment in Mechanical & Nuclear Engineering and Industrial & Manufacturing Engineering, which effectively gives me two “bosses” to please or extra leverage to use, depending on how you look at it). Many universities have an established policy for CAREER proposals. The year I won was the least year that Penn State, at the University level, waived overhead on all CAREER proposals as incentive for applying. Meanwhile, the Department and College of Engineering provided teaching release from one course and support for one graduate student each year of the award. Needless to say, my CAREER Award money stretched a lot farther than most, allowing me to enjoy six years of funding thanks to a no-cost extension.

4. Parting Advice

In closing, a good proposal tells a good story, and if you do not “hook” readers within the first page – or better yet, the first paragraph – then they may quickly lose interest wondering where it is going. You should strive to write the first paragraph in “layman’s terms” and follow it up immediately with your research objectives (and educational objectives if relevant at this point), listed as succinctly and with as little technical jargon as possible. Do not make reviewers wait until the 2nd, 3rd or 4th page before telling them what you intend to do. Meanwhile, limit your research objectives to 2-4 bullets that each span 2-3 lines and are stated at a level where reviewers do not have to read the whole proposal in order to understand them. The story also needs a good ending, and this is where the Intellectual Merit and Broader Impacts sections come into play. This is where you tell reviewers how your work is going to save the world and benefit society, or at least do something extraordinary for some group of people somewhere.

Finally, do not be afraid to use formatting (e.g., italics, underline, bold) to add effect and *call attention to important points that you are trying to make*. Did you catch, for instance, how many times I stressed the importance of Intellectual Merit and Broader Impacts in this chapter? The underlined text makes it easy for the reader to identify these two important criteria and read what I had to say about them. Formatting makes it easy for reviewers to find things – and helps keeps their minds from wondering as they read through fifteen pages of text – but use it sparingly; otherwise, it loses its effect. The same goes for tables, figures, and high quality photographs: learn how to use them to improve the effectiveness of your storytelling and make your writing more memorable. Many people forget that the vast majority of engineers and scientists – the people reviewing your proposal – are visual thinkers. Good luck!

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The Essence of the CAREER Award: Preparing for and Writing the Proposal, During the Five Year Period of the Award, and Afterwards

Henry J. White, PhD, PE
Stony Brook University
Materials Processing Group
Stony Brook, New York

1. Welcome

So you have left your industry job, just completed your PhD, or just finished your postdoctoral experience and have just accepted a tenure track position as an Assistant Professor, Congratulations! Okay, now its time to roll up your sleeves and get started on writing your Career Proposal (<http://www.nsf.gov/pubs/2005/nsf05027/nsf05027.pdf>). STOP!

2. Key Points

Don't put all your eggs in one basket. Don't operate in a vacuum. FIND A MENTOR. There are plenty of NSF career awardees and well established professors/ scientist in the world. Find someone, who doesn't necessarily have to be within your immediate Department or University, who can spend ADEQUATE TIME with you during your preparation.

The deadline for CAREER Proposal Submissions is in July, assuming that you started your tenure track position in the Fall, you'll have approximately 10 months to "properly prepare" your proposal (find the time and spend a good 6 months). Do some research and find organizations (not only the NSF) that would have an interest in supporting your research (i.e. a great proposal submitted to the wrong program/ organization is a failed proposal). Review the guidelines for proposal submission and/ or try to visit some of these organizations. Understand the deadlines and try to get a few proposals (non CAREER) written and submitted during the first few months. If you can win an award prior to submitting your NSF CAREER Proposal it takes a lot of pressure off. If these initial proposals don't get funded, feedback is essential. You'll get feedback from your colleagues (individuals who are expert in your proposed field of research) that will help you determine if your proposal is novel, if the science is correct, if you have a true understanding of the literature, etc. Feels like you're starting your own company! Sounds pretty intense! I agree.

When July comes around, if you already have a proposal funded, you may or may not have an interest in submitting a CAREER Proposal. I know of some cases where Assistant Professors didn't bother submitting CAREER Proposals at all (had two unsolicited proposals funded within the first couple years). If your initial proposals are not funded, review the comments and decide whether or not you are able to compete in the proposed area of research. Feedback from a mentor at this time is essential. My rule of thumb is if you can't cite at least 100 references you do not understand the literature, if none of the 100 references are yours, you more than likely will have a difficult time competing in the proposed area of research.

FIND A MENTOR. Along the way, you'll learn that the contents of a CAREER Proposal are very different from a standard unsolicited proposal. While unsolicited proposals are typically of shorter duration (three years instead of five) and tend to be heavier on the science/ research side, a successful CAREER Proposal will provide the initial funds needed to balance science/ research with education/ outreach over the course of your career. When we were all kids, we were posed with the question: What do you want to be when you grow up? I'm sure we've made terrible mistakes in response to this question. When writing your CAREER PROPOSAL, ask yourself the following questions: What are you going to do for the next 20 to 30 years and how (financially, beyond NSF support) are you going to get this accomplished????

3. My Experience: The Good and Bad

I have three degrees (BS, MS, PhD) from three different Universities and I have written three theses on three different topics. I'm not a graduate of *Ultimate University* and my PhD is not from *Dr. Nobel Prize*. I am by no means a traditional faculty member (i.e. I did not go straight through the process: BS- MS- PhD- Postdoc- Professor) and have managed to work in industry over ten years prior to my postdoctoral experience and before accepting a tenure track Assistant Professorship. As a result I've made all possible mistakes, learned from them, and was able to craft a successful CAREER proposal during my 3rd consecutive and final submission.

Prior to my year 1 submission, I submitted a few unsolicited proposals in an exciting area of research in which I had limited experience (only one conference publication). The reviewers' comments were disturbing, but right on target: limited experience in the proposed area of research, no publication history, not worthy of funding, etc. My objective was to try to distance myself as far as possible from my PhD advisor/ Postdoctoral advisors area of research (not a bad idea- it's your Career not theirs!). For me this was extremely important and necessary because we are both faculty members in the same department. I sensed problems ahead if I continued along the same path of research (this seems like a continuation of your advisors research-commented one proposal reviewer).

Unprepared: CAREER Proposal 1st Submission

As I think back on my first submission, the proper word to describe the experience is unprepared. Due to other research related commitments (non NSF exploratory research grant), I was away from the University while preparing my 1st CAREER submission. I performed experimental research during the day, and spent endless hours carefully reviewing the literature in the evening. Definitely a major mistake!! Stick around campus!! It is very difficult to get letters of support during the summer- most academics are on hiatus. Since I was also away, it became even more difficult.

I took a shot! I crafted my 1st CAREER proposal submission (in two months) and similar reviews came back: the PI has limited experience in the proposed field of research; the PI should talk to someone senior about "how to write a CAREER Proposal", etc. Being from a Department with mostly senior/ well endowed faculty and that has never had a CAREER Awardee, I selected one of the "kinder members" of the department faculty to mentor me through the process. The MENTOR reviewed my original submission and suggested properly that I need to create an

equal balance of science/ research and education/ outreach within the 15 pages of the proposal, but was not familiar with the area of research. Discouraged from the reviewers' science/ research related comments, I decided to select a different area of research for my second submission.

Still Fishing: CAREER Proposal 2nd Submission

New idea in hand, I shopped idea number two around prior to submission. The idea couldn't find a home and it bounced from one division of the NSF to another- too Edisonian (experimental). I spent six months on submission number two (spent the summer at the University without summer support). The MENTOR gave superb advice about the educational/ outreach portion of the proposal, but the research/ science still wasn't there. I was defeated even before I submitted the proposal via FASTLANE (<https://www.fastlane.nsf.gov/jsp/homepage/proposals.jsp>). The comments were negative, as expected, and I became depressed. I, however, did learn something from one of the comments. The reviewer said, "The proposed research is short term and probably could be completed within the first couple years of the grant". Definitely not CAREER material.

Hope: CAREER Proposal Final Submission

Prior to submitting my final CAREER Proposal, I was invited to serve on a few NSF SBIR/ STTR panels. While I was there one of the senior well spoken panelists made a comment on: "The Essence of a Good Proposal". He said when preparing your proposal think of the five C's. *Is it CLEAR? Is it CONCISE? Is it CORRECT? Is it COMPELLING? Is it COMPLETE?*

My Thoughts

CAREER Proposal I- Clear, Concise, sort of Correct, far from Compelling (typical), Not Really Complete

CAREER Proposal II- Clear, Concise, sort of Correct, Compelling, not Really Complete
Armed and Ready- Final Submission

We'll it's the Fall of 2002, I'm preparing for the academic year, and I knew that I had another summer ahead without salary (can't afford to go away and do research- I understand the consequences). *COMPELLING* idea in hand, I secured a MENTOR who could assist me with bring *CLARITY* to the science/ research, and spent the rest of the year contacting supports (National Laboratories, Industry, Academia, etc.) to assist me with performing some related preliminary experiments. I chose a topic that I worked on at the age of 22 while in industry. Researchers still today are struggling to find a solution. I guess my advantage was that I was able to look at the problem from the outside in. There was a disconnect between industry and academia and since I've been on both sides of the fence, I was able to creatively describe the problem and craft a feasible solution using an array of state of the art analytical instrumentation. Writing the proposal was an emotionally draining experience. I wrote freely about everything I learned in industry, I wrote about applicable theories from my graduate lectures, I wrote about how all the analytical research tools that I've learned about from my graduate career through my professorship could be used to develop and demonstrate a via solution to the problem. My MENTOR was an Emeritus Professor who is well known in the field of one of my graduate

course lectures. I argued with him about the significance of the problem, about the proposed solution, about the related theory, etc. He thought the idea was *CLEAR*, *CONCISE*, and *COMPELLING*, but he wasn't sure if my model was *CORRECT*! When he was a Prof., there were hardly any computer simulations. He started to write the code for a lot of this work in the later 70's early 80's (unfinished work). I embraced his prior efforts, ran some preliminary simulations at NIST to demonstrate the feasibility of the proposed study, showed him some of the results, but he still wasn't convinced (*CORRECT*, but not *COMPLETE*). I became enraged and decided to part ways and submit the proposal. In December 2003, I received a call. Proposal Funded! The MENTOR was the second person to know.

4. Parting Thoughts

In this section, I think it's fair to describe what happens during and afterwards. On the plus side, the award gave me the opportunity to support my own students (undergraduate and graduate), to publish independently, to find additional channels of funding via related consultation and industrial sponsorship, and to do some pretty exciting research.

On the minus side, however, two years after receiving the award, I was denied tenure and have been retained (the tenure clock has stopped). While I was able to successfully divorce myself from my advisors' research and establish my own research niche, this was uncommon and I was forced to abandon past collaborative research efforts (20 publications with 300 citations). While most of my colleagues were not successful with the CAREER Program, they managed to survive doing collaborative research (don't put all your eggs in one basket). I guess there is a penalty for receiving a CAREER AWARD late in one's career (year three). It might leave you vulnerable, and you probably will have to work till near completion of the award to bear some of its fruits. No need for despair, keep bringing in research funds, you will (I will) survive.

Communicate Your Enthusiasm

Daniel Attinger
Columbia University
2005 CAREER awardee

Receiving a CAREER award was a life-changing experience. To me, it signified that the scientific community believed in me, that they believed in my potential to become both a quality researcher and a quality educator. If I had to give some advice to professors writing their CAREER proposal, I would mention the following three tips. First, make sure that you know how your proposal will be judged. Try to participate to a panel, try to see how panelists argue about proposals, what criteria they use to judge you. If you drop an email to your program manager mentioning your field and your interest to participate to a panel, you will very likely be invited for a free stay in Washington. Second, write an excellent summary. You will find hard to express your research project in one page, but this simply means that you still need to shape your research project in a more coherent way. Ask your friends: a good summary is understandable by any educated layperson, and should carry your enthusiasm. Keep in mind that the average reviewer spends about 45 minutes per proposal, so it is extremely important that the summary describe your project as precisely as possible, explaining exactly how you want to improve science and society. Finally, enjoy the proposal writing time. I love writing proposals because I feel like an eagle, flying on top of a five-year research landscape, figuring out in what directions to go to discover a maximum of new things. The proposal writing time is also a good opportunity to approach other scholars who might contribute to your proposal and write support letters for you. I remember sleeping on the floor of my office the two nights before the CAREER proposal deadline: I was exhausted, but very proud. As a summary, you want to give your very best, and in a way that suits the people who will judge you.

Maximizing Your Chances

Ana Muriel
University of Massachusetts Amherst
Amherst, MA

1. Introduction

The purpose of this article is to provide clear and specific steps that might help you in writing a winning CAREER proposal to the National Science Foundation, or any other proposal for that matter. The tips for success that I would like to share with you are based on my own experience in writing the CAREER proposal (twice) and a good number of other proposals, both successful and unsuccessful, as well as the invaluable insight obtained through participating in multiple proposal review panels.

As I am sure you have heard a number of times, the most important thing is to have a great idea, a compelling vision. I would not dare give you advice on how to get that one; my goal here is to help you put that vision forth in the best possible light to get it funded.

I will start by giving some general advice in writing and revising the proposal. First, understand your audience. The review panel is composed of experts in fields related to the proposals under scrutiny. These are *not all* experts in *your specific* area. The panel typically has about 15 proposals to discuss and those more familiar with a topic have a more prominent role in the proposal reviews. As you can imagine, reading 15 proposals is not an easy task. So here is my advice: be clear and concise, avoid long-winded sentences at all cost, make good use of figures and schematics, and have a number of people read and comment on your proposal. You may want an expert in your area read it, but this is not essential. I personally had my department head at the time, an expert in grinding, and my husband, an expert in acoustics, read my CAREER proposal on logistics to get invaluable feedback. Second, be aware that the spirit of the CAREER proposal goes beyond a single project; it is meant to jump-start the career of a very promising junior faculty. Thus, it is important to present the “entire package” in the proposal. More details on this will be given below. Finally, a good way to learn what the ingredients of a winning CAREER proposal are is to read some proposals that have been funded in the recent past. You should know that the full proposal documents associated with any current NSF award are public information and available for your perusal upon request.

The following sections correspond to the different sections in the proposal and detail the major points to cover in each of them. This is done, of course, from my subjective, personal, and frank perspective. My own experience is integrated within those sections.

2. Project Summary

This is the single most important part of the proposal. **Everyone** will read this section in detail. It is their first encounter with your project and, most likely, with you in general. It sets the stage.

As we all know, first impressions are hard to overcome. This is the place to get their full attention and interest in reading all the details in the remainder of the proposal.

In one page you need to:

1. concisely describe the proposed work, while providing sufficient motivation and perspective relative to the state-of-the-art;
2. demonstrate the importance of the work through the required statements of intellectual merit and broader impact;
3. show that you have what it takes to do it!

The last point may need some clarification. In only one page, there is not much you can do about explaining how you plan to accomplish your vision in a credible way. You can, however, hint to previous work that you are building upon, the strong collaborations you have built with companies or organizations that support your vision, the resources at your disposal, etc., to show that you are the right person for the job.

It is especially this section that you want to have a number of people read and comment on. It should be clear enough for a non-technical person, say a family member, to understand your vision and buy into the importance of the work.

3. Project Description

This section can be subdivided in different ways. I suggest here an approach that has worked for me. This is not standard, especially the first section below.

3.1 Preliminaries

The purpose of this section is to introduce yourself as a researcher and educator, explain the big picture of your career and help the reviewers get to know you. This section is well-suited for the CAREER proposal since it is specifically meant to help the individual junior faculty develop in a holistic manner; I would not include it in a different type of proposal.

You are writing your **career** plan. It must fit with your capabilities, your current activities, and your long-term interests. You can describe your current activities and achievements, explain your vision and long-term plan (beyond the CAREER project) and help the reviewers in understanding how it all fits together. This is the place where you can present the big picture of your career in both the short and long term, who you are and who you want to become.

In my own CAREER proposal I titled it “Research Interests and Prior NSF Support.” I there described my ongoing research activities, the general issues I am interested in tackling in the short and long term, and how the proposed research fits within this picture. I briefly touched upon teaching.

3.2 Research Plan

You are writing a 5-year research plan. It should be appropriately ambitious for such a time commitment. In research, risks need to be taken to reap high rewards. However, make sure to keep it focused and cohesive; including a variety of somewhat disjoint issues does not work well in general. Show previous success in developing the foundation you are building upon, demonstrate deep knowledge of the state-of-the-art in the field and clearly explain your research approach, or approaches; it is understandable that your proposed approach may fail when you are trying to break new grounds, and alternative (fallback) strategies can be described.

As mentioned in the introduction, the single most important thing to write a winning proposal is to choose the right topic. You need to define your vision and follow your passions...But you also need to follow the money. Be savvy to identify new areas where your knowledge and skills can be applied to topics that are being emphasized by the foundation. NSF provides plenty of literature online discussing their initiatives.

You, of course, also need to clearly state your intellectual merit and broader impact - how your research will advance science and affect society.

3.3 Education Plan

The education plan needs to be well integrated with the research agenda. They should go hand in hand with a unified theme. Research and education are clearly intertwined in the formation of graduate students, the integration of research results into courses and the involvement of undergraduates in research activities. These are standard activities that one can find in most proposals. You may want to set yourself apart, perhaps through curriculum innovation, the development of educational materials or the introduction of technology in the classroom. Your research may require interdisciplinary work, interuniversity collaboration or close interaction with industry; students could tremendously benefit if appropriately involved in these. I also encourage you to get involved in outreach activities ranging from attracting women and minorities into science and engineering, to introducing community service projects in your courses. Non-profit organizations are used to working with volunteers and tend to be welcoming to students. It is a great way to give back to the community while improving the students' learning experience.

Finally, it is important to show that you walk your talk. Show commitment to education through your previous activities and by presenting a well thought-out plan that builds on those.

3.4 Project Management

You may be intellectually capable of performing the work, but...Can you manage the people and resources required? Can you budget your time appropriately? You need a business plan!

Include a clear plan of how you will accomplish your goals in the five years of support and with the funds available. For this purpose, you can break the proposed work down into manageable tasks over quarters, semesters or years. The best way to illustrate your plan is through a Gantt

Chart displaying the duration and start/completion times of each task, the personnel and resources associated with each task, and possibly milestones to achieve over time.

Given the 15-page limitation, a very brief discussion explaining the chart suffices to complete this section.

3.5 Dissemination

Your plan for disseminating your research and educational findings should also be described in the proposal. Besides the typical outlets - journals, trade magazines, conferences, courses, website- you may want to think of less explored means to spread your results and set yourself apart. Examples include the wide dissemination of materials through an interactive website that provides access to the software developed for research or educational purposes, case studies based on the interaction with industry, the development of educational software games, the organization of workshops (e.g., to discuss the state-of-the-art and identify the key research challenges in the area), etc. Finally, a great place to disseminate your work is the NSF Grantee's Conference.

4. Letters of Support

Industry collaborations serve many purposes: They show the relevance of the research, help in developing practical assumptions and validating the models, are a great source of data and testing grounds, ensure a quick technology transfer mechanism, and could be a means to get additional funding and resources. They are therefore an important component for strengthening your proposal.

Industry collaborations should be backed up by letters of support describing the relationship and level of commitment. In particular, it is important that the letter shows that the company is well aware of your work, highly interested in the potential results, and strongly committed to supporting the research. Support can be provided in many ways. Funding is just one of them. Personnel time, equipment, data sharing, student internships, testing availability are a few other ways through which strong commitment can take place.

It is also advisable to show the support of your institution, and once again support is demonstrated by a commitment of money or resources. These could take the form of cost-sharing, a waiver of indirect costs in the proposal, facilities, personnel time, etc. Understand that your institution will share in your success, so don't hesitate to ask or negotiate this. In my case, I got an indirect cost waiver. This is basically getting 33% more out of each dollar from NSF.

Depending on your proposed work, you may want to seek out other resources such as the teaching center at your institution, research institutes or industry consortiums. Once more, show their support through letters that clearly specify what the relationship is and what they are committing.

5. Conclusion

As my own CAREER award is coming to an end, it is most gratifying for me to share with you what I have learned through the years. I cannot overemphasize the tremendous push that this award is for one's beginnings as an academic. The CAREER award not only provides you the funding to jump-start your professional career, it also brings you instant respect and credibility from your peers. This turns out to open doors that might otherwise have been hard to cross. I would like to encourage all of you to put your best effort forth. It is all well worth it. In the worst case scenario, you don't get the award but have formulated a clear vision of where you want to go. There are many other sources of funding, ranging from industry, to internal university awards, to different state and government agencies. It will most likely be a harder road, but the toughest part, uncovering your passion, has already been established.

To summarize my advice in a nutshell, a winning proposal needs to highlight the relevance of the proposed work and show that you are the right person to do it. First, clearly explain how important it is from both the perspective of advancing science (intellectual merit) and that of making this a better world (broader impact). Second, show that you are already on track through your previous activities and accomplishments in line with the proposed ones. Third, demonstrate that you have done the legwork: (1) you know the literature and state-of-the-art; (2) you have thought things through and have a promising approach, plus possibly fallback positions in case that one fails; and (3) you have built appropriate collaborations with industry, institutions within and/or outside the university, and perhaps with other researchers. Fourth, impress the reviewer with your management skills by drawing a detailed timeline of events and milestones, as well as illustrating how all the resources are in place.

Best of luck!

Thoughts on Preparing an NSF CAREER Proposal

Maria C. Yang
Daniel J. Epstein Department of Industrial and Systems Engineering
University of Southern California
Los Angeles, CA

1. Introduction

The following are some general thoughts on preparing a CAREER proposal that compiles advice from colleagues that have won CAREER awards, program directors at NSF, and also my personal experience. I hope these are helpful to you as you prepare your own proposal.

2. Before writing

- **Learn about the NSF.** First, decide which program or programs are likely candidates for your proposal submission. If no one program stands out to you as an obvious choice, search through recent award abstracts on nsf.gov to see which topics and investigators have proposed research most closely related to your topic, and then find out what programs they submit to. These abstracts may also give you a better sense of how to frame your own proposed work more appropriately. If at all possible, attend an NSF sponsored CAREER workshop for hands-on experience reviewing and writing. It will be well worth your time and effort.
- **Remember that a CAREER proposal is more than a “regular” proposal.** It is tempting to take a proposal you’ve submitted to another solicitation and modify for the CAREER proposal, but chances are this will not lead to a winning submission. It is better to think of the CAREER in the context of your overall faculty career. It can be somewhat intimidating to consider what you plan to do over the next several years or even decades but doing so will help contextualize your work in a way that the review panel can understand your larger career aims. Questions to ask yourself include: Where do you see your research, teaching, and service in 5 years? In 10 years? In 20 years? Even if you decide not to include the answers explicitly in your proposal, going through this question-answering process will likely influence your writing enough so that your reviewers will get a better sense of your ambitions. And if you know of successful, senior people in your field, it would be advantageous to ask their advice in mapping out your own vision as they will likely have a “big picture” view of the world.

For those of you who have submitted a CAREER proposal before without success, a friendly suggestion is that you rewrite your proposal from scratch. This is not necessarily because your previous proposal was not high quality, but because in the year or more since you submitted the proposal, it is likely that you have developed your ideas further and generated new and interesting work, and it’s important for your next submission to take that into consideration, along with the advice from the review panel.

- **Read other CAREER proposals.** Read other people’s CAREER proposals, if you happen to have access to them. Perhaps you can ask a colleague who recently submitted one, or can attend an NSF CAREER workshop mock panel review. Do not concern yourself about whether the proposal was successful or not. In fact, unsuccessful proposals are very helpful to read because they make it clear what to avoid in writing your own proposal.
- **Get feedback.** The most useful proposal preparation one can do is to find accomplished, experienced individuals in your field to give you advice on your proposal. Not only will they be able to offer you comments that will add depth to your work, but, more importantly, they can make suggestions to increase the breadth of vision crucial for a CAREER proposal. If they are willing, ask them to read over your draft before you submit it. Your university may sponsor sessions on proposal writing or even CAREER proposals, and these may also be helpful forums to get advice on proposal writing.

3. Writing the proposal itself

1. **Start early.** A CAREER proposal is more than a well written project description and summary. It’s important to leave ample time for gathering letters of support (if applicable), putting together a program for broader impacts, and getting feedback from others before submission.

Establish collaborations with industry. For some types of work, strong industry collaborations are very useful in showing the wider applications of your work, and it can greatly strengthen your research if you can build relationships with relevant companies. Again, it takes time to work with outside companies and to gather letters of support. For such collaborators, start at least a year early, if possible, to establish how you might work together or even generate some preliminary results. Longer term partnerships like this are more substantive and show how your work is complementary.

Leave enough to leave time for review by others. All of your colleagues are at least as busy as you are, and this probably applies even more to the senior people who you will want to review your proposal. Allot at least a few weeks for other people to read your proposal so that they can give you useful, constructive feedback. Prod them gently and graciously if they don’t respond in a timely fashion.

Think carefully about your “Broader Impacts” activities. The broader impacts of a proposal show how elements of your work can be made accessible to the rest of world, and there are a number of ways to accomplish this. Your broader impacts are also an excellent opportunity to differentiate your proposal from others in your field. For example, a proposal might say something about creating a new graduate class to disseminate their findings to others. However, if you can find other forums in your city or populations to share your results that will be even better, and it is important to start early enough to provide enough time for discussion and letter writing by potential collaborators such as high school teachers and museum directors.

2. **Make the first 2-3 pages of proposal accessible** to a technical layman. Program directors at NSF often say that a proposal writer should write a project summary suitable for a reader of *Scientific American* magazine. From a program director's point of view, there may be a number of reasons for this, but the way I think of it is this: Imagine a roomful of panel reviewers reading your proposal. More likely than not, only a few of these individuals will be able to understand your topic in great depth. At the same time, every reviewer needs to be able to appreciate the larger goals of your proposal, even if they aren't familiar with the details of your particular area of research. It is crucial that the thrust of your proposal be clear and compelling to them. Ask your husband/wife, partner, best friend, parents, or siblings to review your proposal. Your mother may be a dentist and wouldn't know the first thing about nanotubes, but if she has a general grasp of the first 3 pages of your proposal, there's a good chance the review panel will also be able to understand it.

Craft a one sentence summary of your proposal. This may sound simple, but a concise summary can be time consuming to write. A crisp concept is critical in helping reviewers understand your work immediately. This sentence should be one of the first sentences of your Project Summary, and should be as broad as possible. For example, "My interest is in determining the limits of x in the domain of y to fundamentally reframe our understanding of z" is more expansive than "I want to incrementally improve x using technology y."

4. Final thoughts

If someone were to ask you today to write a 15 page summary of all of the work you want to do in your overall over next several years, including research, teaching, and service it should probably look something like a CAREER proposal. Remember when writing your proposal to project the appropriate amount of confidence – too much confidence and it will not be believable, not enough confidence and reviewers will not take you seriously. The right attitude in your proposal will signal to others that you are willing to invest your time and vision into your proposed work. You will succeed!

Building a New CAREER in Laser Nanomanufacturing

Shaochen Chen, Associate Professor
Department of Mechanical Engineering
The University of Texas at Austin
Austin, TX78712

1. Vision

The NSF CAREER proposal is about the main focus of one's academic career. A clear vision is the key to his/her success. My graduate work at UC-Berkeley is about laser micro-scale texturing of materials for computer hard disk drive applications in collaboration with IBM Research Center. To differentiate my own career from those of my advisor and other colleagues in the same field, I focused my career on laser nanomanufacturing with applications in biomaterials and medicine, and integrated educational plans in micro and nanotechnology. I personally appreciated very much NSF's vision since at that time there was no "Nanomanufacturing Program" yet in NSF!

2. Scientific Merits

You may know that laser manufacturing by nature is micro-scale or mesa-scale processing. And traditionally laser manufacturing has been used for metals and ceramics. In my career proposal, I planned to create a new field by exploring new frontiers of laser processing with extremely short time scale, length scale, and new materials and applications. I studied how a femtosecond laser pulse interacts with biodegradable polymers and develop micro- and nano-devices for biotechnology applications.

The proposed research is a unique combination of nanomanufacturing, polymer science, and bioengineering. It provides a general solution to fabricate micro- and nano-scale features on various materials in the field of manufacturing science and technology. For the first time in the field, this work makes it possible to pattern biodegradable polymers on the micro- and nano-scale without any chemical involvement in the process. It is a fast and single-step process with "direct write" capability. The non-invasion nature of laser material processing eliminates possible contamination from the machining tool or chemicals. Most importantly, this novel approach is expected to minimize thermal damage to the surrounding material. It is unique to process biodegradable polymers for bioMEMS and biomedical applications such as nerve regeneration and tissue scaffolds. It is expected that these efficient, cost-effective, and high-precision manufacturing processes will have a significant impact in the emerging important field of bioMEMS and bionanotechnology.

Understanding the laser material interaction on the micro- and nano-meter length scale and femtosecond time scale is of vital importance to the control of the surface modification process. It will also make a significant contribution to the science of laser material interaction on extremely small time and length scales since the classical heat transfer models are no longer valid on such scales.

Biodegradable polymer materials used in this project are excellent substrate materials for many biomedical engineering applications, especially in tissue engineering. This project provides first time knowledge and manufacturing system for the manufacture of 3D nano-micro-meso scale devices used for nerve regeneration, cell culture, and other bioengineering applications. Because of the inherent difficulty associated with surgically retrieving small-scale medical implants made of silicon or metals from tissues, it is advantageous to apply biodegradable polymers, such that the micro-devices would naturally degrade and disappear in tissues over a desired period of time without the need of 2nd surgery.

3. Educational Plans

I believe that a strong research program and integration of the research activities into the undergraduate and graduate curriculum, coupled with innovative teaching methods, constitute the foundation for excellence in education. My educational objectives are as follows:

- 1) **Curriculum Development:**
 - a) Develop a new course - “Nano and Micro-electro-mechanical Systems” for senior undergraduates and graduate students.
 - b) Develop a new “Laser Applications Teaching Laboratory (LATL)” to provide hands-on experience for undergraduate and graduate students and area K-12 students and teachers.
 - c) Implement micro- and nano-manufacturing technologies in traditional manufacturing courses for both undergraduate and graduate students.
- 2) **Mentoring:**
 - a) Mentor and supervise undergraduate and graduate students from various departments in research projects.
 - b) Encourage women and under-represented group to participate in research in the emerging manufacturing technologies.
- 3) **Outreach:**
 - a) Expose K-12 students and teachers to laser technology.
 - b) Visit related manufacturers to improve teaching and develop potential research collaboration.

4. Other Comments

My suggestions in writing a successful CAREER proposal also include:

- 1) Start earlier. You need to give yourself enough time in preparing the proposal, especially the educational plan.
- 2) Talk to your NSF program director with an outline of your proposal. I learned a lot from my conversation with the NSF program director.
- 3) Be unique. Show the reviewers why your proposal is unique in both the research plan and the integrated educational plan.
- 4) Use good quality graphics to show your ideas in the proposal. A good picture means thousands of words.
- 5) Read your proposal several times as a reviewer before submission (so start earlier).

- 6) Ask senior faculty members especially those with a CAREER grant to read your proposal.
- 7) Experience in a NSF review panel will tell you how to write a good proposal from a reviewer's point of view. So tell your program director your expertise and your willingness to serve on the review panels.
- 8) Keep trying and take actions. Try to be a leading member of your community.

The Complete Idiot's Guide to Writing a CAREER Proposal

James E. Smay, PhD
School of Chemical Engineering
Oklahoma State University

1. Introduction

About me

Pardon my lifting of the title of the popular self-help reference book series from Penguin Group, but in this context it refers to the author's opinion of himself concerning giving advice on writing a CAREER proposal. That said, let me introduce myself: I'm Dr. Jim Smay from Oklahoma State University. I work in a Chemical Engineering department, but my degrees are in Mechanical Engineering (BS, OSU) and Materials Science (PhD, UIUC). I came straight from grad school into the Assistant Professor rank. More importantly, I have two wonderful children and try to be the best father to them that I can. Oh, I also received a CAREER award in 2005 followed by selection for the PECASE. I know what you're thinking: "It's easy to be glib about a CAREER award once you have one in hand." True, but I hope the tenor of my chapter in this book leaves you with the impression that getting a CAREER award is not the beginning and ending of your struggle for tenure. If your administration is like mine, everyone from the dean to the department head makes a big deal about writing your CAREER proposal, so winning one will make them very happy, but I think that achieving balance between the rigors of research and teaching along with a happy, healthy home life is the key to a successful career and, oddly enough, a successful CAREER proposal.

About the NSF

FYI, you are writing the CAREER proposal to the National Science Foundation. This may seem too obvious to state, but if you've been to Washington, DC, and listened to chatter for more than two seconds, you'll hear an alphabet soup of government agencies and programs clamoring for their slice of the federal budget. NSF was born in 1950 by an act of congress and has about a \$5.5 billion budget to fund about 20% of the basic research carried out at universities (i.e., you and me). I would suggest going to <http://www.nsf.gov/about/glance.jsp> to learn about the NSF as an organization. **You'll find that they focus on research at the forefront of science and place high emphasis on discovery and rarely, if ever, mention the word "development". This is because the NSF's mandate prevents them from funding developmental work that should be done by other agencies or private industry. Also, the NSF does a lot to lead scientific education in the US.** I put that last part in bold, because it is very important that you craft your proposal to reflect the values of the agency to which you are proposing the work. If you go to a conference or watch PBS for a while, you'll undoubtedly see credit being given to the NSF for funding these works.

Who is the NSF? Well, there are some permanent staff members that watch the shop and a great professional services staff, but by-in-large, the NSF keeps at the forefront of science by

borrowing active researchers from academia and industry to manage programs. Also, the people who will be reviewing your proposal are most likely currently or previously NSF funded researchers. Hence, the organization is well aware of the scientific forefronts and it has a strong identity about its mission.

About the CAREER award

FYI, you are applying for the "Faculty Early Career Development (CAREER) Program". As best as I can tell there is no meaning to the letters in CAREER, but everyone at NSF knows what it is. The website for really learning about the objectives of the CAREER program is: http://www.nsf.gov/funding/pgm_summ.jsp?pims_id=5262 . On this site you'll find the following synopsis of the program: *"The Faculty Early Career Development (CAREER) Program is a Foundation-wide activity that offers the National Science Foundation's most prestigious awards in support of the early career-development activities of those teacher-scholars who most effectively integrate research and education within the context of the mission of their organization. Such activities should build a firm foundation for a lifetime of integrated contributions to research and education. NSF encourages submission of CAREER proposals from junior faculty members at all CAREER-eligible organizations and especially encourages women, members of underrepresented minority groups, and persons with disabilities to apply."* I think the main thing to take from this is that the people reviewing your proposal not only know the goals of NSF, but that they also are well aware of the prestige of the CAREER awards and the **emphasis they place on integrating research and education.**

2. Essentials

Know thy self

"... in support of the early career-development activities of those teacher-scholars who most effectively integrate research and education within the context of the mission of their organization." As you can see, the NSF is really interested in the payback you will give the scientific community over the long haul, not just the five years of this particular award. Ergo, you need to know what *you* will be doing after five years of spending taxpayer dollars. When I wrote my first CAREER proposal (the one that was rejected), I didn't articulate a clear vision of how my career as a teacher-scholar would unfold. In the second version, I spent about three quarters of the first page in un-scientific active first person writing describing where my career would take me in the next five, ten, fifteen, and twenty years. Obviously the detail is much easier in the short term, but I could identify several milestones like tenure, full-professor, number of publications per year, number of PhD students, international reputation, etc.

At the outset of your proposal, you should clearly and unambiguously articulate where your career is headed and how this first five years of funding is going to get you going on that path. When it comes review panel time, the reviewers will have big silly grins on their faces if they know what your career goals are and how this proposal supports them by the time they get to the bottom of the first page. On the flip side, if you leave it up to the reviewers to guess, they will not be in a very good mood while reading the proposal. They usually have about eight to ten of

these things to read and they are all full of technical detail that can be boring if you don't get them excited to begin with.

I've always led my life with a loose plan. I think this is best articulated by Doug Larson - "*Establishing goals is all right if you don't let them deprive you of interesting detours.*" As a scientist it is the interesting detours I find most alluring, but it makes you sound like a flake on a proposal. Maybe a better approach is to follow Charles C. Noble's advice - "*You must have long term goals to keep you from getting frustrated by short term failures.*" That sounds like good advice and a grown-up, responsible approach toward planning your career. Nevertheless, I tend to lean toward Jon Bon Jovi's words - "*Map out your life, but do it in pencil.*" When it came to writing my career plan, I found it best to write out a clear path even if my actual path may deviate from this. It makes the reviewer's comfortable that at least you know how to reach for the stars. By the way, there is not a career path police once you get the award, so don't feel like you are locking yourself into time-share condo contract here.

Know thy institution

"... *in support of the early career-development activities of those teacher-scholars who most effectively integrate research and education within the context of the mission of their organization.*" Have you read your university's mission statement? Does your activity help support this mission statement? I bet the answer to this second question is YES, but you should state how in your proposal. How about reading your college and department mission statements? Again, I bet you can craft your description of your career path to be integrated with these mission statements. There is real benefit to being in concert with your institution in that you will likely find the most support from your administration in this work. It is good to tell the reviewers that this is the case. This is a bit of salesmanship.

If you do some looking at your university, you will probably find that the NSF funds or has funded some programs that were successful. These may be research centers, equipment grants, or educational programs. At OSU, we have the Louis Stokes Alliance for Minority Participation (LSAMP) that is funded by NSF. It was easy to talk to the director and volunteer to host a summer research student from this program and be able to integrate this into my proposal that I was going to do it. Your university may already have a REU program or other programs that will help you get going on the education part. Don't be shy about asking your department head or dean for help in identifying these programs on campus because sometimes they may not be well advertised.

Know thy funding agency

I already wrote about the NSF, but within the NSF you will have to select a program for which to submit your proposal. My advice is to start by browsing the different program areas to see which one(s) best fit your basic skill set. Then, draft a rough outline of the proposal and prepare (1) a hypothesis statement for your research idea, (2) a brief statement of your education goals, and (3) quick responses to the questions "What is the technical merit of your idea?" and "What are the broad impacts of your work?" Then, and only then, call your program officer. Do all this prep work before the phone call to avoid the embarrassment of sounding unprofessional and

unprepared when the program manager asks these obvious questions. The program managers don't get to pocket the money if there is some left over, so their goal is to fund as many great proposals as their budget allows. The operative word in the last sentence is "great." You need to fit their goals, but at the same time, propose something that gets them and the reviewers excited. If you call them and they are not interested, ask them to suggest another program or modifications to your plans that may make the research more palatable to them.

A solid research plan

The people you are competing against to get the CAREER are all bright, inventive, hard working professors just like you. They will all have good research ideas. What is expected is that you will have done a thorough lit review, but have it streamlined to fit your specifically proposed idea. The main purpose of the background section is just to show that you are aware of the state of the art in your field. The rest of the proposal is where you get to sell your idea(s). The main question the reviewer will be trying to answer while reading your proposal is: "What is the technical merit of this proposal." In other words, does this proposal break any laws of physics, can it be done within the confines of the time and funding level of the award, and will it be a significant advance for the field. The other question they will try to answer is: "Does this work have application outside the narrow field in which it is proposed or will it have significant influence within the sphere of people who care about this area?" It's a good idea if you answer these questions explicitly on the summary page and within the first two pages of your proposal. Don't leave it up to the reader to guess the answers to these questions. Generally, CAREER proposals do well in this area and you probably already have a handle on this, so I'll digress and move on to other sections.

An even more solid education plan

Since this is more than just a research proposal (as evidenced by the mission of NSF and the synopsis of the CAREER program) you should spend about as much time on the educational component as on the research. For me, it was easier to write the research part because that was what I knew how to do. For the education part, I had received no formal training as I suspect many of you have not. Fortunately, there is a lot of educational journals out there and the NSF and other government agencies have whole programs devoted to studying education. I suggest you do some reading.

My approach was to try to treat the education part just like the research part. It's much easier to figure out what to do if you know what problem you are trying to solve. I bet you already have a research hypothesis in mind, but have no clue about the educational program objective other than to fulfill the requirements of the proposal. My strategy was to pick a problem and propose a solution. I chose to work with Native American high school students in addition to the standard fare of teaching graduate and undergraduate students how to do research and classroom education. I found that the educational literature had many studies and theories about the causes and solutions for minority participation in Science, Technology, Engineering and Mathematics (STEM). I would suggest having at least ten references to the education literature to let the reviewers know you are serious in this area. In my particular case, I included a \$5K per year budget to support my outreach program. This got good reviews.

Follow the rules (written and unwritten)

Not much to say here about the written rules. Just make sure your formatting is exactly what the NSF wants. There are a couple of unwritten rules of which I've become aware. First, you should make it abundantly clear within the first paragraph of the project summary, exactly what your proposal is about. You want readers to pick up this proposal and know right away that it's about: "Creating nanocomposites with single wall carbon nanotubes in a polymer matrix by a novel dispersion technique and that the educational outreach program caters to disadvantaged children in the inner city by providing them access to your labs resources." If you don't think your subject is simple enough to put in this kind of language, think about how you would tell your grandmother what you are doing in research. Second, you should avoid using the word "develop" at all costs. The NSF funds cutting edge research at the frontiers of science, not developmental work. I think this is a gray area. In fact, it seems that you can actually propose quite a bit of developmental work as long as it is couched in terms like "discover", "understand", "explore", etc. Of course, reviewers will read right through this if you don't have a fundamental core that is not developmental. One more tidbit: Check the details with your particular program monitor, but when the NSF says the budget minimum is \$400K, that is also close to the maximum amount (though they don't publish this). The reviewers are, however, aware of this fact and will be a little put off if you propose a \$1M budget.

3. Getting an edge

TMI-TLI

I've read proposals chock full of all kinds of technical detail. Wow, this is great if you are in exactly that area with the background and interest to appreciate it. So you may make one reviewer really happy with lots of dry equations. On the other hand, there are three reviewers on the panel, so you want to make them happy too. In my opinion, you should just try to know your audience and make the level of detail appropriate. The reviewers have broad knowledge and an appreciation for good science. I would approach this by writing your proposal to be very readable and only give the background necessary to make your ideas understandable. Hence an exposition of all facets of the literature is probably not necessary, but a targeted approach that supports your ideas is. When you are in the meat of your research idea, state the fundamental premise of your ideas as early in the sub-section as possible. Then fill in the details in ensuing paragraph. The proposal reviewer will be able to quickly read the sub-sections and can jump over details they may already know.

On the other hand, you don't want to give too little information. If you propose some new idea, the worst thing you can do is leave it up to the reviewer's imagination to figure out how you are going to execute on this idea. You only have limited space to do this, but you can give a reasonable skeleton of an idea about the way your work will proceed on every facet. This includes how you will use your budget. You probably won't get much favor from reviewers with a detailed Gantt chart either, but an approximate timeline and benchmarks for the project is a good idea. This applies to both the research and the education plan.

Taking criticism

We all had a ton of red ink on our dissertations, so we're not naïve about the usefulness of constructive criticism. All your colleagues expect you to seek out constructive criticism and nearly all of them would be happy to oblige should you ask them. I would suggest going away from those very close to your research area. Try to find senior colleagues in different departments that have been successful in the NSF funding arena to read your proposal. Chances are they have served on review committees and know a good proposal when they see one. You might also consider passing this by a colleague steeped in STEM education. They can let you know if your proposal rises to the level of excellent in their eyes as well.

Ignoring criticism

Although I respect my colleagues and am grateful for their criticism, ultimately the proposal is my work and I must follow my own direction. This means that I may need to listen to their criticism and then ignore it. This is easier to do on your first and second submission for CAREER than on your third. I would caution about letting senior colleagues unduly influence your selection of research direction. You should be true to your interests because your enthusiasm will shine through in your research and education plan.

Letters of support-oration

According to the NSF guidelines for writing the proposal, letters of "support" are forbidden, but letters of "collaboration" are not. Essentially, you want letters of support to be the part where some outside person brags about how great you and your idea are. You can get that in a letter of collaboration if you get the letter writers to go the extra mile to commit to a collaboration such as going to their company for consulting, they donate in-kind engineering support, or they provide materials and equipment for you. In the education arena, it is particularly easy to get collaborators to help execute your plan and they can say all kinds of good things about you in the letters. This is sort of another unwritten rule, but these letters of support-oration are expected.

Brushing shoulders

Maybe one of the most important things you can do to prepare for a successful CAREER proposal is to visit personally with your program monitor. This means you should go to Washington, DC and serve on a review panel for the program to which you are thinking of applying. It will open your eyes to the process and will let the program manager know you are a good citizen in the scientific community. The program managers are amazingly un-biased, but it certainly helps everyone if the proposer knows the system and the things that the program values. Also, you will get to meet your fellow review panelist who may be reviewing your proposal some day.

The CV - Constant Velocity?

Spend some time making your curricula vitae put your career in the best light possible. There is a specific format, so you should follow it. Your education, employment and publication records should show a steady progress toward the goals you are articulating in your description of your career goals early on in the proposal. The reviewers will look at your CV last, but the main

reason to do this is to see that you have the background and track record to have a reasonable chance for success in executing the proposed work. I just changed the passenger side half axel on my minivan and it had a CV (constant velocity) joint that had gone bad. I think your CV should reflect your constant velocity toward your career goals.

Bragging right

I know we are all humble professors who want their accomplishments to speak for themselves, but the only way the reviewer will know you is by your proposal. I took an approach in my CAREER proposal that may or may not work for you. In addressing the broader impact, I stated that the award I had received from the American Chemical Society and the notoriety in C&E News showed the interest of the scientific community in my work. Of course, I gave other details about why my work would have broad impact, but I shamelessly self promoted that my work would be high profile. You may not go to this level, but don't undersell yourself in the proposal. You can mention your previous success in research and education, especially if it supports your assertion that you are using your past experience to move toward your stated career goals. I wish you the best luck on your CAREER proposal and hope you find one or two of these comments helpful.

Writing a Good NSF/CAREER Proposal

Gary J. Cheng
Departments of Industrial Engineering and Engineering Technology
University of Houston
Houston, TX 77204

Writing a good NSF CAREER proposal is a big homework for assistant professors. Your **goals of the homework** are:

1. How to convince reviewers that this is a good idea?
2. How to convince you are the best person to implement the proposal?
3. How to write a focused proposal with good integrated plan for your career in the next 10 years?

You want to write 15 pages of interesting materials to convince the reviewers and get the best comments from them. In the following sections, I'll highlight some of the key points that, in my opinion, are necessary to achieve these goals:

A) Presentation of a good idea – objectives and significance

Don't start writing until you are 100% sure that it is an excellent idea. You have to convince yourself first that it is a fundamental and interesting work, and will have a lot of impact in real life if successful. Ensure that you have an appropriate rationale for each objective: Why is your work important? During writing, make sure your goals are specific and clear - Constantly keep these goals in focus. The most common critic is that the research is not focused.

B) Research Plan of your work

During this part, you want to convince people that you are the best person to do this work. Describe previous experiments carefully and clearly – show that you are a careful and critical scientist, and include appropriate controls for every experiment. If you have papers submitted for publication, make sure they are referred in appropriate places. When designing your experiments, present in details about the following things: a) how are you going to do the work, b) do you have enough experience with the proposed research, c) have you used the right methods that will generate good results?

In a CAREER proposal, you want to devote a paragraph to putting your proposed research in a long-term context - Distinguish between those you wish to achieve in the proposed grant and your long term interests and objectives. Don't propose too many things in five years. It is one of the most common mistakes to proposing much more work than can possibly be achieved during five years.

Referring other people's work is important. Be sure to give credit to all your sources. If you use some results from an article in your introduction, put it in quotes and cite the source. It is very possible that one of the authors of the articles is reading your proposal.

C) Write a good education plan.

Keep in mind that educational part of the proposal is as critical as research part. You want to propose unique teaching philosophy. It is not enough to just propose something that everybody does, such as a new graduate curriculum, undergraduate research experience, and recruiting good students. These are what professor supposed to do. You must make your education plan as an integrated part of the whole proposal. You have to make interesting and innovative education plans.

D) Make your proposal exciting – let reviewers remember the concepts in short period of time.

Your primary audience is the reviewing panelist. You need to figure out what reviewer wants. Panelists are each reading 10-15 proposals. The proposals they remember are ones they rank highly. Your job is to make the reviewers enjoy the reading. There is no general formula for it. Your proposal needs to explain the work in simple, logical progression. You need to discuss all the important questions about your plan. Please don't make any technical mistake – it is different from writing a paper when you still have chance to make several minor mistakes.

At the end of the proposal, you should be confident that you have written an excellent proposal, and that you presented a well integrated package. You need to convince reviewers that you have great chance to be very successful and make a deep impact in your field.

CAREER Proposal Writing – My Perspective and Experience

Dr. Mario Richard Eden
Department of Chemical Engineering
Auburn University
Auburn, AL

1. Introduction

Every new faculty member is expected to apply for the NSF CAREER award. It is one of the standard sources of funding every faculty candidate lists in his or her research plan when applying for faculty positions. However, unlike a regular research proposal, which has a finite timeline, a CAREER proposal should describe your long-term career goals and provide a detailed plan for the first five years that will enable you to achieve these goals. It is important to remember that you are planning your career not just your CAREER proposal. The CAREER award provides a wonderful foundation for your future, but it is not likely to singlehandedly make or break your academic career. It is only one of many ingredients in a life-long career in integrated research and education, and numerous faculty members have been extremely successful in their careers without ever winning the CAREER award.

In this contribution I will give a description of my CAREER proposal preparation experience and discuss the lessons I learned along the way in terms of what to do and perhaps more importantly, what **NOT** to do. The most important thing to remember when you read my recommendations is that you should look at each one critically and ask yourself whether this particular piece of advice works for you.

2. My Background and Experience

My path to academia was in many ways unconventional, but I believe my background and the opportunities provided to me during my graduate studies provided a unique perspective on my vision and approach to academic life. I received my MS and PhD degrees from the Technical University of Denmark and as part of my PhD studies I spent nine months as a visiting researcher in the Department of Chemical Engineering at Auburn University (AU). My academic career started when I was offered a position as visiting lecturer at AU. At the time I had no intention to pursue an academic career, but the offer presented a tremendous challenge and an opportunity to help a Department that had been very valuable to my research progress. However, the lectureship and the environment I became part of showed me that a faculty position would enable me to pursue my ambitions of conducting high quality, industrially relevant research and conveying my passion and enthusiasm for the field of chemical engineering through engaging and educating future undergraduate and graduate students.

January 1, 2004 I started my position as Assistant Professor at Auburn University. As most new faculty members I began preparing my first proposal and quickly had my first draft completed. I have kept the first draft of that as a reminder of the constant need for improving my skills and capabilities. I asked my Department chair, a friend and mentor, to read it before I submitted it.

To say the least it was an eye-opening experience. I had made the common mistake of writing the proposal much like a technical paper, which I have since learned is not what reviewers look for. Although the technical content was of good quality, the proposal did not generate any excitement nor did it make a compelling case for why the funding agency should be funding me rather than someone else. Along with many helpful suggestions on improving the language and structure of the proposal, my Department chair explained to me how the review process works: ***“Funding agencies do not fund good projects – they fund good people with good projects!”*** I don’t think I quite understood his comment at the time, but after serving on review panels and reading several proposals both good and bad, I understand what he meant. Naturally, the technical quality has to be high, but a really strong proposal makes it clear not only why the research is important, but also why that particular PI is the most qualified to ensure its successful completion.

Given that I had only started my faculty position in January, I did not feel that I was ready to submit a CAREER proposal the following July, and thus did not want to waste one of my three attempts on a sub-standard proposal. I came across an announcement for a CAREER proposal writing workshop which I applied for as I felt it would provide valuable information for when I would submit my first CAREER proposal in July 2005. I was not accepted for the 2004 workshop, but reapplied and was accepted for the next one, which was held in May 2005. Prior to the workshop the participants were given eight proposals (of which four were successful) to review. The review process helped me tremendously in terms of getting in the right mindset for writing my own proposal. Surprisingly, the successful proposals proved more valuable to me in terms of what I did **NOT** want to do than in terms of what I needed to include in my own proposal. Most CAREER proposals are generally structured as follows:

- ❖ Project Summary
- ❖ Research Plan
- ❖ Education Plan
- ❖ Integration of Research and Education

The general rule is that the research and education aspects are equally important and thus should be balanced in the proposal. Furthermore, a strong integration of research and education is required. Since the research aspects are unique to each PI and discipline, I will give some general comments in the next section and focus on the educational aspects here as it related to my own proposal. The following educational items must be addressed in any CAREER proposal:

1. Instruction
2. Mentoring
3. Addressing Diversity in Science and Engineering
4. Outreach
5. Integration of Research and Education

In terms of integrating research and education, I am very fortunate in that my research area is closely related to the classes I am teaching, so integrating the two by infusing research results in my classes was fairly straightforward. This will definitely not be the case for everyone! I spent a significant amount of time during the planning stages of the proposal trying to write two

balanced sections for research and education respectively, but finally accepted that I was not able to do it without repeating or paraphrasing other parts of the proposal. So I decided to write the proposal in a truly integrated manner, where the majority of the educational aspects were included as logical extensions of the research tasks. So in the actual proposal, the section entitled “Education Plan” is only about one page in length, but still addresses items 1-4 above!

Teaching undergraduate classes and developing a special graduate level elective course focusing on your specific research area is pretty much par for the course, however it still needs to be there. The same applies to mentoring and training of graduate students and undergraduate researchers. Involvement in other mentoring activities such as honor societies and professional societies is also more or less standard. In my opinion these aspects of the proposal do not carry much positive value; however reviewers do notice if they are omitted!

The challenge of increasing diversity in science and engineering is a sensitive subject as it is addressed differently at each institution and in each discipline. Utilize the infrastructure of your institution to provide channels for you to explore. You are **NOT** expected to solve this issue all by yourself so capitalize on what is unique in your region, for example through establishing connections with a nearby HBCU or other minority institution for you to recruit minority students into your group.

From the CAREER proposals I had reviewed as part of the workshop, I found that the amount and extent of outreach activities in many cases was far beyond what would work for my research area. My work focuses on method development for design and optimization, and as such is very mathematical as well as computational in nature. Some of the outreach activities described in the proposals I reviewed were truly innovative and commendable, however if the PIs actually intend to do all of it, then there would not be much time left for research. It often read as if these were token statements included simply because an outreach component is required. For example, one proposal stated that the PI intended to introduce K-12 students to statistical tools for quality assurance in nano-scale manufacturing. I decided that I would only propose what would be feasible, practical and more importantly what made sense to me and my research. So rather than simply stating that I would introduce systematic design and optimization methods in K-12, I proposed to inspire K-12 students to pursue careers in engineering rather than computer science by showing them all the important and complex problems that engineers solve using mathematics and computers. The outreach component is an important part of the activities of any faculty member, however any such activities should make sense to undertake, and new approaches should not be proposed just for the novelty. Most universities already have procedures and channels in place for establishing contact to K-12 students and teachers, so use the infrastructure that is there, rather proposing to do it all yourself. There is no reason to reinvent the wheel, nor is there any reason to invent a square wheel, just because it would be a novel approach.

3. General Pieces of Advice

As mentioned in the introduction, the CAREER proposal is unlike a regular research proposal as your goal is to convince the reviewers of your qualifications and promise for a life-long career of contributions in research and education. This means that reviewers need to be made aware of

your **vision** from the very beginning and the proposal should provide a solid foundation for advancing your career towards achieving that vision. The “Project Description” narrative of the CAREER proposal used to be called “Career Development Plan”, and that in my opinion is a much more accurate description of how a CAREER proposal should be structured. It also has a significant impact on how you write the proposal. Unlike a proposal solicited for a specific technical topic, *the CAREER proposal represents your career development plan, which means that the research and educational activities proposed should be things you are going to do regardless of whether the proposal is successful!* Since this proposal is meant to cover all of your activities, it will inevitably have significant topical overlap with other proposals you may have submitted or are in the process of preparing. In the following I have summarized my general recommendations as they apply to the four main items that the proposal must contain:

Project Summary: This is the first thing the reviewers see and thus should make the reviewers excited about reading the rest of the proposal! First impressions are hard to change! If you can not succinctly explain why your work is important and why you are just the person to do it, then you are off to poor start. The project summary is the one part of the proposal, where having a non-technical person read it has tremendous value. If a non-technical person can get excited about your proposal then someone with a technical background will be excited to see how you plan accomplish your goals. Help the reviewers find the unique contributions of your proposed work, i.e. make the intellectual merits and key broader impacts stand out from the page through bullets, italics or bold fonts. Don’t make the reviewers look for your contributions!

Research Plan: First you will need to establish your career development objectives, i.e. what do you want to achieve in 5 years (the end of the proposal), 10 years, and throughout your career. The funding provided through the CAREER award is for five years, so be ambitious but remain focused. You also need to convince the reviewers that you are the most qualified person to ensure successful completion of the project. This means that you need to establish your track-record as a researcher through preliminary results, prior funding, and letters from collaborators. Letters can provide additional validation of your work, especially if it is from a collaborator who is willing to invest money, equipment, data or engineering time in the project! With respect to letters, it is important to remember that the letters should be letters of collaboration and not letters of recommendation. They should illustrate knowledge of your work and describe clearly what support is being provided by the partner.

Education Plan: It is very important that you integrate your research and education activities. Depending on the type of courses you are responsible for teaching this will be of varying ease. However, all research results can be translated into something that has educational value and infused into the classroom (or disseminated more widely) in the form of tabletop experiments, computational tools, interactive websites, case studies highlighting aspects of importance to a given class etc. Be creative, but only propose what is feasible and makes sense to you and your work. It is very easy to go overboard on the educational activities; however the truth is that your academic career (particular in the formative years) will be driven by your research efforts, so be critical about how you integrate research and education. Propose only what you would like to do anyway, **NOT** what you think the reviewers would like to see.

4. Final Thoughts

Preparing a CAREER proposal has many benefits that may not be apparent during the proposal preparation stage. You are forced to take a critical look at what you want to achieve in your career, and requires that you prepare a clear roadmap that will help you achieve your goals. This is an extremely valuable exercise regardless of whether the proposal is funded or not. Remember, that your career should **NOT** depend on your CAREER proposal! The truth is that regardless of the reviews of your CAREER proposal, you will not be radically changing research directions. You will continue to pursue your scientific curiosity in your chosen field, train students, and improve your teaching skills and all the other things that make for a successful career in academia. Remember, that the CAREER proposal describes **your career development plan** and as such should not depend on the success on this one particular proposal!

The CAREER Adventure

O. Burak Ozdoganlar
Mechanical Engineering Department
Carnegie Mellon University

Although I heard about the CAREER award during my graduate studies, I was not aware of the importance of this proposal for my career until later. My first look at the NSF web page and search the word “career” was the day I got a call for my first academic interview. It was not until I started working as an assistant professor, however, I began to think seriously about the CAREER proposal.

If there is only one advice you will follow, let it be that **you should start your preparations early**, possibly at least six months earlier than the due date. While in some cases the CAREER proposal will be an extension of your doctoral research, in others it will have significantly new components. You have an exciting idea, but it is critical that the idea was not investigated before, at least not thoroughly. Yet, before completing a preliminarily literature review, you will not know whether what you are planning on proposing was done before or not. Therefore, the first step is to spend some time in one of the citations search engines. I suggest being very flexible at this stage when you are shaping your main focus/idea. In your proposal, the literature review will be one of the most important sections. It will tell the reviewers that you are knowledgeable about the work previously done in this area, and to a level, that you are qualified to conduct the proposed research. If you set your objectives within this framework, it will also help making the point that your idea is new and unique.

At an early stage, you should arrange to attend an NSF review panel as a reviewer, possibly one from the program to which you will submit your CAREER proposal. This was very helpful to me. Although clearly the panel was not a CAREER panel, it helped me to understand how reviewers---including myself---approach reviewing proposal. What were the common issues that make many otherwise good proposals not be placed in the upper echelon? I noted my observations from the review panel carefully, including the approach the panelists using for evaluating the proposal. It was very interesting for me to find out that I was in line with most other reviewers. What I am trying to stress is that, if you can step back and separate yourself from your proposal, and that you impose your evaluation criteria onto your own proposal, you can determine many of the deficiencies (and strengths) of your proposal. Ask yourself what *you* would expect from a proposal like yours. What are possible areas that may bring up critical issues? Do not forget that unlike the paper review process you will not have a chance for rebuttal!

Attending an NSF panel also provides you with the great opportunity to meet with your program manager face to face. Most program managers are very helpful. In my case, my program manager (Dr. George Hazelrigg) asked me many questions about the proposal, mainly making me think about what I will be really proposing, whether my objectives are clear or not, etc. I should tell you that I was very disappointed in my idea when I left his office. It came to me soon after that point that this was an opportunity, and I had ample time to shape my ideas until the

deadline. The best thing is for you to prepare a one-sentence objective statement even before you talked to the program manager.

Another very helpful thing was attending an NSF-CAREER workshop. This not only taught me about the CAREER proposal, but NSF proposals in general. I had a chance to interact with others like me, hear recommendations from earlier CAREER awardees, and talk to a number of program managers.

The best way to comprehend the overall organization, scope, etc., of CAREER proposal is to obtain the previous years' successful CAREER proposal from your colleagues both within and outside your institutions. Clearly, the subject area of each proposal can be quite different from your own. You should try to identify the common trends of those successful proposals. For instance, even though a successful CAREER proposal is not in your area, you could expect that you will understand a considerable portion of the proposal: What the proposer is trying to do (his/her objectives, both for research and for education)? Why is the proposed work important (motivations)? Does the PI project significant background/knowledge in the area? Is there a well-organized work plan? Does the work plan correspond to the objectives laid out? And most importantly, whether the PI is laying out a plan for his career (including a detailed plan for the next five years), or is this just a research proposal?

A few weeks before the deadline, with a well-written draft, you should seek preliminary reviews of your proposal from your colleagues. Try to do this enough so that you can get the pre-reviews back from your colleagues and make appropriate changes. Be prepared that these changes may be quite extensive in some cases. Obviously, you have to choose which of the suggestions you will take and implement. However, I still suggest keeping an open mind and not being afraid of making considerable changes even at this point.

Some insights about the body of the proposal: First, make sure that you do not cram too much information. A large, possibly 12 pt Serif font is generally the best choice. The Sans-Serif fonts are generally harder to read. You want your reviewer to have a pleasant experience in reading your proposal. So make it nice looking, including informative illustrations, but most importantly, with concise, unclouded statements. Second, make sure the proposal is well organized. The reviewer is assessing your qualification somewhat unconsciously through the way your proposal is written. Think about what you are projecting if your proposal is sloppy, loaded with grammatical errors, typos, sloppy illustrations, etc. Third, do not propose too much or too less. This is a hard balance to achieve. However, being realistic about what you can really accomplish is your best guidance. Fourth, spend ample amount of time in writing your Summary. The summary is the first thing the reviewer will read (and possibly the last thing as well). Most people suggest that a review based solely on the summary correlates well with a review based on the whole proposal. And fifth, make sure your excitement shines through your proposal! I would say, if you are not excited about doing the research and educational activities you are proposing, don't even bother writing the CAREER proposal. And if you are really excited about your proposal, make sure the reviewers get that point as well.

Your creativity may also pay off for the education portion of the proposal. The boilerplate stuff does not get much attention, as a matter of fact, can hurt you to include. Try to come up with

some creative and relevant approaches for educational component. The more integrated the education and research is, the better.

To me, CAREER proposal felt quite different from any other proposal I have written. It also took far more time than the others. However, looking back, I really enjoyed the process. It help me find myself, in a sense, help me more clearly define my research and educational goals and learn how to write proposals. So, although your CAREER journey will be somewhat painful and sleepless at times, it is a rewarding experience itself. Enjoy!

Some Thoughts on CAREER Proposal Writing

Gracious Ngaile
Department of Mechanical and Aerospace Engineering
North Carolina State University
Raleigh NC

1: Introduction

A faculty position provides numerous opportunities. In addition to imparting valuable knowledge to students, a professor can conduct research of his/her own choosing as long as it has a well-defined objective. I came to North Carolina State University after my postdoctoral work at Ohio State University. The excitement of becoming a professor came with a lot of expectations such as being able to quickly furnish my laboratory with necessary equipment and have a sizable group of students to work with. Soon I noted that without a postdoctoral advisor any longer, I would have to establish new contacts, deal directly with both good and average students who may have different goals from mine, write proposals, and convince private and government granting agencies that I can deliver. I came to the realization that some of my expectations were unrealistic. But despite the challenges, hardship, and responsibilities, I intend to keep focused, as I find a lot of enjoyment in being a professor.

In this article, I will discuss my personal experience in writing a CAREER proposal, the key components of the proposal, what distinguishes CAREER proposals, and the dilemmas and confusion facing a PI when preparing a proposal for which a decision will take six months.

2: What Distinguishes CAREER Proposals

Prior to writing a CAREER proposal, I had the opportunity to submit a few proposals to NSF and to other government organizations. The format and style were pretty straightforward: provide rationale for the proposal, state the goals and objectives, provide a concise literature review, identify possible areas for research, present one's research approach, state detailed tasks and how to execute them. The main focus is to provide enough technical content to convince experts in the field that your proposal is worth funding. While a lot of elements may be similar in a CAREER proposal, I have observed that some elements may need special attention:

Vision: As stated in the NSF proposal guideline, a career development plan should build a firm foundation for lifelong contribution of integrated research and education. Therefore a well thought out plan with a grand vision is key. The reviewers will be looking for this vision along with solid technical content, novel ideas, and convincing methodologies by which the goals put forth in the proposal can be achieved.

PI Credibility: In a CAREER proposal, the credibility of the PI has more weight than in other types of proposals. In addition to novel ideas, well laid out technical methodologies, and a concise description of the state-of-the-art / literature review, the proposal needs to persuade

reviewers that the proposed goals are achievable. As a junior faculty member, however, you may not have an impressive resume. Thus, the only way to raise your credibility is to present the relevant work you have done thus far, while clearly distinguishing what you have done from what other researchers have done. Therefore, the literature review needs to be structured very carefully.

Review Board Composition: Because you will not know in advance the expertise of the reviewers, you should position your proposal for a diverse audience. This does not mean you need to dilute the technical content, but that the project description should be well articulated with clear objectives and tasks, relevant assumptions, systematic technical methodologies, etc. The review panel is extremely likely to include members who have little knowledge in your field. This segment of reviewers will critically examine the intellectual merits, broader impacts, and most important, how methodical you are in defining the proposed tasks.

In an effort to justify that your methodologies are novel, you may be tempted to be overly critical of other fields of specialty. However, you need to remain fair, as you do not know who will be reviewing the proposal. For example, if I, as a researcher in metal forming, were to state that “novel microforming processes are cost effective and the only method for mass production of miniature components” and that “currently used machining processes are unsuitable because they are slow and lead to loss of materials,” a reviewer who is an expert in machining would consider this naïve.

Integration of Research and Education: This may be one of your more difficult tasks. Because you are constrained to 15 pages, you may be wondering how much space you should devote to education. If you discuss your education in only two pages, reviewers will feel that you have marginalized the educational component. Perhaps it is best to critically assess unique features in the proposed research topics that can be linked to the educational activities.

Appearance and Package: Well laid out technical details are not enough. Reviewers will be tempted to infer the studiousness of the PI from how well designed the proposal is with regard to style, continuity, neat illustrations, etc. Furthermore, you should expect that reviewers will be subject to a time constraint. A well-packaged proposal will tend to excite the reviewer, who will probably spend more time reading it.

3: Challenges in Preparing a CAREER Proposal

Metal forming and Tribology have been my areas of research since I started my MS degree. Since then I have been discovering how little I know about this field. The first challenge I encountered when I started to work on the CAREER proposal was how to select a suitable topic. I thought of a few topics about which I feel passionate and confident, but I had to ask myself a number of questions: Are these topics of interest to the program manager? Will reviewers consider them worth pursuing? Are there important broader impacts associated with the topics? Aside from their intellectual merits, will these topics lead to potential applications? Will reviewers regard the forecasted outcome from these topics as measurable? Are these topics considered exciting? Some of my close friends in academia told me that they do not think NSF

will fund metal forming, because this field is not exciting. However, I finally picked a topic that I considered to be more appealing.

The second challenge I encountered was what style of writing would allow me to fit in research and an educational development plan in 15 pages. I had thought that my previous experience with writing proposals would be to my advantage. But surprisingly, assembling the conceived research development plan in accordance with the career proposal guidelines was a nightmare. I then decided to have my first draft proofread by a non-technical person, who corrected the grammar and advised that the flow needed to be improved. After carefully reading the guidelines and searching for example CAREER proposals from the internet and other sources, I finally decided to reformat the proposal with the focus on: (a) vision, (b) a few chosen major topics that are separately discussed and include primary data from my current research work, (c) educational plans that are well tied to the major research topics proposed.

The revised version seemed okay, although the proposed tasks were a bit ambitious to be accomplished in five years. But I had to take this risk because the proposal contents reflected a long-term vision beyond five years.

I spent over three months working on the CAREER proposal, yet at the time of submission I still felt that it was unfinished. However, the experience gained in the course of preparing this proposal was invaluable.

4: General Comments

Look for opportunities to meet with program managers. If there are questions that the program manager cannot answer directly, you may be able to infer what is expected. Before scheduling a meeting with the program manager, be sure that you have thoroughly read the proposal guideline, otherwise you will lose credibility.

In the course of writing the career proposal, I had the opportunity of meeting the NSF program manager, who answered even my naïve questions and encouraged me to submit. I did not have the opportunity of asking past reviewers or CAREER grantees. I think my proposal would have benefited had I the opportunity to ask meaningful questions such as what a program manager would like to see addressed in a proposal that past applicants may have overlooked, how much time a reviewer spent on a given proposal, or how one would revise a proposal after participating in a review process.

I would discourage submitting a CAREER proposal solely for the sake of getting feedback that you can incorporate in a second submission. I do not really believe that that the reviewers' comments will be adequate, particularly if the proposal was not prepared well to start with.

5: Conclusion

As stated in one of the guides for proposal writing (<http://www.learnerassociates.net>), "Grant seeking is a multibillion-dollar-a-year business, if it were a single company it would rank at the top of the Fortune 500 list." The question is how large a share we faculty can grab from this

multibillion-dollar business. Despite all the uncertainties, this multibillion-dollar industry keeps my dreams alive.

I wish you all the best in your CAREER proposal preparation and other grant opportunities.

The Difference between a CAREER Proposal and a Regular Research Proposal –Tips on CAREER Proposal Writing

Wei Li
Department of Mechanical Engineering
University of Washington
Seattle, WA 98195-2600

Needless to say, winning a NSF CAREER award is very important to a new faculty just started his/her academic career. The CAREER proposal is different from a regular research proposal. In this short article, I will briefly discuss the differences between them, provide some tips on CAREER proposal writing, and share the outline of my CAREER proposal as an example.

1. The Differences Between a CAREER Proposal and a Regular Research Proposal

A CAREER proposal must have both research and education components. Although nowadays regular research proposals often address the impact of their research on education, the education component of a CAREER proposal should be much more substantial, demonstrating your commitment to education. After all, you are expected to be an excellent teacher as well as an excellent researcher.

While a regular research proposal has goals to answer specific scientific questions, the CAREER grant is intended to help establish the careers of promising faculty members who have potential to make significant impact. The proposed research of a CAREER proposal, therefore, should address not only specific scientific questions, but also how the research program will help build a solid foundation for the faculty's long-term career. For that, the long-term career goals of the faculty should be clearly identified and its relation to the proposed research clearly discussed.

2. Tips on CAREER Proposal Writing

The following tips are by no means complete, nor will they guarantee the winning of your CAREER proposal. But I feel they have helped in my proposal writing. Hope they will do the same in yours.

- Propose a research program that will help establish your career

A well-defined research program with clear long-term vision is critical to winning the CAREER award. You propose a five-year research plan. However, your career is much longer. You should discuss how the proposed research will help you to achieve your long-term career goals. A good way to think about this is to think about where you want your career to be in ten years and what you have to do in the first five.

- Build your research program within a supply chain

NSF looks for big impact research. One good way to show that your research will have big impact is to plug yourself into a supply chain for something bigger. Identify critical links of this supply chain, *i.e.*, to identify your collaborators. Discuss how others' research results can be used by you and how yours can be used by others. Work with your collaborators and get them to support your ideas.

- Get familiar with the literature of current education research

Education itself is a research area for many who study subjects such as how people learn and what constitutes effective communication. While you are not expected to conduct research in education, it carries a lot of weight if you make a connection between the approaches you will be taken and the findings of current education research. Developing new courses and recruiting woman and minority students are becoming standard language. Showing your understanding of education research can make your proposal stand out.

- Do not be afraid of repeating, use bold and italic fonts to emphasize key ideas

Keep in mind the reviewers may have 15 to 20 proposals to evaluate at the same time. Do not expect they will allocate a big chunk of undivided time to read your proposal. Your main points must be clear. Do not be afraid of repeating what you have said, of course, under the condition of not causing repetitiveness feelings. You can say it in different ways and at different places. The goal is to emphasize what you want the reviewers to remember. Another good way is to use bold and italic fonts for key words and sentences. These should be your punch lines. If the reviewers do not read your entire proposal, they should be able to get a pretty good idea on what you are proposing from reading these punch lines only.

- Be specific

Avoid talking too broadly on activities you plan to do. Specific information can help enhance the credibility. For example, if you plan to work with your College Center for Teaching and Learning, do not just say "I plan to work with the College Center for Teaching and Learning." Provide the name of a contact person. Show that you have consulted with him/her. Little efforts like this will help to convince the reviewers that you have done your homework and that you are serious about carrying out your plans.

3. The Outline of My CAREER Proposal

I listed below the subtitles of my CAREER proposal, as an example to show how a CAREER proposal could be structured. Since the titles are fairly self explanatory. I will just leave them as that. Good luck on your CAREER proposals!

Results from Prior NSF Support

1. Objectives and Significance

2. Relationship to the Current State of Knowledge in the Field

- 2.1 Relationship of the planned research activities to the current state of knowledge*
- 2.2 Relationship of the planned educational activities to the current state of knowledge*
- 3. Plan for Research Activities*
- 4. Plan for Educational Activities*
- 5. Project Timeline and Milestones*
- 6. Relation to the PI's Career Goals, Job Responsibilities, and Institutional Goals*
- 7. Summary of Prior Research and Educational Accomplishments*
- 8. Impact of the Proposed Research and Educational Activities*

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