Fellowship Application Primer

Los Alamos Dynamics Summer School

http://institutes.lanl.gov/ei/

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Some Fellowship Possibilities
NSF Fellowship
for 2013 2064 Fellowships awarded. 86 ME, 23 CE, 30 Aerospace, 48 EE, 98 CS, 11Nuclear;
for 2014 2053 Fellowships awarded. 93 ME, 21 CE, 24 Aerospace, 52 EE, 98 CS, 4 Nuclear ,
http://www.nsf.gov/funding/pgm_summ.jsp?pims_id=6201
DOD SMART Fellowships http://smart.asee.org/
DOD Fellowships, www.asee.org/ndseg
NASA Graduate Student Researchers Program, www.nasa.gov
DOE Physical Science Consortium Fellowships (www.npsc.org)
DOE Computational Science Graduate Fellowships (http://www.krellinst.org/csgf/)
DOE NNSA Stewardship Science Graduate Fellowship (http://www.krellinst.org/ssgf/)
Private foundations, (e.g. Hertz: www.hertzfndn.org)
Graduate Fellowships for Minorities in Science and Engineering (GEM)
(www.gemfellowship.org/)

Los Alamos Dynamics Summer School fellowship recipients or honorable mentions and graduate schools they attended (note this does not reflect the numerous students that have been awarded departmental or faculty research project fellowships)
Blue indicates students affiliated with the UC Campuses:

1. **Mandy Rutherford, 2000 Class, NSF Fellowship (Virginia Tech, UCSD)**
2. Dan Peairs, 2000 Class, NASA Graduate Fellowship (Virginia Tech)
3. **Jeni Wait, 2000 Class, Nat. Defense Science & Eng. Grad Fellowship (UCSD)**
4. Tim Johnson, 2001 Class, National Defense Science and Engineering Grad (Purdue)
5. **Tim Fasel, 2001 Class, Nat. Defense Science & Eng. Grad Fellowship (UCSD)**
6. Joshua Clough, 2001 Class, NSF Fellowship (Univ. of Maryland)
7. Scott Green, 2002 Class, NSF Fellowship (Industry then grad school)
8. **Colin Olsen, 2002 Class, Nat. Defense Science & Eng. Grad Fellowship (UCSD)**
9. Isaac Salazar, 2002 Class, GEMS Fellowship (Texas A&M)
10. Lillian Chang, 2003 Class, NSF Fellowship (Carnegie Mellon)
11. Kai Yu, LADSS 2003 Class, NSF Fellowship honorable mention (Carnegie Mellon)
12. **David Mascarenas, 2003 Class, GEMS Fellowship (UCSD)**

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13. Cory Rupp, 2003 Class, NSF Fellowship, (Univ. of Colorado)
14. Garnett Simmers, 2003 Class, DOE Physical Science Consortium Fellowship (Virginia Tech)
15. **Stuart Taylor, 2003 Class, NSF Fellowship (UCSD)**
16. John "Scot" Hart, 2004 Class, NSF Fellowship (Stanford)
17. **Heather Chiamori, 2004 Class, NSF Fellowship (UC Berkeley)**
18. Laura Jacobs, 2004 Class, NSF Fellowship (Georgia Tech)
19. Amy Askin, 2004 Class, Nat. Defense Science & Eng. Fellowship (Stanford)
20. **Eric Flynn, 2005 Class, NSF Fellowship (UCSD)**
21. **Catherine Whyte, 2005 Class, NSF Fellowship honorable mention (UC Berkeley)**
22. Manny Gonzales, 2005 Class, DOE Physical Science Consortium Fellowship (Northwestern)
23. Ben Kosbab, 2005 Class, NSF Fellowship (Georgia Tech)
24. Emily Prewett, 2006 Class, NSF Fellowship (Purdue)
25. Nathan Yoder, 2006 Class, NSF Fellowship (Purdue)
26. Steve Anton, 2006 Class, NSF Fellowship honorable mention (Virginia Tech)
27. Joel Marquez, 2006 Class, NSF Fellowship honorable mention (Texas)
28. Daniel Walker, 2006, NSF Fellowship (Stanford)
29. Christine Tower , 2007 NSF Fellowship (Stanford)
30. William Cash, 2007 Class, NSF Fellowship (Stanford)
31. **Tarisa Lerro, 2007 Class, NSF Fellowship (UC Berkeley)**
32. Stephen Schnelle, 2007 Class, NSF and Nat. Defense Science & Eng. Fellowship (Rice)
33. **Ken Ogorzalek, 2008 Class, NSF Fellowship (UC Berkeley)**
34. Yan-Jin Zhu, 2008 Class, NSF Fellowship (Northwestern)
35. Michael Garcia, 2008 Class, NSF Fellowship (Arizona St.)
36. Peter Radecki, 2008 Class, Nat. Defense Science & Eng. Fellowship (Cornell)
37. **Scott Ouellette, 2009 Class, NSF Fellowship (UCSD)**
38. **Colin Haynes, 2009 Class, NSF Fellowship (UCSD)**
39. **Dustin Harvey 2009 Class, NSF & Nat. Defense Science and Eng. Fellowships (UCSD)**
40. Jenni Rinker, 2011 class, NSF Fellowship (Duke)
41. Ezra Jampole, 2011 class, NSF Fellowship (Stanford)
42. Adam Hehr, 2011 class, NSF Fellowship (Cincinnati)
43. Justin Scheidler, 2011 class, NSF honorable mention, NASA Aeronautics Scholarship (Ohio St.)
44. **Sydney Sroka, 2012 class, NSF Fellowship** (M.I.T.)
45. Gordon Chipka, 2012 class, NSF Fellowship (Cornell)
46. George Lederman, 2013 class, NSF Fellowship (Carnegie Mellon)
47. Ben Winter, 2013 class, NSF Fellowship (Michigan Tech)
48. Garrison Stevens, 2013 class, NSF honorable mention (Clemson)
49. Jessica Block, 2013 class, NSF Fellowship (Georgia Tech)
50. David Goodman, 2013 class, NSF Fellowship (Michigan)
51. Kaitlyn Kliewer, 2014 class, NSF Fellowship (Princeton)
52. Elizabeth Wheeler, 2014 class, NSF Fellowship (Clemson)
53. Hannah Ross, 2014 Class, NSF Fellowship (Washington)

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Proposal Writing Advice for Fellowship Applications

Chuck Farrar:
If the fellowship application does not define specific topics that should be addressed in the research proposal, then a good way to organize the proposal is to answer the "Banker's questions":

1. What are you trying to do?
2. How is it done today, and what are the limitations of current practice and previous approaches?
3. What is the new approach, and why do you think it will work?
4. Assuming success, how important is it, and what are the implications (e.g. life safety benefits, economic impact/competitiveness)?
5. How long will it take? What will it cost? What are the "midterm" and "final" exams? (note: "time" and "cost" issues may not be appropriate for fellowship applications)

Even if there are specified topics to be addressed in the proposal, make sure somewhere within these topics you address the "Banker's Questions"

Read the application material and find out how the fellowship sponsor will be "grading" the proposal and application. Make sure you address all of these grading criteria in your application. The review sheets that former students have provided show the "grading criteria" for an NSF Graduate Fellowship.

Remember the people reviewing your fellowship application are reviewing lots of applications. You want to **GRAB** their attention in the first two sentences of your research proposal. You want to stand out from the rest of the applicants. Also, you want to make the reviewers curious and excited to read the rest of the proposal. Here is an example from a proposal I did: "*We propose to develop a technology that can be as society-serving as any ever conceived at Los Alamos. That technology is referred to as "Damage Prognosis"*. Realize that the rest of the proposal has to support this type of strong opening statement otherwise this tact may backfire.

Use heading, bold-face type, italics to help the reader extract information from your proposal (See Joshua Clough and Scot Hart's Proposals, Eric Flynn's advice). Remember the reviewers are looking at a lot of proposals. Make it easy for them to find the key points in your proposal.

Listed below are some of the negative statements that I've pulled out of the reviewers' comment pages. You should try to make sure your proposal material does not have any of these short comings. Note that a lot of these comments are on the "broader impacts" portion of the proposal.

"Broader impact question not directly addressed"
"…should seek additional opportunities to serve his community. He has much to offer society, but lacks a strong vision of that purpose"
"..few cited references"
"not much outreach or diversity"

"…encouraged to think how to have a more specific, broader impact"
"Proposal does not spell out a clear plan for encouraging diversity and broadening opportunities"
"Research hypothesis was not formulated as a scientific question"
"no discussion of future efforts in this area (broader impacts)"
"proposed research has compelling need, but essay does not convey a clear research question with supporting objectives and task"
"Need to provide clear integration of research and educational goals (past and future)"
"Weak service record and broader commitment to scientific education"
"You just need to tie your research plan to benefit society"
"It would be nicer if you indicated how as an NSF fellow, you would continue to engage and actively participate in educational outresearch"
"The plan is sell described, but would benefit from a more well defined research question"
"Proposal would benefit from a more detailed plan"
"The applicant does not mention broader impact in any way in personal statement. Instead, broader impacts is only discussed almost as an after thought in research proposal."
"The plan of research is relatively weak in spite of your excellent preparation"
"You show little interest in integrating research and education."
"The research plan addresses the benefits of the work to the discipline and to businesses but does not talk about the benefits to society."
"The applicant has previous research experience but it has not resulted in any publications to date"

James Smith, Texas Tech University,
(James served on NSF fellowship review panels for 3 years).

The research statement is very important and one place where the student can have significant input. Be very specific. Most successful awardees have specific research programs and have usually been involved in publications and presentations of their research work. They also have a continuing involvement of research, with many starting in their freshman year. The worst thing an applicant can write is "I am interested in several areas of research for my graduate work and I will try to take a variety of courses in grad school to see where I might want to develop a research program".

Another area that is important from a personal statement perspective is involvement in outreach or community service activities, especially if they can relate to the student's educational background. Volunteering at the local charity of choice car wash is probably not going to win any points, while a project at the State School where a new system was designed to help the students or school operate easier or better would be much more powerful.

Another important area is the letters of recommendation. Make sure that the student gets very strong letters. I have seen students hurt by a letter that basically says that the student was a good student. The best letters start by saying that "Joe Blow was among the best students I have taught in my 20 years of teaching. He/she made significant contributions (discussing specific projects, research or otherwise)." The more details that a reference can provide, the stronger the case and the more assurance that the review panel has that this is truly an outstanding student worthy of a NSF Fellowship. Letters should not be over 2 pages long, however.

Finally, areas where the student has little control are gpa, gre scores, institution attended, etc. There is some strength if a student specifically identifies the grad school where he/she will use the Fellowship.

These are obviously very highly competitive Fellowships. It is not uncommon to review a student from a place like MIT or Cal Tech with a 3.75 gpa, gre scores over 1300 (v+q) with mediocre research plans and have the committee basically wonder why the student thought he/she might be competitive. Outstanding letters of reference and personal statements can make a huge difference here!

Darryl James, Texas Tech University
(Darryl has served on NSF fellowship review panel).

First, realize that during the initial proposal reading you must grab the attention of the reviewer quickly. I would estimate that each initial review is performed in about 10 minutes; therefore, you need to stand out. This can be accomplished by making your proposal easy to follow with well thought out headings to guide the reviewer. Tie your personal statements to the proposal and make it concise.

In the proposal description, it helps if you have some preliminary results to present. Also, make sure that you reference prior work relevant to your proposal so that you convey to the reviewer that you have done your homework. It helps if you have prior conference, or journal, publications as this demonstrates to the reviewer the capability of working in a research environment. Try and be specific with regards to your proposed research. Remember that you are competing with hundreds of other well qualified students.

It is very important to realize that the intellectual merit (IM) criteria and the broader impacts (BI) criteria carry equal weight. I read many quality research proposals that did not make the top quarter because of the BI. In the BI it is not enough to philosophize, you need action. By that I mean you need to have actively participated in activities that address each of the topics listed under BI.

Glenn Y. Masada, University of Texas at Austin
(Glenn has served on the NSF panel for three years)

Professors Darryl James and James Smith have addressed a number of critical issues. I will add or emphasize a few more.

1. The Broader Impact statements in Essay 1 are very, very important—they can easily take an excellent Intellectual Merit application down to the honorable mention category. The strongest statements show **demonstrated** evidence of **committed** contributions. For example, to benefit society, a student may have for the last four years volunteered in Salvation Army kitchens,

Habitat for Humanity, Area Food Bank, etc. Better yet, the student organized peers to participate—shows leadership as well as contributions to society. Statements such as, 'I have plans to (address these criteria)....', do not resonate well with panelists. Students that commit to and integrate broader impact criteria into their daily lives stand out among the rest. Also understand the criteria—one does not adequately address encouraging diversity by being a woman or minority applicant.

2. Make your strongest statements early in the essays. Panelist have only 10-15 minutes to assess the entire application, so strong early statements make the reader more interested in carefully reading (rather than skimming) the rest of the essay.

3. Students must have Previous Research Experience to be competitive—many applicants have two or three projects to write about. Work done on 'Senior Design Projects' should not be included in this category—gives the impression that you do not understand research.

4. Take the GRE. What do you have to hide?
   The degrees to which the GRE scores influence panelists vary widely.

5. Get the best letters of recommendations you can, preferably from faculty members. It is better to get an outstanding letter from an 'unknown' faculty member than to receive a lukewarm letter from a well-known faculty member. Letters from industrial/governmental contacts are good if they are very strong, address specific evidence on your potential to do independent research work, or show that your contributions have made a significant impact on their industry.

6. Use action verbs and descriptive adjectives in your essays and make your statements come alive—make liberal use of the Thesaurus.

The NSF Graduate Fellowship Selection Process, Lori Olson, Rose-Hulman Institute of Technology

All of the applications are evaluated by a panel of engineering faculty from a variety of schools, including research and teaching schools. Applicants for the same field (e.g. Mechanical Engineering) are evaluated by the same panel. This year the mechanical engineering panel we participated in had more than 20 members, and evaluated roughly 400 applications. The applications are sorted by level: level 1 is for those who are in their final undergraduate year, level 2 is for those who have just started their graduate programs, and there are also levels 3 and 4. While all those who are in level 1, level 2, etc are evaluated simultaneously (with criteria appropriate to the level), the final decisions on who to fund are not done by level.

NSF has two basic criteria for evaluating the applications: intellectual merit and broader impacts. ***They are weighted equally***. After a "calibration exercise" which is designed to arrive at a kind of panel-wide understanding of what would constitute intellectual merit and broader impacts, each application is read by two panelists and scored (out of 50) in each category. One panelist reads a single application in about 15-20 minutes. Panelists can not read any applications for which they have a conflict of interest (e.g. the student is planning to attend the graduate school that the panelist is affiliated with and work with that panelist).

At the end of these the reviews by the two panelist, applications get two Z-scores, where

$$Z = \frac{\text{Applicant's Score} - \text{Mean Application Score for that Panelist}}{\text{Application Standard Deviation Score for that Panalest}}$$

The Z-score is created to adjust for the fact that some panelists score applications much higher (on average) than others. The average of the Z-scores is used to rank the applications. Applications in the top 35% of the ranking get a review by a third panelist, as do any applications that have a wide discrepancy on their Z-scores. (The discrepancies are identified by computer and by the panelists.) The remaining 65% of the applications are retired, meaning they get no further consideration. After the third review, applications that have widely varying Z-scores are returned to the 3 panelists for additional discussion and a resolution.

Finally, a new ranking of this top 35% group is created from the mean of the three Z-scores. The top 20 or so in this ranking are in Quality Group 1 who are recommended for definite funding. (Notice that this is only 5% of the applications.) The next 40 or so are in Quality Group 2—honorable mention and possible funding. The top people in this group may get funded, depending on available resources. Also, this group is screened for recipients of special focus awards, programs for under-represented groups, etc. and such decisions are made by NSF The next 40 or so are in Quality Group 3—honorable mention. The rest are in Quality Group 4 and don't get an award. In the end, roughly 10% of those *who apply* for these fellowships will receive them. The applicants are all amazing individuals.

ADVICE FROM FORMER LOS ALAMOS DYNAMIC SUMMER SCHOOL STUDENTS REGARDING THE GRADUATE FELLOWSHIP APPLICATIONS PROCESS

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Yan-Jin Zhu, LADSS '08 NSF Fellowship winner
1. The IMAC conference proceeding helped a great deal as the rating paper have indicated. So work hard.

2. The first time I applied, I was very concerned with the application formatting. But I think this time, I wasn't as concerned. The formatting seemed different from one application to another. The best way to present yourself to the panel of reviewers is the best way to write the paper. That is how I wrote my personal statement.

3. I think the first year graduate students are at an advantage when it comes to NSF proposals because seniors who applied for NSF have a lot of uncertainty in their future to write exactly what they want. Then, the second year graduate students are put to a higher expectation. However, I think what helped my application is that I mentioned the reason I picked my graduate school, the step by step research plan and the reason why the school I choose was the best for my research plan, and the educational component that enhance the research proposal. I use each paper to emphasize each of these points.

4. I was very fortunate to have worked on a project that I can built upon to develop my proposal. I think this made my application even stronger because I had a background in this area. Thus, I think it's a good idea to write about something you know, instead of something you think that the panel would like. It's hard to please all 3 random reviewers.

Stephen Schnelle, LADSS '07 NSF and NDS&EG Fellowship winner
For NSF, I started pretty early in grad school with a club promoting math and science in middle-schools here in Houston, and I made sure to emphasize that. I also had started talking with a professor in the ME/Civil department at Rice, and I think NSF really likes interdisciplinary work (note Stephen is an EE). Also, last year when I had applied, I had not included any references in my work, and the reviewers did not appreciate that, so I corrected that this year. For applying to the DoD (NDSEG) fellowship, ASEE wants contact information to verify everything (whether they actually check, I don't know) and dates for all memberships and awards. Hence I started gathering this well before starting on the essay. The essay is quite short for DoD, especially since NSF was due in November and DoD in January, filling 3000 characters was not difficult. (Staying within the limits actually more of a problem throughout application, even when they just ask for a summary of leadership activities, teamwork activities)

Ben Kosbob, LADSS '05, NSF Fellowship winner
I applied last year, but had no assistance about my research proposal from anybody. This year, I had great interaction with my graduate advisor to tweak the proposal and, even though my other two essays were nearly unchanged, the reviews were much better. The proposal seems to be extremely critical, and is up to the reviewer to decide what it should look like. For instance, last year I went with a very detailed plan, and was scathed by not developing the motivation enough. This year, I had a very thorough motivation and a fairly general "plan" and, while I received a fellowship, one reviewer felt the plan was rather undeveloped. Luck of the draw, I say.

Eric Flynn, LADSS ’05, NSF Fellowship winner

- The broader impacts criterion is important. Make sure you hit ***every*** topic, and you hit it hard.
- Remember that you aren’t committed to follow your research plan. You aren’t committed to your chosen school or major either. In fact, you aren’t required to do anything remotely close to what you propose (it probably still has to be in science). I ended up with a different advisor, at a different school, with a different major, and a different research topic.
- With the previous bullet in mind, tailor your research proposal to fit the scoring criterion (especially broader impacts). If your research proposes to improve engine performance on luxury sports cars for the richest 0.01% of the country, come up with a different topic. If that’s really your thing, you can always go back to it *after* you get the award (assuming your conscience will let you). Just make sure that your credentials show that you are capable of completing the proposed research.
- Divide your essays into sections. Your reviewers will be going through dozens of these, and nothing will make them more frustrated than a two page block of text. Even putting an extra line between paragraphs is a relief. Having headings for each section will give the reviewer a layout of the breadth of your experience.

Laura Jacobs, LADSS ’04, NSF Fellowship Winner

The broader impacts criterion is weighted equally with the intellectual merit criterion. You should be sure to include statements that incorporate what they are looking for as part of the broader impacts criterion in your personal statement and your research proposal.

Give yourself plenty of time to write all three essays, because these are what are going to set you apart from the other applicants. Get started early, the deadline approaches a lot faster than you might realize, especially when you are really busy. Remember that you are going to be working on this application at the same time you are applying to graduate school and maybe even doing your senior design project. Research what is being done in the field that interests you. You may be inspired and you will find some background information to include in your proposal. Have other people read through what you have written.

Heather Chiamori, LADSS ‘04, NSF Fellowship Winner

It helps to discuss your proposal and ideas with many people- especially professors, mentors, and graduate students already involved in your area of research interests.

Write more than necessary— then tighten the proposal later. Writing, letting the draft “rest” then rewriting (multiple times) is a method that works for me. It is easier to write when your mind is fresh and you’ve had a chance to step away from the material. Starting the proposal earlier helps— you won’t be as rushed as the deadline approaches and you still have applications and finals to consider. It is also extremely helpful to look at previous successful proposals like those in the document Chuck gave you and/or those available in your graduate school offices.

Scot Hart, LADSS ‘04, NSF Fellowship Winner

My biggest piece of advice for the NSF fellowship is to spend a significant amount of time on your proposal. I have a feeling a lot of applicants spend only an hour or two cranking out a proposal and its got to be pretty easy for the reviewers to tell who spent the time and who didn't. I personally chose to write my proposal on two topics I have some background in, turbomachinery and structural health monitoring. Not only was it easier to write on topics I knew a bit about, but I figure it had to look good to have a common theme to both my past and proposed research. At the same time however, don't be afraid to write about something that sounds a little crazy. Complex difficult proposals that sound like they'll take at least 5 or 6 years to complete are really what the reviewers are looking for. I also suggest doing some library research before hand so you can include a reference or two (just remember references take up space, which is very limited). Have a professor or your mentor from Los Alamos read over each rough draft you compose. I had 4 rough drafts of my proposal before I finally got to one I had enough confidence in to submit. Remember professors and mentors are excellent resources for figuring out just what to write about and how a good proposal should be written. I wouldn't have gotten anywhere if it weren't for all the help I got from one of my professors. In fact, here is some of his advice:

- Use as many advanced technological terms as possible (MEMS, fiber-optic, wireless, etc.)
- Multidisciplinary topics are always a plus, and so is the actual word *multidisciplinary*.
- Have a legitimate reason (like a certain professor or a particular lab) for selecting the school you say you wish to attend. Don't just say I want to go to so and so university because it's the number one ranked school in the country. (And remember you don't actually have to go to the school you write about in your application.)

Also, I have a bit of advice on the Hertz Foundation fellowship. They only give out 20 or so Hertz fellowships a year and have an application pool consisting of all the science and engineering students in the country. As such, it's probably the most prestigious of the fellowships. Luckily it's a relatively easy application and there is a decent chance of getting honorable mention (which is definitely a *huge* resume boost but doesn't come with any money). I highly suggest sending in the application; just don't get your hopes too high. Its also good practice for writing the longer more detailed applications such as NSF, Homeland Security, etc. that have later due dates.

Cory Rupp, LADSS '03, NSF Fellowship Winner, Finalist Hertz Foundation Fellowship
For NSF fellowships you do not have to use the full three years of funding. You can use this fellowship just for a 2-year MS degree. You do not have to go on for a Ph. D. Also, you can take a break. The NSF provides the funding for three years and you can take up to five years to use this funding.

The proposed research is NOT expected to be carried out. This is very important, it allows the student to write about more than they are capable of. From my understanding, the proposal is used to give the reviewer an idea of the student's creativity, academic background/abilities, and ability to focus ideas into a possible real proposal in the future.
-start writing down specific ideas now, no matter how crazy. Not-so-good ideas can be sifted out later, but at least they are there occupying an otherwise empty list.
-Do NOT procrastinate. It takes MUCH longer than one would think.

-Discuss proposal ideas with professors, grad students, etc.
-Talk to references very early (four are needed), pick them well. The references are probably the most important part of the application. Make sure they don't just use a generic letter, it won't make the application look bad but it may hurt it overall because it will stick out less.

The DoD and Hertz are very different. The DoD has three VERY short essays (limited to only 1700 characters or so) making it difficult to get anything across well. Not exactly sure what they are looking for.

The Hertz application is kind of strange. The questions are relatively simple and standard. Be sure the references have PLENTY of time to write and submit as it is ridiculously long (ask Pete). If chosen for an interview, be very scared (until the interview of course) and very brushed up on fundamentals (Calc, basic mechanics, any previous research). It is fashioned after a graduate oral exam and probably as difficult as one (I know very few people who would be able to get through it without a hitch, and I am not one of them).

Kai Yu LADSS '03, Honorable Mention NSF Fellowship
I would encourage the applicants to start as early as possible, because it is difficult to write fellowship and graduate school applications while taking classes. Talking to professors is very useful, because they can help tell you the general research trends.

Tim Fasel, LADSS '01 Winner National Defense Engineering and Science Fellowship
I would say my only real advice is that NSF appears to take that whole broader impact criterion thing much more seriously that I would have thought. On one of the rating sheets I got a pretty low score apparently because the reviewer did not like the stuff I made up about helping the community. So you better make up something good (or actually have done something good) if you are applying to NSF.

Joshua Clough, LADSS '01 NSF Fellowship winner
This fellowship has given me a wonderful opportunity and I would highly recommend everyone to apply for it. The best advice I can give, especially regarding the research proposal, is to not be too concerned about the specific topic chosen. I spent a lot of time trying to decide what topic I would really want to cover for my research, but eventually realized that this proposal is not a commitment to actually do that work, but just an opportunity to demonstrate the ability to define a problem and an appropriate approach to solving it.

EXAMPLE RESEARCH PROPOSALS FROM LADSS STUDENTS THAT EITHER WON OR WERE HONORABLE MENTIONS IN NATIONAL SCIENCE FOUNDATION OR NATIONAL DEFENSE SCIENCE AND ENGINEERING GRADUATE FELLOWSHIP COMPETITION

IN SOME CASES, THE NSF REVIEWER COMMENTS ARE ALSO PROVIDED

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NSF Research Proposal – Joshua Clough - 2001

The biggest limitation of modern space travel is the cost of reaching orbit. The Space Shuttle, although an amazing machine, is very expensive and inefficient. It costs approximately $10,000 to carry one pound of payload into orbit on a Space Shuttle [1] and the minimum turnaround time between missions is approximately two months [2]. Further progress in space requires a less expensive means of transporting people and cargo into orbit. Scramjet propulsion is a technology that could be used in the next generation of vehicles designed to reach space. Scramjet, or Supersonic Combustion Ramjet, uses oxygen from the atmosphere for combustion, eliminating the need to carry oxidizers in tanks, like the Space Shuttle rocket propulsion. A Scramjet powered aircraft would also fly horizontally, using aerodynamic lift to carry the aircraft, not just pure thrust, like the Shuttle.

While Scramjet is a promising technology, much research is still needed before it will be completely functional. At the hypersonic speeds for which Scramjet is best suited, the integration of the engine and airframe is essential. So, research is needed on the shockwave dynamics, engine inlet and exit configurations, and on the structural design of possible airframes. The airframe design needs to optimize the airflow into the engine as well as help provide aerodynamic lift.

I would be interested in researching the integration of the airframe and engine for Scramjet propulsion. More specifically, I would want to find out what designs encourage the best combination of airflow into the engine and aerodynamics for the plane. This research would involve four main phases: research into the hypersonic shockwave and aerodynamic theory, computer modeling of various designs, wind tunnel testing, and, if possible, flight tests.

Theory and Past Research

The first task of any research work that I would do would be to research the theory and past work that has been completed in the field. For Scramjet propulsion, I would delve into the gas dynamics behind shockwave propagation and the high-speed aerodynamics needed to keep the aircraft aloft. Since this would not be the first work ever done on Scramjets, I would also want to learn about past research that has been done in the field. I have no desire to re-invent the wheel, so I would try to find out what areas have been researched heavily and what areas are still more of a mystery. However, at the same time, I would still be skeptical and not assume that just because research has been done, that aspect is no longer of interest. I have actually done some of this research work already, in completing my final report on Scramjet Propulsion for my Technical Communications class and a report on the Hyper-X program for my Propulsion Systems class.

Computer Models

For Scramjet research, only limited tests can be performed in wind tunnels and flight-testing is expensive, so the use of computer simulated tests is especially important. The creation of computer models and simulations helps with the design of experiments, and validates experimental results. Finite Element or CFD codes can be used to model experimental situations. By testing the system on a computer, poor designs could be eliminated early. Computer modeling can also help design testing procedures by presenting a general view of the system response. With this overview of the system, I would be able to see more clearly what would be observed and would need to be measured in wind tunnel and flight tests. This type of modeling was one of the main focuses of my work at Los Alamos National Labs this past summer.

Wind Tunnel Tests

While computer modeling is very powerful, there is still no substitute for actual, real-world tests. Wind tunnel tests could be used to validate the computer models and to account for the myriad of details that cannot be modeled. These tests would be performed on different, predetermined shape models, and designed using the Design of Experiments techniques I have learned to help understand what features in the engine/airframe configuration most effect performance.

Flight Tests

If resources were available, flight tests would be the final phase of the research. NASA's Hyper-X project is an example of a Scramjet flight test program. Of course, the resources needed for a project of that magnitude are far beyond what might be available to me as a graduate student, but in an ideal situation, that would be the final stage of my work.

I believe that research in better engine/airframe integration would help lead to a fully functional Scramjet engine, and to a more efficient means of reaching Space. The steps needed to complete this research would be study into the theory behind Scramjet propulsion, research regarding past work on Scramjet propulsion and engine/airframe integration, computer modeling and simulation to help understand the important aspects of engine/airframe integration, wind tunnel tests to validate the computer models, and if possible, flight tests to prove the feasibility of the results. By completing these steps, I could contribute to the better understanding of Scramjet propulsion and help lead to the next generation of space launch vehicles and the future of space travel.

References

[1] Heiser, W. and D. Pratt. 1994. *Hypersonic Airbreathing Propulsion*. Washington DC: American Institute of Aeronautics and Astronautics.

[2] Shuttle reference. *NASA Spaceflight Homepage*. http://spaceflight.nasa.gov/shuttle/reference/ (01 November 2001).

NSF Research Proposal – Cory Rupp - 2004

A major focus of my research at the Center for Biofilm Engineering has been finding the material property data of bacterial biofilms. We have found conclusive evidence that biofilms are viscoelastic and can be modeled by the linear viscoelastic Burger's model (Towler et al., 2003). Evaluation of the parameters governing this constitutive law, however, has been far from easy. This statement is not restrictive to biofilms or the Burger's model alone but is also true of viscoelastic materials in general.

The constitutive law of a viscoelastic material can be represented by mechanical models consisting of combinations of springs (elastic elements) and dashpots (viscous elements). The Burger's model is an example consisting of a Maxwell model (a spring and dashpot in series) connected in series with a Kelvin model (a spring and dashpot in parallel). We found this model to be the best mechanical analog for the material properties of biofilms. Other materials, however, require a larger number of elements to quantify the whole response of the material. Once a mechanical analog to a material is found, the values of the parameters making up the model must be determined. The difficulty of this task increases greatly with each element added to the constitutive model because each element adds a degree of freedom to the problem. Most methods for finding the parameter values, usually curve fitting algorithms, have trouble with this problem. Even a new algorithm based on the minimization of weighted residuals developed specifically for this problem has difficulty with large numbers of elements. I propose here a new method for extracting viscoelastic parameters based on mechanical analogs through the means of experimental application of theoretically derived stress functions.

Linear viscoelasticity theory is heavily reliant on the Bolzmann superposition principle by which the response function can be separated into a sum of individual component response functions (Christensen, 1971). As mentioned above, the larger the number of elements, the more difficult it is to find their values. Solving for the parameters of a small number of elements is thus an easier task. Because a viscoelastic model can be separated into its individual parts, it may be possible to isolate smaller sets of elements for examination from which the parameters can be easily extracted. This process would constitute a new iterative procedure for parameter extraction which would be done by a combination of experimental and theoretical techniques.

The first step in the procedure would consist of performing a standard constant stress creep test from which the experimental creep compliance $J_e(t)$ would be found. From the compliance, the experimentalist would choose the simplest mechanical analog to fit the data and retrieve the parameter values. This step would be relatively simple as long as the number of elements is small. A theoretical compliance function $J_T(t)$ could then be formed from the mechanical analog, which would be a crude representation of the true compliance. The theoretical compliance would be the sum of the individual compliances of the established simple mechanical analogs provided in previous iterations,

$$J_T(t) = \sum_k J_k(t) \approx J_e(t)$$

where $J_k(t)$ is a simple mechanical analog. A stress function σ(t) would then be derived from the theoretical compliance for which the theoretical strain response ε(t) is unity or a minimized function of time that would provide for experimentally applicable stress and strain functions.

$$\sigma(t)J_T(t) = \varepsilon(t)$$
$$\varepsilon(t) = 1 \qquad or \qquad \varepsilon(t) = f(t)$$

The stress function, when applied in a new experiment, will produce a new compliance response from which the theoretical compliance can be easily separated through Bolzmann's superposition principle. The remaining residual response is then a function of the only the remaining parameters to be defined. The residual would then be used in the next iteration to find the next set of parameters. Iteration would end when the theoretical compliance is sufficiently close to the original experimental compliance or the residual response is sufficiently close to zero.

Research involved in evaluating this method would include a theoretical assessment of possible stress and strain functions that would be best for the method and verification that the method is a viable solution to the problem of finding parameter values. Theoretical assessment of the method would comprise of finding the mathematical restrictions of the procedure. The set of stress functions that would be used in this method are limited by their experimental applicability. This also applies to the set of strain functions. These functions cannot have any singularities or discontinuities and must be of the same scale as the original compliance function. The function must also stay within the linear range of the material so that linear viscoelasticity theory is still applicable. A theoretical investigation may reveal optimum stress and strain functions for a given theoretical compliance or it may reveal problems that could be used to refine the method.

The purpose of the proposed method is to find the best mechanical analog constitutive law for a viscoelastic material. An important question arises to as whether of not this statement is true. Part of the verification procedure that would need to be done as a part of the research is to answer this question. A number of studies would need to be done. One of the first steps would be to verify that the final model successfully represents the properties of the material. Various kinds of experiments such as oscillation or relaxation tests could be performed and compared to the analytical solution provided by the model. Another step would be to compare the parameter values to those produced by alternate methods such as curve fitting of the whole response curve. Validation is the most important part of the research into using the method.

If the parameter extraction method presented in this proposal is an effective solution, it will make defining the properties of viscoelastic materials easier and possibly more accurate. It is possible that the method could also be applied to other types of materials, albeit in a different form. The combination of experimental and theoretical ideas into the same process is a method that could prove useful not only in viscoelasticity but also in experimental science as a whole.

The Mechanics program at the University of Minnesota – Twin Cities has many professors who specialize in non-linear mechanics. Viscoelasticity is a prime example of non-linear mechanical behavior. Although my proposed plan of parameter finding may not end up as a viable solution to the parameter extraction problem, it involves the type of abstract thinking that is needed in non-linear studies. I am very interested in the subject of non-linear mechanics and believe my background in viscoelasticity theory will help my studies in that area.

References:

Christensen, R. M. 1971. “Theory of Viscoelasticity: An Introduction.” Academic Press, New York.

Towler, B., Rupp, C., Cunningham, A., Stoodley, P. 2003. "Linear viscoelastic constitutive law for a mixed culture biofilm from rheometer creep analysis." Biofouling. In press.

2004 NATIONAL SCIENCE FOUNDATION GRADUATE RESEARCH FELLOWSHIPS

Rating Sheet

APPLICANT: Rupp, Cory James

PANEL: MECHANICAL ENG (U1) FIELD: E/MECHANCS

INTELLECTUAL MERIT CRITERION	Excellent	Very Good	Good	Less Competitive	Insufficient Basis for Judgment	
Proposed Plan of Research:	X					7.[illegible]
Previous Research Experience:	X					10
Academic Record:		X+				8.2
Reference Reports:	X					9.1
GRE Tests Scores:				X		3.[illegible]

BROADER IMPACTS CRITERION *Past, current, and future efforts to:*	Excellent	Very Good	Good	Less Competitive	Insufficient Basis for Judgment	
Foster integration of research and education:		X				7.8
Advance diversity in science:			X			6.5
Enhance scientific and technical understanding:	X					8.4
Benefit society:	X					8.4

COMMENTS TO APPLICANT: GRE verbal & particularly analytic scores not competitive, letters extremely good! really exceptional Prior work ++

· Broader impact question not directly address, but indirectly indicated through actions

Reviewer comments to the applicant on this rating sheet should be constructive and reflect the two NSF merit review criteria. Upon request, NSF will send the applicant a copy of this rating sheet without the name of the reviewer. Maximum protection will be given to the reviewer's identity subject to the policy stated above and the Freedom of Information Act, 5 usc 552.

05549 Rupp, Cory James

Panelist Code:	SCORE	SCORE CHANGE 1	SCORE CHANGE 2
U1K	2.00		

Review of Cory Rupp's NSF Proposal

Los Alamos

Dynamics Summer School

NSF Research Proposal – Tim Fasel - 2004

Many aerospace, civil, and mechanical systems continue to be used despite aging and the potential for damage accumulation and unpredicted failure. The 1994 Northridge earthquake showed that steel moment-resisting frame structures are susceptible to brittle joint failure. During this earthquake, over 70% of steel frame buildings in Northridge suffered from some form of damage at moment-resisting joints. However, many of the damaged joints remained undetected until one was accidentally found. The cost of visually inspecting a single joint, by removing the architectural cladding and fire retardant, was approximately $10,000. There are currently many nondestructive evaluation (NDE) techniques for identifying damage in structures. However, these NDE methods are based on costly visual procedures or localized experimental methods such as acoustic or ultrasonic methods, magnetic field methods, radiograph, eddy-current methods and thermal field methods [1]. These approaches are limited in usage, as the vicinity of the damage must be known *a priori* and easily accessible. If a damage detection method using sensors embedded in a structure can be developed, it would constitute a more economical and quantifiable technique than is currently available. Such a damage identification scheme can potentially provide significant life-safety benefits by preventing unforeseen catastrophic failures and can reduce total maintenance costs through automated assessment.

These structural health monitoring (SHM) schemes often involve extracting damage-sensitive features from structural vibration responses. I propose to research the capability of guided waveforms to probe structures for damage. These guided waveforms include Rayleigh-Lamb waves, which are useful because an exact analytical solution for their propagation is known. I want to use the Rayleigh-Lamb waves in conjunction with a time reversal technique, which involves emitting a test signal from one embedded sensor and receiving the signal at various other sensor locations. These received signals can then be time-reversed and re-emitted from those sensor locations back to the source. Under certain assumptions, such as narrow bandwidth of the originally emitted signal, the detected signal at the source should be identical (exactly correlated) to the originally emitted signal (within some minimum noise floor). If damage is present in the signal paths, the time-reversed signal will be less correlated with the originally emitted signal than if no damage were present. This loss in correlation occurs because it is developed using an assumption of linear propagation through the structure, and damage most commonly produces local nonlinear propagation. Therefore, the time reversal method appears to be an excellent candidate for identifying and localizing damage within a structure. This method also solves a large problem with guided wave interrogation, which is signal-to-noise ratio. One mechanism that degrades this method is waveform dispersion, or the fact that waves at different speeds propagate at different velocities. One new and interesting area which I wish to investigate is the design of specialized waveforms that are tunable-bandwidth but have minimized spectral leakage, as these characteristics will minimize dispersion and maximize signal-to-noise ratio, allowing optimal resolution in detection capability.

Another new area of particular interest is the use of deterministic chaotic waveforms for interrogation of damaged structures. Chaotic waveforms are inherently low-dimensional (as opposed to, for example, white noise) and may be used to study the steady-state dynamic response of a structure, as opposed to the transient properties of other waveform-based methods. The low-dimensionality of the signal makes analysis of the steady-state chaotic attractor, for changes due to damage, possible. The works of Todd et al. [2-4] have shown that if low-frequency chaos is imparted to the structure, the resulting steady-state chaotic structural response can be analyzed for damage-sensitive features such as attractor variance or cross-prediction error. I propose that chaotic waveforms may be shifted to the higher frequency range of normal Rayleigh-Lamb propagation to investigate the interaction between the chaotic waveform and crack initiation sites. I believe the nonlinear interaction between the two may result in signal amplification or even bifurcation, resulting in a very sensitive detection strategy with very little energy imparted into the structure.

I became interested in the area of SHM while working for Los Alamos National Laboratory over the last two years. I began by attending the Los Alamos Dynamics Summer School, which is an eight week program over the summer in which 12-15 upper-level undergraduate or first-year graduate students come to learn about the field of structural dynamics. All students must also work on a project that results in submission of a paper to a conference. I enjoyed this program so much that I returned the next year, after I had finished my undergraduate education, to work full-time at Los Alamos National Laboratory in the field of SHM. During this time I produced two conference papers and submitted a full review of work I had completed for publication in the Earthquake Engineering and Structural Dynamics Journal. In this paper, I investigated the applicability of an auto-regressive model with exogenous inputs (ARX) in the frequency domain to SHM. I extracted damage sensitive features from the ARX model that explicitly consider nonlinear system input/output relationships. Furthermore, because of the non-Gaussian nature of the extracted features, I employed Extreme Value Statistics (EVS) to develop a robust damage classifier. EVS provides superior performance to standard statistical methods because the data of interest are in the tails (extremes) of the damage sensitive feature distribution. I applied this ARX/EVS approach in the laboratory using vibration data obtained from a scaled three-story building model. I found that the vibration-based method, while able to discern when damage is present in the structure, was unable to localize the damage to a particular joint. This research led me to investigate an impedance-based active sensing method using piezoelectric (PZT) material as both an actuator and a sensor as an alternative solution to the problem of damage localization.

I believe that the University of California, San Diego, is an excellent school at which to study these research topics. It is the only university in the nation to have an engineering department holistically dedicated to structures. It is also home to the Charles Lee Powell Structural Laboratory, which has the USA's largest reaction wall/strong floor system, state-of-the-art data acquisition systems, and computer-controlled programmable hydraulic actuators. Furthermore, UCSD and Los Alamos National Laboratories (LANL) are jointly developing a graduate research-based degree program in structural diagnostics and prognostics, which directly supports my proposed research area. There are two projects associated with this program that give me an excellent opportunity to develop and test my research ideas on applications of national significance and visibility in the defense area. First, the Predator unmanned aerial vehicle is suffering from a wing fatigue crack issue, due to mission reconfiguration without redesign. Second, the U.S. Navy's next-generation DD-X ship class design is likely to involve a hybrid composite-to-metal construction that requires the use of many bolted joint connections between dissimilar materials. These joints are known to creep under load, leading to the inability of the joint to bear its load. The opportunity to work on these projects gives me the chance to take a leading role in the damage diagnostics development processes used to solve some real engineering problems outside of the laboratory. Finally, UCSD has several faculty such as Professors Michael Todd, Francesco Lanza di Scalea, John Kosmatka, and Joel Conte whose research areas in waveforms, signal processing, SHM, and advanced sensing hardware give me the opportunity to interact synergistically with experts in this field. I strongly believe that my combination of analytical and experimental skills would, in conjunction with resources at UCSD, allow me to make a significant impact in the field that extends well beyond a classroom setting.

[1] Bray D, McBride D. *Nondestructive Testing Techniques*; John Wiley & Sons: New York, 1992.

[2] M. D. Todd, J. M. Nichols, L. M. Pecora, and L. N. Virgin, ``Vibration-Based Damage Assessment Utilizing State Space Geometry Changes: Local Attractor Variance Ratio,'' *Smart Materials and Structures*, **10**, 1000--1008, 2001.

[3] J. M. Nichols, M. D. Todd, and J. R. Wait, ``Using State Space Predictive Modeling with Chaotic Interrogation in Detecting Joint Preload Loss in a Frame Structure Experiment,'' Smart Materials and Structures, **12**, 580--601, 2003.

[4] J. M. Nichols, M. D. Todd, M. Seaver, and L. N. Virgin, ``The Use of Chaotic Excitation and Attractor Property Analysis in Structural Health Monitoring,'' *Physical Review E*, 67/016209, 2003.

2004 NATIONAL SCIENCE FOUNDATION GRADUATE RESEARCH FELLOWSHIPS

Rating Sheet

APPLICANT: Fasel, Timothy Raymond

PANEL: CIVIL & ENV ENG (R1) FIELD: E/CIVIL

INTELLECTUAL MERIT CRITERION	Excellent	Very Good	Good	Less Competitive	Insufficient Basis for Judgment
Proposed Plan of Research:	☐	☑	☐	☐	☐
Previous Research Experience:	☐	☑	☐	☐	☐
Academic Record:	☑	☐	☐	☐	☐
Reference Reports:	☐	☑	☐	☐	☐
GRE Tests Scores:	☑	☐	☐	☐	☐

BROADER IMPACTS CRITERION *Past, current, and future efforts to:*	Excellent	Very Good	Good	Less Competitive	Insufficient Basis for Judgment
Foster integration of research and education:	☐	☐	☑	☐	☐
Advance diversity in science:	☐	☑	☐	☐	☐
Enhance scientific and technical understanding:	☐	☐	☑	☐	☐
Benefit society:	☐	☐	☑	☐	☐

COMMENTS TO APPLICANT: This incredibly gifted candidate should seek additional opportunities to serve his community. He has much to offer society, but lacks a strong vision of that purpose.

Reviewer comments to the applicant on this rating sheet should be constructive and reflect the two NSF merit review criteria. Upon request, NSF will send the applicant a copy of this rating sheet without the name of the reviewer. Maximum protection will be given to the reviewer's identity subject to the policy stated above and the Freedom of Information Act, 5 usc 552.

05911 Fasel, Timothy Raymond

Panelist Code:	SCORE	SCORE CHANGE 1	SCORE CHANGE 2
R1I	3.0		

Review of Tim Fasel's NSF Proposal

Los Alamos

Dynamics Summer School

2004 NATIONAL SCIENCE FOUNDATION GRADUATE RESEARCH FELLOWSHIPS

Rating Sheet

APPLICANT: Fasel, Timothy Raymond

PANEL: CIVIL & ENV ENG (R1) FIELD: E/CIVIL

INTELLECTUAL MERIT CRITERION	Excellent	Very Good	Good	Less Competitive	Insufficient Basis for Judgment
Proposed Plan of Research:	☐	☑	☐	☐	☐
Previous Research Experience:	☐	☑	☐	☐	☐
Academic Record:	☑	☐	☐	☐	☐
Reference Reports:	☐	☑	☐	☐	☐
GRE Tests Scores:	☑	☐	☐	☐	☐

BROADER IMPACTS CRITERION *Past, current, and future efforts to:*	Excellent	Very Good	Good	Less Competitive	Insufficient Basis for Judgment
Foster integration of research and education:	☐	☑	☐	☐	☐
Advance diversity in science:	☐	☑	☐	☐	☐
Enhance scientific and technical understanding:	☐	☑	☐	☐	☐
Benefit society:	☐	☑	☐	☐	☐

COMMENTS TO APPLICANT: The applicant has an excellent academic record and an excellent GRE score. He has some publications in progress but he did not use published work to substantially justify proposed research; few cited references. Overall, a competitive candidate

Reviewer comments to the applicant on this rating sheet should be constructive and reflect the two NSF merit review criteria. Upon request, NSF will send the applicant a copy of this rating sheet without the name of the reviewer. Maximum protection will be given to the reviewer's identity subject to the policy stated above and the Freedom of Information Act, 5 usc 552.

05911 Fasel, Timothy Raymond

Panelist Code:	SCORE	SCORE CHANGE 1	SCORE CHANGE 2
R1A	2.10		

Review of Tim Fasel's NSF Proposal

Los Alamos
Dynamics Summer School

NDS&EGF Research Proposal – Tim Fasel - 2004

Many aerospace, civil, and mechanical systems continue to be used despite aging and the potential for damage accumulation and unpredicted failure. If a damage detection method using sensors embedded in a structure can be developed, it can provide significant life-safety benefits by preventing unforeseen catastrophic failures and can reduce total maintenance costs through automated assessment. The research in this field is multidisciplinary, drawing from fields such as sensors, signal processing, statistical modeling, fracture mechanics, and many others.

I propose to research the capability of guided waveforms to probe structures for damage. These guided waveforms include Rayleigh-Lamb waves, which are useful because an exact analytical solution for their propagation is known. I will use these waves in conjunction with a time reversal technique, which involves emitting a test signal from one embedded sensor and receiving the signal at other sensor locations. These received signals can then be time-reversed and re-emitted from those sensor locations back to the source. Under certain assumptions the detected signal at the source should be exactly correlated to the originally emitted signal. If damage is present in the signal paths, the time-reversed signal will be less correlated with the originally emitted signal than if no damage were present. This loss in correlation occurs because it is developed using an assumption of linear propagation through the structure, and damage most commonly produces local nonlinear propagation. This method also solves a large problem with guided wave interrogation, which is signal-to-noise ratio. One mechanism that degrades this method is waveform dispersion. Therefore, a new area I wish to investigate is the design of specialized waveforms that are tunable-bandwidth but have minimized spectral leakage, as these characteristics will minimize dispersion and maximize signal-to-noise ratio, allowing optimal resolution in detection capability.

NSF Research Proposal – Colin Olson - 2004

Optimization of Chaotic Structural Excitation for Structural Health Monitoring Using a Genetic Algorithm

The fields of structural health monitoring and non-destructive evaluation continue to garner excitement in the research community. Real-time, *in situ* structural health monitoring (SHM) has the potential to reduce total ownership costs (including service life increases) and increase safety in fields ranging from earthquake engineering to naval defense. For example, the Navy is officially transitioning from a time-based to a condition-based maintenance philosophy as it seeks to reduce manpower. In the DD-X next-generation surface-ship class, a targeted 70% reduction in onboard manpower demands the implementation of automated solutions to perform maintenance-related activities. Furthermore, companies such as Caterpillar are beginning to implement a business strategy of equipment rental charges based on equipment life used rather than time used; such a strategy implies intelligent assessment of the equipment to establish cost. These are just a few examples of many applications in which structural health monitoring will play a central role.

One important component of structural health monitoring is the extraction of damage-sensitive features from structural dynamic responses. Recent works by Todd *et al* [1] present a new method that capitalizes on the sensitive interaction between an intentionally chaotically-excited structure and its response. In principle, a chaotic excitation is used to excite a structure, which is viewed as a filter for the chaotic signal. The excitation and structure act as a coupled system to produce a steady-state attractor. If a baseline system attractor is produced for an undamaged structure then the attractor can be used to predict the evolution (behavior) of subsequent attractors produced by the same system. If the structure is damaged (i.e. the filter is modified) then the baseline attractor will fail to accurately predict the evolution of the damaged attractor. This predictive scheme implicitly assumes that the structure and excitation are well coupled, which leads to the point of this proposal.

I propose to use a genetic algorithm (GA) to optimize the excitation and improve the predictive capabilities of this chaotic interrogation technique. If this method is to be applied to structures ranging from ships to heavy equipment, then there is a need for efficient determination of the optimal excitation specific to a given structure. A GA could be used to breed customized chaotic excitation signals for these individual structures. A brief explanation of the relationship between the excitation and response of a structure will help illustrate the utility of a GA in this context.

In theory, the fractal dimension of an attractor is uniquely related to the Lyapunov exponents (LEs) of a system. In this case the LEs are the combination of the excitation LEs (positive, negative, and zero) and the many (negative) structural LEs. If damage occurs to the structure, then the LEs (which are related to structural damping and stiffness) and correspondingly the dimension of the attractor will be altered. Theory indicates that a structural LE affected by damage must be greater than the negative LE produced by the excitation; otherwise the attractor dimension will not be affected. Likewise, if the absolute value of the affected structural LE is greater than the positive LE produced by the excitation, the dimension of the attractor will increase, complicating the analysis. Thus, there is a window of excitation LEs that can be used to excite the structure, and within this window there is an optimum excitation that produces a good structural response (i.e. noticeable change in the attractor dimension) while still producing an attractor of low dimension. Genetic algorithms are effective at finding global optima given a large search space [2], which would be useful for finding an appropriate excitation function given the potentially infinite search space of all combinations of functions and real numbers. Another proposed excitation method would filter environmentally induced stochastic vibrations to create an attractor. In this case, a GA could be used to determine the specific bandwidth required to properly excite the structure.

In addition to excitation optimization, a GA could be employed to improve the prediction techniques used to determine the evolution of chaotic attractors. For example, one method of predicting the evolution of the attractor is to select a hyper-volume of points around a reference point and use the average of those points at some moment in the future to determine the evolution of the attractor. A GA could be used to optimize the radius that defines this hyper-volume. Perhaps there is a correlation between this radius and the LEs of the excitation function. It is conceivable that a heretofore-unknown theoretical correlation could be derived from an empirical relationship determined by the GA.

There are a number of questions that need to be answered before GAs could be implemented. First, what are the bounds on the search space? The possible search space for the algorithm is infinite (all real numbers, algebraic functions, trigonometric functions, etc.) therefore limits must be placed on the search space. In addition, what is a good initial population for the algorithm? Theoretically the algorithm could start with a random bounded set of numbers and functions, however, it would probably be beneficial to start with collections of known chaotic functions and allow the GA to operate on the functions. What type of crossover and mutation rates would allow the GA to produce chaotic functions most efficiently? Depending on the initial population, a high mutation rate would prevent the algorithm from finding local as opposed to global maximums.

Of paramount importance would be the fitness function used to test the efficacy of the GA solutions. For example, when optimizing the excitation the fitness function could calculate the LEs of a generated function and then select chaotic excitations (those with a positive LE) as well as excitations with a large negative LE (to ensure sufficient structural excitation) for crossover. Once a collection of functions was generated they would need to be tested in the laboratory to determine their effectiveness in coupling to a given structure. For example, initial tests could be performed on a simple bolted-frame structure. Loosening a bolt or combination of bolts on the structure would simulate damage. Optimum coupling could be determined by noting the change in fractal dimension given a specific damage event and excitation function. Once the technique has been applied to a simple model it would be beneficial to test larger and more complicated structures, which is why the University of California in San Diego (UCSD) is a good choice of schools for me to attend.

The Structural Engineering program at UCSD is renowned for the strength of its program as well as its world-class laboratories. For example, the Powell Labs are home to one of the country.s largest reaction wall/strong floor systems in addition to state-of-the-art data-acquisition systems and computer-controlled hydraulic actuators. Additionally, UCSD is collaborating with Los

Alamos National Laboratories (LANL) for the creation of a joint graduate research-based degree program in structural diagnostics and prognostics. Two large projects currently underway at UCSD associated with this program provide an incredible opportunity for me to develop and test my research ideas on applications of national importance. The Predator unmanned aerial vehicle was originally configured for surveillance but mission changes have required it to deliver weaponry, which has caused serious wing fatigue concern. Secondly, the DD-X ship class mentioned above is likely to employ a hybrid composite/metal construction, which requires the use of many hybrid bolted-joint connections. These hybrid joints are known to creep under load, leading to the inability of the joint to bear its load. My ability to work with these projects at their inception provides me the chance to inject novel scientific analysis into and to take a leading role in the iterative design and diagnostics process used to solve real problems outside a controlled laboratory setting.

My interest in GAs stems from what I have read in journals and the popular scientific literature. I am fascinated by the idea of applying the process of natural selection and evolution as an optimization method and chaos theory has been an interest of mine since I was a child. I was excited to learn that I could study an applied chaotic technique and after reading about the details of the chaotic interrogation method it seemed like a perfect match for GA optimization. My interest in SHM was sparked by my experience at the LANL Dynamics Summer School in the summer of 2002. I participated in a research project exploring the random variation in the baseline response of a structure to a given impulse. Our group performed modal analysis, structural dynamic modeling, and statistical analysis of the response of an experimental structure. These and other techniques I studied at Los Alamos may be directly applied to the experimental components of my research at UCSD.

In conclusion, I came to UCSD to work on a project that would require a combination of experimental and theoretical groundwork. I am excited about applying my ideas to a very real and practical application of chaos theory that would be beneficial to society. I believe that the successful implementation of a GA to breed chaotic functions and optimize feature extraction would have implications that extend beyond the optimization of a single technique into the world of pure and applied mathematics. Given sufficient resources I believe that I could use my combination of experience and enthusiasm to make a significant contribution to society.

[1] Nichols J M, Todd M D, Wait J R 2003 Using state space predictive modeling with chaotic interrogation in detecting joint preload loss in a frame structure experiment *Smart Materials and Structures* **12**, 580-601.

[2] Mitchell M 1998 *An Introduction to Genetic Algorithms* (Cambridge: MIT Press).

2004 NATIONAL SCIENCE FOUNDATION GRADUATE RESEARCH FELLOWSHIPS

Rating Sheet

APPLICANT: Olson, Colin Charles

PANEL: CIVIL & ENV ENG (R1) FIELD: E/CIVIL

INTELLECTUAL MERIT CRITERION	Excellent	Very Good	Good	Less Competitive	Insufficient Basis for Judgment
Proposed Plan of Research:	☐	☒	☐	☐	☐
Previous Research Experience:	☒	☐	☐	☐	☐
Academic Record:	☐	☒	☐	☐	☐
Reference Reports:	☐	☒	☐	☐	☐
GRE Tests Scores:	☒	☐	☐	☐	☐

BROADER IMPACTS CRITERION *Past, current, and future efforts to:*	Excellent	Very Good	Good	Less Competitive	Insufficient Basis for Judgment
Foster integration of research and education:	☐	☒	☐	☐	☐
Advance diversity in science:	☒	☐	☐	☐	☐
Enhance scientific and technical understanding:	☐	☐	☒	☐	☐
Benefit society:	☐	☒	☐	☐	☐

COMMENTS TO APPLICANT: ______________________

Reviewer comments to the applicant on this rating sheet should be constructive and reflect the two NSF merit review criteria. Upon request, NSF will send the applicant a copy of this rating sheet without the name of the reviewer. Maximum protection will be given to the reviewer's identity subject to the policy stated above and the Freedom of Information Act, 5 usc 552.

06170 Olson, Colin Charles

Panelist Code:	SCORE	SCORE CHANGE 1	SCORE CHANGE 2
R1K	2.15		

Review of Colin Olson's NSF Proposal

Los Alamos
Dynamics Summer School

2004 NATIONAL SCIENCE FOUNDATION GRADUATE RESEARCH FELLOWSHIPS

Rating Sheet

APPLICANT: Olson, Colin Charles

PANEL: CIVIL & ENV ENG (R1) FIELD: E/CIVIL

INTELLECTUAL MERIT CRITERION	Excellent	Very Good	Good	Less Competitive	Insufficient Basis for Judgment
Proposed Plan of Research:	✓				
Previous Research Experience:	✓				
Academic Record:			✓		
Reference Reports:		✓			
GRE Tests Scores:			✓		

BROADER IMPACTS CRITERION *Past, current, and future efforts to:*	Excellent	Very Good	Good	Less Competitive	Insufficient Basis for Judgment
Foster integration of research and education:					
Advance diversity in science:		✓			
Enhance scientific and technical understanding:		✓			
Benefit society:		✓			

COMMENTS TO APPLICANT:

Reviewer comments to the applicant on this rating sheet should be constructive and reflect the two NSF merit review criteria. Upon request, NSF will send the applicant a copy of this rating sheet without the name of the reviewer. Maximum protection will be given to the reviewer's identity subject to the policy stated above and the Freedom of Information Act, 5 usc 552.

06170 Olson, Colin Charles

Panelist Code:	SCORE	SCORE CHANGE 1	SCORE CHANGE 2
R1F	2.1		

Review of Colin Olson's NSF Proposal

2004 NATIONAL SCIENCE FOUNDATION GRADUATE RESEARCH FELLOWSHIPS

Rating Sheet

APPLICANT: Olson, Colin Charles

PANEL: CIVIL & ENV ENG (R1) FIELD: E/CIVIL

INTELLECTUAL MERIT CRITERION	Excellent	Very Good	Good	Less Competitive	Insufficient Basis for Judgment
Proposed Plan of Research:			✓		
Previous Research Experience:	✓				
Academic Record:	✓				
Reference Reports:		✓			
GRE Tests Scores:	✓				

BROADER IMPACTS CRITERION *Past, current, and future efforts to:*	Excellent	Very Good	Good	Less Competitive	Insufficient Basis for Judgment
Foster integration of research and education:			✓		
Advance diversity in science:				✓	
Enhance scientific and technical understanding:		✓			
Benefit society:		✓			

COMMENTS TO APPLICANT: Excellent GREs, GPA, research background; Not much outreach or diversity. Detailed research program

Reviewer comments to the applicant on this rating sheet should be constructive and reflect the two NSF merit review criteria. Upon request, NSF will send the applicant a copy of this rating sheet without the name of the reviewer. Maximum protection will be given to the reviewer's identity subject to the policy stated above and the Freedom of Information Act, 5 usc 552.

06170 Olson, Colin Charles

Panelist Code:	SCORE	SCORE CHANGE 1	SCORE CHANGE 2
R1R	1.95		

Review of Colin Olson's NSF Proposal

Los Alamos
Dynamics Summer School

NDS&EGF Research Proposal – Colin Olson - 2004

A structural health monitoring (SHM) system that is a highly multidisciplinary blend of sensor technology, materials science, statistical pattern recognition, and chaos theory has recently been proposed. This vibration-based SHM method capitalizes on the interaction between a chaotically excited structure and its response and promises to radically increase the sensitivity and reliability of a real-time, *in situ* health management system. In principle, a chaotic waveform is used to excite a structure, which is viewed as a filter for the signal. The attractor produced by the structure is used to compare between a baseline case and subsequent cases in an effort to detect damage. However, this method is sensitive to the waveforms used to excite the structure locally and to the metric of response comparison. To improve the method's diagnostic and prognostic capabilities, I propose to use a genetic algorithm (GA) to breed chaotic waveforms that are specific to individual structures and applications.

Our group at UC San Diego has two test beds on which to test such a system. The next-generation DD-X ship class and the Littoral Combat Ship employ a composite/metal construction requiring the use of many hybrid bolted-joint connections that are prone to creep failure. Additionally, new mission requirements for the Predator UAV have led to a wing fatigue problem. Our goal is to develop a system of actuators and fiber-optic sensors that can assess the state of such structures and recommend repairs on a condition-based rather than time-based schedule. Employing such a system effectively would require vibration response data to be acquired in real-time from multiple sensors located at various locations on a structure and then rapidly reconstructed into attractors for statistical comparison. I will aid in the development of the sensor network and comparison algorithms in addition to making a unique contribution by developing a GA to improve the predictive capabilities of the system.

NSF Research Proposal - Heather Chiamori - 2005

Thousands of miles of pipeline carry natural gas, crude oil, water, and other items vital to the stability of the United States economy throughout the country. The Trans Alaska Pipeline System is 800 miles long and travels through environmentally sensitive areas, as well as crossing the Denali fault [1]. Over their service lives, pipelines degrade from age, harsh operating conditions, and exposure to adverse environmental conditions. Additionally, catastrophic system failure can occur due to an extreme event, such as an earthquake. A real-time structural health monitoring (SHM) system implemented on a large scale pipeline system could provide rapid assessment of the system and potentially save human lives, reduce maintenance costs, and help speed system recovery after catastrophic events.

Last summer I conducted feasibility studies on the use of piezoelectric active materials for pipeline structural health assessment as part of the Los Alamos Dynamics Summer School (LADSS) program at Los Alamos National Laboratory. The Macro-fiber composite (MFC) patches are used as both sensing and actuation devices. MFC actuator/sensors are more durable and flexible than piezoceramic patches [2]. The flexibility is advantageous for direct application to a curved pipe surface. I found conclusive evidence that the integrated use of active-sensing techniques, including impedance-based structural health monitoring [3] and Lamb wave propagations [4], provides an effective and efficient way to detect and locate pipeline damage at the joints and along the length of the piping structures. However, I felt that critical research issues needed to be addressed before active-sensing techniques can be fully applied to real-world structural applications.

In an effort to create a more robust SHM system for pipeline structures, I propose to study the effects of damage and environmental variability on piezoelectric actuator/sensors. One potential method of diagnosing the piezoelectric active sensors and their bond condition is based on the impedance method. The impedance-based monitoring technique measures the real-time mechanical impedance of a structure. Since mechanical impedance is difficult to measure, the electromechanical coupling effect of piezoelectric materials bonded to a host structure is utilized. Due to the direct and converse piezoelectric effects, changes in the host structure mechanical impedance results in measurable changes in the piezoelectric material electrical impedance, allowing monitoring of mechanical properties using measured electrical parameters. In addition to structural damage, it is important to note that adhesive layers between the actuator/sensor and host structure also affect impedance measurements, so the shifts of electrical impedance measurements may be the result of a changed bonding condition or sensor degradation [5]. The changes caused by sensor failures are different from those due to structural damage. However, it is known that the imaginary part of the impedance is also sensitive to temperature changes [3], so being able to distinguish actuator/sensor failure as a result of debonding, breakage, or temperature change should be addressed. Using the impedance-based method, I will try to identify statistically significant features that are correlated with changes in electrical impedance resulting from sensor failures caused by the bonding condition, breakage or temperature changes.

One important issue to consider in active-sensing SHM is how to distinguish between response changes caused by structural damage, ie loose bolts or corrosion, and changes caused by actuator/sensor failure. Actuator/sensor failure can include piezoceramic breakage or cracking and the associated degradation of mechanical and electrical properties; adhesive layer debonding; and changes in electrical impedance due to temperature variations. Because mechanical and electrical properties of piezoelectric materials can gradually degrade over their service lives, the degradation of an actuator/sensor itself can lead to inaccurate damage assessments. As a bond material ages, the bond integrity between an actuator/sensor and host structure can deteriorate and result in false-positive indicators of damage. I found that the issues associated with long-term reliability of the active sensors under the real-world operating conditions, and the methods and metrics that can be used to assess the degradation of the piezoelectric actuator/sensor quality, have not been sufficiently researched in the past. Therefore, developing an ability to diagnose the actuator/sensors and their bond conditions will significantly enhance the robustness of a pipeline SHM system.

The immediate research goal is to identify MFC and piezoelectric actuator/sensor response trends specific to pipeline structures using various bonding conditions, temperature ranges, and fiber or piezoceramic patches with breakage. To achieve this goal, it may be advantageous to begin with a flat plate configuration and investigate various bonding and sensor breakage conditions at constant temperatures and then varying temperatures over a wide range to try to isolate any distinct responses due to temperature changes with known bond degradation. This approach is advocated because (1) the geometry of the flat plate is not as complex as the curved surfaces of a pipe; (2) installing multiple MFC and piezoceramic patches with different bonding conditions is easier and faster on the flat surface; and (3) impedance based analytical solutions developed specifically for flat plates can be used to develop and verify the procedure. The modified impedance model incorporating bonding layer effects [5] can be used for comparison with experimental results. Significant deviations from expected results may be traced to temperature variations. Partial fiber or piezoceramic breakage will alter loading conditions of the actuator/sensor which will result in changes to the electrical impedance measurements. These experiments should be performed at constant temperature and then over a wide temperature range to establish breakage trends and associated effects due to temperature changes. With a fiber or piezoceramic breakage model, it may be possible to consider that the effective geometry of the sensor is reduced by an effective length, which changes the effective sensor area and results in predictable changes in the impedance measurements. Actuator/sensor response trends can be identified and the results readily compared with analytical solutions.

Initial comparison of the analytical and experimental results with MFC and piezoceramic patches bonded to the flat plate surface will be useful for determining trends in debonding and fiber or piezoceramic breakage. The additional component of environmental conditions in the form of temperature variation should have noticeable trends differentiable from debonding or breakage. The next step involves similar experiments performed on pipe structures to obtain results with the more complicated geometry and compare with the flat plate results. If discrepancies exist, a new analytical model for the complex geometry of the pipe structure needs to be developed and should incorporate both adhesive layer and fiber breakage parameters as well as geometric features that can be adjusted depending on the sensor dimensions, adhesive type, bond surface geometry and associated temperature factors. If successful, validation of MFC actuator/sensor responses caused by piezoceramic breakage, debonding, and environmental effects is established, then a sensor diagnostic metric can be created from these results. MFC and piezoceramic actuator/sensors can be replaced once a critical value is reached.

Assessing the robustness of actuator/sensor responses will strengthen SHM systems for large-scale pipeline structures. The actuator/sensor self-diagnostic capability based on the impedance method utilizes the existing equipment of the damage detection system, which will reduce the SHM system cost. When applied to pipeline systems similar to the Trans Alaska Pipeline system, the potential benefits of this research include saving human lives, protecting the environment, and reducing maintenance costs. Even though this study focuses on pipeline structures, the research findings can be used for any other active-sensing based SHM applied to other types of complex structures.

REFERENCES

1. Alyeksa Pipeline Service Company. <http://www.alyeska-pipe.com\>
2. Sodano, H. A., G. Park, and D.J. Inman. "An investigation in the performance of macro-fiber composites for sensing and structural vibration applications." *Mechanical Systems and Signal Processing* 18 (2004): 683-697.
3. Park, G., H.H. Cudney, and D.J. Inman. "Impedance-based Health Monitoring of Civil Structural Components." *Journal of Infrastructure Systems* 6, no. 4, December (2000): 153-160.
4. Alleyne, D.N., M.J.S. Lowe, and P. Cawley. "The Reflection of Guided Waves From Circumferential Notches in Pipes." *Journal of Applied Mechanics* 65 (1998): 635-641.
5. Park, G., C.R. Farrar, A.C. Rutherford and A.N. Robertson. "Piezoelectric Active Sensor Self-Diagnostics using Electrical Admittance Measurements." *ASME Journal of Vibration and Acoustics,* submitted

NSF Graduate Research Fellowship Program

APPLICANT RATING SHEET

Applicant: **CHIAMORI, HEATHER**

Panel: Mechanical Engineering

Intellectual Merit Criterion

Demonstrated intellectual ability and other accepted requisites for scholarly scientific study, such as the ability (1) to plan and conduct research; (2) to work as a member of a team as well as independently; and (3) to interpret and communicate research findings.

Overall Assessment of Intellectual Merit ☐ Excellent ☒ Very Good ☐ Good ☐ Less Competitive

Basis for assessment:

Very good potential for completing the research because of previous training

Academic strength is not well demonstrated

Broader Impacts Criterion

Contributions that (1) effectively integrate research and education at all levels, infuse learning with the excitement of discovery, and assure that the findings and methods of research are communicated in a broad context and to a large audience; (2) encourage diversity, broaden opportunities, and enable the participation of all citizens--women and men, underrepresented minorities, and persons with disabilities--in science and research; (3) enhance scientific and technical understanding; and (4) benefit society.

Overall Assessment of Broader Impacts ☐ Excellent ☒ Very Good ☐ Good ☐ Less Competitive

Basis for assessment:

Good potential for encouraging participation of underrepresented minorities

Good potential for benefiting the society

NSF Graduate Research Fellowship Program

APPLICANT RATING SHEET

Applicant: **CHIAMORI, HEATHER**
Panel: Mechanical Engineering

Intellectual Merit Criterion

Demonstrated intellectual ability and other accepted requisites for scholarly scientific study, such as the ability (1) to plan and conduct research; (2) to work as a member of a team as well as independently; and (3) to interpret and communicate research findings.

Overall Assessment of Intellectual Merit ☑ Excellent ☐ Very Good ☐ Good ☐ Less Competitive

Basis for assessment: Excellent Plan and good knowledge of literature. She has already contributed some work.

Broader Impacts Criterion

Contributions that (1) effectively integrate research and education at all levels, infuse learning with the excitement of discovery, and assure that the findings and methods of research are communicated in a broad context and to a large audience; (2) encourage diversity, broaden opportunities, and enable the participation of all citizens--women and men, underrepresented minorities, and persons with disabilities--in science and research; (3) enhance scientific and technical understanding; and (4) benefit society.

Overall Assessment of Broader Impacts ☑ Excellent ☐ Very Good ☐ Good ☐ Less Competitive

Basis for assessment: Clear sense of benefiting humankind. Excellent dedication to assisting underrepresented minorities and in safety research. Excellent letters of reference.

Reviewer comments to the applicant on this rating sheet should be constructive and reflect the two NSF merit review criteria. Applicants

NSF Graduate Research Fellowship Program

APPLICANT RATING SHEET

Applicant: **CHIAMORI, HEATHER**
Panel: Mechanical Engineering

Intellectual Merit Criterion

Demonstrated intellectual ability and other accepted requisites for scholarly scientific study, such as the ability (1) to plan and conduct research; (2) to work as a member of a team as well as independently; and (3) to interpret and communicate research findings.

Overall Assessment of Intellectual Merit ☐ Excellent ☒ Very Good ☐ Good ☐ Less Competitive

Basis for assessment:

- Good GPA & intensive work experience &
- Good GRE
- well-thought plan of work.
- Good recommendation letters.

Broader Impacts Criterion

Contributions that (1) effectively integrate research and education at all levels, infuse learning with the excitement of discovery, and assure that the findings and methods of research are communicated in a broad context and to a large audience; (2) encourage diversity, broaden opportunities, and enable the participation of all citizens—women and men, underrepresented minorities, and persons with disabilities—in science and research; (3) enhance scientific and technical understanding; and (4) benefit society.

Overall Assessment of Broader Impacts ☐ Excellent ☒ Very Good ☐ Good ☐ Less Competitive

Basis for assessment:

- Research impacts & benefits society
- enhances diversity.
- structural health monitoring for pipelines strongly impacts US economy.

Reviewer comments to the applicant on this rating sheet should be constructive and reflect the two NSF merit review criteria. Applicants

NSF Research Proposal – Scot Hart – 2005

Indirect Vibrometry in Noisy Environments through Directional Acoustics

High Cycle Fatigue (HCF) failure of bladed compressor disks has always been a problem in high-speed machinery, and particularly in gas turbine engines used in aircraft propulsion. The high speeds of rotation and associated centrifugal stiffening of the blades produces resonant frequencies that typically fall in the range of the aerodynamically induced unsteady forcing functions acting on the blades. This crossing of forcing function and resonant frequencies results in a ripe environment for HCF. To avoid potentially catastrophic failure, fatigue-life predictions are currently used. Complicating the problem, however, is the fact that engines in the field often mature differently depending on mission, and this aging process can affect the onset of HCF [1]. An ideal solution to this problem consists of an advanced diagnostic method to monitor the blades for signs of premature fatigue. Such a system would significantly increase the safety and decrease the maintenance cost of gas turbine engines.

One effective way to monitor for premature fatigue is to measure the vibrational characteristics of a structural member and compare it with its original or undamaged characteristics. Currently detailed characterization of blade vibration can only be monitored in test rigs using state-of-the-art methods. One such method is a tip-pass timing system which measures the time between the passing of each successive rotor blade past a laser beam. From these measured passage times and prior analysis of blade mode shapes, the amplitude and frequency of the vibration of the blades can be deduced. This method is limited by the fact the laser only “sees” the tip of the blade and is therefore limited to a planar 2-D view of the blade vibration. Unfortunately, implementation of such optical systems in production engines is not practical for many reasons, the most obvious of which is the eventual degradation of optical surfaces.

Proposed Research

To continue my studies in gas turbine aeromechanics, acoustics, and modal analysis I would like to spend my time in graduate school investigating two untested yet promising methods to measure blade vibrations which can be borrowed and modified from radar theory: Doppler and ranging vibrometry. The difference in the two methods is the way the returning signal is analyzed. Classic radar uses the time of flight of the signal to determine the objects position or range, while Doppler radar examines the shift in frequency of the returning echo to determine the velocity of the object. These methods benefit from the ability to look at the entire blade surface and form a more complete 3-D picture of the blade and its vibrational characteristics, potentially eliminating the need for a prior modal analysis. To make these methods practical for use in gas turbine engines, high frequency acoustic waves emitted from a transducer in the side wall of the engine can be used as the carrier signal, eliminating the need for transparent surfaces. Another advantage of acoustic signals is that the technology needed to produce the acoustic signals needed is already available on the market and well understood. Piezoelectric ultrasonic transducers are in wide use in both non-destructive testing and medical imaging. While both these applications of acoustic waves work as ranging systems, the technology should be easily modifiable to measure the Doppler shifts in the echoes coming from vibrating blades.

The tip-timing, ranging, and Doppler systems all use a harmonic carrier signal to measure the vibrations of the blades. The properties of the carrier signals including wavelength, speed of propagation, and frequency play a large role in the effectiveness of the vibration measurements. For good contrast, the wavelength of the signal must be smaller then the object, or portion of the object, to be detected. For example, to minimize the blurring of the sharp edges of a blade, tip-timing systems require the very small wavelengths of an optical signal (500-600 nm). To characterize the vibration of an engine blade using the ranging or Doppler approach the position or velocity of several roughly millimeter-size sections of the blade surface are needed. This limits the wavelength of the carrier signal to about 1 mm or less. For acoustic signals with a velocity of 350 m/s this limits the signal to frequencies above 350 kHz.

On the other hand, the attenuation of sound waves in air puts an upper limit on the frequency of the carrier signal leaving a fairly narrow range of potential frequencies. Acoustic signals decay at a rate proportional to the square of the signal's frequency. As a result, current ultrasonic technology using a 500 kHz signal can only reliably investigate an object placed no more then 2 or 3 cm from the transducer [2]. While this distance would be sufficient for determining the range or velocity of the blade tip, lower frequencies or more sensitive microphones would be needed to image the complete blade surface.

Further limits on the carrier signal frequency come from the noise produced by gas turbine engines. Gas turbine engines are inherently noisy environments. In the lower frequency region, they are flooded with broad band flow noise. At higher frequencies, high amplitude discrete frequency noise at the blade pass frequency (BPF) and its harmonics propagate throughout the engine. For an acoustic signal to be measurable above this background noise it must be at a frequency high enough to be separated from the flow noise and sufficiently separated from the BPF and its harmonics. Additionally the Doppler shift in the echo's frequency must not cause the echo to be at a frequency too close to the background noise.

Signal Detection and Processing

To detect the weak echoes from the blade surfaces, microphones based on novel technology will most likely be needed. They must have the necessary sensitivity and be robust enough to survive the harsh engine environment. While further research into microphone choice is needed, work by Linero et al. [3] has shown that a fiber-optic lever sensor can be used as a microphone in such environments. The sensor relies on a beam of light emitted from a fiber-optic cable reflecting off a lever. Any movement of the lever due to acoustic pressures can be measured by the intensity modulation of the reflected beam gathered by additional fiber-optic cables. It has been shown that such a sensor with a surface area less then 0.5 mm can be used as a microphone in high temperature (538 C) hypersonic flow to measure sound pressure levels between 130-160 dB at frequencies in excess of 100 kHz, with further improvements possible.

To focus on the echoes returning from small areas on the blade surface, an array of microphones can be used. By changing the complex gain for each microphone of the array, the array can focus on a small area without physically moving any of the microphones. While the processing technology needed to implement such a directional acoustic array has been around for the past few decades, it requires extensive computation to provide the directional precision needed in blade vibrometery. Further research is needed to determine the optimal compromise between precision and computational cost of such an array.

Implementation

To begin basic research on the feasibility of the ranging and Doppler methods of blade vibrometery, a simple test rig should be built consisting of a box containing an excited blade with known vibrational characteristics. A low frequency acoustic source and a conventional low frequency microphone array can be used for initial testing. By adjusting the number of microphones in the array, the shape of the array, and the processing parameters, guidelines can be developed to ensure the accuracy of the blade vibration measurement. These guidelines can then be used to determine the sensor array setup and processing parameters to be used with the high frequency signal in a gas turbine engine.

Conclusion

While using directional acoustics to measure the vibration of rotor blades in gas turbine engines is a high risk proposition, the potential benefit is huge. Not only could the technology be used to prevent failure of engines used in aircraft propulsion and power generation, but the technology could be readily transferred to other harsh environments where high-cycle fatigue concerns exist such as automotive engines, or space craft launch vehicles.

I believe Purdue University's Zucrow Laboratory is an ideal place to study the potential of ranging and Doppler based acoustic blade vibrometry. The labs features actual full-scale compressor test facilities, including a transonic compressor and a high speed three stage compressor, thus providing ample opportunity to test the proposed system's effectiveness in various environments. Combined with my introduction to Zucrow over the past year conducting research on distortion generator design for test rigs, I should be able to begin research almost immediately. Additionally, Purdue's recent efforts to enable multidisciplinary studies will make it possible to select mentors and base my coursework in such key areas in aeromechanics, acoustics, signal processing and controls, and micro-fabrication without regard to traditional department boundaries.

References:

[1] B.E. Powell, J.Byrne, R.F. Hall, "The Effects of LCF Loadings on HCF Crack Growth," Report A405493, October 2000, Portsmouth University Dept. of Mechancial and Manufacturing Engineering.

[2] Thomas Claytor. "Re: Question for you." Personal e-mail communication, 9 Sept. 2004.

[3] A. Linero, H. Jalali, R. P. Joshi, A. J. Zuckerwar, "Theoretical and Experimental Study of Fiber-Optic Lever Sensors," Proc. IEEE Southeastcon '95. Visualize the Future, 1995, pp. 257-60.

NSF Graduate Research Fellowship Program

APPLICANT RATING SHEET

Applicant: **HART, JOHN**

Panel: Mechanical Engineering

Intellectual Merit Criterion

Demonstrated intellectual ability and other accepted requisites for scholarly scientific study, such as the ability (1) to plan and conduct research; (2) to work as a member of a team as well as independently; and (3) to interpret and communicate research findings.

Overall Assessment of Intellectual Merit ☐ Excellent ☑ Very Good ☐ Good ☐ Less Competitive

Basis for assessment:

Well presented research plan.

Broader Impacts Criterion

Contributions that (1) effectively integrate research and education at all levels, infuse learning with the excitement of discovery, and assure that the findings and methods of research are communicated in a broad context and to a large audience; (2) encourage diversity, broaden opportunities, and enable the participation of all citizens--women and men, underrepresented minorities, and persons with disabilities--in science and research; (3) enhance scientific and technical understanding; and (4) benefit society.

Overall Assessment of Broader Impacts ☐ Excellent ☐ Very Good ☑ Good ☐ Less Competitive

Basis for assessment:

Largely discusses personal history but does not address how you would integrate science and engineering into items 1-4.

Reviewer comments to the applicant on this rating sheet should be constructive and reflect the two NSF merit review criteria. Applicants

NSF Graduate Research Fellowship Program

APPLICANT RATING SHEET

Applicant: **HART, JOHN**
Panel: Mechanical Engineering

Intellectual Merit Criterion

Demonstrated intellectual ability and other accepted requisites for scholarly scientific study, such as the ability (1) to plan and conduct research; (2) to work as a member of a team as well as independently; and (3) to interpret and communicate research findings.

Overall Assessment of Intellectual Merit ☑ Excellent ☐ Very Good ☐ Good ☐ Less Competitive

Basis for assessment:

- excellent credentials & preparation for research

Broader Impacts Criterion

Contributions that (1) effectively integrate research and education at all levels, infuse learning with the excitement of discovery, and assure that the findings and methods of research are communicated in a broad context and to a large audience; (2) encourage diversity, broaden opportunities, and enable the participation of all citizens--women and men, underrepresented minorities, and persons with disabilities--in science and research; (3) enhance scientific and technical understanding; and (4) benefit society.

Overall Assessment of Broader Impacts ☐ Excellent ☑ Very Good ☐ Good ☐ Less Competitive

Basis for assessment:

- very good essays and adequate personal involvement

Reviewer comments to the applicant on this rating sheet should be constructive and reflect the two NSF merit review criteria. Applicants

NSF Graduate Research Fellowship Program

APPLICANT RATING SHEET

Applicant: **HART, JOHN**
Panel: Mechanical Engineering

Intellectual Merit Criterion

Demonstrated intellectual ability and other accepted requisites for scholarly scientific study, such as the ability (1) to plan and conduct research; (2) to work as a member of a team as well as independently; and (3) to interpret and communicate research findings.

Overall Assessment of Intellectual Merit ☐ Excellent ☒ Very Good ☐ Good ☐ Less Competitive

Basis for assessment:

Good research plan — but hard to see relevance of 1/4 ton pickup ~~truck~~ truck and the BSA.

Broader Impacts Criterion

Contributions that (1) effectively integrate research and education at all levels, infuse learning with the excitement of discovery, and assure that the findings and methods of research are communicated in a broad context and to a large audience; (2) encourage diversity, broaden opportunities, and enable the participation of all citizens--women and men, underrepresented minorities, and persons with disabilities--in science and research; (3) enhance scientific and technical understanding; and (4) benefit society.

Overall Assessment of Broader Impacts ☐ Excellent ☒ Very Good ☐ Good ☐ Less Competitive

Basis for assessment:

BSA is a fine organization — but not relevant here.

Reviewer comments to the applicant on this rating sheet should be constructive and reflect the two NSF merit review criteria. Applicants

Los Alamos
Dynamics Summer School

NSF Research Proposal –Stuart Taylor – 2006

Introduction

Advances in structural health monitoring have enormous potential to benefit society by increasing the general public safety, providing more effectively for the public defense, reducing unnecessary expenditures brought about by unanticipated structural failures, and saving valuable resources currently employed in replacing unnecessarily discarded structural members.

Objective

The objective of the proposed research is to develop a new mathematical framework for structural damage detection, location, and quantification using Ritz vectors. These analytical results will be experimentally validated on a scale model of a spacecraft cargo bay frame. The proposed Ritz vector approach will circumvent the challenges limiting the current knowledge base built on modeshapes. The outcome of my research will address the reduced measurements problem by requiring fewer degrees of freedom in the analytical model used for health monitoring.

Background

Structural health monitoring has several inherent challenges that researchers have yet to overcome. Most notable among these is the reduced measurements problem. Many proposed algorithms for damage detection involve the identification of global modeshapes; however, in any damage detection algorithm, the location of damage must be isolated to a particular degree of freedom in a finite element model. In experimental testing, the number of degrees of freedom for which measurements are available is a small fraction of the total degrees of freedom in the analytical model. Structural damage, which is most often a local phenomenon, is difficult to pinpoint using modeshapes that only reflect the global behavior of the structure.

Load dependent Ritz vectors[1] provide an alternative to modeshapes as a set of basis vectors describing the behavior of a structure. The first Ritz vector is the static deflection of the structure due to a prescribed load, with subsequent orthogonal Ritz vectors constructed recursively using the structure's mass and stiffness matrices. Ritz vectors have been shown to be more sensitive to damage than modeshapes[2] while also being less sensitive to measurement noise[3]. As such, Ritz vectors constitute a highly desirable set of basis vectors for use in developing damage detection algorithms. Even so, Ritz vectors bring with them their own suite of associated challenges, with the two most paramount as follows:

1. Most time-domain system identification techniques were developed primarily for modal parameter identification. The Eigensystem Realization Algorithm[4], for example, identifies the system state matrix and the output influence matrix with sufficient accuracy to extract modeshapes. However, the algorithm identifies the input influence matrix with unknown accuracy. Because the input influence matrix is essential to the extraction of load-dependent Ritz vectors, improved system identification techniques must be explored.
2. Because the first Ritz vector is the static displacement of the structure, a simple static reduction provides an exact transformation of the first Ritz vector from the measurement locations to the full analytical degrees of freedom. However, subsequent Ritz vectors are subject to errors when the same transformation is applied, requiring an improved model reduction technique for error-free transformations of these vectors.

Execution of Research

Overcoming the difficulties inherent in the structural damage detection problem and meeting the challenges of applying Ritz vectors to the problem requires a systematic approach outlined by the following tasks:

Proposed Plan of Research Stuart Taylor

Page 2 of 2 Applicant ID: 1000041823

1. Develop improved methods for time-domain identification and extraction of Ritz vectors without sacrificing any of Ritz vectors' advantages over modeshapes.
2. Determine the best model reduction method for use in applying Ritz vectors to the reduced measurements problem. If there is no satisfactory model reduction method, develop a new Ritz vector-based model reduction method.
3. Demonstrate the applicability of Ritz vectors to techniques previously developed using modeshapes as basis vectors, including modeshape expansions[5], minimum rank perturbation theory[6], and stiffness matrix disassembly methods for dynamic residual expansion[7].
4. Develop damage detection methods that exploit the load-dependent nature of Ritz vectors to increase the detection algorithm's sensitivity to critical structural areas and establish the superiority of these methods over those demonstrated in Task 3.
5. Verify the methods utilized and developed in Tasks 1 through 4 using experimental data of healthy and damaged versions of a model of a spacecraft cargo bay frame[8], as well as other carefully planned tests involving practical structural damage.

Broader Impacts of Research

Advances in structural health monitoring and damage detection will benefit almost every industry. Automatic damage detection and repair capabilities would prove invaluable for the successful operation of autonomous vehicles, which are employed by the Department of Defense, by the offshore oil industry, and in space exploration. With commercial and military aircraft operating well beyond their original design life, health monitoring of the nation's fleet is paramount to the defense of the country and to the lives of our pilots and passengers. Early detection of defective circuit boards would save expensive chips and valuable precious metals from being wasted to produce faulty electronics. Improved fatigue assessment of wind turbine blades, especially when installed in hurricane-prone areas such as the Gulf of Mexico, could make renewable wind energy a cost-effective solution for millions of homes across the globe.

Long-term Research Goals

My undergraduate thesis has formed the basis for this research plan, having brought to light many of the questions and challenges associated with damage detection, and in particular with the application of Ritz vectors to structural health monitoring. Likewise, my Master's thesis, answering these questions and meeting these challenges, will form the basis for my Ph.D., integrating damage detection with autonomous repair through intelligent active control.

[1] Wilson, E. L., Yuan, M.W. and Dicken, J. M., "Dynamic Analysis by Direct Superposition of Ritz Vectors," *Earthquake Engineering and Structural Dynamics*, vol. 10, 1982, pp. 813-821.

[2] Cao, T. and Zimmerman, D.C,, "Application of Load Dependent Ritz Vectors in Structural Damage Detection," Proceedings of the 15th SEM International Modal Analysis Conference, 1997, pp. 1319-1324

[3] Cao, T., and Zimmerman, D.C., "Procedure to Extract Ritz Vectors from Dynamic Testing Data," *ASCE Journal of Structural Engineering*, Vol. 125, No. 12, pp. 1393-1400.
[4] Juang, J. N. and Pappa, R. S., "An Eigensystem Realization Algorithm for Modal Parameter Identification and Modal Reduction," *Journal of Guidance and Control Dynamics*, vol. 8, 1985, pp. 620-627.
[5] Zimmerman, D. C., Smith, S. W., Kim, H. M., and Bartkowicz, T. J., "An Experimental Study of Structural Damage Detection Using Incomplete Measurements," *ASME Journal of Vibration and Acoustics*, vol. 118, no. 4, October 1996, pp. 543-550.
[6] Kaouk, M. and Zimmerman, D.C., "Structural Damage Assessment Using a Generalized Minimum Rank Perturbation Theory,"AIAA Journal, Vol. 32, No. 4, 1992, pp. 836-842.
[7] Zimmerman, D. C., H.-M. Kim, T. J. Bartkowicz, and M. Kaouk. "Damage Detection Using Expanded Dynamic Residuals," *Journal of Dynamic Systems, Measurement, and Control,* vol. 123(4), December 2001, pp. 699-705.
[8] Taylor, Stuart and Zimmerman, D.C., "Damage Detection in a Cargo Bay Frame Using Ritz Vectors," *Proceedings of the 23rd IMAC*, Orlando, FL, 2005.

Rating sheets missing a required element will be returned to the panelist for completion.

NSF Graduate Research Fellowship Program

APPLICANT RATING SHEET

Applicant: Taylor, Stuart
Panel: Mechanical Engineering

Intellectual Merit Criterion

Demonstrated intellectual ability and other accepted requisites for scholarly scientific study, such as the ability (1) to plan and conduct research; (2) to work as a member of a team as well as independently; and (3) to interpret and communicate research findings.

Overall Assessment of Intellectual Merit ☒ Excellent ☐ Very Good ☐ Good ☐ Less Good ☐ Fair

Mandatory - explain assessment to the applicant:

- Good grades
- Excellent research background
- outstanding research proposal

Broader Impacts Criterion

Contributions that (1) effectively integrate research and education at all levels, infuse learning with the excitement of discovery, and assure that the findings and methods of research are communicated in a broad context and to a large audience; (2) encourage diversity, broaden opportunities, and enable the participation of all citizens--women and men, underrepresented minorities, and persons with disabilities--in science and research; (3) enhance scientific and technical understanding; and (4) benefit society.

Overall Assessment of Broader Impacts ☐ Excellent ☒ Very Good ☐ Good ☐ Less Good ☐ Fair

Mandatory - explain assessment to the applicant:

- research has strong potential scientific and societal impact
- student demonstrates strong leadership abilities

Reviewer comments to the applicant on this rating sheet should be constructive and reflect the two NSF merit review criteria. Applicants will be able to view a copy of their rating sheets without the name of the reviewer on a secure web site. Maximum protection will be given

Los Alamos
Dynamics Summer School

Rating sheets missing a required element will be returned to the panelist for completion.

NSF Graduate Research Fellowship Program

APPLICANT RATING SHEET

Applicant: Taylor, Stuart

Panel: Mechanical Engineering

Intellectual Merit Criterion

Demonstrated intellectual ability and other accepted requisites for scholarly scientific study, such as the ability (1) to plan and conduct research; (2) to work as a member of a team as well as independently; and (3) to interpret and communicate research findings.

Overall Assessment of Intellectual Merit ☐ Excellent ☑ Very Good ☐ Good ☐ Less Good ☐ Fair

Mandatory - explain assessment to the applicant:

- Well written research plan
- Published 2 conf. papers
- Spent summer at Los Alamos and NASA Johnson Space Center

Broader Impacts Criterion

Contributions that (1) effectively integrate research and education at all levels, infuse learning with the excitement of discovery, and assure that the findings and methods of research are communicated in a broad context and to a large audience; (2) encourage diversity, broaden opportunities, and enable the participation of all citizens--women and men, underrepresented minorities, and persons with disabilities--in science and research; (3) enhance scientific and technical understanding; and (4) benefit society.

Overall Assessment of Broader Impacts ☐ Excellent ☐ Very Good ☑ Good ☐ Less Good ☐ Fair

Mandatory - explain assessment to the applicant:

- Member of ASME International Petroleum Technology Institute's Collegial Council
- Created the Graduate Student Association (GSA) within the dept
- Is still encouraged to think how to have a more specific, broader impact.

Reviewer comments to the applicant on this rating sheet should be constructive and reflect the two NSF merit review criteria. Applicants will be able to view a copy of their rating sheets without the name of the reviewer on a secure web site. Maximum protection will be given

Los Alamos

Dynamics Summer School

Rating sheets missing a required element will be returned to the panelist for completion.

NSF Graduate Research Fellowship Program

APPLICANT RATING SHEET

Applicant: Taylor, Stuart

Panel: Mechanical Engineering

Intellectual Merit Criterion

Demonstrated intellectual ability and other accepted requisites for scholarly scientific study, such as the ability (1) to plan and conduct research; (2) to work as a member of a team as well as independently; and (3) to interpret and communicate research findings.

Overall Assessment of Intellectual Merit ☐ Excellent ☒ Very Good ☐ Good ☐ Less Good ☐ Fair

Mandatory - explain assessment to the applicant:

Very worthwhile, ~~[illegible]~~ well planned and well described research project on structural health monitoring. Student has done extensive research in the area as an undergrad at LANL as a participant in their summer school. Should be able to carry out the project tasks.
Very strong motivation.
Strong letters.

Broader Impacts Criterion

Contributions that (1) effectively integrate research and education at all levels, infuse learning with the excitement of discovery, and assure that the findings and methods of research are communicated in a broad context and to a large audience; (2) encourage diversity, broaden opportunities, and enable the participation of all citizens--women and men, underrepresented minorities, and persons with disabilities--in science and research; (3) enhance scientific and technical understanding; and (4) benefit society.

Overall Assessment of Broader Impacts ☐ Excellent ☒ Very Good ☐ Good ☐ Less Good ☐ Fair

Mandatory - explain assessment to the applicant:

Broader impact of research in a variety of applications clearly explained.
Extensive extracurricular activity as a student leader.
Seeks career in ~~[illegible]~~ academia or gov. lab.

Reviewer comments to the applicant on this rating sheet should be constructive and reflect the two NSF merit review criteria. Applicants will be able to view a copy of their rating sheets without the name of the reviewer on a secure web site. Maximum protection will be given

Los Alamos
Dynamics Summer School

NSF Research Proposal –Laura Jacobs – 2006

Modal Analysis of Smart Structural Components for Use in Seismically Active Zones

Keywords: Civil engineering, structural engineering, earthquake engineering, smart materials, shape memory alloys, modal analysis

I have not formulated a specific research plan, because the actual project will depend on what opportunities are available at the graduate school I eventually attend. To my knowledge, this proposal is original and does not duplicate work being performed elsewhere.

Research Topic of Interest: The area of research that is of most interest to me is the use of smart materials in structures in seismically active zones. My interest in this area has developed throughout most of my life. When I was six years old I read a book about the 1906 San Francisco earthquake. Many people died during the earthquake due to the collapse of the various structures, and I remember that I wondered if there was something that could be done to prevent the buildings from collapsing. When I was 12, I went to a Society of Women Engineers Girl Scout Day at the University of Michigan. They showed us the earthquake lab, and I was excited to learn that there was research being done in the area of earthquake engineering. During my sophomore year of college, I took a class in Mechanics of Materials. During the class, my professor said that the key to earthquake engineering was in the materials, not the structure itself. From that point on, I wanted to do research in the materials that could be used in structures in seismically active zones to prevent them from collapsing.

Background: Smart materials, such as Nickel-Titanium alloys (Nitinol), have been used over the past few decades in the aerospace, mechanical and biomedical engineering fields. More recently, researchers have experimented with using smart materials in structures in civil engineering. Smart materials, or shape memory alloys (SMA), are ones that can self-adapt, can self-sense, and have memory. They can change their material properties like the Young's modulus, damping, and internal forces. Natural frequencies and modes of vibrations can be tuned to desired values. These characteristics suggest multiple applications for structures in earthquake zones. [2]

Several researchers at the Georgia Institute of Technology have studied the feasibility of using SMA in civil structures to mitigate damage during earthquakes. In his doctoral thesis, Bassem Andrawes proved that SMA could be used as restrainers on bridges to prevent excessive movement of bridge superstructures. [1] Reginald DesRoches also performed experiments using SMA for restrainers in bridges. [3] Both engineers proved that SMA restrainers reduced hinge replacements and limited the relative openings on bridges compared with conventional steel restrainers. [1], [3]

Intellectual Merit: Much is understood about the properties of SMA and there have been experiments done on the feasibility of using SMA to mitigate damage to structures during earthquakes. However, no modal analysis tests have been done on civil structures or structural elements that contain SMA parts to see how they would affect the modal characteristics of civil structures. I **hypothesize** that adding SMA to a structure will change its modal characteristics.

Research Proposal: I propose to do experiments using modal analysis techniques on structures and structural elements to see how their modal characteristics would change with the introduction of SMA. My research would be conducted in two parts. The first would be a simple spliced connection, where one of the elements was made from SMA. The second part would be a larger scale bridge structure, with SMA connections and expansion joints.

During the first phase of my research, I will test two different connections: a simple splice connection with a SMA gusset plate sandwiched between two steel plates and connected with steel bolts (experimental), and a similar connection with three steel plates, (control). I will then perform a modal analysis in a manner similar to the one I learned at the Los Alamos Dynamic Summer School. I will connect a series of accelerometers to the plates and hit the plate in various locations with a modal hammer. I will divide the plate into a grid with different locations for actuation and measurement, in order to get a clear picture of the mode shapes of the plates. This experiment will allow me to determine the modes and mode shapes of spliced connections that consist of all steel and of a combination of SMA and steel and compare them. This will lay the ground work for determining how the addition of SMA will change the modal characteristics of a structure.

Part two of my research will extend the tests to a simple bridge structure. I will construct a small, bridge made completely out of steel (control), and a similar bridge that contains some SMA elements in the connections (experimental). I will then conduct modal tests by attaching accelerometers to various members of the bridge. I will then actuate the vibrations using a shake table. I will vary the frequency of the shake table until I determine the first five modes of the structure. By performing this test on both bridges, I will be able to show how the addition of SMA can affect the modal characteristics of a bridge.

Broader Impacts: SMA have the potential to make structures safer, and save countless lives during earthquakes. This proposal takes a cross-disciplinary approach to a better understanding of how SMA affect a structure and its modal properties, and is an important step to making SMA more widely used. Once the modal characteristics of structures containing SMA are understood, then enough information will be known about them to start including provisions for using SMA in building codes. My proposed research will lay the ground work that is necessary for SMA to become commonly used materials in construction of civil engineering structures. It may also allow us to design alloys that are inexpensive enough to incorporate into structures in developing nations, where earthquakes are frequent and resources are few. I anticipate presenting the results of this research both in refereed publications and at national and international conferences.

References

1. Andrawes, Bassam. "Seismic Response and Analysis of Multiple Frame Bridges using Superelastic Shape Memory Alloys." Diss. Georgia Institute of Technology, 2005.

2. Cai, C.S., Wenjie Wu, Suren Chen, and George Voyiadjis. Applications of Smart Materials in Structural Engineering. Baton Rouge, LDOT, 2003

3. DesRoches R., and M. Delemont. "Seismic Retrofit of Simply Supported Bridges using Shape Memory Alloys." Engineering Structures 24 (2002). 6 Nov. 2005 http://www.elsevier.com/locate/engstruct

Los Alamos
Dynamics Summer School

Rating sheets missing a required element will be returned to the panelist for completion.

NSF Graduate Research Fellowship Program

APPLICANT RATING SHEET

Applicant: Jacobs, Laura

Panel: Civil and Environmental Engineering

Intellectual Merit Criterion

Demonstrated intellectual ability and other accepted requisites for scholarly scientific study, such as the ability (1) to plan and conduct research; (2) to work as a member of a team as well as independently; and (3) to interpret and communicate research findings.

Overall Assessment of Intellectual Merit ☒ Excellent ☐ Very Good ☐ Good ☐ Less Good ☐ Fair

Mandatory - explain assessment to the applicant: BSc. Civil Purdue - GPA 3.86. Desired Grad GA Tech - Civil/Structural. Strong letters. Wants to study low cost new materials to improve earthquake resistance of structures. Has become fluent in Spanish. Research experiences at Los Alamos, and Milwaukee School of Engineering in related work. Multiple scholarships and academic honors, including Dean's list every semester. Study abroad at U. Canterbury, New Zealand. Good general description of research ~~p~~ idea and proposed method of study.

Broader Impacts Criterion

Contributions that (1) effectively integrate research and education at all levels, infuse learning with the excitement of discovery, and assure that the findings and methods of research are communicated in a broad context and to a large audience; (2) encourage diversity, broaden opportunities, and enable the participation of all citizens--women and men, underrepresented minorities, and persons with disabilities--in science and research; (3) enhance scientific and technical understanding; and (4) benefit society.

Overall Assessment of Broader Impacts ☐ Excellent ☒ Very Good ☐ Good ☐ Less Good ☐ Fair

Mandatory - explain assessment to the applicant: Interested in an academic career. Has become fluent in Spanish and would like to influence students from Latin America to study seismic engineering & related fields. Gave a nice discussion of her ~~intere~~ view of the broader impacts of her proposed study.

Reviewer comments to the applicant on this rating sheet should be constructive and reflect the two NSF merit review criteria. Applicants

Los Alamos

Dynamics Summer School

Rating sheets missing a required element will be returned to the panelist for completion.

NSF Graduate Research Fellowship Program

APPLICANT RATING SHEET

Applicant: Jacobs, Laura

Panel: Civil and Environmental Engineering

Intellectual Merit Criterion

Demonstrated intellectual ability and other accepted requisites for scholarly scientific study, such as the ability (1) to plan and conduct research; (2) to work as a member of a team as well as independently; and (3) to interpret and communicate research findings.

Overall Assessment of Intellectual Merit ☑ Excellent ☐ Very Good ☐ Good ☐ Less Good ☐ Fair

Mandatory - explain assessment to the applicant:

- Excellent academic record
- Supporting documents show an ability to conduct ~~re~~research independently
- Notes importance of multi-disciplinary approach to research.
- Functions well on teams.
- Author/Co-author of 2 conference presentations/Proceedings
- Good research plan.

Broader Impacts Criterion

Contributions that (1) effectively integrate research and education at all levels, infuse learning with the excitement of discovery, and assure that the findings and methods of research are communicated in a broad context and to a large audience; (2) encourage diversity, broaden opportunities, and enable the participation of all citizens--women and men, underrepresented minorities, and persons with disabilities--in science and research; (3) enhance scientific and technical understanding; and (4) benefit society.

Overall Assessment of Broader Impacts ☐ Excellent ☐ Very Good ☑ Good ☐ Less Good ☐ Fair

Mandatory - explain assessment to the applicant:

- Highlights the benefits of research to society.
- Supporting documents indicate student whose active in organizations
- Proposal does not spell out a clear plan for encouraging diversity & broadening opportunities

Reviewer comments to the applicant on this rating sheet should be constructive and reflect the two NSF merit review criteria. Applicants

Rating sheets missing a required element will be returned to the panelist for completion.

NSF Graduate Research Fellowship Program

APPLICANT RATING SHEET

Applicant: Jacobs, Laura

Panel: Civil and Environmental Engineering

Intellectual Merit Criterion

Demonstrated intellectual ability and other accepted requisites for scholarly scientific study, such as the ability (1) to plan and conduct research; (2) to work as a member of a team as well as independently; and (3) to interpret and communicate research findings.

Overall Assessment of Intellectual Merit ☐ Excellent ☐ Very Good ☒ Good ☐ Less Good ☐ Fair

Mandatory - explain assessment to the applicant:

- The proposed plan of study of modal analysis of smart structural components is well laid out
- The candidate has the background to perform the work
- The area of inexpensive smart materials should be given more prominence

Broader Impacts Criterion

Contributions that (1) effectively integrate research and education at all levels, infuse learning with the excitement of discovery, and assure that the findings and methods of research are communicated in a broad context and to a large audience; (2) encourage diversity, broaden opportunities, and enable the participation of all citizens--women and men, underrepresented minorities, and persons with disabilities--in science and research; (3) enhance scientific and technical understanding; and (4) benefit society.

Overall Assessment of Broader Impacts ☐ Excellent ☒ Very Good ☐ Good ☐ Less Good ☐ Fair

Mandatory - explain assessment to the applicant:

The broader impacts of the proposed work are well outlined

Reviewer comments to the applicant on this rating sheet should be constructive and reflect the two NSF merit review criteria. Applicants

Los Alamos

Dynamics Summer School

NSF Research Proposal –Emily Prewett – 2006

Personal Statement

No single event is compelling me to pursue an advanced degree. It is a fusion of two experiences that inspires this objective: (1) my Polaris work experience, which taught me 'why' these analysis and problem-solving skills are useful and (2) my reduced-gravity undergraduate research experience, which taught me 'how' to analyze and solve engineering mechanics problems. Throughout these experiences, I have demonstrated substantial leadership ability and initiative as well as exceptional academic aptitude. A National Science Foundation Graduate Research Fellowship will assist me in continuing my education so I can develop the expertise needed for analyzing and solving complex engineering challenges and will allow me the opportunity to fulfill my potential.

My Polaris internship was a pivotal event in determining the focus of my research and honing the skills needed to succeed next year. Working for Polaris transformed the way I think about engineering mechanics and its applications in industry. Previously, I had focused exclusively on the engineering theories I learned in my classes. I had one course on introductory vibration theory but no opportunity to observe the behavior of real physical systems. Experimental vibrations, specifically modal analysis, were merely abstract ideas and formulas when I started the internship, but through active reading of technical papers, textbooks, and lecture material throughout the summer my thinking transformed and made me wonder when analytical models are appropriate and how to perform experiments that validate and improve models. I was shocked to find how seldom the linear models work in 'real world' applications when joints, complicated materials, or complex geometries are involved. My quest for knowledge was not satisfied by the end of the internship and fed my desire for higher education. Following this experience, I want to focus on vibrations pertaining to the reliability of aero-mechanical systems. I am now much more curious why one theory is better than another. During my internship, I observed that professional engineers often do not have the time to learn new ideas to handle new problems. This was an insightful realization because it made me define the type of life-long learner I want to be as an engineer. One of the reasons I would like to work on nonlinear vibrations is because I want to contribute new views to industry, and it does not appear there is much focus on nonlinearity. Industry has a tendency to conduct analysis in a perfunctory way and not utilize the full spectrum of technology and techniques available. I realized that heading into this field with only a B.S. would limit my possibilities to explore problems more completely and to discover and integrate new methods to perform the analysis more completely. This internship also provided the opportunity to demonstrate my competency. While I was left to work independently for much of the summer, my supervisors were impressed with my ability to learn highly technical material with such little guidance. Since my direct managers were not aware of my day to day activities, I had the opportunity to exercise and improve my skills in oral presentations and written reports as these were the only means of documenting my findings. These two skills, the ability to apply theory to practice and strong communication skills, will prove to be essential in my pursuit of higher education.

My participation in undergraduate research is the second fundamental experience that has prepared me for graduate school. I have participated in NASA's Reduced Gravity Student Flight Opportunities Program (RGSFOP) for three years. This program provides undergraduates the opportunity to design, build, and fly a unique experiment onboard the DC-9 aircraft. The capstone of the program and NASA's primary objective, however, focuses on outreach. The outreach I was involved in focused on those who might not otherwise be interested in science and engineering, or even in college in general. My team talked with middle and high school students, especially those in schools with a low percentage of graduates attending college. We particularly reached out to minority students to encouraged participation in science, technology, engineering, and mathematics (STEM). Our activities included presentations, working with Big Brother/Big Sister, and published articles in local newspapers and campus magazines. Participation in Engineering Expo at the University of Wisconsin was our largest outreach activity. Thousands of students as well as adults and members of the community visit Expo to view student research exhibits. These outreach opportunities have made me grateful for the experiences I have been fortunate enough to have and helped me realize the importance of giving back and encouraging the next generation of scientists and engineers. It is inspiring seeing the hope and possibility in the faces of younger students and knowing that I had a small role in encouraging them to pursue their dreams. The RGSFOP also gave me significant leadership experience. Throughout three years of participation, I learned the different roles of working in a team, and in my last year of participation I successfully co-led a team of eight undergraduate students with little input from our faculty advisor. The skills I developed include supervision of other team members and management of time, schedules, and budgets. I recognized that leading by example, maintaining a high level of integrity, and positive reinforcement and encouragement are vital qualities of a good leader. Overall, the RGSFOP was one of the most significant elements of my undergraduate education. This program taught me how to be an engineer and solve real time challenges, how to work as a team, and the qualities of effective leadership.

Throughout college, I have gained other leadership experiences as well. I am currently the vice president of the student chapter of the American Institute of Aeronautics and Astronautics (AIAA). I have previously held the position of outreach chair for AIAA. I have also participated in the LeaderShape Institute, a program focused on developing integrity in leadership. It concentrates on living in a state of possibility, making a commitment to a vision, and then working to bring that vision to reality, all while maintaining a high level of integrity.

In addition to my professional, research, and leadership experiences I have maintained a high level of academic excellence in a well respected program at a world class university. I have been selected for the Dean's Honor List every semester of my undergraduate work, as well as been the recipient of multiple scholarships. I am also a member of the National Society of Collegiate Scholars and Tau Beta Pi, an engineering honor society. I feel that these achievements compiled with the plethora of extracurricular activities like RGSFOP, AIAA, Tau Beta Pi, co-op experiences, etc., demonstrate my intellectual merit.

I am excited about the new possibilities obtaining a graduate degree will present. I would like to do vibration and non-destructive testing in a research and development environment. Specifically I want to work in the aerospace industry, and I have a particular interest in future space vehicles. I would love to work on the spaceships that take humans back to the moon and onto Mars. It is an exciting time in this country's space program, and I desire to be a contributing member as the next steps are taken. Contrary to the past, much of the work will likely be done by small, private contractors. In such small companies, it is especially important each person be as qualified as possible. Attaining an advanced degree and receiving a notable fellowship such as this one would be a significant contributing factor to gaining such a position.

An NSF Graduate Research Fellowship would provide the flexibility to engage in the important research challenges I wish to pursue. Part of my desire for attaining an advanced degree is that I have specific questions to address to satisfy my intellectual curiosity. With the aid of this fellowship, I will be able to focus completely on my nonlinear vibration research rather than becoming diverted by activities required by other funding sources such as additional research or teaching. Receiving this prestigious award would contribute significantly to bolstering the level of excellence I can achieve during my course of study.

Research Proposal

Background Information

Historically, aircraft were bought and sold as complete entities by companies such as Boeing, Northrop, Grumman, Douglas, and other suppliers of aircraft components (brakes, landing gear, avionics, etc.). Soon commercial airlines will lease aircraft instead of buying them, similar to automotive rental companies today. This trend is accelerating due to the dire financial situation of the major airline companies. These changes require new technologies for monitoring the condition and maintaining the integrity of these components. For example, if brakes are leased instead of sold, then the manufacturer of each the brake assumes responsibility for the performance each time the aircraft flies and therefore must have a system in place to evaluate the condition of the brake in a non-intrusive manner.

Objective

Because of my interest in aircraft safety and the mechanics of engineering materials under different types of operating loads, I propose to develop vibration and temperature monitoring sensors, models, and data analysis techniques to monitor the health of some aircraft component such as a metallic or hybrid metal-ceramic brake. Based on my experiences as an intern dealing with real-world vibrating systems that often exhibit nonlinear characteristics, my hypothesis in this proposed research is the nonlinear and the linear features in the vibration response at various temperatures will each illustrate distinctive features that can characterize the damage. My advisor and I would need to define the specific component, and perhaps I could also work in conjunction with an aircraft component manufacturer.

Approach

To achieve this objective, I would need to complete the following tasks:

1. Drawings and spare parts need to be obtained from a manufacturer in order to design and fabricate an experimental test bed. One challenge in this task is the complexity of the thermal and mechanical boundary conditions presented by an actual aircraft that must be duplicated in an experimental setting. I will utilized thermal and vibration models determine a design for the test fixture that replicates the thermal (conduction, radiation, and convection) and the mechanical (stiffness, loading) boundary conditions. A second challenge is the high temperatures and strains at which brakes operate in a real system. A system imposing high temperatures and mechanical loads simultaneously must be employed. One potential advisor has a system capable of producing just that: high temperatures (> 800 deg F) and dynamic loads (1 inch of stroke at 100 Hz).
2. Models of the heat transfer and vibrations of the component also need to be developed. These models are necessary so the variables that cannot be exclusively known can be accurately estimated using the available senor data. The modeling challenges involve the nonlinear mechanical responses typical of these components. These nonlinearities are attributed to the material properties and the complex assembly of joints and complicated geometries. Unfortunately, however, current finite element software does not provide the means to estimate these nonlinear parameters. I propose to use linear finite element models and incorporate simple

nonlinear models of damping and stiffness to describe component responses to operating loads. These models need to be combined with thermal models as well. Experiments should be conducted to estimate model parameters that cannot be analytically determined such as nonlinear stiffness and damping coefficients. Additional experiments need to be conducted to validate these models.

3. Data analysis techniques need to be developed for the test fixture using the models described above. The approach I propose is to continuously compare the model vibration and thermal responses to the measured responses. The challenge in this task is the data to be analyzed is operational data. The operating environment controls the level and frequency of the measured responses Also there is a risk of not being able to identify flaws in the component (wear, anomalous load, or excess stress in the brake, etc.) if the response does not highlight the damage of interest. In addition, the component behaves nonlinearly resulting in large changes in the frequency bandwidth of the vibration response even in a healthy response measurement. To address these challenges, I will utilized both time and frequency methods for analyzing the data. For example, spectrograms provide plots of the response amplitude as a function of time and frequency. These plots can then be used to assess the component health at various temperatures. My hypothesis can then be validated with this data analysis.
4. Analytical simulations need to be performed at even higher temperatures and in a greater variety of situations than experiments will allow. Challenges involve verifying the authenticity of the results at these elevated extreme temperatures. These challenges can be addressed by designing boundary conditions properly and utilizing high-temperature accelerometers and thermo-electric sensors in the experimental setting.

Merit Criteria

This proposed research plan demonstrates both intellectual merit and satisfies the broader impacts criterion. The intellectual component of this research entails the nonlinear thermo-mechanical models to be developed, the data analysis methods to be employed, and the simulation and experimentation design needed to confirm my hypothesis that nonlinear response characteristics at various operating temperatures will enhance the ability to characterize damage. The safety implications on air travel and the business implications of this proposed model for monitoring the health of aircraft components fulfill the broader impacts criterion.

Conclusion

The NSF Graduate Research Fellowship would allow me to pursue a project described here with the help of my advisor. The success of this research has the possibility of having a profound effect on the aeronautics and aerospace industries. The techniques proposed as part of this research plan can be employed by other industries requiring a non-intrusive, efficient, and reliable means of monitoring the structural integrity of components. In the near future, this technology could be implored by NASA to monitor the health of the Space Shuttle tiles, and in the more distant future, private space companies could use similar models and data analysis methods to validate expensive rockets and payload before sending them into the extreme environments of the space. On a personal level, I can naturally elaborate this plan to work on a PhD to develop improved models and analysis methods to study more complicated problems such as a spacecraft.

Rating sheets missing a required element will be returned to the panelist for completion.

NSF Graduate Research Fellowship Program

APPLICANT RATING SHEET

Applicant: Prewett, Emily
Panel: Mechanical Engineering

Intellectual Merit Criterion

Demonstrated intellectual ability and other accepted requisites for scholarly scientific study, such as the ability (1) to plan and conduct research; (2) to work as a member of a team as well as independently; and (3) to interpret and communicate research findings.

Overall Assessment of Intellectual Merit ☐ Excellent ☒ Very Good ☐ Good ☐ Less Good ☐ Fair

Mandatory - explain assessment to the applicant:

- past research experience was primarily completed in a group rather independently
- research hypothesis was not formulated as a scientific question
- important researcharea,

Broader Impacts Criterion

Contributions that (1) effectively integrate research and education at all levels, infuse learning with the excitement of discovery, and assure that the findings and methods of research are communicated in a broad context and to a large audience; (2) encourage diversity, broaden opportunities, and enable the participation of all citizens--women and men, underrepresented minorities, and persons with disabilities--in science and research; (3) enhance scientific and technical understanding; and (4) benefit society.

Overall Assessment of Broader Impacts ☐ Excellent ☐ Very Good ☐ Good ☒ Less Good ☐ Fair

Mandatory - explain assessment to the applicant:

- middle + high school outreach / good leadership experience through RGSFOP
- no discussion on future efforts in this area.

Reviewer comments to the applicant on this rating sheet should be constructive and reflect the two NSF merit review criteria. Applicants will be able to view a copy of their rating sheets without the name of the reviewer on a secure web site. Maximum protection will be given

Los Alamos
Dynamics Summer School

Rating sheets missing a required element will be returned to the panelist for completion.

NSF Graduate Research Fellowship Program

APPLICANT RATING SHEET

Applicant: Prewett, Emily

Panel: Mechanical Engineering

Intellectual Merit Criterion

Demonstrated intellectual ability and other accepted requisites for scholarly scientific study, such as the ability (1) to plan and conduct research; (2) to work as a member of a team as well as independently; and (3) to interpret and communicate research findings.

Overall Assessment of Intellectual Merit ☒ Excellent ☐ Very Good ☐ Good ☐ Less Good ☐ Fair

Mandatory - explain assessment to the applicant:

Outstanding research project, clear and focused presentation.
Student's passion for research is impressive.
Her research topic, health monitoring of aircraft components, is of great national and international interest.
Excellent GPA, 3 scholarships, internship at Pelcris, undergrd research at NASA as co-leader of team.
Very strong recommendations.

Broader Impacts Criterion

Contributions that (1) effectively integrate research and education at all levels, infuse learning with the excitement of discovery, and assure that the findings and methods of research are communicated in a broad context and to a large audience; (2) encourage diversity, broaden opportunities, and enable the participation of all citizens--women and men, underrepresented minorities, and persons with disabilities--in science and research; (3) enhance scientific and technical understanding; and (4) benefit society.

Overall Assessment of Broader Impacts ☒ Excellent ☐ Very Good ☐ Good ☐ Less Good ☐ Fair

Mandatory - explain assessment to the applicant:

Numerous outreach activities including work with middle and high school students, outreach chair for AIAA. Commitment to bringing women into engineering. Interest in helping professional engineers in developing their analytical skills.

Reviewer comments to the applicant on this rating sheet should be constructive and reflect the two NSF merit review criteria. Applicants will be able to view a copy of their rating sheets without the name of the reviewer on a secure web site. Maximum protection will be given

Rating sheets missing a required element will be returned to the panelist for completion.

NSF Graduate Research Fellowship Program

APPLICANT RATING SHEET

Applicant: Prewett, Emily
Panel: Mechanical Engineering

Intellectual Merit Criterion

Demonstrated intellectual ability and other accepted requisites for scholarly scientific study, such as the ability (1) to plan and conduct research; (2) to work as a member of a team as well as independently; and (3) to interpret and communicate research findings.

Overall Assessment of Intellectual Merit ☑ Excellent ☐ Very Good ☐ Good ☐ Less Good ☐ Fair

Mandatory - explain assessment to the applicant:

- Research Plan is well laid out, especially considering that the applicant has not yet started grad-study
- very relevant past research experiences which probably led to a good research plan.
- has given presentations to groups
- Plan to participate in a course at national Lab to ~~just~~ get a good start on grad. work.

Broader Impacts Criterion

Contributions that (1) effectively integrate research and education at all levels, infuse learning with the excitement of discovery, and assure that the findings and methods of research are communicated in a broad context and to a large audience; (2) encourage diversity, broaden opportunities, and enable the participation of all citizens--women and men, underrepresented minorities, and persons with disabilities--in science and research; (3) enhance scientific and technical understanding; and (4) benefit society.

Overall Assessment of Broader Impacts ☐ Excellent ☑ Very Good ☐ Good ☐ Less Good ☐ Fair

Mandatory - explain assessment to the applicant:

- Participated in outreach during undergraduate experience at NASA
- Leadership role in student organizations
- appreciates safety and business implications of research
- Could have better outlined some specifics of a plan to address this criterion

Reviewer comments to the applicant on this rating sheet should be constructive and reflect the two NSF merit review criteria. Applicants will be able to view a copy of their rating sheets without the name of the reviewer on a secure web site. Maximum protection will be given

NSF Research Proposal –Ben Kosbab – 2005

Seismic Assessment of Container Cranes via Integrated Large Scale Simulation
Key Words port, container crane, earthquake, large-scale testing, hybrid testing, vulnerability

Motivation Recent earthquakes in the US and abroad have illustrated the vulnerability of the built infrastructure to damage – both in terms of loss-of-life as well as economic impact. Earthquakes pose a significant threat to the largest of US seaports such as Los Angeles, Long Beach, Seattle, Oakland, Charleston, Savannah, and others (National Research Council, 2003), which serve as critical gateways for international trade. As the world's largest trading nation, the US economy is exceedingly vulnerable, with over forty percent of the value of U.S. international trade ($811 billion in 2003) passing through these ports, making shipping the most prevalent mode of trade (Bureau of Transportation Statistics, 2004). However, as noted by a recent National Research Council report, "Preventing Earthquake Disasters," ports have received little attention compared with other infrastructures (i.e., building and bridges) and significant damage to a major port may have a significant impact on the economy, and pose a threat to national security. A poignant international example was seen in 1995, when the Hyogoken-Nanbu earthquake struck the Port of Kobe. Kobe fell from being the 6th largest port worldwide, and has recovered to only the 35th largest (Lloyd's, 2005). One of the most vulnerable components of a port are the container cranes that are used to load and unload container ships. Container cranes have been increasing in size, thereby becoming more susceptible to earthquake damage. These rigid frame non-redundant structures are uniquely designed for each port, and their replacement in the event of failure often takes longer than a year, resulting in oft-insurmountable indirect losses. However, little previous work has been performed related to their performance during earthquakes, despite heavy earthquake damage observed in the form of local buckling of plates and global buckling of legs, as well as derailment and other connection issues to the rail.

Hypothesis A better understanding of the dynamic behavior of cranes, via a unique coupled experimental and analytical program using the Network for Earthquake Engineering Simulation (NEES) facilities, will enable the development of more resilient ports.

Research Plan My research project will involve field testing, large-scale testing, and detailed analytical studies, culminating in the development of design recommendations for container cranes. Through NEES, I will be part of a 16-member interdisciplinary team focused on assessing the vulnerability of ports, including wharfs, piles, storage facilities, and other infrastructure. NEES, a program funded by the National Science Foundation, is a collaboratory network of unique earthquake equipment sites across the nation. One unique aspect of this project is the coupling that will take place between the "engineering" and the "non-engineering" parts of the project. To start, non-destructive in-situ field testing will be performed on representative container cranes at vulnerable ports to obtain baseline dynamic properties. This data will be invaluable in validating, correlating, and fine tuning the project's resulting analytical model, as well as identifying specific focus issues for laboratory experiment. Innovative experimental testing is now possible utilizing the new NEES test sites. This project will utilize a physical crane model at 1 to 6 scale, making it the largest structural crane model ever tested. It will be representative of the typical crane, with accurate dispersion of mass and stiffness while maintaining true connection details to help represent the damping characteristics and allowing simple modifications to reflect a multitude of crane types, including the new "supercranes." The complex support condition involving the crane rail and quay must be effectively modeled; the inherent non-linearity of this contact/uplift condition presents certain challenges that can be addressed with innovative pseudo-dynamic hybrid testing schemes now possible through NEES in which shake table input motion is calculated in real-time via numerical models of soil/structure interaction. Field and laboratory data will be combined to create and validate a holistic, non-linear analytic model encompassing all of these aspects of dynamic crane response. These resulting analytic models will facilitate the creation of fragility relationships of cranes to aid in disaster prevention through risk analysis and decision sciences. I plan to work closely with industry leaders to ensure model accuracy and usefulness. Presidents of the two largest firms (Michael Jordan, CEO of Liftech Consultants, Inc, and William Casper of Casper, Phillips & Associates, Inc.) that specialize in the design of container cranes have agreed to work closely with me on the project to ensure that the results of the research can be quickly translated to industry standards that can be used by designers from all over the world.

Anticipated Findings It is anticipated that derailment of the wheels, localized buckling of key brace connections, and overturning will be found to be key aspects of the seismic performance of container cranes. Current crane design approaches will be modified to account for earthquakes without compromising crane speed or capability or significantly increasing crane cost

.

Education and Outreach An education and outreach program has been created as part of this research project and will center on developing education models focused on ports and natural hazards. Through NSF sponsorship, an REU has been set up for under-represented students to spend a summer working directly with me on the crane research project. Also, I will be working with a local high school in Atlanta with predominantly African-American population. Through this effort, I hope to show students that not only is engineering crucial to our society, but that it can be exciting as well. To do this, I will utilize the unique tele-presence capabilities of the partner NEES sites so that students may track experimental progress from their classroom. Students will feel connected by real-time audio and video web-based feeds of the experiment. The large-scale shake table tests should leave a lasting impression on these students.

Intellectual Merit and Broader Impacts The proposed research program will be the first comprehensive study of the seismic performance of cranes and their effect on the operation of a port, demonstrating this project's originality. The study will use state-of-the-art experimental facilities supported by the NSF collaboratory, Network for Earthquake Engineering Simulation (NEES), to develop a unique large-scale test of a typical container crane. Using the results of the experimental tests, detailed analytical models will be developed to represent the highly nonlinear behavior of the cranes. Such models currently do not exist. The results of the research will have an immediate impact on the design and safe construction of container cranes, ultimately serving to make our ports more resilient to natural hazards. Working closely with leaders in industry will ensure rapid knowledge transfer, while the proposed education program for this project will help educate and excite K-12 students about the role of Civil Engineers in society.

Bureau of Transportation Statistics. (2004). *America's Freight Transportation Gateways: Connecting our Nation to Places and Markets Abroad*, U.S. Department of Transportation, Washington DC.
Lloyd's. (1981-2005). *Ports of the World*. Informa Publication Group, London.
National Research Council. (2003). *Preventing Earthquake Disasters: The Grand Challenge in Earthquake Engineering – A Research Agenda for the Network for Earthquake Engineering Simulation (NEES)*. National Academies Press, Washington, DC.

Rating sheets missing a required element will be returned to the panelist for completion.

NSF Graduate Research Fellowship Program

APPLICANT RATING SHEET

Applicant: Kosbab, Benjamin

Panel: Civil & Environmental Engineering

Intellectual Merit Criterion

Demonstrated intellectual ability and other accepted requisites for scholarly scientific study, such as the ability (1) to plan and conduct research; (2) to work as a member of a team as well as independently; and (3) to interpret and communicate research findings.

Overall Assessment of Intellectual Merit ☒ Excellent ☐ Very Good ☐ Good ☐ Fair ☐ Poor

Mandatory - explain assessment to the applicant:

- an exemplary record shows student well-prepared for research career.
- research plan is well-motivated and described, and, critically, is quite novel.

Broader Impacts Criterion

Contributions that (1) effectively integrate research and education at all levels, infuse learning with the excitement of discovery, and assure that the findings and methods of research are communicated in a broad context and to a large audience; (2) encourage diversity, broaden opportunities, and enable the participation of all citizens--women and men, underrepresented minorities, and persons with disabilities--in science and research; (3) enhance scientific and technical understanding; and (4) benefit society.

Overall Assessment of Broader Impacts ☐ Excellent ☒ Very Good ☐ Good ☐ Fair ☐ Poor

Mandatory - explain assessment to the applicant:

- Good record of outreach
- excellent view of civil engineering's place in society.

Los Alamos
Dynamics Summer School

Rating sheets missing a required element will be returned to the panelist for completion.

NSF Graduate Research Fellowship Program

APPLICANT RATING SHEET

Applicant: Kosbab, Benjamin
Panel: Civil & Environmental Engineering

Intellectual Merit Criterion

Demonstrated intellectual ability and other accepted requisites for scholarly scientific study, such as the ability (1) to plan and conduct research; (2) to work as a member of a team as well as independently; and (3) to interpret and communicate research findings.

Overall Assessment of Intellectual Merit ☐ Excellent ☐ Very Good ☒ Good ☐ Fair ☐ Poor

Mandatory - explain assessment to the applicant:

Strong academic record w/ some weaknesses when compared to national standards. Very strong references and evidence of strong communication skills. Previous research has served as invaluable source of skills, but do not present a convincing case to development of research question and independent thought. Proposed research has compelling need, but essay does not convey a clear research question w/ supporting objectives and tasks. Need greater synthesis of all components of package to paint clear picture of candidate & career

Broader Impacts Criterion

Contributions that (1) effectively integrate research and education at all levels, infuse learning with the excitement of discovery, and assure that the findings and methods of research are communicated in a broad context and to a large audience; (2) encourage diversity, broaden opportunities, and enable the participation of all citizens--women and men, underrepresented minorities, and persons with disabilities--in science and research; (3) enhance scientific and technical understanding; and (4) benefit society.

Overall Assessment of Broader Impacts ☐ Excellent ☒ Very Good ☐ Good ☐ Fair ☐ Poor

Mandatory - explain assessment to the applicant:

Has several leadership experiences, which is a great strength. But need greater awareness of role model potential. Outreach and diversity activities to be applauded. Clear understanding of impact of research on society ~~to~~ and some understanding of impact on technical knowledge-base. Need to provide clear integration of research and educational goals (past & future)

Los Alamos
Dynamics Summer School

Rating sheets missing a required element will be returned to the panelist for completion.

NSF Graduate Research Fellowship Program

APPLICANT RATING SHEET

Applicant: Kosbab, Benjamin

Panel: Civil & Environmental Engineering

Intellectual Merit Criterion

Demonstrated intellectual ability and other accepted requisites for scholarly scientific study, such as the ability (1) to plan and conduct research; (2) to work as a member of a team as well as independently; and (3) to interpret and communicate research findings.

Overall Assessment of Intellectual Merit ☒ Excellent ☐ Very Good ☐ Good ☐ Fair ☐ Poor

Mandatory - explain assessment to the applicant:

- background from several special programs (REU, Fldor, etc) are very useful & strong activities
- plan is well argued & unique. I like the completeness of the idea — up to field testing etc.
- Simply outstanding & completely well-rounded proposal.

Broader Impacts Criterion

Contributions that (1) effectively integrate research and education at all levels, infuse learning with the excitement of discovery, and assure that the findings and methods of research are communicated in a broad context and to a large audience; (2) encourage diversity, broaden opportunities, and enable the participation of all citizens--women and men, underrepresented minorities, and persons with disabilities--in science and research; (3) enhance scientific and technical understanding; and (4) benefit society.

Overall Assessment of Broader Impacts ☒ Excellent ☐ Very Good ☐ Good ☐ Fair ☐ Poor

Mandatory - explain assessment to the applicant:

- Good extension of research to outreach activities — Atlanta school project, minority community
- research topic is broadly set in context of response to natural disaster

NSF Research Proposal –Eric Flynn – 2005

Assessment of Structural Health Monitoring
Techniques through Long Term Monitoring of a Concrete Dam

Keywords: Structural Health Monitoring, Dam Safety, System Identification, Model Updating

Introduction With aging critical structures under the constant threat of natural and other disasters, the effective monitoring and maintenance of the nation's and the world's infrastructure is becoming increasingly important. The goal of the proposed research is to experimentally verify and improve theoretical structural health monitoring techniques through the long term evaluation of a concrete dam. In addition, this research will provide a basis for effective health monitoring of dams and similar structures. I became interested in structural health monitoring (SHM) through my research in the field as an undergraduate. As a civil engineering student, however, I see a great potential for more effective application of the numerous theoretical methods to real structures. This research would help push the field of SHM towards its original goal of making real structures safer and more reliable.

Background One of the most promising forms of SHM has been in numerical model updating through Bayesian probabilistic approaches [1]. These methods iteratively compute and track the most probable structural stiffness and mode shape parameters based on noisy, incomplete data collected from a structure. Testing of these methods, however, has been limited to simulations and small scale lab structures. Currently Caltech is studying the Caltech Millikan Library and UCLA Factor Building as part of a SHM research initiative [2]. However, the focus of this study has been on observing small natural changes in structural behavior as a basis for SHM, and not as a direct way of testing SHM methods. While many dams are already instrumented for basic long term monitoring, the extent of this instrumentation rarely exceeds a small number of sensors for measuring peak accelerations or GPS units for tracking bulk deformation. This falls far short of the necessary sensor density for fully defining a dam's long term behavior and tracking its structural health.

Hypothesis The constantly changing behavior of dams makes them unique among civil structures. I propose that the different environmental and functional states that a dam undergoes over the period of a year, month, or even day serve as an effective basis for testing current SHM techniques, which rely on tracking changes in structural parameters. The changes that are normal in the day-to-day behavior of a dam would be indicative of damage in most other civil structures. I hypothesize that SHM techniques will be able to track and localize changes in dam behavior during high and low reservoir levels, with flood gates opened or closed, with hydro-electric gates opened or closed, during the day and at night, during the summer and winter, and before, after and during a storm or seismic event. In addition, I believe the long term evaluation and subsequent analysis will provide a SHM baseline of normal dam behavior and a more quantitative explanation of natural changes in dam behavior.

Research Plan This research will be based at the California Institute of Technology, whose civil engineering program is involved with the most up-to-date health monitoring methods and long term instrumentation studies, and under the advising of both of Professor James Beck (theoretical) and Professor Thomas Heaton (experimental). The majority of the instrumentation (accelerometers, shaker, and DAQ equipment) will be obtained from the shared inventory at Caltech and Harvey Mudd College. Due to the complexity of this instrumentation and subsequent data analysis, I will be giving undergraduates from either or both schools the opportunity to participate in this research effort. The first year of research will be in preparation of the dam instrumentation and investigation of applicable SHM methods. I will work with organizations such as the Bureau of Reclamation, the Army Corps of Engineers, and the California DWR in securing funding and choosing a suitable dam for monitoring. A highly active, accessible large scale arch or gravity dam with preliminary instrumentation will be the most useful in this research. I will develop a numerical model for this dam, determine the most useful degrees of freedom for tracking changes, and design the instrumentation setup based on these degrees of freedom [3]. Once the dam is instrumented, the next two to three years will be spent creating a detailed record of all unique events and states and linking them to the corresponding sets of data. For each of these events, I will hypothesize the expected change in system parameters, apply the SHM techniques, evaluate their ability to track and localize these changes, and improve them where possible.

Presentation The primary presentations will be in the form of journal articles and a research thesis, which will describe the effectiveness of the various SHM methods implemented, their qualifications, how they can be improved, and recommendations for their real world implementation. They will also include the observed changes in dam behavior and their relationship to real events as well as findings on the most effective way to monitor the structural health of dams and related structures.

In addition, the dam will be linked into either the Southern or Northern California Seismic Network (SCSN and NCSN) so that data will be available online to other researchers. I will also be making use of my programming experience to develop online tools for educators, non-engineers, as well as myself to run calculations based on live data and view features such as resonant frequencies, animated mode shapes, and peak event captures (such as earthquakes).

Finally, I will be taking over a graduating PhD student's role in giving interactive demonstrations on resonance to underrepresented students from surrounding school districts using a shaker on top of Millikan Library as part of Caltech's outreach program. I will tie my dam research in with these presentations since there are very few things as effective at getting students excited about engineering as seeing a large scale dam in action (it worked for me). I would also like the occasional opportunity to be a part of grade school field trips to the dam, as I accidentally was during research at Folsom Dam.

Qualifications I strongly believe that my previous research experiences make me uniquely qualified for taking on this research. As a senior at my undergraduate institute, I was regarded as a data acquisition expert, being asked by students and professors alike for advice on the proper instrumentation of their experiments and interpretation of their data. I have already spent two years with a dam and its vibration data, so I am familiar with how to effectively instrument such a large scale structure as well as how to properly process the resulting data. In fact, it was this experience with dams and their dramatic (and often quite frustrating) month-to-month and even day-to-day changes in behavior that inspired this research initiative. Between my collapse monitoring and honeycomb damage identification research, I've pored over dozens of SHM methods and worked on understanding and applying them to burning structures and aerospace systems. I am familiar with the most current advances in the field and am confident in my ability to apply them to a structure as complicated as a dam. I am excited to have the opportunity do this **original** work that builds on these personal experiences in structural dynamics.

[1] Beck, James, et al. "Monitoring Structural Health Using a Probabilistic Measure." Computer-Aided Civil and Infrastructure Engineering 16 (2001): 1-11.

[2] Bradford, S. C., et al. (2004) Results of Millikan Library Forced Vibration Testing. Technical Report: Caltech EERL:EERL-2004-03. California Institute of Technology.

[3] Papadimitriou, Costas, et al. "Entropy-Based Optimal Sensor Location for Structural Model Updating." Journal of Vibration and Control 6 (2000): 781-800.

Rating sheets missing a required element will be returned to the panelist for completion.

NSF Graduate Research Fellowship Program

APPLICANT RATING SHEET

Applicant: Flynn, Eric

Panel: Civil and Environmental Engineering

Intellectual Merit Criterion

Demonstrated intellectual ability and other accepted requisites for scholarly scientific study, such as the ability (1) to plan and conduct research; (2) to work as a member of a team as well as independently; and (3) to interpret and communicate research findings.

Overall Assessment of Intellectual Merit ☑ Excellent ☐ Very Good ☐ Good ☐ Less Good ☐ Fair

Mandatory - explain assessment to the applicant:

- Well developed research

- Very nice job on presenting research in structural dynamics

Broader Impacts Criterion

Contributions that (1) effectively integrate research and education at all levels, infuse learning with the excitement of discovery, and assure that the findings and methods of research are communicated in a broad context and to a large audience; (2) encourage diversity, broaden opportunities, and enable the participation of all citizens--women and men, underrepresented minorities, and persons with disabilities--in science and research; (3) enhance scientific and technical understanding; and (4) benefit society.

Overall Assessment of Broader Impacts ☑ Excellent ☐ Very Good ☐ Good ☐ Less Good ☐ Fair

Mandatory - explain assessment to the applicant:

- Eric plans to link his data and results to Northern or Southern Cal Seismic Network online - very good link for educators in K-12
- He also plans to present for outreach

Reviewer comments to the applicant on this rating sheet should be constructive and reflect the two NSF merit review criteria. Applicants

Rating sheets missing a required element will be returned to the panelist for completion.

NSF Graduate Research Fellowship Program

APPLICANT RATING SHEET

Applicant: Flynn, Eric

Panel: Civil and Environmental Engineering

Intellectual Merit Criterion

Demonstrated intellectual ability and other accepted requisites for scholarly scientific study, such as the ability (1) to plan and conduct research; (2) to work as a member of a team as well as independently; and (3) to interpret and communicate research findings.

Overall Assessment of Intellectual Merit ☑ Excellent ☐ Very Good ☐ Good ☐ Less Good ☐ Fair

Mandatory - explain assessment to the applicant:

Excellent academics and superb undergraduate research experience. Research proposal well written on a timely topic. Not as exciting as previous work, perhaps it will become a path-breaking project after student actually gets into it as his record attests.

Broader Impacts Criterion

Contributions that (1) effectively integrate research and education at all levels, infuse learning with the excitement of discovery, and assure that the findings and methods of research are communicated in a broad context and to a large audience; (2) encourage diversity, broaden opportunities, and enable the participation of all citizens--women and men, underrepresented minorities, and persons with disabilities--in science and research; (3) enhance scientific and technical understanding; and (4) benefit society.

Overall Assessment of Broader Impacts ☐ Excellent ☑ Very Good ☐ Good ☐ Less Good ☐ Fair

Mandatory - explain assessment to the applicant:

Remarkable ability to integrate research and education, and enhance scientific and technical understanding. Weak service record and broader commitment to scientific dissemination and education.

Reviewer comments to the applicant on this rating sheet should be constructive and reflect the two NSF merit review criteria. Applicants

Rating sheets missing a required element will be returned to the panelist for completion.

NSF Graduate Research Fellowship Program

APPLICANT RATING SHEET

Applicant: Flynn, Eric

Panel: Civil and Environmental Engineering

Intellectual Merit Criterion

Demonstrated intellectual ability and other accepted requisites for scholarly scientific study, such as the ability (1) to plan and conduct research; (2) to work as a member of a team as well as independently; and (3) to interpret and communicate research findings.

Overall Assessment of Intellectual Merit ☒ Excellent ☐ Very Good ☐ Good ☐ Less Good ☐ Fair

Mandatory - explain assessment to the applicant:

- Coursework performance and research exposure performance as an undergraduate were excellent
- Recommendations fully ~~[illegible]~~ certify the applicant's capability for independent research at the PhD level
- Interdisciplinary research
- 4 publications to date
- Several awards & honors

Broader Impacts Criterion

Contributions that (1) effectively integrate research and education at all levels, infuse learning with the excitement of discovery, and assure that the findings and methods of research are communicated in a broad context and to a large audience; (2) encourage diversity, broaden opportunities, and enable the participation of all citizens--women and men, underrepresented minorities, and persons with disabilities--in science and research; (3) enhance scientific and technical understanding; and (4) benefit society.

Overall Assessment of Broader Impacts ☒ Excellent ☐ Very Good ☐ Good ☐ Less Good ☐ Fair

Mandatory - explain assessment to the applicant:

- The effect of research on Dam safety and safety of residents near a dam is significant
- Research proposed, at the instrumentation and data acquisition level can involve both undergraduate & graduate students: good for education & research
- Teaching and Research internships and assistantships

Reviewer comments to the applicant on this rating sheet should be constructive and reflect the two NSF merit review criteria. Applicants

NSF Research Proposal –Stephen Schnelle – 2007

Structural Health Monitoring via Compressed Sensing

Keywords: Structural Health Monitoring, Wireless Sensor Networks, Compressed Sensing

Introduction: Structural Health Monitoring (SHM), the approach of using sensors to monitor and assess the condition of a structure, is a critical but underdeveloped area of research due to the large amount of cooperation required among engineering disciplines such as mechanical, civil, and electrical. Measurements at regular intervals can be used to determine flaws in a structure, often provided warnings before minor defects cause system failure. Earlier this year, a Mississippi River bridge in Minneapolis collapsed, killing thirteen people. Boeing has adopted the use of sensors into their airframes to insure their integrity, and the FAA is also working towards adopting this idea. Aircraft are currently stripped down every 18-24 months for inspection, a very lengthy and expensive process. With SHM, we could prevent some disasters, but our monitoring capabilities in this area severely lag the need.

Wireless sensor networks consist of multiple sensor nodes distributed over a region collecting data independently from each other, and communicating with one another and/or a central node through the use of a wireless transceiver. For simple monitoring applications, the fact that wireless networks must rely on batteries or stored energy may discourage their use. On the other hand, the desire for more and better data is rapidly increasing the size of sensor networks, and in many applications, wireless sensor networks are now the best option. For example, large amounts of wires add extra weight and reduce space available in a plane for other equipment and wiring an existing building may be too costly

Challenges: While wireless networks provide valuable information on a structure, analyzing the data can be quite burdensome. Sensors cannot directly tell if a structure is damaged. Features from the sensors must be extracted to make assessments. Waveform or image comparisons can be performed (pattern recognition), errors between measured and predicted responses can be analyzed, and model parameters can be utilized. Statistical modeling of the data set is required to make a full assessment.

Compressed Sensing: Compressed sensing offers one potential solution to the data overhaul and power consumption issues. While many conventional data compression algorithms reduce large amounts of acquired data to smaller sets using techniques such as wavelets, Huffman coding, or even the Karhunen-Loeve Transform, compressed sensing attacks the acquisition problem itself. Rather than acquire enormous amounts of data and then compress it, the data is acquired directly in a compressed format. However, the feasibility of this technique results from acquiring the data in a fashion not normally expected.

The math for compressed sensing has been developed over the last three years [1]. The key idea is that projecting a sparse signal onto a random basis allows the signal to be reconstructed with very few samples. If K of N signal coefficients are non-zero (K<<N implies K is sparse), with a combinatorial search, only K+1 measurements are required for reconstruction; for a more practical linear programming algorithm, c(K log(N/K)) are needed, where c is a small constant. Samples are taken in a random basis, or pseudo-random in practice, which is incoherent with the basis in which the data would normally be acquired. While using a random basis seems quite counterintuitive, researchers at Rice University have already implemented some of the theory on a “single-pixel camera.” Data need not be images in the visible spectrum, however.

Procedure, Hypothesis, and Resources: Obtaining a comprehensive view of the current state of a structure is ideal but difficult; to do this SHM should be performed from both local and global perspectives. Local SHM generally involves active sensing; examples of three major techniques are lamb wave propagation, impedance method, and time reversal analysis. Global SHM is often more passive, and utilizes low frequency response data from the structure. Methods rely on modal testing, system identification, and operational environmental monitoring. Among the local SHM tests, lamb-wave propagation would seem to offer the best data sets for compressed sensing, but many test sets would be analyzed. After starting with the local SHM data, combining results from both local and global health monitoring would be another phase of the research, handling inter-signal and intra-signal correlations [2].

Data must be further processed for damage prognosis to estimate the remaining life of the structure. While determining whether the structure is damaged and where can be done simply, determining the type and extent of damage and outlook for the structure requires learning algorithms using test variables such as waveform or image comparisons, model parameters, and residual error between measured and predicted responses. Additional phases of the work include tracking changes in the structure for learning algorithms in structural health monitoring using compressed sensing, and analyzing how often compressed sensing data at a node should be shared with other nodes. The residual error between measured and predicted responses may be particularly well-suited for compressed sensing methods.

Rice University is one of the leading centers in compressed sensing, and has begun to develop a framework for the use of compressed sensing in sensor networks [2]. Additionally, I have begun discussing the application of compressed sensing to structural health monitoring with Professor Satish Nagarajaiah of the Civil and Mechanical Engineering departments, who directed me to publications from a civil engineering professor at Lehigh University for an NSF CAREER Award on data compression for structural health monitoring [3]. Rice's small environment makes it suitable for interdisciplinary work. My assignment at the Los Alamos Dynamics Summer School this past summer has provided background in structural health monitoring, in addition to several key contacts in the field, including Chuck Farrar and Matt Bement.

Conclusions: My previous work at Los Alamos National Laboratory optimizing image processing algorithms will be beneficial for determining how to best condition data sets for the application of compressed sensing; furthermore, through my work this summer at the lab, I have developed skills working with other engineering disciplines: civil, structural and mechanical. Besides publishing results of my work in the traditional IEEE journals such as IEEE Transactions on Signal Processing, my work would also be a viable candidate for publication in Structural Health Monitoring: An International Journal, Journal of Structural Control and Health Monitoring, and the standard ASME and ASCE journals. Integrating compressed sensing into structural health monitoring, would greatly increase the reliability of planes, bridges, and other structures. Data could be analyzed quickly and efficiently, reducing costs and saving lives.

References:

[1] E. Candès, J. Romberg, and T. Tao. Robust uncertainty principles: Exact signal reconstruction from highly incomplete frequency information. (IEEE Trans. on Information Theory, 52(2) pp. 489 - 509, February 2006. Originally Submitted June 2004)

[2] D. Baron, M. Wakin, M. Duarte, S. Sarvotham, and R. Baraniuk. Distributed compressed sensing. (Preprint 2005).

[3] Y. Zhang and J. Li. Integrated Structural Health Monitoring System for Seismic Hazard Mitigation Application. US-Taiwan Workshop on Smart Structural Technolgy for Seismic Hazard Mitigation. Paper NO: 004. Taipei, Taiwan. October 12-14, 2006.

I attest that this proposal is my original work, with advice from Richard Baraniuk and others.

Los Alamos
Dynamics Summer School

Rating sheets missing a required element will be returned to the panelist for completion.

NSF Graduate Research Fellowship Program

APPLICANT RATING SHEET

Applicant: Stephen, Schnelle

Panel: Electrical Engineering

Intellectual Merit Criterion

Demonstrated intellectual ability and other accepted requisites for scholarly scientific study, such as the ability (1) to plan and conduct research; (2) to work as a member of a team as well as independently; and (3) to interpret and communicate research findings.

Overall Assessment of Intellectual Merit ☑ Excellent ☐ Very Good ☐ Good ☐ Fair ☐ Poor

Mandatory - explain assessment to the applicant:

Excellent application: strong academic credentials, research experiences, plan & potential.

Broader Impacts Criterion

Contributions that (1) effectively integrate research and education at all levels, infuse learning with the excitement of discovery, and assure that the findings and methods of research are communicated in a broad context and to a large audience; (2) encourage diversity, broaden opportunities, and enable the participation of all citizens--women and men, underrepresented minorities, and persons with disabilities--in science and research; (3) enhance scientific and technical understanding; and (4) benefit society.

Overall Assessment of Broader Impacts ☑ Excellent ☐ Very Good ☐ Good ☐ Fair ☐ Poor

Mandatory - explain assessment to the applicant

Abundant indicators of contributions to BI.

Reviewer comments to the applicant on this rating sheet should be constructive and reflect the two NSF merit review criteria. Applicants

Rating sheets missing a required element will be returned to the panelist for completion.

NSF Graduate Research Fellowship Program

APPLICANT RATING SHEET

Applicant: Stephen, Schnelle

Panel: Electrical Engineering

Intellectual Merit Criterion

Demonstrated intellectual ability and other accepted requisites for scholarly scientific study, such as the ability (1) to plan and conduct research; (2) to work as a member of a team as well as independently; and (3) to interpret and communicate research findings.

Overall Assessment of Intellectual Merit ☒ Excellent ☐ Very Good ☐ Good ☐ Fair ☐ Poor

Mandatory - explain assessment to the applicant:

Your publication record & academic record speak highly of your intellectual ability.

Broader Impacts Criterion

Contributions that (1) effectively integrate research and education at all levels, infuse learning with the excitement of discovery, and assure that the findings and methods of research are communicated in a broad context and to a large audience; (2) encourage diversity, broaden opportunities, and enable the participation of all citizens--women and men, underrepresented minorities, and persons with disabilities--in science and research; (3) enhance scientific and technical understanding; and (4) benefit society.

Overall Assessment of Broader Impacts ☐ Excellent ☒ Very Good ☐ Good ☐ Fair ☐ Poor

Mandatory - explain assessment to the applicant:

Your work ~~with~~ with school kids promoting science & engineering is of high importance to our society. Your international experience is also of high value. You just need to tie your research plan to benefit society.

Reviewer comments to the applicant on this rating sheet should be constructive and reflect the two NSF merit review criteria. Applicants

Los Alamos

Dynamics Summer School

Rating sheets missing a required element will be returned to the panelist for completion.

NSF Graduate Research Fellowship Program

APPLICANT RATING SHEET

Applicant: Stephen, Schnelle
Panel: Electrical Engineering

Intellectual Merit Criterion

Demonstrated intellectual ability and other accepted requisites for scholarly scientific study, such as the ability (1) to plan and conduct research; (2) to work as a member of a team as well as independently; and (3) to interpret and communicate research findings.

Overall Assessment of Intellectual Merit ☒ Excellent ☐ Very Good ☐ Good ☐ Fair ☐ Poor

Mandatory - explain assessment to the applicant

Excellent academic ~~record~~ triple major. Distributed sensor network. Highly recommended. Excellent previous research (LANL). Conference paper & poster. structural health monitoring (SHM). critical & underdeveloped research area. Data processing ~~using~~ using novel algorithms.

Broader Impacts Criterion

Contributions that (1) effectively integrate research and education at all levels, infuse learning with the excitement of discovery, and assure that the findings and methods of research are communicated in a broad context and to a large audience; (2) encourage diversity, broaden opportunities, and enable the participation of all citizens--women and men, underrepresented minorities, and persons with disabilities--in science and research; (3) enhance scientific and technical understanding; and (4) benefit society.

Overall Assessment of Broader Impacts ☒ Excellent ☐ Very Good ☐ Good ☐ Fair ☐ Poor

Mandatory - explain assessment to the applicant

Industry / academia interest in topic. SEEK co-founder (student engineers educating kids). leadership qualities demonstrated ~~the~~ EWB engineers w/o borders work - Mexico. worked intensively with minorities

Tremendous outreach & community services.

Reviewer comments to the applicant on this rating sheet should be constructive and reflect the two NSF merit review criteria. Applicants

Los Alamos
Dynamics Summer School

NSF Research Proposal –SYan Jin Zhu– 2008

Intelligent Structural Health Management of Wind Turbine Blades

Keywords: Structural Health Management, Wind turbine blades, Acoustic Emission, Fiber Bragg Grating Sensors, Active Blade Control

There has been a growing interest in the development of alternative energy sources due to increasing sensitivity to the effects of global warming and the concerns about the security of national energy security. Wind energy is inexhaustible, domestically produced, and has the least adverse environmental impact compared to alternative methods of generating electricity. The wind turbine system captures wind energy with a revolving propeller-like blade mounted on a rotor. The rotor is connected to the main shaft in a generator unit that spins to create electricity. Less than 1% of domestic electricity is supplied by wind power even though the nation has enough wind area to supply more than one and a half times of the current electricity consumption. A recent DOE technical report proposed the potential for meeting 20% of the nation's energy needs through wind power [1]. Furthermore, the report projected that by 2030, the US wind industry could support roughly 500,000 jobs in the US and increase annual commercial property tax revenues to more than $1.5 billion. Consequently, wind power could supply enough energy to displace projected emissions of CO2 by 25%. This amount is equivalent to taking 140 million vehicles off the road. To achieve this goal, it is necessary to develop advance turbine systems for increased efficiency and better performance at an economical cost. The objective of this research is to develop an intelligent structural health management (ISHM) scheme that can perform condition monitoring to assess the structural integrity and at the same time, actively control wind turbine blades for performance enhancement of the overall turbine system. The implementation of the ISHM based on a fundamental understanding of failure mechanisms in blades will minimize the adverse incidence due to cascading failure in the wind power generation systems; thereby leading to a significant reduction in operational costs. The ISHM scheme involves a multi-component system that comprises acoustic emission fiber Bragg grating sensors for damage monitoring, finite element modeling for failure prediction, and a feedback control system for optimization of wind capture and minimization of fatigue loading on the wind turbine blade during operation.

Acoustic emissions (AEs), which are stress wave produced by transient stress field in a material, are widely used in nondestructive evaluation techniques for monitoring defect formation in structural composite materials [2]. AEs may result from the initiation and growth of cracks, fiber breakage and debonding in fiber reinforced composites, etc., making AEs particularly suitable for structural damage monitoring. Fiber Bragg grating (FBG) sensors are excellent tools for detecting AEs' and offer numerous advantages compared to competing techniques [3]. FBG sensors are low cost and readily available, light-weight, and immune to electromagnetic noise sources. These sensors can be surface mounted or embedded in a structure; the latter being particularly advantageous in real-time AEs monitoring in composite structures. In addition, FBG sensors can be used for multipoint sensing. When a FBG sensor is locally strained by an AE, the wavelength of the reflected light in the fiber is shifted and can be monitored with an appropriate demodulator. A variety of spectral demodulation techniques have been developed including optical spectrometers, scanning tunable filters, and homodyne interferometers. However, these demodulation techniques are limited either by their bandwidth, or inability to demodulate multiple FBG responses simultaneously [3]. Professor Sridhar Krishnaswamy at Northwestern University, who leads the center where I will be conducting the research, recently developed a two wave mixing (TWM) interferometer that allows for high frequency spectral demodulation of FBG sensor signals in an InP photorefractive crystal (PRC) [4]. The performance of the demodulation system is superior to other available systems; the interferometer is self-adaptive, broadband, and allows for multiplexed demodulation of several FBG sensor responses simultaneously. This innovative FBG demodulation system will be used in this research. The FBG sensor responses will then be used to predict the damage state of the blades and as inputs to an active feedback control system that would be developed to enhance wind energy capture and to minimize periodic loading on the blades.

The following specific tasks will be addressed in this research:
(1) Implement FBG based AE monitoring in a laboratory model of a composite wind turbine blade to track the evolution of damage in the blade on a continuous basis allowing for prediction of the functional lifetime of blade.
(2) Study the sensitivity of the sensor parameters to dynamic loading and damage evolution in the blades. Experimental comparison of AE detection using the piezoelectric and FBG sensors would be also conducted.
(3) Develop a finite element model of the wind blade to predict the mechanical and structural integrity and damage evolution of the blade. I plan to work with a world-renowned Northwestern University faculty in computational mechanics for this aspect. .
(4) Design and implement a feedback blade pitch control system using a real-time load identification algorithm based on sensor inputs to optimize the position of the blade.
(5) Implement the ISHM scheme developed on a pilot wind turbine blade in the field. I intend to collaborate with the National Renewable Energy Laboratory in Colorado to achieve this goal.

Intellectual Merits:

The proposed research would facilitate the fundamental understanding of the loading characteristics, materials properties, dynamics, and failure mechanisms of the wind turbine blade. This system would aid in the prevention of blade overload and the estimation of blade lifetime. At the same time, the system would actively control the blade to optimize wind energy capture, and reduce fatigue loadings on the blade, thus attenuate drive train torque. Designs of lighter and more economical turbine components will lead to widespread use of wind turbines and reaching the national goal of 20% by 2030.

Broad Impacts:

An integrated FBG sensor based ISHM system will lead to a steady growth in the energy market share of wind power allowing for revenue generation and the diversification of the nation's energy portfolio. Additionally, this will strengthen the national energy security through reduced reliance on foreign sources of fossil fuels. These cost reductions will allow for significant reduction in operational costs for wind power generation systems by limiting the incidence of catastrophic system failure. Furthermore, it will allow for cost effectiveness and improve the competitive advantage of wind power generation compared to other energy sources.

References:

[1] U.S Department of Energy. "20% Wind Energy by 2030." July 2008
[2] Tandon GP, Kim RY. "Multi-sensor approach to non-destructive evaluation of damage around circular holes in composite laminates." ASME. 599-600. (2005)
[3] Wolfgang Ecke, et. al. "Fiber Bragg Grating Sensor System for Operational Load Monitoring of Wind Turbine Blades." SPIE. (2008)
[4] Qiao Y., Zhou Y., and Krishnaswamy S., "Adaptive demodulation of dynamic signals from FBGs using two-wave mixing technology", Appl. Opt. 45 (21), 5132-5142, (2006)

2009 NSF GRFP Ratings Yan-Jin Zhu

2009 Rating Sheet 1
Overall Assessment of Intellectual Merit: Excellent
Explanation to the applicant: Proposed plan of research is very good. The intellectual merits and broad impacts of the research are clearly identified. The applicant's academic preparation is very strong.
Overall Assessment of Broader Impacts: Very Good
Explanation to the applicant: Your participation in extracurricular activities while at UMBC are noteworthy. As is your involvement with outreach programs such as the K-12 educational program designed by DSVL at UMBC. It would have been nicer if you indicated how as an NSF fellow, you would continue to engage and actively participate in educational outreach.

2009 Rating Sheet 2
Overall Assessment of Intellectual Merit: Excellent
Explanation to the applicant: The applicant intends to investigate the intelligent structural health manganese of wind turbine blades. the applicant has provided a proposed plan of research that has excellent discussion on hypothesis, methodologies and expected results. The applicant has received a good background in independent research as well as project management through internship and other research. Academic achievements of the application seems to strong compare to other applicants. Letters of recommendation seems to be strong.
Overall Assessment of Broader Impacts: Very Good
Explanation to the applicant: If successful, the proposed research will have cost-effective applications of wind power generation compared to other energy sources. The applicant has shown any evidence of leadership experience. There is evident of outreach activities as involvement with outside community.

2009 Rating Sheet 3
Overall Assessment of Intellectual Merit: Excellent
Explanation to the applicant: Previous exposure to research activities are extremely positive, and the evidence of independent work is a particularly positive note. The contribution to a scholarly paper to be presented at IMAC indicates the level of intellectual rigor this applicant has already achieved. The proposed research into the health management of wind turbine blades for the development of wind energy resources is very interesting and timely. The plan is well described, but would benefit from a more well defined research question.
Overall Assessment of Broader Impacts: Excellent
Explanation to the applicant: The applicant's previous experience with student organizations is positive, and have lead to leadership and outreach opportunities. Her work with minority high school students is very positive, as is the work in helping k-12 students become excited about engineering through Project Lead the Way. This is particularly true due to her development of the educational activities - rather than just implementing previously designed ones. She has tangible plans to integrate her graduate work with these efforts. The proposed research plan contains a clear statement on broader impact onto society.

NSF Research Proposal –Michael Garcia– 2008 (Note this proposal was first submitted in 2009 and Mike received an honorable mention, it was improved upon and resubmitted in 2010. Mike was selected for an NSF fellowship in 2010)

Piezoelectric Nanocomposites with Giant Coupling, Synthesized using Single Crystal Piezoelectric Nanostructures, for Energy Harvesting

Keywords: piezoelectric, nanocomposite, energy harvesting

There is an impending demand for the use of structurally reliable and economically safe energy sources. Over the past decade, numerous researchers have studied the use of monolithic piezoelectric materials for energy harvesting to convert ambient vibrations around almost all systems to usable electrical energy. Piezoelectric materials are desirable because the energy conversion is intrinsic to the crystal structure and thus does not require additional circuitry or moving components such as the case in electromechanical harvesting systems. However, the use of monolithic materials present severe limitations including high cost, significant lead content, poor strength and challenging bulk processing and manufacturing techniques for large scale applications. Lead zirconium titanate (PZT) has been shown to be the ideal piezoelectric material for energy harvesting due to its high coupling coefficient and low damping, however its lead content makes it undesirable due to the negative environmental effects and increased weight. To alleviate these issues, piezoelectric nanocomposites were developed, but were shown to be unrealistic for energy harvesting due to their low coupling. My proposed NSF fellowship program will use recent results demonstrating that the electromechanical coupling of this class of materials can be increased by more than an order of magnitude through control of the filler morphology at the nanoscale [1]. These research efforts will include performing fundamental studies to characterize the growth, electromechanical properties and size effects of nanostructured single crystal piezoceramics as well as the identification of the structure-property relations in active nanocomposites. The goal will be to develop a theory defining the fundamental mechanisms controlling the giant piezoelectric response so that the findings can be applied to other material systems. Additionally, the proposed techniques will produce nanocomposites with equal energy harvesting performance to monolithic materials while using 70-90% less lead, making them safer for the environment and significantly lighter.

Intellectual Merit and Proposed Methods: The objective of the proposed research is to characterize single crystal PZT nanostructures and gain an understanding of the effects that inclusion morphology has on the electromechanical coupling of the nanocomposites. The goal will be to create nanocomposites with electromechanical coupling and energy storage properties equal to or greater than current monolithic materials while using less than 20% piezoelectric material. This goal will be achieved through the synthesis of single crystal piezoelectric nanostructures with controlled morphology. At the Multiscale Adaptive Sensors and Structures (MASS) Lab, a preliminary investigation was performed by synthesizing PZT nanowires using a hydrothermal method and randomly dispersing them in an epoxy matrix. My preliminary results (the details of which are beyond the scope of this proposal) have shown that even without optimization of the nanocomposite's microstructure or alignment of the nanowires, a coupling coefficient of 630pm/V could be achieved with 30% volume fraction of PZT nanowires. This result is as high as the best monolithic PZT (PZT-5H) and more than 19 times greater than a nanocomposite using PZT-5H particle filler. This groundwork clearly demonstrates the potential of this new synthesis procedure to create nanocomposites with unprecedented properties.

While the nanocomposites proposed exhibit exceptional electromechanical coupling the mechanism responsible for the giant coupling is not understood. This research will discover the mechanisms that lead to the giant coupling ultimately providing an understanding of how the properties can be applied to other fillers or matrix materials. Single crystal piezoceramics are well known to exhibit electromechanical coupling significantly higher than their monolithic counterparts, however the properties of PZT crystals are not well known. Through my experience at the MASS lab, I have gained the background and necessary skills required to perform materials characterization. I will use piezoresponse force microscopy (PFM) and transmission electron microscopy (TEM) studies to characterize the domain and crystal structure. A variety of nano-electromechanical tests will be performed on the nanocomposites to elucidate the material's structure-property relations. Finite element modeling coupled with micromechanics theory will be developed to verify the experiments and further understand the giant coupling phenomena. The research will define the mechanics of the how the nanostructures provide such a marked increase in coupling and provide an understanding of how the properties can be applied to other engineering materials. The fundamental knowledge gained from this effort will allow the design of next-generation energy harvesting materials.

Broader Impacts: My research will lead to a practical and theoretical understanding of how nanoscale shape morphology and alignment of piezoelectric nanostructures affect the piezoelectric response of nanocomposites. The impacts of this work will be demonstrated on several fronts. These active nanocomposites are industrially relevant for many emerging technologies such as medical ultrasound, energy harvesting, energy storage, sensing, structural health monitoring, etc. More broadly, the fundamental theories obtained on how morphology of nanostructured inclusions affect the bulk electromechanical properties of a composite will provide the foundation to allow this theory to be transferred to other materials. It is anticipated that the knowledge achieved throughout this research effort will provide a basis for the creation of new and exotic materials with unprecedented properties, thus creating endless possible applications.

In addition to providing state of the art research on advanced nanocomposites, the concept of energy harvesting from unconventional sources, such as vibration, can excite and energize young students about the various engineering disciplines. As part of my NSF fellowship, I will disseminate my research results through small scale experiments and demonstrations to generate enthusiasm and ignite a scientific curiosity in young students. As a life-long resident of the Phoenix Metropolitan area and a member of the Hispanic community, I have experienced the reality of the limited exposure that under-represented minorities have to the engineering discipline. I will partner with Katherine Sisulak, director of outreach activities at ASU, and with the Arizona Engineering, Mathematics, and Science Achievement (MESA) Region chapter, to gain access to underrepresented minority middle and high school students. I will develop an educational program that will use my research in nanotechnology and energy harvesting to spark their curiosity and encourage them to pursue an engineering or science career. This program will be designed as a hands-on experiment in which the students create (1) a speaker using piezoelectric nanocomposite bonded to a disposable plastic bowl and (2) create an energy harvesting beam which can supply low power to electronics such as a wrist watch.

While pursuing graduate study at ASU, I will have the opportunity to continue my growth as a researcher, with the guidance of expert faculty and mentors, especially Dr. Henry Sodano, who has made numerous research contributions to smart material systems and engineering education. This invaluable experience of a graduate level education, will lay the foundation for me to make new discoveries and to share my passion for learning with others.

I, Michael Garcia, herby declare the proposed research is my own original work.

[1] Feenstra, J. and Sodano, H.A., 2008, "Enhanced Active Piezoelectric 0-3 Nanocomposites Fabricated through Electrospun Nanowires," ***Journal of Applied Physics***, 103:**124108.**

2009 Rating Sheet 1
Overall Assessment of Intellectual Merit: Very Good
Explanation to the applicant:
Proposed research seems quite innovative. Additional context demonstrating the innovation would be helpful, for example, what is the closest similar work out there? Is SMP required or would any thermoplastic matrix be effective? Proposal would benefit from a more detailed plan.
Overall Assessment of Broader Impacts: Excellent
Explanation to the applicant: Has demonstrated commitment to outreach and mentoring via tutoring and peer mentor programs. In addition, proposes a new outreach program for Hispanics in partnership with the Arizona Science Foundation.

2009 Rating Sheet 2
Overall Assessment of Intellectual Merit: Good
Explanation to the applicant:
Prepared with undergraduate research experiences which he has clearly benefited from. Has chosen an interesting area for investigation and has considered some of the difficulties that he will face. His colleagues think highly of his abilities. Academic preparation is adequate - shows an improvement as he moves into his area of interest.
Overall Assessment of Broader Impacts: Very Good
Explanation to the applicant:
Interested in bringing education/research opportunities to the Hispanic community. Wants to share passion for learning with others.

2009 Rating Sheet 1
Overall Assessment of Intellectual Merit: Good
Explanation to the applicant:
Proposal is well presented and his academic preparation is good. The proposal is good+ for a level 1. The applicant has a conference paper and presentation, and excellent experience at los Alamos. The letter bring out points associated with the applicants service and leadership.
Overall Assessment of Broader Impacts: Good

Explanation to the applicant:
The applicant does not mention broader impact in any way in personal statement. Instead, broader impacts is only discussed almost as an after thought in research proposal. No discussion as to why diversity people, their backgrounds, their experiences, thoughts, ideas, of experience is a good thing, or why bringing research into undergraduate instruction is a good thing. Applicant only takes narrow view of broader impact of the research topic itself. So in this regard the broader impacts is less competitive that the better level 1 applications

NSF Research Proposal –Michael Garcia– 2008 (revised proposal submitted in 2010)

Piezoelectric Nanocomposites with Giant Coupling, Synthesized using Single Crystal Piezoelectric Nanostructures, for Energy Harvesting

Keywords: piezoelectric, nanocomposite, energy harvesting

There is an impending demand for the use of structurally reliable and economically safe energy sources. Over the past decade, numerous researchers have studied the use of monolithic piezoelectric materials for energy harvesting to convert ambient vibrations around almost all systems to usable electrical energy. Piezoelectric materials are desirable because the energy conversion is intrinsic to the crystal structure and thus does not require additional circuitry or moving components such as the case in electromechanical harvesting systems. However, the use of monolithic materials present severe limitations including high cost, significant lead content, poor strength and challenging bulk processing and manufacturing techniques for large scale applications. Lead zirconium titanate (PZT) has been shown to be the ideal piezoelectric material for energy harvesting due to its high coupling coefficient and low damping, however its lead content makes it undesirable due to the negative environmental effects and increased weight. To alleviate these issues, piezoelectric nanocomposites were developed, but were shown to be unrealistic for energy harvesting due to their low coupling. My proposed NSF fellowship program will use recent results demonstrating that the electromechanical coupling of this class of materials can be increased by more than an order of magnitude through control of the filler morphology at the nanoscale [1]. These research efforts will include performing fundamental studies to characterize the growth, electromechanical properties and size effects of nanostructured single crystal piezoceramics as well as the identification of the structure-property relations in active nanocomposites. The goal will be to develop a theory defining the fundamental mechanisms controlling the giant piezoelectric response so that the findings can be applied to other material systems. Additionally, the proposed techniques will produce nanocomposites with equal energy harvesting performance to monolithic materials while using 70-90% less lead, making them safer for the environment and significantly lighter.

Intellectual Merit and Proposed Methods: The objective of the proposed research is to characterize single crystal PZT nanostructures and gain an understanding of the effects that inclusion morphology has on the electromechanical coupling of the nanocomposites. The goal will be to create nanocomposites with electromechanical coupling and energy storage properties equal to or greater than current monolithic materials while using less than 20% piezoelectric material. This goal will be achieved through the synthesis of single crystal piezoelectric nanostructures with controlled morphology. At the Multiscale Adaptive Sensors and Structures (MASS) Lab, a preliminary investigation was performed by synthesizing PZT nanowires using a hydrothermal method and randomly dispersing them in an epoxy matrix. My preliminary results (the details of which are beyond the scope of this proposal) have shown that even without optimization of the nanocomposite's microstructure or alignment of the nanowires, a coupling coefficient of 630pm/V could be achieved with 30% volume fraction of PZT nanowires. This result is as high as the best monolithic PZT (PZT-5H) and more than 19 times greater than a nanocomposite using PZT-5H particle filler. This groundwork clearly demonstrates the potential of this new synthesis procedure to create nanocomposites with unprecedented properties.

While the nanocomposites proposed exhibit exceptional electromechanical coupling the mechanism responsible for the giant coupling is not understood. This research will discover the mechanisms that lead to the giant coupling ultimately providing an understanding of how the properties can be applied to other fillers or matrix materials. Single crystal piezoceramics are well known to exhibit electromechanical coupling significantly higher than their monolithic counterparts, however the properties of PZT crystals are not well known. Through my experience at the MASS lab, I have gained the background and necessary skills required to perform materials characterization. I will use piezoresponse force microscopy (PFM) and transmission electron microscopy (TEM) studies to characterize the domain and crystal structure. A variety of nano-electromechanical tests will be performed on the nanocomposites to elucidate the material's structure-property relations. Finite element modeling coupled with micromechanics theory will be developed to verify the experiments and further understand the giant coupling phenomena. The research will define the mechanics of the how the nanostructures provide such a marked increase in coupling and provide an understanding of how the properties can be applied to other engineering materials. The fundamental knowledge gained from this effort will allow the design of next-generation energy harvesting materials.

Broader Impacts: My research will lead to a practical and theoretical understanding of how nanoscale shape morphology and alignment of piezoelectric nanostructures affect the piezoelectric response of nanocomposites. The impacts of this work will be demonstrated on several fronts. These active nanocomposites are industrially relevant for many emerging technologies such as medical ultrasound, energy harvesting, energy storage, sensing, structural health monitoring, etc. More broadly, the fundamental theories obtained on how morphology of nanostructured inclusions affect the bulk electromechanical properties of a composite will provide the foundation to allow this theory to be transferred to other materials. It is anticipated that the knowledge achieved throughout this research effort will provide a basis for the creation of new and exotic materials with unprecedented properties, thus creating endless possible applications.

In addition to providing state of the art research on advanced nanocomposites, the concept of energy harvesting from unconventional sources, such as vibration, can excite and energize young students about the various engineering disciplines. As part of my NSF fellowship, I will disseminate my research results through small scale experiments and demonstrations to generate enthusiasm and ignite a scientific curiosity in young students. As a life-long resident of the Phoenix Metropolitan area and a member of the Hispanic community, I have experienced the reality of the limited exposure that under-represented minorities have to the engineering discipline. I will partner with Katherine Sisulak, director of outreach activities at ASU, and with the Arizona Engineering, Mathematics, and Science Achievement (MESA) Region chapter, to gain access to underrepresented minority middle and high school students. I will develop an educational program that will use my research in nanotechnology and energy harvesting to spark their curiosity and encourage them to pursue an engineering or science career. This program will be designed as a hands-on experiment in which the students create (1) a speaker using piezoelectric nanocomposite bonded to a disposable plastic bowl and (2) create an energy harvesting beam which can supply low power to electronics such as a wrist watch.

While pursuing graduate study at ASU, I will have the opportunity to continue my growth as a researcher, with the guidance of expert faculty and mentors, especially Dr. Henry Sodano, who has made numerous research contributions to smart material systems and engineering education. This invaluable experience of a graduate level education, will lay the foundation for me to make new discoveries and to share my passion for learning with others.

I, Michael Garcia, herby declare the proposed research is my own original work.

[1] Feenstra, J. and Sodano, H.A., 2008, "Enhanced Active Piezoelectric 0-3 Nanocomposites Fabricated through Electrospun Nanowires," *Journal of Applied Physics*, 103:124108.

2010 Rating Sheet 1
Overall Assessment of Intellectual Merit: Very Good
Explanation to the applicant:
The applicant's academic preparation is strong. His research experience is also strong including working as an undergraduate research assistant and participating a summer research program at Los Alamos. He has published two conference papers. The research plan is well structured in general.
Overall Assessment of Broader Impacts: Excellent
Explanation to the applicant:
The applicant's experience as a peer mentor and a tutor demonstrates his potential to reach diverse audiences. The research plan includes specific details regarding impact on society, integrating research and education, and providing opportunities to underrepresented minority middle and high school students.

2010 Rating Sheet 2
Overall Assessment of Intellectual Merit: Very Good
Explanation to the applicant:
Your past research discussion explains your path through research and the skills you developed and lessons you learned. It could have benefited from an discussion of the importance of the work. Your research plan has a well defined objective. More specifics about the methods (synthesis, testing, modeling, etc) would have been helpful however. Your publication record enhances your intellectual merit.
Overall Assessment of Broader Impacts: Excellent

Explanation to the applicant: Your experience as tutor and mentor and your personal background and experiences strengthen your ability to make a broader impact. You have a very well laid out plan for taking your research to underrepresentative K12 students and have established connections to make this possible. You will serve as a powerful role model.

2010 Ratings Sheet 3
Overall Assessment of Intellectual Merit: Very Good
Explanation to the applicant: Your write-up about planning and conducting research shows excellent preparation and ground work. The plan of research is relatively weak in spite of your excellent preparation You show that you can work independently mostly, some mention of teaming experiences, but not too much what was gained from that. Your essays show that you can interpret and communicate research results and you have published some of your work. Academic record is very good.
Overall Assessment of Broader Impacts: Very Good
Explanation to the applicant: You show little interest in integrating research and education. You are aware of diversity issues, and show me how to broaden opportunities and enable the participation of others You show how your research will enhance scientific and technical understanding and you show how society will benefit from the work you propose

NSF Research Proposal –Colin Haines– 2010

Proposed Research Essay

Implementing life cycle management is of critical importance as the nation's infrastructure continues to age and the threat of unexpected failures grows. Wind energy represents a particularly interesting and important technology where implementing life cycle management will be essential in the future. Recent studies by the Department of Energy suggest that wind energy could make up as much as 20% of total U.S. power generation by 2030. As the trend goes toward larger and larger turbines (many already exceed 100 m in diameter), ensuring the reliability and minimizing maintenance costs for these units will be critical to establishing the economic viability of wind power while maintaining environmental sustainability.

The Structural Health Monitoring (SHM) process would bring significant advantages to the wind turbine application by moving the maintenance paradigm to condition-based maintenance rather than time-based maintenance. The current time-based maintenance might prescribe a set time for replacement of blades or other components such as gearboxes, whether or not these components are in need of replacement. However, wind turbines are typically located in remote and windy sites which make them expensive and even dangerous to repair. Current inspection techniques cost about two percent of the initial wind turbine cost annually[1]. A SHM system would identify the state of damage of turbine components and reduce the uncertainty associated with time-based maintenance, allowing repairs to be made when a part is actually damaged. Such a system would also mitigate the high cost of unexpected catastrophic failure caused by undetected damage. Much headway has been made toward implementing structural health monitoring systems at UCSD across the fields of civil, mechanical, and aerospace engineering. The plan I have for my own original research is to develop a SHM system that can accurately, reliably, and efficiently assess the state of a wind turbine structure and perform damage prognosis to advise the owner when maintenance is required.

The first step of the SHM process is to evaluate the structure that is to be monitored. My previous research at the Los Alamos National Laboratory (LANL) included developing a modeling technique for extracting the tip deflection of the turbine blade from one single sensor reading—the tip acceleration[2]. In addition to being instructive as to the loads going through the structure, tip deflection can be a good indicator of stiffness changes that can be caused by damage such as delamination. In a similar fashion, other modeling work can be done to select which physical quantities should be measured to give the most complete state assessment within practical limitations (e.g. sensor count, computational power, etc.). In fact, work is already being done at UCSD to develop algorithms for determining the optimal sensor placement that yields the maximum probability of damage detection (POD) using a Bayesian inference technique[3].

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[1] Operation and Maintenance Costs for Wind Turbines. 12 May 2003. <http://www.windpower.org/EN/tour/econ/oandm.htm>.

[2] Haynes, Colin, Nick Konchuba, Gyuhae Park, and Kevin M. Farinholt. "Modeling, Estimation, and Monitoring of Force Transmission in Wind Turbines," Proceedings of IMAC XXVIII: A Conference on Structural Dynamics, Jacksonville, Florida, Feb 1-4, 2010.

[3] Flynn, Eric B. and Michael Todd. "A Bayesian approach to optimal sensor placement for structural health monitoring with application to active sensing" *Mechanical Systems and Signal Processing*, doi:10.1016/j.ymssp.2009.09.003

My research would also include determining the active and passive systems that would provide the best representation of damage in the structure. Since wind turbine blades are being made with composite laminates, guided acoustic waves are particularly attractive. Research has already been done at UCSD showing that guided waves can be successfully used in aerospace structures despite some susceptibility to noise in such applications[4]. Furthermore, my research team at LANL worked on using guided acoustic waves generated by various PZT patches. The technique shows promise, despite having several obstacles—for instance, providing full coverage of the immense turbine blades with a limited number of sensors. In the realm of passive sensing, monitoring the macroscopic vibrations of a structure has shown promise as a damage-detection tool as well, although this technique provides limited information on damage location.

The particular sensor which I propose to research is a Macro-Fiber Composite (MFC) sensor-actuator. MFCs are themselves composite structures using piezoelectric materials to couple mechanical and electrical fields. There are several advantages to using MFCs in health monitoring applications. MFCs are very light, thin, conformable, and efficient compared to other piezoelectric materials. Because of these properties, they are ideally suited for use on wind turbines without impacting the turbine's performance. Several of these sensor-actuators would be placed in the most critical locations along the blade. The energy of the normal operating vibrations would be harvested and stored. Later, the energy would be used for in-situ active sensing, where the MFC would ping the structure with guided acoustic waves. Using state assessment techniques such as those currently being researched at UCSD, any damage between the sensors would be identified and quantified. These periods of active sensing could also be supplemented by passive sensing using the vibrational response of the structure. The MFC would already be placed in locations where vibration is most significant, and therefore it would be quite natural to design a system whereby the MFC monitors the vibrational response and registers appropriate indicators that trigger the active sensing approach. Such multi-mode sensing makes full use of the capabilities of a sensor array in the SHM system.

Finally, all of the data being obtained from the MFC sensors must be put into a decision-making hierarchy in order to perform the damage prognosis. This process evaluates the structure in terms of remaining life and the necessity of repair. Damage prognosis is a difficult task based on models of the structure itself, loading conditions, damage evolution (both microscale and macroscale), and probabilistic assessments of the uncertainty in all of those factors. However, such analysis is feasible, and it is this step which enables the performance of condition-based maintenance and real time evaluation of the health of the structure. These assessments have the capability to provide significant economic benefits over the design life of a wind turbine.

I believe that UCSD is the ideal place for me to undertake research on this proposed multi-mode structural health monitoring system for wind turbines. Firstly, UCSD has the only department of Structural Engineering in the country, from which I recently graduated. I have been exposed to a curriculum that emphasizes fundamental mechanics and structural analysis tools that can be applied to any structure. Furthermore, UCSD is a well-recognized national leader in developing SHM technologies and educating graduate researchers in a unique multi-disciplinary

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[4] Matt, H., Bartoli, I, and Lanza di Scalea, F., "Ultrasonic guided wave monitoring of composite wing skin-to-spar bonded joints in aerospace structures" *Journal of the Acoustical Society of America*, 118(4), pp. 2240-2252, 2005.

way (requiring training in 4 separate engineering departments) through their partnership with Los Alamos National Laboratory (The Engineering Institute). In particular, Professor Michael Todd (Campus Director for the Engineering Institute) has a great deal of experience in the SHM field, and has won numerous awards for his work. I believe that with the resources available at UCSD, I can use my technical proficiency to successfully complete a very relevant thesis that will have a significant impact on the wind energy field.

2010 Rating Sheet 1
Overall Assessment of Intellectual Merit: Excellent
Explanation to the applicant: The applicant's academic preparation for graduate school is excellent. He has several, varied undergraduate research experiences - at a national lab, a university abroad, and a company. The research plan is well thought out and clearly written. Letters of reference discuss some additional accomplishments and strengths that weren't mentioned in the application. It appears that the student's only opportunity to interpret and communicate research findings is through one conference paper.
Overall Assessment of Broader Impacts: Excellent
Explanation to the applicant: The applicant has integrated research and education through a project that introduced over 2,000 6th graders to seismic engineering. He had a major role in developing and executing the project which communicated technical information to a broad audience and made it possible for a wide range of people to participate in science and research. The research plan addresses the benefits of the work to the discipline and to businesses but does not talk about the benefits to society.

2010 Rating Sheet 2
Overall Assessment of Intellectual Merit: Very Good
Explanation to the applicant: The applicant has shown excellent academic achievement as an undergraduate student, and demonstrated significant research experience. The research plan was well thought out and clearly planned, but needs more scientific evidence to make it more convincing. One area the applicant needs to put more attention on is publication. Disseminating your research findings to any potential audience at large is a very important component for any research, and it is a good way to establish your credit and reputation in your research area.
Overall Assessment of Broader Impacts: Good
Explanation to the applicant: The applicant has participated in several outreach activities. However, in the application, he only mentioned briefly that his proposed research is going to benefit society. The application lacks details of how the applicant is going to do with his proposed research in terms of integration of the research and education and benefiting society. The proposal needs to put more emphasize on the broader impacts of the proposed research.

2010 Rating Sheet 3
Overall Assessment of Intellectual Merit: Very Good
Explanation to the applicant: An applicant with a very good undergraduate experience in research and outreach activities. Has been involved in a number of undergraduate research projects, at both industry and government labs. The proposed work is on application of structural health monitoring for wind turbines.

Overall Assessment of Broader Impacts: Very Good
Explanation to the applicant: The applicant exhibits awareness, perspective and prior experience in broader impact activities. NSF and this panel seriously considers this kind of activities, along with the applicant's perspectives on extending the technical and professional aspect of the research into broader-impact activities.

NSF Research Proposal –Scott Ouellette– 2010

Closed-Loop SHM Paradigm for Civil and Marine Infrastructure
Keywords: Structural Health Monitoring, Energy Harvesting, Sensor Networks

Introduction The nation's economy and security depend on the reliability of our infrastructure; and with critical structures continuing to age, effective monitoring and maintenance are becoming increasingly important. The goal of this research is to develop a closed-loop structural health monitoring (SHM) paradigm for civil and marine structures, whereby the energy provided to the sensing and data instruments is harvested from the structure and its environment via corrosion. I became interested in energy harvesting and SHM through my research as an undergraduate. As a structural engineering student, I recognize great potential for applications of energy harvesting to power sensor networks on vital structures. This research would progress sensing instruments and methodologies to become commonplace for ensuring the safety of our national infrastructure.

Background In 1992, Shirole and Holt completed an extensive survey of bridge failures since 1950, and noted that engineers had a reactive mentality to structural failure [1]. Presently, bridge monitoring and inspection is performed largely by visual and nondestructive evaluation (NDE) techniques, and the FHWA mandates this process be done biennially. However, the current NDE techniques have a limited scanning area, thus prior knowledge of critical locations is necessary for efficient inspection. In addition, these methods cannot be employed in a continuous manner, and require that the portion of structure being inspected is readily accessible [2]. There is a growing need for an effective, continuous, and low-maintenance monitoring system for our national infrastructure. In many applications, particularly in remotely located civil or marine infrastructure, power provision can become a limiting factor for wireless sensor networks. The usual powering strategy for wireless networks is a battery; however, batteries require replacement, as their useful shelf lives often do not exceed the intended service of their host structures (e.g., decades). Energy harvesting has emerged as a class of potential network powering solutions in which one form of energy available on the structure is harvested and converted to useful electrical energy.

Hypothesis The dynamic behavior of bridges and marine structures makes them unique. The changing environmental and operational states these structures endure demand periodically updated information regarding its ability to perform as designed in light of inevitable aging and degradation. *I hypothesize that proper application of energy harvesting technology on a civil structure can sustain a closed-loop sensor network for continuous measurements of structural state throughout its operational lifetime.* In addition, these sensors can be placed in remote locations on a structure that are often neglected during visual inspection due to inaccessibility.

Research Plan This research will be based at the University of California, San Diego, whose structural engineering program is a leader in the principles and application of SHM technology. The research will also be done in conjunction with the Los Alamos National Laboratories (LANL) Engineering Institute. I will be under the advising of both Professors Michael Todd and Charles Farrar, both of whom are pioneers in the field of SHM and damage prognosis. The majority of the instrumentation (sensors, computers, and DAQ equipment) will be obtained from the shared inventory at the Engineering Institute, a joint research and educational collaboration between UCSD Jacobs School of Engineering and LANL. Due to the large amount of data and instrumentation, I will be giving undergraduate students a hands-on opportunity to participate in this investigation.

The first year of research will be in the development of the sensor nodes, which includes embedded programming, and implementation of the sensor network on the Scripps Pier. At present, wireless sensors operate in within a voltage range in which few harvesting methods can currently support unilaterally. Novel energy harvesting techniques, such as corrosion energy, can sustain a wireless sensor network with the support of silicon-based integrated circuits. I will work with the Scripps Institute of Oceanography (SIO) at UCSD to use their pier as a large-scale test apparatus. With the seawater acting as the electrolyte for the corrosion-based power source, the pier is a perfect candidate for measuring long-term wave loading and degradation in marine structures. In collaboration with LANL, I will also have access to the Alamosa Canyon Bridge in Truth-or-Consequences, New Mexico, for large-scale testing of corrosion-based energy harvesting techniques on bridge structures. At present, this decommissioned bridge serves as a test bed for new SHM technology, and will be a great complimentary structure for energy harvesting strategies in differing operational and environmental conditions. The next two to three years will be devoted to monitoring the effects of long-term cyclic wave loading on marine structures and the effects of a corrosive environment on sensors. The primary goal of this research is to determine the potential of corrosion-based energy harvesting techniques to serve as long-term powering solutions for SHM applications.

Presentation The primary presentation will be in the form of journal articles, conference submissions, and a research thesis; all of which will describe the effectiveness of corrosion-based energy harvesting, how it can be improved, and recommendations for implementation on completed structures. In addition, I plan to develop a webpage in which all measured data, analysis, and publications will be available to researchers and the public. An example of information that will be made available would be the measured changes in the longterm performance of the pier relative to the environmental cycles.

In addition, I plan to integrate my research into a grade school presentation on energy harvesting by teaching basic chemistry combined with a lab experiment on concrete mixing. The students will be placed in small groups and provided with materials to make their own concrete battery. Once the concrete has cured, the students will take a planned field trip to the beach to measure and record the output voltage of each battery and compare them to more traditional energy cells, like a lemon or potato. I will also work with SIO to provide the students a tour of Scripps Pier in order to immerse them in an active research environment. Studies show that educating students in a fun and engaging manner increases their learning capacity, and my goal for these lectures and experiments will be to inspire the next generation of scientists and engineers.

Qualifications I strongly believe that my research as an undergraduate student makes me uniquely qualified for advancing the techniques of energy harvesting. I am already experienced with multiple energy harvesting technologies, data acquisition, and circuit design. In fact, my experiences in energy harvesting at LANL and with developing the concrete battery at UCSD have inspired me in this full-scale research initiative. I am familiar with the most current advances in the field of SHM, and am confident in my ability to implement them into this closedloop paradigm. I am excited to have the opportunity to develop this ***innovative*** system that builds on all my undergraduate research experiences.

[1] Shirole, A.M. and R.C. Holt, 1991, "Planning for a Comprehensive Bridge Safety Assurance Program", *Transportation Research Record,* 1290, p. 39-50.
[2] Todd, M.D. and Charles Farrar, 2007, Testimony Provided to the House Committee on Science andTechnology Hearing on "Bridge Safety: Next Steps to Protect the Nation's Critical Infrastructure."

NSF **GRFP** RESULTS

Scott Ouellette | logout

Rating Sheets

2010 Rating Sheet 1
2010 Rating Sheet 2
2010 Rating Sheet 3

Overall Assessment of Intellectual Merit: **Very Good**

Explanation to the applicant:
Scott, You have an impressive academic record and meaningful prior educational outreach and prior research experiences. The application could benefit, though, if you were more reflective on how these prior experiences have shaped the researcher you are today or inspired to you pursue your given research ideas. Your passion is not showing through on your essays.

Overall Assessment of Broader Impacts: **Very Good**

Explanation to the applicant:
Your problem statement is clearly articulated and the relationships to broader impacts are also clearly formulated. The passion noted above could be strengthened / needs to shine through more on the essays.

OTHER YEARS

2010
2009

OUTSIDE LINKS

Fastlane
NSF GRFP Program Announcement

National Science Foundation Graduate Research Fellowship Program
Operations Center Administered by: American Society for Engineering Education (ASEE)
1818 N Street NW, Suite 600 Washington, DC 20036 | 866-NSF-GRFP, 866-673-4737
(toll-free from the US and Canada) or 202-331-3542 (international) | info@nsfgrfp.org

NSF GRFP RESULTS

Scott Ouellette | logout

Rating Sheets

2010 Rating Sheet 1
2010 Rating Sheet 2
2010 Rating Sheet 3

Overall Assessment of Intellectual Merit: **Excellent**

Explanation to the applicant:
Scott is proposing to develop a closed loop structural health monitoring paradigm for infrastructure. He has clearly articulated his research plan in his essay. He has a strong academic background. His research experiences include working as an RA for structural health monitoring; Summer undergraduate Research Scholar investigating concrete battery and research at the Los Alamos National Lab investigating Energy harvesting strategies for SHM wind turbine blades. he has several awards

Overall Assessment of Broader Impacts: **Very Good**

Explanation to the applicant:
There have been several concerns over the state of the US infrastructure. Scott's proposed work is directed at improving decision making with respect to rehabilitation and maintenance through improved monitoring. Scott has impacted on his peers through working as a TA. In addition he has engaged in several other initiatives eg Earthquake engineering outreach o K12, Society of Civil and Structural Engineers executive officer. He has made two conference presentations

OTHER YEARS

2010
2009

OUTSIDE LINKS

Fastlane
NSF GRFP Program Announcement

NSF GRFP RESULTS

Scott Ouellette | logout

Rating Sheets

2010 Rating Sheet 1
2010 Rating Sheet 2
2010 Rating Sheet 3

Overall Assessment of Intellectual Merit: **Very Good**

Explanation to the applicant:
Your supporting materials are outstanding. Your academic record is a bit uneven, particularly at the beginning of your undergraduate studies. It would have been wise to address this in your personal statement. However, your extensive involvement in research (including your research award), your prior dissemination of research results, and your clear enthusiasm for the topic of SHM suggest that you will be successful in your pursuit of a doctoral degree at your selected institution.

Overall Assessment of Broader Impacts: **Excellent**

Explanation to the applicant:
Scott, your statements convey remarkable maturity. Your prior achievements demonstrate your creativity in research and outreach (via K'NEX modules). You have also thoughtfully included such outreach and dissemination into your research plan. These are real strengths of your application.

OTHER YEARS

2010
2009

OUTSIDE LINKS

Fastlane
NSF GRFP Program Announcement

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(toll-free from the US and Canada) or 202-331-3542 (international) | info@nsfgrfp.org

Sydney Sroka NSF Research Proposal 2012: Design of a Variable Twist Wind Turbine Employing a Smart Material Actuation System

Motivation

As wind energy begins to compensate for an increasing percentage of the nation's energy needs, the resilience and efficiency of turbines is becoming more critical to the national infrastructure. To supply more energy, wind turbine blades are becoming larger, and the stresses on critical hub components, more intense. Not only are the upfront maintenance costs of components like the gearbox expensive, but the indirect cost of an out-of-service turbine is also of great concern. A database in Germany puts the average offline time of a turbine with a failed gearbox at 14 days [1]. If smart materials were introduced to regulate blade speed and better control the aeroelastic torque, the lifetime of both the drive train and the blade could be extended.

Morphing Wings

Morphing wings is a field attempting to improve aircraft efficiency by allowing the aerodynamic properties of the wings to adapt for varying flight conditions. Of the many techniques currently investigated, camber change is a promising candidate for adaptation to wind turbine blades. The degree of twist, created by a gradual change in camber along the blade, can modify the drag and lift properties to maintain the speed of the turbine blades and reduce, or potentially eliminate, the responsibility of the brake.

A successful camber change was achieved by Elzey et. al. using shape memory alloy (SMA) actuators to dictate the curvature of vertebrae within a wing section [2]. The technique employed an antagonistic flexural cell unit (AFC) with two one-way SMA actuators on opposite faces of a vertebra that is restrained to bend about only one axis. A gradual change in curvature along the length of the wing section created a variable, and completely reversible, twist. Advantages of this system include its lightweight and energy efficient design; for instance, after the actuators cool, no additional energy is needed to maintain the twist.

There will need to be a few modifications to adapt the technology to turbine blades, including the source of actuation and composition of the internal blade structure. A control system, mounted in the nacelle, will monitor and maintain the speed of the blades. Proportional integral (PI) control systems have been successful in regulating variable pitch turbines, and will be implemented in the variable twist design [3]. The interior structure of the blades will need to be sufficiently flexible so as not to inhibit the flexure of the vertebra about its rotational axis, but rigid enough to resist excessive rotation about the other two orthogonal axes. Elzey et. al. utilized a honeycomb cross-section to achieve the desired anisotropic strength properties, and the low- density design kept the wing lightweight [2].

Advantages over variable pitch blades include a stiffer connection at the hub, more efficient adaptation for varying wind conditions, and better resistance to torsion. While a variable pitch turbine necessitates a bearing at the connection near the hub, a variable twist turbine can take advantage of a fixed connection to better resist the bending moment at the base. Small modifications in camber will regulate the speed with less energy than a variable pitch system that needs to rotate the entire blade, some of which exceed 60 meters in length. The variable twist blade will be able to realize a more efficient geometry and better adapt to different loading conditions than a variable pitch blade that requires a uniform change in the angle of attack along the entire length of the blade. Finally, the AFC will add considerable rigidity, especially near the vertebrae, to better resist torsional deflection.

Research Plan

In the first year of funding, an optimization study will be conducted to determine the desired range of variable twist. A finite element simulation was recently developed at UCSD to model the fluid-structure interaction and aerodynamic properties of a wind turbine [4]. This simulation, which incorporates fully coupled aerodynamic and structural properties, indicates that the aeroelastic torque of each blade is highly variable and largely dependent on the position of the blade during rotation. Understanding the variability in torque is crucial since the large torsional loads, induced by increasingly larger blades, can cause a gearbox failure. The simulation can be used with an appropriate optimization scheme to determine the desired range of twist. Then, the number of vertebrae will be predicated on the optimized geometrical profiles.

During the second year of funding, a fatigue test of the SMA actuators will be conducted to ensure that they can withstand the high frequency loading cycles. Simple thermomechanical treatments have been shown to extend the life of the actuators [5]. Gradual plastic strain is less of a concern because the control system will be able to overcome at least minor deviations by increasing the power until the desired shape is attained.

Intermediate experiments will include experimental modal analysis (similar to the experiments I conducted for my research project during the Los Alamos Dynamics Summer School) of the turbine at progressive angles of twist and a quasi-static test to validate the predicted torsional stresses from the finite element model under different loading conditions. These experiments will provide a fantastic opportunity for outreach events, and is especially well suited for the COSMOS program at UCSD. This summer program invites high-achieving, secondary school students to learn about science and engineering through lectures, lab tours, and experiments. Modal testing is a perfect opportunity to engage students and illustrate the basic principles of dynamic equilibrium with demonstrations and finite element animations. I plan to work closely with the UCSD COSMOS structural engineering outreach director, Yael Van Den Einde, to help facilitate and improve the program.

The ultimate goal, in the final year of funding, is a test of a prototype wind turbine blade. UCSD test facilities, Englekirk Structural Engineering Research Center (ESEC) and the Charles Lee Powell Structural Systems Laboratory, have a well-known history of full-scale testing. ESEC has conducted tests on a 70-foot tall wind turbine, and Powell is currently hosting non-destructive tests on a CX-100 turbine blade. I intend to pursue a PhD at UCSD to work with the excellent faculty and staff who are highly experienced testing full-scale structures.

Conclusion

As the world's energy needs are met with cleaner and more sustainable sources, the demand for more robust equipment is amplified accordingly. Investigation of a variable twist turbine will contribute to the pool of resources available to improve the efficiency and longevity of turbine blades and drive trains. My graduate research efforts will provide an excellent platform for inspiring youth with science and engineering, and an NSF fellowship will provide the means to achieve these goals.

References

[1]Milborrow, David. "Breaking down the cost of wind turbine maintenance." *Windpower Monthly* 15 June (2010).
[2]Elzey DM, Sofla AYN, Wadley HNG. A bio-inspired, high-authority actuator for shape morphing structures. In: Smart structures and materials 2003: active materials: behavior and mechanics. Proceedings of SPIE 2003;5053
[3] Bartmann, Dan, and Dan Fink. *Homebrew Windpower: A Hands On Guide to Harnessing Wind*. Masonville: Buckville Publications LLC, 2009. 88.
[4] Hsu, Ming-Chen, Yuri Bazilevs. "Fluid–structure interaction modeling of wind turbines: Simulating the full machine" *Computational Mechanics* July (2012).
[5] Karhu, Marjanna, and Tomi Lindroos. "Long-Term behavior of binary Ti-49.7Ni (at.%)SMA actuators-the fatigue lives and evolution of strains on thermal cycling." *Smart Materials and Structures* vol. 19, 28 Sept. (2010).

Sydney Sroka 2012 NSF Previous Research

When I reflect on the opportunities and undertakings which characterize my undergraduate experience, it is clear that my involvement in a variety of research efforts offered more exciting challenges and helped me internalize concepts more fully than my coursework. My journey began as an assistant, and is continuing as a member of a non-destructive evaluation research group. I have requested more responsibility in each successive project to prepare myself for the independent and self-motivated study that graduate school requires.

My two years of employment as an Undergraduate Engineer at the Charles Lee Powell Structural Systems Laboratory offered a fantastic vantage point for exposure to many different areas of research within structural engineering. My principle tasks were installing the necessary strain gauges, potentiometers, inclinometers, and accelerometers, which required that I quickly interpret instrumentation plans, maintain superior organization of the site, and understand the different voltage excitations for each instrument. My responsibilities prepared me for a career in research by ingraining fundamental skills including interpreting erection drawings, troubleshooting sensor malfunctions, and maintaining a well-documented log of progress. I developed a tremendous appreciation for the amount of care and precision with which an experiment is conducted, and I am proud to have assisted with novel research where test specimens ranged from 3-story moment frames to tiny aeronautical components measuring only a few feet in length.

Upon observing an experiment related to structural health monitoring (SHM), I decided to pursue a research opportunity with Professor Mike Todd's SHM research group. The group satisfied my every curiosity about their research as I began to develop a fundamental understanding of SHM and sensor networks. My contributions to the group over the summer consisted of both SolidWorks™ modeling and data acquisition of waveforms from piezoelectric sensors for damage detection applications.

In an effort to diversify my research experience, the following year I began to conduct research with Professor Petr Krysl, who is investigating the auditory systems of fish with finite element (FE) techniques. The auditory organs in fish involve a dense piece of bone suspended in a viscoelastic matrix where it is free to translate and rotate. When the system is excited by a planar acoustic wave, the high-density bone moves out of phase with the surrounding, lower density, tissue. The experimental FE model idealized the system as an acoustically small, rigid scatterer. Subjecting the bone, modeled as a hemisphere, to progressively higher frequency waves, revealed that the ratio of angular to linear acceleration exhibited an abrupt and substantial increase. This behavior is only possible for frequencies well above the upper bound of fish hearing. My efforts concentrated on the characterization of this interesting, and potentially advantageous, phenomena. I varied two parameters, frequency of the acoustic wave and trajectory of the excitation, to construct surface plots of the response amplitude, then began to vary the number of nodes in the system. My research included a new potential application of the behavior, in which I proposed a filtration system that would separate particulates of a precipitate by size with acoustic waves (the larger particles would be rotating, but nearly stationary, while the smaller particles would be persuaded downstream). This research experience was invaluable because it clearly demonstrated the intrinsic multidisciplinary nature of engineering to me as we explored the intersection of biology and fluid mechanics with the model. I co-presented the research and potential application at the UCSD student symposium.

This summer I was immersed in an environment of curiosity and creativity as I conducted research at Los Alamos National Laboratories through the Dynamics Summer School. I collaborated with two colleagues to assist the International Space & Response Technologies division in improving the efficiency of one of their qualification test fixtures.

Satellites are subject to a pyroshock event during launch, and the high frequency, high amplitude excitation can severely compromise the electronics onboard. My project concerned a shock test fixture that administers different amplitude and frequency spectra to a test specimen based upon the configuration of several tuning parameters in order to simulate a pyroshock without live ordnances. Unfortunately, the flexibility of the setup necessitated tedious adjusting, predominantly by trial-and-error, to produce the desired shock response spectrum (SRS). We were responsible for improving the efficiency of the tuning procedure by, developing a FE model of the system, conducting experimental modal tests, and developing an original analytical model to predict the excitation for a given configuration of tuning parameters.

We conducted experimental modal tests to extract mode shapes and natural frequencies, which were compared against the mode shapes from the FE model with a modal assurance criteria (MAC) plot. After the FE model was adjusted to better represent the experimental results, we developed an original analytical model in MATLAB using the mode shapes from the FE simulation and acceleration time histories from experimental shock tests to be implemented as the delivered excitation. The solution from the analytical model produced SRS at each point of interest. We were very pleased with our progress over the summer, and I will be one of the presenters of the research at the 2013 International Modal Analysis Conference (IMAC XXXI). The experience reinforced my confidence in planning, executing, and documenting research.

Upon returning from Los Alamos I began to conduct research within Professor Lanza di Scalea's group. My efforts have concentrated on preparing for a modal test of a 9-meter CX100 turbine blade that was manufactured with more than 20 prescribed defects. I have started developing an original program that will accommodate both an impact hammer test and a random excitation test using a shaker. I am working on this project with minimal guidance and I am confidently accepting the responsibility of independent research as the only undergraduate in the group.

I have learned to conduct research by contributing to several, unique efforts during my undergraduate education and am anxious to begin my graduate research as a PhD candidate. An NSF fellowship would allow me the freedom to concentrate my energy on the intersection of structural health monitoring and structural dynamics, an area that is of tremendous importance to society, and the area of research for which I am most passionate. I will strive to encourage communication between disciplines within the sciences, and my previous research experience has provided me with the expertise I need to begin a research project that integrates several existing bodies of knowledge in to one very promising endeavor.

Publications

Sroka, Sydney "Finite Element Analysis of Otolith Response to Planar Acoustic Waves", UCSD Undergraduate Research Symposium, May 2012.

Sroka, Sydney, Richard Hsieh, Robert Moore, Chris Stull, Pete Avitable "Analysis and Dynamic Characterization of a Resonant Plate for Shock Testing" to be presented at IMAC XXXI, February 2013.

Los Alamos

Dynamics Summer School

Sydney Sroka 2012 NSF Personal Statement

Advances in the realms of energy harvesting, smart-materials, and structural design are rapidly improving the state-of-the-art; presenting scientists in this dynamic environment with new and exciting challenges. Exposure to these topics motivated me to study structural engineering as an undergraduate. My passion for science has been cultivated over the last three years through coursework, employment, and research experience, each of which represents a positive step toward pursuing a life-long career as a researcher and educator. I feel my diverse background in engineering research has prepared me to study the intersection of sustainable energy, structural health monitoring, and structural dynamics. By focusing on this area, I can join my colleagues in unraveling small mysteries that culminate in bolstering the efficiency and safety of structural components. Toward this end, I intend to pursue a PhD in structural engineering.

I entered into my undergraduate structural engineering program and soon discovered that my interests in finite element analysis (FEA) and sensor networks were beautifully integrated in the field of structural health monitoring (SHM). I tailored my coursework to reinforce my skills in manipulation of electrical systems, FEA, and modal analysis, which better prepared me for employment as an undergraduate engineer and several research assistant opportunities.

As an Undergraduate Engineer at the Charles Lee Powell Structural Systems Laboratories, I became proficient with instrumentation installation and the LabVIEW data acquisition systems. The incredible breadth of projects that came to this world-class, independent test and research facility during my two years of employment gave me the opportunity to observe many experiments within the civil and aerospace engineering disciplines.

I have obtained research assistantships as an undergraduate that developed my problem-solving and leadership skills in preparation for graduate study. I assisted several research efforts which helped me grasp the fundamental concepts of structural health monitoring, FEA, and non-destructive evaluation.

In addition to work and research, I enjoyed many extracurricular outreach opportunities offered by the Academic Success Program (ASP), the engineering honor society Tau Beta Pi, and the Society of Civil and Structural Engineers (SCSE). ASP is a student-run organization that connects students with tutors to help reinforce the concepts in a specific subject with a weekly problem-solving section and office hour for a ten-week quarter. I tutored three students in *Calculus I* , which required that I prepare example problems for section each week and be able to explain the material clearly. Tau Beta Pi is an engineering honor society which connects students from different disciplines within the sciences, and I have participated in several of the community service and outreach programs through the society. Last year, I completed 25 hours of tutoring through the Tau Beta Pi tutoring program; I had one student and focused primarily on the concepts from the structural engineering course *Introduction to MATLAB*. These experiences have reinforced my communication skills, and I am proud to say that the feedback from all my students was overwhelmingly positive.

In addition to coordinating small tutoring sessions, my participation on the SCSE Steel Bridge Team over the previous 3 years, especially last year as the appointed fabrication lead, substantially matured my leadership capabilities. The team is composed of structural, aerospace, and mechanical engineers. The goal is to design, analyze, and fabricate a 26-foot long steel bridge, which must support a load of 2500lbs and comply with the annually-revised design specifications. Last year, I successfully facilitated safety training for new members while producing the bridge components and other deliverables for which I was responsible. Even with the additional pressure from extracurricular deadlines, I am proud to have been able to inspire new members who observed classroom concepts contribute to an exciting and competitive project.

My involvement with these engineering organizations inspired both myself and my colleagues from different disciplines to facilitate an inter-disciplinary event. Girl's Day Out offers young ladies in middle school the opportunity to meet industry professionals and college-age mentors who represent a small, but significant, female minority in their field of study. Since its inception, the event has burgeoned, increasing in number of participants and number of engineering organizations involved. We were sponsored by SPAWAR, and recruited participation from many engineering organizations to help young women become enthusiastic about science. The day began with 40 participants and their parents enjoying a keynote address that introduced new and exciting topics in science. Afterwards, we lead smaller groups on a tour of the campus and lab facilities. Then a couple of my colleagues and myself sat on a student panel, where we briefly described our research experiences and answered questions about the research opportunities available to secondary school students and incoming undergraduates. In the afternoon, the young ladies engaged in entertaining and playful experiments orchestrated by several engineering organizations. Last year, the program grew to accommodate 100 participants and I look forward to expanding next year's event to better serve the San Diego community with the goal of encouraging gender diversity among the sciences.

Discourse between fields of study is an important driver of innovation; similarly discourse within one field is most useful when a variety of perspectives are shared. It is this notion that attracts me to events like Girls' Day Out, the Steel Bridge Team, Tau Beta Pi, and ASP. I will continue to pursue similar opportunities as a graduate student. I want to coalesce diverse and unique perspectives to improve the quality of scientific discourse created by people of different genders, race, and ethnicity.

I am very fortunate to have had role models that confidently accept leadership positions, exemplify a diligent work ethic, and organize outreach events; they have helped me define the type of scientist and person I hope to become. My experiences have reinforced my communication skills, and my academic record underscores my commitment to science. It is important that I continue with my education because an advanced degree in structural engineering with a focus in structural health monitoring will better prepare me to conduct independent research, to collaborate with colleagues in different fields of study, and inspire the next generation of scientists and engineers.

Score for Sroka, Sydney

Intellectual Merit Criterion

Overall Assessment of Intellectual Merit
Very Good

Explanation to Applicant

The applicant has an excellent academic record and has shown initiative, experience and success in research. Good luck! There is no discussion of the choice of university for graduate study and the fit between that university's facilities and the proposed research theme. On a side note, the unofficial transcript format is hard to read (for a reviewer outside the applicant's institution it is unclear what MATH20F or TDMV120 stand for0. The reviewer suggests adding a key for the course numbers or using an alternative format.

Broader Impacts Criterion

Overall Assessment of Broader Impacts
Excellent

Explanation to Applicant
The applicant explains clearly hot the proposed research topic contributes to technical understanding and benefits society. The applicant has an excellent history of involvement in professional associations and outreach events and an excellent plan to continue these activities.

Score for Sroka, Sydney

Intellectual Merit Criterion

Overall Assessment of Intellectual Merit
Excellent

Explanation to Applicant
The applicant has an excellent academic record. The applicant was an undergraduate engineer and has several undergraduate research experiences which resulted in a future conference presentation and an internal presentation. The applicant also proposed a good research plan for graduate study. The reference letters clearly indicated the applicant's capability to perform research.

Broader Impacts Criterion

Overall Assessment of Broader Impacts
Excellent

Explanation to Applicant
The applicant tutored students through the Academic Success Program (ASP) and the engineering honor society, participated in several community service and outreach programs, such as Girl's Day out. The applicant also played the leadership role in the Society of Civil and Structural Engineers (SCSE) Steel Bridge Team. The proposed research will integrate research and education outreach and have broad impact on wind energy development.

Score for Sroka, Sydney

Intellectual Merit Criterion

Overall Assessment of Intellectual Merit
Excellent

Explanation to Applicant
The applicant has an outstanding academic record coupled with a wealth of undergraduate research experiences. She has participated in four diverse areas, giving her a good background for her graduate research. Several presentations have resulted from these activities.

Broader Impacts Criterion

Overall Assessment of Broader Impacts
Excellent

Explanation to Applicant
The applicant has actively participated in many outreach activities, both recruiting (Girl's Day Out) and retaining (tutoring)STEM students. I am confident that she will continue to be involved in these activities and will be a wonderful role model for young people.

George Lederman NSF Research Proposal 2012: Indirect Vibration Based Structural Health Monitoring of the Pittsburgh Light Rail Line: A Model Free Approach Using Anomaly Detection

Background: As a nation, we continue to use 70,000 bridges which have been classified as deficient. As these bridges continue to deteriorate, we are faced with a daunting challenge. We must ensure public safety and minimize service disruptions as our entire infrastructure ages beyond its intended design life.

To address this problem, decision makers need the best possible information on the state of each bridge. This information can facilitate more efficient maintenance programs, and more effective capital replacement projects. Significant progress has already been made in the field of structural health monitoring, but proven technologies remain expensive [1]. Most of these systems monitor local phenomena, so likely damage locations must be known *a priori*, and sensors placed with precision, often in areas which are difficult to access. These proven techniques are too expensive to be deployed nation-wide.

Vibration based structural health monitoring provides an economical solution, where a few sensors, placed without prior knowledge of the structure, can monitor the health of the structure as a whole [2]. The sensors can even be mounted within a vehicle, a practice known as Indirect Structural Health Monitoring. This way the sensors have a reliable power supply, they are not exposed to the harsh bridge environment, and a single vehicle can monitor a large number of bridges. This technique has been successfully demonstrated both theoretically [3], and with experiments [4] but it has not yet been applied to an operational environment.

The transition from experimental data to operational data is significant. Under experimental conditions, damaged and undamaged states are known, so classification is a supervised pattern recognition problem. But in an operational environment, only the undamaged state is known (in the best case), so classification is a semi-supervised pattern recognition problem. Classification is further complicated by extreme environmental variations which obscure the detection of faults.

Proposal: I propose to collect large amounts of operational vibration data from the Pittsburgh Light Rail Line and to use an anomaly detection approach to detect structural faults. Anomaly detection algorithms have been shown to differentiate between environmental changes and faults for a wide variety of applications, by only flagging “contextual” anomalies [5]. One promising technique is kernel principal component analysis, a technique which has been successfully applied for model-free fault detection in spacecraft [6].

The Pittsburgh Light Rail Line offers an opportunity to continuously collect real data in an operational environment. In general, trains are ideal for the indirect method because they excite large amplitude vibrations and follow a regular path on each crossing of a bridge [7].

The Port Authority of Allegheny County has been active in research projects at Carnegie Mellon, and Steve Bland, the Chief Executive, has expressed interest in expanding this collaboration. As a backup to working with the Port Authority, we will also approach the operators of the Carnegie Mellon Shuttle Bus. The goal is to collect large amounts of data from a vehicle-bridge interaction which is replicated as often as possible.

Method: The first task is to design robust hardware that will efficiently log data at a high frequency. The data acquisition system will include a GPS device, a triaxial accelerometer, a triaxial gyroscope (to measure displacement as a cross check of the GPS, or when the GPS signal is lost) and a high sensitivity uniaxial accelerometer to record the vertical vibrations of the vehicle-bridge interaction. The device will be located in the conductor’s booth near other existing instruments where it will be safe, and have an external source of power. The device will record data to a local hard drive; we will download the data periodically from the device itself.

Recording the baseline dynamic response of the 20 bridges along the train's route could take a long time. We will work with the Port Authority in order to keep abreast of planned construction, maintenance and evaluations of the bridges. This will ensure that temporarily anomalous vibrations (due, for example, to temporary construction loads) are not recorded as part of the bridge's baseline behavior. In addition, if a bridge deteriorates significantly while we are recording the baseline behavior, we will either remove it from the set of bridges we are studying, or make a separate model to account for the deterioration.

As no experiments will be performed on the operational system, validation will occur when the algorithm is able to detect a fault of statistical significance which can be verified through other means.

We will apply proven signal processing techniques to look for damage within our data set like kernel principle component analysis, Bayesian inference, and transductive support vector machines. But we will also periodically publish our data, so that other interested researchers in the fields of data mining, machine learning or pattern recognition can try other techniques which may provide better statistical methods for identifying anomalies.

Expected Significance: Ideally, our technique will be able to determine the severity of any damage, the location of the damage, and the remaining life of the structure. However, simply detecting a statistically significant change in the structure would, on its own, be a huge breakthrough. This detection would allow owners to know when to send structural inspectors to a bridge. If nothing has changed in the bridge since the last inspection—this technique could save money. If something has happened before a scheduled inspection—this technique could save lives.

Existing infrastructure around the world continues to deteriorate each year. But more and more vehicles come equipped with accelerometers and communication systems like OnStar®. If we can harness the information collected by these devices, indirect structural health monitoring may provide a cheap method for monitoring every bridges across the globe on a daily basis.

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George Lederman NSF Previous Research

Undergraduate Research: I have had two significant opportunities to conduct my own research. First, during my junior year abroad at Oxford University, I studied new mechanisms to allow shape change in aircraft wings under Dr. Zhong You. The second opportunity was my senior thesis at Princeton, where I designed, modeled, and tested a novel deployable bridge under Dr. Branko Glisic. My senior thesis combined the knowledge of deployable structures I had gained at Oxford, with my own passion for infrastructure.

After my experiences in Ethiopia, I became more interested in engineering on an international scale; I applied and was accepted to the competitive Princeton-Oxford Exchange in Engineering. As part of the program, I took "Senior Independent Project," a full year course intended as the capstone independent work for students receiving a Masters in Engineering Science at Oxford.

My advisor, Dr. You had just begun a new project to investigate shape changing aircraft wings. The work was inspired by research at the University of Delft which demonstrated that by changing the geometry of the wing (like a swift) the flight envelope for aircraft in various modes of flight could be optimized. We took a modular approach to building the structure of the wing, where one mechanism was repeated many times, an approach which had been pioneered by Dr. George Lesieutre's group at Pennsylvania State University.

Dr. You provided preliminary reading on this topic, but as a graduate-level independent project, we met only occasionally. This freedom was daunting as first; I had to learn some kinematics and dynamics on my own to understand the mechanisms in the literature. But I soon found this freedom to be empowering. I could go to the library, read about a new mechanism, model the mechanism in a finite element package and prototype the mechanism in the machine shop, all on my own.

After investigating many mechanisms, I felt the most appropriate was the octahedral variable geometry truss, which had been studied extensively at NASA in the 1980s. I made some modifications to this mechanism for our application, then modeled and prototyped it. We presented some of my findings at the NATO AVT-168 conference on Morphing Vehicles in Evora, Portugal [1].

In retrospect, when I began the research, I did not have a clear idea about the paper I would write at the end. I should have performed tests on the physical model to verify the predictions of the finite element model, particularly due to the number of joints in the structure. But the models I built in the machine shop had structurally weak hinges, so any load tests would have been meaningless. This insight proved crucial to the success of my research the following year at Princeton.

While working on the wing project, I began to think that mobile bridges could be improved using similar high efficiency mechanisms. This idea lead to my thesis at Princeton on a novel type of deployable bridge, which both used fewer actuators to deploy and achieved higher structural efficiency once deployed than the mobile bridges currently employed by the US military. From the beginning of the project, I tried to amass as much data as possible in order to support my ultimate conclusions. My advisor, Dr. Glisic was an expert on fiber optic strain gauges, so we designed and built a 3m bridge prototype large enough to monitor with the fiber optic strain gauges. Verifying the stresses in the bridge turned out to be complex due to stress concentrations near the hinges and the variability of the wood used to make the model. But in the end we were able to identify suitable locations for the strain gauges and found accurate methods for determining the Young's modulus of each piece of wood. Our results were close to our predictions, indicating that a full size model may possess some of the structural advantages we saw in the numerical models.

The planning that had gone into the project proved successful--the project won an award for the best thesis my year in Civil Engineering. At the end of my senior year, I chose not to publish my work, and instead applied for a provisional patent. I tried to work with WFEL, a British bridge maker, to further develop the technology, but due to the complexity of the intellectual property ownership, no licensing agreement could be reached. As a result, Dr. Glisic, Dr. You and I are currently finalizing a manuscript on this work for publication [2].

Graduate Research: I started at Carnegie Mellon University in the Advanced Infrastructure Group this past August, working with Dr. Jacobo Bielak and Dr. James Garrett on Structural Health Monitoring. Just as I was starting, Fernando Cerda defended his dissertation on Indirect Structural Health Monitoring, the practice of monitoring a bridge from the vibrations recorded in a passing vehicle. Cerda demonstrated he could detect a wide variety of damage conditions, by collecting accelerometer data from a moving vehicle on scaled model bridge.

I, along with another graduate student, have expanded on Cerda's work by running experiments on a campus parking garage: a real structure subject to many of the same environmental variations which affect bridges. The fundamental frequency, ω, of a span with mass, m, and stiffness, k, is shown in equation (1).

$$\omega^2=k/m \tag{1}$$

Typically damage (like cracks or loss of cross-sectional area) changes the stiffness of a bridge. Because we cannot induce damage in the garage, we simulate damage by placing masses on the span. The applied mass changes the fundamental frequency as per equation (1).

In our experiments we run a 50kg robot across one span of the parking garage, both with and without the simulated damage. We use the accelerometer data from the robot to teach a Support Vector Machine algorithm the pattern of both damaged and pristine conditions. When applying this algorithm to later runs, we have achieved 95% classification accuracy for a mass weighing 0.3% of the weight of the garage span. We will present the results from these experiments at the 2013 International Workshop on Computing in Civil Engineering this coming summer [3]. And we will present more details on our signal processing techniques, particularly techniques used to remove signal noise due to temperature variation, at the 10th International Conference on Damage Assessment of Structures [4].

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George Lederman NSF Personal Statement

I can track my interest in engineering to my freshman year at Princeton, when I traveled to Ethiopia. For most of my life, I had not appreciated the importance of infrastructure. But in Ethiopia, I saw for the first time how difficult life can be without water, electricity or roads. The trip instilled in me a new appreciation of technology. Adequate water supply was one of the many barriers that stood between the villagers and a more productive life, a barrier that I could, as a future engineer, help the people overcome.

After this moving experience, I became more involved in the Ethiopia Project, and soon transferred into the engineering school. My sophomore year, I was elected Project Manager, and coordinated another trip to Ethiopia that winter. Besides working on engineering design and planning, as project manager, I also applied for funding and tried to motivate other students to get involved in the project. My goal was to get people excited about addressing the needs of the villagers, and about solving the engineering problems. And we were successful in these goals—that year we gained several dedicated new members and raised more than $5,000 for the project.

However, I began to see the limitations of our work. Our next trip to the village, we found that the irrigation system we had installed previously, was not working. The intake had silted up because it had not been properly maintained. I realized that in order to achieve lasting economic development, the infrastructure systems we implemented would have to be more reliable. Instead of redesigning these systems myself, I became interested in implementing the sophisticated and robust infrastructure systems used in the developed world.

As a student group, the Ethiopia Project did not have the resources to install such systems. But after graduating, I had the opportunity to implement infrastructure systems on a much larger scale. For 20 months, I worked for Symbion Power in Tanzania on a $110 million design-build electrification project to bring power to 250,000 people in rural areas. The project was funded by the Millennium Challenge Corporation, a branch of the United States Government. As a part of a consortium with Alstom Grid, we upgraded 26 electrical substations across Tanzania, bringing state-of-the art-technology to some of the most remote areas.

When I arrived in Tanzania, I began work reviewing structural drawings from our civil designers. As the project progressed, I assumed the responsibility for coordination between the designers and the construction team. The biggest challenge we had to overcome was the general lack of knowledge about the state of the existing system. Often as we started working on a substation, existing components were found to be deficient, so our design had to be changed quickly in order to keep work on schedule. To make this work smoothly, I communicated daily with Alstom's electrical designers in France, our civil designers in England and Tanzania, officials from the state utility, TANESCO, and our own site foreman (sometimes in English, but often in Swahili.)

This work further stimulated my interest in infrastructure. Engineers at the Tanzanian utility company did not know the state of their own network. This meant they couldn't prioritize maintenance, and they couldn't plan capital investments effectively.

But it wasn't just the electrical infrastructure that was poorly managed. I became interested in the traffic patterns in Arusha, where I was living. Traffic downtown was caused largely by mini-busses, but most of these buses moved so slowly that the passengers got out to walk. I found this strange, because the mini-buses were privately owned, so naturally, I thought they would seek out routes with more passengers. As I got to know the drivers, I learned that each mini-bus had to pass through the central bus station on each route in order to pay a tariff from the Tanzanian Revenue Authority (TRA). So the majority of congestion downtown was entirely avoidable, but the TRA was not interested in distributed tariff collection points. I convinced some of my Tanzanian colleagues to help me collect data on the traffic—perhaps if the TRA wasn't interested in the problem—some international NGOs would be. We installed a passive GPS device on one of the mini-buses. However, after several days of collecting data, word had spread about our device. The driver removed our device out of fear of the TRA. This fear is one of the many barriers to performing research in the developing world.

I decided to return to the United States to pursue more formal infrastructure research in the Advanced Infrastructure Systems group at Carnegie Mellon. The project described in my proposal is the synthesis of research currently underway at Carnegie Mellon, along with my own interest in monitoring infrastructure, and the complexities associated with the task.

When I was applying for graduate school, I encouraged some of the brightest Tanzanian engineers I had worked with, to also pursue higher degrees in the United States. The most promising engineer, Hanington Kagiraki, a graduate of the University of Dar es Salaam, is scheduled to take his TOEFL and GRE this winter. I look forward to working with him on his applications over the summer. Perhaps someday, Kagiraki and I will have the opportunity to collaborate and collect more complete data sets about Tanzanian traffic patterns.

When I graduate from Carnegie Mellon, I plan to continue teaching, researching, and practicing engineering. I have been inspired by Theodore Zoli who taught me, "Design of Large Scale Structures: Bridges," at Princeton. Zoli is the National Chief Bridge Engineer at HNTB Corporation and has designed many notable bridges such as the Leonard P. Zakim Bridge in Boston, and the Blennerhassett Island Bridge over the Ohio River. Zoli's exceptional work has been inspired by his research; he has studied blast resistant structures, lightweight materials and network arch bridges. In turn, his research and practice make him an inspiring teacher, as he can draw from his rich experience in both realms.

My research experiences will be described in the next essay, so I will briefly describe one of my teaching experiences.

The summer after my junior year, I had the opportunity to teach at Duke TIP, a program for talented 7th and 8th grade students, who score in the top 5% on their standardized tests. I was hired as a teaching assistant for a class called, "Engineering Problem Solving" at Trinity University in San Antonio. The day before the class began, the instructor quit unexpectedly and took with her the material she had prepared for the class. In her absence, I was asked to teach the first couple of days. It seemed daunting; 18 students for 6 hours each day, and no syllabus. I went to the Trinity library, borrowed several freshmen engineering textbooks, and selected some of my favorite topics.

The only goal of the course was to stimulate the students' interest in engineering. So in the mornings, I would quickly go over some basic theory, for example electricity, aerodynamics, or optics, and in the afternoons, we would build something that could demonstrate the properties of the morning lecture, like a motor, a parachute, or a solar water heater. I found teaching these talented students to be an incredible privilege—when given a simple problem to solve, the students had creative (although sometimes totally impractical) solutions. Most of the instructors were graduate students or full time teachers, but by the end of first week, Duke TIP administrators promoted me to a permanent instructor for the summer course.

These are some of the experiences—working in Ethiopia, in Tanzania and as a teacher at Duke TIP—which have fueled my commitment to study engineering, to solve complex engineering problems, and to share my passion for engineering with students throughout my life.

Score for Lederman, George

Intellectual Merit Criterion

Overall Assessment of Intellectual Merit

Excellent

Explanation to Applicant

The applicant participated in 2 undergraduate projects and current research project. As a result, the applicant has 1 conference proceeding with another one in preparation, and 2 presentations accepted for conferences in 2013.
The applicant's numerous publication and presentation document breadth of knowledge.
The applicant provides an in-depth research plan.
The applicant's references offer strong evidence of the applicant's potential success.

Broader Impacts Criterion

Overall Assessment of Broader Impacts

Excellent

Explanation to Applicant

The applicant's Ethiopia Project - worked on irrigation system for a village, post BS employment with a power company in Tanzania, teaching to top 5-7% middle school students "Engineering Problem Solving" give the applicant a global perspective on engineering and humanity. The proposal research potentially could potentially impact infrastructure safety on a global basis.

Score for Lederman, George

Intellectual Merit Criterion

Overall Assessment of Intellectual Merit

Good

Explanation to Applicant

The applicant has experience in teaching, but his research experience is limited. Therefore, there are no strong indication of how he will perform in this project. The applicant should build his career from bottom up, getting involved in smaller research projects and working his way up.

Broader Impacts Criterion

Overall Assessment of Broader Impacts

Good

Explanation to Applicant

Applicant has traveled to foreign countries, which is important for broad perspective in issues. However, the research may be too big to handle giving his lack of experience. He does not have enough good reference from his mentors.

Score for Lederman, George

Intellectual Merit Criterion

Overall Assessment of Intellectual Merit
Excellent

Explanation to Applicant
The applicant completed his BS in CE at Princeton University and is the first year graduate student at Carnegie-Mellon with 3.66//4 and 4/4.3 GPA, respectively. He has extensive research record in US and oversees. At Carnegie Melon he is collaborating with the infrastructure Systems group. At Princeton he researched in a joint Oxford-Princeton aircraft wing design project. He also conducted research on a bridge safety project. In his freshman year the applicant traveled to Ethiopia to observe the infrastructure issues. In his sophomore year he was elected to manage an irrigation project. His research projects has produced 4 papers. The applicant has received strong letters of recommendations in support of his NSF proposal. The proposal suggest using indirect vibration monitoring system to measure bridge deterioration process. He has properly defined the project, explained steps required to run experiments and plans to implement the outcome. The applicant has proved his ability to conduct the high quality research.

Broader Impacts Criterion

Overall Assessment of Broader Impacts
Excellent

Explanation to Applicant
The applicant received CEE Book Award, presented to the senior with the best thesis. He also received David W. Carmichael Prize, presented in recognition of outstanding thesis. He has published and presented 4 papers. In his freshman year the applicant traveled to Ethiopia to observe the infrastructure issues. In his sophomore year he was elected to manage an irrigation project. After graduation he decided to work for a power company in Tanzania on an electrification project to bring electricity to 250,000 people. The project which was funded by the US government lasted 20 months. As an engineer he had to tackle many issues related to the project. Later he worked with the Tanzanian Revenue Authority to address to address the traffic congestion issues in Arusha Tanzania. During the summer of his Junior year he worked for Duke TIP Program where he taught talented 7h and 8th grade students. He has received very strong letters of recommendation from his references on his ability to transfer research into application. He has strong record of communal activities in US and overseas.

NSF Research Plan: Ben Winter

Aerodynamic Stability Enhancement for Structures using a Novel Wind Isolation System

Keywords: Aero-elasticity; Shape-memory polymer; Structural control

Introduction: Buildings are vulnerable to aero-elastic interactions in high winds (*e.g.,* threat to tornadoes and high-wind loading). Historically, tornadoes have rarely traveled through big cities damaging structures. However, due to expansion of cities, taller building construction, and climate change, this occurrence is becoming more common [1]. For example high magnitude tornadoes frequently hit Oklahoma City and Fort Worth, TX causing significant damage to infrastructure and several high-rise structures, respectively [2]. Climate change has been shown to alter the properties of cyclonic wind storms [1], leading to damage of structural components and non-structural cladding elements [3]. This research plan proposes a novel approach for active mitigation of wind loading on structures through real-time modification of building envelope geometry. It includes a detailed computational and experimental program to test the effectiveness of this mitigation technique, as well as to quantify changes in aero-elastic loadings and to understand the limits of the proposed approach.

Background: Structural control techniques based on leveraging inertial forces (*e.g.,* active, tuned mass, or viscoelastic dampers) or real-time alterations of stiffness/damping properties of a structure (*e.g.,* semi-active dampers) have been proven to be successful in mitigating the damaging effects of wind as well as improving occupant comfort [4]. Actuated appendages have also been applied to structures (specifically bridges) for uplift relief in vortex critical areas [5]. However, such approaches are often based on linear-control techniques, not aero-elastic understanding [6], rendering them less effective for control of aero-elastic instabilities; also these technologies are aimed to protect structural components, not cladding [4].

Hypothesis: I hypothesize that controlled smart envelopes can be designed to provide direct wind damage mitigation through deflection, similar to base isolation systems. Base isolation uses lead and rubber bearings to separate a building from the ground for direct seismic energy transfer reduction to a structure. The smart building envelope will be made of shape-memory materials that can allow structures to adapt to high-wind by taking advantage of active corner softening, morphing appendages, and synthesized double curvature. This technique has been proven effective in NASA aircraft [7]. Bi-directional shape changing materials, using heat to morph to a desired shape and cooling to revert to the original form, has already been used in medical fields [8]. Specifically, shape-changing polymers (SCP), are suitable for structural wind control due to their multi-shape temperature response and ability to heal after being pierced by debris [8].

Research Plan: This research plan proposes a novel approach to structural control for high-winds and vortex mitigation. I will start by developing a bench-top small-scale prototype system of a basic structural covering made of SCP modules. I will develop a numerical model to determine the fluid-structure interaction properties of one of these modules by tracking vortex changes to idealize the behavior of the SCP for high-wind mitigation. The goal of these steps would be to produce basic understanding of this new mitigation technique. The model can then be used for structural-scale modeling in an array of these devices, representing a building. I will refer to this as a wind isolation system. Based on gathered data and numerical model results, I will develop newly trained SCPs for structure cloaking models. With a change in

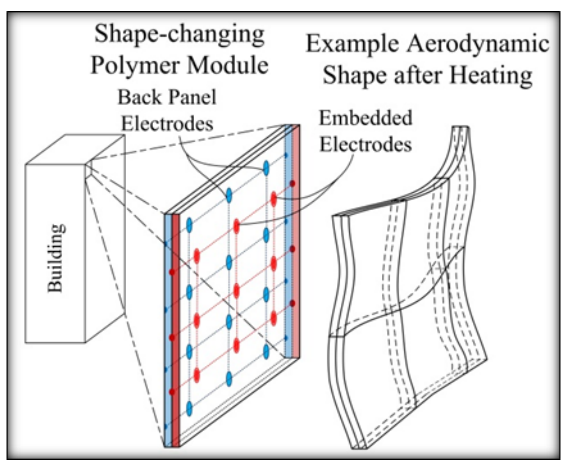

Figure 1

aero-elastic loading on the structure, the SCPs will be designed to change shape to deflect wind of varying direction. In order to activate wind direction deflection shapes in the SCPs, electrodes will be embedded in the polymer (*i.e.,* like electric blanket heating elements) (**Figure 1**). Placed strategically, the electrodes can heat the polymer and activate multiple trained shapes at different temperatures through Joule heating [8], simulating varying levels of corner softening, and double curvature. Building envelope modification will produce a relief in story stresses and improve aerodynamic structural stability. Actively, with structural response feedback, the system can be programmed to make electrode temperature changes in the SCP modules, thus actively tuning the envelope to reduce stresses. This reduction of stresses will be quantified and compared to existing approaches for structural and non-structural components.

Broader Impacts: This work will lead to improvements of technology and practices that will protect structures with a new concept of deflecting loading before it has a structural impact. This approach is adaptive, as opposed to existing active techniques which only react to after-effects of loading. Upon completion of my research in wind engineering, researchers of many other fields, including wind energy and aerospace engineering, can use my computational model to determine effective locations for polymer/electrode placement in turbine blades and aircraft wings, respectively. In addition, this research will allow me to expand my role in education for undergraduate students through giving interactive demonstrations of seismic and wind-excited resonance. I will also present my SCP modules for wind load mitigation and semi-active smart dampers as seismic structural control. I would do this using a shake table with several single-degree-of-freedom and multi-degree-of-freedom structures. Tying my wind research into these demonstrations would provide knowledge to these students about undesired high-wind related structural behavior and mitigation methods.

Intellectual Merit: The proposed research will involve the investigation of changes in aero-elasticity of a structure in high and extreme-wind loading as well as a computational model for tracking vortex changes and the fluid-structure behavior around structural boundaries. Understanding these changes will provide the basis for a novel wind control techniques in civil engineering. For the development of bench-top and larger-scale prototypes methods this work would use methods shown to be effective in aerospace engineering combined with active feedback of system stresses and story displacements. This novel idea tackles the issue of wind loading, but opens up the possibility to approach different loading scenarios by eliminating loads that cause issues in structures comparative to base isolation for earthquake energy mitigation.

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Score for Winter, Benjamin
Intellectual Merit Criterion

Overall Assessment of Intellectual Merit
Very Good

Explanation to Applicant
The applicant has previous research experience but it has not resulted in any publications to date.

Broader Impacts Criterion

Overall Assessment of Broader Impacts

Very Good

Explanation to Applicant

The applicant has explained the impacts of the research.

Summary Comments

Overall, the application is fairly strong.

Score for Winter, Benjamin
Intellectual Merit Criterion

Overall Assessment of Intellectual Merit

Very Good

Explanation to Applicant

The applicant has undergraduate and graduate academic records that are good and excellent, respectively. The applicant has participated in several academic projects as an undergraduate. The applicants recent graduate research experiences has resulted in the submission of two conference papers selected for presentation in 2014 as well as the expected publication of their masters thesis. The applicants research plan proposes a novel approach to structural control for high-winds and vortex mitigation. The applicant provides an in-depth research plan and shows a unique perspective on protecting structures with a new concept of deflecting loading before it has a structural impact. The applicants written communication skills are outstanding. Collectively, the applicants reference letters offer evidence regarding the applicants potential to be highly successful in graduate school.

Broader Impacts Criterion

Overall Assessment of Broader Impacts

Excellent

Explanation to Applicant

The applicant works with several students to teach members of the community to use relevant and affordable software packages for green building design. The applicant also volunteers at their former high school helping to train students enrolled in junior engineering programs and participating in summer band camps. Each fall semester, the applicant works with undergraduate students to design small-scale bridges to compete in the National Seismic Bridge Design Competition. The applicants research findings related to the computational model to determine effective locations for polymer/electrode placement in turbine blades and aircraft wings are expected to be used by researchers of many other fields, including wind energy and aerospace engineering. In addition, the research findings will allow the applicant to expand their role in educating undergraduate students by giving interactive demonstrations of seismic and wind-excited resonance. By using the applicants research via interactive demonstrations, this will provide knowledge to students about undesired high-wind related structural behavior and mitigation methods.

Summary Comments

The applicant has a wide set of practical skills and research experience that provides the foundation to pursue research aimed at understanding undesired high-wind related structural behavior and mitigation methods. The applicant has cultivated the necessary skills set to successfully implement their proposed research plan. The applicant is expecting to share their research findings through the submission of two conference papers selected for presentation in 2014 as well as the publication of their masters thesis. The applicants research have the potential to advance scientific knowledge about a novel approach to structural control for high-winds and vortex mitigation as well as develop a diverse, globally competitive STEM workforce.

Intellectual Merit Criterion

Overall Assessment of Intellectual Merit
Excellent

Explanation to Applicant
The investigation of changes in aero-elasticity of a structure in high and extreme-wind loading as well as a computational model for tracking vortex changes and the fluid-structure behavior around strcutural boundaries

Broader Impacts Criterion

Overall Assessment of Broader Impacts
Excellent

Explanation to Applicant
protect strcutures with a new concept of deflecting loading before it has a structural impact

Summary Comments
Green building certificate, LEED