My contributions to Michigan State University in teaching, service, and research are built on a foundation of multidisciplinary education and experience that has enabled me to conduct internationally recognized leading research. This foundation has enabled me to see exciting research problems in the gaps between established fields. My enthusiasm for drawing undergraduates into the professional world has also led to substantial service in professional societies (including accreditation organizations), which has enhanced the visibility of my research. This visibility has helped bring strong research funding that has enabled high rates of publication and subsequently, citations to my publications. According to Scopus, there have been over 1390 citations in Scopus after 1995 to 120 of my papers, and 21 have been referred to 21 or more times. By this metric, I am the 3rd most highly cited member of the ChEMS faculty (and probably 5th in the college). In addition, since 1995 there have been 228 citations not listed by Scopus, as well as at least 500 more citations prior to 1995 to papers published earlier.

The foundation of this scholarly leadership is my deep curiosity to discover the why behind experimental observations, particularly in interdisciplinary areas that have not yet been examined. The foundation of this success started with my undergraduate degree in solid mechanics, to which I have returned in recent years after developing three other areas of expertise that have enabled me to develop multidisciplinary teams that can solve problems that have not yet been attempted. To put these accomplishments into focus, I will describe how my rather unusual educational track has led to my success in interdisciplinary research, and then how my choices to develop new skills has led to research funding in a very competitive area. I will close with descriptions of how this research is tied to service and teaching at both the undergraduate and graduate levels.

My undergraduate program gave me a foundation in continuum mechanics, but my interest in materials led me to earn a M.S. in Ceramic Engineering, where I took core materials undergrad courses in addition to grad courses, and started to develop expertise in a second discipline. My mechanics background allowed me to participate in a multi-disciplinary research project with a mechanical engineer as a thesis advisor; I helped develop a thermal finite element (FE) code to study thermal shock in ceramics. This FE experience gave me fundamental insight into computational mechanics that would be built upon later. Though encouraged to continue for a Ph.D., interesting job opportunities were plentiful, and I left ceramics behind and got involved in experimental characterization of large strain plasticity at high strain rates while working at Sandia National Laboratory in Livermore in an experimental mechanics group. However, I was wooed away from this direction for awhile to develop expertise in physical metallurgy, by completing my Ph.D. in Materials Science.

My Ph.D. investigation of high strain rate superplasticity took advantage of my mechanics foundation. My research set a new world record for the rate of superplasticity, which exceeded 1/s for the first time, leading to a best paper award at the 1988 International Conference on Superplasticity and Superplastic Forming. Superplasticity had previously been known to be too slow for large scale production, but this and related foundational work set the stage for GM to quietly develop an industrially practical superplastic warm forming process for manufacturing aluminum body panels about a decade later – now a production process. While at MSU, I continued to publish in this field, culminating in an overview article on high strain rate superplasticity published in *Acta Metallurgica et Materialia*, which has been cited over 170 times. Research described in 13 papers on superplasticity have been referred to at least 513 times in the ISI system (most of these papers are prior to 1996, and not recognized by Scopus).

When I joined MSU, funding for superplasticity research had dried up, so I developed expertise in two new areas, creep deformation in TiAl, and crystallographic texture characterization (distribution of crystal orientations). Howmet Corp. in Whitehall, MI was developing technology for cast TiAl turbine engine blades, and I obtained contracts for nearly 10 years that supported 4 M.S. and 2 Ph.D. students in investigations of alloying and processing effects on primary creep deformation. Our work on primary creep is some of the most extensive work in the literature, as this topic that is rarely investigated in depth. We discovered very unusual mechanical twining during primary creep, which was noted with considerable discussion in a major review of mechanical twinning by [redacted] in 1995. Our work was well received, leading to an invitation to participate in a multi-university and industry based AFOSR 5 year project to investigate transition issues of TiAl for engines. GE just introduced this alloy into the engines that will be used in the Boeing 787 Dreamliner, which contributes to the significant increase in fuel efficiency that will come in future commercial airplanes. Our research in primary creep and mechanical twinning won a best paper award at a focused conference on intermetallics. This award enhanced my reputation in the Air Force, so I took a sabbatical in 1999 at the Air Force Research Laboratory at Wright Patterson Air Force Base, and worked on crystallographic texture and hot deformation relationships in Ti-6Al-4V, the most important Ti alloy.

My expertise in crystallographic texture developed from the opportunity to use equipment obtained by a world leader in texture analysis, [redacted] after he left our department to become the head of a physical metallurgy institute (RWTH) in Aachen, Germany. Having no training in this area, my first Ph.D. student and I learned this area together. I used two summers at NASA-Glenn to further develop my skills in texture analysis, and was then invited to Los Alamos to get training in computational simulation of texture evolution by one of the other world leaders in this field [redacted] I wrote part of the users manual for this computer code that helped make it available for public use. This new skill enabled me to study effects of primary processing on anisotropic properties of Ti-6Al-4V during my 1999 sabbatical. I also trained myself to use orientation imaging microscopy (OIM), a new tool for characterizing texture and microstructure. I was the first successful user of OIM at the AFRL, and my success established momentum for this technique that facilitated investigations by fellow researchers at the AFRL and the Ohio State University. My sabbatical work and subsequent summer collaborations provided the first convincing reasons for why regions of similar grain orientation persist and stimulate cavity formation during primary processing of Ti-6Al-4V. This causes fatigue cracking in turbine disks, a problem of great importance to the aerospace industry, as evident by 160 citations to this body of work. Another outcome was an invitation to write the article on Titanium alloys for the Encyclopedia on Condensed Matter Physics.

My 1999 sabbatical provided time to think, reflect, and retool, which was effective for developing funding for 4 new research programs: a collaborative program with M.A. Crimp on investigating damage nucleation in TiAl funded by AFOSR; a project funded by NSF in collaboration with [redacted] on lead-free solder; an industrially funded project to understand the reasons for a high reject rate in manufacturing Ti-6Al-4V fasteners; and a project with the MSU Cyclotron Superconducting Radio Frequency cavity development group.

One project that followed my 1999 sabbatical was with Fairchild Fasteners (City of Industry, CA). They had been making titanium fasteners for decades, and made incremental changes to a process defined 30 years ago by [redacted] but they reached the edge of their envelope with 30% reject rates. In two years, a team consisting of several of their people, me, and my grad student identified a number of issues that needed attention as we characterized the physical metallurgy behind their process. Their reject rate dropped to a $\Sigma 5$ level (1 in 10^5), and they hired this grad student even as the company was being bought out. This is perhaps the most immediate influence my work has had on making a difference in a manufacturing technology. While this project has closed, I continue to consult with ATI Allvac, which produces titanium alloys in North Carolina. With the increase in demand for titanium alloys required for the Boeing 787, this will probably develop into a funded research program in the coming years.

The NSF Focused Research Group grant came out of a collaboration built upon my expertise in high temperature deformation and texture to investigate lead-free solders. This work was initially funded with [redacted] through the manufacturing research consortium led by [redacted] This NSF grant came as automotive industry funding for our lead-free solder research was drying up and it enabled our group to make a very significant advance in understanding the physical metallurgy of tin (Sn) in the context of lead-free solder joints. Unlike Pb-Sn solder joints, which have about 30 vol% of soft lead, Sn based lead-free solders have ~95% Sn with the remainder being hard intermetallic phases, which makes the deformation process completely different from Pb-Sn solders. Our efforts revealed the importance of how Sn deforms and affects the reliability of lead-free solder joints. This work is important because most solder joints must be lead-free by international policy set in 2006, and because 70% of electronic system failures are solder joint failures, the reliability of electronic systems for the foreseeable future will depend on our ability to predict how Sn deforms. The 52 articles tabulated in the Web of Science have been referred to at least 805 times, and one has been referred to 71 times. In subsequent collaborations, we have shown that most solder joints are single or tri-crystals, something that has been hard for many to accept, including one of my co-PIs. Because of the extreme elastic and plastic anisotropy of Sn, we can explain why failures are often found in positions in a package that never fail when Pb-Sn joints are used (in a major paper just published in IEEE CPT Transactions). This work has led to an invited overview paper in the MRS Bulletin, an invitation to write an article on lead-free solders for the Encyclopedia of Materials: Science and Technology, a request to participate in an international electronics manufacturing initiative (iNEMI) to investigate early failures in lead-free solder, and an invited talk for a lead-free workshop at the TMS meeting next spring. Funding from Cisco Systems Inc. is currently in place to support a Ph.D student.

The research grant funded by AFOSR led to identification of a deformation mechanism based fracture initiation parameter in TiAl, a material challenged by low ductility. The significance of this work is that the vast majority of research involving cracks assumes that they already exist, something that is simply not true, as any material supplier will tell you. How a crack comes into existence is an unexplored mystery that can now be examined with available experimental and modeling technology. The significance of our fracture initiation parameter was recognized by [redacted] (ranked 1st place of the TOP-10 list of the most important scientists in Germany below the age of 45), one of the four department heads of the Max-Planck-Institut für Eisenforschung in Düsseldorf, with whom I spent my 2006 sabbatical. During this sabbatical I learned how to do crystal plasticity finite element modeling, which provided an additional skill valuable for solving multidisciplinary problems. I have used this capability to show that the fracture initiation parameter is more robust than experiments alone can imply. Subsequent experiments in collaboration with [redacted] (MSU) also show that the fracture initiation parameter works in creep of a cubic superalloy, a very different material and deformation process.

The collaboration that developed from my 2006 sabbatical continues, as we won a prestigious NSF Materials World Network grant that is combined with a DFG (German version of NSF) grant for a joint multidisciplinary research program that is investigating if this fracture initiation parameter approach will work for pure titanium and dual phase steel, and to further develop this into a predictive tool within the finite element setting. This project involves annual personnel exchanges and visits across the Atlantic. Another outcome of this collaboration is that I am a co-author of an invited overview of crystal plasticity finite element modeling that is submitted to *Acta Materialia* (the leading journal for Materials Science), and we have signed a book contract on this subject for next year.

Finally, since my 1999 sabbatical, I have become increasingly involved with the Superconducting Radio Frequency Cavity development group at the National Superconducting Cyclotron Laboratory. This group is investigating how to optimize the performance of high purity niobium for accelerator cavities operating at ~ 2K. Cavities are complex evacuated tubes that accelerate particles for high energy physics experiments. The constraints on this design optimization problem are enormous: at the end of the production path, cavities must have perfectly smooth interiors in complicated shapes, in metal that has as few defects (dislocations or impurities) as technologically possible. Our efforts to bring physical metallurgical understanding to this optimization problem has made our MSU group one of the major players in the world, as the condition of Nb limits the achievable accelerator energies for high energy physics research. Evidence for the significance of my contributions include: receiving a DOE grant to support this research over and above funding that support this group. I have obtained subcontracts to investigate texture issues in a SBIR based project to develop a novel large strain processing strategy with another researcher in Texas. I have been asked to give the introductory talk when MSU hosts a workshop this fall on materials science of Nb cavities. We have integrated crystal plasticity and thermal property expertise (with ME professors [redacted]) into the materials science based optimization problem. Funding is in place to bring a new Ph.D. student into this project.

My classroom teaching certainly reflects my passion about the fascinating aspects of metals, and my interest in and appreciation for polymers has increased with time and exposure to the activities of my chemical engineering colleagues. I am serious about having students gain true understanding sufficient to communicate it clearly in presentations and papers, and I value this more than their ability to do plug and chug exercises. This philosophy results in having students work harder in my classes than in other classes. Comments from alumni show that my emphasis on communication is valued. A consequence of this is that undergrad students who choose to work with me are usually sufficiently self motivated to be able to succeed in their projects; 12 have been co-authors on reviewed conference proceeding or archival journal papers.

In terms of graduate education, I have advised 18 students who have earned 14 M.S. and 6 Ph.D. degrees. Three have won best poster or paper awards at international conferences. My former Ph.D. students are working in government and industrial research labs, and one is a tenured faculty in a more teaching oriented university.

I am deeply involved in undergraduate curriculum and accreditation, both in our department, and as an ABET evaluator for programs on other campuses (which gives me good ideas for our own curriculum). I chair the MSE curriculum subcommittee that is responsible for running the undergraduate MSE program. We reinvented our curriculum in 2001-2003 to introduce a more attractive and flexible curriculum that can accommodate the range of materials oriented skills that our future alumni will need, and this led to a new surge of interest in the major from undergraduates (for example, 100% of our students who complete the bio-materials major who have applied to medical school have been accepted). We are continuously adjusting the content to strengthen the bio and polymer content of the curriculum without undermining the fundamentals of crystalline materials. We have concurrently implemented systematic feedback infrastructure that has been effective, as it has led to significant improvements in our ability to function as a team in training the next generation of materials engineers.

For about 2/3 of the years I have served as a faculty member I have also been the faculty advisor for the MSE Society, where I have enthusiastically encouraged students to get engaged in the professional world to see how they can contribute when they graduate. Leading by example, I have been active in TMS and ASM committees, having served on 14 committees, and chaired one. I have been an organizer for 13 symposia, which has enhanced my research visibility. I have been sufficiently responsible in these activities to be drawn ever higher into leadership within the society. I am presently on the Materials Processing and Manufacturing Division Council, as its representative to the TMS programming committee, and I represent TMS in the multi-society MS&T programming committee that plans overall structure of this large multi-society annual conference. I have said no to higher positions, as I have not wanted to compromise my research activity any more than it already is. My leadership is also evident in the 20-30 manuscript reviews I am asked to do per year, many of which are for the highest ranked journals in both the materials and mechanics fields. I am a key reader for *Metallurgical and Materials Transactions*, and have been asked to be on the editorial board of a new open journal, *Journal of Metallurgy*, where I choose reviewers for manuscripts and evaluate reviews. I also review several proposals per year, many from overseas.

The purpose of this essay is to highlight my contributions, but they were not possible without the students who did most of the work, along with collaborative thinking with other bright researchers. Hence, *our* synergistic research efforts have been very successful; they are not built on coattails. Our research has addressed a wide range of metallurgical challenges, and most of these investigations have led to widely recognized scholarship, and helped to develop new technologies. I have understanding of experimental and computational modeling of metallurgical phenomena at deformation rates that cover 15 orders of magnitude from 2K to the melting point, which provides a strong foundation for developing new projects in the future.

My interdisciplinary skills give me vision and visibility that help me leverage my skills with others to make new discoveries. This foundation of both experimental and computational physical metallurgy, texture/microstructure analysis, solid mechanics, and crystal plasticity modeling is particularly strategic for the quantitative prediction of material property evolution from the solidification or deposition stage to final product. I have regularly gained new skills to keep my vision and capabilities sharp, which has enabled me to build multidisciplinary teams. In such teams, the impact of my understanding can only increase, as exemplified by the current NSF-DFG project that requires mathematicians, mechanicians, and metallurgists to develop new computational paradigms for predicting damage nucleation, and optimizing material reliability. Predicting damage nucleation at a fundamental level is remarkably unexplored, but it requires multidisciplinary competency to make an effective and sustained impact. As fundamental understanding of damage nucleation is crucial for all aspects of engineering endeavors in both mechanical and electrical systems, our continuing efforts in this area will make a global impact that will positively enhance affect all aspects of engineering activity. This will further build the reputation of the MSU College of Engineering as we develop material processing paths that enable reduced cost, increased lifetimes, better fuel economy and less greenhouse gas production in a wide variety of applications.

Statistics:

Number of M.S. Degrees: 14
Number of Ph.D. Degrees: 6 + 3 current students
Cumulative research funding \$2,535,218;
 pro-rated (joint research) \$1,440,080
Number of publications: 186
Number of citations: at least 1618 (see plot)
Citations to top 10 papers:

- 183 Acta Mater., 1995 Overview on Superplasticity
- 99 Scripta Mater., 1988 on high strain rate superplasticity
- 91 J. Elect. Mater., 1999 on lead-free solder
- 75 Mater. Sci. Eng.A 1990 on high strain rate superplasticity
- 61 Acta Mater., 1997 on high strain rate superplasticity
- 49 Acta Mater., 2001 on hot working in Ti-6Al-4V
- 45 Phil. Mag. A, 1995 on twinning in TiAl
- 43 J. Elect. Mater., 2000 on lead-free solder
- 43 J. Elect. Mater., 2001 on lead-free solder
- 39 J. Elect. Mater., 1999 on lead-free solder