

**NOMINATION COVER SHEET**  
**2010 Virginia Outstanding Faculty Awards**

<b>1. <u>NAME</u></b>	
Full (Legal): Romesh Chander Batra	Preferred First Name: Romesh
<b>2. <u>INSTITUTIONAL INFORMATION</u></b>	<b>3. <u>PROFESSIONAL INFORMATION</u></b>
Institution: Virginia Tech	Academic Discipline: Engineering Mechanics
Rank/Position Title: Professor	Specialization/Field: Material Failure under Blast Loads
Year Rank/Title Attained: 1994	Type of Terminal Degree: Ph.D.
Years at Institution: 15	Year Awarded: 1972
Campus Email Address: rbatra@vt.edu	Awarding Institution: Johns Hopkins University
Campus Phone: 540-231-6051	
Campus Mailing Address: Dept of Engineering Science & Mechanics (0219) Blacksburg, VA 24061	
Campus Communications Contact:  -Name: Larry Hinker  -E-mail: hinker@vt.edu	

***Please check only one box:***

- RESEARCH/DOCTORAL INSTITUTION NOMINEE:
- MASTERS/COMPREHENSIVE INSTITUTION NOMINEE:
- BACCALAUREATE INSTITUTION NOMINEE:
- TWO-YEAR INSTITUTION NOMINEE:
- TEACHING WITH TECHNOLOGY NOMINEE:
- RISING STAR NOMINEE:

**Table of Contents**

Cover Sheet .....	1
Mission Statement .....	2
Summary of Accomplishments.....	3
Personal Statement.....	9
Abbreviated Curriculum Vitae .....	11
Letters of Support (Excerpted) .....	13
Additional Documentation .....	16

Signature (President or Chief Academic Officer) Mark McNamee

Printed Name: Mark McNamee

E-mail address: mmcnamee@vt.edu Telephone: 540-231-6123

## **MISSION STATEMENT OF THE UNIVERSITY**

Virginia Polytechnic Institute and State University is a public land-grant university serving the Commonwealth of Virginia, the nation, and the world community. The discovery and dissemination of new knowledge are central to its mission. Through its focus on teaching and learning, research, and outreach, the university creates, conveys, and applies knowledge to expand personal growth and opportunity, advance social and community development, foster economic competitiveness, and improve the quality of life.

Approved by the Board of Visitors, June 4, 2001; revised in 2006

## Summary of Accomplishments

Professor Romesh C. Batra, Ph.D., D. Sc. (Honoris Causa) joined Virginia Tech's Engineering Science and Mechanics Department (ESM) in 1994 as the Clifton C. Garvin Professor of Computational Mechanics. He is a world-recognized leader in the Failure of Materials Exposed to Extreme Loads, such as those produced by the improvised explosive device (IED) as described in television and print news media. His research work has been continuously funded by the Department of Defense (DOD) for the last 26 years with total funding exceeding \$11M. He is the only one from the Commonwealth of Virginia whose expertise has been sought by the National Research Council in serving on Warhead Mechanics and Survivability and Lethality Panels.

Dr. Batra has excelled in teaching, discovery, integration of knowledge and service. He is the only faculty member to win the College of Engineering (COE) Dean's Awards of Excellence in research, outreach, and service in 1997, 2005 and 2007, respectively. He won the Virginia Tech Alumni Award for Excellence in Research in 2004 for his work on material failure. His honorary D.Sc. degree's citation states "...His research has revealed new mysteries on the behavior of materials."

Dr. Batra won the prestigious Alexander von Humboldt Award in 1992 for his pioneering work in developing an understanding of the failure of materials subjected to shock loads. The Humboldt is awarded to "Outstanding scientists and scholars from outside Germany whose fundamental discoveries, new theories, or insights have had a significant impact on their own discipline and who are expected to continue producing cutting-edge achievements in the future." He won the 2009 Engineering Science Medal from the Society of Engineering Science (SES) for his singular work on material failure (in the 40 years history of the SES besides Romesh only 1 other Virginian has won this award), the 2009 Lee Hsun Research Award from the Chinese Academy of Sciences for his work on understanding material behavior under explosive loads (Romesh is the only one in Virginia to win this award), the 2000 Reissner medal for his fundamental work in simulating the penetration of a missile into a tank wall (Romesh is the only one in Virginia to win this). His discoveries and dissemination of theories of material failure have earned him the grade of Fellow in four societies: American Academy of Mechanics (AAM), SES, American Society of Mechanical Engineers (ASME), and American Society of Engineering Education (ASEE). Dr. Batra served the AAM as Secretary (2003-2005) and the Chair of the Awards Nominating Committee from 2005 to 2008. As the SES President in 1996 he was instrumental in starting student chapters at several universities.

In 2007, the *Journal of Sound & Vibration* honored him as one of the most cited authors. His Dec. 2007 paper, coauthored with 2 Ph.D. students, published in the *Smart Materials and Structures* was downloaded more than 1000 times in one year, which is the highest of any paper published in the Institute of Physics 75 journals, and is nearly four times the average number of downloads for a paper. A paper coauthored with a Ph. D. student published in Nov. 2007 issue of the *Int. J. of Solids & Structures* is the 2nd highest (1028 times) downloaded article published in the journal in 2007.

Dr. Batra organized at Virginia Tech the 2002 US National Congress of Theoretical and Applied Mechanics with over 1050 participants from 40 countries, which the Governor of Virginia recognized by declaring a 'Theoretical and Applied Mechanics Day in the Commonwealth'. The Univ. of California-San Diego Distinguished Professor Nemat-Nasser cited this and the 1999 conference Dr. Batra organized as "superb examples of Romesh's ability and magnetism to bring to Virginia Tech the most prominent researchers and scientists in various aspects of mechanics. Many of these individuals are legends in the field. To be able to have so many great people, all at one place, is a sufficient accomplishment to warrant the recognition that Romesh is nominated to receive." Dr. Batra's colleague, N. Waldo Harrison Prof. M. W. Hyer, states, "...The man is a gem.", and in the 2009 evaluation his Dept. Head wrote, "You are an excellent role model for our younger faculty".

## Teaching

*Background:* The ESM Department at Virginia Tech has an enrollment of nearly 90 undergraduate and 80 graduate students. Students majoring in other engineering fields take our courses resulting in the highest student credit hours taught per faculty member in the COE. Due to student's demands for courses taught by Dr. Batra, he is assigned to teach graduate and senior undergraduate level classes which are also populated by students from other disciplines such as civil, mechanical, aerospace, electrical and computer engineering. His teaching load, the same as that of every faculty in the department, is 3 courses per year.

*Instruction:* For the past 35 years (including 20 prior years at the University of Missouri-Rolla) Dr. Batra has emphasized a thorough understanding of principles of mechanics, and has challenged students in his classes to analyze real world problems. He is a highly respected, sought after but very demanding instructor. He treats students as colleagues, respects their independent thinking, and appreciates their unique way of attempting assignments. He uses reports, oral presentations, problem solutions, class-room discussions, lecture handouts, eye to eye contact, power-point slides, detailed notes on homework solutions, examples from world events, movies depicting simulations of physical phenomena, DVDs of lectures on the internet, and e-mail exchanges to promote students' learning of concepts. He grades home works and answer sheets to learn what concepts need additional emphasis and stresses them in the next class. In order to establish relevance of the material covered in the class to the current literature, the last homework assignment involves students studying a recently published paper and listing in it all concepts learned in the class. The goal is not only to share knowledge with students but encourage them to use it for discovering new things. Students find his courses to be very rewarding and excellent preparation for their research.

In order to illuminate weaknesses in the solution methodologies and develop critical thinking, students are assigned a problem that has no solution but the often used numerical techniques if not properly used provide (of course wrong) a solution. A familiar example is that of derivatives and financial instruments used by money managers on Wall Street that has put us in recession.

Based on students' evaluation of instructors' teaching, Dr. Batra is always on the Dean's list of excellent teachers. Excerpts from students' anonymous evaluations include such phrases as "*He keeps explaining until everyone understands the idea*", "*Excellent knowledge of the subject matter*", "*Excellent communication of principles*", "*Very respectful towards students*", "*Excellent character*", "*Excellent concern and respect for individuals*", "*One of the greatest professors I have ever had*".

Students in his classes work on a project which sometimes results in a refereed journal publication. As a part of the final examination, students present their work to peers and sharpen their communication skills. They then meet individually with Dr. Batra and discuss ways to improve upon the presentation and the work, and what it will take to yield a refereed journal publication. It establishes self-confidence in students, prepares them for a successful job interview, encourages them to extend their learning experience beyond the confines of the class room that will bring well-deserved and rightfully earned exposure of their creativity. Students opting to prepare their project for publication work closely with Dr. Batra, and are overjoyed upon receiving praise of their accomplishments from anonymous referees. His mentee, Bryan M. Love (Ph.D., 2004) writes, "*Through the constant revision and re-revision of journal papers prior to submission, Dr. Batra taught me how to effectively convey my research to the academic community. All of these resulted in me becoming a better researcher, approaching problems with meticulous attention to detail*". H.-K. Ching (Ph.D., 2002) states, "*Batra encouraged me to polish my public speaking skills by presenting the work in the [weekly group] meetings and always showed great patience listening to what I said. This training has proved to benefit my professional growth.*"

Some undergraduate seniors choose to do their design projects with Dr. Batra because of his reputation as a superb scholar and researcher who cares for his students, works closely with them, and helps them disseminate research findings through publications in international journals. Two seniors have analyzed the failure of structures exposed to shock loads produced by IEDs, pursued graduate degrees at very prestigious schools such as Stanford University and enhanced Virginia Tech's reputation for providing excellent preparation for research. Dr. Batra strives to seek funding for undergraduates to enhance their learning experience through summer internships.

Dr. Batra's reputation as an excellent mentor of students has extended beyond the US; four students from Italy and France, and two from China have come at their own expense to Virginia Tech to work on design projects under his tutorship. He has delivered invited tutorial lectures at the National Science Foundation funded US-China Workshops on Nanotechnology held in Dalian (2005) and Beijing (2007). As a Midwestern Mechanics Lecturer in 2004, he gave graduate student seminars at four US universities. He taught one-third of the short course on Designing Smart Structures ten times at different locations including Munich, Germany and Edinburgh, Scotland.

*Student Development and Learning:* Since joining Virginia Tech in 1994, Dr. Batra has advised to completion 18 doctoral students (averaging 1.2/year or 4 times the COE average), 10 M.Sc. students, and is presently advising 5 doctoral, 1 master, 1 undergraduate junior, 2 postdoctoral and 3 visiting scholars. According to the 2009 *US News and World Report*, in the highest rated MIT doctoral program a professor graduates 1 doctoral student/year and advises 4.2 doctoral students; in Virginia Tech's COE a professor mentors 2.6 doctoral students. Dr. Batra has served on the advisory committees of over 100 doctoral students in different departments. He has mentored 30 postdoctoral fellows at Virginia Tech with several supported by their home institutions. His research group has had members of different cultures, ethnicities, and from several countries including the US, Columbia, Italy, France, Russia, Korea, China, Taiwan, Thailand, Ukraine and Egypt.

Perhaps one's greatest instructional achievements are seen in the accomplishments of one's students after they leave the University. The following examples indicate that Dr. Batra has done an excellent job. S. S. Vel (Ph.D., 1999) won the 2006 AAM Distinguished Young Researcher Award, and M. Porfiri (Ph. D., 2006) won a much coveted NSF Career Award in 2007. Of the 18 former doctoral students at Virginia Tech, 7 are faculty members, 3 are enhancing their research skills as postdoctoral fellows, and 8 are employed in the public and the private sectors. M. H. Lear (Ph.D., 2005) was promoted to supervisor at the Applied Physics Lab in 2008, and B. M. Love (Ph.D., 2004) has received several recognitions at the Army Research Lab.

### **Discovery**

Dr. Batra is a world-recognized scholar in Engineering Mechanics with 338 peer-reviewed publications (228 since joining Virginia Tech) in journals of high impact factors. His publication rate of 15 refereed journal papers per year is more than 5 times that of an average faculty member in Virginia Tech's COE. The Univ. of Maryland's Alfred Gresso Professor, Inderjit Chopra, writes "*If we are asked to choose the three most distinguished researchers in the area of engineering mechanics who have made the most impact in the field during the past two decades, Dr. Batra, in my opinion, will make this list. His research shows creativity, relevance and diversity.*"

Batra's graduate level text book *Elements of Continuum Mechanics* (published in the American Institute of Aeronautics and Astronautics Education series, 2006) has been adopted at numerous US universities including Virginia Tech's peer institutions, University of Illinois-Urbana, and Texas A & M University. What distinguishes this book from others on the same subject is the elaborate and authoritative discussion of material modeling. He has signed a contract with Springer Verlag to deliver the manuscript of the book "Finite Element and Meshless Methods" by 31 December 2009.

Results of his group's research have appeared in several books, and as invited book chapters.

Dr. Batra's research work has been continuously funded by the DOD since 1985, and by the NSF, NASA and private industries, with total funding exceeding \$11M. He actively participates in interdisciplinary grants, and collaborates with researchers from all over the world bringing recognition to the work of his students and to Virginia Tech.

The Web of Science lists journal articles of Dr. Batra's group having received more than 3,770 citations with 15 papers cited more than 50 times each, and 2 cited over 100 times each. Four research areas that have received the most recognition are: (a) failure of solids under explosive loads produced by the detonation of IEDs, (b) functionally graded materials that are the next generation of advanced materials, (c) smart structures that can be exploited to harvest energy, and (d) modeling of carbon nanotubes.

The impact of Dr. Batra's discovery on society is felt through the following projects that included undergraduate and graduate students' participation as integral members of the team. They, in turn, have taken this knowledge and used it to continue the scientific and learning processes.

- Improved design of armors (bullet proof vest, helmets made of lightweight composite materials, tank wall, shields to protect vehicles against an IED generated blast load, transparent armor such as goggles and windshields, marine vessels exposed to underwater shock loads), anti-armors (environmentally benign ceramic bullets, kinetic energy rods to break steel reinforced concrete bunkers).
- Development of computational tools and mathematical models for Pratt & Whitney to analyze damage induced by bird strikes to engine blades composed of next generation lightweight materials (recall the potential disaster caused by the failure of both engines of the US Air flight from New York to Charlotte, NC).
- Computational tools for designing rubber-covered rolls used in paper mills, and photocopying machines.
- Quantification of damage and crack in the solar probe panels and the cooling system caused by the impact of dust particles moving at 300 miles/second (imagine traveling from Virginia Tech to DC in 1 second); the launch date for the probe will be decided by NASA shortly.
- Micro-electro-mechanical systems that open air bags in a car upon impact or crash, potentially detect bioagents in air, water and soil to protect the Nation from terrorist activities.
- Smart structures that monitor vibrations and health of structures, make car rides quieter and smoother, help orthodontists adjust teeth, automatically modify configurations of airplane wings to improve upon their energy efficiency.
- Functionally graded materials for the space shuttle, flow of oil in pipes under extreme environmental conditions, and increasing the life of jet engine blades.
- Carbon nanotubes for designing lighter and more fuel efficient airplanes than Boeing's 787 Dreamliner, and as carriers of drugs to targeted areas (e.g. cancerous tissues) in the body.

Besides providing research tools and algorithms, Dr. Batra's discovery team develops human talent by educating the next generation of engineers and scientists. His contribution is in making these young minds think independently, critically, and question scientific assumptions made by other investigators until they are satisfied that nothing better could be done with the tools currently available, and always searching for more efficient techniques. He cultivates the discovery process in his students by challenging them to filter through different aspects of a real world problem, and focusing on its essential elements that incorporate the relevant science to formulate a simple

mathematical model, delineate effects of various assumptions, and validate the model by comparing results with experimental observations.

Dr. Batra has edited/co-edited 10 books and special issues of journals, and has been invited by Springer Verlag to co-edit the Handbook of Computational Mechanics. He gave plenary lectures at the 16<sup>th</sup> Int. Congress of Composite Structures, Portugal, 2009, and the SES/ASME/ASCE Conf. held at Virginia Tech, 2009, and key-note lectures at several National and International conferences including the US-France Workshop on Impact and Penetration Problems, 2008. He is an editor of two International journals, and is a member of the editorial board of several other journals.

### **Knowledge Integration**

Dr. Batra's integration of current research results into teaching attracts students from various disciplines to his classes. Examples include (i) teaching the propagation of shock waves in a composite bar that illustrates essential elements of studying structural failure due to explosive loads but can be managed in the class room environment, (ii) analyzing deformations of marine vessels due to underwater shock loads (e.g., the ship Cole damaged by terrorists) to illustrate how explosive loads in air and in water react differently with structures, (iii) discussing the fragmentation of a ring into several pieces rather than that of a vehicle, (iv) introducing meshless methods that were developed recently and enable one to delineate crack paths dictated by the physics of the problem. About ten years ago, the meshless method was introduced to overcome some limitations of the other numerical techniques. A doctoral student completed his dissertation with Dr. Batra in this subject in 2002 and the material has been integrated in the graduate level course since then. A significant improvement of the technique, symmetric smoothed particle hydrodynamics method, discovered by Dr. Batra's research team three years ago has been integrated into the curriculum. Two Aerospace Engineering doctoral students who learned it in Dr. Batra's class have adopted it in their dissertation research. Thus, the integration of discovery and knowledge is an evolving process. He has also integrated knowledge in the teaching of short courses to practicing engineers, and was invited by the Eglin Air Force Base Officials to teach a 6-hour short course on material failure.

Dr. Batra's discovery of a technique to verify computer codes and teaching it in his computational mechanics classes through lectures and home works has trained a new generation of engineers in performing diagnostics on their computational tools. Using this technique, Dr. Batra's former advisee, A. G. Varghese (Ph.D., 2008), found a serious error in a commercial computer code being used for 20 years by several companies studying impact problems.

Dr. Batra's expertise in integrating discovery with knowledge has been sought by other Institutions. He has been invited by the Nanjing University of Science and Technology, China and the Lanzhou University of Technology, China to work closely with their faculty and enhance their doctoral programs. A faculty member from each university spent a year at Virginia Tech collaborating with Dr. Batra in research and learning the art of successfully mentoring doctoral students. Dr. Batra is an Honorary Professor of these two Universities.

At the invitation of the Rector of the International Center of Mechanical Sciences, Udine, Italy, Dr. Batra shared his pioneering research on material failure by teaching one-fourth of a week-long course to international researchers. A 90-page chapter based on these lectures has appeared in the book *Localization and Fracture Phenomenon in Inelastic Solids*, (P. Perzyna, Ed.), Springer, 1998.

### **Service**

Dr. Batra has conducted high-profile service within the university, the department and the profession. His colleague, M. W. Hyer, writes, "*Batra is generally engaged in three or four major activities at one time: serving as the director of the departments' extensive graduate program, co-*

*chairing an international conference, editing a book, serving as an officer for a professional society, all while regularly meeting with his students, postdoctoral research associates, visiting scholars and teaching classes.*” In June 1999, he organized and co-chaired the 3-day ASME – Mechanics and Materials Conference on the Campus attended by nearly 750 scientists from all over the world. This and the 5-day 2002 US National Congress of Theoretical and Applied Mechanics has brought enormous visibility to Virginia Tech, enabled Virginia Tech’s researchers and students interact with managers of research programs and world’s leading scientists.

Dr. Batra co-founded the journal “*Mathematics and Mechanics of Solids*” in 1995, and has been co-editing it since then. It attracts manuscripts from world’s eminent researchers. He is a co-founder and co-Editor-in-Chief of the *Int. J. of Computational Methods* established in 2004. He serves on the editorial board of the *Polish J. of Theoretical and Applied Mechanics*, and has completed his terms on editorial boards of *Continuum Mechanics and Thermodynamics* (1994-2005), *Computational Mechanics* (1997-2006), *Int. J. of Plasticity* (1988-2002), and as an Associate Editor of the *ASME’s J. of Engineering Materials and Technology* (1996-2001).

He served as the Director of the Graduate Program for five years (2001-2005). In this capacity he represented the Department at the COE, the Graduate School, and at International Universities such as the Politecnico di Milano, Italy, the Univ. of Roma, La Sapienza, Italy, the Tsinghua Univ., China, the Indian Institute of Technology (IIT) – Delhi, the IIT-Chennai, and the Thapar Univ., India. His overview of the Department’s Graduate Program in presentations at National and Int. Conferences has enhanced the program’s visibility and attracted applications from exceptionally qualified persons. He was instrumental in forming an external blue-ribbon panel of four National Academy of Engineers members to review the ESM graduate program. The panel members highly appreciated the study-ahead material Dr. Batra prepared, and the program received glowing reviews.

For the last several years, Dr. Batra has been serving on the Department Promotion and Tenure Committee, Honorifics Committee, and the Graduate Committee. As Chair of the Faculty Search Committee in the AY 2005-06, he contacted several colleagues at other universities to seek a diverse group of talented applicants. From nearly 360 applications received, the committee shared its vision, during on-campus visits, with 13 potential colleagues who were perceived to have the potential to be world class leaders in their fields. Three persons accepted offers to join ESM.

Since 2005, Dr. Batra has been serving on the Honorifics Committee of the Industrial Engineering and Systems Department, the COE, the University, and the Alumni Associations committee for Awards for Excellence in Research. Last year he chaired the Search Committee to select a named professor in Virginia Tech’s Aerospace and Ocean Engineering Department.

Examples of Dr. Batra’s service on scientific advisory committees of international conferences are: (i) Co-chair of the 1<sup>st</sup>, 2<sup>nd</sup> and 3<sup>rd</sup> Int. Congress on Mechanical Engineering and Mechanics co-hosted by Nanjing Univ. of Science & Technology, City Univ. of Hong-Kong, and Virginia Tech that were held, respectively, in Nanjing (2005), Wuxi (2007), and Beijing (2009) China; (ii) Co-organizer with Dr. A. Ferreira (Univ. of Porto, Portugal) of the Symposium “Functionally Graded Materials (FGMs)” for the European Conf. on Computational Mechanics, 2006; (iii) The 9<sup>th</sup> Int. Symp. on Multiscale and FGMs, Honolulu, Hawaii, October, 2006 (also reviewed papers submitted for possible publication in the Conference Proceedings); (iv) Int. Conf. on Computational & Experimental Engineering Sciences, Chennai, India, 2005; (v) 3<sup>rd</sup> M.I.T. Conf. on Computational Fluid and Solid Mechanics, 2005; (v) Int. Confs. on Advances in Mechanical Engineering and Mechanics, Tunisia, 2006, ‘08, ‘10; (vi) 16<sup>th</sup> European Conf. on Fracture, Greece, 2006.

## PERSONAL STATEMENT

I developed a passion for teaching and sharing knowledge with others during my high school and college days. I lived with my single elder brother in a large city (of the size of Baltimore, MD) in India rather than with my parents in a small town, since the nearest college was 15 miles away from my parent's house and there was neither convenient public nor private transportation available. I tutored my neighbor's children in return for home cooked meals, which is the only compensation they could afford. My love of teaching and joy of seeing young minds benefit from coaching cemented my desire to become a professor in Thapar College of Engineering where I was an undergraduate student. With a lot of luck, and without taking TOEFL and GRE examinations, I received a graduate teaching assistantship from the University of Waterloo, Canada, to pursue my studies for the M. Sc. degree. Waterloo University required four graduate courses for the M. Sc. degree and a thesis. While working on my thesis research, I came across Ericksen's and Truesdell's works on continuum mechanics that propelled me to apply to the Johns Hopkins University for doctoral studies. That was one of the most fortunate and riskiest decisions of my life, since earning a Ph.D. degree at Waterloo entailed conducting research to write the dissertation and no more exams were to be taken after successfully defending the M. Sc. thesis. Hopkins required a series of written and oral tests to be passed every year before becoming a candidate for the doctoral degree. Fortunately, I earned my Ph.D. degree in essentially the same time as I would have at Waterloo, but was equipped with a broader set of scientific tools and a more inquisitive mind that enriched my life. The training at Hopkins instilled in me a love for research and discovery to the point that I abandoned my goal of returning to Thapar College and made the USA my home. This did not appease my parents and brother which I appreciated only after my and Manju's (my wife since 1972) two daughters moved to Missouri and California after earning their B.Sc. degrees from Virginia Tech. Subsequently, both daughters have earned M.Sc. degrees, and are productive members of the Society. Manju and I are very fortunate in having raised them well, and cultivated in them good social and cultural values.

Some of the guiding principles in my life have been to be honest, treat others as you wish to be treated by them, realize that all of us are blessed with equal intelligence, and everyone has special skills. My goal has been to impart enough skill sets in my advisees so that they will potentially do better in their professional lives than I have done. It has not been easy since I often get asked "Why do I have to compare my solution with that of other investigators? I have already solved the problem one way, why do I need to check the solution by a different method?" Students invariably do not like the answer "The problem we are studying is new and we need to ensure that our solution is correct".

In Eastern culture, parents' success in bringing up siblings is measured by how much more the children achieve than their parents did. The sincere desire has been to pass the torch on to academic children as Professors Ericksen and Truesdell did to me, and continue their legacy and keep the academic family tree growing; fortunately, I was awarded the Engineering Science Medal this past June that Ericksen received in 1988. Only time will tell how far I have succeeded in this; the early signs are very promising since Dr. Ru (former post-doctoral fellow), Dr. Qian (former research collaborator), Dr. Vel (former doctoral student), and Dr. Porfiri (former doctoral student), to name a few, are doing exceedingly well in their academic careers. One person who took four of my graduate level courses (half of his course requirements for the M. Sc. degree) has served as a Program Manager at the NSF. It is very rewarding and satisfying to see these young minds mature and explore new frontiers of knowledge. It gives me immense pleasure to see that I have mentored well the next generation of scientists.

Being the only one in my family to have earned a Ph.D. degree, I looked to Professors Ericksen and Truesdell as my role models. Even in 1972 both were world-renown authorities in their fields of research, and scholars from all over the world came to Hopkins to work with them as Post-doctoral

researchers. One of my goals was to attain that level of success without sacrificing my family life. My duties at home included helping the daughters with their home works every day. My wife and I regularly attended parents/teacher conference, accompanied them to their sports on weekends, and encouraged them to study well. During a parents/teacher conference I asked the teacher “What can we do to enhance chances of our daughter’s admission into an Ivy League School?” I was disappointed to hear the response “The High School prepares them for admission into State Universities”. I’ve been trying my best to keep the course material current and at least comparable to that in the most prestigious universities in the world. Fortunately, the Internet has made life easier in this respect.

Both Professors Ericksen and Trusedell’s research work was analytical and I inherited that taste from them. To some degree it was natural since undergraduate students in Asia are given more extensive training in Calculus than those in the US; it was true in 1970’s as it is true today. I see this in my classes and it has been widely reported in numerous studies. However, to seek solutions to real-world problems that involved complex geometries and complicated initial and boundary conditions, I soon realized that it was better to use computational methods and find solutions that provided considerable insight into the deformation fields and response of materials. I learned, on my own, first the finite element method and subsequently the boundary element and meshless methods, and developed my own software and algorithms to analyze mechanics problems. In order to verify these tools and quantify errors in the numerical solution, I developed a technique now called “the method of manufactured solutions” to find a solution to a nonlinear problem by using fictitious body forces. My competency in these methods soon increased to a level that I published my work in leading journals in the field. Computational mechanics is now a well recognized field of research in the scientific community. The NSF requests proposals in this area and the DOD relies on it to design nuclear weapons that cannot be tested because of environmental concerns. I now cherish seeking numerical solutions to complex systems and enthusiastically impart to my students the notion that they must quantify errors in their computed numerical solution.

All ESM graduate students are required to take the continuum mechanics course which is highly analytical and requires integrating concepts from different undergraduate courses. Keeping in mind that we admit cream of the crop from a pool of highly qualified applicants, my first task is to create learning atmosphere rather than that of competition. A student has described my classroom philosophy as follows: *“First, Dr. Batra immerses you in the material by talking with you about the material instead of talking at you about the material. His vast knowledge of the course material and ease in explaining concepts make this lecture style all the more effective. Secondly, Dr. Batra constantly challenges you to think about the material during the class period as he poses questions to the class or allows a student’s question to be answered by the group.”*

I am highly accessible to students either in person or via email. Even if I cannot answer their questions immediately, it helps to discuss various ways of looking at the same problem. It is a joy to see their eyes light up when they get their first peer-reviewed paper accepted for publication in a journal. One of the doctoral students (Love) working with me won the COE outstanding student award, another (Lear) served as the student marshal in the Graduate School Commencement, another (Pacheco) won two departmental scholarships that happened for the first time, and another (Varghese) won the 2<sup>nd</sup> place in the COE Paul E. Torgersen Research Award. Each student publishes two or three papers from his/her doctoral dissertation in peer-reviewed journals.

I am very grateful for the opportunity to work as the Clifton C. Garvin Professor of Engineering Science and Mechanics at Virginia Tech and in the Commonwealth of Virginia, and return to the society dividends of the investment the US has made in me. I plan to continue working with students and other professional colleagues, and serving the society as best I can.

## Abbreviated Curriculum Vitae

### a. Education:

Ph.D., 1972, Mechanics and Materials Science, The Johns Hopkins University, Baltimore  
M.A.Sc., 1969, Mechanical Engineering, University of Waterloo, Ontario, Canada.  
B.Sc., 1968, Mechanical Engineering, Thapar University, Patiala, India.

### b. Teaching Experience:

1994-present, Clifton C. Garvin Professor, Department of Engineering Science and Mechanics, Virginia Polytechnic Institute and State University, Blacksburg, Virginia  
1974-76, 77-94, University of Missouri-Rolla (Assistant Professor 1974-76, Associate Professor 1977-82, Professor 1982-94), Rolla, MO  
1976-77, Assistant Professor, Univ. of Alabama-Tuscaloosa

### Visiting appointments:

11/02-12/02, 7/99-1/00; 6/87, Technical University of Berlin, Germany  
5/90, University College, Ireland  
1/85 – 6/85, Univ. of Minnesota  
7/80, University of Pisa, Italy

### c. Scholarly Works and Activities

**Text Book** – *Elements of Continuum Mechanics*, AIAA Educational Series, 2005.

**Number of papers in refereed journals = 338**

#### Currently Active Grants:

- Failure analysis of structural components of solar probe due to impact by dust particles, NASA (subcontract through Applied Physics Lab), 3/1/09-4/30/10, \$145K, PI.
- Development of a helmet design optimization tool using computational modeling, NAVSEA (subcontract through Applied Physics Lab) 9/1/09 – 8/31/10, \$146K, PI.
- Optimal design of marine sandwich structures and nano-composites for mitigation of thermo-mechanical shocks, 4/1/06-3/31/10, \$519,887, ONR, PI.
- Multilayered technologies for armored structures and composites: Teaming the Army Research Laboratories with Virginia Tech, 1/07-05/10, \$3M, ARL, Co-PI (15% credit).
- Fracture of adhesive bonds under mixed mode loading: experiments in a dual actuator load frame and numerical simulations, 8/08-7/10, \$438K, NSF, Co-PI (33% credit).
- Progressive Damage Analysis of Ultra-thick Composites, 10/1/09-9/30/12, \$300K, Airbus, Co-PI (50% credit).
- Failure of Composites due to impact loads, 9/1/09-8/31/12, \$300K, Pratt-Whitney.

#### Selected Books/Special issues of journals edited (Total = 10)

- R. C. Batra (Editor), *Contemporary research in Engineering Science*, Springer, 1995.
- R. Armstrong, R. C. Batra, M. Meyers and T. W. Wright (Eds.), *Shear instabilities and viscoplasticity theories*, a special issue of *Mechanics of Materials J.*, **17**, 83-328, 1994.
- R. C. Batra and H. M. Zbib (Eds.), *Material instabilities: theory and applications*, *ASME Press*, 1994.
- R. C. Batra, Y. D. S. Rajapakse and A. J. Rosakis (Eds.), *Failure mode transitions under dynamic loading*, a special issue of *Int. J. Fracture*, vol. **101**, 1-180, 2000.
- H. M. Zbib, T. Shawki and R. C. Batra (Eds.), *Material Instabilities*, a special issue of *Applied Mechanics Reviews*, **45**, 1-173, 1992.

#### Graduate Students/Post-doctoral Fellows Advised:

Completed: Ph.D. = 28; MS = 16; Postdoctoral Fellows = 40

Present: Ph.D. = 5; Postdoctoral Fellows = 2, Visiting Scholars = 3.

### **Selected Journal Publications out of 338 (Doctoral students names underlined)**

1. W. Jiang and R.C. Batra, Molecular Statics Simulations of Buckling and Yielding of Gold Nanowires Deformed in Axial Compression, *Acta Materialia*, **57**, 4921-4932, 2009.
- N. M. Hassan and R. C. Batra, Modeling Damage in Polymeric Composites, *Composites B*, **39**, 66-82, 2008.
- A. Caba, A. L. Loos and R. C. Batra, Fiber-Fiber Interactions in Carbon Mat Thermoplastics, *Composites A*, **38**, 469-483, 2007.
- B. M. Love and R. C. Batra, Determination of Effective Thermomechanical Parameters of a Mixture of two Thermoviscoplastic Constituents, *Int. J. Plasticity*, **22**, 1026-1061, 2006.
- R. C. Batra and M. H. Lear, Adiabatic Shear Banding in Plane Strain Tensile Deformations of Eleven Thermoelastoviscoplastic Materials with Finite Thermal Wave Speed, *Int. J. Plasticity*, **21**, 1521-1545, 2005.
- A. Sears and R. C. Batra, Macroscopic Properties of Carbon Nanotubes from Molecular-Mechanics Simulations, *Physical Reviews B*, **69**, Art. No. 235406, 2004.
- S. S. Vel and R. C. Batra, Exact Solutions for Thermoelastic Deformations of Functionally Graded Thick Rectangular Plates, *AIAA J.*, **40**, 1421-1433, 2002.

### **d. Selected Public and Academic Service**

- Editor (1995-) Mathematics and Mechanics of Solids, Sage Publisher
- Co-Editor-in-Chief (2004-) Int. J. of Computational Methods, World-Scientific Publishers
- Co-Editor (2009-), Handbook of Computational Mechanics, Springer-Verlag.
- Member – Int. Organizing Committee, Thermal Stresses, 2005, Vienna, Austria, May 2005; Organizing Committee, Int. Conf. on Computational Methods, Singapore, 2004; Scientific Advisory Board, Third MIT Conf. on Solid and Fluid Mechanics, June 2005; Co-Organizer and Co-Chair, Symposium on Functionally Graded Materials, Int. Congress of Theoretical and Applied Mechanics (ICTAM), Warsaw, August 2004; Co-Organizer and Co-Chair, Symposium on Fracture and Fatigue, Int. Cong. of Theoretical and Applied Mechanics, Adelaide, Australia, August 2008; Scientific Committee, 3<sup>rd</sup> Canadian Conf. on Nonlinear Solid Mechanics, Toronto, 2008; Int. Scientific Committee-10<sup>th</sup> US Congress on Computational Mechanics, Ohio, 2009.
- Co-Chair, Int. Cong. of Mechanical Engineering & Mechanics, China, 2005, 2007, 2009.

### **e. Selected Awards**

- 2009 Engineering Science Medal, Society of Engineering Science.
- 2009 Lee Hsun Research Award, Chinese Academy of Sciences, China
- 2009 Plenary Lecture, 19<sup>th</sup> Int. Congress of Composite Structures, Portugal
- 2007 Virginia Tech's College of Engineering Award for Excellence in Service
- 2006 D. Sc (Honoris Causa), Thapar University, India
- 2005 Virginia Tech's College of Engineering Award for Outreach Excellence
- 2005 Honorary Professor, Lanzhou University of Technology, China
- 2004 Alumni Award for Excellence in Research, Virginia Tech
- 2004 Honorary Professor, Nanjing University of Science & Technology, China
- 2003 Elected Secretary of the American Academy of Mechanics for a 3-year term
- 2003 Frank J. Maher Outstanding Faculty Award, ESM Department, Virginia Tech
- 2000 Eric Reissner Medal from the Int. Cong. of Comp'l and Engineering Society
- 1997 Virginia Tech's College of Engineering Dean's Award for Excellence in Research
- 1996 President of the Society of Engineering Science
- 1992 Alexander von Humboldt Award

## EXCERPTED LETTERS OF SUPPORT

It is no exaggeration to label Dr. Batra's accomplishments in scholarship as staggering both in quantity and quality. In the past five years alone, he has published (with his co-workers) well over 15 journal articles per year in refereed journals. In a field where it is considered acceptable for faculty members to publish 2-3 articles a year, this is truly a mind-numbing accomplishment. He is one of the leaders, both nationally and internationally, of novel applications of mechanics principles that are both timely and long-lasting. This is especially true in the area of plate and shell mechanics, where his contributions are innovative, powerful, and of lasting impact. He has also produced a powerful group of graduate students, many of whom are making substantial contributions to other areas of engineering at other universities.

The most significant and easily accessed means of evaluating impact is by an analysis of Dr. Batra's citations. Here again, his accomplishments dazzle. Recent years have seen an average of over 400 citations of his work each year, with an H-index of 32 (meaning he has 32 papers that have been cited at least 32 times). As means of comparison, I was just told by a colleague in an outstanding department that they were considering a lucrative funded chair position, but all candidates had to have an H-index of 25. These are world-class standards and give clear evidence of Dr. Batra's scholarship.

Dr. Batra is a truly dominating presence in engineering mechanics. He is a valued reviewer, textbook author, and teacher. My only regret is that he is not my colleague at the same university.  
**Paul Heyliger, Professor, Colorado State University.**

Dr. Batra is a one-of-a-kind when it comes to university faculty members. While departments generally consist of some faculty members who generate research funds and advise graduate students, some who concentrate on teaching, others who tend to make a career out of serving on committees, and yet others who are quite involved in professional activities, including outreach, Dr. Batra does *all* of the above, and with a high level of dedication, enthusiasm, and energy, and with many accomplishments and awards to show for his involvement....He approaches problems from a very sophisticated level, and this sets him apart from many other researchers. His approach puts him in contact with many well-known researchers around the world in the highest ranked institutions. This is very beneficial to the department, college, university, and to the Commonwealth of Virginia, as it provides exposure that may not otherwise occur. It brings well-known people to Virginia and to campus, and puts the name of the institution and the Commonwealth in front of individuals who make important decisions. **M. W. Hyer, Former President, American Society of Composites, N Waldo Harrison Professor of ESM, Virginia Tech.**

*If we are asked to choose the three most distinguished researchers in the area of engineering mechanics who had made the most impact in the field during the past two decades, Dr. Batra, in my opinion, will make this list. His research shows creativity, relevance and diversity.* It appears that every one of his graduate students has published a couple of archival papers from their dissertations and it is a testimony of his good graduate advising. In fact, I attended presentations of his students at smart structures conferences and they seem to be quite clear and confident of their work. Again, this is a reflection of his thorough graduate advising. There is no doubt that he has been instrumental [in] producing a very high caliber scholars in engineering mechanics, who are now making enormous contributions to the state-of-art in this field.

I certainly think that Dr. Batra is at the forefront of his research field and enjoys an international recognition of his work. His research work *is basic, innovative and significant.* Today it is extremely difficult to find a *star faculty* who is a committed educator and productive researcher and inspires

and motivates young students. I see a rare combination of these qualities in Dr. Batra. **Inderjit Chopra, Alfred Gessow Professor & Director, Alfred Gessow Rotorcraft Center, Univ. of MD.**

I've been following over the years one area of his [Batra's] research which is the formation of adiabatic shear banding and application of this theory to predict dynamic failure of components subjected to extreme loads and weapon effects [IEDs]. His constitutive model (I am referring here to a series of papers published in the mid-1990s, when I started work myself on ductile fracture) was relatively simple and yet very effective. It allows the prediction of failure in thin-walled structures with very little computational effort and apparently good accuracy. Subsequently, Dr. Batra has improved this model, but its underlying fundamentals and simplicity still remain. A separate area of Dr. Batra's activities for which he could be awarded distinctions every year is his success in bringing a large volume of funding and building a very strong team at Virginia Tech. It is very interesting that the sources of his current research support are similar to mine with the only difference being the level of support, which in his case is much higher.

For me, it was very instructive to learn that Dr. Batra is receiving a number of awards for his teaching quality. This is again quite unusual, because typically a faculty successful in research and putting so much of his time and effort into that activity must compromise other areas, such as teaching. That is clearly not the case with Dr. Batra, and it makes me wonder how he organizes his and his teamwork. **Tomasz Wierzbicki, Professor, MIT, Cambridge, USA.**

A constitutive relation [material model] proposed by Professor Batra has been implemented in Department of Defense (DOD) design hydrocodes (computer codes to analyze impact and penetration problems) through an in-house project at the ARL [Army Research Laboratory]. His research work is very highly rated by the DOD/Department of Energy (DOE) scientists and engineers. *Realizing the importance of his research on ASBs [adiabatic shear bands], the U.S. Army Research Office, in an unprecedented move, funded his research continuously for 15 years.*

In 1990, I had a unique opportunity of studying works on ASBs for including it in the chapter *Material Characterization at High Strain Rates* in the book *Impact Dynamics* published by John-Wiley. *While I was preparing this article, it became clear to me that Professor Batra's earlier work on ASBs had led to several breakthroughs in modeling the complex material failure process under severe loading conditions.* I have taught a highly specialized 3-day short course on High Strain Rate Behavior of Materials several times to scientists and researchers affiliated with the DOD, the DOE, Universities and Industries. My teaching material included Professor Batra's approach to modeling the ASB.

*As an Army Scientist, I understand the importance and need for such [computational] platforms to address several of the extreme harsh environment problems that our country is facing in Iraq and Afghanistan. Professor Batra's pioneering research and development work on Adiabatic Shear Bands, ductile failure of solids and structures, numerical algorithms based on state of the art meshless methods, and other theories and governing laws/equations that describe nonlinear phenomena associated with blast and ballistics are all outstanding contribution to integration knowledge.*

A recent Ph.D. graduate student (Dr. Bryan Love) of Professor Batra was hired by ARL and it is greatly benefiting the laboratory on a research area that has incredible defense importance. I consider this as one of the greatest services that a Professor could render to his or our country. **Dr. A. M. Rajendran, Chief Scientist, US Army Research Office, Research Triangle Park, NC**

My personal experience working under Dr. Batra showed him to be an excellent academic advisor,

as well as a caring person concerned with the welfare of his students. He pushed me to learn not only my research area, but also fundamental concepts that would be applicable to any area in mechanics. At his encouragement, I explored the literature to give me a deep understanding of my particular research problem. In weekly graduate student meetings, the constructive criticism of Dr. Batra and my fellow graduate students taught me to look for *holes* in my own work....I always felt that his office door was open, and he always showed me a great deal of respect as a person. I continue to speak to Professor Batra, on a professional and personal level, over the years after graduation—and I hope to continue doing so for years to come. **Bryan M. Love, Ph.D., 2004**

The Ph.D. degree in Engineering Mechanics I earned under his [Dr. Batra's] supervision in Spring 2006 is my second doctoral degree. I received a Ph.D. degree from the University of Rome “La Sapienza”. The advising and research skills of Dr. Batra are absolutely superior to those of faculty I interacted with in Italy and France. Dr. Batra is fantastically talented in advising his graduate students by providing unique research directions, teaching them research methods and valuing their contributions. Being one of the most respected and prolific experts in mechanics, he is extremely capable of discovering unexplored and prolific research areas, and is uniquely experienced in mentoring young researchers. I am currently an Assistant Professor in the Mechanical and Aerospace Engineering Department of the Polytechnic Institute of New York University that I joined in Fall 2006. In 2008, I was awarded the NSF CAREER grant to study guidance and control of animal groups through bio-mimetic robots. I sincerely think that most of these successes have to be attributed to his guidance during my doctoral studies. He has been the perfect example of what a world class faculty should be: always willing to foster critical thinking in young minds, and always eager to learn more and address new problems that are important to the society. He is the most gifted and creative scholar I know. **Maurizio Porfiri, Ph.D., 2006, Assistant Professor, Polytechnic Univ. New York.**

Dr. Batra has been the single biggest influence on my professional development. I had little experience in research and lacked any clear career plans when I began working under his guidance. He taught me how to systematically tackle challenging research problems and instilled in me a passion for research and teaching that led me to an academic career. During the last nine years as a faculty member at the University of Maine, I have had the opportunity to advise several graduate students and I have in turn gained a deeper appreciation of the excellent advising that I was fortunate enough to receive from Dr. Batra. I now fully understand the amount of time, patience and encouragement it takes to nurture the talents of students and bring out the best in them. As a prolific researcher and excellent teacher, Dr. Batra balances a plethora of distinct tasks each and every day. Despite the demands on his time, he has shown a continual and deep commitment to mentoring graduate students and he has always placed the interest of the student over his own personal priorities. He provides his students the perfect balance between technical direction and the freedom to pursue their research interests. As a result of his excellent mentoring, many of his former graduate students have gone on to have successful careers in academia and industry. **Senthil S. Vel, Ph.D., 1999, Associate Professor, Univ. of Maine.**

Dr. Batra is an exceptional graduate advisor. Professor Batra held a weekly group meeting. In the meeting, we discussed the research works of every group member. This has given us a valuable opportunity to learn from our peers and broaden our horizon. Furthermore, I would point out that, as a foreign graduate student, the oral communication in English was important but not easy for me. Dr. Batra encouraged me to polish my public speaking skills by presenting the work in the meeting and always showed great patience listening to what I said. This training has proved to benefit my professional growth. Besides, Dr. Batra has an open-door policy. The Ph.D. training enabled me to become a mature professional. **Hsu-Kuang Ching, Ph. D., 2002.**

## ADDITIONAL DOCUMENTATION

Workshop on Soldier Survivability, London, UK, 8 Dec. 2009 Led by Dr. Batra

**www.soldiersurvivability.com**

**Pre-Conference Workshop: Tuesday 8th December**

**13.30 - 16.30 Lightweight Materials and Structures for Defence**

There is a high demand for the continued development and design of lightweight materials for warfighter protection. Reducing the weight of materials and structures for personnel body armour is crucial to the mobility of the warfighter. Components with maximized protection capabilities that are ultra-light also reduce costs and result in higher performance. This session will focus on the development of lightweight materials and structures for soldier survivability. An in-depth discussion on mass and weight reduction as well as using various configurations of lightweight materials and hollow or sandwich structures will take place.

**How you will benefit:**

- Gain insight into the problems that include structural degradation and how to increase lifetime, reliability and efficiency of each plate even while in harsh environments
- Improve your understanding of optimizing structural integrity by using protective coatings or honeycomb or bonded structures

**Learn about:**

- Production and processing practices of materials
- Design, fabrication and assembly of the structure
- Ceramic matrix composites and nickel alloys

**Led by: Professor Romesh Batra, Department of Engineering Science and Mechanics, Virginia Polytechnic Institute and State University**



Left: Dr. Batra laying the foundation stone for the Alumni House at his Alma Mater, Thapar University, India; Right: Dr. Batra receiving the Honorary Doctoral degree (the Indian Express, 10/20/2006).

### Courses Taught:

*UMR*: Statics, Dynamics, Mechanics of Deformable Bodies, Continuum Mechanics, Elasticity, Finite Element Method, Machine Design.

*Virginia Tech*: Introduction to Continuum Mechanics, Nonlinear Elasticity, Computational Mechanics, Finite Element Approximation I, Finite Element Approximation II.

### Sampling of additional comments of Dr. Batra's teaching and letters from alumni and colleagues

*"Understanding the course material really well and excellent in delivering the subject", "Always willing to offer help", "Challenges the students with assignments", "Relates analysis techniques to problems of interest in engineering", "The projects were invaluable in learning the material", "Helped a lot in computer programming", "His repetition of important concepts was excellent".*

I chose to attend Virginia Tech because of Dr. Batra's reputation in the field of computational mechanics. During the four years I worked with him I grew to respect him not only because of his preeminence in his field but also, and perhaps more deservedly, for his strong sense of integrity. In

spite of what it would do to his reputation or his position at the university or his standing among other faculty, he always holds true to his beliefs and his standards. For instance, when a good friend and colleague asked him for an endorsement for his latest book, Dr. Batra gave him an honest assessment. The book was not very good, his colleague was not very happy, and Dr. Batra had strained a tie to someone who otherwise was a good friend. I'm sure he was tempted to acquiesce, but he didn't. He held to his standards in spite of the personal hardship. When I spoke to him about it he said that he couldn't allow people to purchase the book based upon his recommendation. Through his example, he demonstrated to me not only the character to have a conviction but more importantly the courage to stand up for it. He recognized that he had a duty to the scientific community that even a friendship could not overcome. *To this day I use this and the many other similar examples he showed as a benchmark against which to measure my own character.*

Throughout our association, Dr. Batra has continually impressed me with his tremendous compassion to his students. He knew my wife, he knew my children, and regularly made a point to ask how they were doing. He and his wife would hold an annual celebration for the entire research group and their families. During these times he would talk to and play with my children and they would always look forward to their visits. It was during one of these gatherings, while my son sat on his lap talking about his new school, that I realized how much more than an advisor Dr. Batra was. Consequently, the April 2007 shootings had a profound impact not only on me but also on my entire family. The first question my children asked was, "Is Dr. Batra all right?" Unfortunately, at the time, I didn't know. I only knew that Dr. Batra's office was on the second floor of Norris Hall and that he regularly taught classes in the rooms where the tragedy occurred. Finding out he was safe was a great relief and a call to action.

Despite the disruption to his own work and despite the tragic loss of his colleague and friend, Liviu Librescu, Dr. Batra's first thought and most ardent desire was to guarantee the continued well-being of his students. I cannot conceive of a more profound testament to his deep sense of service to his University and to its students.

Dr. Batra expects nothing short of the best effort from all those around him and always expects even more from himself. Over the last nine years he has not only been my teacher and advisor but he has also become a trusted mentor and friend. *Virginia Tech's reputation lives and grows in the reputation of its alumni. Not just in their amazing discoveries or great inventions, but also in day-to-day demonstrations of honor and integrity. Dr. Batra's other students and I have learned these traits and witnessed them in action through our relationship with him. His effect on us is clearly demonstrated in the great things that we have accomplished during and since our time at Virginia Tech.* **Matthew H. Lear, Ph.D. 2005, JHU Applied Physics Laboratory**

Attending his [Dr. Batra's] classes in computational mechanics, I perceived him as a great teacher through his capability to communicate to students his knowledge and his passion. Because of this peculiarity, typical of great and devoted scientists, I decided to move to the ESM department after having received the Master Degree at the University of Roma, "La Sapienza", and I have been honored to have him as my advisor.... The work published in my first journal paper co-authored with Dr. Batra started when I was taking his *Advanced Finite Elements* class, in the framework of a recently developed numerical method that he taught in the course. This has been for me the example of how an outstanding scientist and teacher can be capable of filling the often open gap between topics taught in class and possible related research. Under his guidance and his continuous support, I had the great privilege to dedicate myself to research, motivated from his example towards excellence, enlightened by his passion for science and his intellectual integrity. The scientific interaction with Dr. Batra has always been an occasion of intellectual growth. He is a

worldly renowned scholar, always open to learning from his interlocutor with the humility characteristic of outstanding scientists.... **Daive Spinello, Ph.D., 2006.**

The first aspect of Dr. Batra's classes that stands out is his respect for his students. As a student I felt Dr. Batra respected my willingness and drive to learn. In turn I, and all of his students I know, always respected Dr. Batra, for both his professional achievements and his willingness and drive to educate. This mutual respect fostered a unique classroom experience where Dr. Batra treated us, the students, as he would a colleague. Treating the students as colleagues transformed class lectures into involved discussions. By approaching the class lecture as a discussion Dr. Batra accomplishes two things that allow the learning process to be facilitated. First, Dr. Batra immerses you in the material by talking with you about the material instead of talking at you about the material. His vast knowledge of the course material and ease in explaining concepts make this lecture style all the more effective. Secondly, Dr. Batra constantly challenges you to think about the material during the class period as he poses questions to the class or allows a student's question to be answered by the group. The combination of these two teaching methods along with Dr. Batra's drive to educate, create a classroom atmosphere where knowledge is continuously absorbed through the teacher, other students, and individual students themselves. In my experience as a student this unique type of educational atmosphere in a classroom greatly facilitates the learning experience.

Dr. Batra's methods of discussion and challenging students also stand out in his approach to homework. The homework assigned by Dr. Batra always challenged the students to expand on the concepts learned in class, meaning students were challenged to learn on their own. Dr. Batra rarely gave formal solutions to homework problems. Instead the class discussed individual solutions as a group, deciding what the correct solution was based on what we had learned. While treating homework in this manner followed Dr. Batra's classroom methods and allowed students to learn more about the course material, in my opinion it also served a greater purpose. That purpose was to prepare us, as graduate students, for our professional careers by teaching us to learn. *By giving us homework that forced us to expand on basic principles taught in the classroom, Dr. Batra really taught us how to learn, expand our knowledge about any problem we encounter, how to communicate and defend our own work. In essence, Dr. Batra taught me how to prepare myself for my professional life, by continually challenging myself, by learning from whatever sources are available, and by communicating the knowledge I learn to others.*

Outside of the classroom I have also become more aware of Dr. Batra's own enthusiasm to discover and acquire new knowledge. I believe this enthusiasm to discover to be the second part of why Dr. Batra is an outstanding professor. He is not only an outstanding teacher but he is also an outstanding learner. **Bradley Klenow, Ph.D., 2009, Aerospace Engineering (AE), Virginia Tech.**

Of all my course work to this point in my academic career, Dr. Batra's FEM [Finite Element Method] course was both the most challenging and the most rewarding. Dr. Batra is excellent at providing challenging educational assignments that truly help to facilitate learning. He was available whenever I needed assistance, but was diligent to only direct my efforts as oppose showing me how to proceed. My experience with Dr. Batra on my Ph.D. committee is not different from that from a classroom section. In my Ph.D. preliminary exam, Dr. Batra asked a question to which I initially had no idea how to respond with regards to the difference between "collocation methods" and "Galerkin methods." However, Dr. Batra asked additional directing questions through which I was able to deduce how to proceed. His warm but firm personality made a potentially stressful situation very educational. I would guess that very few people can honestly leave their preliminary Ph. D. exam and say "I have learned something today. **Wesley Slemp, Doctoral Student, AE, Virginia Tech.**

In the classroom Dr. Batra brings a unique approach to teaching: challenging his students to challenge themselves – to think beyond the physical and to trust the math and physics to tell them the stories about their problems. Teaching more than just established methods of modeling, Dr. Batra brings to the classroom the problems that are being solved right now and the methods applied to solving these problems. He presents multiple ways to solve these problems allowing students to learn a vast number of approaches that can later be applied in their research. *In addition Dr. Batra was recognized in 2003 for his teaching excellence, receiving the Frank J. Maher Outstanding Faculty Award at Virginia Tech.* “Ut Prosim” (That I may serve!), is the mission of VT and can be seen throughout Dr. Batra’s career. He has been serving the institution and the community of VT as an educator and researcher. As evidence of this commitment to education and the ESM program at VT, Dr. Batra and his wife, Manju, have established a new (as of May 2005) doctoral scholarship in the ESM department at Virginia Tech: *The Amir Chand and Dewki Bai Batra Scholarship.* **Julian Davis, Ph.D., 2007, Virginia Tech.**

I came to know Romesh when we worked together on a Multi-University Research Initiative funded by the Air Force. Faculties from six institutions were involved with Georgia Tech being the lead. We held bi-weekly teleconferences. Romesh was the only person from our partner institutions that we could always count on to attend. Not only that but he would send in the information in the required format and, more importantly, we could always count on him to deliver what was needed by the team. This is a testimony to the integrity and professionalism of Romesh. Romesh invests in people....**Farrokh Mistree, Professor and Associate Chair, Mech’l Eng’g, Georgia Tech.**

Dr. Batra’s noteworthy contributions in material failure recognized by world leaders in the field include (i) identifying material and geometric parameters that influence the initiation and propagation of cracks, and the penetration of a target by a missile, (ii) developing a failure criterion suitable for incorporation in computer codes, (iii) exhibiting effects of heat conduction on the width of damaged material, and (iv) showing that the failure propagation can be slowed by adjusting the composition of a particulate composite. *He has edited 10 books or special issues of journals dealing with this subject, taught a part of the short course on this topic at the International Center for Mechanical Sciences, Udine, Italy, and published a 90-page book chapter...* I have enjoyed studying parts of his book *Elements of Continuum Mechanics*, and found the material on constitutive relations most illuminating. *He continues to integrate new knowledge into his research and teaching as evidenced by several recent results included in his book....* **George Z. Voyiadjis, Boyd Professor, and Bingham C. Stewart Distinguished Prof. of Eng’g, LSU, SES President, 2008.**

*Throughout his research, he has emphasized quality, respect for fundamentals, and thoroughness of the work. There are very few researchers in the world whose depth and breadth of Engineering Mechanics equals that of Dr. Batra.* Dr. Batra’s research group is the *first one* to analyze material failure at high strain rates by refining the finite element mesh adaptively. This work has numerous applications in both defense and civilian industries as it is relevant to the design of structures exposed to blast loads. *Engineers are using some of his work to design military and civilian components.* **Jacob Fish, The Rosalind and John J. Redfern Chair in Engineering, Jr. '33 Chaired Professor, RPI, Troy, NY.**

Over these many years, Romesh has distinguished himself not only with the quality of his research, but also with the way he has professionally related to other researchers and to technical societies. He is one of the few individuals that I consider to be “socially very intelligent.” His efforts in integrating over disciplines and over societies, through conferences and symposia that he has spearheaded, have cultivated much new interactive research with an obvious immensely positive reflection on his institution.” **Sia Nemat-Nasser, University Distinguished Professor, University of California – San Diego.**