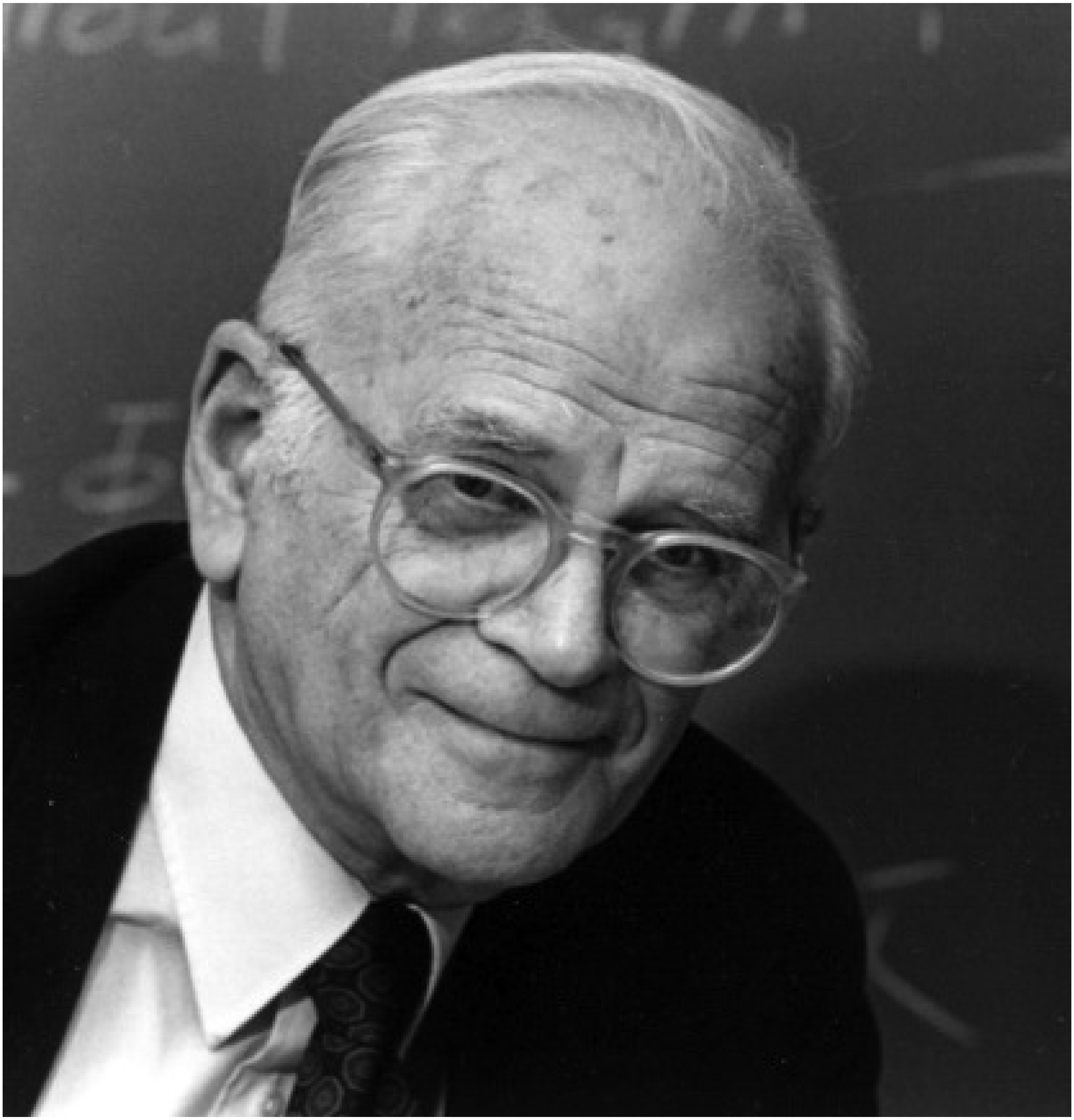

**Professor Bernard Budiansky (1925 – 1999)**

On this and the next page: A Biographical Memoir by Professor James R. Rice, et al, written in 2000

**Memorial Minute on the life and services of the late Professor Bernard Budiansky,** ***Gordon McKay Professor of Structural Mechanics, Emeritus,*** **and** ***Abbott and James Lawrence Professor of Engineering, Emeritus***

Bernard Budiansky was an unabashed enthusiast about his profession, family, friends, and many other good things in life. He made innovative contributions to nearly every subfield of solid mechanics — the science of how materials and structures stretch, shake, buckle and break. His work as an applied mathematician and mechanical engineer strongly influenced structural engineering and materials technology, and even seismology and biomechanics. He died from cancer at 73 years on 23 January 1999.

Bernie was born in New York on 8 March 1925 to Russian immigrant parents who soon separated, and was raised by his mother and grandfather. He obtained a Bachelor of Civil Engineering degree from CCNY in 1944 when he was barely over 19, a remarkable fact which, characteristically, none of us ever recall his mentioning.

He was a child of the heroic era of large engineering structures, and his love of structural mechanics was to be lifelong. But while at CCNY he became equally enamored with mathematics and physics, and could not fail to be attracted by the then new challenges of aeronautical structural mechanics. Accordingly, he jumped at a first job offer as an aeronautical research scientist with a newly formed unit of the National Advisory Committee for Aeronautics (NACA, forerunner to NASA) at Langley, Virginia, concerned with high speed flight.

Although Bernie departed New York at a tender age, the imprint on him was indelible. His love for the city, its cultural references, its humorists (Henny Youngman, especially), and its lifestyle was to stay an integral part of him, along with an abiding pride in his generation at CCNY.

The NACA years began his rapid rise to eminence, with new understanding of the dynamics of elastic plates, shells and their combination in various thin-walled structures essential for aviation. His work there, and later at Harvard, addressed failures by buckling, especially the strong sensitivity to small initial imperfections, the mathematical foundations of elastic shell theory, and the vexing problem of flutter of airplane wings.

He took an educational leave from NACA to enroll in 1947 in the newly established graduate program in Applied Mathematics at Brown University; but he lingered no longer there than at CCNY, completing his Ph.D. in 1950. (Years later when Brown established a Graduate Citation to recognize distinguished graduate alumni, Bernie was the first recipient.)

Bernie returned to Langley in 1950 and, in 1952, was appointed Head of the Structural Mechanics Branch. That year was far more memorable because he married the charming, erudite, and mathematically trained Nancy Cromer, a South Carolinian who worked in the group assisting with computations at NACA. They made for an enduringly warm and wonderful couple, deeply interested in literature and the arts, in politics, travel and good food, and with Nancy being a cheerful participant in Bernie's love of horse races.

He came to Harvard in 1955 as a tenured Associate Professor in the Division of Engineering and Applied Physics (now DEAS). Bernie's renowned wit and clarity quickly established him as one of the finest teachers in the Division, even if his forcefulness and passionate expressions of opinion were found a bit intimidating by those who had not yet discovered the underlying warmth. The acerbic nature of his wit, and perhaps growing impatience, did loom larger in his later years. He remained as fulfilled as ever with his lectures to graduate students, who knew of him already as a legend, but expressed frustration that the undergraduates just didn't seem to be getting his jokes any more. We wondered who might tell him that perhaps they were too terrified to laugh!

Bernie dedicated himself to building the mechanics program at Harvard. He helped recruit his NACA colleague, the late J. Lyell Sanders, and had a major role in recruiting the current tenured members of the group. Bernie's area of solid and structural mechanics at Harvard has been influential on the world stage well out of proportion to its size. A distinguished academic, when learning of his death, referred to that area as "the house that Bernie built," and nothing could be closer to the mark. Indeed, Bernie's dedication and charm made the entire Harvard mechanics group an unusually cohesive group of faculty members.

In addition to his seminal work in structural engineering fundamentals, he also made widely cited contributions on the way that fissures and joints in rocks affect the propagation of seismic waves, which has become a standard basis for inferring rock properties in the Earth, and contributed to understanding stressing and deformation in the inflation of the human lung. His work of the last 20 years was focused on problems in the domain of materials science, explaining mechanical properties of solids in terms of microscopic mechanisms. Bernie referred to this important area as "Micromechanics". He was one of its pioneers, and contributed to explanation of the fracture of ductile metals and the toughening of normally brittle ceramics and composite materials.

Appropriately, Bernie was elected to the National Academies, of Science in 1973 and Engineering in 1976, and as a Foreign Member of the Royal Netherlands Academy. He won the highest scientific awards for achievement in mechanics, namely the Timoshenko Medal of the American Society of Mechanical Engineers (ASME) and the von Kármán Medal of the American Society of Civil Engineers, and won the ASME Medal recognizing "eminently distinguished engineering achievement". He received honorary doctor of science degrees from Northwestern and the Technion at Haifa. He served for many years on NASA advisory committees on aircraft structures and space technology, including during the time of the Apollo moon landing.

Bernie was a wonderful and valued colleague and friend, funny, acerbic and kind, a great original whose likes we can hardly expect to see again. He delighted in sharing his enthusiasm for current literature, good food and other pleasures with graciousness and charm. Intellectually, and as a scientist, he was still in his prime when fate took him at 73. He is survived by Nancy and their children Michael and Stephen.

Frederick H. Abernathy
Henry Ehrenreich
John W. Hutchinson
Richard J. O'Connell
James R. Rice (chair)

24 October 2000

# 1999:

# PROFESSOR EMERITUS BERNARD BUDIANSKY

Bernard Budiansky, 73, died January 23, 1999 at his home in Lexington, MA. Dr. Budiansky was born in New York City and received his B.C.E. in 1944 from City College of New York. He joined the Structures Research Division at Langley, quickly becoming one of the preeminent researchers in that group. He earned his doctorate in applied mathematics from Brown University in 1950. He was head of the structural mechanics branch from 1952 to 1955, when he left to join the faculty of Harvard University. He was the Gordon McKay Professor of Structural Mechanics, Emeritus and the Abbot and James Lawrence Professor of Engineering, Emeritus in the Division of Engineering and Applied Sciences, Harvard University.

Budiansky was a theoretician in the fields of solid and structural mechanics. He published research papers on a wide variety of subjects including buckling and post-buckling behavior, elasticity, plasticity, fracture mechanics, biomechanics, and aeroelasticity. In recent years his work focused on mechanical behavior of composite materials, especially compressive kinking of fiber-composites, and the tensile strength and toughness of ceramic-matrix composites reinforced by ductile particles, transforming particles, and fibers. (He even worked on certain geophysical problems--the mechanics of rocks--in connections with the development of earthquake prediction models.)

He continued to serve as an adviser to NASA. From 1966-1970 he was a member of NASA's research and technology advisory subcommittee on aircraft structures and from 1974-1984 as a member of NASA's space systems and technology advisory subcommittee. He has also served on boards for the National Research Council; the DARPA Materials Research Council; and the U.S. National Committee on theoretical and applied mechanics.

Budiansky has won many honors including the AIAA 1970 Dryden Research Lecturer; CCNY 1974 Townsend Harris Medal; ASCE 1982 von Karman Medal; Society of Engineering Science 1985 Eringen Medal; ASME 1989 Timoshenko Medal. He has received honorary doctorates from Northwestern University 1986 and Technion Israel Institute of Technology. In addition he was a member of the National Academy of Sciences, the National Academy of Engineering, the American Academy of Arts and Sciences; the Royal Netherlands Academy of Arts and Science; and the Danish Center for Applied Mathematics and Mechanics. Professional affiliations included: ASCE, ASME, AIAA, and AGU.

Budiansky made a lengthy tribute to his mentors at Langley in his Acceptance Speech for the 1989 Timoshenko medal:

“To conclude these reflections, I would like to flip quickly through some verbal snapshots of a few of the people who have enriched my professional life. I had a remarkable trio of bosses in my first job in the Structures Research Division of NACA in 1944: Pai-Chuan Hu, a fresh Ph.D. in Engineering Mechanics from the University of Michigan, whose knowledge and intellect were awesome; Sam Batdorf, a renegade physicist, whose insightful way of thinking about problems in applied mechanics has been an enduring inspiration; and the big boss, the Chief of Structures Gene Lundquist, a great pioneer of structures research whose legacy as a research leader has been enduring. It was an exciting time at NACA, in those pre-space days of aeronautical research, and my experience there has left me fiercely supportive of scientific civil servants, who are at least as smart and hard-working as those in the private sector, but often are slandered by invidious comparisons. I was lucky to meet and even interact technically with some famous people at NACA outside my field of structures, like Ed Garrick, Carl Kaplan, and the great aerodynamicists Robert T. Jones and Adolph Busemann, who had independently conceived of swept wings for high-speed flight--Jones in America, Busemann in Germany. Jones told me how to calculate the lift on a swept wing, so that I could go on to study its aeroelasticity. Busemann got sufficiently interested in plasticity to join Lyell Sanders, John Hedgepeth and me in many happy hours of exploration of 6-dimensional stress space. Buseman had a marvelous, infectious technical vocabulary in English; an eavesdropper would have heard us earnestly discussing Humpty-Dumpties, meaning hyperspheres; stalactites, meaning hypervectors; and stalagmites, vectors pointing the other way!"

From *Reflections* by Bernard Budiansky, published in the *ASME Applied Mechanics Newsletter, Spring 1990*.

## 1989 ASME Timoshenko Medal Acceptance Speech by Bernard Budiansky

### Reflections

Many thanks for honoring me with the Timoshenko Medal. Forty-five years ago, fresh out of college with a bachelor's degree in civil engineering, I started my first job at Langley Field, Virginia, with the National Advisory Committee for Aeronautics, and my very first assignment was to learn about buckling of plates from Timoshenko's famous book on the theory of elastic stability. Timoshenko's extraordinary influence on research and education in applied mechanics all over the world, and his central role in this country, needs no reiteration. Like so many others, I was seduced by his book into a life-long infatuation with buckling problems, and so to receive this award bearing his name from my fellow applied mechanikers is very heart-warming, and I am very grateful.

On occasions like this, it is traditional for the speaker to grapple with cosmic issues of research, educations, scholarship and the like, even though he would feel much more comfortable giving a technical lecture. One distinguished colleague managed to rattle me thoroughly by saying – I think mischievously – that he looked forward to my "words of inspiration"; on the other hand, John Hutchinson simply suggested that I keep it short.

Not only will I follow John's advice, I will also avoid major matters of science and technology, because I neither have any profundities to peddle, not do I wish to contribute any new cliché's or buzzwords to these subjects. The present supply is quite adequate. I have to admit that I was really impressed the first time I heard the phrase "the cutting edge of technology" (even though the imagery did no quite match that of Tom Lehrer's immortal line about "sliding down the razor blade of life") but after several hundred repetitions, the effect has grown dull. Words and phrases invented inside the Beltway do spread like wildfire. One popular Washington proverb I can do without is: "If it ain't broke, don't fix it." This is a perfect prescription for the technological stagnation that is often deplored in the next breath. In the last few years, we have been deluged with "initiatives" – Strategic Defense Initiative (SDI), Universities Research Initiative (URI), Accelerated Research Initiative (ARI), and so on. My current favorite is the recently announced BNI – Bold New Initiative – which sounds exciting, but I have forgotten what it's for. Heavy phrases like technological innovation, manufacturing productivity, international competitiveness, and environmental disaster are on everybody's lips. I certainly do not wish to demean either the importance of the issues they represent, or the seriousness with which the problems are being confronted. However, I am sure you will be relieved to learn that these topics are beyond the scope of the present talk.

What I will do is reflect a bit about applied mechanics and applied mechanikers. At the same time, I will try to avoid excessive introspection, which I consider to be a dangerous practice that can lead to a morbid preoccupation with the meaning of life. Fortunately, it seems to me that most of us in applied mechanics do enjoy a fairly un-self-conscious approach to our work, relatively free of subjective inner contemplation. To varying degrees, we simply love to do research in our fields, we accept the frustrations, false starts, and dead ends that go with the territory, and do not make a habit of either melancholy self-doubt or manic self-adulation. And so, to those who assert that the unexamined life is not worth living, I say, speak for yourselves, and let me get back to work!

But if research in applied mechanics is such a happy enterprise, why are we occasionally afflicted with the Rodney Dangerfield syndrome, namely: “We don’t get any respect!”? We share a monumental intellectual legacy of knowledge and achievement, and our contributions to many branches of engineering and applied sciences are central, vital, and growing. And yet, the visibility and recognition of applied mechanics as a coherent discipline has been diminishing, not only in the eyes of the general public, where it has always been negligible, but within the scientific and technical establishments as well. Starting at the top, applied mechanics as a field of learning and research is surely terra incognita to the President of the United States, his cabinet, most members of Congress, the CEO’s of the Fortune 500, all but a handful of university presidents, and about a quarter of a billion other Americans, including even the Vice-President. University departments or division tagged with the applied mechanics name seem to be in a process of extinction. With some exceptions, governmental funding agencies tend not to assign the applied mechanics label to the research they support. Neither the National Academy of Engineering nor the National Academy of Sciences nor the American Association for the Advancement of Science contains a section in applied mechanics. I have yet to see the words “applied mechanics” in the science pages of any newspaper or newsmagazine, and I suspect that they have rarely, if ever, appeared in general science publications like Science or Nature or Scientific American. But we do exist! We are like members of a closely knit secret society, with clandestine cells in mechanical, civil, chemical, and aerospace engineering, in geophysics, in materials science, in biotechnology – but we’re quite ready and willing to have our cover blown!

There are two obvious reasons for this lack of visibility, one sublime and one ridiculous. Our very success in promulgating the role of applied mechanics within such a large number and variety of fields has led to the seamless integration of substantial parts of applied mechanics into the various fields I mentioned. This, of course, is very welcome. But as a natural consequence, subsequent research in such an incorporated segment of applied mechanics tends to assume the identity of its host. The absurd reason for our lack of status is that we still don’t know what to call ourselves! Can it be that this is the crux of the problem? We are not the only group whose activity cuts broadly across traditional disciplinary boundaries, but mathematicians, engineers, physicists, biologists, and computer scientists proudly retain their identities, no matter how scattered and diverse their working environments, and, of course, their titles provoke instant recognition. But what are we? In informal conversation, “applied mechaniker” is all right, but is clearly too whimsical and slang-ey for general acceptance. Some years ago, Norman Goodier urged the adoption of the appellation “applied mechanicist” but this never really took hold, and “applied mechanician” doesn’t seem to make it either.

Well, so what? Is this a true identity crisis, or just an annoying pinprick to our collective ego? After all, we do respond with acceptable answers when our neighbors ask us what we do for a living, or when we have to fill in the blanks labeled “occupation” on our income-tax forms or passport application. I suppose most of us say “engineers”, some say “mathematician”, others (like Irwin Corey) simply say “professor”, or “educator”, or “geophysicist”, or something else as respectable. The fact is, we all do have at least one profession we can honestly claim besides our beloved applied mechanics. I am reminded of Josephine Baker’s song “J’ai deux amours, mon pays et Paris”, but the analogy is not apt, because everybody’s heard of Paris! Furthermore, most of us certainly do not want to sever our professional allegiances to the traditional fields. The engineering profession, in particular, has its own serious problems that may be worthy of our attention. And since applied mechanics should be truly interdisciplinary, might not intellectual isolation and sterility be an unhappy consequence of the greater autonomy that would inevitably flow from increased visibility for applied mechanics? And therefore, shouldn’t we leave well-enough alone? Finally, we obviously do enjoy substantial communal ties. Here we are in the Applied Mechanics Division of the ASME, there is a parallel Engineering Mechanics Division of ASCE, we have a National Congress of Applied Mechanics and an International Congress every four years, and we have umpteen journals as outlets for our research publications. So why worry?

I have almost persuaded myself to adopt the Panglossian view that everything has happened for the best – but not quite. First, and maybe foremost, greater visibility would obviously attract more talented young people to applied mechanics, and I know that most of you share my belief that this is very much needed. Next, greater autonomy for groups in applied mechanics could enhance interfield communication, and spark the effective spread of applied mechanics into new areas. (The models for this are the spectacular rise of biomechanics in the last few decades, and the vigorous growth of mechanics in materials science and geophysics.) There’s more: applied mechanics and applied mathematics have gone hand in hand for a long time, with applied mechanics people taking major responsibility for university instruction in applied math. Weaken applied mechanics and you weaken applied mathematics, and this has been happening. In connection with applied math, let me say a word about computing; our applied mechanics community has led, and continues to lead, the exploitation of computers in scientific and technological research. As a long-time addict, I am enthusiastically pro-computer, and I never used to take very seriously the gloomy prediction of some of my uncontaminated colleagues, who deplored the inanities of massive, mindless computations as substitutes for elegant classical analysis, and foresaw the loss of analytical skills that would be induced by excessive reliance on computers. But now I believe that the balance has finally tipped, that applied mathematics in the classical sense, needs rescuing and that strengthening applied mechanics may be the best way to do it. Finally, we need the extra power and freedom that would flow from greater visibility and prestige in order to secure the right to do what I would call pure applied mechanics. Such research is intended to nourish the heart and soul of applied mechanics, and is not particularly meant to be “useful” in any prosaic sense. Its virtues – something funding agencies would, of course, have to judge – would be measured on the basis of depth, beauty, and truth, the same graces that characterize and justify good pure mathematics. Incidentally, I have no patience with the widespread myth that pure math, done without applications in mind inevitably turns out to be “useful”; sometimes it does, but more often, it doesn’t. However, the phony promise of ultimate utility is not necessary to justify support of pure math, and I demand equal treatment for a certain amount of pure applied mechanics!

So if we agree that we should burst the bonds of anonymity, perhaps we should begin by coming to grips with the question of our job description. I could live with either “applied mechanicist” or “applied mechanician”. Why not boldly start using one or the other at every opportunity, and let the better one survive! Then – let’s lobby scientific and technical societies, honorary or otherwise, that have not yet seen the light, to establish applied mechanics divisions! In universities, reverse the slide into oblivion and recommend that establishment of applied mechanics committees across standard departmental lines, maybe empowered to grant degrees as well as give courses! Preach to funding agencies about the merits of interdisciplinary sections of applied mechanics! Give interview, or write popular articles, about applied mechanics and its practitioners! Run for Congress!

Well, enough agitation, which does not fall within my area of expertise, anyhow. To conclude these reflections, I would like to flip quickly though some verbal snapshots of a few of the people who have enriched my professional life. I had a remarkable trio of bosses in my first job at the Structures Research Division of NACA in 1944; Pai-Chuan Hu, a fresh Ph.D. in Engineering Mechanics from the University of Michigan, whose knowledge and intellect were awesome; Sam Batdorf, a renegade physicist, whose insightful way of thinking about problems in applied mechanics has been an enduring inspiration; and the big boss, the Chief of Structures Gene Lundquist, a great pioneer of structures research, whose legacy as a research leader has been enduring. It was an exciting time at NACA, in those pre-space days of aeronautical research, and my experience there has left me fiercely supportive of scientific civil servants, who are at least as smart and hard-working as those in the private sector, but often are slandered by invidious comparisons. I was lucky to meet and even interact with some famous people at NACA outside my field of structures, like Ed Garrick, Carl Kaplan, and the great aerodynamicists Robert T. Jones and Adolph Busemann, who had independently conceived of swept wings for high-speed flight – Jones in America, Busemann in Germany. Jones told me how to calculate the lift on a swept wing, so that I could go on to study its aeroelasticity. Busemann got sufficiently interested in plasticity to join Lyell Sanders, John Hedgepeth and me in many happy hours of exploration of 6-dimensional stress space. Busemann had a marvelous, infectious technical vocabulary in English; an eavesdropper would have heard us earnestly discussing Humpty-Dumpties, meaning hyperspheres; stalactites, meaning hypervectors; and stalagmites, vectors pointing the other way! When I went to Brown University for graduate study in applied math, what an extraordinary group of professors I had: Prager, Drucker, Carrier, Lee, Handelman, Greenberg, Diaz – all of whom taught me much more than simply the material in their courses. During those early post-war years, Brown attracted a fantastic international brigade of graduate students: among my special buddies were Frithiof Niordsen, Carl Pearson, Jean Kestens, Pei-ping Chen, and Hirsch Cohen – respectively, from Stockholm, Vancouver, Brussels, Peking and Milwaukee. (As you see, I am name-dropping shamelessly.) It has become a cliché that one learns as much from fellow students in graduate school as from faculty – and was this ever true in my case! As I look back over my life in applied mechanics during the decades that followed, I realize that I always think first of people rather than problems. (If this be introspection, make the most of it.) I suppose I love applied mechanikers as well as applied mechanics, and I had better start rationing my sentimental recollections. But I particularly want to mention Eli Sternberg, sadly gone now, our pre-eminent elastician, whose extraordinary charm, wit, and intelligence brightened and blessed us all, and whose friendship I cherished for over forty years; and the incomparable Max Krook, astrophysicist, applied mathematician, and certainly applied mechaniker, who actually knew everything. I have been enormously influenced, instructed and encouraged by Warner Koiter, the sage of Delft; and now, for over a decade, by Tony Evans, the ceramics guru of the western world. A little more introspection, despite by vow: there are many styles of research, none intrinsically superior, but I have to be able to exchange ideas freely, and talk things out, face-to-face with others. Recently, I was stopped by a camera crew doing snap interviews on campus, and was asked what I liked best about Harvard. Without any chance to reflect, I popped out the answer: colleagues. And so it is, even after reflection. How very fortunate I have been to enjoy the company of such a splendid group of kindred spirits in applied mechanics. I owe them more than they would be willing to believe, and here’s who they are: George Carrier and Howard Emmons, recently inducted into the ranks of the emeritus professors; and the remaining hardy band of applied mechanikers Fred Abernathy, John Hutchinson, Dick Kronauer, Tom McMahon, Jim Rice, Lyell Sanders, and Howard Stone. We will do our best to keep and promulgate the faith, and I hope you will too! Thank you.