Neal Lane

Malcolm Gillis University Professor
Professor of Physics and Astronomy, Rice University
Senior Fellow, Rice University's Baker Institute for Public Policy

Statement to
The Senate Committee on Commerce, Science and Transportation

On behalf of

The American Academy of Arts & Sciences Committee on

New Models for U.S. Science and Technology Policy

Hearing on

The Federal Research Portfolio: Capitalizing on Investments in R&D

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Chairman Rockefeller, Ranking Member Thune, and Members of the Committee: I am honored to be invited here today to discuss the federal government's investments in research. I am the Malcolm Gillis University Professor and Professor of Physics and Astronomy at Rice University, and also hold an appointment as the Senior Fellow in Science and Technology Policy at Rice University's Baker Institute for Public Policy. Prior to returning to Rice University, I served in the Federal government during the Clinton Administration as Assistant to the President for Science and Technology and Director of the White House Office of Science and Technology Policy, from August 1998 to January 2001, and as Director of the National Science Foundation (NSF) and member (*ex officio*) of the National Science Board, from October 1993 to August 1998.

I am also honored to be a Fellow of the American Academy of Arts and Sciences and to appear on its behalf today. Founded in 1780 by John Adams and other scholar-patriots to encourage dialogue among leaders of science, the arts, business and public affairs, the American Academy of Arts & Sciences is an independent policy research institute that engaged in the study of complex problems vital to our nation's future. Through its projects and studies, and publications like its recent *ARISE I* and *ARISE II* (*Advancing Research in Science and Engineering*) reports, the Academy pursues practical policy responses to pressing national and global problems.

I am particularly honored to co-chair, with Norman R. Augustine, retired CEO and chairman of Lockheed Martin Corporation, the American Academy's Committee on New Models for U.S. Science and Technology. This group has been working over the past year to develop recommendations of policy actions that we believe will help ensure the long-term sustainability of the U.S. science and engineering research enterprise. While my testimony today generally reflects the group's conclusions, I should state at the outset that my remarks represent my own views and not necessarily those of the study group, the American Academy, or Rice University.

The Role of Research in Sustaining Economic Prosperity

In a 1988 radio address to the nation, President Ronald Reagan said that "although basic research does not begin with a particular practical goal, when you look at the results over the years, it ends up being one of the most practical things government does… Major industries, including television, communications, and computer industries, couldn't be where they are today without developments that began with this basic research." Many presidents – Democrats and Republicans – have emphasized the importance of science, engineering and technology to the nation's leadership in the world, the strength of its economy, and the welfare and prosperity of its people. And I want to emphasize that research, in this context, refers to all fields – the physical and life sciences (including medical research, mathematics, computer science, and engineering) and the social and behavioral sciences.

As President Reagan and other presidents have realized, virtually every new technology is traceable to a research discovery or series of discoveries, often made by individuals having no idea of how their research might help create jobs and benefit millions of people in other ways years or even decades in the future. To expect continued technological advancement, a strong economy, job growth and other public benefits without investing in research is akin to operating an automobile factory without a receiving dock for raw materials.

In short, new knowledge and technologies, which are the products of research, are the lifeblood of today's accelerating high-tech, knowledge-based economy. If the U.S. is to remain a leader in this new economy, it will have to ensure that it has a skilled workforce particularly in STEM (science, technology, engineering and mathematics) areas, and a robust science and engineering research enterprise that matches the challenge. It should be clear that both education and science and engineering research play a critical role in the economic and personal wellbeing of Americans in this "Land of Opportunity."

This is what we used to call the "American Dream." The American Dream is a national ethos whose foundation is rooted in opportunity: the opportunity for a quality job and career, a quality life, a quality education, and the opportunity for our children to achieve more and have a better life. It imbues the nation with a spirit of hard-work and determination - if you study hard, work hard and play by the rules, you can have a good life. Late last year, we lost to cancer a great American and champion of science, engineering and education, Charles (Chuck) Vest, who grew up in West Virginia and became President of MIT and, more recently, served as President of the National Academy of Engineering. Chuck often spoke about having lived the American Dream. Growing up in the oil fields of Oklahoma, I have also lived the American Dream, and so did many of my generation. But we don't hear much about it anymore. America's expectations – and the hopes and dreams of Americans - seem less ambitious today, and that should scare us. Without opportunity, the American Dream fades, and with it a key part of our identity as a nation.

Ensuring opportunity for all Americans will require significant improvements in education and learning, especially in STEM areas, as well as a strong economy. With regard to economy, research has demonstrated a strong correlation between job growth and Gross Domestic Product (GDP) – creating jobs on a large scale requires growing the nation's GDP. Numerous studies, including Robert Solow's Nobel Prize-winning research, have shown that the predominant driver of GDP growth over the past half-century has been scientific and technological advancement. It seems likely, given the current accelerating pace of progress in science, engineering and technology, that this observation will continue to hold for the decades ahead.

Yet too often the role of research, particularly basic research, in the nation's scientific and technological advancement has been undervalued. Hunter Rawlings, the president of the American Association of Universities, has observed that the fundamental technologies that underlie today's remarkable consumer electronics, including GPS, multi-touch screens, LCD displays, lithium-ion batteries, and cellular networks, were all derived from research supported by the federal government and conducted in universities and government laboratories. Of course, America has led in these areas because it has a diversity of companies – large and small – which have been willing to take risks, try new innovative practices, invest in their own R&D needs, and take chances on new technologies. America also has an investment community willing to help fund these efforts and regulations to insure fair competition in the marketplace. But basic research, much of which is government-funded, is necessary to cultivate an ecosystem rich enough in new knowledge and ideas to enable these breakthrough achievements.

The power of America's economic system and the role its universities, industry and government have played in its effectiveness have not gone unnoticed by other countries competing in the global job market. In fact, they seek not only to copy it but to improve upon it. The influential National Academies' report *Rising Above the Gathering Storm* and its updates[1, 2] make the case that instead of racing to meet the challenge, America instead is permitting this highly successful system of discovery and innovation, that has served this nation well since the end of WWII, to atrophy. This is not a formula for success in a highly competitive world that is advancing at an accelerating rate.

The Role of the Federal Government

If science, engineering and technology are key drivers of economic growth, as the evidence strongly indicates, one metric of the adequacy of a nation's commitment to the future of its citizens is its total investment in R&D as a fraction of GDP, relative to competitor nations. The total U.S. investment (1/3 public and 2/3 private[3]) in R&D continues to fall short of the national goal adopted by several U.S. presidents of 3% of GDP, even as America's economic competitors move aggressively to increase their own investments. The U.S. has fallen to 10th place among OECD countries (Figure 1). For

[1] National Academy of Sciences, National Academy of Engineering, and Institute of Medicine. *Rising Above the Gathering Storm: Energizing and Employing America for a Brighter Economic Future*. (Washington, DC: The National Academies Press, 2007).

[2] National Academy of Sciences, National Academy of Engineering, and Institute of Medicine. *Rising Above the Gathering Storm, Revisited: Rapidly Approaching Category 5*. (Washington, DC: The National Academies Press, 2010).

[3] Although industry funds 2/3 of total U.S. R&D, it is worth noting that the vast majority of this funding (95%) is devoted to applied research and development. Over half of all basic research is funded by the federal government (55% of total national basic research funding).

example, China's R&D investment is growing at an average annual rate of 8% above inflation, and is on a path to overtake the U.S. in just 8 years. America is failing to make the R&D investments that are necessary to remain a global leader in industry and commerce.

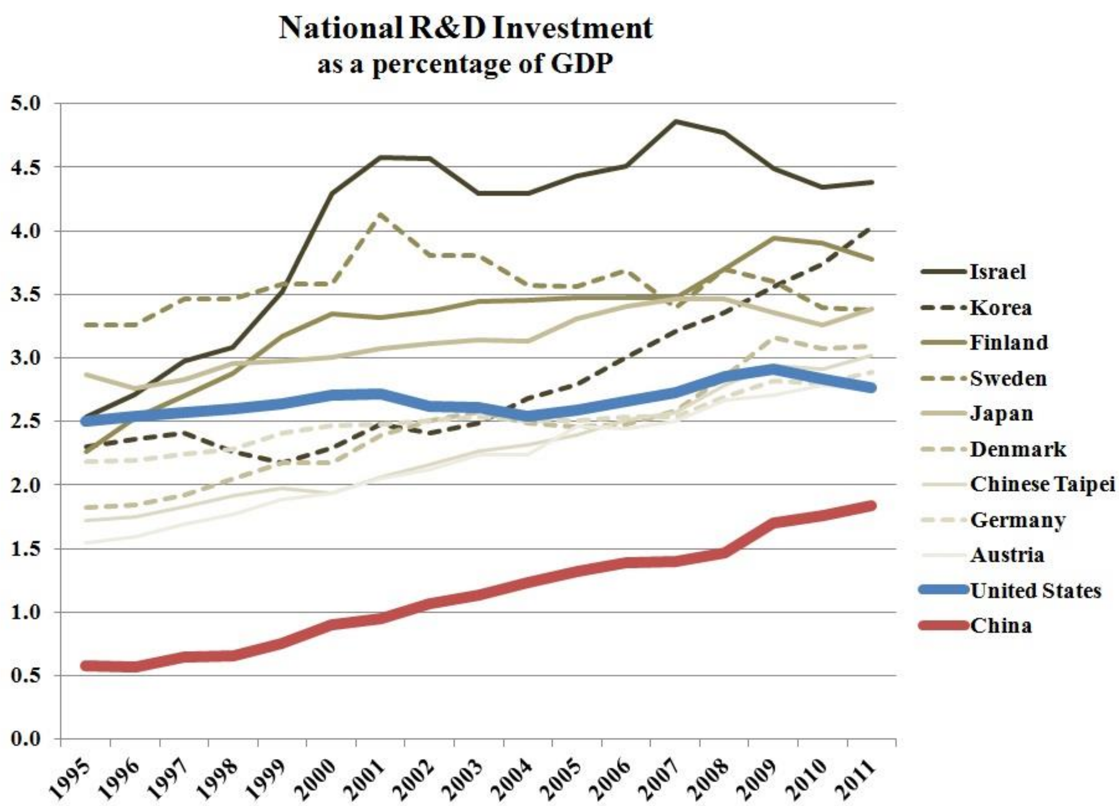

Figure 1. The U.S. is failing to keep pace with competitors' investments in R&D. Among OECD nations, the U.S. ranks 10th in national R&D investment as a percentage of GDP, or R&D intensity. As China's R&D intensity (red line) rapidly grows at an average of 8% per year in pursuit of the globally-recognized 3% GDP goal, U.S. investments (blue line) have pulled back. At this pace, China will surpass the U.S. by this measure in about eight years.
Data Source: OECD, Main Science and Technology Indicators, 2013, Gross Domestic Expenditures on R&D as a percentage of GDP. Available at: http://stats.oecd.org/.

These disturbing trends have created a gap between what America *is* investing and what it *should be* investing to reclaim our global competitiveness and ensure a strong future economy. This has been described as running an "innovation deficit"[4]

To be sure, most of America's innovation and high-quality jobs are created in private industry. But companies depend on a continuous stream of new scientific discoveries and early-stage technologies that flow from the federal government's investments in research, particularly basic research, carried out at research universities and national laboratories. Companies working closely with academic and government researchers benefit most from timely translation of research results into marketable applications and from early access to talented scientists and engineers trained largely at American universities.

Some may ask why America shouldn't just let other nations pay for the research and then simply apply the resulting discoveries to grow markets and create jobs within our own borders. That approach may have worked for other nations in the past, but it is not a winning strategy for the future. Given the pace at which technological innovation is accelerating today, being second to market is now considered by many executives to be tantamount to failure. Craig Barrett, the retired CEO of Intel, has noted that 90 percent of the revenues that firm receives at the end of its fiscal year are derived from products that did not even exist at the beginning of that year.[5] Such a system would not work without a rich base of knowledge and discoveries and strong links to industry.

Some have expressed the hope that the decline in the federal investment in research could be compensated by increased investments in other sectors. This hope is almost certainly in vain: companies are increasingly concentrated on applied research and development, arguing that they cannot justify spending money on basic research which could benefit other companies, public research universities are in no position to substantially increase research investments due to declining state support; and philanthropic organizations and individuals, while an important and growing source of support for American science, still

[4] See http://www.innovationdeficit.org/.
[5] N.R. Augustine, *Is America Falling Off the Flat Earth?* (Washington, DC: The National Academies Press, 2007).

contribute a small portion of the national research investment. Foundations spend about $2 billion annually on basic research.[6] While this is a substantial contribution, it represents less than 3% of total national spending on basic research.[7]

This leaves the federal government as the primary supporter of fundamental research for the foreseeable future. Thus, the recent decline in the federal investment in basic research has left the U.S. in danger of being overtaken by other nations that are rapidly advancing in science, engineering and technology.

Two goals must be met in order to reverse this trend. First, we must ensure that the American people receive maximum benefits from federal investments in research, in part by strengthening partnerships across governments, universities, and industry and business. Second, we must develop a sustainable approach to research funding.

These two goals have guided the work of the American Academy committee that I have the privilege to co-chair with Norman R. Augustine. I will briefly discuss what our 23 eminent colleagues, who include Nobel laureates, corporate executives, university presidents and deans, and other leaders in science and engineering,[8] have determined must be done in the near future to achieve these goals.

Ensuring that the American People Receive Maximum Benefits from Federal Investments in Research

As I have argued earlier, federal research investments are vital to America's leadership in SE&T. But many current policies and practices in government, industry and universities hinder the most effective use of those investments. Given the accelerating pace of technological advancement in many parts of the world, particularly in Asia, a rapid response is needed. Policy changes in all sectors are necessary to accelerate the discovery of new knowledge and the translation of new insights and tools into technological

[6] Based upon estimates from the Foundation Center: "Distribution of Foundation Grants by Subject Categories, circa 2011" in the categories of "Medical Research" and "Science and Technology". See http://foundationcenter.org/findfunders/statistics/pdf/04_fund_sub/2011/10_11.pdf.
[7] Fiona Murray, "Evaluating the Role of Science Philanthropy in American Research Universities," *Innovation Policy and the Economy*, 13 (2013):1-40.
[8] www.amacad.org/newmodels

innovation to ensure that the American people enjoy the benefits of their investment in research.

First, we must streamline those regulations and practices governing federally-funded research that add to universities' administrative overhead while yielding questionable benefits. No more cost-effective step could be taken to increase the productivity of America's researchers, particularly those based at universities. Unquestionably, the federal government has an obligation to ensure that the money it provides to universities to support research on their campuses is used for the intended purposes and that research practices are held to high standards of performance – thus, regulations and administrative policies are necessary. However, many regulations and business practices are ineffective, vary from agency to agency across the federal government, and constitute unnecessary and costly burdens to researchers and their institutions that have the unintended consequences of reducing research productivity and forcing the institutions to use their own funds to cover the portion of research administrative costs not funded by the agencies. The full set of relevant regulations and practices should be examined with the objective of maximizing the effectiveness of the federal research investment.[9]

Second, all parties must work together to uphold America's unparalleled system of expert peer review. Competitive expert peer review is the best way to assure excellence. Hence, peer review should remain the mechanism used by federal agencies to make research award decisions, and review processes and criteria should be left to the discretion of the agencies themselves. In the case of basic research, scientific merit, based on the opinions of experts in the field, should remain the primary consideration for awarding support. This system has been used, successfully, for well over half a century. No better system has been devised, particularly for basic research where the likely outcome cannot be predicted.

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[9] See, for example, the March 2014 National Science Board report, *Reducing Investigators' Administrative Workload for Federally Funded Research*.

Third, the public benefits of federal research investments can be more readily realized by establishing a more robust national government-university-industry research partnership. Other countries recognize this need and are taking active steps to put such national research partnerships in place. Yet in the U.S., the accumulation of decades of policies and practices in each sector, as well as shifting priorities of the states and unpredictable federal research funding levels, are allowing our nation to slip steadily behind.

The Bayh-Dole Act (Patent and Trademark Law Amendment Act), signed into law in 1980, allows universities, small businesses and not-for-profit organizations to pursue ownership of an invention arising from federally funded research, subject to a number of conditions. This landmark legislation has been highly effective in getting IP into the hands of companies that can develop products from the technology and move them to market, and has enabled a small number of universities to derive substantial income from licensing. However, the majority of universities have found that the cost of maintaining a technology transfer office, filing for patents, and negotiating IP licensing exceeds the income generated from licensing. Licensing negotiations with companies can also pose a high barrier to collaboration, often delaying or preventing the transfer of technologies to a company and, potentially, a market. These realities have spurred many universities to reconsider the value of IP ownership. Some universities are experimenting with new policies to enhance the transfer of IP to the market and are implementing novel technology transfer practices in line with this policy. More universities should pioneer such experiments, the outcomes of which should be evaluated to derive best practices. And as universities choose to adopt more flexible approaches to handling IP, companies should explore forming stronger research partnerships with universities for mutual benefit.

University and corporate leadership and cooperation will be the key to advancing these reforms; and the professional science and engineering societies will continue to play an important role by keeping their members informed about best practices. The federal government should encourage universities to explore steps in this direction, including experimenting with innovative models for technology transfer, enhancing early exposure of students (including doctoral students) to a broad range of non-research career options, and increasing the interactions of university researchers with industry.

The result can be a richer, more innovative research environment that benefits all participants. The opportunity for strengthening the university-industry partnership has never been better.

Making the R&E (Research and Experimentation) tax credit permanent, as recommended by the National Academies, the American Academy, the Business Roundtable, the President's Council of Advisors on Science and Technology (PCAST), and many others, would provide an incentive for industry to invest in long-term research, including collaborative research with universities. Not doing so significantly reduces the potential benefits that federally supported academic research can provide to American taxpayers. That fact should override any arguments for the status quo.

Another recommendation that has been made by many other organizations, including PCAST[10] and the National Academies,[11,12] is to increase the number of H-1B visas and reshape policies affecting foreign-born researchers. Graduate students from around the globe seek an advanced education at American research universities, not only for the quality of training they receive but to advance their careers. For these reasons and others, most of these talented international students and researchers would stay in the U.S. if given the opportunity. However, international competition for talented scientists and engineers has grown fierce. If we fail to both attract and retain the best and brightest scientists and engineers, we risk not only steering American entrepreneurs overseas in their search for highly skilled workers, but further exacerbating the current shortage of educated workers that fuel American R&D and high-tech manufacturing sectors.

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[10] President's Council of Advisors on Science and Technology, *Transformation and Opportunity: The Future of the U.S. Research Enterprise*, 2012.

[11] National Academy of Sciences, National Academy of Engineering, and Institute of Medicine. *Rising Above the Gathering Storm: Energizing and Employing America for a Brighter Economic Future*. (Washington, DC: The National Academies Press, 2007).

[12] National Research Council. *Research Universities and the Future of America: Ten Breakthrough Actions Vital to Our Nation's Prosperity and Security*. (Washington, DC: The National Academies Press, 2012).

Securing America's Leadership in Science and Engineering Research - Especially Basic Research - by Providing Sustainable Federal Investments

Reestablishing America's competitiveness as a nation will require that federally funded research, particularly basic research, become a higher priority than has been the case in over two decades. In emphasizing basic research, I am not suggesting that the federal role in supporting applied research and development are unimportant – such activities support the missions of many federal agencies. But basic research is often where the breakthroughs occur that change paradigms and revolutionize technologies. The research efforts that led to the invention of the transistor and laser were not the result of trying to design a better vacuum tube or light bulb.

During the 18 years from 1975 to 1992, the federal investment in basic research grew at an average annual inflation-adjusted rate of over 4%, despite serious challenges including the 1973 oil embargo, the Great Inflation of 1979–1982, and the final tumultuous years of the Cold War. Leaders in both parties, in the White House and Congress, were able to agree that investments in research should be a particularly high priority for federal support. In recent years, however, the nation's research funding has stagnated. As a function of U.S. economic output, federal support for basic research is actually *lower* than it was twenty years ago.

While I recognize the difficulty of significantly growing federal research funding in a period of fiscal constraint, it would be difficult to overstate the urgency of once again putting research funding on a sustainable growth path. Investments in basic research are just that: *investments*. America's economic ascendency in the 20th century was due in large part – perhaps even primarily – to its investments in science and engineering research. Basic research lies behind every new product brought to market, every new medical device or drug, every new defense and space technology, and many innovative business practices. Given the accelerating pace of technological advancement in many parts of the world, particularly in Asia, it follows that the U.S. must accelerate both discovery of new scientific knowledge and translation of that knowledge to useful purpose.

Simply put, if the U.S. is to remain a leader in providing these benefits, the federal government must make the necessary investments. Failure to act now may put us in a position from which we cannot recover, given the fast pace of global scientific advancement.

Conclusion

The American Academy report, to be released in early fall, will outline a series of specific actions that could be taken immediately to achieve the goals I have described. I look forward to sharing our ideas with this Committee. Real progress will depend on the extent to which the public and private sectors can cooperate effectively in support of a coherent national roadmap to strengthen the U.S. research enterprise, and to drive American innovation throughout the 21st century. As the President observed in this year's State of the Union address, "We know that the nation that goes all-in on innovation today will own the global economy tomorrow. This is an edge America cannot surrender."

I look forward to your questions. Thank you again for the invitation to appear today.

Biography

Neal F. Lane

Malcolm Gillis University Professor
Senior Fellow, Rice University's Baker Institute for Public Policy
Department of Physics and Astronomy
Rice University
http://www.ruf.rice.edu/~neal/index.htm
http://www.bakerinstitute.org/personnel/fellows-scholars/nlane
(Email: neal@rice.edu)

Dr. Neal Lane is the Malcolm Gillis University Professor and Professor of Physics and Astronomy at Rice University in Houston, Texas. He also holds an appointment as Senior Fellow in Science and Technology Policy at Rice University's Baker Institute for Public Policy.

Prior to returning to Rice University, Dr. Lane served in the Federal government during the Clinton Administration as Assistant to the President for Science and Technology and Director of the White House Office of Science and Technology Policy, from August 1998 to January 2001, and as Director of the National Science Foundation (NSF) and member (ex officio) of the National Science Board, from October 1993 to August 1998.

Before becoming the NSF Director, Dr. Lane was Provost and Professor of Physics at Rice University in Houston, Texas, a position he had held since 1986. He first came to Rice in 1966, when he joined the Department of Physics as an assistant professor. In 1972, he became Professor of Physics and Space Physics and Astronomy. He left Rice from mid-1984 to 1986 to serve as Chancellor of the University of Colorado at Colorado Springs. In addition, from 1979 to 1980, while on leave from Rice, he worked at the NSF as Director of the Division of Physics.

Widely regarded as a distinguished scientist and educator, Dr. Lane's many writings and presentations include topics in theoretical atomic and molecular physics and science and technology policy. Early in his career he received the W. Alton Jones Graduate Fellowship and held an NSF Doctoral Fellowship (University of Oklahoma), an NSF Post-Doctoral Fellowship (while in residence at Queen's University, Belfast, Northern Ireland) and an Alfred P. Sloan Foundation Fellowship (at Rice University and on research leave at Oxford University). He earned Phi Beta Kappa honors in 1960 and was inducted into Sigma Xi National Research Society in 1964, serving as its national president in 1993. He served as Visiting Fellow at the Joint Institute for Laboratory Astrophysics in 1965-66 and 1975-76. While a Professor at Rice, he was two-time recipient of the University's George R. Brown Prize for Superior Teaching.

Through his work with scientific and professional organizations and his participation on review and advisory committees for Federal and state agencies, Dr. Lane has contributed to public service throughout his career. He is a fellow of the American Physical Society, the

American Academy of Arts and Sciences (member of its governing council), the American Association for Advancement of Science, and the Association for Women in Science. He serves on several boards and advisory committees.

Dr. Lane has received numerous prizes, awards, including the AAAS Philip Hauge Abelson Award, AAAS William D. Carey Award, American Society of Mechanical Engineers President's Award, American Chemical Society Public Service Award, American Astronomical Society /American Mathematical Society/American Physical Society Public Service Award, NASA Distinguished Service Award, Council of Science Societies Presidents Support of Science Award, Distinguished Alumni Award of the University of Oklahoma, and over a dozen honorary degrees. In 2009, Dr. Lane received the National Academy of Sciences Public Welfare Medal, the American Institute of Physics K.T. Compton Medal for Leadership in Physics, and the Association of Rice Alumni Gold Medal for service to Rice University

Born in Oklahoma City in 1938, Dr. Lane earned his B.S., M.S., and Ph.D. (1964) degrees in physics from the University of Oklahoma. His thesis advisor was Chun C. Lin (now at the University of Wisconsin – Madison). He is married to Joni Sue (Williams) Lane and has two children, Christy Saydjari and John Lane, and four grandchildren, Allia and Alex Saydjari, and Matthew and Jessica Lane.