JOURNAL OF AIRCRAFT
Vol. 38, No. 1, January–February 2001

Aircraft Technology Investment: The Affordability Problem

AIRCRAFT technology investment serves the U.S. well; with this no one should disagree. Prior (past 20 years or more) investments in aircraft technology, such as in stealth, night vision, and precision munitions, have contributed substantially to today's U.S. military superiority. Just as military air vehicles are essential to this country's national security, both military and civil air vehicles remain critical to the economic security of the United States. Beginning with a top-level perspective, total U.S. transportation contributes 11% of America's Gross Domestic Product (GDP). That translated to $777 billion of a $7.25 trillion GDP in 1995. According to the Aerospace Industries Association Indicator, combined military and civilian industry annual aerospace sales in 1999 were approximately $157 billion, and, including airlines, this industry provided over 800,000 high-quality jobs. Civil and military exports accounted for over $60 billion in positive trade balance, this country's largest for manufactured products. The projected demand for global air travel is anticipated to grow at an average rate of 5% per year into the new century, creating a potential air transport market in excess of $800 billion over the next 20 years. This potentially lucrative market has attracted very significant competition from around the world. In spite of the sound rationale presented for the national aviation science and technology (S&T) investment, the budget projections are discouraging and have prompted an assessment by the National Research Council.

In 1999, NASA commissioned the Aeronautics and Space Engineering Board (ASEB) of the National Research Council (NRC) to conduct a four-month evaluation of the U.S. aeronautics program.* The intent of the study was to provide a timely review of national support of S&T in traditional aeronautics S&T. The assessment found symptoms of a serious national problem—that the aeronautics segment of the economy is becoming less competitive. Data presented in the assessment show that the U.S. share of world aerospace markets fell from nearly 70% in the mid-1980s to 55% in 1997. The absolute level of aeronautical sales has also dropped in the United States during the 1990s. Aviation is an S&T-intensive industry. Maintaining a successful, state-of-the-art aeronautics industry has required that a higher percentage of net sales be invested in S&T than other industries associated with rapid innovation and application of scientific advances. As alluded to above, although certain aeronautical advances are immediately useable, more often, aeronautics S&T advances are evolutionary, and a substantial number of years can pass before the aviation systems making use of these advances enter service. However, data are presented in the assessment showing that aeronautics R&D funded by U.S. industry dropped by almost 50% between 1988 and 1991, followed by reductions in sales and employment. Similar declining S&T funding trends are presented for NASA and DOD. With regard to economic factors, a recent market study summarized in the assessment projects a world-wide civil aircraft market of $810 billion from 1999 to 2008. The study showed that large civil transports account for over one-half of this market. The remainder is comprised of regional/corporate airplanes, military airplanes, and civil and military rotorcraft. In addition, $274 billion in gas turbine engine sales are projected over the same period, more than one-half for aviation uses, and the projected market for aircraft retrofitting and modernization is $20 billion. In total, the world market for aeronautics products is expected to exceed $1 trillion over the next 10 years, and most of it will be captured by companies (and countries) that have made and continue to make sizeable investments in aeronautics S&T.

Significant technological advances in key areas, especially in the area of affordability, will be needed to allow the U.S. aircraft industry to expand or even maintain its position in this highly competitive world market. As we head into the new millenium, it is not clear whether or not the nation really understands these fundamental arguments. If we are to continue to have military superiority and economic competitiveness 10–20 years down the road, then we must make the investment now in the required new technologies. However, from 1999 to 2000 overall DOD aeronautics-related science and technology investments dropped by 20%. Current five-year projections show little change from this reduced level. One substantial factor contributing to this trend is the growing cost of military readiness. Most military weapon systems are entering a second extremely costly life cycle. This draws resources from the modernization side of the equation and offers a paradox we can't afford to initiate technology programs to yield longer life for new affordable vehicles, and so we must continue to fly the old ones.

The aircraft technology community needs to respond quickly to these declining investment trends by offering solutions to the affordability problem. Unmanned systems, including unmanned combat systems, will no doubt lead the way to affordable aircraft as well as affordable air operations and support. Full exploitation of information technology, virtual prototyping, modeling and simulation, advanced metallic and composite materials, capturing the revolutions in nanotechnology and biotechnology, and fully integrated vehicle health management (including built-in nondestructive evaluation) are some of the emerging technology innovations. They offer to revolutionize the airplane and its components and support elements while yielding affordable solutions to the currently declining investments in U.S. aviation science and technology. Papers on any technical or economic aspect of the problem and/or solution to the aircraft affordability problem will be welcomed by this journal.

Turning now to some journal business, we welcome Ndaona (Nd) Chokani from the North Carolina State University as a new Associate Editor. He also serves ably on my Advisory Board. Nd handles papers on aerodynamics.

My staff of Associate Editors has experienced several occasions where non-U.S. authors needed some extra help with paper preparation, sometimes due to language difficulties. This is one of the reasons we have an International Board of Editors representing most of the countries with sustained contributions to this journal. These Board members are listed on the inside front cover. Please contact them with any questions regarding international publication.

Submittal of papers has been at a normal rate, and the ratio of papers declined for publication has remained at about 25%. I have initiated a Design Forum in the journal, based on Editorial Advisory Board member Dan Raymer's suggestion in January 2000. Design Forum papers, like Engineering Notes, will ordinarily not require review but can be as long as a full paper. Twelve such papers have been submitted so far in 2000.

I customarily complete my annual editorials with special recognition for all the folks, both volunteer and professional, who make this journal possible. Beginning with the volunteers, at the top of my most valuable supporters' list are the fine Associate Editors appearing as the "2000 Team." These people serve with high dedication to help you transform your manuscripts into archival papers.

I formed our Editorial Advisory Board in 1993 to help better link the journal to the appropriate AIAA Technical Comittees, (TCs). This Board is made up of members of several AIAA TCs, which I try to visit each year. They help represent journal publication at their TC meetings, as well as to encourage journal publication of good meetings papers. Some of these Board members serve as Publications Committee members on their respective TCs. Over the

*Available from Aeronautics and Space Engineering Board, HA 292, 2101 Constitution Avenue N. W., Washington, DC 20418, (202) 334-2855.

past several years, they have helped identify "Best Papers" from technical sessions, which are identified to me and placed on a fast track. My thanks to the members of the Editorial Advisory Board.

We publish the names of the past year's reviewers (through mid-October) in this issue. You will, of course, recognize many of these individuals. I thank them for providing the technical insight to assure that the published article is accurate, timely, important to the readers, and will have lasting value. Authors of declined papers are provided with good feedback on ways to improve future offerings. This journal would not exist without dedicated peer reviewers.

Turning to the professional staff, Norma Brennan is the AIAA Director of Publications. She ably directs all journal activity in AIAA, along with other publication activity. She always finds time to answer my questions and provide encouragement to me and the Associate Editors. Brian Haefs served very capably as Managing Editor over much of last year, but has moved on to newer things, and our new Managing Editor, Aimée Munyan, is also highly capable, efficient, and excellent to work with.

Thomas M. Weeks
Editor-in-Chief

Editor-in-Chief

THOMAS M. WEEKS completed his degree work at Syracuse University, Department of Mechanical and Aerospace Engineering, in 1965. He entered active commissioned service that year, assigned to the Air Force Flight Dynamics Laboratory (now the Air Vehicles Directorate of the Air Force Research Laboratory) at Wright–Patterson AFB, Ohio. His initial work was in the field of electrogasdynamics at the nearly completed 50 MW wind tunnel facility. In 1968, he separated from the Air Force but took a civil position at the same location. He worked on a variety of projects, including unsteady hypersonic heating, transonic test techniques, and sonic boom before becoming the Manager of the External Aerodynamics Group. He served first as the Deputy and then the Manager of the DARPA/NASA/USAF X-29 Advanced Technology Demonstrator. He served as Chief of the Wind Tunnels Branch and of the Technology Strategy Branch. He served as Acting Chief Scientist and Acting Deputy Director of the Directorate. He served as the Chief of the Integration and Operations Division. He retired from the Air Vehicles Directorate in August of 1998 and has taken a part time position as a Senior Scientist at the Ball Aerospace Technology Corporation in Fairborn, Ohio.

Associate Editors

NDAONA CHOKANI is a Professor of Aerospace Engineering at North Carolina State University. He received his BA (Honors) in engineering science from Oxford University in 1984 and Ph.D. in engineering from Cambridge University in 1988. Dr. Chokani joined the faulty at NC State University in 1988, where he has been actively involved in teaching and research. His graduate advising has resulted in 7 Ph.D. and 12 M.S. degrees. His current research interests include experimental aerodynamics, flow diagnostics, active flow control systems, transition of laminar-to-turbulent flows, and digital signal and time-series processing techniques. He is an Associate Fellow of the AIAA and serves on the Aerodynamic Measurement Technology Technical Committee.

INDERJIT CHOPRA is an Alfred Gessow Rotorcraft Professor in Aerospace Engineering and Director of the Alfred Gessow Rotorcraft Center at the University of Maryland. Also, he has been a Minta-Martin Research Professor since 1996. He received a B.Sc. in engineering from Punjab Engineering College, Chandigarh, India, in 1965, an M.E. from Indian Institute of Science, Bangalore, India, in 1968, and a Sc.D. from the Massachusetts Institute of Technology (MIT) in 1977. He worked at the National Aeronautical Laboratory in Bangalore from 1966 to 1974. His research there included aeroelastic analysis and wind-tunnel testing of scaled models of airplanes and launch vehicles. At MIT, he worked on dynamic analysis of wind turbines. In 1977, he joined NASA Ames/Stanford University Joint Institute of Aeronautics and Acoustics, where he worked for four and a half years on the development of aeroelastic analysis of advanced rotor systems and testing of full-scale helicopters in the NASA Ames 40×80-ft wind tunnel. In 1981, he joined the University of Maryland. He has been working on problems associated with aeromechanics of helicopter and smart structures, including aeromechanical stability, active vibration control, modeling of composite rotors, rotor head health monitoring, aeroelastic optimization, smart rotor development, and comprehensive analyses of bearingless, tilt-rotor, servo-flap, teetering and circulation control rotors. His graduate advising resulted in 29 Ph.D. and 55 M.S. degrees. An author of over 115 archival papers, Dr. Chopra has been an Associate Editor of the *Journal of the American Helicopter Society* (1987–91), and *Journal of Intelligent Materials and Systems* (1977–cont.). Also, he has been a member of the editorial advisory board of three journals, *Vertica* (1987–91), *Smart Materials and Structures* (1994–cont.), and *SADHANA* (1991–95). He is a member of the Army Science Board and a Fellow of AIAA, the American Helicopter Society, and the Aeronautical Society of India.

ROBERT E. DUFFY is currently president of RED Associates, a research, development, and consulting firm. A former member of the faculty of the Department of Mechanical Engineering, Aeronautical Engineering, and Mechanics at Rensselaer Polytechnic Institute, he was, for a number of years, the chairman of the aeronautical engineering academic program. He is the author of over 65 published papers and research reports in the areas of applied aerodynamics, flight mechanics, and experimental fluid dynamics. Dr. Duffy has served as a consultant to numerous governmental agencies, industrial concerns, and individuals. He is a past member of the Atmospheric Flight Mechanics Technical Committee and is an Associate Fellow of AIAA.

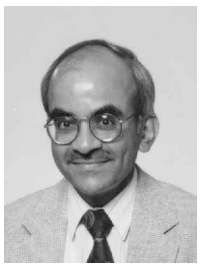
FRANKLIN E. EASTEP is a Professor of Aerospace Engineering at the University of Dayton. He received a B.S. from Ohio State University in 1958, an M.S. in Aeronautical Engineering from the Air Force Institute of Technology in 1963, and a Ph.D. in Aeronautics and Astronautics from Stanford University in 1968. Dr. Eastep has been teaching and conducting research within the technical areas of structural dynamics, aeroelasticity, and unsteady aerodynamics since 1968. During this period, he has been the principal thesis advisor for 15 doctoral students and over 35 master's students. He served on active duty with the U.S. Air Force for 20 years, retiring in 1978. Dr. Eastep is a member of the American Academy of Mechanics and an Associate Fellow of AIAA.

AHMED A. HASSAN is currently an Associate Technical Fellow at the Boeing Company in Mesa, Arizona. His area of expertise is computational fluid dynamics (CFD). Dr. Hassan received his B.S. and M.S. degrees from the University of Cairo in 1974 and 1976 respectively. He then received his Ph.D. degree from the University of Arizona in 1981. He was on the faculty of Arizona State University from 1981 to 1987 as an Assistant Professor. He joined the Boeing Company (then McDonnell Douglas Helicopter Company) in 1987 where he conducted research related to the application/development of CFD design and analysis tools to rotorcraft problems. He is the company representative on the corporate-wide CFD working group, an Associate Fellow of the American Institute of Aeronautics and Astronautics (1981 to the present) and a member of the American Helicopter Society (1987 to the present). He is currently serving as the Associate Editor for the AIAA *Journal of Aircraft* in the area of CFD. Dr. Hassan has published more than 30 archival studies and presented more than 60 papers at national and international conferences. He holds six patents and has four additional patents pending with the US Patent and Trademark Office. His work has focused on modeling the aerodynamics of rotor blade-vortex interactions and investigating novel flow control techniques for rotorcraft applications.

RONALD A. HESS received his B.S., M.S., and Ph.D. degrees in aerospace engineering from the University of Cincinnati. After completing his doctoral work, he joined the faculty of the Department of Aeronautics at the U.S. Naval Postgraduate School in Monterey, California. In 1976, he took a position at the Flight Systems Research Division at NASA Ames Research Center. In 1982, he joined the faculty at the University of California, Davis, where he is currently a Professor in the Department of Mechanical and Aeronautical Engineering. Dr. Hess' research interests lie in the areas of automatic and manual control of aircraft and in human/machine systems. He is an Associate Fellow of AIAA, a Senior Member of IEEE, and a member of Sigma Xi and Tan Beta Pi. He is also an Associate Editor of the *IEEE Transactions on Systems, Man, and Cybernetics*, and the *Journal of Aerospace*.

KENNETH J. HOLT retired from McDonnell Douglas Corporation in 1990. He had been involved in flight test operations and marketing. He received his B.Sc. from Hampton University in Virginia and his M.B.A. from the University of Missouri, St. Louis. He served 20 years in the U.S. Air Force and retired as a lieutenant colonel and a command pilot. His background is in fighters: he has flown the F-86, F-100, F-4, F-15, and F-18 and spent tours in the Air Training Command and Strategic Air Command. He joined McDonnell in 1973. There he flew production test flights and was the company's interface with the military and Federal Aviation Administration for test flights. He developed much of the flight test operating procedure for the F-18 and AV8B, and was the McDonnell flight operations consultant to the Government Aircraft Factory F-18 facility at Avalon, Australia. He retired from active flying in 1984. Mr. Holt served as chairman of the Aircraft Operations Technical Committee from 1985–1987. He is a Senior Member of AIAA.

MARK J. JOHNSON is the Advanced Structures Team Leader in Airframe Integration for Boeing-Phantom Works in St. Louis. He is a Program Manager and Principal Investigator on several research and development efforts, developing new aircraft structural technologies from the conceptual to the EMD-ready stage. Dr. Johnson holds degrees from Saint Louis University in aerospace engineering and Washington University in Saint Louis in civil engineering and mechanical engineering. He currently serves on the AIAA Survivability and the Structures Technical Committees and is a member of Sigma Xi, the American Helicopter Society, and the American Society of Mechanical Engineers. Dr. Johnson previously served in the U.S. Air Force in Aerospace Control and Warning.



MAHENDRA C. JOSHI is a Manager in the Noise and Emissions group at Boeing Commercial Airplanes in Seattle, Washington. Prior to this assignment, he was responsible for acoustics and propulsion technologies in the Phantom Works organization of McDonnell Douglas in Long Beach, California. Dr. Joshi has more than 20 years of experience in the development of acoustic technology for air and space vehicles. This includes prediction and control of engine and airframe noise sources, sonic loads, and transmission of noise inside vehicles. He was selected as MDC Technical Fellow in 1993. He conducted rotorcraft noise research at Bell Helicopter Textron in Fort Worth, Texas, for four years and was a Postdoctoral Research Associate at NASA Langley Research Center for two years. He is an Associate Fellow of AIAA and was a member of the Aeroacoustics Technical Committee. He received his Ph.D in aerospace/mechanical engineering from the University of Tennessee Space Institute in 1977.

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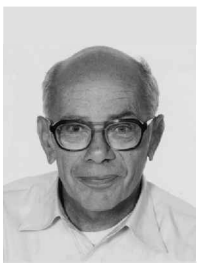

MURRAY TOBAK is a Senior Staff Scientist at NASA Ames Research Center. He has degrees from the University of California and Stanford University, and has been a Research Scientist at NACA–NASA Ames Research Center since 1948. He has specialized in theoretical studies of fluid and flight dynamics of high-speed aircraft and missiles. His studies have been aimed at identifying problems in nonlinear dynamics, flow stability, 3D separated flow, and vortex phenomena requiring basic research and new analytical and experimental tools for their solution. He is an AIAA Associate Fellow and has received NASA's Exceptional Service Award.