stations are approximately 0.3 of the scaled engine height. The thickening of the boundary layer on the centerline decreases with angle of attack. Since boundary-layer thickening degrades engine performance, further research is required to develop optimum forebody shapes, which provide acceptable inlet flowfields for airframe-integrated scramjets.

References

[1]Kirkham, F.S. and Jones, R.A., "Joint USAF/NASA Hypersonic Research Aircraft Study," AIAA Paper 75-1039, Aug. 1975.

[2]Lawing, P.L. and Hunt, J.L., "Aerodynamic Heat-Transfer to a Hypersonic Research Aircraft Model (X-24C) at Mach 6," *Journal of Aircraft*, Vol. 13, Dec. 1976, pp. 1018-1020.

Technical Comments

Comment on "Advanced Subsonic Transports – A Challenge for the 1990's"

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IN a recent paper, Black and Stern[1] too quickly dispose of a decade or more in the projected appearance of an advanced technology transport without truly exposing the fundamental constraint on aeronautical progress in the proper historical context. The delay cannot be written off simply as one pending a general economic upturn leading, in turn, to improved air transportation economics and increased fuel efficiency through the judicious application of advanced technology. For convenience, the advanced technology is recognized here as the array: supercritical aerodynamics, composite materials, active controls, and cleaner, quieter, and more efficient propulsion.

Since about 1965, the year aptly designed by Hoener[2] as that heralding the renaissance or rediscovery of the airplane, the AIAA literature has provided extensive coverage of prospects for aeronautics, particularly with respect to civil aviation (Refs. 3-29, for example). Not one of these (including projections for the new air transports of the 1980s by Black et al.[20,21]), nor actually any at all, is recognized in Ref. 1, even though the underlying thrust common to a majority of the sources cited is germane to placing in proper perspective the observation relative to R&D effort, including transportation systems analysis, being promoted by Black and Stern: namely, that future technology advances will require substantial R&D before they can be incorporated into commercial designs. For the nearer term, they conclude that worldwide economic, social, and political environments and the rising cost of fuel presage long and profitable lives for the present wide-bodied jets and their derivatives. This conclusion echoes those of contemporary Refs. 22 and 23, both of which point to the small likelihood that an advanced technology transport can be expected before, presumably, 1985, in view of economic considerations and the absence of an as yet unpredicted technological breakthrough or advance. Indeed, in Ref. 23, the 10 years ahead are referred to as the decade of derivatives.

In the years 1964-68, which span the period between the presentations of the 27th and 31st Wright Brothers Lectures, Schairer,[3] Hawkins,[4] Bisplinghoff,[5] Brizendine and Strang,[6] Raymond,[7] Chatham,[8] and Harper[9] addressed to varying degrees the general topic of future progress in aeronautics. The singular transmission providing the common denominator to these essays is an urgent call for renewed and continued emphasis on and commensurate support of R&D in view of the growth potential, socioeconomic overtones, and impact on the U.S. economy of civil aviation. To this group must be added the sage counsel offered the readership of AIAA publications by Karth[10] in 1968, in which he called attention to the strong relationship existing between technology and social progress, the requirement for the former to be responsive to the latter, and the fact that a strong case could be made to continue supporting vigorous R&D efforts in the U.S. subject to the realization that directions and priorities would have to change from time to time. It was in 1968, also, when Harper concluded that aeronautics R&D had neglected to examine the socioeconomic impact of its activities and that it would require a well-organized, agressively pursued R&D program, taking full advantage of all new technology, to reduce to a financially acceptable level the technical risks associated with improved air-transport capability.

From 1970 on, or commencing roughly with the presentation of the 33rd Wright Brothers Lecture by Cleveland,[11] the advanced technology has been a consideration in the references cited, with more and more emphasis being directed toward its specific potential for high-subsonic- and transonic-speed transports (Refs. 12-23, for example). Concomitantly, studies directed more to the interaction of technical, social, political, and economic forces than to the advanced technology *per se* have appeared as well (Refs. 24-29, for example).

In view of the foregoing, it would appear that Black ana Stern have long been preempted in their pronouncements that the design requirements for advanced subsonic transports will be established, to a large degree, by future economic, social, and political conditions and that these requirements will necessitate an extensive and in-depth (advanced) technology base that is not only relevant to the airplane but also to the total air transportation system. As noted earlier, the airplane was rediscovered in 1965; unfortunately, in the very critical, immediately subsequent years, the formulation and support of an R&D program that would first recoup lost ground and then accelerate the technical progress leading to the economically viable and environmentally acceptable air transportation system now projected to, at least, the 1990's by Black and Stern did not see fruition, the conclusions, recommendations, pleas, warnings, and forebodings of authoritative sources notwithstanding. Paradoxically, the very branch of the federal government whose Senate Committee on Aeronautical and Space Sciences, after 2 years of deliberations, recommended adoption of a more comprehensive and coherent policy for aeronautical R&D in 1968 has yet to recognize the full impact of unchecked erosion of the R&D base.

That the decade or more delay projected in Refs. 1, 22, and 23 for the appearance of advanced technology transports is rooted more in deteriorated aeronautical R&D support throughout the post-Sputnik era rather than in the market downturn and rising fuel costs of the 1970's is no more poignantly illustrated than by succinctly reviewing the promise versus the progress of composite materials, one of the key building blocks of the advanced technology. In 1968,

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Hotz[30] editorialized as follows:[11] "The surge of composites will change the face of the aerospace industry radically during the next decade. The increments of increased payload and profitability they offer for all types of flying vehicle are fantastic. Their widespread application will eventually set new standards of technical and economic performance and create a demand for still another generation of military and commercial equipment. This brief history of the composites growth from the laboratory to the air in less than a decade provides a good example of how the sparks struck by research and fanned by perceptive development produced the new technology that will push the aerospace industry up new curves of growth onto new plateaus of prosperity." In 1976, Harris[31] assessed the future of advanced composites for application to commercial aircraft as follows: "In commercial transport aircraft, advanced composites will be the basis for an evolutionary increase in secondary structure applications, provided they are cost-effective. This effectiveness will have to cover, of course, both the initial cost and maintenance (cost of ownership). However, no one at this time has the confidence or the background to commit composites to use in primary structure. Wings now cost on the order of $40 per pound and any new material must be competitive in terms of life-cycle costs." A far more extensive and sobering illustration, replete with hard R&D funding data (1953-1973) and a pessimistic forecast for the remainder of the 1970s is presented by Bagby.[32] Other examples outside the AIAA literature can be referenced, of course, perhaps none more extensive than the National Academy of Engineering CARD study published in 1968[33] and the CARD study conducted by agencies of the federal government for the federal government and published in 1971.[34] These studies provide positive in-depth evaluations of the R&D role in raising both the levels of U.S. aircraft performance, economy, reliability, and safety and the benefits that accrue to the U.S. from a viable civil aviation responsive to socioeconomic factors.

In conclusion, the die was cast for both the current and projected status of civil aviation by the aeronautics R&D environment of the decades just prior to and subsequent to 1965, respectively. Black and Stern have no doubt established the most valid projection to date for the appearance of an advanced technology transport, but not for the most valid reason. In overlooking aeronautical R&D history, they have failed to recognize that which was inevitable before the 1970's ever were penetrated. The economic downturn and fuel crisis of the 1970's have served only to exacerbate the far-reaching effects of retrenched government support and encouragement of aeronautical R&D for a period which now transcends twenty years.

References

[1]Black, R.E. and Stern, J.A., "Advanced Subsonic Transports – A Challenge for the 1990's, "*Journal of Aircraft*, Vol. 13, May 1976, pp. 321-326.

[2]Hoener, R.F., "Aeronautical Structures Technology – 1965," AIAA Paper 65-368, San Francisco, Calif., July 1965.

[3]Schairer, G.S., "Some Opportunities for Progress in Aircraft Performance," 27th Wright Brothers Lecture, New York, January 1964; also, *Journal of Aircraft*, Vol. 1, March-April 1964, pp. 49-70.

[4]Hawkins, W.M., "The Next 50 Years in Aviation," *Astronautics & Aeronautics*, Vol. 3, July 1965, pp. 90-99.

[5]Bisplinghoff, R.L., "New Horizons in Aeronautics," 3rd von Karman Lecture, San Francisco, Calif., July 1965; also, *Astronautics & Aeronautics*, Vol. 3, Dec. 1965, pp. 28-37.

[6]Brizendine, J.C. and Strang, C.R., "The Future Transport World," *Journal of Aircraft*, Vol. 4, Nov.-Dec. 1967, pp. 481-486.

[7]Raymond, A.E., "Air Transport History and a Glimpse Into the Future," Ninth Annual Lester D. Gardner Lecture, Cambridge, Mass., May 1968; also, *Astronautics & Aeronautics*, Vol. 6, July 1968, pp. 60-69.

[8]Chatham, G.N., "Toward Aircraft of the 1980's," *Astronautics & Aeronautics*, Vol. 6, July 1968, pp. 26-38.

[9]Harper, C.W., "Prospects in Aeronautics Research and Development," 31st Wright Brothers Lecture, Washington, D.C., Feb. 1968; also, *Journal of Aircraft*, Vol. 5, Sept.-Oct. 1968, pp. 417-428.

[10]Karth, J.E., "Aerospace R&D Challenges Today," *Astronautics & Aeronautics*, Vol. 6, July 1968, pp. 4-5.

[11]Cleveland, F.A., "Size Effects in Conventional Aircraft Design," 33rd Wright Brothers Lecture, Los Angeles, Calif., July 1970; also, *Journal of Aircraft*, Vol. 7, Nov.-Dec. 1970, pp. 483-512.

[12]Loftin, L.K., Jr., "Aeronautical Vehicles – 1970 and Beyond," AIAA Paper 70-1262, Houston, Texas, October 1970; also, *Journal of Aircraft*, Vol. 8, Dec. 1971, pp. 939-951.

[13]Roberts, L., "The Promise of Aeronautics," *Astronautics & Aeronautics*, Vol. 9, May 1971, pp. 24-31.

[14]Cortright, E.M., "The New Civil Aviation Within Our Grasp," *Astronautics & Aeronautics*, Vol. 10, Jan. 1972, pp. 30-34.

[15]Braslow, A.L. and Alford, W.J., "Overview," Ayers, T.G., "Supercritical Aerodynamics – Worthwhile Over a Range of Speeds," Beheim, M.A., Antl, R.J., and Povolny, J.H., "Advanced Propulsion – Cleaner and Quieter," Goble, R.L., "Composites – Lighter and Cheaper," and Hood, R.V., "Active Controls Changing the Rules of Structural Design," In: "Advanced Subsonic Transport Technology," *Astronautics & Aeronautics*, Vol. 10, Aug. 1972, pp. 26-55.

[16]Williams, B., "Advanced Technology Transport Configuration," AIAA Paper 72-756, Los Angeles, Calif., Aug. 1972; also, *Journal of Aircraft*, Vol. 10, June 1973, pp. 323-333.

[17]Lange, R.H., "Parametric Analysis of ATT Configurations," AIAA Paper 72-757, Los Angeles, Calif., Aug. 1972.

[18]Carline, A.J.K., "Economic Impact of Applying Advanced Technologies to Transport Airplanes," AIAA Paper 72-758, Los Angeles, Calif., Aug. 1972.

[19]Ardema, M.D. and Williams, L.J., "Automated Synthesis of Transonic Transports," AIAA Paper 72-794, Los Angeles, Calif., Aug. 1972; also, NASA TM X-62, 1972.

[20]Black, R.E. and Murphy, D.G., "Advanced Technology Applications to Present and Future Transport Aircraft," *Journal of Aircraft*, Vol. 10, May 1973, pp. 259-266.

[21]Black, R.E. and Stern, J.A., "Expanding Horizons for Long-Haul Air Transportation," AIAA Paper No. 73-14, Washington, D.C., Jan. 1973.

[22]Shevell, R.S., "Technology, Efficiency, and Future Transport Aircraft," *Astronautics & Aeronautics*, Vol. 13, Sept. 1975; summary and quantitative update of portions of 6th von Karman Lecture, "The Evolution and Future of Transport Aircraft," presented to 16th Israel Annual Conference on Aviation and Astronautics, Tel Aviv, Aug. 1974 and published in *Israel Journal of Technolgoy*, Vol. 12, Jan. 1974, pp. 1-22.

[23]Sim, G. and Hopps, R.H., "Commercial Transports – Decade of Derivatives?," *Astronautics & Aeronautics*, Vol. 13, Feb. 1975, pp. 24-32.

[24]Smelt, R., "Air Transportation Boundaries for National Planning," *Astronautics & Aeronautics*, Vol. 9, Nov. 1971, pp. 27-32.

[25]Lickley, R.L., "New Patterns for a Healthy Aviation," The 1971 Wright Brothers Lecture, Seattle, Washington, July 1971; also, *Astronautics & Aeronautics*, Vol. 10, July 1972, pp. 66-75.

[26]Borger, J.G., "Influences of International Operations on Aircraft-Transport Design," *Astronautics & Aeronautics*, Vol. 11, July 1973, pp. 24-34.

[27]Attiyeh, R.S., Friberg, E.C., and Cohen, R.E., "U.S. Aerospace Industry at the Crossroads," *Astronautics & Aeronautics*, Vol. 11, Nov. 1973, pp. 44-51.

[28]Wheatcroft, S., "Airline Airplanes for the Eighties," *Astronautics & Aeronautics*, Vol. 12, March 1974, pp. 34-41.

[29]Steiner, J., "Airline Airplanes for the Eighties – A Response," *Astronautics & Aeronautics*, Vol. 12, March 1974, pp. 42-51.

[30]Hotz, R., "A New Materials Revolution," Editorial, *Aviation Week & Space Technology*, Vol. 89, Sept. 1965, p. 11.

[31]Harris, L.A., "Advanced Composites – An Assessment of the Future," *Astronautics & Aeronautics*, Vol. 13, March 1976, pp. 22-33.

[32]Bagby, F.L., "A Unified View of the R&D Economy," *Astronautics & Aeronautics*, Vol. 12, Jan. 1974, pp. 32-39.

[33]"Civil Aviation Research and Development: An Assessment of Federal Government Involvement," Summary report, Aeronautics and Space Engineering Board, National Academy of Engineering, Washington, D.C., Aug. 1968; also, *Astronautics & Aeronautics*, Vol. 6, Aug. 1968, pp. 72-92.

[34]"Civil Aviation Research and Development Policy Study," DOT TST-10-4/NASA SP-365, March 1971, Washington, D.C.