

# ADVANCED AERODYNAMICS AND ACTIVE CONTROLS TECHNOLOGY

## SESSION INTRODUCTION

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## INTRODUCTION

The purpose of this section is to report on the results, status, and plans of NASA sponsored advanced aerodynamics and active controls technology activities.

Since most of the work underway in these areas is focused on development of subsonic, energy efficient transport aircraft technologies and is sponsored by the Energy Efficient Transport (EET) Element of the Aircraft Energy Efficiency (ACEE) Project (refs. 1 and 2), the material to be presented in this introductory paper is intended to set the stage for the section by providing a synopsis of the EET activities; the titles and authors of the ten section papers; and how the efforts represented by the papers are related to the over-all EET plan.

It should be noted that most of the work being reported on has been underway for less than a year and, therefore, in-depth or complete results are not yet available.

## ABBREVIATIONS

ACEE	aircraft energy efficiency
ACT	active controls technology
ARC	Ames Research Center
B	Boeing Commercial Airplane Company
DC	Douglas Aircraft Company
DFRC	Dryden Flight Research Center
EET	energy efficient transport
EMS	elastic mode suppression
FLT	flight tests
GA	gust load alleviation

HASCW	high-aspect-ratio supercritical wing
IEM	integrated energy management
L	Lockheed-California Company
L.S.	low speed
LaRC	Langley Research Center
M	maintainable
Max. Ben.	maximum benefit
MFLDN	mixed-flow, long-duct nacelle
MLA	maneuver load alleviation
NASA	National Aeronautics and Space Administration
NLF	natural laminar flow
OAST	Office of Aeronautics and Space Technology
PFC	primary flight control system
R	reliability
RPRV	remotely piloted research vehicle
RSS	relaxed static stability
R&T	research and technology
SCW	supercritical wing
WLA	wing load alleviation
W.T.	wind-tunnel tests
WTE	wing tip extension
WTW	wing tip winglet

#### ENERGY EFFICIENT TRANSPORT PROJECT

The EET project is one of the elements of the NASA OAST Advanced Civil Aircraft Systems Technology Program (ref. 2) whose objectives are to:

"Expedite industry acceptance and application of advanced aerodynamics and active controls technology in an integrated manner to achieve energy, economic, and aircraft sales benefits."

As illustrated in figure 1, the focus of the EET activities is on advanced subsonic CTOL aircraft of both the near-term derivative category (i.e., B-747, DC-10, and L-1011) and farther-term, new or advanced derivative aircraft (i.e., B-7X7, DC-X-200, and L-RE-1011) category.

A schedule of the EET technology development and evaluation activities is presented in figure 2. The activities consist of NASA-LaRC defined and implemented (with contractor involvement, as appropriate) advanced aerodynamics and active controls efforts and selected concepts contracts with Boeing, Douglas, and Lockheed. These activities, which were initiated in 1976, intensified in 1977 and are expected to continue through fiscal year 1982. Associated research and technology resources are slightly in excess of eighty-five million (then year) dollars.

### Advanced Aerodynamics

The advanced aerodynamics activities (fig. 2) focus on three areas: cruise conditions, low-speed conditions, and design methodology.

In the cruise area, high-aspect-ratio supercritical wing airplane models have been designed and are being tested in the Langley 8-foot transonic pressure tunnel to establish a data base for variations in wing characteristics and controls. Analytical and experimental activities are also underway to optimize wing-winglet geometry and to assess wide-body transport applications of winglets. Propulsion/airframe integration experiments are planned to minimize interference effects of below-the-wing pylon-mounted nacelles. Early results of these efforts are presented in reference 3.

Current results and status of the cruise aerodynamics activities are contained in papers 1 and 2 of this section, entitled "NASA Supercritical-Wing Technology" by Dennis W. Bartlett and James C. Patterson, Jr., and "Experimental Results of Winglets on First, Second, and Third Generation Jet Transports" by Stuart G. Flechner and Peter F. Jacobs, respectively. These four authors are aerospace technologists associated with the LaRC Transonic Aerodynamics Branch.

In the low-speed area, efforts are underway to define the high-lift system requirements for high-aspect-ratio supercritical wing configurations and to assess the impact of active controls requirements on high-lift systems. A model has been designed, fabricated, and tested in the Langley V/STOL tunnel. Another model is being designed for fabrication and testing at higher Reynolds numbers in the Ames Research Center (ARC) 12-Foot Tunnel.

Design methodology developments are aimed at expediting three-dimensional, optimum, supercritical wing design capability and mixed-flow-juncture analysis methods. The approach, using computer aided design tools, is to: couple 3-D

boundary layer programs to transonic wing analysis procedures; extend 3-D transonic wing programs to operate in a design mode with either constrained loading or geometry specifications; and to incorporate non-planar capability in the wing programs. There are two papers in this section dealing with advanced transonic flow computational aerodynamics. The first is entitled "Recent Experiences With Three-Dimensional Transonic Potential Flow Calculations" by David A. Caughey of Cornell, Perry A. Newman of LaRC, and Antony Jameson of NYU. This activity was sponsored by NASA in the OAST R&T Base Program (ref. 2). The second paper is entitled "Towards Complete Configurations Using an Embedded Grid Approach" by Charles W. Boppe of Grumman. This and all of the other work being reported on in this section was sponsored by the ACEE/EET Project (ref. 2).

### Active Controls

Still referring to figure 2, the active controls technology activities consist of two major developments: integrated analysis and design techniques; and reliable, maintainable flight control systems (ref. 4).

The objective of the integrated analysis and design techniques activity is to evaluate existing analytical and experimental tools for the integrated application of aerodynamics, structures, and controls. The technical approach is to design, under contract (NAS1-14665, with Boeing-Wichita), a high-aspect-ratio supercritical wing incorporating structurally critical gust load alleviation, maneuver load alleviation, and active flutter suppression systems. Three aeroelastic semispan wings including the control systems will be fabricated. One set of two will be flight tested at DFRC utilizing a modified BQM-34E/F "Firebee II" RPRV. The other semispan wing will be tested in the Langley transonic dynamics tunnel. The expected results of this activity will be a comparison and evaluation of the analytical, wind-tunnel, and flight test results including: control system performance, loads, flutter, and unsteady aerodynamic and aeroelastic characteristics. The design methods to be evaluated through test activities are discussed in the last paper of this section, entitled "Active Controls Technology to Maximize Structural Efficiency" by James M. Hoy of Boeing-Seattle and James M. Arnold of Boeing-Wichita.

The principal thrusts of the reliable, maintainable flight controls systems activity are: design of a cost-effective system, using state-of-the-art technology for near-term, non-flight-critical application; and design and evaluation of an advanced, reliable, maintainable system for far-term application. Elements of these activities include: (1) a state-of-the-art assessment by collecting, analyzing, and documenting current airlines avionics systems reliability data, maintenance experience, and operational practices and procedures; (2) development and validation of system evaluation models incorporating control system reliability and performance, aircraft flight safety, airline operations (e.g., route structure, maintenance, delays, etc.) and cost; (3) development and evaluation of two advanced fault-tolerant computer systems: Stanford Research Institute's Software Implemented Fault Tolerance (SIFT) and Charles Stark Draper Laboratory's Fault Tolerant Multiprocessor (FTMP); and (4) studies of fault-tolerant flight control system architectures. Early results of some of these activities are presented in references 5 to 7. Some

current results were given in the oral presentation on fault tolerant computer technology for active controls.

### Selected Concepts

To achieve the earlier stated objective of the ACEE/EET Project, a strong NASA/industry partnership is being implemented with the technology focus being that which NASA and the commercial transport industry mutually agree is most relevant for both near-term (current transport derivatives - 1983) and far-term (new aircraft design - 1985+) applications. (See fig. 1.) The three industry participants are Boeing, Douglas, and Lockheed. As indicated in figure 2, selected advanced concepts are being implemented in two phases. Phase I, which is currently underway, is illustrated in figure 2 by the activities listed in the solid rectangles. These activities are primarily developmental in nature lasting through FY-79. Phase II, which is to be initiated this year, is illustrated in figure 2 by the dashed rectangles. These activities are primarily evaluative and demonstrative in nature and are expected to continue through FY-82. Ongoing and planned contractual activities with each company are described below.

Boeing.- In Phase I, there are two contractual activities with Boeing. One of these has a near-term focus (NASA contract NAS1-14741 for selected advanced aerodynamics and active controls technology concepts development on a derivative B-747 aircraft). The tasks include development and analysis, engineering design, and evaluation of wing-tip extensions, wing-tip winglets, wing load alleviation, wind-tunnel testing of these various modifications, choice of a final configuration, and evaluation and recommendations for further work. Some results to date and status of this work are presented in the paper entitled "Application of Winglets and/or Tip Extensions With Active Load Control on the Boeing 747" by Robert L. Allison, Brian R. Perkin, and Richard L. Schoenman of Boeing-Seattle.

The second Boeing contractual activity has a farther term focus (NASA contract NAS1-14742 for selected advanced aerodynamic and active control concepts development). The tasks of this program include: B-747 primary flight control system reliability and maintainability study; integrated energy management; natural laminar flow; high-lift characteristics of high-aspect-ratio supercritical wings; and a maximum benefit of active controls technology planning study. Although a complete status report on these activities is not presented herein, some of the more important considerations related to methods of integrated design to maximize the benefits of active controls are discussed in the paper entitled "Active Controls Technology to Maximize Structural Efficiency" by James M. Hoy of Boeing-Seattle and James M. Arnold of Boeing-Wichita.

Current plans for Phase II include: wind-tunnel testing of the final B-747 configuration selected in Phase I and, possibly, some engineering flight tests; and an in-depth assessment of the integrated application of ACT followed by identification of ACT system design and test requirements.

Douglas.- In Phase I there are also two contracted activities underway with Douglas. The first has a near-term focus (NASA contract NAS1-14743 for selected winglet and mixed-flow long-duct nacelle development for DC-10 derivative aircraft). The tasks include: design and wind-tunnel tests of winglets on a DC-10 wing; and analytical and wind-tunnel investigation of the interference effects of mixed-flow long-duct nacelles on a DC-10 wing. Early results and the status of this work are presented in the paper entitled "Winglet and Long-Duct Nacelle Aerodynamic Development for DC-10 Derivatives" by A. Brian Taylor of Douglas-Long Beach.

The second contractual activity has a farther term focus (NASA contract NAS1-14744 for selected advanced aerodynamic and active control concepts development). The tasks include: wind-tunnel testing of a high-aspect-ratio supercritical wing; definition and study of an optimum wing-winglet combination; definition of a high-lift system for a high-aspect-ratio supercritical wing; and assessment of a low-risk stability augmentation system for current and advanced transports. The status and results of this work are presented in the paper entitled "Advanced Aerodynamics and Active Controls for a Next Generation Transport" by A. Brian Taylor of Douglas-Long Beach.

Current plans for Phase II include: further DC-10 mixed-flow, long-duct nacelle and winglets wind-tunnel testing and flight test demonstrations; further high-aspect-ratio supercritical wing wind-tunnel testing; and in-depth assessment of an active controls transport including the identification of system design and test requirements.

Lockheed.- In Phase I there is a single effort by Lockheed with a near-term focus (NASA contract NAS1-14690 for accelerated development and flight evaluation of active control concepts for subsonic transport aircraft). The tasks include: flight test of a wing load alleviation system on an L-1011 aircraft; addition of 4.5 foot wing-tip extensions and flight tests with a wing load alleviation system; and moving-base simulation testing to develop active stability augmentation permitting a smaller horizontal tail on future L-1011 derivatives. The status and results of this program to date are presented in the paper entitled "Development and Flight Evaluation of Active Controls in the L-1011" by J. F. Johnston and D. M. Urie of Lockheed-California.

Current plans for Phase II call for further development and evaluation of a wing load alleviation system for subsonic commercial transport aircraft.

#### CONCLUDING REMARKS

Most NASA-sponsored advanced aerodynamics and active controls technology development for CTOL transports is embodied in the ACEE/EET project. The other papers in this section report selected early results of this program. So that their context is clear, this paper has briefly summarized the EET ongoing and planned efforts indicating which are represented by the papers that follow and outlining the nature of the work not reported.

## REFERENCES

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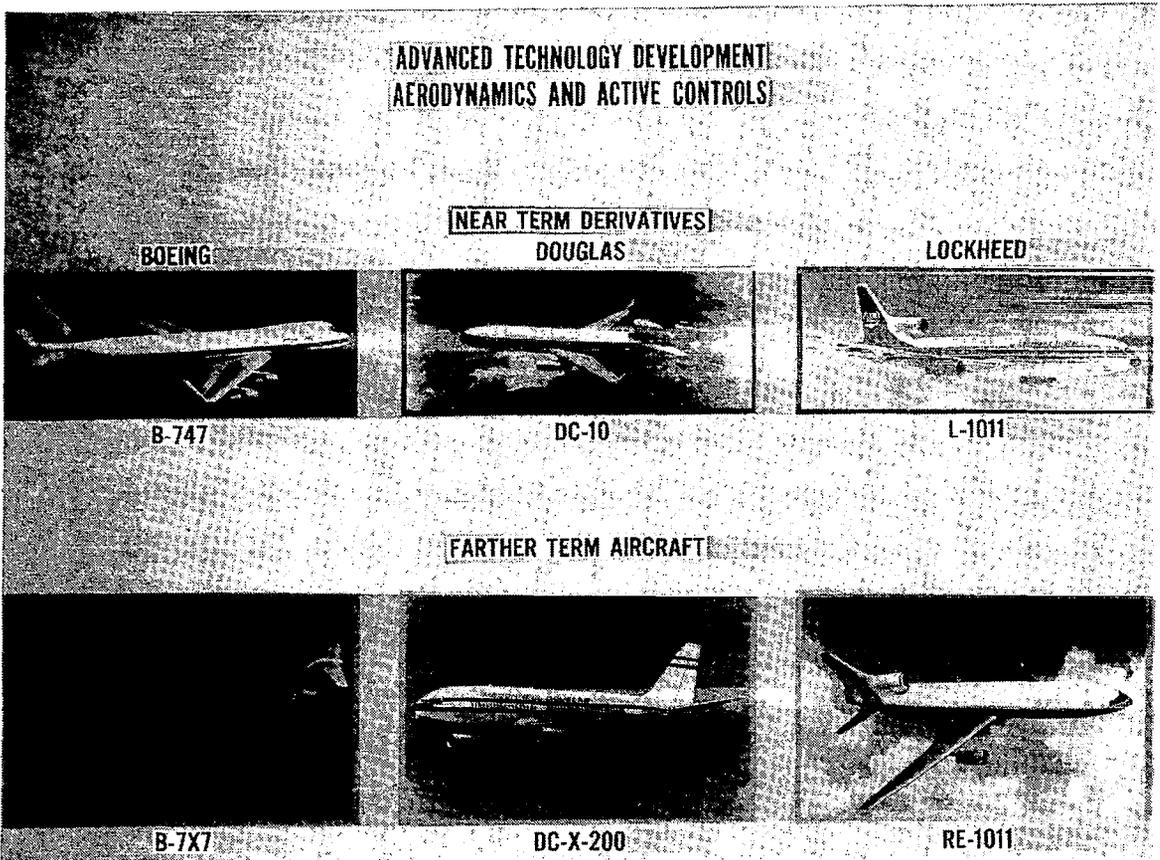


Figure 1.- Energy efficient transport - illustrations of advanced subsonic CTOL aircraft.

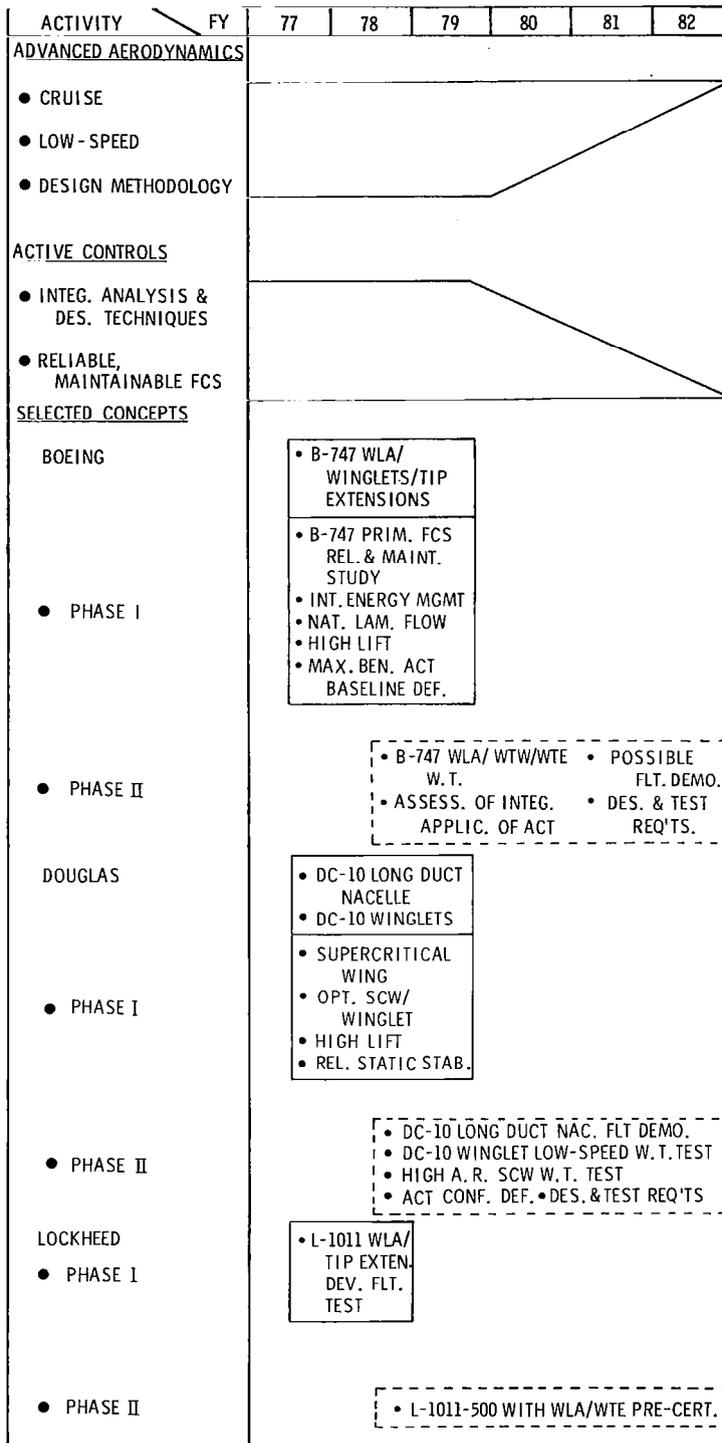


Figure 2.- Energy efficient transport - advanced aerodynamics and active controls technology development and evaluation schedules.