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ACEE PROGRAM RATIONALE AND IMPLEMENTATION

WILLIAM S. AIKEN, JR., AND RICHARD H. PETERSEN

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National Aeronautics and
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Langley Research Center
Hampton, Virginia 23665

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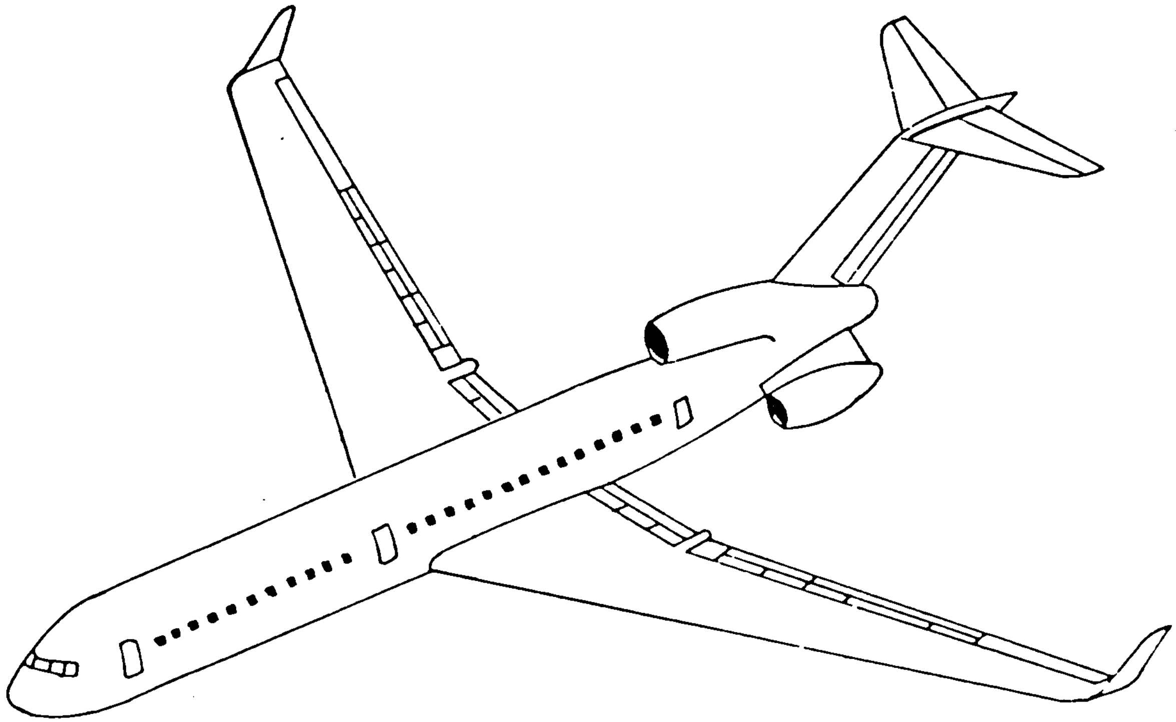
INTRODUCTION

NASA's Aircraft Energy Efficiency (ACEE) Program was begun in 1976 following a year of planning. This paper very briefly reviews the rationale for this intensive NASA effort, but looks at the issues behind the ACEE Program, as well as its implementation, from the perspective available in 1981.

THE AIRCRAFT ENERGY EFFICIENCY PROGRAM



A principal reason for concern for air transport fuel efficiency, of course, is everybody's critical dependence today on air transportation.

In the United States, our dependence on air travel increased substantially over the past five years and air transport now accounts for ten times as many domestic passenger miles as its nearest public transportation rival--the bus system.

But in 1980 airline passenger miles declined sharply.

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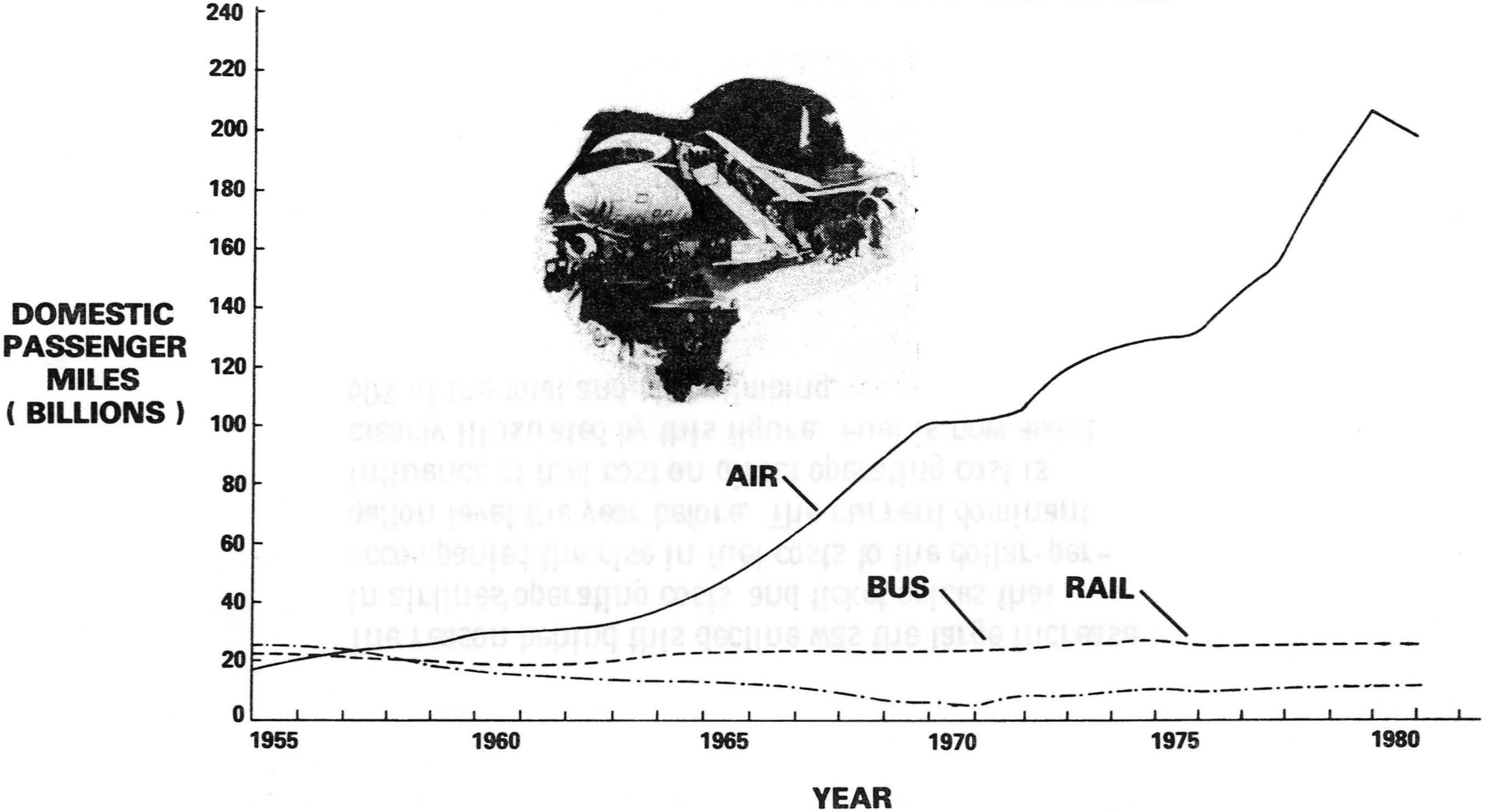
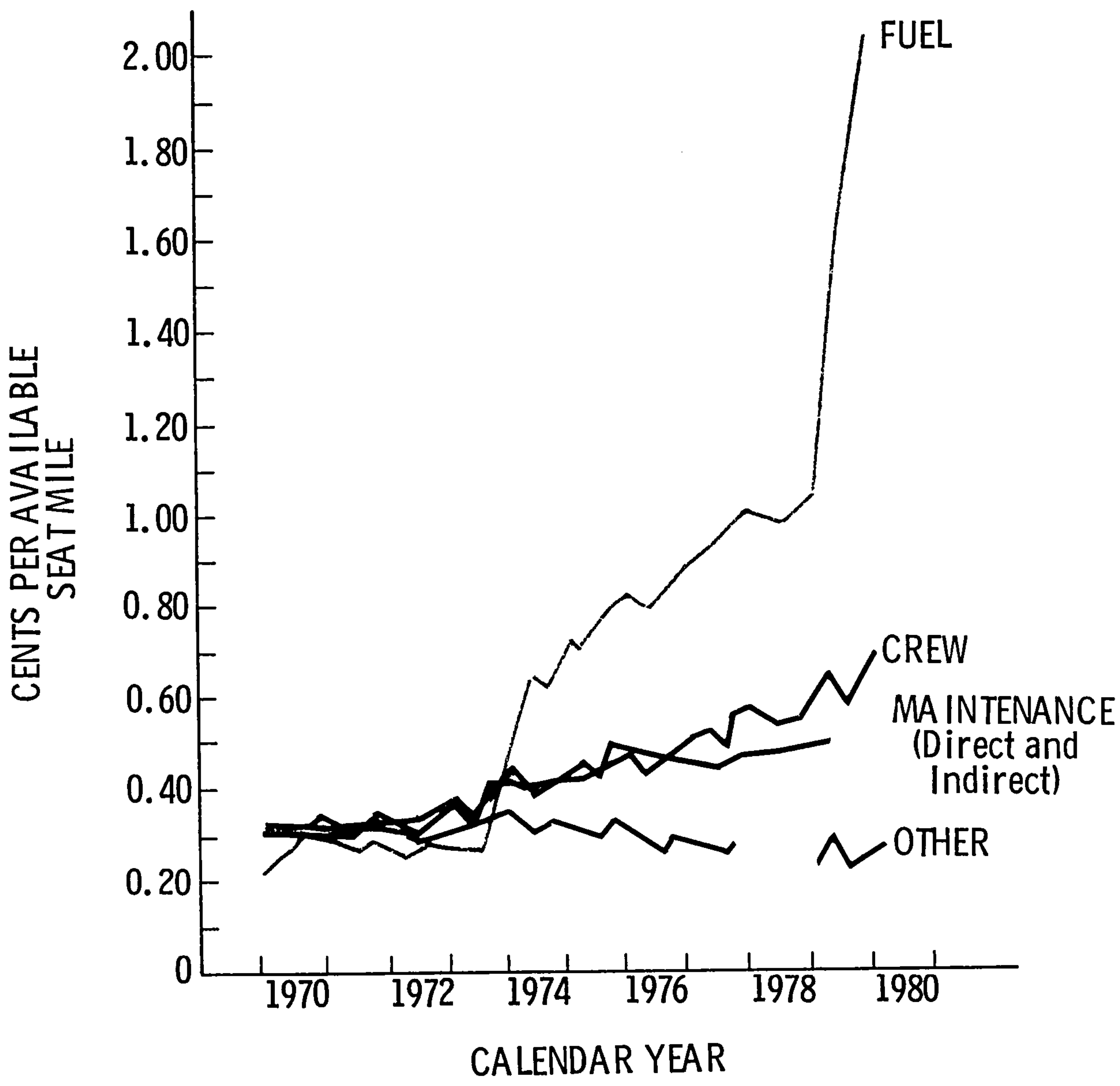
WE HAVE BECOME DEPENDENT ON AIR TRAVEL



The reason behind this decline was the large increase in airlines' operating costs and ticket prices that accompanied the rise in fuel costs to the dollar-per-gallon level the year before. The current dominant influence of fuel cost on direct operating cost is clearly illustrated by this figure. Fuel is now about 60% of the total and still climbing.

ELEMENTS OF AIRLINE DIRECT OPERATING COST



Another, perhaps even more critical, issue is our air transport industry's increasingly important impact on the balance of U. S. trade. It has long been the leading industrial contributor of positive trade balances to partially offset our import of autos, oil and other products and, in 1980, produced a 6-billion-dollar surplus.

AIR TRANSPORT IMPORTANCE TO U.S. TRADE BALANCE
1980 POSITIVE BALANCE WAS 6 BILLION DOLLARS

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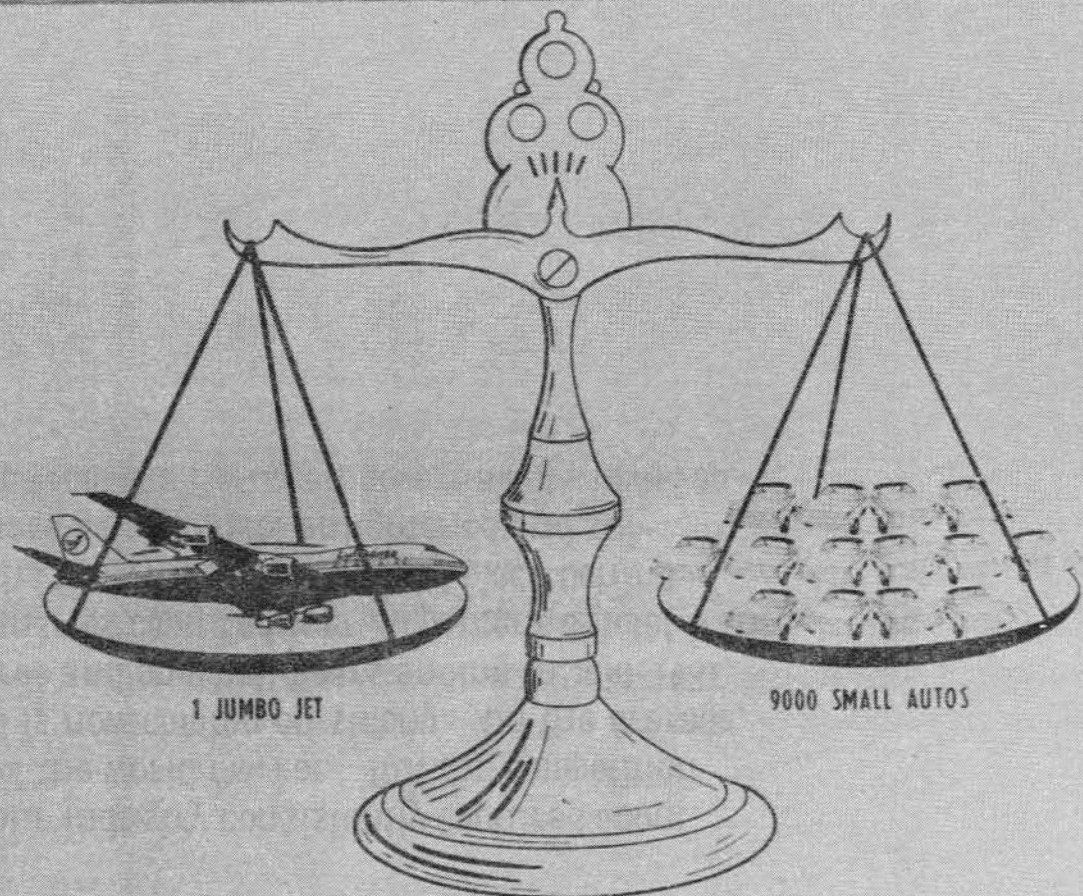
3/81



Until 1977 our industry consistently captured about 95 percent of the world market. But the competition from abroad is now coming on strong. On the average, over the three and one-half years ending in mid-1981, Airbus Industries captured over 20 percent of total transport sales and firmly took over second place behind Boeing. These gains reflect enlightened and substantial help from the European governments involved.

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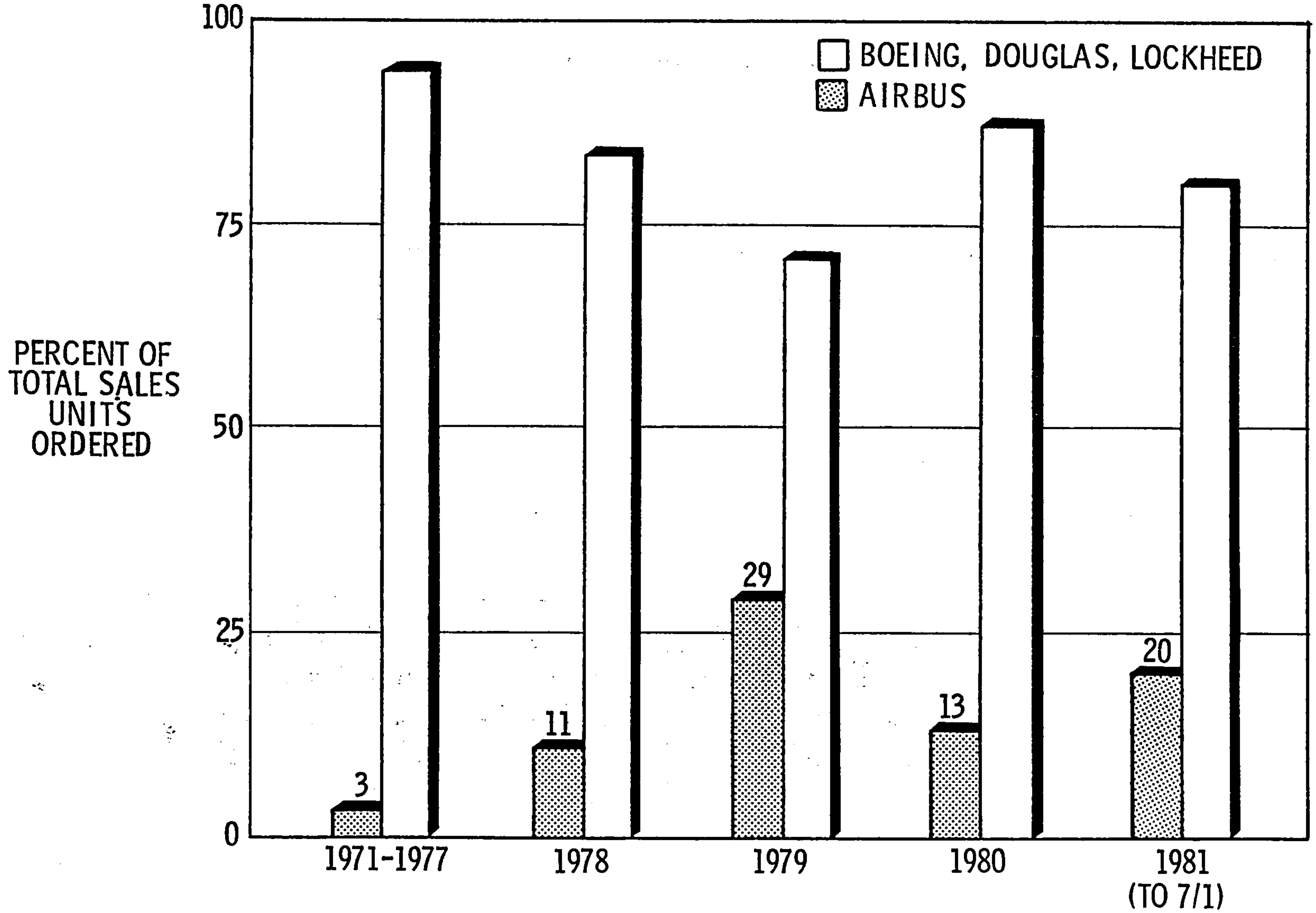
THE AIRBUS HAS IMPACTED U.S. SALES



And the worst news of all is the outlook for future fuel costs. These are forecasts, compiled by the Air Transport Association, that project three-dollar-per-gallon fuel by the end of this decade. Clearly, if we want to both keep our airlines healthy and keep a dominant share of the air transport market, we must produce fuel-efficient transport aircraft.

FUEL PRICE FORECAST

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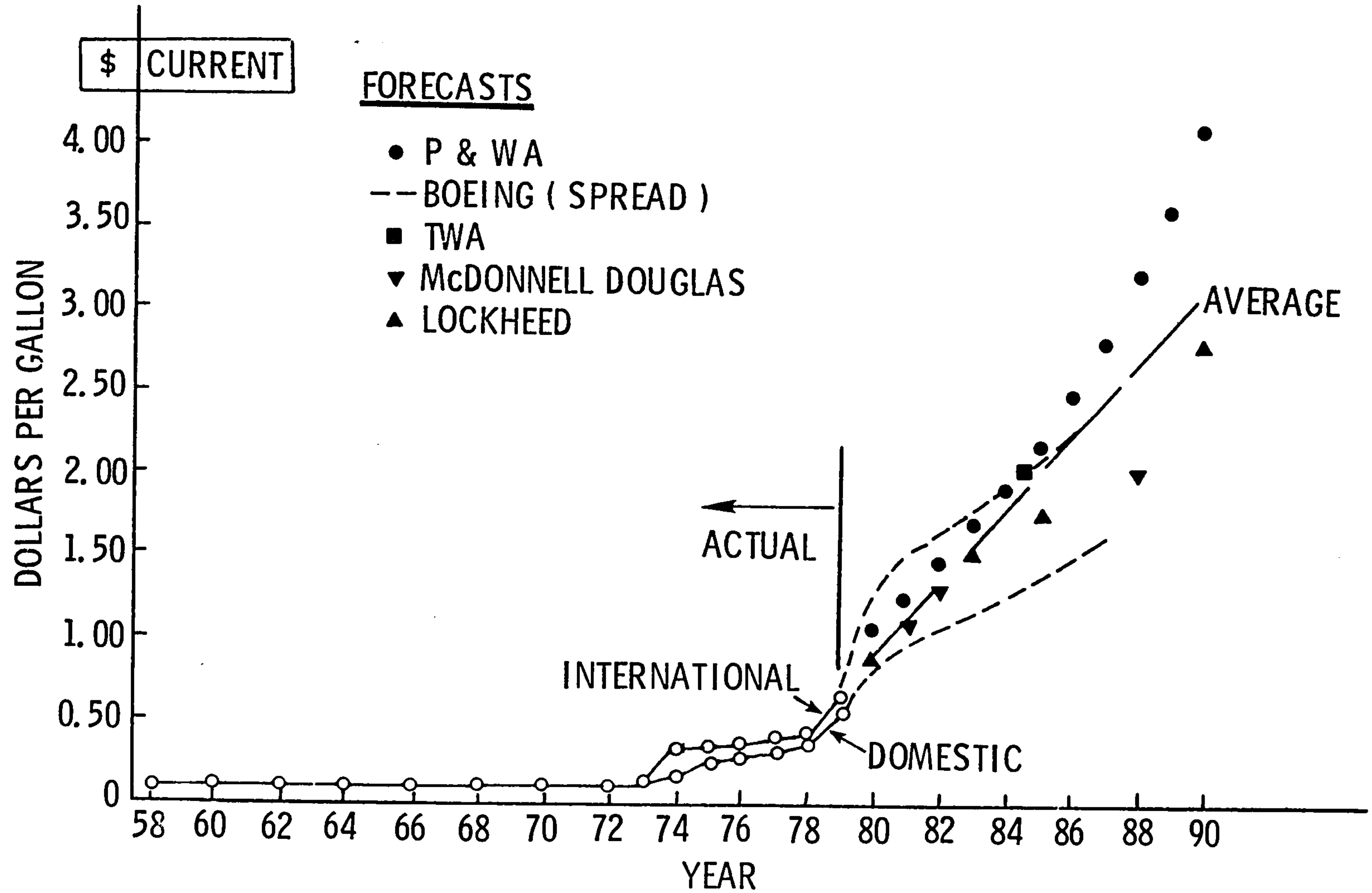

Thus, when one looks back six years to the formulation of the ACEE Program by a NASA Task Force and a number of supporting groups, the Program's rationale, as it was stated in this early 1976 viewgraph, still appears valid.

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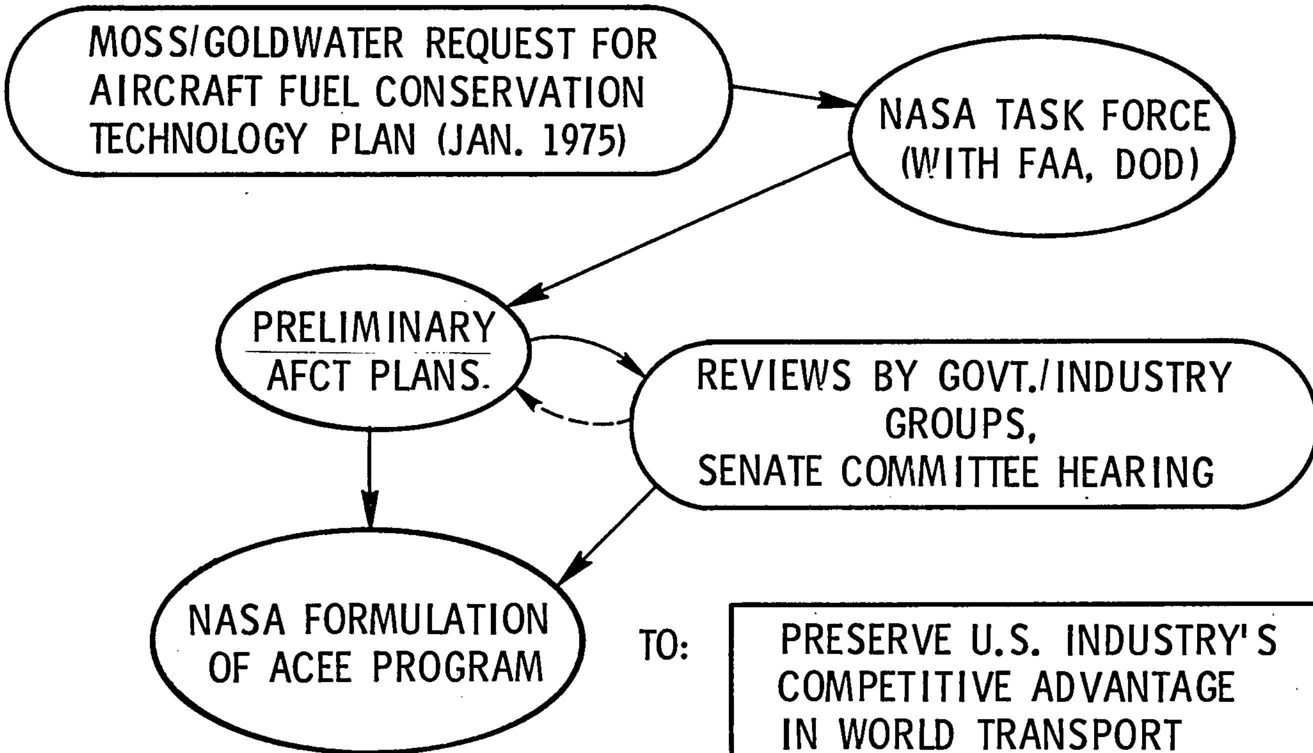
EVOLUTION OF THE AIRCRAFT ENERGY EFFICIENCY (ACEE) PROGRAM



TO:

PRESERVE U.S. INDUSTRY'S COMPETITIVE ADVANTAGE IN WORLD TRANSPORT AIRCRAFT MARKETS THROUGH TECHNOLOGY FOR FUEL EFFICIENCY

The content and timing of the initially approved ACEE Program is shown here. There were six separate efforts started and all but one were planned with future phases that were to be dependent on the outcome of the earlier efforts. Thus, the program plan was inherently dynamic and changes were indeed made as the preceding effort and external events dictated.

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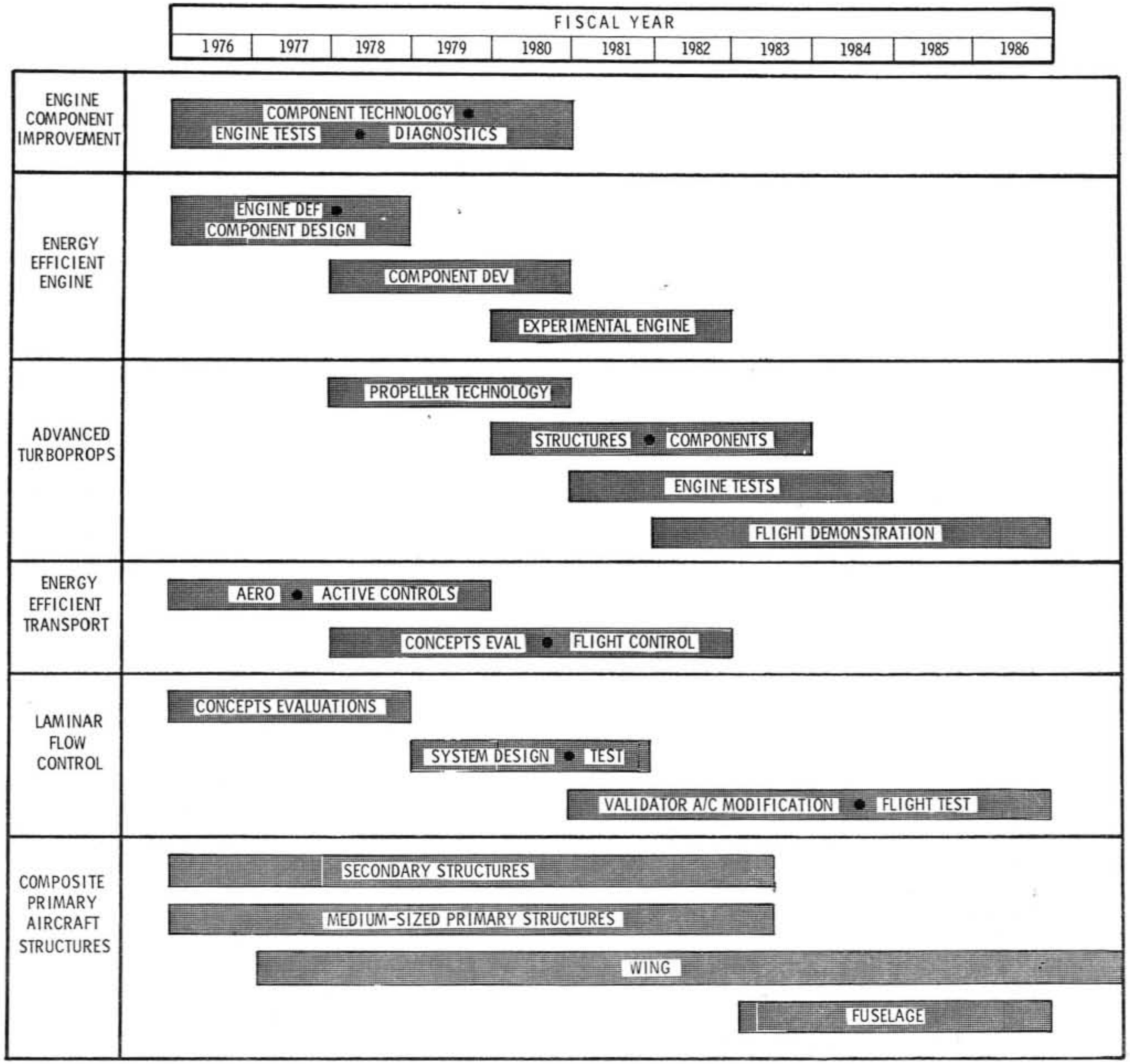
ACEE

INITIALLY APPROVED PROGRAM

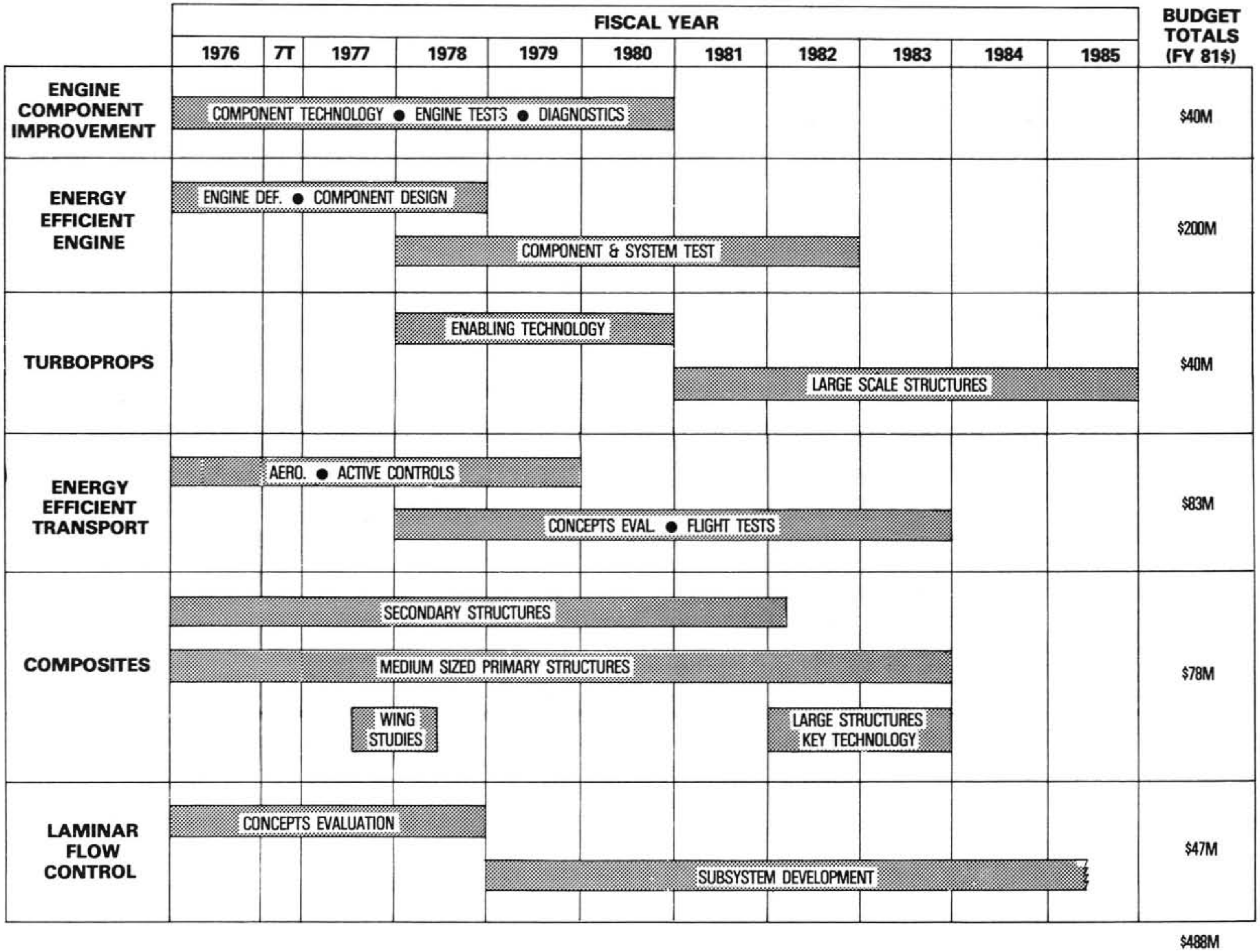


The actual timing and funding of all of the six separate programs now comprising the ACEE effort is shown here. The dollar totals on the right include budgets for the next four years in terms of FY-81 dollars. The program total is almost a half-billion dollars even without major add-ons.

The top three programs are the engine programs being implemented by NASA's Lewis Research Center. The Engine Component Improvement program is essentially complete, having developed selected improved components in current engine designs and, with diagnostic testing, identified causes of short and long term engine performance deterioration. The Energy Efficient Engine Program is also nearing completion with just one funding year left. Here, two new designs are being taken to ground tests of prototype engines. The Advanced Turboprop Program is just beginning its second phase which includes ground test of large scale prop-fan structures.

The first of three ACEE airframe programs is the Energy Efficiency Transport (EET) Program that embodies selected advances in active controls and aerodynamics and is nearly complete. The second airframe effort is the Composite Primary Aircraft Structures (CPAS) Program, where secondary structures development and wing studies are complete, medium primary structures development is nearly complete, and a "large structures key technology effort" is just beginning. And the final ACEE effort, well into its subsystem - development phase, is demonstration of the commercial viability of Laminar Flow Control.

AIRCRAFT ENERGY EFFICIENCY PROGRAM



Some of the selected advances in active controls and wing aerodynamics that are part of the Energy Efficient Transport program are indicated here. Early efforts in this program led to introduction over a year ago of an active system for maneuver and gust-load control on the L-1011-500 to permit a 9-foot wing span extension. In operation, this combination has so-far consistently produced more than the expected three percent fuel savings. The more recent EET active controls efforts have been directed toward relaxed static stability. The EET aerodynamics efforts have filled critical gaps in NASA wind tunnel research on high-aspect-ratio super-critical wing configurations and taken winglet development beyond the wind tunnel.

ADVANCED TECHNOLOGY FEATURES

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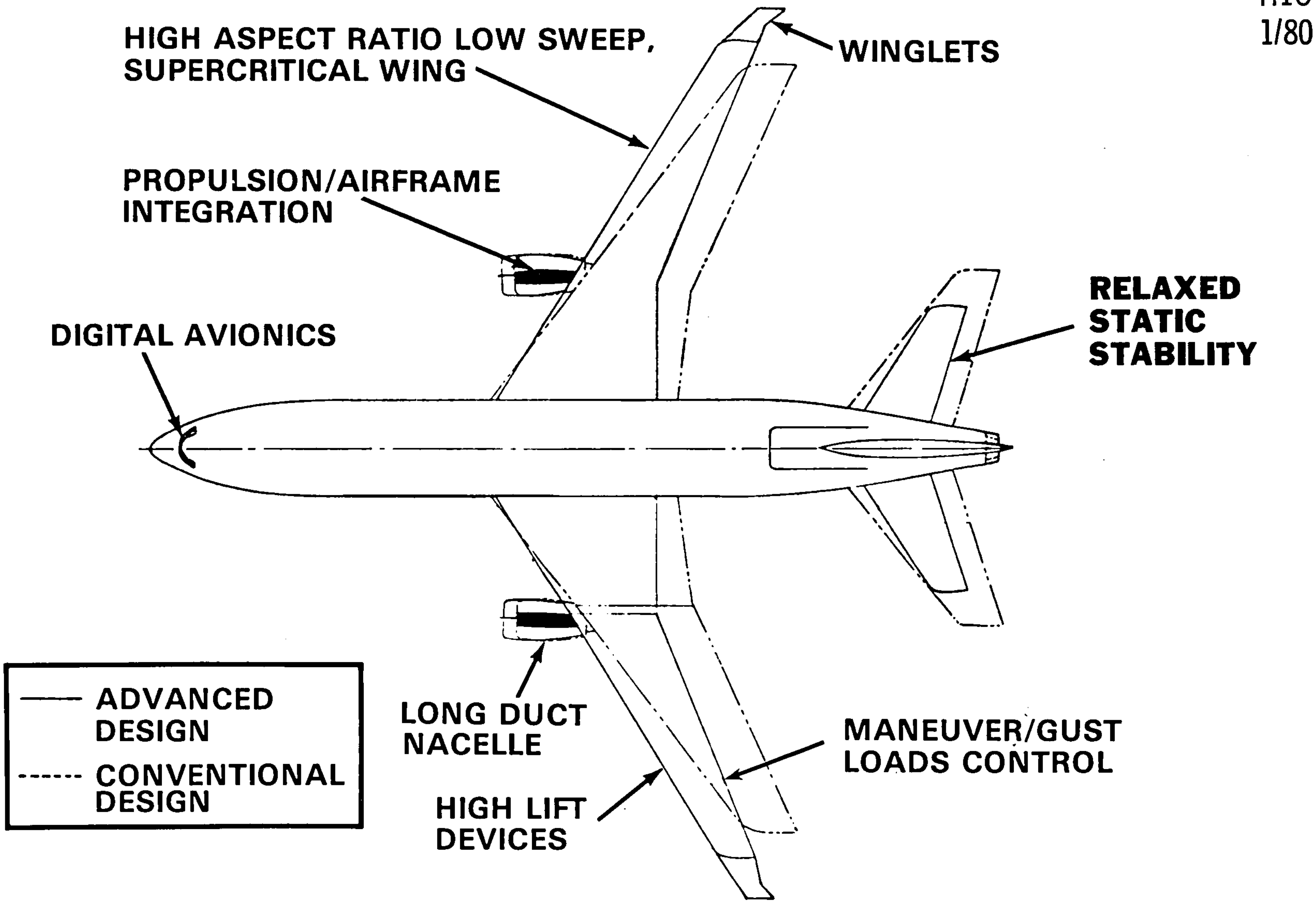
1/80



In fact, the EET program funded flight tests of winglets on the Air Force's KC-135 indicating potential fuel savings of 7%.

KC-135 WINGLET FLIGHT DEMONSTRATION

H2C2
3/80

And EET flight tests of winglets on the Douglas DC-10 show a desirable fuel savings benefit potential on this aircraft, but also the need for some design changes.

FLIGHT TEST OF DC-10 WITH WINGLETS

H6E5
10/81

The ACEE CPAS effort on secondary structures has involved development of selected composite control surfaces--the upper aft rudder on Douglas DC-10, inboard ailerons for the Lockheed L-1011, and elevators for Boeing's 727. These secondary structures efforts now involve only flight service for maintenance evaluation and have already spurred commitment of the control surfaces on two new transports to all-composite construction.

The CPAS Program's development of "medium primary" tail-surface structures includes development of composite vertical stabilizers for the Douglas DC-10 and Lockheed L-1011 and a composite horizontal stabilizer for Boeing's 737. A number of these structures have been fabricated and full-scale tests are well underway. While this effort appears to have prepared the industry to use composites in corresponding new-airplane structure, preparation for wing and fuselage applications has barely begun with small CPAS contracts to close selected key design-technology gaps. The CPAS Program plan includes a proposed composite-wing-structure development phase, beginning in 1983.

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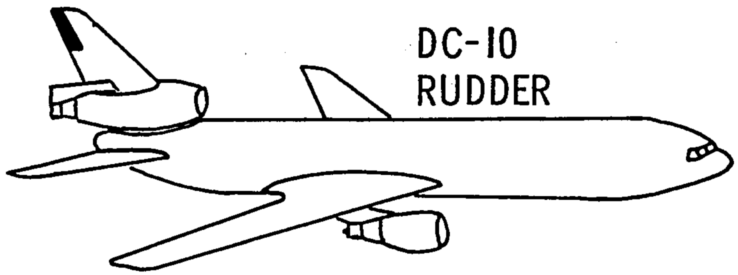
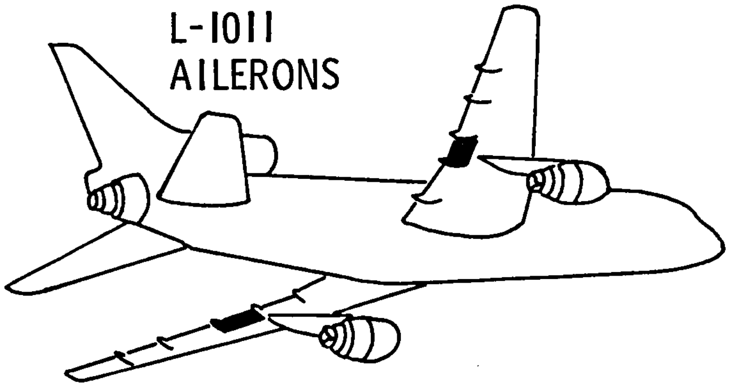
A C E E COMPOSITE COMPONENTS

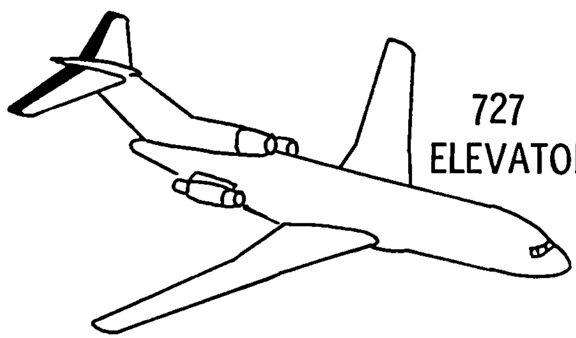
SECONDARY STRUCTURES



DC-10
RUDDER

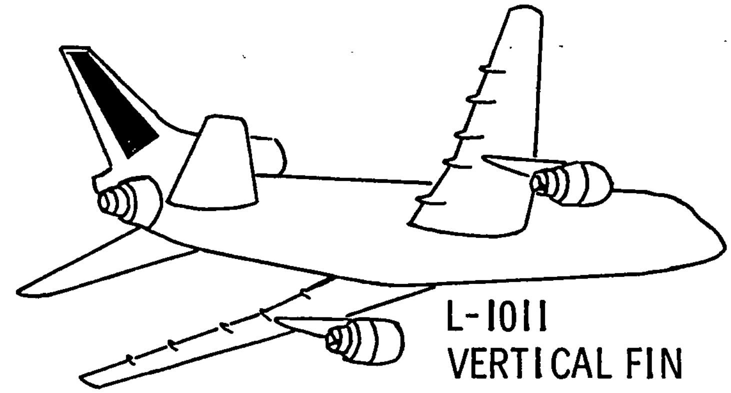


L-1011
AILERONS

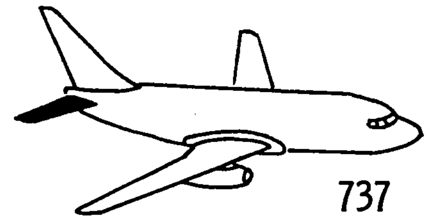


727
ELEVATORS

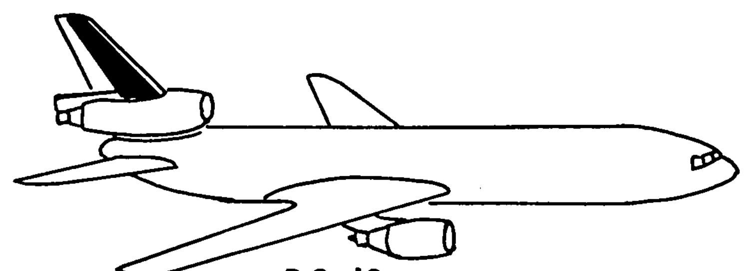
PRIMARY STRUCTURES



L-1011
VERTICAL FIN



737
HORIZONTAL TAIL



DC-10
VERTICAL FIN

Finally, the ACEE Laminar Flow Control (LFC) Program now involves major wind tunnel and flight tests to evaluate potentially practical systems for maintaining the surface "boundary layer" of air over the wings in a smooth, laminar state through suction. This program includes a planned third, integrated-system-flight-test phase to demonstrate readiness of this technology for industry exploitation.

WHAT IS LAMINAR FLOW CONTROL ?

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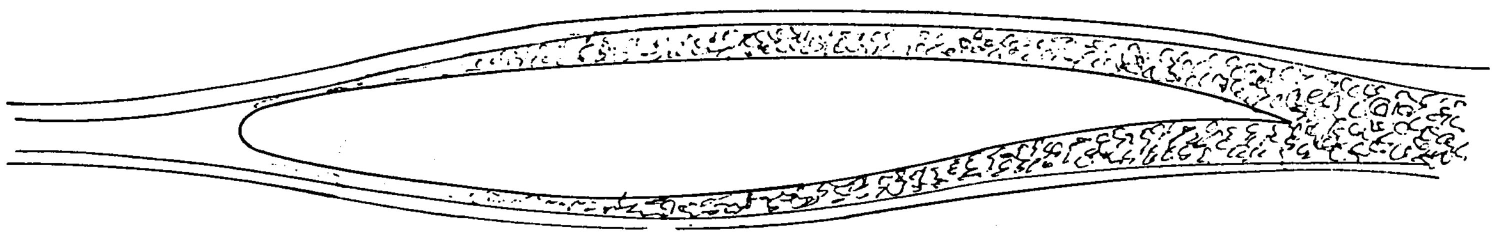
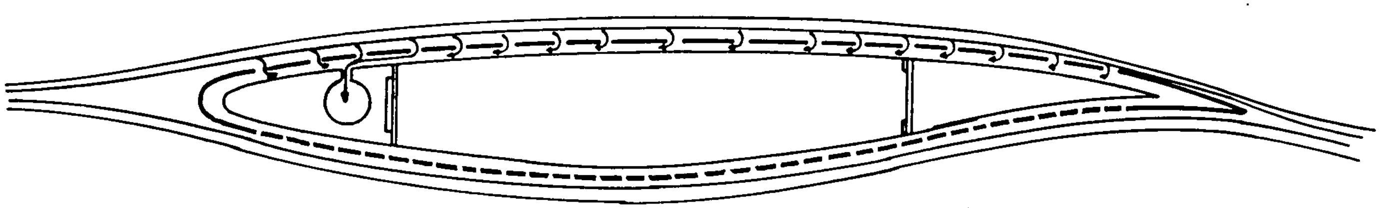
- **NORMAL SURFACE LAYER**



THICK AND TURBULENT WITH HIGH DRAG

- **SUCTION - STABILIZED SURFACE LAYER**



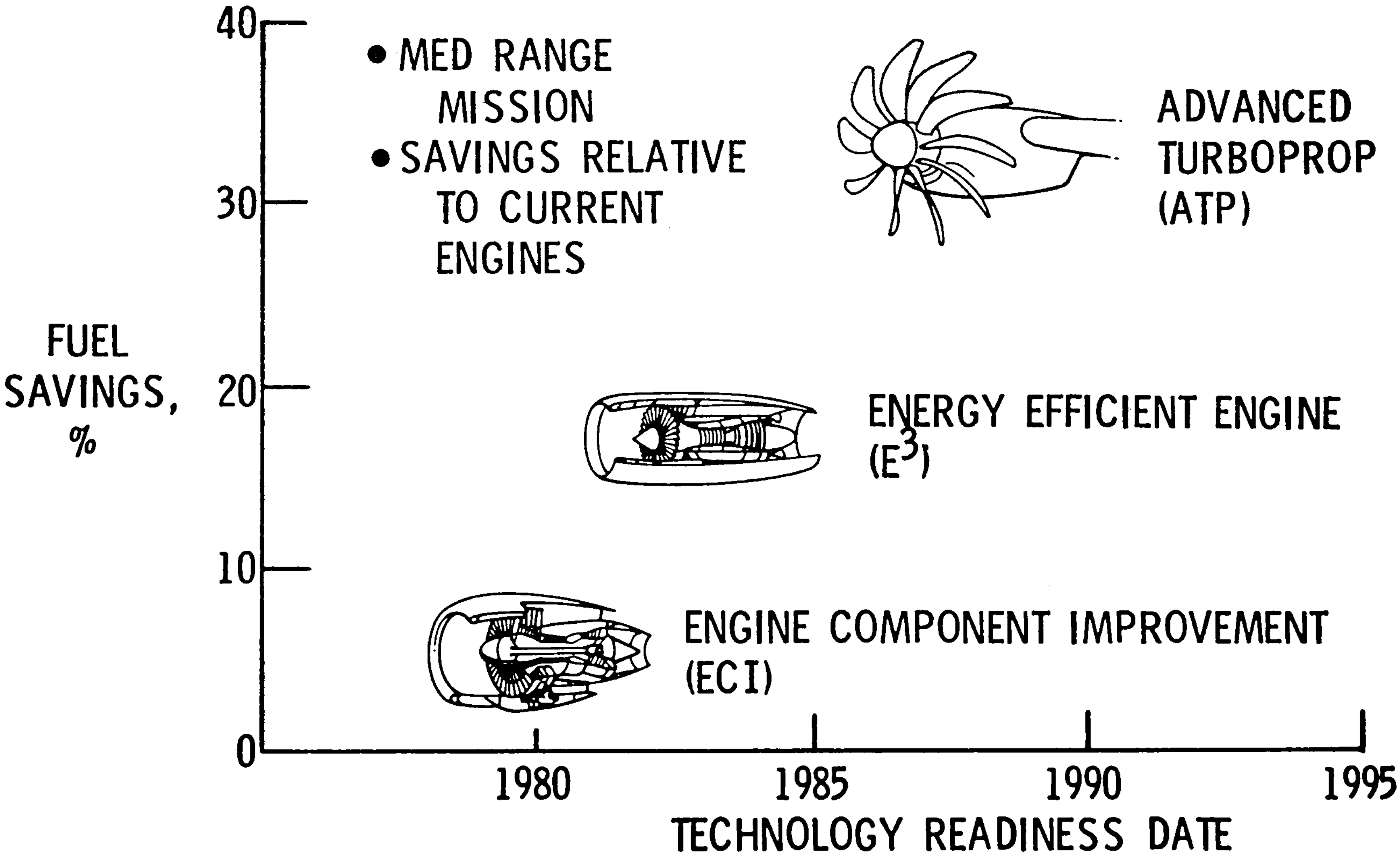
THIN AND LAMINAR WITH LOW DRAG

- **BENEFIT: MINIMUM 20% FUEL SAVING OVER FUTURE TURBULENT TRANSPORTS**

The current outlook for benefits and technology readiness of the three ACEE Engine Programs is shown here. Engine component improvements, developed in the ECI program are already being incorporated into new production copies of three current engine designs and the projected 5% fuel-savings benefit will apparently be achieved. Energy Efficient Engine technology readiness for development is projected at about 1984 with expected fuel savings in the 15-20 percent range. Advanced Turboprop technology readiness is expected late this decade with projected fuel savings over current transports now in the 30-40 percent range. Achieving this is dependent on NASA implementation of a third demonstration phase of this project.

ACEE PROPULSION PROJECTS

PROJECTED FUEL SAVINGS & TECHNOLOGY READINESS DATES



The current outlook for benefit potential from ACEE airframe technologies is summarized here. The EET and CPAS programs have already assured applications of active wing load alleviation and composite secondary structure for about five percent fuel savings potential. By the end of this decade, it appears the industry will be ready with advanced supercritical wings, winglets, active stability augmentation, and composite primary structure, including wing structure if the CPAS plan is implemented, for total savings in the 20 percent range. And by the late 1990's, Laminar Flow Control readiness will bring with it fuel savings potential over current aircraft of 40 percent or more.

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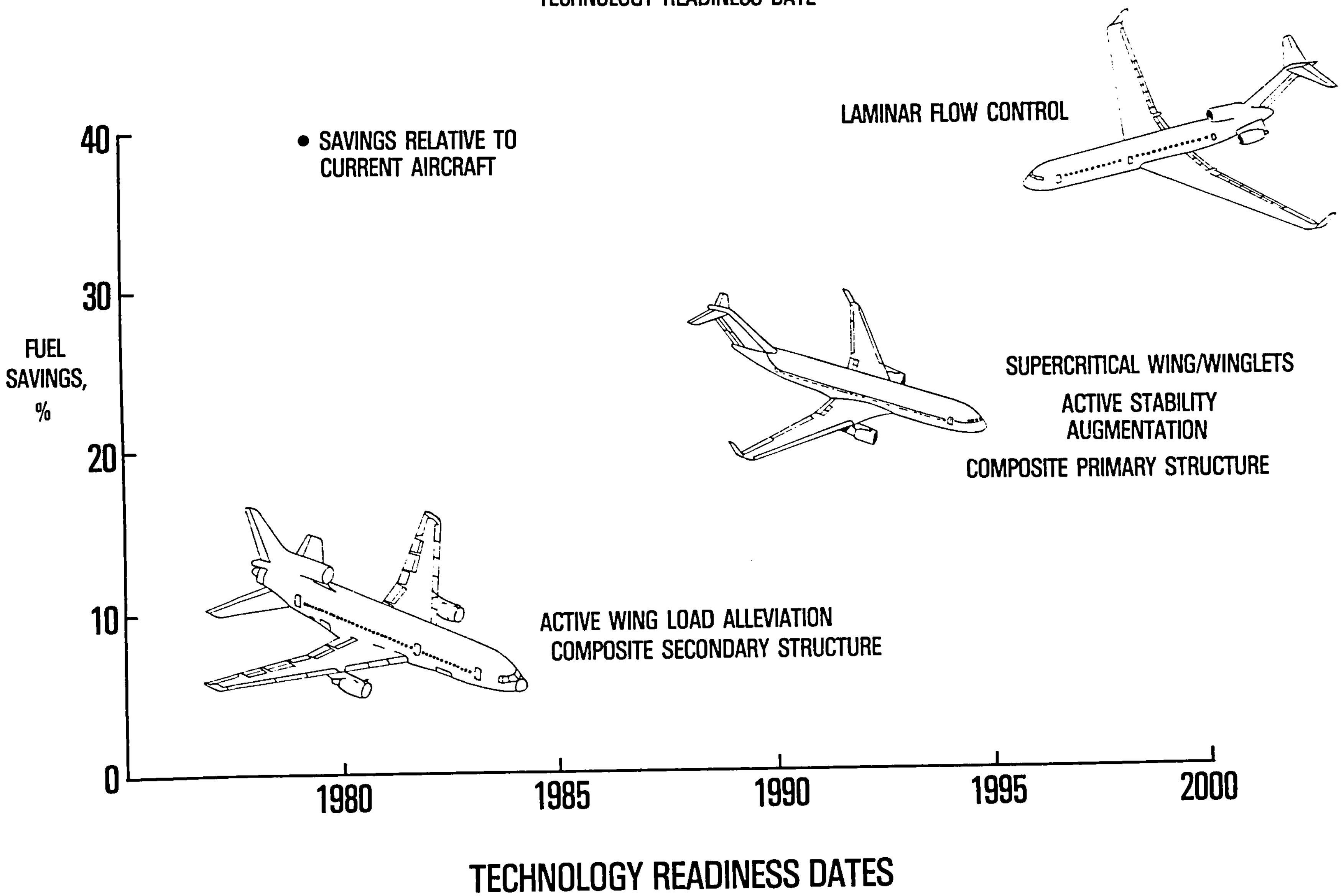
ACEE AIRFRAME TECHNOLOGIES

PROJECTED FUEL SAVINGS &
TECHNOLOGY READINESS DATE



CONCLUDING REMARKS

It must be emphasized that the benefit potentials and technology readiness dates projected here depend on completion of the ongoing and planned ACEE efforts on schedule. The realization of fuel saving benefits from ACEE Program technologies depends also on the rate and manner in which they can be implemented by the air transport industry after technology readiness is achieved. Their implementation will clearly be as rapid as the industry's market opportunities and economics will allow. The benefit from their combined implementation on a single new aircraft would not be the sum of the benefit potentials cited above but could easily exceed the 50% potential that was cited when the ACEE Program was initiated.

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**Deputy Director, NASA Langley Research Center
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16. Abstract

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