Walt Lounsbery

AERODYNAMIC TECHNOLOGY ORIENTATION HANDBOOK

"We are embarked as pioneers upon a new science and industry in which our products are so unusual that it behooves no one to dismiss any novel idea with the statement that 'It can't be done.' Our job is to keep everlastingly at research and experiment . . to let no improvement in flying equipment pass us by."

William E. Boeing

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  "HOW DECISIONS ARE MADE:
  MAJOR CONDSIDERATIONS FOR AIRCRAFT PROGRAMS"

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INTRODUCTION

As a new member of Aerodynamic Technology you probably have many questions about the organization. If you are just beginning your career with Boeing you may have many general questions, too. You are probably finding that information is all around you; a little bit here, a little bit there. This handbook is meant to be a source of information with many useful "bits" contained under one cover.

You may find yourself wondering what goes on outside your immediate group. Each day you work hard supporting your group's activities, learning the important details of the job. But what about those other groups you've heard of: Performance, Configuration, Stability & Control, Research & Development and the Wind Tunnel? This handbook will give you a brief overview of each of these groups, describing their functions and responsibilities. To appreciate the role that Aerodynamic Technology plays in the development and support of the Company's products it is important to understand these functions.

PRODUCT DESCRIPTION

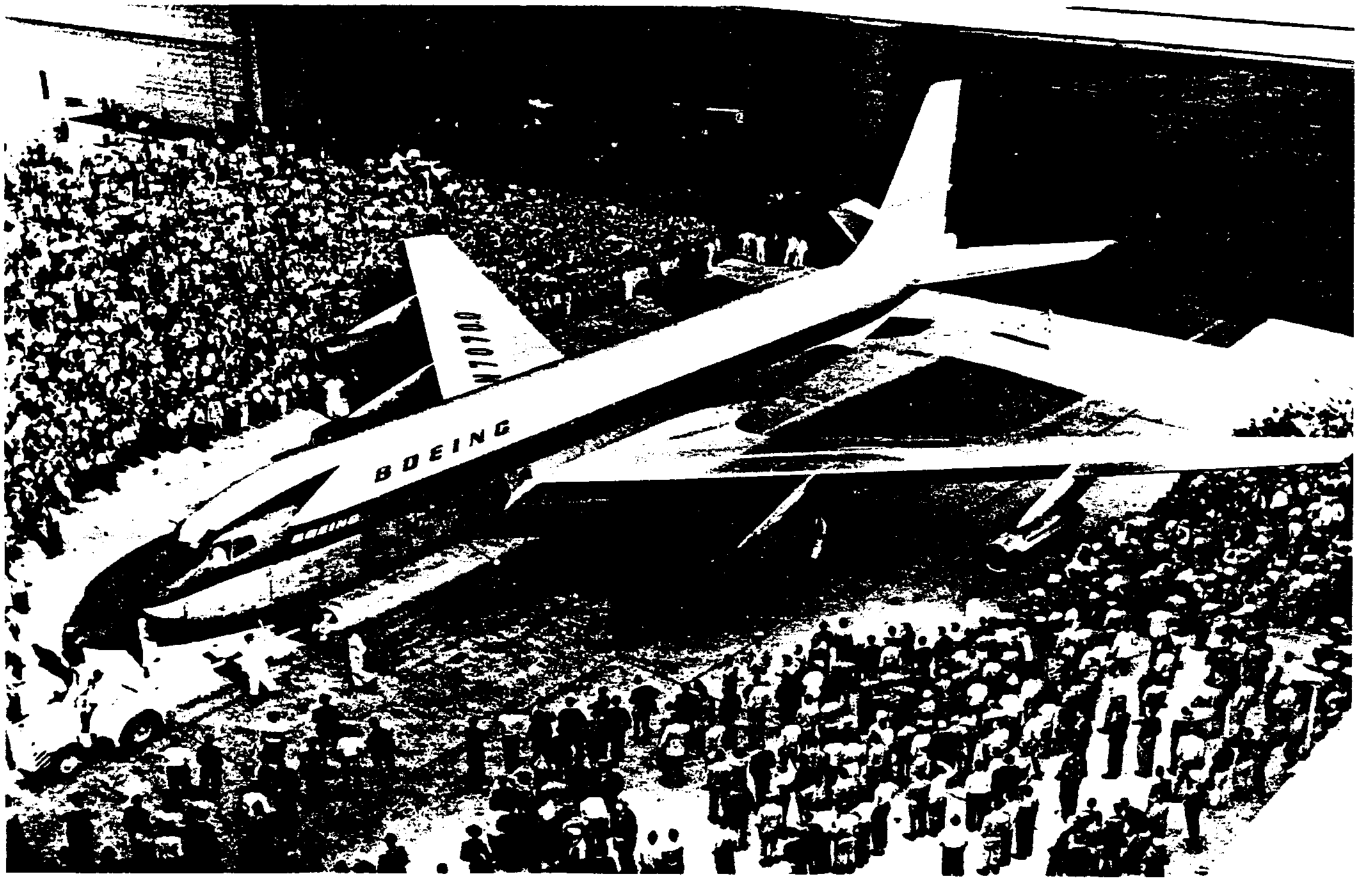
Boeing realized in 1949 that major advances in transport airplane performance could result only from replacement of the traditional piston engines with gas turbine jet engines. In August 1952, Boeing announced that it was investing $16 million of its own funds to build the prototype of an entirely new jet-powered transport.

MODEL 367-80

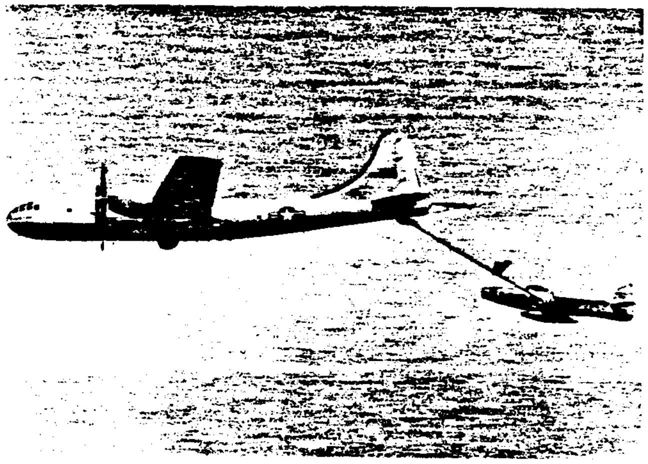
Although the production version of the new jet was to be called 707, the prototype was designated 367-80, both as a camouflage in the interest of secrecy and because many of the early design studies had evolved from advanced versions of the C-97 (the 367). This resulted in two names being applied simultaneously to the same airplane: "dash eighty" by technicians and "707" by sales personnel and the public.

The American jet transport era began when the 367-80 lifted off the Renton airport runway at exactly 14 minutes and 47 seconds past 2 p.m. on July 15, 1954. The 707 made a regal descent on Boeing Field a little past 3:30 p.m. America has been experiencing the jet age ever since.

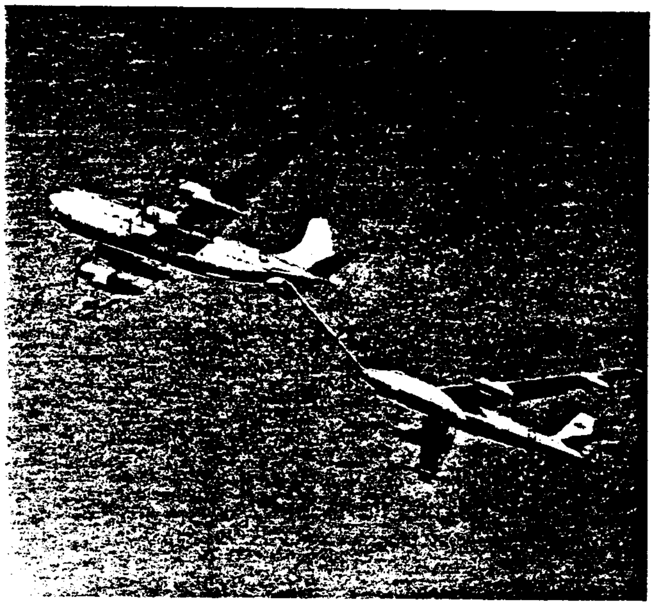
During its long, active history, the 367-80 became what is probably the most modified airplane ever. It underwent many major aerodynamic and structural changes in developing and testing jet transport improvements. From this, advanced features of later Boeing jets were flight tested and proved before commitment to the new aircraft. The "dash eighty" was donated to the Smithsonian Institution on May 26, 1972. It is displayed as one of the "12 most significant aircraft of all time."



People Who Helped Make the 707 Prototype Watched Rollout in July 1954



KB-29P



KC-97G

MODELS KC-135 AND C-135

The 367-80 was built to demonstrate both commercial and military capabilities. The KC-135A was a logical outgrowth of the basic 707 design, and was given the company designation 717.

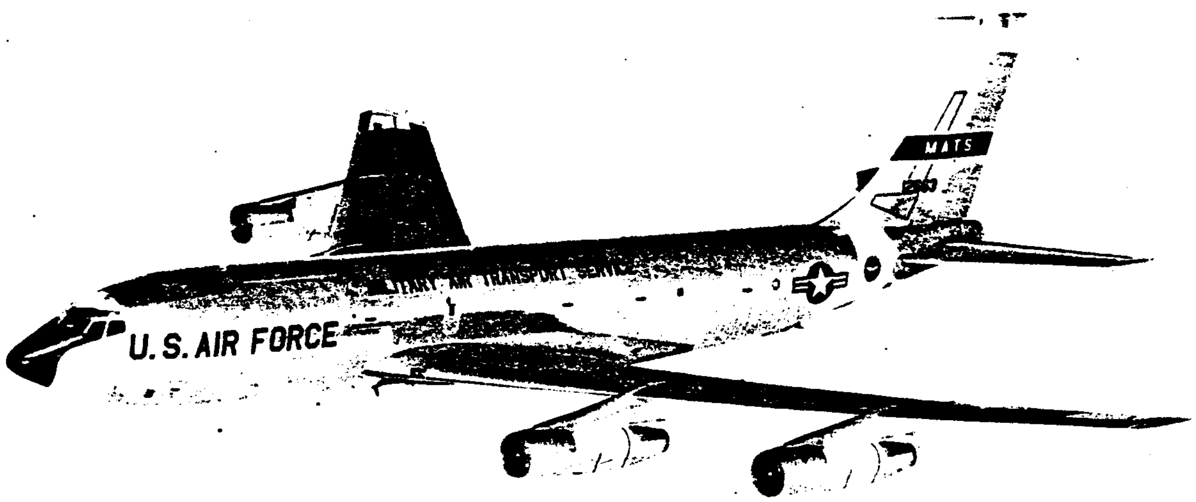
Aerial refueling as a means of extending the range of the bombers and fighters began with Boeing conversion of 72 B-29s to flying tankers with a single large fuel tank filling each bomb bay. These aircraft were designated KB-29M. Later 116 B-29s were modified at Renton as KB-29P flying boom tankers.

Of 50 C-97As built for the Military Air Transport Service (MATS), three were modified as KC-97A flying boom tankers. Eventually, 592 KC-97Gs were built. These could be distinguished by the addition of 700-gal. B-50-type external underwing fuel tanks.

As a follow-on to the successful KC-97 series tanker-transports, the new KC-135 jet was ordered into limited production in July 1954. The KC-135A stratotanker is similar in design and overall size to the 707 prototype but has only a single large cargo door, instead of two. Fuel tanks are located in the lower lobe of the two-deck body and in the wings.

After delivery of several hundred KC-135As to the Strategic Air Command (SAC), the airplane was also ordered by MATS in 1961, as the C-135A and C-135B, to reequip its logistic transport fleet.

Except for a larger 707-type vertical tail and elimination of the aerial refueling capability, the C-135As are almost identical to their SAC counterparts. The C-135Bs have advanced turbofan engines, similar to those powering "B" model 707s and 720s, giving the military transport much greater performance capabilities.



C-135A

KC-135R

The KC-135R, with its new, fuel-efficient, and quieter CFM56 engines, is providing a needed boost to the American tanker fleet. Two reengined KC-135Rs can do the work of three KC-135As. Boeing Military Airplane Company in Wichita, Kansas, is the prime contractor for the program. The CFM56 engine is manufactured by CFM International, a company jointly owned by SNECMA, of France, and General Electric of the United States.

MODELS 707 AND VC-137

The production 707 emerged with basically the same lines as the 367-80. But it was larger and had a greater gross weight.

707-120

The 707-120s inaugurated U.S. transcontinental services on January 25, 1959. American Airlines flew the Los Angeles to New York route at a record-breaking pace. The 707-120B has turbofan engines and a range of 3500 miles. The earlier 707 models have turbojet engines and a 500-mi lesser range.

707-220

The 707-220 has the same dimensions as the standard model but is equipped with more powerful turbojet JT4A-3 engines to provide increased performance.

VC-137

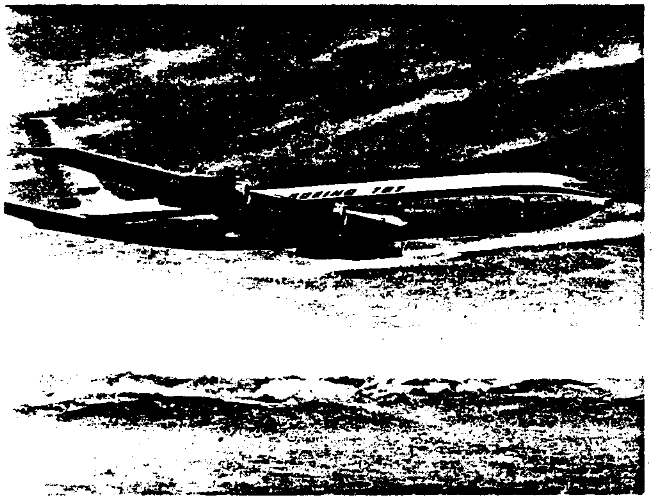
The Military Air Transport Service ordered three 707-120s under the designation VC-137A. Built to commercial specifications, the interiors were modified to provide special compartments, communication equipment, and other fittings for their worldwide missions of state.

The designation VC-137B was assigned to VC-137s reequipped with turbofan engines.

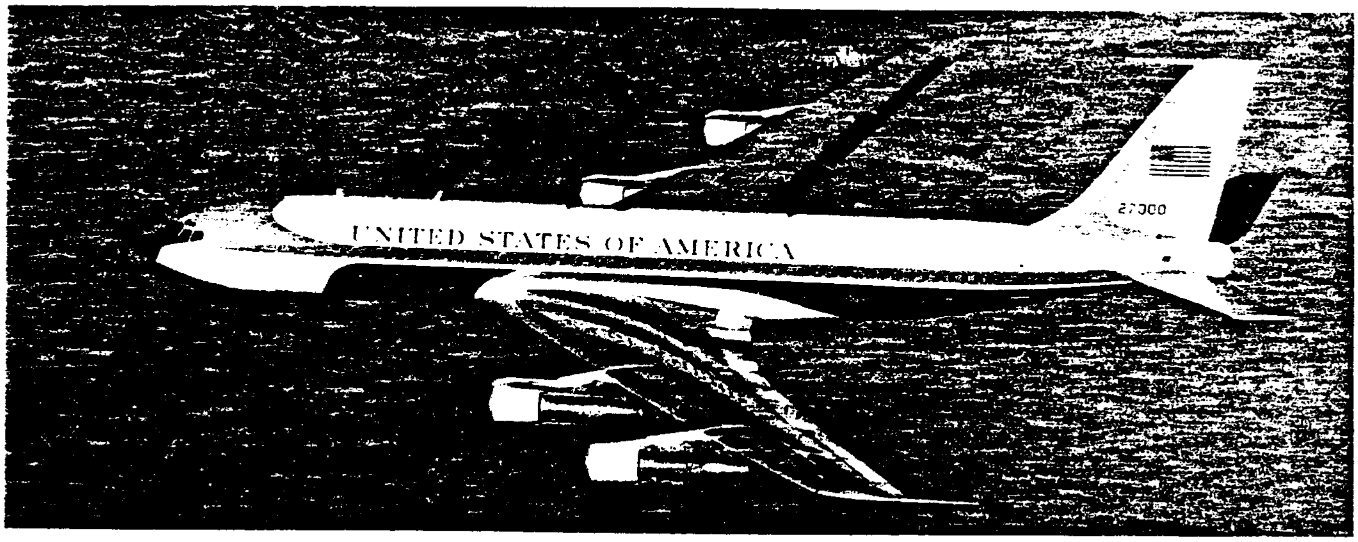
707-320, VC-137C, and 707-420

The largest members of the 707 family are the "intercontinentals"—long-range transports capable of carrying as many as 189 passengers. A large wing, longer body, and the use of Pratt & Whitney JT4 (in the -320) or the Rolls-Royce Conway (in the -420) are major differences over the first 707s. The latest airplane in this model series is the 707-320C.

One 707-320B, fitted with additional communication equipment, increased electrical capacity, and special interior arrangements and furnishings, was delivered to the Special Air Missions Squadron of MATS as VC-137C.



707-120



VC-137C

720

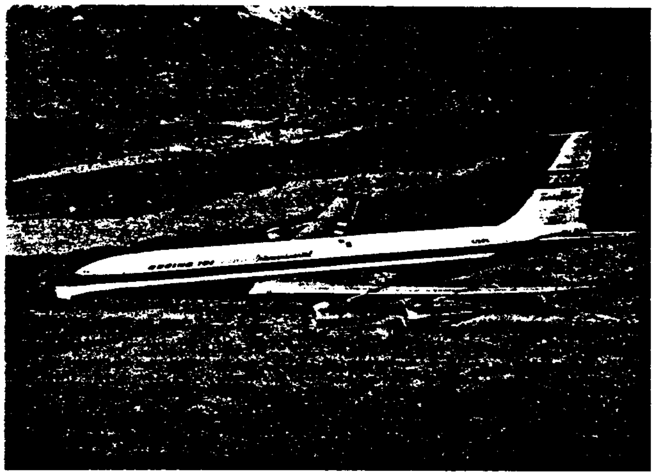
The next development of the basic 707 was the lighter weight 720, designed specifically for short air routes of the world. First of the 720s went into service in July 1960.

The change to P&W JT3D turbofan engines resulted in the 720B in October 1960. Outwardly, the 720B appears like the standard 720 except for larger nacelles to house the 41% more powerful engines.

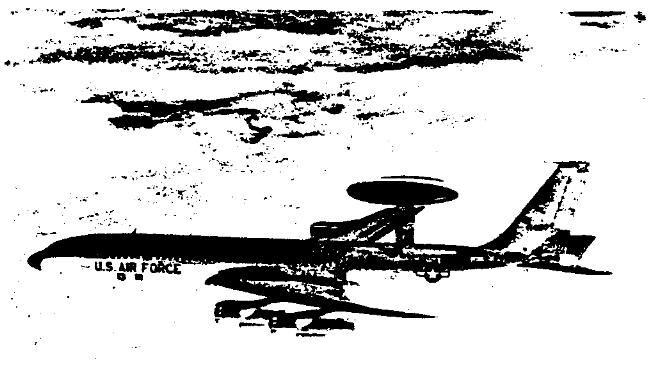
E-3A

The E-3A aircraft has a modified Boeing 707-320B commercial airframe. A large, rotating radome houses its radar, identification friend or foe (IFF), and data link fighter-control (TADIL-C) antennas. The standard turbofan engines have been replaced with more powerful Pratt & Whitney TF-33 turbofans. Boeing received an Air Force contract in July 1970 to develop and flight test the aircraft. Flight tests were conducted in 1972.

720B



707 Intercontinental



E-3A

MODEL 727

Boeing developed the three-jet 727 as a departure from the basic four-engine design adhered to since the 367-80 of 1954. The 727 grew out of studies made of market possibilities of a short-range jet to replace the many piston and turboprop airplanes in service. The rear mounting for the three engines was logical for safety, economy, and performance.

Some 68 different designs and more than 4500 hours of wind tunnel testing preceded the final 727 design. On November 27, 1962, the first 727 rolled out of the Renton factory.

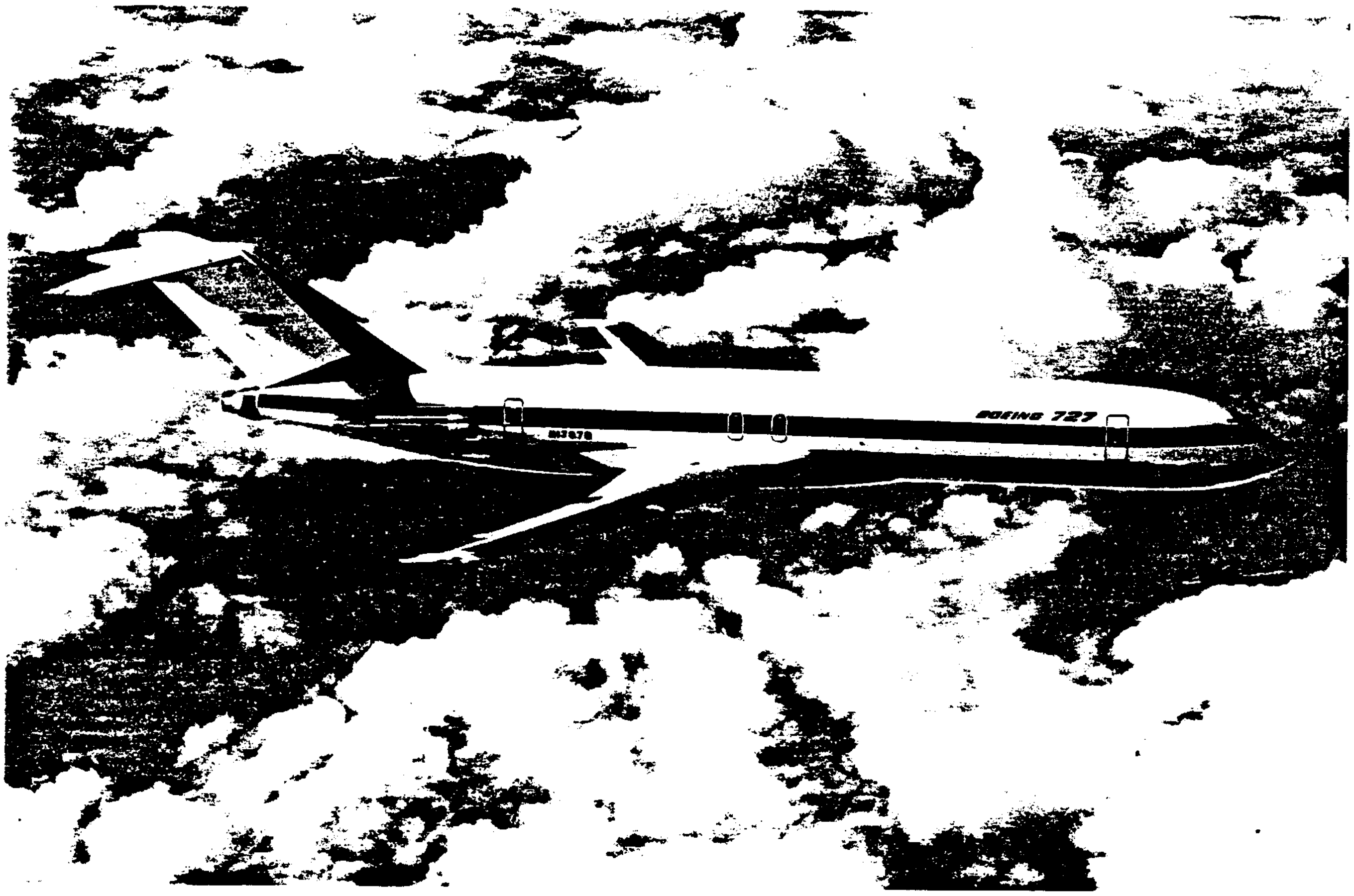
Equipped with P&W JT8D turbofan engines with Boeing-designed thrust reversers, the 727 is easily capable of operation from 5000-ft runways. Design range is from 1500 to more than 2500 miles.

The development of the 727 series has resulted in numerous versions. The 727C in all-cargo or combination arrangement opens the way to high-volume freight operations in many new markets. The 727QC (for quick change) conversion system is a revolutionary development in airplane productivity. The interior can be altered quickly to fit specific needs for passenger-cargo combinations.

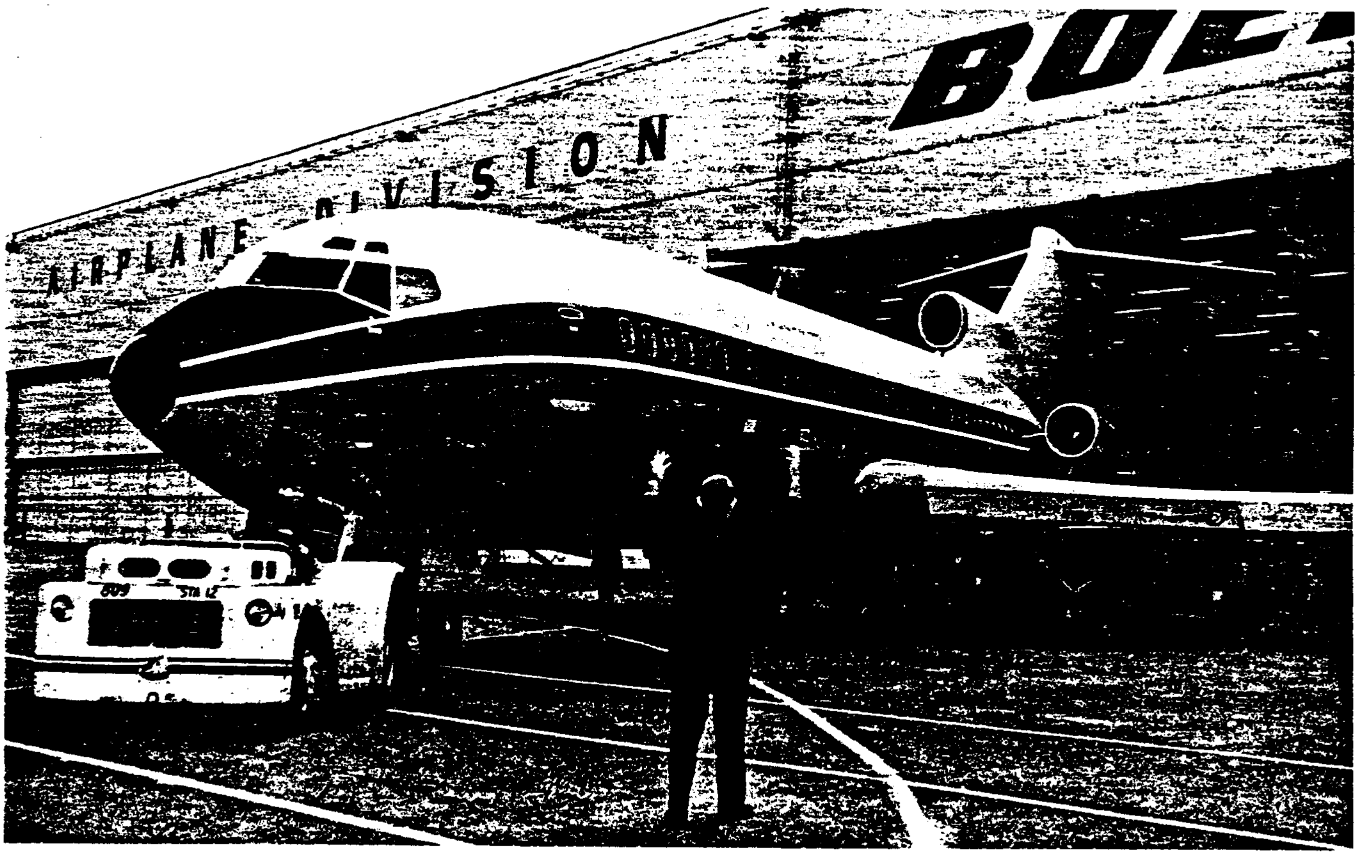
727s Awaiting Delivery

727-200

By extending the cabin length 20 feet, the 727-200 accommodates up to seven additional rows of seats. The 160-passenger 727-200 provides 41 more seats than the standard 727 with similar seating.



727



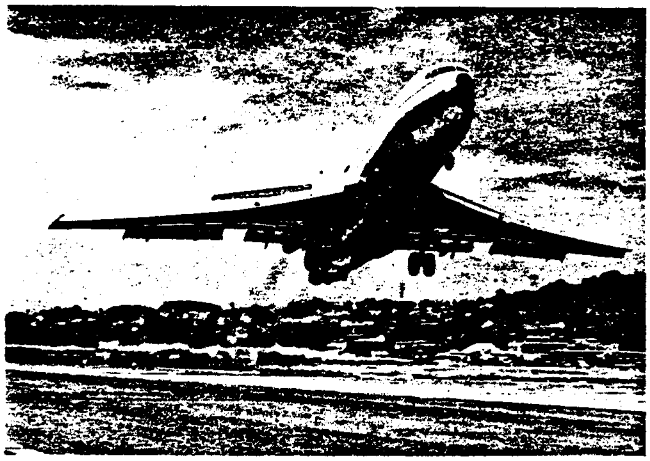
727C

Structural improvements, more powerful engines, and greater fuel capacity led to the introduction of the Advanced 727 in May 1971. The advanced trijet offered improved payload and range capability, better performance from given runway lengths, and a completely restyled interior as standard equipment. With optional fuel cells, range was increased by 800 miles over that of the standard 727-200 with typical payload.

The new-interior program deserves special mention. With no change in body cross section and the installation of all-new sidewall and ceiling panels, a roomier passenger cabin has been created that compares favorably in its "feeling of spaciousness" with the wide-body aircraft. The old hatrack has been replaced by enclosed stowage compartments blended into the overhead panels. Access to window seats is greatly improved. Indirect fluorescent lights and white interior panels make for a brighter cabin interior.

Lufthansa and Air Algerie put 727s with the new interior into service in April 1971. Passenger response was enthusiastic, and Boeing offered the interior in retrofit kit form for all 727s, then 737s, and finally for 707s. By November 1972, it was standard equipment on all current production aircraft.

Later performance improvements for the 727 included another gross weight boost, from a maximum 170,000 pounds to 191,000 pounds for the advanced version. On February 3, 1972, another increase—to 208,000 pounds—was announced, together with the purchase of three of the "heavyweights" by Sterling Airways of Denmark. Sterling has been operating the three Advanced 727s since December 1973.



727 Taking Off

MODEL 737

Members of the 737 series twin-engine jet transports have been designated 737-100, 737-200, 737-200C/QC, 737-300, 737-400, and 737-500 has been proposed. Deliveries of fully certificated 737s began in late 1967.

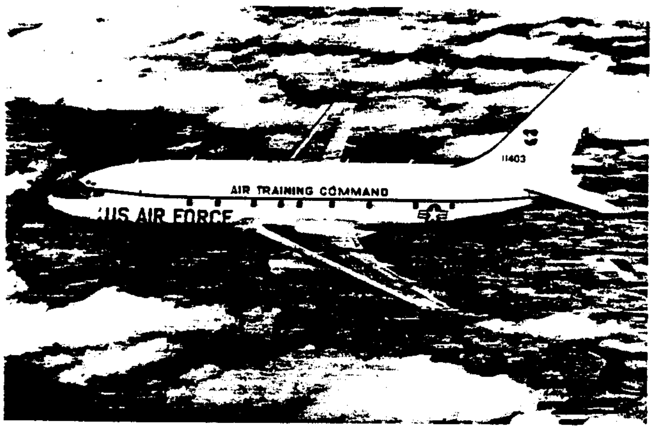
737-100

The 737-100 design draws heavily from its companion aircraft, the 727. Commonness between the two airplanes is apparent in the body structure and in identical doors, side panels, ceilings, seats, and engines. Components common to 727 and 737 powerplants include thrust reversers, basic nose cowl, starter, and valves. Commonness results in lower maintenance costs and reduced spares inventories for those airlines flying both planes.

737-200

The longer 737-200, in an all-tourist interior, carries 113 passengers and baggage 1050 miles. With a similar interior arrangement, the 737-100 carries 99 passengers and baggage 680 miles. Range of both aircraft is extended when optional takeoff weight is increased.

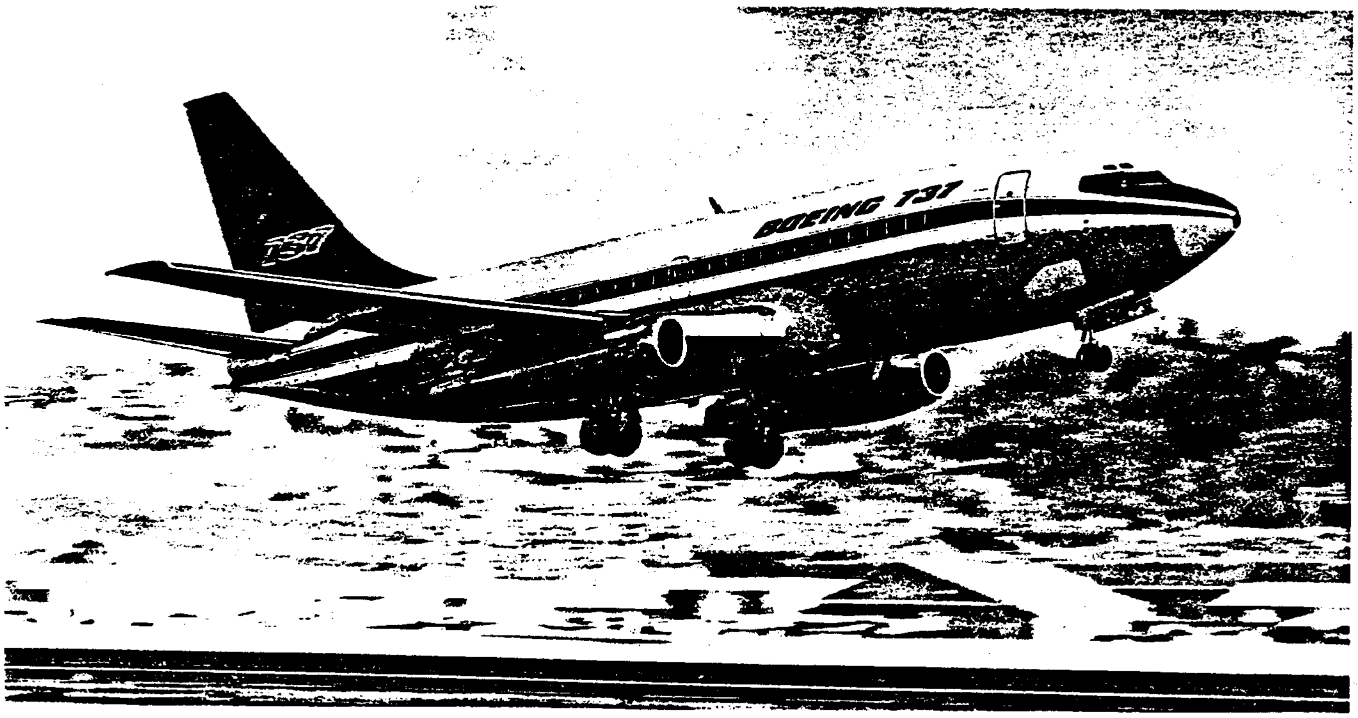
The first Advanced 737-200 was delivered to Japan's All Nippon Airways on May 20, 1971. Featuring improved aerodynamics, some changes to the high-lift devices, a new antiskid system, and fully automatic brakes, the advanced version has a 15% improvement in landing and takeoff performance over the standard 737-200. The aircraft can be stopped 500 feet shorter on a dry runway, for example, or 700 feet shorter on a wet field. Takeoff distances were shortened as much as 1150 feet with the use of more powerful engines. Airlines can profitably operate the 737 into runways as short as 4000 feet.



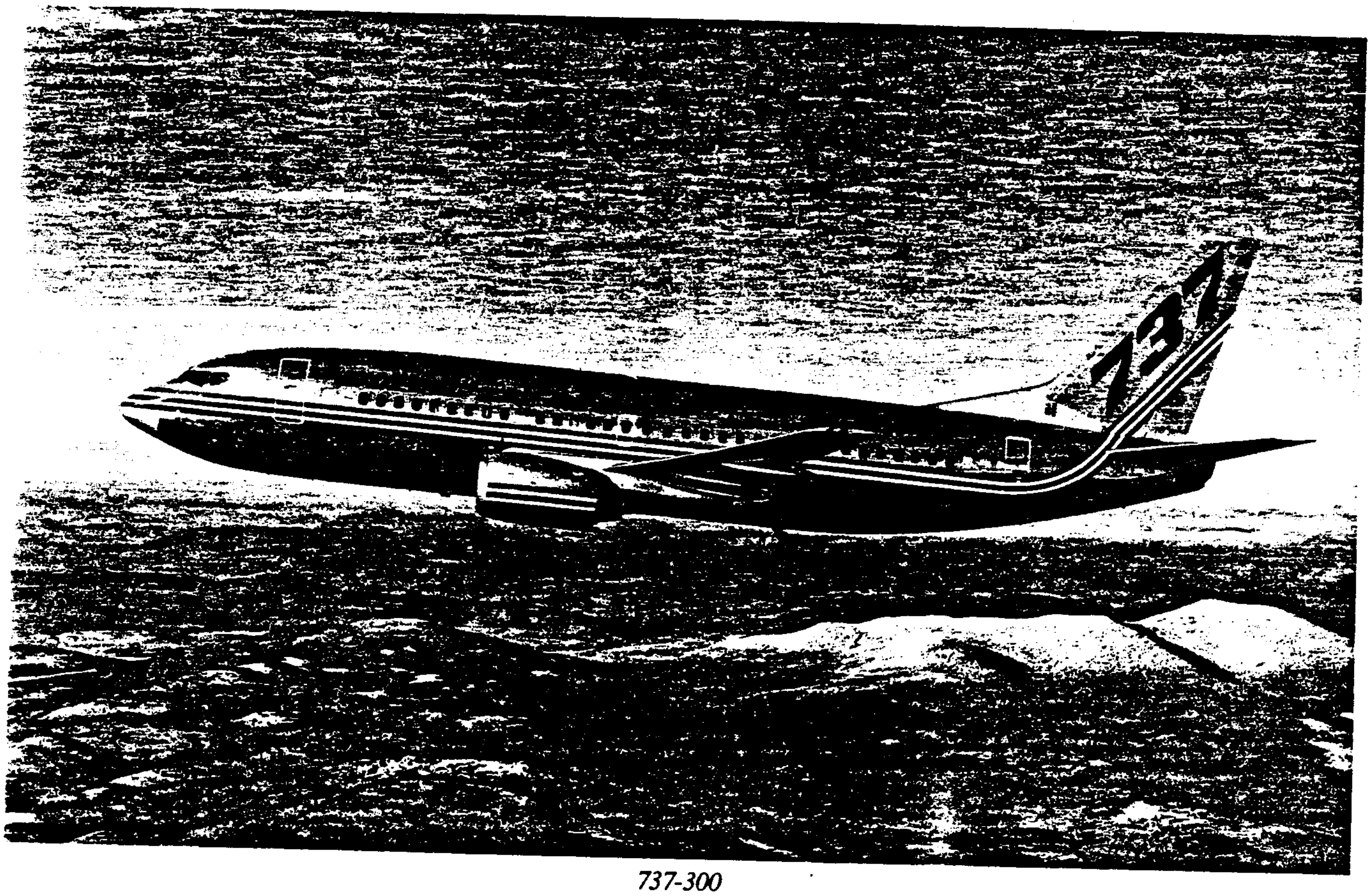
T-43A

T-43A NAVIGATION TRAINER

The U.S. Air Force uses 19 military derivatives of the 737-200 for undergraduate navigator training. These derivatives are designated T-43As, and they have been operational since mid-1973. The mission of the T-43A is to provide a realistic navigation training environment that will allow student navigators to make an easy transition to modern, high-performance jet aircraft. Each airplane has 19 navigation training stations designed to cover all types of navigation systems now in the Air Force inventory.



737



737-300

737-300

The next addition to the 737 family is the 737-300, designed to take advantage of the more efficient CFM56-3 turbofan engines and to carry more passengers than earlier 737s. The new airplane went into production at the Renton plant in March 1981, and the first airplane delivery took place in November 1984.

Design changes resulted in a lower direct operating cost and a 20% reduction in fuel burned per seat over the 737-200.

Visible differences from the standard 737-200 are the 104-in fuselage extension, giving the airplane an overall 9 foot 7 inch greater length, and the larger engines mounted forward of the wing on struts (737-100 and 737-200 engines are tucked up directly under the wing). The new 737-300 also has 6 feet of span added to the horizontal tail and small wingtip extensions.

Comparisons with interiors of the 737-200 show the following differences: in mixed-class service with a 38/34-in pitch ypical U.S. configuration), seating will increase from 100 to 120; for inclusive-tour charter operations (30-in pitch), the increase will be from 130 to 148 seats.

The flight deck reflects the latest technology digital instrumentation, even more advanced than that installed on Advanced 737-200s in 1981. Use of this equipment provides current 737 operators with substantial commonality benefits in equipment and training cost savings.

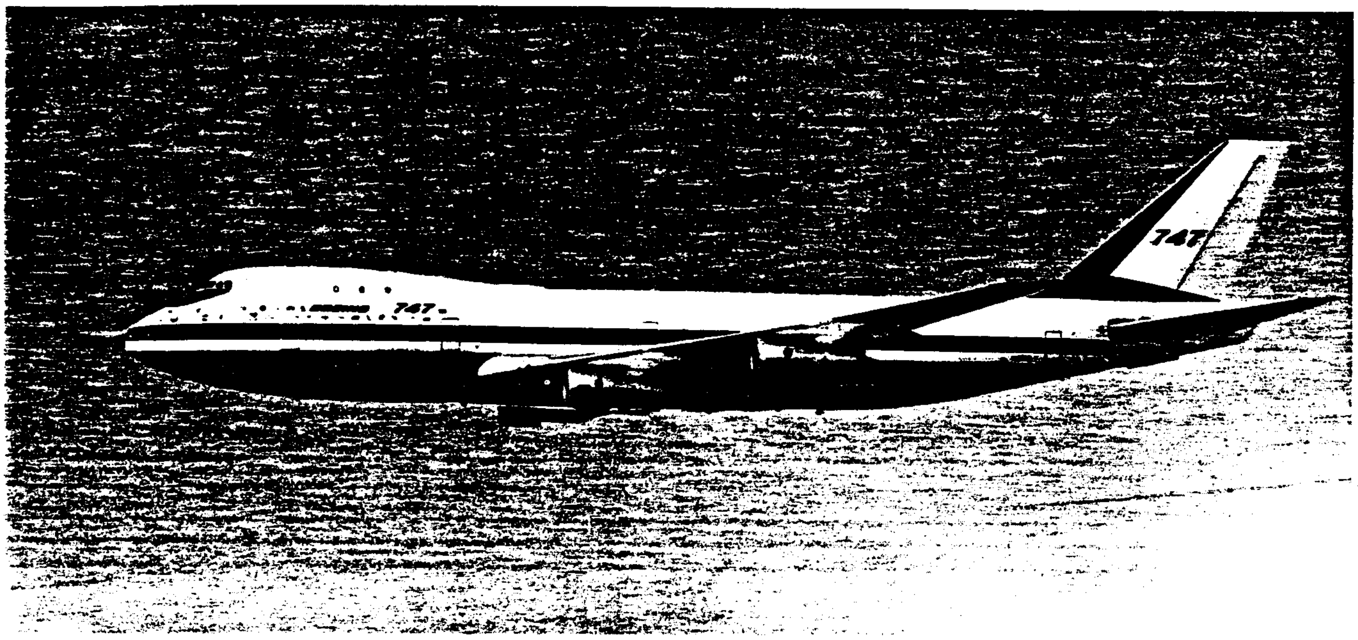
The 737-300, although having 80% commonality with the 737-200, is considered a new-generation airliner because of much greater use of composites inside and out as well as the new engines and avionics.

737-400

The 737-400 has much in common with the 737-300, including CFM56-3 engines, digital flight deck, systems, interiors, and flying characteristics.

The 737-400's fuselage is 9 feet 6 inches longer than the 737-300. This enables airlines to carry 18 more passengers on the 737-400 and still retains the same low fuel burn, low noise, and low operating costs as its popular predecessor.

Design changes from the 737-300 include the lengthened fuselage, strengthened wing and landing gear, more over-wing exits, added tail skid, and increased maximum design landing weight and zero-fuel weight.



747

MODEL 747 JUMBOJET

The 747 is the largest aircraft ever built for commercial use. First details of this transport, popularly known as the "jumbojet," were announced April 13, 1966, with the news that Pan American World Airways had placed an order for 25. The first 747 was rolled out on September 30, 1968. First flight was February 9, 1969, and the aircraft entered service January 21, 1970.

The first million passengers were carried by 747s within 6 months after entering commercial service. By the end of December 1977, deliveries totaled 313 to 46 leading world airlines, with sales at 351. Flight hours logged by that time had exceeded five million, and an estimated 185 million passengers has been carried.

Able to carry from 100 to 500 passengers profitably (average seating capacity is about 350 first-class and tourist), the 747 operates generally over ranges of 3000 to 6000 miles. A more advanced airplane than its predecessors in passenger comfort, roominess, and instrumentation, it is quieter and more stable. It stands 63 feet 5 inches high at the tail, has a wingspan of 195 feet 8 inches, and is 231 feet 4 inches long.

The 747 is the first triple-deck commercial airplane and the first since the Boeing Stratocruiser of the late 1940s and early 1950s with passenger accommodations on two decks. Passenger versions have a circular staircase leading to an upper-deck lounge behind the flight deck. The flight deck (or cockpit) is above the main deck so that in the cargo versions the nose of the airplane can swing up to permit straight-in loading.

The 747 comes in eight versions, seven of which have the same basic dimensions:

STANDARD 747

The standard 747 is a passenger plane with a 710,000-lb maximum takeoff weight and a growth version of 735,000-lb maximum takeoff weight.

747-200B

The 747-200B is a passenger plane with a 775,000-lb maximum takeoff weight and a growth version of 785,000-lb maximum takeoff weight.

747-200F

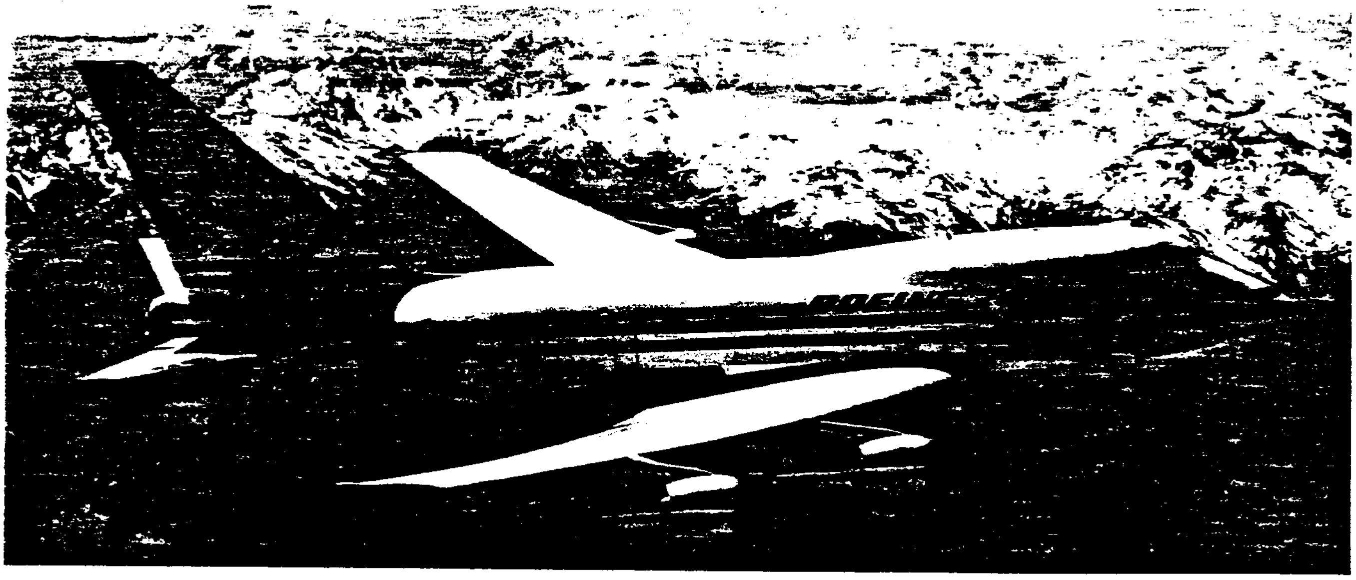
The 747-200F (freighter), which can carry 250,000 pounds of net payload, has a maximum takeoff weight the same as the 747-200B.

747-200C

The 747-200C is a convertible passenger-cargo airliner that can carry up to 500 passengers or 250,000 pounds of cargo or a combination of passengers and cargo. Its maximum gross weight is also the same as that of the 747-200B.

747-100B/SR

The 747-100B/SR, a short-range version designed specifically for high-capacity transports on routes as short as 200 miles, retains its long-range capability. The airplane,



747SP

with gross weight varying from 520.000 pounds from takeoff on short-range missions, to 735,000 pounds for long-range flights, retains identical flight characteristics with the earlier 747s. Components are 99% common in terms of airplane weight with the basic 747.

747SP

The 747SP (special performance) is 47 feet shorter overall than the other models. It was designed to fly higher, faster, and farther than any other wide-body airliner and to serve with excellent economy on the world's long-distance air routes when passenger traffic does not require airplanes as large as the other 747 models. The 747SP can carry 331 passengers nearly 6900 statute miles. The first SP was rolled out May 19, 1975, and flew on July 4. The type was certificated on February 4, 1976.

747-300

The 747-300 program was kicked off in the summer of 1980 and the first airplane was delivered in March 1983. This derivative incorporates a 280-in extension to the 747's upper deck. Besides changing the 747's upper deck profile, the extension also includes new exit doors, additional upper deck windows, and placement of the interior stairway in the aft section—rather than in the forward section—of the upper deck. The 747-300 is also available with Combi and SR (short range) options.

747-300

747-400

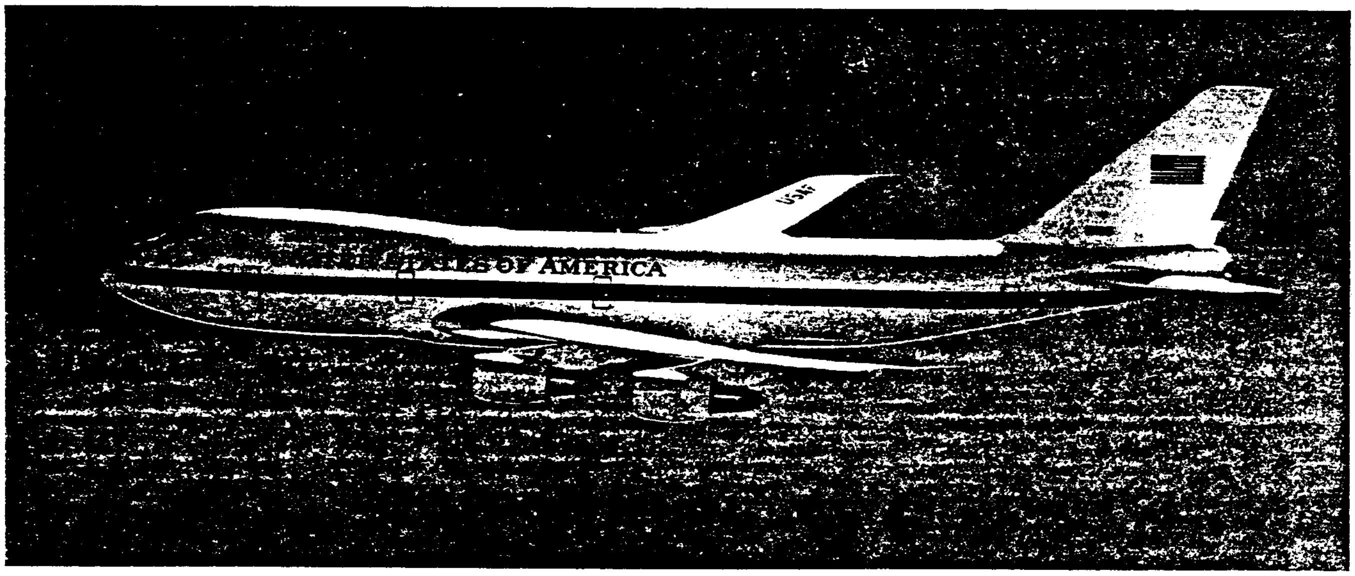
747-400

The 747-400 fuselage has the same dimensions as that of the 747-300. Its wingspan, however, has been increased to 211 feet with the incorporation of wingtip extensions and new winglets set at an angle to the horizontal surface of the main wing. Compared to the 747-300, the 747-400 has a new two-crew, digital flight deck, a new interior, increased range capability, better fuel economy, and the lowest operating costs per seat of any wide-body airplane.

Its 1000-mi range increase over the 747-300 extends the 747-400's capability beyond 7100 nautical miles (with a typical payload of 412 three-class passengers). The popular Combi option (freight carried on the main deck aft of all passengers) will also be available on the 747-400.

AIRBORNE COMMAND POST

Boeing modified the 747 airplane with extensive electronic equipment so that it could serve as a survivable command, control, and communications link in the event of nuclear attack. It is designed to provide the President, or his designee, and SAC with the means to direct the nation's strategic retaliatory forces. The aircraft communications system has been hardened to withstand both thermal and electromagnetic pulse effects of a nuclear burst. A fleet of six of these advanced command posts is planned, each with up to 72-hour mission capability.



E-4A Command Post

MODEL 757

Boeing first announced go-ahead on the 757 on March 23, 1979, and rollout of the first airplane occurred on January 13, 1982. The airplane flew a month later on February 19, 1982. The FAA certified the new twinjet on December 21, 1982, after 10 months and 1380 hours of flight testing. Eastern Airlines took initial delivery on the next day.

757-200

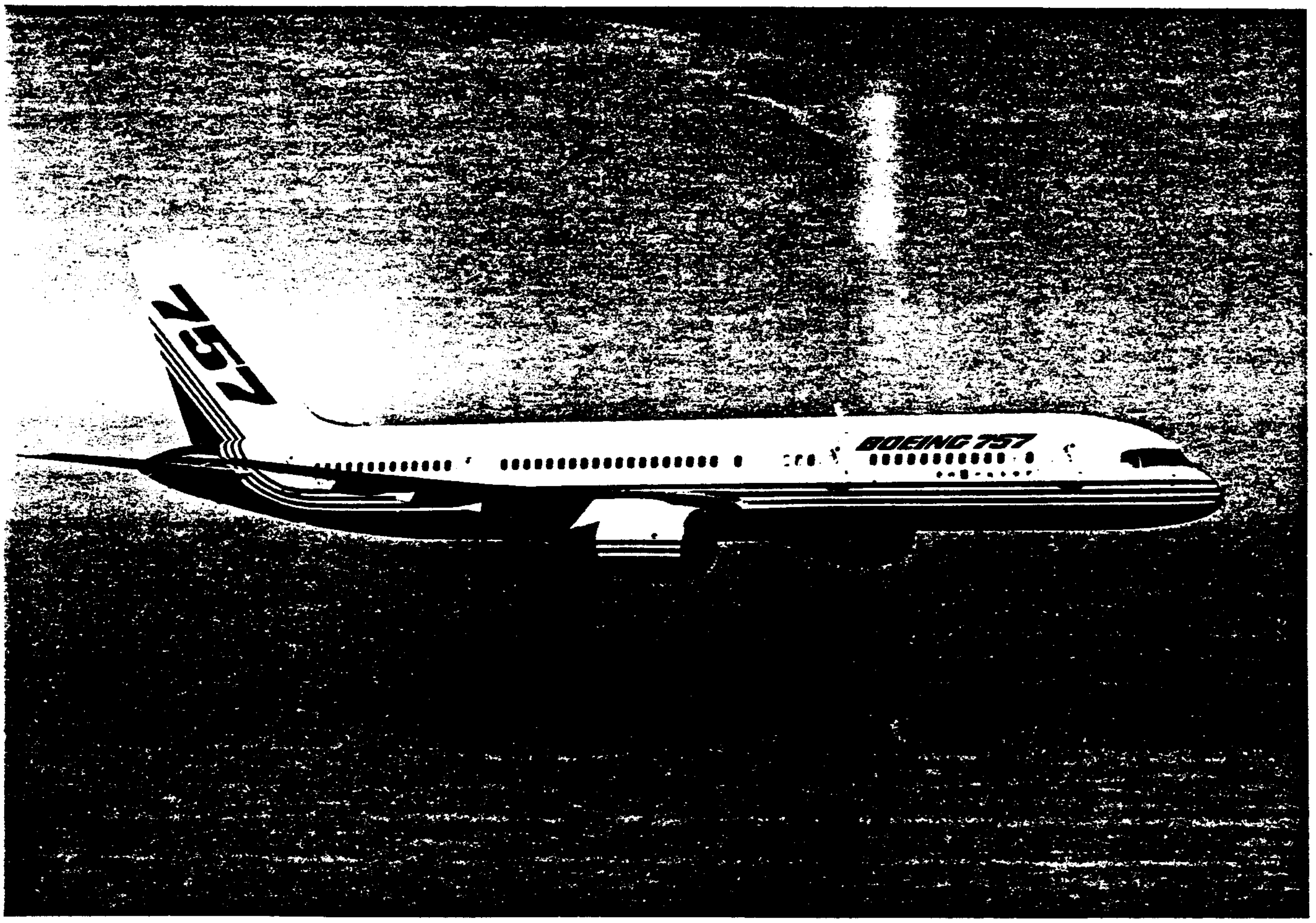
The 757-200 is the world's most fuel-efficient twinjet, burning considerably less fuel per passenger than the older trijets it is designed to replace. The advanced composites and improved aluminum alloys in the 757 contribute to fuel efficiency by reducing the airplane's weight—as do the tough new carbon brakes. Other factors that contribute to the airplane's unique economy come from its advanced technology wing and engines and efficient flight deck that allow crews to fly more precise, fuel-saving routes.

The 757's passenger capacity is between that of the 727-200 and the 767. It is capable of carrying 186 passengers in a typical U.S. airline six-abreast, mixed-class arrangement, or it can accommodate more than 230 passengers in a high-density, all-tourist configuration.

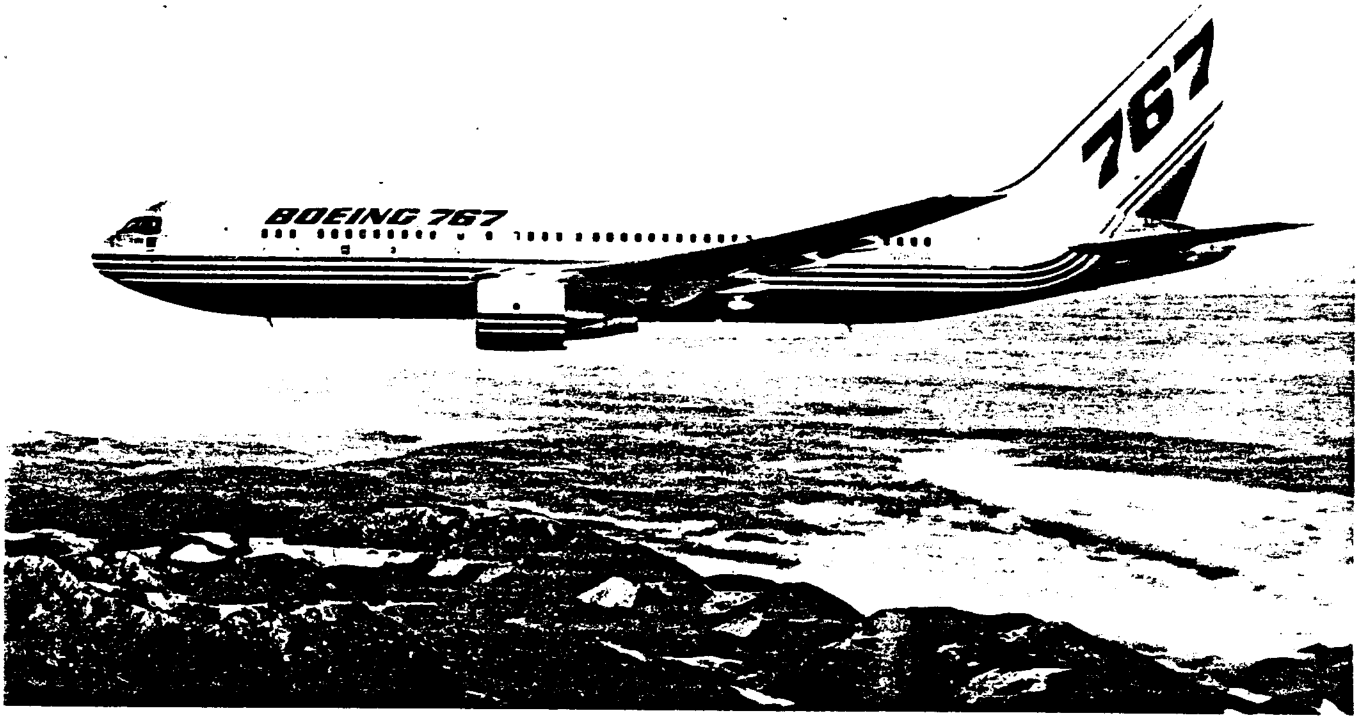
The airplane originally was designed in 1979 to have a range of about 2500 statute miles and a fuel efficiency of 40% more seat-miles per gallon than the 727-200. Since then, increased gross weights, new engines, and other design improvements have resulted in an airplane that can fly more than 4500 miles with 76% better fuel efficiency than the 727-200.

757-200 PF

The 757-200 Package Freighter is the same size as the passenger version and brings a new level of technology and efficiency to the fast growing overnight package delivery industry. With the additions of a large cargo door on the left side of the forward fuselage and the absence of all passenger windows and doors, a significant weight and reduction was achieved, enabling this midsize freighter to carry 70,000 pounds of payload coast to coast in the United States.



757-200



767

MODEL 767

The first 767 entered commercial service on September 8, 1982. Today, the wide-body 767 twinjet is a multimarket success.

767-200

The size of the 767's wide body is also complementary to the 747. Fuselage length is 159 feet 2 inches; wingspan is 156 feet 1 inch. The basic 767-200 carries 216 two-class passengers 3330 nautical miles. Higher gross weight options extend this range to 3965 nautical miles and higher density seating arrangements extend capacity up to 290 passengers.

767-200ER

The Boeing 767-200 Extended Range airplane flies 5500 nautical miles with a typical payload of 174 three-class passengers. To achieve the extended range, Boeing has increased the takeoff gross weight to 351,000 pounds. In addition, half of the fuel bays have been activated in the wing center section to store an added 3750 gallons of fuel, for a total capacity of 20,450 U.S. gallons.

767-300

Further adding to the 767 family of airliners, the 767-300, entered commercial service in September 1986. The fuselage is over 21 feet longer than the 767-200s flying today and carries 21% more passengers while adding eight additional LD-2 containers to the lower hold (960 cubic feet more volume). This extra lower hold volume in the 767-300 translates into 34% more revenue cargo space.

The 767-300's hydraulic, pneumatic, electrical, and fuel systems are nearly identical to those of current 767-200s. The flight decks are identical.

A FAMILY OF 5000

Boeing has always strived to design airplanes that meet the operating requirements of its customers. These designs have incorporated state-of-the-art technology, while allowing for growth to meet future requirements. The variety of body sizes permit each airplane to fit its place in the market.

A combination of market analyses, customer requests, technological advancements, and service experience has resulted in a continuing series of improvements in the family of Boeing jetliners, which serve our worldwide customers. The Boeing Company has a commitment to continue this tradition.

On August 17, 1986, Boeing delivered the 5000th jetliner to KLM, a 737-300. Derivation of the 5000th airplane came from the total number built to date. A summary of this total follows:

Model 707	826	Model 747	654
Model 720	154	Model 757	109
Model 727	1832	Model 767	150
Model 737	1275		

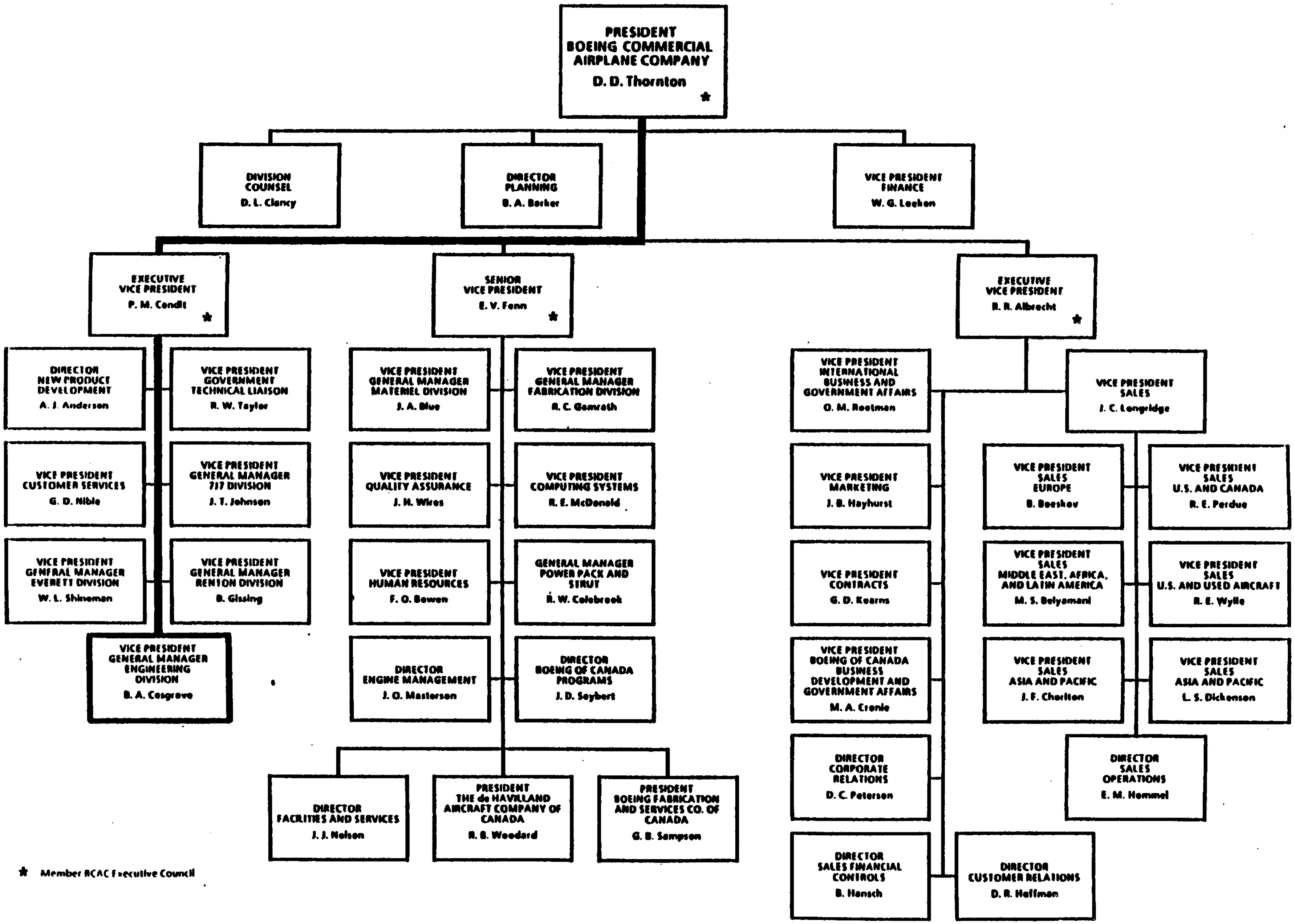
The 5000th Jetliner Was a 737-300 for KLM

ORGANIZATIONAL OVERVIEW

An overview of Aerodynamic Technology's position within the Boeing Commercial Airplane Company (BCAC) is provided in the following pages. The organization charts present the chain of command within BCAC which connects each individual with his immediate group and that group's line of communication up through the various levels of management.

Management within BCAC follows a matrix organization concept. Each program (737,747,757,767,etc.) is managed by a product organization with product managers. Each engineering discipline (Aerodynamics, Flight Systems, Structures, etc.) is managed by a subject organization with subject managers. Bob Wickemeyer is a subject manager. Product support managers (Unit Chiefs) report to both subject and product management. They are responsible for applying consistent subject perspective in support of a particular product.

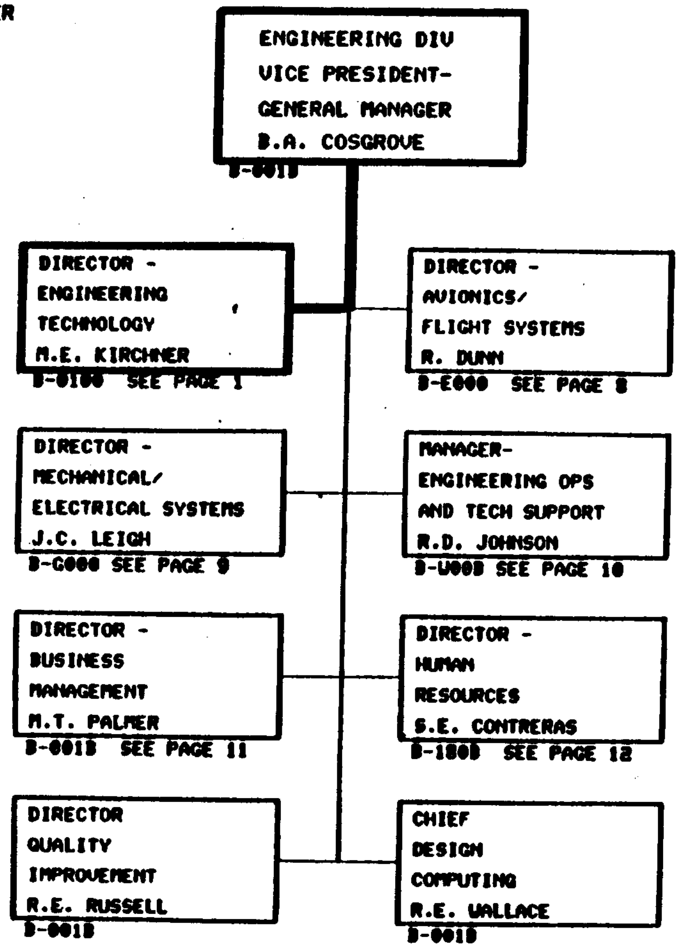
Boeing Commercial Airplane Company
October 1987



* Member BCAC Executive Council

B.A. COSGROVE
VICE PRESIDENT-GENERAL MANAGER
ENGINEERING DIVISION

JUNE 1, 1987



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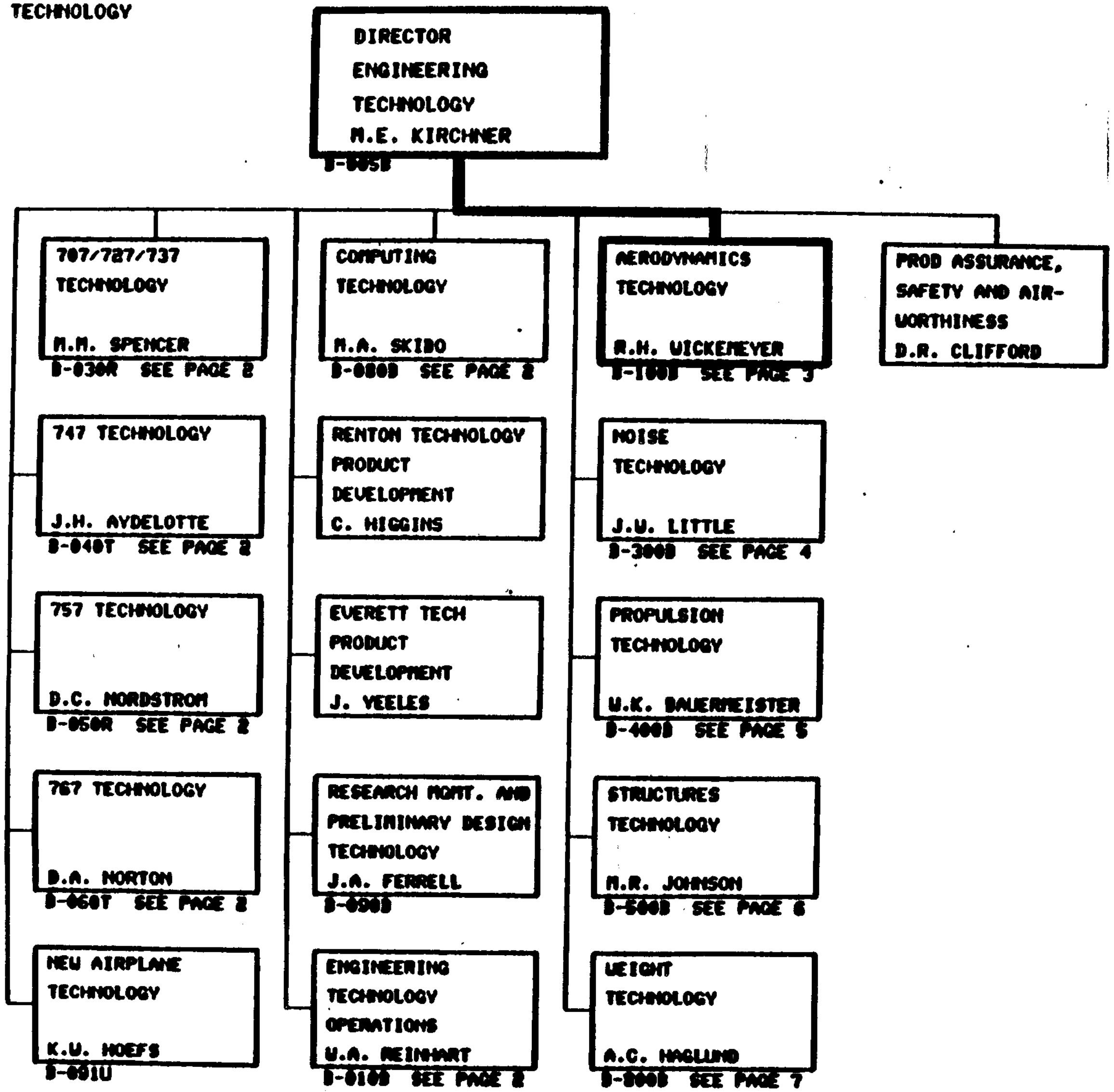

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- AERODYNAMICS TECHNOLOGY — R.H. WICKEMEYER — B-100B
  SEE PAGES 3 AND 3B
  - 7J7 PROGRAM — W.B. GILLETTE — B-170U
    - CONFIGURATION — W. MCINTOSH — B-171U
    - PERFORMANCE — D. HINTON — B-172U
    - STABILITY AND CONTROL — D.J. CLYMER — B-173U
    - ALTERNATE 7J7 CONFIG. AND ENGINES — W.B. GILLETTE (ACT — B-174U
  - AERO SUPPORT PROGRAMS — J.L. DORN — B-101B
    - REGULATIONS, AFM ENGINEERING — D.A. SCHELP — B-102B
    - AFM PRODUCTION — R.D. SCOTT — B-103B
    - Y-7 MODIFICATION STUDY — R.J. MONTGOMERY — B-104B
  - 747 PROGRAM — A.S. MAHAL — B-140T
    - PERFORMANCE SALES SUPPORT AND PD — C. WEICHERS — B-141T
    - CONFIGURATION AND CERTIFICATION — G.E. BEAN — B-142T
    - STABILITY AND CONTROL, PMS/FMC — F.C. HALL — B-144T
  - RENTON DIVISION — G.W. NELSON — B-150R
    - PERFORMANCE AND FMCS — R.J. HALVARSON — B-151R
    - CONFIGURATIONS AND BASIC CERT. — E.G. HILL — B-152R
    - STABILITY AND CONTROL — P.M. JACOBSEN — B-154R
    - SALES SUPPORT — D.D. ANDERSON — B-153R
    - PRODUCT DEVELOPMENT — D.L. WILSON — B-155R
  - 767 PROGRAM — M.E. BUETOW — B-160T
    - PERFORMANCE, FMCS CERTIFICATION AND SALES — J.M. SHULTZ — B-161T
    - CONFIGURATION, AOA AND PD — J.L. LUNDRY — B-162T
    - STABILITY AND CONTROL — C. ROTH — B-166T
    - ADVANCED DEVELOPMENT — A.J. NAGEL — B-116B
  - AERO RESEARCH — R.L. BENGELINK — B-110B
    - CFD LABORATORY — J.L. LEE — B-111B
    - AGPS AND COMPUTING FOCAL POINT — W.M. STAAB — B-112B
    - CFD DEVELOPMENT — P.E. RUBBERT, L-7120 — B-113B & L-7120
    - PERF. AND DATA METHODS SOFTWARE — S.A. HOLMGREEN — B-114B
    - AERO PHYSICS — M.D. MACK — B-115B

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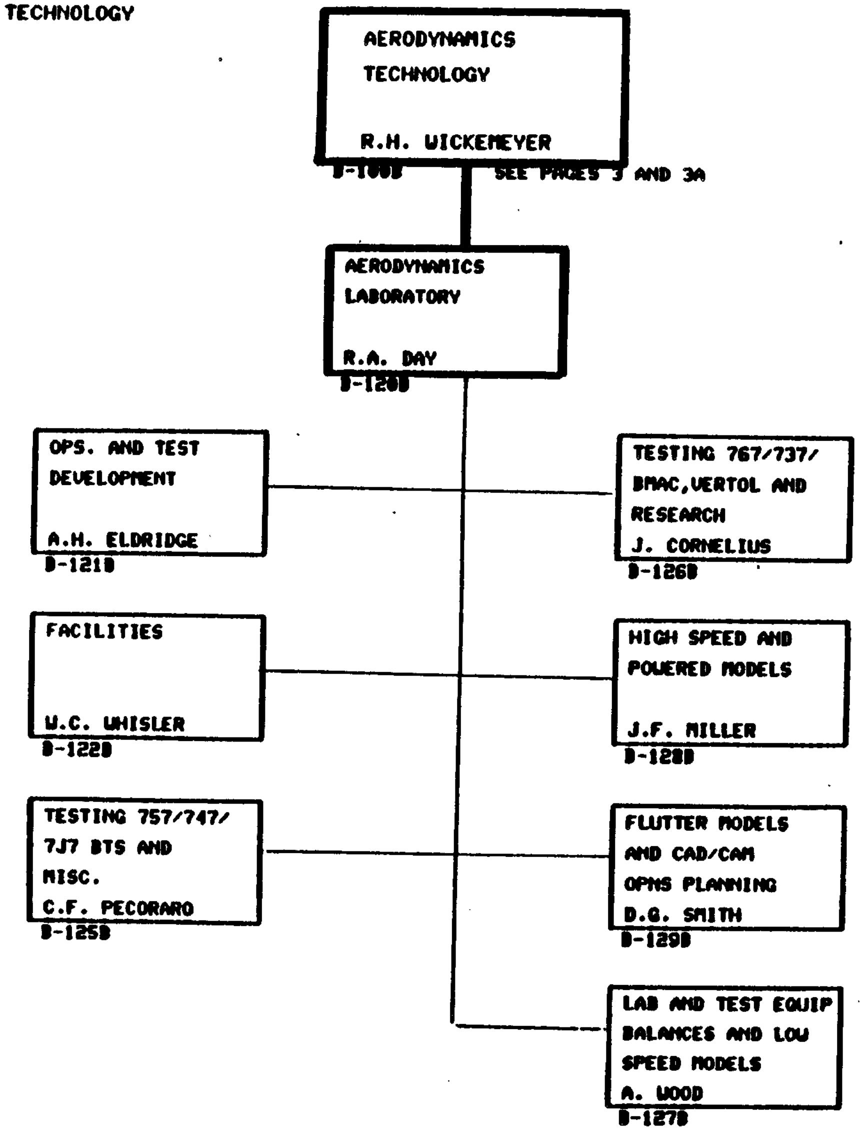
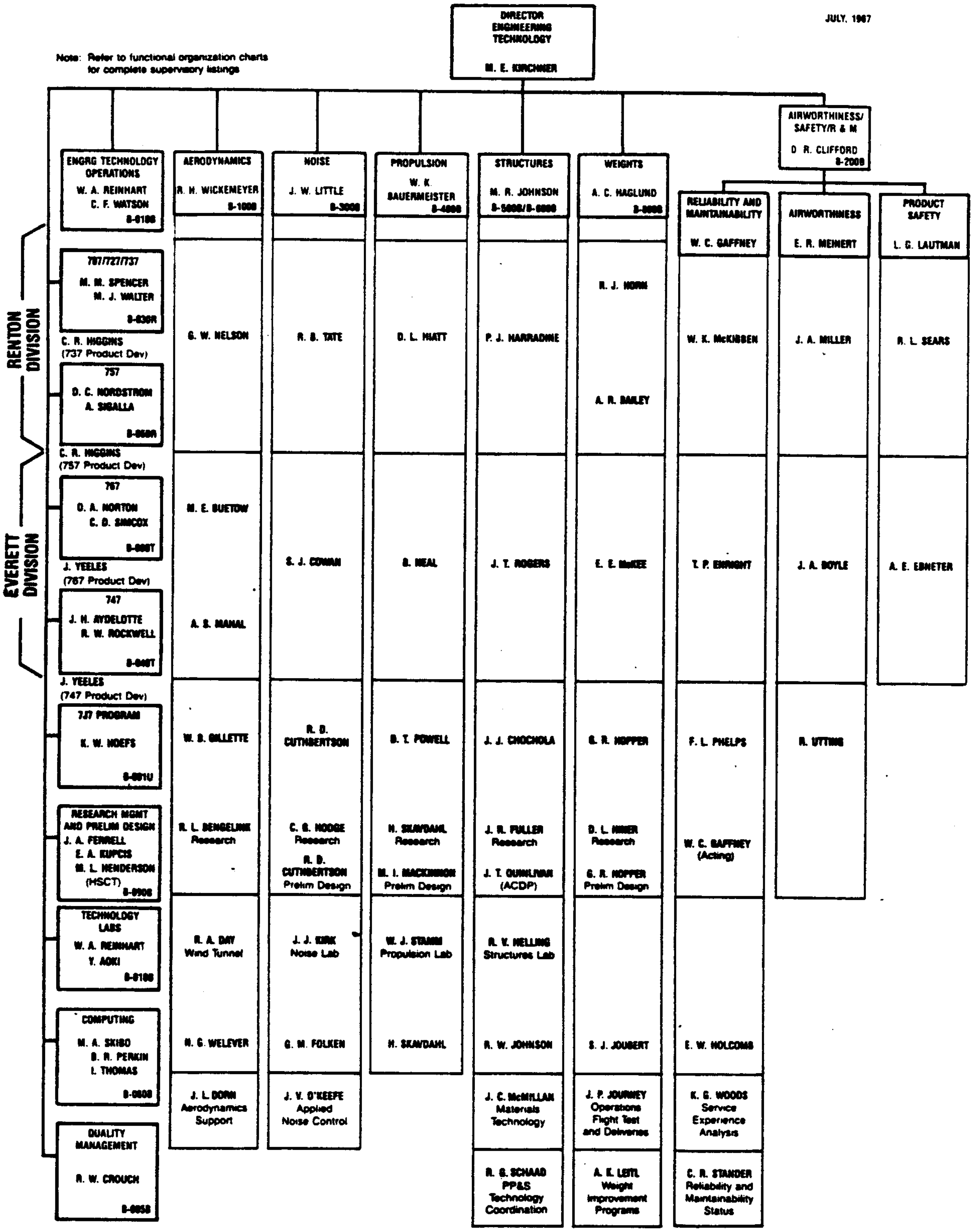
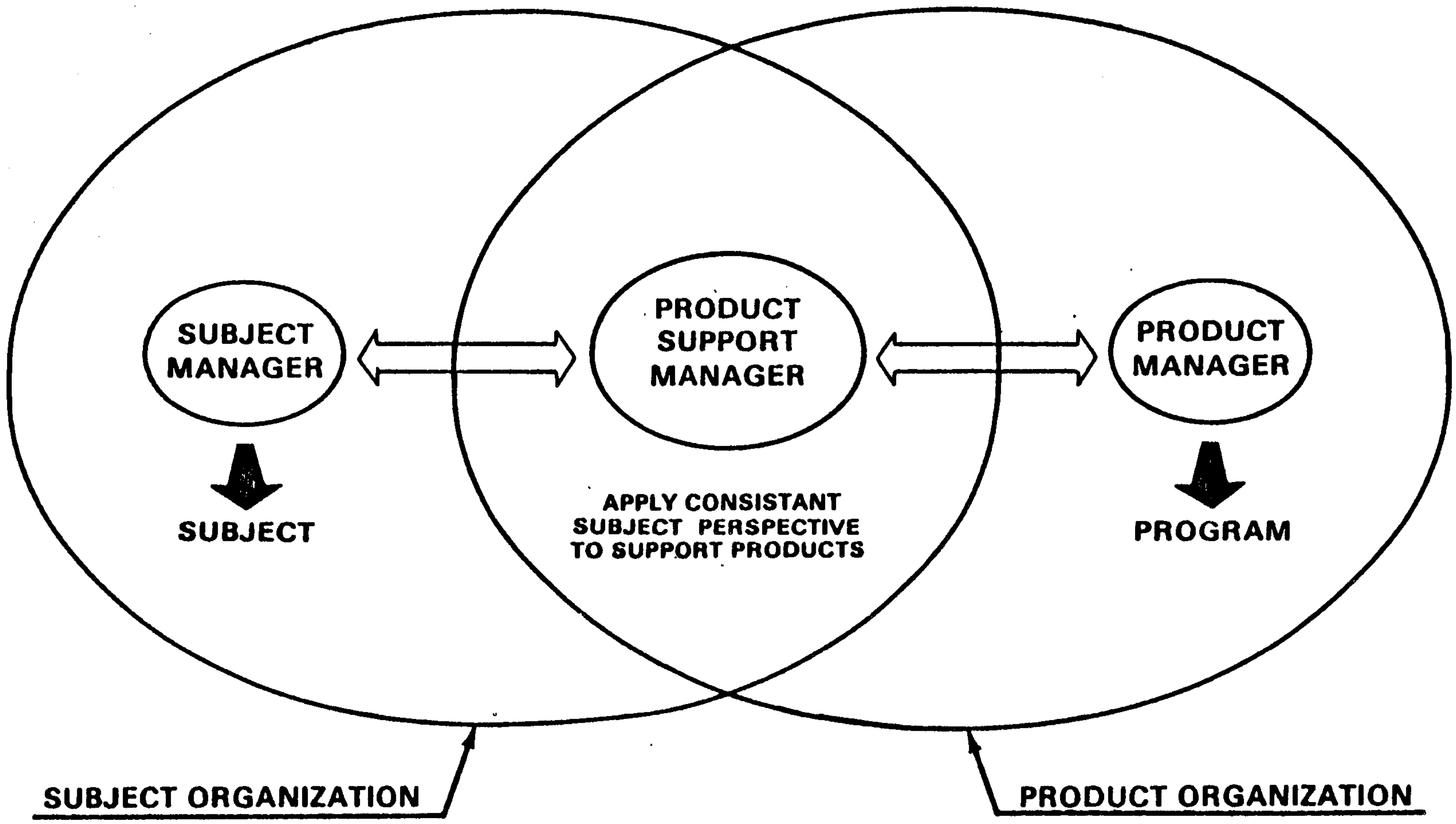


JULY, 1987

Note: Refer to functional organization charts for complete supervisory listings



ORGANIZATION:
MATRIX ORGANIZATION CONCEPT



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GENERAL INFORMATION

General information about resources which you may find useful is provided on the following pages. Included in this section is information regarding:

- o **ENGINEERING SERVICES**
- o **LIBRARY RESOURCES**
- o **LEARNING CENTER RESOURCES**
- o **AERO RESOURCE CENTER**
- o **PHONE BOOK INFORMATION**

Also included in this section is a list of commonly used **acronyms** and a list of **computer programs** for Aero applications. The list of programs is by no means exhaustive.

ENGINEERING SERVICES

Administrative groups within the Boeing Services Division are responsible for providing and maintaining services to support engineering programs. Some of these services are supplies, microfilm files, classified data files, the technical library, graphics, reproduction services, inplant mail service, and maintenance of engineering manuals. Manuals periodically serviced are parts standards, process specifications, material specifications, drafting standards, and design manuals.

A detailed listing of all BSD services is in the BSD Administrative Services users guide.

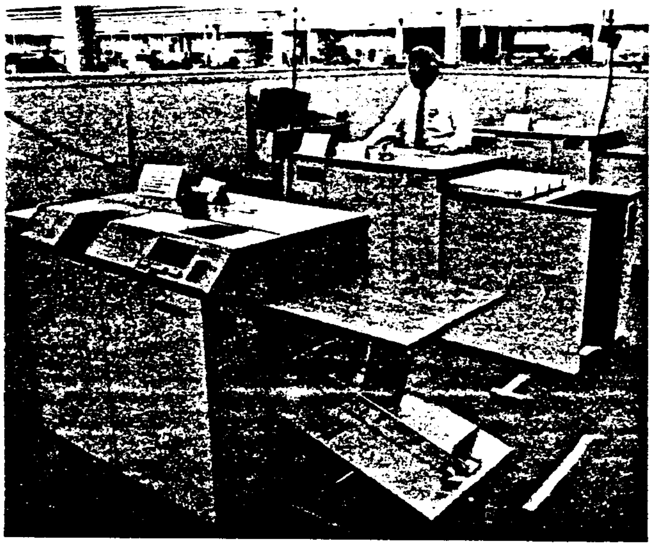
SUPPLIES

To obtain everyday supplies such as pencils, engineering pads, notebooks, scissors, etc., contact your group clerk or secretary. For items like desks, bookcases, file cabinets, or special needs, contact your immediate supervisor.

MICROFILM FILES

Basically all Boeing drawings are on microfilm, and a microfilm file is readily available in most Engineering areas.

The microfilms can be used in viewers located in the immediate file area and/or used to reproduce an 18- by 24-in print (not to scale).



Microfilm Printers

Recordak 35 mm Planetary Microfilm Camera Prepares Film for Aperture Cards

Microfilm Viewers

CLASSIFIED DATA FILE

The classified data file maintains data classified as confidential, secret, or Boeing limited. To obtain data from this file, it is necessary to provide the file clerk with confirmation of a security clearance. In addition, the file clerk must verify need-to-know with the employee's supervisor before releasing data. Upon receiving security clearance, each employee is provided detailed instructions for obtaining and safeguarding classified data.

BOEING TECHNICAL LIBRARIES

The Boeing Technical Libraries are the focal point for the dissemination of published information needed by employees to accomplish work assignments. Information from the libraries is used in engineering studies, product design and development, manufacturing research, proposal efforts, sales campaigns, competitive intelligence, management development, and general business analyses.

The libraries contain diverse collections of information, including technical books and reports, such as symposia, NASA and Air Force reports, conference papers, and engineering and computing texts; scientific and engineering journals, trade magazines, newsletters, and business periodicals; commercial and military specifications and standards; reference books, such as dictionaries, encyclopedias, handbooks, and directories; and reference files of selected Boeing documents.

ONLINE CATALOG

DOBIS, the online integrated library catalog, is a menu-driven system from which books, reports, Boeing documents, and videocassettes can be retrieved by title, personal and corporate author, subject, and report or contract number. Many items have been cataloged with descriptive abstracts.

Online Catalog

One advantage of DOBIS is that, in addition to access from customer terminals in each library, the system can be accessed from any remote site using an appropriate IBM terminal or a PC with an Irma board that emulates the terminal. Contact the library staff for information on accessing DOBIS from your work area.

In addition to its use as a catalog, DOBIS is used by the library staff to circulate materials to customers and to order publications used within the Company.

ACCESS TO JOURNAL ARTICLES AND OTHER PUBLICATIONS

Although DOBIS covers all of the books and many of the technical reports held by the libraries, the system does not index everything in the libraries. Journal articles and individual conference papers, for example, are not included because they are well indexed in commercial data bases and in published indexing services, such as *Engineering Index* and *International Aerospace Abstracts*.

In addition, the library has thousands of technical reports on microfiche from the National Technical Information Service (NTIS), the National Aeronautics and Space Administration (NASA), and the Defense Technical Information Center (DTIC). These are indexed in the NTIS, NASA, and DTIC data bases as well as in published indexes. Access to the full text of many newspapers, newsletters, and magazines is available through the NEXIS online data base and selected files on the Dialog commercial online data base service. The library staff will help you locate these materials.

CUSTOMER SERVICE

Among the many services available from the Technical Library are the following:

RESEARCH. Research librarians prepare customized bibliographies and information surveys in support of company business activities. Information sources include several hundred commercial online data bases covering technical, scientific, and business subjects; hard-copy indexes; and specialized collections. Customers with a continuing research interest, such as composite materials, may receive monthly updates of new publications in their subject area. Information centers outside Boeing are contacted as needed for supplemental information.

REFERENCE AND USER ASSISTANCE. Reference librarians explain available resources to library customers, including the use of DOBIS; answer factual questions ranging from the correct spelling of a word to the properties of a

Renton Technical Library

Librarian at Renton Technical Library

specific alloy; and locate specifically requested books, articles, and reports.

LOAN AND COPY SERVICE. Books and reports are available for a standard loan period of four weeks and may be renewed. Copies of reference materials and periodical articles will be provided within the provisions of copyright law. The Boeing Technical Libraries borrow materials from each other as well as from the University of Washington and Seattle public libraries. Publications not available locally usually can be borrowed from academic, industrial, or government information centers throughout the world.

CURRENT AWARENESS. As part of its current awareness service, the library routes periodicals covering subjects in an employee's field of interest. Supervisory authorization is required to be placed on the routing for a particular journal.

PUBLICATION ACQUISITION. In addition to acquiring publications for the library collections, the libraries obtain work-related publications for individuals and groups. Purchase of permanent issues for individuals is subject to the policies and controls of the requester's organization and to provisions of Office Instruction 520.

VENDOR CATALOGS AND MILITARY/COMMERCIAL SPECIFICATIONS. Microfilm services containing vendor catalogs and indexes to those catalogs are purchased by the library and are located throughout the Company. Many of these services also include military specifications and standards as well as commercial standards. Call the library to determine the nearest location.

HISTORICAL SERVICES. As part of the Technical Libraries, the Company archives retain historical information relevant to engineering, business, legal, and personnel activities. Also included are product, organizational, manufacturing, and marketing information.

SERVICE LOCATIONS

Boeing Technical Libraries are located in Renton, Kent, and Bellevue. Telephone and mail stop information is listed in the alphabetical section of the Boeing directory under "Libraries." *The Renton Library* in the 10.95 building primarily serves the information needs of Boeing Commercial Airplane Company employees and should be contacted by BCAC engineers needing service.

The Kent Library in the 18.04 building primarily serves the Boeing Aerospace Company, the Boeing Electronics Company, and the Boeing Military Airplane Company—Seattle. *The Bellevue Library* in the 33.07 building primarily serves Boeing Computer Services employees in Bellevue. Publication acquisition is handled centrally from the Renton Library, as are the indexing and cataloging of publications into DOBIS. *Historical Services* is located at Plant 2 and is listed in the telephone directory under "Historical Services."

HOW TO RECEIVE SERVICE

Requests for library service may be made in person or by telephone and mail. The libraries are open Monday through Friday from 8:00 a.m. to 4:30 p.m., with telephone service from 10:00 a.m. to 4:30 p.m.

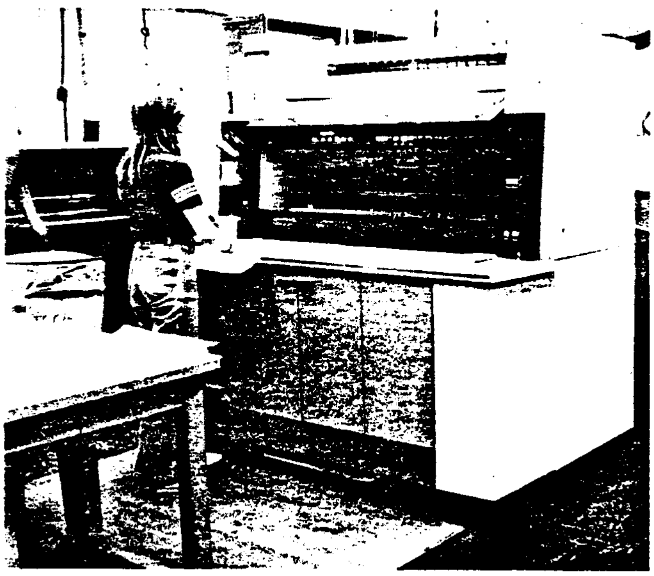
GRAPHICS

BSD Graphics is a full-service multimedia resource center. Designers, illustrators, production artists, writers, editors, typographers, and computer aided graphics specialists staff the resource center.

Services include planning, organizing, and directing the development and production of manuals, documents, catalogs, brochures, viewfoils, and most other forms of multimedia communication. For service, contact BSD Graphics Planning and Scheduling.

REPRODUCTION SERVICES

Drawing originals may be obtained from the Engineering Drawing Vault (on an as-needed basis), and full-size prints can be made at any reproduction service counter. For other available reproduction services, see Figure 13-1.



Full Size Blueprint Reproduction Machine

INPLANT MAIL SERVICE

Here are some do's and don'ts for using the service.

DO's

Do—Print legibly.
Do—Verify your correspondent's mail stop.
Do—Cross out preceding addresses.
Do—Separate personal U.S. mail from Company U.S. mail.
Do—Deposit your mail in its correct slot.
Do—Pick up your boxes and packages promptly.
Do—Report problems to supervisor or lead at the nearest mailroom (listed in the Boeing telephone directory).
Do—Observe proper security rules for transmittal of classified material.
Do—Be sure to update your mail stop with the A and L System through your Personnel Office.
Do—Be sure to keep your home address correct. Use the "Address Change Notice" form D0-6000-3560.
Do—Use home address for periodicals, advertisements, trade magazines, and publications (reference Office Instruction No. 305).
Do—Return to sender any incorrectly addressed inplant mail.

DON'Ts

Don't—Mail personal items.
Don't—Mail cash or valuables.
Don't—Mutilate or staple inplant mail envelopes (they are reusable).
Don't—Use two or more address lines for a single address.
Don't—Use the mail station as a trash receptacle.

Boeing Services Division Mailroom Clerks Distributing Mail

ENGINEERING REPRODUCTIVE SERVICES

SERVICE	APPLICATION	REMARKS*	ORDER FORM	AUTHORIZED SIGNATURE
Whiteprint (B&W), blueprint, blueline, Van Dyke, autopositive	Check prints, reference prints, work prints, engineering and production file copies	1	●	Requestor
Photo template (made from second original of undimensioned master drawing)	Tooling templates	2	▲	Supervisor
Second originals	Restoration of worn drawings, reproduction to incorporate major changes or additional drawing development		▲	Supervisor
Original photography	Reference or publication (for documents, test reports, etc.)	3	▲	Supervisor
Photographic printing		4	▲	Supervisor
Process camera photography	Artwork	5	▲	Supervisor
Electrostatic photocopying	Reference copies, letters, document pages, etc.		●	Requestor
Continuous flow photographic processes	Reduction of drawings, illustrations, and other data	6	●	Requestor
Microfilm	Reduction of file space occupied by inactive data, provide engineering data to customers	7	Contact engineering production	
Motion picture photography	Presentations, documentation, studies	8	Coordination sheet or memo	Project engineer
Photographic instrumentation	Test programs	9	Contact engineering production	Supervisor
Offset printing	Brochures, documents, engineering changes, etc.	10	●	Supervisor Requestor
Silk screen	High-quality graphic presentations, decals, drawing sheet forms, instrument panels, signs, placards, etc.		▲	Supervisor
Typositor photocompositor	Preparation of lines of lettering for pasteup in art layouts, signs, labels, etc.		▲	Supervisor
Bindery aids	Preparation of documents, reports, brochures, etc.	11	●	Requestor Supervisor
Theater	Audiovisual presentation, motion and still picture projection	12	Contact motion picture group, engineering reproduction	

*See page 13-6.

● ORDER FORMS IN REPRODUCTION AREA

▲ ORDER FORMS IN PHOTO UNIT AREA

Figure 13-1. Engineering Reproductive Services

REMARKS

NOTES

1. Roll or sheet drawings or data, up to 42-in width, from translucent positive- or negative-type originals.

2. Accurate reproduction on dimensionally stable materials.

3. Still, black and white, or color. Studio or inplant, remote area. Polaroid, on-call basis.

4. Enlargements, reductions, color, or black and white.

5. Line, continuous tone, halftone, separation halftones (for color printing), negative strip-in, page layout work, and silk screen positives.

6. Reduction of one-half or one-third.

7. 16 mm, 35 mm, 105 mm, card mount, continuous roll, engineering or sheet film. Microfilm duplicating. Microviewers and viewer-printer.

8. Photography, script writing, editing, black and white or color, with or without synchronous sound.

9. Still, sequential, normal and high-speed motion picture photography, Spark Shadowgraph, Schlieren photography, macrophotography, oscilloscope and oscillograph photography. Development of photo-optical systems. Other techniques for recording specific test results are available.

10. Up to 19- by 25-in monocolor, multicolor, or four-color halftones.

11. Collating, spiral binding, paper drilling, wire stitching, stapling, and mechanical folding.

12. Film storage, editing, full-time projectionist, equipment loans of slide and film projectors, tape recorders. Closed circuit television.

Figure 13-1. Engineering Reproductive Services (Continued)

Boeing Libraries

The services of the Boeing libraries and their collections are available to employees for use in their work assignments. These services include:

- answering factual questions
- preparing customized bibliographies and information surveys
- loaning books and reports
- reproducing journal articles
- interlibrary loan service
- routing periodicals
- purchasing publications

Information Services

Boeing information librarians explain library resources, answer factual questions from reference sources, and locate books, reports, and journal articles.

Research Services

The libraries' research staff will prepare customized bibliographies and information surveys on any given subject upon request. Sources of information for this service include the several hundred online data bases in business and technology as well as relevant manual indexes, the libraries' online catalog, and our International Data Bank. Governmental and private information centers are often contacted for supplemental information.

Current Awareness

Boeing employees are alerted to recent developments in their fields through a library bulletin that announces and abstracts additions to the libraries' collections and new Boeing documents. The library will route periodicals in work-related subject areas and can provide monthly updates of bibliographies on selected topics.

Ordering

The libraries will purchase or obtain work-related publications as required. A Technical Library Publication Request form (D0 6000 2980) and appropriate approval signatures are required.

Online Library Catalog

DOBIS is an online integrated library system that contains references to the holdings of the Boeing Technical Libraries and group files. Publications and Boeing documents may be retrieved by title, author, subject, and report or contract number. Abstracts are included for many items. Access to DOBIS is available from terminals in each library and in selected work areas.

The Collections

The libraries provide access to thousands of books, periodicals, reports, and symposia papers. Each library has extensive reference collections of technological and business information. Coverage of world literature is provided through online data bases and other diverse index and abstract services. Many reports are available on microfiche, and most books and reports may be loaned. Journal articles may be reproduced within the provisions of copyright laws. Reference materials, while kept in the library because of heavy demand, may be selectively reproduced.

Interlibrary Loan

The libraries borrow extensively from the University of Washington and Seattle Public libraries. Publications not available in the Seattle area may usually be borrowed from other libraries and information centers.

Library Locations

The two main libraries at Kent and Renton have collections reflecting the subject interests of their primary clients: BCAC at Renton, and BAC and BMAC at Kent, BCS, BECo and Corporate personnel are served by all libraries. The Bellevue Library contains computing literature, with an emphasis on artificial intelligence.

Library Locations

Bellevue Library
BCS Bellevue Complex
33.07 Bldg, 4th floor, Door 42D1
Organization 4-8440
M/S 7L-61
Telephone: 865-3266

Kent Library
Kent Space Center,
18.04 Bldg., Bay C-1
Organization 4-8440
M/S 8K-38
Telephone: 773-0590

Renton Library
Renton Plant, 10-95 Bldg.
Organization 4-8440
M/S 74-60
Telephone: 237-8311

Historical Services
Plant II, 2.63 Building, Bay C-18, Door 6
Organization 4-8440
M/S 1R-24
Telephone: 655-4586

LEARNING CENTER

The Learning Center offers the employee the opportunity to expand his knowledge on a large variety of subjects. Six Learning Centers are situated around the Puget Sound area for convenience. Employee's may study during Learning Center hours any course in the Center's inventory. These mediated courses make extensive use of audiotape, videotape, sound slide, filmstrip, and add greater freedom and flexibility in choosing the time for taking a course. Contact your Learning Center for time schedules. The following pages present the courses available from the Centers and a map of their locations.

INDEPENDENT STUDY

BAC and BCAC EMPLOYEE TRAINING AND DEVELOPMENT provides independent study courses at the Auburn, Everett, Kent, Plant 2, and Renton Learning Centers. Arrangements may be made by an employee to study independently before work, during lunch or after work.

LEARNING CENTER STUDY — Employees may study during Learning Center hours any course in the Center's inventory. These mediated courses make extensive use of audiotape, videotape, sound slide, filmstrip, and add greater freedom and flexibility in choosing the time for taking a course.

HOME STUDY — Home Study course materials are available for purchase or checkout by employees. Requests should be sent by in-plant mail to the appropriate course location. Course completions will be entered on your training transcript.

Course descriptions are available at the Kent and Plant 2 Learning Centers for BAC courses and, the Auburn, Everett and Renton Learning Centers for BCAC courses.

ENROLLMENT —

- Enrollment in Learning Center Study is done by submittal of signed and dated Voluntary Training Request Form DO 6000 3480.
- Enrollment in Home Study is done by submittal of a Payroll Deduction Card, Form D3 4300 0720.

All enrollments are on a first-come, first-serve basis.

PAYROLL DEDUCTION —
All deposits and purchases are by Payroll Deduction Form D3-4300-0720. The rate schedule is:

(1) Language books and tapes as noted on course list.
(2) Loan Audio Cassettes and Books — $30 deposit per tape/book.
NOTE: not deducted unless tapes or books are not returned.
(3) Loan Filmstrip Player $150 deposit.
(4) Loan Disk — $60 per set.
(5) Loan ½" VT — $100 per tape.
(6) Loan Audio Cassette Player — $100 deposit.

WHEN REQUESTING A COURSE, BE SURE TO SPECIFY THE TITLE
DO NOT GIVE YOUR PAYROLL DEDUCTION CARD TO YOUR TIMEKEEPER

CONTACT YOUR LEARNING CENTER FOR TIME SCHEDULE

AUBURN LEARNING CENTER: M/S 5C-07, 931-3862	Registrar, Organization 6-1080 Bldg. 17-10 East end of balcony
EVERETT LEARNING CENTER: M/S 07-14, 342-0442	Registrar, Organization 6-1080 Bldg. 40-56 S.E. end col M-8
KENT LEARNING CENTER M/S 3C-01, 773-8460	Registrar, Organization 2-1846 Bldg. 7-131, 1st flr, 12.1
PLANT 2 LEARNING CENTER M/S 15-15, 655-1829	Registrar, Organization 2-1846 Bldg. 2-44, 1st flr, col V-1"
RENTON LEARNING CENTER: M/S 80-11, 237-8780	Registrar, Organization 6-1080 Bldg. 4-03, 2nd flr, North end of Cafeteria

NOTE — Plant II L/C has moved from 2-25 bldg. to S.E. corner of 2-44 bldg. on 1st floor

NOTE: BCAC LEARNING CENTERS (AUBURN, EVERETT, RENTON) EXCHANGE TAPES WHEN REQUESTS ARE RECEIVED. ALSO BAC L/C's (Plant II & Kent exchange tapes).

B = Book
F = Filmstrip
D = Disk
V = ¾" Umatic Video Tape
S = Sound on Slide
VT = ½" VHS Video Tape
CAI = Computer Aided Instruction

LEARNING CENTER STUDY

Please note: These videotape courses will be available for a limited time only at the BCAC Learning Centers based on the following schedules:	EVERETT	AUBURN	RENTON
"The Telephone Doctor" "Successful Delegation" "Giving Bad News" "The Go Giver"			JANUARY
"Corporate Computer Security Strategy" "Motivation: It's Not Just Money" "Up The Organization" "Everything You've Always Wanted To To Know About Supervision"		JANUARY	FEBRUARY
"What Have You Done For Yourself Lately" "Prototyping Applications: An Overview" "Balanced Goal Setting"	JANUARY	FEBRUARY	MARCH
"Relational Data Base Concepts" "Where Do I Go From Here" "Success In Your Career" "Memory Course, Part I"	FEBRUARY	MARCH	APRIL
"Memory Course, Part II" "The Entrepreneurs" "If You Don't, Nobody Else Will" "Telephone Courtesy Pays Off"	MARCH	APRIL	MAY

AVAILABLE YEAR AROUND

# TAPES/DISKS	AUBURN	EVERETT	KENT	PLANT 2	RENTON	
						BUSINESS
1	x					A Team of Two (V)
2	x	x			x	Change Masters, The (V)
12	x	x	x	x	x	Cost and Price Analysis (V)
1	x	x			x	Customers, A Passion For (V)
10				x		Grammar — GED (V)
1	x	x			x	Intrepreneurship: How to Encourage Organizational (V)
1					x	J&J Story, The (V)
1					x	Japan vs. USA-High Tech Shootout (V)
1		x		x		Japanese, Business with the (V)
6					x	Negotiating Successfully (V)
1	x	x			x	Negotiation and Bargaining Skills (V)
1	x					Office Worker, Effective (V)
3					x	People, Art of Managing (V)
1		x			x	Problem-Solving, Creative (V)
1					x	Productivity, American Yen for Japanese (V)
1	x	x			x	Productivity and the Self-Fulfilling Prophecy (V)
1					x	Productivity Circles, Fab. Div. (V)
1					x	Productivity Payoff (V)
5					x	Robotics, An Introduction (V)
2	x					The Secretary and Her Boss (V)
1	x	x			x	Transitions: Letting Go and Taking Hold (V)
1			x	x		Typing, Beginning (D)
1	x		x	x		Typewriter Tech. (Selectric) (V)
1		x				What You Are Isn't Necessarily — Money (V)
1					x	Work Smarter, Not Harder (V)
						COMMUNICATIONS
4			x			A/V Presentation, Producing Effective (F)
11				x		Communicating Successfully — Productive Meetings (V)
5	x					Communication, Effective (V)
6			x			Communication Skills (F)
5	x					Communication, Two Person (V)
1	x	x			x	Conversation (V)
1	x					Count to Ten (V)
7				x		Effective Listening (V)
1	x	x			x	Handling Disagreements (V)
1	x					I Told 'em Exactly How To Do It (V)
7	x	x			x	Listener, The Complete (V)
1	x	x			x	Listening, Power of (V)
1	x	x			x	Meeting Robbers (V)
1	x	x			x	Meetings: State of Art (V)
1	x	x			x	Meetings, Successful Sales (V)
1	x	x			x	Meeting, How To Hold (V)
1	x	x				Perception (V)
2	x	x			x	Persuasion, The Psychology of (V)
1	x					Presentation, Anatomy of (V)
14			x			Presentation, Effective Tech (V)
2					x	Presentation Excellence (V)
2	x	x			x	Public Speaking, The Basics of (V)
12	x	x			x	Reading Efficiency (V)
8	x	x	x	x	x	Reading, Speed (V)
1			x			Reading, Speed — The Computer Course (D)
2	x					Selling on the Telephone (V)
2	x	x	x	x		Speaking, Effective (V) (F)
1	x	x	x	x	x	Telephone Usage, Boeing (V)
1					x	Viewfoils, Producing Effective (S)
6	x					Writing for Executives, Effective (V)
2	x		x			Writing Skills, Business (FS/V)
7	x	x			x	Writing, Put It In (V)
6	x	x			x	Your Speaking Image: When Women Talk Business (V)
						COMPUTER/ MICROPROCESSOR
27			x		x	Ada Ichbiah, Barnes and Firth (V)
6		x	x			Ada-satellite Teleconference I (V)
5			x			Ada Satellite Teleconference II (V)
8			x			Apollo System Programming (V)
10	x					APT, Basic (V)
10	x	x	x	x	x	BASIC Computer Programming, Beginning (V)
10	x	x	x	x	x	BASIC Computer Programming, Advanced (V)
4	x	x			x	BASIC Data Communication (V)
12	x	x			x	Bits and Bytes (V)
3	x	x			x	CATIA Graphics System (V)
16	x	x			x	"C" Language, Computer Programming (V)
4			x			Communication, Data (Basic) (V)
5					x	Communication, Data, Update

AVAILABLE YEAR AROUND

# TAPES/DISKS	AUBURN	EVERETT	KENT	PLANT 2	RENTON	
9			x			Computer Aided Manufacturing (V)
1	x	x			x	Computer Calc: Electronic Spreadsheets (V)
11			x			Computer Education Series (S)
1					x	Computer Graphics, Human Side of Design (V)
1	x	x			x	Computer Images: Computer Graphics (V)
1			x	x		Computer Keyboard Typing (A)
8					x	Computer, Software Engineering for Systems
1			x	x		Computer Spreadsheets, Introduction to (V)
1	x	x			x	Computer Talk: Microcomputer Communications (V)
1	x	x			x	Computerized Airplane Design & Mfg. (V)
1			x	x		Computers, Intro. to Personal (V)
1			x			Computing Concepts, Personal (V)
1	x	x			x	CPM, How to Use (D)
8	x	x	x	x		CPM, Personal Computers (V)
1	x	x			x	Database Management (D)
2	x	x			x	dBase II (D)
28	x	x	x			dBase II (V)
1	x	x	x	x	x	dBase II, An Intro. (V)
1	x	x			x	dBase III (V) (D)
2	x	x			x	dBase III, How to Use (D)
4	x	x			x	dBase III Plus (V)
18				x		DEA, 3D Measuring Machine (V)
1	x	x			x	Electronic Words: Word Processing (V)
1	x	x			x	Electronic Worksheets (V)
6	x			x	x	FORTRAN Short Course, Computer Programming (V)
1		x			x	Fourth Decade, The (V)
2	x	x			x	Framework, How to Use (D)
8			x			HP RTE Fortran IV (V)
1	x	x			x	IBM PC, A Beginners Guide To
1	x	x	x			IBM PC and IBM PC/XT, Intro. to (D)
3	x	x	x	x	x	IBM PC, How to Use in 10 Easy Lessons (V)
3			x			IBM PC, How To Use Your
1	x	x	x	x	x	IBM PC, Intro. to DOS & Sys. Operations (V)
1			x			IBM Primer, The (V)
12			x			IEEE-488 Bus. Ops. (GPIB) (V)
19			x			Industrial Microcomputer, Introduction (V)
21			x			Industrial Microcomputer, Intermediate (V)
8			x			INGRESS, Basic
13			x			INGRESS for Programmers
1	x	2x			x	Interactive Computer Graphics (V)
15			x			Jovial J73 (V)
1	x	x			x	Keeping Track: Database Management (V)
4		x			x	Knowledge Based Systems and Artificial Intelligence (V)
6					x	Local Area Networks (V)
1	x	x	x	x	x	LOTUS 1-2-3, Adv. (V)
2	x	x			x	LOTUS, How to Use (D)
1	x	x	x	x	x	LOTUS 1-2-3, Intro. (V)
24	x	x		x		Making It Count (V)
8	x					Math, Fingertip (V)
1	x	x	x	x	x	MBASIC, How to Use (D)
2	x	x			x	Microprocessor, Advanced (B) (8086/8088 Lab)
33			x			Microprocessor Hardware 8080 (V)
12			x			Microprocessor Interfacing (V)
16			x	x	x	Microprocessors, Designing With (V)
2		x			x	Microprocessor, Real Time Interfacing (B) (8080A Lab)
18					x	Microprocessor, Real Time Interfacing and Control Sys. (V)
12					x	Microprocessors, A Comprehensive Intro. (V)
2	x	x			x	Microprocessors, Software & Hardware (B) (8080A Lab)
1	x	x			x	Microsoft Word, How to Use (D)
19			x			Minicomputers, Introduction to (V)
1	x	x			x	MS-DOS (D)
2	x	x			x	MS/PC-DOS: Using DOS With Hard Disk Systems (V)
1	x	x			x	MULTIPLAN (D)
2	x	x			x	Multiplan, How to Use (D)
5			x			Nova/4 Maintenance
12			x			Nova 800 (V)
4			x			OTRONA Personal Computer Overview

LEARNING CENTER STUDY

AVAILABLE YEAR AROUND

# TAPES/DISKS	AUBURN	EVERETT	KENT	PLANT 2	RENTON	COURSE
2	x	x	x	x	x	PC-DOS, How to Use (D)
26	x	x	x		x	PASCAL Programming (V)
15				x		PDP-11, Introduction to (V) (Manufacturing Process Control Computer)
5			x			Project Life Cycle: Structured Software Dev.
3	x	x			x	R:Base 5000 (D)
3	x	x			x	R:Base System V, Introducing (D)
1	x	x			x	SUPERCALC (D)
1	x	x	x		x	Symphony I (V) (D)
1	x	x	x		x	Symphony II (V) (D)
1	x	x			x	Typing Tutor III (CAI)
1		x			x	UNIX — An Executive Perspective (V)
6		x			x	UNIX Overview (V)
15		x			x	UNIX Fundamentals for Programmers (V)
13		x			x	UNIX Shell (V)
8			x	x	x	VAX 11 — Concepts (V)
12			x	x	x	VAX 11 — Instruction Set (V)
5			x			VAX/VMS, Using (V and CAI)
22			x			Very Large Scale Integration (VLSI) (V)
25			x			VLSI Design Course
1	x	x			x	VISICALC, How to Use (D)
1			x	x		VISICALC, Introduction to (V)
1	x	x	x	x	x	Word Processing (V)
1	x	x			x	Word Processing, Introduction to (D)
2	x	x	x	x	x	Wordstar, How to Use (D)
21			x			Z-80 Assembler Language (V)
						ELECTRICAL/ELECTRONICS
14				x	x	Digital Electronics Troubleshooting
30		x	x			Digital Hardware Design (V)
21			x			Digital Signal Processing, Advanced (V)
5			x			Electronic Communications, Networks for (V)
15			x			Electronic Interconnection (V)
12	x	x	x		x	Fiber Optics (V)
24				x		Semiconductors, Understanding (V)
1			x	x		Static-ESDS (V)
1			x			Static Safeguard Systems (V)
6				x		Tektronix Oscilloscope Operation (V)
3			x			Television, How It Works (V)
1			x			Voltage Power Supplies, Mfg. of High (V)
1		x		x	x	Wire Wrap Techniques (V)
						ENGINEERING/TECHNICAL
1		x			x	Airplane, New Technology (V)
4		x			x	APL for Planners (V)
1		x			x	Appearance Counts (V)
6	x	x			x	Blueprint Reading Fundamentals (D)
1	x	x			x	CAD/CAM: Age of Transition (V)
3	x	x			x	CAD/CAM, Intro to (V)
1	x		x			CAM — Computerized Sys: Project Overview (V)
1	x		x			CAM — Production Sys: Performance Evaluation Model (V)
1	x	x			x	Deburring, Introduction to (V)
1		x	x		x	Electrostatic Discharge Sensitive (V)
1	x	x			x	Engineering Standards - Design Standards (V)
1	x	x			x	Engineering Standards - Design/Drafting Overview (V)
1	x	x			x	Engineering Standards - Drafting Standards (V)
1	x	x			x	Engineering Standards - Executive Perspective (V)
1	x	x			x	Engineering Standards - General Overview (V)
1	x	x			x	Engineering Standards - Material Standards (V)
1	x	x			x	Engineering Standards - Parts Standards (V)
1	x	x			x	Engineering Standards - Process Standards (V)
1	x	x			x	Engineering Standards - Subject Index Module (V)
5						Fiber Optics Tech. & Application (V)
12			x			Finite Element Methods
11	x	x	x		x	Flight Systems Technology Parts 1-11 (V)
14	x	x	x		x	Geometric Dimensioning & Tolerancing, (Engineers and Designers) (V)
8	x	x	x		x	Geometric Dimensioning & Tolerancing, (Interpreting) (V)
13	x	x			x	Graphite Composite Series (V)
1		x			x	Hydrofoil, Introduction to (V)
11				x	x	Improvement Curve (V)
7			x	x		IRSO's, Understanding (V)
1	x	x			x	Joining (V)
3			x			Logic Design, High Speed (V)
14					x	Machine Technology, Basic (V)
10				x		Manufacturing Quality Control (V)
1	x	x			x	Material Removal (V)
1	x	x			x	Metal Forming (V)
3				x		Metrics, Basic (F)
1				x		Metric, Thinking (S)
73					x	Modern Control Theory (V)
12	x					Numerical Control, Intro to (V)
7		x			x	Omnibus Concepts (V)
1	x	x			x	Productivity Breakthroughs (V)
1	x	x			x	Productivity Challenge (V)
18			x			Quality Engineering Certification Refresher (V)
10				x		Quality Planning (V)
4	x					Statistical Process Control, Introduction to
1	x				x	Tool Design Overview (V)
5			x	x		Test Management — Informs engr. test conductors of the std. operating procedures (V)
1		x			x	Traveler, The Unwelcome (V)
						GENERAL
1		x				Absenteeism, Controlling (V)
1	x	x			x	DATAC Wiring System of Tomorrow (V)
1		x			x	Drop Me Net (V)
1			x			Impressions, First
15				x		Machine Shop Practices — Basic (V)
6	x	x	x	x	x	Retirement, How to Plan for (V)
6	x	x			x	737-300, Introduction & Fam. (V)
1	x	x			x	747, Introduction & Fam. (V)
11	x	x			x	757, Introduction & Fam. (V)
12	x	x			x	767, Introduction & Fam. (V)
2	x	x			x	The Train and The Miracle Man (V)
1		x			x	Winner, Lining Up a (V)
						MANAGEMENT
1	x	x			x	Abilene Paradox (V)
1		x				A Perfectly Normal Day (V)
2			x			Conference Leading Skills (V)
2	x	x			x	Conway: Right Way To Manage (V)
1	x					Decision Making, ABC's of (V)
1	x					Delegate, Don't Abdicate (V)
1	x	x			x	Delegating (V)
1	x	x				Delegation, No Nonsense (V)
1	x					Discipline, Preventive: Insubordination (V)
1	x					Discipline, Preventive: Unsatisfactory Work (V)
1		x			x	Excellence, A Passion for (V)
5	x	x				Executive, Effective (V)
1	x	x			x	Group Dynamics: Group Think (V)
1	x					I'd Like a Word With (V)
1		x				If Japan Can, Why Can't We? (V)
1					x	Keep Reaching: Power of High Expectations (V)
1	x					Making the Pieces Fit (V)
4		x				Manage by Objectives, How to (V)
1	x					Manage by Results, How to (V)
1	x	x			x	Managing the Overseas Assignment (V)
6	x					Management, Modern (V)
1					x	Manager, The One Minute (V)
1					x	Manager, The One Minute, Building Skills (V)
1					x	Manager, The One Minute, Leadership (V)
1					x	Manager, The One Minute, Putting to Work (V)
6	x	x				Manager and the Organization (V)
5		x				Managing for Tomorrow (V)
9	x	x			x	Managing Quality Seminars (V)
1	x	x			x	Motivation: The Classic Concepts (V)
1	x					One Small Step (V)
1	x					Overcoming Resistance to Change (V)
2		x				Productivity & Efficiency, Increasing (V)
1	x					Recipe for Results: Making MBO Work (V)
4	x	x			x	SPC II Masters Series (V)
3	x					Supervision, Advanced (V)
10	x					Supervision, Effective (V)
1					x	Supervisor's Role in Preventing Theft (V)
1	x	x			x	Team Building (V)
2	x					Thanks 'A Plenty Boss (V)
1	x					Time Management (V)
						QUALITY IMPROVEMENT
6	x	x			x	Conway: New Management System (V)
1	x	x			x	I Know It When I See It (V)
16	x	x			x	Juran on Quality Improvement (V)
1	x	x			x	Management's Five Deadly Diseases (V)
1	x	x			x	Quality Is Free (V)
16	x	x			x	Quality, Productivity, and Competitive Position Deming (V)
1	x	x			x	Quality: Pursuit of Excellence (V)
1	x	x			x	Quality: The Competitive Advantage (V)
1	x	x			x	Roadmap for Change: The Deming Approach, Part I (V)
1	x	x			x	Roadmap for Change: The Deming Legacy Part II (V)
8	x	x			x	Taguchi Methods of Experimental Design (V)
1	x	x			x	Team Excellence (V)
3	x	x			x	Tribus: Action Plans for Implementing Quality and Productivity (V)
						TEACH/TRAINING
2	x					Classroom Instructor, The Supervisor as a (V)
6			x			Getting It on Video I (F)
5			x			Getting It on Video II (F)
1			x			Producing AV Sound Tracks (S)
1			x			Sound: Recording & Reproducing (F)
2	x		x		x	Teaching, Elements of Effective (F) (V)
2			x			Television Instruction, Improved Candid Classroom (V)
1			x			Video Editing — SMPTE Time Code
3		x				Video Production, Sight & Sound (V)
8			x			Video Recording, Basic (V)
1					x	Visual Aids, Making Sense With (V)
1	x	x				Visuals, Using the Classroom (V)

PROGRAMMED INSTRUCTION BOOK COURSES (FOR PURCHASE)

Self-paced program instruction/Self-Teach courses are available for purchase at the Plant 2 and Everett Learning Centers for home study. Preview copies are available at the Auburn, Kent, Plant 2, Everett, and Renton Learning Centers.

To order any of the books listed below, submit a separate Training Payroll Deduction Card (D3-4300-0720) for each book to the Learning Center designated below.

Boeing Training-Transcript credit may be earned for some of the courses upon completion of a final examination. Arrangements can be made with the Learning Center where purchase was made.

Plant 2 Learning Center, Orgn. 2-1846, M/S 15-16, 655-1829
Everett Learning Center, Orgn. 6-1089, M/S 07-14, 342-0442

Commercial Airplane Company personnel must submit their request to the Everett Learning Center.

COURSE TITLE	PRICE	PLANT 2	EVERETT
BUSINESS			
Accounting Essentials	$ 7.95	X	X
PERT	22.95	X	
COMMUNICATIONS			
Better Business Letters	8.97		X
Communication Systems, Understanding	6.95	X	X
Effective Business and Tech. Presentations	10.95		X
Listening	9.60		X
Vocabulary for Adults	3.95	X	X
Writing, Clear	7.95		X
COMPUTERS/MICROPROCESSORS			
"Absolutely Essential Utilities for the IBM PC"	22.00		X
APT (Automatic Program Tool)	7.50		X
6502 Assembly Language Programming	11.95	X	X
8080/8085 Assembly Language Programming, Intro. to	10.95	X	X
8080/8085 Primer	13.33		X
BASIC Book, The	6.40		X
BASIC, Data File Programming in	11.95	X	X
BASIC, 2nd Edition	12.95	X	X
"C" Programming Language	21.44		X
CP/M Using	14.95	X	
COBOL, Structured	10.95	X	X
Computer Science, Understanding	11.40	X	X
Computer, Your First	9.95		X
CP/M for the IBM, Using CP/M-86	11.95	X	
Data Processing, Intro. to	9.95	X	X
D-Base III Plus Power	14.50		X
Flowcharting	8.95	X	X
FORTRAN IV (Wiley & Sons)	11.95	X	
Hard Disk Management	14.50		X
IBM PC Data File Programming	11.95	X	
FORTRAN 77	11.50		X
Lotus 1-2-3 Business Application, The Power of:	12.04		X
Lotus 1-2-3 Complete Reference, The Power of:	12.04		X
Math for Computer World, Background	8.75	X	X
Microprocessor, Understanding	6.95	X	X
MS-DOS and PC-DOS User's	15.95	X	
PASCAL Applications for the Sciences	12.95	X	
PASCAL, First Course in Comp. Prog.	18.19		X
PASCAL, Oh!	24.95		X
PC DOS, Running — The Power of	15.95		X
PC DOS — Using The IBM Operating System	14.95	X	
PC Graphics	12.75	X	
R-Base 5000: The Power of	13.40		X
R-Base System V Users Guide	13.75		X
Turbo Prolog	16.95		X
ELECTRICAL/ELECTRONICS			
AC Circuits — Basic Circuits	18.25	X	
Algebra, Boolean and Logic Design	10.95	X	
Digital Electronics, Understanding	11.85	X	X
Electricity, Basic	7.95	X	X
Electronics	9.27	X	X
Optronics, Understanding	6.95		X
Solid State Electronics, Understanding	14.95	X	X
ENGINEERING/TECHNICAL			
Algebra, Matrix	22.95	X	
Algebra, Practical	8.95	X	X
Calculus, Quick	7.95	X	X
Electrical Engineering Review	22.95	X	
Engineering Fundamentals	22.95	X	X
Laplace Transforms	22.95	X	
Linear Algebra with Computer Applications	10.35	X	X
Mathematics, Finite	7.95	X	
Mech. Eng. for PE Exam	14.72		X
Statics, Intro. to	25.95	X	
and Notebook	8.80	X	
Statistics 2nd Ed.	10.95	X	X
MANAGEMENT			
Effective Performance Appraisals	5.95		X
30 Minute Supervisor	5.45		X
Managing Behavior on the Job	10.35		X
Organizational Success, Planning For	10.35	X	
Quality Interviewing	5.95		X
Successful Negotiation	5.95		X
Supervisor As An Instructor	12.00		X
Team Building	5.95		X
Time Management, Successful	8.75	X	
GENERAL			
Arithmetic, Quick	7.95	X	X
Attitude: Your Most Priceless Possession	5.00		X
Chemistry, Concepts and Problems	8.95	X	
Geometry and Trigonometry for Calculus	8.75	X	X
Graphs and Tables, Using	6.95	X	
Math, Shop	12.34	X	
Mathematics Made Simple	3.45		X
Physics, Basic	7.95	X	X
Preventing Job Burnout	5.00		X
Stop Procrastinating — Do It!	1.49		X
Study Skills	5.95		X
Trigonometry	5.50	X	X

HOME STUDY

AVAILABLE YEAR AROUND: LOAN ONLY

All courses are audio cassette except those noted as disk based (D) or 1/2" VHS video tape (VT) and computer aided instruction (CAI).

These courses require the following deposit:
Audio Cassette—$30 per tape
Disks—$60 per set
1/2" Video Tape—$100 per tape
Computer Aided Instruction—$60 per set.

# Tapes/Disks	Auburn	Everett	Kent	Plant 2	Renton	
						BUSINESS
1				x		Accounting, Basic
6	x	x			x	Accounting Basics
10	x	x			x	Algebra, Beg.
6	x	x			x	Budgeting and Finance, Understanding
6	x	x			x	Budgeting, Fundamentals
30	x	x			x	Business Law I & II
3	x	x		x	x	Career, How To Manage Your
1	x	x			x	Change Masters, The
1	x	x			x	Climbing the Corporate Matterhorn
14	x				x	Dictation Speedbuilding 40-80 WPM
6				x		Dictation & Transcription (60,70,80)
2				x		Dictation Speedbuilding, 40 wpm
6				x		Dictation Speedbuilding, 50 & 60 wpm
6				x		Dictation Speedbuilding, 70 & 80 wpm
6				x		Dictation Speedbuilding, 90 & 100 wpm
6				x		Dictation Speedbuilding, 110 & 120 wpm
6				x		Dictation Speedbuilding, 130 & 140 wpm
1	x	x			x	Dictation, The Art of
6	x	x			x	Encounters With the Future
1	x	x			x	Entrepreneurial Life, The
4				x		Finance and Accounting, Basics of
6			x	x	x	Finance and Accounting for Non-Finance Managers
6	x	x			x	Harvard Business School, What They Don't Teach You
1				x		Image, The Professional (VT)
6	x	x		x	x	Innovation, The Art of"
3	x	x			x	Interview Power
1				x		Marketing Imagination
5		x		x		Math Solution, The
6	x	x		x	x	Mathematics, General
10				x		Negotiating Leverage
8	x	x		x	x	Negotiating, The Art of
1				x		Negotiating, The Psychology of
6				x		Negotiating — Volume 1, The Art of
6				x		Negotiating — Volume 2, The Art of
2	x	x			x	Negotiating, Win-Win
6				x	x	Negotiator, How To Be Successful
1	x	x			x	New Roles, New Relationships
6	x	x		x	x	Office, The Automated
6				x		Padgett/Thompson's Seminar for Secretaries
1	x	x			x	Problem-Solving & Decision Making, Rational
6	x	x			x	Problem-Solving, Creative
6	x	x			x	Reinventing the Corporation
1				x		Sale, The Art of Closing the
6	x	x		x	x	Secretarial Seminar
6	x	x		x	x	Secretarial Seminar, Advanced
4				x		Secretary, Professional
20	x	x			x	Shorthand, Personal (Speedwriting)
6				x		Short Letter Dictation I (50,60,70)
9				x		Short Letter Dictation II (60,70,80)
9				x		Short Letter Dictation III (70,80,90)
6		x			x	Statistics
6	x	x			x	Strategies, Relationship
6				x		Typing Skills, Improving
1				x		Typing Teacher
6	x	x			x	Typewriter, Beyond the
1	x	x			x	When Can You Start?
4	x	x			x	Women, Image and Self-Projection for Today's
4	x	x			x	Women: Power, Politics & Positive Influence for
						COMMUNICATIONS
6	x	x		x	x	Communicate What You Think
1	x	x		x	x	Communicate with Confidence
3				x		Communication, Non-Verbal
1	x	x			x	Conversation (VT)
1	x	x			x	Disagreeing & Confronting
8	x	x		x	x	English
6	x	x		x	x	English Pronunciation, Improve Your (for Non-Native Americans)
1	x	x		x	x	Excellence, First Steps to
1				x		Grammar & Usage
1				x		Grammar, Corporate
1	x	x			x	Handling Disagreements (VT)
6	x	x		x	x	Listen and Be Listened To
1	x	x			x	Listen, How to Effectively (VT)
3				x		Listen Your Way to Success
1	x	x			x	Listening & Communicating Skills
1	x	x		x	x	Listening, Art of Creative
3	x	x		x	x	Listening on the Job
2	x	x			x	Listening Skills, How to Improve
1				x		Listening Test
1	x	x			x	Meetings, How to Organize
6	x	x		x	x	Meetings, How To Run Productive
2				x		Meetings, Leading
6	x	x			x	People, Communicating With
1	x	x			x	People, How to Read (VT)
6	x	x			x	People, Working With
1	x	x			x	Persuasion, the Psychology of (VT)
1	x	x			x	Public Speaking, The Basics of (VT)
3	x	x			x	Punctuation
6				x		Reading/Plus: Speed, Comprehension, and Retention
4	x	x		x	x	Reading, Rapid Comprehension
1	x	x			x	Speak Easy: How To Talk Your Way To The Top
6	x	x			x	Speak For Yourself!
1	x	x		x		Speak & Listen, How to
6	x	x		x	x	Speaker, How to be a Successful Public
6	x	x		x	x	Speaker, The Compleat
4	x	x		x	x	Speaking Effective for Managers
1	x	x		x	x	Speaking, The Art of Public
1	x	x			x	Speech Impact
12	x	x		x	x	Speech, Power
8	x	x			x	Spelling

# Tapes/Disks	Auburn	Everett	Kent	Plant 2	Renton	
2				x		Telephone Know-How
2	x				x	Telephone Techniques, Effective
6	x	x		x	x	VOCAB
4					x	Vocabulary Development, Business
1	x	x			x	Vowel Sounds & Silent Letters
1		x				Words, Winning
12	x					Writing, Letter, for the Office
4	x	x		x	x	Writing, Power
8	x	x			x	Writing, Practical Technical
1	x	x		x	x	Writing Sense
2	x	x			x	Writing Skills, How to Improve
6	x	x		x	x	Writing, Speaking & Listening Skills, Executive
						COMPUTER/ MICROPROCESSOR
1	x	x			x	Artificial Intelligence, Solving Real Problems With (VT)
	x	x			x	Artificial Intelligence, Teach Yourself About (D)
	x	x			x	ASSEMBLY LANGUAGE Computer Programming (BOOK ONLY)
8	x	x			x	BASIC Computer Programming, Beg. (Computer Terminal Required)
3	x	x		x	x	BASIC Computer Programming, Beg. (VT)
3	x	x			x	Basic, Teach Yourself on the IBM PC (CAI)
12	x	x			x	Bits and Bytes (VT)
2	x				x	CadKey, Using (CAI)
3	x	x			x	Catia Graphics System (VT)
9	x	x		x	x	COBOL, Programming in
1	x	x			x	Computer Calc: Electronic Spreadsheets (VT)
1				x		Computer Communications
4					x	Computer Concepts Process
6	x	x			x	Computer Fundamentals for Managers
7				x		Computer — Small System Concepts
1	x	x			x	Computer Images: Computer Graphics (VT)
6					x	Computer, Interactive Systems Concepts
3					x	Computer Literacy — Introduction to Programming
6					x	Computer Literacy — Introduction to Data Processing
1	x	x			x	Computer Talk: Microcomputer Communications (VT)
1				x		Computers, Introduction to (VT)
2	x	x			x	Computers, Introduction to Small
3	x	x		x	x	CPM, How To Operate Your Computer Under
3	x	x			x	CP/M-86, How To Operate Your Computer Under
1	x	x			x	CP/M, How To Use (D)
5	x	x			x	CP/M Operating System
5				x		CP/M Personal Computers
1	x	x			x	Crosstalk Program, IBM Communications for (CAI)
1	x	x			x	Database Management (D)
3				x	x	Data General Computer Hardware Fundamentals
1	x	x		x	x	dBASE II, An Intro. (VT)
2	x	x		x	x	dBASE II, How To Use (D)
1	x	x			x	dBASE III (VT) (D)
2	x	x			x	dBASE III, How To Use (D)
2	x	x			x	Displaywrite (VT) (D)
3	x	x	x		x	EASYWRITER II, How To Use
3	x	x			x	Easywriter II, Training for the (CAI)
1	x	x			x	Electronic Words: Word Processing (VT)
1	x	x		x	x	Electronic Worksheets (VT)
6	x	x		x	x	FORTRAN Computer Programming
8					x	Data Processing
22				x		FORTRAN IV Computer Programming (student provides computer time and consultant)
2	x	x			x	FRAMEWORK, How to Use (D)
2	x	x			x	IBM Asynchronous Communication (CAI)
1	x	x			x	IBM PC, Exploring the (D)
1	x	x			x	IBM PC, How to Get Started (VT)
1	x	x			x	IBM PC, How to Use Software (VT)
3	x	x			x	IBM PC, How to Operate
1	x	x		x	x	IBM PC, How To Use (D)
1	x	x		x	x	IBM PC, How To Use in 10 Easy Lessons (VT)
2				x		IBM XT & AT, How to Operate Your
1	x	x			x	Keeping Track: Database Management (VT)
1	x	x		x	x	Lotus 1-2-3, Adv. (VT)
1	x	x		x	x	Lotus 1-2-3, Intro. (VT)
4	x	x		x	x	Lotus 1-2-3, How To Use
2	x	x		x	x	Lotus 1-2-3, How To Use (D)
	x	x			x	MACRO-86 Assembly Language Course (B)
	x	x			x	MACRO-86 Programming Algorithms (B)
1	x	x		x	x	MBASIC, How To Use (D)
9	x	x			x	Microcomputer Literacy Program
7	x	x			x	Microprocessor, Programming
8	x	x		x		Microprocessors, from Chips to Systems
4				x		Microprocessor Sys., Military
3				x		Microprocessors Sys., Industrial
6				x		Microprocessors — Bit Slice
4				x		Microprocessor, Interfacing Techniques
2				x		Microprocessor, Programming
3	x	x			x	MICROSOFT BASIC Computer Programming
1	x	x			x	MICROSOFT WORD, How To Use (D)
5	x	x			x	MS-DOS
4	x	x		x	x	MULTIPLAN, How To Use
2	x	x		x	x	MULTIPLAN, How To Use (D)
5	x	x			x	PASCAL Computer Programming
2	x	x		x	x	PC-DOS, How To Use (D)
3	x	x			x	R:Base 4000 (D)
3	x	x			x	R:Base 5000, Introducing (CAI)
1				x		Spreadsheets, Introduction to Computer (VT)
4	x	x			x	SUPERCALC, How To Use
1	x	x			x	SUPERCALC, How To Use (D)

# Tapes/Disks	Auburn	Everett	Kent	Plant 2	Renton	
2	x	x			x	SYMPHONY, How To Use (D)
1	x	x			x	Symphony I (VT) (D)
1	x	x			x	Symphony II (VT) (D)
1	x	x			x	Turbo Pascal Tutor (CAI) (D)
1	x	x			x	Typing Tutor (D)
1				x		VISICALC — Intro. to Electronic Spreadsheet (VT)
4	x	x		x	x	VISICALC, How To Use
1	x	x			x	VISICALC, How To Use (D)
1	x	x		x	x	WORD PROCESSING (VT)
1	x	x	x		x	WORD PROCESSING, Introduction to (D)
2	x	x		x	x	WORD STAR, How To Use (D)
3	x	x		x	x	WORDSTAR, How To Use
4				x		WORDSTAR WITH MAILMERGE, How To Use
						ENGINEERING/TECHNICAL
8		x		x	x	Aerodynamics, Applied Computation
10				x		Aerodynamics, Transonic (10 Tapes)
11		x			x	Aeroelasticity
30		x			x	A/P Flight Dynamics & Automatic Flight
3	x	x			x	CAD/CAM, Intro to (VT)
8		x			x	Calculus, Basic
6					x	Chromatography, Basic Gas
12					x	Chromatography, Modern Liquid
6			x			Digital Board Testing (Kent)
18		x				Digital Board Testing
2		x			x	Digital Flight Control
1	x	x			x	Engineering Standards - Design Standards (VT)
1	x	x			x	Engineering Standards - Design/Drafting Overview (VT)
1	x	x			x	Engineering Standards - Drafting Standards (VT)
1	x	x			x	Engineering Standards - Executive Perspective (VT)
1	x	x			x	Engineering Standards - General Overview (VT)
1	x	x			x	Engineering Standards - Material Standards (VT)
1	x	x			x	Engineering Standards - Parts Standards (VT)
1	x	x			x	Engineering Standards - Process Standards (VT)
1	x	x			x	Engineering Standards - Subject Index Module (VT)
11	x	x			x	Flight Systems Technology Parts I-II (VT)
2		x			x	Fracture Mechanics
13					x	Fracture Mechanics (VT)
5					x	Infrared Spectra, Interpretation of Controls
2					x	Ion-Selective Membrane Electrodes (a useful tool for determining the ionic composition of solutions)
6				x		Microwave Equipment, Understanding
8					x	Spectroscopy, Intermediate NMR
4	x	x			x	Trigonometry, Numerical
						MANAGEMENT
1	x	x			x	Abilene Paradox (VT)
2					x	Appley in Action
12	x	x			x	Behavioral Sciences, What Every Manager Should Know
5		x		x	x	Bennis on Leaders
6				x		Career Success, Strat. for Women on the Move
1	x					Complaints & Grievances, Handling
1	x	x			x	Conway: Right Way to Manage (VT)
6				x		Corporation, Reinventing the
20	x					Decision Making, Analysis for
1				x		Decision Making, The Art of
1				x		Decision Making, Tough-Minded
6	x	x		x	x	Decisions, How To Make Better
1	x	x			x	Delegation, Do's and Don't of
3				x		Delegation, Process of
6	x	x		x	x	Delegation, Successful
6	x	x			x	Delegation, The Fine Art of
2		x			x	Discipline, Constructive on the Job
6				x		Discipline for Supervisors, Constructive
3				x		Effective Dictation for Managers & Executives
2	x	x				Employees, Handling Problem
4	x	x			x	Excellence, Achieving
6	x	x		x	x	Excellence Challenge, The (Tom Peters)
1	x	x		x	x	Excellence, In Search of (Tom Peters)
2	x	x			x	Excellence, Managing for
6	x	x			x	Excellence, The New Masters of (Tom Peters)
6	x	x				Executive, How To Be an Effective
8	x			x		Executive Seminars in Sound
1	x	x		x	x	Executive Style and Confidence
3	x					Executive, The Mature
1				x		Executive, Qualities of a Successful
4	x	x				How to, Drucker
6	x	x			x	Iacocca Tapes
6	x	x			x	Interpersonal Relations
1		x			x	Interview, Appraisal & Career Counseling
1		x			x	Interview, Exit
1		x			x	Interview, Information
1	x	x			x	Interview, Problem Employee
1		x			x	Interview, Selection
4	x					Interviewing, Selection
2	x					Interviews, Conducting Lawful
10				x		Job Well Done, Getting the
1	x	x			x	Leadership Challenge, The
6	x	x			x	Leadership, New: Managing People and Change
6				x		Leadership Skills, Winning With
1	x	x			x	Leading for Superior Results
1				x		Magic of Thinking Big

HOME STUDY

AVAILABLE YEAR AROUND: LOAN ONLY

All courses are audio cassette except those noted as disk based (D) or 1/2" VHS video tape (VT) and computer aided instruction (CAI).

These courses require the following deposit:
Audio Cassette—$30 per tape
Disks—$60 per set
1/2" Video Tape—$100 per tape
Computer Aided Instruction—$60 per set.

# TAPES/DISKS	AUBURN	EVERETT	KENT	PLANT 2	RENTON	Course
7		x		x	x	Manage, How Successful Managers
12		x			x	Management and Organization Development
6	x	x			x	Management & Supervision, Fundamentals of
12				x		Management Applications
3				x		Management, Basics of
6	x			x		Management, Batten
12	x	x		x	x	Management by Objective — Executive Skills
12	x	x		x	x	Management by Objective — Supervisory Skills
1	x	x			x	Management by Objectives & Results — Overview
6	x	x			x	Management, High Output
1				x		Management, Power in
6				x		Management Techniques for Women
4		x		x	x	Management, Face-to-Face
4	x	x			x	Management for the 80's
1		x		x	x	Management, Human Values in
6	x	x		x	x	Management, Objective-Focused
8	x	x		x	x	Management, Peter Drucker
6	x	x		x	x	Management, Project
1	x	x		x	x	Management, Quality and Style
5	x					Management, Successful — The Expert's Way
1		x		x	x	Management, The Art of
1				x		Management, Shirt Sleeves
6	x	x		x		Management, Total Time
1		x		x	x	Management, Tough Minded
6	x	x		x	x	Manager, How to be an Effective Middle
3	x				x	Manager, Self Discovery
1				x		Manager, Talking With the One Minute
1	x	x			x	Manager, The First Time
2	x	x		x	x	Manager, The One Minute
1					x	Manager, The One Minute (VT)
1					x	Manager, The One Minute, Building Skills (VT)
1					x	Manager, The One Minute, Leadership (VT)
1					x	Manager, The One Minute, Putting to Work (VT)
6	x	x			x	Manager, The One Minute: Leadership
3	x	x			x	Manager, The One Minute, Meets the Monkey
2	x	x			x	Manager, The One-Minute, Putting to Work
1				x		Manager to Work, Putting the One Minute
9		x				Manager, Professional Woman
6	x	x			x	Manager, Values Driven
6	x	x		x	x	Managerial Authority, Using
1		x		x	x	Managerial Communications
2	x	x			x	Managerial Courage
1		x		x	x	Managerial Creativity
6	x	x			x	Managerial Effectiveness, Uncommon Leader I
5				x		Managerial Skills
7	x	x			x	Managerial Skills, Four Essential
4	x	x		x	x	Managerial Planning, Organizing & Controlling
6	x			x	x	Managerial Skills for New and Prospective Managers
1				x		Manager, The Self-Reliant
6				x		Manager's Role — Women in Workforce
1				x		Manager, The First Time
1		x		x	x	Managers, Action Tools for
1	x	x		x	x	Managers Make, The 22 Biggest Mistakes
1	x	x			x	Managing
1					x	Managing an Organization
6					x	Managing Assertively
1	x	x			x	Managing by Goals and Results
5	x	x		x	x	Managing Conflict
1				x		Managing Conflict Between Groups
4				x		Managing Conflict Productively
1				x		Managing Conflict Within Committees
6	x					Managing Labor Relations
9	x	x			x	Managing Quality Seminars (VT)
6					x	Managing the Application Development Process
1	x	x			x	Managing the New Generation
1				x	x	Mistakes Managers Make, 22 Biggest
6		x		x	x	Motivation and Discipline
4	x	x			x	Motivation, Face-to-Face
1	x	x			x	Motivation, Fallacies of Employee
1	x				x	Motivation, Gellerman on
3					x	Motivation, Putting Back Into Work
1	x	x			x	Motivation through the Work Itself
1		x			x	Motivational Factors in Management
4		x			x	New Dimensions for Today
4				x		Organization Development, Concepts & Theories
1	x	x		x	x	Organization, Further Up the
4					x	Organization — Predictions/Prescriptions, Presented by Chris Argyris
1		x			x	Performance Standards and Specific Objectives
6	x					Personnel Administration by Objectives
4				x		Personnel Management, Basics of
2				x		Planning & Scheduling for Supervisors
4	x	x		x	x	Problem Solving Skills for Supervisors
1	x	x			x	Productivity, Gellerman on
1	x	x			x	Productivity, Goal Setting
1		x			x	Productivity, How To Inspire Your Subordinates
6	x	x			x	Productivity, Increase, Uncommon Leader II
6	x	x			x	Productivity, Supervisor's Guide to Boosting
5	x	x			x	Project Planning & Management, Effective
12	x	x		x	x	Robert Townsend Seminar
4				x		Secretary as a Manager
6	x	x			x	Self Starters, How to Grow People into
1				x		Strategic Thinking — Putting It All Together
1				x		Success and Failure, Beyond
1				x		Stress, How to Manage
1				x		Stress Management
10	x					Supervising, The Practice of
6	x	x			x	Supervision, Basic ($11.15 fee for materials)
10					x	Supervision, The Fundamentals of Face-to-Face Human Relations and Communication
1		x		x	x	Supervision, Job of
12	x				x	Supervision, Sounds of
26				x		Supervision, Sounds of
6	x					Supervisor, How to be an Effective
8	x	x			x	Supervisor, Organizational Role of
14	x	x		x	x	Supervisor, The New
6		x			x	Supervisory Effectiveness
6	x	x			x	Supervisory Leadership, Developing
7				x		Supervisory Success
1		x			x	Team Building: Conflict & Negotiation
6	x	x			x	Team Building, Effective
6	x	x			x	Teamwork and Commitment, Building
6	x	x			x	Teamwork, Winning through
4	x			x		Time Control, Clues to Executive
6		x			x	Time, Effective Management of
1		x			x	Time, Effective use of Management
4	x	x			x	Time Management, Beyond
6				x		Time Management
10				x		Time Management for Secretaries
9	x			x	x	Time Management for Secretary/Manager Team
4				x		Time Management, Secretarial
6				x		Time Management, Total
6	x	x			x	Time Management, The New
9	x	x		x	x	Time Managing
10	x	x		x	x	Time, Managing Management
2				x		Time on the Job, Making the Most of Your
1				x		Time Organization, How To Master
2	x	x			x	Top Executive Performance
3				x		Tough Minded Team Building
6	x	x			x	Unsatisfactory Performer, Managing The
6	x	x			x	Women, Leadership & Supervisory Skills for
6	x	x		x	x	Women on the Move, Strategies for Career Success

GENERAL

# TAPES/DISKS	AUBURN	EVERETT	KENT	PLANT 2	RENTON	Course
8		x			x	Achievement Dynamics
1	x	x			x	Acres of Diamonds
2	x	x			x	Assertion Training
4		x				Assertiveness Training, Self-Directed
1	x	x			x	Attitude, How to Build a Success (VT)
2	x	x			x	Becoming An Everyday Genius: Communications Series (VT)
2	x	x			x	Becoming An Everyday Genius: Creativity Series (VT)
1	x	x			x	Becoming An Everyday Genius: Improving Your Memory (VT)
2	x	x			x	Becoming An Everyday Genius: Mind Mapping Series (VT)
3		x			x	Bigamy, Corporate
1				x		Biscuits, Fleas & Pump Handles
1					x	Born to Win
6	x	x			x	Build a Better You
1	x	x		x	x	Career Directions — Accountant (VT)
1	x	x		x	x	Career Directions — Computer Programmer/Analyst (VT)
1	x	x		x	x	Career Directions — Computer Science (VT)
1	x	x		x	x	Career Directions — Drafting (VT)
1	x	x		x	x	Career Directions — Electrical Engineer (VT)
1	x	x		x	x	Career Directions — Electronic Technician (VT)
1	x	x		x	x	Career Directions — Estimator (VT)
1	x	x		x	x	Career Directions — Manufacturing Engineer (VT)
1	x	x		x	x	Career Directions — Methods Analyst (VT)
1	x	x		x	x	Career Directions — Numerical Control Programmer (VT)
1	x	x		x	x	Career Directions — Plastics Technology (VT)
1	x	x		x	x	Career Directions — Purchasing Agent (Buyer) (VT)
1	x	x		x	x	Career Directions — Structural Engineer (VT)
1	x	x		x	x	Career Directions — Tool and Production Planner (VT)
1	x	x		x	x	Career Directions — Tool Builder (VT)
1	x	x		x	x	Career Directions — Word Processing (VT)
3				x		Career, How To Manage Your
1	x	x			x	Control of Your Time and Your Life
6				x		Coping Effectively With Difficult People
2	x	x			x	Creative Mystique
7	x	x			x	Creativity, Everyday
1				x		Double Your Reading Speed
10	x	x			x	Effectiveness, Developing Personal
6	x	x			x	Effectiveness, Increasing Human
1	x	x		x	x	Enthusiasm, How To Develop the Power of
1		x			x	Everybody Wins
1	x	x			x	Excuses
1	x	x			x	Excellence, Achieving (VT)
1	x	x			x	Excellence, Achieving Personal (VT)
7	x	x		x	x	Focus (Self Image Psychology)
6	x	x			x	Getting Things Done Now
1	x	x			x	Go For It! How to Win at Work, Love and Play
1	x	x			x	Goal Development, Personal Balanced
1	x	x		x	x	Goal Setting
4	x	x			x	Goal Setting: Getting Your Act Together
1	x	x		x	x	Goal Setting, Power of
6	x	x			x	Goals, Setting & Achieving Personal
3				x		Habits of Highly Effective People, Seven
2	x	x			x	High Performance in a Changing Environment
6	x	x		x	x	How to be a No Limit Person
1	x	x			x	How To Be A No Limit Person (VT)
6	x	x			x	How To Exceed Yourself
1	x	x			x	How To Get Results With People (VT)
1	x	x		x	x	How To Save Two Hours a Day
1	x	x			x	I'm OK — You're OK
1		x			x	Imagination, Applied
1				x		Imaging, Positive
4				x		Instrument Flying — IFR Charts
12	x	x			x	It's Time for You
1				x		Keys to Creative Living
6	x	x		x	x	Lead the Field
1	x	x			x	Leadership, Maximizing People Potential (VT)
1	x	x		x	x	Magic of Getting What You Want, The
6	x	x			x	Megatrends: Ten New Directions
1		x		x		Memory, How To Improve Your
1				x		Memory, Improving Your
3	x	x		x	x	Memory Made Easy
1	x	x		x	x	Memory Magic
6	x	x		x	x	Memory, Power
1	x	x			x	Memory, What's In It for Me (VT)
1	x	x			x	Motivating Four American Generations (VT)
1		x		x	x	Motivation, Key to
1	x	x			x	Motivation, Personal
3	x	x			x	No, The Positive
1	x	x			x	Opening Closed Minds
1	x	x			x	Organize Yourself for Success
1	x	x			x	Peak Performance (VT)
4		x			x	People, Dealing With Difficult
1	x	x		x	x	People, Getting Through to
1	x	x			x	People, How to Motivate
1	x	x		x	x	People, How to Use Tact & Skill in Handling
4	x	x		x	x	People, How to Work With Irate
6	x	x			x	People, Managing
1	x	x			x	People, Power With
8	x	x			x	People, Results With
6	x	x		x	x	Performance, Peak
1	x	x			x	Performers, How to Develop Top (VT)
1	x	x		x	x	Potential, Realize Your
1	x	x		x	x	Procrastinating, Stop—Do It!
6	x	x			x	Psychology of High Self-Esteem
1	x	x		x	x	Remembering, Art of
1	x	x		x	x	Retirement, How to Plan for (VT)
1	x	x		x	x	Risk Taking, A Guide To Personal
1	x	x		x	x	Risking
2				x		Secretarial Time Mgmt.
6				x		Secretaries/Admin. Ass't., Guide for Executive
8	x	x			x	Secrets of the Universe
6	x	x		x	x	Seeds of Greatness
1	x	x			x	Self-Management, the Psychology of (VT)
1		x			x	Selling the Sizzle
1	x	x			x	Selling With Service (VT)
3	x	x			x	737-300 Intro & Familiarization (VT)
1	x	x			x	747, Intro & Familiarization (VT)
5	x	x			x	757, Intro & Familiarztion (VT)
5	x	x			x	767, Intro & Familiarization (VT)
6	x	x			x	Speaking of Success, Volume I
6	x	x			x	Speaking of Success, Volume II
3	x	x			x	Stress, Coping With
2	x	x		x	x	Stress, Dealing With Job Related
6	x	x			x	Stress Free Living, Strategies for
1				x		Stress, How To Turn Off
4	x	x			x	Stress Management for Professionals
1	x	x			x	Stress, Success and the Type A Report Card (VT)
2	x				x	Stress, Success Without
6	x	x		x	x	Stress, Understanding & Managing
1	x	x		x	x	Success, Formula For
1				x		Success for Women, Steps to
8				x		Success is a State of Mind
1				x		Success, Secrets of
12		x				Success, Science of Personal
6		x			x	Success Series
6	x	x			x	Success, Seven Strategies for Wealth & Happiness
6				x		Success, Six Secrets of Business & Personal
6	x	x			x	Superwoman Syndrome
6	x	x			x	Take Charge of Your Life
1				x		Taking Charge on the Job
2	x	x			x	The Train and The Miracle Man (VT)
6	x	x		x	x	Thinking, Creative
6	x	x			x	Thinking, Strategic
1	x	x			x	Time Management (VT)
1				x		Time, Stop Wasting
1					x	Transactional Analysis Overview
1		x				Transactional Analysis — Success through
1				x		Whack on the Side of the Head, A
6	x	x			x	Winner, The Inner
1	x	x				Winners and Losers
1	x	x		x	x	Winner's Edge, The
12	x	x			x	Winning
1	x	x			x	Winning In Action, The Psychology of (VT)
6	x	x			x	Winning Moves: The Body Language of Success
1	x	x			x	Winning Over Shyness
1	x	x			x	Winning, the Inner Game of
6				x		Winning, the Psychology of
6	x	x			x	Women, Success Seminar for Working
6	x	x			x	Yonger Tapes

TEACHER/TRAINING

# TAPES/DISKS	AUBURN	EVERETT	KENT	PLANT 2	RENTON	Course
12	x	x	x		x	Grownups, How To Teach
1	x	x			x	Supervisory Skills: Training and Orientation

FOREIGN LANGUAGES

Languages listed below are for purchase only. *Indicates two payroll deduction cards are required if purchased from Plant 2 or Kent Learning Center. One for tapes and one for book. If purchased from the Renton Learning Center, only ONE payroll deduction card for the total cost of tapes and book is required. No asterisk indicates one payroll deduction card is required for tapes and book.

FOR YOUR INFORMATION: The following courses are located in the Plant 2 Learning Center:
All French Language Audio Tapes
Fortran IV Audio Tape Series
All Home Checkout VHS Video Courses
All Home Checkout ASI Computer Presented Courses

KENT LEARNING CENTER, M/S 3C-01 773-9460
PLANT 2 LEARNING CENTER, M/S 15-16 655-1829
RENTON LEARNING CENTER, M/S 99-11 237-9789

Commercial Airplane Company personnel must submit their request to the Renton Learning Center.

LANGUAGE	TAPE COST	BOOK COST	TOTAL COST	LOCATION
AMHERIC I			$31.00	RTN
AMHERIC II			$14.75	RTN
CANTONESE I			$20.75	PLT2/RTN
* CANTONESE II			$18.80	PLT2/RTN
STANDARD CHINESE —				
Module 1 & 2		$ 6.05		Kent
Module 1 — Orientation	$ 6.84			Kent
Module 2 — Biographic Info.	$16.72			Kent
Module 3 & 4		$ 5.64		Kent
Module 3 — Money	$129.2			Kent
Module 4 — Directions	$11.40			Kent
Module 5 & 6		$ 7.44		Kent
Module 5 — Transportation	$18.72			Kent
Module 6 — Arranging A Meeting	$16.72			Kent
Module 7 — Society	$ 7.60	$ 3.91	$11.51	Kent
Module 8 — Traveling in China	$ 7.60	$ 3.54	$11.14	Kent
Resource Module — Pronunciation and Romanization; Numbers: Time and Dates; Classroom Expressions	$ 6.84	$ 1.30	$ 8.14	Kent
Option Module — Personal Welfare	$ 2.28	$ 1.43	$ 3.71	Kent
Optional Module — Customs Surrounding Marriage, Birth and Death	$ 2.28	$ 2.14	$ 4.42	Kent
Optional Module — Restaurant; Hotel; Post Office and Telephone; Car	$ 7.60	$ 2.13	$ 9.73	Kent
FRENCH I — PART I			$27.25	PLT2/RTN
FRENCH I — PART II			$24.50	PLT2/RTN
FRENCH II — PART I			$36.00	PLT2/RTN
FRENCH II — PART II			$18.25	PLT2/RTN
FRENCH PHONOLOGY			$13.84	PLT2/KSC
GERMAN I			$28.50	PLT2/RTN
GERMAN II			$34.75	PLT2/RTN
GREEK			$23.00	PLT2/RTN
* HEBREW			$40.00	KSC/RTN
ITALIAN I			$31.00	PLT2/RTN
JAPANESE I			$23.75	PLT2/RTN
JAPANESE II			$22.75	PLT2/RTN
KOREAN I			$32.00	KSC/RTN
KOREAN II			$24.95	KSC
* PERSIAN (FARSI)	$17.85	$ 4.40	$22.25	PLT2/RTN
* PORTUGUESE I	$19.88	$18.00	$37.88	PLT2
PORTUGUESE II			$29.24	PLT2
RUSSIAN (MODERN)			$34.75	PLT2/RTN
SAUDI ARABIC			$21.75	PLT2/RTN
SPANISH I (PROGRAMMATIC)			$29.24	KSC
SPANISH II (PROGRAMMATIC)			$22.16	KSC
SPANISH I			$24.00	RTN
SPANISH II			$31.25	RTN
SPANISH III			$26.25	RTN
SPANISH IV			$27.25	RTN
* SPANISH TO PORTUGUESE	$ 2.28	$ 3.35	$ 5.63	PLT2
* SWEDISH	$21.80	$ 7.70	$29.50	KSC/RTN
* TURKISH	$17.16	$ 7.75	$24.91	PLT2
TURKISH			$17.25	RTN

Language "Take-Along" Kits

These kits are made up of two audio cassette tapes and a phrase dictionary and study guide designed to help the traveler at hotels, restaurants, post offices, travel terminals, business places, and other locations. To receive a kit, submit a Training Payroll Deduction Card (D3-4300-0720) for $10.75.

KENT LEARNING CENTER, M/S 3C-01 773-9460
PLANT 2 LEARNING CENTER, M/S 15-16 655-1829
RENTON LEARNING CENTER, M/S 99-11....237-9789

Commercial Airplane Company personnel must submit their request to the Renton Learning Center.

ARABIC	HEBREW	PORTUGUESE
CHINESE (MANDARIN)	INDONESIAN	RUSSIAN
DANISH	ITALIAN	SERBO-CROATION
DUTCH	JAPANESE	SPANISH
FRENCH	KOREAN	SWAHILI
GERMAN	NORWEGIAN	SWEDISH
GREEK	PERSIAN	TURKISH

In addition, the Renton Learning Center has the following language books available:
Japanese in 10 minutes a day
French in 10 minutes a day
Spanish in 10 minutes a day
German in 10 minutes a day

These books consist of a series of 10-minute sessions which quickly provide the necessary skills to communicate abroad. They provide travel and cultural tips while increasing your word power, and are an excellent companion to the Take-Along Kits described above. Submit a training payroll deduction card to the Renton Learning Center, M/S 99-11, for $9.34.

PROGRAMMED INSTRUCTION BOOK COURSES (CHECK OUT)

(NOTE: THESE COURSES ARE ONLY AVAILABLE FROM THE EVERETT, AND PLANT 2 LEARNING CENTERS.
PLANT 2 LEARNING CENTER, M/S 15-16..........655-1829
EVERETT LEARNING CENTER, M/S 07-14..........342-0442

Personnel from the Commercial Airplane Company must submit their requests to the Everett Learning Center.

Programmed instruction courses consist of individual books which have been designed to enable students to work at their own pace. Each book contains from 5 to 10 study units. Each unit contains self-graded quizzes which allow students to evaluate their progress.

You may enroll in all of the courses for a particular series, or may enroll in selected courses within any series.

To enroll in a programmed instruction course, submit a payroll deduction card ($30.00 deposit, which is not deducted unless the book is not returned) to the Everett or Plant 2 Learning Center. Indicate on the "ITEM" line of the card the series or the particular book that you wish to check out. The book will be mailed to your mail stop as soon as it becomes available. Only one book can be checked out at a time. Programmed instruction courses are available in the following series:

AIR CONDITIONING AND REFRIGERATION SYSTEMS MAINTENANCE
Book 1 Intro. to Air Conditioning & Refrigeration
Book 2 Refrigerants and Refrigerant Oils
Book 3 Compressors
Book 4 Evaporators
Book 5 Condensors and Cooling Towers
Book 6 Piping Systems
Book 7 Air Handling Systems for Air Conditioning
Book 8 Control Systems for Air Conditioning
Book 9 Troubleshooting Refrigeration Systems
Book 10 Troubleshooting Air Conditioning Systems

ELECTRICAL MAINTENANCE
Book 1 Intro. to Electricity & Electronics
Book 2 Batteries and D-C Circuits
Book 3 Transformers and A-C Circuits
Book 4 Electrical Measuring Instruments
Book 5 Electrical Protective Devices
Book 6 D-C Equipment and Controls
Book 7 Single-Phase Motors
Book 8 Three-Phase Systems
Book 9 A-C Control Equipment
Book 10 Electrical Troubleshooting

INDUSTRIAL ELECTRONICS
Book 1 Semiconductors
Book 2 Power Supplies
Book 3 Amplifiers
Book 4 Oscillators and Multivibrators
Book 5 Logic Circuits

INSTRUMENTATION AND PROCESS CONTROL
Engineer and Maintenance Technicians
Book 1 Introduction to Process Control
Book 2 Foundations of Measurement Instrumentation
Book 3 Pressure Measurement
Book 4 Force, Weight, and Motion Measurement
Book 5 Flow Measurement I
Book 6 Flow Measurement II
Book 7 Level Measurement
Book 8 Temperature Measurement
Book 9 Final Control Elements
Book 10 Safety, Testing and Calibration Procedures

MACHINE SHOP PRACTICES
Book 1 Machine Shop Practice
Book 2 Machine Shop Turning Operations
Book 3 Machine Shop Shaping Operations
Book 4 Job Analysis
Book 5 How to Turn Work Between Centers
Book 6 How to Machine Work
Book 7 Using Basic Milling Procedures
Book 8 Using Indexed Milling Procedures

MAINTENANCE FUNDAMENTALS
Book 1 Measurement
Book 2 Basic Blueprint Reading
Book 3 Reading Schematic and Symbols
Book 4 Basic Shop Math
Book 5 Using Hand Tools
Book 6 Using Portable Power Tools
Book 7 Protecting Safety and Health in the Plant
Book 8 Developing Troubleshooting Skills
Book 9 Working With Metals
Book 10 Working With NonMetals

MAINTENANCE MANAGEMENT FOR FIRST LINE SUPERVISORS
Book 1 Implementing a Preventive Maintenance Program
Book 2 Resource Management and Control
Book 3 Improving Maintenance Performance

MECHANICAL MAINTENANCE
Book 1 Elements of Mechanics
Book 2 Lubrication
Book 3 Drive Components
Book 4 Bearings
Book 5 Pumps
Book 6 Piping Systems
Book 7 Basic Hydraulics
Book 8 Hydraulic Troubleshooting
Book 9 Basic Pneumatics
Book 10 Pneumatic Troubleshooting

MICROPROCESSORS
Book 1 Microprocessors, Microcomputers
Book 2 Microprocessors
Book 3 Application I/O
Book 4 System I/O
Book 5 Maintaining/Troubleshooting

PACKAGING MACHINERY MAINTENANCE
Book 1 Introduction to Packaging
Book 2 Packaging Machinery
Book 3 Casing Packaging

POWER PLANT UNITS
Book 1 How Power Plants Work
Book 2 Generating Steam in the Power Plant
Book 3 Using Steam in the Power Plant

RIGGING AND EQUIPMENT INSTALLATION
Book 1 Rigging
Book 2 Equipment Installation

SUCCESSFUL WRITING (EVT. only) 1 Book
Unit 1 The Pride Strategy: An Overview
Unit 2 Personal Purposes: Receiver Attitudes Situational
Unit 3 Personal Purposes: Receiver Attitudes Predetermined
Unit 4 Task Purposes: Receiver Attitudes Predetermined
Unit 5 Impact and Design: Initial Phase
Unit 6 Impact and Design: Follow-Up and Pay-Off phases
Unit 7 Design: Applications and Summary
Unit 8 Execution: Letters and Memoranda
Unit 9 Execution: Reports
Unit 10 Execution: Forms
Unit 11 Execution: Clarity, Correctness, and Coherence

EFFECTIVE PRESENTATION (EVT. only) 1 Book
Unit 1 Personal Communicativeness
Unit 2 Structure and Thesis
Unit 3 The Kinds of Structure
Unit 4 The Functional Approach
Unit 5 Idea Support and Reinforcement
Unit 6 Outlining and Data Gathering
Unit 7 Idea Integrity
Unit 8 Visual and Other Aids
Unit 9 Preparing to Face the Audience
Unit 10 At the Podium

DIAL-A-COURSE

(EARN BOEING TRANSCRIPT CREDIT VIA YOUR PHONE)

Dial-A-Course is designed for the employee who wishes to use 15 to 40 minutes listening to audio cassette courses on a variety of subjects. The telephone is the link to the audio tape.

There is NO CHARGE for Dial-A-Course and it is easy to use. If you are on the Greater Seattle exchange, simply pick up your telephone and call a special Plant 2 extension at a specific time and date. You will then be able to hear the audio tape.

Beginning January 11, 1988, noontime and evening courses will be offered through the Dial-A-Course System. The number of tapes per course is shown in parenthesis. To enroll, check no more than FOUR choices from the total list below. Be sure to CIRCLE the time that you prefer to hear the course(s) of your choice. Mail this form by December 11, 1987 to: DIAL-A-COURSE, ORGN. 2-1846, MAIL STOP: 15-16. Telephone registration WILL NOT be accepted. For information ONLY call 655-1829.

If you have not received an enrollment notification by December 23, 1987, your request was received too late to be processed for winter quarter.

All enrollments are handled on a first come, first served basis. If the time slot you selected has been filled, you will be assigned the alternate time slot if available.

CIRCLE TIME PREFERENCE

NOON TIME	EVENING COURSES	
	8:00	Action Tools for Managers - Robert Townsend (1)
	8:00	The Art of Creative Listening (1)
	6:00	The Art of Innovation (6)
11:30	7:00	Becoming A More Persuasive Person (1)
	7:00	Choosing Your Own Greatness - Dr. Wayne Dyer (6)
12:00	6:30	Communicate with Confidence (1)
	6:30	Computers and Communications (3)
11:00		The Double Win - Dennis Waitley (6)
11:30		How to Grow People Into Self-Starters (6)
12:00	7:30	How to Influence and Persuade Others (1)
12:00	8:30	How to Use Tact and Skill in Handling People (1)
	7:30	Marketing Imagination (1)
	8:30	Memory Made Easy (3)
	7:30	The New Masters of Excellence - Tom Peters (6)
11:00	7:30	Positive Imaging — Dr. Norman Vincent Peale (1)
11:00	7:30	The Power of Goal Setting (1)
	7:00	The Psychology of Negotiating (1)
	7:00	Secrets of Success - Og Mandino (1)
11:30	6:00	Seven Habits of Highly Effective People (3)
12:00		The Situational Leader (6)
	6:30	Speak to Win (6) - NEW COURSE
11:00	8:00	Taking Charge On the Job (1)
	8:30	Tough Times Never Last, Tough People Do (6)
11:00	6:00	Turning People On (1)
12:00	8:00	22 Biggest Mistakes Managers Make (1)
	8:00	Winning Through Teamwork (6)

COMPLETE ALL INFORMATION REQUESTED BELOW:

NAME ______________________________

SSN ______________________ ORGN. ________

PHONE ________ PAY CODE ________ MAIL STOP ________

MAIL TO: DIAL-A-COURSE, ORGN. 2-1846, M/S 15-16

PERSONAL COMPUTER LAB COURSES

The following Personal Computer Lab Courses are offered at the Kent Learning Center. All PC lab courses must be scheduled.

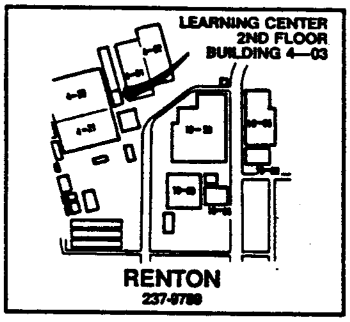
Lab hours are 3:30 p.m. to 6:15 p.m., Monday thru Friday. Fill out a VOLUNTARY TRAINING - REGISTRATION REQUEST form DO-[illegible] and mail to P.C. LAB M/S 3C-01, or phone 773-[illegible].

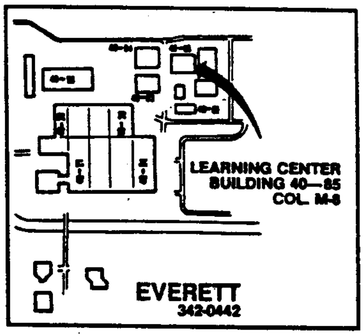
COURSE TITLE	COURSE NUMBER	COURSE HOURS
MACINTOSH COMPUTER		
Computer Keyboarding, Famil., Intro	V3256.0	12.0
MacChart - Tutorial	V[illegible]	4.0
MacMultiplan - Tutorial	V[illegible]	4.0
Macintosh, Basic	V[illegible]	6.0
Macintosh Draw, Basic	V[illegible]	4.0
HP-150 COMPUTER		
HP-150 Familiarization	V[illegible]	3.0

COURSE TITLE	COURSE NUMBER	COURSE HOURS
IBM COMPUTER		
A.I. and Knowledged Based System Famil.	V3019.4	8.0
Personal Computer Familiarization	V[illegible]	8.0
Application Software Familiarization	V[illegible]01.1	8.0
IBM PC/XT Familiarization	V[illegible]	2.0
MS-DOS Familiarization	V[illegible]	4.0
Computer Keyboarding, Famil., Intro	V3256.0	12.0
Speed Reading - The Computer Course	V3015.3	16.0
IBM PC and IBM PC/XT, Intro. -Tutorial	V3186.7	4.0
PC DOS Intro and Adv. - Tutorial	V3186.9	4.0
dBASE II - Tutorial	V3188.5	4.0
Wordstar - Tutorial	V3187.1	4.0
MBASIC - Tutorial	V3187.0	4.0
Lotus - Tutorial	V3187.3	4.0

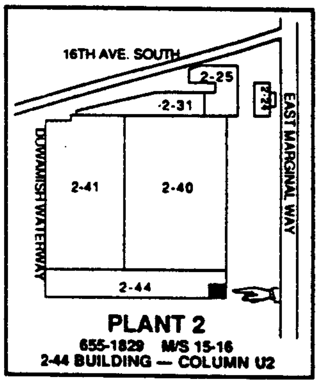
COURSE TITLE	COURSE NUMBER	COURSE HOURS
APOLLO/MENTOR COMPUTER		
Apollo Workstation. An Intro To The	V[illegible]	3.0
Mentor Graphics Design Capture	V[illegible]	12.0
VAX 11 COMPUTER		
VAS/VMS - VMSCAI	V[illegible]	8.0
VAX/VMS - EDTCAI	V3101.3	8.0
VAX/VMS - EVECAI	V[illegible]	4.0
VAX/VMS - DATATRIEVE CAI	V[illegible]	3.0
VAX/VMS - Using	V[illegible]	12.0
TRS-80 RADIO SHACK COMPUTER		
* Computer Keyboarding	V3175.0	12.0
CANON ELECTRONIC TYPEWRITER		
Canon Electronic Typewriter, Intro	V[illegible]	4.0

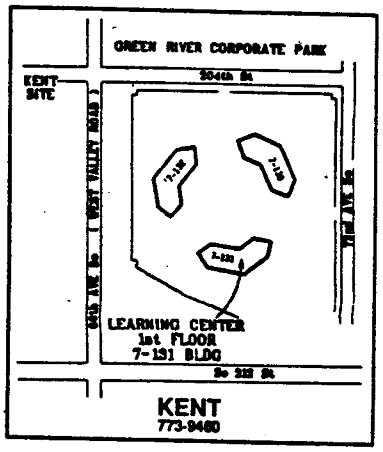
* Also Available at Plant II Learning Center - 2-44 Bldg. M/S 15-16.

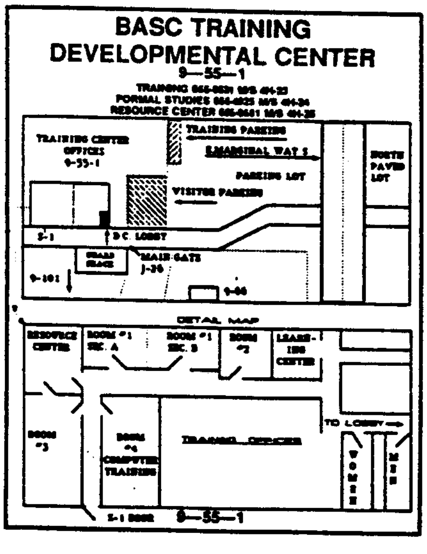


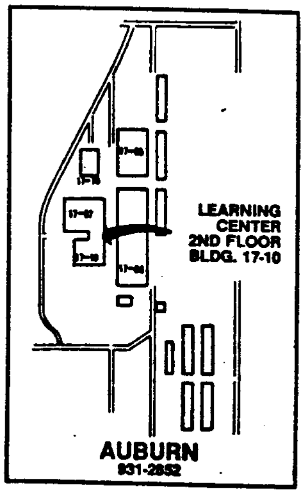


DO YOU KNOW YOUR LEARNING CENTER LOCATION?









PHONE BOOK INFORMATION

The Boeing telephone directory is a useful source of information in many ways. It is more than just a repository of thousands of employee phone numbers. For example, if you found a message on your desk to call an individual whose name you didn't recognize, you might learn something about him from the directory. The individual's budget number is listed with his name. The directory also provides a list of all Boeing organizations, sorted by budget number. Thus, before you called you would know your caller's organization and possibly the nature of his call. The following information is contained in your directory:

o EMERGENCY PHONE NUMBERS

o EMERGENCY PROCEDURES

- BOMB THREAT
- ELEVATOR EMERGENCY
- EVACUATION
- FIRE
- INJURY
- SAFEGUARDING CLASSIFIED MATERIAL
- TORNADOES
- CARDIOPULMONARY RESUSCITATION (CPR)

o PROCEDURES FOR SENSITIVE MATERIAL

- BOEING PROPRIETARY
- BOEING LIMITED

- o CALLING INSTRUCTIONS
  - - BOEING TELECOMMUNICATIONS NETWORK (BTN)
  - - INTERNATIONAL CALLS
  - - LOCAL CALLS
- o MAILING INSTRUCTIONS
- o TRANSPORTATION MILEAGE CHARTS
- o PLANT MAPS
- o FACSIMILE SERVICES
- o LISTING OF ORGANIZATIONS
  - - ALPHABETICALLY
  - - BY BUDGET NUMBER
- o INTERNATIONAL OFFICES

AERO PROGRAMS

	CL	PROGRAM	VER	REV	TITLE	STATUS
***	4	A001	H	00	PROGRAM COMPILER (PC) SYSTEM	ACTIVE
*	3	A002	1	01	GEOMETRY CONTROL SYSTEM (GCS)	ACTIVE
*	4	A004	C	00	AIRPLANE SIZING AND DESIGN SELECTION	ACTIVE
*	4	A008	P	00	TAKE-OFF AND LANDING PERFORMANCE	ACTIVE
*	4	A011	D	00	LIOR LIST PROGRAM FOR PROGRAM COMPILER (PC) GENERATED PROGRAMS	ACTIVE
*	4	A015	G	00	AERO PERFORMANCE DATA RETRIEVABLE	ACTIVE
*	4	A031	K	00	CALCULATION OF F.A.R. TAKE-OFF FLIGHT PATH FLIGHT PATH	ACTIVE
*	4	A045	G	00	CLIMB GRADIENT OR RATE OF CLIMB AT CONSTANT EQUIVALENT AIR SPEEDS	ACTIVE
*	4	A055	B	00	TURBULENT BOUNDARY LAYER PROFILE ANALYSIS	ACTIVE
*	4	A087	C	00	CALC. OF BRAKING COEFFICIENT AND TOTAL BRAKE ENERGY	ACTIVE
*	4	A136	P	00	CALC. OF ALL-ENGINE TAKEOFF FLIGHT PROFILE FOR NOISE EVAL.	ACTIVE
*	4	A200	F	00	2-D OR AXI-SYM. LAMINAR AND TURBULENT BOUNDARY LAYER ANALYSIS	ACTIVE
*	4	A242	D	06	LOAD ANAL OR OPT LOADING FOR MIN INDUCED DRAG OF GEN CONFIG	ACTIVE
*	4	A264	C	00	WAKE SURVEY REDUCTION	ACTIVE

AERO PROGRAMS (cont'd)

	CL	PROGRAM	VER	REV	TITLE	STATUS
*	4	A274	E	00	SUBSONIC AIRPLANE DRAG ESTIMATION PROGRAM	ACTIVE
*	4	A280	C	00	2-DIM/AXISYMMETRIC POTENTIAL FLOW BY METHOD OF SINGULARITIES	ACTIVE
*	4	A314	C	00	MILITARY TAKEOFF PROGRAM	ACTIVE
*	4	A315	F	00	MATHEMATICAL MODEL FOR 2-D MULTI-COMPONENT AIRFOILS IN VISCOUS FLOW	ACTIVE
*	3	A323	D	00	INDUCED DRAG AND LIFT FROM SPARSE SPAN LOADING	ACTIVE
*	4	A328	B	00	BODY PANELING AND LOFTING PROGRAM	ACTIVE
*	4	A340	E	01	JOB LIST AND MANPOWER VISIBILITY	ACTIVE
*	2	A348	J	00	AIRPLANE PERFORMANCE DOCUMENT PLOTTING	ACTIVE
*	4	A362-01	B	00	AIRCRAFT DRIFTDOWN CALCULATION PROGRAM (HOBO)	ACTIVE
*	4	A362-08	B	00	AIRCRAFT DRIFTDOWN CALCULATION PROGRAM (PRIME)	ACTIVE
*	4	A366-01	A	00	MISSION ANALYSIS PROGRAM	ACTIVE
*	4	A366-02	A	00	MISSION ANALYSIS PROGRAM	ACTIVE
*	4	A366-03	A	00	MISSION ANALYSIS PROGRAM	ACTIVE
*	4	A366-04	A	00	MISSION ANALYSIS PROGRAM	ACTIVE
*	4	A366-05	A	00	MISSION ANALYSIS PROGRAM	ACTIVE

AERO PROGRAMS (cont'd)

	CL	PROG	VER	REV	TITLE	STATUS
*	4	A366-06	A	00	MISSION ANALYSIS PROGRAM	ACTIVE
*	4	A366-07	A	00	MISSION ANALYSIS PROGRAM	ACTIVE
*	4	A366-08	A	00	MISSION ANALYSIS PROGRAM	ACTIVE
*	4	A370	C	00	ONLINE PLOTTING PROGRAM FOR TE A280 POTENTIAL FLOW	ACTIVE
*	4	A375	C	00	LOW SPEED PERFORMANCE COMPUTER PROGRAM	ACTIVE
*	4	A411M	J	00	3-D BOUNDARY LAYER PROGRAM	ACTIVE
*	4	A414	F	00	ALL ENGINE APPROACH PROFILE	ACTIVE
*	4	A423	I	01	ANALYSIS OF AIRFOIL SECTIONS IN TRANSONIC VISCOUS FLOW	ACTIVE
*	4	A424	C	00	DYNAMIC STALL SIMULATION PROGRAM	ACTIVE
*	4	A425	D	00	TABLE SORTING BY DIMENSION	ACTIVE
*	4	A428	D	02	SFC TABLE PREPROCESSOR FOR BLEED CROSSOVER	ACTIVE
*	4	A441	D	00	TABLE PROGRAM CONVERSION	ACTIVE
*	3	A442	C	04	WING PLANFORM PARAMETERS PROGRAM	ACTIVE
*	4	A443	C	00	HIGH SPEED DRAG POLAR PREDICTION METHOD	ACTIVE
*	4	A444	C	01	GRAPHIC PREPROCESSOR (GPP)	ACTIVE
*	4	A445	C	00	TAKEOFF SORTING AND GENERAL GRAPHICS PACKAGE (GGP3)	ACTIVE

AERO PROGRAMS (cont'd)

	CL	PROG	VER	REV	TITLE	STATUS
*	4	A446	D	00	EQUIVALENT WEIGHT PROGRAM	ACTIVE
*	4	A447	C	00	DATA RETRIEVAL SYSTEM FOR WIND TUNNEL ABSTRACTS	ACTIVE
*	4	A448	B	00	CROSS INDEX FOR AERO NOISE JOB CATEGORIES	ACTIVE
*	4	A449	I	00	ADVANCED LIFTING SURFACE METHODS	ACTIVE
*	4	A453	M	01	SUBROUTINE LIBRARY FOR SUPPORT OF CERTIFIED PERFORMANCE PROGRAMS	ACTIVE
*	4	A455	B	03	LOW SPEED DRAG POLAR PROGRAM	ACTIVE
*	3	A456	F	00	SUBSONIC AIRFOIL SECTION SYSTEM	ACTIVE
*	4	A472	D	02	THRUST TABLE CORRECTION PROGRAM	ACTIVE
*	4	A473	A	00	CALCULATION OF TAKEOFF ACCELERATION OR RETARDING FORCE	ACTIVE
*	5	A484	A	00	CRUISE ANALYSIS FOR AIRPLANE FLIGHT TEST (CRAFT) PDP 11/70	ACTIVE
*	5	A487	A	00	TRANSITION ANALYSIS PROGRAM SYSTEM	ACTIVE
*	4	A488	G	02	TRANSONIC WING/FUSELAGE/NACELLE/STRUT/PLUME ANALYSIS SYSTEM	ACTIVE
*	5	A497	A	00	INTERACTIVE POLAR ADJUSTMENT PROGRAM	ACTIVE
*	5	A498	A	00	CRUISE ANALYSIS FROM FLIGHT TEST (CRAFT) PHASE II (PDP 11/70)	ACTIVE
*	5	A500	A	00	GCSMPX	ACTIVE

AERO PROGRAMS (cont'd)

	CL	PROGRAM	VER	REV	TITLE	STATUS
*	4	A501	A	00	A501 PLOTTING PROGRAM	ACTIVE
*	4	A502	F	02	PANAIR PILOT CODE	ACTIVE
*	4	A507	C	00	REAL MATRIX SOLVER	ACTIVE
*	4	A511	C	00	SCIENTIFIC DATA MANAGEMENT SYSTEM	ACTIVE
*	4	A513	A	00	FMC/BSP TEST CASE RESULTS COMPARATOR PROGRAM	ACTIVE
*	4	A515	D	00	LOW SPEED AERODYNAMIC PREDICTION PROGRAM	ACTIVE
*	5	A543	A	00	A055--NASA LANGLEY INTERFACE PROGRAM	ACTIVE
*	4	A545	P	00	OBSTACLE CLEARANCE PROGRAM	ACTIVE
*	4	A556	A	01	TWO-DIMENSIONAL INVERSE DESIGN PROGRAM	ACTIVE
*	4	A558	B	01	PERFORMANCE DATABASE INTERFACE PROGRAM	ACTIVE

PROGRAM CROSS REFERENCE AND DESCRIPTION
(Listed In Alphabetical Order)

PROGRAM	COMPUTER	DESCRIPTION
A008	CYBER	Takeoff and Landing
A031	CYBER	FAR Takeoff Flight Path
A045	CYBER	Climb Gradient
A087	CYBER	Stopping Distance
A136	CYBER	All Engine Takeoff and Climb With Noise
A348	CYBER	Performance Document Plotting Utility
A355	CRAY	Climb, Cruise, Descent, Speed, Etc.
A362	CRAY	Driftdown
A366	CRAY	Mission Analysis
A414	CYBER	All Engine Approach With Noise
A440	CYBER	Drag Polar Development/Plotting
A441	CYBER	Table Conversion Utility
A497	CYBER/PDP	Drag Plotting
A545	CYBER	Obstacle Clearance
A08IN1	CYBER	A008 Preprocessor
AEROPRC	CYBER	Processor Utility
AETO	CYBER	All Engine Climb Performance
AFMPS	CYBER	Store/Extract/Manip/Plot Utility
APAN3	PDP	Open Chart Reader Preprocessor
APEX	HARRIS	Mission Analysis
APLFTD	CYBER	Approach and Land
AUTOSTP	CYBER	Stopping Distance
BSP'S	CRAY	Boeing Standard Programs (FMC)
CDLISTB	CYBER	Drag Polar Table Reformat Utility
CONTEA	CYBER	Processor Utility (Low Speed Programs)
CPLOT	HP2647	Plotting, Labeling
DBGET	CYBER	A355, 366,362 Preprocessor
DOCPLT	PDP	General Plotting
FNLISTB	CYBER	Thrust Table Reformat Utility
GGP	PDP	General Plotting
LETTERING PRGM.	HP2647	Plot Labeling
MAPFTD	CYBER	Missed Approach
MISSAN	PDP	Mission Analysis (Perf. Doc. Lookup)

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PROGRAM CROSS REFERENCE AND DESCRIPTION
(Listed In Alphabetical Order)

OPEN CHART READER	PDP	Flight Manual Table Lookup
PDI	CYBER	BAPDMS Interface
PREPOL	PDP	Creates File For Polar
PREWIND	PDP/CYBER	Enroute Winds/Temperature
POLAR	PDP	Circle Chart Plotting
ROUT	PDP	Enroute Diversion Analysis
RTHRUST	CYBER	Merge Idle and Reverse Thrust
SPINDOWN	CYBER	Engine Spindown Table Creation
THUMBPRINT	CYBER/IBM	Airplane Sizing
UPLOT	HP2647	Plot Labeling
WFLISTB	CYBER	Fuel Flow Table Reformat Utility
XEQWIND	CYBER	Enroute Winds/Temperature

COMPUTER PROGRAMS USED BY AERO CONFIGURATION

PROGRAM CROSS REFERENCE AND DESCRIPTION

(Listed in Numerical Order)

PROGRAM	COMPUTER	DESCRIPTION
A008	EKS	TAKEOFF AND LANDING PERFORMANCE
A087	↓	BRAKING PERFORMANCE
A137	↓	TAKEOFF AND LANDING PERF OF PD AIRPLANES(SST)
A200	↓	2D BOUNDARY LAYER ANALYSIS
A230	↓	3D POTENTIAL FLOW
A236	↓	SUBSONIC WING DESIGN
A242	↓	SPAN LOADING DESIGN/ANALYSIS
A274	↓	COMPUTERIZED FINCH DOCUMENT
A280	↓	2D/AXISYMMETRIC POTENTIAL FLOW
A315	↓	2D/MULTI-SEGMENT AIRFOIL WITH CONFLUENT FLOW
A323	↓	INDUCED DRAG ANALYSIS PLANAR WING
A355	↓	MISSION SEGMENT PERFORMANCE
A411	↓	3D WING BOUNDARY LAYER
A423	↓	2D AIRFOIL TRANSONIC VISCOUS ANALYSIS
A424	↓	DYNAMIC STALL SIMULATION
A441	↓	FUEL FLOW TABLE REFORMAT
A442	↓	WING PLANFORM PARAMETERS
A455	↓	LOW-LAM, LOW SPEED LIFT/DRAG ESTIMATIONS
A456	↓	SUBSONIC AIRFOIL DESIGN/ANALYSIS
A488	↓	3D TRANSONIC ANALYSIS
A497	↓	DRAG POLAR ASSESSMENT & REFORMATTING
A502	↓	3D POTENTIAL FLOW
A505	↓	MULTIPLE REGRESSION CURVE FIT
A515	↓	LOW SPEED AERO PARAMETER PREDICTION
A517	↓	CROSS-REFER. PROG. FOR LOW SPEED JOB BOOKS
A524	↓	BSP PROPULSION DATA BASE EXTRACTION
A531	↓	BSP TRAJECTORY PREDICTION
A588	↓	VISCOUS TRANSONIC NACELLE ANALYSIS

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PROGRAM CROSS REFERENCE AND DESCRIPTION
(Listed in Alphabetical Order)

PROGRAM	COMPUTER	DESCRIPTION
A-LOOKUP	PDP	TABLE INTERPOLATION
AGPS	VAX	GENERAL 3-D AERO LOFTING & PANELING
BIGPLOT	PDP	OFFLINE PLOTTING PROGRAM
CADS		ANALYSIS OF CLIMB/DESCENT F/T DATA
CHART/TCHT		TABLES AND CHART GRAPHICS
CONFTR		FLIGHT TEST REDUCTION PROGRAM
CRAFT I		FLIGHT TEST DRAG & FUEL MILEAGE ANALYSIS
CRAFT II		INTERACTIVE GRAPHICS FOR CRAFT 1 FAIRING CREATION
DAM		DATA ANALYSIS & MANIP/PLOTTING
DGP		DIGITIZER GRAPHICS
DOCPLOT		GRAPHICS MODULE IN THE VAAMP SYSTEM
FTDGEN		LAST FILE TO CRAFT I REFORMAT
FTGFC		TIME HISTORY TO GGP REFORMAT
GANTT		SCHEDULE GENERATING PROGRAM
GCP	PDP	GRAPHICS CONTOUR PROGRAM (3D CONTOURS)
GCS	EKS	GENERAL 3-D AERO LOFTING
GGP	PDP	GENERAL GRAPHICS PROGRAM FOR DATA PLOTTING/MANIPULATION
KULFAN F-FUNCTION		COWL LOFTING PROGRAM
MOD1655	EKS	CONVERT 1655 FORMAT DATA TO PDP FORMAT
MPIX/OPIX	PDP	3D GEOMETRY WITH ROTATIONAL CAPABILITY
P-PRIME		PLOTTING FILES FROM FUEL FLOW DECKS
PROBE		FLIGHT TEST WAKE RAKE ANALYSIS
RADEM	EKS	HIGH SPEED DRAG POLAR PREDICTION METHOD
RIM	EKS	RELATIONAL INFORMATION MANAGEMENT SYSTEM
SIGMA	PDP	2D LOFT & SMOOTHING
STCA	PDP	AERO PARAMETER EXTRACTION FROM FLIGHT DATA (VAAMP MODULE)
TABLET	PDP	TABLE MANIPULATION, TRANSFORMATION, AND INTERPOLATION
TX95	EKS	MDD LOFTS
VAAMP	PDP	VERSATILE AERODYNAMIC ANALYSIS/MANIPULATION
WT1655	EKS	DATA ANALYSIS & MANIP/CALCOMP PLOTTING

AERODYNAMICS / STABILITY AND CONTROL - EXISTING PROGRAMS

PROGRAM	COMPUTER	NAME AND DESCRIPTION
ACTS	EKS	AEROELASTIC CORRECTIONS AND TRIM SOLUTIONS - A program which performs various types of longitudinal trims for a rigid or flexible airplane. It combines longitudinal aerodynamic data derived from the wind tunnel or flight test with aeroelastic data, propulsion data, and the characteristics of the primary and automatic flight control systems.
ACTS 6	EKS	6 DOF AEROELASTIC CORRECTIONS AND TRIM SOLUTIONS An extension of the ACTS program from 3 degrees of longitudinal freedom to 6 degrees of longitudinal and lateral-directional freedom. It performs various 6 degrees of freedom trims for a rigid or flexible airplane by combining the longitudinal and lateral - directional aerodynamic and aeroelastic data with propulsion data and the complete primary and automatic flight control system.
STCA	EKS	LONGITUDINAL FLIGHT TEST EXTRACTION PROGRAM - A program which extracts longitudinal aerodynamic coefficients from the time histories of flight test maneuvers such as level flight trims, elevator-stabilizer trades, stalls and wind-up turns. It derives these coefficients for the flexible and rigid airplane with the horizontal tail on and off and compares these results with predictions.
STCA 6	EKS	6 DOF FLIGHT TEST EXTRACTION PROGRAM - An extension of the STCA program from 3 degrees of longitudinal freedom to 6 degrees of longitudinal and lateral-directional freedom. This program has been developed but has not been checked out thoroughly and is not currently in operation.
TAKOFA	EKS	TAKEOFF ROTATION PROGRAM - A MIMIC program which calculates time histories of the longitudinal characteristics that occur during takeoff rotations including the effects of the gear and the proximity of the ground plane.
VMCG	EKS	VMCG PROGRAM - A MIMIC program that calcuates time histories of the lateral motion of the airplane on the ground following an engine failure.
HTSIZE	TEMPORARILY INACTIVE	HTSIZE PROGRAM - A compilation of programs that calculate the horizontal tail and elevator sizes that are required to satisfy established preliminary design sizing criteria.

AERODYNAMICS / STABILITY AND CONTROL - EXISTING PROGRAMS

PROGRAM	COMPUTER	NAME AND DESCRIPTION
VTSIZE	IGDA	VTSIZE - A DIGITAL COMPUTER PROGRAM FOR VERTICAL TAIL AND RUDDER SIZING - A program which sizes the vertical tail and directional control surfaces to satisfy certain preliminary design criteria such as engine failure, directional stability, crosswind capability, tameness or dutch roll damping.
LOSD	TEMPORARILY INACTIVE	LONGITUDINAL STABILITY DERIVATIVES AND THEORY COMPUTER PROGRAM - A program which defines and calculates the longitudinal static and dynamic stability and control derivatives for the rigid and flexible airplane with and without the horizontal tail.
LDSD	EKS	METHODS AND PROGRAM FOR CALCULATING THE NINE LATERAL - DIRECTIONAL DYNAMIC STABILITY DERIVATIVES - A program which defines and calculates the nine lateral-directional dynamic stability derivatives for the rigid and flexible airplane with and without the vertical tail using current semi-empirical methods.
TEA 132	EKS, IGDA	LONGITUDINAL AND LATERAL DIRECTIONAL SMALL DISTURBANCE EQUATIONS OF MOTION, INCLUDING LATERAL AND LONGITUDINAL CONTROL RESPONSE - A program that solves the longitudinal and lateral-directional small disturbance equations of motion for the basic roots of the characteristic equations and the transfer function numerators due to control inputs. The stability characteristics are presented in terms of frequency, period and times to half or double amplitude. The ratios between degrees of freedom and the transfer functions between degrees of freedom and control inputs are also computed.
FRMS (FAST)	EKS, IGDA	FLIGHT TEST FILE/RECORD MANAGEMENT SYSTEM - A file/record management system that is hosted on an IGDA site after data preparation on EKS. It receives data from flight test on EKS, catalogues and sorts the data by maneuver type, and transmits the data to an IGDA site for storage on appropriate disk packs. The operation of FRMS on EKS is identified as the FAST program.

AERODYNAMICS / STABILITY AND CONTROL - EXISTING PROGRAMS

PROGRAM	COMPUTER	NAME AND DESCRIPTION
VAAMP/ FLTCON	IGDA	VERSATILE AERODYNAMIC ANALYSIS AND MANIPULATION PROGRAMS - VAAMP and FLTCON are, respectively, the graphics and timesharing hubs of a system of modular routines which perform various data management and analysis operations on GGP random files at IGDA sites. Currently there are 30 subroutines or modules available in VAAMP and 16 modules available in FLTCON. The most commonly used modules are listed below:

VAAMP

MODULE NO.	NAME	BRIEF DESCRIPTION
1.	DOCPLT	Advanced user friendly data plotting package for multigrid plots on millimeter grid using refresh graphics. Includes plot library to save/retrieve plots.
2.	FETCH	Retrieves selected runs/parameters from a file.
3.	TAILOR	Evaluates user defined algorithms. User writes fortran like equations and TAILOR handles inout/output etc. Significant flexibility due to ability to substitute run and/or parameter names at execution time.
4.	RENAME	Changes the run and/or parameter names in file.
5.	TABDAT	Tabulates selected portions of a GGP random file on the line-printer. For interactive use, it shows precise parameter list and number of points in a run.
6.	MODCON	Modifies or add single-valued parameters to a run.
7.	FERRET	Graphically selects specific data segments to be retrieved from runs.
8.	BRKPT	Creates output runs(s) with new breakpoints using user selected interpolation.

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VAAMP (Continued)

MODULE NO.	NAME	BRIEF DESCRIPTION
9.	DELRUN	Deletes runs(s) from a file.
10.	INCREM	Calculates increments between runs (choice of 3 equations).
11.	TINKER	Interactive graphical data editor for the engineer to "refair" the data in a manner similar to that which is done with a French curve at his desk.
12.	DELGAR	Deletes point(s) from a run using interactive graphics.
13.	CRERUN	Creates run(s) by interpolation between existing runs.
14.	DERIVE	Calculates derivatives at each breakpoint.
15.	RUNSYN	Creates new run(s) by a method similar to crossplotting.
16.	CMRUNS	Appends two or more runs to form a single run.
17.	FILTER	Filters out "noise" from data using fast Fourier transform. This is particularly valuable for flight test data.
18.	DNWASH	Calculates downwash angle as a function of angle of attack.
19.	TRANCG	Calculates changes in aerodynamic coefficients corresponding to a center of gravity transfer.
20.	SYNDER	Computes derivatives over a user defined range.
21	SMPINC	Calculates simple increment between two runs.
22	REYNO	Corrects wind tunnel data for Reynolds number scale effects.

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VAAMP (Continued)

MODULE NO.	NAME	BRIEF DESCRIPTION
23.	ZSHIFT	Shifts data through origin (o,o), E.G., yawing moment vs. beta data must pass through the origin for a symmetric airplane. Wind tunnel data normally shows an offset.
24.	CLALPH	Calculates and shapes lift coefficient derivative (CL-ALPHA) for ACTS program.
25.	TLLIFT	Calculates tail lift as a function of tail angle of attack.
26.	MERPRM	Merges unique parameters from two or more runs into one run.
27.	LRAVG	Changes the sign of "negative points" and merges them with "positive" points.

FLTCON

MODULE NO.	NAME	BRIEF DESCRIPTION
1.	ENQUIRE	Gives the user status information for VAAMP background computing jobs.
2.	CRETAB	Creates or modifies files that are used for table look-up in the TAILOR program.
3.	RANSIM	Converts files from RFSC and/or ACTS format (DATAN and FDHS) to the IGDA GGP random binary data file format.
4.	TVAAMP	Prepares data in FDHS format for use in RFSC and/or ACTS.
5.	SIMTAPE	Converts GGP random files containing flight test data into format suitable for use in the simulation model at RFSC.

FLTCON (Continued)

MODULE NO.	NAME	BRIEF DESCRIPTION
6.	SEARCH	Searches flight test data base to find those flight conditions satisfying user defined criteria.
7.	FILHIS	Allows user to view/print/update/ modify the file history information which is generated for each file created by VAAMP.
8.	SIMREAD	Reads a tape created by SIMTAPE and produces a hardcopy printout.
9.	FORSIT	Prepares data for use in the STCA program on EKS or VAX. This includes both reformatting the time history data and setting up case cards.
10.	COMRAN	Compares data files for aerodynamic data from either RFSC or EKS with the master data base on IGDA. The program matches up file names and parameter names as well as pairing up runs between the files to be checked and those in the master data base. The user is alerted to any discrepancies or missing data.
11.	SRTGGP	Puts run and/or parameter names in GGP files into Alpha/Numeric order.
12.	ADDATA	Combines flight test conditions for similar flight maneuvers into the same file. Adjusts for the time skews when merging supplementary data with existing data.
13.	ADDKEY	Generates data base used by the SEARCH program.
14.	EDITKE	Modifies or updates the keys data base that is used by SEARCH to retrieve flight test data.

COMMONLY USED ACRONYMS

ACARS	ARINC COMMUNICATIONS ADDRESSING AND REPORTING SYSTEM
ACR	APPROXIMATE CYCLIC REDUCTION
ACTS	AEROELASTIC CORRECTION & TRIM SOLUTIONS
ADAMS	AIRBORNE DATA ANALYSIS - MONITOR SYSTEM
ADC	AIR DATA COMPUTER
ADCN	ADVANCED DRAWING CHANGE NOTICE
ADF	AUTOMATIC DIRECTION FINDER
ADI	ATTITUDE DIRECTOR INDICATOR
AEO	ALL ENGINES OPERATING
AEROPRC	AERO PROCEDURES FOR PERFORMANCE COMPUTER PROGRAM CONTROL CARD GENERATION
AF	APPROXIMATE FACTORIZATION
AFCF	AIRFLOW CALIBRATION FACILITY
AFM	AIRPLANE FLIGHT MANUAL
AFW	AIRFRAME WEIGHT
AGARD	ADVISORY GROUP FOR AEROSPACE RESEARCH AND DEVELOPMENT
AGL	ABOVE GROUND LEVEL
AGPS	AERO GRID & PANELING SYSTEM
AIAA	AMERICAN INSTITUTE OF AERONAUTICS AND ASTRONAUTICS
AIC	AERODYNAMIC INFLUENCE COEFFICIENTS
ALDS	AERODYNAMICS LABORATORY DATA SYSTEM
AOG	AIRPLANE ON GROUND
APACS	AIRBORNE POSITION & ATTITUDE CAMERA SYSTEM
APU	AUXILIARY POWER UNIT
ARC	AMES RESEARCH CENTER
ARINC	AERONAUTICAL RADIO INCORPORATE
ASAP	AS SOON AS POSSIBLE

ATC	AIR TRAFFIC CONTROL
A/L	AIRLINE
APL	AIRPLANE
A/P	AIRPLANE / AUTOPILOT
BAC	BOEING AEROSPACE COMPANY
BBL	BODY BUTTOCK LINE
BCAC	BOEING COMMERCIAL AIRPLANE COMPANY
BCAR	BRITISH CIVIL AVIATION REGULATIONS
BCS	BOEING COMPUTER SERVICES
BEC	BOEING ELECTRONICS COMPANY
BECU	BOEING EMPLOYEE CREDIT UNION
BEGNF	BOEING EMPLOYEE GOOD NEIGHBOR FUND
BFE	BUYER FURNISHED EQUIPMENT
BIE	BOUNDARY INTERGRAL EQUATION
BITE	BUILTIN TEST EQUIPMENT
BLC	BOUNDARY LAYER CONTROL
BMA	BOEING MANAGEMENT ASSOCIATION
BMAC	BOEING MILITARY AIRPLANE COMPANY
BRGW	BRAKE RELEASE GROSS WEIGHT
BRWT	BOEING RESEARCH WIND TUNNEL
BS	BODY STATION
BSWT	BOEING SUPERSONIC WIND TUNNEL
BTS	BOEING TECHNOLOGY SERVICES
BTWT	BOEING TRANSONIC WIND TUNNEL
BVC	BOEING VERTOL COMPANY
BVWT	BOEING VERTOL WIND TUNNEL
BWL	BODY WATER LINE
CAA	CIVIL AVIATION AUTHORITY (UK)
CAD	COMPUTER AIDED DESIGN
CAM	COMPUTER AIDED MANUFACTURING
CATS	COMPETITIVE AIRPLANE TECHNOLOGY STAFF

CDL	CONFIGURATION DELETION LIST
CDP	PARASITE DRAG COEFFICIENT
CDR	CRITICAL DESIGN REVIEW
CEI	CRITICAL ENGINE INOPERATIVE
CEO	CRITICAL ENGINE OPERATING / CHIEF EXECUTIVE OFFICER
CFD	COMPUTATIONAL FLUID DYNAMICS
CFV	CRITICAL FLOW VENTURI
CFL	COURANT-FRIEDRICHS-LEWY
CIP	COST IMPROVEMENT PROGRAM
CG	CENTER OF GRAVITY / CONJUGATE GRADIENT
CRAFT	CRUISE ANALYSIS FROM FLIGHT TEST
CRDC	CUSTOMER REQUEST FOR DESIGN CHANGE
CSEU	CONTROL SYSTEM ELECTRONIC UNIT
CVR	COCKPIT VOICE RECORDER
CWA	COMPUTING WORK AUTHORIZATION
CWR	COMPUTING WORK REQUEST
DAM	DATA ANALYSIS MODULE
DER	DESIGNATED ENGINEERING REPRESENTITIVE
DCN	DRAWING CHANGE NOTICE
DDM	DESIGN DECISION MEMO
DFDR	DIGITAL FLIGHT DATA RECORDER
DME	DISTANCE MEASURING EQUIPMENT
DOC	DIRECT OPERATING COST
DR&O	DESIGN REQUIREMENTS & OBJECTIVES
DTC	DESIGN TO COST
EADI	ELECTRONIC ATTITUDE - DIRECTION INDICATOR
ECM	ENGINEERING CHANGE MEMO
ECP	ENGINEERING CHANGE PROPOSAL
ECS	ENVIRONMENTAL CONTROL SYSTEM
EEC	ELECTRONIC ENGINE CONTROL
EET	ENERGY EFFICIENT TRANSPORT

EFIS	ELECTRONIC FLIGHT INSTRUMENT SYSTEM
EGT	EXHAUST GAS TEMPERATURE
EHSI	ELECTRONIC HORIZONTAL SITUATION INDICATOR
EICAS	ENGINE INDICATION CREW ALERTING SYSTEM
EKS	ENHANCED KRONOS SYSTEM
ELR	ENGINEERING LIASON REQUEST
EOALT	ENGINE OUT ALTITUDE CAPABILITY
EPR	ENGINE PRESSURE RATIO
EROPS	EXTENDED RANGE OPERATIONS
ERT	EMPLOYEE REQUESTED TRANSFER
ESAD	EQIVALENT STILL AIR DISTANCE
ESDU	ENGINEERING SCIENCE DATA UNIT
ESP	ELECTRONICALLY SCANNED PRESSURE SYSTEM
ETAP	ENGINEERING TECHNOLOGY AUTOMATION PLAN
ETPR	ENGINE TEST PARTS RELEASE
EWIS	ELECTRONIC WAKE IMAGING SYSTEM
EWA	ENGINEERING WORK AUTHORIZATION
EXR	BCAC EXECUTIVE REPORTING SYSTEM
FAA	FEDERAL AVIATION ADMINISTRATION (US)
FADEC	FULL AUTHORITY DIGITAL ELECTRONIC CONTROL
FAJ	FINAL ASSEMBLY JIG
FAR	FEDERAL AVIATION REGULATIONS
FAST	FLIGHT TEST DATA ANALYSIS, SCREENING AND TRANSFORMATION PROGRAM
FC	FLIGHT CHANGE
FCC	FLIGHT CONTROL COMPUTER
FDE	FINITE-DIFFERENCE EQUATIONS
FEM	FINITE ELEMENT METHOD
FFM	FUTURE FLIGHT MANAGEMENT
FFT	FAST FOURIER TRANSFORM
FMC	FLIGHT MANAGEMENT COMPUTER

FMCS	FLIGHT MANAGEMENT COMPUTER SYSTEM
FP	FULL POTENTIAL
FRMS	FLIGHT TEST RECORDS MANAGEMENT SYSTEM
FR	FACILITIES REQUEST
FSC	FLT SIMULATION CHAMBER
FSEU	FLAPS SLATS ELECTRONIC UNIT
FSL	FLIGHT SYSTEMS LAB
FSP	FINANCIAL SECURITY PLAN
FTCS	FLIGHT TEST COMPUTING SYSTEM
FTIR	FLIGHT TEST INSTRUMENTATION REQUESTS
FVM	FINITE VOLUME METHOD
GCP	GENERAL CONTOUR PACKAGE
GCS	GEOMETRY CONTROL SYSTEM
GGP	GENERAL GRAPHICS PACKAGE
GMRES	GENERALIZED MINIMAL RESIDUAL ALGORITHM
HSI	HORIZONTAL SITUATION INDICATOR
IATA	INTERNATIONAL AIR TRANSPORT ASSOCIATION
IC	INFLUENCE COEFFICIENT
ICAC	INITIAL CRUISE ALTITUDE CAPABILITY
ICAO	INTERNATIONAL CIVIL AVIATION ORGANIZATION
IDG	INTEGRATED DRIVE GENERATOR
IDWA	INTERDIVISIONAL WORK AUTHORIZATION
IGDA	INTERACTIVE GRAPHICS DATA ANALYSIS
ILS	INSTRUMENT LANDING SYSTEM
INS	INERTIAL NAVIGATION SYSTEM
IOC	INDIRECT OPERATING COST
IPC	ILLUSTRATED PARTS CATALOG
IRS	INERTIA REFERENCE SYSTEM
IRU	INERTIA REFERENCE UNIT
ISA	INTERNATIONAL STANDARD ATMOSPHERE

JARP	JOINT ADVANCED RESEARCH PROJECT
KCAS	KNOTS CALIBRATED AIRSPEED
KEAS	KNOTS EQUIVALENT AIRSPEED
KIAS	KNOTS INDICATED AIRSPEED
KIT	KRONOS INTERACTIVE TIMESHARING
KTAS	KNOTS TRUE AIRSPEED
KTS	KNOTS
LBA	GERMAN CERTIFICATION AUTHORITY
LE	LEADING EDGE
LFC	LAMINAR FLOW CONTROL
LHV	LOWER HEATING VALUE (FUEL - BTU/LB)
LNAV	LONGITUDINAL NAVIGATION
LRC	LONG RANGE CRUISE
LRU	LINE REPLACEABLE UNIT
LTPT	LOW TURBULENCE PRESSURE TUNNEL
LVDT	LINEAR VARIABLE DIFFERENTIAL TRANSDUCER
MAPS	MICROWAVE AIRPLANE POSITION SYSTEM
MBRGW	MAXIMUM BRAKE RELEASE WEIGHT
MBTWT	MODEL BOEING TRANSONIC WIND TUNNEL
MCLT	MAXIMUM CLIMB THRUST
MCNT	MAXIMUM CONTINUOUS THRUST
MCRT	MAXIMUM CRUISE THRUST
MCV	MULTIPLE CRITICAL FLOW VENTURI
MDD	MASTER DIMENSIONS DEFINITION
MDI	MASTER DIMENSIONS IDENTIFIER
MEL	MINIMUM EQUIPMENT LIST
MEW	MANUFACTURER'S EMPTY WEIGHT
MG	MULTIGRID
MHD	MAGNETO-HYDRODYNAMICS
MLW	MAXIMUM LANDING WEIGHT
MMO	MACH - MAXIMUM OPERATING

MPIX	MULTIPLE PICTURE DISPLAY PROGRAM
MRB	MANUFACTURING REVIEW BOARD
MRC	MAXIMUM RANGE CRUISE
MSL	MEAN SEA LEVEL
MSWT	MODEL SUPERSONIC WIND TUNNEL
MTBF	MEAN TIME BETWEEN FAILURES
MTBR	MEAN TIME BETWEEN REMOVALS
MTOGW	MAXIMUM TAKEOFF GROSS WEIGHT
MTS	MULTI-TEST SITE DATA SYSTEM
MZFW	MAXIMUM ZERO FUEL WEIGHT
NAAL	NORTH AMERICAN AERONAUTICAL LABORATORIES
NAM	NAUTICAL AIR MILE
NAMS	COMMON SLANG FOR FUEL MILEAGE (NAM/LB)
NFSP	NON-FUNCTIONING SUPERVISORY PERSONNEL
NJE	NETWORK JOB ENTRY
NLF	NATURAL LAMINAR FLOW
NLR	NATIONAL LABORATORY OF RESEARCH
NOS	NULL OPERATING SYSTEM
NPD	NEW PRODUCT DEVELOPMENT
NRT	NICKEL RESISTANCE THERMOMETER
NTF	NATIONAL TRANSONIC FACILITY
OAT	OUTSIDE AIR TEMPERATURE
ODE	ORDINARY DIFFERENTIAL EQUATIONS
OEW	OPERATIONAL EMPTY WEIGHT
OPTP	ONE PAGE TEST PLAN
PAN AIR	PANEL AERODYNAMICS
PAS	PITCH AUGMENTATION SYSTEM
PCU	POWER CONTROL UNIT
PDE	PARTIAL DIFFERENTIAL EQUATIONS
PDGS	PRESSURE DATA GRAPHICS SYSTEM

PDR	PRELIMINARY DESIGN REVIEW
PDS	PROGRAM DEVELOPMENT SYSTEM
PDU	POWER DRIVE UNIT
PEM	PERFORMANCE ENGINEER MANUAL
PIC	POTENTIAL INFLUENCE COEFFICIENTS
PL&D	PLANS LOGS & DATA
PNS	PARABOLIZED NAVIER-STOKES
PR	PURCHASE REQUEST
PRR	PRODUCTION REVISION RECORD
PRT	PLATINUM RESISTANCE THERMOMETER
PSU	PASSENGER SERVICE UNIT
PTU	POWER TRANSFER UNIT
QLML	QUICK LOOK MEASUREMENTS LIST
RAT	RAM AIR TURBINE
RDMI	RADIO DISTANCE MAGNETIC INDICATOR
RFP	REQUEST FOR PROPOSAL
RFSC	RENTON FLIGHT SIMULATION CENTER
RIM	RELATIONAL INFORMATION MANAGEMENT
RIP	REQUEST FOR INSTRUMENTATION PREFLIGHT
RJE	REMOTE JOB ENTRY
ROI	RETURN ON INVESTMENT
RRCM	RUDDER RATIO CONTROL MODULE
RSL	RENTON SIMULATION LAB
RVDT	ROTARY VARIABLE DIFFERENTIAL TRANSDUCER
RVR	RUNWAY VISUAL RANGE
R/C	RATE OF CLIMB
R/W	RUNWAY
R&D	RESEARCH AND DEVELOPMENT
SAD	STILL AIR DISTANCE
SAE	SOCIETY OF AUTOMOTIVE ENGINEERS
SAM	STABILIZER - AILERON MODULE

SAT	STATIC AIR TEMPERATURE
SCD	SPEC CONTROL DRAWING
SCN	SYSTEM CHANGE NOTICE
SCM	SPOILER CONTROL MODULE
SCR	SOFTWARE CHANGE REQUEST
SDM	STANDARD DATA MODULE
SEWA	STUDY ENGINEERING WORK AUTHORIZATION
SFC	SPECIFIC FUEL CONSUMPTION
SFE	SELLER FURNISHED EQUIPMENT
SIAM	SOCIETY FOR INDUSTRIAL AND APPLIED MATHEMATICS
SLOR	SUCCESSIVE LINE OVER-RELAXATION
SLST	SEA LEVEL STANDARD TEMPERATURE
SM	STABILIZER MODULE
SOB	SIDE OF BODY
SOR	SUCCESSIVE OVER-RELAXATION
SPEEA	SEATTLE PROFESSIONAL ENGINEER EMPLOYEE ASSOCIATION
SRNMPP	NAMS (FLIGHT TEST NOMENCLATURE = SPECIFIC RANGE NAUTICAL MILES PER POUND)
SST	SUPERSONIC TRANSPORT
STR	SUPLIMENTARY TEST REQUEST
T-R	TRANSFORMER-RECTIFIER
TA	TRAVEL AUTHORIZATION
TAI	THERMAL ANTI-ICE
TAT	TOTAL AIR TEMPERATURE
TBC	THE BOEING COMPANY
TBD	TO BE DETERMINED
TBV	TO BE VERIFIED
T/C	THERMOCOUPLE
TCAM	TEST CONTROL AND ACQUISITION MODULE
TE	TRAILING EDGE
TIA	TYPE INSPECTION AUTHORIZATION

TIP	TEST ITEM PLANNING
TIRL	TEST ITEM REQUIREMENTS LIST
TMC	THRUST MANAGEMENT COMPUTER
TMS	THRUST MANAGEMENT SYSTEM
TO	TAKEOFF
TOC	TOTAL OPERATING COST
TVD	TOTAL VARIATION DIMINISHING
UDF	UNDUCTED FAN
UWAL	UNIVERSITY OF WASHINGTON AERO LABORATORY
VAAMP	VERSATILE AERODYNAMICS ANALYSIS & MANIPULATION PROGRAM
VASI	VISUAL APPROACH SLOPE INDICATOR
VD	VELOCITY - DIVE
VHF	VERY HIGH FREQUENCY
VIP	VOLUNTARY INVESTMENT PLAN
VMCA	VELOCITY MINIMUM CONTROL - AIR
VMCG	VELOCITY MINIMUM CONTROL - GROUND
VMO	VELOCITY - MAXIMUM OPERATING
VMU	VELOCITY MINIMUM UNSTICK
VNAV	VERTICAL NAVIGATION
VOR	VHF OMNIDIRECTIONAL RANGE
VSI	VERTICAL SPEED INDICATOR
WBL	WING BUTTOCK LINE
WBS	WORK BREAKDOWN SYSTEM
WEM	WARNING ELECTRONICS MODULE
WIP	WEIGHT IMPROVEMENT PROGRAM
WIS	WAKE IMAGING SYSTEM
WL	WATER LINE
WPR	WORK PERFORMANCE REVIEW
WR	WEATHER RADAR
W/B	WING BODY

YAS	YAW AUGMENTATION SYSTEM
YDM	YAW DAMPER MODULE

CAREER DEVELOPMENT

Information which may be helpful in planning your career development is provided on the following pages. Included in this section is information regarding:

- **ENGINEERING SKILL CODE**
- **TOTEM**
  - ENGINEERING
  - TECHNICAL AIDE
- **WORK PERFORMANCE**
- **RETENTION INDEXING**
- **EDUCATION AND TRAINING OPPORTUNITIES**

ENGINEERING SKILL CODE

Engineering skill codes are assigned with the following intent:

- o PRIMARY SKILL CODE

  That skill description that best describes the work the employee is most capable of performing.

- o SECONDARY SKILL CODE

  Those skill descriptions that best describe other work the employee is fully capable of performing.

Within Aerodynamic Technology the following skill codes exist:

CODE	DESCRIPTION
A A 2	Aerodynamic/Hydrodynamic Analysis

Analyze vehicle performance, variations and flight path dynamics as affected by aerodynamic/hydrodynamic configuration, propulsion characteristics, vehicle weight and mode of operation. Establish vehicle sizing based on performance requirements for preliminary design purposes. Conduct stability and control analysis and vehicle configuration and trade studies. Develop flight path or trajectory computational models, conduct simulations and apply tailoring or optimization techniques to define configuration trades and modes of operation for best vehicle performance within operating criteria, and participate in overall design process. Define and manage wind tunnel and tank test programs including data analysis. Analyze flow processes, develop methodology, conduct research in fluid dynamics and apply to vehicle design and development. Define and participate in flight tests leading to performance validation and vehicle certification.

AA7 Computational Fluid Dynamics

Develop and refine advanced computational methods for simulating detailed fluid flows such as occur in aerodynamics. Requires a breadth of high level, multi-disciplined scientific expertise encompassing the fields of advanced mathematics, theoretical fluid dynamics and advanced scientific computer application. Entails (1) coupling of sound scientific principals with physical intuition to model physical flows as proper mathematical formulations, (2) innovative development, implementation and evaluation of candidate solution algorithms, and (3) establishment of optimal problem and algorithm formulations with respect to computer system characteristics. An ability to gain early access to rapidly evolving technology within the scientific community through contacts arising from the achievement of scientific stature and recognition is expected.

AG4 Aerodynamic Stability and Control Analysis

Aerodynamic stability and control analysis, including: airplane configuration development, trade studies, balance, aerodynamic controls and empennage design, aerodynamic controls hinge moments, deflections and rate requirements; aerodynamic methodology development and application; handling qualities criteria development and aircraft evaluation; wind tunnel testing, flight simulation testing and flight testing to support airplane design development and flying qualities evaluation through certification; evaluation of aircraft operation and safety, systems operation and reliability, and investigation of accidents and incidents.

TA1 Aerodynamic Testing

Planning and conducting fluid dynamic testing in steady flow and impulsively generated flow from subsonic through hypersonic range. Requires knowledge of test operation, model design, data acquisition, analysis, reporting and test technique and facility development.

TOTEM

o ENGINEERING

The engineering payroll at Boeing is a "person rated" compensation system. Each engineer is rated by management based on his "worth" to the company (as opposed to being rated based on his job description). Management determines the relative ranking of engineers within the company. The ranking process is referred to as "toteming" (i.e., stacking people in order of ranking/worth as on a totem pole).

The first step in performing a relative ranking of engineers is deciding on the proper comparison group. Typically, management uses one of the following two methods for determining a comparison group: (1) all engineers having the same primary skill code within a major organization; (2) all engineers working on the same project. Within Aero the method depends upon the skill code. For example, all AG4 engineers (Stability & Control) are totemed together. However, AA2 engineers are separated into two groupings for the purpose of toteming; Configuration and Performance. These two groups are totemed separately.

The ranking of engineers within a comparison group is referred to as the B-Totem. Once the ranking is complete, engineers are ordered on a list from highest to lowest ranking. The B-Totem is broken down into smaller groups consisting of only those engineers having the same grade (e.g., all grade 16 engineers in the B-Totem group). This sub-grouping is called an A-Totem. The same rank ordering as arrived at in the B-Totem ranking is preserved in the A-Totem group, as well.

The B-Totem is important in the salary review process. Since the engineering payroll is a "person rated" compensation system, salaries generally fall in the same ordering as the B-Totem ranking. Generally, when an engineer's salary ranking is lower than the B-Totem ranking, management is more likely to raise his salary. Likewise, if an engineer's salary ranking is higher than his B-Totem ranking then he is less likely to get a raise.

o **TECHNICAL AIDES**

The technical aide payroll is a modified "job rated" compensation system. The aide is essentially paid according to the job performed as defined by grade level. The system is not a true "job rated" system in that there is a salary range for each grade level. An employee is ranked according to his or her "worth" within his level in a similar manner to a "person rated" system. Management determines the relative ranking of employees within a grade level. This ranking process is referred to as toteming.

The employee review and ranking is important in the following ways:

1) Salaries within a grade level generally fall in the same ordering as the totem ranking.

2) The ranking process requires that management review each person's job performance. If manage ment determines that a person performs work in the next grade level, he is reclassified to that level. Such a reclassification usually includes a salary increase, increased salary potential and more challenging assignments.

The descriptions of the six grade levels within Aerodynamic Technology are described in the following paragraphs:

LEVEL 01

Working from general directions on recurring tasks, or specific instructions on semiroutine tasks, and selecting from a limited choice of clearly prescribed and established methods and techniques, perform tasks such as preparing presentation material by plotting, inking, and lettering graphs. Assist with the running of computer programs by the assembling of program inputs, making punch card corrections, and detecting deviations from required input format. Prepare simple sketches and drawings. Contacts are generally limited to others within the organization for the purpose of obtaining information.

LEVEL 02

Under general supervision and utilizing a variety of standard methods and techniques, perform semiroutine tasks in calculating and preparing charts and tabulations of aerodynamic information. Using computer output and/or data derived by hand calculation, make plots and fair lines that represent an accurate portrayal of data trends and levels. Assist with the input of parameters to the computer by stacking input decks and/or operating a remote terminal. Make preliminary layouts of text, keys, titles and call-outs on reproduction copy. Contact others, usually within the organization, for the purpose of furnishing or obtaining information on routine matters.

LEVEL 03

From assignments which are normally well defined, and applying well established methods and techniques, and with numerous precedents available, perform work requiring problem solutions and occasional decisions. Assist in the preparation of documents (e.g., guarantee compliance, performance, test summary, design analysis, etc.) by selecting the computer programs, parameters and conditions required for input to satisfy job requirements.

Set up the mathematical approach to be followed to hand calculate any additional needed information. Format data arrays, geometry, or other aerodynamic information by viewing, scaling, sketching and laying out the reproduction copy. Frequently contacts others, both inside and outside the organization, for the purpose of furnishing and obtaining information.

LEVEL 04

With assignments given in terms of specific objectives and applying recently developed, but proven methods and techniques with numerous precedents available, perform tasks requiring solution of complex problems based on several choices of possible action. Prepare or assist in the preparation of major programs involving the construction of aerodynamic support documents (such as complex mission analysis and guarantee compliance documents). Determine the proper variables for airframe and environmental conditions. Input applicable computer programs and trouble-shoot suspect returning data to identify errors or inadequacies in input parameters or tables. Determine the appropriate presentation schemes and formats to show directly and in the clearest manner that segment of aerodynamic technology which is being studied. Contact others, both inside and outside the organization, on matters requiring explanation and discussion leading to approval.

LEVEL 05

Working with considerable latitude in planning and carrying out assignments with some precendents available, perform tasks requiring a solution of a variety of complex problems based on a wide choice of possible actions such as develop pertinent data relative to the interrelationships which occur when airframe and engine parameters are varied in determining airplane design and performance. Develop aerodynamic, engine and configuration parameters from raw data supplied by outside groups and determine the degree of sophistication to which they will be reduced to accomplish study goals. Perform research from various engineering data to prepare complex graphical displays, drawings, and reproduction copy. Develop new methods to maintain and improve analytical approaches. Negotiate and coordinate the inputs of other organizations.

<u>LEVEL 06</u>

Work assignments, which must clearly exceed those described in the Level 05 Technical Aide-Aerodynamics job level description, are given in terms of major objectives requiring interpretation, selection, adaptation and application of many guidelines, precedents, principles and practices and involving work of a broad scope and complexity generally limited to a specialized technical field within a major discipline.

WORK PERFORMANCE

The Company is vitally interested in how well each employee does his or her job. Work performance is reviewed as follows:

A WORK PERFORMANCE REVIEW (WPR) is conducted once a year. The primary purpose is to address the employee's job performance, including the employee's work assignment(s) and the supervisor's appraisal of the employee's performance. Engineering and Technical employees may also request an optional WPR during specified periods six months following the regular review, as will as request a supplemental WPR under certain conditions.

NEW EMPLOYEE PROGRESS REVIEW is conducted upon completion of 30, 90, 180 and 360 days on the payroll. It provides an opportunity for a positive, constructive exchange between a supervisor and a newly-hired employee. The exchange is to encourage job progress and growth.

SALARIED EMPLOYEE PROGRESS AND PERFORMANCE REVIEW for all salaried employees with continuous Company service in excess of 12 months. Each employee's job performance and efforts toward continuous improvement is assessed. Performance that needs remedy will be identified and discussed with employees and remedial action required outlined.

ENGINEERING RETENTION INDEXING

OBJECTIVE:

Retention indexes are intended to enable management to retain those engineers best able to maintain or improve the efficiency of the company, further its progress, and contribute to the successful accomplishment of current and future business.

FACTORS:

Retention indexes are to be assigned by consensus of managers who have knowledge of the engineer's work and the relative priority of each job assignment in relation to others. Consideration is to be given to each engineer's competence, diligence and demonstrated usable capabilities based upon the engineer's current performance and previous experience.

DISTRIBUTION:

The index distribution within each major organization must be such that, as nearly as mathematically possible, 23% to 27% of the engineers in each skill code are in each retention position (quartile).

EDUCATION AND TRAINING OPPORTUNITIES

The broadening field of continuing education encompasses numerous opportunities for further training and education both within the Company and at schools in areas near your work or home. The next few pages describe the opportunities, from paid-time training to graduate study programs.

You are invited to contact the training organization for assistance in selecting courses for further study.

PAID-TIME TRAINING

Several sections of "The Boeing Engineer" relate to training courses offered as paid-time training. Classes are scheduled for such training at the request of managers or supervisors. Training courses scheduled during the regular 40-hr week are conducted entirely at Company expense. The employee pays no tuition or book fees and receives full salary while attending classes.

University of Washington Campus

EVENING PROGRAM

The evening program of Continuing Education is sponsored by the Company to assist the scientist, engineer, or other technical employee continually to improve and broaden his or her professional knowledge and capability. Many of the course offerings are initiated for the technical employee at Boeing because the universities are unable to conduct these classes.

Tuition is not charged, but textbooks, course notes, etc., may be purchased by payroll deduction.

Evening program classes are held at convenient locations and are conducted by instructors who are specialists in their subjects. The following courses are typical of the quarterly offerings announced by the BCAC training organization:

- Aerodynamics for Engineers
- Aerodynamics for Wings and Bodies
- Aircraft Configuration
- Airline Marketing
- Airplane Performance
- Applied Stress Analysis
- BCAC Cost Accounting
- BCAC Cost and Price Estimating
- Cardiopulmonary Resuscitation (CPR)
- CAM Familiarization
- Computer Programming
- Detail Design and Analysis
- Effective Presentations
- Fatigue Analysis and Design
- Fundamentals of Using an IBM PC/XT
- Hydraulic Systems Analysis
- Introduction to CAD
- Manufacturing Systems Overview
- Modern Digital Control
- Modern Control Theory
- Stability and Control in Transport Design
- Structural Damage Tolerance
- Technical Writing

Evening classes have been variously called off-hour and after-hour training. The Company sponsors such courses to help the graduate engineer or technical employee keep pace with the rapidly changing and advancing technology of his or her field and other fields.

BCAC LEARNING CENTERS

The BCAC training organization operates three Learning Centers that offer self-taught courses in a wide variety of subjects. Among these are courses in business, communications, computers, electrical/electronics, engineering, management, and languages. Study of Learning Center material is not tied to academic quarter or semester timing, but is available at any time during the year. This allows maximum freedom and flexibility in course study planning.

Courses are available in one of two study modes:

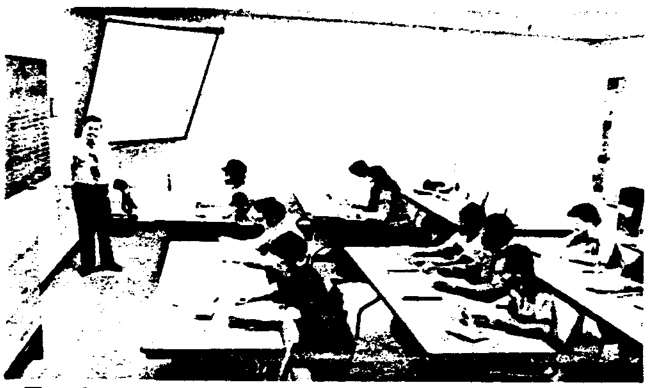
Learning Center Study—Employees study at the Learning Center using its equipment and resources (e.g., videotape, 8086/8088 and 8080A microprocessors, IBM PC-XT personal computers, etc.).

Home Study—Course materials are available for checkout or purchase, allowing employees to study at locations of their own choosing.

The Resource Center is the distribution area for the entire Learning Center.

The Renton Learning Center is located on the second floor of the 4-03 building behind the cafeteria and is open from 7:00 a.m. to 6:00 p.m., Monday through Thursday, and 7:00 a.m. to 4:00 p.m. on Friday. It consists of a resource center, two classrooms, and an individual study room equipped with seven study carrels.

The Everett Learning Center is located in the 40-85 building and is open from 7:00 a.m. to 6:00 p.m., Monday through Thursday, and 7:00 a.m. to 4:30 p.m. on Friday. It consists of a resource center, two classrooms, and an individual study room equipped with nine study carrels.



The classrooms can be used for traditional lecture classes or as monitored classrooms for video presentations.

The Auburn Learning Center is located in the 17-10 building on the east end of the balcony, and is open from 7:00 a.m. to 6:00 p.m., Monday through Thursday, and 7:00 a.m. to 4:00 p.m. on Friday. It consists of a resource center, seven classrooms, and an individual study room equipped with 10 study carrels.

The individual study carrels are used for viewing videotapes, audiocassette programs, and to work with 8-bit and 16-bit microprocessors.

Employees can schedule training before work, during lunch break, or after work. No tuition or enrollment fee is charged for the voluntary courses. Employee costs involve only study materials and textbooks. For most classes, study materials can be loaned to students. Foreign language courses consist of cassette tapes and workbooks that must be purchased.

Each quarter, a schedule of Voluntary Off-Hour courses is published in the Boeing News. A list of available independent study tapes (audio and video) is included in the schedule. The Learning Center staff can provide complete information on current course offerings, how to register for these courses, and will schedule student training.

COLLEGE AND UNIVERSITY STUDIES

Boeing encourages employees to make use of external educational programs as part of their efforts to fully develop their abilities. Financial assistance can be requested by employees for one of the tuition reimbursement programs outlined.

Applications and more detailed information can be obtained from the BCAC College Studies Office.

GRADUATE DEGREE PROGRAM

The Graduate Degree program is available to employees pursuing a master's or PhD degree. The degree program must maintain or enhance the employee's competence to the advantage of the Company.

To qualify, the degree program must be evaluated by the program coordinator as acceptable under the guidelines of this program. It must be offered by a college or university evaluated as an acceptable educational institution. (Most public and private colleges and universities in the Puget Sound area are acceptable.) You must be fully accepted into the graduate school of an acceptable college or university. You must remain on the active payroll from the quarter start date through the quarter end date.

To apply, complete form X-20369, Application for Admission to the Graduate Study Program. Include a letter of recommendation from your immediate supervisor, a signature from your department head, and a copy of your letter of acceptance as a full graduate student. Then submit the completed application to the BCAC College Studies program coordinator *prior* to the start date of the quarter.

To receive reimbursement, once the program is approved, you must notify the coordinator each quarter of courses in which you are enrolled (a form is provided). A maximum of two courses per quarter/semester can be reimbursed. All courses must be graduate level courses, which apply directly to degree requirements. Each course must be completed with a B or better grade. Reimbursement is made for tuition, required fees, and a per-credit-hour allowance.

For doctoral candidates, each year there will be an opportunity for candidates for doctoral degrees to be granted educational leaves of absence, with certain financial assistance, to fulfill the requirements for the doctorate.

UNDERGRADUATE DEGREE PROGRAM

The Undergraduate Degree Reimbursement program is available for employees pursuing a community college technical certificate, 2-year associate, or 4-year bachelor's degree. The certificate/degree must enhance or maintain the employee's competence to the advantage of the Company.

To qualify, the degree program must be evaluated by the program coordinator as acceptable under the guidelines of this program. It must be offered by a college, community college, or university evaluated as an acceptable educational institution. (Most public and private colleges and universities in the Puget Sound area are acceptable.) You must be on the active payroll from the quarter start date through the quarter end date.

To apply, complete form X-20523, Application for Undergraduate Degree Program, and include a letter of recommendation from your immediate supervisor and a signature from your department head. Then submit the completed application to the BCAC College Studies program coordinator *prior* to the start date of the quarter.

To receive reimbursement, once the program is approved, you must notify the coordinator each quarter of the courses in which you are enrolled (a form is provided). A maximum of two courses per quarter can be reimbursed. All courses must apply to the degree program you are pursuing. Each course must be completed with a C or better grade. Reimbursement is made for tuition and required fees only.

INDIVIDUAL COURSE PROGRAM

The Individual Course Reimbursement program is used by employees to pursue a technical certificate or take courses to upgrade their skills. Courses must, by evaluation, maintain or enhance the employee's competence to the advantage of the Company.

To qualify, the course must be offered by a college, university, community college, or public technical institute. Courses offered by colleges or universities must be taken for credit. The course must be at least one quarter or semester in duration and must be available on a schedule that does not interfere with your regularly assigned shift. A maximum of two courses per quarter or semester may be requested for reimbursement. You must be on the active payroll from the quarter start date through the quarter end date.

To apply, complete form X-25280 (or X-21066) Application for Reimbursement of Tuition. Then submit the completed application to the BCAC College Studies program coordinator *prior* to the course start date.

To receive reimbursement, once approved, you must complete the course(s) with a C or better grade or successfully complete the course if no grades are given. Reimbursement is made for tuition and required fees only.

NEARBY COLLEGES AND UNIVERSITIES

CITY UNIVERSITY

City University is an independent, decentralized nonprofit higher educational institution. Its primary purpose is to provide educational opportunity to a segment of the population not being fully served through other traditional processes. In accordance with student needs and demands, classes are offered at downtown and neighborhood locations and at hours convenient for employed adults. City University offers the following programs (not a complete listing) of particular interest to Boeing employees:

- Certificate Programs
  - Computer Programming
  - Accounting
- Associate in Science
  - Accounting
  - Business and Administration
  - Data Processing
- Bachelor of Science
  - Business Administration
  - Computer Information Systems
- Master of Business Administration
- Graduate Certificate
  - Management
  - Information Systems

COGSWELL COLLEGE

Cogswell College is an independent technology college located in Kirkland, associated with Cogswell College in San Francisco, California. The regular academic year consists of three 10-week quarters and a summer session. Courses are offered primarily in the evening and on weekends. Cogswell College offers the following programs of particular interest to Boeing employees:

Bachelor of Science—Mechanical Engineering Technology
* Bachelor of Science—Electronic Engineering Technology
** Bachelor of Science—Electrical Engineering

* Accredited by Accreditation Board for Engineering and Technology (ABET)
** Currently being reviewed for ABET accreditation (3/87)

Technology degrees are also covered by accreditation of the main campus.

PACIFIC LUTHERAN UNIVERSITY

Pacific Lutheran University (PLU) is a private liberal arts university in Tacoma. The calendar year is composed of two 14-week semesters, separated by a 4-week interim, and a summer session. Day and evening classes are offered. PLU offers the following programs (not a complete list) of particular interest to Boeing employees:

* Bachelor of Business Administration
Bachelor of Science—Computer Science
* Master of Business Administration

* Accredited by American Assembly of Collegiate Schools of Business

SEATTLE PACIFIC UNIVERSITY

Seattle Pacific University (SPU) is a private liberal arts university located on the north side of Queen Anne Hill in Seattle. The regular academic year consists of three 10-week quarters and a summer session. Day and evening courses are offered. SPU offers the following programs (not a complete list) of particular interest to Boeing employees:

Bachelor of Arts—Business Administration
Master of Business Administration
Master of Science—Information Systems Management

SEATTLE UNIVERSITY

Seattle University (SU) is a private, coeducational Catholic university under the sponsorship and direction of members of the Society of Jesus. The regular academic year consists of three 10-week quarters and a summer session. Day and evening programs are offered. SU offers the following programs (not a complete list) of particular interest to Boeing employees:

** Bachelor of Arts in Business Administration
Bachelor of Civil Engineering
* Bachelor of Electrical Engineering
* Bachelor of Mechanical Engineering
Bachelor of Computer Science
Bachelor of Science—Physics
** Master of Business Administration
Master of Software Engineering
Master of Transportation Engineering

* Accredited by Accreditation Board for Engineering and Technology
** Accredited by American Assembly of Collegiate Schools of Business

UNIVERSITY OF PUGET SOUND

The University of Puget Sound (UPS) is a private, liberal arts university located in Tacoma. The academic year is set up with a 4-month fall semester, a 1-month winter interim in January, and a 4-month spring semester. UPS offers the following programs (not a complete list) of particular interest to Boeing employees:

Bachelor of Arts—Business Administration
Bachelor of Science—Computer Information Systems
Bachelor of Science—Computer Science/Mathematics

UNIVERSITY OF WASHINGTON

The University of Washington is the oldest state-assisted institution of higher education on the Pacific coast. The university is organized into five colleges and eight major schools. University instruction is offered during autumn, winter, and spring quarters, each lasting approximately 11 weeks. The 9-week summer quarter is divided into two 4-1/2-week terms. Opportunities for evening study at the University are varied to serve individual students' interests and academic goals. Because day and evening credit classes are integrated, students may enroll in courses during the day or night or a combination of the two. University Extension offers an evening credit program and noncredit evening programs.

The University of Washington offers many degree programs relevant to Boeing Company needs. It is the only university in the Puget Sound area to offer graduate level engineering degree programs.

The School and Graduate School of Business Administration is accredited by the American Assembly of Collegiate Schools of Business.

The College of Engineering offers bachelor of science degrees accredited by Accreditation Board for Engineering and Technology (ABET) in aeronautics and astronautics, ceramic, chemical, civil, electrical, mechanical, and metallurgical engineering.

TELEVISED INSTRUCTION IN ENGINEERING

In response to a need for post-baccalaureate educational opportunities for employed professionals, the University of Washington College of Engineering offers its Televised Instruction in Engineering (TIE) program. The TIE program takes advantage of regularly scheduled on-campus courses by holding selected courses in specially equipped TV studio/classrooms and transmitting them to classrooms at participating firms over a cable TV network; companies that cannot be reached by cable TV are served by a videotaped version of the program.

It is currently possible to pursue a master of science degree program in electrical engineering, aeronautics and astronautics engineering, and mechanical engineering.

As a TIE student, you are a fully participating member of an accredited program in engineering at the University of Washington; you are able to talk with the professor in the on-campus classroom over audio talk-back links; you have access to the instructor's telephone office hours for consultation; and, as a member of the TIE class, you receive the class notes and homework via daily courier.

The majority of the coursework can be completed by taking only televised courses. However, TIE master's students must accomplish some of their work on campus; final exams and some midterms take place on campus; laboratory courses requiring on-campus facilities have special sections scheduled in the evenings and/or on weekends for TIE students.

The admission and academic requirements for the TIE graduate programs are identical to the corresponding on-campus programs.

Boeing Commercial Airplane Company currently offers TIE courses in Renton at the 7-011 building via live transmission and videotape and in Everett at the 40-85 building via videotape only.

For more information call the BCAC College Studies Office.

NOTES

EVOLUTION OF AN AIRPLANE

A successful airplane program begins long before first delivery. Seven to eight years prior to certification initial activity is underway. Potential markets are analyzed to target opportunities for a future airplane. The anticipated needs and desires of potential customer airlines are evaluated. The Company's long range goals in terms of competing in the market place must be considered including the effect of a new airplane on existing Company products. Technology assessments determine what advancements may be ready for application to the future airplane.

Assuming the exploratory design process has produced promising results, the next step is to proceed with the preliminary design phase of the airplane. This phase may last two to three years and is aimed at defining the actual configuration of the airplane. Although the design is considered preliminary at this point, significant effort and resources may be expended. The exploratory design results and proposed technology advancements must be verified.

Projected cost of the program must be defined, also. In a market driven environment, where the selling price of an airplane is not based on the cost to make that airplane, controlling costs is a program imperative. Trade studies identify cost differences in competing component designs, allowing the selection of the most cost efficient candidate. Make/buy decisions determine the degree of subcontracted vendor participation, taking advantage of the vendors' skills and past experience.

At this point in the design the final configuration of the airplane will be selected and frozen. Performance estimates are finalized and operational guarantees developed so that the airplane may be offered to the customers. At this stage the Company must decide if it is willing to pursue a multi-billion dollar risk. The estimated costs of the program must be weighed against the anticipated market for the airplane.

Now the pace of the program really begins to quicken. Program go ahead is given with the announcement of secured orders. At this point the airplane is approximately four years away from certification and delivery. An intense product design effort is underway, concentrating on all of the many design details of the airplane. Project engineering must translate all of the design activity into the plans and specifications which will support the manufacture of the airplane.

Meanwhile, work has begun on the fabrication of the airplane's subassemblies. Whether it be wing spars, landing gear struts, hydraulic actuators or computers, these components must be available to support the start of the major assembly process. Major assembly begins approximately two years prior to certification. The airplane takes shape as it moves through the factory until finally, after about one year, it is ready to be rolled out.

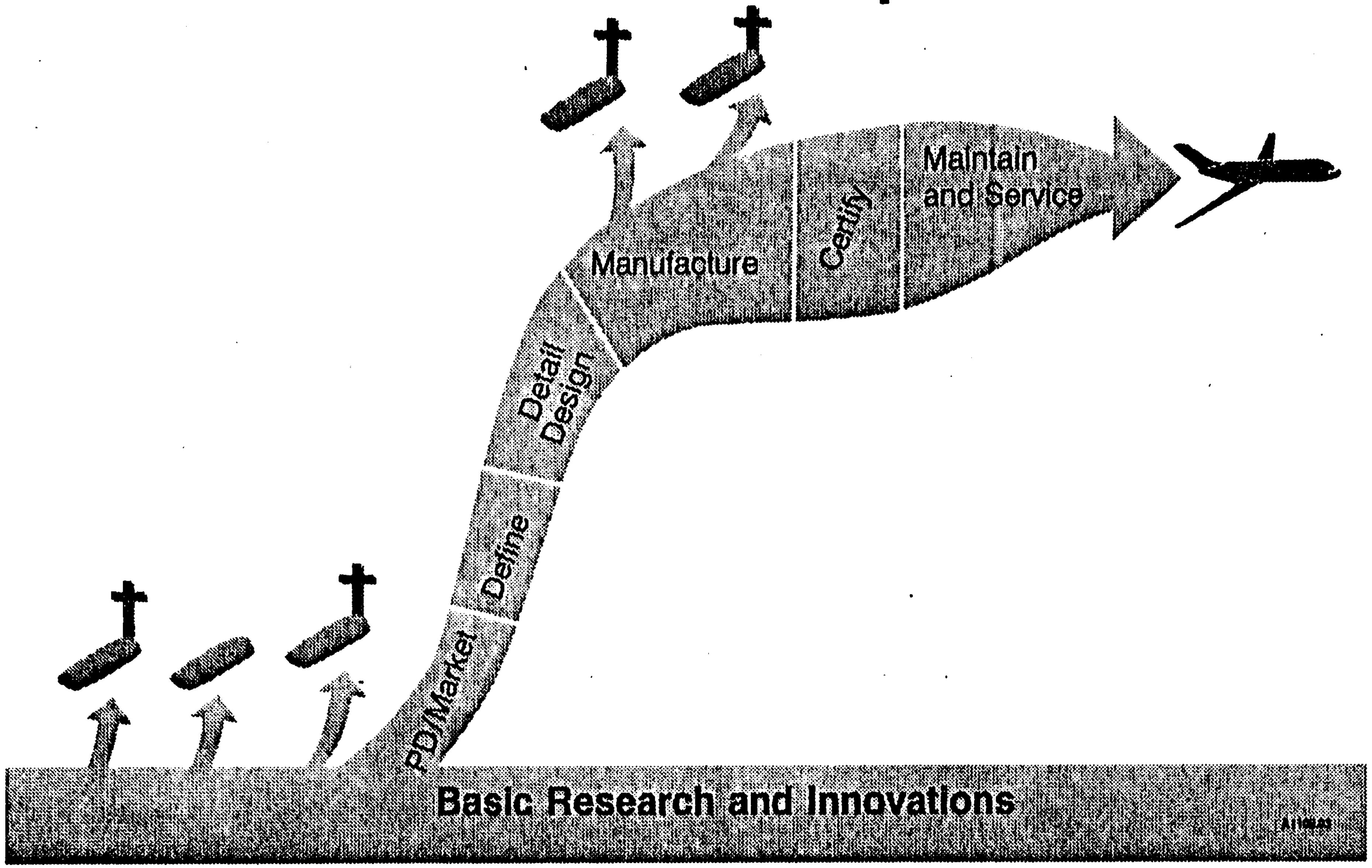
The final year prior to certification is probably the most intensive of the program. All effort is directed towards preparing the airplane for certification and delivery. After several months of rigorous ground checks the airplane is ready to fly. Flight is the culmination of the past seven or eight years of work. A thorough pre-certification test program is conducted to verify the characteristics of the airplane. Any problems must be quickly understood and remedied since the alternative would be a delay in the delivery of the airplane.

Finally, the certification process begins. The airplane flying characteristics must be demonstrated to the certifying agency (FAA) as well as the operation of all of the many airplane systems. The airplane's handling qualities are evaluated and its performance capabilities measured. Engines, autopilots, radios, landing gear, etc. are all tested and evaluated against specific requirements. Upon completion of certification the airplane is awarded its airworthiness certificate and may be delivered.

It should be noted that several more rounds of certification are usually required to satisfy the requirements of other countries. For example, the British CAA requires the demonstration of special flight conditions not required by the FAA. Thus, additional flying is required before the airplane may be certified to fly in that country.

Delivery of the airplane marks the final phase of the initial design process but it is really just a beginning. Consider that the airplane, if it is successful, may continue to sell for the next twenty years. Airline customers will need problems solved and questions answered. Derivatives of the original model will be developed involving product improvements and adjustments to the market. As technology advances the airplane continues to evolve.

Evolution of an Airplane



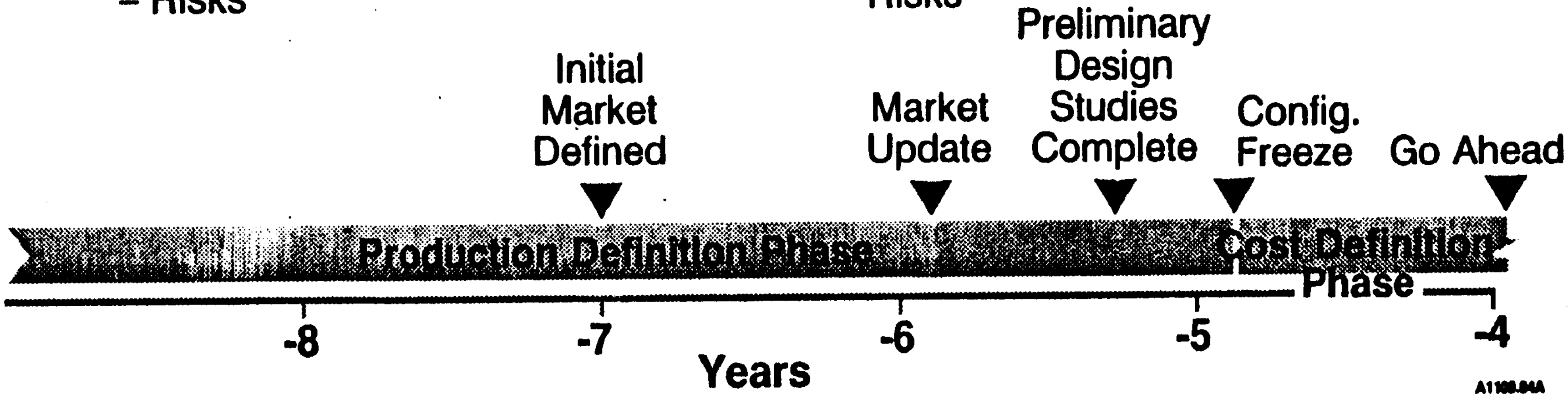
Evolution of an Airplane - The Design Process

First...

- Exploratory design
  - Product definition - general design concepts
  - Issues
    - Market
    - Mission
    - Technology
    - Company goals
    - Customer interest
    - Risks

Looks good. So...

- Preliminary design
  - Product definition - configuration definition and cost definition
  - Issues
    - Verify exploratory design results
    - Trade studies
    - Guarantee development
    - Supplier contact
    - Customer involvement
    - Risks



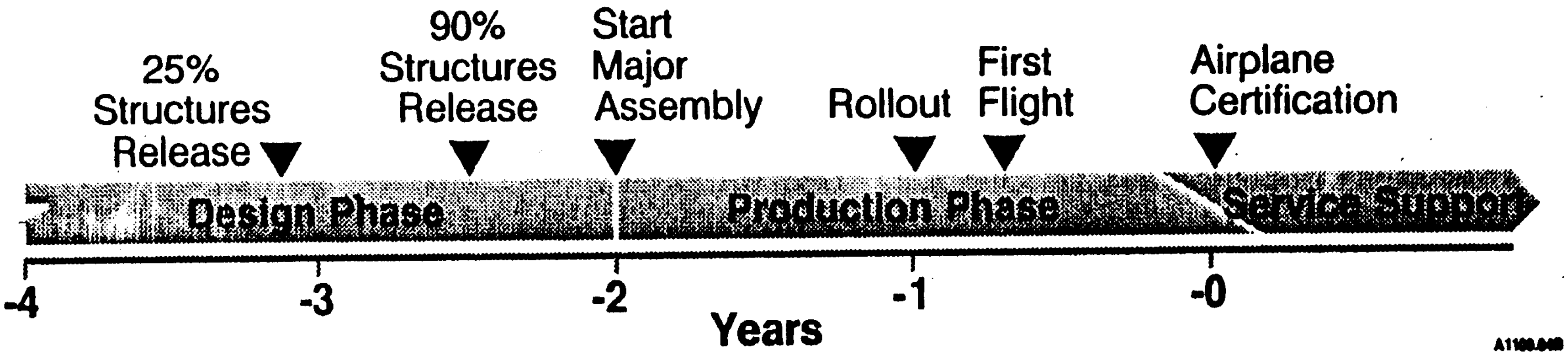
Evolution of an Airplane - The Design Process

Customer bought. Now...

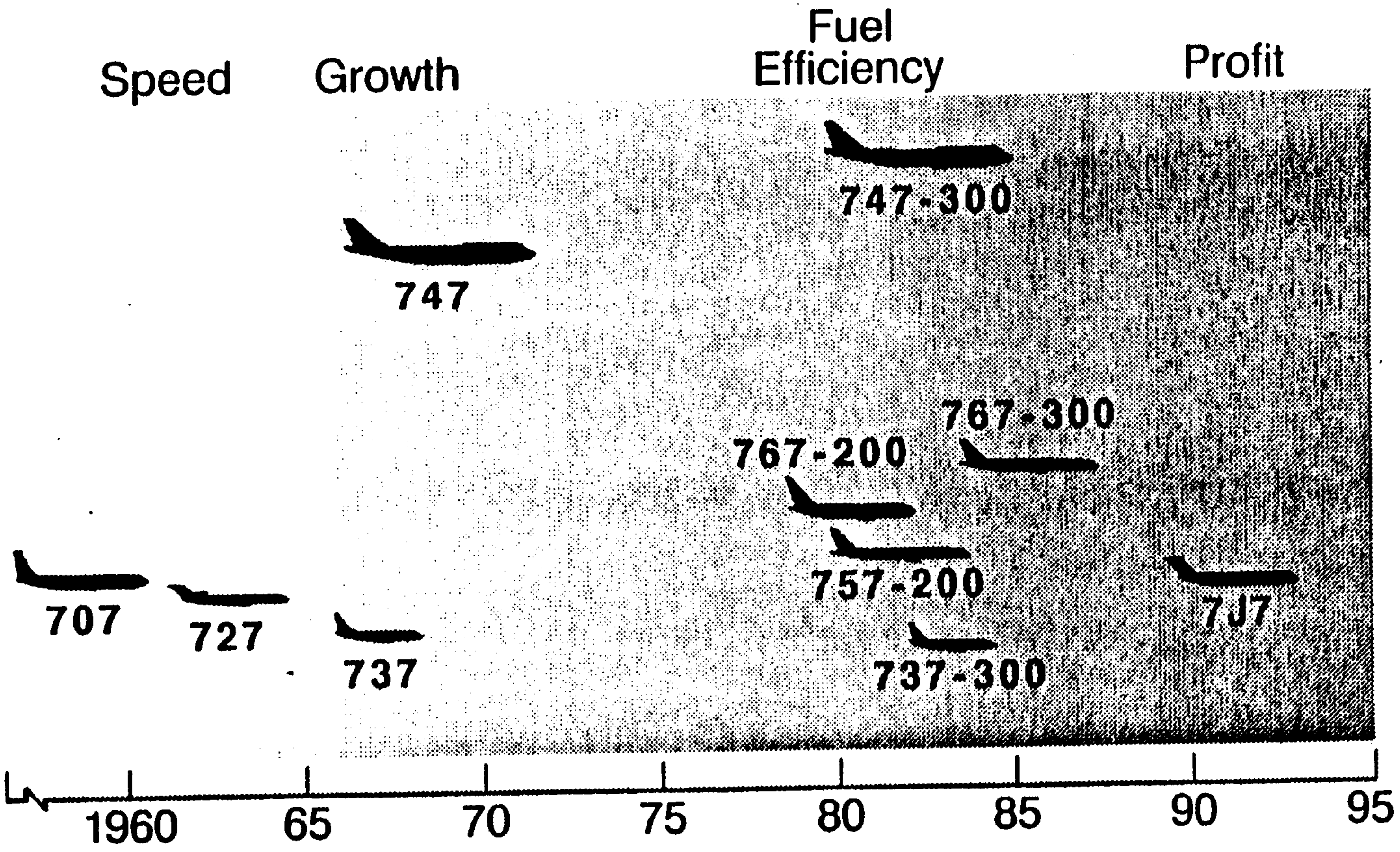
- **Product design**
  - **Detailed design and production**
  - **Issues**
    - Detail design developed
    - Customer involvement
    - Guarantees/warranties
    - Risks

Now we get feedback...

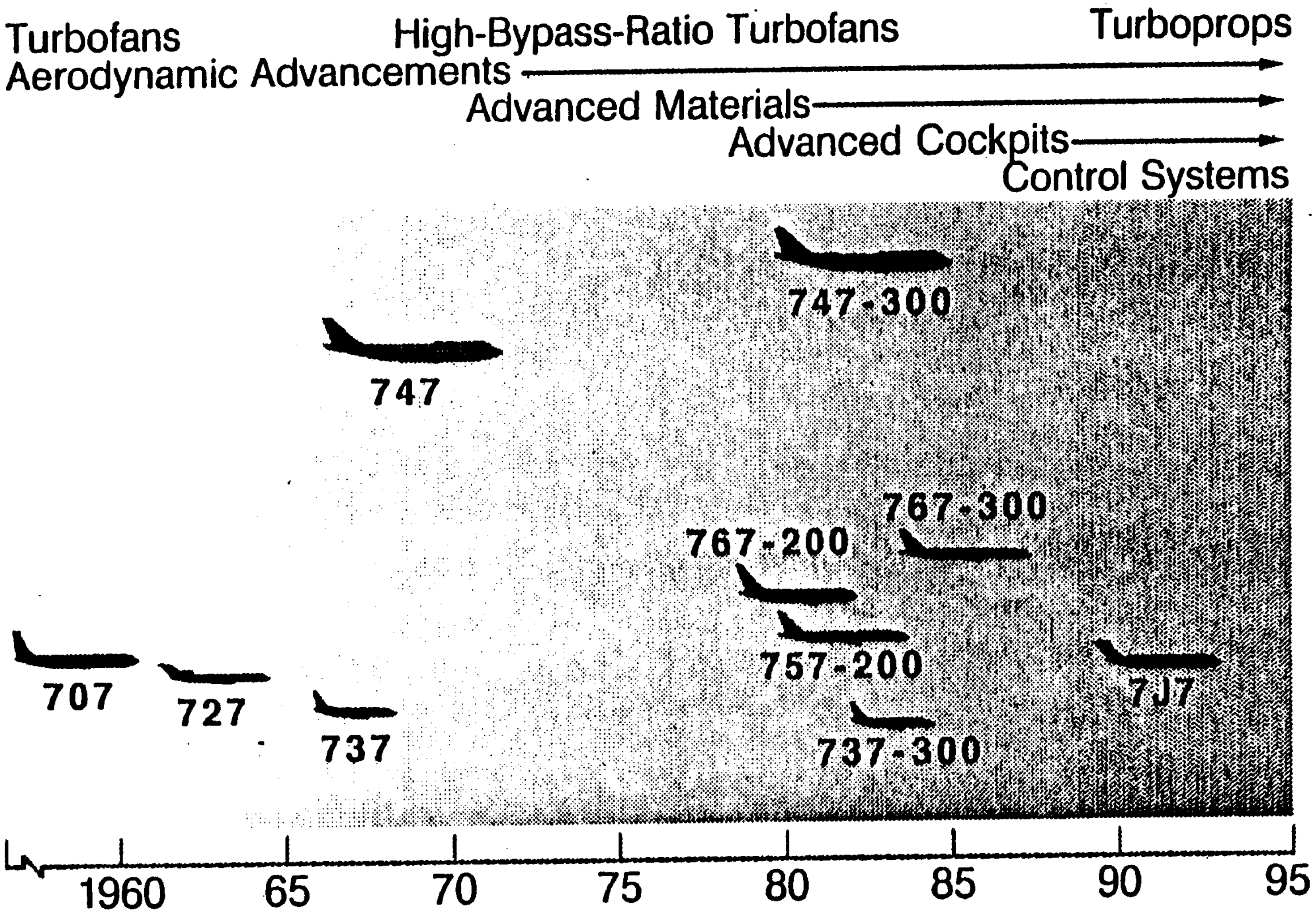
- **Service support**
  - **Keep flying**
  - **Issues**
    - Technology verified
    - Product improvement
    - Warranties
    - Fixes
    - Customer goodwill



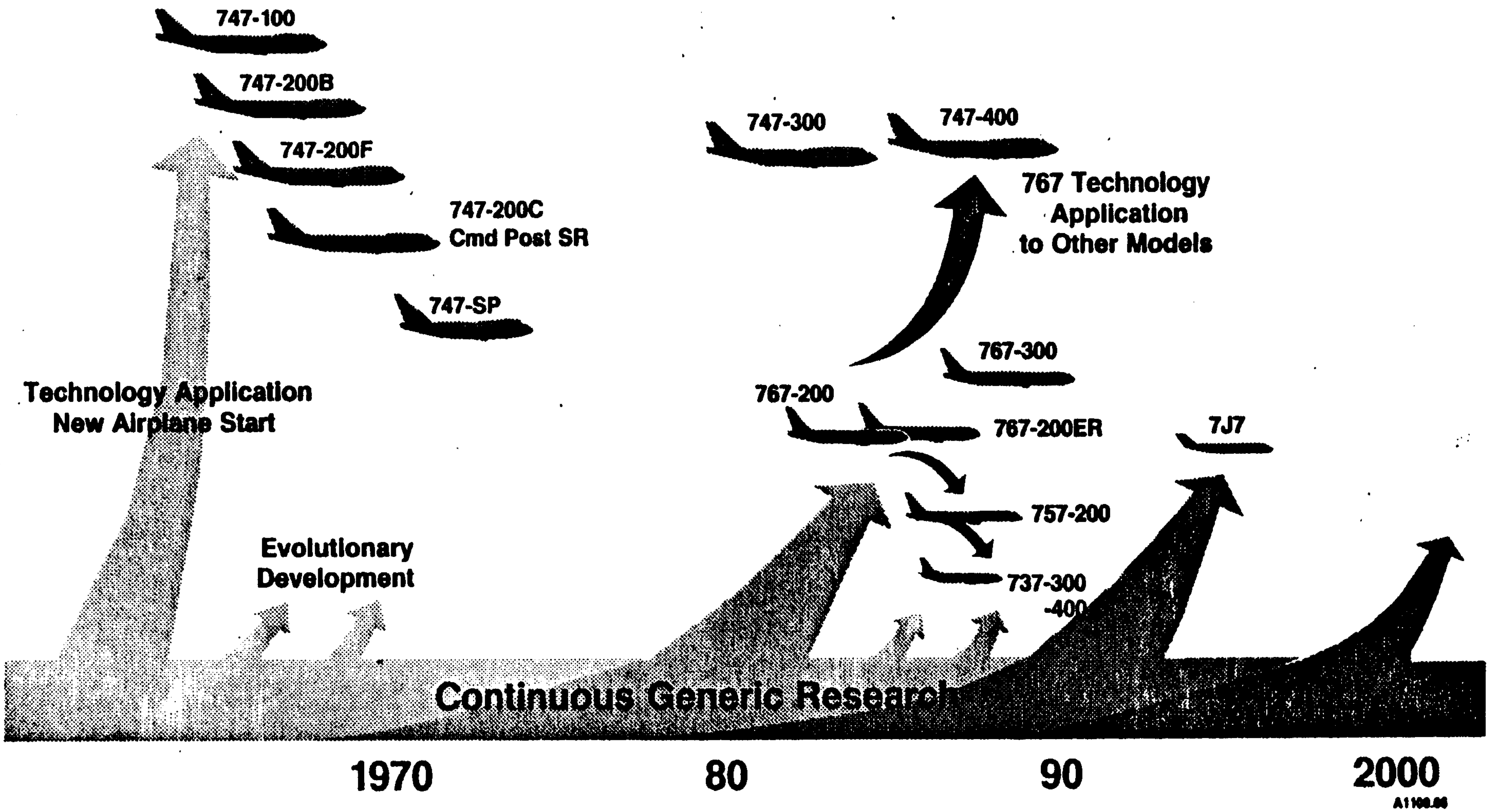
Evolution of an Airplane - Airline Market Imperatives



Evolution of an Airplane - Enabling Technologies

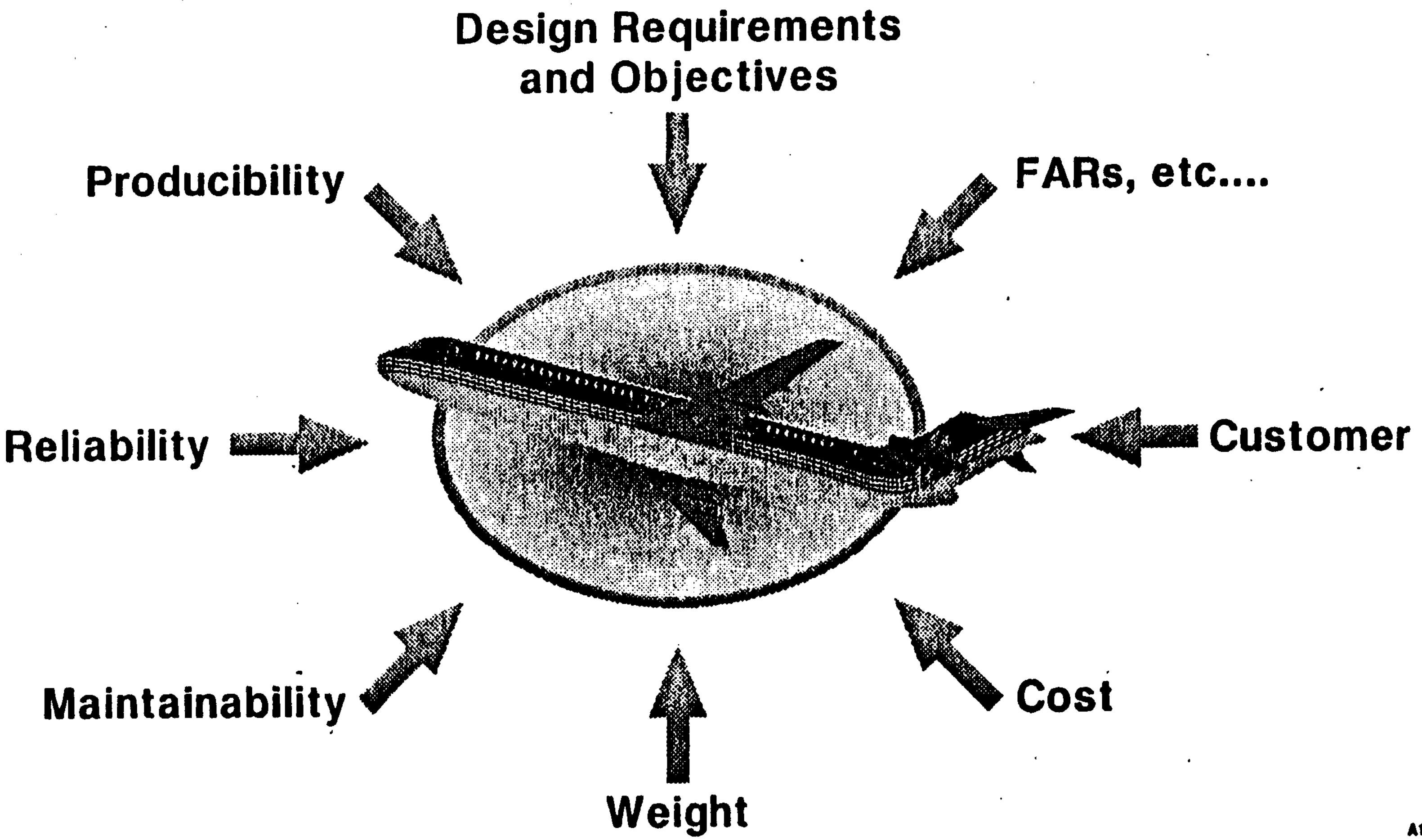


Technology Application
(Approximately 10-Year Cycles)



Evolution of an Airplane - Design Determinants

Ideal ⇒ Real



A1109.87

Evolution of an Airplane - Design Requirements and Objectives

- Used to formally document technology staff requirements for project engineering
- Used to ensure that the final design provides safe and practical operation
- Based on certification requirements, customer requirements, and past experience
- Used to ensure that future designs provide equivalent or superior quality than previous designs
- Used in conjunction with a design standards manual

Evolution of an Airplane - Design Requirements and Objectives Document Contents

Performance
- Airplane performance
- Weight and balance
- Noise

Environment

Safety

Product Assurance
- Reliability
- Maintainability

General Airplane Design
- Aerodynamic smoothness
- Corrosion prevention

Structures

Systems
- Landing gear
- Flight controls
- Hydraulic power
- Electrical

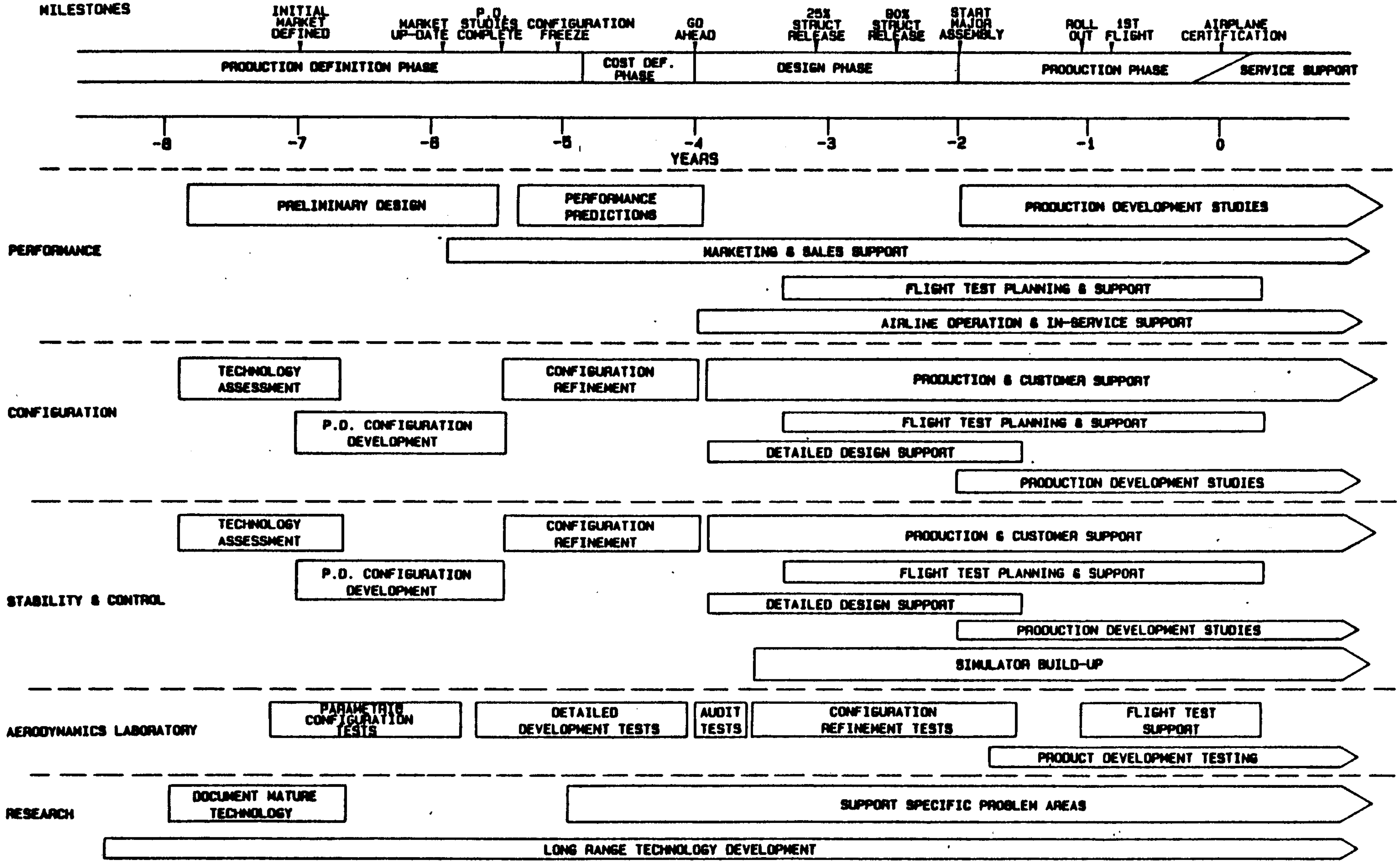
Propulsion
- Engine/nacelle
- Fuel system
- Auxiliary power

Payload Systems

Materials and Material Processing

A1100.00

EVOLUTION OF AN AIRPLANE - AERODYNAMICS TECHNOLOGY STAFF'S ACTIVITIES



EVOLUTION OF AN AIRPLANE - BOEING COMMERCIAL AIRPLANES

AIRPLANE	INITIAL FLIGHT TEST PERFORMANCE RELATIVE TO PREDICTIONS	WIND TUNNEL OCCUPANCY HRS PRIOR TO 1ST FLIGHT	MAJOR MODIFICATIONS DURING DEVELOPMENT
707	?	?	WING GLOVE (720)---------------- FIN TIP EXTENSION WING AREA INCREASE (-300/400) ----VENTRAL (VMU) KRUEGER FLAP SPAN INCREASE (720)- POWER ASSISTED RUDDER SLOTTED KRUEGERS (300 B/C)-------TIRE FUSE PLUGS TURBO FAN APPLICATION (720B/100B)-WING VG'S
727	BETTER	4230	CENTER INLET SHAPES (-200)-------- VG'S ON VERTICAL/ CENTER INLET FENCE ON WING ----------------- KRUEGER FLAP COMMONALITY (-100) TRIPLE SLOTTED FLAPS------------ CASCADE THRUST REVERSERS ENGINE LOCATIONS---------------BODY STRETCH
737	DRAG WORSE NAMS WORSE	7966	EXCRESCENCE CLEAN-UP (-100)----- SIDE MOUNTED ENGINE ASSY (-300) AFT BODY - W/B FAIRINGS (-100)-----APU INLET (-200) THRUST REV. NACELLE MOD (-100)---WING VG'S (-100) AFT BODY VG'S - VERTICAL BOUNCE--FMCS (-300) (-200) 3 CREW 2 CREW (-300)------------GRAVEL R/W OPERATION
747	DRAG OK (MCRIT WORSE) NAMS WORSE (THRUST, SFC, BLEED PROBLEMS) COMMUNITY NOISE WORSE	14414	HI BIPASS RATIO TURBO FANS-------W/B FAIRING MOD (SP) VARIABLE CAMBER KRUEGER------- LONGER UPPER DECK (300) COROGARD PAINT DRAG------------ ELEVATOR RERIG HORIZONTAL TAIL LE CAMBER------- FLAP RERIG HORIZONTAL TAIL STRAKELET--------FLAP TRACK FAIRINGS MOD PYLON AFT FAIRING (ALL PW ENG)

10-1-86
TF 35783

EVOLUTION OF AN AIRPLANE - BOEING COMMERCIAL AIRPLANES.

AIRPLANE	FLIGHT TEST PERFORMANCE RELATIVE TO PREDICTION	WIND TUNNEL OCCUPANCY HRS PRIOR TO 1ST	MODIFICATIONS CONSIDERED DURING DEVELOPMENT	FLIGHT TEST ACTIVITY
757	DRAG BETTER NAMS BETTER	18716	ADVANCED COCKPIT DESIGN CAB CHANGE T-TAIL ⟶ LOW TAIL SLAT SHAPE CHANGE SEAT CAPACITY INCREASE BRILES RIVETS COMPOSITES ANTENNAS/LIGHTS/AIR DAMS STRAKELET KRUEGER VENT SCOOP/RADOME STRIPS LONG DUCT NACELLE	WING VG'S HEATED SPINNER (535C) AUTOSLAT ON FOR CERT. TORQUE TUBE SEAL ECS INLET/EXIT ECS EXIT HOT PAD MOVE OBSERVERS SEAT UP 1" INBD 7" ELEVATOR/BODY SEAL NON COMPLIANT BLEED CONTROLLERS
767	DRAG BETTER NAMS BETTER	20800	STOL CONCEPTS OVERWING NACELLE TRI-JET CONFIG. LOW, MID & T-TAILS BODY WIDTH VARIATIONS ADVANCED COCKPIT DESIGN 3 CREW ⟶ 2 CREW BODY VANE/WING VG'S ANTENNAS/LIGHTS VENT SCOOP/RADOME STRIPS BRILES RIVETS ENGINE EARS NEW PASSENGER DOOR DESIGN LD-2 CONTAINERS WING/NAC. STRUT AREA RULE	WING VG'S SLAT STRUCTURE SLAT TAILORING INCREASED DESCENT IDLE SPLIT ELEVATOR LAND. GEAR DOOR GE EXTERIOR PILOT TUBE ECS EXIT HOT PAD COMPOSITE PANEL BUCKLING

10-1-86
TE 357

PERFORMANCE GROUP

FUNCTION

The performance group oversees the operational characteristics of the airplane. Early in the design phase of an airplane, performance requirements and objectives are defined. Range capability with design payload, cruise altitude, cruise speed, flight envelope, takeoff and landing field lengths, approach speeds, etc. are all specified. These specifications drive the aerodynamic design of the airplane.

As the design phase progresses performance predictions are generated and continually updated to verify that the design is converging on the requirements and objectives. As customer interest solidifies, an achievable performance prediction is committed and marketing and sales support intensifies. Studies of airline requirements, competitive analysis, and contract support are performed.

Flight test planning and support will begin several years prior to first flight. The flight testing is necessary to demonstrate the airplane performance levels for certification purposes. This effort leads to verification and documentation of the airplane's operational characteristics. In the period just prior to initial deliveries an intense effort is expended in producing performance data for the Airplane Flight Manual (which must be approved by the certifying agency), the Operations Manual, and the Flight Crew Training Manual.

Continued support is provided by the performance group once an airplane enters service. Answers to airline customer inquiries are provided to help them with their operational planning, the in-service performance of the aircraft is monitored, and support is provided to help airlines recover performance levels where short falls are indicated.

AERODYNAMICS: PERFORMANCE

PRELIMINARY DESIGN

- WING SIZING
- TAIL SIZING (V_{MCG}, V_{MCA})
- FLIGHT MANAGEMENT COMPUTER SYSTEM
- ENGINE SIZING (THRUST REQUIREMENTS)
- TIRE SPEED AND BRAKE ENERGY REQUIREMENTS
- SYSTEM DESIGN
  - OXYGEN REQUIREMENTS
  - HYDRAULIC REQUIREMENTS
    - GEAR UP TIMES
    - FLAP RETRACTION TIMES

10-3-85
TE 32120

757 PERFORMANCE REQUIREMENTS AND OBJECTIVES

ITEM	REQUIREMENT OR OBJECTIVE	CRITERIA	COMMENTS
0 RANGE CAPABILITY ATH-LHR STL-SEA LGA-IAH DEN-SEA DEN-ATL	 REQ. REQ. REQ. REQ. OBJ.	ESAD-1558 NMI, BA INTERIOR, BA MISSION RULES ESAD-1747 NMI, EA INTERIOR, EA MISSION RULES ESAD-1618 NMI, EA INTERIOR, EA MISSION RULES, (WINTER OPERATION) ESAD-1000 NMI, TYPICAL DOMESTIC INTERIOR, ATA DOMESTIC MISSION RULES T.O. TEMP.=84°F ESAD-1061 NMI, DELTA INTERIOR, DELTA MISSION RULES, T.O., TEMP.=90°F	DETERMINES DESIGN MAX. TAKEOFF WEIGHT DETERMINES DESIGN MAX. TAKEOFF WEIGHT DETERMINES T.O. THRUST, LOW SPEED CONFIG., LOADING GUAR. CONFIG. DETERMINES T.O. THRUST, LOW SPEED CONFIG., BRAKE TORQUE & ENERGY DETERMINES T.O. THRUST, LOW SPEED CONFIG., BRAKE TORQUE & ENERGY
0 CRUISE SPEED OPTIMUM LRC MACH	REQ.	≥0.8 MACH OPTIMUM W/δ 'S	DETERMINES WING SECTION, SWEEP
0 TAKEOFF 0 T.O. FIELD LENGTH 0 V_{MCG} LIMITED TAKEOFF	 OBJ. OBJ.	T.O.F.L. ≤ 7000 FT, S.L. 84°F, @ MAX T.O. WT. TAKEOFF PERFORMANCE SHALL BE UNRESTRICTED BY V_{MCG} OVER AT LEAST 75% OF THE NORMAL TAKEOFF GROSS WEIGHT RANGE	DETERMINES T.O. THRUST, LOW SPEED CONFIG. DETERMINES VERTICAL TAIL/RUDDER SIZE
0 DESIGN CRUISE ALTITUDE CAPABILITY INITIAL CRUISE ALTITUDE CAPABILITY AT MAXIMUM CRUISE WEIGHT DESIGN MAXIMUM ALTITUDE	 REQ. REQ.	≥35,000 FT (A) LEVEL FLT, M.80 MCRT (CRUISE) (B) 300 FPM M.76 MCLT (END OF CLIMB) ≥40,000 FT CERTIFICATION ALTITUDE	DETERMINES M C_R THRUST, M $_{CL}$ THRUST, MINIMIZES DESIGN MISSION FUEL DETERMINES M $_{CL}$ THRUST
0 ONE ENG. INOPERATIVE ALT. CAPABILITY DENVER TO WEST COAST OPERATION	REQ.	≥15,500 FT @ OEW FOR 1000 NMI MISSION, TYPICAL DOMESTIC INTERIOR, A/C FROM APU, A/I OFF, ATA DOMESTIC MISSION RULES	DETERMINES MAX. CONT. THRUST, APU SIZE 14,500 FT TERRAIN +1000 FT CLEARANCE
0 LANDING FAR WET LDG. F.L. @ SEA LEVEL OPERATIONAL LDG. F.L. @ SEA LEVEL	 OBJ. OBJ.	LDG. F.L. ≤ 5000 FT. @ MISSION LDG. WT., TYPICAL DOMESTIC INTERIOR, ATA DOMESTIC MISSION RULES LDG. F.L. ≤LDG. F.L. FOR 727-200 (δ_F=40) @ MISSION LDG. WT.	DETERMINES VAPP, ANTI-SKID SYSTEM REQUIREMENTS DETERMINES VAPP, THRUST REVERSER REQUIREMENTS
0 APPROACH SPEED V_{APP} @ MISSION LDG. WT. V_{APP} @ MAX LDG. WT.	 OBJ. OBJ.	≤125 KEAS @ MAX. LDG. FLAP ≤135 KEAS @ MAX LDG. FLAP	DETERMINES WING AREA, LOW SPEED CONFIG. DETERMINES WING AREA, LOW SPEED CONFIG.
0 MAXIMUM SPEEDS/BUFFET V_{MO}/M_{MO} CRUISE BUFFET MARGIN LOW SPEED BUFFET MARGIN	 OBJ. OBJ. OBJ.	MATCH 727-200 @ S.L. & COMPETITION ABSOLUTE MAX. LEVEL FLT. MACH @ MISSION LDG. WT. +0.01 MACH (A) $M_{I/B}$ ≥ MAX LEVEL FLIGHT MACH AT EACH ALTITUDE @ MISSION LDG. WT. +0.01 MACH (B) MARGIN OF 0.3g TO INITIAL BUFFET @ LRC MACH AND MAX USEFUL W/δ MARGIN OF .41g (45° BANK) TO INITIAL BUFFET @ 250 KCAS @ TAKEOFF CLEAN UP, MAX. TAKEOFF WEIGHT OPERATION	V_{MO} = 350 KCAS V_{MO} = .85

AERODYNAMICS: PERFORMANCE

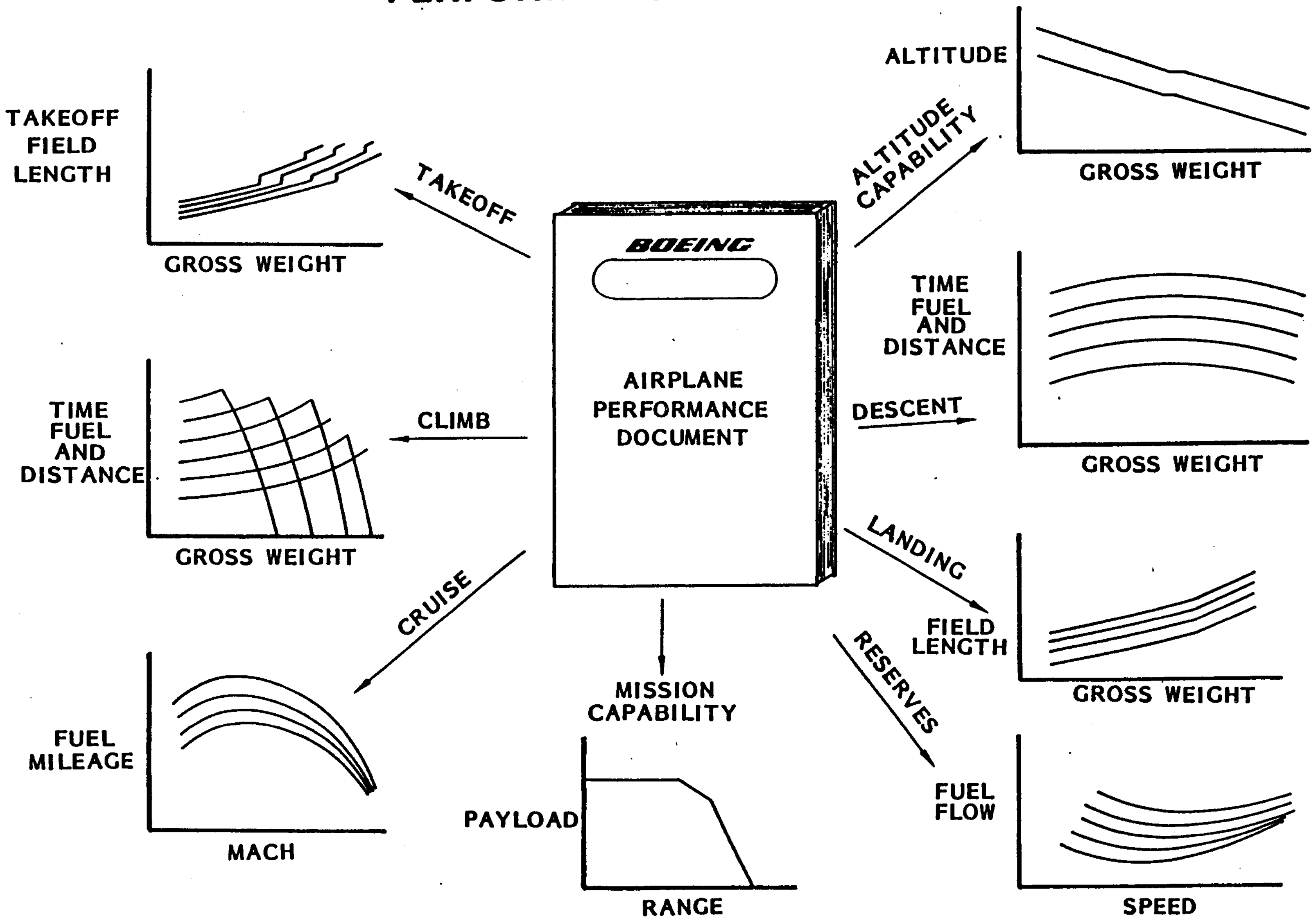
PERFORMANCE PREDICTION

- TAKEOFF & LANDING
  - BRAKE ENERGY & TIRESPEEDS
  - RUNWAY LOADING
  - NOISE
  - CONTAMINATED RUNWAYS
- CLIMB & DESCENT
- CRUISE FUEL MILEAGE
- ACCELERATE TO CRUISE SPEED
- ALTITUDE CAPABILITY
  - ALL ENGINE
  - ENGINE OUT
  - DRIFTDOWN
- TAXI & APPROACH
- HOLDING & RESERVES
- MISSION CAPABILITY

10-16-86
TE 32115

AERODYNAMICS: PERFORMANCE

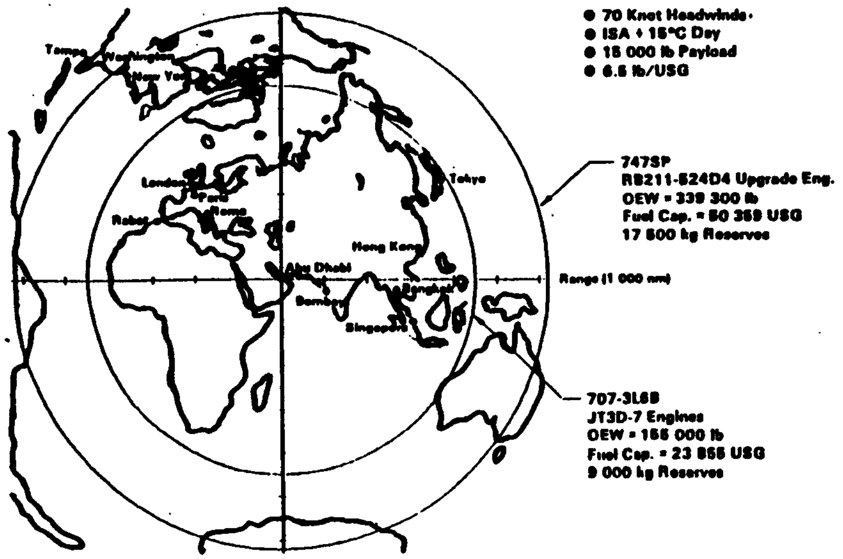
PERFORMANCE PREDICTION



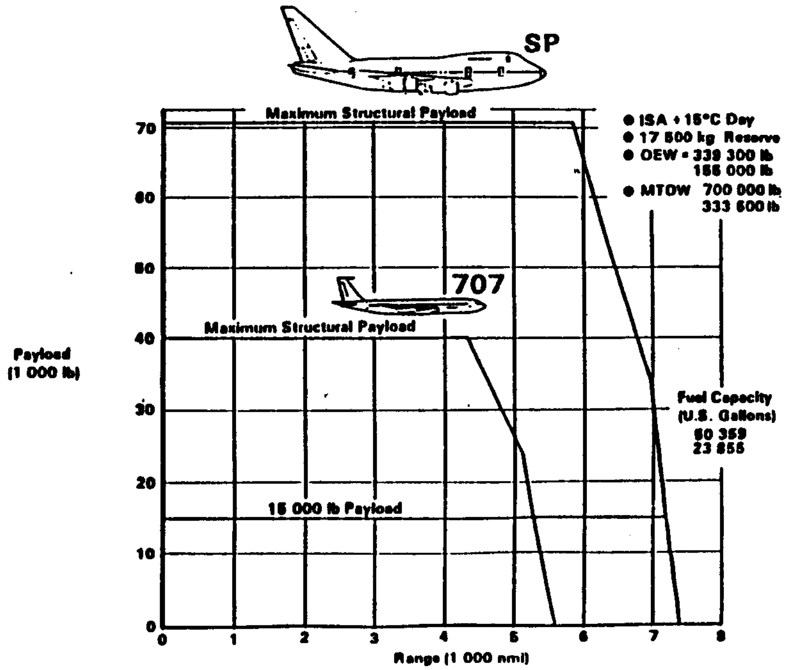
9-10-86
TE 32175.1

AERODYNAMICS: PERFORMANCE
MARKETING AND SALES SUPPORT
AIRLINE STUDY: RANGE CAPABILITY

RANGE FROM ABU DHABI

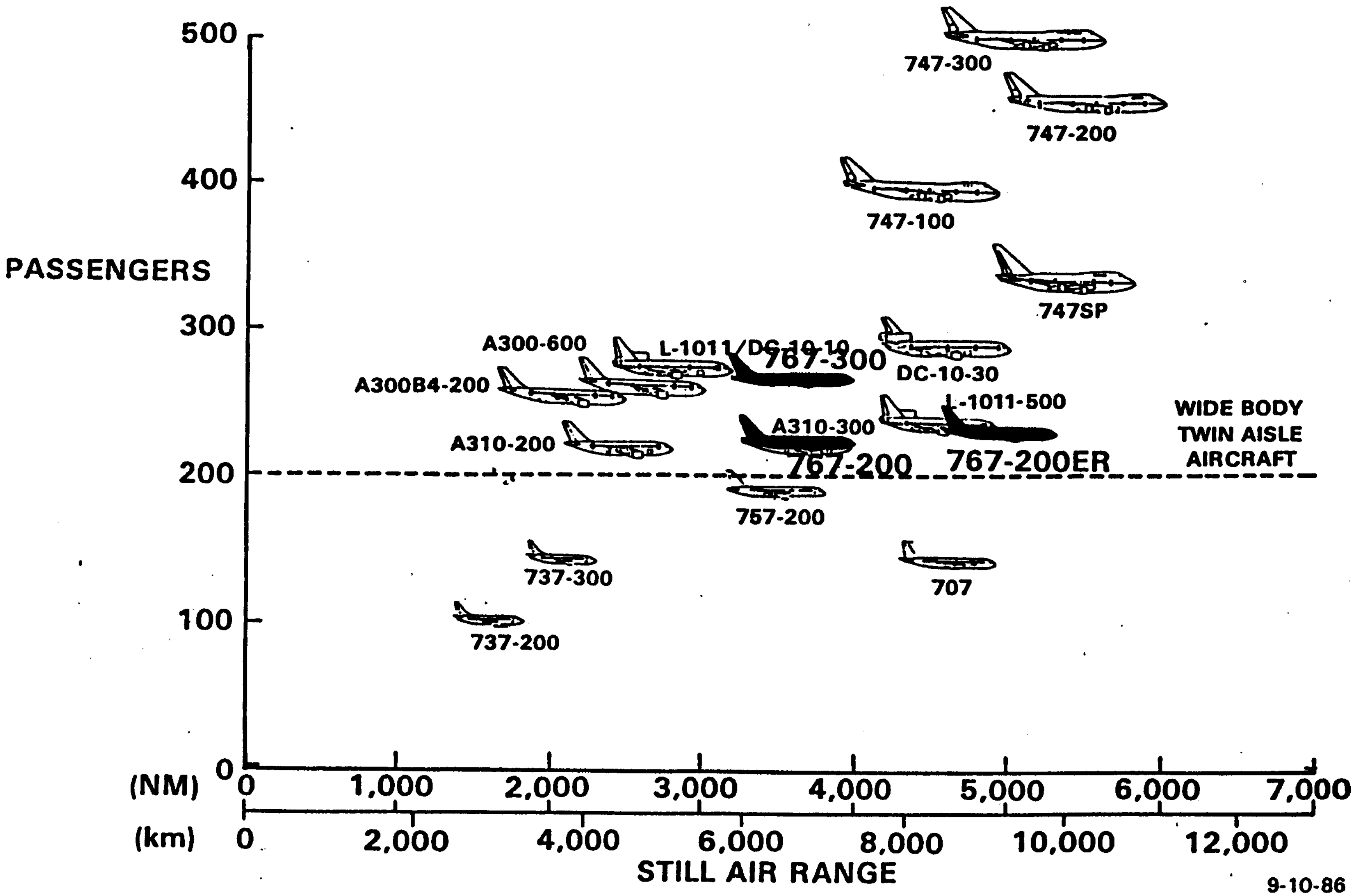


PAYLOAD vs RANGE



9-10-86
TE 32144.1

AERODYNAMICS: PERFORMANCE
COMPETITIVE ANALYSIS: MARKET FIT



9-10-86
TE 35463
RED O/L TO TE 35463

15

AERODYNAMICS : PERFORMANCE

CONTRACT SUPPORT

DURING AIRCRAFT PURCHASE

- CONFIGURATION SELECTION (ENGINE, MAX WTS, ETC)
- GUARANTEE PREPARATION
- GUARANTEE NEGOTIATION
- GUARANTEE STATUS
- SIDE LETTERS
    - FLIGHT TEST
    - INTERM CERTIFICATION
    - PERFORMANCE RETENTION

AT DELIVERY

- GUARANTEE COMPLIANCE
- CONTRACT DELIVERY SUPPORT

10-16-86
TE 32166

AERODYNAMICS: PERFORMANCE

CONTRACT SUPPORT

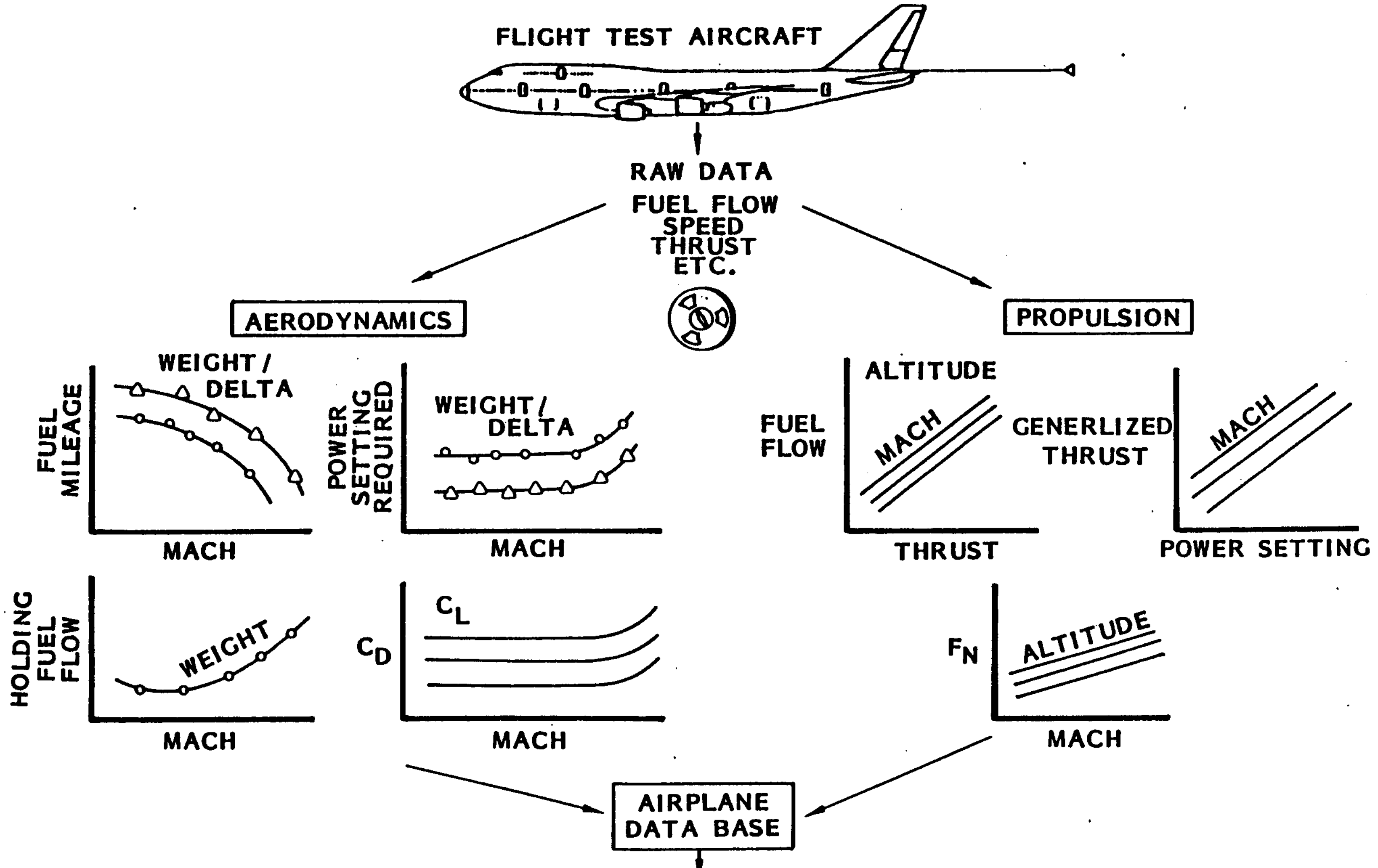
GUARANTEE CONTENT

- ITEMS REQUIRED TO DEFINE BASIC PERFORMANCE CAPABILITY OF AIRPLANE
  - TAKEOFF AND LANDING
  - CRUISE SPEED
  - FUEL BURN (RANGE)
  - ALTITUDE CAPABILITY
  - MANUFACTURER'S EMPTY WEIGHT

- ADDITIONAL CONDITIONS FOR SPECIFIC AIRLINE REQUIREMENTS
  - UNIQUE AIRPORT CONDITIONS
  - CRITICAL MISSIONS
  - NOISE
  - RUNWAY LOADING

10-17-86
TE 32117

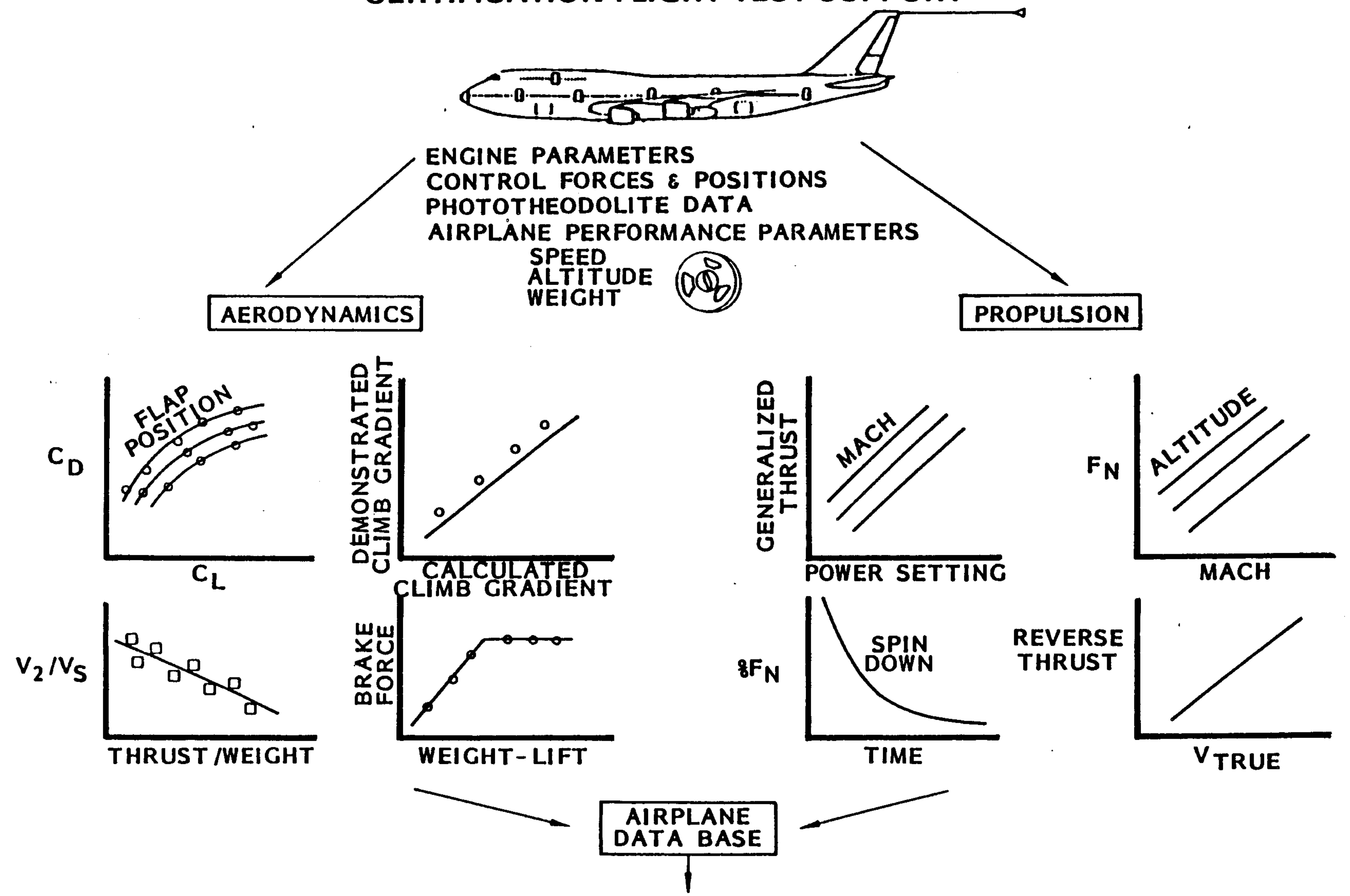
AERODYNAMICS: PERFORMANCE
FLIGHT TEST PLANNING AND SUPPORT
CRUISE FLIGHT TEST PERFORMANCE SUPPORT



GUARANTEE COMPLIANCE DOCUMENT
PERFORMANCE DOCUMENT
PERFORMANCE ENGINEERS MANUAL
OPERATIONS MANUAL
PERFORMANCE STUDIES

9-10-86
TE 32177.1

AERODYNAMICS: PERFORMANCE
FLIGHT TEST PLANNING AND SUPPORT
CERTIFICATION FLIGHT TEST SUPPORT



CERTIFICATION SUBSTANTIATION DOCUMENT
APPROVED AIRPLANE FLIGHT MANUAL
PERFORMANCE STUDIES

9-10-86
TE 32176.1

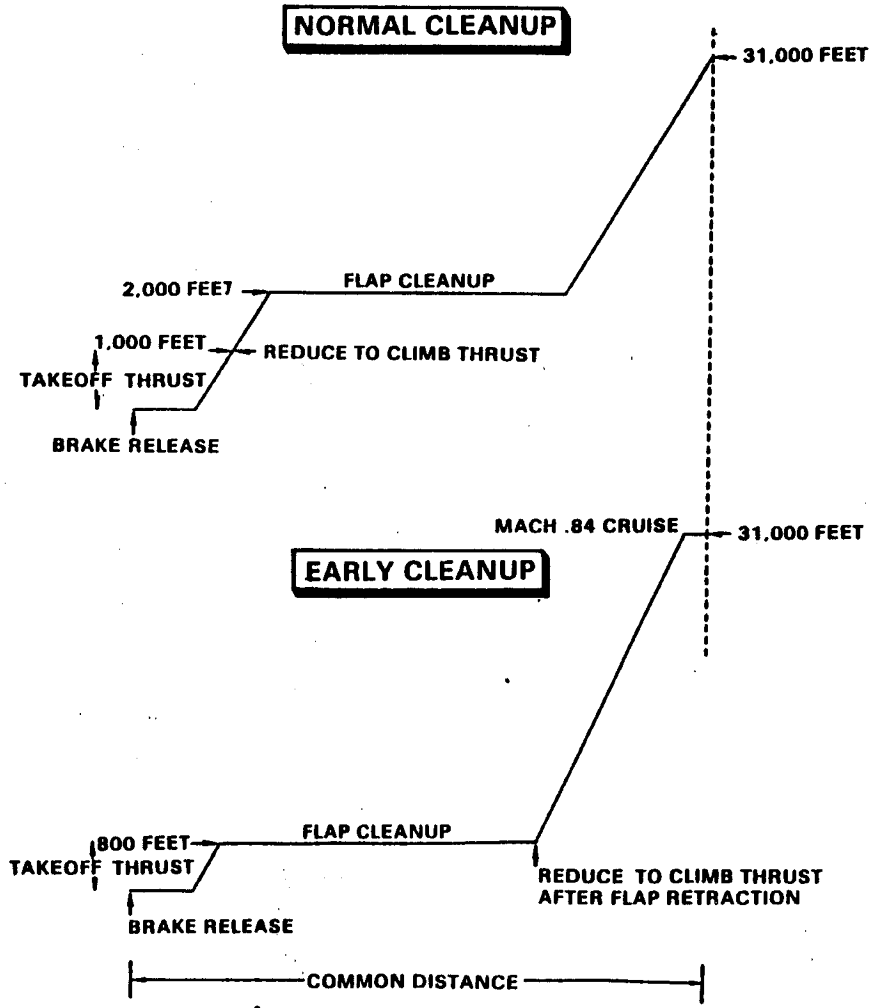
AERODYNAMICS PERFORMANCE
AIRLINE OPERATIONS & INSERVICE SUPPORT

- CERTIFICATION
  - FLIGHT TEST CERTIFICATION DOCUMENTATION
  - AIRPLANE FLIGHT MANUAL
- OPERATIONAL SUPPORT
  - OPERATIONS MANUAL
  - FLIGHT CREW TRAINING MANUAL
  - PERFORMANCE ENGINEERS MANUAL
- FLEET SUPPORT
  - PROCEDURAL
    - WIND SHEAR STUDIES
    - WET/SLUSH COVERED RUNWAYS
    - FERRY FLIGHTS
  - OPERATIONAL
    - TAKEOFF STUDIES
    - ROUTE ANALYSIS
    - EROPS
  - INSERVICE SUPPORT
    - FLEET INSPECTION
    - FLEET MONITORING
    - AIRLINE QUESTIONS/RESPONSE

10-4-85
TE 32158

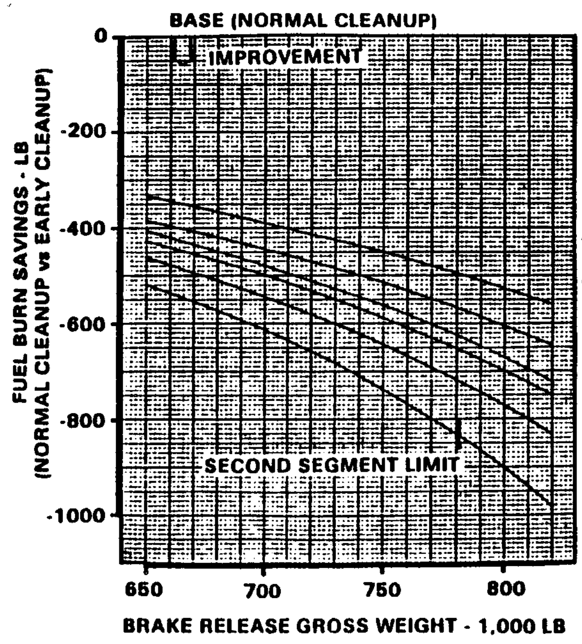
AERODYNAMICS: PERFORMANCE
AIRLINE OPERATIONS & IN-SERVICE SUPPORT
CUSTOMER SUPPORT EXAMPLE

- FUEL BURN BENEFIT FOR EARLY FLAP RETRACTION AFTER TAKEOFF (PHILIPPINE AIRLINES QUESTION)



CLEANUP FUEL BURN SAVINGS FOR AN EARLY CLEANUP

- CF6-50E2 ENGINES
- STANDARD DAY
- SEA LEVEL AIRPORT
- FUEL BURN COMPARED ASSUMING TAKEOFF, CLIMB TO 31,000 FT., AND CRUISE TO A COMMON DISTANCE

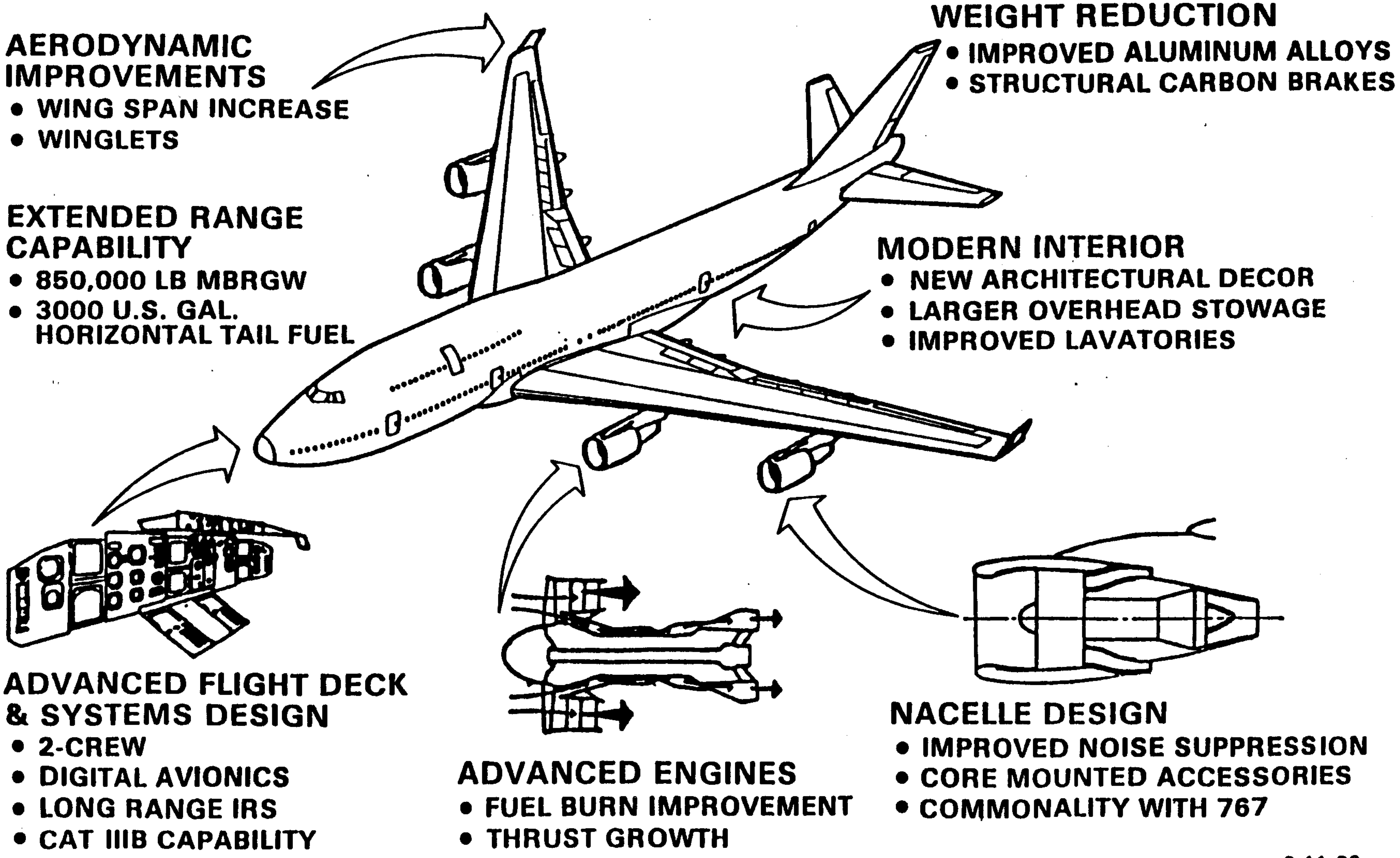


TAKEOFF FLAPS	TAKEOFF THRUST RATING
10	FULL
10	DERATE 1 (50E -4%)
20	FULL
10	DERATE 1 (50E -4%)
20	DERATE 1 (50E -10%)
20	DERATE 2 (50E -10%)

10-17-86
TE 32147

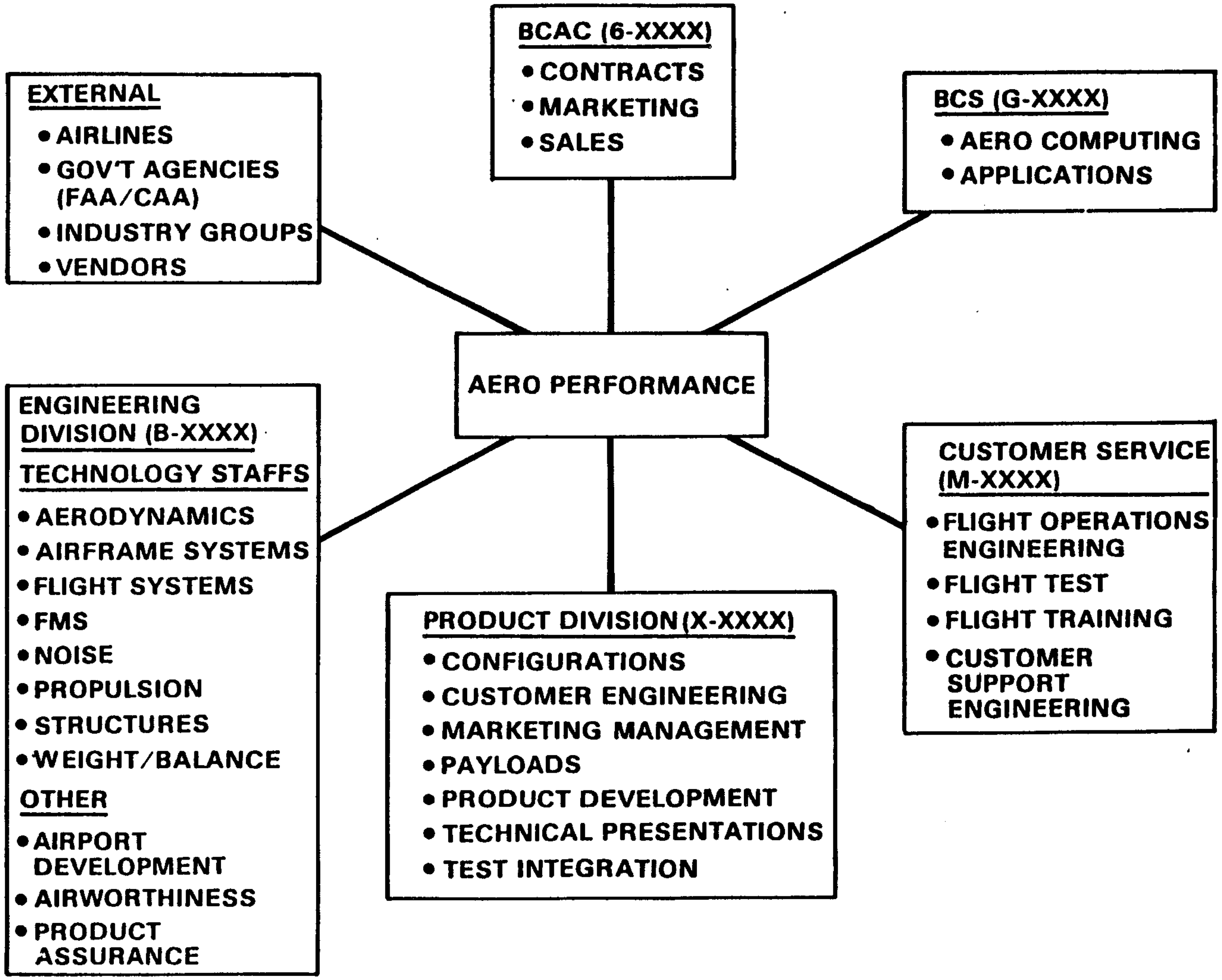
AERODYNAMICS: PERFORMANCE

PRODUCT IMPROVEMENT: 747-400 DESIGN FEATURES



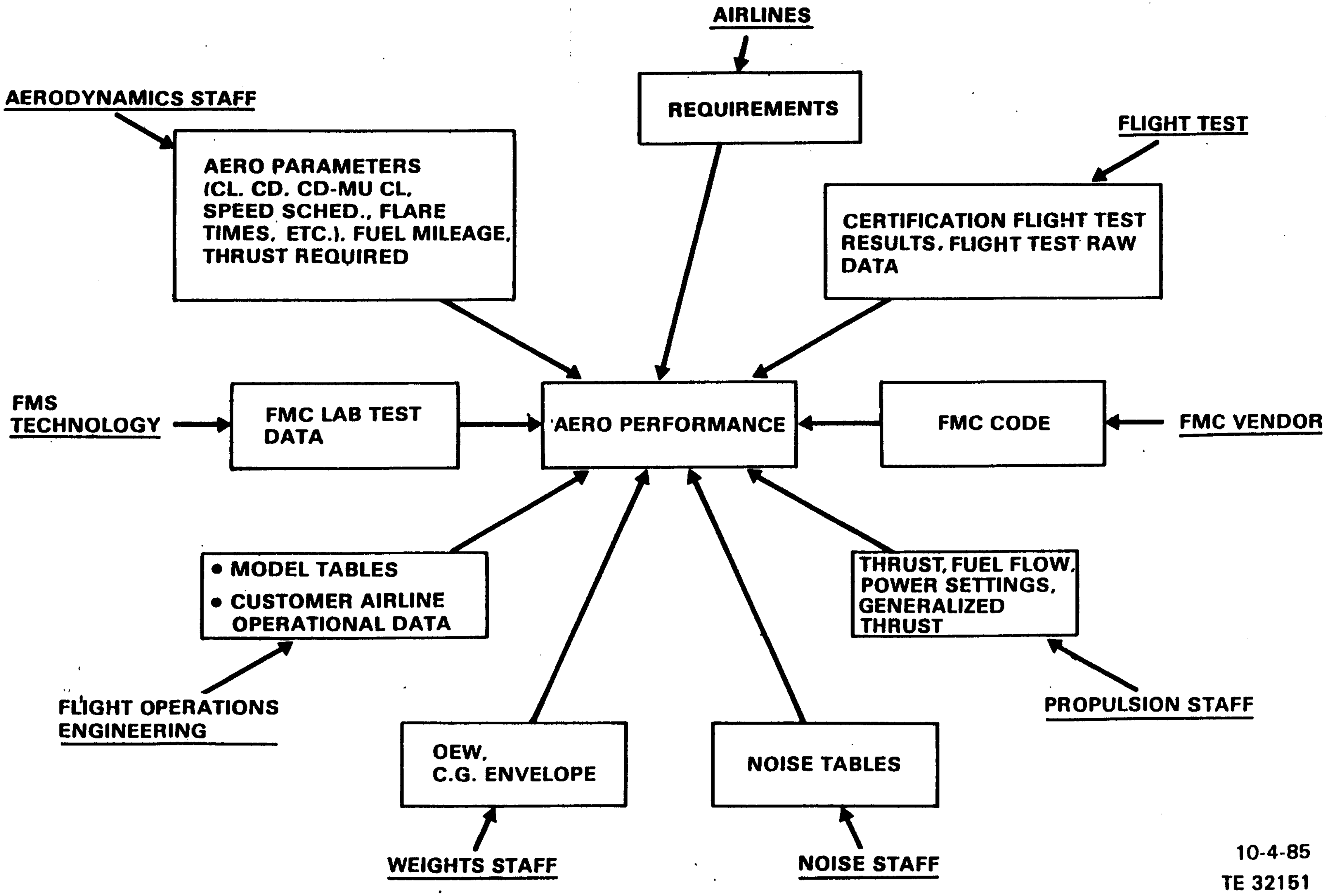
9-11-86
TE 35485

AERO PERFORMANCE ORGANIZATIONAL INTERFACES



10-17-86
TE 32150

DATA FLOW TO AERO PERFORMANCE



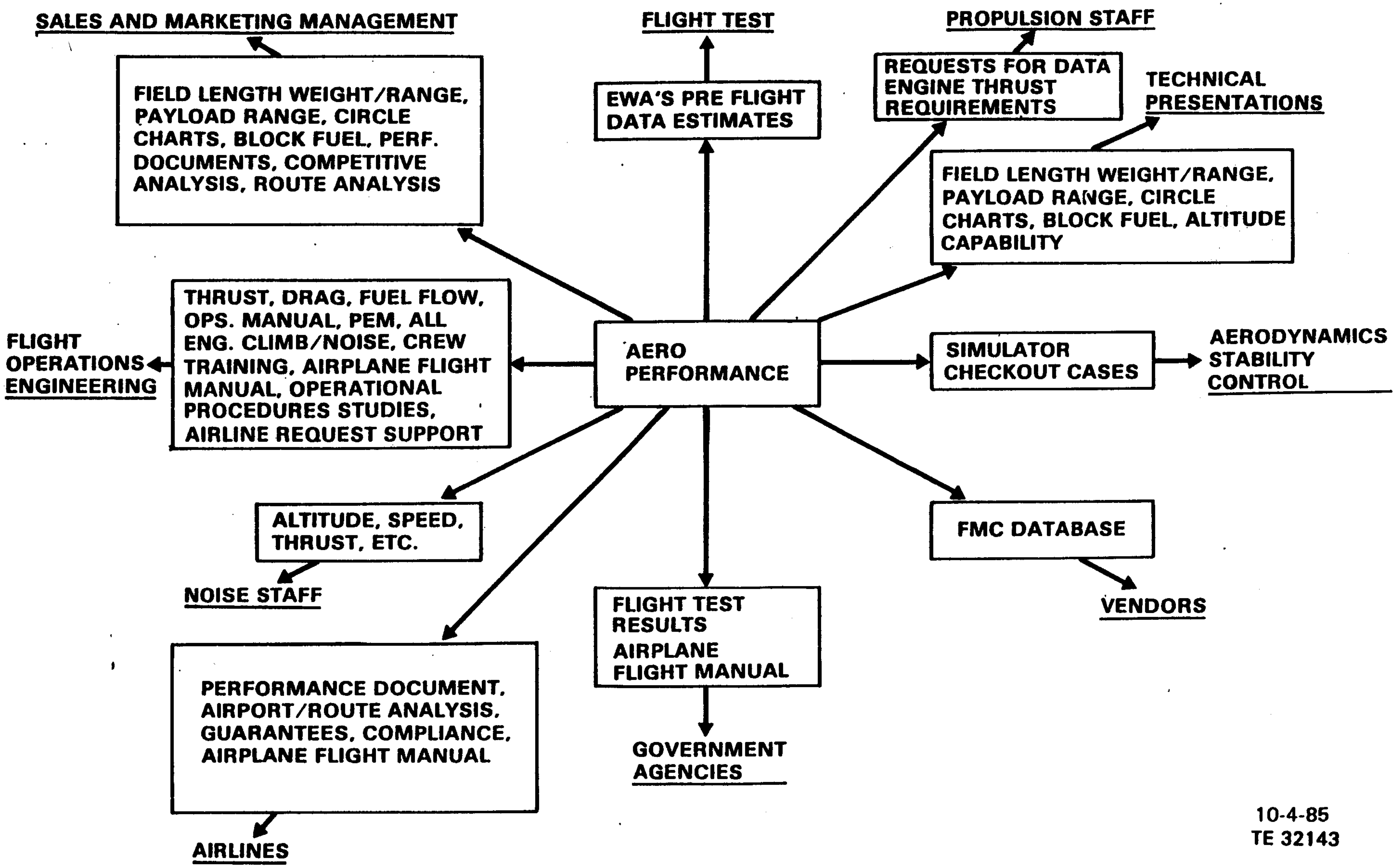
10-4-85
TE 32151

DATA FLOW TO AERO PERFORMANCE

	ORIGINATING ORGANIZATION	DATA DESCRIPTION	METHOD OF DATA FLOW
1.	AERODYNAMICS STAFF (CONFIGURATIONS	o High Speed Drag o Other Aero Parameters C_L, C_D, C_D-MU C_L Speed Schedules, Flare Times, etc.	- EKS File Transfer Plotted and Tabulated Data
2.	FLIGHT TEST	o Flight Test Data "Last Tapes" Time Histories	- Magnetic Tape and EKS File Transfer - Computer Print Out
3.	FMC VENDOR	o FMC Source Code	- Microfiche
4.	PROPULSION STAFF	o Thrust Tables PRIME and YTERP Format o Power Setting Charts o Fuel Flow o Generalized Thrust	- EKS File Transfer - Plotted Data - EKS File Transfer - EKS File Transfer or Plotted Data
5.	NOISE STAFF	o Noise Tables	- EKS File Transfer
6.	WEIGHT STAFF	o OEW'S o C.G. Envelope	- Tabulated Data - Plotted Data
7.	FLIGHT OPERATIONS ENGINEERING	o Model Tables (Open Chart Reader)	- PDP File Transfer
8.	FMS TECHNOLOGY	o FMC Lab Test Data	- EKS File Transfer and Hand Written Data

JH:ns
6218w/3

DATA FLOW FROM AERO PERFORMANCE



10-4-85
TE 32143

DATA FLOW FROM AERO PERFORMANCE

	DESTINATION ORGANIZATION	DATA DESCRIPTION	METHOD OF DATA FLOW
1.	FLIGHT TEST	o Engineering Work Authorizations (EWA's)	- Hand Typed
2.	PROPULSION STAFF	o Requests for Data	- Coordination Sheet
3.	TECHNICAL PRESENTATIONS	o Brochure Data	
		Field Length vs. Weight	- Hand Plotted
		Field Length vs. Range	- Hand Plotted
		Payload Range	- Hand Plotted
		Circle Charts	- PDP Plotted
		Block Fuel	- Hand Plotted
		Altitude Capability	- Hand Plotted
4.	AERODYNAMICS STABILITY & CONTROL	o Simulator Checkout Cases	- Hand Plotted
5.	VENDORS (SPERRY)	o FMC Data Base	- IBM Cards and EKS File Transfer
6.	GOVERNMENT AGENCIES	o Flight Test Results (Bible)	- Hand Typed & Hand Plotte
		o Airplane Flight Manual	- Auto & Hand Plotted
		o Thrust Reverser Effectiveness	- Hand Typed & Hand Plotte
7.	AIRLINES	o Performance Document	- Auto and Hand Plotted - Magnetic Tape
		o Airport Analysis	- Hand Plotted
		o Route Analysis	- Auto & Hand Plotted
		o Performance Guarantees	- Hand Typed
		o Guarantee Compliance	- Hand Plotted
		o Airplane Flight Manual	- Auto & Hand Plotted

JH:ns
6218w/4

DATA FLOW FROM AERO PERFORMANCE

DESTINATION ORGANIZATION	DATA DESCRIPTION	METHOD OF DATA FLOW
8. NOISE STAFF	o Aero Performance Altitude, Speed Thrust, etc.	- EKS File Transfer - Hand Typed
9. FLIGHT OPERATIONS	o Thrust, Drag, Fuel Flow	- EKS File Transfer
	o Operations Manual Data	- Typed & Hand Plotted
	o Perf. Engineers Manual	- Auto & Hand Plotted
	o All Engine Climb and Noise Document	- Auto & Hand Plotted
	o Flight Crew Training Manual Data	- Hand Plotted
	o Airplane Flight Manual	- Auto & Hand Plotted
10. SALES	o Performance Document	- Auto & Hand Plotted - EKS File Transfer
	o Airport Analysis	- Hand Plotted
	o Route Analysis	- Hand Plotted
11. MARKETING MANAGEMENT	o Brochure Data	
	Field Length vs. Weight	- Hand Plotted
	Field Length vs. Range	- Hand Plotted
	Payload Range	- Hand Plotted
	Circle Charts	- PDP Plotted
	Block Fuel	- Hand Plotted
	Altitude Capability	- Hand Plotted
	o Airport Analysis	- Hand Plotted
	o Route Analysis	- Hand Plotted

JH:ns
6218w/5

AERO PERFORMANCE - TASKS / FUNCTIONS

5.1 PRELIMINARY DESIGN PHASE

1. PRODUCT REQUIREMENTS DEVELOPMENT
   - o Mission Requirements
   - o Performance Requirements/Objectives

2. AIRPLANE DESIGN SELECTION STUDIES
   - o Parametric Studies (Airplane Geometry Comparisons)
   - o Engine Evaluations
     - o Number of Engines
     - o Sizing Studies

3. PRELIMINARY PERFORMANCE ESTIMATES
   - o Configuration Performance Evaluations
   - o Sales Support (Takeoff Performance, Mission Analysis)
   - o Competitive Analysis
     - o Competitive Airplane Database

1f/6132w/3

5.2 CONFIGURATION DEFINITION PHASE

1. AIRPLANE DESIGN SELECTION STUDIES
   - o Parametric Studies
     - o Wing Planform Evaluation
     - o Tail Configuration
   - o Engine Evaluations
     - o Thrust Sizing

2. PRELIMINARY PERFORMANCE ESTIMATES
   - o Configuration Performance Evaluations
   - o Sales Support
     - o Takeoff Performance
     - o Mission Analysis
   - o Competitive Analysis

3. PRELIMINARY PROJECT COORDINATION
   - o Configuration Sizing (Wing Area, Tail Area, etc.)
   - o Preliminary DR&O Inputs

4. PRELIMINARY STAFF COORDINATION
   - o Structures - Fatigue Missions
   - o Propulsion - Thrust Ratings, Engine Spec.
   - o Systems - Performance Requirements/Evaluations
   - o FMS Technology - FMC Development

5.3 PROGRAM GO-AHEAD TO ROLLOUT PHASE

1. FINAL CONFIGURATION DEFINITION
   - o Flap Deflections
   - o System Capabilities

2. DETERMINATION OF GUARANTEED PERFORMANCE
   - o Final Audit Support
   - o Performance Document
   - o Database Development

3. SALES SUPPORT
   - o General Performance Data Packages
   - o Airline Studies (Airport and Route Analysis, etc.)
   - o Performance Guarantees
   - o Competitive Airplane Performance

4. CUSTOMER INTRODUCTION
   - o Airport Analysis
   - o Route Analysis

5. PERFORMANCE STATUS TRACKING
   - o Performance Guarantees
   - o DR&O

6. DETAILED STAFF COORDINATION
   - o Structures - Fatigue Missions
   - o Propulsion - Thrust Ratings
   - o Systems - Performance Evaluations
   - o FMS Technology - FMC Development/FMC Database

7. CERTIFICATION PLANNING
   - o AFM Scheduling
   - o Methodology
   - o Preliminary AFM
   - o Flight Test Specification

5.3 PROGRAM GO-AHEAD TO ROLLOUT PHASE (Continued)

8. PRODUCT DEVELOPMENT SUPPORT
   - Mission Requirements
   - Performance Requirements
   - Parametric Studies
   - Engine Evaluations

9. FLIGHT CREW TRAINING SUPPORT
   - Recommend/Evaluate Procedures
   - Preliminary Performance Data Packages

10. FLIGHT OPERATIONS ENGINEERING SUPPORT
   - Preliminary OPS Manual Data
   - Preliminary Performance Engineers Manual Data

11. SIMULATOR SUPPORT
   - Performance Check Cases

5.4 ROLLOUT TO INITIAL DELIVERY PHASE

1. AIRPLANE FLIGHT PERFORMANCE LEVEL DEVELOPMENT
   - o Performance Databases

2. CERTIFICATION SUPPORT
   - o Data Development to AFM
   - o Certification Flight Test Support
   - o Flight Test Certification Reports
   - o FAA Coordination
   - o Operational Procedures

3. PERFORMANCE GUARANTEE COMPLIANCE
   - o Customer Guarantee Compliance Documents

4. SALES SUPPORT
   - o General Performance Data Packages
   - o Takeoff Analysis
   - o Route Analysis
   - o Performance Guarantees
   - o Competitive Airplane Performance

5. CUSTOMER INTRODUCTION
   - o Airport Analysis
   - o Route Analysis

6. PERFORMANCE STATUS TRACKING
   - o Performance Guarantees
   - o Drag, SFC, Weight Improvement Programs

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5.4 ROLLOUT TO INITIAL DELIVERY PHASE (Continued)

7. PRODUCT DEVELOPMENT SUPPORT
   - Mission Requirements
   - Performance Requirements
   - Parametric Studies
   - Engine Evaluations

8. FLIGHT CREW TRAINING SUPPORT
   - Flight Tested Data Packages

9. FLIGHT OPERATIONS ENGINEERING SUPPORT
   - OPS Manual Data
   - Performance Engineers Manual

10. FMC Database
   - Development and Checkout of Database

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5.5 INSERVICE SUPPORT PHASE

1. PRODUCT IMPROVEMENT PERFORMANCE ESTIMATES
   - Performance Databases

2. FOLLOW ON CERTIFICATION SUPPORT
   - Certification Flight Test Support
   - Certification Reports
   - FAA Coordination
   - New Flight Manuals and Appendices

3. PERFORMANCE GUARANTEE COMPLIANCE
   - Customer Guarantee Compliance Documents

4. SALES SUPPORT
   - General Performance Data Packages
   - Airline Studies (Airport and Route Analysis, etc.)
   - Performance Guarantees
   - Competitive Airplane Performance

5. CUSTOMER INTRODUCTION/SUPPORT
   - Airline Studies
   - Customer Requested Data Packages
   - Airline Problem Resolution

6. PERFORMANCE STATUS TRACKING
   - Performance Guarantee Status
   - Product Improvement Programs

7. PRODUCT DEVELOPMENT SUPPORT
   - Mission Requirements
   - Performance Requirements
   - Parametric Studies
   - Engine Evaluations

CONFIGURATION GROUP

FUNCTION

The configuration group is responsible for the airplane's contour design affecting the performance characteristics of the airplane. The major specialties of this group include the high speed design of the wing characteristics for optimum cruise performance as well as development of the high lift system which determines the airplane's takeoff and landing performance. The group is also responsible for the aerodynamic integration of the engines with the airplane.

Configuration engineers work closely with members of the research and development group to develop important computational fluid dynamic (CFD) analysis tools. These tools are used extensively for the analysis and design of airfoil sections, wings, empennage, body and nacelles. The codes provide information about airflow interactions and attendant forces associated with these items. The CFD codes and both high and low speed wind tunnel facilities are the configuration engineer's primary design tools.

The configuration group must also have a close working relationship with the stability and control group. The pursuit of optimum performance must be closely balanced with the tailoring of the airplane's flight characteristics. Horizontal tail sizing, control surface sizing, stall characteristics, center of gravity envelope, etc., must all be considered as a part of the design process.

The actual type of configuration work done depends on the phase or maturity of an airplane program. New concepts and methods may be explored during the initial phases of a design period. As the design progresses this new technology is verified and refined. This effort may include new approaches to wing design such as increased thickness ratios, high aspect ratio and wing tip devices.

Next the overall configuration of the airplane must be developed. This may involve multiple iterations before the final configuration evolves. The definition of this final configuration, or detail lines release, must be generated so that fabrication of the airplane may begin. Design compromise is often required at this point to ensure that the airplane may be built for a reasonable cost and weight. For example, the aspect ratio of the wing is limited by structural considerations.

During the manufacturing process, time is spent in the factory ensuring that aerodynamic design requirements and tolerances are adhered to. Coordination with the factory solves manufacturing problems which may affect the aerodynamic contours defined in the lines release. When the new airplane is rolled out, it is carefully inspected by the configuration group.

The configuration group is heavily involved in the flight testing and certification of the airplane. Design objectives must be verified and any problems resolved. The pace of activity is intense to ensure on time delivery. Once the airplane enters service customer support activities begin. In service problems which may arise are addressed such as performance short falls or premature buffet.

AERODYNAMIC TECHNOLOGY

CONFIGURATION

Phases of an Airplane Program:

- **Preliminary Design -** Conceptual
- **Product Development -** Technology
- **Configuration Development -** Detail Lines
- **Detailed Design Support -** Project Coordination
Excrescence
- **Manufacturing Support -** Problem Solving
Rejection Tags
- **Certification Support -** Flight Test
- **Customer Support -** Inservice Difficulties
Customer Unique

AERODYNAMIC TECHNOLOGY

CONFIGURATION

Aerodynamics Fields of Interest:

Function	Assigned To:	Technology
Airplane Performance	Performance Aerodynamicist	Aerodynamics
Airplane Configuration Contour Design	Configuration Aerodynamicist	Aerodynamics
Airplane Computational Fluid Dynamics Tool Development	Configuration Aerodynamicist	Aerodynamics
Airplane Performance Characteristics	Configuration Aerodynamicist	Aerodynamics
Airplane Flight Characteristics	Stability & Control Aerodynamicist	Aerodynamics
Component and Surface Loads	Airloads Aerodynamicist	Structures
Propulsion System Internal Airflow	Propulsion Aerodynamicist	Propulsion

AERODYNAMIC TECHNOLOGY

CONFIGURATION

- **Responsible For:**
  - **Outside Shape Design**
  - **Flows About Airplane and Attendant Forces**
  - **Flows Through Airplane and Attendant Forces Except Propulsion**
- **Research Group Supplier of Computational Fluid Dynamics (CFD) Tools**
- **Close Working Relationship With Stability and Control**
- **Type of Work Dictated by Phase / Maturity of Airplane Program**

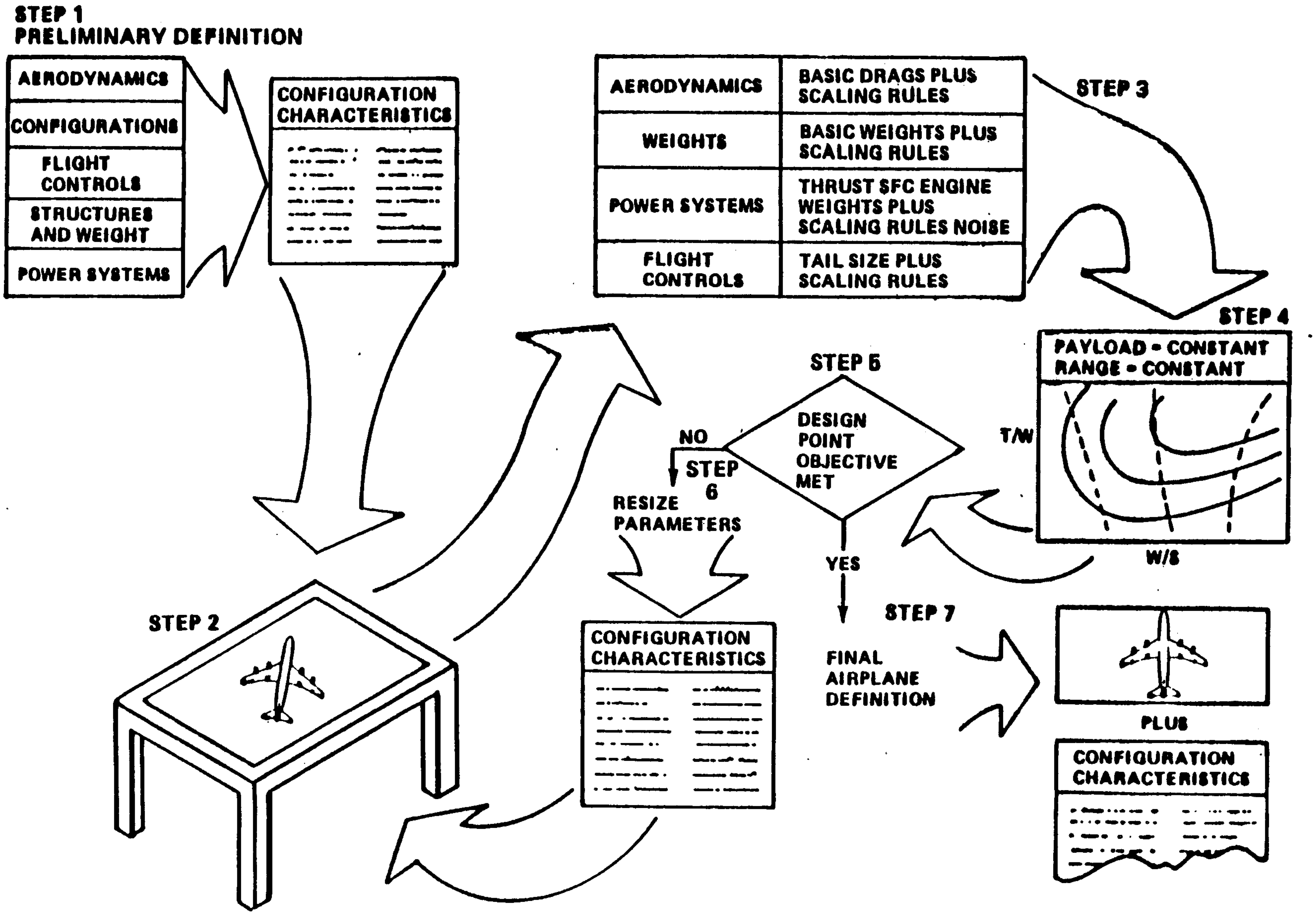
AERODYNAMIC TECHNOLOGY

CONFIGURATION

Configuration Aerodynamics Tool Available:

- **Empiricism / Handbooks**
  - **D6-24229 Drag Prediction For Subsonic Airplanes**
  - **Wind Tunnel / Flight Methods**
  - **Excrescence Drag Methodology**
- **CFD Methods**
- **Wind Tunnels**
  - **Boeing Wind Tunnels**
  - **NASA Wind Tunnels**
  - **Other / Foreign Tunnels**

DESIGN SYNTHESIS PROCESS



AERODYNAMIC TECHNOLOGY

CONFIGURATION

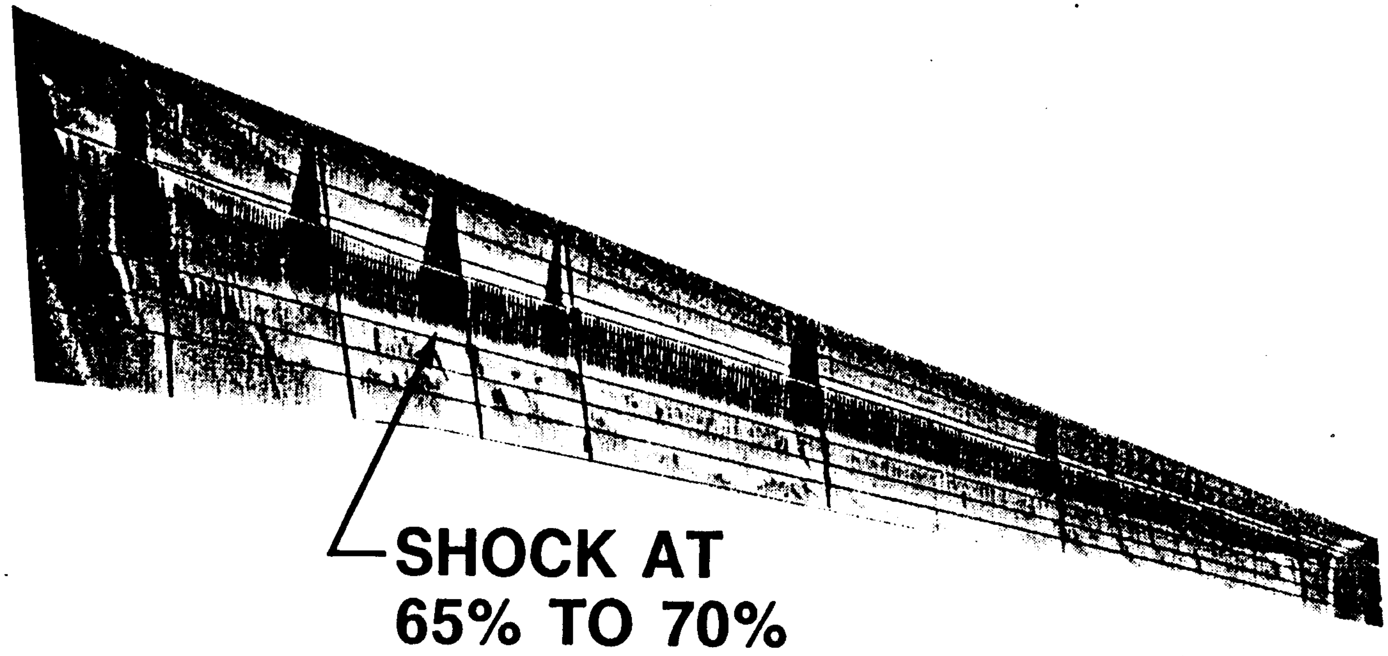
Major Specialties:

High Speed

High Lift

Research

ADVANCED WING TECHNOLOGY: AIRFLOW CHARACTERISTICS



Aerodynamic Technology

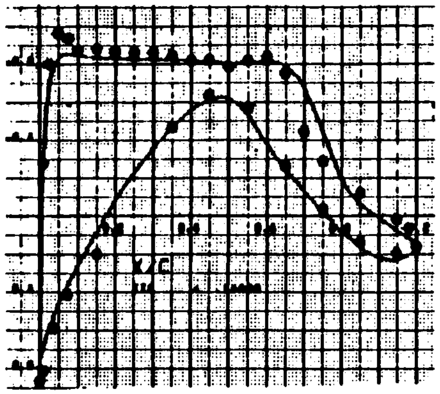
Configuration

Major CFD Codes

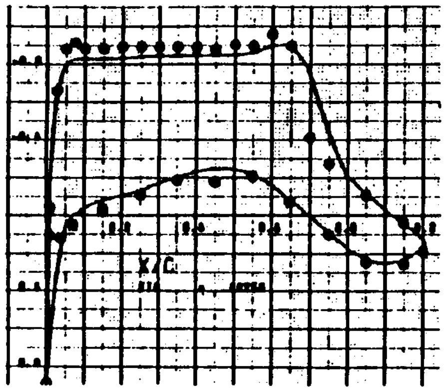
Code	Method	Use
A423	Transonic Full Potential W/Coupled Boundary Layer	2-D Transonic Airfoil Analysis
A585	Transonic Euler W/Coupled Boundary Layer	2-D Transonic Airfoil Analysis and Design
A456	Subsonic Linear W/Coupled Boundary Layer, Separated Wake	2-D High Lift Airfoil Analysis and Design
A449	Subsonic Linear Lifting Surface Inviscid	3-D Wing Body High Lift Analysis
A502	Subsonic/Supersonic Linear Panel Method, Inviscid	General 3-D Configuration Analysis
A488	Transonic Full Potential W/Coupled Boundary Layer	3-D Wing-Body, Wing-Body-Strut-Nacelle Analysis
A555	Transonic Full Potential W/Coupled Boundary Layer	3-D Wing-Body, Wing-Body-Strut-Nacelle Wing Design
A411	Finite Difference Boundary Layer	3-D Boundary Layer For Wings Body, etc.

TEST-THEORY COMPARISON
7J7 WING PRESSURES

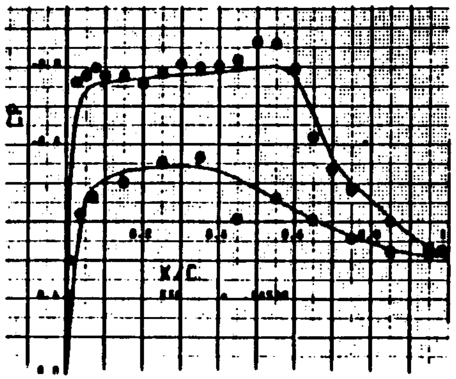
- CRUISE CONDITIONS



SIDE OF BODY

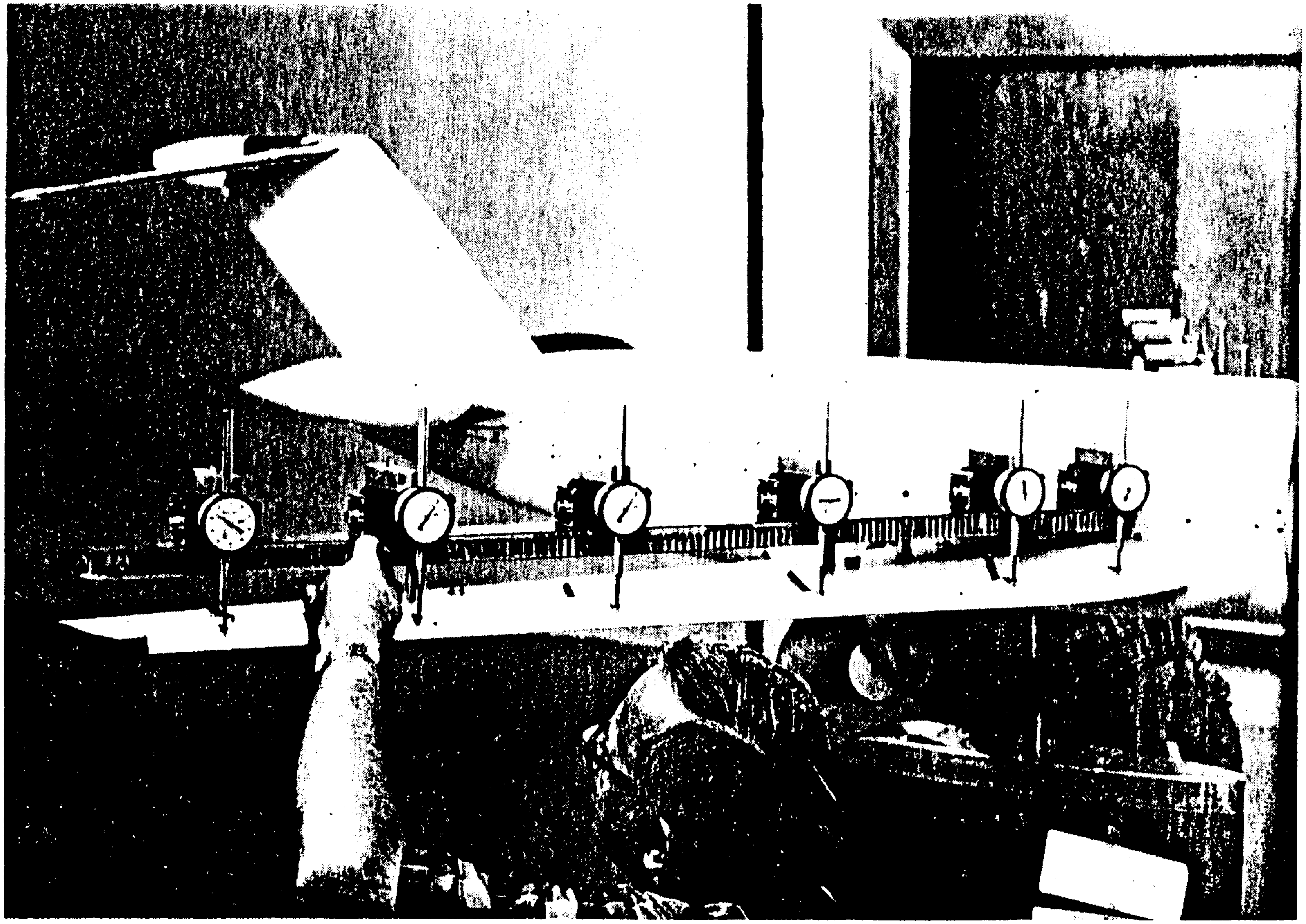


MID-SPAN

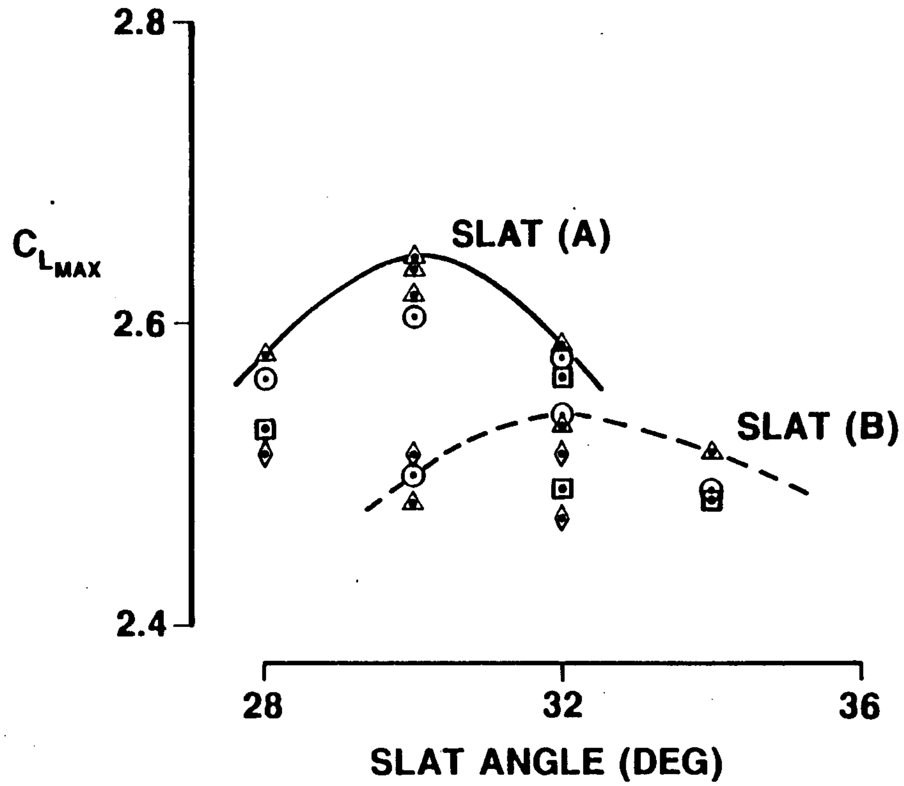


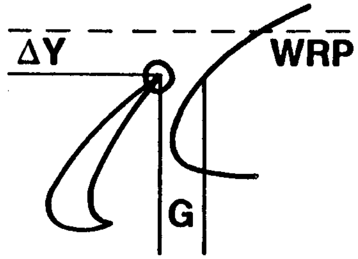
TIP

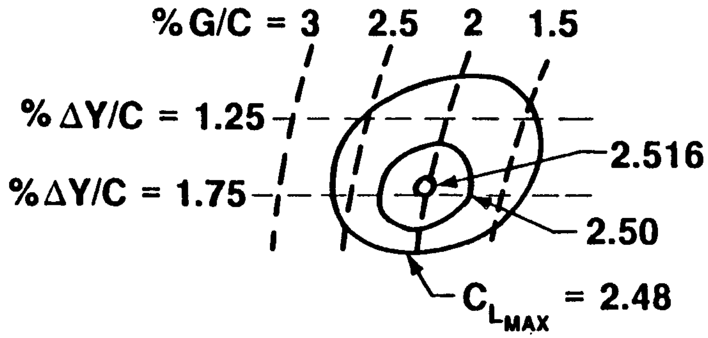
SLAT OPTIMIZATION
MODEL INSTALLATION



SLAT OPTIMIZATION



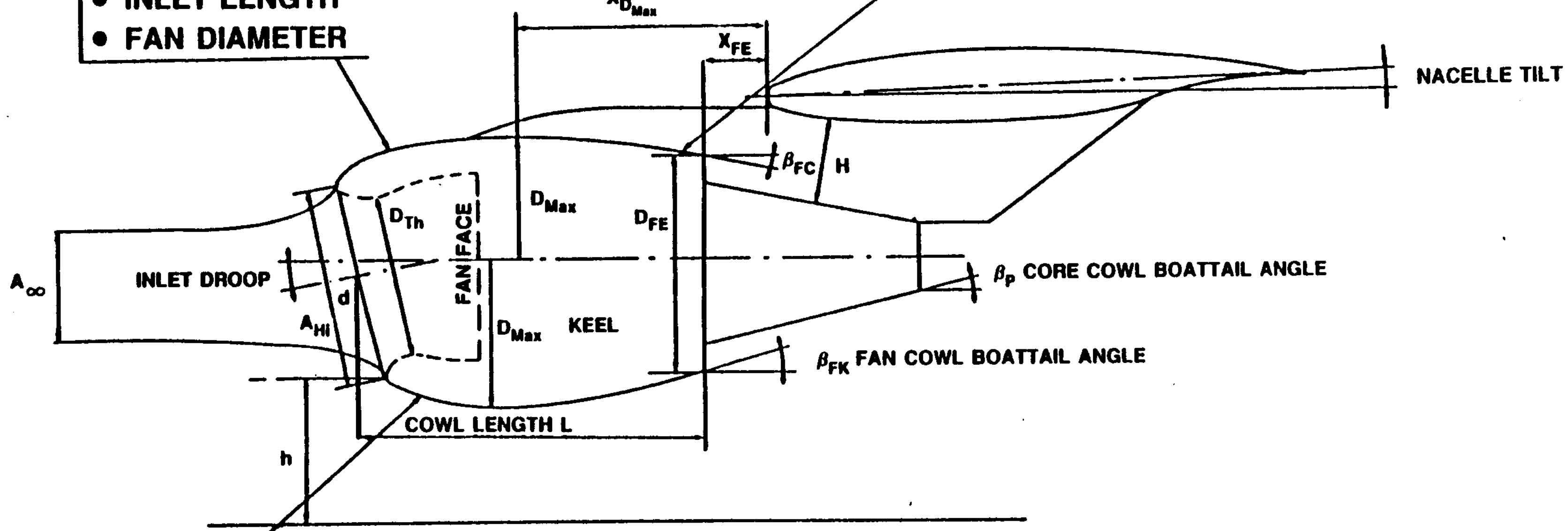




NACELLE DEVELOPMENT:
GEOMETRY

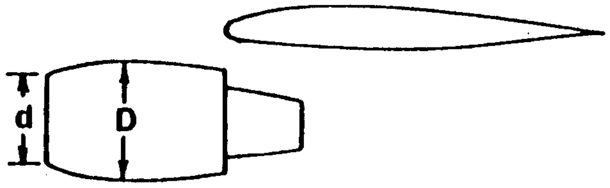
- STRUT/WING INTERSECTION
- D_{Max} LOCATION
- FAN EXIT LOCATION
- FAN EXIT DIAMETER
- FAN DUCT LENGTH

- d/D_{Max} RATIO
- CONTRACTION RATIO A_{Hi}/A_{Th}
- AREA RATIO A/A_{Hi}
- INLET LENGTH
- FAN DIAMETER

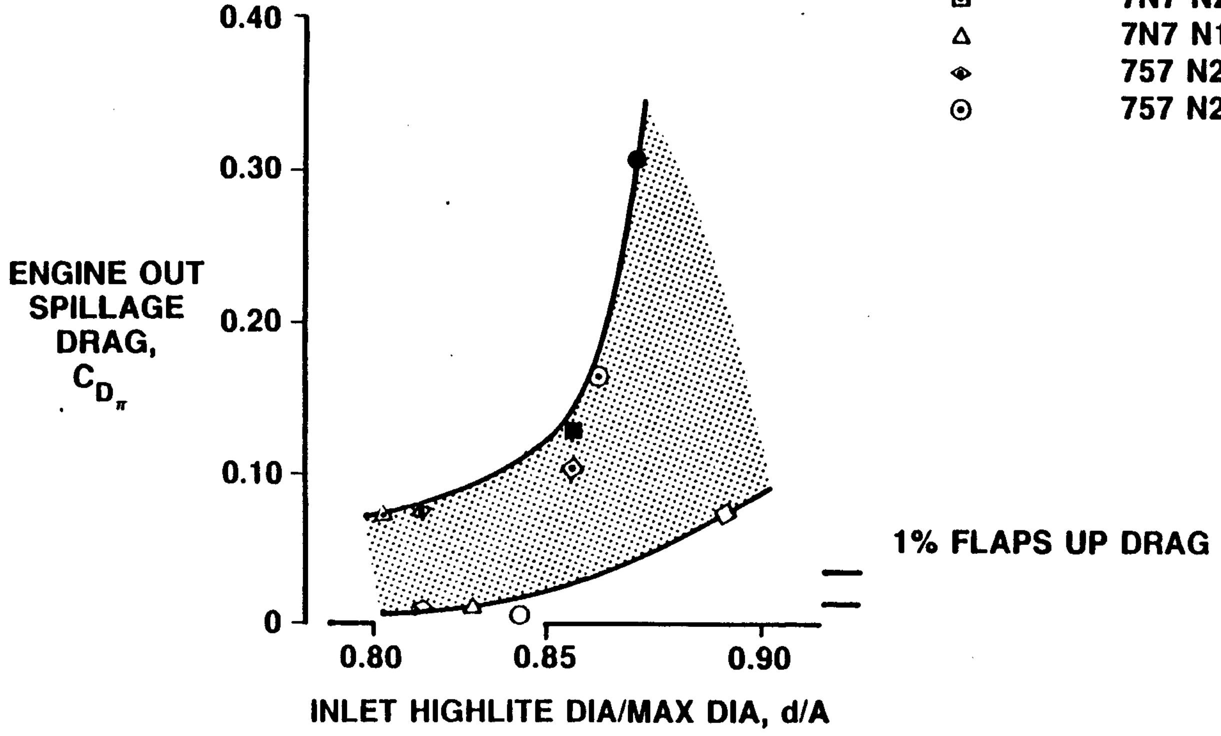


- GROUND CLEARANCE h/d
- GEOMETRIC FINENESS RATIO L/D_{Max}
- ACCESSORY PACKAGE
- NACELLE POSITION, LONGITUDINAL AND VERTICAL

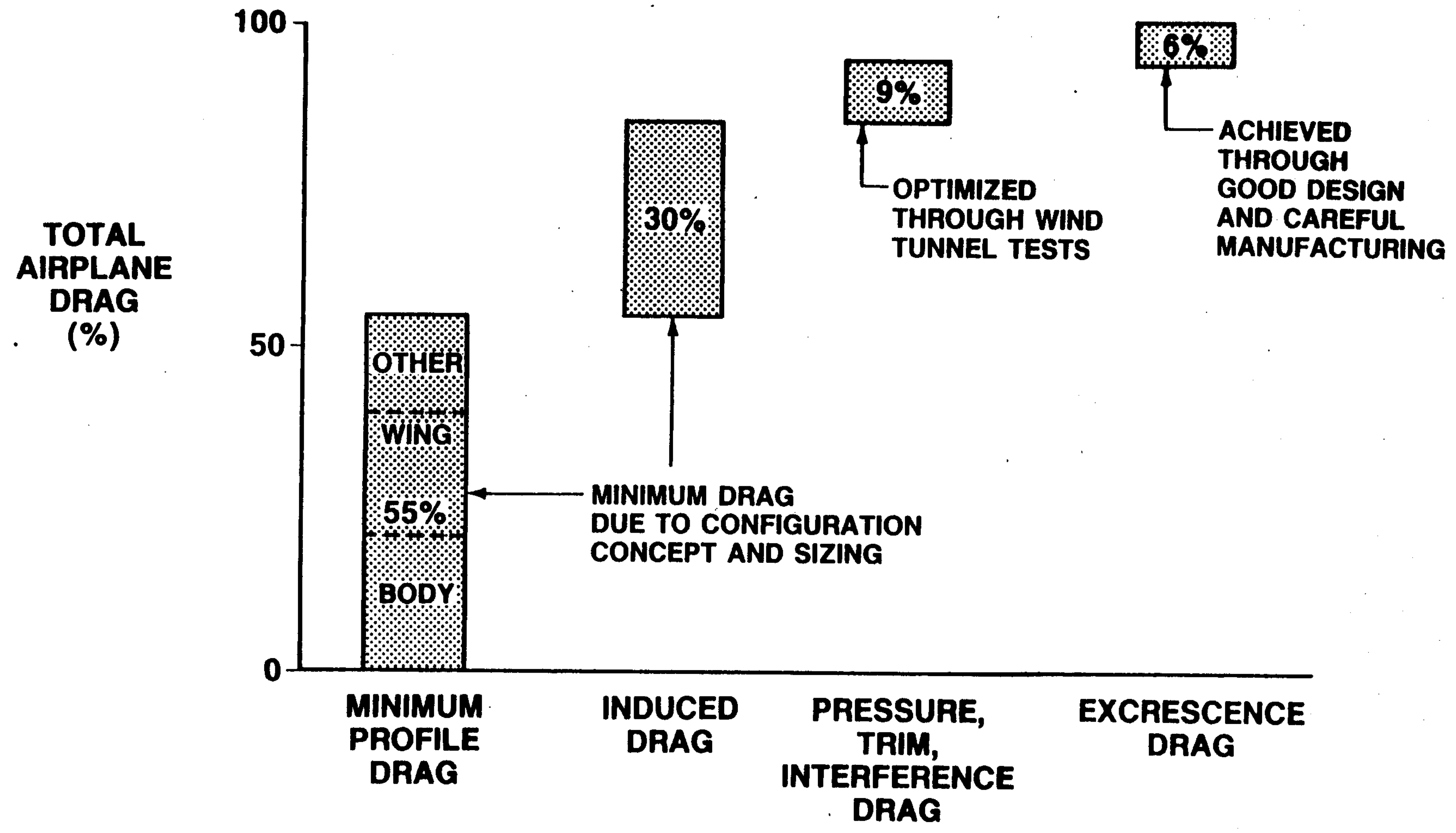
NACELLE DEVELOPMENT:
DIAMETER RATIO SELECTION



SYMBOL	AIRPLANE	DATA SOURCE
■	727-100	FLIGHT TEST
○	737-100	FLIGHT TEST
●	747-100 BID NAC	FLIGHT TEST
▲ (in △)	747-200 CF6-50	FLIGHT TEST
□	747-200 RB211-524	FLIGHT TEST
◇	7N7 N26	BTWT 1573
▣	7N7 N25	BTWT 1573
△	7N7 N14	BTWT 1544
◈	757 N27	BTWT 1645
⊙	757 N28	BTWT 1645

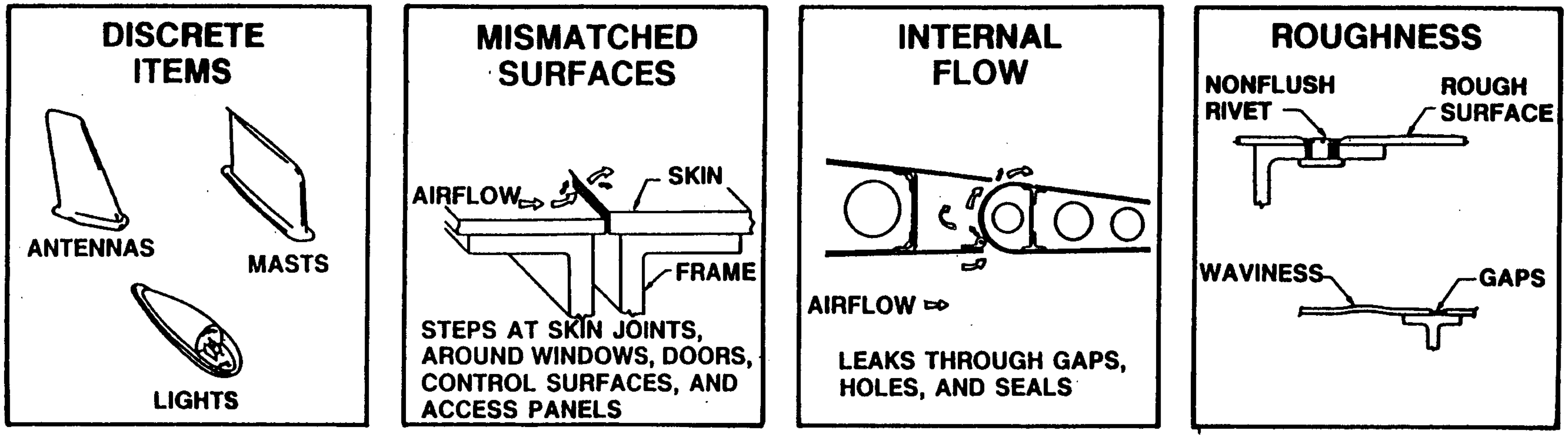


AIRPLANE DRAG DISTRIBUTION
BASED ON 7J7

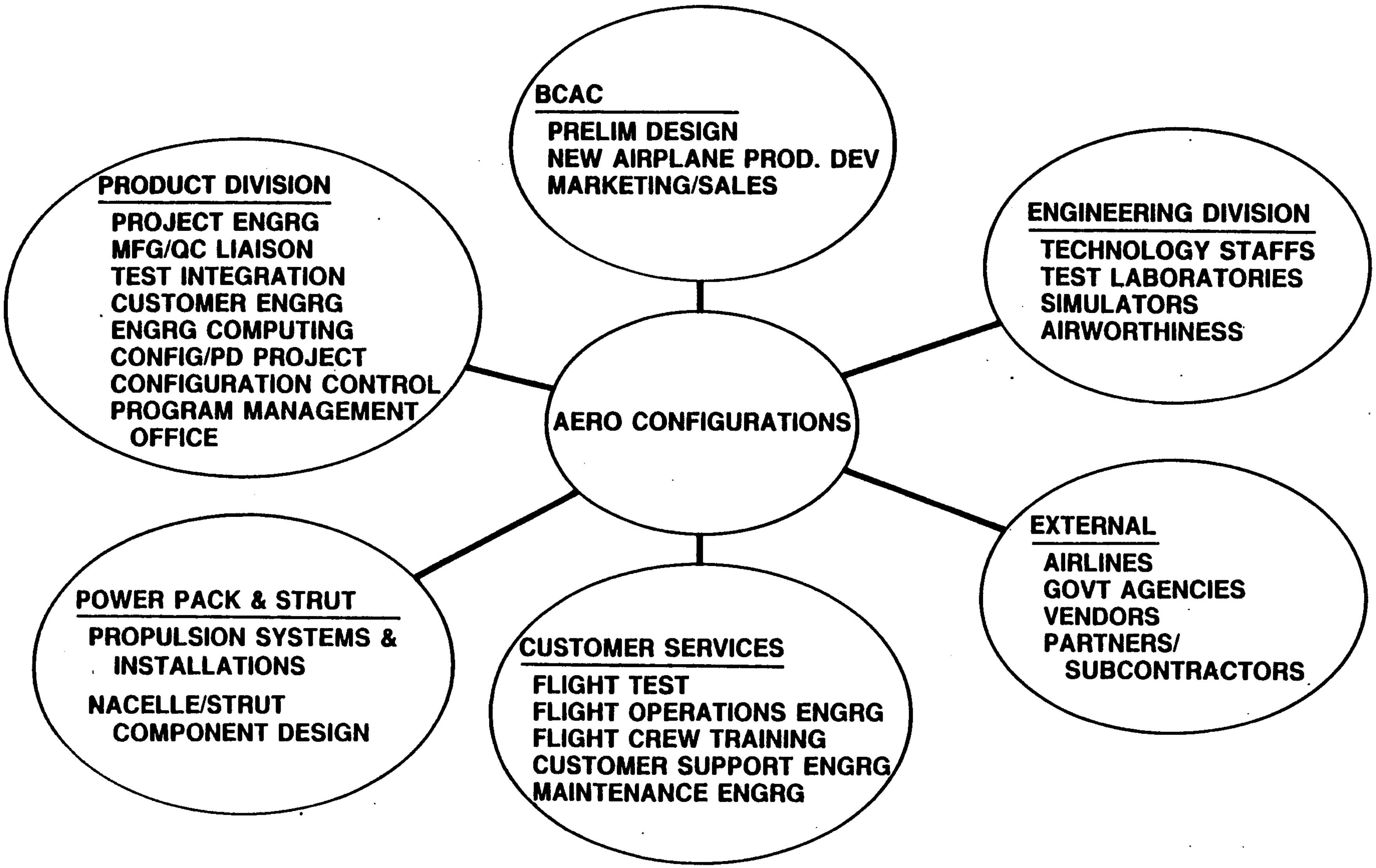


EXCRESCENCE DRAG
BASED ON 7J7

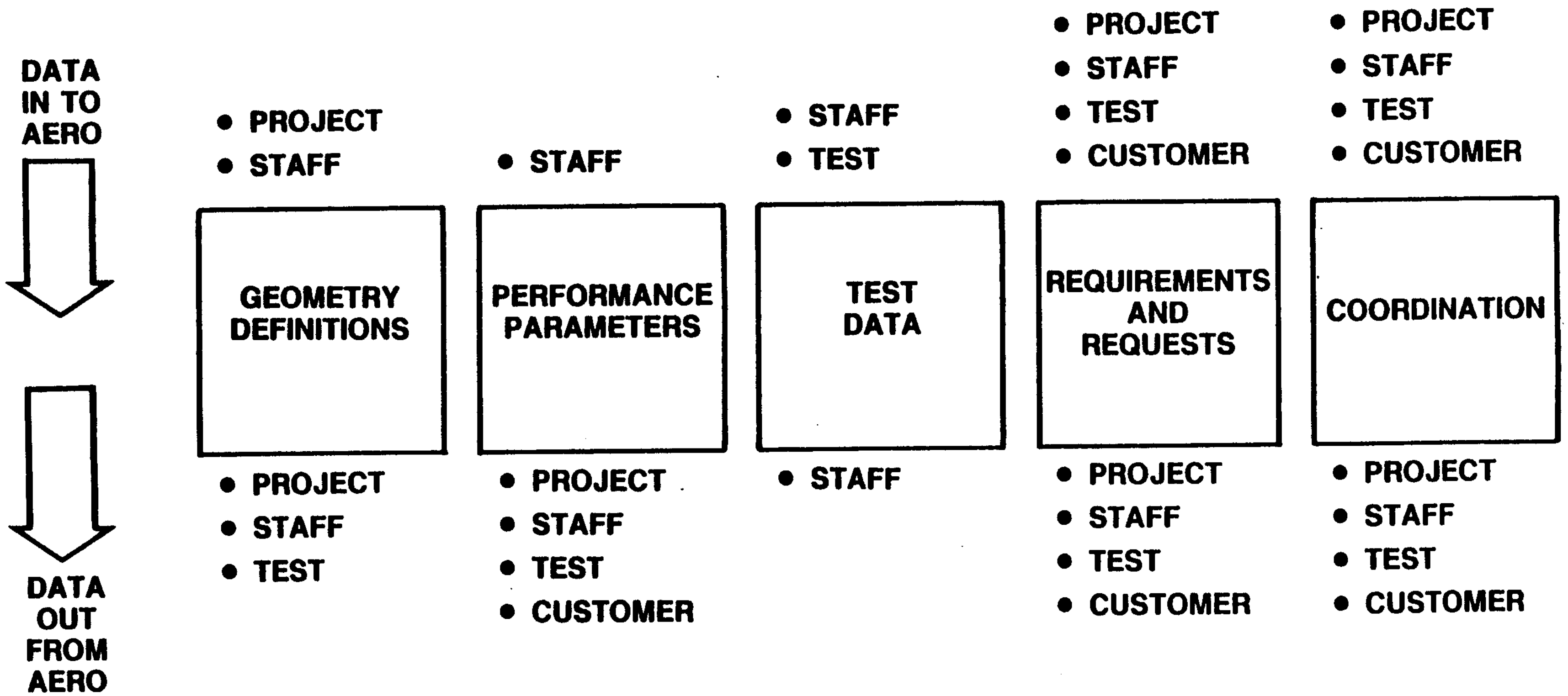
- 5% TO 7% OF TOTAL AIRPLANE DRAG



AERODYNAMICS: CONFIGURATIONS ORGANIZATIONAL INTERFACES



DATA FLOW TO/FROM AERO CONFIGURATION



DATA FLOW TO AERO CONFIGURATION

ORIGINATING ORGANIZATION		DATA DESCRIPTION	METHOD OF DATA FLOWS
1.Configuration/PD Project	o	Preliminary Layouts	Drawings
	o	Configuration Definitions	C/S
	o	Study Definitions	C/S
	o	Trade Study Results	C/S
	o	Extended Geometry of Candidate High Lift Systems	Drawings
2. Project Design Groups Including			
Wing	o	Design Requirements	C/S, Meetings
Body Sections	o	System Requirements	C/S, Meetings
Horizontal	o	Design Reviews	Meetings
Vertical	o	Producibility Requirements	Face to Face, C/S
Fairings	o	Parts Commonality Requirements	C/S
Control Surface	o	MDD Definitions (with Engineering Computing)	EKS File From TX95
Control Systems			
Propulsion System	o	Aero Smoothness Drawings	Drawings ↓
Fuel Systems	o	Detail Design Drawings	↓
Flight Deck	o	Drawings to Implement PRR's	↓
ECS	o	FC's	↓
	o	Manufacturing Coordination	Face to Face
	o	Factory Problem Identification	Telcon
	o	Inspection Reports	Informal Paperwork
3. Engineering Computing	o	MDD Loft Definitions	EKS Files, Drawings
	o	MDD Loft Extractions	EKS Files, Drawings
	o	Definitions of Extended High Lift System and Control Surfaces.	EKS Files, Drawings

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DATA FLOWS TO AERO CONFIGURATIONS (Continued)

ORIGINATING ORGANIZATION	DATA DESCRIPTION	METHOD OF DATA FLOWS
4. Manufacturing/QC/Liaison	o Factory Problem Identification	Informal
Including	o Performance Assessment Requests	Informal
Factory	o Inspection Reports	Informal Paper
Flight Line	o Coordination for Fit/Fair Checks	Face-to-Face
5. Partners/Vendors/ Subcontractors	o Performance Assessment Requests	Letter
6. Test Integration	o Engine/Airplane Certification Plans/Schedules	Drawing
	o EWA Approval System	
	o Cost Estimate Coordination	Formal Paperwork
	o Flight Test Schedules	Informal Paperwork
7. Configuration Control	o PRR's	Formal Paperwork
	o PRR Implementation Dates	↓
8. Program Management Office (PMO)	o Program Directives	Formal Paperwork
	o Implementation Memos	↓
	o Firing Order	↓
9. Propulsion Technology	o Engine Specification	Document
Including	o Engine Manufacters Coordination	Informal
Performance	o Inlet Internal Lines	EKS Files, C/S
Nacelle Aero	o Primary Cowl Lines	EKS Files, C/S
Engine S&C	o Thrust Calibrations/ Techniques (W/T)	Informal Paperwork
Installations		
Fuel Systems	o Thrust Calibrations and Calculation (F/T)	Document
Engine Management		
	o Engine Thrust Tables	Data Files

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DATA FLOWS TO AERO CONFIGURATIONS (Continued)

ORIGINATING ORGANIZATION	DATA DESCRIPTION	METHOD OF DATA FLOWS
9. Propulsion Staff	o Power Setting Curves	Plots
	o Fuel Flow Decks	Data Files, C/S
	o Generalized Thrust	Data Files, C/S
	o Mass Flows	C/S
	o EPR-FPR, N1-FPR	Informal
	o EPR,N1,N2, EGT Relationships	↓
	o Bleed & TCC Switching	↓
	o Windmill Drag	Plot
	o Power Extraction Corrections	↓
	o Production Engine TSFC Tracking	C/S
	o Performance Improvements Packages	C/S
10. Structures Technology Including Loads, Flutter, Stress	o Structural Design Problem Identification	Informal
	o Aeroelastic Deflections	C/S
	o Jig Twist on Wing/Tail	C/S
	o High Lift and Control System Jig Positions	C/S
	o Detailed Loads Model Pressure Data	Data Plots, Data Files
	o Flight Limitations	Formal Paperwork
	o Flap Placards	↓
	o Flight Test Coordination	
11. Weights Technology	o Component Weights	C/S
	o CG Data and Limits	C/S

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DATA FLOWS TO AERO CONFIGURATIONS (Continued)

ORIGINATING ORGANIZATION	DATA DESCRIPTION	METHOD OF DATA FLOWS
12. Airframe Systems Technology Including ECS, Hydraulics and Landing Gear, Electrical Systems	o ECS System Requirements and Data Requests	C/S
	o ECS System W/T Test Coordination	
	o CPCS System Requirements and Data Requests	C/S
	o Engine Bleed Air System Checks on Airplane	Informal
	o System Actuation Times	C/S
	o Reliability/Failure Analysis	C/S
13. Flight Systems Technology Including FMS, Flight Deck, Avionics, EICAS, Primary & Secondary Controls	o ADC Requirements and Data Requests	C/S
	o FMC Requirements and Data Requests	C/S
	o Performance Assessment Requests	C/S
	o Lateral Control System Trim Coordination	Informal
14. Noise	o Performance Evaluation Requests	C/S
	o Limits on Approach Thrust to Meet Noise Certification Requirements	C/S
15. Aero Performance Including Performance, Certification, FMC, Sales Support	o Airplane Performance Data	C/S, Documents
	o Airplane Sizing Study Results	C/S
	o Drag/Weight Trades	C/S
	o Data Requests	C/S, Informal
	o Airline Guarantee Conditions	Formal Documentati

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DATA FLOWS TO AERO CONFIGURATIONS (Continued)

ORIGINATING ORGANIZATION	DATA DESCRIPTION	METHOD OF DATA FLOWS
15. Aero Performance (Cont'd)		
	o Airline Data Requests	Informal
	o Sideletter Guarantee Flight Test Requirements	Formal Documentation
	o Performance Documents	Document
	o Experimental Flight Handbook	Informal Document
	o Coordination with AFM Group	
16. Aero Stability & Control	o Horizontal Tail Sizing	C/S
	o Vertical Tail Sizing	C/S
	o Control Surface Sizing and Definitions	C/S
	o Stabilizer Trim Limits	C/S
	o Stab. Angles to Trim Estimates	C/S
	o Handling Characteristics Assess. High Speed Low Speed	Informal, C/S
	o Estimated Pitching Moments	C/S
	o Minimum Control Speeds	C/S
	o System Requirements Mach/Speed Trim Stick Nudger Slat Gapper Stability Augmentation	C/S
	o Simulator Coordination	C/S
17. Aero Research	o CFD and Lofting Programs	C/S
	o Computer Program Problem Resolution	Informal
	o Consultation Assistance	Informal
	o Coordination with Research Community	C/S
	o Program Documentation	C/S
	o Design Methods	C/S

DATA FLOWS TO AERO CONFIGURATIONS (Continued)

ORIGINATING ORGANIZATION	DATA DESCRIPTION	METHOD OF DATA FLOWS
18. BCS Support(767 Aero)	o Computer Programs	Informal
	o Consultation Assistance	Informal
	o Program Documentation	C/S
19. Wind Tunnel Labs Including	o Design and Construction of Wind Tunnel Models	Drawings
Model and Equipment Design	o Design and Construction of Model Balances	Drawings, C/S
Test Operations	o Force and Moment Test Data	Data Files
Testing Development	o Pressure Data	Data Files
Test Programs	o Flow Visualization Data	Photos
Facilities	o Calibration Data for Thrust/Internal Drag	Informal Paperwork
	o Tunnel Flow Parameters	C/S
	o Recommended Test and Data Acquistion Procedures	C/S
	o Data Reports	Document
	o Test Schedules	Informal Paperwork
	o Coordination with Outside Wind Tunnel Facilities	
20. Flight Test Including	o Design and Installation of Required Instrumentation	Informal Paperwork, Drawings
Analysis		
Operations	o Construction and Installation of Required Parts Defined by FC	Informal Paperwork, Drawings
Instrumentation	o Calibration Data	Informal Paperwork
Pilots	o Provide Required Measurements (Condition Average and/or Time History Data)	Data Files, Tab, Plots
Manufacturing/QC/ Liaison		

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DATA FLOWS TO AERO CONFIGURATIONS (Continued)

ORIGINATING ORGANIZATION	DATA DESCRIPTION	METHOD OF DATA FLOWS
20. Flight Test (Cont'd)	o Pressure Data	Data Files, Plots
	o Flow Visualization Data	Photos, Videotapes, Movie
	o Recommend Test and Data Acquisition Procedures	C/S
	o Data Reports	C/S, Document
	o Test Schedules	Informal Paperwork
	o Coordination with FAA/CAA	Formal Paperwork
	o Coordination at Off-Site Test Locations	
21. FAA/CAA and Other Certification Agencies	o Regulations	Formal Paperwork
	o Flight Test Coordination	
22. Airworthiness	o FAA/CAA etc. Coordination	Formal Paperwork
23. Flight Operations Engineering	o Airline Requests/Coordination	Informal
	o AFM, Operations Manual, and PEM Publications	Formal Documents
	o Airline Performance Audits	Informal
24. Flight Crew Training	o Requirements and Data Requests	C/S
	o Operational Procedures	Formal Document
25. Customer Engineering	o Customer Coordination	C/S, Letter
	o Airline Requests	C/S, Informal
	o Airline Detail Spec.	Document

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DATA FLOWS TO AERO CONFIGURATIONS (Continued)

ORIGINATING ORGANIZATION	DATA DESCRIPTION	METHOD OF DATA FLOWS
26. Customer Support and Maintenance Engineering	o Structural Repair Manual (SRM)	Document
	o Fuel Conservation Thru Maintenance Document	Document
	o Customer Requests	Informal
27. Airline Customers	o Performance Demonstration Requirements	Formal Paperwork
	o Data Requests	Letter, Informal

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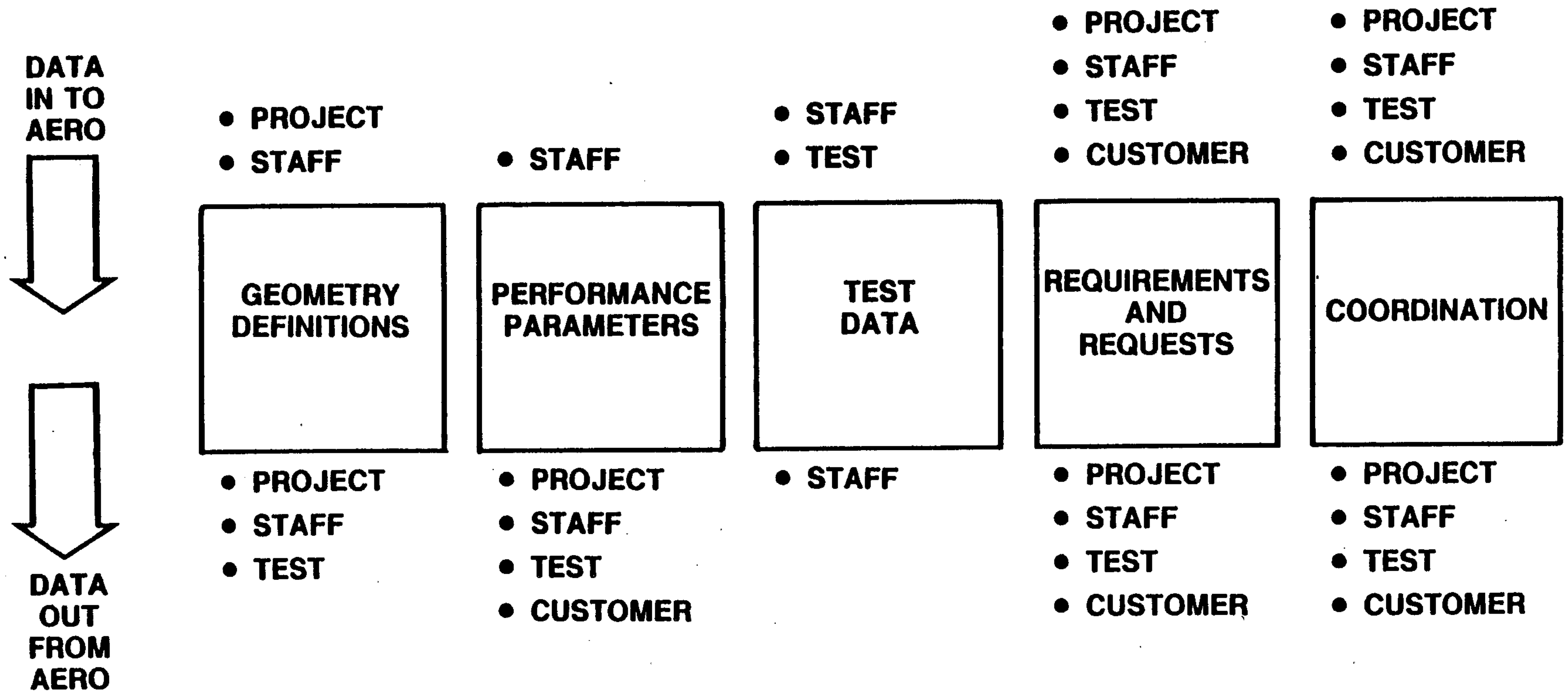
DATA FLOW TO/FROM AERO CONFIGURATION



DATA FLOW FROM AERO CONFIGURATION

DESTINATION ORGANIZATION	DATA DESCRIPTION	METHOD OF DATA FLOWS
1. Configuration/PD Project	o Geometry Requirements and Definitions o Cruise Configuration o High Lift System Including Kinematic Variables	C/S, Informal
	o Preliminary Aero Lofts	C/S, Data Files, Plots
	o Performance Assessments (Drag, Stall Speeds, Etc.)	C/S
2. Project Design Groups Including Wing Body Sections Horizontal Vertical Fairings Control Surfaces Control Systems Propulsion Systems Fuel Systems Flight Deck ECS	o Cruise Configuration Geometry Requirements and Definition	C/S
	o High Lift and Control System o Extended Geometry Requirements and Tolerances o Redundancy/Failure Requirements o Rigging, Drive, and Control System Tolerances o System Failure Detection and Annunciation o System Actuation Times	C/S
	o Aero Lofts (Cruise Configuration & Flaps)	Data Files, C/S, Plots
	o Performance Assessments	C/S
	o Excrescence Drag Presentation	Pitch, Videotape
	o DR&O Smoothness Section	C/S
	o Airspeed Calibration	C/S
	o Fuel Flow Meter Calibrations	C/S
	o Alpha Vane Calibrations and Limits	C/S
3. Engineering Computing	o Aero Lofts	Data Files, Plots
	o Requests for MDD Loft Extractions	Informal Paperwork
	o Requests for Kinematic Math Models and Combined MDD Extractions	Informal Paperwork

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DATA FLOWS FROM AERO CONFIGURATIONS (Continued)

DESTINATION ORGANIZATION	DATA DESCRIPTION	METHOD OF DATA FLOWS
4. Manufacturing/QC/ Liaison Including Factory Flight Line	o Performance Assessments	Informal
	o Excrescence Drag Presentation	Pitch, Videotape
	o Problem Resolution Assistance	Informal, C/S
5. Partners/Vendors/ Subcontractors	o Performance Assessments	Informal Letter
	o Excrescence Drag Presentation	Pitch, Videotape
6. Test Integration	o OPTP's	C/S
	o EWA's	Formal Paperwork
	o Manpower/Facility Estimates	C/S
7. Configuration Control	o Implementation Requirements	C/S
8. Program Management Office (PMO)	o Recommendations	C/S
9. Propulsion Technology Including Performance Nacelle Aero Engine Stab & Cont. Installations Fuel Systems Engine Management	o External Fan Cowl And Inlet Lines	Data Files, C/S
	o Strut Geometry	↓
	o Engine Location Performance Trades	C/S
	o Inlet Operational Limits	C/S
	o APU Inlet Design	C/S
	o Performance Assessments	C/S, Informal
	o Pressure Data	C/S
	o Wing Tip Fuel Vent Inlet Design Coordination	C/S
	o Engine Performance Data From Aero Flight Tests	Data Files
	o Cockpit Fuel Flowmeter Calibrations	C/S
	o Joint Wind Tunnel Test Coordination	
	o Joint Flight Test Coordination	

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DATA FLOWS FROM AERO CONFIGURATIONS (Continued)

DESTINATION ORGANIZATION	DATA DESCRIPTION	METHOD OF DATA FLOWS
10. Structures Technology	o Airplane Geometry	C/S, Data Files
Including	o Wind Tunnel Model Definitions	C/S, Data Files
Loads	o Aero Lofts	C/S, Data Files
Flutter	o Preliminary Loads	C/S
Stress	o Pressure Data	C/S
	o Wing Span Loads Estimates	C/S
	o Flap Load Estimates	C/S
	o Aero Performance (Drag, Stall Speeds, Initial Buffet, $C_{L_{MAX}}$)	C/S
	o Flaps Design Requirements	C/S
	o Recommended Flap Placard Speeds	C/S
	o Estimated Cavity Pressures	C/S
	o Flight Test Cavity Pressures Measurements	C/S
	o Joint Wind Tunnel Test Coordination	
	o Joint Flight Test Coordination	
	o Joint Airplane Structural Problem Resolution	C/S
11. Weight Technology	o Aero Lofts	C/S, Data Files
	o Airplane Geometry	C/S
12. Airframe Systems	o ECS Inlet Recovery Estimates	C/S
Including	o Joint Wind Tunnel Tests to Support ECS Design	
ECS		
Hydraulics and Landing Gear	o Performance Assessments and Trade Data	C/S
Electrical Systems	o Fuselage Pressure Data	C/S
	o Reliability Requirements and Allowables	C/S
	o System Actuation Time Requirements (Gear, Flaps, Slats)	C/S

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DATA FLOWS FROM AERO CONFIGURATIONS (Continued)

DESTINATION ORGANIZATION	DATA DESCRIPTION	METHOD OF DATA FLOWS
13. Flight Systems Technology Including	o Estimated Airspeed Calibration Data	C/S
FMS	o Static Port Locations	C/S
Flight Deck	o SSEC Correction From Flight Test Data	C/S
Avionics	o Descent Flight Tests for T-D Corrections	
EICAS	o Alpha Vane Calibration	C/S
Primary & Secondary Controls	o Stick Shaker Vane Angle	C/S
	o EICAS Fuel Flow Calibration	C/S
	o EICAS Message Requirements	C/S
	o Reliability & Accuracy Requirements	C/S
	o Flight Speeds and Limitations	C/S
	o Airplane Performance	C/S
14. Noise	o Cab Geometry	C/S
	o Flight Test Support	
	o Takeoff & Approach Attitudes	C/S
	o Takeoff & Approach L/D	C/S
15. Aero Performance Including	o Cruise Performance Aero Parameter Estimates	C/S
Performance	o Drag Polars	C/S, Data Files, Informal Paperwor
Certification		
FMC	o Initial Buffet	C/S
Sales Support	o $C_{L_{MAX}}$	C/S
	o Lift Curves	C/S
	o Trim Drag	C/S
	o Reynolds Number Corrections	C/S
	o Flaps Down Aero Parameter Estimates	
	o Drag Polars	C/S
	o Yaw Drag	C/S
	o Stall Speeds	C/S
	o Initial Buffet	C/S
	o $C_{L_{MAX}}$	C/S

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DATA FLOWS FROM AERO CONFIGURATIONS (Continued)

DESTINATION ORGANIZATION	DATA DESCRIPTION	METHOD OF DATA FLOWS
15. Aero Performance (Cont'd)		
	o Lift Curves	C/S
	o Body Contact Margins	C/S
	o Speed Schedules	C/S
	o Ground Roll Parameters	C/S
	o Flare Times	C/S
	o Ice Drag	C/S
	o Estimated Aero Parameters for Abnormal Configurations	C/S
	o Extracted Flight Test Cruise Aero Performance Parameters	
	o Fuel Mileage	C/S
	o Drag Polars	C/S, Data Files
	o Initial Buffet	C/S
	o Max. Demonstrated Lift	C/S
	o Lift Curves	C/S
	o Trim Drag	C/S
	o Reynolds Number Corrections	C/S
	o All Engine Climb Performance Substantiation	C/S
	o Descent Performance Substantiation	C/S
	o Descent T-D Tables	C/S, Data Files
	o Taxi Fuel Flow	C/S
	o Extracted Flight Test Flaps Down Aero Performance Parameters	
	o Engine Out Check Climb Performance	C/S
	o Drag Polars	C/S
	o Yaw Drag	C/S
	o Stall Speeds	C/S
	o Initial Buffet	C/S
	o $C_{L_{MAX}}$	C/S
	o Lift Curves	C/S
	o Body Contact Margins	C/S
	o Speed Schedules	C/S

DATA FLOWS FROM AERO CONFIGURATIONS (Continued)

DESTINATION ORGANIZATION	DATA DESCRIPTION	METHOD OF DATA FLOWS
15. Aero Performance (Cont'd)	o Ground Roll Parameters	C/S
	o Flare Times	C/S
	o Ice Drag	C/S
	o Extracted Flight Test Aero Parameters for Abnormal Configurations	C/S
	o Cruise Performance Substantiation	Document
	o Cruise Performanace Methods	Document
	o Sideletter Guarantee Compliance Flight Testing, Analysis, and Documentation	Document
	o Competitive Airplane Performance Assessments	C/S
	o Cruise Performance Parameters	
	o Flaps Down Performance Parameters	
	o Airline Presentation Material	C/S
16. Aero Stability and Control	o Airplane Geometry Definitions	C/S
	o Aero Performance Parameters(Estimated and Flight Test Extracted)	C/S
	o Drag Polars (Flaps Up & Down)	
	o Takeoff and Landing Parameters	
	o Initial Buffet Boundaries	
	o $C_{L_{STALL}}$	
	o $C_{L_{MAX}}$	
	o Takeoff Speed Schedules	
	o Ground Effect Data	
	o Engineering and Crew Training Simulator Aero Data Parameters (Estimated and Flight Test Extracted)	C/S, Data F
	o Drag Polars	
	o Lift Curves	
	o $C_{L_{STALL}}$	
	o $C_{L_{MAX}}$	
	o $C_{L_{STICK\ SHAKER}}$	
	o Airplane Math Model Requirements	

DATA FLOWS FROM AERO CONFIGURATIONS (Continued)

DESTINATION ORGANIZATION	DATA DESCRIPTION	METHOD OF DATA FLOWS
16. Aero Stability and Control (Cont'd)	o Simulator Model Checkout and Proof of Match	C/S
	o Configuration Development of Control Surfaces (Joint) o Inflight and Ground Speed Brakes o Aileron Droop o Tailoring for Minimum Engine-Out Drag o Effect of Stab/Elevator Rigging and Gearing on Performance	C/S
	o Configuration Development for Handling Characteristics/Performance (Joint) o Cruise Wing Design o VG's, Fences, Etc. o L.E. Flap Geometry and Spanwise Tailoring o Horizontal Tail Location	C/S
	o Secondary Flight Controls Reliability, Failure, and Redundancy Requirements (Joint)	C/S
	o Joint Wind Tunnel Test Coordination	
	o Joint Flight Test Coordination	
17. Aero Research	o Computer Program Problem Identification	C/S, Telcon
	o New Code/Modified Code Requirements	C/S
	o Code Output Comparisons with Test Data	C/S
	o Joint Wind Tunnel Tests	
18. Aero BCS Support	o Software Requests	C/S, Informal Paperwor

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DATA FLOWS FROM AERO CONFIGURATIONS (Continued)

DESTINATION ORGANIZATION	DATA DESCRIPTION	METHOD OF DATA FLOWS
19. Wind Tunnel Labs	o Instrumentation Requirements	EWA, Informal Paperwor
Including	o Test Requirements	
Model & Equipment	o Model Parts Definitions	STR's, Drawings, GCS F
Design	o Data Reduction Requirements	STR's
Test Operations	o Data Accuracy Requirements	STR's
Testing Development	o Planning and Direction of Tests	Informal
Test Programs	o Post Test Critique	Meetings
Facilities		
20. Flight Test	o Instrumentation Requirements	EWA, Informal Paperwor
Including	o Test Requirements	
Analysis	o Data Reduction Requirements	
Operations	o Data Accuracy Requirements	
Instrumentation	o Parts Definitions Requirements	
Pilots	o Planning and Direction of Tests	Informal
Manufacturing/QC/	o Data Correction Curves	C/S
Liaison	o Assistance in Writing Flight Test Spec.	C/S
21. FAA/CAA and Other Certification Agencies	o Data Analysis Reports for FTCR (Bible)	Formal Paperwork
22. Airworthiness	o Certification Data	C/S
23. Flight Operations Engineering	o Response to Airline Questions/Problems	C/S, Informal
	o Performance Audit Analyses	C/S, Informal
	o Plans/Schedules for Airplane/Engine Product Development Programs	C/S, Informal

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DATA FLOWS FROM AERO CONFIGURATIONS (Continued)

DESTINATION ORGANIZATION	DATA DESCRIPTION	METHOD OF DATA FLOWS
24. Flight Crew Training	o Recommended Operational Procedures	C/S
	o Performance Analysis	C/S
25. Customer Engineering	o Airline Spec. Inputs	C/S, Informal
	o Response to Customer Questions/Performance Assessments	C/S
	o Documentation for Transmittal to Customer	C/S
26. Customer Support and Maintenance Engineering	o Responses to Customer Questions/Performance Assessments	C/S, Informal
	o Structural Repair Manual (SRM) Assistance	C/S
	o Fuel Conservation Thru Maintenance Publication Assistance	C/S
	o Allowable Damage Recommendations	C/S
27. Airline Customers	o Response to Questions/Performance Assessments	Telcon, Letter
	o Conduct Performance Demonstrations	
	o Flight Test Demonstration Data Analysis and Documentation	Document, Letter
	o Assistance for Airline Performance Audits	Letter

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AERO CONFIGURATION - TASKS / FUNCTIONS

5.1 PRELIMINARY DESIGN PHASE

1. PRODUCT REQUIREMENTS DEVELOPMENT
   - Mission Requirements
   - Performance Reqmts/Objectives
   - Parametric Studies Support

   } Numerous Configurations Evaluated

2. TECHNOLOGY DEVELOPMENT
   - Cruise Wing
   - Flap System
   - Engine Size/Location
   - Cowl Design/Integration
   - Empennage

   } Accumulation of Available Test Data, Analytical Programs, and Limited Wind Tunnel Testing

3. PRELIMINARY GEOMETRY DEFINITIONS
   - Layout Support
   - Preliminary Lofts

4. PRELIMINARY PERFORMANCE ESTIMATES (HANDBOOK METHODS)
   - Cruise Drag/M_{CRIT}, Etc.
   - L/S Drag, $C_{L\ STALL}$, Takeoff Speed Sched, Etc.

5. PLANNING FOR WIND TUNNEL TEST PROGRAM
   - Review Previous Development Programs
   - Testing Requirements/Plans

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AERO CONFIGURATION TASKS/FUNCTIONS

5.2 CONFIGURATION DEFINITION PHASE

1. MAJOR ITEM DETAIL AERO DESIGN/REFINEMENT
   - o Cruise Wing
   - o L.E. & T.E. Flap
   - o Eng/Cowling/Strut
   - o Empennage/Aft Body
   - o Fairings
   - o Cab

   } Multiple Recycles Based on CFD Analysis, W/T Data Analysis, Project/Staff Coord., New Requirements, Etc.

2. PRELIMINARY PROJECT COORDINATION
   - o Geometry Requirements
   - o Loft Definitions
   - o Manufacturing Constraints/Trades
   - o Project Drawing Support
   - o Preliminary DR&O Inputs

3. WIND TUNNEL TEST PROGRAM (MULTIPLE ENTRIES H/S & L/S)
   - o EWA'S Written
   - o Parts Definitions to W/T Model Design
   - o Test Coordination/Planning/Conduct
   - o Data Reduction/Analysis
   - o Test Reports

4. DETAILED PERFORMANCE ESTIMATES
   - o Apply Wind Tunnel Test Data to Data Base
     - o Drag Polars (H/S & L/S)
     - o $C_{L\ MAX}$, $C_{L\ STALL}$, Initial Buffet, Attitudes, Etc.
   - o Mini-Audit Performance Support

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5. PRELIMINARY STAFF COORDINATION
   - o Configuration Development
     - o Structures Staff - Wing, Aft Body, Empennage
     - o Propulsion Staff - Nacelle
     - o Aero Stab. and Control - Wing, Nacelle, Aft Body, Empennage
   - o Aerodynamic Parameter Estimates
     - o Aero Performance - Drag Polars, $C_{L\ STALL}$
     - o Structures Staff - Initial Loads
     - o Propulsion Staff - Nacelle Location
     - o Aero Stab. and Control - Drag Polars, $C_{L\ STALL}$

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5.3 PROGRAM GO-AHEAD TO ROLLOUT PHASE

1. FINAL CONFIGURATION DEFINITION
   - o Aero Loft Conversion to MDD's
   - o MDD Loft Support

2. DETERMINATION OF GUARANTEED PERFORMANCE LEVELS
   - o Preflight Nominal Performance
     - o Polars, $C_{L\ STALL}$, Initial Buffet
     - o Ground Roll Parameters, Speed Schedules, Attitudes, Etc.
   - o Final Audit Support
   - o Sales Support Pitches

3. DETAILED PROJECT CO-ORDINATION
   - o Project Drawing Support & Design Reviews
   - o Systems Support ECS, CPCS, ADC, Stall Warning, Etc.
   - o Loads Support External & Cavity Pressures
   - o W/T Testing to Support Project/Performance Trades & Detail Design Studies
   - o Excrescence Drag Calculations
   - o Miscellaneous L/S Drag & $C_{L\ STALL}$ Increments
   - o Flap Kinematics
   - o Final DR&O Inputs

4. DETAILED STAFF COORDINATION
   - o Aero Performance
     - o Final Estimated Performance Levels
   - o Structures Staff
     - o Aeroelastic Deflections/Jig Shapes
     - o Joint Wind Tunnel Tests
     - o Estimated Cavity and External Pressures
     - o Estimated Performance Levels
   - o Propulsion Staff
     - o Final Lines - Nacelle/Strut/Inlet
     - o Joint Wind Tunnel Tests

- o Airframe Systems
  - o Inlet Design/Recovery Estimates
  - o Joint Wind Tunnel Tests
- o Aero Stability and Control
  - o Joint Wind Tunnel Tests
  - o Final Lines - Wing, Empennage, Aft Body
  - o Handling Characteristics Tailoring
- o Flight Systems
  - o Airspeed System Design Coordination
  - o α_{VANE}, AFDS, FMC, Stall Warning System Design Coordination

5. PERFORMANCE STATUS TRACKING
   - o Final Preflight W/T Tests (Final T&I)
   - o Final Preflight Performance Levels & Risk Assessments
   - o Excrescence Drag Control
   - o Competitive Airplane Assessments
   - o Miscellaneous W/T Tests to Support Flight Program

6. FLIGHT TEST PLANNING
   - o Review Previous Programs
   - o Training/Flight Test Aids
   - o EWA Preparation, FTIR, Etc.
   - o FC Requirement & Definition
   - o Define/Develop Unique Data Reduction Programs

7. FLIGHT CREW TRAINING/OPERATIONS SUPPORT
   - o Recommend/Evaluate Procedures
   - o Aero Data Packages

8. SIMULATORS SUPPORT BASED ON WIND TUNNEL TESTS
   - o Simulator Model Definition
   - o Aero Data Package
   - o Checkout

9. DOCUMENTATION
   - o Development Documents
   - o Preflight Performance Status Documents

AERO CONFIGURATION TASKS/FUNCTIONS

5.4 ROLLOUT TO INITIAL DELIVERY PHASE

1. FLIGHT TEST PROGRAM (MULTIPLE TESTS)
   - o Test Coordination/Planning/Conduct
   - o Data Reduction/Analysis
   - o Reports

2. CONFIGURATION DEVELOPMENT & PROBLEM RESOLUTION
   - o Apply Results From Initial Flight Tests
   - o Staff Coordination
   - o Requirements/Parts Definition To Project/Flight Test
   - o Project Support For Required Design Changes
   - o Systems Support

3. AIRPLANE FLIGHT PERFORMANCE LEVEL DEVELOPMENT
   - o Cruise Fuel Mileage, Drag, TSFC Levels
   - o Climb/Descent Performance
   - o Flaps Down Polars/Yaw Drag
   - o Stall Speeds
   - o Ground Roll Parameters
   - o Braking/Takeoff/Landing Performance
   - o Final Systems Inputs Based on Flight Data
   - o Operational Data Support (OPS/PEM/FMS/BAPDMS)

4. CERTIFICATION SUPPORT
   - o Data Development to AFM
   - o Flight Test Certification Reports
   - o FAA Coordination
   - o Operational Procedures

5. PERFORMANCE GUARANTEE COMPLIANCE SUPPORT
   - o Customer Requested Performance Demonstrations
   - o Sideletter Guarantee Compliance
   - o Data Support To Guarantee Compliance Documents
   - o Guarantee Status Report Support

AERO CONFIGURATION TASKS/FUNCTIONS (Continued)

6. SIMULATOR DATA PACKAGE UPDATES BASED ON FLIGHT TEST
   - o Simulator Model Definition
   - o Aero Data Package
   - o Checkout and Proof Of Match

7. DOCUMENTATION
   - o Flight Test Methods Document
   - o Cruise Performance Substantiation Documents
   - o Miscellaneous Documents Prepared For Customers
   - o Wind Tunnel To Flight Comparisons

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5.5 INSERVICE SUPPORT PHASE

1. PRODUCT IMPROVEMENT
   - Flight Tests
   - Wind Tunnel Tests
   - Project/Staff Coordination
   - Reports

2. CUSTOMER SUPPORT
   - Customer Requested Data Packages
   - Airline Problem Resolution
   - Inservice Performance Tracking/Analysis
   - Miscellaneous Drag Calculations For Airline Purposes
   - Pitches For Sales Support Activities

3. PROJECT SUPPORT
   - Miscellaneous Drag Calculations
   - Project Co-ordination & Tracking Of Configuration Changes

4. FOLLOW-ON CERTIFICATION SUPPORT
   - Conduct Flight Tests
   - Reports

5. MANUFACTURING SUPPORT
   - Fit/Fair Problem Resolution
   - Miscellaneous Drag Calculations

6. ONGOING SIMULATOR UPDATES

STABILITY & CONTROL GROUP

FUNCTION

The stability and control group is responsible for the handling characteristics of the airplane. This includes defining control requirements and the definition of the airplane's static and dynamic stability. This group's efforts ensures that the airplane flying qualities (how the pilot flies the airplane) are acceptable.

Stability and Control (S&C) engineers work closely with members of the configuration group during the preliminary design phases of an airplane. The S&C engineer must determine the proper sizing of the horizontal and vertical empennage as well as the sizing of the elevator, rudder, aileron and spoiler control surfaces. Empennage sizing determines the airplane's stability and control levels. Control surfaces are sized to ensure adequate control authority for normal maneuvers (e.g. takeoff rotation) and for system failures or unusual flight situations.

The location of the wing and landing gear is affected by S&C considerations. Wing placement is determined by airplane loadability, forward c.g. control and aft c.g. stability considerations. The placement of the landing gear is a compromise between aft c.g. ground handling and forward c.g. takeoff rotation considerations. Thus, stability and control requirements have a strong influence on the configuration of the airplane.

Extensive wind tunnel testing is conducted during the development of an airplane configuration. The S&C engineer uses the wind tunnel for a variety of developmental functions. This includes the validation of tail sizes and stability levels as well as control surface sizing and controllability levels. Control surface hinge moments must also be determined. The wind tunnel also provides the data for the development of the engineering and crew training flight simulators. The preparation of the aerodynamic data base for the simulator is primarily an S&C responsibility.

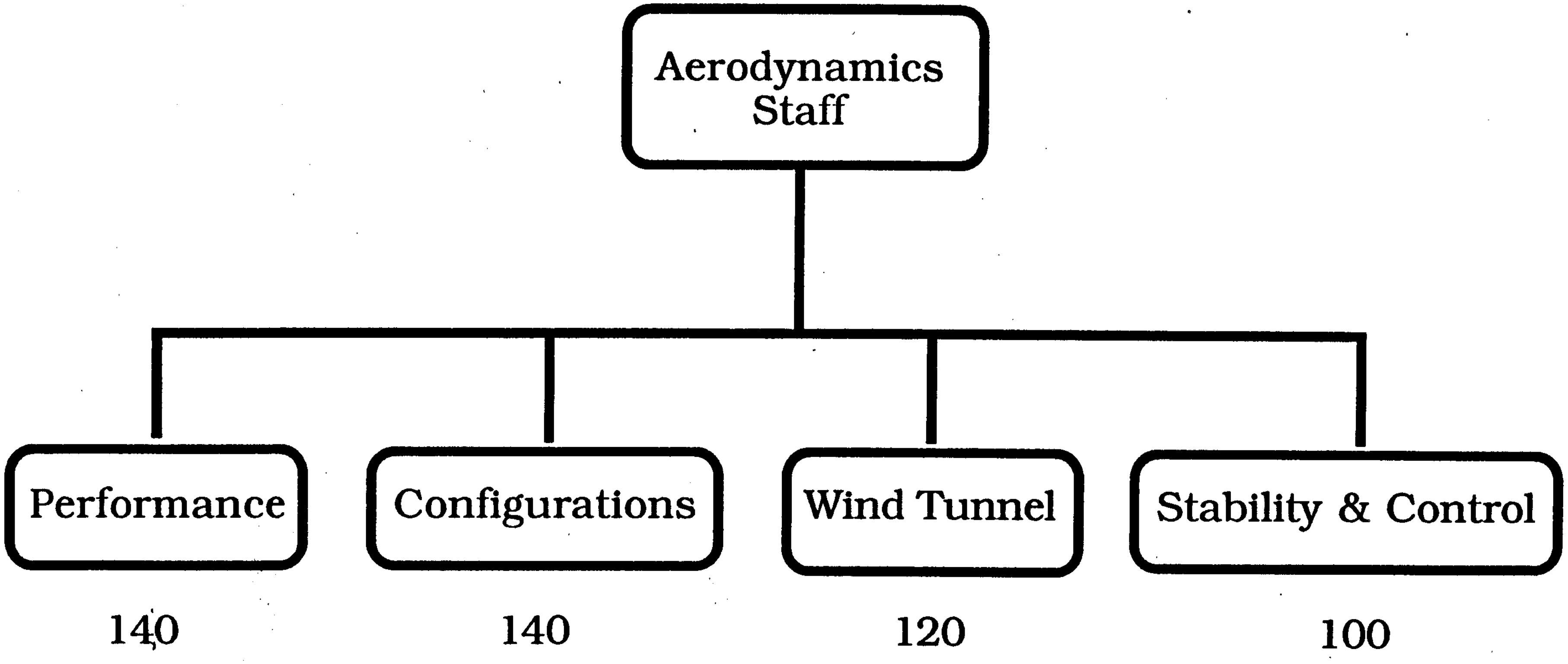
The engineering simulator has many uses. It allows the evaluation of airplane handling qualities with a pilot "in-the-loop" and the analysis of failure conditions. The development of flight systems such as autopilots and yaw dampers relies heavily on the simulator. The simulator allows initial pilot training for a new airplane program and the development of the flight test plan. Critical failures, which could not be demonstrated in flight, are certified using the simulator. Finally, the simulator may be used for the purpose of accident investigation.

In addition to participating in the development of the airplane configuration, the S&C engineer is involved in the integration of the flight control systems. Flight characteristics requirements influence the design of hydraulic and electrical power distribution and the size of the control surface actuators. These requirements are based on operation of the systems in both normal and failure modes. The control system integration effort also includes the evaluation of flight control laws and controller design.

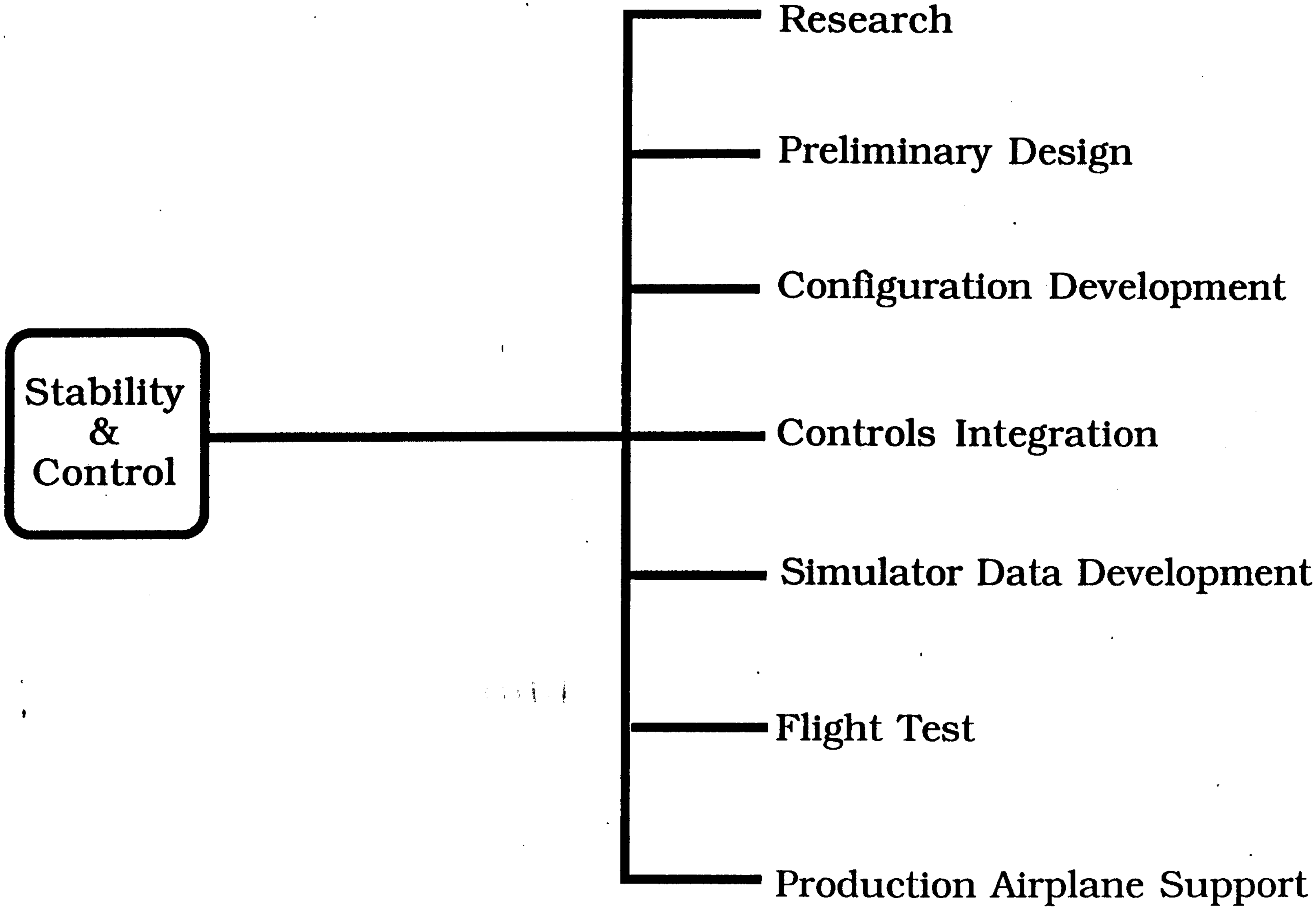
The Stability and Control group is heavily involved the flight testing and certification of the airplane. Pre-certification testing includes verification of stability levels, controllability, handling qualities and minimum control speeds. Flight data are collected for the purpose of updating the predicted aerodynamic data base of the flight simulator. An accurate data base is required if the simulator is to be certified for crew training purposes. Certification testing of the airplane demonstrates compliance with FAR Part 25 regulations and the regulations of foreign certification agencies.

Once an airplane enters service, support is provided to the airline customers. Questions relative to the flight characteristics of the airplane are answered, support of crew training flight simulators is provided, accident/incident investigations are conducted, etc.

STABILITY & CONTROL



STABILITY & CONTROL



Stability & Control

Research

- Analysis Techniques
- Test Techniques
- Computation
- Data Handling

Stability & Control

Preliminary Design

- Work Hand-In-Hand with Aero Configuration
- Tail Sizing
  - Horizontal, Determines Stability Levels
  - Vertical, Influences Engine Location and Minimum Control Speed
- Control Sizing
  - Elevator
  - Rudder
  - Ailerons
  - Spoilers
- Wing / Gear Location
  - Affects Airplane Loadability
  - Affects Longitudinal Control / Stability Requirements

Stability & Control

Configuration Development

- Work Hand-In-Hand with Aero Configuration and Performance
- Define Wind Tunnel Test Requirements
- Perform Wind Tunnel Configuration Development and Validation Tests
- Use Wind Tunnel Data to:
    - Validate Tail Sizes, Stability Levels
    - Validate Control Sizes, Controllability Levels
    - Assist in Wing / Gear Location Balance Trade Studies
    - Define Control Surface Hinge Moments
    - Assess Static and Dynamic Handling Qualities
    - Assess Criticality of Control Failures
    - Develop Flight Simulator Data Base
- Design Requirements

Stability & Control

Controls Integration

- Hydraulic and Electrical Power Distribution
- Actuation
- Failure Effects
- Control Law Evaluation
- Controller Evaluation
- Design Requirements

Stability & Control

Flight Simulator

- Engineering Simulator
  - Handling Qualities Evaluation with Pilot-in-Loop
  - Failure Analyses
  - System Development (Augmentation On and Off)
  - Initial Pilot Training
  - Development of Flight Test Program
  - FAA Certification (Critical Failures)
  - Accident Investigation
  - Basis for Training Simulator Package

Stability & Control

Flight Simulator

- Crew Training Simulator
  - Airline Crew Training
  - Boeing Crew Training
  - Pre-Certification Phase II Simulator for Initial Crew Training
  - Full Phase II & III Requires Matching and Validation to Flight Data

FAA Advanced Simulation Plan

Phase	Training credit	System Requirements
I	• Recency of Landings • Night Takeoff & Landings • Proficiency Check Landings	• Aero Data Must Match Airplane With Emphasis on Ground Effects • Night Visual System • 3-D Motion system
II	• Transition and Upgrade Training Pilot can receive airplane type rating without flying the airplane.	**Phase I Plus:** • Crosswind and Windshear • Ground Handling • Contaminated Runway • Control Feel Dynamics • Dusk Visual System • 6 DOF Motion • Special Cockpit Sounds
III	• All pilot training and certification can be done in the simulator.	**Phase II Plus:** • Characteristic Buffet Motion • Icing, Mach and Reverse Thrust Effects • Daylight Visual • Enhanced Cockpit Sounds

Stability & Control

Flight Test

- Pre-Certification Tests to Verify:
  - Stability Levels
  - Controllability
  - Handling Qualities
  - Minimum Control Speeds

- Certification Tests to Demonstrate:
  - Compliance with FAR Part 25 Regulations
  - Compliance with CAA, D of A, etc. Regulations

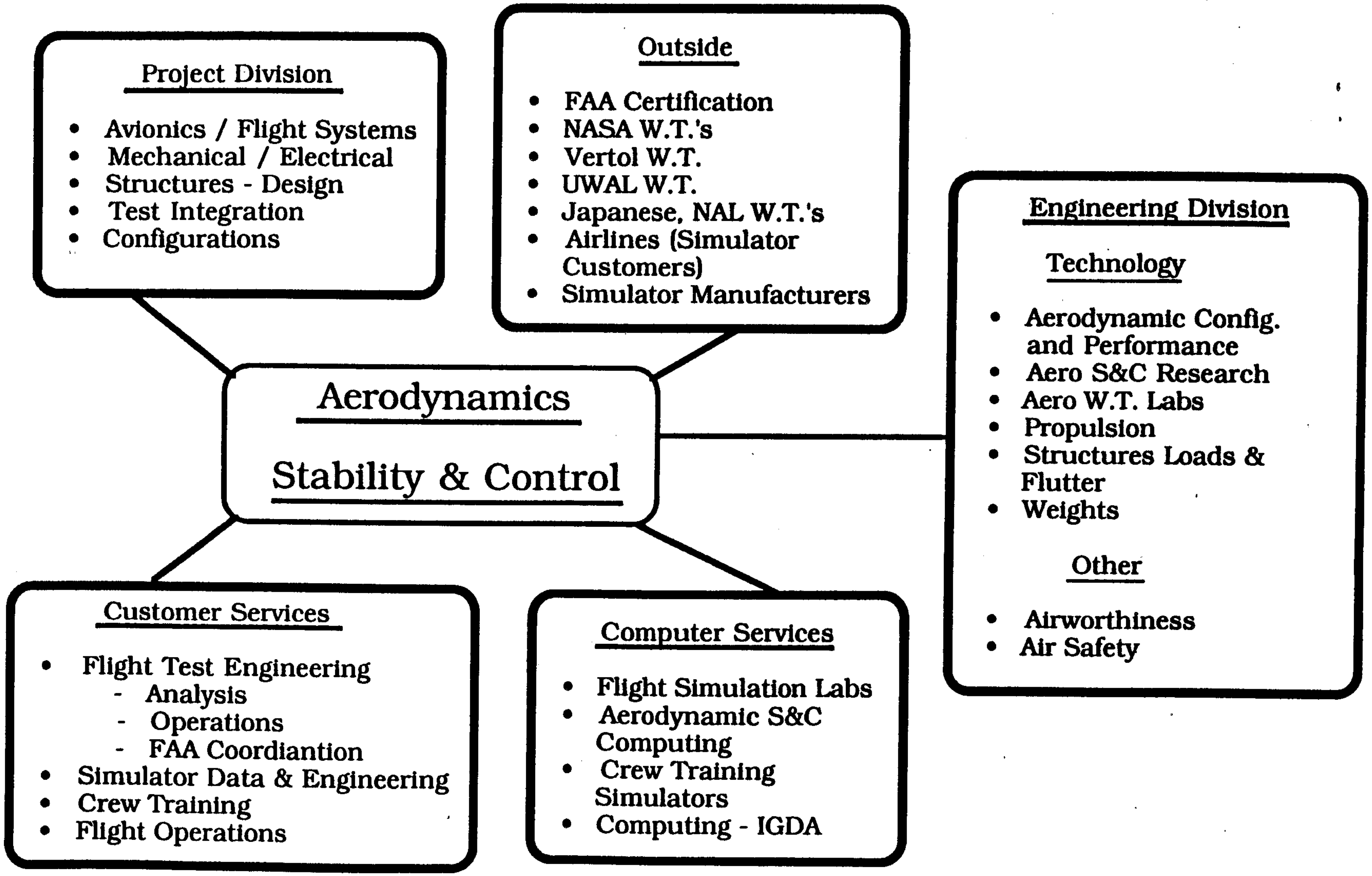
- Flight Data for Simulator Validation

Stability & Control

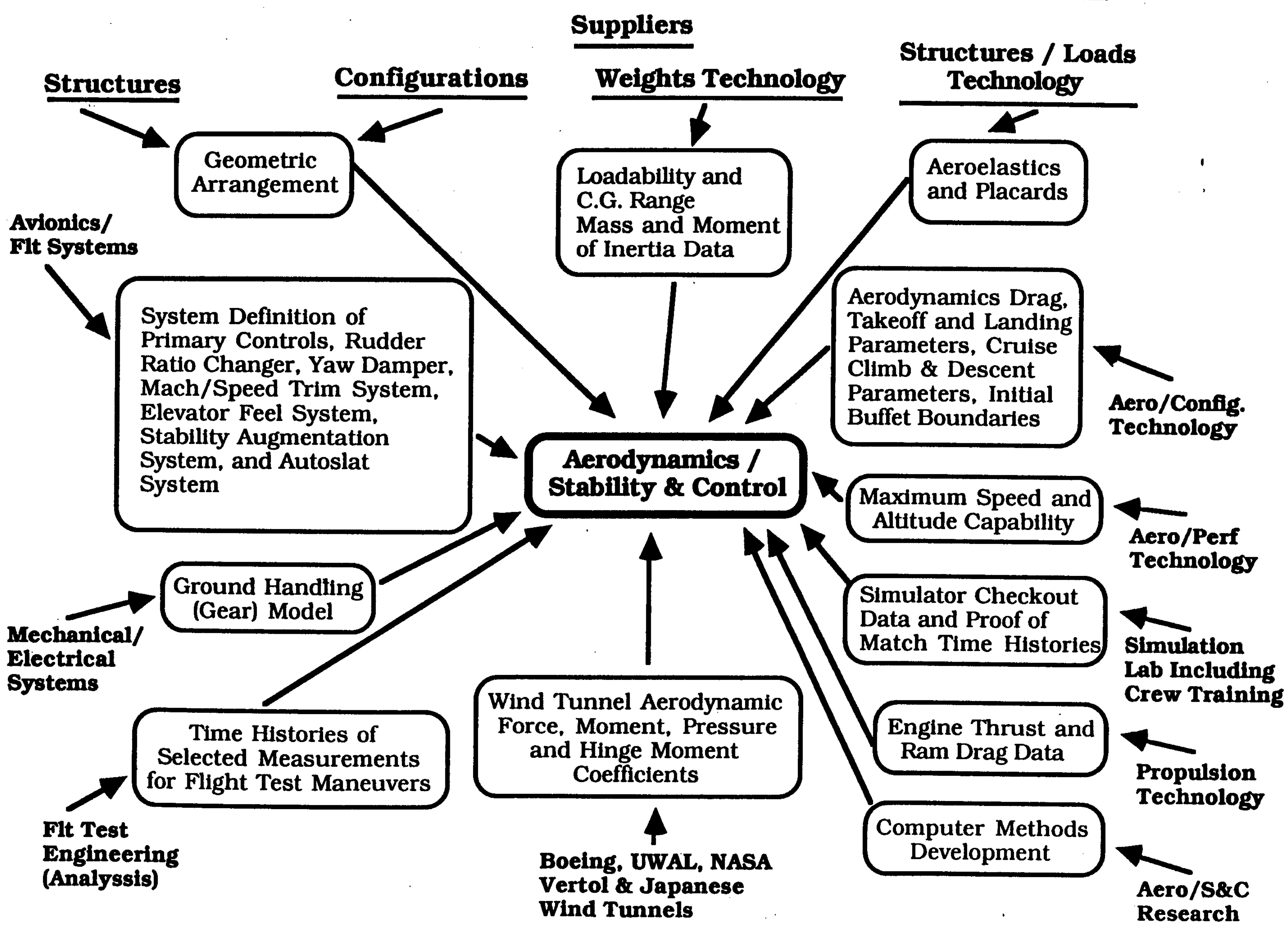
Production Airplane Support

- Fleet Support
  - Problem Airplane Assistance
  - Permission to Ferry
- Production Support
  - Rejection Tags
  - Support Boeing Flight Tests
- Accident / Incident Investigation

Aerodynamics / Stability & Control Organizational Interfaces



Major Data Flow to Aerodynamics / Stability & Control



DATA FLOW TO AERO STABILITY & CONTROL

ORIGINATING ORGANIZATION	MAJOR DATA DESCRIPTION	CURRENT METHODS OF DATA TRANSMISSION
1. Structures and Controls Project 2. Configurations	o General Geometric Layout (3-Views). o Specific Configuration Definition of Primary and Secondary Control Surfaces. o Geometric Installation of Engine Nacelles.	Drawings, Design Memos and Coordination Sheets. ↓
3. Weights Technology	o Loadability. o C.G. and Gross Weight Envelopes. o Mass and Moment of Inertia Data.	Coordination Sheets. ↓
4. Structures/Loads Technology	o Longitudinal and Lateral-Directional Aeroelastic Characteristics. o Structural Mach/Speed/Altitude Placards. o Limit Load Factors.	IGDA Data Files. ↓ Coordination Sheets. ↓

MAJOR DATA FLOW TO AERODYNAMICS / STABILITY AND CONTROL

	ORIGINATING ORGANIZATION	MAJOR DATA DESCRIPTION	CURRENT METHODS OF DATA TRANSMISSION
5.	Primary Flight Controls Technology	System Definition and Mechanization Description of the: o Primary Flight Control Systems (Stabilizer, Elevators, Rudders, Ailerons and Spoilers). o Rudder Ratio Changer. o Yaw Damper. o Mach/Speed Trim System. o Stick Nudger. o Elevator Feel System. o Stability Augmentation System. o Slat Gapper System.	Coordination Sheets and Flight Controls System Description Document. ↓
6.	Aerodynamics / Configurations Technology	o Aerodynamic Drag Characteristics. o Takeoff and Landing Speeds. o Flaps Down Maximum C_L's (1g and FAR). o Cruise, Climb and Descent Parameters. o Flaps Up Initial Buffet Boundaries	Coordination Sheets. ↓

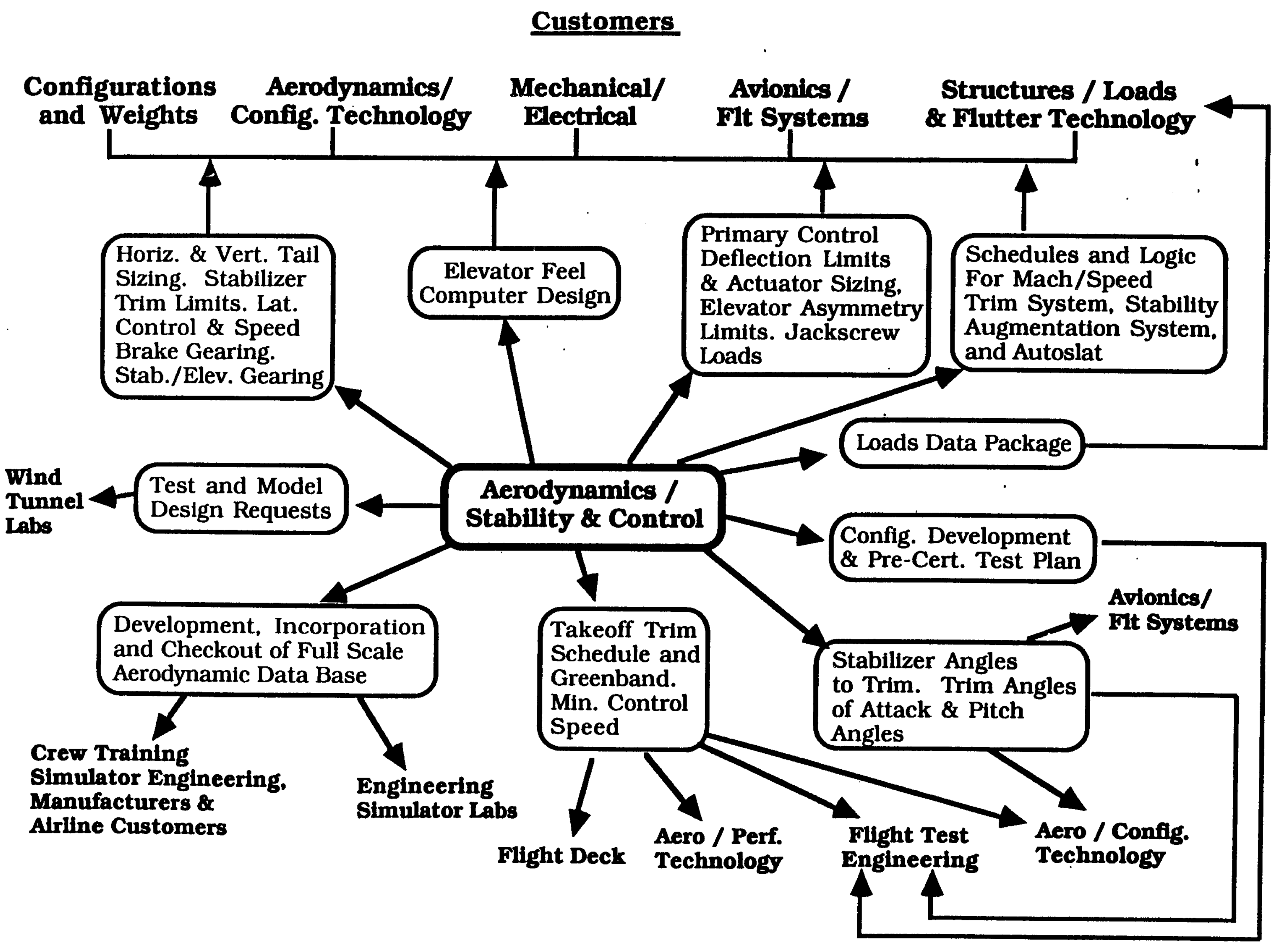
MAJOR DATA FLOW TO AERODYNAMICS / STABILITY AND CONTROL

ORIGINATING ORGANIZATION	MAJOR DATA DESCRIPTION	CURRENT METHODS OF DATA TRANSMISSION
7. Aerodynamics / Performance Technology	o Maximum Mach / Airspeed Capability. o Maximum Altitude Capability.	Coordination Sheets and Performance Documents.
8. Simulation Lab, (Engineering and Crew Training Simulation)	o Data for Simulator Data and Crew Training Checkout Documents. o Proof of Match Time Histories.	Electronic Data Transfer from Harris Simulator Computer to the IGDA Sites.
9. Propulsion Technology	o Engine Thrust Data (Takeoff, Climb, Maximum Continuous, Cruise and Idle Ratings). o Engine Ram Drag Characteristics. o Engine/Cockpit Interface Information.	IGDA Data Files and Coordination Sheets. ↓
10. Aerodynamics / Stability and Control Research Technology	o Development of New Analysis Programs. o Development of New Data Transfer Routines and Links. o Continuous Control and Updating of Existing Programs.	Program Description Memos and User Documents Plus IGDA Files and Data Transfer Links between IGDA Sites. ↓

MAJOR DATA FLOW TO AERODYNAMICS / STABILITY AND CONTROL

ORIGINATING ORGANIZATION	MAJOR DATA DESCRIPTION	CURRENT METHODS OF DATA TRANSMISSION
11. Boeing, UWAL, NASA, Vertol and Japanese Wind Tunnels	o Six Component Aero-Dynamic Force and Moment Coefficient Data. o Hinge Moment Coeff-icient Data. o Surface Pressure Coefficients for Specific Flight Conditions.	Data Tapes and Electronic Data Transfer between Wind Tunnel Computer and IGDA Sites. ↓
12. Flight Test Engineering (Analysis)	o Time Histories of Selected Parameters for all Stability and Control Flt. Maneuvers. o Plans, Logs and Data Summaries for each Stability and Control Flight. o Quick-Look Time Histories of Critical Maneuvers.	Electronic Data Transfer from Flight Test Computer Through EKS to IGDA Sites. Mailed or Hand Carried. ↓ Mailed or Hand Carried. ↓
13. Systems Technology	Ground Handling (Gear) Model.	Ground Handling Description Document.

Major Data Flow From Aerodynamics / Stability & Control



DATA FLOW FROM AERO STABILITY & CONTROL

DESTINATION ORGANIZATION	MAJOR DATA DESCRIPTION	CURRENT METHODS OF DATA TRANSMISSION
1. Structures and Controls Project 2. Configurations 3. Aerodynamics/ Configurations Technology 4. Primary Flight Controls Technology 5. Flight Deck Technology 6. FMS and Automatic Flight Controls Technology 7. Structures/Loads Technology	o Horizontal and Vertical Tail Size. o Mechanical and Electrical Stablizer Trim Limits. o Lateral Control and Speedbrake Gearing. o Stabilizer/Elevator Gearing. o Elevator Feel Computer Design. o Elevator, Rudder Aileron and Spoiler Control Deflection Limits and Actuator Sizes. o Elevator Asymmetry Deflection Limits. o Stabilizer Jackscrew Loads and Actuator Design. o Schedules and Logic for: o Mach/Speed Trim System. o Stability Augmentation System. o Stick Nudger System. o Slat Gapper System.	Informal Contact and and Coordination Sheets. Coordination Sheets. ↓ Informal Contact and Coordination Sheets. ↓

MAJOR DATA FLOW FROM AERODYNAMICS / STABILITY AND CONTROL

DESTINATION ORGANIZATION	MAJOR DATA DESCRIPTION	CURRENT METHODS OF DATA TRANSMISSION
8. Structures/Loads and Flutter Technology	o Loads Data Package.	Coordination Sheets. ↓
9. FMS and Automatic Flight Controls Technology 10. Aerodynamics/ Configuration Technology 11. Flight Test Engineering	o Stabilizer Angles to Trim. o Trim Angles of Attack and Pitch Angles	Informal Contact and Coordination Sheets. ↓
12. Flight Test Engineering	o Configuration Development and Pre-Certification Flight Test Plans.	Engineering Work Authorizations.
	o Cooperative Development of Certification Test Specification.	Formal and Informal Contact.
13. Flight Deck Project	o Takeoff Trim Schedule and Greenband.	Informal Contact and Coordination Sheets.
14. Aerodynamics/ Performance and Configuration Technologies 15. Flight Test Engineering	o Minimum Control Speeds. o Takeoff Trim Schedule and Greenband.	Informal Contact and Coordination Sheets. ↓

MAJOR DATA FLOW FROM AERODYNAMICS / STABILITY AND CONTROL

DESTINATION ORGANIZATION	MAJOR DATA DESCRIPTION	CURRENT METHODS OF DATA TRANSMISSION
16. Engineering Simulator Labs 17. Crew Training Simulator Engineering and Manufacturers 18. Airline Customers 19. FMS and Automatic Flight Controls Technology	o Compilation and Incorporation of Data in the Simulators. o Checkout of the Simulations. o Documentation of Data Stored in the Simulators. o Users Checkout Documentation.	Electronic Transfer Between Harris and IGDA Computers and Released Documents. ↓
20. Wind Tunnel Labs and Engineering	o Model Design Requests. o Test Plans. o Data Formats.	Informal Drawings and Paperwork. Engineering Work Authorizations. Coordination Sheets. Supplimentary Test Requests.

AERO STABILITY & CONTROL - TASKS / FUNCTIONS

1.0 PRELIMINARY DESIGN PHASE

- 1.1 PRELIMINARY WIND TUNNEL TESTING AND DATA ANALYSIS
- 1.2 CONFIGURATION DEFINITION AND CONTROL SYSTEM DESIGN

2.0 CONFIGURATION DEFINITION PHASE

- 2.1 WIND TUNNEL TESTING AND DATA ANALYSIS
- 2.2 CONFIGURATION DEFINITION AND CONTROL SYSTEM DESIGN

3.0 PROGRAM GO-AHEAD TO ROLLOUT PHASE

- 3.1 CONFIGURATION VALIDATION WIND TUNNEL TESTING AND DATA ANALYSIS
- 3.2 LOADS DATA PACKAGE
- 3.3 DEVELOPMENT OF PREDICTED FULL SCALE AERODYNAMIC DATA BASE
- 3.4 DEVELOPMENT OF PREDICTED FLIGHT CHARACTERISTICS FROM WIND TUNNEL BASE
- 3.5 DEVELOPMENT OF ENGINEERING FLIGHT SIMULATOR FROM WIND TUNNEL BASE
- 3.6 DEVELOPMENT OF CREW TRAINING FLIGHT SIMULATOR FROM WIND TUNNEL BASE
- 3.7 PILOTED SIMULATION STUDIES USING ENGINEERING SIMULATOR

4.0 ROLLOUT TO INITIAL DELIVERY PHASE

- 4.1 FLIGHT TEST PROGRAM AND CERTIFICATION
- 4.2 EXTRACTION OF UPDATED AERODYNAMIC DATA BASE FROM FLIGHT TEST RESULTS
- 4.3 ENGINEERING FLIGHT SIMULATION UPDATE BASED ON FLIGHT TEST
- 4.4 CREW TRAINING FLIGHT SIMULATION UPDATE BASED ON FLIGHT TEST
- 4.5 PILOTED SIMULATION STUDIES USING ENGINEERING SIMULATOR

5.0 INSERVICE SUPPORT PHASE

- 5.1 INSERVICE SUPPORT
- 5.2 PRODUCT IMPROVEMENT
- 5.3 FOLLOW-ON CERTIFICATION

AERODYNAMICS / STABILITY & CONTROL - MAJOR TASKS - SUBTASKS

5.1, 5.2 PRELIMINARY DESIGN AND CONFIGURATION DEFINITION PHASES

1. WIND TUNNEL TESTING AND DATA ANALYSIS

   - o Model Design Coordination.
   - o Test Planning.
   - o Outside Tunnel and Model Design Coordination.
   - o Participation in and Direction of Actual Tests.
   - o Test Diaries.
   - o Data Analysis - Data Summaries.
   - o Planning and Analysis of and Participation in Special Wind Tunnel Tests (Hinge Moments, Ground Effects, Turbine Power Simulators).

2. CONFIGURATION DEFINITION AND CONTROL SYSTEM DESIGN

   - o Horizontal Tail Sizing Studies.
     - o C.G. Range-Loadability
     - o Analysis of Critical Stab. & Cont. Flight Conditions
   - o Elevator Size and Deflection Limits Studies.
     - o Dive Recovery - High Speed Hinge Moments
     - o Takeoff Rotation, Jammed Stab. Landings, Elevator Asymmentry - Low Speed Hinge Moments.
   - o Stabilizer Trim Limits / Elev. - Stab. Gearing.
     - o Approach Trim
     - o Low Altitude, Gear Down Descent
     - o Go-Around Maneuver
   - o Vertical Tail Sizing and Rudder Sizing and Deflection Limits.
     - o Minimum Control Speed Analysis
     - o Cross Wind Capability
     - o Rudder Ratio Changer Design

2. CONFIGURATION DEFINITION AND CONTROL SYSTEM DESIGN (Continued)

- Lateral Control Sizing and Gearing Schedule Design.
  - Spoiler / Speedbrake Relationships
  - Wing L.E. and T.E. Asymmetries
  - Lateral Control Linearity
- Sizing of Elevator, Rudder and Lateral Control Actuators and Stabilizer Jackscrew.
  - Critical Flight Condition Analysis
  - Blowdown Capability
- Design of Elevator Feel System (Force Gradients and Elevator Shaping).
  - Initial, Preliminary Design
  - Final Pre-Flight Design
  - Possible Re-Design Based on Flight Test Results
- Development of Schedules for Speed and/or Mach Trim Systems.
  - Preliminary Design
  - Final Pre-Flight Design
  - Possible Modifications to Accomodate Flight Test Results
- Development of Scheduling / Logic for Stability Augmentation, Stick Nudger, or Slat Gapper Systems.
  - Pre-Flight Design
  - Possible Flight Test Modifications
- Cooperative Evaluation and Design of Geometry that Effects Stability and Control.
  - Nacelle / Strut Geometry
  - Thrust Reversers
  - Leading Edge Slat Spanwise Arrangement and Sealing
  - Nacelle Chines

5.3 PROGRAM GO-AHEAD TO ROLLOUT PHASE

1. CONFIGURATION VALIDATION WIND TUNNEL TESTING AND DATA ANALYSIS

- o Model Design Coordination and Test Planning.
- o Outside Tunnel and Model Design Coordination.
- o Participation in and Direction of Actual Tests.
- o Test Diaries.
- o Data Analysis - Data Summaries.
- o Planning and Analysis of and Participation in Special Wind Tunnel Tests (Larger Scale Empennage Models, Half Models and Mounting System Tares and Interference).
- o Documentation of the Wind Tunnel Stability and Control Data Base for the Final Airplane Configuration.

2. LOADS DATA PACKAGE

- o Rigid Tail On and Off Static and Dynamic Longitudinal and Lateral / Directional Stability Derivatives.
- o Rigid Longitudinal and Lateral / Directional Control Derivatives and Tail Effectiveness.
- o Ground Effects.
- o Maximum Rudder Deflections and Associated Maximum Steady Sideslip Capability.
- o Maximum Steady Sideslip Capability With an Engine Out.
- o Maximum Available Elevator Angles.

3. DEVELOPMENT OF PREDICTED FULL SCALE AERODYNAMIC DATA BASE

- o Detailed Analysis of the UWAL and BTWT Tests Selected for the Validation Data Base.
  - o Tail Off / Tail Increment Build Up
  - o Control Increments
  - o Configuration Change Increments
  - o Three (3) Complete Low Speed, Flaps Down Models (Various L.E. Slat Treatments)
  - o Two (2) Complete High Speed, Flaps Up Models (With and Without Aero. Pitch Up Fixes)

3. DEVELOPMENT OF PREDICTED FULL SCALE AERODYNAMIC DATA BASE (Continued)

- o Development of Full Scale Corrections.
  - o Larger Scale Empennage Wind Tunnel Tests (JAL High and Low Speed Tunnels)
  - o Higher Reynolds No. Wind Tunnel Tests (NASA Ames, Low Speed Pressure Tunnel - 3 Dim. Model and Ames, High Speed 11 x 11 Unitary-Half Model)
  - o High Speed Empirical Corrections for BTWT Data
  - o Extensions of Low Speed Data to Full Scale C_{LMAX} - Cooperative Effort With Aerodynamics - Configurations
- o Corrections of UWAL and BTWT Wind Tunnel Data for Mounting System Tares and Interference.
- o Development of Ground Effects From Moving Ground Belt Wind Tunnel Tests (BVWT Testing).
- o Development of Induced Thrust Effects From TPS Wind Tunnel Tests (BVWT Testing).
- o Inclusion of Basic Airplane Drag Polars and Component Drag Increments - Cooperative Development With Aerodynamics - Configurations.
- o Inclusion of Aeroelastic Factors Provided by Structures - Loads and the Associated q -Scaling Parameters.
- o Inclusion of Propulsion Model Including Ram Drag Provided by Propulsion Technology.
- o Inclusion of Models of the Primary Control System, Mach / Speed Trim Systems, Stabililty Augmentation Systems, Rudder Ratio Changer and Stick Nudger or Slat Gapper Systems.

4. DEVELOPMENT OF PREDICTED FLIGHT CHARACTERISTICS FROM WIND TUNNEL BASE

- o Stabilizer Required to Trim.
  - o Level Flight
  - o Increments Due to Thrust
  - o Increments Due to Configuration Changes
- o Trim Angles of Attack and Pitch Angles.
  - o Idle, Takeoff, Max. Continuous Thrust and Thrust for Level Flight

4. DEVELOPMENT OF PREDICTED FLIGHT CHARACTERISTICS FROM WIND TUNNEL BASE (Continued)

  - o Gear Up & Down, Speedbrakes Up and Down
- o Takeoff Stabilizer Trim Schedule.
- o Speed Stability.
  - o Climb, Cruise, Approach, Landing and Takeoff
  - o Effects of Mach / Speed Trim
- o Stall Characteristics.
  - o Effect of L.E. Slat Configurations
  - o Effects of Stick Nudger and/or Stability Augmentation
- o Dynamic Stability Characteristics.
  - o Longitudinal (Short Period and Phugoid)
  - o Lateral / Directional (Dutch Roll, Roll, & Spiral Mode)
- o Longitudinal Maneuvering Characteristics.
  - o Neutral and Maneuver Points
  - o Elevator and Stick Force Per 'g'
  - o Maximum Load Factor Capability
  - o Effects of Aerodynamic Fixes and/or Stability Augmentation
- o Takeoff Rotation and Landing Flare Characteristics.
- o Go Around Characteristics.
- o Longitudinal Mistrim Capability.
  - o Stabilizer - Elevator Trades
  - o Mistrimmed Takeoffs and Landings
  - o Dive Recovery
  - o Jammed Stabilizer Landings
  - o Takeoffs With Jammed Elevator
- o Longitudinal Control Required for Thrust and Configuration Changes.
- o Roll Rate Capability.
- o Sideslip Capability.
- o Crosswind Capability.
- o Engine Out Control.
  - o Minimum Control Speeds
  - o Tameness
- o Lateral / Directional Trim.
  - o Engine Out
  - o Asymmetric Fuel
- o L. E. Slat and T. E. Flap Asymmetry.

5. DEVELOPMENT OF ENGINEERING FLIGHT SIMULATION FROM WIND TUNNEL BASE

- o Incorporation of the Predicted, Full Scale Aerodynamic Data Base Including Drag Characteristics Developed in Cooperation With Aerodynamics - Configurations.
- o Incorporation of Data Supplied by Other Organizations.
  - o Mass and Moment of Inertia Data
  - o Ground Handing (Gear) Model
  - o Primary Control Systems Including Cockpit Controls
  - o Mach / Speed Trim Systems, Stability Augmentation Systems, Stick Nudger and Slat Gapper Systems
- o Incorporation of Necessary Interfaces Between Above Data and Cockpit Controls and Instruments.
- o Checkout of the Simulation and Comparison With ACTS Solutions.
- o Documentation of the Simulation in the Form of a Simulator Document.

6. DEVELOPMENT OF CREW TRAINING FLIGHT SIMULATION FROM WIND TUNNEL BASE

- o Common Development With the Engineering Simulation.
- o Coordination of the Simulation with the Simulator Manufacturers and Airline Customers.
- o Documentation and Checkout in a Simulator Checkout Document.

7. PILOTED SIMULATION STUDIES USING ENGINEERINIG SIMULATOR

- o Evaluation of System Failures.
  - o Leading Edge Slat and Trailing Edge Flap Failures and Asymmetries
  - o Asymmetric Speedbrakes and Spoiler Hardovers or Oscillatory Failures
  - o Autopilot Hardovers and Multi-Axis Hardovers
  - o RAT Operation
  - o Single and Dual Hydraulic Failures
  - o Stability Augmentation System Failures and Hardovers
  - o Elevator and Rudder Actuator Failures and Jams
  - o Wheel Jams
  - o Jammed Elevator Takeoffs and Jammed Stabilizer Landings
  - o Asymmetric Thrust Reversion and Ground Handling With Thrust Reversion

7. PILOTED SIMULATION STUDIES USING ENGINEERING SIMULATOR (Continued)

- o Rudder Ratio Changer Failures and Yaw Damper Hardovers and Oscillatory Failures
  - o Ground or Flight Speedbrake Deployment on Approach
  - o Outboard Aileron Lockout Failures
  - o Single Lateral Control Cable Failures
  - o FAA Control Jams and Cable Failures
- o System Development and Evaluation.
  - o Yaw Dampers
  - o Stabilizer and Rudder Trim Rates
  - o Mach and Speed Trim
  - o Stability Augmentation System
  - o Elevator Feel System
  - o Speed Brake / Spoiler Gearing
  - o Control System Hystersis and Breakout and Column Mass Balance
- o Handling Characteristics.
  - o Stall Speeds and Characteristics
    - o Basic Stalls
    - o Effect of Stability Augmentation and Speed Trim
    - o Effect of Maximum Thrust
  - o Takeoff Speed Stability
  - o Maneuvering Characteristics
    - o Basic Airplane
    - o Effect of Stability Augmentation
    - o Effect of Aerodynamic Fixes
  - o Flight Path Capability
  - o Takeoff Rotation and Trim
  - o Landing Approach and Ground Effects
  - o Wind Shears
  - o Dive Recovery
  - o Go-Around Maneuvers
  - o Ice and Frost Effects
  - o Abrupt Elevator and Rudder Maneuvers for Structural Loads
- o Simulator Development.
  - o Frame Time Studies
  - o Compatibility of Crew Training and Engineering Simulations
  - o Continuity of Simulation Between Flaps Up and Flaps Down Flight

5.4 ROLLOUT TO INITIAL DELIVERY PHASE

1. FLIGHT TEST PROGRAM AND CERTIFICATION

- o Development and Coordination of the Test Plan for Configuration Development and Precertification Flight Testing.
- o Cooperative Development of the Test Specification for Certification Flight Testing.
- o Coordination of Certification Philosophy With Flight Test Engineering and the FAA.
- o Participation in Actual Flight Testing.
  - o Evaluation and Selection of the Flight Change Fixes and the Determination of A Final Configuration During Developmental Testing
  - o Analysis of Flight Characteristics Throughout the Flight Envelope and Determination of their Acceptability
  - o Observation of and Concurrence with the Demonstration of Flight Characteristics During Certification Testing
- o Identification, Compilation and Storage of All Flight Test Maneuvers on the Stability and Control IGDA Computer Sites.
- o Final Approval of Certification Reports Prepared by Flight Test Analysis
- o Documentation of all Analysis of Pertinent Flight Testing in Flight Test Analysis Reports.

2. EXTRACTION OF UPDATED AERODYNAMIC DATA BASE FROM FLIGHT TEST RESULTS

- o Longitudinal Data Base.
  - o Low Speed, Flaps Down
    - o Initial Update of Stabilizer Effectiveness Using Flight Test and Predicted Level Flight Trims
    - o Initial Update of Elevator Effectiveness Using the Initial Update of Stabilizer Effectiveness and Flight Test Elevator Stabilizer Trades

2. EXTRACTION OF UPDATED AERODYNAMIC DATA BASE FROM FLIGHT TEST RESULTS (Continued)

        - Initial Update of Downwash at the Horizontal Tail Using Tail Loads Measured During Level Flight Trims, Elevator-Stabilizer Trades and Stalls
        - Final Iterative Update of Tail Effectiveness and Downwash that Collapses all the Flight Test Trims, Trades and Stalls into a Single Tail Off Pitching Moment Curve for Each Flap Setting
        - Update of Increments Due to Direct and Induced Thrust, Ground Effects, Gear and Speedbrakes Using the Preceding Updated Aerodynamic Model
        - Update of Pitch Damping and Development of Elevator Control Lag Using the Preceding Updated Model and Flight Test Elevator Control Pulses and Steps
    - High Speed, Flaps Up
        - Initial Update of Stabilizer Effectiveness and Aero-elasticity Using Flight Test and Predicted Level Flight Trims
        - Initial Update of Elevator Effectiveness and Aeroelasticity Using the Initial Update of Stabilizer Effectiveness and Aeroelasticity and Flight Test Elevator Stabilizer Trades
        - Initial Update of Downwash at the Horizontal Tail Using Tail Loads Measured During Level Flight Trims, Elevator Stabilizer Trades and Wind Up Turns
        - Final Iterative Update of Tail Effectiveness and Aeroelasticity that Collapses All the Flight Tests Trims, Trades and Wind Up Turns Into A Single, Rigid Tail Off Pitching Moment Curve for Each Selected Mach Number
        - Update of Increments Due to Direct and Induced Thrust, Gear and Speedbrakes Using the Preceding Updated Aerodynamic Model
        - Update of Pitch Damping and Development of Elevator Control Lag Using the Preceding Updated Aerodynamic Model and Flight Test Elevator Control Pulses and Steps
- Lateral - Directional Data Base.
    - Low Speed, Flaps Down and High Speed, Flaps Up

2. EXTRACTION OF UPDATED AERODYNAMIC DATA BASE FROM FLIGHT TEST RESULTS (Continued)

  - o Initial Update of Basic Airplane Aerodynamic Derivatives (Yaw, Roll, Sideforce Due to Side Slip and Yaw, Roll, Sideforce Due to Yaw and Roll Rate) Using Flight Data (Dutch Rolls and Spirals) and Predicted Data
  - o Initial Update of Control Effectiveness (Yaw, Roll, Sideforce Due to Wheel and Rudder) Using Flight Data (Wheel and Rudder Inputs) and Initial Update of Basic Derivatives
  - o Initial Update of Basic Derivatives and Control Surface Derivatives for Large Sideslip Angles and Control Deflections Using Flight Data (Steady State Sideslips and Engine-Out Trims) and Initial Updates for the Basic Airplane and Control Derivatives

- o Low Speed, Flaps Down
  - o Initial Update of Ground Effects on Rudder Effectiveness Using Flight Data (Ground and Air Minimum Control Speeds) and Initital Updates for the Basic Airplane and Control Deriviatives
  - o Final Iterative Update of Basic Airplane and Control Derivatives Using Flight Data (Dutch Rolls, Spirals, Steady State Sideslips, Engine Out Trims, Rudder and Wheel Inputs) and Previous Updates
  - o Final Iterative Update of Ground Effects and Control Derivatives Using Flight Data (Ground, Air Minimum Control Speeds, Tameness, Engine Out Takeoffs/Landings) and Previous Updates
  - o Update of Thrust Increments and Lateral Control Surface Interference Effects Based on Flight Data and Previous Updates
- o High Speed, Flaps Up
  - o Final Iterative Update of Basic Airplane and Control Derivatives Using Flight Data (Dutch Rolls, Spirals, Rudder and Wheel Inputs, Steady State Sideslips, Engine Out Trims) and Previous Updates

2. EXTRACTION OF UPDATED AERODYNAMIC DATA BASE FROM FLIGHT TEST RESULTS (Continued)

   - o Update of Speedbrake Increments, Thrust Increments and Lateral Control Surface Interference Effects Based on Flight Data and Previous Updates

3. ENGINEERING FLIGHT SIMULATION UPDATE BASED ON FLIGHT TEST

   - o Revision of the Predicted Simulation with Data Models Extracted From Flight Test Results - the Drag Update is a Cooperative Effort With Aerodynamics - Configurations.
   - o Comparison (Proof of Match) of the Updated Simulation With Flight Test Time Histories.
   - o Documentation of the Updated Simulation.

4. CREW TRAINING FLIGHT SIMULATION UPDATE BASED ON FLIGHT TEST

   - o Common Revision with the Engineering Simulation Using Flight Test Results.
   - o Coordination of this Updated Simulation with the Simulator Manufacturers and Airline Customers.
   - o Documentation and Checkout of this Update in a Simulator Checkout Document.

5. PILOTED SIMULATION STUDIES USING ENGINEERING SIMULATOR

   - o Piloted Simulation Studies Required to Support the Configuration Development Flight Testing.
   - o Pitoted Simulation Studies Required to Support the Certification of Design Philosophies and Operational Procedures Through the Evaluation of Conditions that are Considered too Dangerous for Actual Flight Demonstration.
   - o Piloted Simulation Studies Required to Checkout the Simulation after its Flight Test Update.

5.5 INSERVICE SUPPORT PHASE

1. INSERVICE SUPPORT

   - Support of Specific Questions from Airlines and Customer Engineering.

2. PRODUCT IMPROVEMENT

   - Development of Improved Elevator Feel System.
   - Support of Increased Gross Weight and Center of Gravity Limits.
   - Support of Drag Improvements like Removal of Elevator Downrig.
   - Development of Improved Analysis Techniques and Prediction Capability of Full Scale Aerodynamics and Aeroelastics.

3. FOLLOW-ON CERTIFICATION

   - Certification of the Configuration Changes Associated with the Product Improvements.

RESEARCH & DEVELOPMENT GROUP

FUNCTION

Aerodynamic research and development within Boeing is directed towards developing new ideas whose applications will result in new or improved products. These efforts begin with basic research to bring forth new ideas, methods, and knowledge. Applied research then transforms this newly developed knowledge into the practical tools and methods which may be used within the engineering community.

A significant portion of the research effort is directed towards the development and application of computational fluid dynamic (CFD) methods. CFD has become an integral part of the airplane design process at Boeing. This approach provides earlier detection and solution of design problems leading to reduced flow time and cost

Other research activity includes the development of prediction methods for Stability & Control and Performance applications. Parameter identification (P.I.) methods support the analysis of dynamic flight test data, allowing the extraction of basic airplane rotary and control derivatives. Semi-empirical methods have been developed to improve the accuracy of wind tunnel derived control derivatives. Preliminary design drag prediction methods provide a low cost "first look" for airplane design purposes.

Advanced design concepts such as laminar flow, wing tip devices, riblets, high lift design, etc. are pursued. Research also supports the development of computer data methods. Two and three dimensional plotting packages have wide applications within the engineering community.

CUSTOMERS

Research supports the entire Aerodynamic Technology organization. Cooperative efforts with government (NASA, etc.) and academic institutions provide a broad base of knowledge to draw upon. Typical customers include:

o **CONFIGURATION GROUP**

- COMPUTATIONAL FLUID DYNAMICS (CFD)
- WING DESIGN
- HIGH LIFT SYSTEMS
- REYNOLDS NUMBER EFFECTS
- PROPULSION INTEGRATION

o **STABILITY & CONTROL GROUP**

- CONTROL EFFECTIVENESS
- WIND TUNNEL TO FLIGHT SCALING
- PROPULSIVE EFFECTS: THRUST INTERFERENCE
- FLIGHT DATA ANALYSIS: P.I.

o **WIND TUNNEL GROUP**

- FLOW VISUALIZATON
- FLOW MEASUREMENT
- DATA REDUCTION AND DISPLAY

o **PERFORMANCE GROUP**

- DRAG PREDICTION
- PERFORMANCE SOFTWARE
- DATA METHODS (APPLICABLE TO ALL GROUPS)

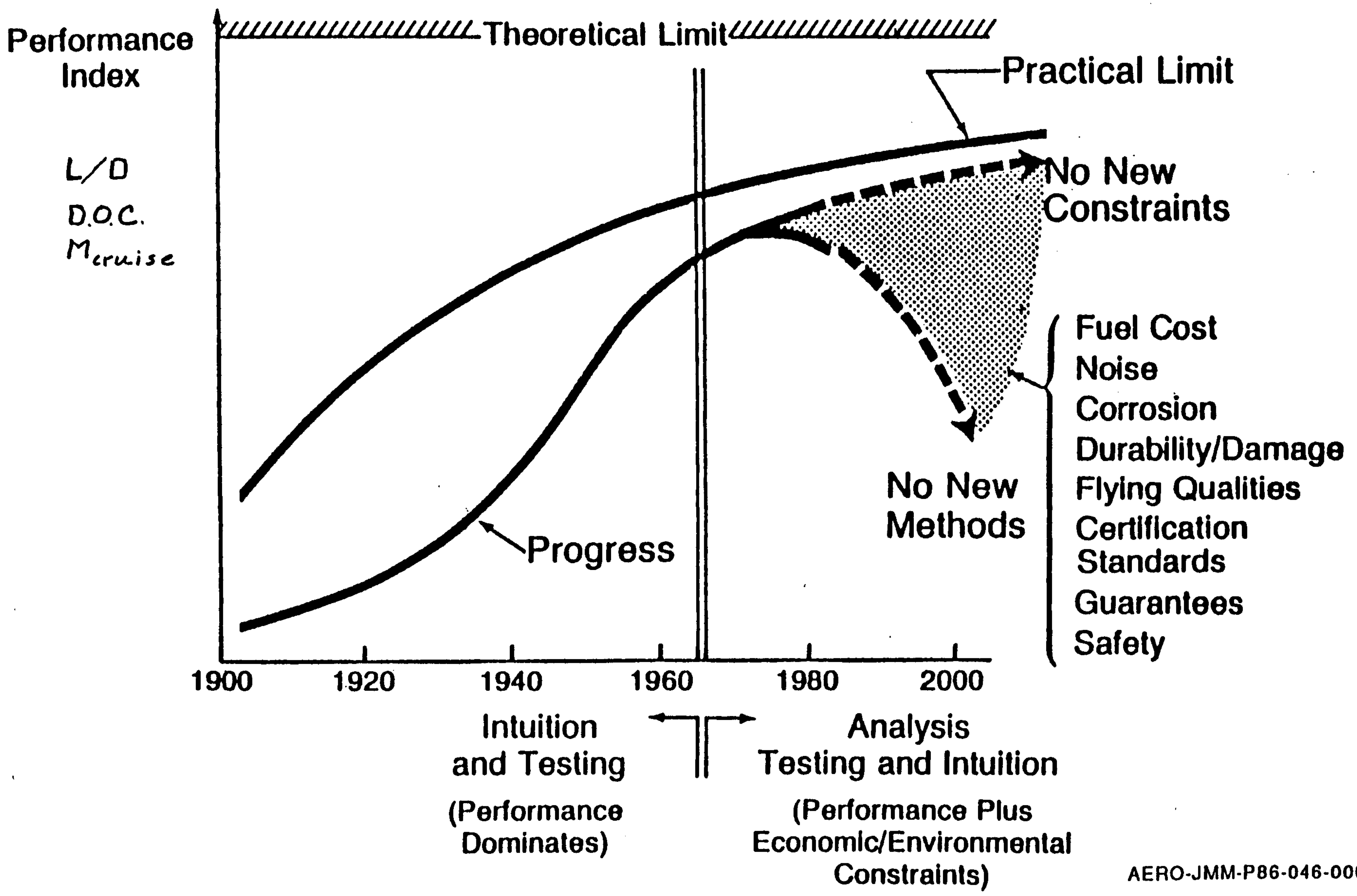
Examples of Research activities are provided on the following pages.

AERODYNAMIC RESEARCH & DEVELOPMENT

IN THE

BOEING COMMERCIAL AIRPLANE COMPANY

TECHNOLOGY DEVELOPMENT



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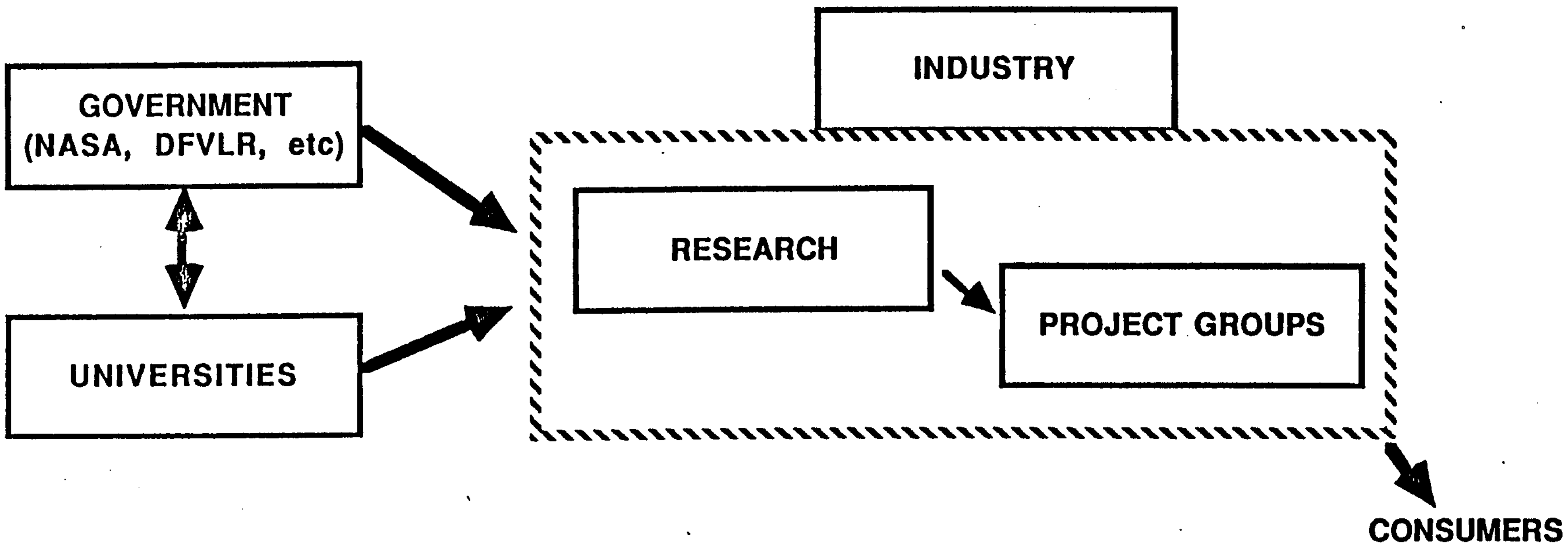
RESEARCH & TECHNOLOGY TRANSFER



BASIC RESEARCH

- o NEW IDEAS
- o NEW METHODS
- o NEW KNOWLEDGE

APPLIED RESEARCH

- o PRACTICAL IDEAS
- o NEW TOOLS

APPLICATIONS

- o NEW PRODUCTS
- o BETTER PRODUCTS

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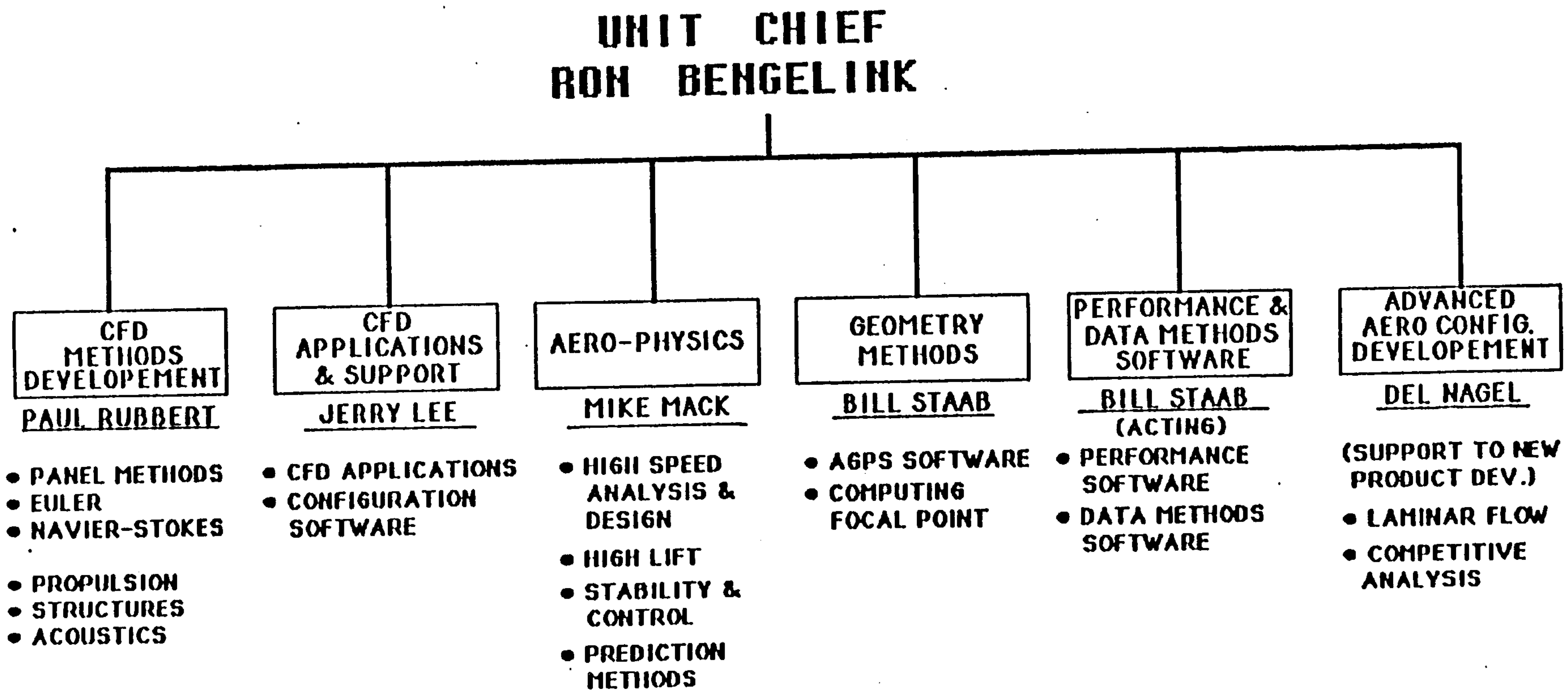
BCAC AERODYNAMICS RESEARCH & DEVELOPMENT ORGANIZATION



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BOEING AERODYNAMIC RESEARCH INTERESTS

CONTROL EFFECTIVENESS -2D AND 3D

- -ICE
- -HIGH MACH
- -NEW CONCEPTS

WAKES / JETS / DOWNWASH

- -CRUISE
- -FLAPS DOWN
- -GROUND EFFECT
- -PROPFAN WAKES

HIGH LIFT

- -MULTI-ELEMENT AIRFOILS
  - -CONFLUENT BOUNDARY LAYER
  - -VISCOUS WAKES
  - -SEPARATED FLOW / MAX LIFT
- -WINGS WITH & WITHOUT FLAPS
  - -3D SEPARATION
  - -VORTICAL FLOWS

AIRFRAME COMPONENT INTEGRATION

- -"WING" / BODY JUNCTIONS
- -AFT BODY / NACELLE / STRUTS
- -PROPULSION EFFECTS INCLUDING STAB & CONTROL

WIND TUNNEL - TO - FLIGHT SCALING

- -RE SCALE EFFECTS
- -REAL GAS SCALE EFFECTS (e.g. FREON vs. AIR)

IMPROVED WIND TUNNEL TEST TECHNIQUE

- -FLOW VISUALIZATION
- -FLOW FIELD MEASUREMENTS TECHNIQUES & DATA REDUCTION
- -IMPROVED DATA DISPLAY

M2TRIP01

AERODYNAMIC RESEARCH & DEVELOPMENT

COMPUTATIONAL FLUID DYNAMICS

- o CFD TECHNOLOGY
- o CFD LAB

AERO-JMM-P86-046-005

Impact of CFD on the Current Boeing Design Process

- CFD has become an integral part of the process
- Complements wind tunnel, changes character of testing
- Reveals fine details of fluid flow - produces understanding
- Provides earlier detection and solution of problems
- Provides greater opportunity for innovative design

The bottom line

- Design leadership
- Reduced risk
- Reduced cost, reduced flowtime in design

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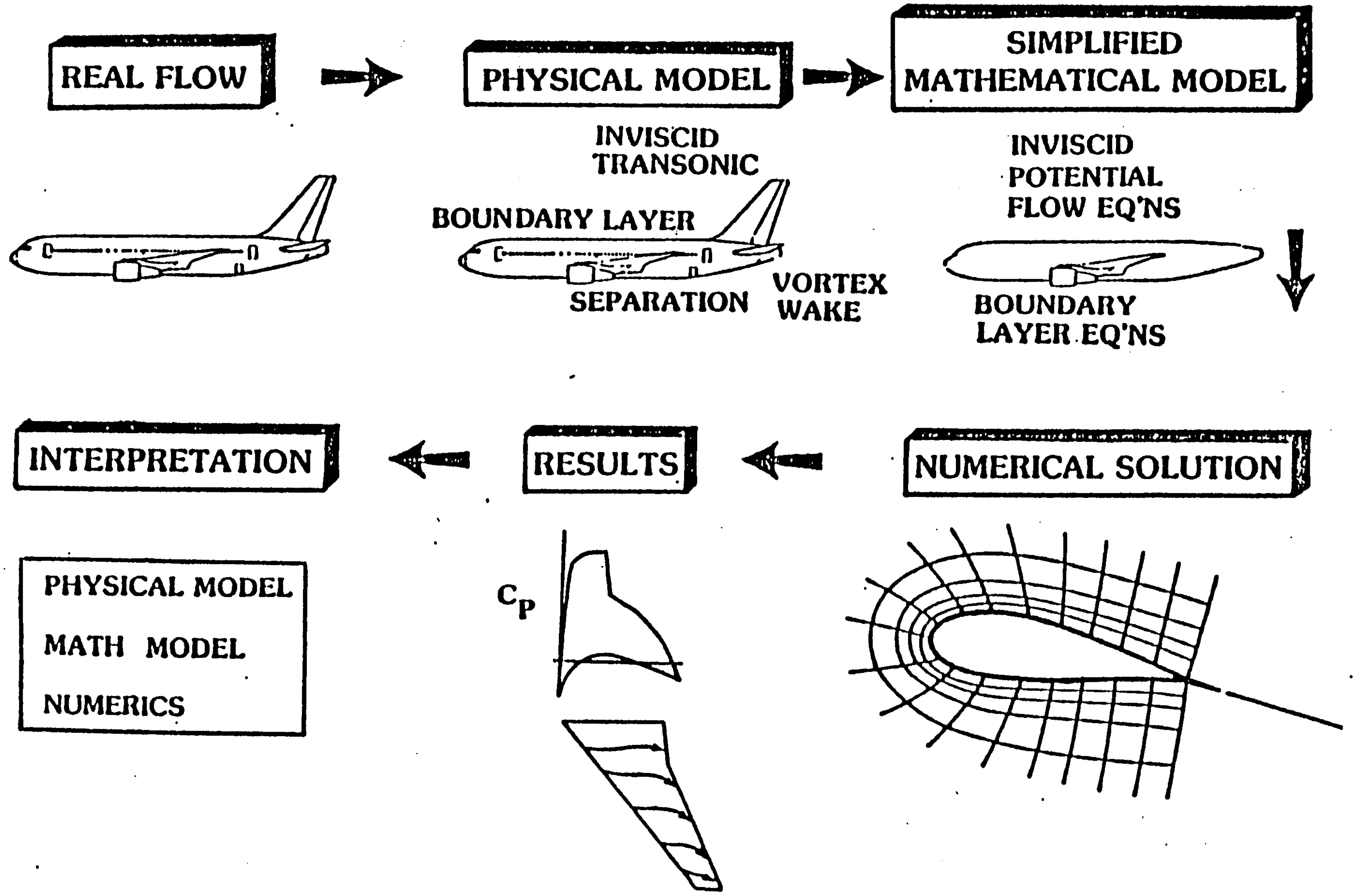
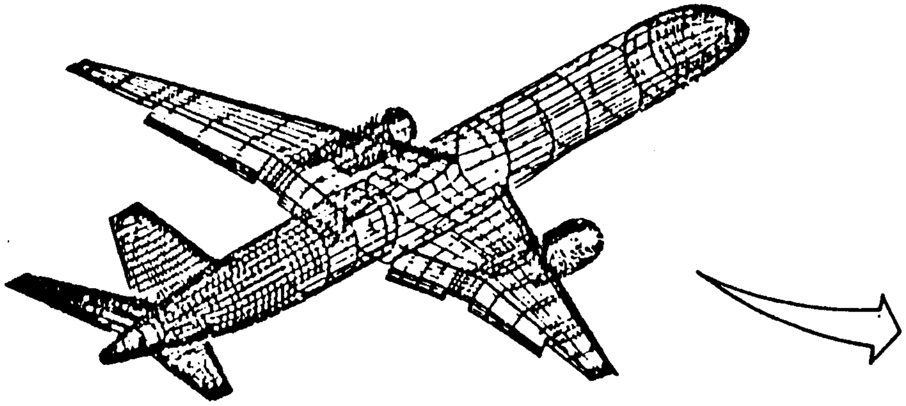
WHAT CFD IS


REAL FLOW
PHYSICAL MODEL
SIMPLIFIED MATHEMATICAL MODEL
INVISCID TRANSONIC
BOUNDARY LAYER
SEPARATION
VORTEX WAKE
INVISCID POTENTIAL FLOW EQ'NS
BOUNDARY LAYER EQ'NS
NUMERICAL SOLUTION
RESULTS
INTERPRETATION
C_P
PHYSICAL MODEL
MATH MODEL
NUMERICS

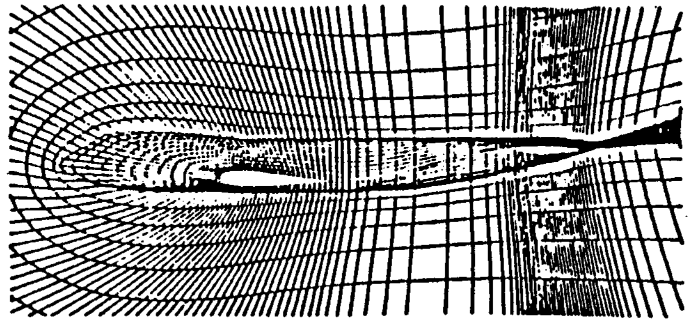
COMPARISON BETWEEN PANEL & FIELD METHODS

SUBSONIC FLOW

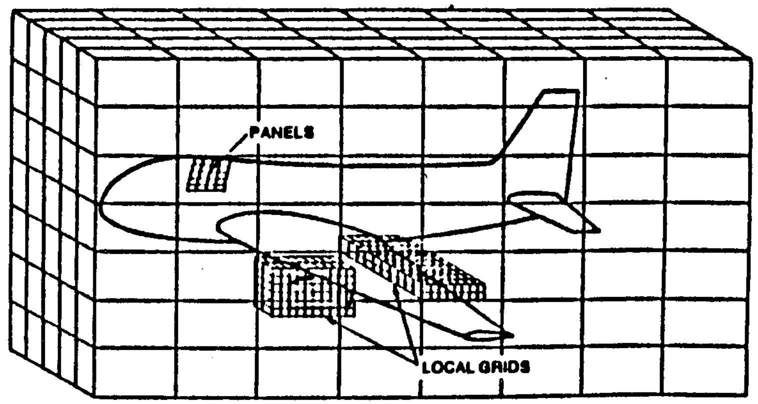
PANEL METHODS
(PANAIR)



TRANSONIC FLOW



COMPLEX SURFACE FITTED GRIDS
(PRESENT FULL POTENTIAL / EULER)



PANEL REPRESENTATION
EMBEDDED IN CARTESIAN MESS
(TRANAIR)

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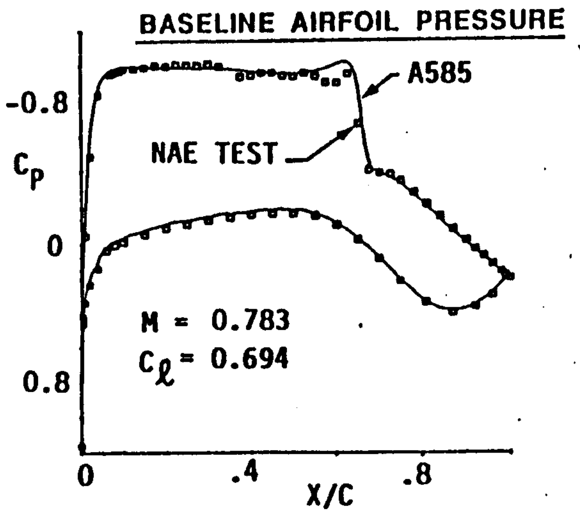
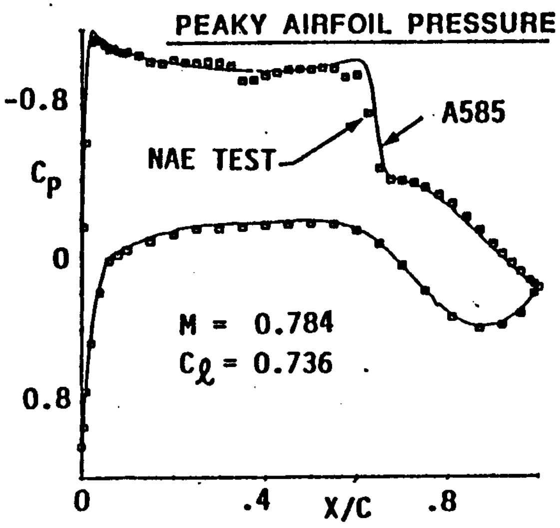
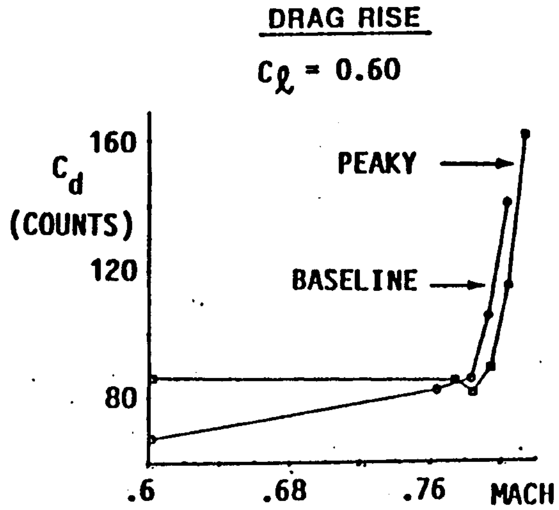
PEAKY AIRFOIL DESIGN

- o NEW DESIGN PHILOSPHY
  - RAPID LEADING EDGE EXPANSION
  - C_P PEAK NEAR X/C - 2% FOLLOWED BY A CONVCAVE RECOVERY
  - CAN BE TESTED ONLY AT HIGH REYNOLDS NUMBER

- o CODE VALIDATION
  - ANALYSIS WAS DONE USING A REDUCED MACH NUMBER (BY 0.01) TO ACCOUNT FOR THE WIND TUNNEL SIDE WALL BOUNDARY LAYERS
  - ACHIEVED PREDICTED IMPROVEMENT IN M_{DD}







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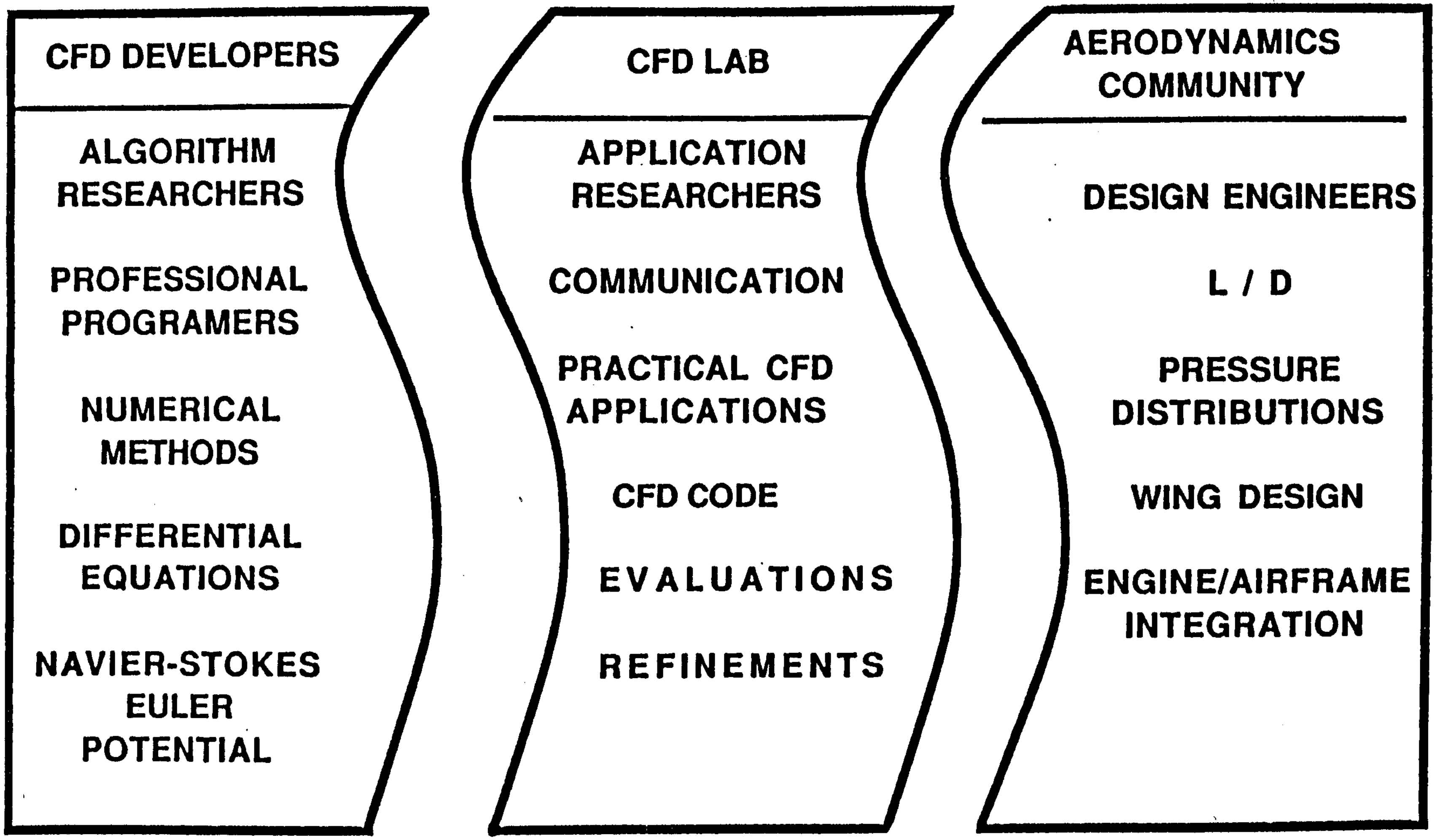
THE GAP



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AERODYNAMIC RESEARCH & DEVELOPMENT

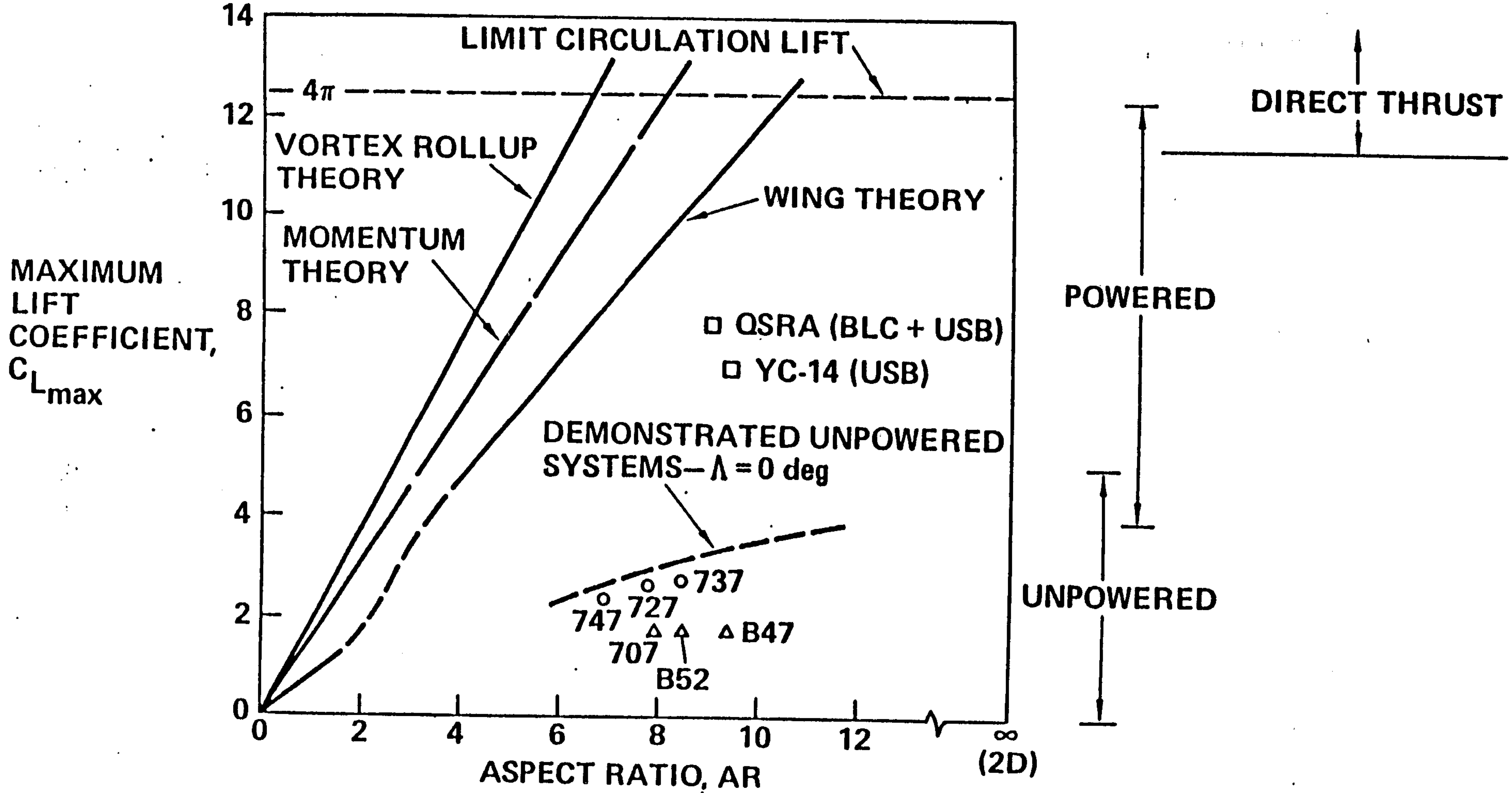
<u>HIGH-LIFT</u>

- o MULTI-ELEMENT AIRFOILS
- o THREE-DIMENSIONAL CONFIGURATIONS

AERO-JMM-P86-046-017

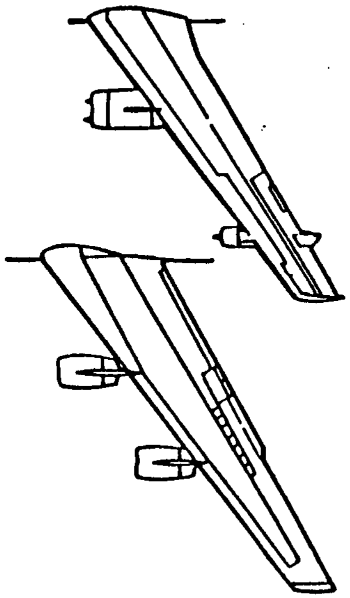
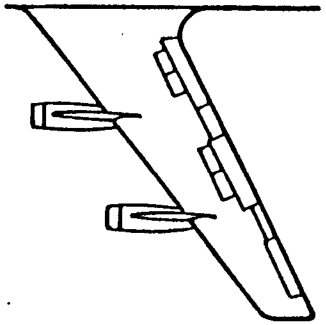
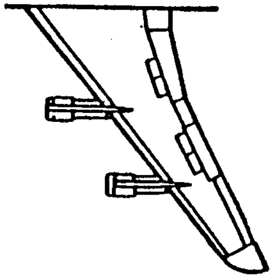
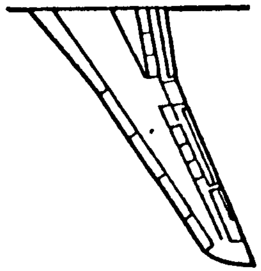
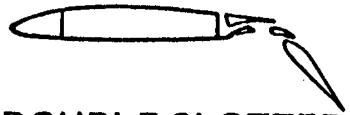
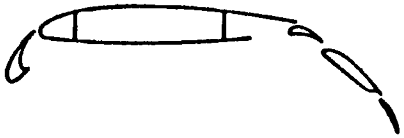
BOEING

Limits of Maximum Lift Coefficient



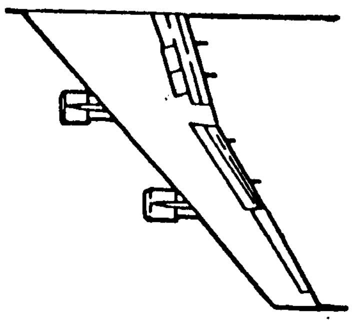
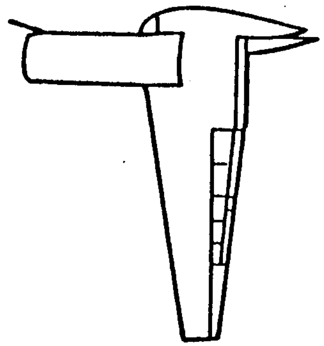
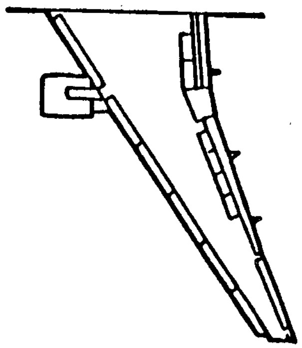
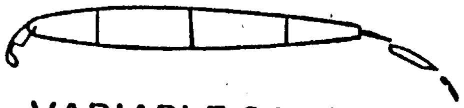
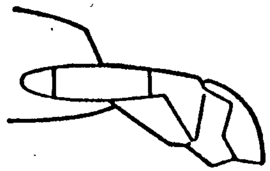
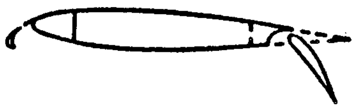
BOEING

Trends in Boeing Transport High-Lift System Development

TYPE	B-47/B-52	367-80/KC-135	707-320/E-3A	727
FIRST FLIGHT	1947/1952	1954	1962	1963
PLANFORM				
TYPICAL AIRFOIL	 SINGLE-SLOTTED FOWLER FLAP	 DOUBLE-SLOTTED FLAP	 DOUBLE-SLOTTED FLAP AND KRUEGER LEADING EDGE	 SLAT AND TRIPLE-SLOTTED FLAP
$C_{L_{max}}$	1.8	1.78	2.2	2.79

BOEING

Trends in Boeing Transport High-Lift System Development

TYPE	747/E-4A	YC-14	767
FIRST FLIGHT	1969	1976	1981
PLANFORM			
TYPICAL AIRFOIL	 VARIABLE CAMBER KRUEGER AND TRIPLE-SLOTTED FLAP	 UPPER SURFACE BLOWING	 SLAT AND SINGLE-SLOTTED FLAP
$C_{L_{max}}$	2.45	7.0	2.45

AERODYNAMIC RESEARCH & DEVELOPMENT

PREDICTION METHODS

- o DRAG PREDICTION
- o WIND TUNNEL-TO-FLIGHT SCALING
- o SEMI-EMPIRICAL METHODS
  - -CONTROL EFFECTIVENESS PREDICTIONS

BOEING

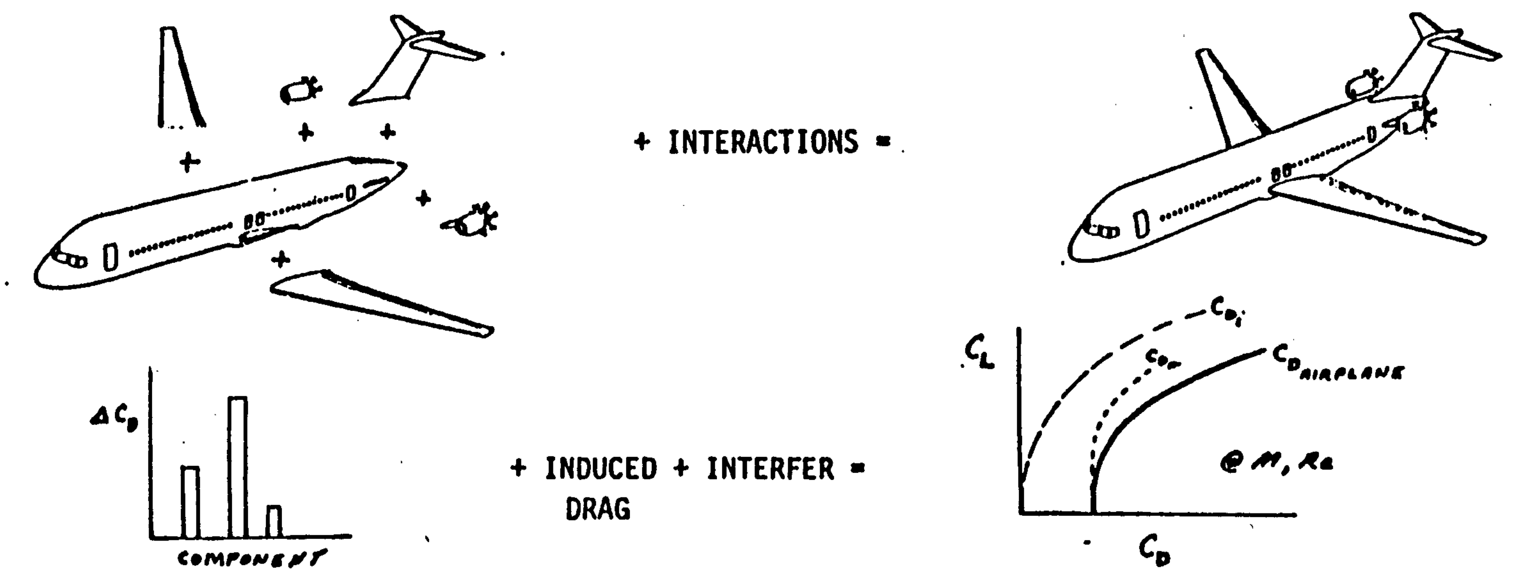
Low-Speed Aerodynamic Prediction Methods

Design level	Accuracy required	Turnaround time	Cost	Method
Conceptual	Approximate (±10–20%)	Negligible	Negligible	Handbook and calculator
Preliminary	Good (±5–10%)	Rapid	Low	Semiempirical
Detail (project group)	High (±2–5%)	Reasonable	Moderate	Full analysis and design Viscous 2-D Inviscid 3-D

DRAG PREDICTION

PROGRAM A274 - PRELIMINARY DESIGN DRAG PREDICTION

- WELL ESTABLISHED HANDBOOK METHOD

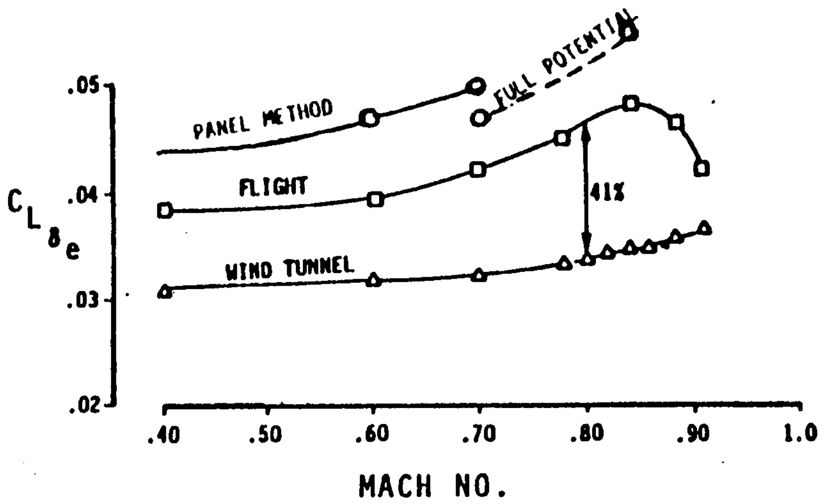


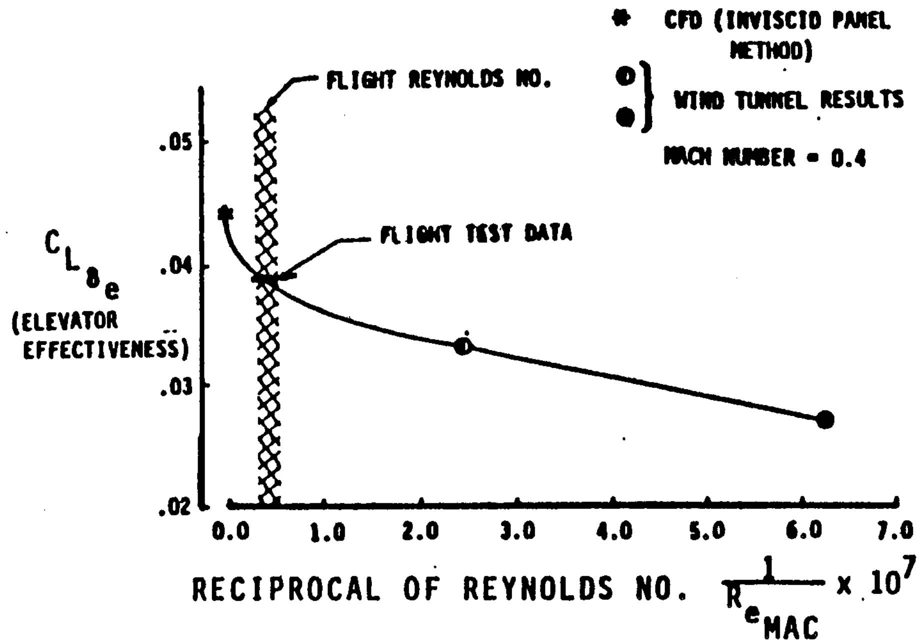
- TECHNICAL IMPROVEMENTS NEEDED
  - -AFT BODY DRAG
  - -NEW PROPULSION SCHEMES (e.g.UNDUCTED FANS)
  - -DATA BASES FOR UNCONVENTIONAL CONFIGURATIONS

- PRESENT COMPUTER VERSION NEEDS IMPROVEMENT

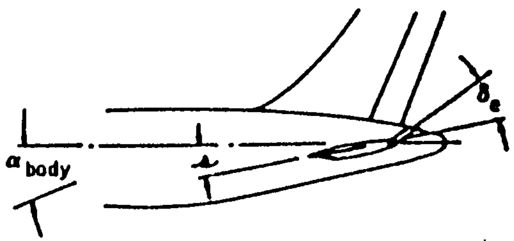
CONTROL EFFECTIVENESS PREDICTION

SEMI-EMPIRICAL INTERPOLATION

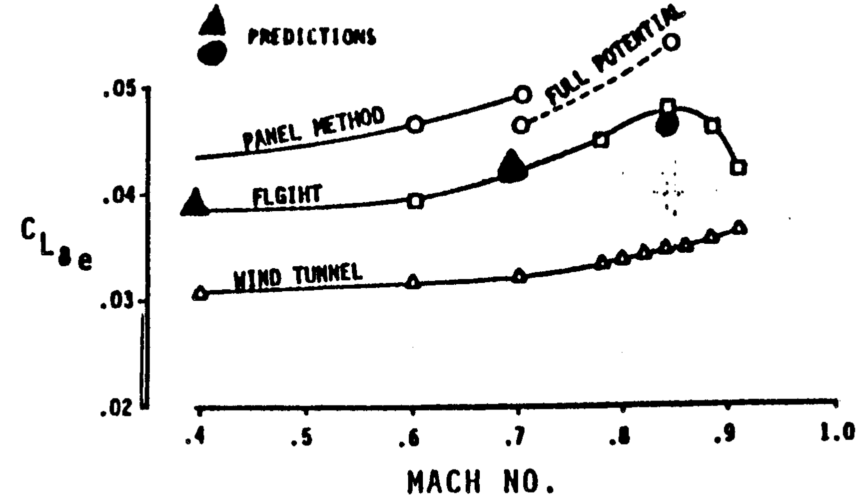




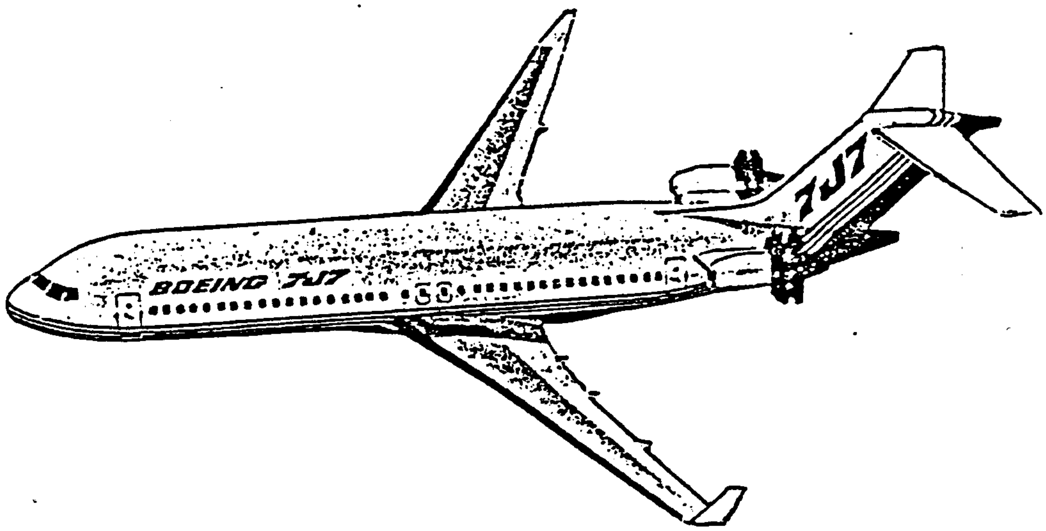
ELEVATOR EFFECTIVENESS

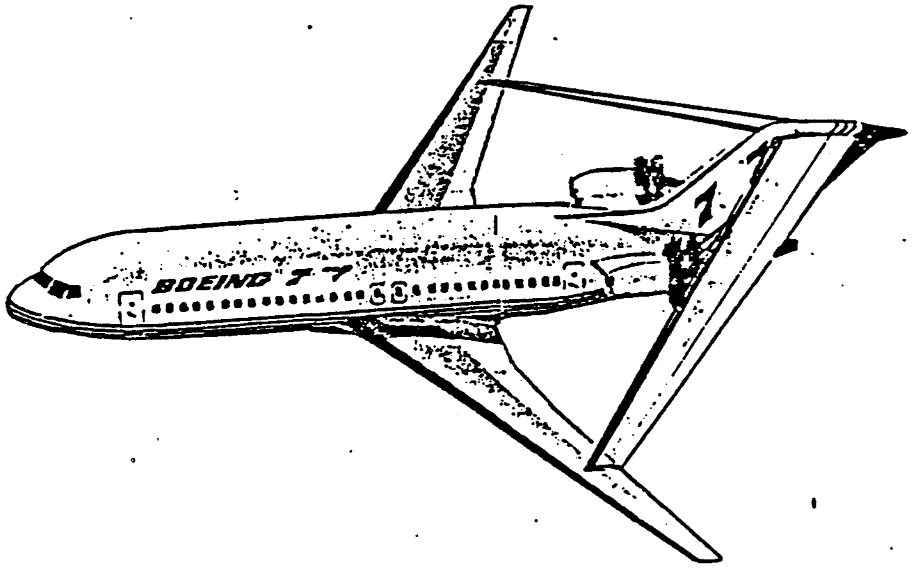


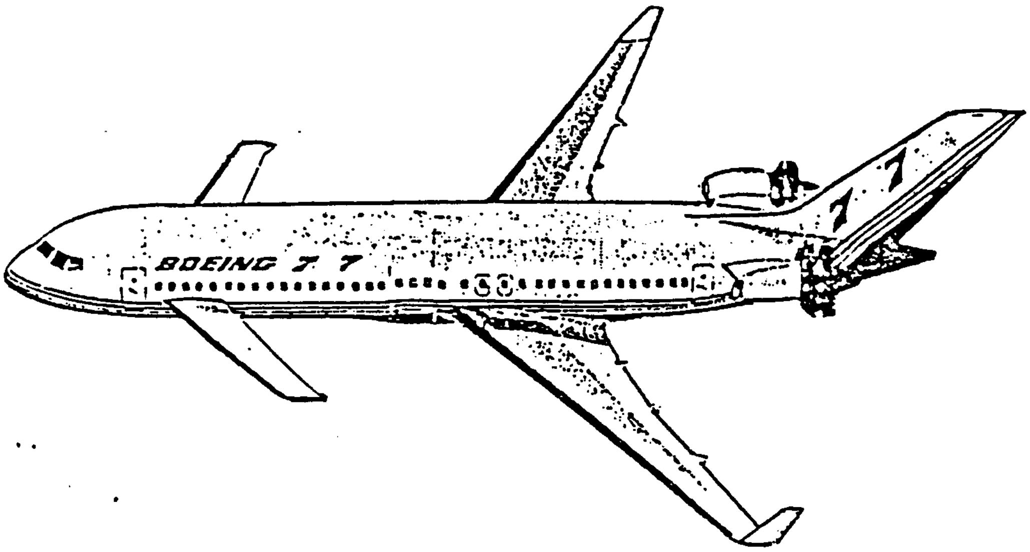
Δ = STABILIZER INCIDENCE
δ_e = ELEVATOR DEFLECTION



INNOVATIVE CONFIGURATIONS







AERODYNAMIC RESEARCH & DEVELOPMENT

SUMMARY

- o APPLIED, FOCUSED RESEARCH
- o HEAVY EMPHASIS ON CFD
- o BALANCED RESEARCH EFFORT
  - -COMPUTATIONS
  - -EXPERIMENT
  - -APPLICATIONS
- o MAJOR EMPHASIS ON TECHNOLOGY TRANSFER

AERO-JMM-P86-046-021

AERODYNAMICS LABORATORY

The aerodynamics laboratory continues our tradition of rigorous testing

Before the first Boeing 747 left the runway on its maiden flight in February 1969, the aircraft had already "flown" for more than 14,000 hours. Perfectly scaled facsimiles of the 747 and its various components had spent the equivalent of nearly 1,800 8-hour days in the precisely controlled air of the Boeing wind tunnel facilities. And when pilot Jack Waddell took the "Spirit of Everett" into the air on that Saturday in 1969, the plane behaved just as the wind tunnel tests had predicted it would.

Wind tunnel testing is crucial to the design and development of modern airplanes. Therefore, The Boeing Company—the world's leading producer of commercial aircraft—has created an integrated aerodynamics laboratory that includes several wind tunnels, a model shop, a data gathering complex, and support services.

This booklet describes the Edmund T. Allen Memorial Research Facilities. Eddie Allen was chief of Flight and Research at Boeing from 1941 to 1943, when this group combined flight testing and aerodynamic research. His death in the crash of a B-29 during a test flight in 1943 terminated a legendary career, but his inspired leadership as an engineer and test pilot and his methodical, penetrating approach to aircraft design had created the basis for the facilities that bear his name today.

Edmund T. Allen, 1896-1943

We've worked with wind tunnels since 1920

Will it fly?

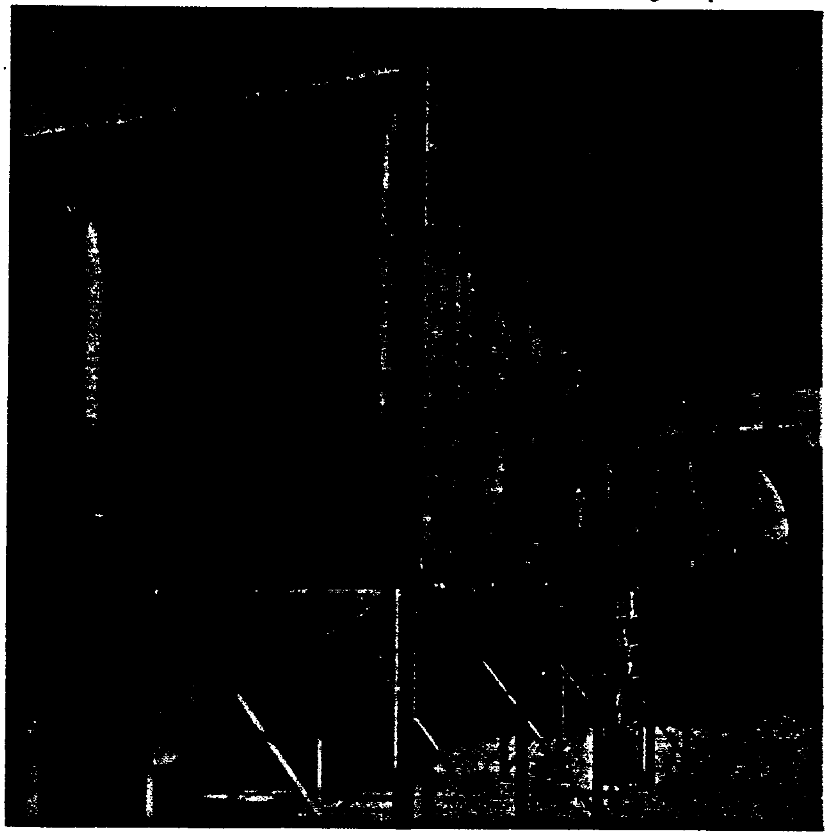
This question led pioneering scientists to develop primitive methods of simulating flight using scaled models in a controlled test environment. As early as 1759, John Smeaton outlined the various methods that may be used in aerodynamic research:

"In trying experiments on windmill sails, the wind itself is too uncertain to answer the purpose; we must have recourse to an artificial wind. This may be done two ways: either by causing the air to move against the machine, or the machine to move against the air. To cause the air to move against the machine in a sufficient volume, with steadiness and requisite velocity, is not easily put in practice; to carry the machine forward in a right line against the air, would require a larger room than I could conveniently meet with. What I found most practicable, therefore, was to carry the axis, whereon the sails were to be fixed, progressively round in the circumference of a large circle."

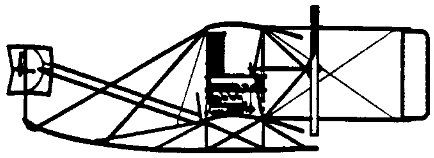
Francis Herbert Wenham, a founding member of the Aeronautical Society of Great Britain, designed the first wind tunnel. Penn's Marine Engineering Works in Greenwich has the distinction of setting up the world's first wind tunnel experiments. In his classic 1871 paper on aerial locomotion, Wenham described these experiments:

"The tunnel was a wooden trunk 18 inches square and 10 feet long. Through it was directed the blast from a fan, driven by a steam engine. The wind velocity was measured with a water gage, various spee up to 40 miles per hour being ed. The wind was not steady, co id- erable fluctuations makin he observations difficult. The c ec- tion of the wind was tested w a vane and said to be f ly straight, although there no mention of a wind straighter of any kind."

This 1920 wind tunnel, built in conjunction with the University of Washington, was the forerunner of today's multitunnel Boeing complex.



Wind tunnel testing has become more demanding and more versatile



The Wright Brothers discovered at Kitty Hawk that their first gliders did not develop the lifting power predicted by published tables, so they turned to the laboratory to resolve the problem. In 1901 they constructed a tunnel 16 inches square and 6 feet long and were able to develop speeds up to 30 mph using a fan and a honeycomb flow straightener. During a year of testing, they investigated more than 200 wing models and developed the first reliable tables of lift forces on simple airfoil shapes. This information was used to design their third glider, which had "aerodynamic qualities far in advance of any tried before."

In line with this tradition, the Boeing Airplane Company recognized the need for experimental research and, in conjunction with the University of Washington, constructed a wind tunnel in 1920 on the university campus. This was the forerunner of a multimillion-dollar, multitunnel complex at The Boeing Company that now operates 24 hours a day to develop aircraft, hydrofoils, missiles, and spacecraft. These facilities have one basic purpose—to produce precise and reliable data that can be used to predict full-scale characteristics.

How well does it fly?

No longer is the primary question "Will it fly?" Today we must understand more subtle aerodynamic details, so wind tunnel models are instrumented both to test the basic design and to examine each element of that design. Competition demands that the last 1% or 2% of capability be achieved; the aerodynamic shaping that provides this excellence must be carefully and methodically determined.

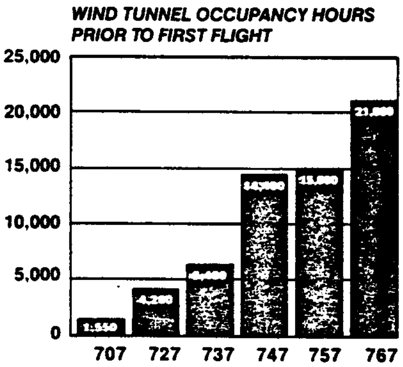
Wind tunnels today vary in size from a test section of a few inches to full-scale chambers measuring more than 100 feet across. Windspeeds range from low (50 to 100 mph) to hypersonic (3,000 mph). Test pressures vary from 5 pounds per square foot to 10,000 pounds per square foot and temperatures from—45°C to +2,000°C. Force measurements up to 50 tons are made, while accuracy levels of 0.01% are required. Power sources up to 250,000 horsepower are needed to turn fans up to 50 feet in diameter. Commonly used working fluids include air, nitrogen, helium, and freon. From these alternatives, the Boeing aerodynamic laboratory has been developed to accommodate the company's specific goals.

We're organized to efficiently support airplane development

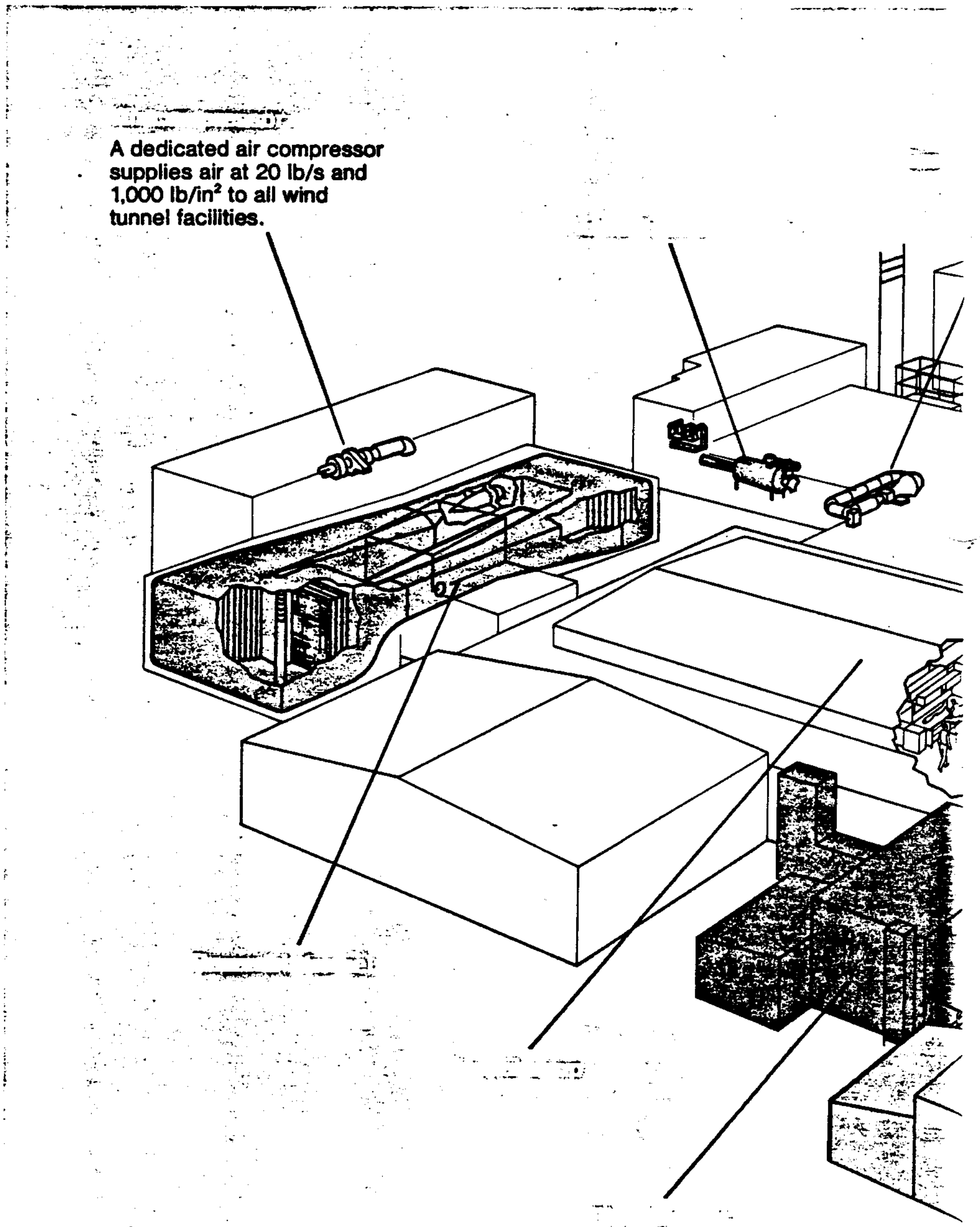
This integrated facility includes several wind tunnels, a large model shop, and a data gathering and design team complex; thus, the craftsmen who build the models work closely with the engineers who design the models and conduct the tests. Most important, the engineers developing the full-scale design have convenient access to all these experts involved in experimental testing.

One of the outstanding features of this integrated and carefully managed complex is the ability to initiate tests and acquire data more quickly than at most similar facilities. This rapid tempo allows designers to investigate more ideas in a given time during critical phases of development.

As airplane performance becomes more critical, wind tunnel testing requirements increase.



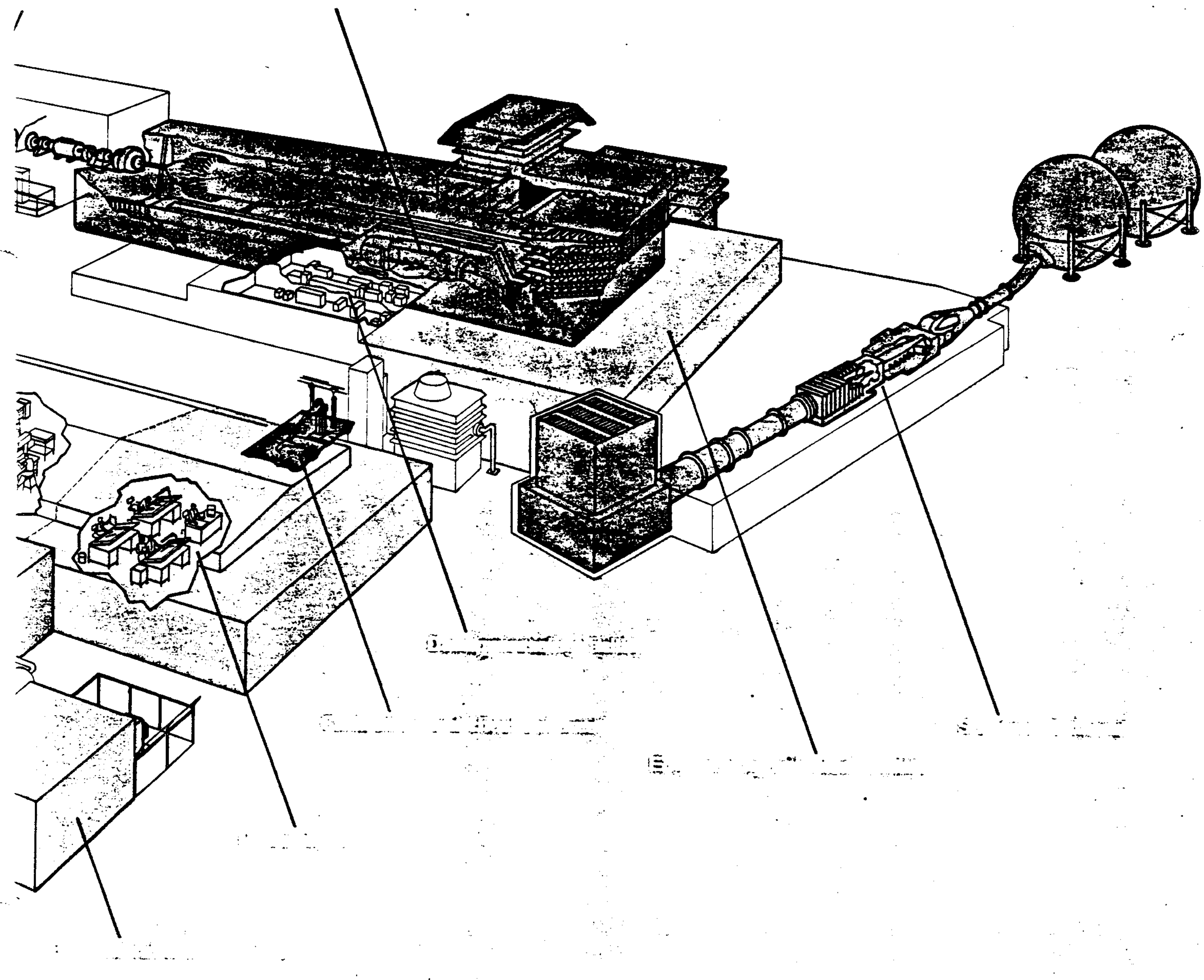
Additional testing was conducted after the first flight of each airplane to support product improvement efforts.



For the past 15 years the wind tunnel laboratories have averaged 11,000 test hours per year. About half of this testing was accomplished in the transonic tunnel.

The chief engineer of the aerodynamics laboratory oversees this complex operation. Reporting to him are several groups that function as a team to plan and schedule wind tunnel activities, design models and equipment, conduct tests, operate and maintain the facilities, perform research and development activities, and manage data computations.

Four supporting organizations permanently assigned to the laboratory provide computer management, programming and operations support, instrumentation services, photographic coverage, and model and equipment fabrication.



About half our tests occur in the transonic tunnel

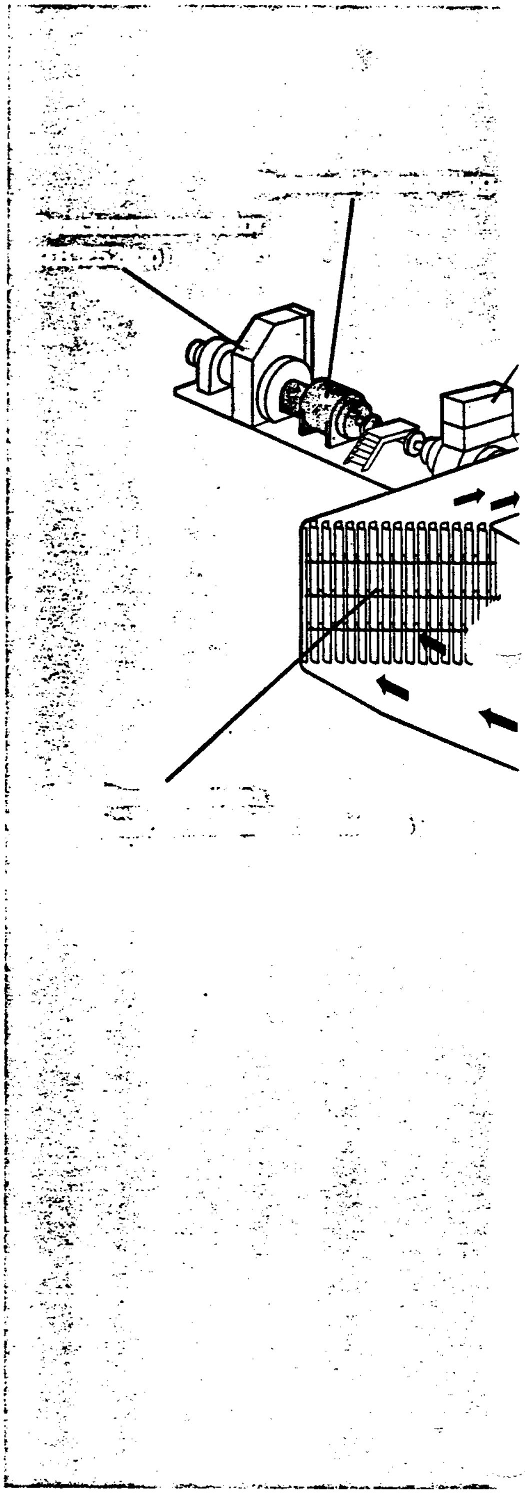
The Boeing transonic wind tunnel is a closed-circuit, single-return system that is vented to the atmosphere at the air exchanger. The normal continuous-flow operating range is from mach 0.3 to 1.1, but tests can be run at lower speeds. Its 8- by 12-foot test section provides the capacity to test a wide range of models, and the operating controls and data gathering equipment are located nearby.

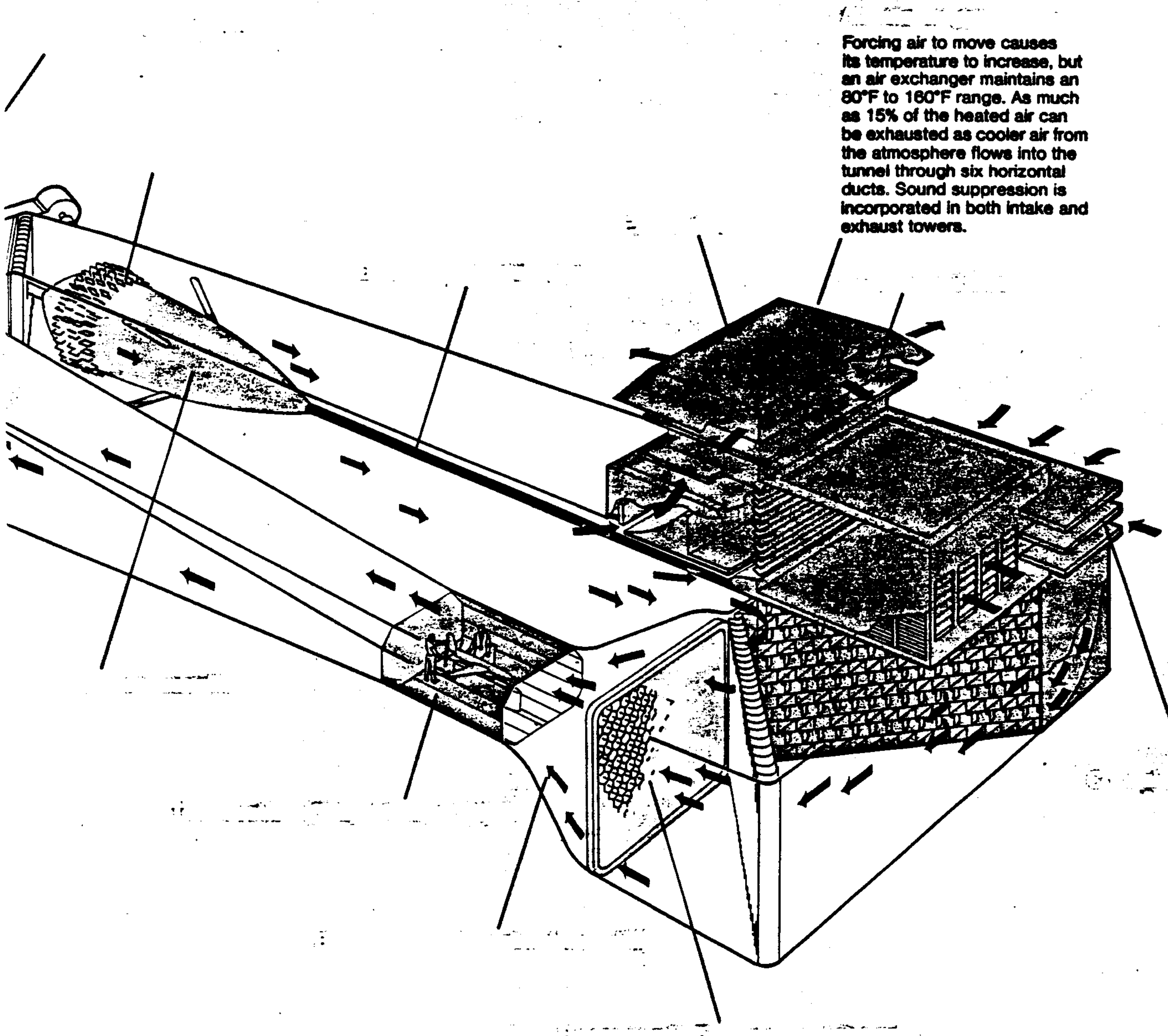
Power source

A two-stage fan with intermediate and downstream stators moves the air in the tunnel. This fan acts as a huge axial-flow compressor, much like a jet engine compressor.

The two fan stages each have 36 fixed-pitch rotor blades mounted on a hub 18 feet in diameter. Airflow is guided between the two fan stages by 33 stator blades cantilevered from the wind tunnel walls, while the 34 downstream stators are designed to remove the rotational velocity from the airstream. There is a 1:1.2 pressure ratio across the fan with a mass airflow equivalent to 4,000 pounds per second at a maximum speed of 480 rpm. A nacelle downstream from the fan distributes the airflow through the larger cross section of the tunnel. The fan is powered by a pair of electric motors providing about 54,000 horsepower.

This downstream nacelle fairing on the two-stage fan helps distribute airflow.




Forcing air to move causes its temperature to increase, but an air exchanger maintains an 80°F to 160°F range. As much as 15% of the heated air can be exhausted as cooler air from the atmosphere flows into the tunnel through six horizontal ducts. Sound suppression is incorporated in both intake and exhaust towers.

Slotted test-section walls provide versatility

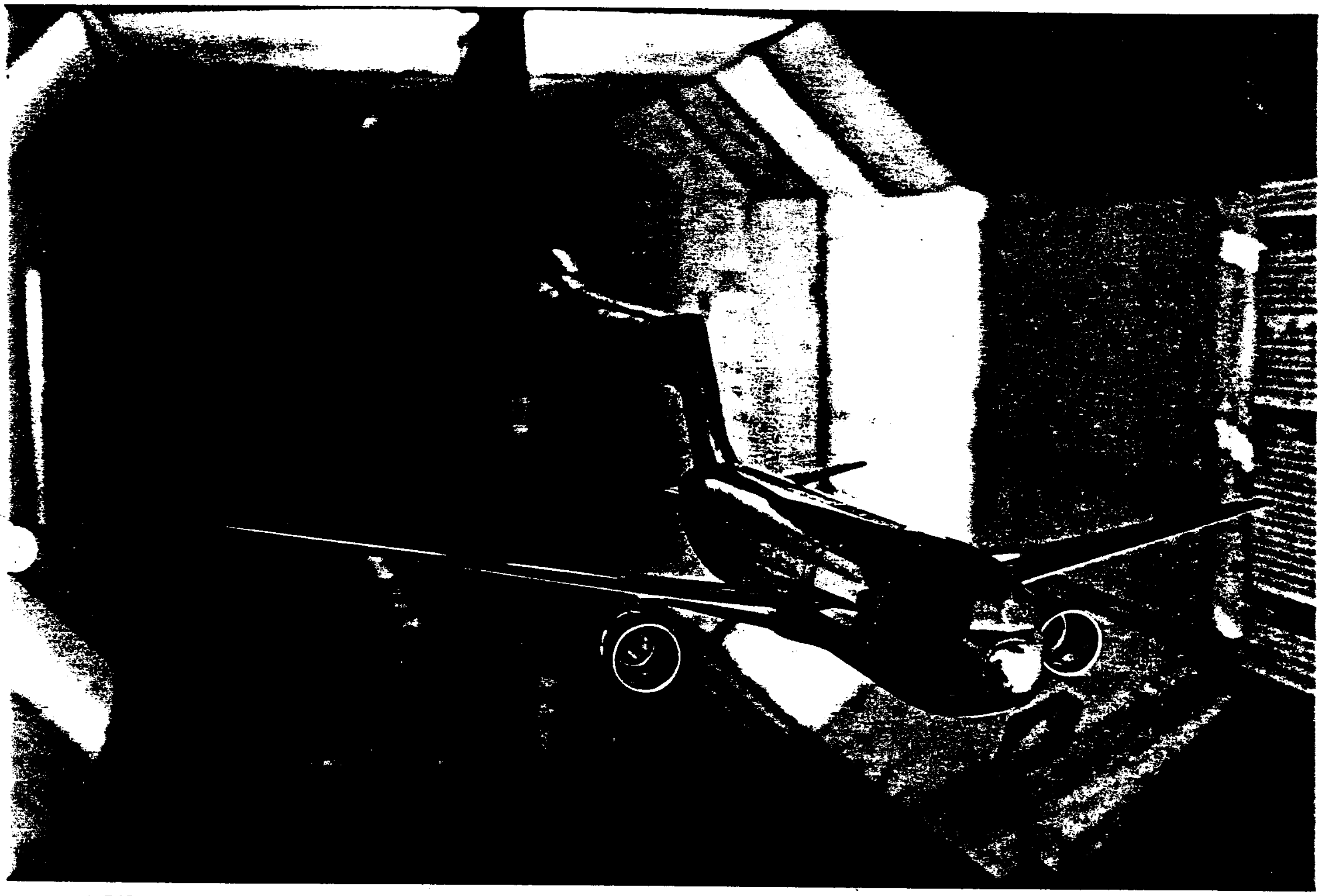
Test section

The four "walls" of the transonic tunnel test section incorporate contoured slots that perform two related functions. They make testing large models at high subsonic speeds (mach 0.95 to 0.99) possible, and they permit tunnel airspeeds to be greater than mach 1.0.

When tunnel air velocity approaches the speed of sound (mach 1.0), local areas of supersonic flow occur around most models and shock wave disturbances create blockage to the flow of air. This blockage causes the air to curve away from and around the model. Solid test-section walls constrict this curvature of the air and block the tunnel from further increase of airspeed. Vented tunnel walls allow the air to curve (expand) through the walls and eliminate velocity-limiting blockage.

When the entire airflow reaches mach 1.0, a shock wave is formed at the beginning of the test section. Unless the test-section volume is allowed to increase, air velocities greater than mach 1.0 cannot be achieved, regardless of the amount of power delivered to the tunnel fan. The vented walls allow the test-section air to expand into a plenum chamber and permit speeds greater than mach 1.0. The plenum chamber airflow re-enters the main tunnel airstream through adjustable doors at the rear of the test section.

Contoured slots in the test-section walls permit transonic flow.



A 767 model mounted to the vertical strut using a strut sting mount.

Sting mount

In the reentry section of the tunnel, there is a permanent vertical strut from which a cantilevered mount called a sting points upstream. Models are mounted on the tip of the sting, and because the airflow encounters the model before the mount, there is minimum interference from the mount. The sting can be positioned by remote control to any angle of attack between ±16 degrees and can be rotated about its axis to combine pitch and yaw. For tests requiring very high angles of attack, a "dog-leg" adapter is used. The virtual center of rotation may be adjusted to any of 11 longitudinal positions along the tunnel centerline. The models, constructed almost entirely of metal to withstand the high loads, may be full configurations or individual components of the aircraft.

The sting carries instrumentation cables to control model components and to allow readout of pressure, force, and temperature data. Data are sensed by pressure transducers, strain gage balances, and thermocouples inside the model.

Plate mount

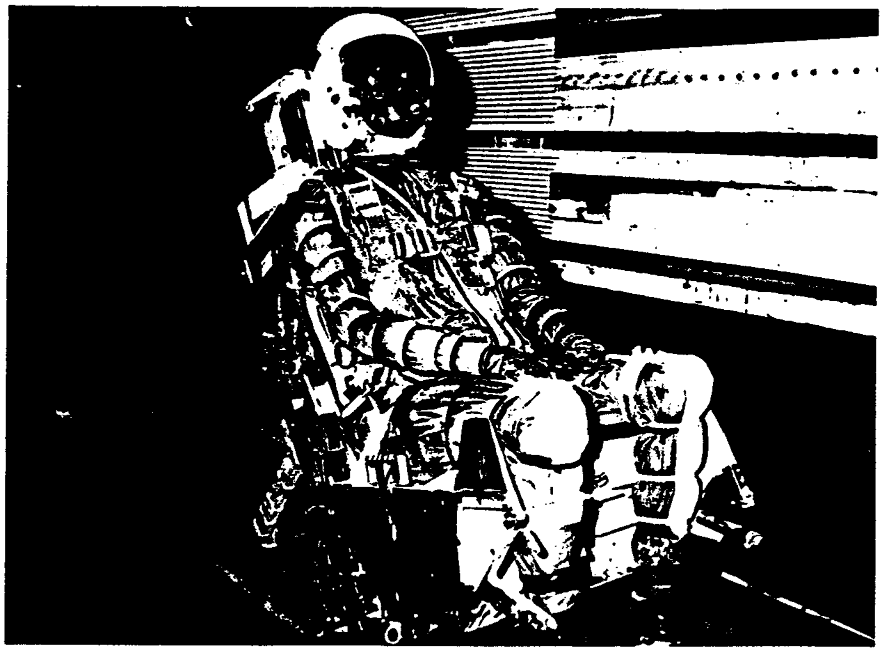
The model can be mounted on a vertical steel plate that is connected to an external balance beneath the test section. This mount is used most often to develop the cruise configuration of an airplane. The external balance is very accurate and the plate mount holds the model rigidly even when the flow is highly separated.

Floor mount

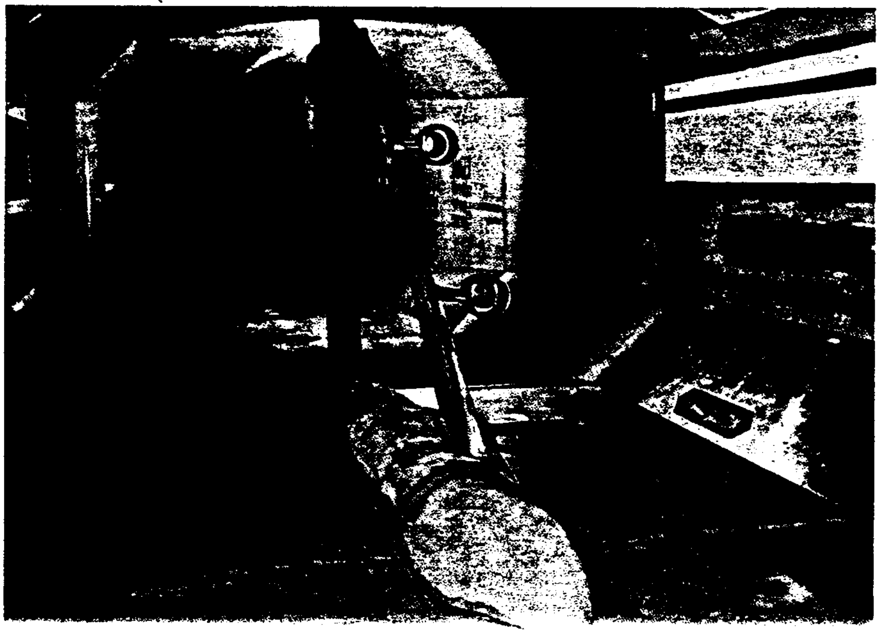
Half-models, split on the vertical centerline of the airplane, sometimes are tested. This allows reduced model costs, increased effective model size, and simplified instrumentation. To avoid the boundary layer at the test-section wall, a reflector (splitter) plate is used to space the model away from the floor. These models normally are mounted on the external balance under the test-section floor. Two-dimensional airfoil testing uses the reflector plate for one wall and a circular endplate (attached to the airfoil) for the opposite wall. In this specialized testing, the main balance is not used and all data are obtained by measuring model surface pressures and wake surveys.

The plate mount uses the main balance under the test section.

High-speed evaluation of a helmet configuration.



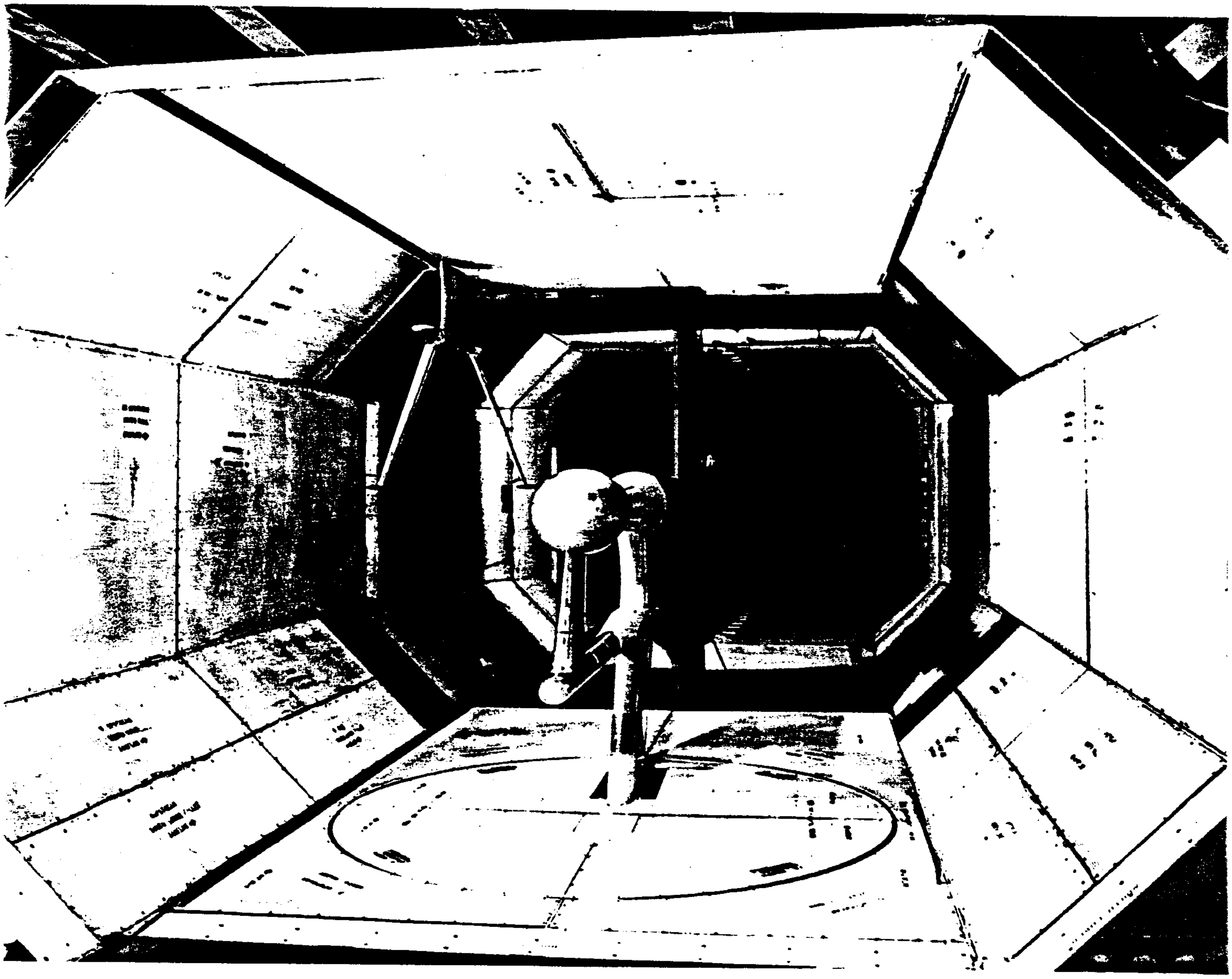
The floor mount often is used to test half-models.



Boeing acoustic test section

To meet requirements for acoustic testing at transonic speeds, an interchangeable test section was developed for the Boeing transonic wind tunnel. The normal slotted walls in the test section are replaced with "soft," acoustically treated walls. These walls absorb, rather than reflect, noise from a test model in the airstream. The use of these walls allows the testing of advanced propfan simulators up to mach numbers of .83.

A propulsion simulation unit mounted in the 8-foot by 12-foot acoustic test section.

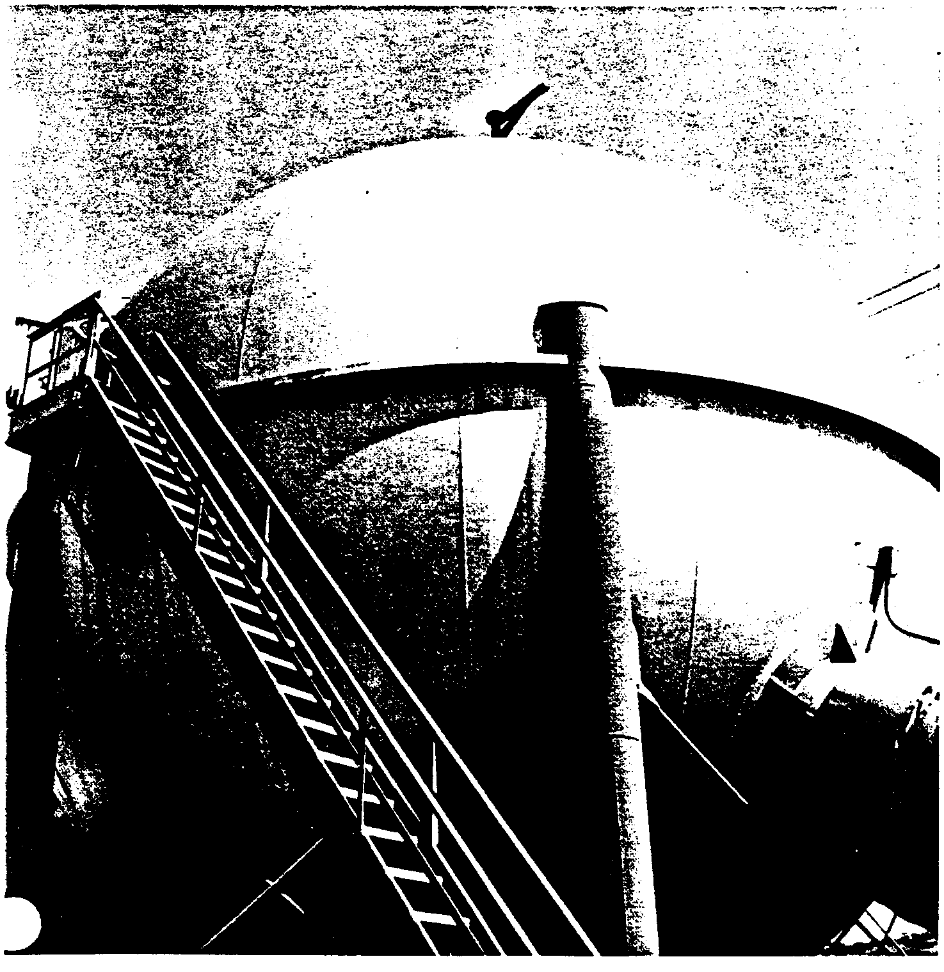


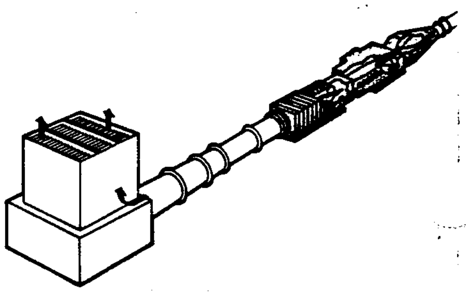
The supersonic tunnel operates at speeds to mach 4.0

The Boeing supersonic wind tunnel —an intermittent operation blowdown facility— uses the potential energy in a supply of compressed air as its power source.

During the blowdown period, the air flows through a hydraulically operated plug valve that maintains a constant pressure in the settling chamber as the pressure in the spheres decreases. When the pressure reaches a cer-

Two 38-ft-diameter spheres store 55,000 ft³ of air for the supersonic tunnel.



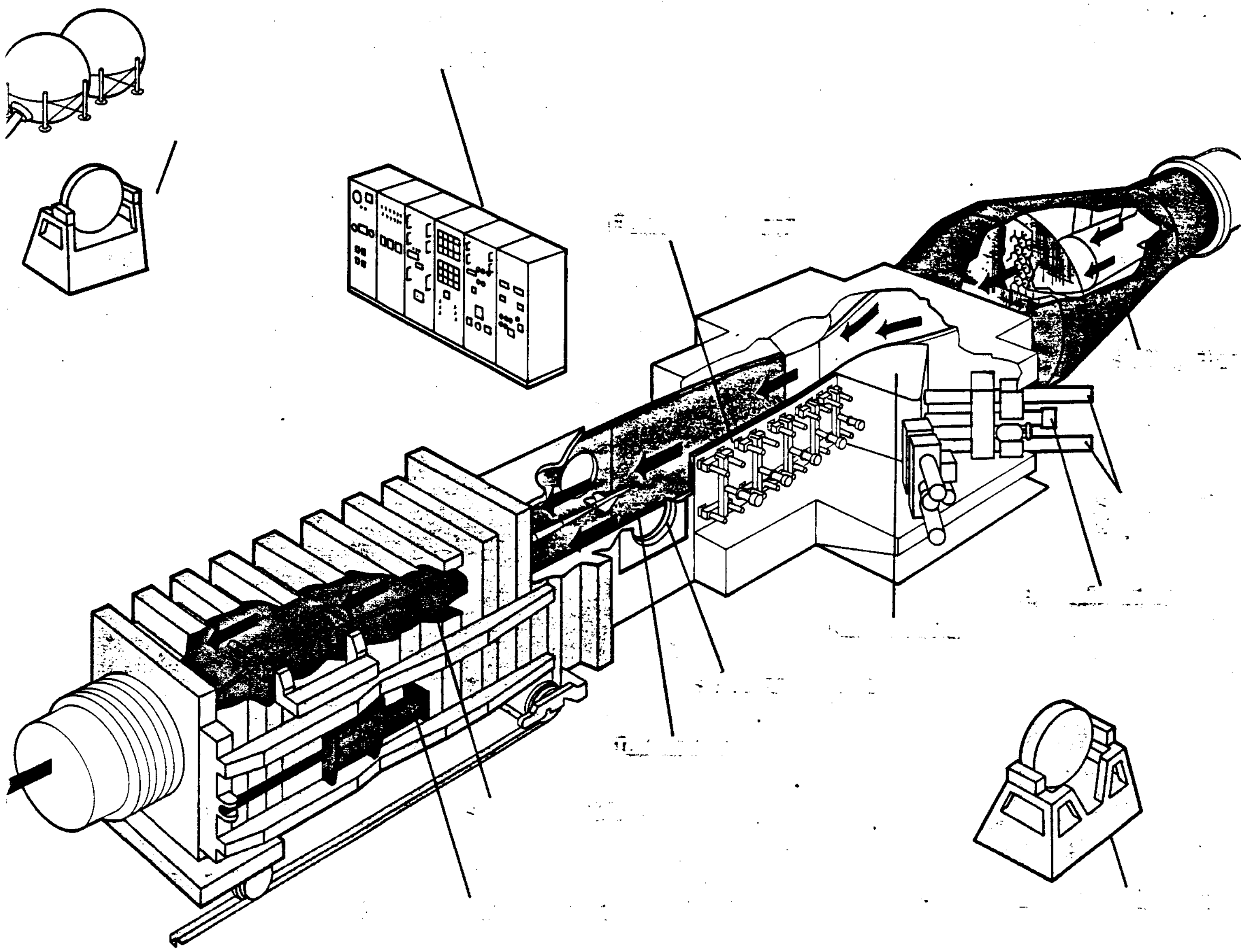


tain minimum, the test run ends. A typical run for force data takes 5 to 35 seconds and, during this time, tunnel flow, model position, and data acquisition are controlled automatically. The normal operating range is mach 1.2 to 4.0, with dynamic pressures of 1,200 to 3,200 pounds per square foot.

Air supply

The 1,000-pounds-per-square-inch aerodynamics laboratory compressor and the 150-pounds-per-square-inch supersonic tunnel compressor supply the high-pressure air. The compressed air is stored in two 38-foot spheres with a total capacity of 55,000 cubic feet. Each sphere is filled with approximately 130 tons of open-ended tin cans that serve as heat accumulators. During discharge, when expanding air normally would cool rapidly, the cans add heat to maintain the blowdown process at nearly constant temperature.

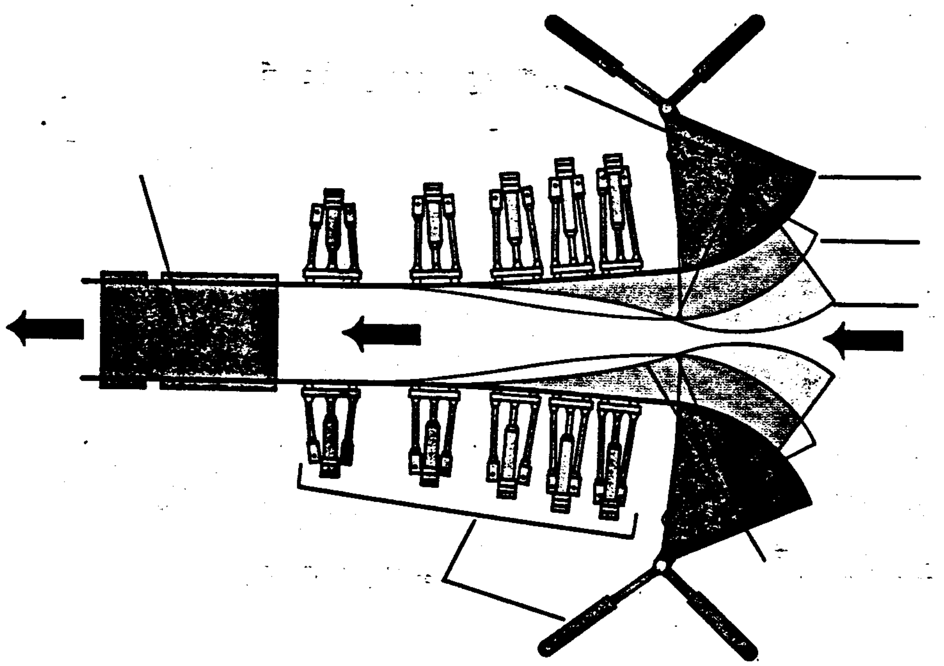
The storage spheres are recharged after each run. With both compressors supplying air, normal recharging time is occupied with model and tunnel changes, which makes an intermittent operation tunnel design practical.



The nozzle controls airspeed

Flow formation

A convergent-divergent nozzle (built of flexible steel plates 15 feet long, 4 feet high, and 1 inch thick) accelerates the airstream in the tunnel to supersonic speeds. Ten hydraulic actuators adjust the plates to the calculated contour for each desired velocity from mach 1.2 to 4.0. Changing the nozzle contour for a different mach number requires 5 to 10 minutes.



This nozzle includes two unusual features:

1.
The forward edge of each flexible plate is faired into an adjustable circular arc sector that forms the throat of the nozzle for velocities above mach 2.5. This combination sector/flexible plate design shortens the nozzle and reduces the number of hydraulic actuators needed for adjustments.

2.
The flexible plates form the sidewalls of the nozzle, rather than the floor and ceiling. This simplifies maintenance on the nozzle and actuation equipment.

The 4- by 4-foot test section offers several refinements

Test section

The test section is 4 feet square. The separation of its sidewalls can be varied to compensate for boundary layer growth, providing a more uniform velocity throughout the section. Two 30-inch disks, called proximity plates, can be extended from the floor and the ceiling to positions just above and below the model. These plates shelter both the model and balance from the severe force of the starting and stopping shock wave pattern; they are withdrawn into recessed cavities while data are taken. A system that replaces one sidewall window allows insertion of half-models into the test section after supersonic flow has been established.

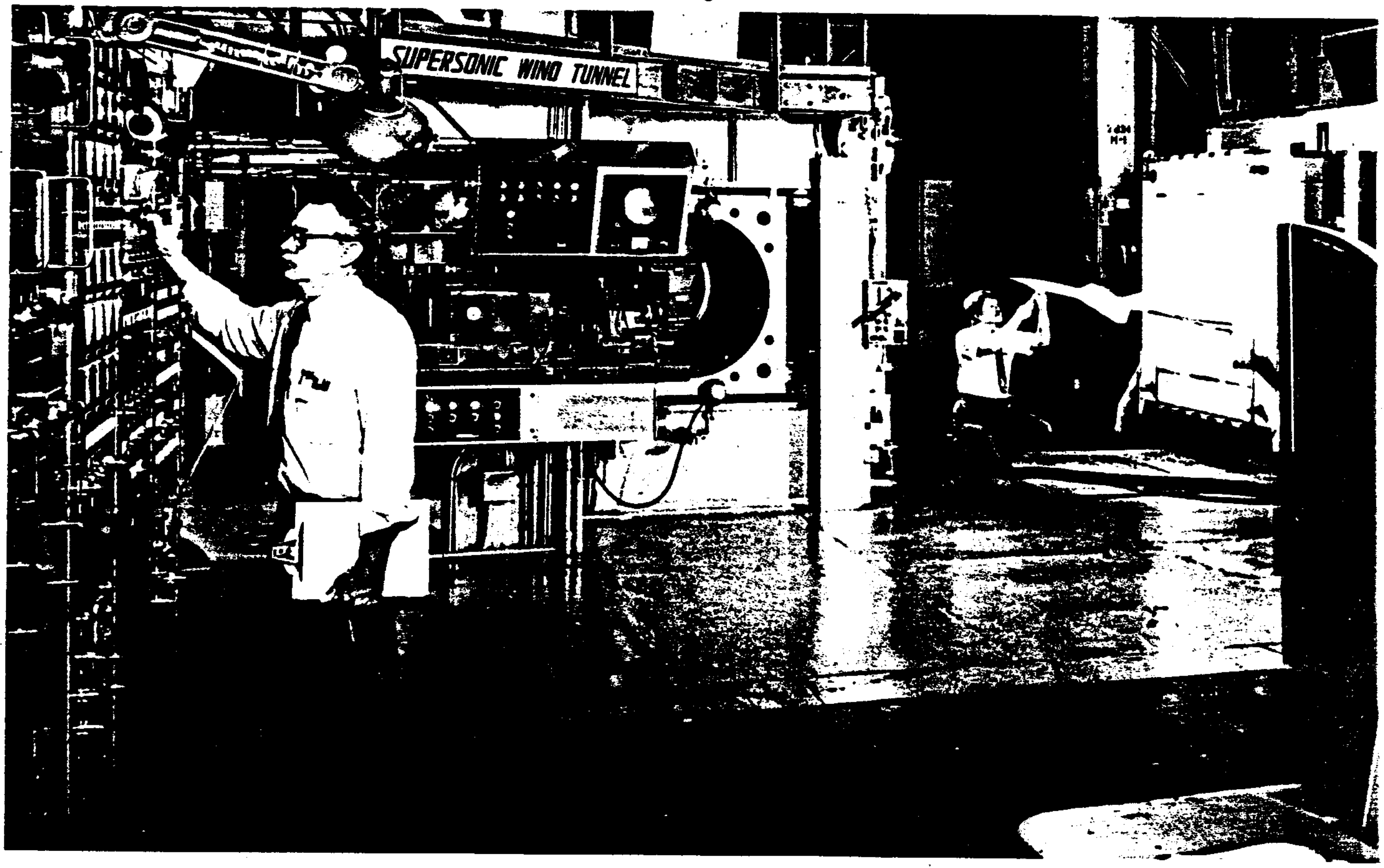
An insert with a 1- by 3-foot ventilated test section can be secured within the test section. It offers two-dimensional testing of airfoils at a mach range from 0.2 to 1.25 with variable stagnation pressure of 25 to 75 pounds per square inch and Reynolds numbers up to 12,000,000 based on a 6-inch-chord airfoil.

Diffuser system

Just behind the test section, a variable-area supersonic diffuser efficiently reduces the air velocity to near sonic speed. After leaving the supersonic diffuser, the air is further slowed by gradual expansion in a subsonic diffuser before it is returned to the atmosphere through a sound-absorbing exhaust tower.

The supersonic diffuser section can be drawn back 10 feet to withdraw the model from the test section and provide access to the tunnel.

The supersonic tunnel test area with the diffuser section drawn back to give access to the model.

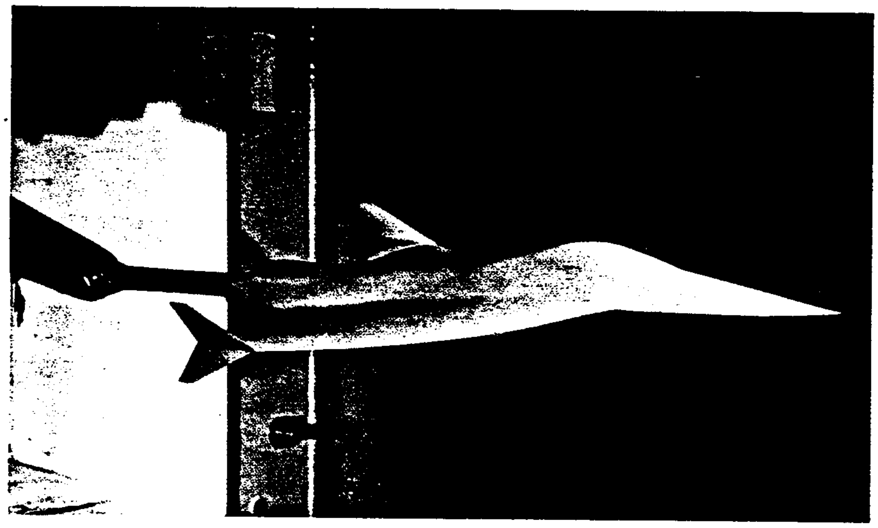


Models and mounting

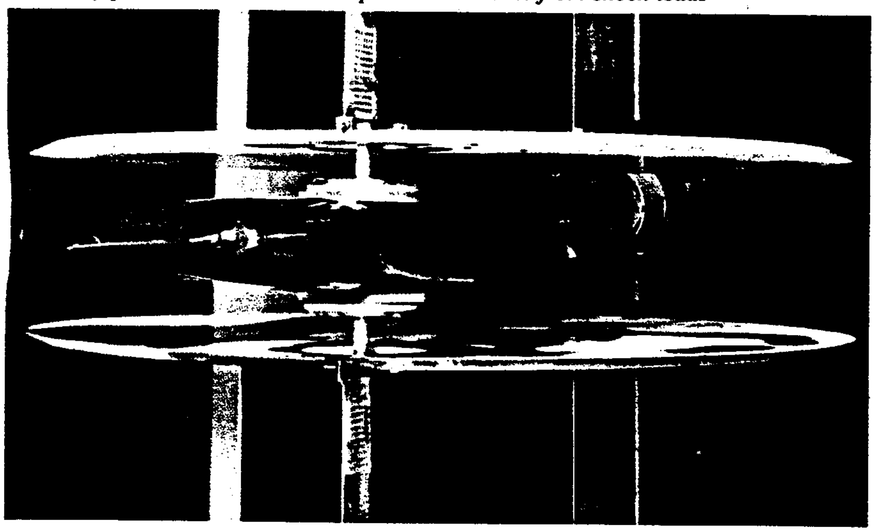
Models are mounted on a sting or on a strut attached to the wall or floor. The sting is attached to a vertical strut that spans the tunnel. Automatic controls for the strut hydraulic actuator can be set (1) to rotate the model continuously at any desired rate up to 20 degrees per second, (2) to rotate through a set angle range with a momentary pause at desired angles, (3) to rotate to a specified angle and return to zero after a set time delay, or (4) to move the model vertically without rotation.

Force models, pressure models, models with ignited rockets or engine inlets, airfoil flutter models, and models of component parts can be tested. Of these, the engine inlet usually is the most complex, for it combines the difficulties of multiple pressure orifices with the problems of movable model parts, the positions of which must be remotely controlled within very narrow tolerances.

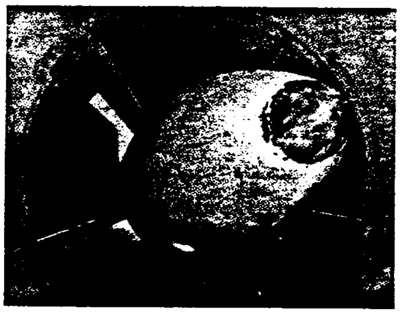
Sting-mounted model.



Proximity plates and minisnubbers protect the model from shock loads



Our research tunnel supports airfoil and laminar flow studies

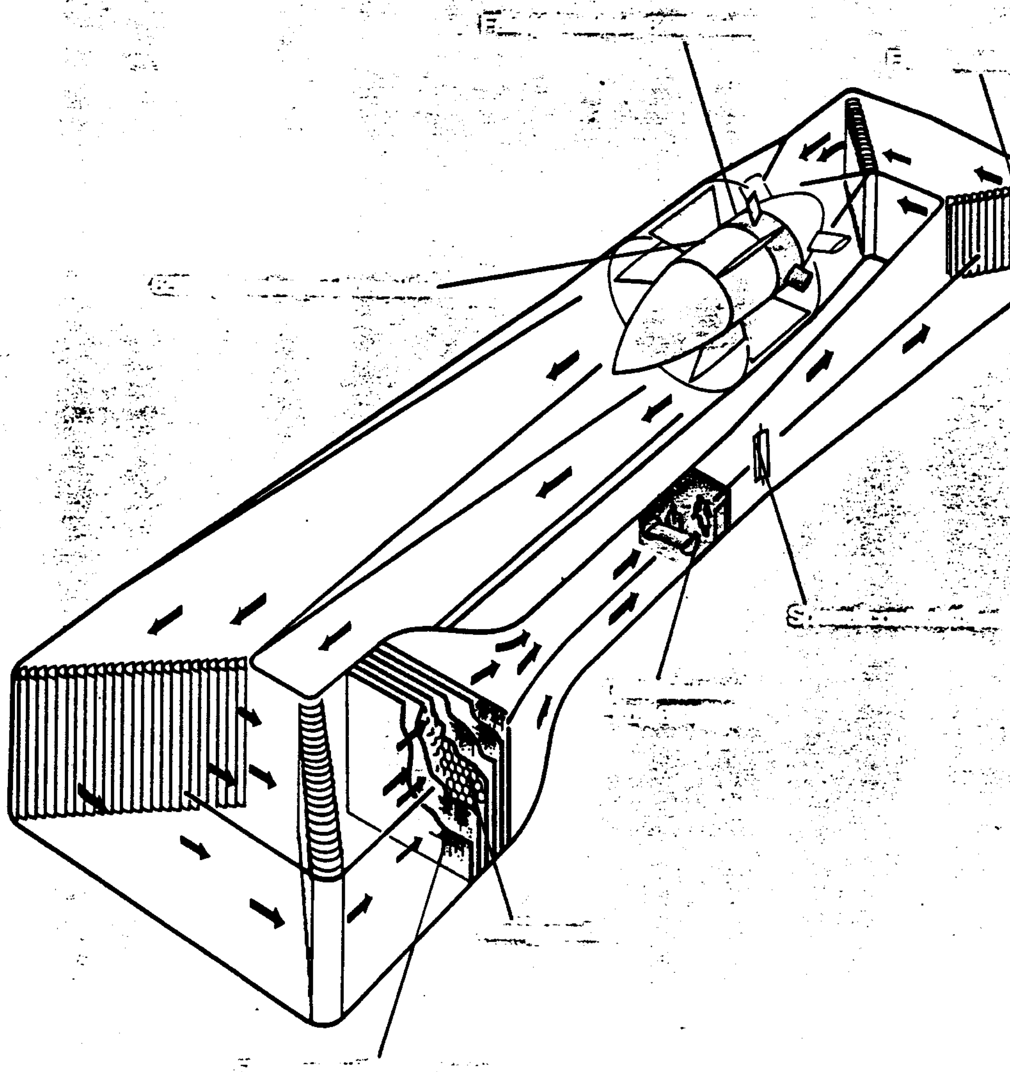


This nacelle houses the 650-hp motor that drives the research tunnel fan.

The Boeing research wind tunnel is a closed-circuit, single-return system. Its normal continuous flow operating range is from 0 to 140 mph, with a dynamic pressure range of 0 to 50 pounds per square foot. The 5- by 8-foot test section is used mainly for two-dimensional airfoil development, leading-and trailing-edge refinement, and jet engine simulator development. The tunnel's low turbulence level permits laminar flow research.

Power source

This tunnel is powered by a 650-horsepower induction motor driving the fan to a maximum of 840 rpm. The fan consists of four variable-pitch blades constructed of fiberglass and foam on a steel core. Each blade has a span of 3 feet with a chord of 1.5 feet. The nacelle that houses the electric motor is held in place by five flow straighteners and is located downstream of the fan.



Generic sting mounted model used for flow visualization research studies.

Typical half-model mounted to the tunnel side wall.

Test section

The test section is 8 feet high, 5 feet wide, and 20 feet long. Ventilation to the atmosphere is through 5-inch-wide slots in each wall at the downstream end of the test section. The boundary layer thickness is reduced by blowing through four slots built into each wall upstream of the test section.

Model mounting

Models can be mounted from both walls, one wall, the floor, on a single strut, or from a sting. Forces and moments for wall, floor, and strut mounted models are measured by an external balance mounted under the test section. Sting models are mounted on an internal balance. Two-dimensional models are mounted between two 36-inch-diameter turntables in the test-section walls. Three-dimensional half-models or strut models can be mounted from the turntables in the wall or on the floor. Like the transonic tunnel, the main balance of the research tunnel has a flexured-bellows air transmission system connected to the wind tunnel's 1,000-pound-per-square-inch air system. The air system is used for sidewall boundary layer control and for models using thrust simulation, powered lift, and laminar flow control.

Precise nacelle drag and engine thrust measurements are required

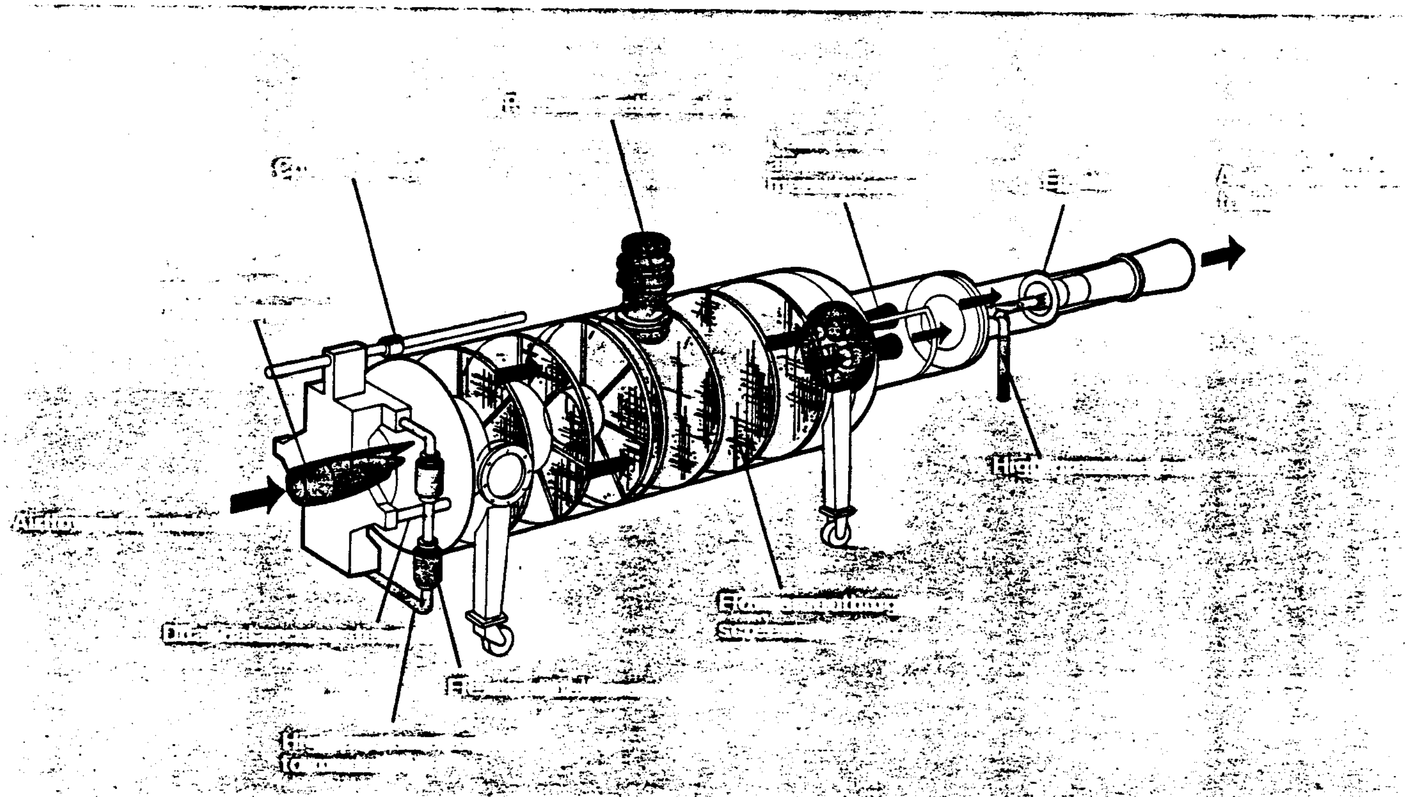
Accurately measuring airflow through ducts, nacelles, or scaled turbine engines has become increasingly important in wind tunnel testing, as has measuring the thrust associated with these components. Modern designs must integrate the propulsion system with the airframe to achieve maximum efficiency in the total airplane. Wind tunnel tests must measure effects that can only be determined by simulating thrust and inlet-exhaust flow characteristics of the propulsion system.

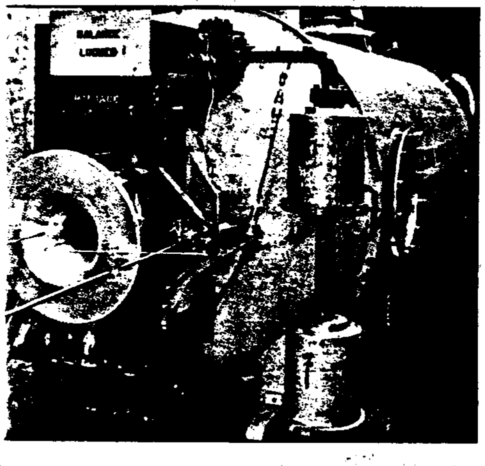
The airflow calibration facility provides these nacelle airflow calibrations and thrust measurements. There are three separate facilities: a nozzle calibration flow tube, a dual-balance thrust stand, and a flight simulation chamber.

In the nozzle calibration flow tube, metering devices are calibrated in series using a Boeing-designed multiple critical flow venturi system.

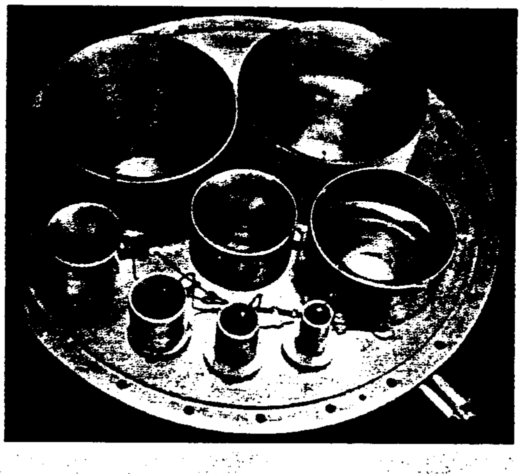
The dual-balance thrust stand provides static thrust calibrations of complete models or isolated parts. Entire wind tunnel models including turbopowered nacelles and blowing jet nacelle simulators can be installed on the stand, exhausting to atmospheric pressure.

The flight simulation chamber is equipped with its own dual-balance force measuring system. Here, model airflow exhausts to controlled pressures less than the surrounding atmosphere, allowing model-scale turbine engines to be calibrated at inlet-exhaust pressure ratios equivalent to the complete mach number range that the model will experience in the transonic tunnel. It also provides the unique capability of determining, experimentally, the internal drag of flowthrough nacelles.

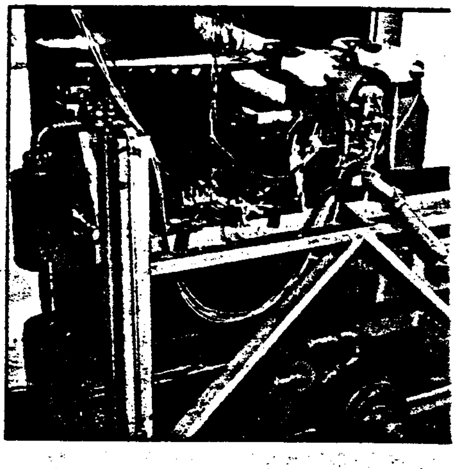




A flowthrough nacelle with bellmouth mounted on the flight simulation chamber balance system.



Critical flow nozzles measure airflow from the flight simulation chamber.



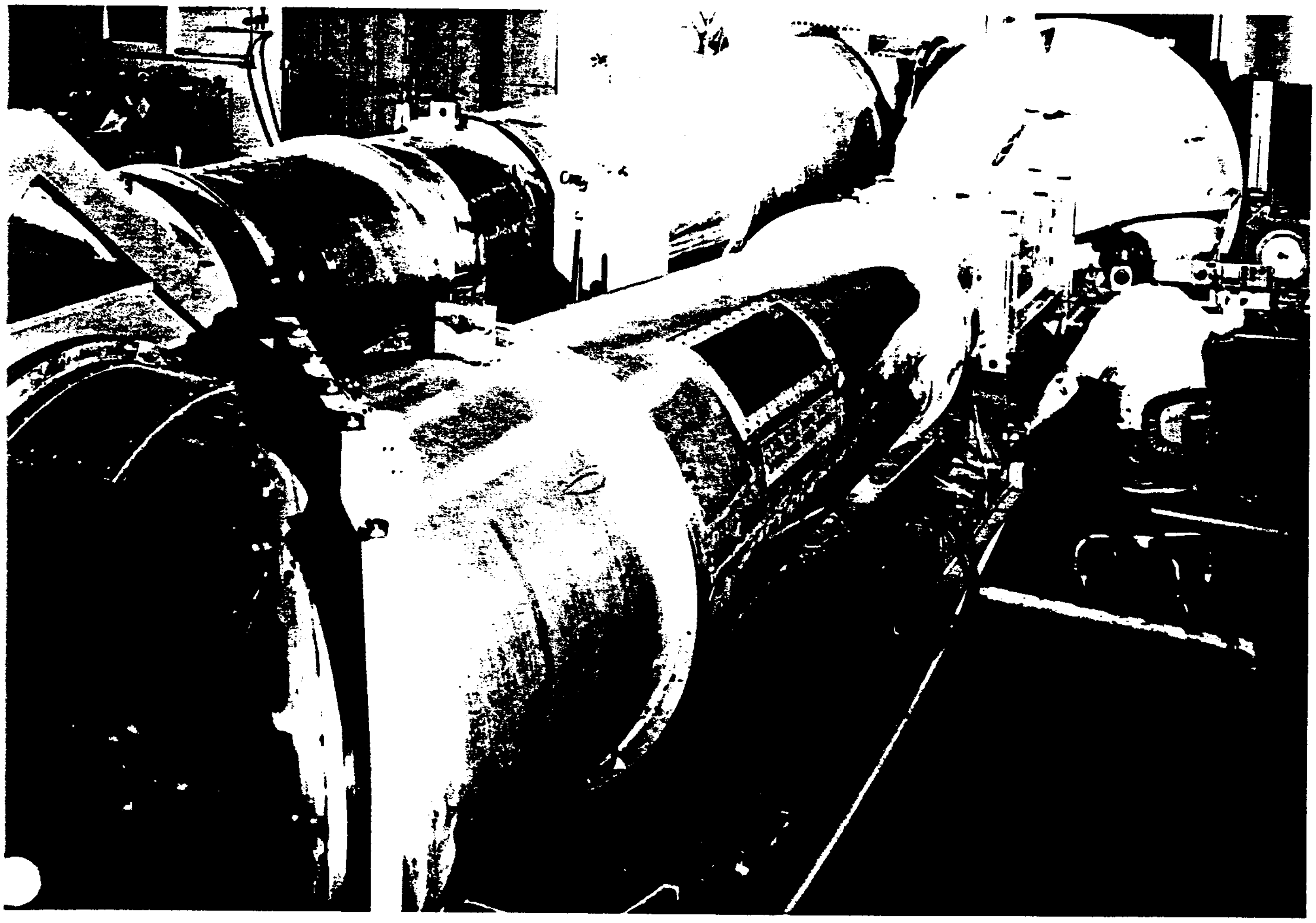
The dual-balance thrust stand calibrates air blowing models.

Our small tunnel develops wind velocities up to 345 mph

Small research wind tunnel

This tunnel is a closed-circuit, single-return system with a 14.4- by 18.3-inch test section vented to the atmosphere. A single-stage fan is driven by a 125-horsepower electric motor and can develop wind velocities up to 345 mph. The dynamic pressure varies from 0 to 300 pounds per square foot. The tunnel is used for calibrating aerodynamic probes, testing small models, and for small-scale research projects. The test section is 43 inches long and has acrylic sides and ceiling. One side swings down to provide access to the test section. The models can be mounted from the floor or from a strut that has a manual system for pitch. There is no external balance built into the system.

The small research tunnel features low turbulence.



Boeing water tunnel

The Boeing water tunnel was originally constructed for testing two-dimensional airfoils in pitching motion to investigate stall flutter. The maximum speed in the 4.5-by 12-inch test section is about 40 feet per second, though the occurrence of cavitation limits practical testing to about 20 feet per second. Recent work in the water tunnel has focused on vortex flows around highly swept half-model configurations at high angles of attack. Current plans include design and fabrication of a 12-by-14-inch test section to permit testing of larger models.

4.5-inch by 12-inch water tunnel.

"Pilot" tunnels duplicate larger versions

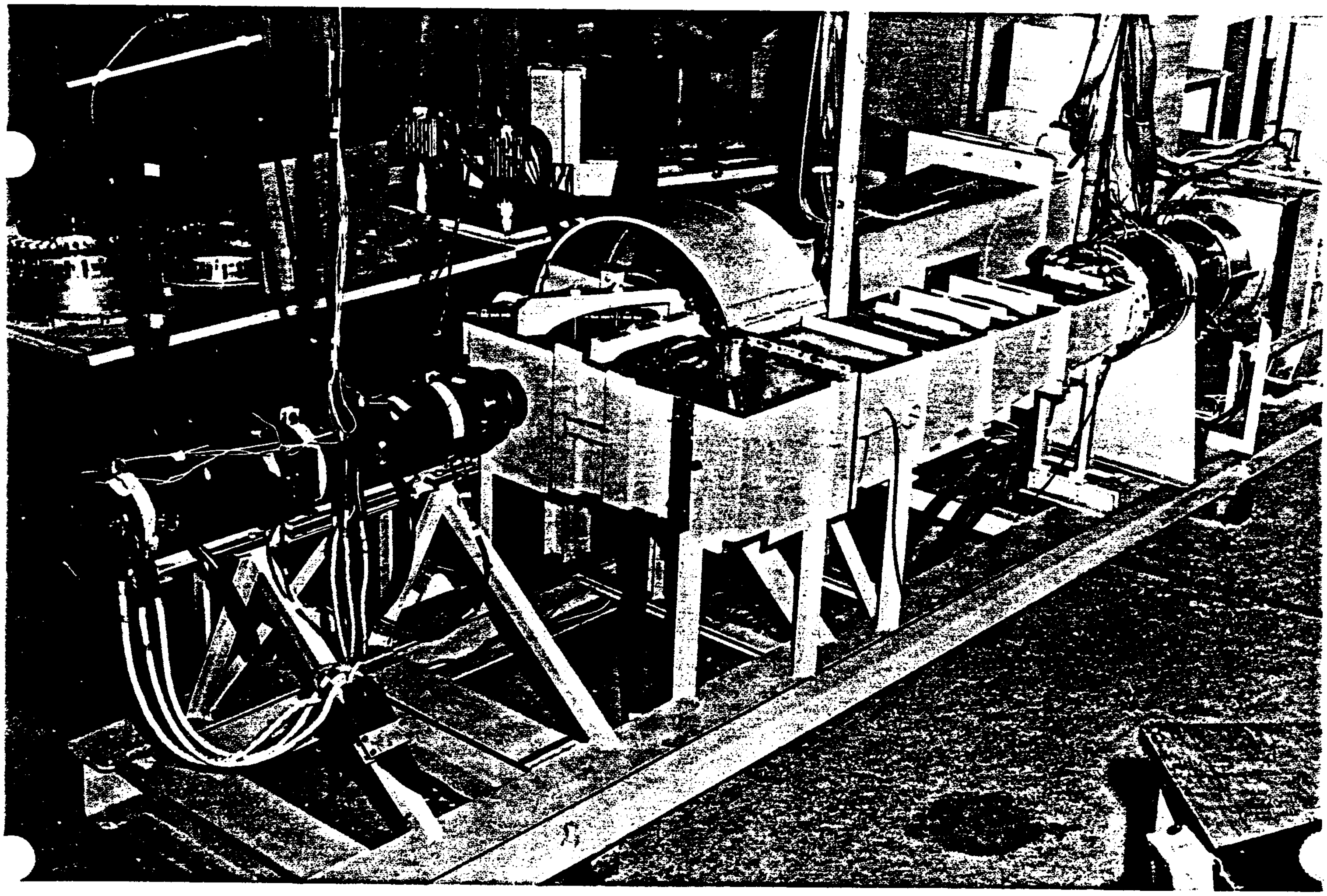
Pilot tunnels

There is a working-scale model, or "pilot" tunnel, for the transonic and supersonic tunnels. They are, respectively, 1/20 and 1/10 the size of the full-scale facilities. Originally built to help in the design of their full-scale counterparts, these small tunnels are used for tunnel-improvement studies and for tests that can be conducted with smaller models.

The pilot transonic tunnel was an integral part of the aerodynamic development of the full-scale facility conversion to transonic speeds in the early 1950s. Since then it has been used extensively for evaluations of full-scale tunnel modifications, circuit internal flow management and manipulation, test section wall slot development, and model mounting techniques unique to The Boeing Company. The facility has also been part of various aerodynamic research and development programs in aeroacoustics, surface boundary layer, and flow visualization.

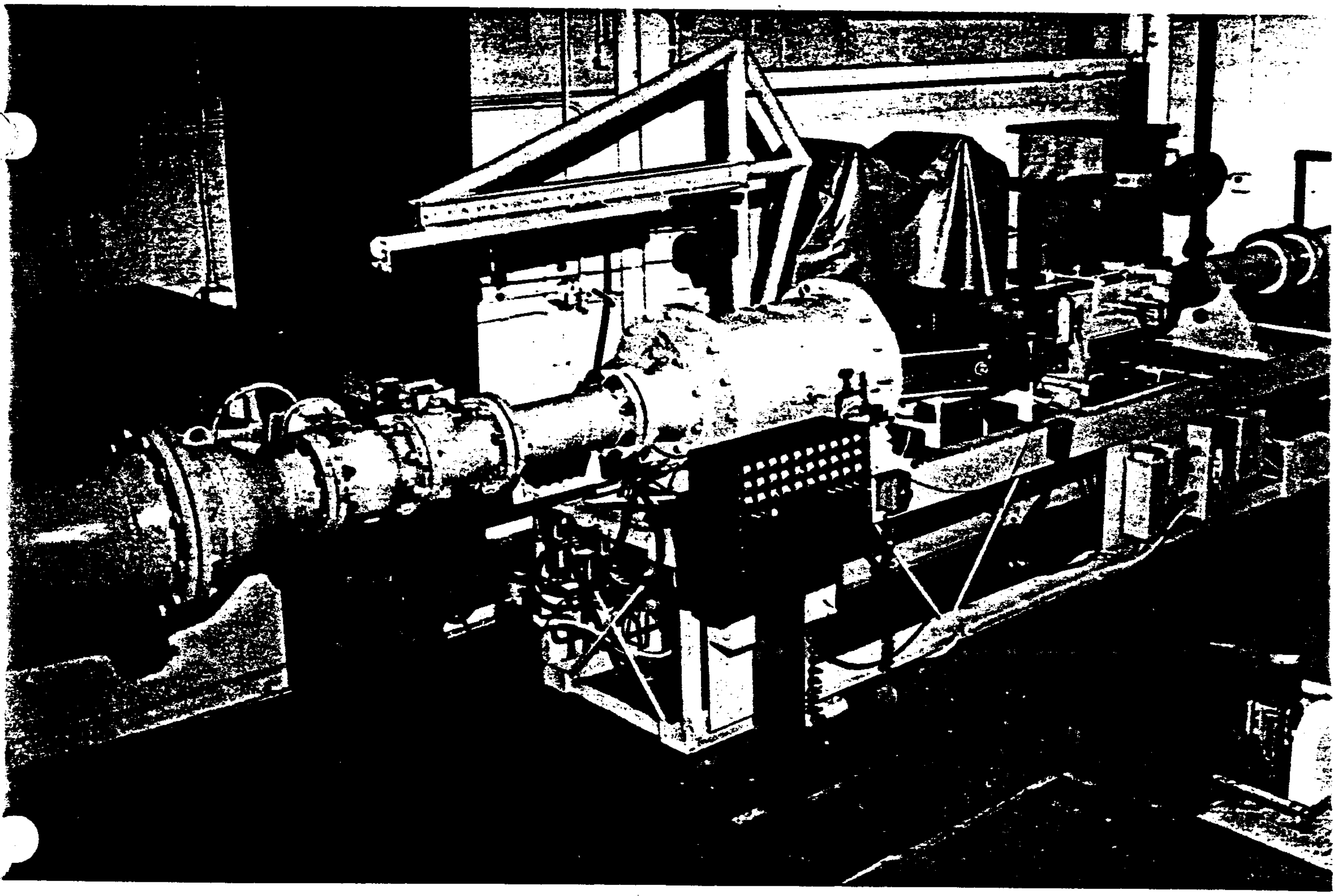
The pilot supersonic facility is the forerunner of the full scale 4-ft by 4-ft supersonic facility. Interior components, interior contours, and operational techniques were developed in this facility prior to construction of the full-scale facility. Modifications to increase tunnel efficiency such as the variable contour diffuser and model starting loads protection in the full-

Pilot model of the transonic tunnel.



scale facility were developed in this pilot facility. The pilot facility has been useful in the verification of full-scale tunnel performance with unusual or large models in the test section. Research studies on axisymmetric and two-dimensional supersonic inlets as well as supersonic loads studies on various vehicles have been conducted in this facility.

Pilot model of the supersonic tunnel.



Our data system features online displays of fully corrected data

The data analysis module offers computer techniques for looking at test data.

Data acquisition and processing

The central purpose of the wind tunnel facility is to acquire data on the forces, pressures, and temperatures acting on models in simulated flight. The aerodynamics laboratory data system, a test control, data acquisition, and computing complex, has been designed to meet the special needs of wind tunnel testing. The data system is composed of several integrated modules.

The test control and acquisition module contains hardware and software needed to condition input signals; to record, store, and display real-time data; and to transmit a copy of these data to the central data base.

The standard data module gives the user the quick access to data needed during a test. It produces fully annotated final data plots on three graphics scope displays and on an electrostatic printer-plotter immediately after a run.

The standard data module rapidly provides graphic or tabular displays of final data.

The system management module provides the shared central services needed to operate all the modules.

The test control and acquisition module controls the data acquisition process.

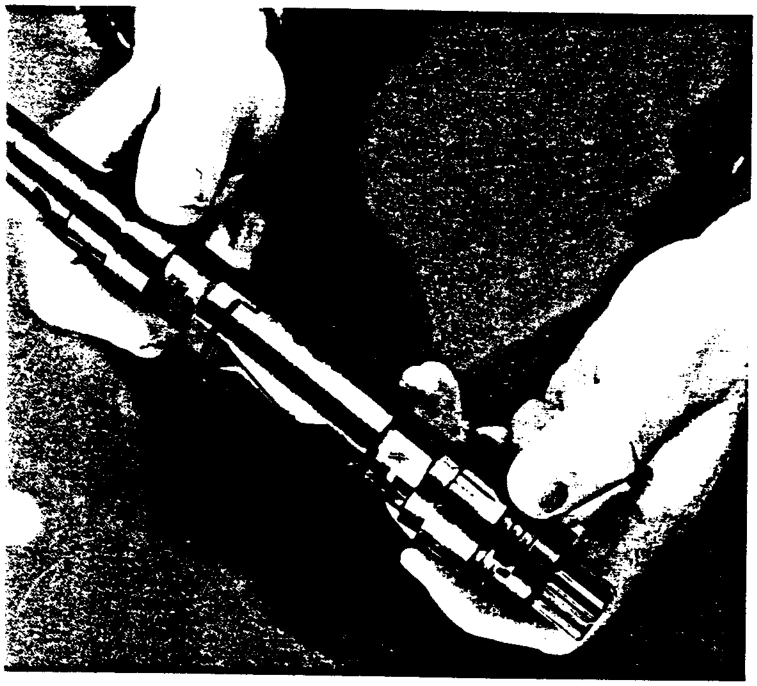
The data analysis module offers access to all current data files. Although it analyzes these data along traditional lines, the process is expedited by the power and speed of interactive computing.

Acting together, these three modules form the basis for data systems for the entire facility. One set of these three modules is dedicated to the transonic tunnel, while a centrally located set supports the operation of the other facilities.

The system management module permits shared use of central services including data base management, batch data computation, tabulation, plotting, and timeshared interactive processing from the various wind tunnel terminals.

Appropriate modules can be isolated and secured for classified testing.

We've developed precise instruments for gathering test data



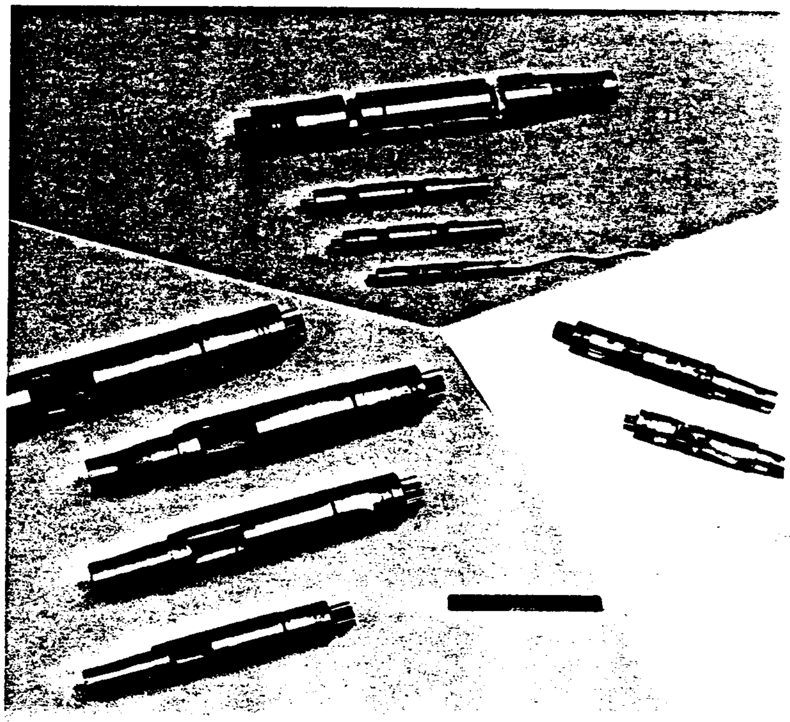
Six-component, one-piece, internal strain gage balance.

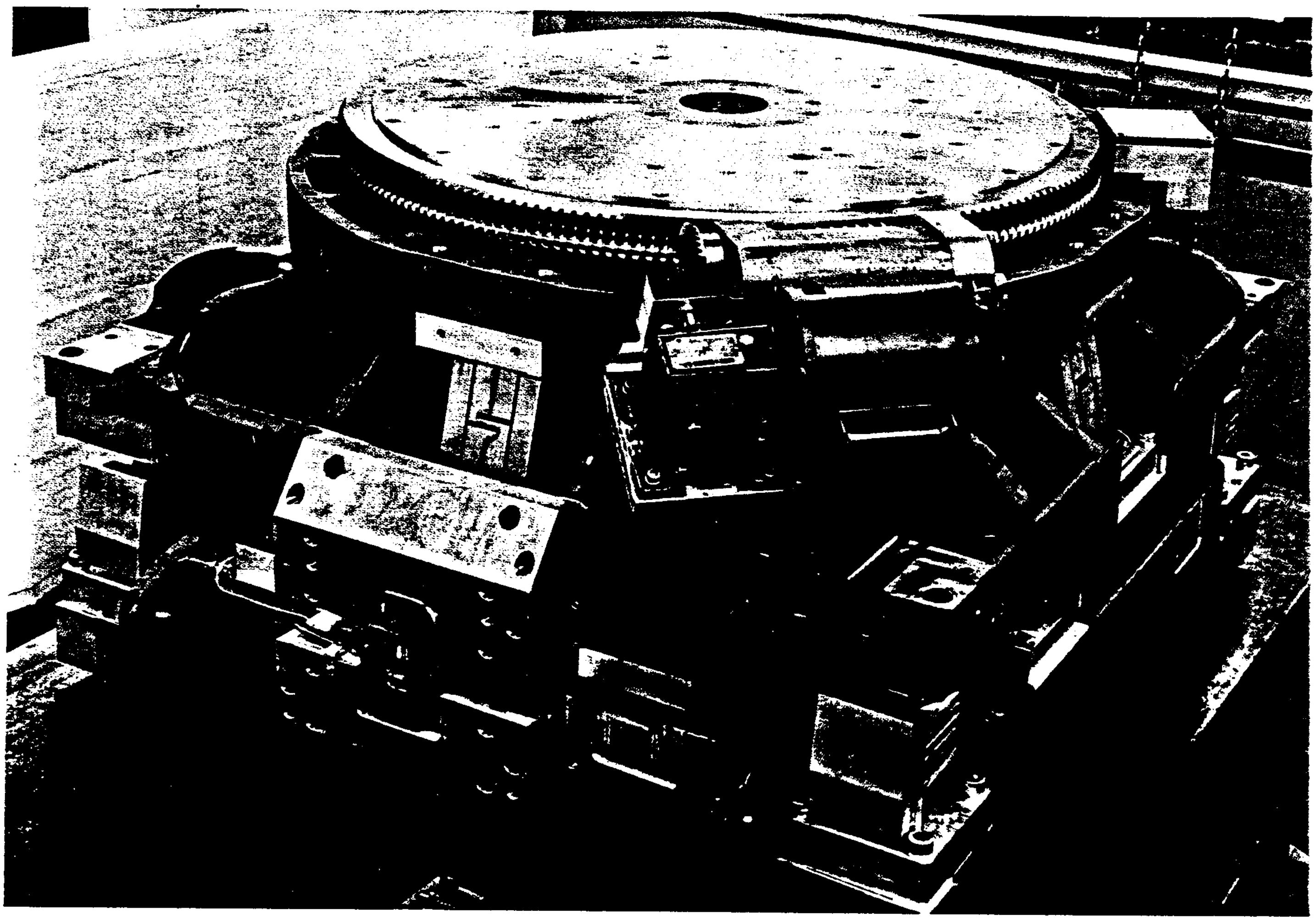
Force and temperature measurements

For more than 35 years, the Boeing aerodynamics laboratory has provided inhouse design, construction, and calibration of sophisticated force instrumentation equipment. A specialized machine shop and strain gage installation laboratory manufacture the complex components required by external and internal multi-component balances.

A wide range of balances has been built to meet the demands of Boeing's various facilities. The inventory of Boeing-designed and fabricated force transducers includes 7 external balances that incorporate the capacity to transmit high-pressure air to models, 170 one-piece, six-component internal

A family of balances to fit various models.





External six-component balance.

(sting) balances, and many specialized balances to measure control-surface forces and structural force components. Fabricating an internal balance from one piece of material minimizes random errors and increases its lift expectancy. A total of 27 of the internal balances incorporate integral water-cooling ducts and reservoirs, 21 incorporate the capacity to transmit high-pressure air to models, and 6 incorporate the capability of force measurement while rotating up to 20,000 rpm.

Most heat-transfer measurements are made with thermocouples, thermistors, platinum resistance temperature sensors, and nickel foil resistance thermometer strain gages. Models utilizing blown nacelles or turbo-powered simulators require up to 50 temperature and 30 pressure measurements per engine.

Dynamics testing measurements

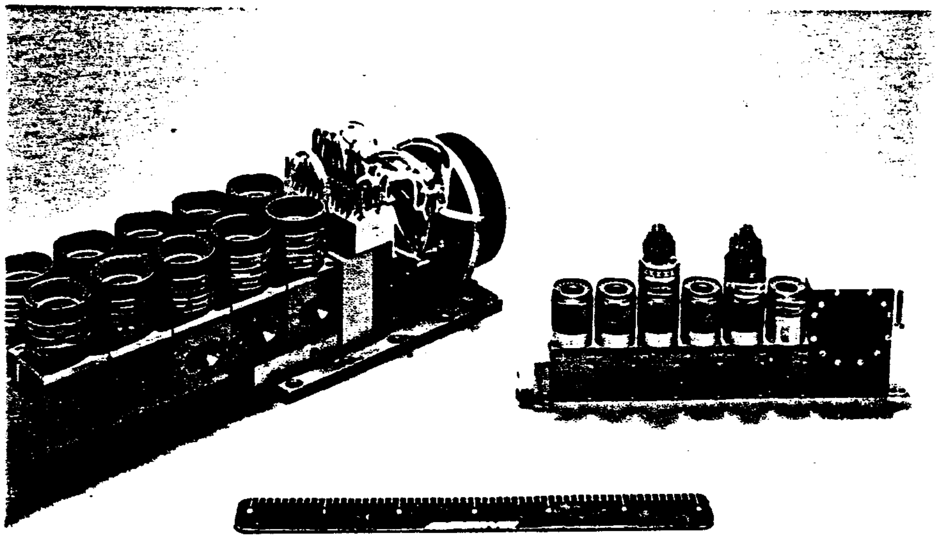
Measuring unsteady or oscillating data such as stall buffet, aircraft flutter, and wake turbulence is a common requirement at the Boeing aerodynamics laboratory.

Complete instrumentation and analysis facilities are available for online and final computing and plotting of the root-mean-square values of oscillating phenomena and the power spectral density for frequency and amplitude analysis. Online analog analysis and control for stability testing at specified airplane trim conditions also are performed.

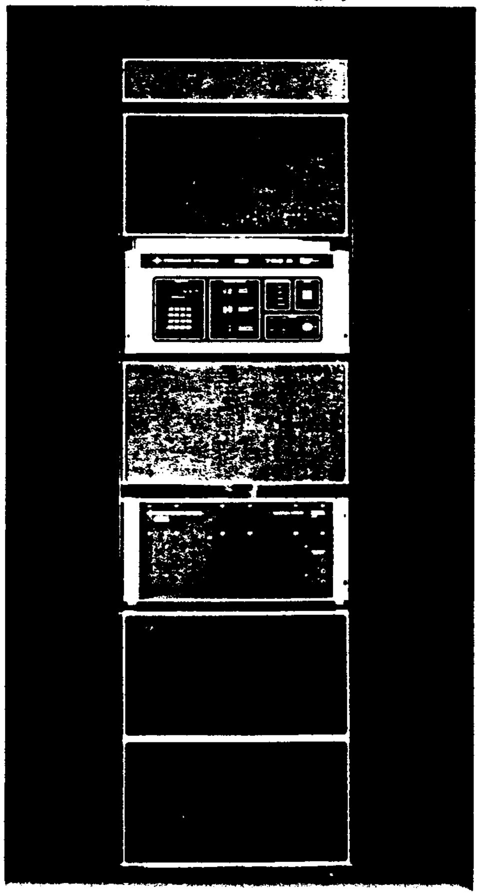
Measurements also are recorded on magnetic tape, videotape, and high-speed motion pictures for offline analysis.

Pressure data are vital to airplane design

Two types of pressure selector assemblies for multiple pressure recordings.



Data acquisition and control unit for the electronic pressure scanning system.



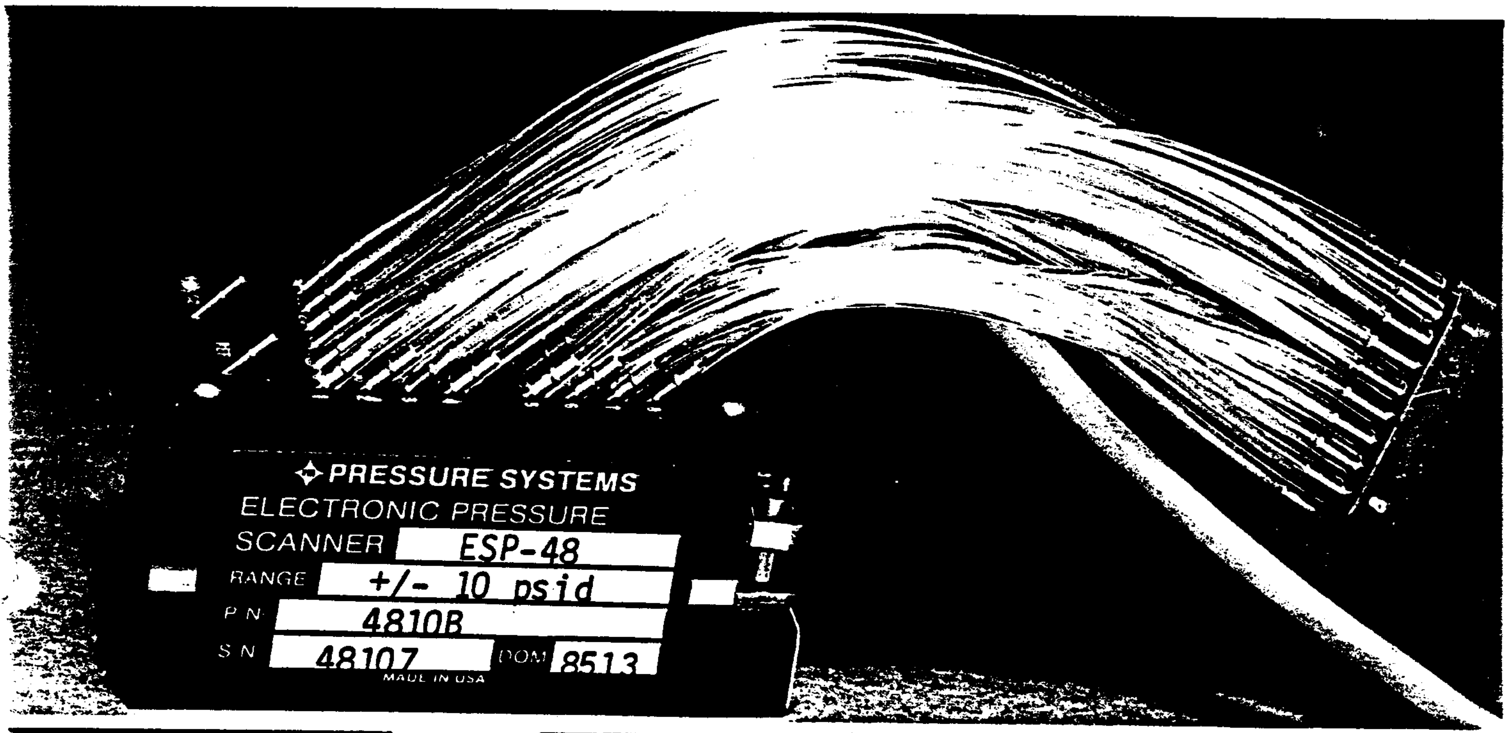
Pressure measurements

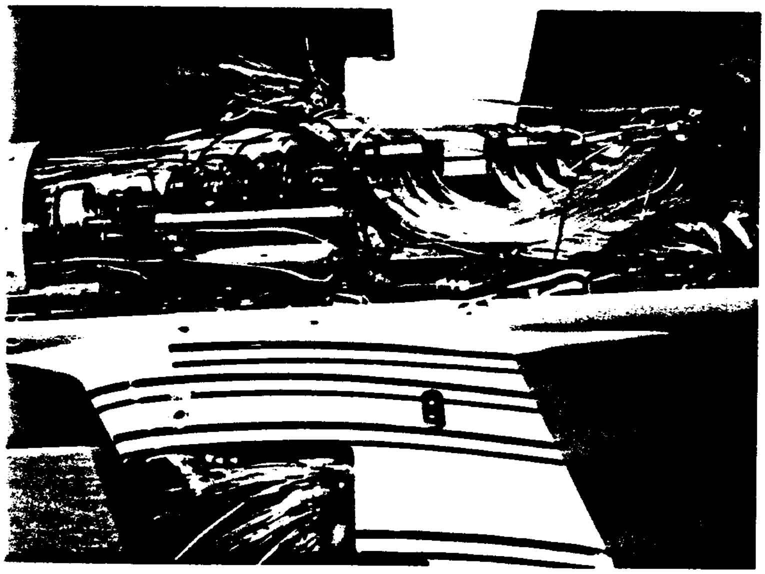
Wind tunnel calibration tests, airflow measurements, structural load tests, and aerodynamic design studies often require many simultaneous pressure measurements. Some models, for example, have had more than 1,000 pressure orifices.

To reduce the number of instrumentation channels required to record large amounts of pressure data, Boeing engineers have employed an electronic pressure scanning system. This system uses modules with an individual pressure sensor for each pressure orifice, and electronically scans the outputs at high speed. A 1,000-pressure-orifice model can be scanned in less than two seconds.

For applications requiring higher accuracy and lower scanning speeds, Boeing engineers developed the lapped-plate pressure selector valve that switches, in sequence, a number of sources to a single pressure sensor. In many cases it is possible to place the electronic pressure scanning units or selector valves inside a model, reducing the length of pressure transmission tubing and, thus, the pneumatic lag problems.

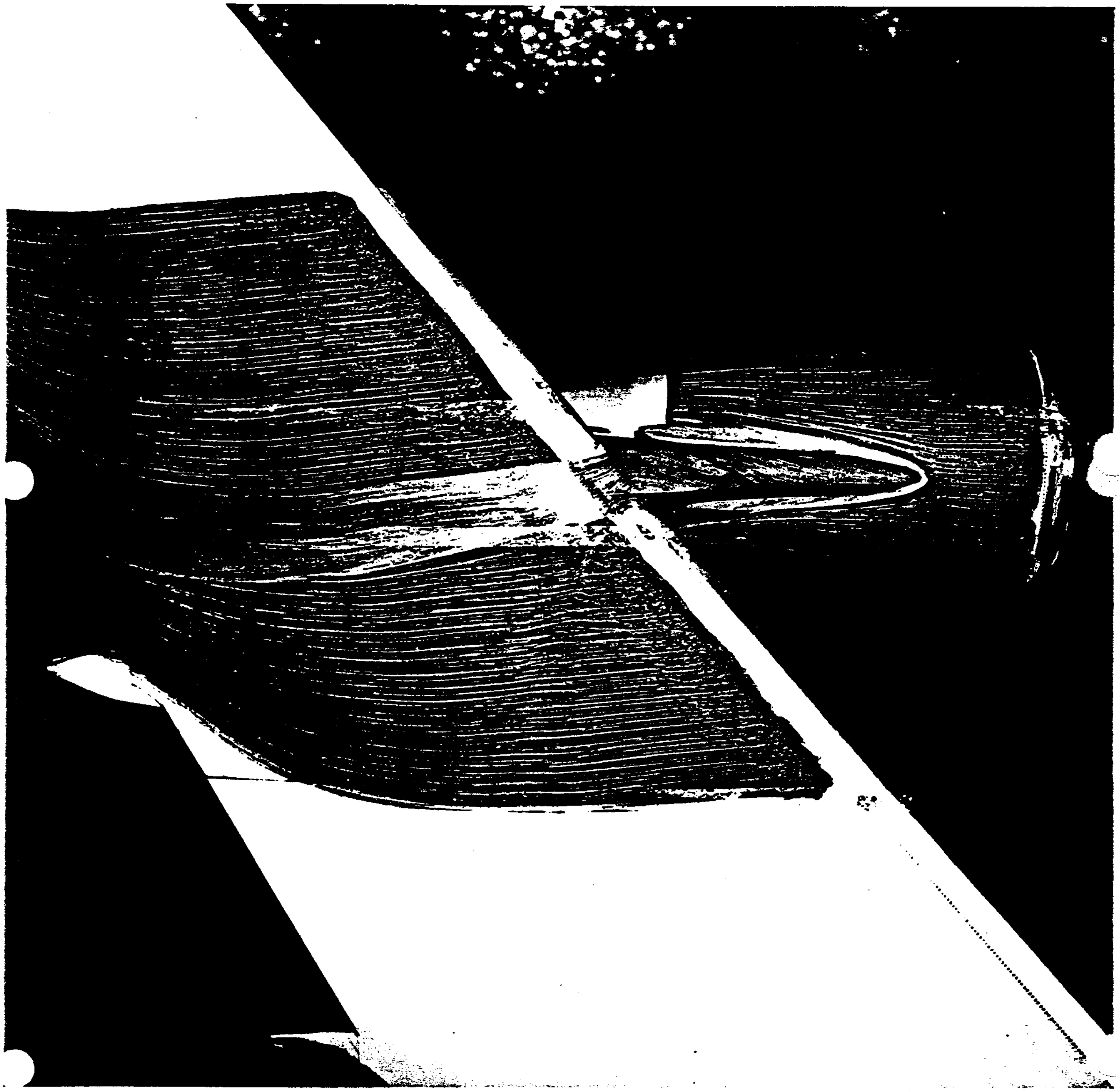
48-channel electronic pressure scanner.





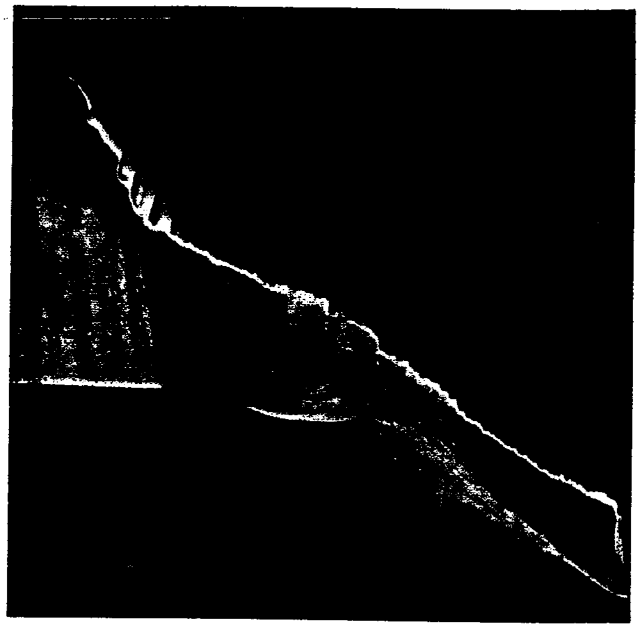
Pressure instrumentation, selector assembly, and connector tubing in a typical pressure model.

Many techniques help us see the effects of airflow

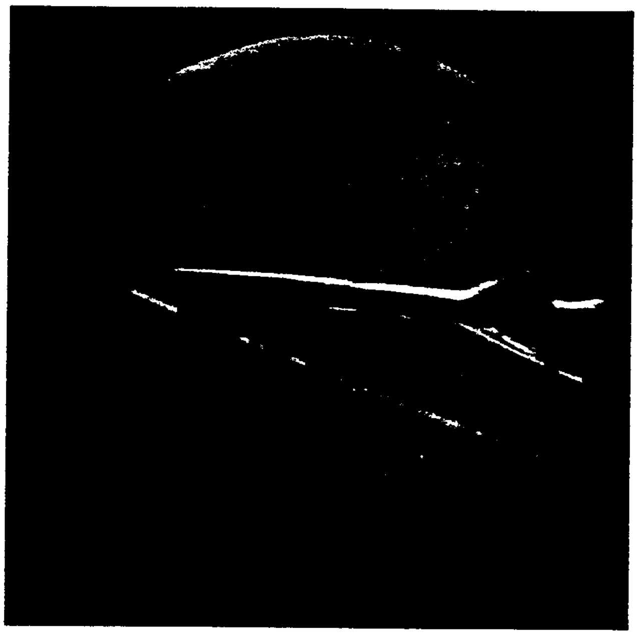


Color oil surface flow visualization highlights airflow patterns.

Visual data often is just as important as numerical data to the wind tunnel user attempting to understand the flowfield surrounding a model. Therefore, a wide variety of flow visualization techniques are available to demonstrate flow, both on and off the surface of any model component. The acquisition and presentation of this data is, in many cases, accomplished in a very short time to improve the efficiency of the testing. Techniques used in low-speed tests to document flow direction and separation include surface flow visualization using thin, highly fluorescent tufts, fluorescent oils, and China clay. Off-body flows can be seen with laser-sheet-illuminated smoke, light-activating pressure sensors, and laser-based, two-dimensional holography. The same techniques are used for most transonic testing, with shadowgraph and schlieren systems available for shock-wave visualization as well. In addition, fluorene-based sublimation is used to document the surface location of transition from laminar to turbulent boundary layer flow in all speed regions.

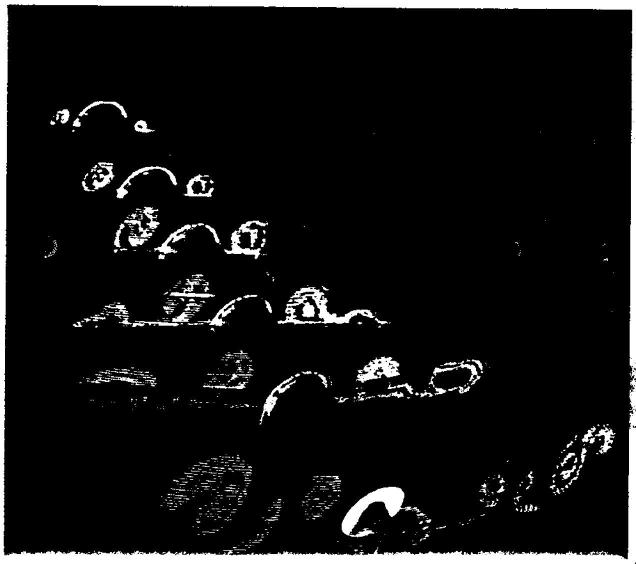


Fluorescent powder in oil displays airflow and shock wave patterns.



Schlieren technique indicates the shock wave pattern as flow passes by a supersonic airplane model.

Flowfield visualization using a combination of surface tufts and the off-surface wake imaging system.



Our design engineers and skilled mechanics work together

For more than 40 years, The Boeing Company has maintained a continuous effort in wind tunnel testing. A staff of highly experienced personnel has been assembled and is dedicated to the production of wind tunnel models and equipment. Facilities and procedures for the design and fabrication of this equipment have been developed and meet the rigorous goals of

- Minimizing flow time from concept to test
- Responding quickly to changing or added requirements
- Promoting direct coordination and progress evaluation by customer and design engineer
- Promoting direct liaison by design engineers with fabrication personnel
- Providing a stable, experienced staff of designers and shop personnel devoted exclusively to wind tunnel models and equipment
- Quick response for design and fabrication of model parts for in-tunnel configuration changes dictated by current test results

The design team has access to many computer services, both inhouse and through a Boeing Computer Services (BCS) network. Inhouse, the design team has a dedicated computer-aided design (CAD) facility, which is a VAX 11-785 computer capable of lofting, stress, and finite element analysis, and producing drawings and numerical control (NC) programming.

The facility can stand alone or function as a component of the BCS computer network. As part of this network, common data bases containing mathematical definitions are accessible for design and manufacture.

Reporting to the chief of model design are personnel whose function is to provide the direct formal link between customer groups and various wind tunnel functions. This group is responsible for tracking all fiscal and scheduling matters concerning wind tunnel design and testing programs.

The wind tunnel manufacturing support shop was created in 1940 as a dedicated facility to fabricate test models and related support equipment. It is colocated with wind tunnel engineering design and test functions to provide an independent and self-contained capability for developmental test hardware fabrication.

The shop is large and fully equipped, with 50,000 square feet of fabrication, assembly, and instrumentation space. The shop has the capacity to manufacture a variety of wind tunnel test models, model-mounting equipment, strain gage balances, and all other associated wind-tunnel-facility equipment.

A 20,000-square-foot, up-to-date machine area is equipped with state-of-the-art machines. Included in the 45 major machine tools are tape, computer, and direct N/C profile milling machines, including two capable of large, simultaneous right- and left-hand contour machining.

Three computer N/C wire EDM machines provide accuracy and productivity unmatched by previous machining methods. Additionally, the inhouse N/C programming capability services all N/C equipment including contour lofting, CAD-generated programs, direct N/C from IBM mainframe computers, and inhouse minicomputer programs.

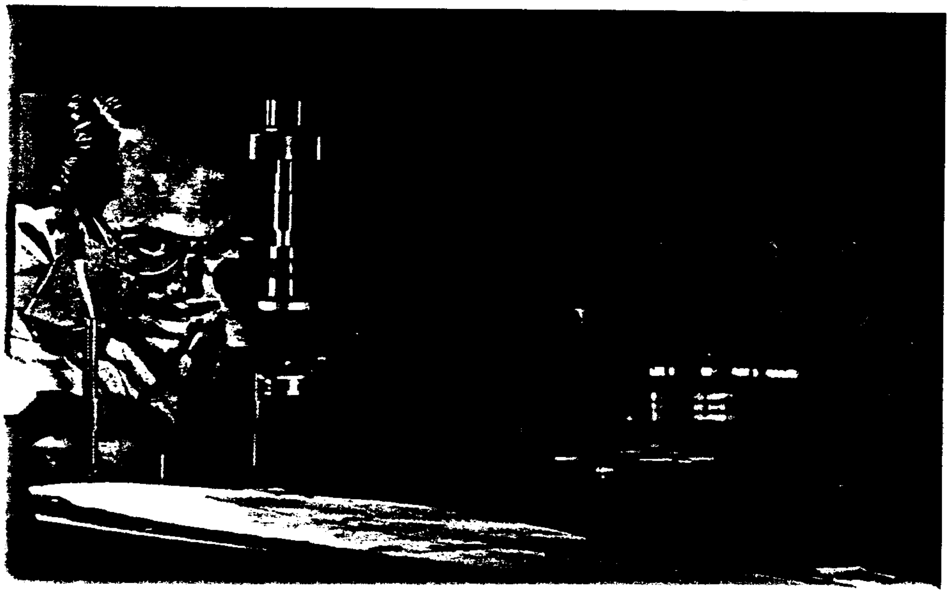
A full complement of conventional machine tools are also used to produce test hardware. Milling machines, lathes, contour planers, conventional EDM machines, and cylindrical and surface grinders are all housed in the wind tunnel fabrication facility. Adjacent to the machine area are 30,000 square feet of fabrication, assembly, instrumentation, and checkout areas. These areas are all equipped with up-to-date machines and tools for prototype and developmental assembly tasks.

The fabrication area can call on the resources of The Boeing Company for new fabrication techniques or for processes not available at the wind tunnel, such

Model design and manufacturing using Intergraph-VAX computing system.

Numerically controlled manufacturing of dual fuselage segments.

Inspection of aerodynamic model surfaces using a Brown and Sharpe validator.



as casting, plating and electron beam welding.

Craftsmen in the assembly area are thoroughly experienced in the fabrication of wind tunnel test models and related support hardware. Precision models and equipment of all kinds are built and assembled in this area. Patterns, tooling, and jigs are constructed, and the assembly and instrumentation of complex mechanisms are accomplished in the assembly area.

Experienced craftsmen with a long tradition of working wind tunnel test hardware programs are assigned in the machine, assembly, and instrumentation areas of the shop. Their special skills in fabricating test hardware are augmented by their close working relationships with engineering designers. The average experience of the craftsmen working in the wind tunnel manufacturing shop is more than 22 years.

Shop management and personnel are all closely attuned to working in a design/fabrication team atmosphere. The close-working relationship developed over the years ensures high productivity and quality hardware. The continuing communication between engineering and shop has proven effective.

Our three major tunnels fulfill Boeing's varied test requirements

Transonic Tunnel

Type of tunnel	Continuous flow, closed circuit, single return
Mach number range	0.0 to 1.1
q range	0 to 900 lb per sq. ft
Reynolds number	0 to 4×10^6 ft
Weight flow	4,000 lb per sec maximum
Static pressure	7 lb per sq in. (minimum at maximum rpm)
Stagnation pressure	Atmospheric (14.7 lb per sq. in.)
Temperature range	80° to 160°F
Maximum run time	Continuous, as required
Power for compressor	36,000-hp wound rotor induction motor may be used alone or in tandem with 18,000-hp synchronous motor
Fan shaft	108 ft long; weighs 22 tons
Fan diameter	24 ft; hub = 18 ft
Fan speed	0 to 480 rpm
Fan construction	72 fixed-pitch fiberglass blades in two stages; 67 hollow-steel stator blades in two stages
Fan weight	21 tons
Pressure ratio across fan	1.2
Bellmouth contraction ratio	8.6
Length of flow-forming region	9.5 ft
Test section	8 by 12 ft
Percent wall area in slots	11%
Length of test section	14.5 ft
Mounting systems	Floor (or wall), sting; plate
External force balance	Six component
Auxiliary air supply	20 lb per sec at 1,000 lb per sq. in.

Supersonic Tunnel

Type of tunnel	Intermittent blowdown
Mach number range	1.2 to 4.0
q range	1,200 to 3,200 lb per sq. ft
Reynolds number	6 to 17×10^6 per ft
Weight flow	800 to 2,200 lb per sec
Stagnation pressure	20 to 115 lb per sq. in.
Temperature range	65°F (±10°)
Maximum run time	7 to 45 sec
Compressor and power	2,250-hp, synchronous, two-stage centrifugal
Storage tank	55,000 cu. ft
Storage pressure	10 atmospheres
Nozzle	Semiflexible plate, 15 ft by 4 ft by 1 in.
Length of nozzle	15 ft
Test section	4 by 4 ft
Length of test section	5 ft
Mounting system	Sting, strut, wall
Auxiliary air supply	20 lb per sec at 1,000 lb per sq. in.

Research Tunnel

Type of tunnel	Continuous flow, closed circuit, single return
Mach number range	0.0 to 0.18
q range	0 to 50 lb per sq. ft
Reynolds number	0 to 1.18×10^6 per ft
Weight flow	660 lb per sec maximum
Static pressure	Atmospheric
Stagnation pressure	14.7 to 15.1 lb per sq. in.
Temperature range	70° to 100°F
Maximum run time	Continuous, as required
Power for compressor	650-hp induction motor
Fan diameter	12 ft; hub = 6 ft
Fan speed	0 to 840 rpm
Fan construction	Four variable-pitch fiberglass and foam blades
Bellmouth	Flow smoothing, using fine mesh screens and small-cell honeycomb
Bellmouth contraction ratio	7.2
Test section	5 by 8 ft
Length of test section	20 ft
Mounting systems	Wall and strut
External force balance	Six component
Auxiliary air supply	20 lb per sec at 1,000 lb per sq. in.

FLIGHT TESTING

Participation in the flight testing of Boeing airplanes is an integral part of the Aerodynamic Technology engineer's job description. Testing may be conducted for various reasons; the main effort is directed towards preparing the airplane for certification and the certification process itself. Other testing may be directed towards gathering data for performance guarantee substantiation, simulator data base development, support of programs such as FMS, or basic research. Whatever its purpose, this testing is an important aspect of our engineering activities.

The following pages provide an overview of the activities and responsibilities involved in the testing of an airplane. The Aero engineer participates in all phases of a test program including planning, execution, analysis and documentation. Close coordination with members of the Boeing Flight Test organization is required.

REASONS FOR AERODYNAMIC FLIGHT TESTING

- CONFIGURATION DEVELOPMENT
- CERTIFICATION
- CONTRACT COMPLIANCE
  - PERFORMANCE GUARANTEES SUBSTANTIATION
  - PERFORMANCE RETENTION
  - DELIVERY FLIGHTS CRUISE DATA
  - SIMULATOR DATA BASE
- PROGRAM SUPPORT
  - NOISE
  - STRUCTURES
  - FMS
- RESEARCH

AERODYNAMIC FLIGHT TESTING

- FUEL MILEAGE
  - BOEING
  - CUSTOMER DELIVERY
  - PERFORMANCE RETENTION
- DRAG
- AIRSPEED CALIBRATION
- HANDLING QUALITIES
- SIMULATOR DATA BASE
- STALLS
- TAKEOFF PERFORMANCE
  - MINIMUM UNSTICK SPEEDS
  - BASIC AND INCREASED SPEED SCHEDULES
  - ACCELERATION PARAMETERS
  - ABUSE TAKEOFFS
  - REFUSED TAKEOFFS
  - CROSS WIND TAKEOFFS
- LANDINGS
- MINIMUM CONTROL SPEEDS
- BUFFET BOUNDARY
- CONFIGURATION DEVIATIONAL LIST
- CUSTOMER ACCEPTANCE SQUAWKS (WITCH HUNTS)
- FMS
- NOISE
- REVERSE THRUST
- SYSTEM MALFUNCTIONS
- RESEARCH

0142P/6

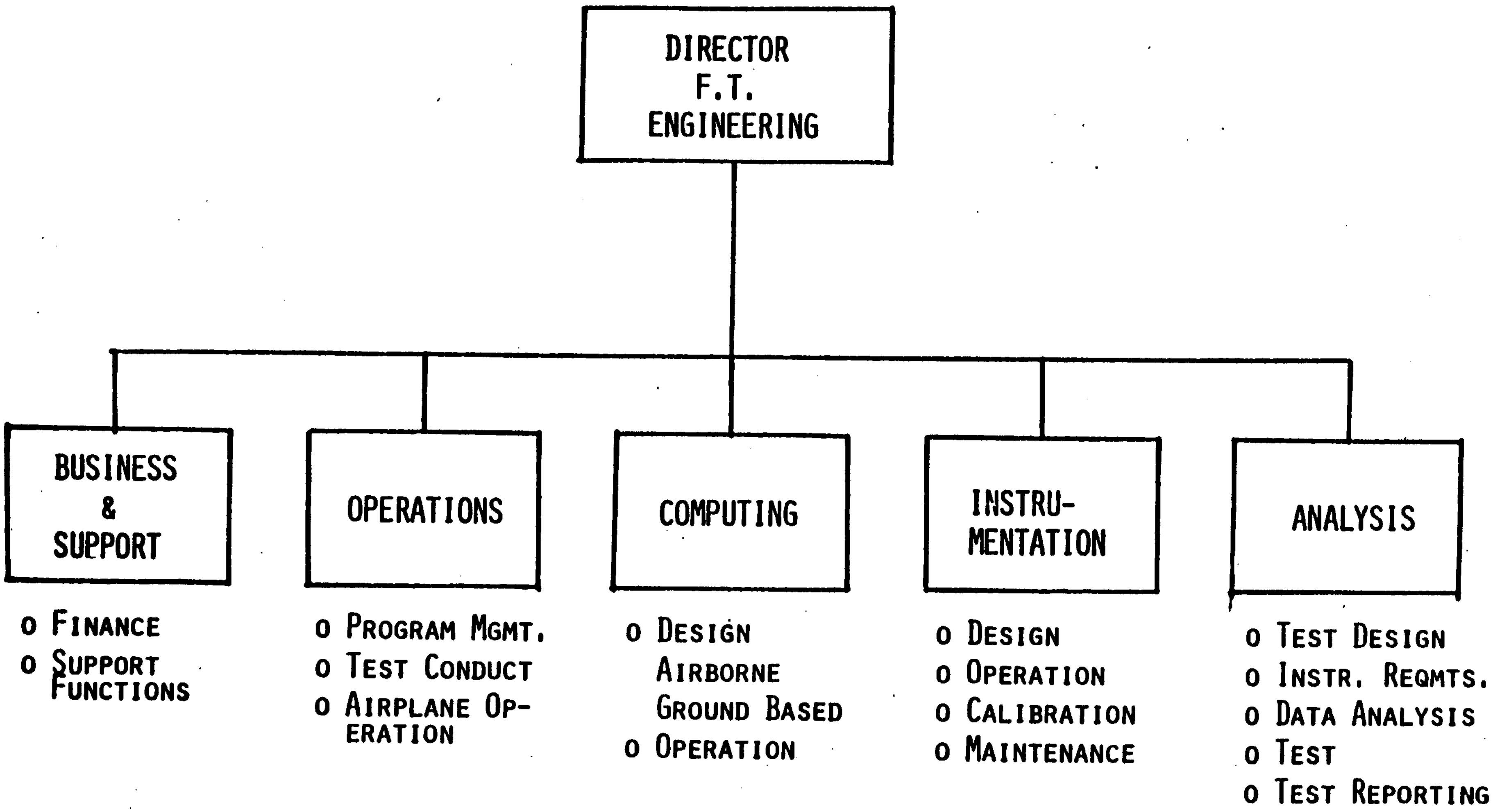
AERODYNAMIC FLIGHT TEST DATA DOCUMENTATION

- AIRPLANE FLIGHT MANUAL
  - AERODYNAMIC CERTIFICATION FLIGHT TEST RESULTS
  - FLIGHT TEST CERTIFICATION REPORT

- PERFORMANCE SUBSTANTIATION
- OPERATIONS MANUAL
- DISPATCH DEVIATIONS GUIDE
- PERFORMANCE ENGINEERS MANUAL
- FLIGHT CREW TRAINING MANUAL
- AIRPLANE MAINTENANCE MANUAL
- PERFORMANCE DOCUMENTS
- FMS AIRPLANE PERFORMANCE DATA BASE DOCUMENTATION
- FLIGHT SIMULATOR DOCUMENTATION

FLIGHT TEST RESPONSIBILITY

- o PROGRAM CHIEF ENGINEER (TEST INTEGRATION)
- o TECHNOLOGY STAFF (B-XXXX)
- o FLIGHT TEST (M-XXXX)
- o CUSTOMER



DIRECTOR F.T. ENGINEERING
BUSINESS & SUPPORT
o FINANCE
o SUPPORT FUNCTIONS
OPERATIONS
o PROGRAM MGMT.
o TEST CONDUCT
o AIRPLANE OP-ERATION
COMPUTING
o DESIGN
AIRBORNE
GROUND BASED
o OPERATION
INSTRU-MENTATION
o DESIGN
o OPERATION
o CALIBRATION
o MAINTENANCE
ANALYSIS
o TEST DESIGN
o INSTR. REQMTS.
o DATA ANALYSIS
o TEST
o TEST REPORTING

AERODYNAMICS FLIGHT TEST PROGRAMS

- o STANDARIZED PROGRAMS DESCRIBED IN D541T007-TN (FLIGHT TEST REQUIREMENTS FOR AERODYNAMICS TECHNOLOGY)
  - o AIRPLANE PROGRAM TYPES
    - o NEW
    - o DERIVATIVE
    - o RE-ENGINE
  - o TYPE TESTING
    - o PERFORMANCE AND CONFIGURATION
    - o STABILITY AND CONTROL

CRUISE PERFORMANCE FLIGHT TESTING

OBJECTIVES

- PRIMARY: FUEL MILEAGE
- SECONDARY
  - DRAG POLAR
  - FUEL FLOW (TSFC)

CATEGORIES

- COCKPIT MANUAL NOTES
  - W/ AND W/O CALIBRATED INSTRUMENTS
  - W/ AND W/O TRAILING CONE
- INSTRUMENTED AIRPLANE
  - PADDS
  - ADAMS
- W/ AND W/O CALIBRATED ENGINES
- PRE AND POST DELIVERY

- TEST PROCEDURES DESCRIBED IN D6-33468 (DETERMINATION OF CRUISE FUEL MILEAGE BY FLIGHT TESTING MODEL 747 PRODUCTION AIRPLANES)

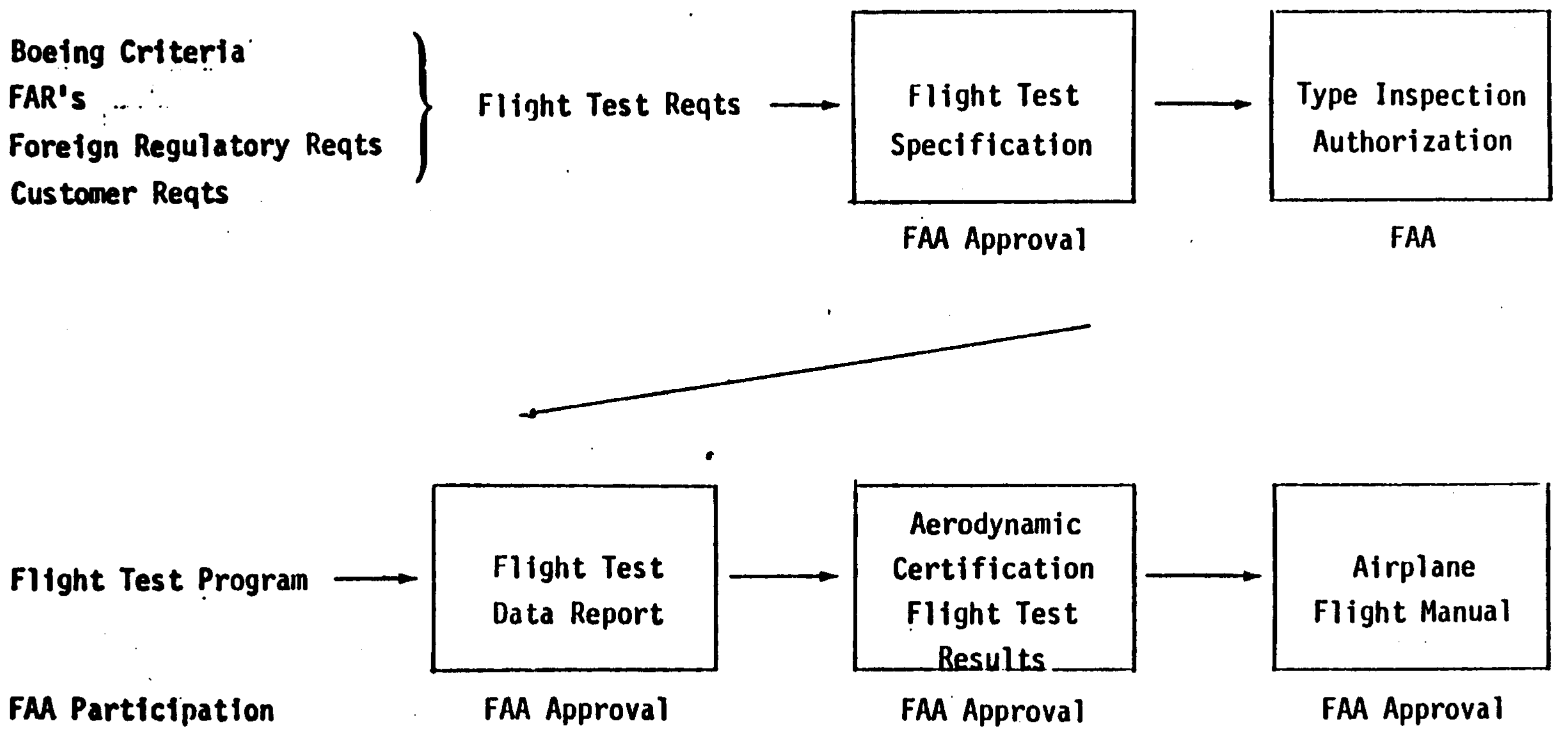
- DATA ANALYSIS
  - AIRBORNE (HP41, PACDES, ADAMS)
  - GROUND (CRAFT)

CERTIFICATION FLIGHT TEST PROGRAM

- AERODYNAMICS STAFF PARTICIPATION
  - CONFIGURATION COMPLIANCE DEMONSTRATION AND DOCUMENTATION
    - PERFORMANCE
    - HANDLING
    - NOISE
    - SYSTEMS
  - AIRPLANE FLIGHT MANUAL PERFORMANCE
- TYPICAL PROGRAM
  - ORGANIZATION
  - CONFIGURATION REFINEMENTS
  - CERTIFICATION TESTING
  - AFM DATA REQUIREMENTS
  - FLIGHT TEST DATA DOCUMENTATION

AERODYNAMIC

CERTIFICATION DATA DEVELOPMENT



FLIGHT TEST FACILITIES

- o BOEING FIELD (KING COUNTY INTERNATIONAL AIRPORT)
- o EVERETT (PAINE FIELD)
- o REMOTE
  - o MOSES LAKE (GRANT COUNTY INTERNATIONAL AIRPORT)
  - o EDWARDS AIRFORCE FLIGHT TEST CENTER/MOJAVE/PALMDALE
  - o GLASGOW
  - o CHEYENNE
  - o ALBUQUERQUE
  - o MEXICO CITY
  - o LAS PAZ
  - o BOGATA
  - o TULSA
  - o OTHERS

<u>AERO STAFF FLIGHT TEST OBSERVER TASKS AND RESPONSIBILITIES</u>

- INSURE ACCEPTABLE TEST EXECUTION AND DATA ACQUISTION
  - ACCURATE DEFINITION OF TEST REQUIREMENTS, INCLUDING TEST CONDITIONS, REQUIRED DATA, AND POST-TEST DATA PROCESSING
  - ASSIST FLIGHT TEST ANALYSIS PERSONNEL DURING PRE-TEST PREPARATION, TEST EXECUTION, AND POST-TEST DATA PROCESSING
  - FAA AND TEST PROGRAM COORDINATION
  - FLIGHT OPERATIONS AND PILOT BRIEFINGS
  - OBSERVE TEST AND ATTEND PRE AND POST-TEST MEETINGS
  - REAL TIME TEST RESULTS TRACKING
  - DATA TRANSFER COORDINATION
- TIMELY DISSEMINATION OF TEST RESULTS
  - GROUP
  - WICKEMEYER
  - OTHERS
- DATA ANALYSIS AND DOCUMENTATION

CALL: (206) 237-7058

DATE ______________________ NAME ______________________

LOCATION ______________________ MODEL ______________________

BOEING TEST ______________________ CERTIFICATION TEST ____________

PURPOSE OF TEST:

RESULTS OF TEST:

<u>FLIGHT TEST DATA CONTROL</u>

- o TREAT ALL DATA AS "COMPANY PROPRIETARY"
- o DISSEMINATION OF AIRPLANE PERFORMANCE FLIGHT TEST RESULTS IS THE RESPONSIBILITY OF THE AERODYNAMICS STAFF
- o PROVIDE MINIMUM REQUIRED DATA TO THE FAA
- o OBTAIN MANAGEMENT APPROVAL PRIOR TO RELEASING DATA OUTSIDE OF BOEING

FLIGHT TEST SEQUENCE

- ONE PAGE TEST PLAN (OPTP)
- ENGINEERING WORK AUTHORIZATION (EWA)
- TEST ITEM PLAN (TIP SHEET)
- PLAN OF TEST
- PRE-FLIGHT MEETING
- TEST
- POST-FLIGHT DEBRIEFING
- WICK-GRAM
- DATA REQUESTS
- DATA TRANSMITTAL
- DATA ANALYSIS
- DOCUMENTATION

AERO FLIGHT TEST OBSERVER EQUIPMENT

- FLIGHT BAG
- CALCULATOR (BATTERIES)
- QUICK REFERENCE MATERIAL
  - BASELINE
  - EXPECTED RESULTS
- TIP SHEET
- PLAN OF TEST
- FLIGHT TEST NOTES FORMS
- DARK PENCILS/PENS
- TEST OPERATIONS LIMITATIONS
- EWA
- FLIGHT TEST SPECIFICATION
- PAPER
  - ENGINEERING PAD
  - CLIPBOARD
- APPROPRIATE DRESS

IMPORTANT: DO NOT USE BLUE INK AS IT WILL NOT REPRODUCE FROM THE ORIGINAL.

SHEET OF	TITLE	MODEL
RECORDER		AIRPLANE
TEST NO. / STA	BOEING	DOC. NO.
DATE		PAGE

TYPICAL FLIGHT TEST CREW

- FLIGHT CREW
- TEST DIRECTOR
- INSTRUMENTATION
- WEIGHT AND BALANCE
- FLIGHT TEST ANALYSIS
- OBSERVERS

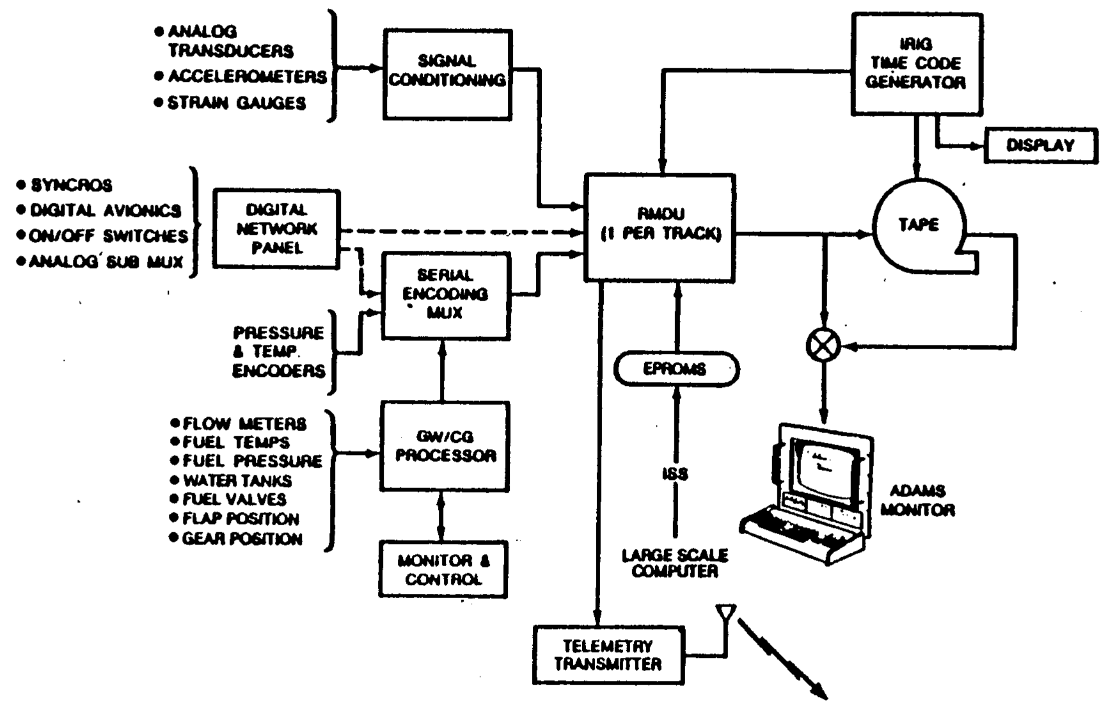
MISCELLANEOUS

- FLIGHT CLEARANCES
  - GREEN
  - YELLOW
- HEALTH
- REST
- PERSONALITY
  - COMPATIBILITY
  - PATIENCE
  - ASSERTIVENESS
- SAFETY

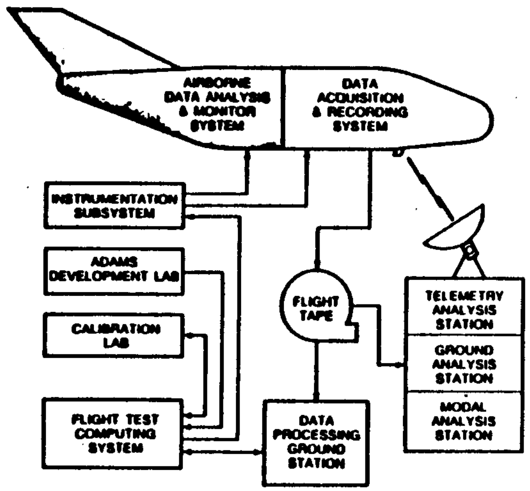
FLIGHT TEST DATA ACQUISITION

- ON BOARD
  - NOTES
  - HIGH SPEED PCM DATA ACQUISITION SYSTEM
    - AIRBORNE DATA ANALYSIS AND MONITOR SYSTEM (ADAMS)
    - GROSS WEIGHT/CENTER-OF-GRAVITY COMPUTING SYSTEM
  - WAKE RAKE
  - PORTABLE AIRBORNE DIGITAL DATA SYSTEM (PADDS)
- TELEMETRY
  - TELEMETRY ANALYSIS STATION
  - GROUND ANALYSIS STATION
  - MODEL ANALYSIS STATION
- POST FLIGHT
  - WEIGHT
  - FUEL LOWER HEATING VALUE

BOEING FLIGHT TEST DATA ACQUISITIONING SYSTEM (HSPCM)

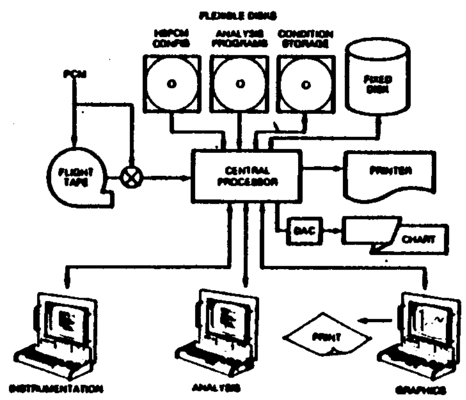


AIRBORNE DATA ANALYSIS AND MONITOR SYSTEM



The airborne data analysis and monitor system (ADAMS) provides real time display of critical parameters to expedite the instrumentation preflight, provide on-board test results for efficient test conduct, monitor the quality of the recorded data, and produce analytical parameters for complete post-test evaluation.

The system also has post-flight playback capability, which is particularly useful when operating at a remote base.



The original ADAMS, developed for the HSPCM system in 1976, has experienced a second-generation growth in both hardware and software and is linked to the data base in a large scale computer to provide efficient updating of the system in the changing environment of a dynamic test program.

The system uses a minicomputer with expanded memory, a fixed-head disk, flexible disk drives, cathode-ray tube (CRT) monitor screens, keyboards, printers, remote digital displays, digital-to-analog converters, direct-write oscillographs, and a graphics CRT.

The HSPCM data being recorded on the flight tape are the source of ADAMS input. The data base files in the large scale computer are the source of each airplane's aerodynamic characteristics and geometry, the engine configuration, and up-to-date HSPCM arrangement and calibration information for each test. This file information, stored on flexible disks, is taken to the airplane for pre-flight and in-flight monitoring of data in engineering units.

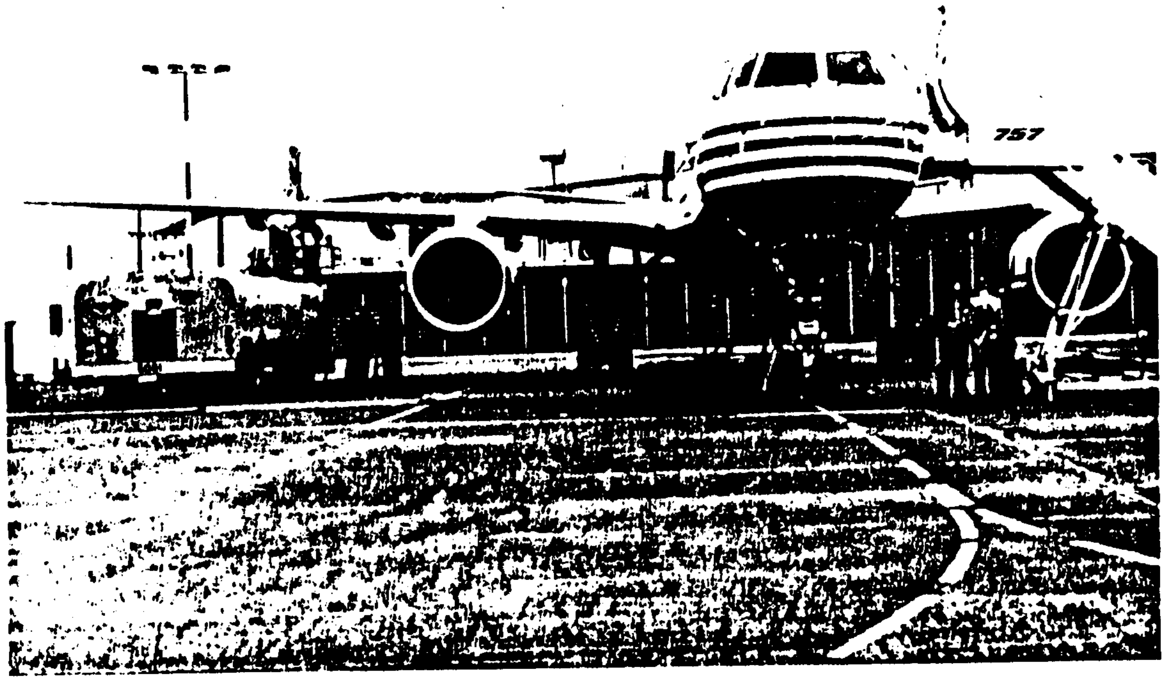
Time correlation is provided throughout the airplane by a common time code generator (TCG) and translators (TCT). Time is also recorded in the PCM bit stream to provide time correlation to the monitors and printers.

ADAMS DATA ANALYSIS PROGRAMS

REF: D6-49954-5, ADAMS DATA ANALYSIS FUNCTION REQUIREMENTS

- GROSS WEIGHT
- BASIC AIRPLANE PARAMETERS
- CRUISE PERFORMANCE
- STALL PERFORMANCE
- STALL SUMMARY
- LOADS PERFORMANCE
- TAKEOFF PERFORMANCE
- TO SUMMARY
- POWER PLANT PARAMETERS
- FLIGHT CONTROL PARAMETERS
- AIRSPEED CALIBRATION
- PRESSURE COEFFICIENT
- LANDING SUMMARY
- RTO SUMMARY
- CALCULATED THRUST

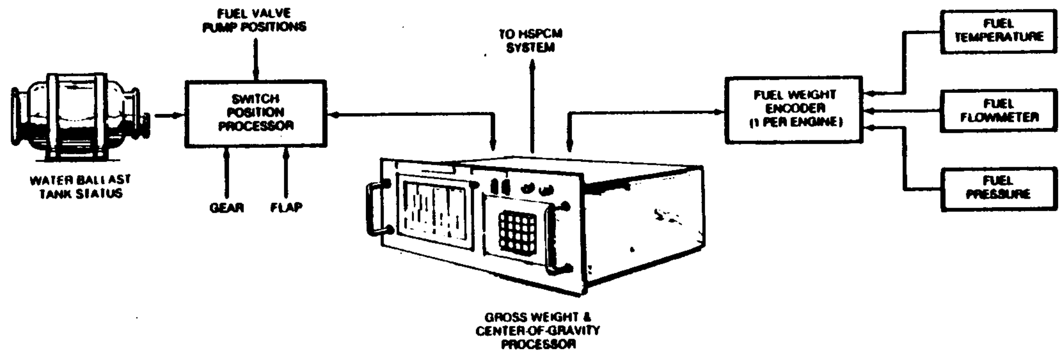
GROSS WEIGHT/ CENTER-OF-GRAVITY COMPUTING SYSTEM



Boeing Flight Test Engineering has designed and developed a gross weight/ center-of-gravity. (GW/CG) computing system to provide accurate gross weight and center-of-gravity data for on-board monitoring and recording on the HSPCM system.

The GW/CG computing system has three major subsystems:

- **Fuel Weight Encoders.** Microprocessors that accept input from fuel flowmeters and pressure and temperature sensors on each engine to compute flow rates and total pounds of fuel used.
- **Position Processor.** A microprocessor that uses water ballast tank, fuel valve, flap, and gear signals and operator input to compute water and fuel weights and moments.
- **GW/CG Processor.** A microprocessor that uses data from the fuel weight encoders and the position processor to compute the current GW/CG for recording on the HSPCM system where it is also available to ADAMS.



Once initialized, the GW/CG system operates without manual intervention except for water and fuel transfers and dumps as required for GW/CG control. The system not only assists in the test conduct but greatly reduces post-test data flow time by recording GW/CG on the flight tape where it is available to all the final data system programs in the large scale computer.

FLIGHT TEST DATA FLOW AND ANALYSIS

- AIRBORNE
  - AERO OBSERVER
    - BASELINE DATA
    - QUICK REFERENCE DATA
    - HAND HELD PROGRAMMABLE CALCULATORS
    - PORTABLE AERODYNAMIC CRUISE DATA EVALUATION SYSTEM, PACDES

- GROUND
  - FLIGHT TEST
    - GROUND ANALYSIS STATION
    - DATA PROCESSING GROUND STATION

  - AERODYNAMICS
    - IGDA
    - VAMPS
    - A087
    - CRAFT
    - D6-7178, D6-7178-1: FLIGHT TEST CERTIFICATION PERFORMANCE METHODS
      BOB PATTON SPECIALS AND OTHERS
      - TIME HISTORY SOFTWARE SYSTEM
      - MAIN FRAME FLIGHT TEST DATA GENERATION (FTGEN)
      - OTHERS

BCAC
COMPETITION

THE BOEING COMPANY

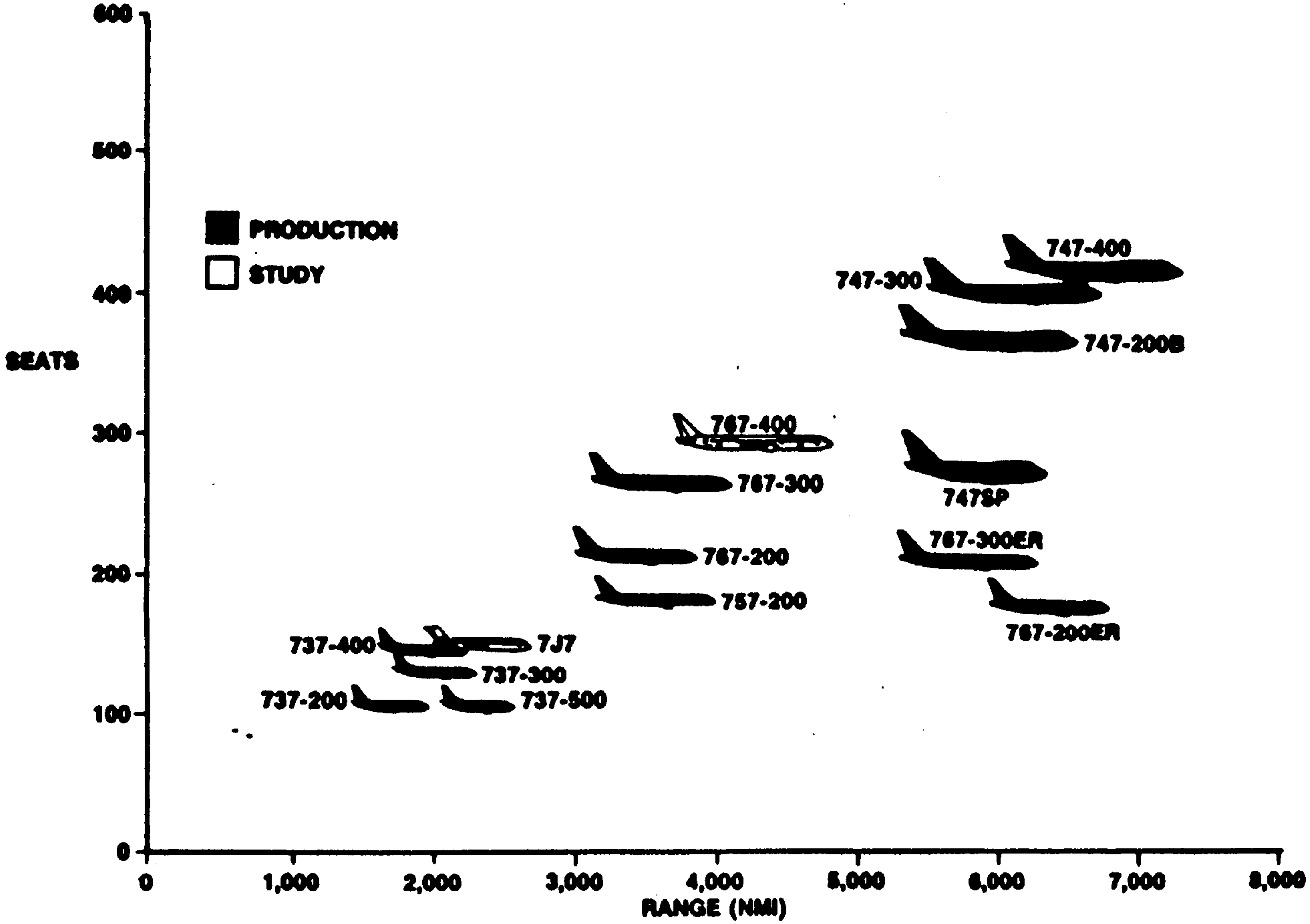
- OBJECTIVE

"The Company believes that its current family of commercial transports coupled with planned and potential derivatives (such as the 737-400, 747-400, the extended range 767-300, a 110 passenger 737, future stretches of the 767 and the DHC-8 Series 300) and the proposed new technology 7J7 model series will meet most worldwide airline requirements ."

BCAC PRODUCTS

	NUMBER SOLD	NUMBER DELIVERED	PRODUCTION PER MONTH
737	1,873	1,444	14
747	814	681	2.5
757	224	140	4
767	263	183	3

BOEING NEW AIRPLANE FAMILY



B87-3 R4
V-10-19

BCAC COMPETITION

- AIRBUS INDUSTRIE
- McDONNELL DOUGLAS
- BRITISH AEROSPACE
- FOKKER

AIRBUS INDUSTRIE

CONSORTIUM MEMBERS:

• AEROSPATIALE - FRANCE	37.9%
• DEUTSCHE AIRBUS (MBB) - FRG	37.9%
• BRITISH AEROSPACE - UK	20%
• CASA - SPAIN	4.2%

ASSOCIATES

- FOKKER - NETHERLANDS
- BELAIRBUS - BELGIUM

AIRBUS INDUSTRIE

- OBJECTIVE

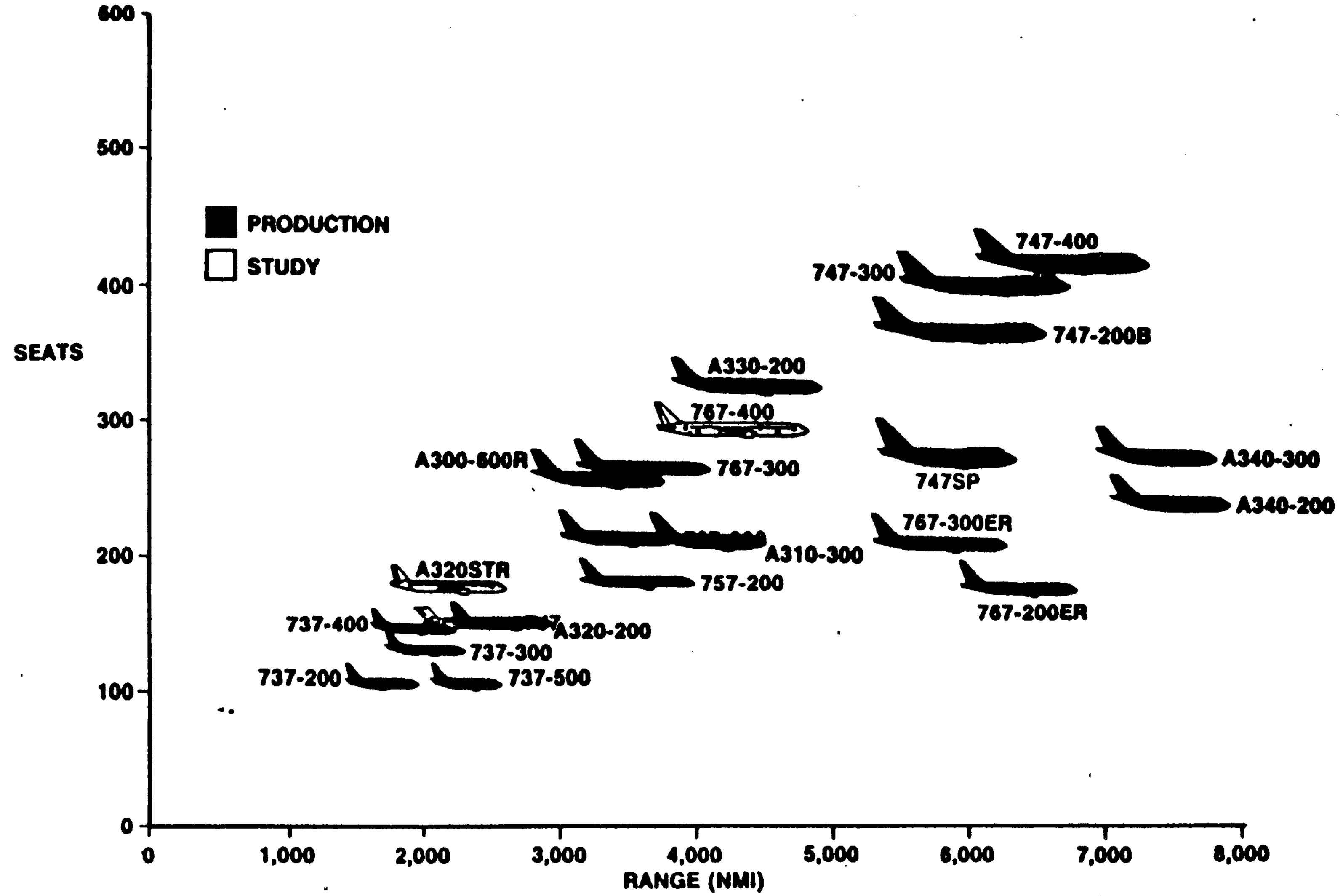
"Airbus Industrie is now developing a full family of commercial airliners with the firm intent of obtaining some 30% of the total market in the western world by the turn of the century. The result will be profitable and self-sustaining civil aircraft business for the European manufacturers, and will ensure that the benefits of industrial competition are brought to the airlines of the world."

AIRBUS INDUSTRIE

- PRODUCTS

	CERT.	NUMBER SOLD	NUMBER DELIVERED	PRODUCTION PER MONTH
A300	1974	310	280	4
A310	1983	150	105	4
A320	1988	287	--	(6.5)
A330	1992	(41)	--	--
A340	1992	(89)	--	--

BOEING NEW AIRPLANE FAMILY



B87-2 R4
V-10-19
B87-2 R4(A)RED

McDONNELL DOUGLAS

- **OBJECTIVE**

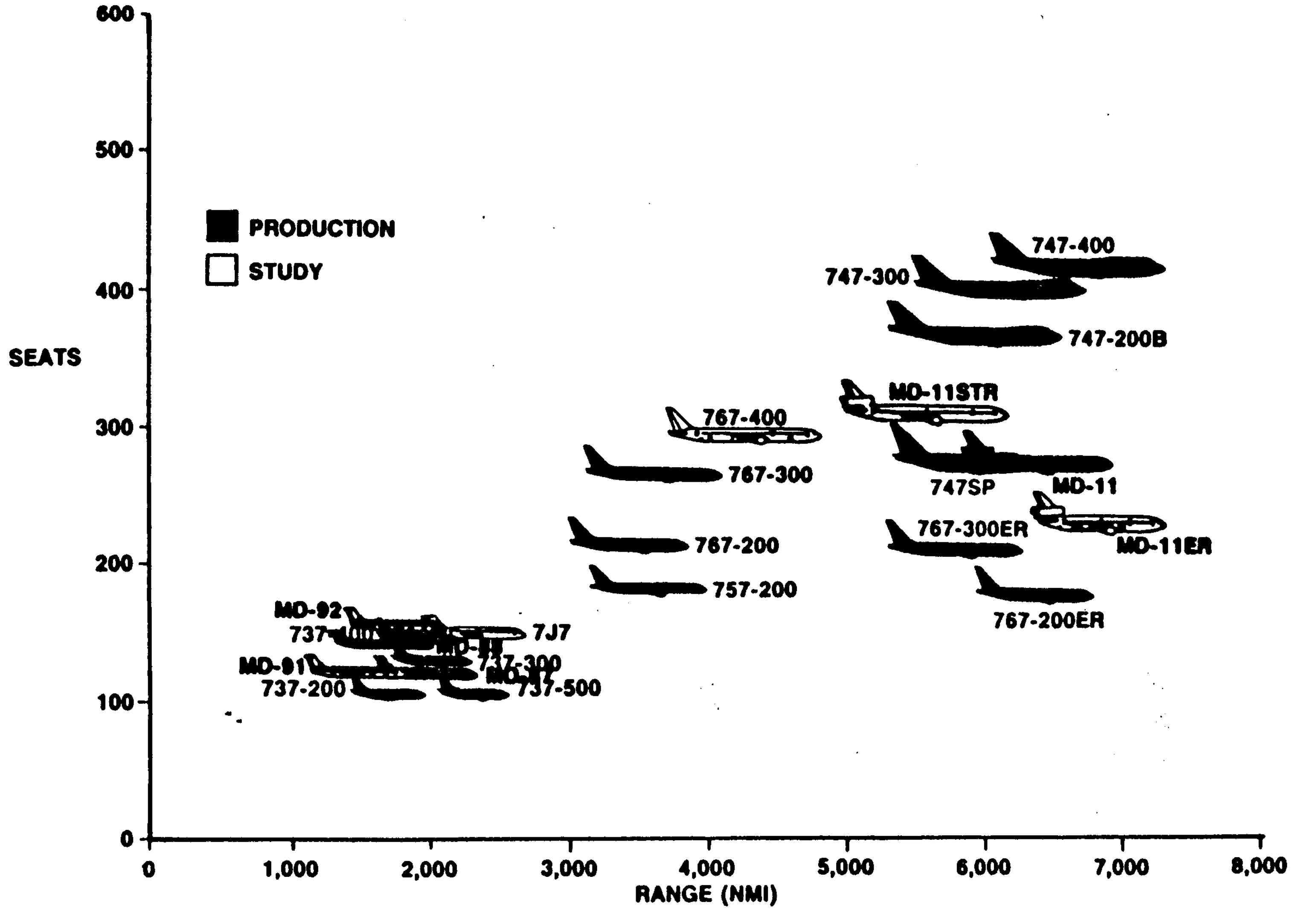
"The Douglas Aircraft Company's commercial product plan is based on continued improvement of both wide-body, twin-aisle (DC-10,MD-11) and standard body, single-aisle (MD-80, MD-91/92) aircraft. These improvements are based on incorporating advanced technologies that produce bottom-line economic benefits for the operators."

McDONNELL DOUGLAS

- PRODUCTS

	CERT.	NUMBER SOLD	NUMBER DELIVERED	PRODUCTION PER MONTH
MD87	1987	43	2	8 (MD87 and MD81,82,83,88 combined)
MD81,82,83,88		857	427	
MD11	1990	117	--	
MD91	(1991)	--	--	--
MD92	(1992)	--	--	--

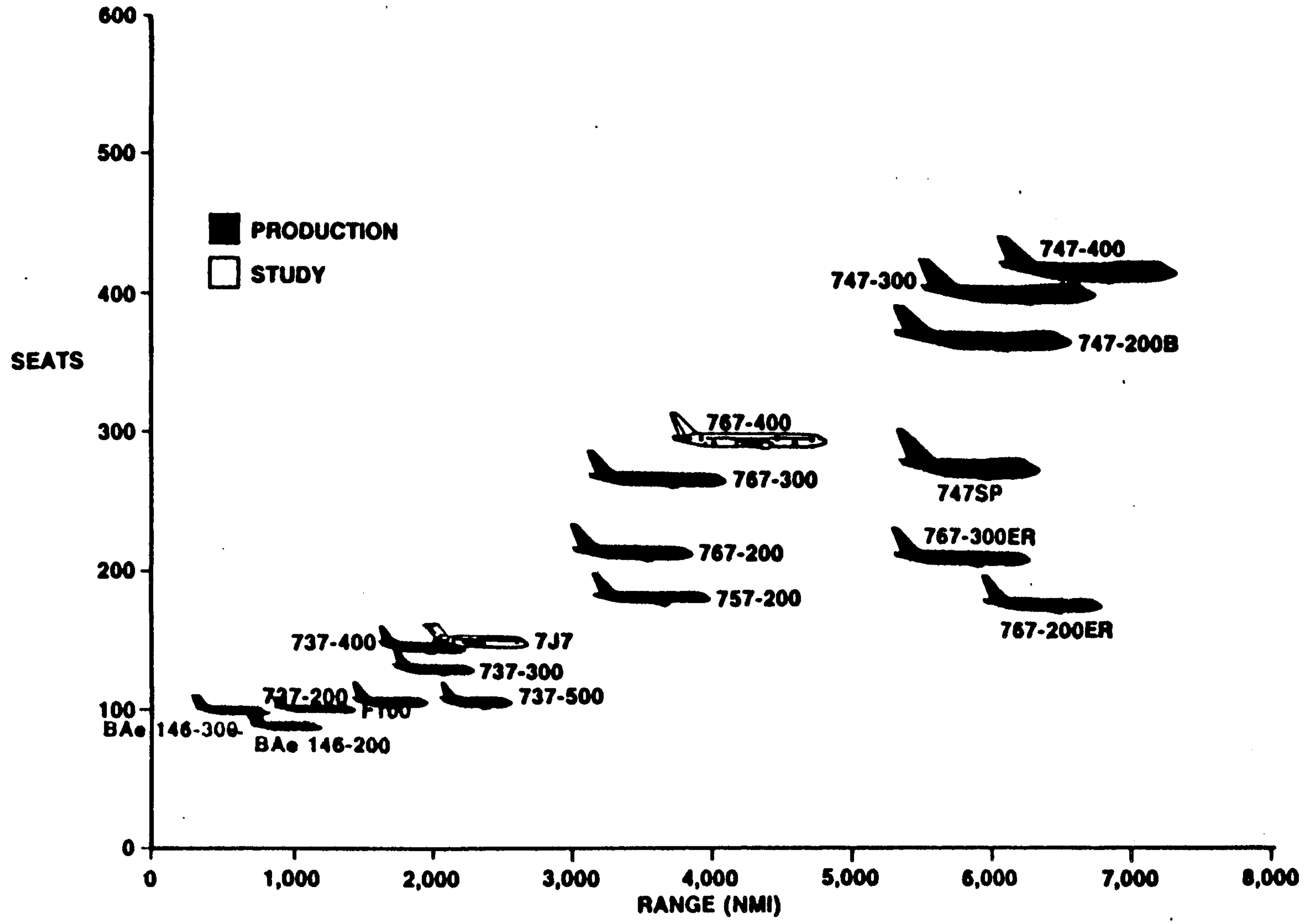
BOEING NEW AIRPLANE FAMILY



B87-2 R4
V-10-19

B87-2 R4(B)BLUE

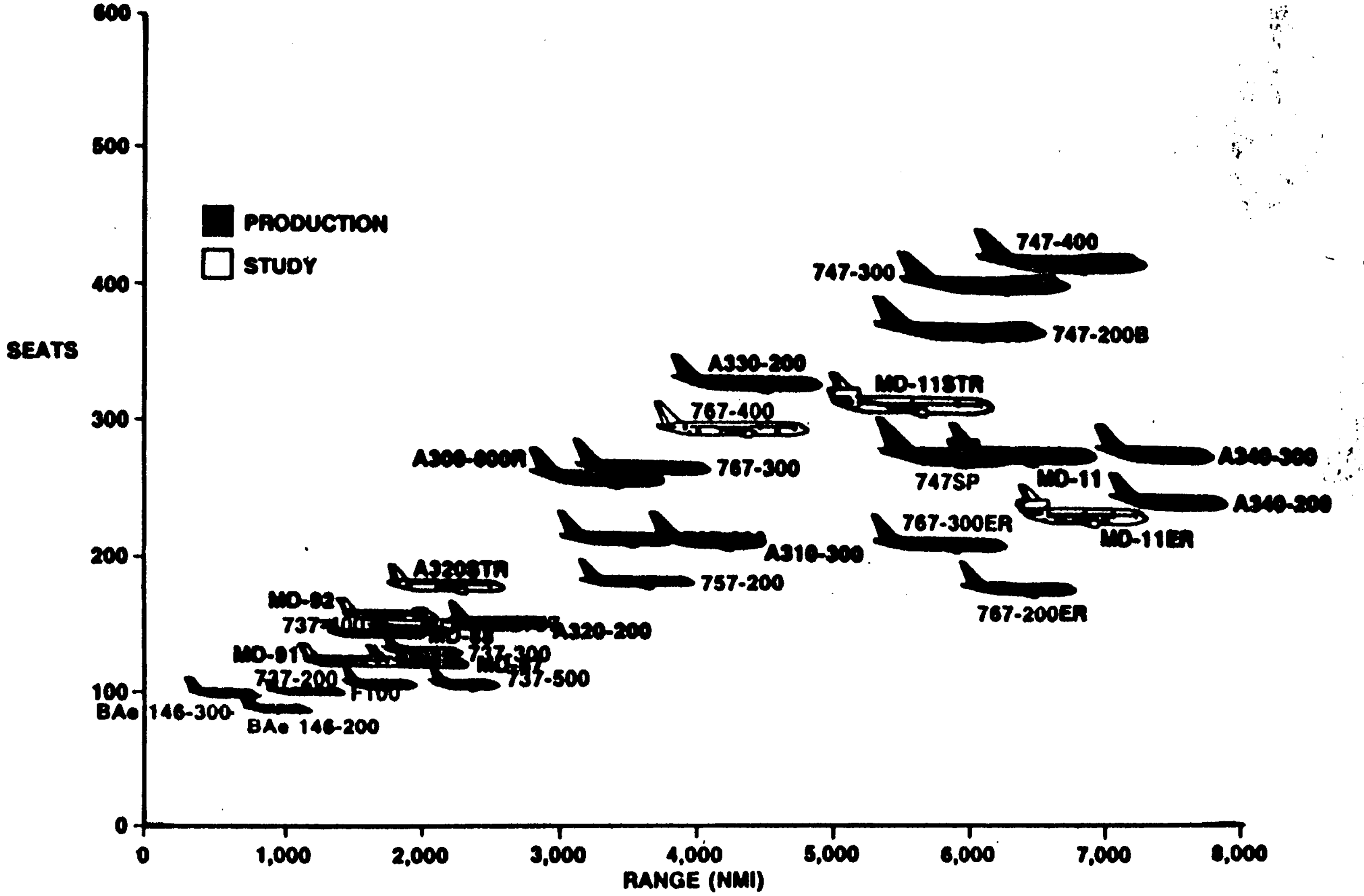
BOEING NEW AIRPLANE FAMILY



B87-2 R4
V-10-19

B87-2 R4(C) GREEN

BOEING NEW AIRPLANE FAMILY



B87-2 R4
V-16-19
B87-2 R4(C) GREEN B87-2 R4(B) BLUE B87-2 R4(A) RED

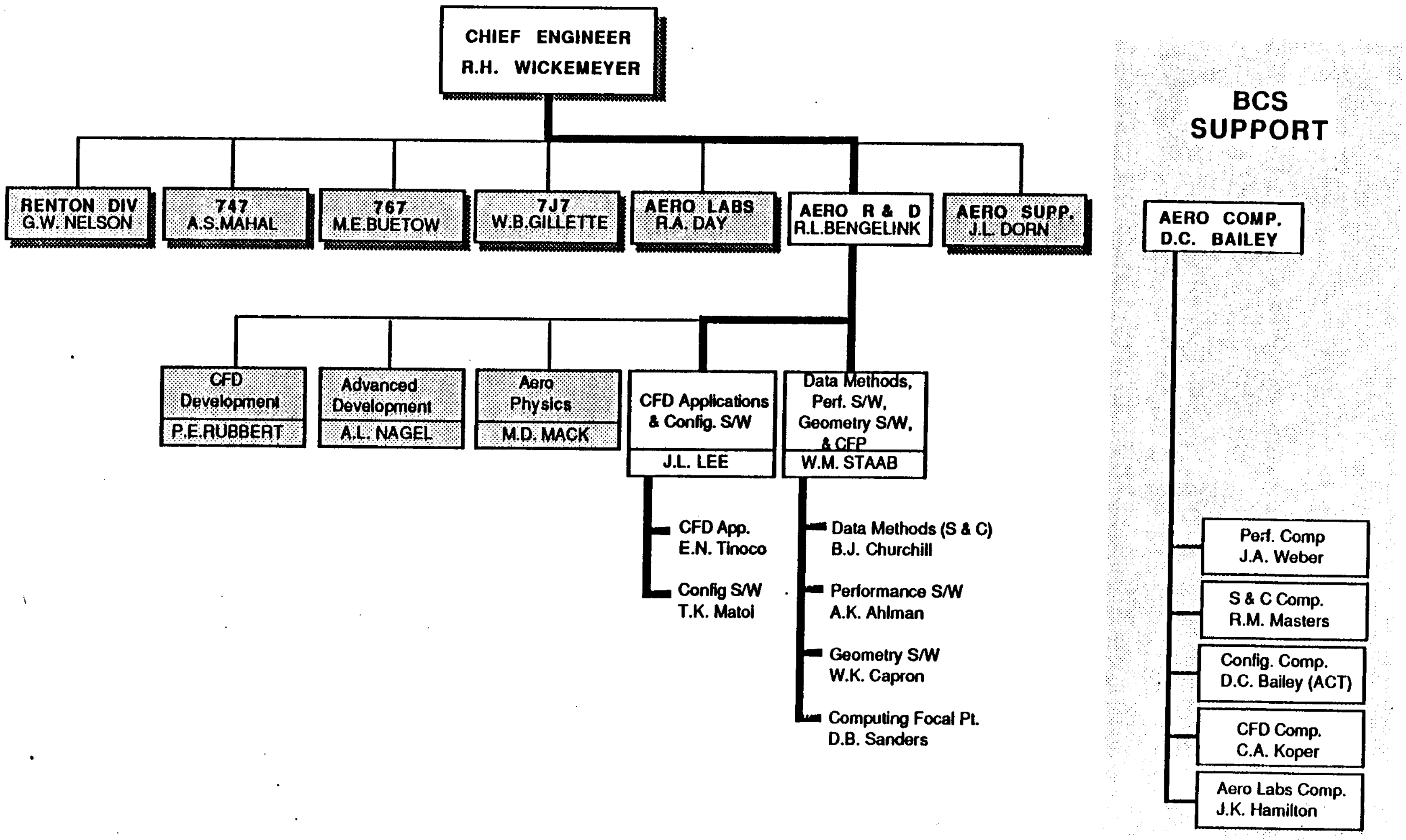
PASSENGER CAPACITY

	SHORT RANGE 36"/32"	MED. RANGE 38"/34"	LONG RANGE 60"/38"/34"
A320-200	150		
A320 STR	175		
A310-300		211	
A300-600R		261	
A330-200		328	
A340-200			245
A340-300			275
MD-87	121		
MD-88	142		
MD-91	120		
MD-92	155		
MD-11			274
MD-11ER			233
MD-11STR			310
F100	102		
BAe146-200	86		
BAe146-300	98		
737-200	110		
737-500	108		
737-300	128		
737-400	146		
7J7	148		
757-200		186	
767-200		216	
767-300		261	
767-200ER			174
767-300ER			210
767-400		293	
747SP			276
747-200B			366
747-300			400
747-400			412

AERODYNAMICS STAFF

COMPUTING OVERVIEW

Organization Chart



Role of Computing in Aero Staff

Support Engineering Analysis and Data Processing

- Data Plots
- Aero Configuration Lofting
- Performance, Configuration, and Stability and Control Tasks
- Flight Manual Performance Charts
- Reduce Engineering Labor

Provide Guidance for Configuration Design

- CFD Analysis
- Wind Tunnel and Flight Test Data Analysis
- Simulation

Existing Hardware

- **EKS**
  - Crays
  - Cybers
- **Interactive Graphics Data Analysis (IGDA)**
  - DEC PDP-11/70
- **General Purpose VAX**
  - DEC VAX 11/780
- **Harris**
  - 8000
  - Satellite Systems
- **PC's**
  - IBM and IBM Clones
  - Macintosh

Existing Software

- Aero developed staff specific software exists for many configuration, performance, stability and control, and data analysis tasks
- Common system software exists for many graphics applications
- Users develop small programs for data manipulation and reformatting

Software Classifications

- Configuration
- Geometry Methods
- Performance
- Stability & Control / Data Methods
- Aero Labs Data Systems
- Common System Software

Development of New Software

- Occurs in all technical areas
- Responsive to Aero Staff's current and future needs
- Cooperative effort between Aero Staff Software Development Groups and BCS Aero Support Groups
- Software Change Request (SCR)

Role of Aero Software Development Group

- Define Requirements (with USER participation)
- Write Functional Specifications
- Schedule and Review Progress
- Validate Finished Product
- Produce User Documentation
- Train and Support Users
- Provide Consultation

Role of BCS Aero Support Group

- Provide Resource Estimates
- Produce System Design
- Build, Test and Maintain Software Systems
- Assure Software Quality, Maintainability and Portability
- Produce Software Maintenence Documentation
- Version Control

Hardware Support

Maintenance

- Phone Number for Service is on Machine

  (refer to DEVICE ID also on Machine)

New Equipment Requests (RFE's)

- Aero Staff Computing Focal Point - Doug Sanders (865-6402)
  - Authorized RFE Functional Computing Equipment Representative for Central Technology computing capital standard equipment

Operating System Consultation

EKS

- EKS Consultation (763-5111)

IGDA

- System Coordinators
- Aero Staff Focal Point - Bryan Callan (865-6404)
- ETAP Manager - Ivor Thomas (656-7872)

VAX

- System Coordinators
- Aero Staff User Representative - Bryan Callan (865-6404)

Apollo

- Ring Administrator - Local to your Building
- Aero Staff Focal Point - Bryan Callan (865-6404)
- ETAP Manager - Ivor Thomas (656-7872)

Computer Training

Courses are available to learn how to use specific computers and how to use specific software packages

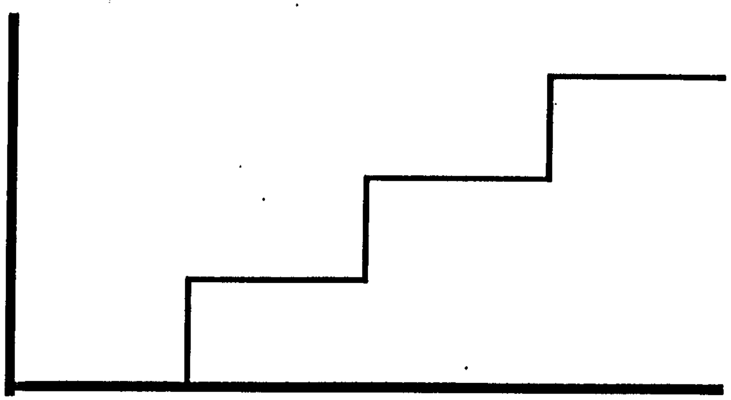
- BCS Catalog / Schedule
- Boeing News / Learning Center Offerings

- Aero Staff Training Coordinator - Mary Yoder-Williams (865-6402)

BCAC Automation Theme

PROGRESSIVE IMPROVEMENT...

NOT POSTONED PERFECTION



Computing Automation Goals

Hardware

- Replacement of Out-of-date Equipment
- Networking
- Faster Processing
- Convienient Access

Software

- Integrated User-Friendly Computing Environment
- State-of-the-Art Graphics

Hardware Goals

- IGDA Phase Out
- VAX Replacement
- Office Automation

Software Goals

- Convert and/or Replace Common System Software to the Workstation Environment
- Convert and/or Replace Staff Specific Software to the Workstation Environment
- Develop New Software to Automate Engineering Tasks and Enhance Engineering Analysis Capabilities

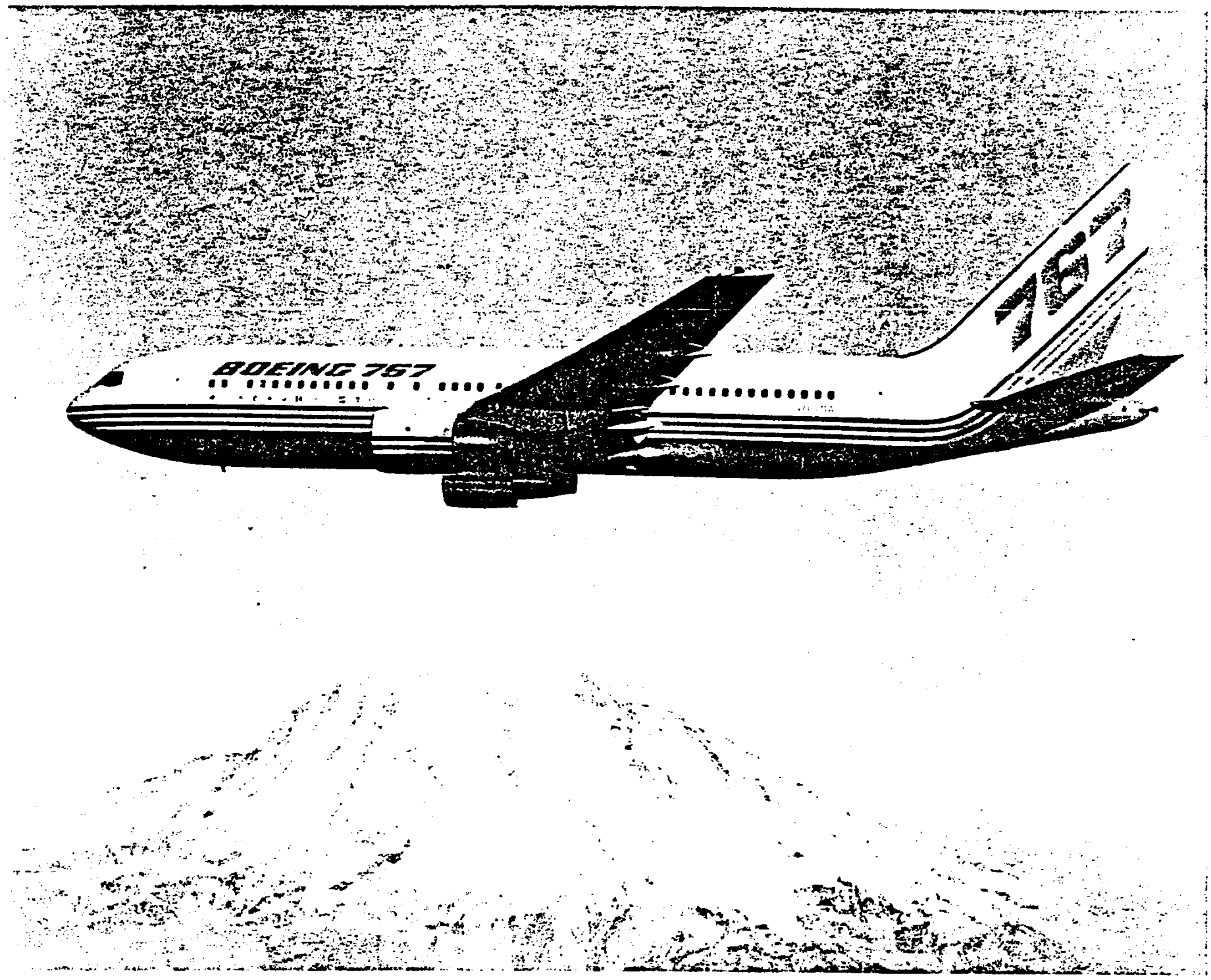
AIRCRAFT FAMILIARIZATION AND GLOSSARY OF TERMS

The technology that today makes advanced jet flight a reality has been the result of continuing research and development in decades of yesterdays. Each step has been bolder than the preceding steps. For the engineer who has little knowledge of airplanes, aircraft familiarization is a necessary step.

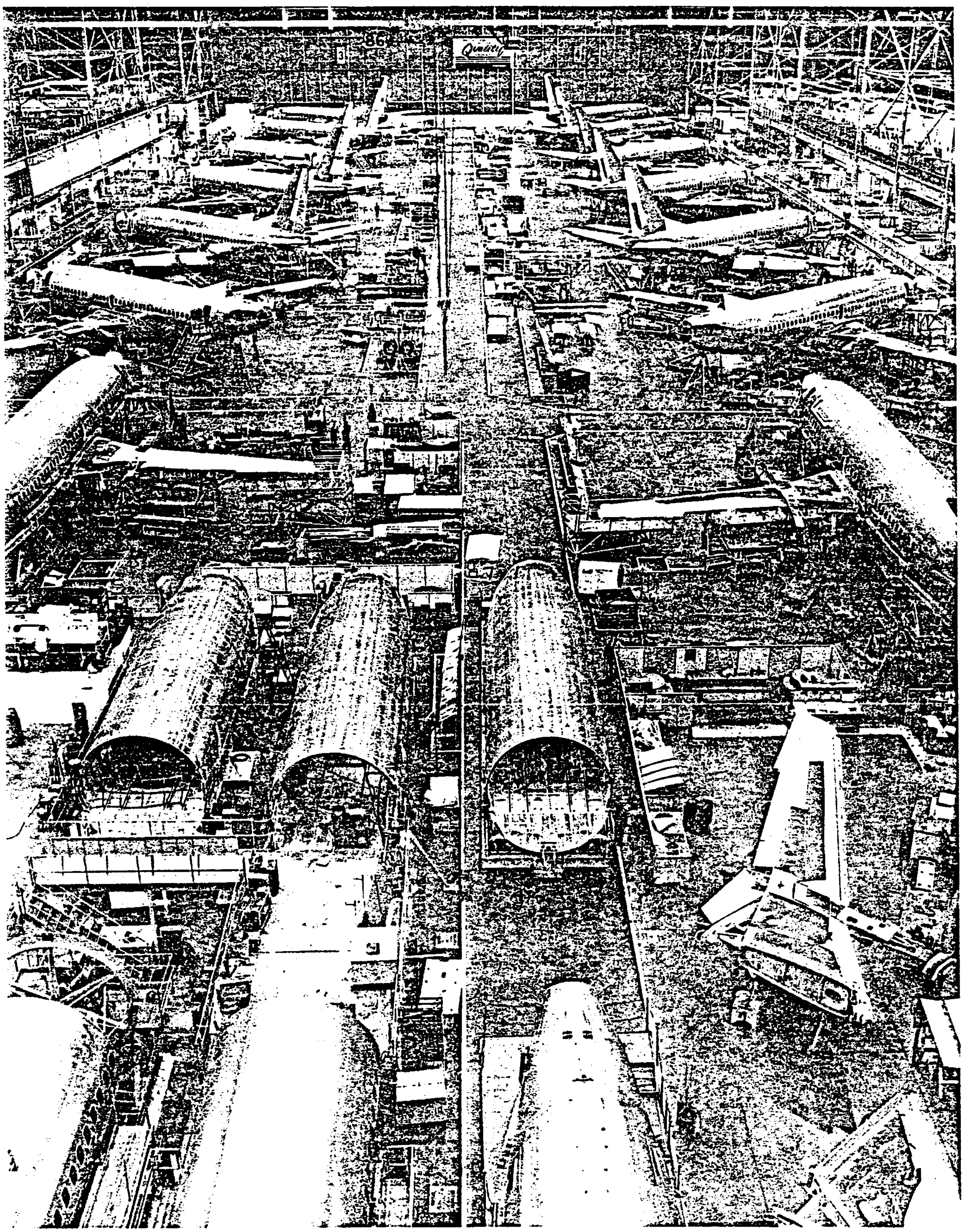
An airplane is more complex than any other commercial passenger-carrying vehicle. We must examine this complexity of components to understand its design, manufacture, and flight.

Diagrams are shown to assist the engineer in understanding flight characteristics, control axes, control surfaces, and reference planes. Other illustrations include a make/buy plan (showing subcontractor roles), Boeing parade of progress, body diameter comparison chart, family of current jets, and a general arrangement and sectional breakdown of several current Boeing airplanes.

Powerplant familiarization is provided. Diagrams of six different types of engines are included for reference.



Model 767



737 Final Assembly Lines (note different sections in foreground)

MAKE/BUY PLAN

Figure 5-1 illustrates a make/buy plan for The Boeing Company's Model 747. Some of the parts are made at Boeing and some are made at various companies and shipped to Boeing, where final assembly of the airplane occurs. A great deal of complex consideration is given when deciding whether to make a particular part or to buy it. Some considerations are: If Boeing is to make a particular part, it must be sure it has the properly skilled labor force, adequate facilities, and sufficient time; and Boeing may buy parts if they can be obtained at a competitive price, acquired according to a particular delivery schedule, or purchased "off the shelf."

The Boeing Company is ultimately a commercial aircraft manufacturer. Although Boeing may make only half of the airplane, Boeing does do the marketing, research and development, coordination, and final assembly.

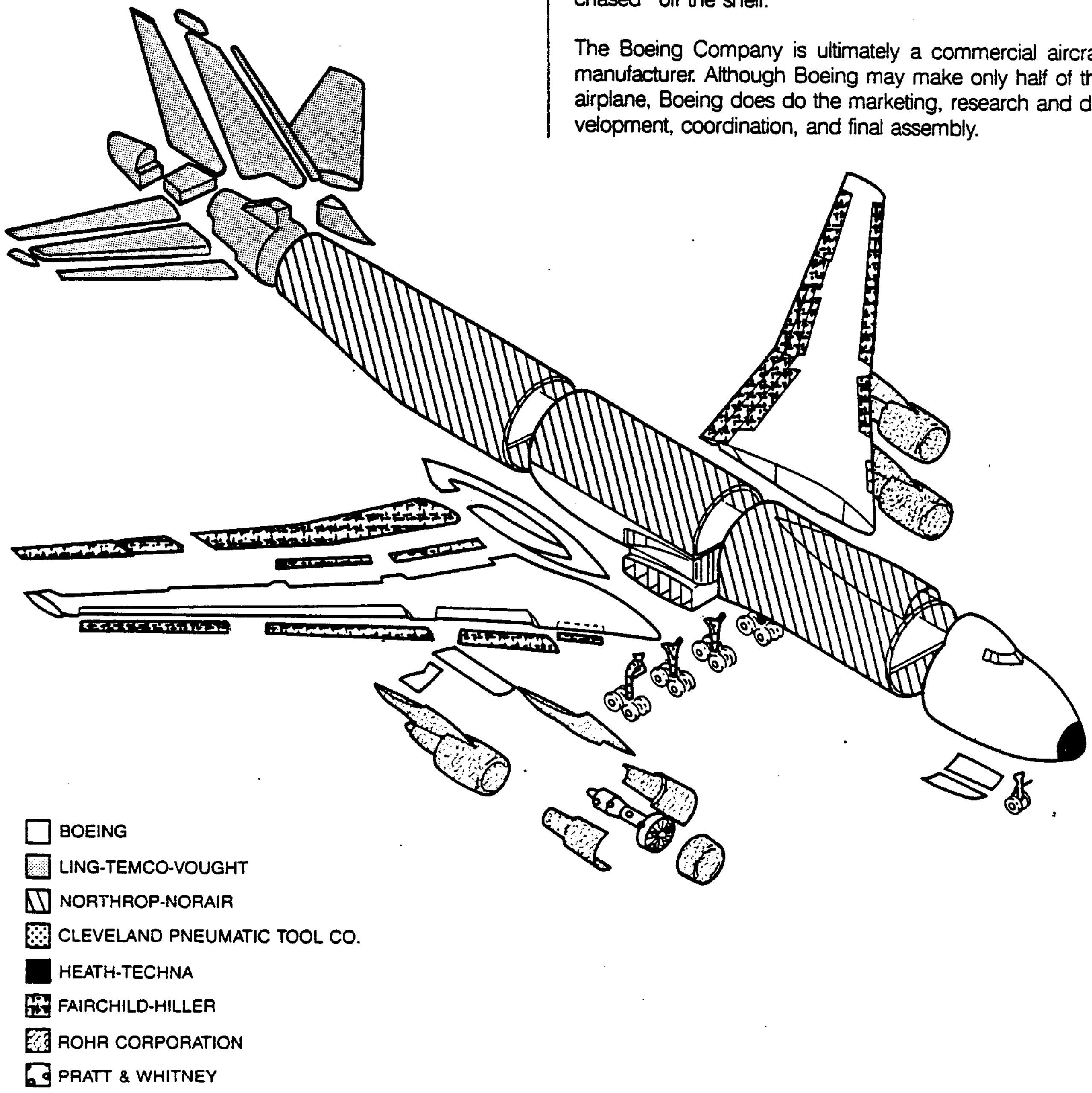
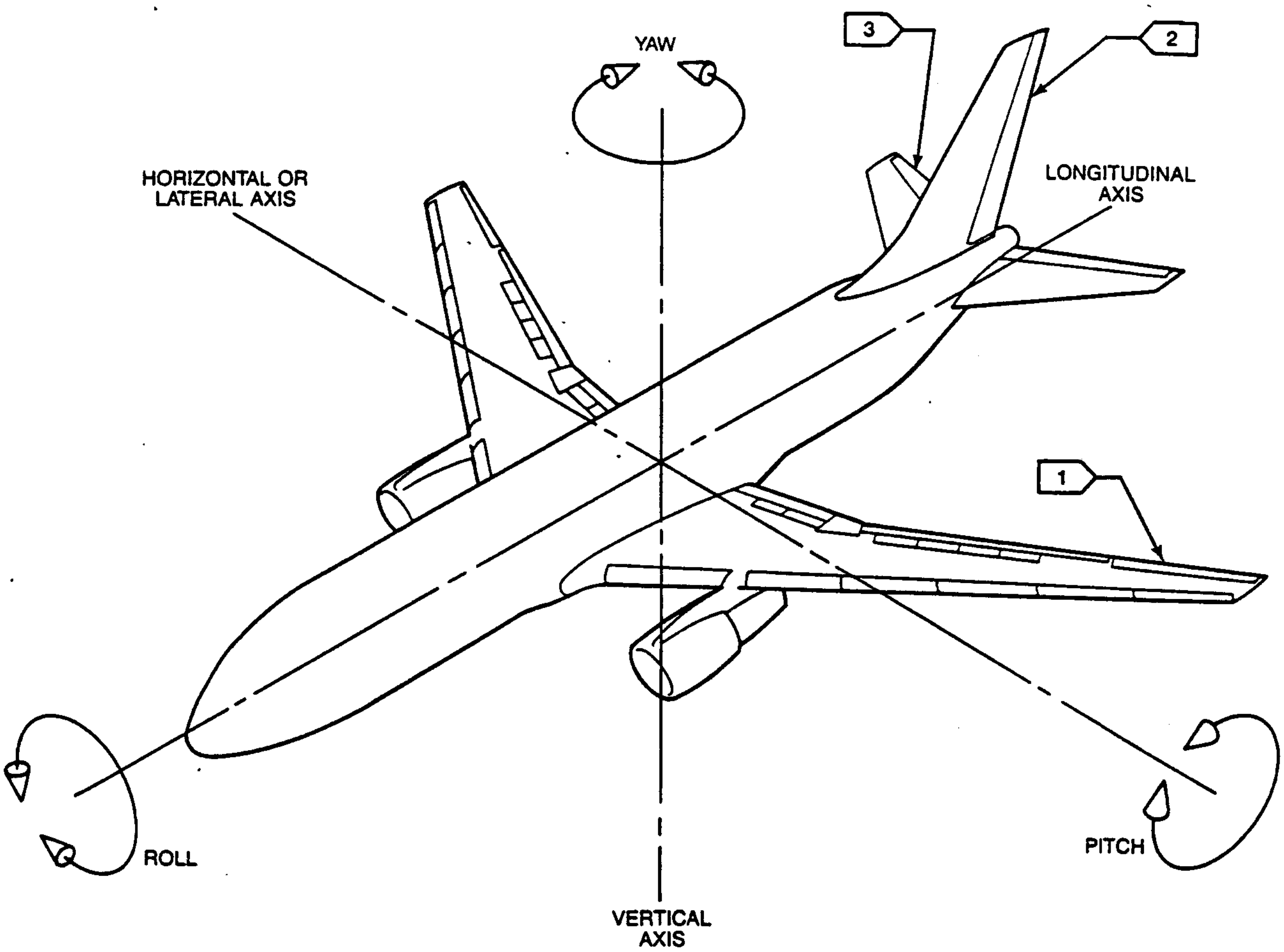


Figure 5-1. Model 747 Make/Buy Diagram

CONTROL AXIS DIAGRAM



1 AILERON—THE HINGED SECTION OF THE TRAILING EDGE OF THE LEFT AND RIGHT WINGS THAT OPERATE IN SERIES TO PROVIDE LATERAL CONTROL. WHEN ONE AILERON IS RAISED, THE OPPOSITE IS LOWERED, PRODUCING ROLLING MOVEMENTS AROUND THE LONGITUDINAL AXIS.

2 RUDDER—THE HINGED OR MOVABLE AUXILIARY AIRFOIL ATTACHED TO THE VERTICAL FIN TO CONTROL YAW.

3 ELEVATOR—THE HINGED SECTION OF THE HORIZONTAL STABILIZER USED TO CONTROL PITCH.

ROLLING MOVEMENTS ARE A FUNCTION OF BOTH AILERONS AND FLIGHT SPOILERS.

Figure 5-2. Model 767-200 Control Axis Diagram

767-200
CONTROL SURFACES

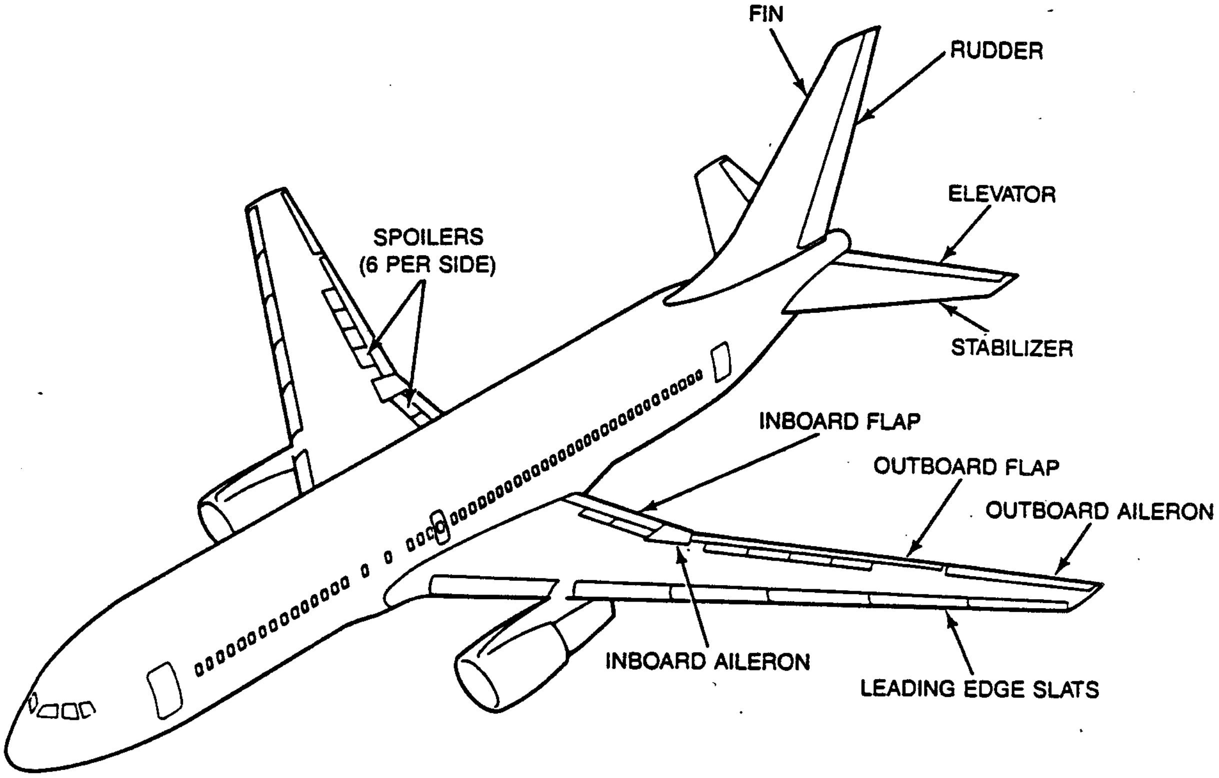


Figure 5-3. Model 767-200 Control Surfaces

767-200
AIRCRAFT REFERENCE PLANES

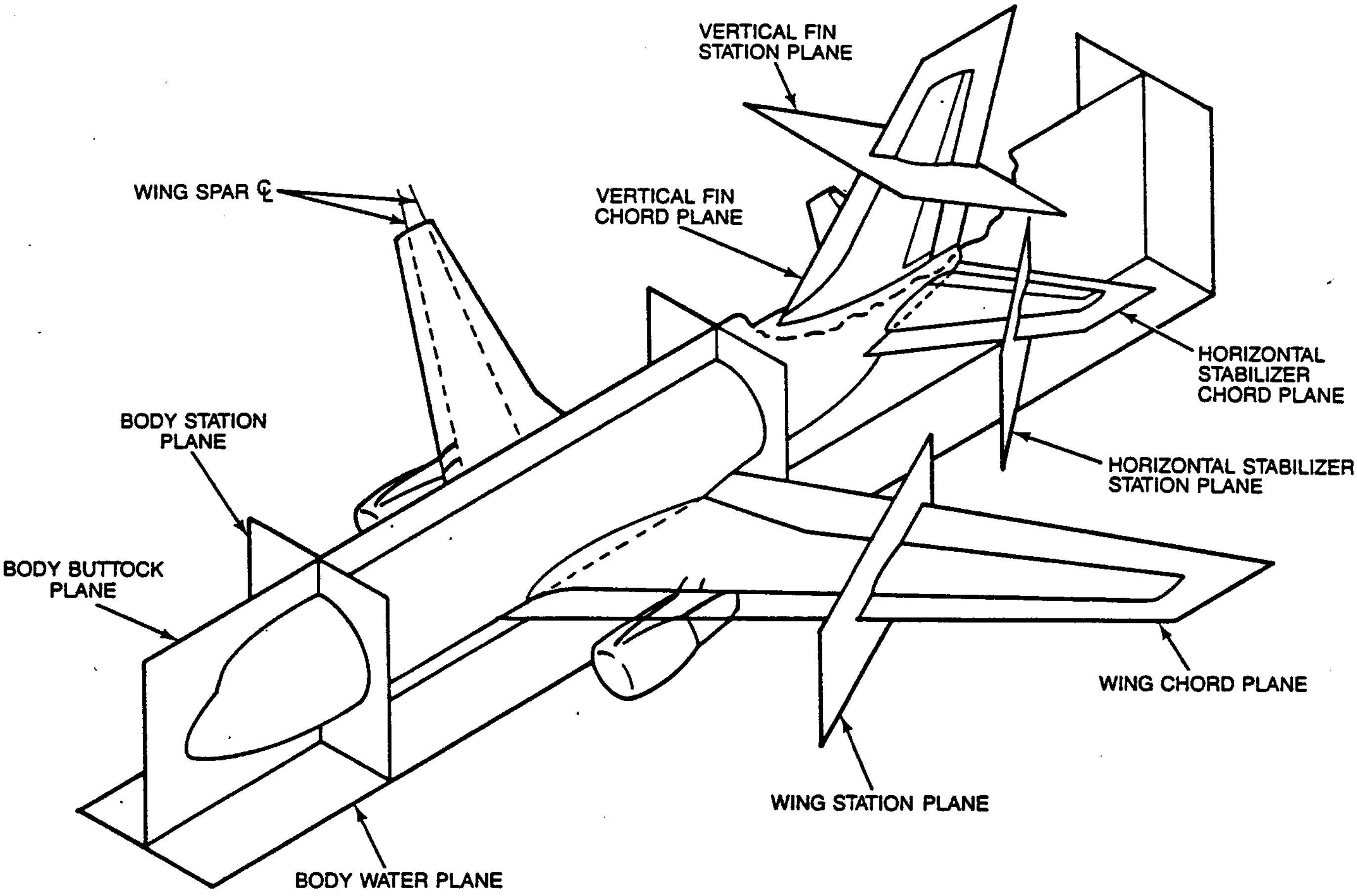


Figure 5-4. Model 767-200 Aircraft Reference Planes

BOEING PARADE OF PROGRESS

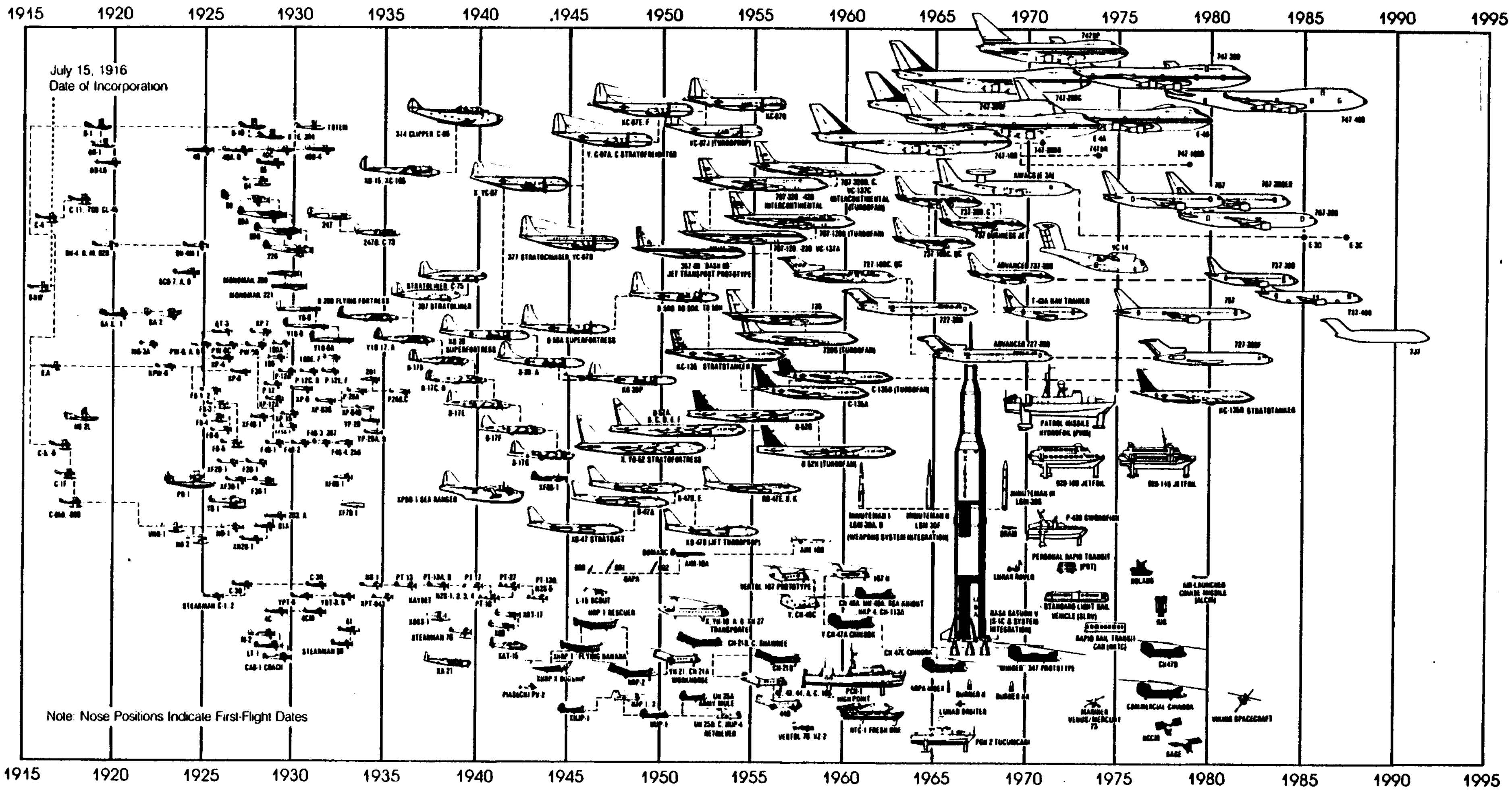


Figure 5-5. Boeing Parade of Progress

5.7

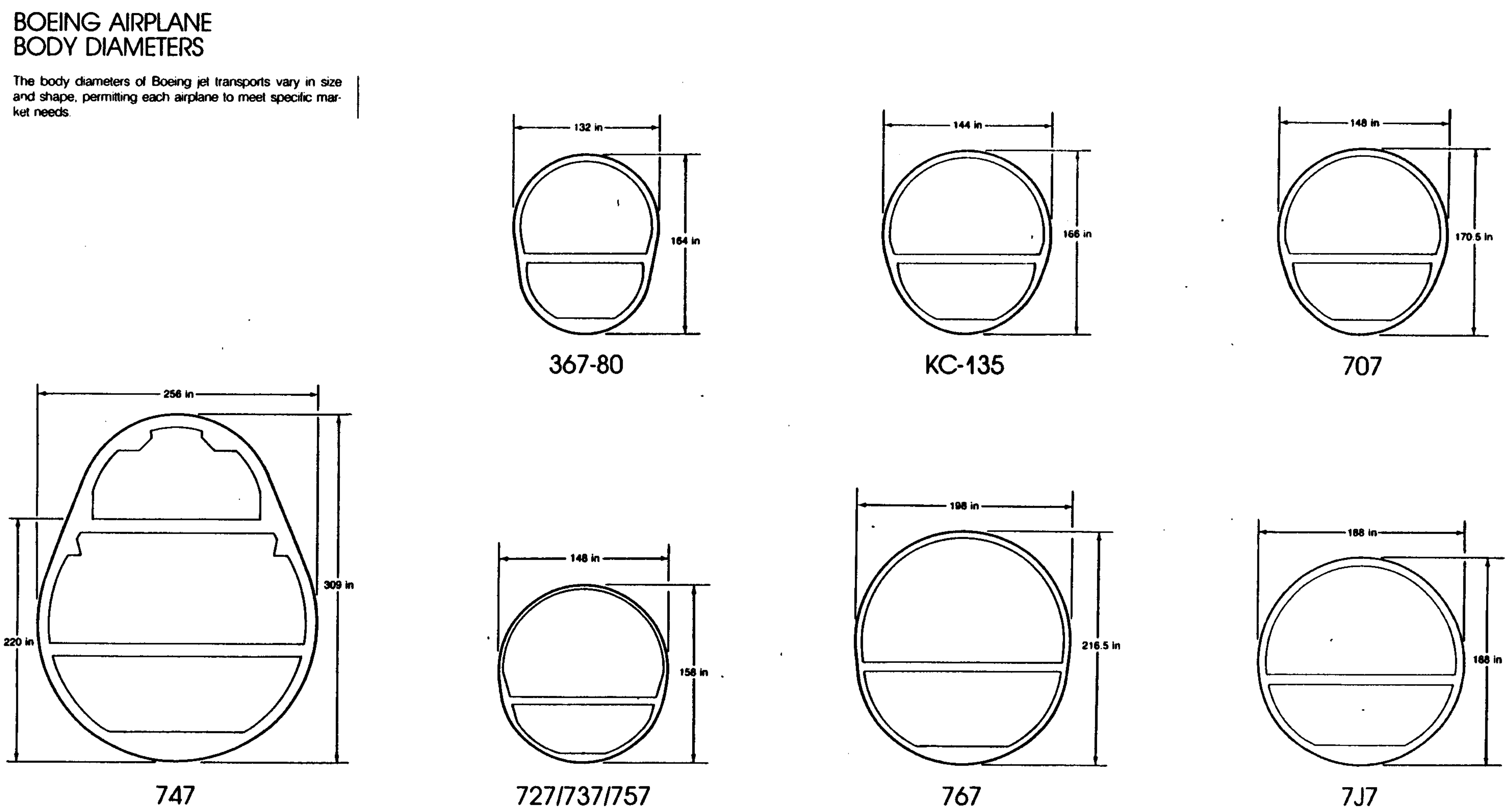


Figure 5-6. Boeing Airplane Diameter Comparison

BOEING FAMILY OF COMMERCIAL AIRPLANES

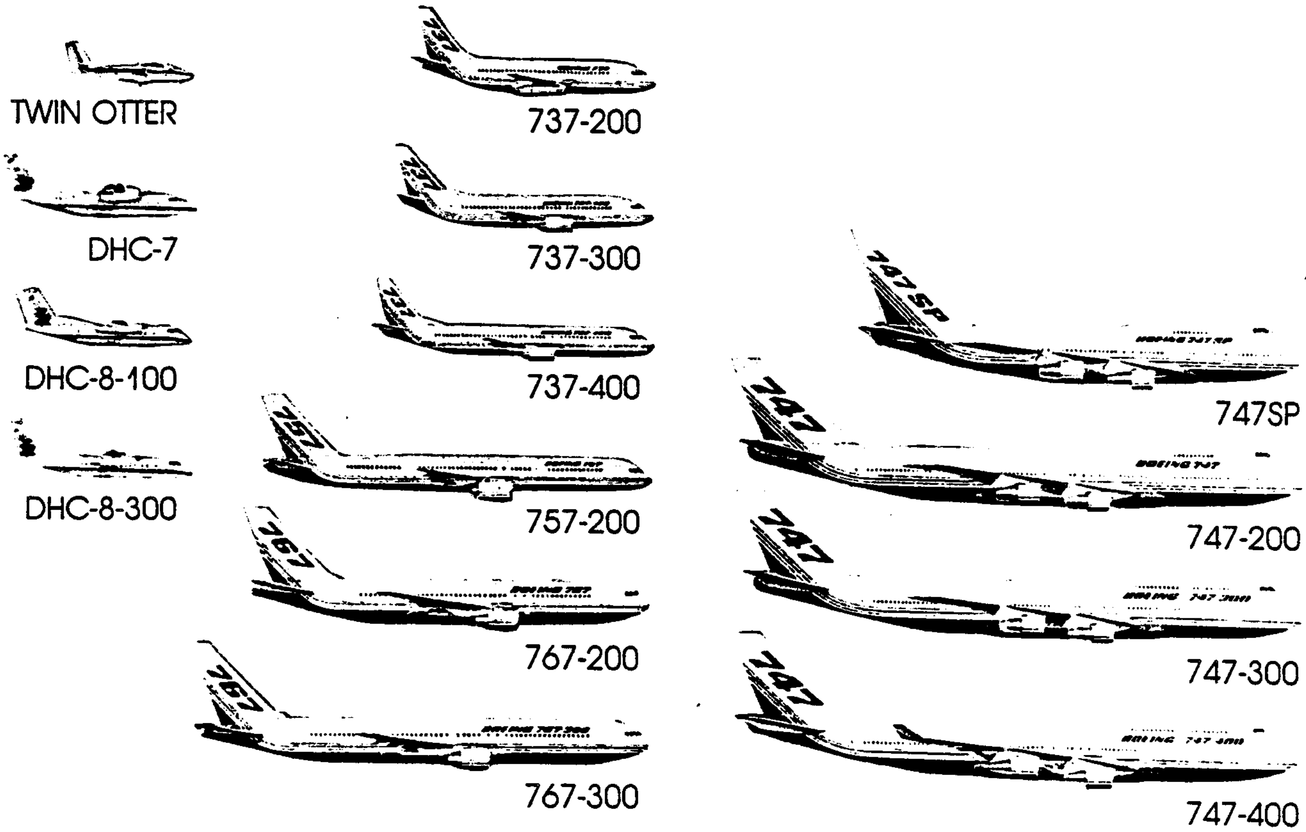


Figure 5-7. Boeing Family of Commercial Airplanes

737-200
GENERAL ARRANGEMENT

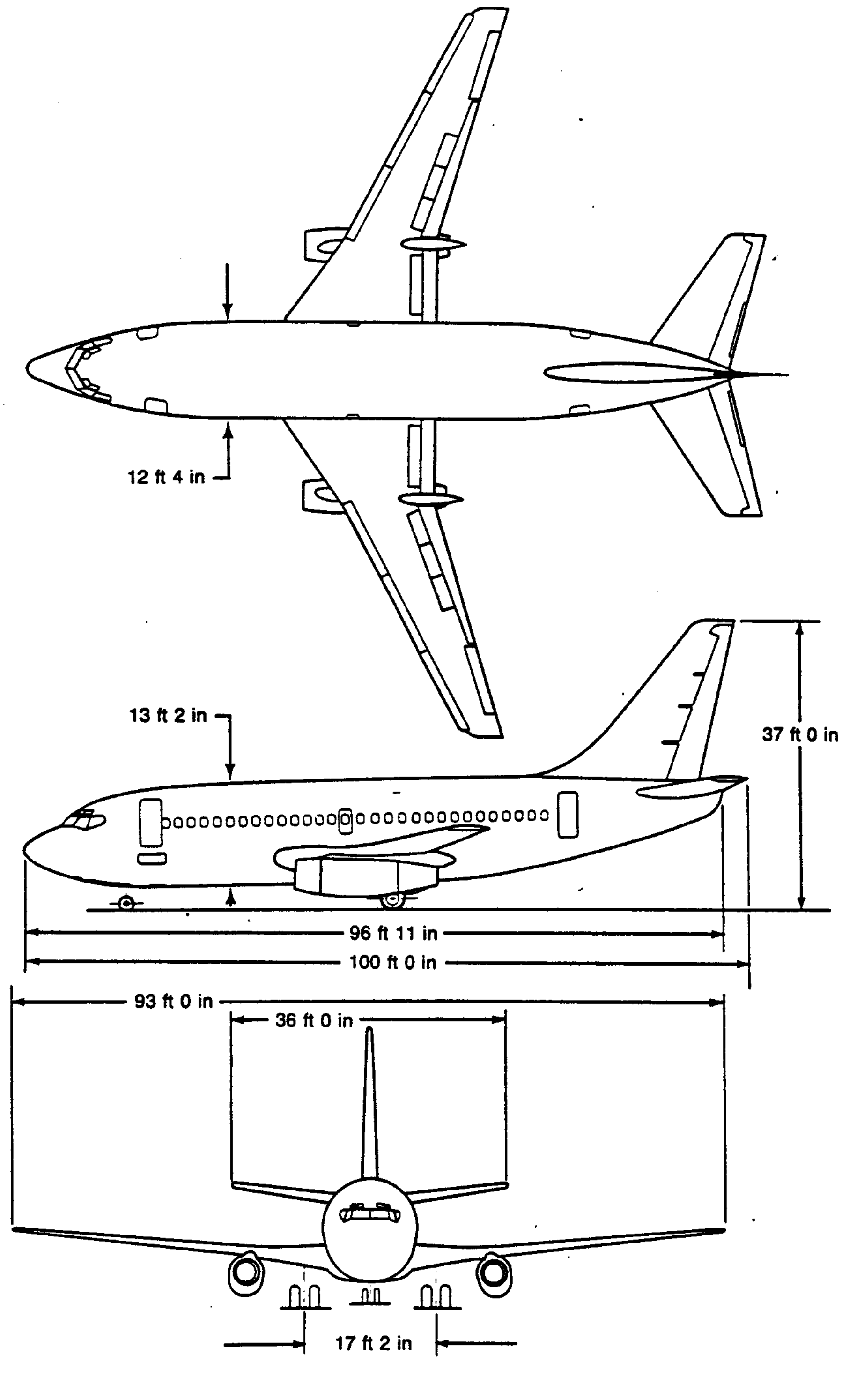
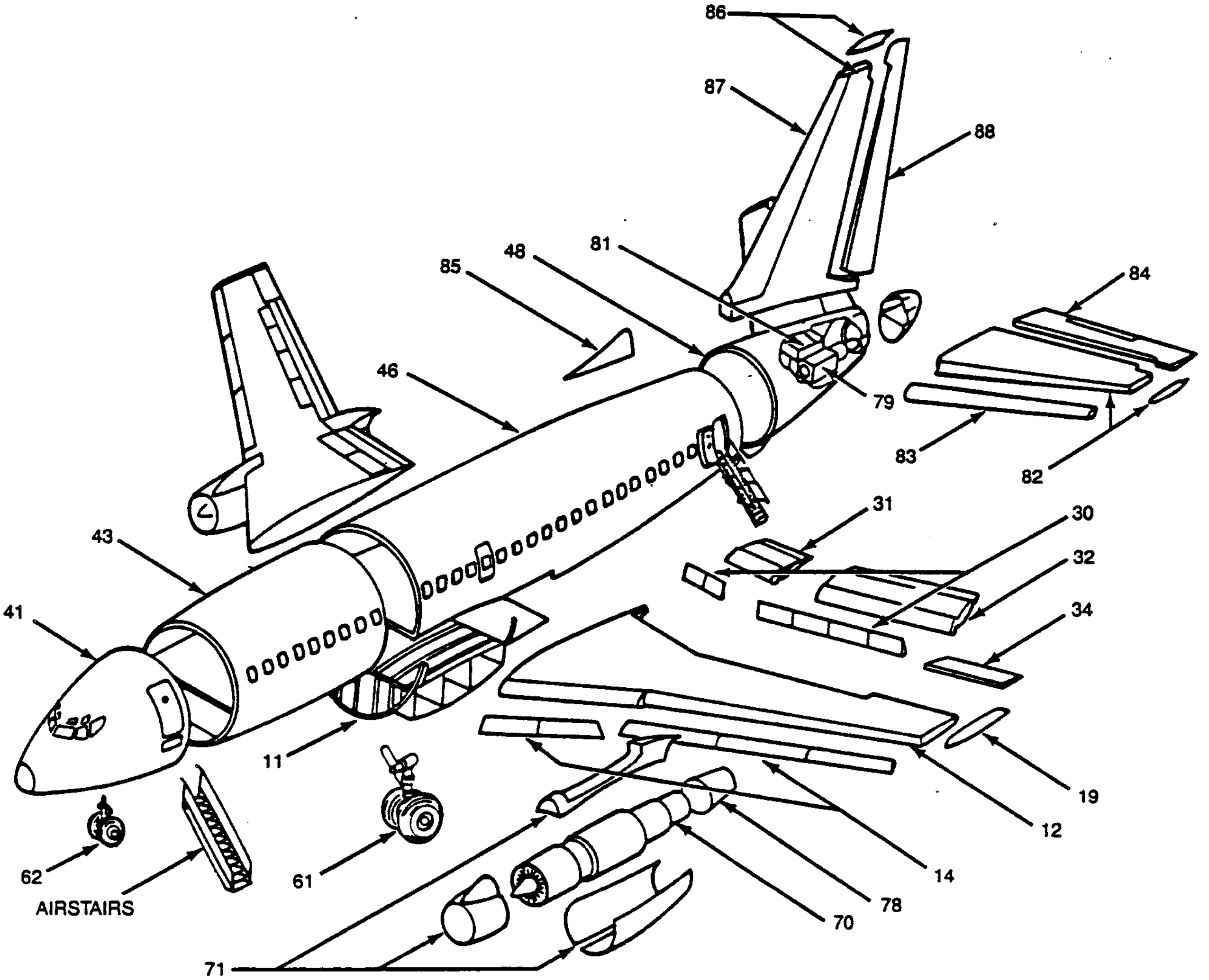


Figure 5-8. Model 737-200 General Arrangement

737-200
SECTIONAL BREAKDOWN



WING

11 WING STUB
12 WING, OUTBOARD
14 SLATS AND FLAPS, LEADING EDGE
19 WINGTIP
30 SPOILERS
31 FLAP, INBOARD
32 FLAP, OUTBOARD
34 AILERON

BODY

41 SECTION 41
43 SECTION 43
46 SECTION 46
48 SECTION 48

LANDING GEAR

61 MAIN GEAR
62 NOSE GEAR

POWERPLANT

70 POWERPLANT
71 COWLING, ENGINE
78 THRUST REVERSER, TAILPIPE
79 AUXILIARY POWER UNIT

EMPENNAGE

81 STABILIZER CENTER SECTION
82 STABILIZER
82 STABILIZER TIP
83 STABILIZER LEADING EDGE
84 STABILIZER ELEVATOR
85 DORSAL FIN
86 FIN
86 FIN TIP
87 FIN LEADING EDGE
88 RUDDER

Figure 5-9. Model 737-200 Sectional Breakdown

737-300
GENERAL ARRANGEMENT

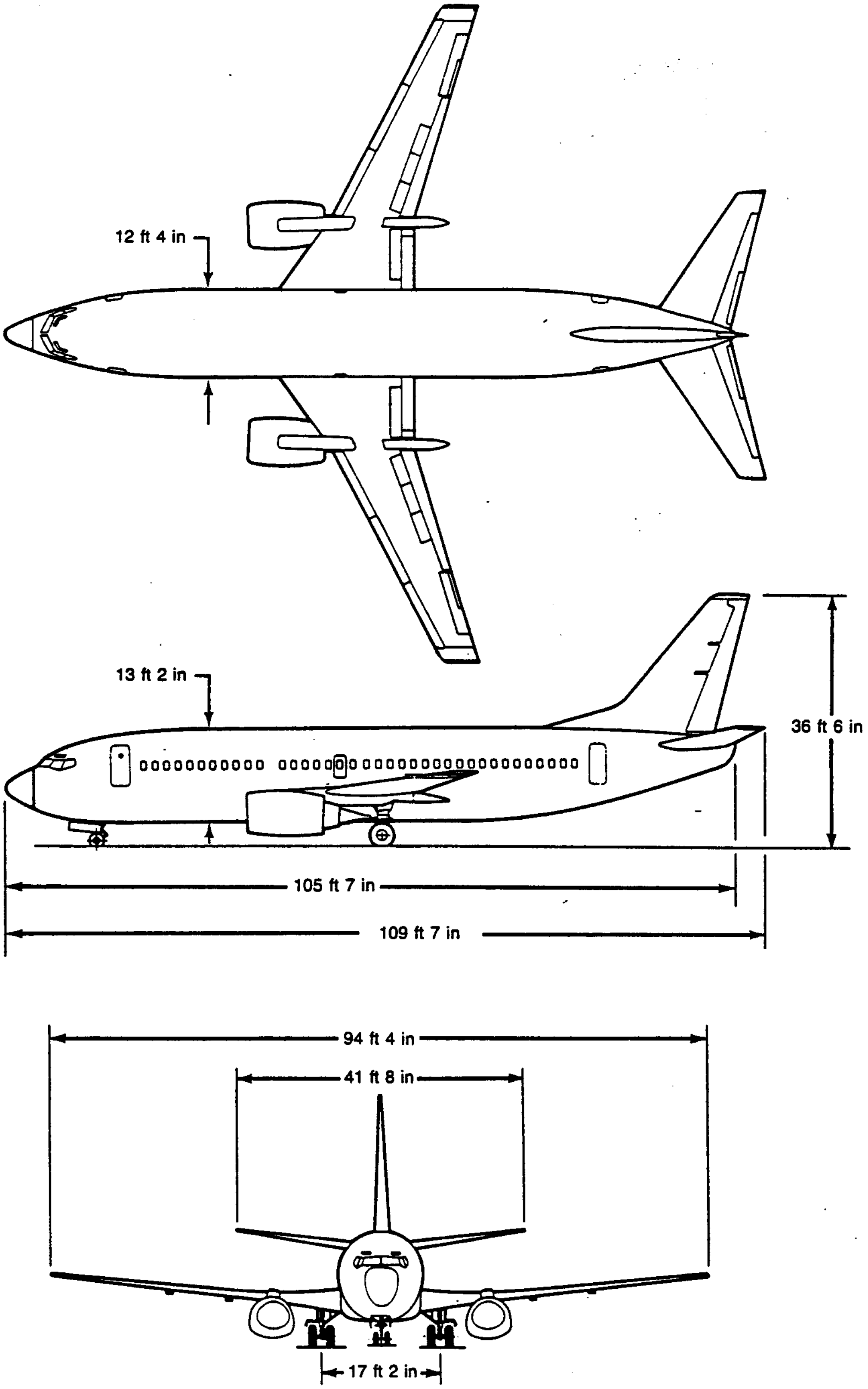
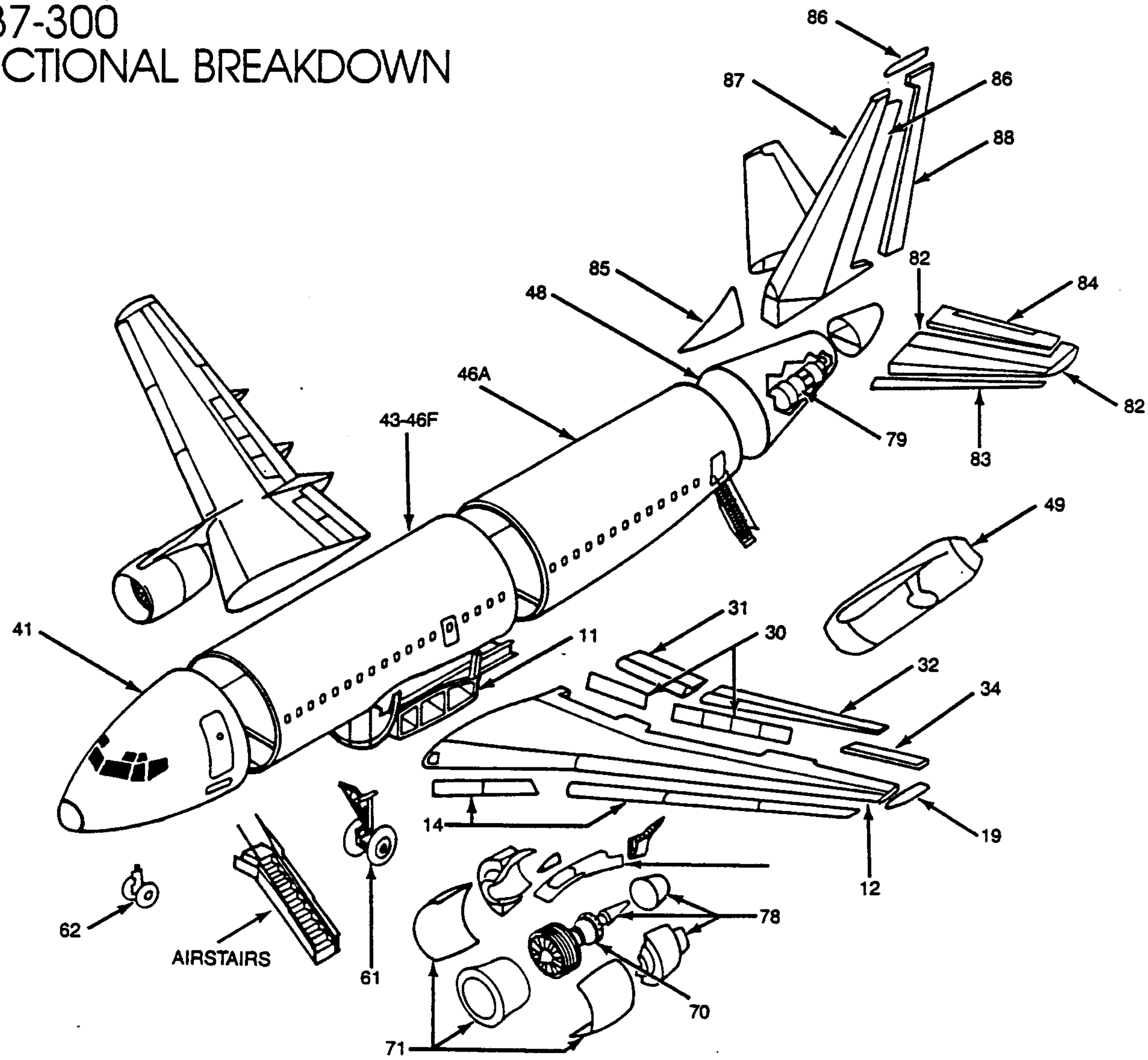


Figure 5-10. Model 737-300 General Arrangement

737-300 SECTIONAL BREAKDOWN



WING

11 WING STUB
12 WING, OUTBOARD
14 SLATS AND FLAPS, LEADING EDGE
19 WINGTIP
30 SPOILERS
31 FLAP, INBOARD
32 FLAP, OUTBOARD
34 AILERON

BODY

41 SECTION 41
43-46F SECTION 43-46 FWD
46A SECTION 46 AFT
48 SECTION 48
49 WING-BODY FAIRING

LANDING GEAR

61 MAIN GEAR
62 NOSE GEAR

POWERPLANT

70 POWERPLANT
71 COWLING, ENGINE
78 THRUST REVERSER, TAILPIPE
79 AUXILIARY POWER UNIT

EMPENNAGE

82 STABILIZER
82 STABILIZER TIP
83 STABILIZER LEADING EDGE
84 STABILIZER ELEVATOR
85 DORSAL FIN
86 FIN
86 FIN TIP
87 FIN LEADING EDGE
88 RUDDER

Figure 5-11. Model 737-300 Sectional Breakdown

747
GENERAL ARRANGEMENT

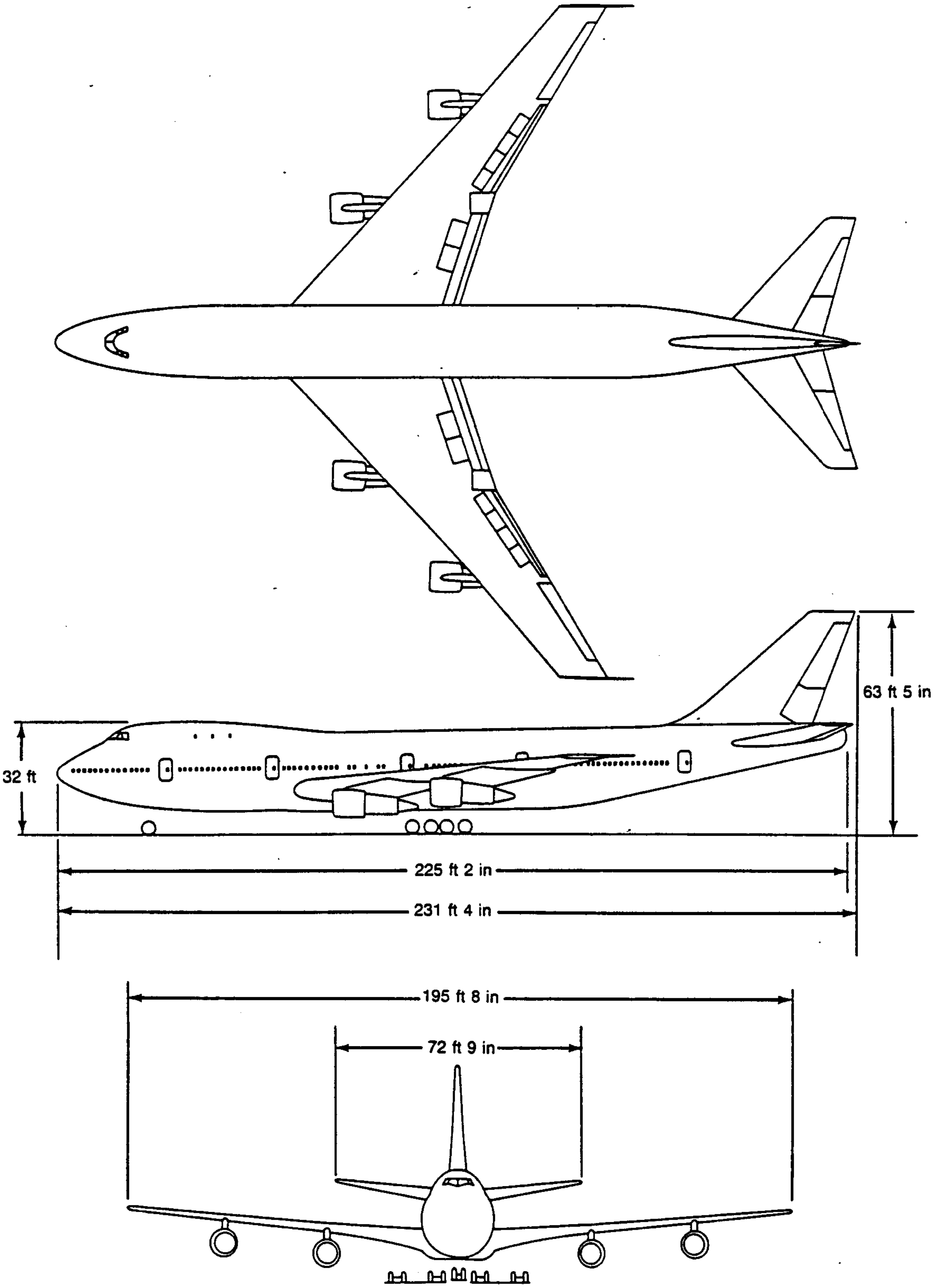
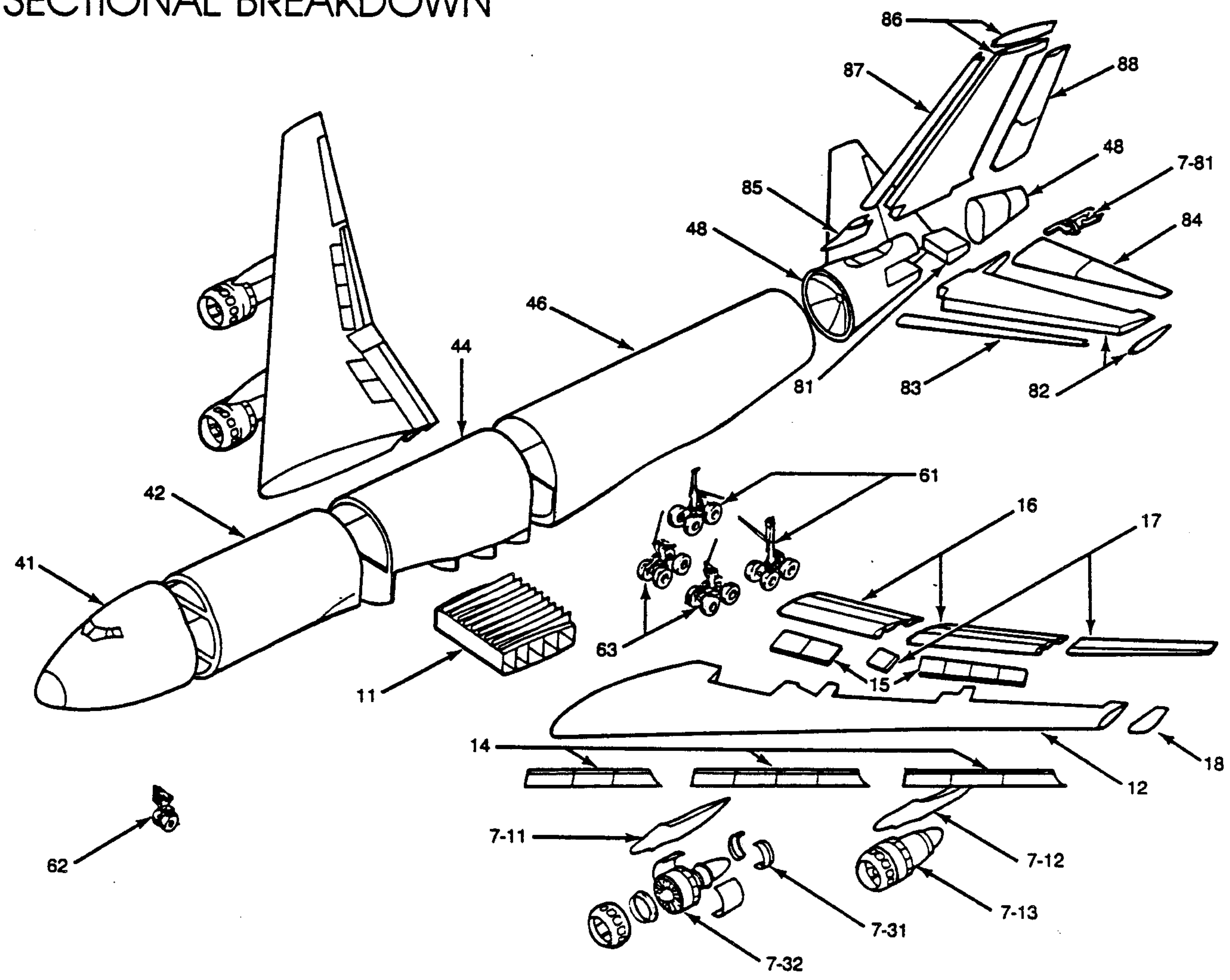


Figure 5-12. Model 747 General Arrangement

747
SECTIONAL BREAKDOWN



WING

11 CENTER SECTION
12 WING SECTION 12
14 LEADING EDGE FLAPS
15 SPOILERS
16 TRAILING EDGE FLAPS
17 AILERON
18 WINGTIP

BODY

41 SECTION 41
42 SECTION 42
44 SECTION 44
46 SECTION 46
48 SECTION 48

LANDING GEAR

61 WING MAIN GEAR
62 NOSE GEAR
63 BODY MAIN GEAR

POWERPLANT

7-11 INBOARD STRUT
7-12 OUTBOARD STRUT
7-13 POWERPLANT
7-31 PRIMARY EXHAUST THRUST REVERSER
7-32 FAN EXHAUST THRUST REVERSER
7-81 AUXILIARY POWER UNIT

EMPENNAGE

81 CENTER SECTION HORIZONTAL STABILIZER
82 OUTBOARD SECTION HORIZONTAL STABILIZER
83 LEADING EDGE HORIZONTAL STABILIZER
84 ELEVATOR
85 DORSAL FIN
86 FIN
87 LEADING EDGE FIN
88 RUDDER

Figure 5-13. Model 747 Sectional Breakdown

757-200
GENERAL ARRANGEMENT

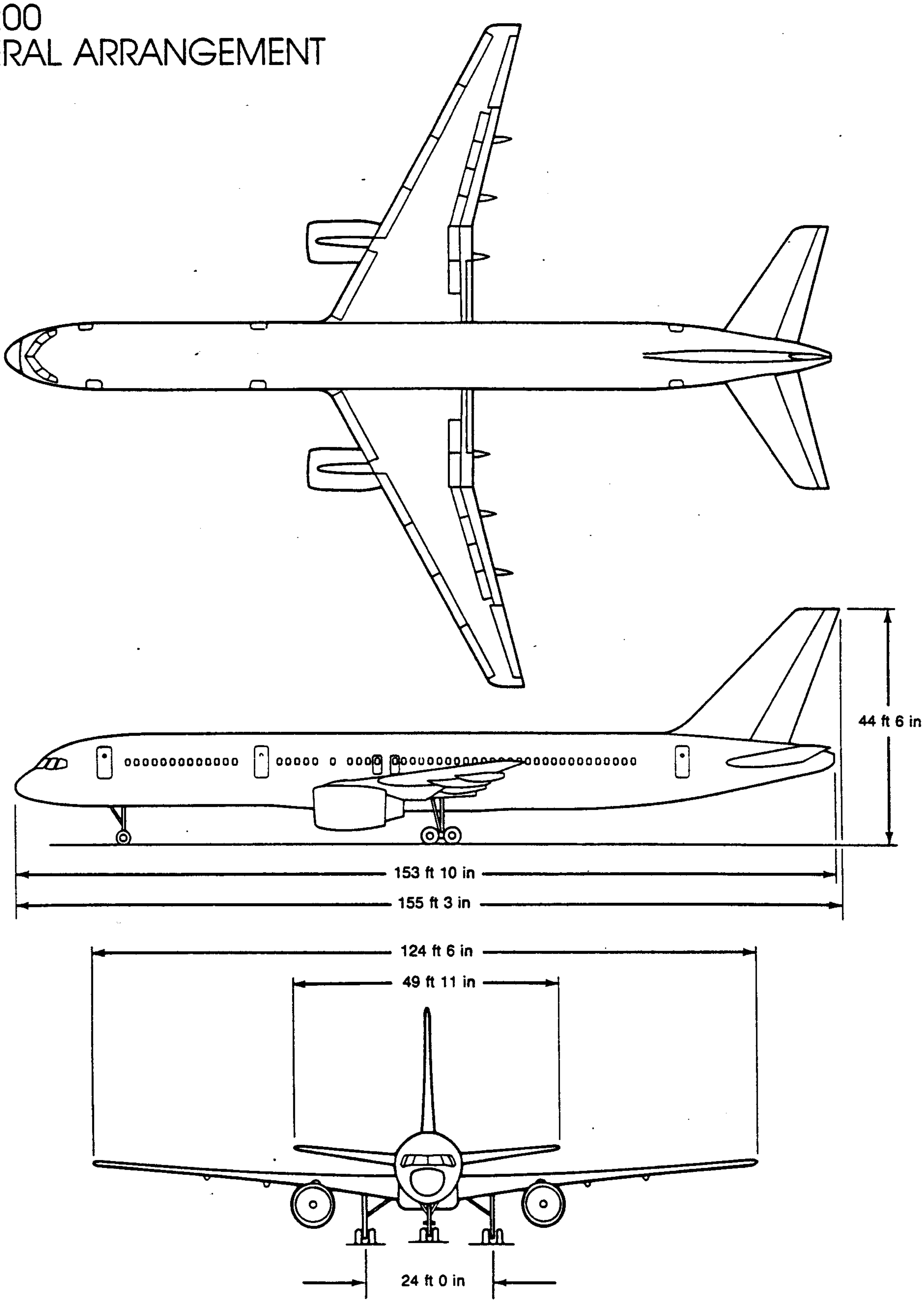
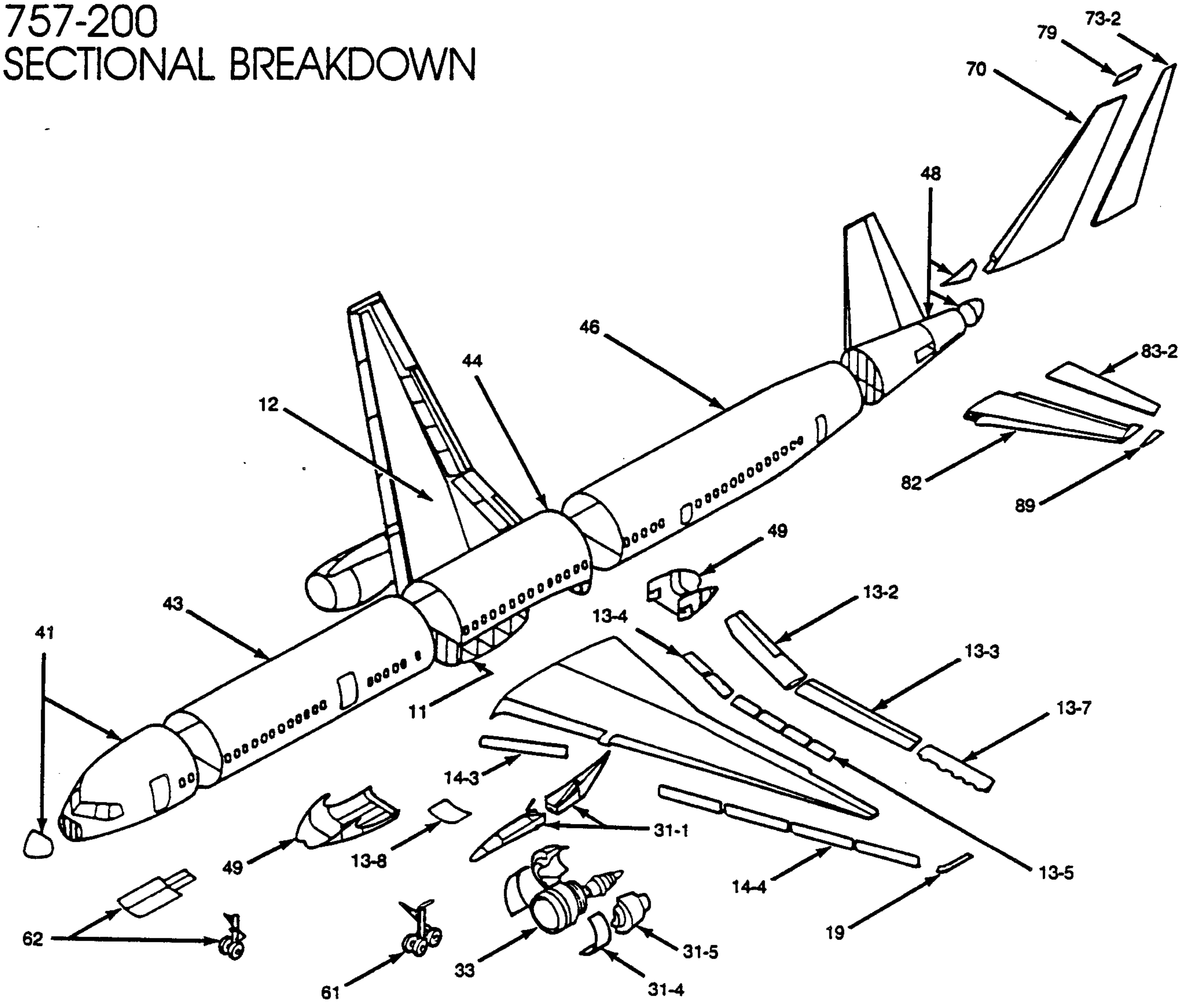


Figure 5-14. Model 757-200 General Arrangement

757-200
SECTIONAL BREAKDOWN



WING

11 WING CENTER SECTION
12 WING, OUTBOARD
13-2 TRAILING EDGE FLAPS, INBOARD
13-3 TRAILING EDGE FLAPS, OUTBOARD
13-4 SPOILERS, INBOARD
13-5 SPOILERS, OUTBOARD
13-7 AILERON
13-8 WING MLG DOOR
14-3 LEADING EDGE SLAT, INBOARD
14-4 LEADING EDGE SLAT, OUTBOARD
19 WINGTIP

POWERPLANT

31-1 ENGINE STRUT
31-4 ENGINE COWLING
31-5 ENGINE FAN THRUST REVERSER
33 ENGINE BUILDUP

BODY

41 FIRST BODY SECTION
43 SECOND BODY SECTION
44 THIRD BODY SECTION
46 FOURTH BODY SECTION
48 FIFTH BODY SECTION
49 WING-BODY FAIRING PACKAGE

LANDING GEAR

61 MAIN LANDING GEAR
62 NOSE LANDING GEAR

EMPENNAGE

70 VERTICAL FIN
73-2 RUDDER
79 FIN TIP
82 STABILIZER
83-2 ELEVATOR
89 STABILIZER TIP

Figure 5-15. Model 757-200 Sectional Breakdown

767-200
GENERAL ARRANGEMENT

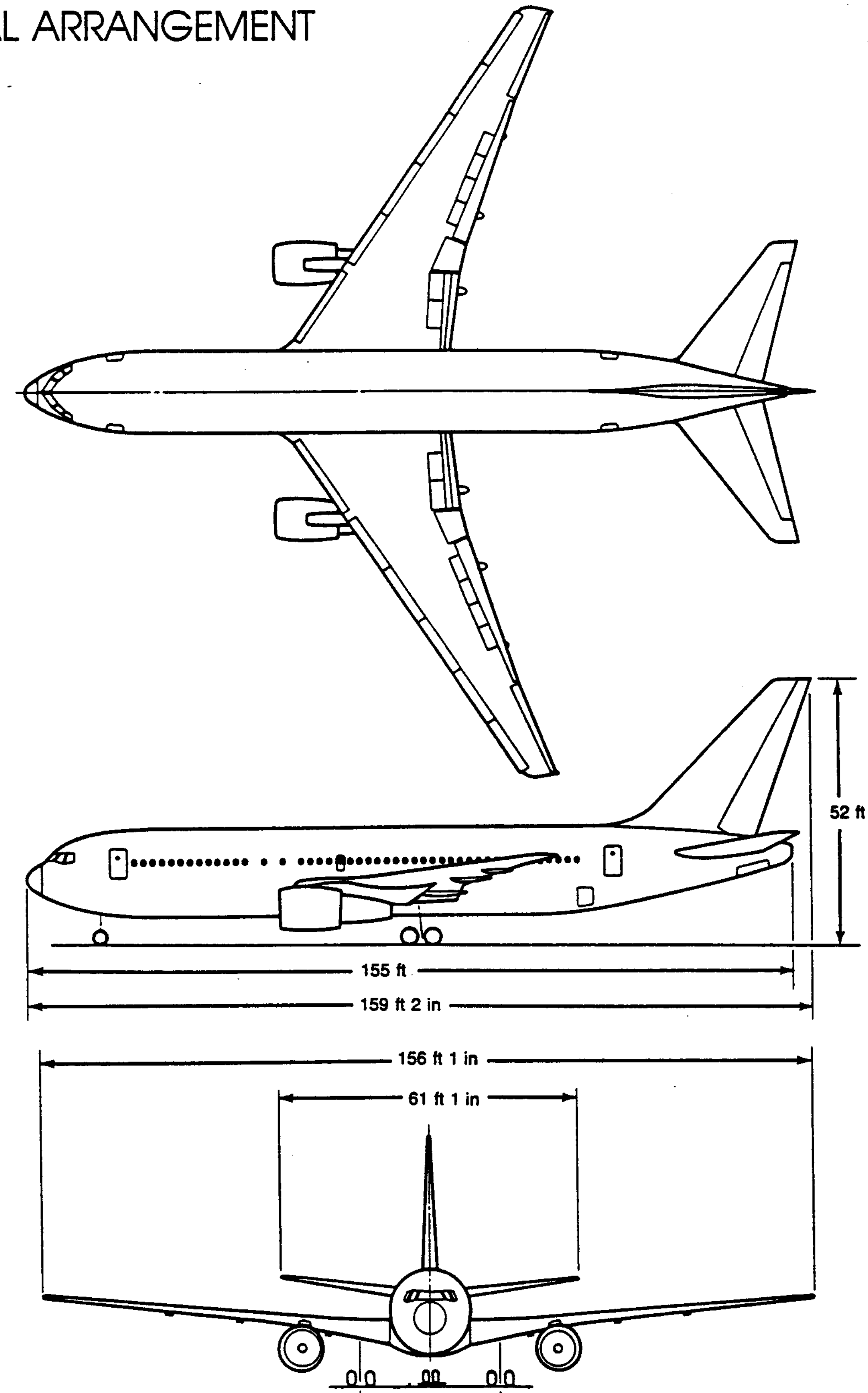
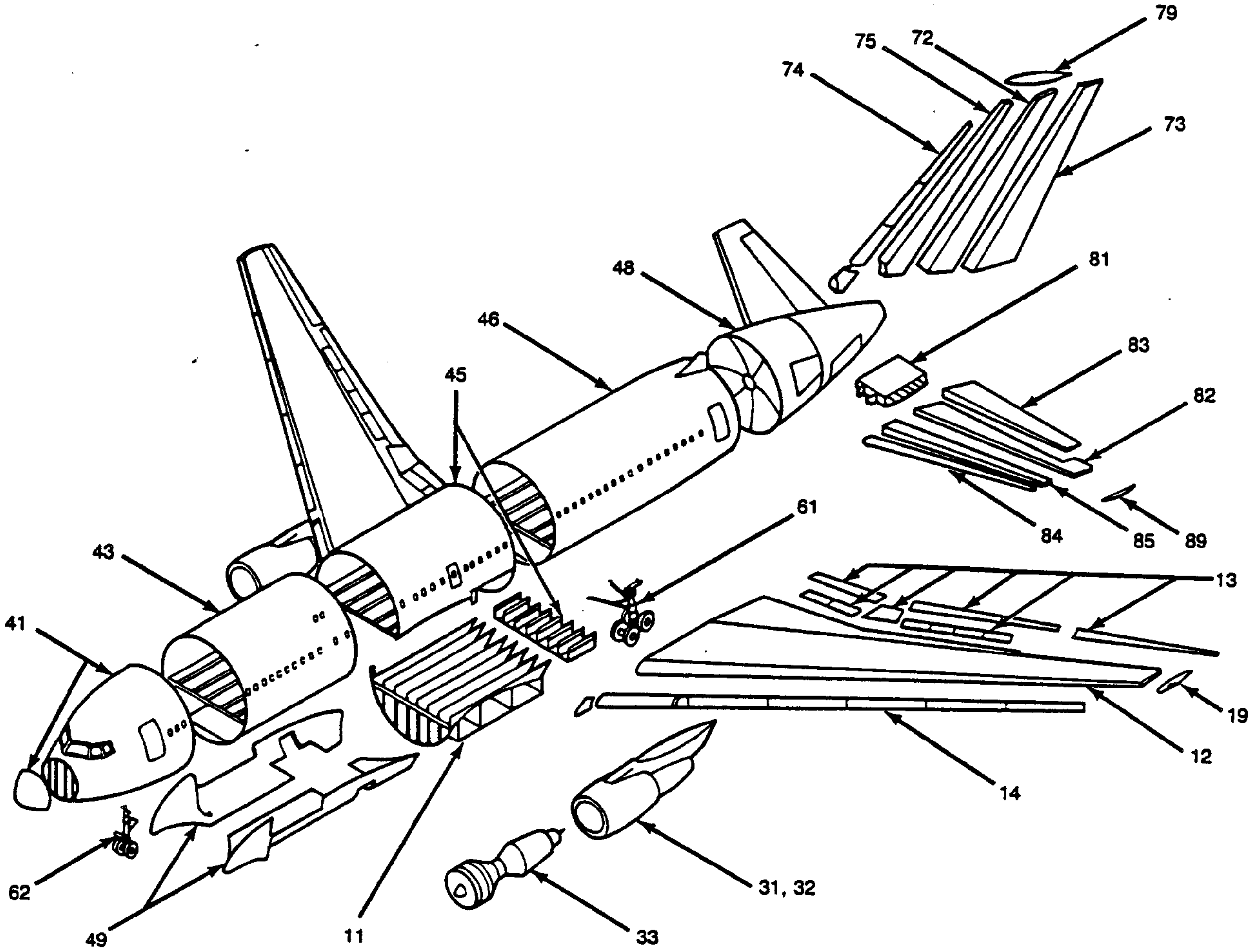


Figure 5-16. Model 767-200 General Arrangement

767-200 SECTIONAL BREAKDOWN



WING

11 WING CENTER SECTION
12 WING OUTBOARD STRUCTURAL BOX
13 WING TRAILING EDGE (INCLUDES AILERONS, FLAPS, AND SPOILERS)
14 WING LEADING EDGE (FIXED AND MOVABLE)
19 WINGTIP

POWERPLANT

31 WING INSTALLATION (STRUT AND COWLING)
32 CENTER INSTALLATION (MOUNT, INLET, DUCTING, AND THRUST REVERSER)
33 BUILTUP ENGINE

BODY

41 FUSELAGE NOSE SECTION (INCLUDES RADOME)
43 FORWARD FUSELAGE SECTION
45 FUSELAGE SECTION, WING JOIN
46 AFT FUSELAGE SECTION
48 FUSELAGE TAIL SECTION
49 MULTISECTION (WING/BODY FAIRINGS)

LANDING GEAR

61 MAIN LANDING GEAR
62 NOSE LANDING GEAR

EMPENNAGE

72 VERTICAL TAIL, AFT TORQUE BOX
73 VERTICAL TAIL, TRAILING EDGE (FIXED AND MOVABLE)
74 VERTICAL TAIL, LEADING EDGE
75 VERTICAL TAIL, FORWARD TORQUE BOX
79 VERTICAL TAIL, TIP
81 HORIZONTAL TAIL, CENTER SECTION
82 HORIZONTAL TAIL, AFT TORQUE BOX
83 HORIZONTAL TAIL, TRAILING EDGE (FIXED AND MOVABLE)
84 HORIZONTAL TAIL, LEADING EDGE
85 HORIZONTAL TAIL, FORWARD TORQUE BOX
89 HORIZONTAL TAIL, TIP

Figure 5-17. Model 767-200 Sectional Breakdown

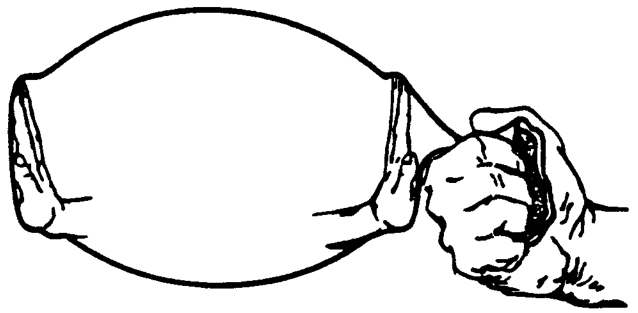
GAS TURBINE ENGINES

The term gas turbine could be misleading. Because the word gas is used so often for gasoline, it might be assumed that the reference is to a gasoline turbine engine. The name, however, means exactly what it says; it is a turbine engine operated by a gas, differentiated, for instance, from one operated by steam vapor or water. The gas that operates the turbine usually is the product of combustion when a fuel is burned with air passing through the engine. In most gas turbines, the fuel is not gasoline but a low-grade distillate such as military JP-4 or commercial kerosene.

HOW THE GAS TURBINE OPERATES

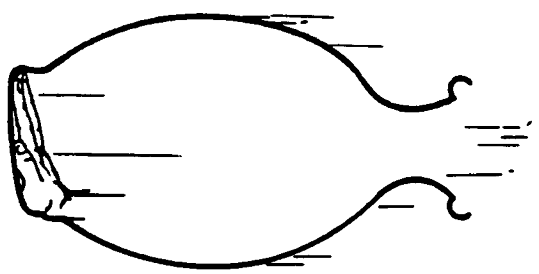
A turbojet engine operates like a toy balloon. Almost every child has discovered that if he blows up a rubber balloon and then suddenly releases the neck of the balloon, it will scoot across the room at fairly high speed for a few seconds. *It is not the escaping air pushing against the outside that makes the balloon move.*

When the balloon is inflated, the inside air pressure, which is stretching the skin, is greater than the outside pressure. When the neck is tied, the inside air pushes equally in all directions, and the balloon does not move. If the balloon could be placed in a vacuum and then the pressure were released at the neck, the escaping air would obviously have nothing to push against. Yet, the balloon would move in a direction away from the neck, just as it does in a normal atmosphere. Why does this happen?

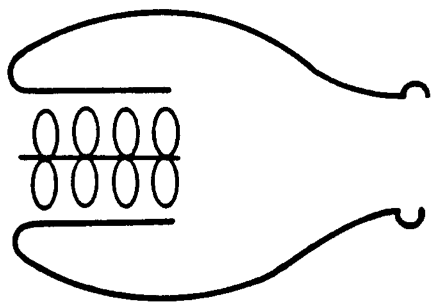


The release of pressure at the neck removes a section of the skin against which air has been pushing from the inside. On the side directly opposite the neck, however, the air continues to push on an equal area of the skin. The push on this opposite area of skin causes the balloon to move in the direction away from the neck.

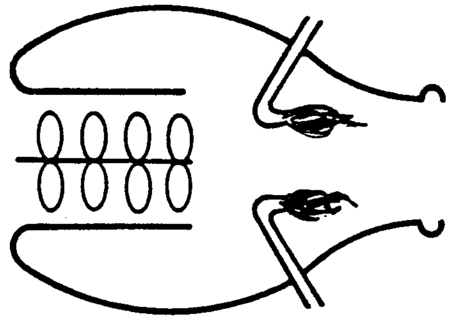
The balloon's flight is short because the pressure within the skin is lost quickly. This handicap could be overcome by pumping air into the balloon with a bicycle pump so that the pressure and airflow are maintained. The bicycle pump makes the toy balloon a complete jet engine that uses all the principles of the powerplant that propels an airplane.



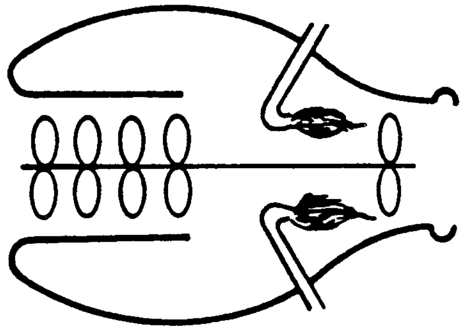
To transform this apparatus into a self-contained turbojet engine, the hand pump must be replaced with a series of fans called a compressor. If the compressor is turned at high speed, huge quantities of air are passed through the balloon under high pressure.



For energy, place a burner in the airstream. The burning of fuel rapidly raises the air temperature and greatly increases the volume of each air particle. The pressure within the compressor blocks forward flow of the air, so the air can move only rearward on the less restricted path leading to the exit.



Place a windmill (turbine) in the path of the heated air. Some of the pressure energy can now be used to spin the turbine, which in turn spins the compressor by means of a connecting shaft. The remaining pressure forces the hot gases through the neck, which is, in effect, a jet nozzle. Now the transformation is complete and the balloon "jet engine" can operate just as long as there is fuel to burn.



Fundamentally, a gas turbine engine consists of four main sections: a compressor, a burner, a turbine, and a tailpipe with a jet nozzle. Turbojet versions of a gas turbine engine are devices to generate pressures and gases, and thereby provide mass and acceleration. Turbojet engines develop their propulsive force through the application of Sir Isaac Newton's third law, which states that for every action there is an equal and opposite reaction. When applied to all gas turbine engines, this can be expressed by saying that for every force generated there will be an equal and opposite force. The opposite force in the turbojet engine is engine thrust.

THRUST

Thrust is the measurement of the amount that an engine pushes against its attachment points. The propulsive force developed by a turbojet is measured in pounds of thrust.

There are two kinds of thrust: net thrust and gross thrust. Net thrust is the thrust that results from the change in momentum of the mass of air and the mass of fuel passing through the engine, plus an additional force at the jet nozzle represented by the difference in static pressure at the nozzle and the ambient static pressure.

Gross thrust is the thrust developed at the engine exhaust nozzle. This includes both the thrust generated by the outgoing momentum of the exhaust gases and the additional force resulting from the difference between the static pressure at the nozzle and the static pressure of the ambient air.

GAS GENERATOR

The term gas generator is often used to describe the basic section of a gas turbine engine. This excludes the inlet duct and jet nozzle of a turbojet, the propeller shaft, and reduction gearing as well as the jet nozzle of a turboprop, and both the fan blades and the jet nozzle of a turbofan engine. The temperatures and pressures from which thrust is derived are generated in the gas generator section of turbine engines.

DIFFUSERS

In the aeronautical sense of the word, a diffuser is a device that reduces the velocity and increases the static pressure of a fluid, such as a gas or air, passing through a gas turbine engine. A diffuser operates on the principle of physics stated by Bernoulli's Theorem, which says that at any point in a tube (or a gas passageway) through which a liquid (or a gas) is flowing, the sum of the pressure energy, the potential energy, and the kinetic energy is a constant. That is, if one of the energy factors in a gas flow changes, one or both of the other variables must also change so that the total energy may remain constant. Specifically, if velocity decreases, the pressure increases.

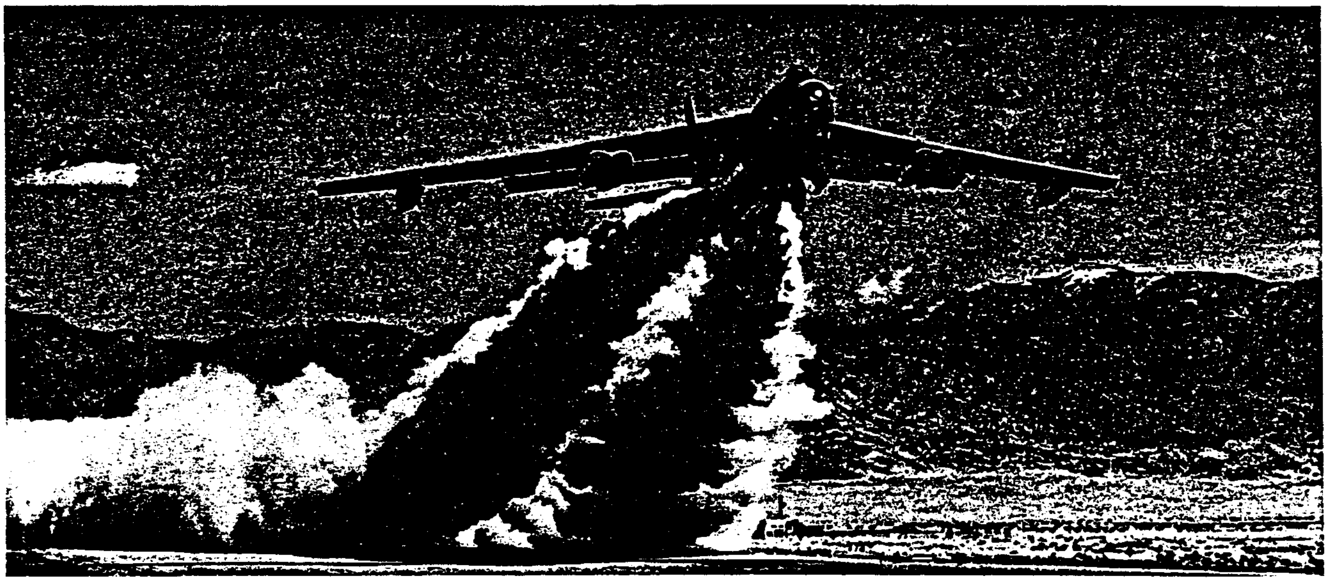
TYPES OF GAS TURBINE ENGINES

THE TURBOJET

If a gas turbine engine relies entirely on jet thrust to develop its propulsive force, it is known at a turbojet (fig. 5-18). These engines are, in turn, further classified by the type of compressor they employ.

The centrifugal compressor works well in the smaller turbojet and turboprop engines where a high compression ratio is not essential. This design was standard for early aircraft gas turbines. Large, high-performance engines require the greater efficiency and higher compression ratio attainable only with an axial-flow compressor. Axial compressors have the added advantages of light weight and small frontal area. Either a single or dual compressor may be used. The latter type results in higher compressor efficiencies, compression ratios, and thrusts. In dual compressor engines, one turbine or set of turbine wheels drives the high-pressure compressor, and another drives the low-pressure compressor. The two rotor systems operate independently except for airflow. The turbine for the low-pressure compressor is the rear turbine. It is connected to its compressor by a shaft passing through the hollow center of the high-pressure compressor and turbine assembly drive shaft. The dual compressor configuration is often called a dual-rotor, two-spool, or twin-spool engine; the single compressor configuration is likewise called a single-rotor or single-spool engine.

Frequently, a turbojet engine is equipped with an afterburner for increased thrust. The increase can be accomplished regardless of the type of compressor used. Roughly, about 25% of the air entering the compressor and passing through the engine is used for combustion. Only this amount of air is required to attain the maximum temperature that can be tolerated by the metal parts. The balance of the air is needed primarily for cooling.



Because of the slow acceleration characteristics of the turbojet engine, B-47 stratojets were equipped with 18 JATO rocket units for take off.

Essentially, an afterburner is a huge stovepipe at the rear of the engine through which all of the exhaust gases must pass. Fuel is injected into the forward section of the afterburner and ignited. Combustion is possible because 75% of the air that originally entered the engine still remains unburned. The result is like a tremendous blowtorch that increases the total thrust of the engine by 50% or more.

Although the total fuel consumption increases almost 2-½ times, the net result is profitable for special bursts of aircraft speed, climb, or acceleration. A turbojet aircraft with an afterburner can reach a given altitude with the use of less fuel by climbing rapidly in "afterburning" than by climbing must more slowly in "nonafterburning." The weight and noise of an afterburner, which is used only occasionally on long flights precludes the device being used in present-day, transport-type aircraft.

THE TURBOPROP

When the turbine shaft is coupled to a propeller as well as to the compressor, the gas turbine engine becomes a turboprop (fig. 5-19). This conversion can be accomplished with either a single or multistage centrifugal compressor, a single axial compressor, or a dual axial compressor. In most configurations, the propeller reduction and drive gearing is connected directly to the compressor drive shaft or, when a dual axial compressor is used, to the low-pressure compressor drive shaft. On still another type, the propeller is driven independently of the compressor by a turbine of its own.

THE TURBOFAN

In principle, the turbofan version of a gas turbine (fig. 5-20) is the same as the turboprop except that the ratio of secondary airflow to primary combustion airflow is much lower, and the geared propeller is replaced by a duct-enclosed, axial-flow fan driven at engine speed. In such an engine, only 30% to 60% of the available propulsive energy is diverted to the fan. Therefore, the propulsive efficiency and thrust of specific fuel consumption fall between those of the turboprop and the turbojet, assuming the use of the same gas generator components in all three types of engine.

Several turbofan engine configurations are possible. Each has advantages and disadvantages. The fan, for instance, can be mounted either in front of the compressor or at the aft end of the engine as a part of the turbine. In the forward-fan engine, the exhaust from the fan can be ducted overboard, or it can be ducted along the outside perimeter of the case of the basic engine to mix or not mix with the turbine exhaust before the gases pass through the jet nozzle. In these last two examples, the fan is driven by a separate turbine, independent of the one that drives the compressor.

Fuel nozzles can be placed in the fan duct of a turbofan engine to inject and burn fuel with the air passing through the duct. This is similar to the burning of additional fuel in an afterburner to produce extra thrust for special purposes such as takeoff and the climbout. An engine of this type is properly called a "heated-duct turbofan engine." Essentially it is an ordinary forward-fan turbofan engine, similar to those just described, that has an air heater in the fan duct routed along the outside of the basic engine case.

The British often call fan engines of these types "bypass" engines. In this country, a bypass engine is generally thought of as one in which the secondary airstream is subject only to ram pressure. In effect, this means a ramjet engine built around the outside case of a turbojet.

THE EVOLUTION OF JET ENGINES

In a conventional jet engine, such as those powering the 367-80 in the years prior to 1960, air is sucked in by the compressor and ducted to the burner section. There, fuel is sprayed into the stream of compressed air and the mixture is burned. The hot gases ram against the turbine blades and, while the spinning turbine wheel turns the compressor on the same shaft, the gases shoot out through the exhaust nozzle at high velocity.

This produces thrust in accordance with Newton's third law. Higher thrust can be obtained by either increasing the acceleration of the exhaust stream or sucking in a larger mass of air and pushing it back more slowly. While the first way means more heat energy and more fuel, the second is the turbofan's thrifty, fuel-saving way.

The world's first turbofan-powered flight was recorded by a Boeing 707-120B long-range jetliner on June 22, 1960. This emergence of the turbofan engine as the ideal transport powerplant is significant in contemporary aviation history.

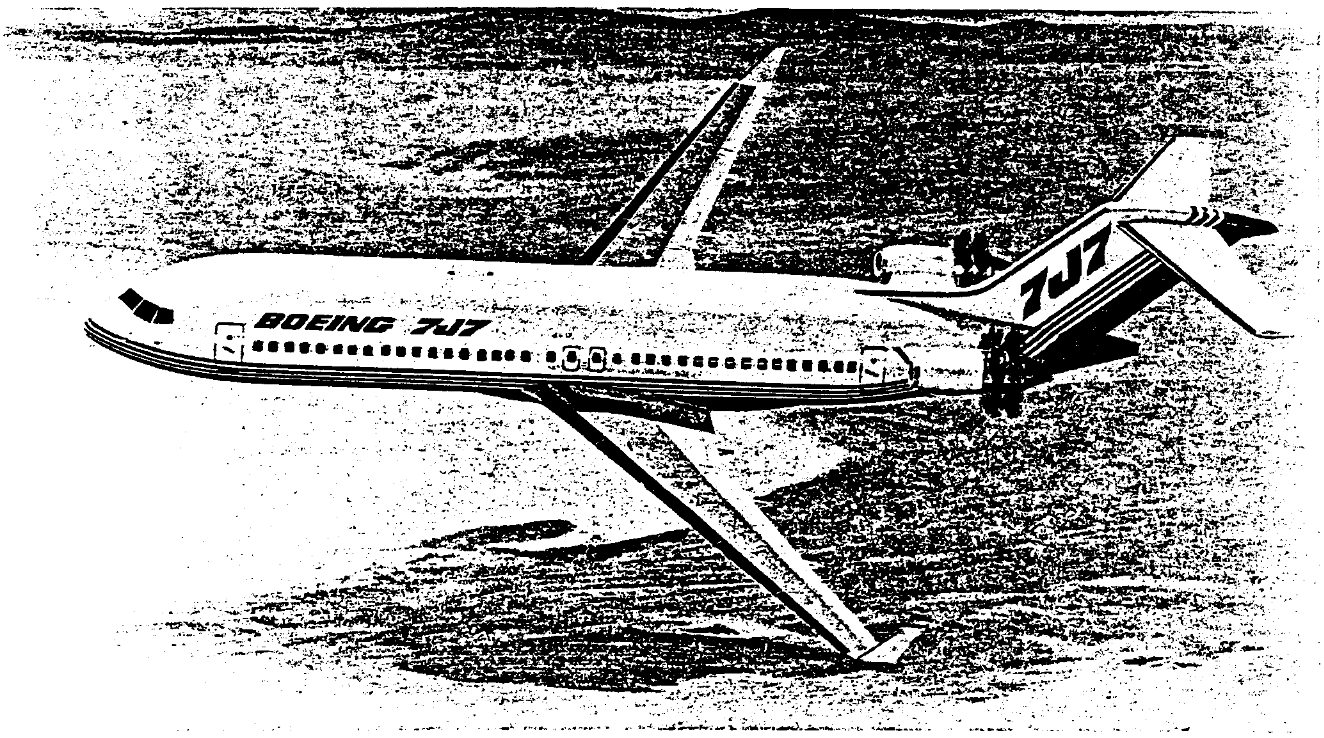
The turbojet engine has proven reliability and wide commercial and military acceptance. With the incorporation of a multistage forward fan replacing the first three stages of the low-speed compressor, and with the addition of a turbine stage, the turbojet became a turbofan—with inherent performance advantages.

The main part of the turbofan is an ordinary high-powered jet engine, but the two front stages of the compressor are enlarged into a fan, very much like an old-fashioned propeller, but one that works more efficiently. Some of the cold air sucked in by the fan still is heated in the burner section. The remaining air is ducted outside of the engine cowling and blown back—cold.

The cold air dumped overboard accounts for about half of the total turbofan thrust. And the fact that this thrust is produced cold without burning extra fuel is the secret of turbofan thrift.

Apart from sizable savings on jet-fuel bills, the turbofan has other important advantages over the straight jet engine of the same power class. The bigger "bite" of the ducted fan results in a higher thrust at lower speeds—something no ordinary jet engine of comparable size can boast. Unlike the ordinary turbojet engine, the turbofan can develop high thrust even while the aircraft is standing still. This provides a turbofan-powered jet transport with more low-speed acceleration for a shorter takeoff. Or, the shorter takeoff can be traded for a bigger payload and a longer range.

Early turbofan engines had a bypass ratio of 1.36:1 (fig. 20). A current 25,000-lb thrust version of an ultrabypass engine has a bypass ratio of 35:1 and a specific fuel consumption rate 25% lower than modern high-bypass-ratio 5:1 turbofan engines (fig. 21). The most recent improvements in turbofan engine design have come in the areas of the very-high-bypass ratio (12-20:1) advanced ducted propeller (fig. 22) and the ultrabypass engine (fig. 23).



7J7 Illustration With Ultrabypass Engines (UBE)

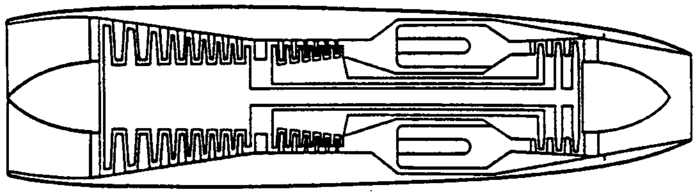


Figure 5-18. Turbojet

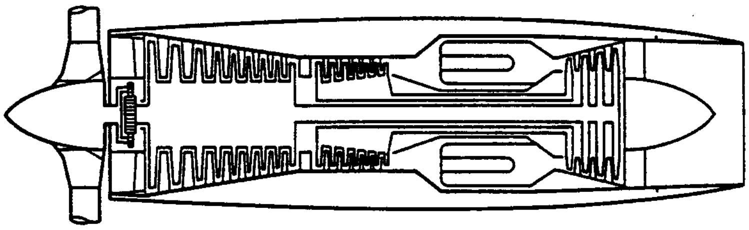


Figure 5-19. Turboprop

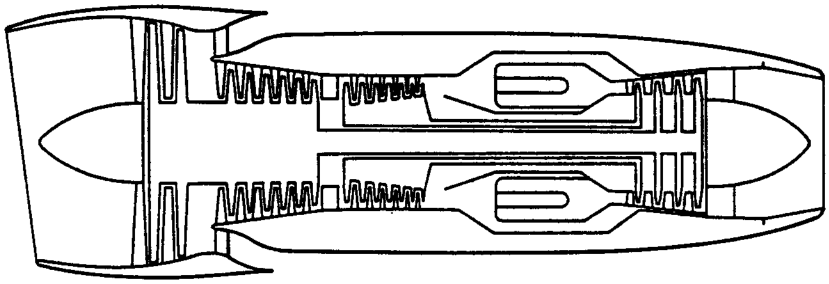


Figure 5-20. Turbofan (Bypass Ratio 1.36:1)

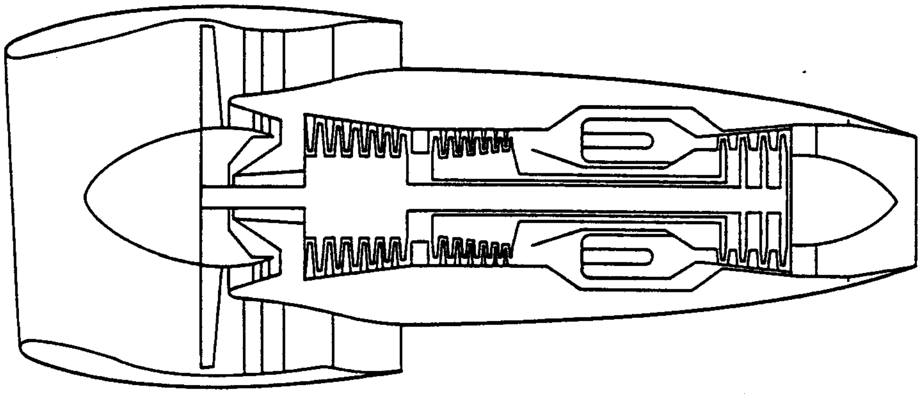


Figure 5-21. High-Bypass-Ratio Turbofan (Bypass Ratios 5:1)

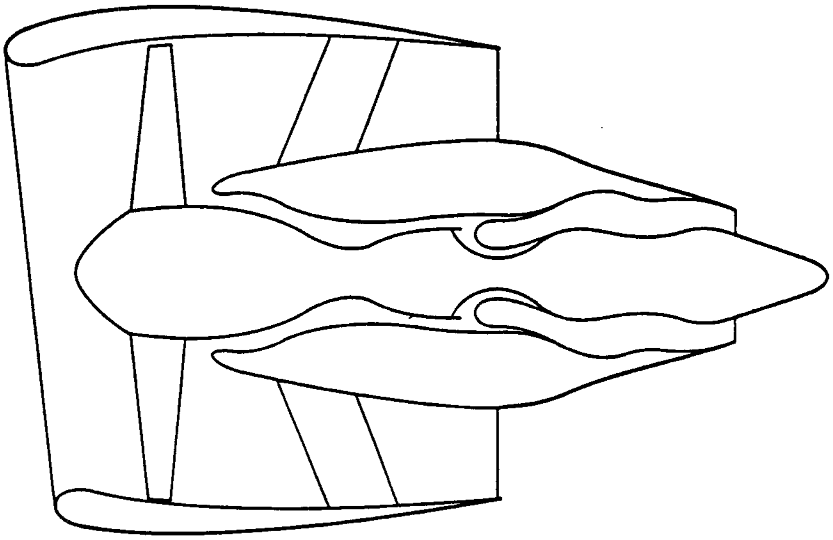


Figure 5-22. Advanced Ducted Propeller (ADP) (Bypass Ratio 12-20:1)

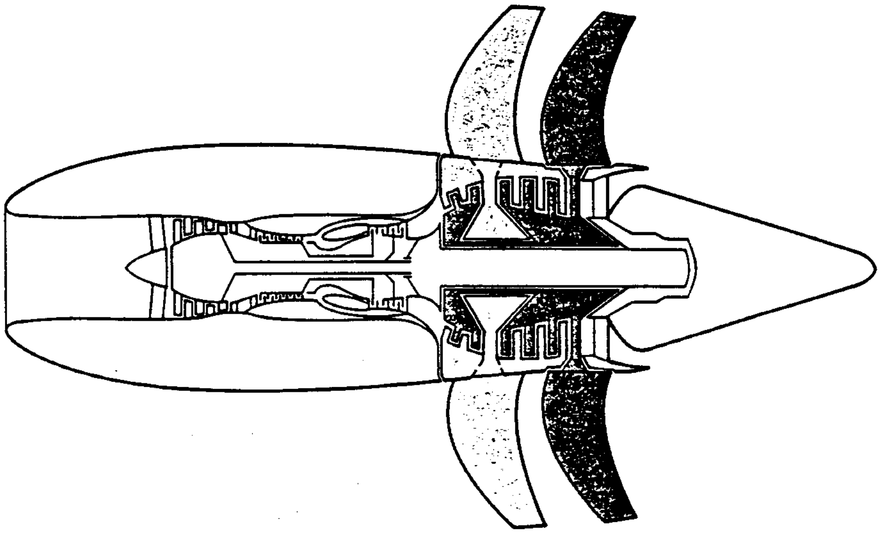
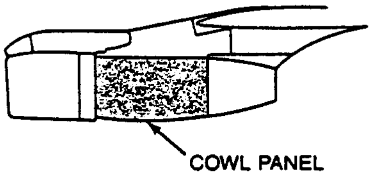


Figure 5-23. Ultrabypass Engine (UBE) (Bypass Ratio 35:1)

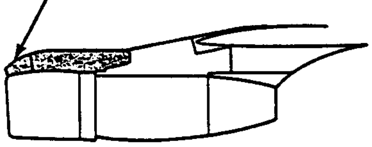
GLOSSARY OF JET ENGINE TERMS

COWL PANEL. The hinged and removable sides of the pod or nacelle that covers an engine.

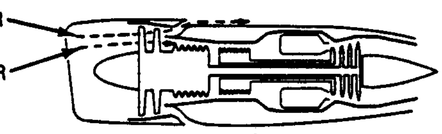


COWLING. A removable covering placed around all or part of an engine.

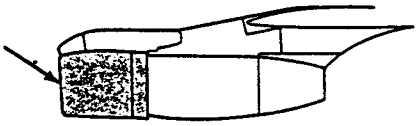
FAIRING. An auxiliary structural member that streamlines and reduces the drag of a part to which it is fitted. It is shaped to provide a smooth flow of air.



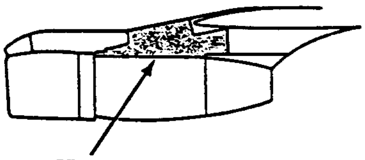
FAN ENGINE. A turbojet engine with a set of compressor blades that operate outside of the basic engine case and move air around the outside of the engine.



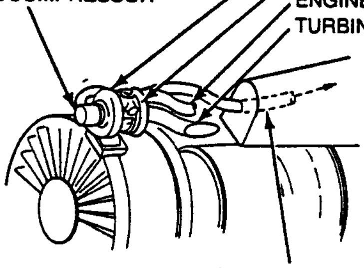
NACELLE. A streamlined enclosure that covers the engine. Sometimes called a pod.



STRUT. A structural member that braces or resists compression or tension loads in the direction of its length. On Boeing airplanes, the pylons that support the engines are called struts.

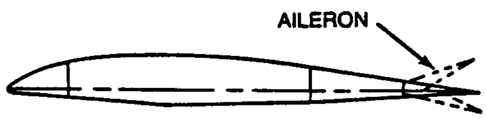


TURBOCOMPRESSOR. A small centrifugal compressor mounted on the upper side of some jet engines. It is driven by air bled from the jet engine and supplies air pressure for the passenger cabin and the pneumatic starting system.



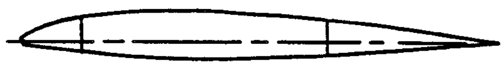
GLOSSARY OF TERMS

AILERON. Hinged sections of the trailing edge of the left and right wings that operate together to provide lateral control. When one aileron is raised, the opposite is lowered, producing rolling movements around the longitudinal axis of the aircraft.

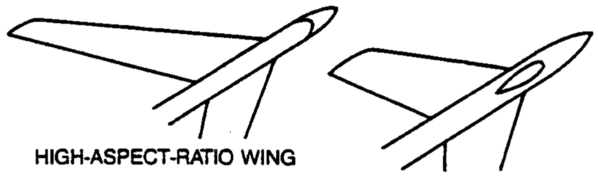


AIR BRAKE. A device to increase the air resistance of an airplane, thus slowing its speed (see SPOILER).

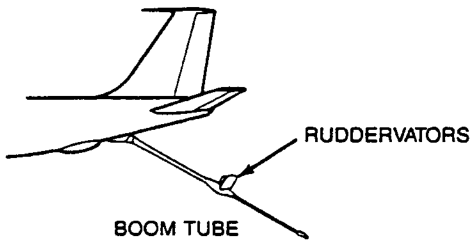
AIRFOIL. A surface, such as an airplane wing, aileron, or rudder, designed to obtain a reaction from the air through which it moves.



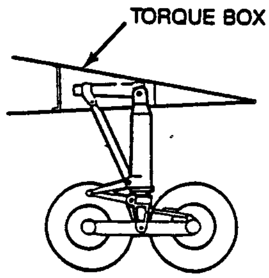
ASPECT RATIO. The relation of wingspan to wing chord, ascertained by dividing span dimension by chord dimension.



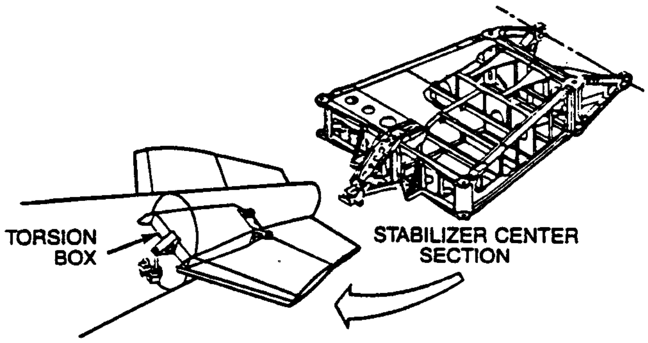
BOOM (flying boom). The extendable refueling tube designed and developed at Boeing for the KC-97 and KC-135 tanker planes. Boom position is controlled by aerodynamic control surfaces, arranged in a V-configuration, called ruddervators.



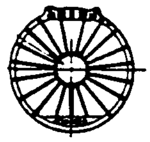
BOX, TORQUE (landing gear). A tapered box-like structure attached to the aft side of the rear spar to support the landing gear on the KC-135 and 707-series aircraft.



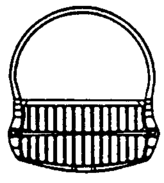
BOX, TORSION (stabilizer). The hinged center section of a horizontal stabilizer that can be raised and lowered to change the angle of incidence of the horizontal tail (flying tail).



BULKHEAD. A heavy structural member in the fuselage to contain pressures or fluids or to disperse concentrated loads. A heavy circumferential frame that may or may not be entirely closed by a web.

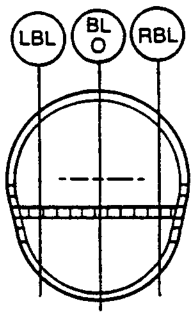


EMPENNAGE PRESSURE BULKHEAD REAR VIEW

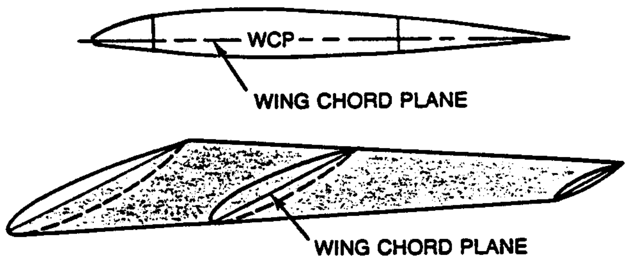


WHEELWELL PRESSURE BULKHEAD REAR VIEW

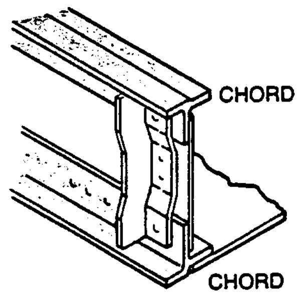
BUTTOCK LINE. A vertical reference line or plane parallel to the centerline of the airplane used to locate points or planes to the left or right of the airplane centerline.



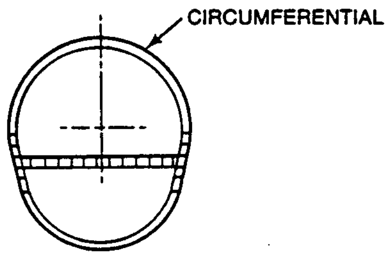
CHORD PLANE, WING. The plane that defines the planform of the wing and around which the airfoil is figured. The wing chord plane scribes a line from the extreme point of the leading edge to the extreme point of the trailing edge, thus giving a datum line to measure incidence and dihedral.



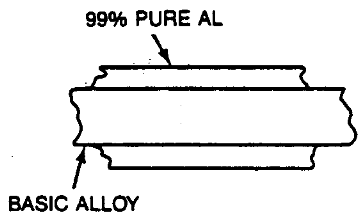
CHORD (structural). Sometimes called a cap. A strong member that forms the edges of beam structures or heavy frames.



CIRCUMFERENTIAL. A frame that is shaped to the fuselage.



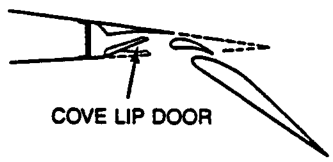
CLAD. A 99% pure aluminum layer, molecular-bonded to the basic alloy by rolling while heated.



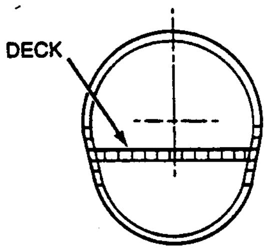
CLIP. Sometimes called bracket. Usually a small angle used to attach lightweight parts such as wiring clamps.

COMPOSITE MATERIAL. Composites are considered combinations of material differing in composition or form. The constituents retain their identities in the composite; that is, they do not dissolve or otherwise merge completely into each other although they act together. Normally, the components can be identified physically.

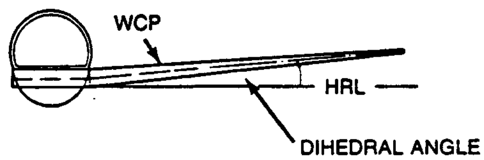
COVE LIP DOOR. A movable door on the under surface of the wing, hinged at the rear spar, that lifts upward when the flaps are lowered. These doors allow high-pressure air to flow through the main flap slots. Used on KC-135, 707, and 720 airplanes.



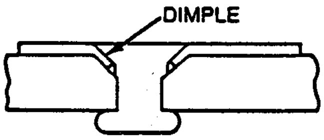
DECK. The horizontal floor in the control cabin or passenger cabin. The horizontal structure to support fuselage tanks in the B-52 (fuel deck).



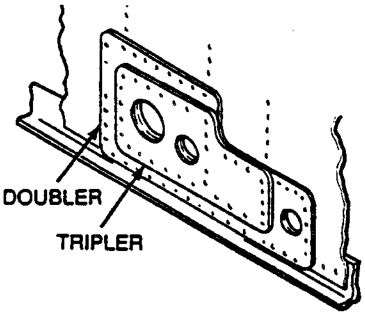
DIHEDRAL. The angle the wing chord plane makes with a horizontal reference plane.



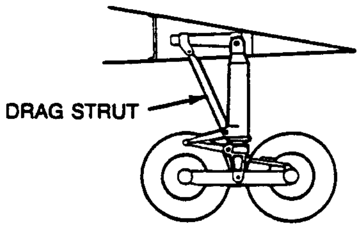
DIMPLE. A depression of the area around the edges of a hole in thin sheet to provide for a countersunk rivet.



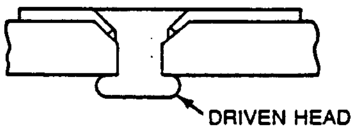
DOUBLER. A second sheet or plate installed next to the web or skin in a small area subject to high local loads to provide a double thickness of material. A tripler is a third sheet to provide three layers of material.



DRAG STRUT. A diagonal brace attached to the forward end of the landing gear trunnion and the lower end of the oleo strut. Absorbs drag loads during ground maneuvers and braking.

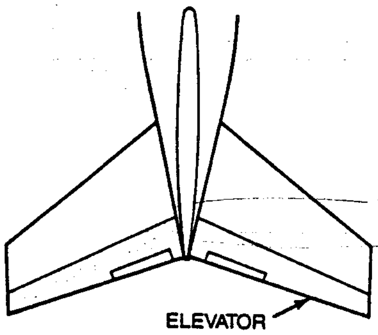


DRIVEN HEAD. The upset portion of a rivet shank that has been hammered flat by the bucking bar during installation.



DUTCH ROLL. A phenomenon peculiar to sweptwing aircraft. A continuous combination of yaw and roll.

ELEVATOR. The hinged section of the horizontal stabilizer used to control pitch.



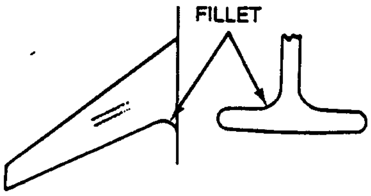
EMPENNAGE. The aft portion of an aircraft, usually consisting of a group of stabilizing planes or fins, to which control surfaces such as elevators and rudders are attached.

EXTRUSION. A part formed by squeezing the material through a die that has a hole cut to the desired cross-sectional shape of the part.

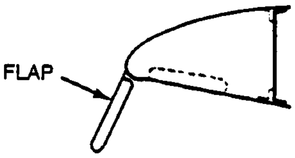
FAIRING. An auxiliary structural member shaped to provide a smooth flow of air and reduce drag.

FAYING SURFACE. A surface that fits, joins, or unites closely with an adjacent surface overlapping it.

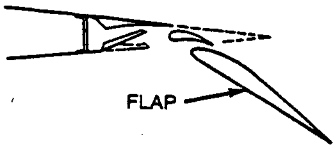
FILLET. A filler that smooths the angle formed by two intersecting surfaces and eliminates an abrupt change of direction. Used on forged or machined parts to prevent stress concentration at the "corner." Used aerodynamically to eliminate angular joints between components.



FLAP, LEADING EDGE. Hinged section of the under side of the leading edge that, when extended, prevents airflow separation over the top of the wing. Leading edge flaps hinge at the leading edge of the airfoil.



FLAP, TRAILING EDGE. Hinged section of the trailing edge of the wing that can be lowered and extended. When lowered, flaps increase airplane lift at low speeds.

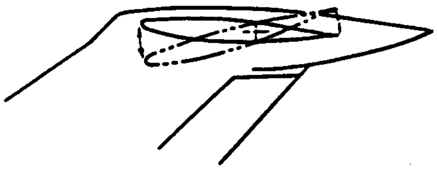


FLAP TRACK. A steel track on which the main landing flaps operate by means of rollers. The curvature of the flap track determines the deflection and position of the landing flaps when they are extended.

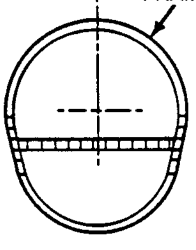
FLAT PATTERN. The overall shape or outline of a sheet metal part before bending operations.

FLYING TAIL. A horizontal stabilizer that is movable and controllable. The entire horizontal tail angle of incidence can be changed to trim the airplane.

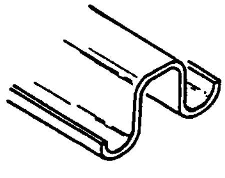
HORIZONTAL TAIL MOVEMENT, 727



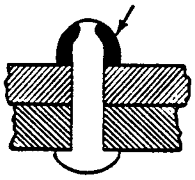
FRAME. A circumferential structural member in the body that supports the stringers and skin. Used in semimonocoque construction (see MONOCOQUE).



HAT SECTION. The cross-section shape of the stringers used in the fuselage. A common rolled shape that looks like a top hat with the brim curled up.

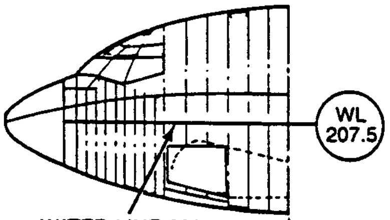


HI-SHEAR RIVET. Trade name for high-shear-strength steel fasteners used in the airplane where heavy loads are encountered. Installed with a swaged collar instead of being upset by a bucking bar. Used in shear applications.



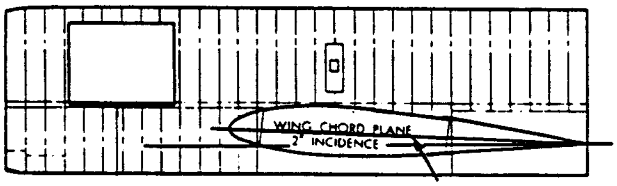
HI-SHEAR RIVET

HRL (horizontal reference line). Will sometimes refer to a water line or can be a special horizontal line to locate a particular plane or points in the airplane's horizontal axis (see WATER LINE).

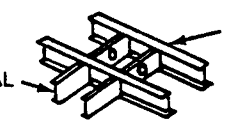


INBOARD. A term applying to the inside. An item nearest to the fuselage (antonym: OUTBOARD).

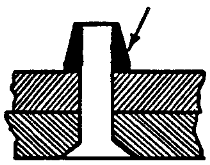
INCIDENCE, ANGLE OF. The fixed angle at which the wing chord plane is set relative to the horizontal datum line of the aircraft. Sometimes erroneously called the angle of attack; angle of attack rightfully refers to the angle of the entire aircraft to relative wind. The angle of attack can be changed by the elevators on the horizontal tail surfaces.



INTERCOSTAL. A small stabilizing beam between and at right angles to larger beams or bulkheads.

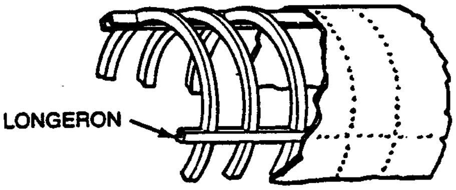


LOCK BOLT. A high-strength steel fastener with a swaged collar on the shank for retention rather than a nut. Used in tension and shear applications.



LOFT LINE. The line or lines that establish and control the shape of an object so that all intersecting cutting planes are smoothly faired.

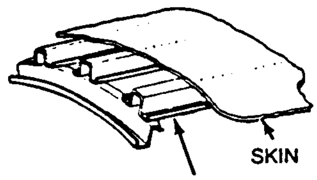
LONGERON. A principal longitudinal member of the framing of an aircraft fuselage or nacelle. Usually continuous across a number of points of support.



MACH NUMBER. A number representing the ratio of the speed of a body to the speed of sound in the surrounding atmosphere. For subsonic speed, the mach number is less than 1 and for supersonic speed it is greater than 1.

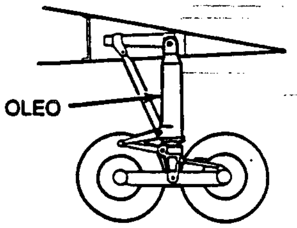
MLG. Abbreviation for main landing gear.

MONOCOQUE. A single-shell construction in which the skin carries all shear and bending stresses. In semimonocoque construction, shear and bending loads in the skin are transmitted to stringers and frames.



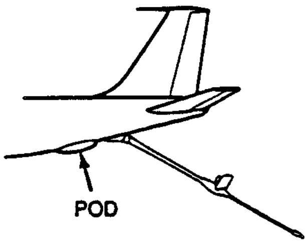
OIL CAN. A term commonly used to describe a buckling or wrinkling in the metal skin of an airplane. The skin normally should be smooth.

OLEO STRUT. A main weight-carrying strut in the landing gear that absorbs the shock of landing by the flow of oil through an orifice in the cylinder of the strut.



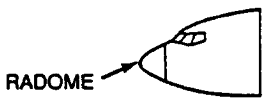
PITOT-STATIC. An airspeed indicating system that operates from ram air pressure in the pitot tube and static pressure of the atmosphere. Gives an airspeed reading that is corrected for altitude.

POD. A term sometimes used for engine nacelle. Indicates an enclosure such as the boom operator's pod on the KC-135 that encloses the boom operator and equipment in a streamlined fairing.

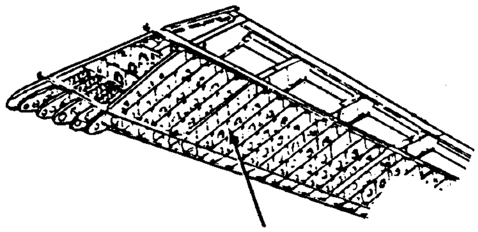


PRESSURE WEB. A web that seals an area to retain cabin pressurization.

RADOME. Coined term for radar dome. A nonmetallic streamlined fairing to cover the radar sweep.

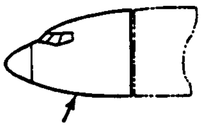


RIB. A fore and aft member of an airfoil structure (wing or aileron) of an aircraft used to give the airfoil section its form and to transmit that load from the skin to the spars.



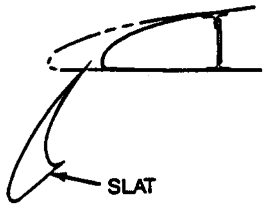
RUDDER. A hinged or movable auxiliary airfoil, attached to the vertical fin, that controls yaw.

SECTION. Any of the large subassemblies of the airplane that are built separately and then joined to form the complete airplane. The airplane is built in sections to ease production and handling problems.

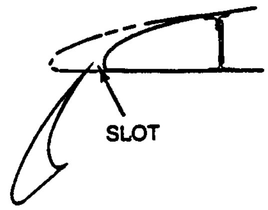


SKIN. The outside covering of an aircraft.

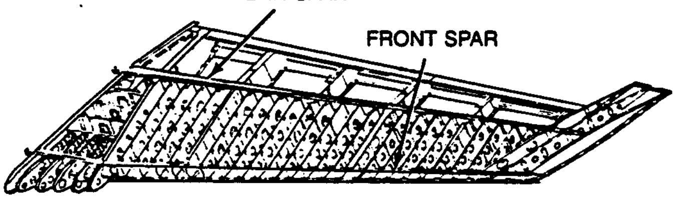
SLAT. A movable auxiliary airfoil attached to the leading edge of the wing. When closed, it forms part of the normal contour of the wing; when opened, it forms a slot and increases lift.



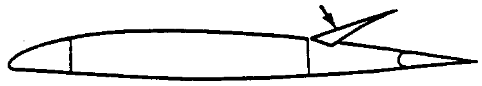
SLOT. An elongated passage through a wing whose primary function is to improve the airflow over the wing at high angles of attack.



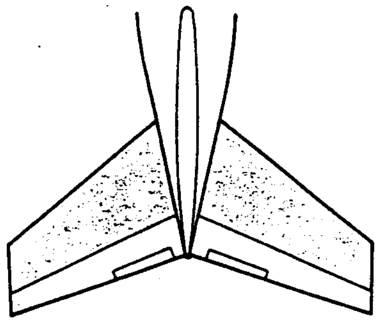
SPAR. A principal spanwise beam in the structure of a wing, stabilizer, rudder, or elevator. It is usually a primary load-carrying member in the structure.



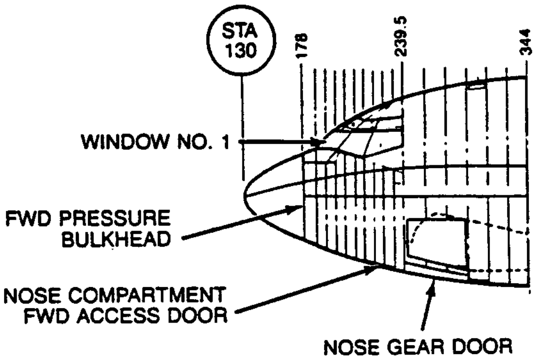
SPOILER. A hinged panel on the upper surface of a wing that "spoils" wing lift when raised. Left and right spoilers can be raised alternately for high-speed lateral control or can be raised together as speed brakes during landing.



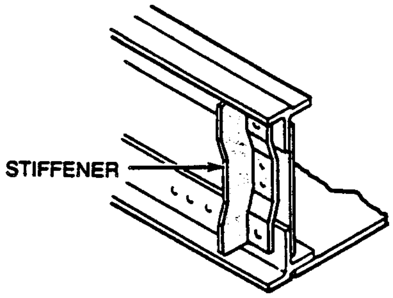
STABILIZER. A fixed horizontal tail surface that maintains stability around the lateral axis of an aircraft.



STATION LINE. All parts of an airplane are identified by a location or station number in inches from a beginning point. Station lines in the fuselage start forward of the nose; those for the wing usually start at the centerline of the fuselage. This forms a locating system that divides the aircraft cross-sectionally into a series of reference planes at right angles to the vertical centerline of the aircraft.

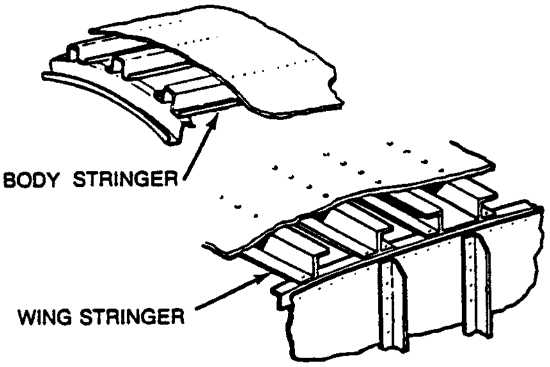


STIFFENER. A metal part, other than flat sheet, formed or extruded and used in the framing of a structure to provide rigidity.

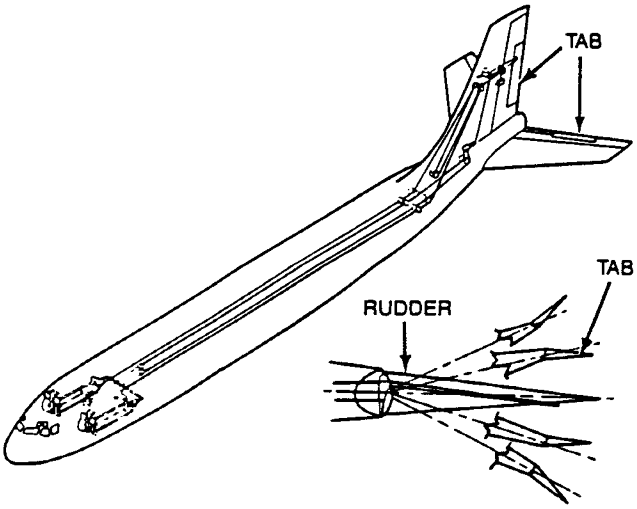


STRETCH FORM. A method used to shape skins or parts by stretching the flat sheet over a die to provide the shape.

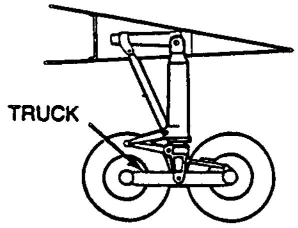
STRINGER. Longitudinal members in the fuselage or spanwise members in the wing to transmit skin loads into the body frames or wing ribs.



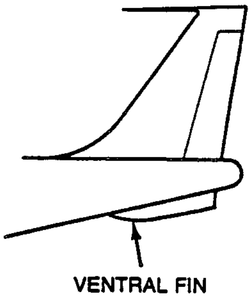
TAB. A small, hinged, auxiliary control surface attached to a primary control surface such as an aileron, rudder, or elevator. When deflected, it moves the primary surface to which it is attached. The primary surface will react in the direction opposite the control tab's deflection.



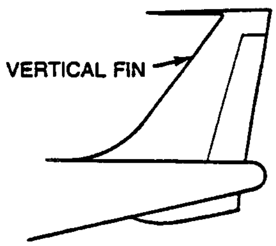
TRUCK. The portion of the main landing gear that is composed of a swiveling beam with an axle and two wheels on each end.



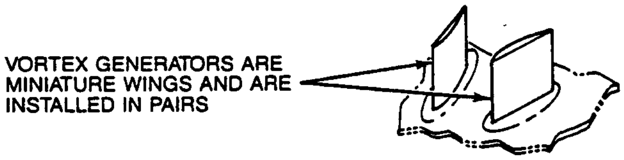
VENTRAL FIN. A stabilizing surface attached to the bottom of the fuselage near the tail.

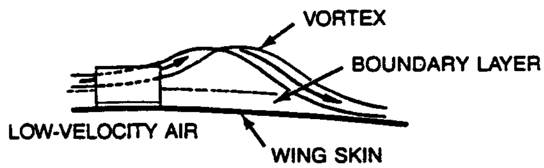


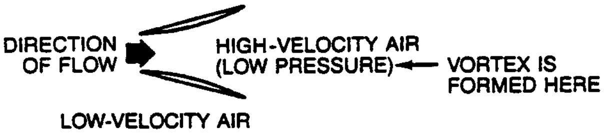
VERTICAL FIN. Sometimes referred to as vertical stabilizer. It is fixed to provide directional stability. The trailing edge is hinged to form the rudder.



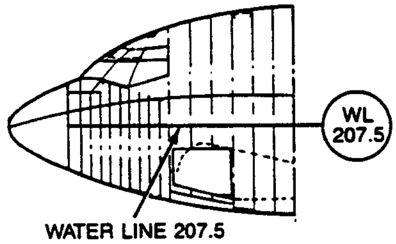
VORTEX GENERATOR. A device used on the wings and tail surfaces to decrease drag caused by the separation of the air flowing over the flight surfaces. Vortex generators appear as a row of small metal tabs set at angles to the air stream. The vortex formed by the tabs pushes the air down to the skin of the flying surface and delays drag producing separation.



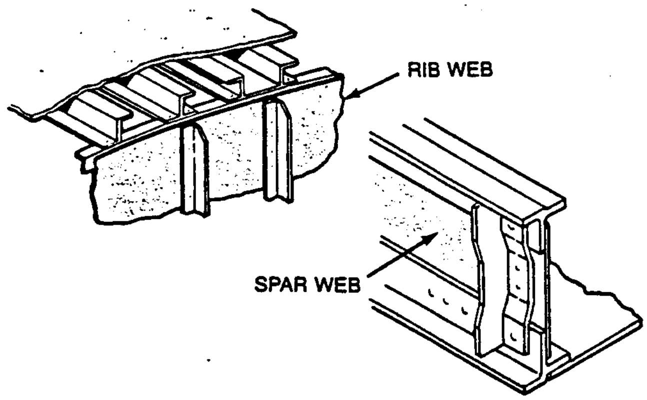




WATER LINE. A reference line or horizontal plane parallel to the ground used to locate points vertically.



WEB. A thin-gage plate of sheet, when supported by stiffening angles and framing, provides great shear strength for its weight. Used in many applications throughout an aircraft because of its strength-to-weight ratio.



INTERESTING READING

"HOW DECISIONS ARE MADE:
MAJOR CONSIDERATIONS FOR AIRCRAFT PROGRAMS"

JOHN E. STEINER

PRESENTED: WRIGHT BROTHERS LECTURE

AUGUST 28, 1982

How Decisions Are Made
Major Considerations for Aircraft Programs

John E. Steiner

Abstract

Aircraft programs, both civil and military, represent complex risk experiences. Success usually involves the attainment of a relatively long-term program to achieve efficient production volumes; this in the face of a constantly changing set of market conditions, competitive actions and technological alternatives. Key decision points are identified, and risk variables in finance, technology, management, and market readiness explored. Decisions are noted that can leverage long-term potentials for success and others, that once made, may become irreversible in view of program cost penalties. The author draws on his involvements and observations of program decision-making over a 40-year career span and involving over a dozen programs. While most are commercial, several fundamental observations applicable to military programs emerge. The character of decisions and influences leading to program success or lack thereof are examined to find the lessons learned and to comment on the road ahead.

I. Introduction

Over 80 years ago, the Wright brothers made decisions that led to the historical successes that this lecture commemorates. It is a great honor for me to be asked to join those who, through the years, have memorialized the Wright brothers and the achievements they attained.

Aircraft programs, both civil and military, represent complex risk ventures that are accomplished in an environment of constantly changing market conditions, competitive actions, and technological alternatives.

World aviation is moving into a new, and, I believe, an even more complex era in which affordability and internationalism are becoming major influences. While some of the historical tenets of aircraft decision making will remain the same, some will not. The objective of this paper is to discuss some of the major factors that have affected past aircraft decisions, and to consider the changes that aviation's new era may imply for the coming generation of decision makers.

We'll approach this by noting the decisionary forces evident following World War II and the major changes thereafter. We'll review technical progress made and note its future extensions. Following this will be an examination of the decisionary forces in play on some past programs and in particular, key decisions that led to their success or failure. Since aircraft program success is highly dependent upon engines, we'll also examine these decisions and their forcing factors as well. We'll then examine the decisionary forces forming the new fleet of commercial aircraft and the track of lessons learned from program decisions, and note their implications with respect to the environment of the road ahead.

II. Post War Overview

Aviation progress, of course, has been immersed in a much greater matrix of time and events, outside the scope of this paper. However, it is important to highlight the environment following World War II, since it involved a period of achievement in military and civil aviation unparalleled in later times.

Aircraft was a natural for post-war development, and a product that could readily respond to civil markets as well as the continued military concerns triggered by cold war events. This period launched a number of military and civil derivative programs, such as the B-50 from the B-29 and the DC-6 and DC-7 from the wartime C-54. Each was an incremental refinement step furthering technologies developed or proven during the war. All new jet-powered military programs were also initiated, such as the F-86 and B-47. This rapid progress turned the 1950s into a bow wave of advancements as this decade saw some 17 major military programs started plus an even larger number on the civil side. The key decision drivers for their go aheads are summarized in figure 1, and they will stand as key drivers for program decisions made today.

Key Decision Drivers

- Market Needs (and Timing)
- Government Actions (and Priorities)
- Competitor Actions
- Technology Readiness
- Fiscal Considerations

Figure 1

Conditions at this time were, for the most part, favorable to the fostering of competitive program starts. There was a large domestic market need (military and civil) and a large industry in place that was backed by a high quality research infrastructure. By comparison, the highly innovative European industry was constrained. This period was largely an American event in scale...it highlighted U.S. domestic markets and competitions.

Europe's industry gradually recovered and, over the following decade, laid the ground work for the many cooperative European developments that followed. Japan's aircraft industry, relatively constrained through this, has now emerged with credentials highly respected by both the U.S. and European industries. This, plus other new competitors and causative factors, has greatly changed the decision environment, as summarized in figure 2.

Changing Decision Environment

- Design Orientations
- Development Costs and Risks
- Military and Civil Priorities
- Internationalism
- Affordability

Figure 2

New requirements and new advancements have obviously affected design orientations and design decisions. Costs, risks, and priorities are not the same worldwide, nor are the affordability values that are attached to them. U.S. priorities were revalued and this has precipitated a dramatic change in the technological fiber of the nation. Nevertheless, as figure 3 illustrates, government outlays for aircraft through this transition remained surprisingly stable.

Federal Outlays for Aircraft, Missiles, and Space FY1947-77

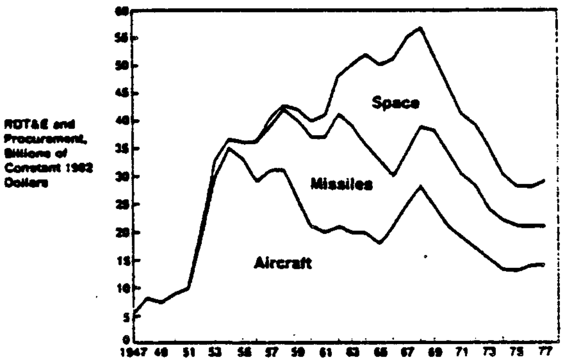
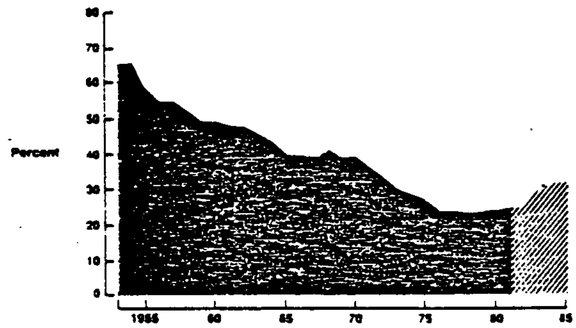


Figure 3

The downward trend that occurred in the late 1960s reflects a massive insertion for social spending with offsetting reductions in other government programs, including defense. The 40 year change in total defense outlays is shown in figure 4.

Defense Outlays: FY 1953 to 1985

(As Percentage of Federal Budget)



Sources: OMB: Budget of U.S. Government FY1976 through 1982; AIA

Figure 4

It should be noted that defense spending (in constant dollars) remained fairly stable, but total outlays increased steadily, thus reducing the defense percentage as shown. The reordering of national priorities has exerted a profound change on the momentum of U.S. aeronautical developments. Through the 1970s for example, new military program starts dwindled to a few, although paper competitions and false starts were many. Much of the advancement momentum was taken over by commercial industry developments. There was good reason for this because the growth realized in world air travel since the mid-1960s was beyond all earlier predictions. The history is illustrated in figure 5.

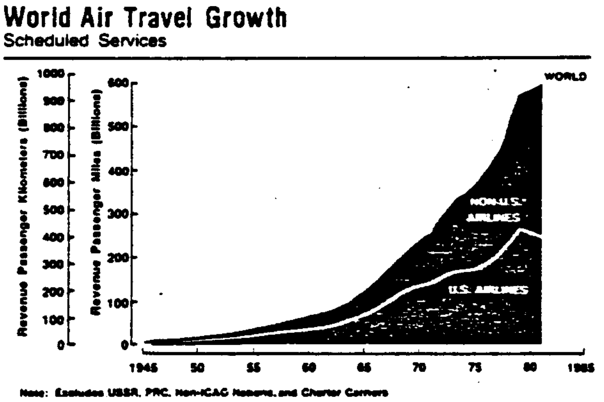


Figure 5

Figure 5 also illustrates the growing significance of the non-U.S. portion of the total world market. The technological achievements contributing to the creation and growth of air travel markets came from many nations to make air travel an affordable alternative, as illustrated by the air fare reduction history shown in figure 6.

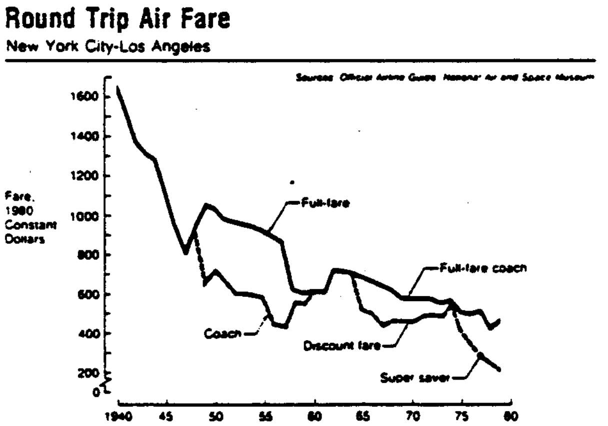


Figure 6

Our overview has shown that the U.S. maintained a healthy technological environment for some two decades beyond World War II. Since then, however, its pace slowed, and the advancement momentum in world aeronautics changed, reflective of the rapid expansions in Europe and Japan.

The pace and state of technology readiness is a major consideration in program competitions, as will be noted later. Therefore, we'll first examine the progress that has occurred in recent decades, and also the potentials that will form program considerations in the future.

III. The March of Technology

Technology decisions are relatively straightforward when the technology base is well understood, the development has been completed, the payoffs are clear and the risks are low. Such is not the usual case when new airplane programs are started or major airplane modifications undertaken. More likely is that competition will push the state of the art, shorten allowable development scheduling, and establish goals that strain credibility and involve considerable risk. It is essential that decisions don't repeat past mistakes but maximize the potential for the future.

You could ask...what causes people and organizations to strive for technology that could prove embarrassing to individuals or risk a company's existence. More and more technical advancement is demanded by the customer, forced by competition, or pressed by a public mandate to improve the environment. Other reasons are probably equally important and the pressures are inescapable. Therefore, goals and requirements must be clearly defined and understood by all participants before risk contracts are signed. Both the buyer and the seller can be seriously injured by overly ambitious dreams or impractical desires.

Aircraft technical advancements flow from many national sources and will continue to do so. The radar, jet engine, swept wing, and much of today's modern electronics are only a few examples of international contributions. Technical secrets are perishable with time, and since the period from discovery to validation and on through to application can take ten years or more, attempts to keep developments proprietary are mostly futile. It is more important that the developer make timely decisions in order to enjoy the advantage of one or more application cycles before outsiders acquire sufficient technical base to proceed with their own.

Trends

The most revolutionary advance in airplane productivity occurred virtually overnight with the introduction of the swept wing and turbojet engine. The resulting increase in speed and improvement in passenger comfort obsoleted the medium- to long-range propeller powered transports. In retrospect, the transition occurred with amazing ease to all concerned. Turbojet and turbofan engine developments have been among the biggest contributors to improvement in airplane efficiency. Figure 7 shows commercial jet engine specific fuel consumption to have decreased some 40 percent over the last 25 years.

Fuel Consumption Improvements

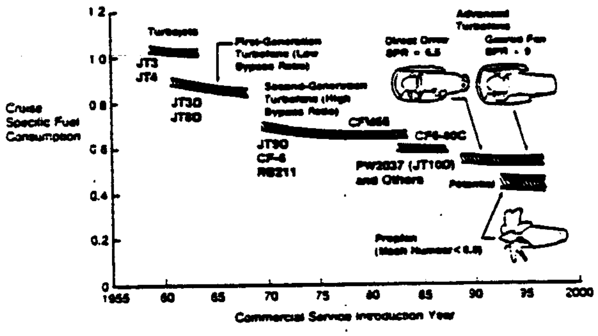


Figure 7

This phenomenal improvement occurred as a result of cooperative investments by both government and industry, but not without considerable pain to the users. Excessive parts replacement and high maintenance costs followed new engine model introductions when the validation periods were foreshortened. Further improvements in fuel efficiency are possible by using geared fans or, more radically, by eliminating the cowl through development of an advanced turboprop system. In these cases, adequate development and validation periods will become increasingly important and may require unreasonable investments.

Introduction of the turbojet engines caused a deterioration in the environment around airports. Since those early installations, progress in noise reduction has been continuous as shown by the trends on figure 8.

New engines are basically quieter than turbojets. Adding extensive acoustic treatment

Noise Reduction Trends

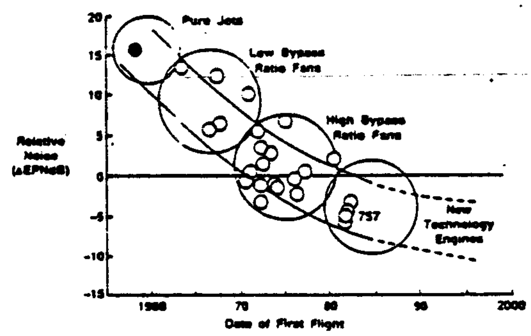


Figure 8

to the integrated nacelle-engine power package has further reduced community noise to the point where public outcries have largely subsided, or will as normal replacement occurs. This has been a painful problem to the aviation industry. Any further technology decisions that have environmental side effects must reckon with public opposition.

The progress in subsonic aerodynamic design over the past several decades has been significant but is more difficult to describe than the improvement in engine specific fuel consumption. This difficulty arises from the fact that airplanes are designed to unique market objectives, and mission requirements will emphasize high and low speed aerodynamic design capability and structural weight trades in differing proportions. This tends to obscure the significance of a specific technology advance such as improvements in high Mach number airfoil design. A good example of the hidden value of aerodynamic progress surfaces if one tries to compare the aerodynamic cruise efficiency of L/D of the 747 relative to that of the 707-320. The significant progress in aerodynamic design technology achieved in the twelve year interval between these programs is concealed by the differing design objectives, most notably the higher 747 cruise speed, and the relative difference in fuselage size. In fact, the L/D of the 320B is actually four to five percent higher than that of the 747 at respective cruise design points.

One way of illustrating the progress in wing aerodynamic design is to examine the trend with time of relative wing weight and streamwise thickness ratio for hypothetical wings designed to a fixed cruise Mach number and span loading.

Figure 9 shows that progress in airfoil aerodynamic design has allowed a steady increase in wing thickness ratio which can be translated into significant wing weight savings.

Aerodynamic Progress
Constant Mach Cruise

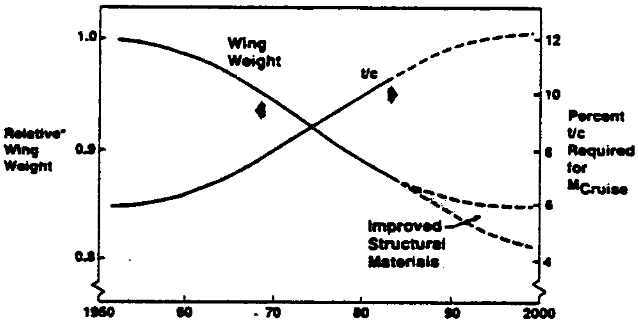


Figure 9

In actual practice there is a tendency to utilize the improvement in allowable thickness ratio to achieve a larger wing span for a given structural weight and to reduce wing sweep for improved low speed performance.

The next ten years offer exciting prospects for aircraft structural designers. New materials such as improved aluminum alloys and advanced composites are receiving widespread attention. A solid data base involving design standards and production techniques is being developed rapidly. If composite and aluminum-lithium structural materials are both successfully developed, a strong possibility exists for designing airplanes that would take maximum advantage of the properties of both. The potential for large structural weight savings is apparent in figure 10.

Future Structural Materials
Trend for Potential Weight Savings

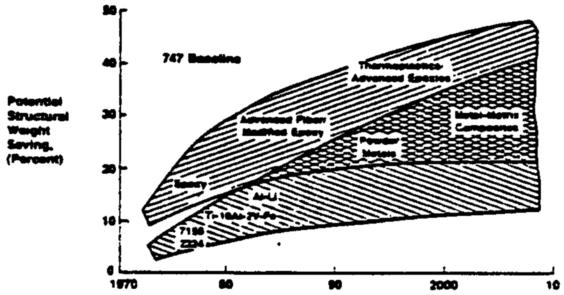


Figure 10

No technologies have advanced as fast as those associated with the electronic industry. In fact, the world expansion of electronic products is indeed revolutionary with no real end in sight.

In the aircraft industry these technologies have been introduced gradually in an evolutionary manner, although digital avionics did take one giant step with the 767/757 flight management systems. The development work to validate airborne applications takes time. For example, the present electronic flight deck displays were initially developed and tested for our SST back in the late 1960s.

Additional systems are becoming available that complement the work accomplished to date. Over the next ten years, for example, we will see increasing applications of fiber optics, flat panel displays, and electric controls, as shown in figure 11.

Avionic System Evolution

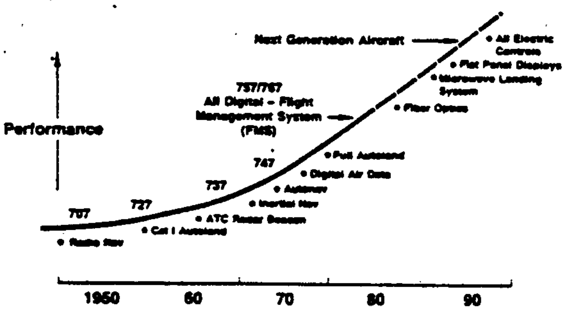


Figure 11

All must be carefully integrated into an efficient, high performance, low risk system. Premature introduction of a digital multiplex passenger accommodation system in the 747 created major situations of inconvenience and annoyance. The system simply wasn't ready. Fortunately, it was not a flight critical system, and safety was not impaired. It is of paramount importance that "flight critical" items such as electronic flight controls be technically ready when put into production.

Throughout commercial air transportation history, designer attention has focused on the "critical mass" of technology that is available for use. The critical mass is really a moving target, and its elements are usually evolutionary in their development and readiness. The next critical mass is now in formation with its roots

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incorporated as some of the improved efficiencies represented by our latest new airplanes. The relationships between these efficiencies and the aiming points of the next critical mass are illustrated in figure 12.

Aiming Points for New Technology Readiness

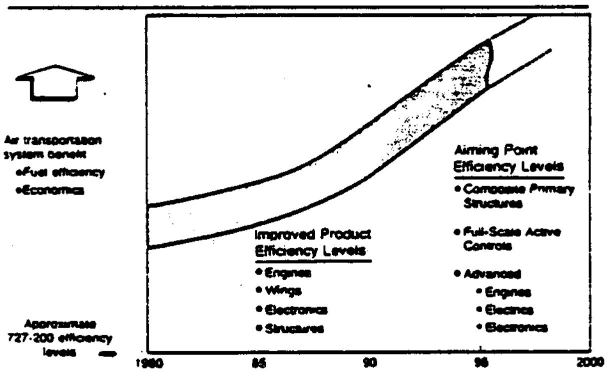

Figure 12

The 757 and 767, incorporating the improvements noted at the left of the figure, have a fuel mileage (seat miles per gallon) advantage over the 727-200 of over 50 percent, even after the effects of scale have been accounted for. The figure indicates that another major improvement of similar magnitude can occur during the decade of the 1990s. Beyond this are other major potentials such as boundary layer management and propfans.

As noted in figure 12, the aiming points will extend into the flight deck with a whole new relationship between the pilot and his aircraft. Control cables and the familiar yoke will disappear, and digitized voice technology can potentially reduce a large element of the communications workload. In their integrated product applications, the new efficiencies may represent a sizable advancement for aviation...perhaps the most significant that we've known since the marriage of the swept wing to the axial flow compressor. The timing of its eventual readiness will be influenced by the levels of effort applied.

Technology development passes through three phases that we sometimes refer to as Phases A, B, and C. Phase A is basic research. Phase B is the assembly of the body of technology until it can support actual use with acceptable risks. Phase C is application to a specific aircraft design. There are many words used to describe the three phases in the terminology of the Air Force, NASA, or others. Phase B tends to be the longest and most expensive. It generally includes a number of parallel actions over a number of years. For example, the increased use of composite applications in the newest airplanes is an evolutionary Phase B step which, along with other steps, will lead to Phase C, the actual use of a composite primary structure in a major commercial or military airplane. A part of the Phase B process is to develop the manufacturing technology required to commit a program to Phase C in this difficult affordability environment.

A good measure of overall technical progress in aviation is illustrated by figure 13.

Fuel Efficiency Trends

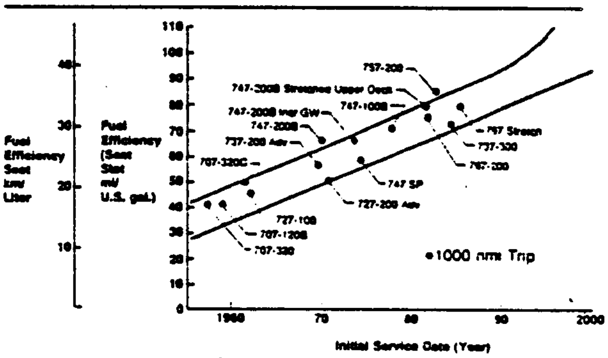

Figure 13

Airplane efficiency, in terms of seat miles per gallon, has increased almost *30 percent per decade* over the past 25 years. The individual technical trends just examined provide confidence that efficiency will continue to improve at this rate through the end of the century.

IV. Program Decisions Revisited

In our experience, we've seen that forces playing on aircraft decisions have frequently changed, often with little if any recognition or warning. Such circumstances can rapidly turn a seemingly sound program decision into a disaster...also, the reverse has happened.

Nonetheless, industry experience has shown a track of predictability through all this, and while not "golden," this track is useful when considering future decision environments that can be anticipated on the road ahead.

Much of this track, I believe, will be illustrated by the decisions and forces highlighted in the ·en programs that we shall examine next. Of necessity, the coverage of each is brief and quite selective.

Boeing 377 Stratocruiser

The 377 Stratocruiser program was a post war commercial offshoot derived from the C/KC-97 series tanker/transports. Like the C-97 series, the 377 incorporated advanced systems that had been developed for the B-50 bomber. The lower portion of its double-bubble design was a B-29 circular cross section. The upper section was superimposed onto the lower as shown in figure 14.

Boeing 377 Cross Section

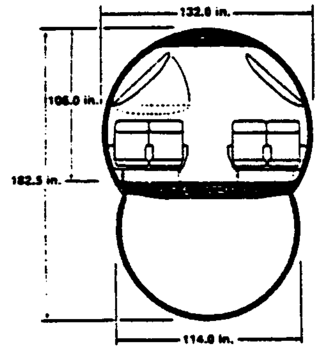

Figure 14

The illustrated design compromise yielded a narrow upper deck floor that proved to make five abreast seating virtually impossible. Similarly, it provided more height than necessary for the lower lobe. This in turn was used for the "lower deck lounge" extrapolation that amplified the airplane's luxury theme. The airplane in flight is shown in figure 15.

Boeing 377 Stratocruiser

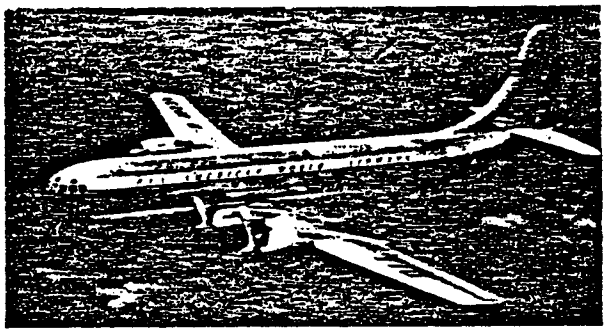

Figure 15

The Stratocruiser was a very large airplane with respect to its passenger capacities, which varied between 50 and 100 depending on route length and service class. Its R-4360 power plant represented the latest in piston engine technology, which at that time had been pushed to its limits with propeller combinations and super-octane fuels for added power gains.

The Pratt & Whitney R-4360 "corn cob" was a four row radial configuration of 28 cylinders. It had 112 spark plugs that were subject to very frequent fouling and change. In total it proved to be a complex and expensive engine, particularly during its introductory years.

The real problem, however, was not the engine but the propeller, particularly Hamilton Standard's. It incorporated new technology developments, which by today's standards, suffered from inadequate validation testing. The blades were constructed with an internal steel tube and a foam-filled external aerodynamic shell. Inspections to maintain airworthiness to commercial standards proved impossible, and most Stratocruiser accidents were due to magnesium housing fires or blade failures, with resulting imbalances that could tear off the engine. Pilots learned to fear the onset of any suspect vibration. In one such instance, a Northwest Airlines 377 was recovered after a water ditching in Puget Sound. Inspection revealed that in this case the propeller was blameless, and the feared vibration had been caused by cowl flaps left in full-open positions. Figure 16 summarizes the power plant difficulties.

377 Propulsion System Observations

- R 4360 engine an ambitious P&WA/Government program yielding higher thrust but lower reliability
  - No commercial experience
- Required major modification program to correct most engine performance and reliability deficiencies
- Hamilton Standard steel tube/foam core blade construction problems
  - Foam core delamination
  - Fatigue inspection difficult
- Implications of potential propeller blade fatigue were very serious
- Alternate propellers were available and were used in some cases

Figure 16

The Stratocruiser achieved a fine reputation for luxury but remained deficient in operating economics and power plant reliability. This led to an early production termination, and, of course, the program was a dismal financial experience for Boeing. I believe, of the many program decisions made, the following are of particular significance to this discussion.

1. The decision to proceed with a new airplane program with success expectations overly dependent upon luxury markets rather than operating economics. Thus, success was premised on premium fares and the higher-income travelers. The airplane could not stand up to competition of air fare reductions that were to become the real stimulants to U.S. travel growth.

2. In part, it could be said that the program's go ahead was justified as a means of holding a military design team together and also in providing that team commercial experience and presence in the post war era. However, it is doubtful that this could stand as a relevant consideration for a U.S. manufacturer today.

3. The Stratocruiser's power plant decisions suffered from use of technology that had not been sufficiently proven. More fundamental, however, was the fact that reciprocating engine technology had been extended *beyond* the limits of its operating efficiency to become overly expensive, complex, and unreliable. As such, this program describes a decision consideration that will remain highly relevant for decades.

B-52 Program

The B-52's concept was derived from the most significant advancement of post war aviation...the *revolutionary integration* of a swept wing with the axial flow compressor, achieved with the Boeing B-47. This development made the jet engine's potentials for high speed flight possible.

Thirty years after its initial flight, the B-52 remains the backbone of the nation's long-range bombardment capability. Almost 750 were produced, and the later models have been continuously updated since production ended in 1962. It is expected to remain a significant component of U.S. strategic forces, possibly into the next century.

The program was started as a large, straight-wing turboprop. It was to become the U.S. second generation long-range bomber, capable of carrying 10,000 pounds for 10,000 statute miles or, by Air Force rules, an operating radius of three-eighths of this (3,800 nautical miles) without refueling. By 1948, it became evident that the necessary engine and propeller for its mission were unavailable, and Boeing was hurriedly asked to provide the Air Force its concepts for a jet alternate. Figure 17 illustrates the evolution of the B-52 from that point into its jet-powered design.

Early Days of the B-52 Evolution

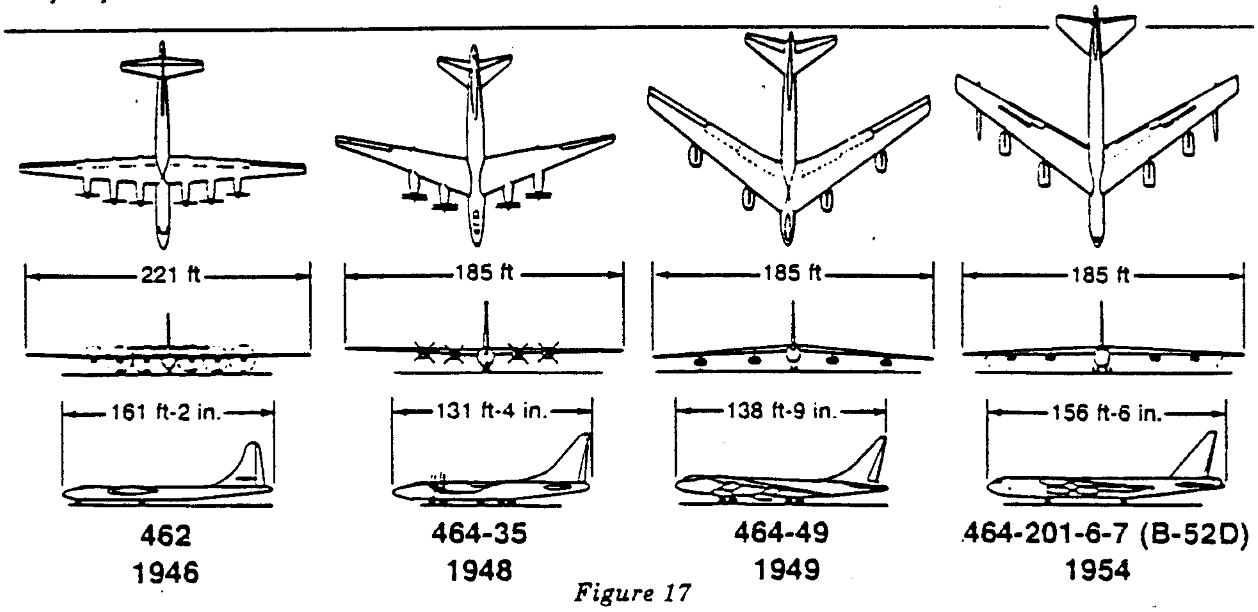

Figure 17

Boeing's successful work in developing the swept wing B-47 greatly encouraged the change, and really validated much of its concept. However, the B-52 involved other problems and the feasibility of proceeding with a jet configuration was also leveraged by the many rapid technological advancements made that were really unrelated to the B-52 objective, or for that matter, any specific design application objectives. One was the independent development of the J57 two-spool jet engine. The full significance of this to U.S. aviation is noted later. The main point, however, is that a new military engine was under development *before* its application was known. The timeliness of the earlier J57 start, of course, resolved the B-52's propulsion dilemma.

Similarly, aerodynamic advancements (unrelated to the B-52's needs) had occurred. Much of this technology readiness work was done by NACA, and much was Boeing's independent high speed airfoil work. Both were major contributors in providing the improved understanding of swept wing technology that was needed to support the jet bomber decision. Boeing's work, for example, had earlier revealed that the wing root could be grossly thickened without adversely affecting the high Mach number characteristics of the integrated airframe. This discovery, illustrated in figure 18, allowed the use of very long span wings on the B-52 without excessive wing weight.

B-52 Wing Thickness vs Span

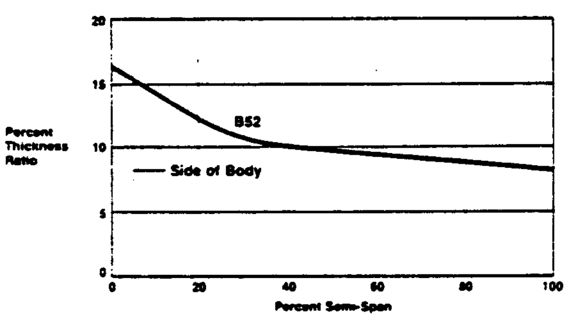

Figure 18

The program involved a prototype phase to validate the application of such advancements. There is much controversy today as to prototype cost-benefit relationships. Military acquisition methodologies of the time routinely included them, and the B-52 prototype cost in relationship with that of the total program is shown in figure 19.

B-52 Program History

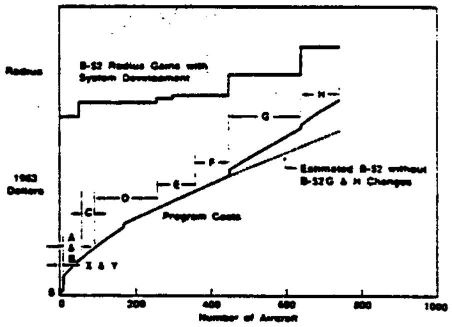

Figure 19

In terms of total program costs, the X and Y prototypes were insignificant. The B-52G and H series have been updated to incorporate a variety of offensive and defensive capabilities, including those shown in figure 20. In total, the airplane has exceeded its original design capabilities significantly and has been redesigned to perform missions for which it was never originally intended.

B-52 Program Phases

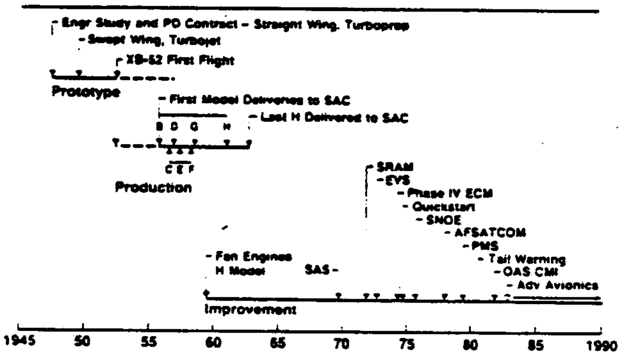

Figure 20

Improved capability costs have no doubt exceeded those of the initial development and prototypes several times over. Nonetheless, the total is probably far smaller than for production of an all-new airplane. I think the fundamental reason that the B-52 has remained in the Air Force's inventory plans for so many years is because of a fundamental change in the technological environment that was of its creation. With this in mind, the following decision points are illustrative.

1. The *then* acceptable government decisions that permitted funding of a new engine development with the intent of new technology readiness, but without specific applications defined. Similarly, the *then* acceptable decision environment that permitted the development of aerodynamic technology *and its validation* to the extent possible, again without the constraint of an audit track to a specific application.

2. The subsequent era of government decision making that has constrained the flow of aeronautical research to support the orderly and timely development of new advancement potentials. This started in the 1960s, at about the time the last B-52s were produced. Within a short span of years, NACA was recast into a different role, military research diminished and the nation has yet to achieve its third generation long-range bomber.

Lockheed Electra/Orion

The Electra program started as a four engine turboprop designed specifically for the medium and short range market beneath the 707 and DC-8. The go-ahead decision was made in 1955 in response to a requirement issued by American Airlines. First delivery occurred in October of 1958, the same month as the delivery of the first 707 commercial airplane. Although the Electra had some wing and power plant structural problems that bothered its early years, it developed into a technically successful commercial airplane. However, timing of the program was poor with respect to the emergence of the jets, and this would have been a financially disasterous program except that Lockheed cleverly exploited its broad product capabilities to use the airframe as an efficient naval surveillance platform. As the military Orion, the Electra has been in production since its first delivery in 1962. The combined program timings are shown in figure 21.

Lockheed has sold about 600 units, and the Orion is now also produced under license in Japan. The Orion military system in its various models was purchased by the U.S. Navy and also the military forces of Australia, Canada, Iran, the Netherlands, New Zealand, Norway, and Spain. The U.S. Navy version is shown in figure 22.

Lockheed Electra/Orion Programs

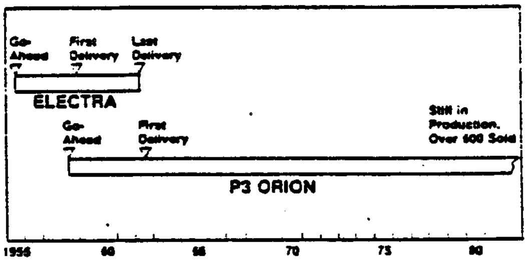

Figure 21

P-3 Orion

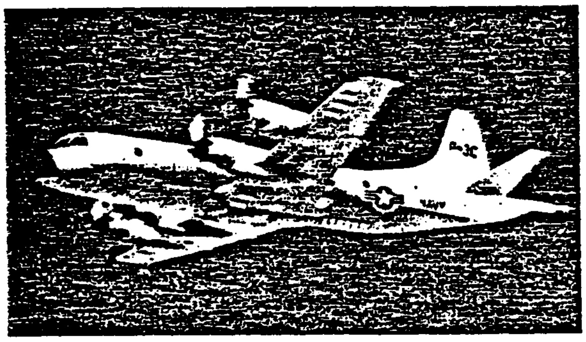

Figure 22

This program illustration exemplifies the hazards of new program starts with respect to market timing and technological obsolescence. The Electra came too late and with the wrong technology for its intended commercial market. It also illustrates a unique situation of extrapolating a failure into a remarkable success. As such the following decisions were key:

1. Failure: The decision to stay with better known technology and launch a four engine turboprop after the Caravelle (a twin engine jet) was launched for the same market. The power plant selected was the Allison 501. It should be noted that more efficient and proven commercial turboprop engines were available from the British industry. However, there was at that time a reluctance to become dependent upon an engine supply line extending across the Atlantic, and consequently a lesser experienced U.S. manufacturer was chosen. We'll discuss engine decisions later, but the point serves now to illustrate that supplier

decisions, if anything, have become more significant today, and programs can readily become win or loss situations by virtue of such decisions.

2. Success: The Orion's success, of course, represents another series of sound decisions that have tracked its long production life. The first of these was Lockheed's decision to market an airborne surveillance system designed around the Electra's obvious competitive advantages in this role. Thus, a competitive failure in terms of commercial requirements was reversed with its military mission.

707 Program

After its Stratocruiser experience, leaving propeller problems to others and proceeding with jet designs was not a difficult decision for Boeing to make. However, company efforts at convincing the military tanker people and commercial airlines that "jet was right" proved fruitless. Finally, after two frustrating years, Boeing's Chairman Bill Allen okayed the go ahead for a company-funded commercial prototype to demonstrate our conviction. This one-of-a-kind, the 367-80, was the beginning of the 707 and KC-135 programs. It was a big day when it rolled out, as shown in figure 23.

Dash 80 Roll Out

Figure 23

The Dash Eighty's first flight occurred on January 15, 1954. However, between go ahead and this event, the Air Force initiated a design competition for a tanker, not unlike the paper version that Boeing had tried to sell the Air Force earlier. Boeing lost the competition (partly due to Boeing's prototype knowledge) but Boeing delivery guarantees (with a prototype in hand) were irresistible, and by late 1954 Boeing was awarded the KC-135 production contract. The win was viewed as an opportunity to gain tooling that would have commonality for commercial production, and this became an influence in the increase of the cross section diameter from the prototype's 132 inches to the KC-135's 144 inches. Douglas came on to the market with a DC-8 which had a slightly wider body that was preferred by certain key airline customers.

The commonality decision was very right at a later time, but in this case it proved wrong for commercial competitiveness, and this forced a very costly redesign to a 148 inch cross section for Boeing. Figure 24 illustrates the three body widths involved.

Body Cross Section Evolution

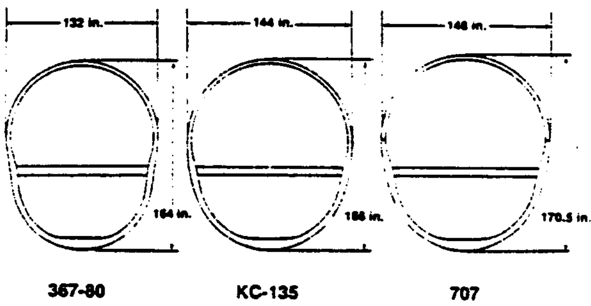

Figure 24

The DC-8 had also offered a larger and longer range wing, causing another major redesign headache and also invalidating what little was left in tooling commonality with the KC-135. The new wing change is illustrated in figure 25.

Wing Planform Comparison
707-120, 320

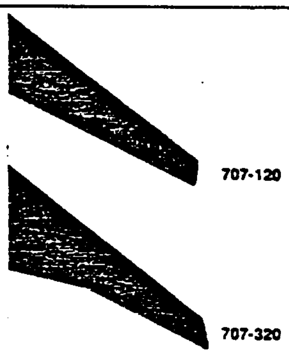

Figure 25

It was obvious from all this that gambling a quarter of the company's total net worth on building a prototype was only the start. Douglas was firmly entrenched in the commercial business and Boeing could either fold or increase its risks to obtain additional customers. Thus before delivery of the first 707, the production program involved two different wings, two body lengths, and two engines. By this time it also involved a commitment to build the 720, a lighter and shorter derivative. There were others as well, and a composite break-even situation developed as shown in figure 26.

Risk-Breakeven 707/720 Program

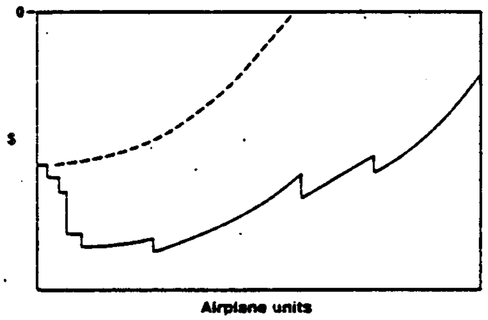

Figure 26

What actually happened is illustrated by the lower line of figure 26, as compared to the expectations which are represented by the upper line. Despite the turbulence of its launching, the program did evolve into a success and, as we've described, some of its more significant decisions were made in the program's early years as competitive pressures from the DC-8 exposed the 707's design vulnerabilities. I would consider the following decision points key to the 707's successful outcome.

1. The commitment (and collective decisions) that were to keep the 707 competitive. Much of this, as noted, was forced by specific competitive actions, and as such, Douglas really made some of the decisions for Boeing. However the commitment was fully a Boeing decision. It really preceded the 707 and has extended much deeper and far beyond the scope of this one program. *That commitment was to become a viable commercial competitor and to remain so.* It sustained the subsequent development of the Boeing jet transport family and over thirty years of continued product advancement. It has involved a continuity of discipline in design and production quality and the formation of a global customer support capability.

2. The second key decision was to proceed with the development of a company funded prototype after the unsuccessful and discouraging efforts in selling paper iterations to either the airlines or military. The prototype was invaluable, not only in paving the way for the 707's commercial acceptance, but for validation of the new technology integrations into its design. We may see this decision resurface in civil transport development within the next two decades.

Obviously referring to fan technology

Convair 880 Program

Convair emerged from World War II as a highly successful builder of the CV240, 340, and 440 series of transports...all for the short-range market. By the mid-1950s, Convair dominated this market segment, and knew its requirements better than the other U.S. manufacturers. Beyond the 440, the company was considering turboprops for additional short-range offerings, either as re-engines for its current designs or possibly as an all new airplane. With the exception of Sud's Caravelle (a tail-mounted twin jet), turboprops had become the primary short-range product focus on both sides of the Atlantic. However, despite its short-range market expertise, the company became enticed with a proposal from Howard Hughes to undertake the design of a big long-range jet transport for TWA. Working with Hughes was difficult, and by 1955 it became apparent that decision procrastinations had left Convair with no hope for a chance in the long-range market. Instead, the company lowered its sights onto the medium-range area with the CV880, a four engine design, thereby deferring its much better short-range market opportunities to other contenders. The timing of Convair's 880 decision with respect to this is illustrated in figure 27.

Go ahead was authorized on an order base of forty...ten from Delta and thirty from TWA. The CV880 was of sound technical design, but it persisted in a five abreast cross section, despite market objections. This made it vulnerable to the six abreast capability that Boeing countered with in offering the 720. The cross section comparison is shown in figure 28.

Competition

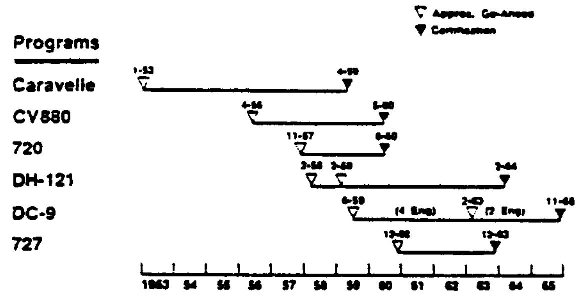

Figure 27

Cross Section Comparisons

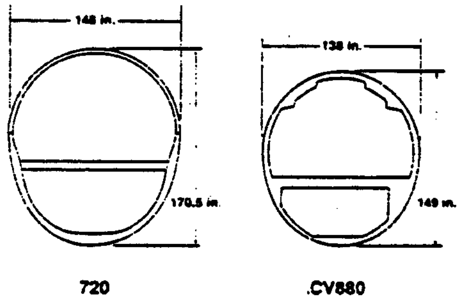

Figure 28

The noted difference in body diameter gave the 720 lower operating costs per passenger mile, and this, along with 707 fleet commonality advantages, virtually eliminated the CV880's market opportunities. Convair tried to recoup with the CV990, a larger version designed around an up-rated aft-fan version of the General Electric CJ805. The CV990 again was a good technical airplane, but continued disputes with Hughes over the CV880 and the high investment and concessions made to American in selling the CV990 were too much. Convair was, for practical purposes, through with the commercial aircraft business.

There were many decisions that affected Convair's fortunes with the CV880, but the following are particularly noteworthy with respect to the initial go ahead.

1. The decision to proceed with a four engine medium-range configuration when an intermediate-range twin-jet competitor was known to exist. Had Convair at this time moved directly into the short-range market, Boeing and Douglas could not have countered because of their other jet aircraft commitments, and the 720 could not have competed against a good short-range entry.

2. The decision to go ahead with the five abreast cross section when opposition from United, a key potential launch customer, was well known. Convair's firm position was not based on passengers; rather the five abreast decision was considered as an aerodynamic and performance solution to satisfy both transcontinental range and short field requirements.

3. The decision to proceed with a small order base and design that were both dominated by Howard Hughes. The pecularities of Hughes' business arrangements were well recognized at the time. In fact, Convair had suffered first-hand experience a few years earlier in an aborted piston transport sale.

deHavilland Trident Program

The Trident was a sound high technology configuration executed by a very competent team that started design work substantially in advance of the 727. Unfortunately, the program was delayed as design requirements became oriented toward the specific needs of British European Airways, a government-owned airline, and also because the British Government was restructuring the industry, which was creating uncertainty as to the future management of the project. Government policy of the day was forcing the domestic carrier to purchase British equipment. The BEA needs produced a tight body cross section, which the earlier 707 and DC-8 competitions had proven as unacceptable to the U.S. market. A comparison is shown in figure 29.

Cross Section Comparisons

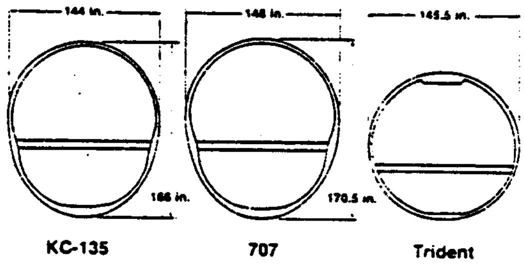

Figure 29

BEA's payload-range requirements and less demanding takeoff field length scaled down the Trident's original design, and at six abreast seating, this produced exceedingly tight shoulder clearances and very narrow swing-in entry doors that wasted floor space. This was all unacceptable to most airline customers. It also caused abandonment of the RB141 engine and start of a scaled-down engine, the RB163 Spey. Technologically, the airplane was very advanced, as noted in figure 30.

Trident Technical Features

- An integrated, clean-wing aft engine configuration having good characteristics in all flight regions
- A very advanced flight control system, combining triplicated power controls, an all-movable horizontal tail, and flight instrument innovations
- An improved bonded structure technology incorporating advanced fail-safe and safe-life techniques
- A new and efficient fan engine; the product of an orderly Rolls-Royce development program

Figure 30

Hawker Siddeley later produced stretch versions which sold at home and abroad. However, despite its technical soundness, only 117 Tridents in total were purchased by some nine airlines, and it was a financially unsuccessful program. It would be speculative to say just how much the British Government's policies flavored the program decisions that were made. Nonetheless, the following were key factors that affected the Trident's opportunity for success.

1. The decision (or decisions) that tailored the airplane's design to the needs of a single customer when only a cursory examination of the world market would have revealed differing requirements.

2. The decisions that cumulatively caused development to stretch into a six year program, thus allowing competitive aircraft to offer earlier deliveries.

<u>727 Program</u>

The 727 program began in May 1958 with a task force effort to identify the technology and configuration that would make a successful short- to medium-range commercial jet to complement the 707. The first designs produced a miniaturized 707, just as the initial "DC-9" was configured as a miniaturized DC-8. For economic reasons, we felt a two engine configuration would have better economics and our prime considerations in 1958 and 1959 were for two engine configurations having engines mounted under the wing. The torturous configuration path that covered the two-and-a-half year period is illustrated in figure 31.

727 Development History

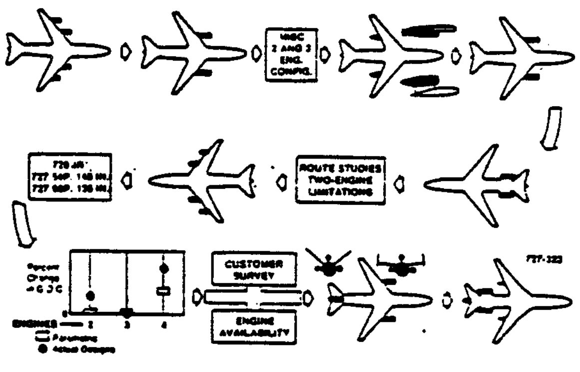

Figure 31

Conditions at that time precluded a European launch customer (due in part to the Trident start), and of the four major U.S. airlines, only United and Eastern were interested or financially capable. Eastern wanted to maximize economics with a two engine airplane, and United was seeking a four engine airplane because of their high altitude Denver requirements.

One must include a mention of the excruciating pain of trying to achieve a common denominator among varying airline requirements. All commercial programs go through a similar process and the engineers must work with a great many airlines, not just the few who are most likely to become program launch customers. It is a painstaking and iterative process, as illustrated in figure 32.

As this occurred on the 727, two other mainstream technical efforts were also proceeding. One was the development and wind tunnel verification of the many potential designs under consideration. The other was on-going technology staff developments that were independent of the program. The latter produced a triple-slotted flap which could yield a higher

One of Life's Frustrations

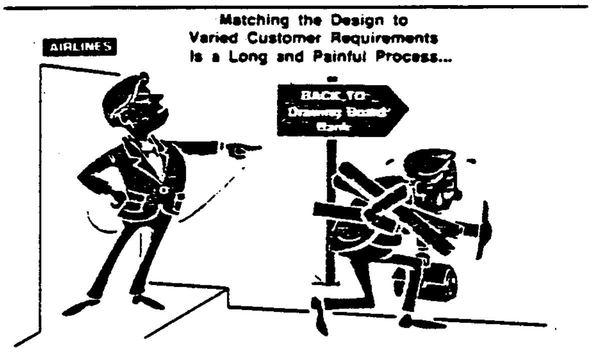

Figure 32

lift coefficient than any swept wing existing or contemplated. A three engine design was accepted as a compromise by both United and Eastern. The triple-slotted flap was incorporated to meet the short field requirement imposed by New York LaGuardia Airport runway 4-22.

The airplane really had two lives, and production rates have been highly variable as shown in figure 33.

727 Delivery History

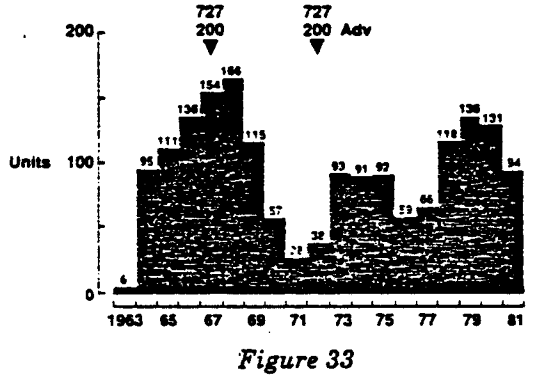

Figure 33

The first life included the original 727-100 and the early version of the 727-200, which made a fundamental mistake of adding body length at the expense of range, resulting in an airplane of limited performance and partially unusable economics. In late 1970 this was rectified by introduction of the "advanced" 727-200 having a higher gross weight, an upgraded engine, a new "wide body" interior and a variety of other improvements. Keeping the airplane competitive over its long production has entailed continuous nonrecurring investments, as illustrated in figure 34.

Cost of Nonrecurring Product Improvements as a Percent of Initial Nonrecurring Cost (Current Dollars)

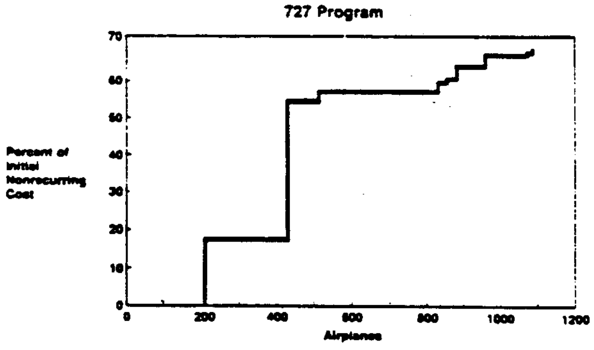

Figure 34

The cumulative investment for improvement has continued with production beyond that illustrated, and currently approaches 100 percent of the cost for initial development.

Evaluations of the 727's estimated market share were carefully made by Boeing's management before the initial production program was authorized. History has shown how wrong and how right these estimates were. This is illustrated in figure 35.

727 Market

Estimates vs Actuals

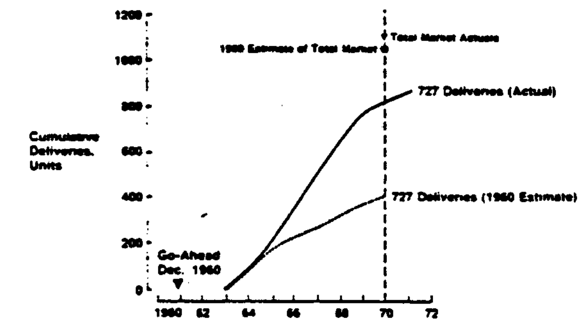

Figure 35

As noted, the 1960 predictions were that by 1970 the total market would stand at slightly over a thousand units, with the 727's share at about 400 units. These forecasts were made on the assumption that the 727 would face a U.S. competitor as well as Caravelle and Trident.

The 727's market position has held on through its "second life" with production approaching 2000 units. Some wrong decisions made by competitors and for the most part, some good decisions by Boeing ultimately gave the 727 the enviable position of being unchallenged. The following decisions by Boeing at the time of go ahead were key. Given different circumstances, they could have become "wrong" decisions, since they represented considerable risk in terms of the company's total situation at the time.

1. The decision to seek a satisfactory (three engine) middle ground solution between conflicting major customer desires for a two engine and a four engine aircraft. (Despite Boeing preference for a two engine configuration).

2. The decision to push state of the art in order to achieve desired competitive performance objectives within the intended market.

3. The decision (and its timing) to commit a major production program for a new state of the art aircraft in a situation of turmoil and without a prototype.

DC-9 Program

Douglas launched the DC-9 in 1963 as a direct competitor to the BAC-111. The British program had a two year lead, and with flying prototypes, it successfully penetrated the U.S. market. The Douglas program was started without a prototype and with Delta as the only customer.

The initial DC-9 series 10 was aimed at the BAC-111, not at a potential Boeing entry. The possibility of Boeing's 737, to an extent, caught Douglas by surprise. Rather than risk defeat by unexpected competition, Douglas decided to "stay with the game." The pace of basic model development increased, and to stall Boeing, work on a *major* improvement derivative (the DC-9 Series 30 for Eastern) was authorized. Douglas successfully curbed the BAC-111 delivery advantage, but the Series 30 derivative failed to stop Boeing's initial 737 sale made in February 1965. Additional stretches were initiated, and Douglas maintained the order advantage. However, the DC-9 market share successes also incurred financial penalties which contributed to the Douglas take-over by McDonnell in 1967. Figure 36 illustrates the DC-9 program timing, and the ambitious pace of its developments before this happened.

DC-9 Program

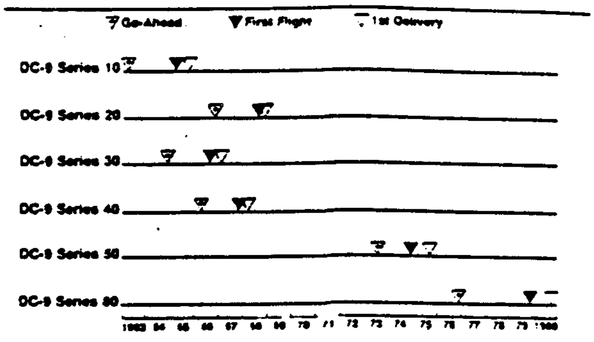

Figure 36

As noted, McDonnell Douglas has continued to stay with the game, and the DC-9's growth has nearly doubled passenger capacities over that of its initial model.

The DC-9 uses a cross section totally different from that of the DC-8, and this was probably a correct decision for the time of its launching. To an extent, however, its smaller dimensions opened the way for a 737 start with cross section and parts common with the 727. This plus the 737's conventional tail and wing-mounted engines produced a much shorter airplane with respect to passenger capacities and made growth versions easier. Figure 37 illustrates the cross section differences between the BAC-111, DC-9, and 737.

Cross Section Comparisons

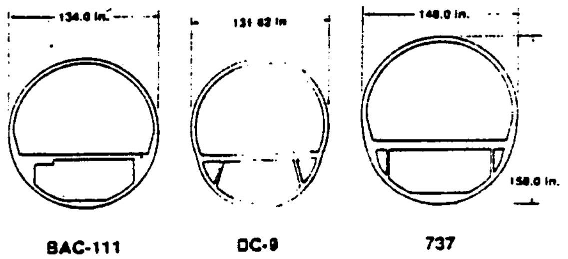

Figure 37

The DC-9 decision had much in common with the 707-320 decision made by Boeing in its earlier competition with the DC-8. It was a matter of staying in the game with additional major nonrecurring investments.

This unquestionably produced better airplanes by both. The real market loser in the DC-9 case was the initial market entrant, the BAC-111. With respect to this, the following DC-9 program decisions are noteworthy.

1. Douglas had correctly assessed its late-start market opportunities in U.S. market competition against the BAC-111. The Douglas airplane featured an upper deck cross section affording superior passenger appeal features (significant to this market), whereas the BAC-111 used the more restrictive circular body favored by the European industry.

2. Boeing probably would not have started the 737 had Douglas initiated the DC-9 program with an airplane more resembling its Series 30 derivative. In this matter, Douglas may have incorrectly assumed that the BAC-111 was the only competitor.

Supersonic Transport Programs

Even as the first subsonic jet transports were developed, the commercial potentials for supersonic flight came under serious study in the four nations that fostered their development. The costs for development were recognized to substantially exceed any civil aircraft program previously accomplished. As such, this caused British and French interests to merge into the Concorde. On this side of the Atlantic, funding required direct U.S. government sponsorship, with a series of competitions that selected Boeing as the airframe manufacturer. The Soviets operated in a manner conventional to their style, with the government assigning the SST task to Tupolev. However, the decisions surrounding the U.S. and European programs were unconventional, and the timing of the two is shown in figure 38.

Supersonic Transport Programs

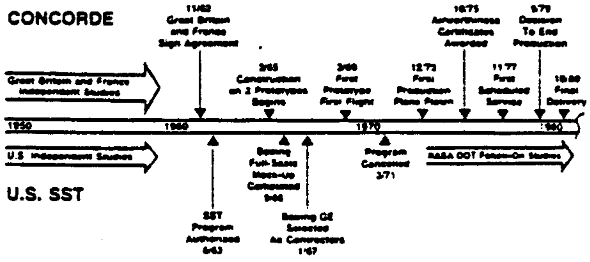

Figure 38

The Concorde, of course, is still in service, but the decision to terminate production was made several years ago as the market could no longer substantiate its economics. The earlier termination of America's SST, in my mind at least, has proven with hindsight to be a right decision but it was made for all the wrong reasons. Unfortunately, these wrong reasons have afflicted the pace of U.S. technology ever since, and the nation has suffered deeply because of this.

Both programs were conceived at a time when fuel prices (in constant dollars) were tracking a downward path. Both were known to be sensitive to fuel, since supersonic cruise requires more energy per unit of payload and range. The subsequent increase in fuel price made the U.S. decision "right" nearly two years after it was made. Nevertheless, the Concorde, shown in figure 39, has been providing safe and reliable Atlantic service since 1976.

Concorde

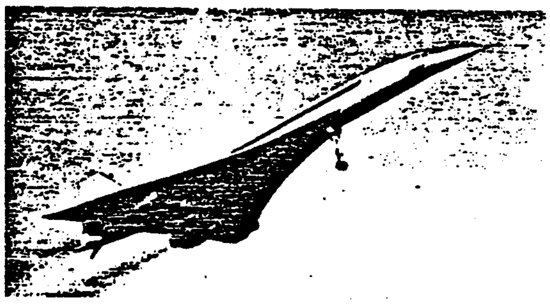

Figure 39

The funding nations, including the U.S., have reaped enormous legacies from their SST programs. A partial summary of the achievements derived from the U.S. program is noted in figure 40.

SST Spin-Off Contributions

- Modern flight deck technology, now being introduced on new generation commercial and military airplanes
- Large scale application of computers to aeronautical engineering problems
- Titanium alloy developments and new structural concepts
- Miscellaneous developments: lightweight seats, fuel tank sealants, noise reductions, guidance, hydraulic tubing, etc.
- Augmented flight control systems having current military and future commercial applications (relaxed static stability - active controls).

Figure 40

4.20

The European experience is similar, although of course, the actual SST production and service have enriched their development knowledge extensively. Both programs are graphic demonstrations that high technology efforts, regardless as to how they are sponsored, will find applications to generate values not thought of at the time.

However, the diverse decisions surrounding these two programs warrant two final observations with respect to their legacies:

1. The Concorde program proved that a large-scale international program could be made to work. Much was wrong, but it forced solutions that paved the way for internationalism that is becoming widespread today.

2. The U.S. decision, unfortunately, may have accomplished the opposite. It appears to have validated a growing trend of public and government opposition to technology that made the 1970s a decade of drought for U.S. research and development. We are reaping the bitter harvest of such decisions today. More specifically, the "wrong" aspect of the SST's cancellation was that, in the absence of a supersonic long-range bomber, it ended the idea of government supported high risk prototypes. Its completion would have made the B-1 and F-16 into better programs and the Space Shuttle a cheaper program. It also would have allowed the earlier introduction of many advancements in new subsonic airplanes.

747 Program

The 747 was conceived at a high point in world travel growth. Mass travel markets were in rapid expansion with the air system and major airports approaching capacity limits. The objective was to design a "super plane" that would capture high performance and low seat mile costs by its economy of scale. The airplane was intended to leap-frog the DC-8-63 and also to be oversized at introduction. It was intended that it become a "market fit" about four years after introduction. Such philosophy guided the DC-8 and 707 developments, and is illustrated in figure 41.

747 Sizing

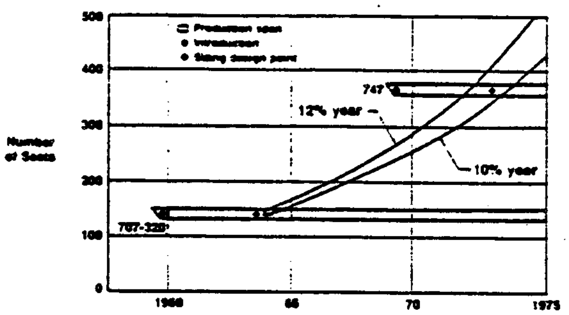

Figure 41

The risks were of a magnitude scale also, and most were recognized before go ahead. It required a new factory concept, and the 747's success would be dependent upon the development of the new and untried JT9D engine. Furthermore, all of the critical elements (factory construction, airplane design, and engine development) had to proceed concurrently to meet delivery schedules. On the plus side of this was the fact that the 747 was establishing a new size platform, one that competitors would be hesitant to challenge.

The expected emergence of the SST as a principal long-haul passenger transport was a significant consideration in both sizing and configuration. The body width had to be sized for freighter efficiency in the event this became a principal job as the SSTs took over passenger service. The resultant cross section, shown in figure 42, had little to do with passenger appeal in its selection, but was marketed as a great passenger comfort "breakthrough" by use of an innovative mockup and promotional campaign.

Body Cross Section Comparison

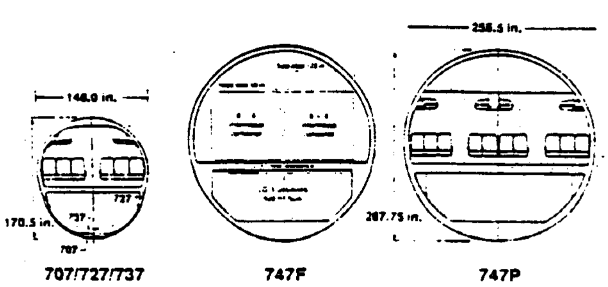

Figure 42

The airplane was designed for higher speed objectives to improve productivity without significant erosion to seat mile costs, which were to be substantially below that of any vehicle flying. Scale, of course, was a major factor, as figure 43 illustrates. However, the results exceeded those of scale effect alone.

Direct Operating Cost Comparisons

1979 U.S. Domestic Rules, 1979 Dollars, 1000 nmi Average Trip

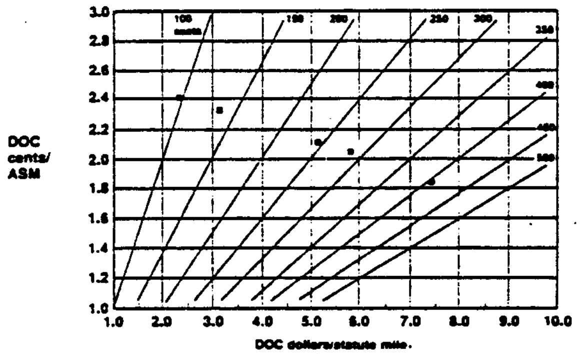

Figure 43

Bringing it all together on time was unquestionably the largest aircraft task (and the greatest risk) that Boeing had faced. The rollout is pictured in figure 44.

The Boeing 747

First Airplane Rollout

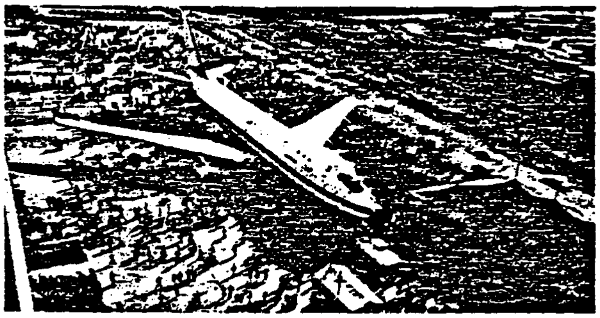

Figure 44

The airplane proved to have extremely good flight characteristics once initial bugs were corrected. Considering its uncontested "platform position," the program has gone on to contain an unusual array of product improvements and derivatives, including some 20 engine options. Figure 45 illustrates this, showing the derivative models available.

Current 747 Family

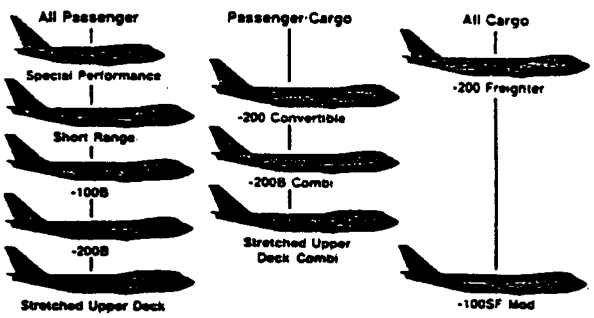

Figure 45

The additional nonrecurring costs for all this have fairly well tracked the 727 program experience noted earlier, by nearly matching initial development costs and following a similar time pattern as well. Critical decisions abounded on this program, in character with its size. However, the following are noted because of their significance to subsequent wide body programs.

1. The decision (before actual go ahead) to rebuild the entire production and management control systems of the company. The 747 really ushered in a new era of production management for Boeing, and without such, the later concurrency of the 767, 757, and 737-300 programs would have been unthinkable.

2. The decision that risked success on the concurrent start and development of both a new airframe and a new engine.

3. The decision to size the airplane to a relatively high assumption of market growth, with a relatively secure confidence that its scale would not be easily challenged.

Head-on Competitions

Many conclusions and contradictions can be drawn from the ten programs we've just covered. However, on the commercial side, decisions that surrounded head-on competitions have appeared particularly critical, and worthy of some special observations. For such, I've selected the four sets of competitions illustrated in figure 46.

Head-on Competitions

CV240 M202	707 DC-8
DC-10 L-1011	767 A310

Figure 46

We noted Convair's successful piston experience earlier. But the first of its post war pistons, the CV240, appeared in the short-range market as a direct challenge to the slightly earlier Martin 202. The objective of both was to replace the DC-3 in a market that was fairly small but had good opportunity for expansion. In this case the M202 was underpressurized and had some structural deficiencies, faults that the CV240 avoided. The market was too small to carry both, or to tolerate fixes. Consequently the M202 was forced to terminate production at 31 units. Convair sold over 570 of the CV240s, and produced a total (including derivatives) of over 1,100 aircraft.

The 707 and DC-8 competed in a market that was sufficiently large for both. Boeing was first, but with some mistakes in size and range requirements that were *immediately* corrected. Had this not been done, the competition might have ended differently. However, it should be noted that the 707's ultimate success is due in part to Douglas' decision to terminate DC-8 production in favor of increased DC-10 sales. The 707 did not put the DC-8 out of production. It was a Douglas decision that favored Boeing.

The DC-10 and L-1011 competition involved a different market situation. These airplanes were caught, along with the A300 and 747, with a market expanding at a substantially slower rate than predicted at the time of their launch. Both were "too big", which depressed their sales while benefitting those of smaller aircraft such as the 727. Both are technically acceptable, but have suffered primarily because the market failed to develop sufficiently to support both or possibly even one.

The 767 and A310 competition must be regarded as still in its infancy. However, they are of a size, a timing and a technology that should support both in the market. The two unknowns at this time are the implications of affordability and internationalism on the market and its decisions. We'll cover this in more detail later.

These cases have pointed out the significance of decisions leading to head-on competitions. Mistakes may be tolerated, but only under circumstances of rapid correction. One can't correct the market need however, and head-on competitions in the face of insufficient market size means that one or both competitors may be unsuccessful.

Military vs Commercial Decisions

The purpose of this section is to briefly explain the fundamental differences between the military and commercial environments in which decisions are made. Commercial practices seem to be more streamlined than military practices and the Department of Defense is spending considerable time studying them. However, one must recognize the basic differences between the two environments. These are overviewed in figure 47.

Commercial vs Military Program Relationships

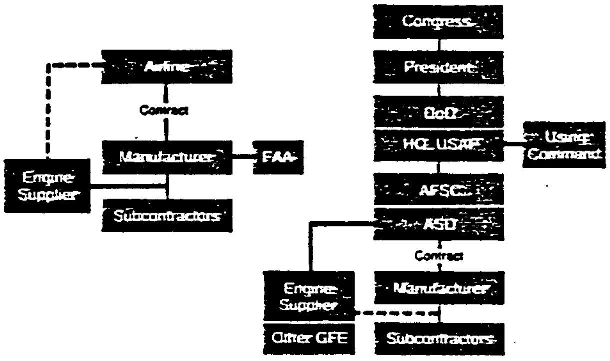

Figure 47

Commercial communication lines are short, including those involving decisions. After the product is agreed upon, manufacturer initiatives dominate. The number of people involved for the airline and for the manufacturer in administrating all aspects of the contract, including technical, is perhaps a dozen or so on each side. The FAA issues type and airworthiness certificates. They also issue a

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407

contractors production certificate. Their interface with the manufacturer in terms of numbers (not influence) is heavily dominated by Designated Engineering Representatives (DERs) and Designated Manufacturing Inspection Representatives (DMIRs) certified for the duty from the manufacturer's ranks.

The illustrated Air Force program is immersed in a far different environment, one which is not easily changed. The buyer is the Air Force Systems Command and its designated Aeronautical System Division as noted. The relationships are much more complex and formal, and Congressional oversight is maintained on a line item approval basis where major aircraft programs are concerned.

The Air Force must be prepared to publicly defend any decision it makes, which is not a requirement in commercial business (*public accountability vs private accountability*). Similarly, the Air Force must be prepared for a formal protest on its procurement decisions and has procedures for this purpose. The method for commercial protest to be heard is the loss of future business. The only established process is through the courts, and this is generally avoided. The commercial product relies on a fixed price based on an end item specification, performance guarantees, service life policies, and warranties. The military system relies upon a complex interface in which every decision must be extensively reviewed and documented. Military logistics and spares requirements tend to prevent in-line product improvement except at rare intervals. Commercial practices assume that such improvement is normal, and no approval is needed so long as performance guarantees, price, and delivery are unaffected.

The military system is much more formal and derives advantages and disadvantages from this situation. Because of this formality, I have chosen to illustrate a common civil/military decision situation with a military chart as shown in figure 48.

The situation is oversimplified but is applicable to either the civil or the military case. For convenience, it uses the military definitions which, of course, have their civil counterparts. It omits the military "milestones". The objective of the system is to reduce risk...hopefully to zero when *production* is finally entered.

Risk and Decision Cost Profile

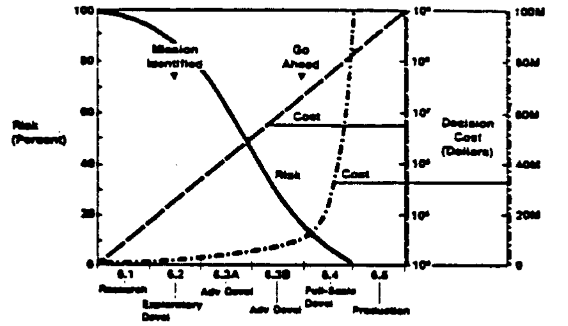


Figure 48

The cost of a major decision is shown on two scales. The diagonal straight line is plotted on a logarithmic scale; the curved line, similarly identified, is plotted on a normal scale. The message (applicable to civil or military) is that pre go-ahead decisions are cheap. But the decisions made after go ahead increase rapidly in cost until they become essentially prohibitive.

Since commercial programs are based on a market price (without relationship to cost), there is a very large incentive to apply large amounts of early capital (before go ahead) to facilitize and train for productivity and low recurring costs. Military programs, on the other hand, have difficulty authorizing large amounts of "up front" money and disincentivize large productivity investment by the contractor. Military program's profit is limited, and, when nonallowables, potential renegotiation, and other contractual burdens are considered, the profit may prove unattractive to some suppliers.

The type of technical and manufacturing decisions to be made are similar. The manner in which they are made is very different and will remain so.

The technology base for military and commercial aircraft is generally the same. At one time the flow was from military into commercial. Today much of the flow is reversed. In addition, the "audit trail" requirements that now force DoD to link research and technology to identified future weapon systems tend to constrain the military input to the base. This tends to increase the military reliance on civil and NASA basic research. Such "compartmentalization" is generally not practiced by other nations in the western world today.

V. Engine Decisions

The success path of an airplane program, whether commercial or military, is heavily dependent upon the success of the propulsion system. From an aircraft manufacturer's standpoint, engine selection is critical and is sometimes more complex than decisions made on the airframe itself because three parties are involved (the airplane manufacturer, the customer, and the engine manufacturer) and because engines take longer to develop than airplanes. The purpose of this section is to discuss a few of the pivotal engine developments and to identify some of the more significant engine decisions involved. Thirty years ago it was commonplace for the U.S. Government to fund development of engines before the airplanes on which they were to be fitted were configured. While the policy has tended to disappear, the facts that supported it have not.

JT3/J57 Program

General Electric and Westinghouse, with sizable experience in turbine and supercharger technologies, were selected as principals to develop the first U.S. turbine engines.

Nonetheless, Pratt & Whitney recognized the probable future of the newer technology and initiated its independent design work on two engines. The larger of these, (the JT3), was a two-spool 10,000 pound thrust design. Its concept looked so promising that the Air Force joined to fund further development as the military J57, the first U.S. engine in the 10,000 pound thrust class, and forerunner to the JT3C and JT3D. The J57 is illustrated in figure 49.

JT3/J57 Engine

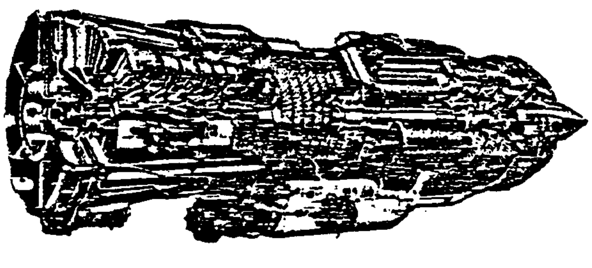


Figure 49

Development was not without difficulty. The original JT3 was designed with a constant external diameter and only two were built. The remainder incorporated a "wasp-waist" constant internal diameter (with higher efficiency, better sealing, and lower weight) and an engine accessory arrangement that reduced its frontal area. As noted earlier, the J57 military version became the propulsive foundation for the B-52. The critical decisions were:

1. The decision by Pratt & Whitney and the Air Force to develop a 10,000 pound thrust jet engine with no identified application.

2. The Pratt & Whitney decision that a two-spool axial flow configuration was correct and that they should work toward an opportunity to develop it and stick with that development.

3. The Air Force decision to change the B-52 from a turboprop to a jet bomber powered by eight J57s.

4. The Boeing decision to back commercial and military programs based on four JT3/J57 engines, which culminated in the decision to build the prototype.

Pratt & Whitney refined the JT3's technology and developed a larger, higher thrust engine called the JT4 (J75). This was the original engine used on long-range versions of DC-8 and 707 aircraft.

Bypass Fan Engine Development

The first bypass engine was a Rolls-Royce Conway with a bypass ratio of 0.3. The U.S. fan-engine developments tracked competitions between two technical paths: the single-spool aft-fan technology followed by General Electric and the two-spool front fan technology pursued by Pratt & Whitney.

Their development and timing were occasioned by Convair's abortive attempt to recoup its CV880 market failure by offering a larger CV990, designed around the CJ805-23. This was a superior aft-fan version of the engine that Convair had used on the CV880. The CV990's success was to depend largely on its being the sole market entry with the much more fuel efficient and higher thrust fan engine. Convair, General Electric, and American Airlines (the CV990 launch customer) were confident that

Pratt & Whitney couldn't counter with a competitive fan engine for Boeing's 720.

Pratt & Whitney was obviously in a spot; however, the company had previously initiated experimental test work on both rear and front fan engines, noting the potentials of the earlier Rolls-Royce Conway. Pratt simply built a front-fan engine by quickly configuring a JT3 demonstrator two-spool engine from which the first three stages were removed, and two stages from the larger diameter J75C were bolted in their place. This demonstrator provided a bypass ratio competitive to that of the CJ805-23. It evolved into the JT3D, and to this day, the engine has no third stage.

The JT3D was quickly adapted to the 720, giving the airplane a 41 percent increase in power and a decisive advantage over the CV990. It eventually powered the 707, DC-8, B-52, and some KC-135 aircraft. A comparison of the General Electric CJ805 aft-fan with that of Pratt & Whitney's JT3D is shown in figure 50.

Aft Fan vs Forward Fan

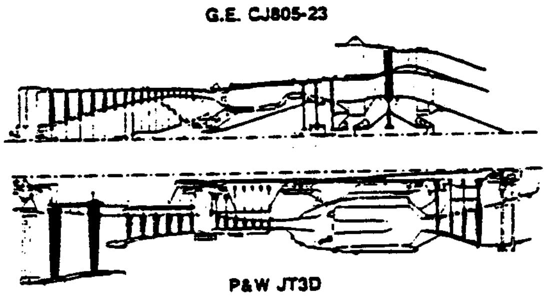


Figure 50

The key decisions appear to have been:

1. Decisions by Convair and American Airlines to launch the CV990 program based on the advanced General Electric aft-fan engine.

2. Pratt & Whitney's decision to immediately counter with a competitive fan engine (based, of course, on earlier experimental work).

The JT8D

Commercial competition of a different type initiated the Pratt & Whitney JT8D program. In this case, Boeing had selected the Rolls-Royce AR963 engine for the 727. The engine was to be assembled in the U.S. by Allison under a Rolls' license. However, Eastern Air Lines, one of the 727's launching customers, insisted that the engine must be totally of U.S. origin to assure that adequate engineering and critical parts support were provided. Boeing attempted to overcome Eastern's objections by persuading Rolls to establish a factory (with adequate technical staff) in this country. Rolls elected not to do so.

This provided Pratt & Whitney the opportunity to offer the JT8D, a fan version of its J52. This engine change was acceptable to the launching airlines, and last minute changes to the airplane were hurriedly made.

The development period was short, and engine failures during the initial 727 flight tests were frequent. However, Pratt corrected the deficiencies with a major redesign and the engine went on to power the DC-9 and 737 as well as all 727s. A "refan" version was later developed, stimulated primarily by noise compliance needs. The circumstances are noted in figure 51.

JT8D Engine

- A rapidly devised, fanned version of the Navy J52 core
- Lack of de-bugging resulted in initial flight hardware that destructed with engine surge (rotor/stator contact)
- Finally resulted in reliable and fuel efficient engine powering half the world's transports. The biggest peace-time engine program ever
- U.S. Government sponsored a re-fan to increase bypass ratio, and improve community noise and specific fuel consumption. The re-fanned engine now powers DC-9 Series 80 aircraft

Figure 51

The most important decisions were:

1. The Eastern Air Lines decision that it could not accept the 727 based on an engine with transatlantic technical and logistics support...coupled with the Rolls-Royce decision not to build a factory in the United States.

2. The Pratt & Whitney decision to rapidly offer an alternative solution.

The RJ500 is an arrangement between Rolls-Royce and Japan Aero Engines Ltd. to design and build an engine aimed at the 150 passenger airplane market. The arrangements may be extended to include other companies, perhaps even Pratt & Whitney. The circumstances for the joint program are still in their early stages and the final outcome is yet to be determined.

Advanced Turboprops

Today, there is a strong possibility that the right way to go for certain civil applications and certain military applications is with an advanced multi-bladed turboprop as shown in figure 56.

Propfan

Figure 56

This may or may not require an all-new gas generator, but it will require all-new gearbox and propeller developments. Although renewed interest in the turboprop was launched under NASA's sponsorship, the major effort and the major funding to support it lies ahead. Assuming that such a development offers fuel efficiency, perhaps 15 percent better than that available with a turbofan, it would appear that the following decisions need to be made:

1. How will the propeller development be funded? Development time appears to be longer than engine and gearbox development time.

2. How will an engine and gearbox development be funded?

3. Will the resulting program be multi-national?

4. What is the correct size for the initial development system?

These questions are based on the probability that such a propulsive system will most assuredly have a development time longer than that of an airframe and that it is probably not feasible to wait until the aircraft requirements are established before such a propulsive system development is committed.

VI. Decisions Forming the New Fleet

Fleet selections for future 1980 decade deliveries will be made from equipment options that are already known, and most of this equipment will incorporate one of the latest fuel efficient high bypass ratio engines that were just discussed. The majority of new commercial airplanes delivered will be selected from the range and size options presented in figure 57.

Commercial Airplanes for the 1980s

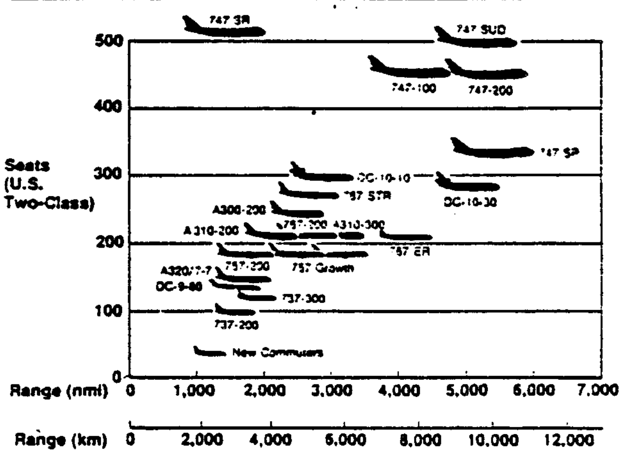


Figure 57

For purposes of discussion, figure 57 has included the A320, 7-7, and 767 stretch, although none have been firmly committed by their manufacturers. We shall next examine decisions leading to the Airbus equipment (A300/A310) and to the 767 and 757.

Airbus

The same high air travel growth rates that stimulated the 747's wide body start for the international market pointed to the need for smaller-sized wide bodies configured for domestic service in Europe and the United States.

The Europeans jointly explored their domestic alternatives for developing a short-haul, high capacity airliner for several years, starting in 1965. However, the less constrained U.S. domestic market acted first, expressing a variety of airline range, airport,and route requirements, thus further tempering the course of the European program's definition.

On the U.S. side, some airlines favored a program committed to transcontinental ranges, and others would accept a shorter initial range with potentials for transcontinental growth. Supporting the latter was the 1966 specification issued by Frank Kolk (American Airlines) for a jumbo twin (high bypass fan engines) carrying 250 passengers (one class) with operating capabilities between La Guardia airport in New York and Chicago and, of course, Chicago to the West Coast. The Denver requirement (which forced the 727 to have three engines) and several other considerations also entered the equation.

However, the fundamental decisions changing to a transcontinental tri-jet and afterwards selecting the DC-10 were made by C. R. Smith, Chairman of American Airlines, who overruled Kolk's specification and demanded an initial transcontinental capability. *Rarely have decisions been so critical as these made by Mr. Smith.* Lockheed, the loser in this competition, decided to proceed in a head-on competition with its L-1011, and the big twin slot was open on both sides of the Atlantic. The timing of the three programs is illustrated in figure 58.

Wide Body Programs
(Post 747)

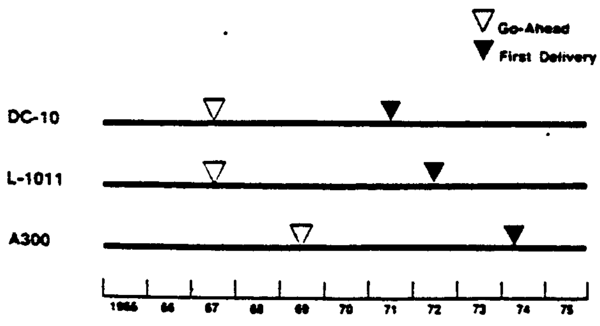


Figure 58

The emergence of the larger-sized U.S. airplanes caused the A300 to be scaled down by about 50 seats and, so sized, the Airbus consortium program was officially sanctioned for go ahead by the participating governments in May 1969. The key forces motivating the decision are summarized in figure 59.

A300 Program Influences

- Provided base for European industry expansion
- Market need recognized by Europe's airlines
- No similar two-engine aircraft competing
- Suitable engine available
- Government support

Figure 59

The timing was right. There appeared to be a definite market need, and it could be years before another opportunity would develop. Furthermore, the program had been carefully planned, recognizing the many difficulties that had surfaced in earlier joint European efforts. The biggest problem was to create an authority that would make binding decisions in the presence of conflicting partnership views... technical, financial, or political.

Affordability, as we have already noted, has different meanings to differing political or societal structures. Nowhere is this more aptly demonstrated than by the European value judgments in the decisions that initially funded the Airbus development and then provided the "staying power" to sustain Airbus through its first six years with less than 30 orders booked and only 13 deliveries.

The decision values considered that the industry was a pacesetter for Europe's technical progress, and as such, its employment must be maintained. It was stated that the Airbus base could provide stability, and, furthermore, it could be sustained by airline profits and the money market, thus reducing the European taxpayer burdens by an equivalent amount. If it could be sold abroad...so much the better.

The A300's start represented far more than the go ahead of a specific airplane. Its decision values stated a cohesive linkage between industry and government objectives, which has no parallel within the U.S. decision-making environment.

4.25

As traffic growth improved, the A300 was more closely sized for a number of world markets than was the DC-10 or L-1011, thus forcing the latter out of production. The European partners committed sizable reinvestments for A300 production needs and also to expand this initial product into the product tree illustrated in figure 60.

Airbus Products

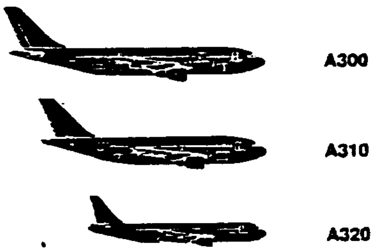


Figure 60

Although the A320 is not firmly committed as yet, we can assume that its go ahead (and also that of the A310) will require levels of competitive reinvestments over time, similar to those experienced by the U.S. industry...essentially doubling the costs of their initial development.

There were significant decisions leading to the Airbus start...we have chosen not to enumerate them. However, the most noteworthy point is the result...a new premise of internationalism and affordability to affect world decisions in commercial aircraft.

The 767 Program

The 767's origins were also very carefully considered, and over a time period that went back to a 1971 alliance with Aeritalia. Thereafter, the Boeing-Aeritalia team gradually recognized a sizable market and product opportunity below the A300 and above the 727-200. This involved replacement of the various 707 and DC-8 airplanes used in this range-size area. These aircraft had excessive range capabilities for the market and were also of an older and less efficient technology, thus of diminishing credibility with respect to market needs. The efforts in the general 1973 time period (7X7 program) were oriented toward the medium-range market, but with transcontinental growth. A Japanese industrial team also joined the program as an additional risk-sharing design and production associate.

There ensued a long period of study during which a three engine configuration appeared best, particularly with the transcontinental potential in mind. This consideration spawned Pratt & Whitney's development of the JT10D, sized for a 200 passenger 7X7 tri-jet configuration with transcontinental capability. However, it later became apparent that a twin engine configuration could be designed for the job with better efficiencies, and the program was so reoriented.

One of the most agonizing decisions was that of cross section. Extensive studies and work with the airlines throughout the 7X7 program identified the lower lobe configuration requirements and also the need for inclusive tour provisions. What was to emerge from this work was confirmed in the 767's larger cross section, which provides a standard seven abreast seating with a dual tight eight abreast inclusive tour provision. The cross section also provides a container and cargo capability that features an eight-foot wide flat floor.

The program's long development history was a plus in many respects, and this is summarized in figure 61.

767 Development

- Unusually long preparation period prior to go-ahead (about six years) allowed exceptional opportunity for orderly program
  - Preparation stressed product and cost definition
- An international collaborative effort from start with Italians and Japanese acting as risk sharing, design and production associates
- May be the most smoothly executed commercial development program in history

Figure 61

The 767 is also the first new aircraft to incorporate the full digital flight management system that was generated from the U.S. SST, then on through the NASA 737 demonstrator to become the new standard, which will eventually be applied to all western world major aircraft. The 767's long development period has also provided for the most thorough pre-production planning that has ever been accomplished. The principal decisions in the 767 program were:

1. The decision on the 7X7 program to carefully prepare for a medium-size, medium-range airplane deliberately placed below the DC-10/L-1011/A300 and above the 727-200.

2. The decision to include Italy and Japan as risk-sharing design and production associates.

3. The decision to develop an all new cross section specifically designed for fuel economy in the specific market intended and offering improved passenger accommodations with an inclusive tour backup.

4. The decision to orient the program specifically to a two engine configuration.

The 757 Program

The need for a successor to the 727 was recognized in the early 1970s. At first it was felt that a wide body version of the 727 with CFM56 engines could be generated, and considerable work was done on a configuration, the 727XX. Later a less ambitious but still expensive derivative (727-300) came close to go ahead but was rejected by United Airlines at the last minute. Fuel prices had escalated rapidly and it became quite apparent that a new wing would be required. The 757 was originally configured as a smaller airplane, but with a new wing, and with a two engine, under-wing configuration, much as it remains today. The cockpit was initially a two crew member modification of the 727 cockpit, but later the new 767 cockpit was adopted along with a great deal of 767 commonality. The design is now a well integrated, *all-new airplane*.

The present 757 size came from the beliefs of the two starting airlines,British Airways and Eastern Air Lines, that the traffic would support the size, and that fuel burn per seat mile would be improved by a size increase. The size was also somewhat influenced by the engines (General Electric and Rolls), both derivatives of larger engines that were down-sized to fit the 757. The smaller size JT10D, that had been developed to fit the three engine 767, was not a candidate when the 757 was originally committed. This situation dramatically changed when Pratt & Whitney offered to completely resize their engine for the 757 as the PW2037. The initial 757s will be delivered with the Rolls engines. The Pratt engine will not be delivered until one-and-a-half years later. The 757 has the *same* direct operating cost in dollars per mile as the 727-200 but has 50 additional seats. The basic 757 decisions were:

1. To optimize the airplane as an all-new design with 727 airplane operating cost but with much lower seat mile and fuel costs.

2. The Pratt & Whitney (and Boeing) decision to build an all-new engine for the 757 (the PW2037).

3. The Rolls-Royce decision to compete by offering a major derivative engine, making the aircraft competively available with either Rolls or Pratt engines.

The 757 and 767 are key members of the new airplane family as is shown in figure 62.

The Boeing New Airplane Family

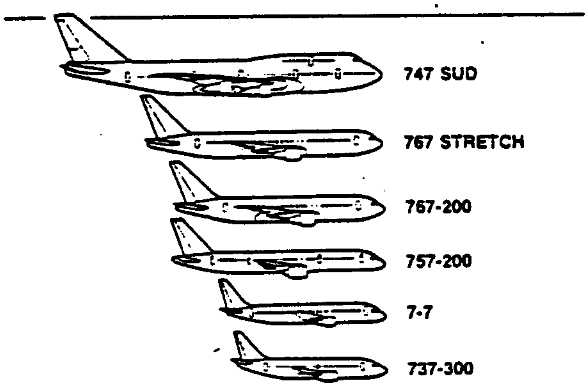


Figure 62

Ultimately, the airplanes noted will incorporate as much commonality as feasible.

Airplane Sizing Considerations

The basic fundamentals of airplane size, of course, include growth in revenue passenger miles. This must be modified by considerations of airline service proliferation and competition, which would drive the size below percentage increase in RPMs, and by airport and air space constraints, such as airport terminal slots, and peak period ATC capability, which would tend to

4.30

keep the size up. All of the original wide body airplanes (747, DC-10, L-1011, and A300) were conceived at a time when RPM traffic growth throughout the world was close to 15 percent per year. It was fundamentally from this 15 percent number that the 11 percent shown in figure 41 was selected for the basic sizing of the 747.

In the decade that followed, traffic growth severely diminished. This and anticipated growth rates for the future are shown in figure 63.

World Revenue Passenger Traffic
All Services

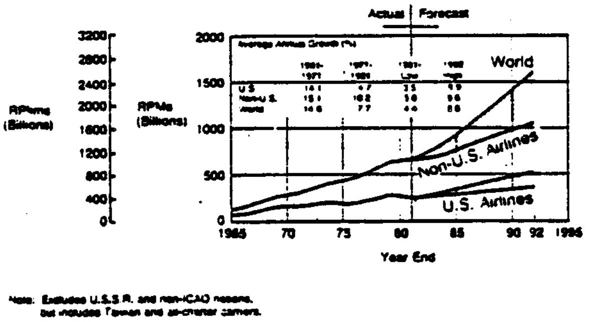


Figure 63

In addition to the lower traffic growth, U.S. domestic competition proliferated by reason of airline deregulation enacted in late 1978. On a somewhat similar basis, international routes increased, due in part to more liberal bilaterals allowing more competition on both long and short range international segments. We are currently in a most unusual situation which finds the world's traffic growth stabilized and the U.S. growth negative. This has not happened before, and all forecasters, I believe, predict future growth within range of the bands shown. We tend to swing in cycles and to design our airplanes oversized when the growth cycle is high and undersized when the growth cycle is low. Since successful airplane programs must be of long duration, it is not appropriate to design new airplanes such that they will be a perfect market "fit" on the year of introduction. As noted in the discussion relative to figure 41, it is proper to design for a market fit three or four years after initial introduction. Figure 64 carries this philosophy to the relationship between the 727 and the 757.

757 Sizing

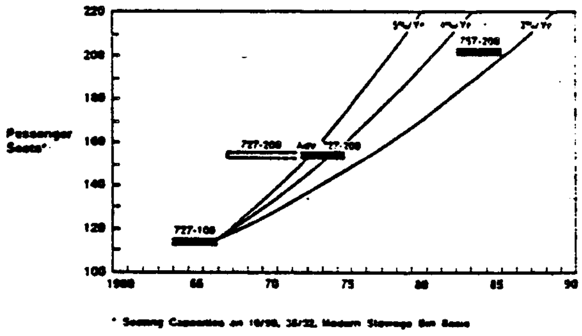


Figure 64

Considering *all* the factors we've noted, figure 64 shows that the 757 is based on a "vehicle size for similar job" growth assumption of about three percent per year. This is far enough below the predicted growth values (highs and lows) of the next decade to account for deregulation and other causes of route proliferation. Unlimited proliferation is not feasible by reason of airport and airway constraints. The PATCO strike has given us a preliminary view of constraints that would have otherwise surfaced several years from now.

Keeping in mind the factors noted, and adding considerations for DOC and fuel burned per airplane mile and per passenger mile, one must conclude that the 757 is on the low side of the replacement spectrum for most of the world's 727 aircraft. The 727's replacement will be by the 757, 767, and A310 aircraft. The latter two depend on a growth from the 727 of about four percent a year instead of three.

The current fixation on a "150 passenger" airplane can only be based on the requirement at the bottom of the trunk system replacing the DC-9 and 737. It most assuredly has nothing to do with replacement of most of the 727s, and the market for such an airplane should be expected to be smaller by far than the combined markets for the 757, 767, and A310. Decisions in sizing must include the following:

1. The overall long-term airplane size for a given job has increased and will continue to do so. The only question is how much.

4.31
415

2. Past decisions which have resulted in improperly sized aircraft indicate that one must moderate thinking between "highs" and "lows" of market growth and seek a middle ground.

New Commuters

There is a worldwide need for new commuter airplanes that are as efficient as possible. In the United States this need has been accelerated by deregulation, which has created a large number of new commuter companies to service short-range segments dropped by the major airlines. To meet the world need there are a number of new programs aimed at the market. Four of these are displayed in figure 65.

Four New Commuters

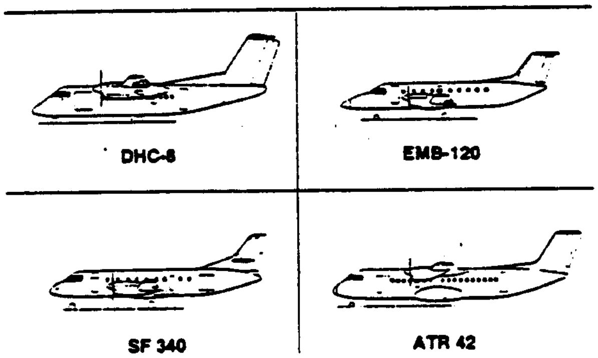


Figure 65

The DHC-8 is a new wing, two engine derivative of the existing four engine DHC-7. It has a four abreast body. It's development is funded by the Canadian Government. The SAAB-Fairchild 340 is an all-new airplane with development substantially funded by the Swedish Government. It involves a joint Swedish-American design accomplished at Fairchild with assembly in Sweden. The Embraer 120 Brasilia is a successor to the Bandeirante and is funded by the Brazilian Government. The ATR 42 is a joint effort between Aerospatiale and Aeritalia and is jointly funded by the French and Italian Governments. Three of the airplanes use a Pratt & Whitney engine manufactured in Canada, and one, the SF 340, uses the General Electric CT7 produced in the United States.

The commuter market has its own growth and constraint situation and growth is quite high. Financially, this market is difficult to design to since the aircraft must be complex enough to fit into the modern airline environment, yet the commuter airlines capital formation capabilities are limited.

This situation illustrates the affordability dilemma confronting the U.S. commuter industry. It is questionable that its risk environment would allow a U.S. company to participate, except in a partnership that would provide foreign risk capital. Also, government supported or not...our past experience would indicate a reasonable prediction of failure for one or more of the programs illustrated in figure 65. Despite the turbulence of the program decision environment, there is a predictable thread that emerges, which we'll examine next.

VII. Lessons Learned

The threads of predictability that we've picked from program decisions form a series of lessons learned. The "learned" appears open to question, since some persist as mistakes repeated. Some have been learned at huge expense...including failure of the company involved. A majority will still be applicable within the environment of internationalism and affordability on the road ahead. There will be new lessons ahead as well, and some of these may be emerging very soon. Nonetheless, the following are offered for consideration:

1. Engines take at least a year longer for development than do aircraft. Funding for a new engine independent of a specific airplane program is advisable unless interim engine use is contemplated or a large risk knowingly accepted.

2. When the market is ready, the successful manufacturer may have to *go*. The eventual prize sometimes goes to the company which is fast on its feet and strong enough...technically and financially.

3. A competitive loss sometimes motivates the loser more than it does the winner. Such possibilities should be examined by both, and in a timely manner.

4. Generally, the highest validated state of the art has produced the longest term, and therefore, the most rewarding program. The

key word is *validated* and the potential for unanticipated costs and risks must be weighed and program actions to minimize them taken.

5. The good designer provides for growth without allowing the accumulation of design team security cushions, which may make the program unsuccessful and invalidate its need.

6. If one wishes to build commercial airplanes, one must be prepared for investments of about twice the original nonrecurring costs. These may cover a ten year period (as in the 727 and 747) or a three year period (as in the 707 and DC-9). A manufacturer must be prepared for either.

7. Commercial programs require "staying power" to carry them over market depressions or unexpected actions by competitors or governments. This is a requirement that will be accentuated in the future.

8. The use of a parallel design team or "red" team to examine alternatives and to play a major devil's advocate role may be a valuable procedure. If used, the team must have access to technical and financial resources and cannot be "throttled".

9. A good airplane requires a great deal of "up-front" money *before* go ahead if lowest recurring costs are to be achieved. This includes commitments for new technology machinery, training, and equipment. There is no provision in U.S. Government acquisitions procedures to adequately accommodate this need.

10. Government paper competitions that start production programs without prototypes *may* result in selection of the bravest and least informed winner, with uncorrectable consequences.

11. The readiness of technology is a long and expensive process and will frequently warrant funding stimulation. The payoff, when the need and technology readiness match, can be enormous.

12. Changes in a manufacturer's management team can change the company's responsiveness to problems and its ability to *use* basic company strengths. This does not mean that changes should be avoided...only that they should be well considered and deliberate.

13. Past decisions that have resulted in improperly sized aircraft indicate that one must moderate one's thinking to seek a middle ground between the "highs" and "lows" of market growth, competitor proliferation, and airport constraints.

14. A good airplane program requires at least two years of concentrated pre go-ahead study and planning. The penalty for omitting this phase is greater exposure to large changes late in the development program.

15. There is no substitute for understanding the real commercial or military market need and opportunity, especially the predictable change with time. The job of the airplane designer is to design the airplane the customer wants *while* still meeting or providing for the product criteria the customer will want five years after all the basic decisions are made.

16. Defining what constitutes "success" in the program is a necessary exercise. Designing two (or more) "head on" airplanes for the same market may result in financial failure (on normal profit criteria) of one unless the market is unusually large or segmented.

17. A good airplane must be designed to meet a broad spectrum of market requirements. Compromises are essential. In the commercial case, *designing* to the detailed requirements of one customer can result in an unsatisfactory program. *Starting* the right program with one customer while designing to a broad market is another matter and can be satisfactory.

18. Product support after delivery is just as necessary as a successful design. It is a commitment burden that grows with success.

19. In the world competition to acquire the most rewarding technology, the prize will go to the nation or manufacturer who runs the fastest. He who stops running will lose, regardless of lead or protection.

20. The most constructive emphasis today or in the future is to build a superior product at the lowest manufacturing cost.

VIII. The Road Ahead

Early in this discussion, we noted that the future contained significant technological advancement potentials. Aeronautics has not reached its maturity and the efficiency gains of the past half century will be continued well into the next. Thus, new program starts prior to the end of the century could *potentially* supersede every airplane now flying, either civil or military. While the road ahead contains an abundance of technical opportunities, capital availability and other financial challenges accompany these opportunities. Furthermore, the long technology readiness process will be at least as difficult and at least as misunderstood.

The road ahead will also require that the manufacturer better understand the real market needs, and in cooperation with the customer, go through the agonizing process of compromise that has formed every successful aircraft program. The slogan "back to the drawing board...back to the bank" shown in the earlier cartoon is symbolic of the process, except now the drawing board has been replaced by a computer terminal, and the bank may be replaced by a trading company. The engine situation will be similar.

We have noted lessons learned and most will be applicable in some context to the future as well. So what will be different? The answer, from many aspects, is "everything."

National Policy and Planning

To an ever greater extent, aircraft have become an increasingly visible part of a much larger and complex high technology, international, commercial, and military scene. In this arena, national security implies a context beyond that of conventional arms balance...it implies a state of *national economic security*. In this field the United States finds itself the exception rather than the rule among the western democracies. For example, economically, the U.S. tends to formulate its domestic and foreign policy in terms of *process*; it sets rules and lets things turn out as they may. Elsewhere, such policy is more often defined in terms of desired economic outcomes; if the rules do not seem to be producing desired *results*, the rules will be changed. U.S. relationships between government and industry tend to be adversarial, while those elsewhere tend to be mutually supportive. The United States has great trouble forming and executing a long-range plan, while other countries, to a greater extent, tend to perform national planning in a more consistent manner. In most cases this has little to do with "democracy" and is more cultural or attitudinal in nature. Whether industries are privately or government owned, or a combination of the two, has some effect, but generally is not a deciding factor.

The U.S. is the major contributor to the western nations' umbrella against Soviet aggression. This means that a greater share of other western nations' GNP or national budgets can be allocated toward stimulation of industrial output, including aircraft.

What has this got to do with aircraft decisions? A lot. For example, if the countries support their aircraft industries by providing capital and by reducing risk through mechanisms of one type or another, or with low interest loans, then U.S. companies have little alternative but to seek alignments with foreign companies having access to such devices. U.S. companies are reluctant to align in mutual support on commercial programs, partially due to their historic competition...which in some cases no longer really exists. A much more forceful reason is fear that they will be exposed to anti-trust litigation. It's *not* the anti-trust law that is the problem, it is the history of an unpredictable and sometimes decade long process of interpreting the law. The volatility of aircraft programs makes exposure to such discontinuity unendurable, and one simply avoids the issue in favor of foreign teaming.

Military Considerations

The technology base for commercial and military aeronautics is the same...compartmentalization is generally not possible. Thus, such teaming exposes the U.S. to some amount of technology transfer which could go to third parties. However, since technology generally has a time value and Western Europe and Japan are running about as fast as the U.S., the transfer value is often more imagined than real, and reverse flow will be of greater and greater value.

Beneath both military and civil "name" manufacturers lies a vast network of suppliers. Programs dip into this network, and accomplishment would be impossible without it. The real "power" of American industry is here, and the reason this industry has been able to accomplish large national programs is because it exists. The start-stop-sputter character of U.S. military programs does far less to maintain the supplier base than do the more consistent commercial programs...so military preparedness, to a great extent, rests upon decisions affecting the health of the commercial industry. Erosion is not apparent until some form of national emergency arises, and it is then much too late to rebuild.

Elements of the base will be tied into foreign entities (or foreign owned entities) because the continuity and strength are improved and risks reduced by so doing.

U.S. military procurement tends to have two flawed characteristics, in addition to its burdensome procedures built to do business under rules of public accountability and potential protest. The real problems are: (a) unreliability of funding, and (b) lack of "up-front" money. Multi-year procurement, if it *really* became the norm and not subject to the whims of ensuing Administrations and Congresses could ameliorate the first, but the second is even more difficult, unless finalists in a government competition are authorized to implement machinery and training for productivity and low recurring costs. In such case, the loser would need to be protected from loss. As it is, commercial airplane manufacturing will be sounder and cheaper, and there is no foreseeable cure for the military problem. As a further consideration, U.S. military aircraft procurement has drifted into a combination of risk reduction focus and audit trail protection which, for many programs, means lower technology than will be available from foreign sources. A means of stabilizing military programs in any country is through foreign sales, and the trend toward a common international technological base is accentuating competition.

Commercial Market Considerations

The U.S. itself was, at one time, a large part of the total world commercial airplane market. Such is no longer true and there are now really three major markets of varying size: the U.S., Western Europe, and all the rest. The latter market is fragmented, but it includes a very important component...developing economies that will become major customers of the future.

Historically, the U.S. airline market has gone through immense cycles of feast and famine. When airlines make money, they buy aircraft. When they don't make money, they can't buy aircraft. U.S. airlines have been highly leveraged and, with predicted long term traffic growth, this will not change. Thus, access to the foreign markets is essential for a U.S. manufacturer if it wishes to reduce risk of financial failure in the cyclical domestic market slumps, and if it is to maintain the decisive economy of scale and program longevity. The governmental ownership of both manufacturers and airlines in Europe has largely closed this market to competitive U.S. products, which are thus very dependent upon the remainder of the world market for financial stability. However, much of the remainder is leveraged due to its growth, and is thus very subject to financing terms. European industry has government support for exports that is generally greater than EXIM and is available with more assurance of continuity.

Very simply, the cost of money has become difficult, and world airline deals may involve far more than aircraft and financing terms. In many cases they are decision drivers and negotiated as government-to-government deals involving other things the buying government wants...almost on a barter basis. Examples are technical assistance in nuclear or petrochemical fields, arranging markets for products or raw materials, military equipment, or bilateral treaties yielding landing rights or possibly military and civil advantages of some other kind.

The GATT offers rules governing a limited portion of these considerations, and some stability may be obtained through its administration. However, procedures are long and facts difficult to prove. U.S. companies must operate in a complex world linkage environment that involves U.S. government decisions. Private trading companies may be deficient in scope. U.S. government and industry, it would seem, are at a crossroads.

Future Considerations

The correct U.S. answer is better aircraft at a lower cost. The role of manufacturing technology is in ascendancy, because it represents a very meaningful solution to affordability. This does not mean an era of simple, cheap products, since the marketplace will call for greater operating efficiency, but at affordable prices. These demands will still dictate technological superiority for the winner. However, complexity must be justified by cost-benefit considerations to an ever greater extent. The situation is also exacerbated by some additional circumstances. Our changed national priorities have gradually increased social obligation until all else is consequentially reduced, and the Federal budget squeeze appears to be with us for decades.

These, then, are the underlying reasons for our new era of "internationalism and affordability" into which the U.S. is already immersed...apparently without recognition by many, in its international context.

Internally the U.S. is still a "free market" for breakfast cereal...but airplanes, whether commercial or military, are in an international environment...one in which success may be dependent upon markets outside the U.S. and even outside Western Europe. Each decision now takes on a new dimension...the most complex dimension of them all.

The bottom line for the U.S. is unquestioned excellence at low manufacturing costs. It is a hard combination. It requires economies of scale, but scale requires an international market...and so on through the complex circumstances already described. The road ahead is surrounded by this environment.

IX. Conclusion

Aircraft programs, both commercial and military, differ, and their individual characteristics will affect the multi-billion dollar decisions made. It has not been my intention to say that any formula can be derived to assure success. There are, however, some trends and lessons that appear to override program individualism. If these have been largely identified, we have been successful.

Even the word *success* must be defined, since in our international world it will mean different things to the companies and governments involved. In many cases success will depend as much on decisions that are made outside the program as those made from within.

Many of the decisions we have noted are factored to market needs and their correct timing...the areas that historically have been the most immediate and critical. This has not really changed in the last 40 years, and I would expect that market needs and timing will also weigh heavily in future decisions.

Successful airplane programs are usually large and long term, almost by definition alone. Commercially, the phrase *bet the company* often applies, and military programs cannot be very constructive for either manufacturer or government if funding is on an unreliable start-stop basis. Advanced technology should be applied if a long program life is to be achieved. The importance of technology validation before application cannot be overemphasized. It requires substantial continuity of effort long before application is defined. Similarly, the fundamental base for manufacturing efficiency must be addressed before a program is started...not during it.

Beyond these influences are others that are exerting a change. *Internationalism* and *affordability* are the two that this discussion has particularly noted. By their nature, we cannot overlook a third...that of governments. Combined, these are powerful forces. They are changing the market's character and exerting a sizable stress on the manufacturing industry. What this implies for tomorrow is the question for today.

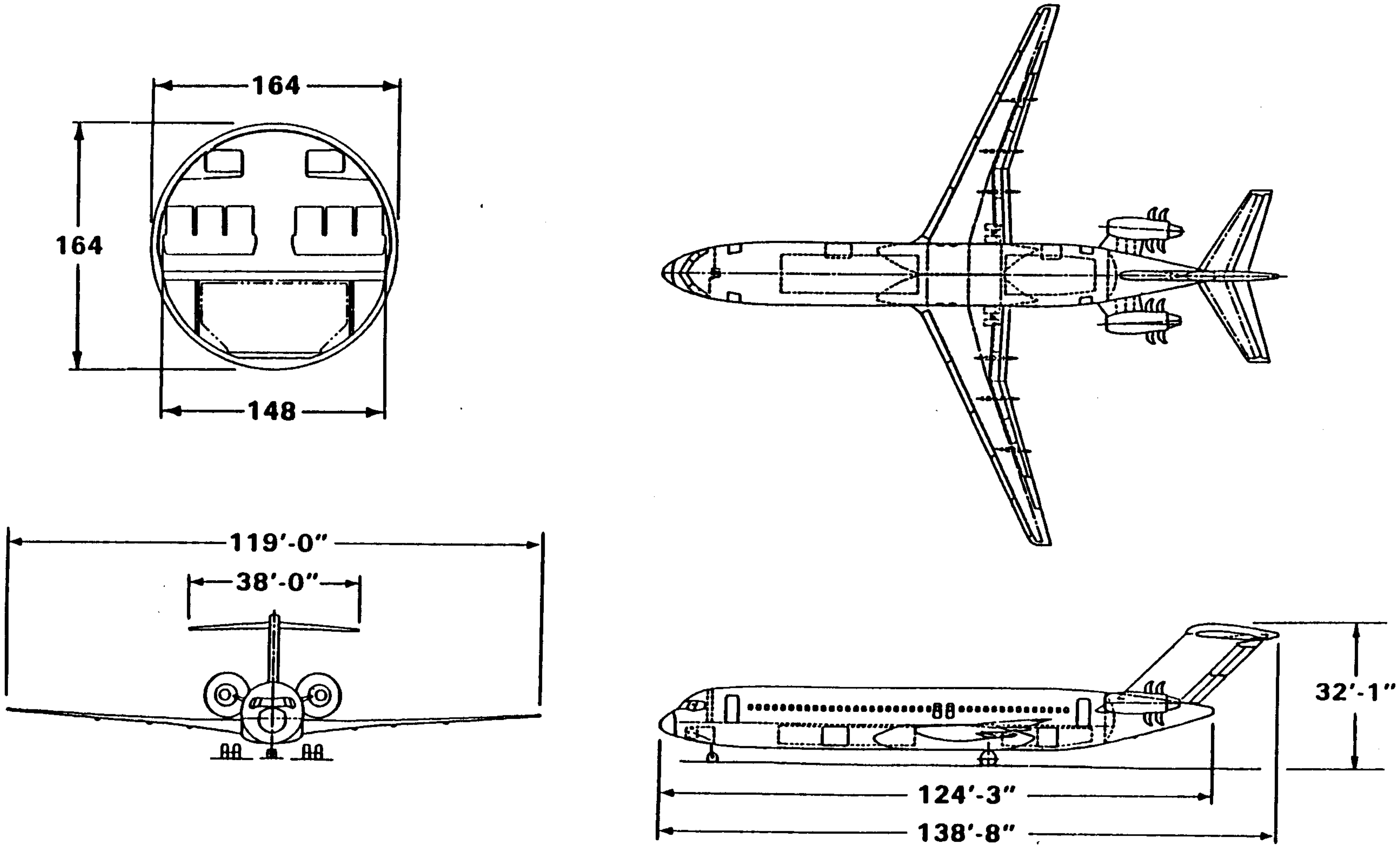
We live in a small world, and this nation is but one of the established players. All are not marching to the same drummer, and the rules of the competition are not constant. Our technology got us to the playing field, but will it get us to the goal? Can we adapt to this difficult situation? I believe the answer is yes. However, it will take understanding and judgment in the decisions we make. It is toward this understanding...in the field of aircraft...that this lecture is respectfully submitted.

ADDITIONAL AIRPLANE 3-VIEWS

GENERAL ARRANGEMENT

7J7 SINGLE AISLE, 153 PASSENGERS, 6 ABREAST

MODEL 789-177E



-177E

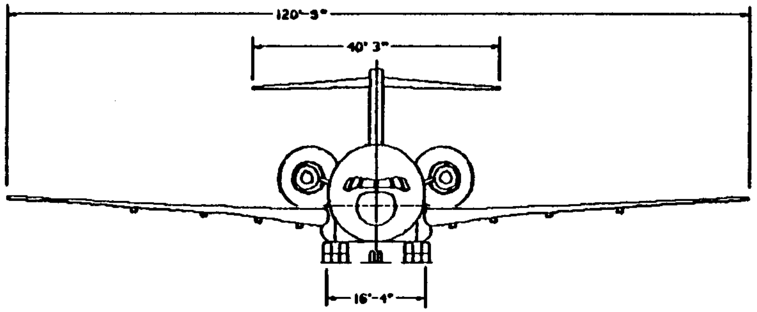
C86-99 R2●
RTN-4-21

GENERAL ARRANGEMENT
MODEL 789-354A

GEOMETRIC CHARACTERISTICS

GEOMETRY		WING	VER TAIL	HOR TAIL
AREA (EFFECTIVE)	SQ.FT.	1281	296	361
ASPECT RATIO	AR	11.38	.787	4.48
TAPER RATIO	λ	.279	0.8	.40
SWEEP C/4	DEG	24.27	50	30
INCIDENCE	DEG	4.08	—	0
DIHEDRAL	DEG	3	—	-3
SOB T/C	%	18.0	11	12
TIP T/C	%	13.5	11	10
ROOT CHORD	IN	193.32	280	152.66
TIP CHORD	IN	54.00	226	61.49
SOB CHORD	IN	194.90	—	—
M.A.C.	IN	136.85	253	113.54
SPAN	IN	1449.93	170	482.76
TAIL ARM	IN	—	695	766
TAIL VOL COEFF	V̄	—	.0946	1.555

BULK CARGO VOLUME CU.FT. : 712 FWD, 980 AFT, 1692 TOTAL
GEAR LOCATED AT 105% MAC
PROPULSION : (2) GE36 ENGINES
FUEL VOLUME (TANK VOLUME OUTBD.) : TBD US GAL.



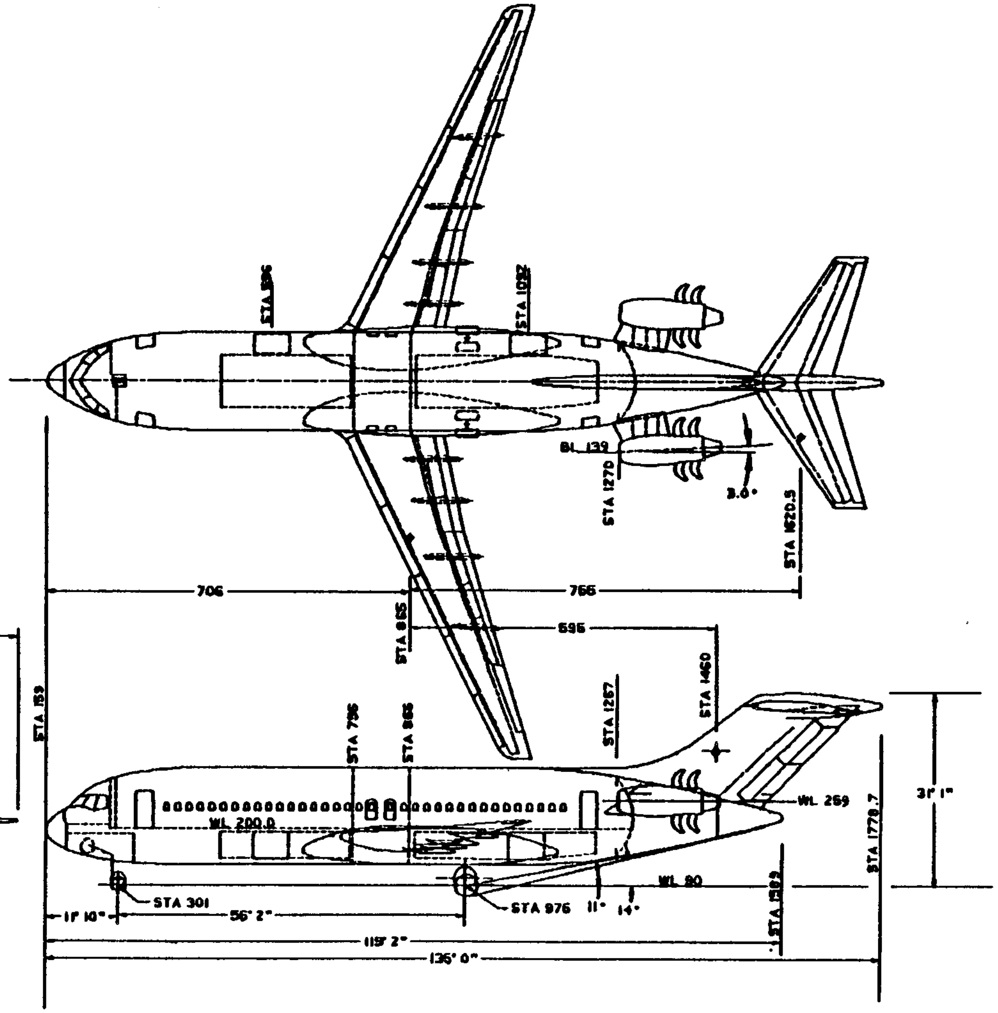


FIGURE 1

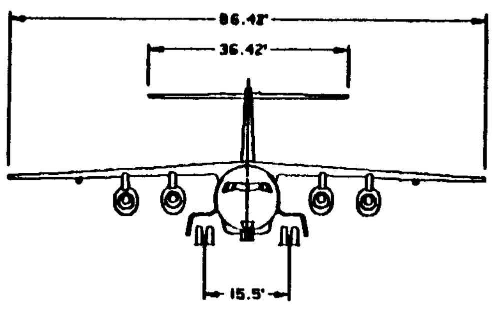
GENERAL ARRANGEMENT
BAE 146-200

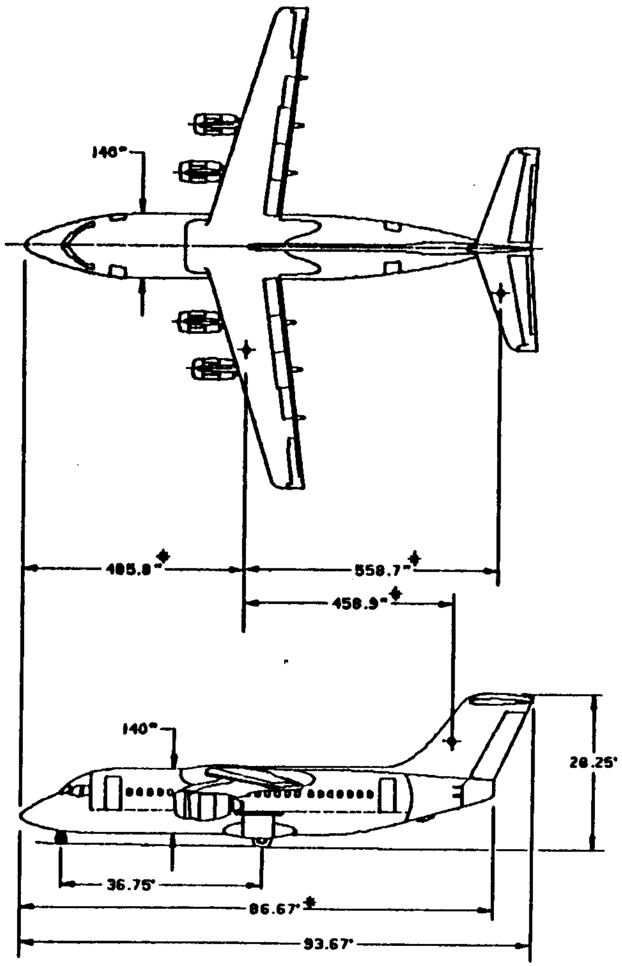
STATUS DATE FEB. 21, 1985

CHARACTERISTIC DATA (TRAP)	WING	HORZ. STAB.	VERT. STAB.
AREA, SQ. FT.	832	276	224
TIP CHORD, IN.	65.3✦	57✦	146.5✦
ROOT CHORD, IN.	165.8✦	125✦	209.8✦
ASPECT RATIO	8.97	4.81	1.0✦
TAPER RATIO	.39✦	.46✦	.70
SWEEP C/4, DEG	15°	16.5°✦	36°✦
DIHEDRAL, DEG	-3°	0°✦	—
MAC, IN.	122.8✦	95.24✦	179.9✦

(✦) DIMENSIONS ARE ESTIMATED

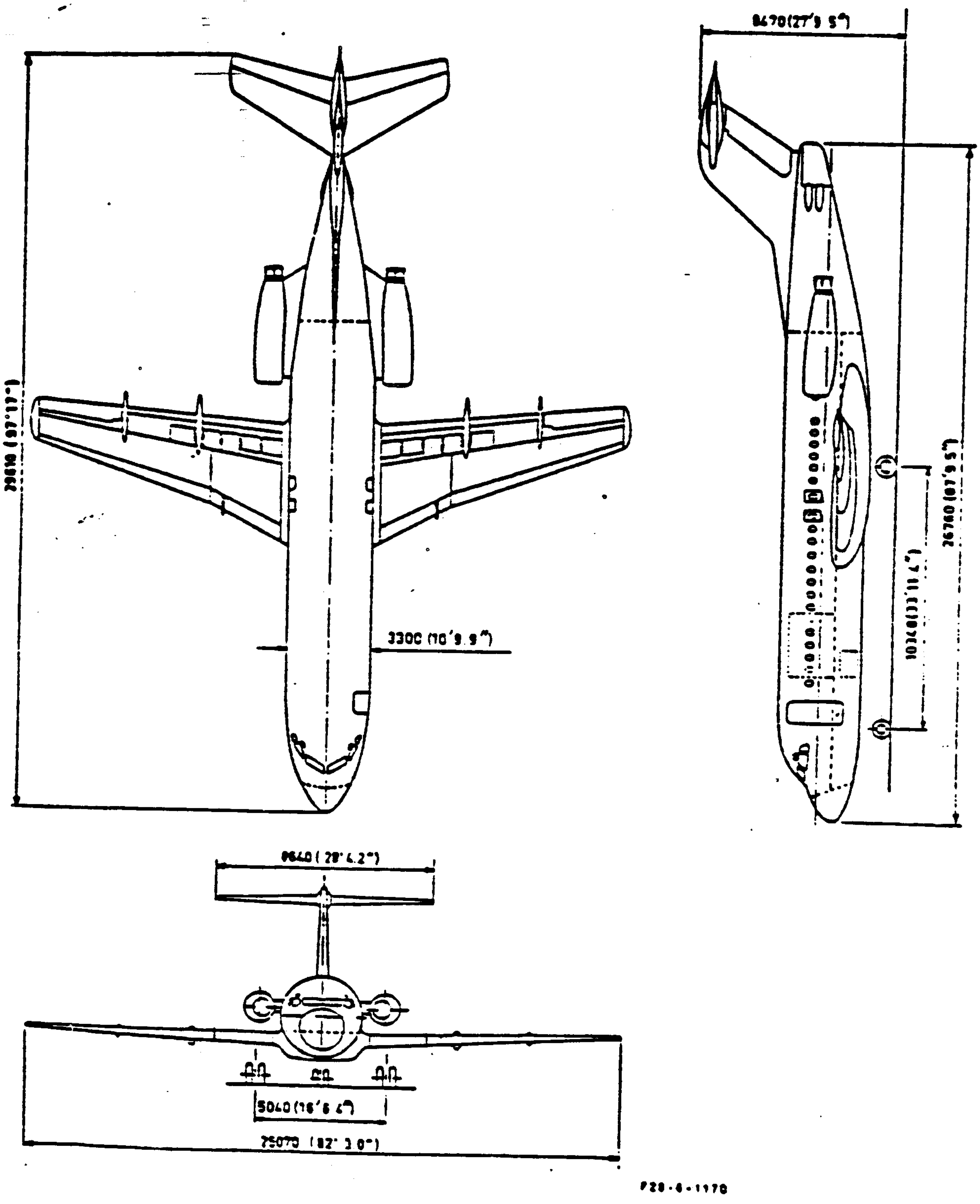
WING AREA, B.A. DEFINITION : 832 SQ. FT.
WING BOEING REFERENCE AREA : 832 SQ.-FT.SQ FT
ENGINE : AVCO LYCOMING ALF 502-5





AERO-88132-C83-050
Attachment 7

FOKKER F-28
FLIGHT HANDBOOK



GENERAL ARRANGEMENT F.28 Mk. 4000

6.19

GENERAL ARRANGEMENT FOKKER 100

STATUS: 2-1-85

CHARACTERISTIC DATA (TRAP)

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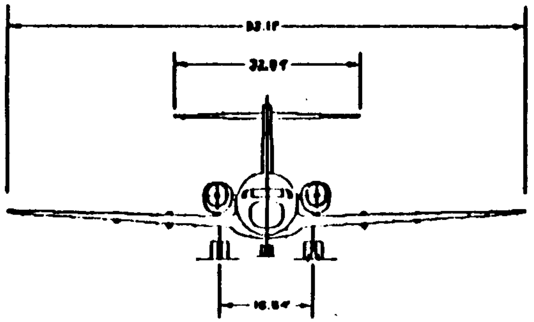
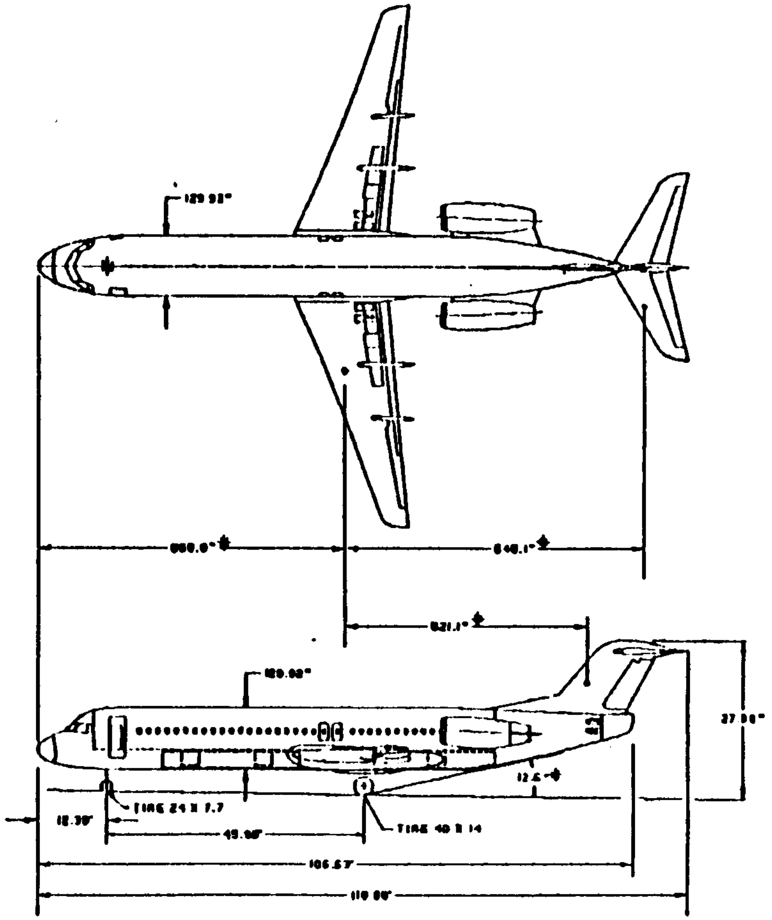
AREA, SQ. FT.	976.8 ✦	▶ 237.7	132.4
TIP CHORD, IN.	60.5 ✦	48.2 ✦	137.0
ROOT CHORD, IN.	204 ✦	125.0 ✦	171.5
ASPECT RATIO	8.69 ✦	4.67	.80
TAPER RATIO	.248 ✦	.38	.80
SWEEP C/4, DEG	17.45	27.5	40.0
DIHEDRAL, DEG	2.5°	0	—
MAC, IN.	142.7 ✦	90.3	155.0

▶ BOEING DEFINITION ✦ ESTIMATED

WING AREA, FOKKER STATED: 1006.4 SQ FT
WING BOEING REFERENCE AREA: 1006.6 SQ FT
ENGINE: ROLLS ROYCE TAY MK620-15





GENERAL ARRANGEMENT
DC-9-30

STATUS DATE: APR 20, 1985

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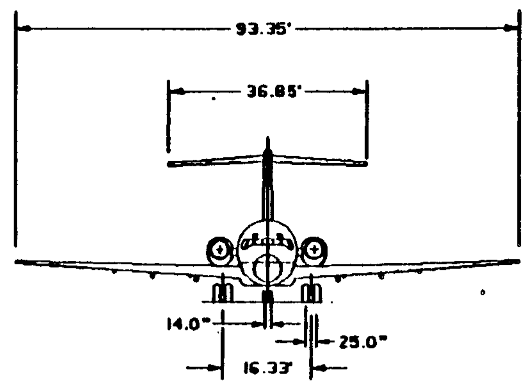
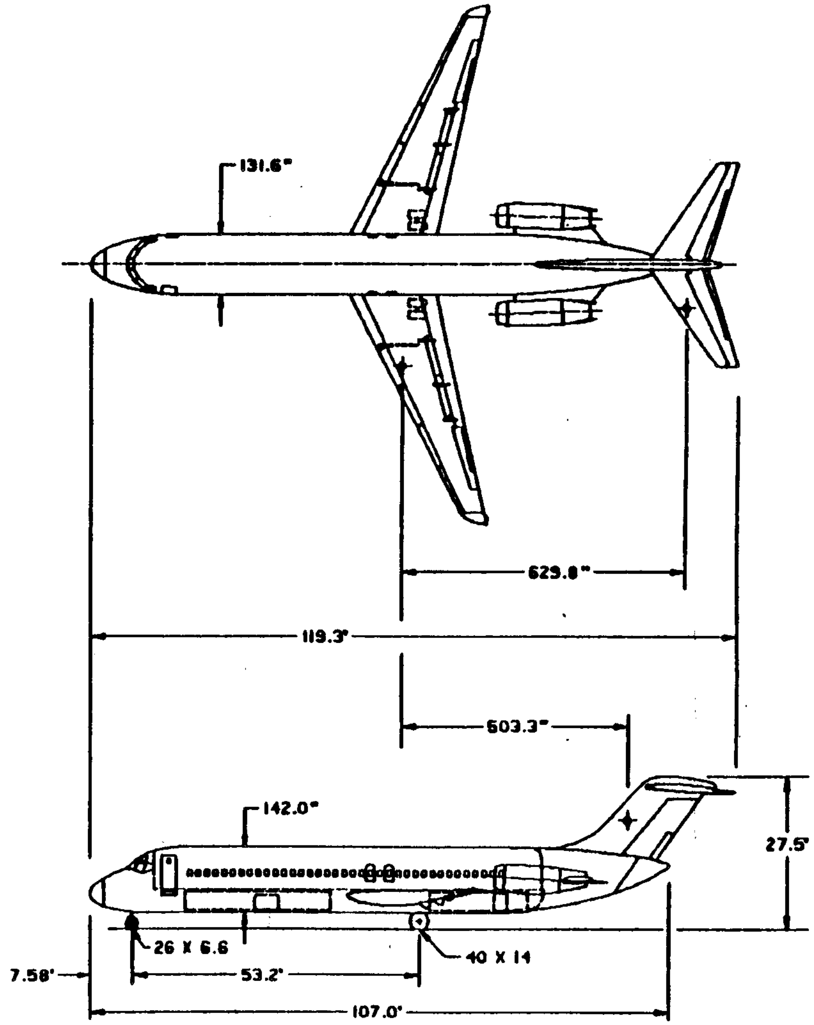
AREA, SQ. FT.	1000.7	275.5	161
TIP CHORD, IN.	43.5	46.8	149.5
ROOT CHORD, IN.	213.8	132.7	186.5
ASPECT RATIO	8.71	4.93	0.82
TAPER RATIO	.203	.353	0.80
SWEEP C/4, DEG	24.5	31.6	43.5
DIHEDRAL, DEG	3	-3	—
MAC, IN.	147.4	96.6	168.8

BOEING EFFECTIVE WING AREA ≈ 1000.7 SQ FT

ENGINE: P & W JT8D-7/-9/-9A





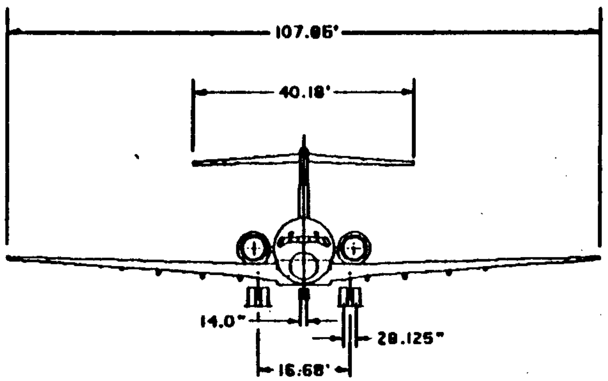
AERO-B8102-C86-048
FIGURE 19a

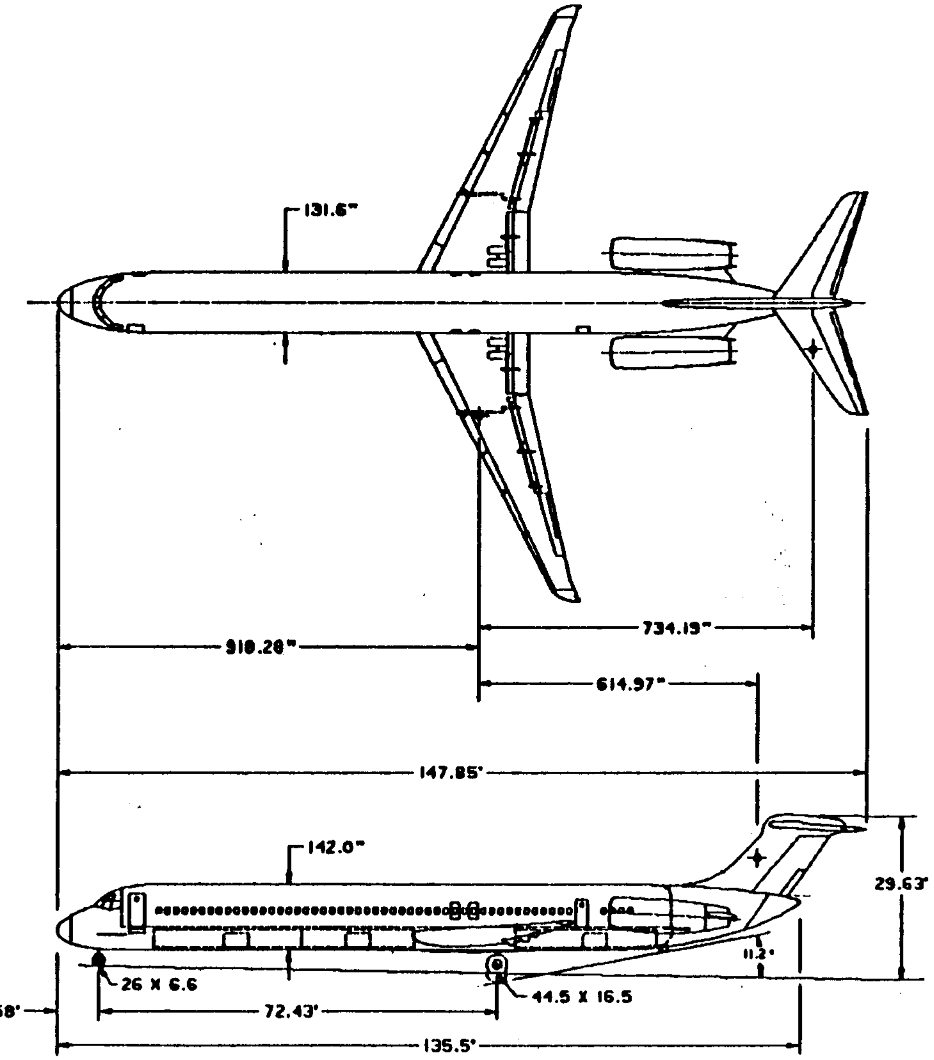
GENERAL ARRANGEMENT
MD-80

STATUS DATE FEB 14, 1985

CHARACTERISTIC DATA (TRAP)	WING	HORZ. STAB.	VERT. STAB.
AREA, SQ. FT.	1209.3	313.1	161
TIP CHORD, IN.	36.2	46.8	149.5
ROOT CHORD, IN.	232.9	140.7	186.5
ASPECT RATIO	9.62	5.14	0.82
TAPER RATIO	0.16	0.33	0.80
SWEEP C/4, DEG	24.5°	31.6°	43.5°
DIHEDRAL, DEG	3°	-3°	—
MAC, IN.	158.5	101.6	168.8

WING AREA, MDD QUOTED : 1209.3 SQ. FT.
WING BOEING REFERENCE AREA : 1243.9 SQ FT
ENGINE : P & W JT8D-209
-217
-217A
-217C
-219





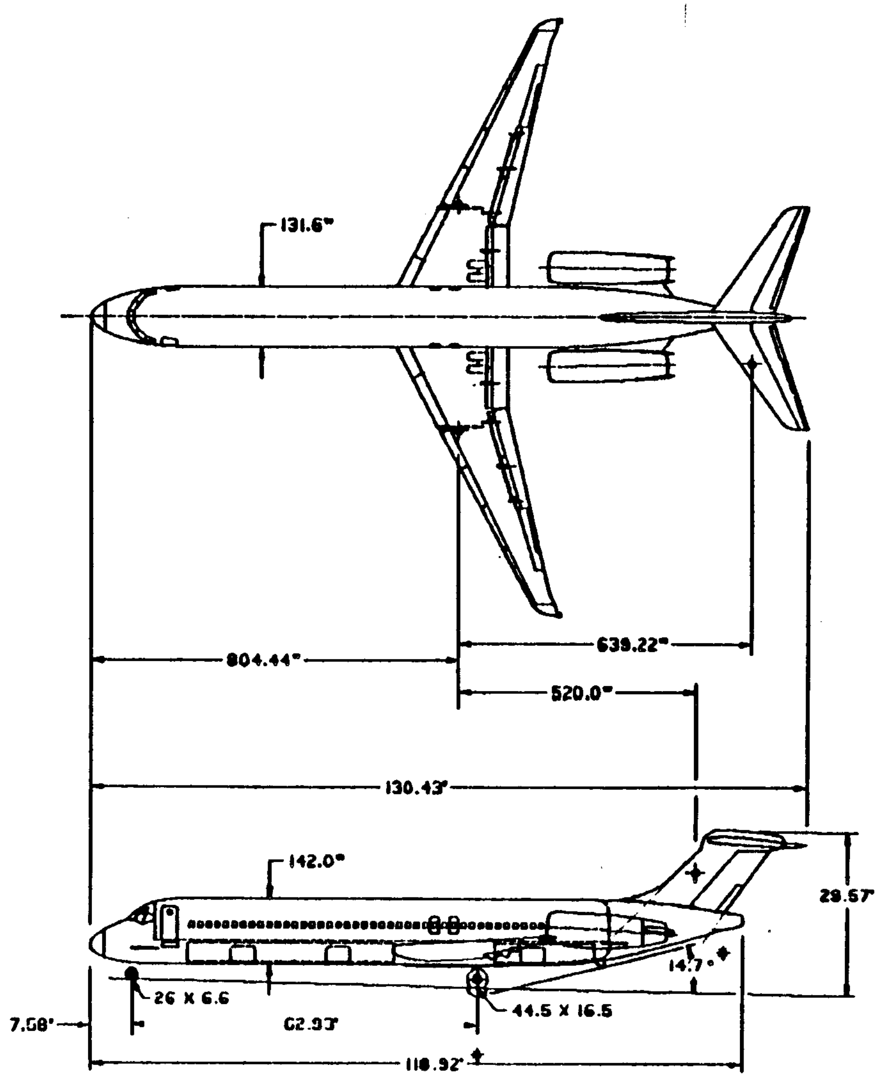
GENERAL ARRANGEMENT
MD-87

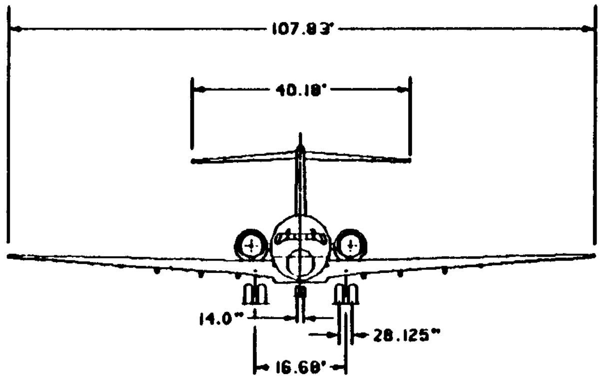
STATUS DATE FEB 18, 1985

CHARACTERISTIC DATA (TRAP)	WING	HORZ. STAB.	VERT. STAB.
AREA, SQ. FT.	1209.3	313.1	161
TIP CHORD, IN.	36.2	46.8	149.5
ROOT CHORD, IN.	232.9	140.7	186.5
ASPECT RATIO	9.62	6.14	0.82
TAPER RATIO	0.16	0.33	0.80
SWEEP C/4, DEG	24.5°	31.6°	43.6°
DIHEDRAL, DEG	3°	-3°	—
MAC, IN.	158.5	101.6	168.8

✦ ESTIMATED

WING AREA, MDD DEFINITION : 1209.3 SQ FT
WING BOEING REFERENCE AREA : 1243.9 SQ FT
ENGINE : P & W JT8D-219
P & W JT8D-217A(1)

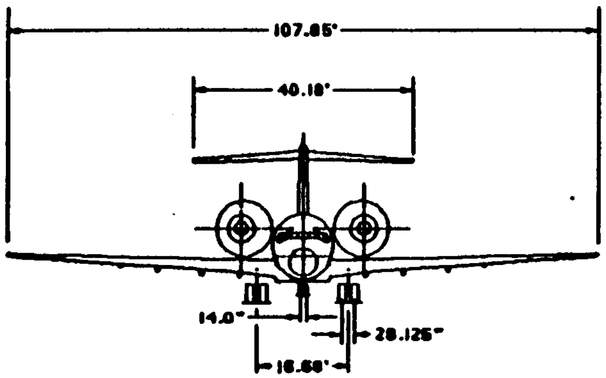


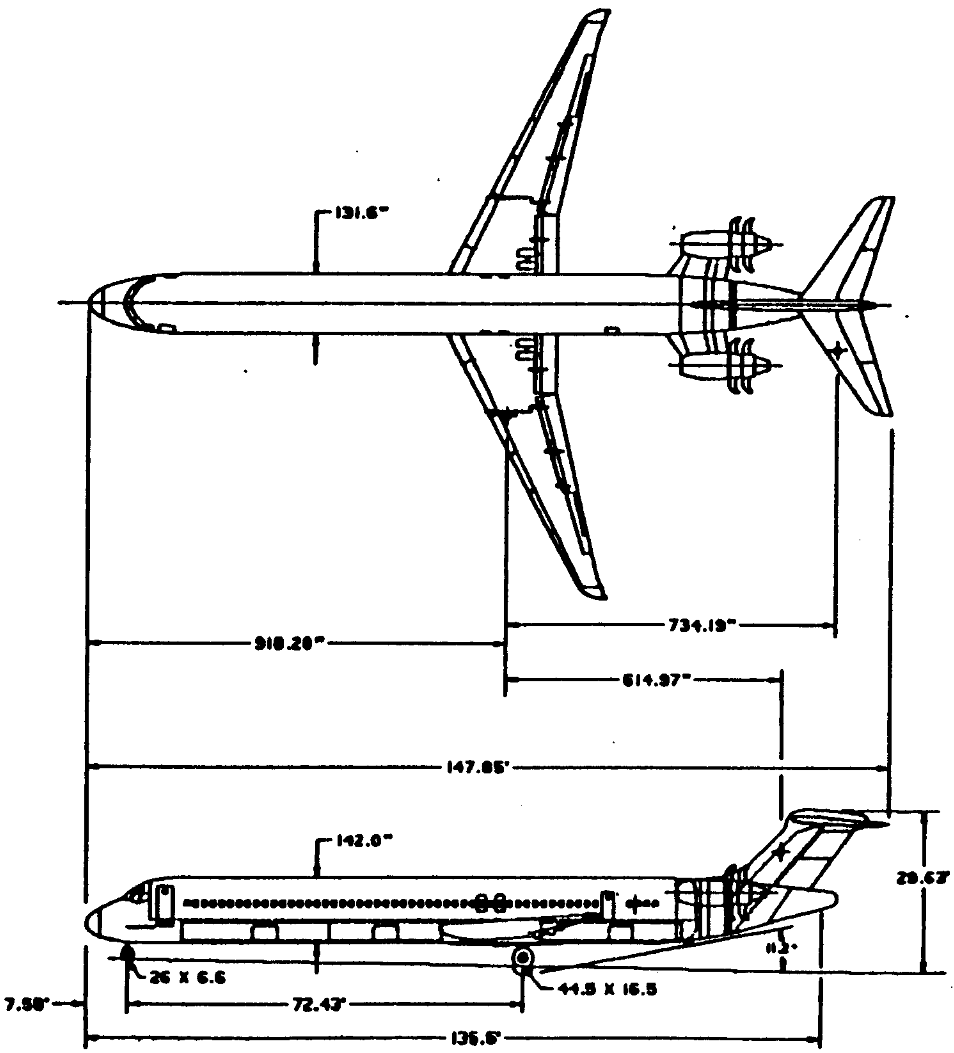


MD-88 (GE36)

CHARACTERISTIC DATA (TRAP)	WING	HORZ. STAB.	VERT. STAB.
AREA, SQ. FT.	1209.3	313.1	161
TIP CHORD, IN.	36.2	46.8	149.5
ROOT CHORD, IN.	232.9	140.7	186.5
ASPECT RATIO	9.62	5.14	0.82
TAPER RATIO	0.16	0.33	0.80
SWEEP C/4, DEG	24.5°	31.6°	43.5°
DIHEDRAL, DEG	3°	-3°	—
MAC, IN.	158.5	101.6	169.8

WING AREA, MDD QUOTED : 1209.3 SQ. FT.
BOEING EFFECTIVE WING AREA : 1243.9 SQ FT





GENERAL ARRANGEMENT
MD-91X-100 (PW/ALLISON 578D3 ENGINES)

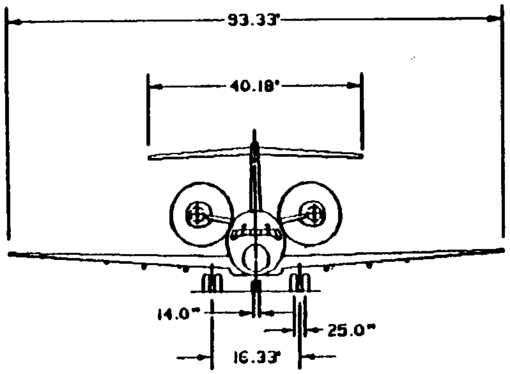
STATUS DATE: JUL 17, 1986

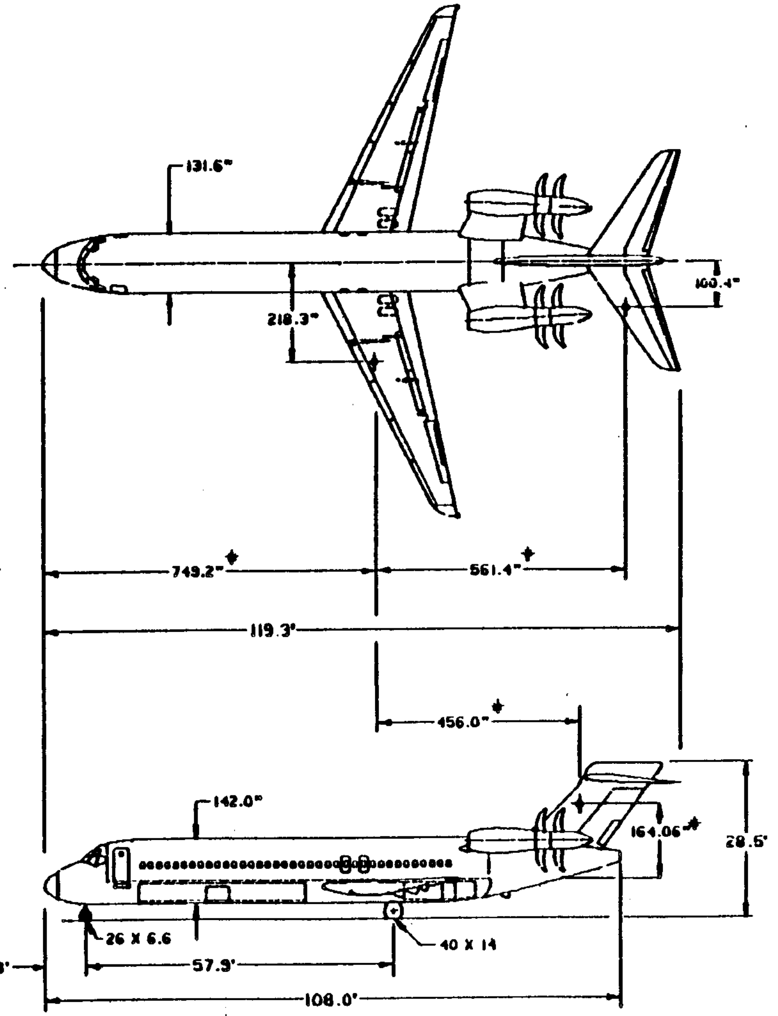
CHARACTERISTIC DATA (TRAP)	WING	HORZ. STAB.	VERT. STAB. ✦
AREA, SQ. FT.	1000.7	313.1	193.3
TIP CHORD, IN.	43.5	46.8	140.9
ROOT CHORD, IN.	213.8	140.7	186.5
ASPECT RATIO	8.71	5.14	1.04
TAPER RATIO	.203	.33	0.76
SWEEP C/4, DEG	24.5	31.6	43.5
DIHEDRAL, DEG	3	-3	—
MAC, IN.	147.4	101.6	164.8

✦ ESTIMATED

BOEING EFFECTIVE WING AREA : 1000.7 SQ FT

ENGINE: (2) PW-AGT 578D3 (ESTIMATED FROM E3: 8" SHORTER, 18" SMALLER DIAMETER PROP.)





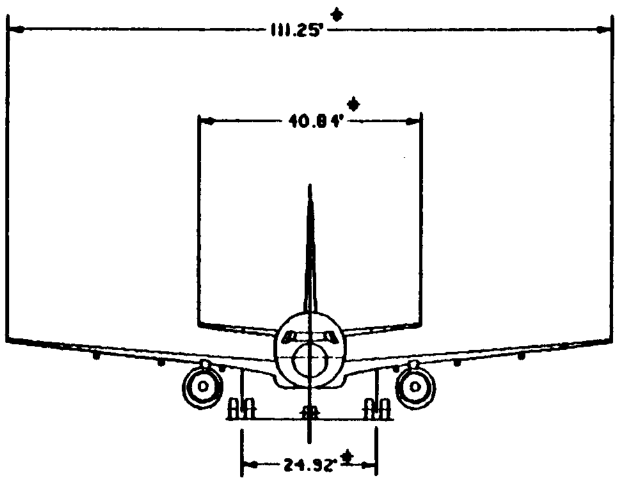
GENERAL ARRANGEMENT
AIRBUS A320

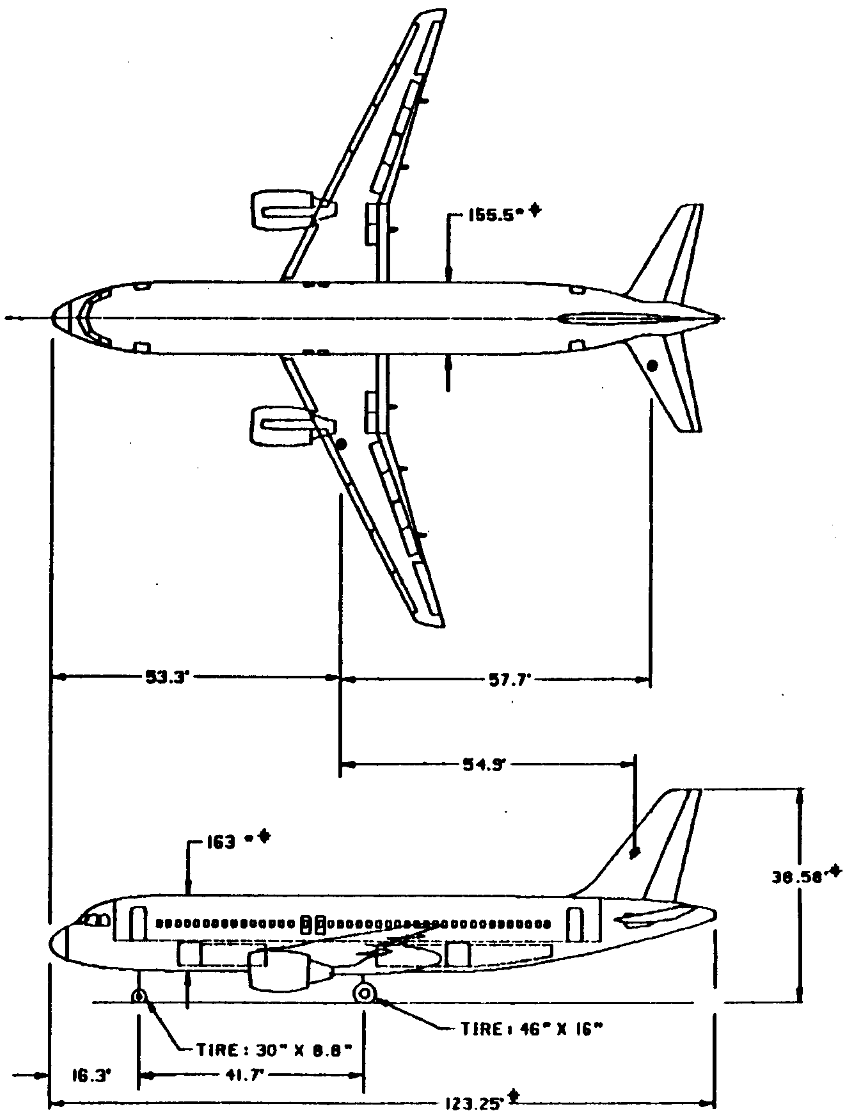
STATUS DATE MAY.7, 1985

CHARACTERISTIC DATA (TRAP)	WING	HORZ. STAB.	VERT. STAB.
AREA, SQ. FT.	1210	334 ✦	233.8
TIP CHORD	58	46.79	75
ROOT CHORD	203	149.5	211.2
ASPECT RATIO	10.23	5.00	1.64
TAPER RATIO	.29	.313	.355
SWEEP, C/4	25° ✦	27.75°	34°
DIHEDRAL	5°	7°	—
MAC, INCHES	143.9	107.1	153.9

ALL DIMENSION ESTIMATED EXCEPT (✦)

WING AREA, A.I. DEFINITION : 1318 SQ. FT. ✦
BOEING EFFECTIVE WING AREA : 1292 SQ FT
ENGINE : V2500 (IAE)





NOTES: