Chapter 1

Lecture 3

Introduction - 3

Topics

1.7.2 Developments upto 1960's

The important developments from 1903 to 1966 can be summarized as follows.

(a) First successful flight in Europe was by Voisin on March 30, 1907.

(b) Louis Bleriot's airplane, flown in 1907, appears to be the first airplane to have ailerons.

(c) A. Verdon Roe's airplane, flown in 1911, was a tractor airplane with engine ahead of wing and with horizontal stabilizer at rear.

(d) Prior to the first World War, the airplanes were developed for military use, namely reconnaissance and for guiding artillery fire and later for throwing grenades and bombs.

(e) During the first World War(1914 – 1918), the airplanes were developed as bombers and fighters. Passenger flights appeared later and by 1925 a variety of airplanes were being designed and used.

(f) By 1930's the following developments had been achieved.

(i) Streamlining of the airplane shape by features like rectactable landing gear, engine cowling, fairing at wing-fuselage joints. (ii) More powerful and reliable piston engines. (iii) New materials with higher strength to weight ratio and
(iv) Better instrumentation for control of airplane.

These developments, brought about bigger airplanes, with improved performance namely higher speed, longer range and higher ceiling as compared to the earlier airplanes.

(g) The speed of the airplanes increased sharply with the availability of jet engines in 1940's.

(h) Supersonic flight was possible in 1950's due to the developments in aerodynamics. The problems associated with changes in lift & drag in the transonic range were tackled. Features like swept back wings, delta wing, fuselage with pointed nose were introduced.

Reference 1.6, chapter 0 summarises developments up to 1970. For example, for the fighter airplanes the maximum speed increased from 150 kmph in 1914 to about 3500 kmph in 1970. The engine power increased from about 60 kW to a thrust of 30,000 kgf and the weight of the airplane increased from about 600 kgf to about 50,000 kgf.

1.7.3 Some of the subsequent developments

Some of the important subsequent developments are as follows.

(a). Supersonic passenger airplane – Concorde in 1971 (Fig.1.6).

Fig.1.6 Concorde in flight

(Adapted from http:// www.concordesst.com)

(b).Variable sweep military airplane - low sweep at low speed & high sweep at high speed (Fig.1.7).

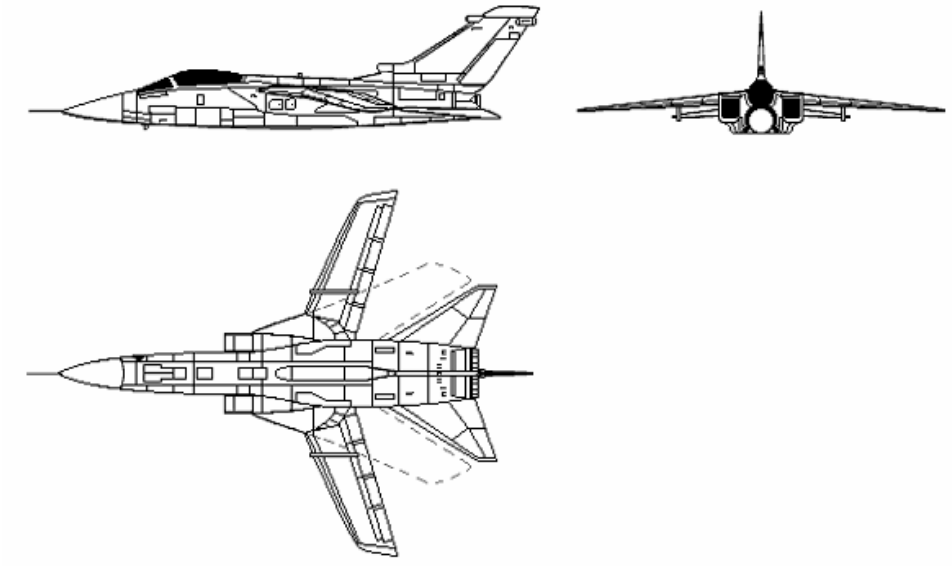


Fig.1.7 Variable sweep airplane – Tornado

(Adapted from : http : //upload.wikimedia.org)

(c). Passenger airplanes with upto 450 seats and range of 12000 km were available in early 1970's (Fig.1.8a).

Fig.1.8a Boeing 747

(Source: www.upload.wikimedia.org)

Currently the seating capacity of 650 passengers is available on Airbus A380 (Fig.1.8b)

Fig.1.8b Airbus A380

(Source: http://www.komar.org/)

(d). Supercritical airfoils with higher critical Mach number were available in 1970's.

(e). Automatic Landing system was introduced in 1960's.

(f). Fly - by -wire control was introduced in 1984. In this case, the movements of the control stick or pedals by the pilot are transmitted to a digital computer. The input to the computer is processed along with the characteristics of the airplane and the actuators of the controls are operated, so as to give optimum performance. According to Ref.1.19 chapter 12, presently fibre optics is used for communication of signals and the system is called Fly-by-light (FBL).

(g). Bypass engine whose developments started in 1950's has become high bypass ratio engine; a bypass ratio of 17 has been achieved (Ref.1.21).

(h). Winglet at wing tips which were studied in 1970's are now found on most of the new jet airplanes (Fig.1.9) and are also being retrofitted on older airplanes.

Fig.1.9 Airplane with winglets – Boeing 737-800

(Source:http://www.travelmanagement411.wordpress.com)

(i). The use of FRP (Fiber Reinforced Plastics) has increased and components like wings are also being made of FRP (for example LCA –Tejas made by HAL, Bangalore,India).

(j). Low Radar cross-section – stealth technology was introduced in late 1980's (Fig.1.10).

Fig.1.10 B2 Stealth bomber

(Source: cdn- channels.netscape.com)

1.7.4 Features of some special airplanes:

1. Largest Airplane: Airbus A380-800F (Fig.1.8b)

Wing span - 79.75 m

4 engines each 355 kN thrust.

Maximum take-off Weight - 590 tons

2. Airplane with advanced technologies:

X-29A airplane (Fig.1.11) has, according to Ref.1.22:

Digital flight control

Negative longitudinal static stability (relaxed stability)

Closely coupled canard.

Forward swept wing

Aero- elastically tailored composite wing.

Thin supercritical wing with discrete variable camber.

Fig.1.11 X-29A

(Source : www.spacemodel.com)

3. Modern fighter:

Lockheed YF-22 Advanced tactical fighter (Fig.1.12)

Span: 13.1 m; Length: 19.6 m; Height: 5.4 m; Wing Area : 77.1 m^2;

Basic Empty weight : 15441 kgf.

Fig.1.12 Lockheed YF-22 Advanced tactical fighter

(Source: www.aeroflight.co.uk)

4. Reusable vehicle:

X-38 (Fig 1.13)

Length: 8.7 m

Wingspan: 4.4 m

Empty weight: 7260 kgf.

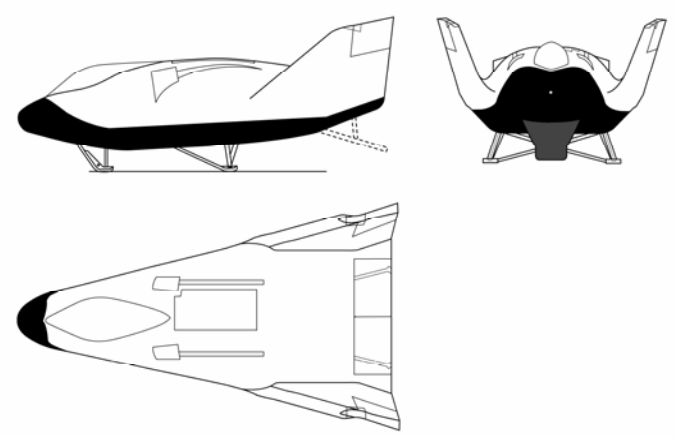


Fig.1.13 Reusable vehicle

(Adapted from: http://upload.wikimedia.org)

Remarks

(i) Self study topic:

Features of four special airplanes are briefly mentioned above. From internet (www.google.com) study the feature of (a) SR-71 black bird (b) human powered airplane (Gossamer Condor) (c) solar powered airplane (Solar impulse) and (d) tilt rotor aircraft (Bell-Boeing V-22 Osprey)

(ii) See Ref.1.23 for historical developments in civil transport airplanes.

(iii) Some problem areas in the development of airplanes, at present are :

(a) Supersonic passenger airplanes are not as economical as subsonic airplanes.

(b) A suitable engine is not available for sustained hypersonic flight.

1.8. Course outline

The aim of this course is to enable the student to appreciate the aerodynamic aspects of the preliminary design. The following topics are covered and are illustrated through an example on preliminary design of a jet airplane which is presented in Appendix 10.2.

(I) Data collection and preparation of preliminary three view drawing.

(II) Weight estimate in three stages.

(a) Based on data collection.

(b) Refinement of fuel fraction.

(c) Assessment of empty weight.

(III) Choice of wing loading and thrust loading.

(IV) Engine selection and adjustment of wing loading

(V) Wing design.

(VI) Fuselage design.

(VII) Location of engine(s).

(VIII) Layout, and c.g. calculations.

(IX) Determination of the areas of horizontal & vertical tails and control surface areas.

(X) Final drag estimation, performance calculations and preparation of

brochure.

Remarks :

(i) It may be recalled that the process of preliminary design begins with the specifications for the airplane being designed. In airplane design bureaus, the specifications are arrived at, after consideration of the factors mentioned in subsection 1.2.1. Further, for military airplanes the requirements of military authorities namely army/navy/air force need to be considered. In the case of civil airplanes the specifications would include the following.

(a) Payload

(b) Performance parameters like cruising speed, cruising altitude, maximum speed, service ceiling, maximum rate of climb at sea level, range, endurance, take-off distance and landing distance.

(c) Operating conditions regarding landing and take-off field length, weather conditions in flight and near landing/take-off sites.

(d) Air worthiness requirements to be satisfied viz.. Federal Aviation Regulation (FAR) in USA, Joint Air-worthiness Regulation (JAR) of European Aviation Safety Agency(EASA).

In the case of military airplanes, the specifications, in addition to those mentioned earlier, would include expected level of maneuverability and special regulations for military airplanes.

(ii) In the case of student design projects, the specifications may be given by the instructor. However, the students are encouraged to study relevant material on the design philosophies of different airplanes. For example, AIAA has brought out case studies of some airplanes. Reference 1.16 presents design studies of (a)long range business jet, (b) military trainer, (c) dual mode(road/air) vehicle, (d)deep interdiction airplane, (e) high altitude uninhabited vehicle and (f) amphibian airplane. These studies indicate the factors that decide the specifications.

Appendix 10.2 presents design of a 150 seater jet transport. The design philosophy is briefly discussed in the beginning of the appendix.

(iii) The specifications of the airplane would be refined as the design progresses.

Keeping in view the previous discussion in this section, the subsequent material in this course is divided into the following chapters.

Chapter 2 : Data collection and preliminary three- view drawing

Chapter 3 : Weight estimation.

Chapter 4 : Estimation of wing loading and thrust loading

Chapter 5 : Wing design - selection of wing parameters

Chapter 6 : Fuselage and tail sizing

Chapter 7 : Special considerations in configuration layout

Chapter 8 : Weights and centre of gravity.

Chapter 9 : Cross-checks on design of tail surfaces.

Chapter 10: Miscellaneous topics.

Remarks:

(i) In this introductory course attention is mainly focused on design of subsonic airplanes. The design of supersonic airplanes can be done in a similar manner, but attention needs to be given to the following aspects.

a) Large changes in drag coefficient, lift coefficient and pitching moment coefficient that occur in transonic flight.

b) Wings have features like low aspect ratio and thin airfoil section.

c) Use of supersonic turbojet engine.

For information about design of such airplanes, consult Refs.1.11, 1.15, 1.18, 1.19 ,1.20 and 1.24.

(ii) At the end of the course, students are expected to develop ability to enrich their knowledge by self-study. To develop this ability, Appendix 10.1 presents a list of term paper topics. The students may choose a topic, study the relevant literature and make presentation before the teacher and fellow students.

(iii) Appendix 10.2 presents application of the course material to the design of a 150 seater jet airplane.

1.9. Background expected

For better understanding of the material in this course, the student should have undergone courses on (a) Aerodynamics (b) Airplane engines (c) Airplane performance and (d) Airplane stability and control.

Appendices

Information about Aircraft Design Bureaus of Airbus Industry and Boeing Aircraft Company are given in the Appendices 1.1 and 1.2.

Remark :

The study of Appendices 1.1 and 1.2 can be assigned to the students, as self-study topics.

Appendix 1.1

Airbus Industry

(Permission for write-up and figures granted by airbus)

For latest details see: www.airbus.com

History

- Airbus Industry began as a consortium of European aviation firms to compete with American companies such as Boeing and McDonnell Douglas. In the 1960s European aircraft manufacturers competed with each other as much as the American giants.
- In September 1967 the British, French and German governments signed a Memorandum of Understanding (MoU) to start development of the 300 seat Airbus A300.

Airbus formed

- Airbus Industry was formally set up in 1970 following an agreement between Aerospatiale (France) and Deutsche Aerospace (Germany) (joined by CASA of Spain in 1971).
- Each company would deliver its sections as fully equipped, ready to fly items.
- The name "Airbus" was taken from a non-proprietary term used by the airline industry in the 1960s to refer to a commercial aircraft of a certain size and range, for this term was acceptable to the French linguistically.

Airbus today

- Today Airbus, headquartered in Toulouse, France, produces a comprehensive range of 14 aircraft - renowned for their fly-by-wire technology, commonality and extensive use of composites - and employs 55,000 people worldwide.
- The product line includes the new 555-seat A380, the world's biggest and most advanced passenger aircraft. Airbus also plans to build the A350, a longer-range twin-engine aircraft. The company's 16 manufacturing sites in France, Germany, Spain and the UK are formed into a range of Centers of Excellence covering all aspects of the aircraft design and production

process.

Civilian Products

- The Airbus product line started with the A300, the world's first twin-aisle, twin-engined aircraft. A shorter variant of the A300 is known as the A310. Building on its success, Airbus launched the A320 with its innovative fly-by-wire control system. The A320 was a great commercial success. The A318 and A319 are shorter derivatives with some of the latter under construction for the corporate business-jet market (Airbus Corporate Jet). A stretched version is known as the A321 and is proving competitive with later models of the Boeing 737.
- The longer range products, the twin-jet A330 and the four-jet A340, have efficient wings, enhanced by winglets.

Military Products

- Airbus established a separate company, Airbus Military S.A.S., to undertake development and production of a turboprop powered military transport aircraft (the Airbus Military A400M). The A400M is being developed by several NATO members, Belgium, France, Germany, Luxembourg, Spain, Turkey, and the UK, as an alternative to the C-130 Hercules.
- Expansion in the military aircraft market will reduce, but not negate, Airbus' exposure to the effects of cyclical downturns in civil aviation.

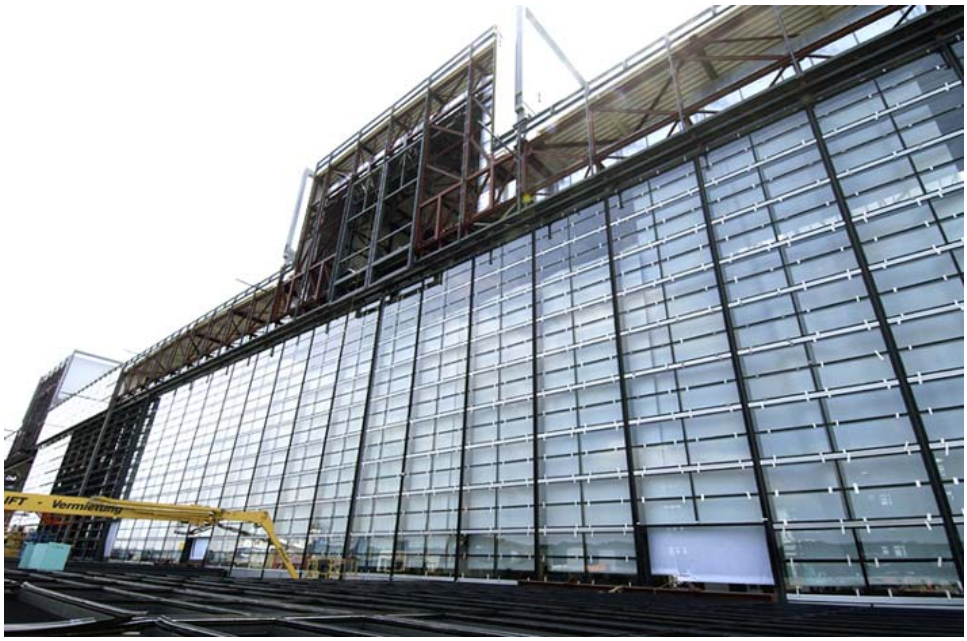
Airbus' Broughton, U.K. Manufacturing Facility (wing-making factory)

Getafe, Spain Airbus component production

(manufacturing horizontal tail for all Airbus aircraft)

France: Saint Nazaire building

(manufacturing of forward and central fuselage for all Airbus aircraft)



Germany: Hamburg Equipment Hall

(Headquarters of cabin and cargo customization, fuselage integration – structural assembly and equipment installation)

Airbus' Final Assembly building for the A380 is located in Toulouse, France, and is one of the world's largest of its kind

Germany: Dresden test hangar

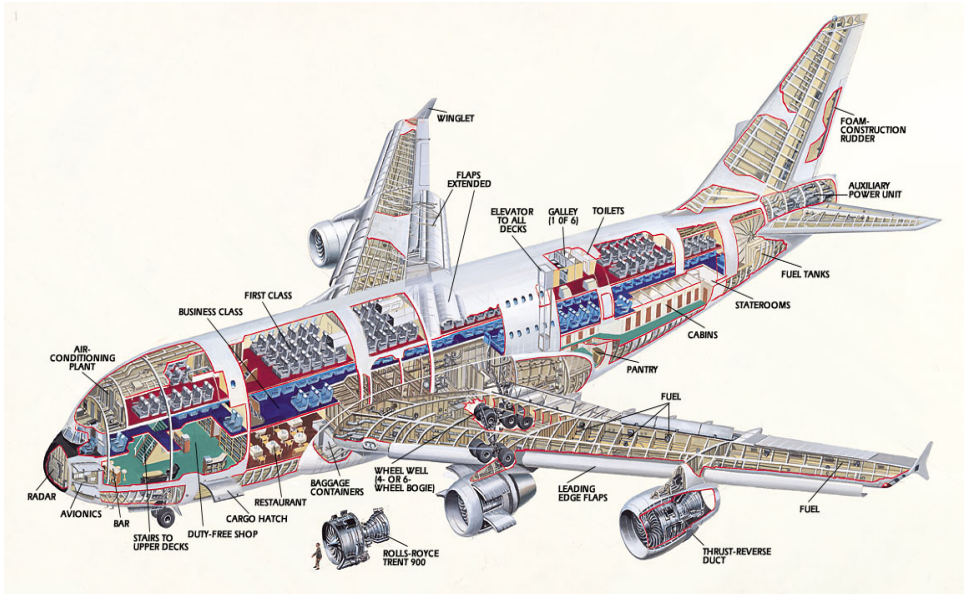
(Test hangar for the operational strength tests on the Airbus A380)

Airbus' U.S. Engineering Centre, at Mobile, Alabama, will help develop the A350's cabin interior

Airbus A300-600

Airbus A330-300

Airbus A340-600



Airbus A380 Cut-away section

Airbus A350-900

Comparison between different Airbus aircraft

Appendix 1.2

Boeing Aircraft Company

(Permission for write-up and figures granted by Boeing)

For latest details see: www.boeing.com

The Boeing Company

Overview

History

- Founded in 1916 in the Puget Sound region of Washington state
- Became a leading producer of military and commercial aircraft
- Undertook a series of strategic mergers and acquisitions to become the world's largest, most diversified aerospace company
  - Aerospace pioneers now part of the Boeing enterprise include:
    - North American Aviation
    - McDonnell Douglas
    - Rockwell International (space and defense business)
    - Hughes Space & Communications
    - Jeppesen

A heritage that mirrors the history of flight

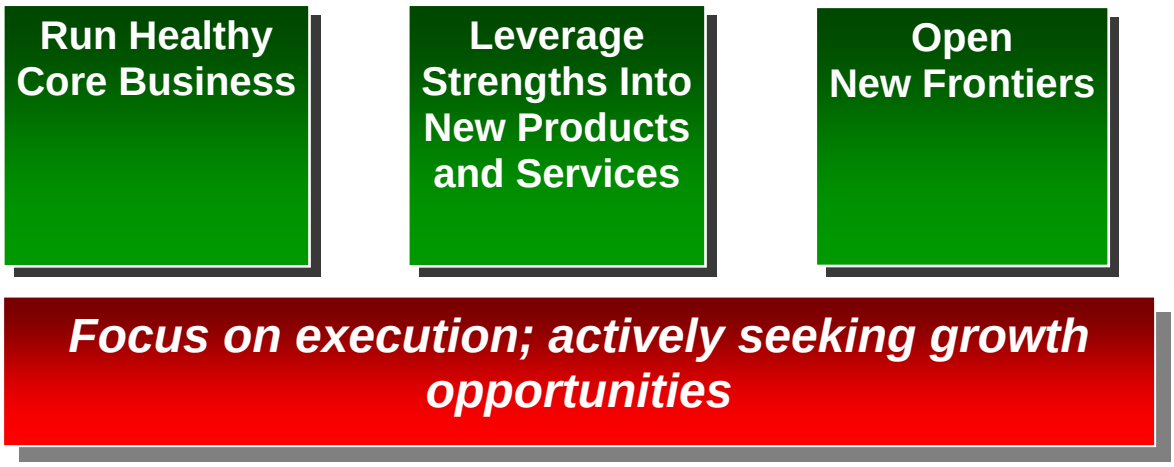
What We Do Today

- Design, assemble and support commercial jetliners

  - Boeing 7-series family of airplanes lead the industry
  - Commercial Aviation Services (CAS) offers broad range of services to passenger and freight carriers
- Design, assemble and support defense systems
  - World's largest designer and manufacturer of military transports, tankers, fighters and helicopters
  - Support Systems provides services to government customers worldwide
- Design and assemble satellites and launch vehicles
  - World's largest provider of commercial and military satellites; largest NASA contractor
- Integrate large-scale systems; develop networking technology and network-centric solutions
- Provide financing solutions focused on customer requirements
- Develop advanced systems and technology to meet future customer needs

Connect and protect people globally

Operating Philosophy



Vision 2016

People working together as a global enterprise for aerospace leadership

Strategies	Core competencies	Values
Run healthy core businesses	Detailed customer knowledge and focus	Leadership
Leverage strengths into new products and services	Large-scale systems integration	Integrity
Open new frontiers	Lean enterprise	Quality
		Customer satisfaction
		People working together
		A diverse and involved team
		Good corporate citizenship
		Enhancing shareholder value

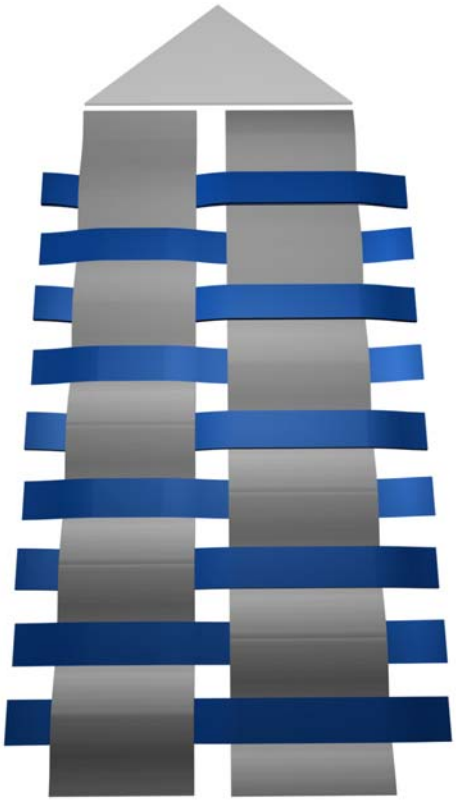
Global Boeing

- Customers in more than 90 countries
  - Total revenue in 2008: $60.9 billion
  - 70 percent of commercial airplane revenue historically from customers outside the United States
- Manufacturing, service and technology partnerships with companies around the world
  - Contracts with 22,000 suppliers and partners globally
- Research, design and technology-development centers and programs in multiple countries
- More than 160,000 Boeing employees in 49 states and 70 countries

Partnering worldwide for mutual growth and prosperity

How We Are Organized

World-class performance



Corporate functions:

Business Development and Strategy

Communications

Engineering, Operations and Technology

Finance / Shared Services Group / Boeing Capital Corp.

Human Resources/Administration

International

Law

Office of Internal Governance

Government Relations

Two businesses supported by nine corporate functions

Company Leadership

Corporate Offices

- Headquartered in Chicago with presence in several other locations around the world
- Focused on:
  - Global growth strategies
  - Financial goals and performance
  - Sharing best practices, technologies and productivity improvements
  - Leadership development
  - Ethics and compliance

Driving long-term growth and value creation

Boeing Commercial Airplanes

- Headquartered in the Puget Sound region of Washington state
- 2008 revenues of $28.3 billion
- Approximately 68,000 employees
- Offering a family of airplanes and a broad portfolio of aviation services for passenger and cargo carriers worldwide
  - Boeing airplanes represent three quarters of the world's fleet, with nearly 12,000 jetliners in service
  - Approximately 70 percent of Boeing commercial airplane sales (by value) go to customers outside of the United States

The industry's source for customer-focused solutions

Integrated Defense Systems

- Headquartered in St. Louis, Mo., with global operations in 4 nations and 21 states
- Formed in 2002 integrating Boeing's defense, space, intelligence and communications capabilities
- Designing, building and supporting net-enabled platforms and systems for government and commercial customers
- Balanced backlog across all markets including a strong mix of development, production and support contracts
- 2008 revenues of $32 billion
- Approximately 70,000 employees

Delivering the future

Boeing Capital Corporation

- Headquartered in the Puget sound area of Washington state
- Financing subsidiary of The Boeing Company
- Focused on assets that are critical to the core operations of Boeing customers
- Arranging and/or providing financing for customers of Boeing products
- Year-end 2008 portfolio of $6.0 billion

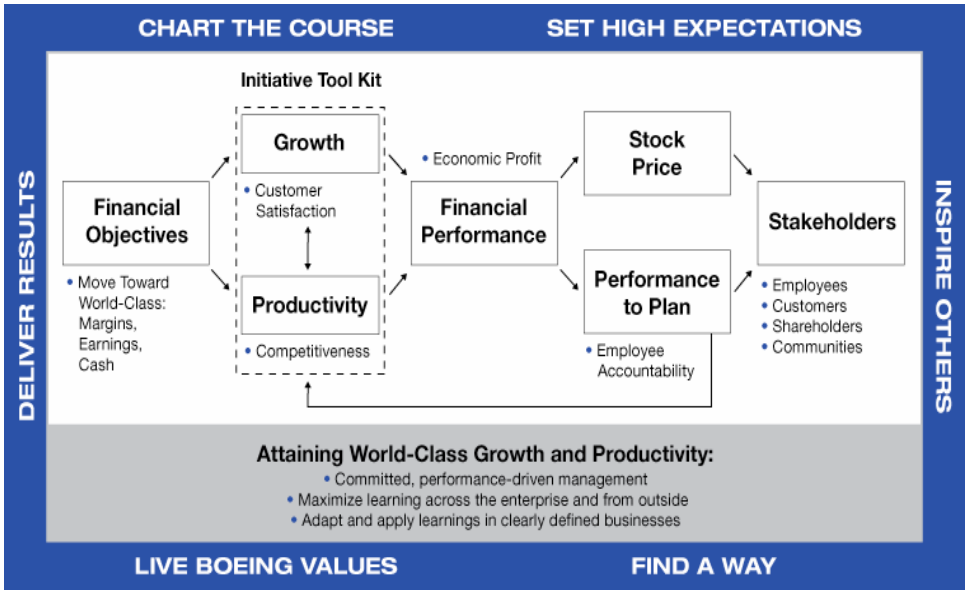
Providing financial services in support of Boeing sales

Engineering, Operations & Technology

- Formed in 2006 to establish technical and functional excellence for the enterprise by maximizing Boeing's R&D yield
- Ensuring technology readiness
- Providing efficient, effective, secure IT solutions
- Protecting, leveraging intellectual property
- Executing safe and efficient test operations
- Driving environment, health & safety performance
- Establishing common systems/processes for Engineering, Operations and Supplier Management

Pursuing technical & functional excellence for the enterprise

How We Operate: Boeing Management Model



Driving performance through growth and productivity and leadership development

Leadership Development

Boeing utilizes a high-quality, integrated leadership development approach that:

- Reinforces Boeing values and “one-company” culture
- Focuses on business and leadership skills, utilizing a Leaders Teaching Leaders methodology
- Supports the company's strategic business objectives through education, training, mentoring and candid performance assessments
- Tackles real business challenges and gathers candid feedback at a state-of-the-art leadership center

Boeing Leadership Center
St. Louis, **Mo.**

As our leaders grow, Boeing grows

Corporate Citizenship

- Boeing is committed to being a good corporate citizen.
  The company and its employees work in partnership with communities globally.
- Currently, we are partnering with community organizations in 26 states, 14 countries and six regions outside the U.S.
  - In 2008 Boeing contributed $58 million to organizations in communities where employees work and live.
  - Boeing employees gave an additional $31 million through the Employees Community Fund, one of the largest employee-owned funds in the world.
  - Employees also contributed more than $12 million through a company gift-matching program, and volunteered thousands of hours of personal service.

Giving back to our communities – a Boeing core value

Our Environmental Actions and Commitments

- Pioneering Environmentally progressive technology
  - Each new generation of commercial airplane will be at least 15 percent more fuel- and CO_2 -efficient
  - Developing air traffic management solutions that offer substantial near-term environmental improvements
  - Advancing renewable energy sources, such as sustainable biofuels, fuel cells and solar cells
- **Relentlessly Reducing Our Environmental Footprint**
  - Targeting 25 percent cuts in greenhouse gas emissions intensity and hazardous waste and 25 percent increases in energy efficiency and recycling rates by 2012, even as our business grows
  - Certifying 100 percent of major manufacturing sites to ISO 14001 by the end of 2008
- **Strengthening the Industry's Environmental Focus**
  - Leading and aligning the aerospace industry on environmental-improvement opportunities

Creating a better future

Boeing 707
(Adapted from: www.aerospaceweb.org)

Boeing 737-758
(Adapted from :www.icfn.net)

Dryden Flight Research Center EC96-43518-1 Photographed 4/96
Shuttle STS-76 is transported to Kennedy Space Center in Florida
by a NASA 747 after landing at Dryden. NASA Photo

Boeing 777
(Adapted from :www.im02.galawallpapers.net)