Commercial Air Wars:
Strategies That Changed Commercial Aviation
Props to Turboprops

Jim Rauf
• Lockheed Aircraft Company
• Lockheed Vega
• Lockheed Electras
• Lockheed World War II
• Boeing Flying Boats
• Boeing Stratoliner
• Lockheed Constellations
• Douglas DC-6/-7
• Boeing Stratocruiser
• Jet Engines, Turboprops
• Vickers Viscount Turboprop
• Lockheed L-188 Electra Turboprop
A Bit of History  Lockheed Aircraft Company  Vega

• Allan Loughead and his brother Malcolm Loughead had operated an earlier aircraft company, Loughead Aircraft Manufacturing Company, which was operational from 1912 to 1920

• The company built and operated aircraft for paying passengers on sightseeing tours in California and had developed a prototype for the civil market, but folded in 1920 due to the flood of surplus aircraft deflating the market after World War I

• Allan went into the real estate market while Malcolm had meanwhile formed a successful company marketing brake systems for automobiles

• On December 13, 1926, Allan Lockheed, John Northrop, Kenneth Kay and Fred Keeler secured funding to form the Lockheed Aircraft Company
A Bit of History  Lockheed Aircraft Company  Vega

• Allan Loughead and his brother Malcolm Loughead had operated an earlier aircraft company, Loughead Aircraft Manufacturing Company, which was operational from 1912 to 1920

• The company built and operated aircraft for paying passengers on sightseeing tours in California and had developed a prototype for the civil market, but folded in 1920 due to the flood of surplus aircraft deflating the market after World War I

• Allan went into the real estate market while Malcolm had meanwhile formed a successful company marketing brake systems for automobiles

• On December 13, 1926, Allan Lockheed, John Northrop, Kenneth Kay and Fred Keeler secured funding to form the Lockheed Aircraft Company

• This new company introduced the Vega in 1928

One pilot  Six passengers  Cruise speed 165 mph  Range 725 miles
132 various Vega models were built from 1927 and 1931

• By April 1929 Lockheed’s 300 employees were producing 5 aircraft per week

• In July 1929, majority shareholder Fred Keeler sold 87% of the Lockheed Aircraft Company to Detroit Aircraft Corporation

• In August 1929, Allan Loughead resigned
A Bit of History  Lockheed Aircraft Company  Model 10 Electra

- The Great Depression ruined the aircraft market, and Detroit Aircraft went bankrupt
- A group of investors headed by brothers Robert and Courtland Gross, and Walter Varney, bought the company out of receivership in 1932
- The syndicate bought the company for a mere $40,000
- 1934, Robert E. Gross was named chairman of the new company, the Lockheed Aircraft Corporation, which was headquartered at what is now the airport in Burbank, California
- His brother Courtlandt S. Gross was a co-founder and executive, succeeding Robert as chairman following his death in 1961
- The company was named the Lockheed Corporation in 1977
A Bit of History  Lockheed Aircraft Company  Model 10 Electra

• The Great Depression ruined the aircraft market, and Detroit Aircraft went bankrupt

• A group of investors headed by brothers Robert and Courtland Gross, and Walter Varney, bought the company out of receivership in 1932

• The syndicate bought the company for a mere $40,000

• 1934, Robert E. Gross was named chairman of the new company, the Lockheed Aircraft Corporation, which was headquartered at what is now the airport in Burbank, California

• His brother Courtlandt S. Gross was a co-founder and executive, succeeding Robert as chairman following his death in 1961

• The company was named the Lockheed Corporation in 1977

• Lockheed Model 10 Electra was a twin-engine, all-metal monoplane airliner developed in the 1930s to compete with the Boeing 247 and Douglas DC-2

• The type was flown by Amelia Earhart on her attempted around-the-world expedition in 1937

• 149 Model 10 Electras were built
A Bit of History  Lockheed Aircraft Company Model 10 Electra

Model 10 Electra  10 passengers and 2 crew

Model 14 Super Electra  354 variants  produced
Introduced 1937
12-14 passenger and 2 crew
**A Bit of History  Lockheed Aircraft Company Model 10 Electra**

<table>
<thead>
<tr>
<th>Model</th>
<th>Year</th>
<th>Passengers</th>
<th>Cruise</th>
<th>Range</th>
<th>Production</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lockheed Super Electra</td>
<td>1937</td>
<td>12-14 passengers</td>
<td>215 mph</td>
<td>850 mi</td>
<td>354</td>
</tr>
<tr>
<td>Boeing 247</td>
<td>1933</td>
<td>10 passengers</td>
<td>189 mph</td>
<td>745 mi</td>
<td>75</td>
</tr>
<tr>
<td>Douglas DC-2</td>
<td>1934</td>
<td>14 passengers</td>
<td>190 mph</td>
<td>1,000 mi</td>
<td>156</td>
</tr>
<tr>
<td>Douglas DC-3</td>
<td>1936</td>
<td>21+passengers</td>
<td>207 mph</td>
<td>1,580 mi</td>
<td>455 (10,174)</td>
</tr>
</tbody>
</table>

**Model 14 Super Electra**
- 354 variants produced
- Introduced 1937
- 12-14 passenger and 2 crew

**Model 10 Electra**
- 10 passengers and 2 crew

**Model 14 Super Electra**
- 354 variants produced
- Introduced 1937
- 12-14 passenger and 2 crew
During WW II Lockheed, along with all other U.S. aircraft manufacturers, built aircraft for the military.

- **Lockheed** built 19,278 aircraft for the military:
- 2,600 PV-1 Venturas
- 2,750 B-17
  - Under license from **Boeing**
- 2,900 Hudson bombers
- 9,000 P-38 Lightning fighters
## A Bit of History  Boeing 314 Clipper

<table>
<thead>
<tr>
<th>Specification</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>First flight</strong></td>
<td>June 7, 1938</td>
</tr>
<tr>
<td><strong>Model number</strong></td>
<td>314A</td>
</tr>
<tr>
<td><strong>Classification</strong></td>
<td>Commercial transport</td>
</tr>
<tr>
<td><strong>Span</strong></td>
<td>152 feet</td>
</tr>
<tr>
<td><strong>Length</strong></td>
<td>106 feet</td>
</tr>
<tr>
<td><strong>Gross weight</strong></td>
<td>84,000 pounds</td>
</tr>
<tr>
<td><strong>Top speed</strong></td>
<td>199 mph</td>
</tr>
<tr>
<td><strong>Cruising speed</strong></td>
<td>184 mph</td>
</tr>
<tr>
<td><strong>Range</strong></td>
<td>5,200 miles</td>
</tr>
<tr>
<td><strong>Ceiling</strong></td>
<td>19,600 feet</td>
</tr>
<tr>
<td><strong>Power</strong></td>
<td>Four 1,500-horsepower Wright GR-2600 Double Cyclone engines</td>
</tr>
<tr>
<td><strong>Accommodation</strong></td>
<td>10 crew, 74 passengers Number Built 12</td>
</tr>
</tbody>
</table>
A Bit of History  Boeing 314 Clipper
A Bit of History  Boeing 307 Stratoliner

First flight  December 1938
EIS  Pan Am  July, 1940

### Specification (SA-307B Stratoliner)

- **Type:** long-range pressurized airliner
- **Dimensions:**
  - wing span 32.70m (107ft 3in), length 22.70m (74ft 4in), height 6.30m (20ft 9in)
- **Gross weight:** 19,050kg (42,000lb)
- **Powerplant:** four 1000hp Wright GR-1820 Cyclone radial piston engines
- **Maximum speed:** 396km/h (246mph)
- **Range:** 3846km (2390 miles)
- **Service ceiling:** 7985m (26,200ft)
- **Flight crew:** 3
- **Passengers:** 33 (later 38)

The **307 Stratoliner** was based on the **B-17**
A Bit of History  Boeing 307 Stratoliner

- The **Stratoliner** was the first airplane to have a flight engineer as a member of the crew
- The engineer was responsible for maintaining power settings, pressurization and other subsystems, leaving the pilot free to concentrate on other aspects of flying the aircraft
- **Boeing** built 10 Stratoliners
- In 1940, the 307s started flying routes to Latin America and from New York to Los Angeles
- Production stopped at the onset of war
- Five were drafted into the Army Transport Command as **C-75** military transports
A Bit of History Lockheed Aircraft Company

• In 1939, **Howard Hughes** began buying **Trans World Airlines (TWA)** stock and had a controlling interest

• He was looking for a company that could build him an aircraft that would give him the jump on **United** and **American**

• The deals were done in secret, with the proviso that no other airline would be allowed to purchase the **Lockheed** developed airplane until **TWA** had 35 of them

• The **Constellation** was the result of Hughes’ influence

• It had the first hydraulically boosted power controls, was faster than many WWII fighters and had a pressurized cabin to allow the plane to fly above most of the weather disturbances

• Military got first aircraft

• For many years following introduction with **TWA** in 1949, **Connie** was the only passenger aircraft that offered the pressurization needed to fly at high altitudes
A Bit of History  Lockheed Constellation, Super Constellation

1943

<table>
<thead>
<tr>
<th>Specification (L-1049C)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Type:</strong> Constellation (unless otherwise stated) long-range airline</td>
</tr>
<tr>
<td><strong>Dimensions:</strong> wing span 37.49m (123ft), length (with radar nose) 35.42m (116ft 2in), height 7.56m (24ft 9in)</td>
</tr>
<tr>
<td><strong>Maximum take-off weight:</strong> 60,329kg (133,000lb)</td>
</tr>
<tr>
<td><strong>Powerplant:</strong> four 3250hp Wright R-3350-972TC18DA-1 18-cylinder turbo-compound radial piston engines</td>
</tr>
<tr>
<td><strong>Maximum speed:</strong> 602km/h (374mph)</td>
</tr>
<tr>
<td><strong>Operational range:</strong> 6470km (4020 miles)</td>
</tr>
<tr>
<td><strong>Service ceiling:</strong> 7071m (23,200ft)</td>
</tr>
<tr>
<td><strong>Flight crew:</strong> 3 to 5</td>
</tr>
</tbody>
</table>

Capacity: 47 to 107 passengers
A Bit of History Lockheed Aircraft Company

• As the first commercial aircraft to fly above 12,500 feet, it took passengers out of the 'air sickness' zone where the weather was more active

• Settling into the jetstream at 20,000 feet plus was not only more comfortable for passengers, but also less fuel-intensive, enabling the Constellation to operate the first nonstop coast to coast US commercial flights

• More than 800 aircraft were built in total

• As the development of the Constellation moved forwards, the aircraft got larger and generally slower

• However, range improvements and massive jumps in the MTOW made the larger variants popular with airlines

• Both the L-1049 Super Constellation and the L-1649 Starliner were instrumental in the development of the transatlantic market, used by carriers on both sides of the pond to make connections between the continents
A Bit of History Lockheed Aircraft Company

- As the first commercial aircraft to fly above 12,500 feet, it took passengers out of the 'air sickness' zone where the weather was more active

- Settling into the jetstream at 20,000 feet plus was not only more comfortable for passengers, but also less fuel-intensive, enabling the Constellation to operate the first nonstop coast to coast US commercial flights

- More than 800 aircraft were built in total

- As the development of the Constellation moved forwards, the aircraft got larger and generally slower

- However, range improvements and massive jumps in the MTOW made the larger variants popular with airlines

- Both the L-1049 Super Constellation and the L-1649 Starliner were instrumental in the development of the transatlantic market, used by carriers on both sides of the pond to make connections between the continents

<table>
<thead>
<tr>
<th></th>
<th>L-649</th>
<th>L-749</th>
<th>L-1049</th>
<th>L-1649</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crew</td>
<td>5</td>
<td>6 – 8</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Capacity</td>
<td>60 – 81</td>
<td>60 – 81</td>
<td>47 – 106</td>
<td>99</td>
</tr>
<tr>
<td>Length</td>
<td>95’3”</td>
<td>97’4”</td>
<td>113’7”</td>
<td>116’2”</td>
</tr>
<tr>
<td>Wingspan</td>
<td>123’</td>
<td>123’</td>
<td>123’</td>
<td>150’</td>
</tr>
<tr>
<td>MTOW</td>
<td>94,000lb</td>
<td>107,000lb</td>
<td>120,000lb</td>
<td>156,104lb</td>
</tr>
<tr>
<td>Speed</td>
<td>327 mph</td>
<td>345 mph</td>
<td>304 mph</td>
<td>280 mph</td>
</tr>
<tr>
<td>Range</td>
<td>2,280 – 3,995 mi</td>
<td>2,600 – 4,995 mi</td>
<td>5,150 mi</td>
<td>4,840 – 6,180 mi</td>
</tr>
</tbody>
</table>

Boeing 707 4 engine jet

<p>| |</p>
<table>
<thead>
<tr>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Crew</td>
</tr>
<tr>
<td>Capacity</td>
</tr>
<tr>
<td>Cruise speed</td>
</tr>
<tr>
<td>Range</td>
</tr>
</tbody>
</table>
A Bit of History Lockheed Aircraft Company **R6V Constitution**

- The **Lockheed R6V Constitution** was a large, propeller-driven, double-decker transport aircraft developed in the 1940s as a long-range, high-capacity transport and airliner for the **U.S. Navy** and **Pan American Airways**
- First flight 1946
- Only two of the aircraft were ever built, both prototypes
- The **Constitution** design ultimately proved underpowered and too large for practical airline use at the time

- **Crew**: 12
- **Capacity**: 168 passengers
- **Length**: 156 ft 1 in
- **Wingspan**: 189 ft 1 1/4
- **Max takeoff weight**: 184,000 lb
- **Powerplant**: 4 × Pratt & Whitney R-4360-22W radial train, 3,500 hp each
- **Ferry range**: 6,300 mi
- **Service ceiling**: 27,600 ft
A Bit of History  Douglas  DC-6, DC-7

1946

**Specification (DC-7C)**

<table>
<thead>
<tr>
<th>Type:</th>
<th>long-range airliner</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dimensions:</td>
<td>wing span 38.86m (127ft 6in), length 34.21m (112ft 3in), height 9.70m (31ft 10in)</td>
</tr>
<tr>
<td>Maximum take-off weight:</td>
<td>64,864kg (143,000lb)</td>
</tr>
<tr>
<td>Powerplant:</td>
<td>four 3400hp Wright R-3350-18A-1 turbo-compound radial piston engines</td>
</tr>
<tr>
<td>Maximum speed:</td>
<td>653km/h (405mph)</td>
</tr>
<tr>
<td>Range:</td>
<td>7411km (4605 miles)</td>
</tr>
<tr>
<td>Service ceiling:</td>
<td>6615m (21,700ft)</td>
</tr>
<tr>
<td>Flight crew:</td>
<td>3</td>
</tr>
<tr>
<td>Passengers:</td>
<td>105</td>
</tr>
</tbody>
</table>

DC-6 (1946-1958) and DC-7 (1953-1958) Both were pressurized
A Bit of History   Boeing 377 Stratocruiser

Boeing 377 Stratocruiser was developed from the C-97 military transport

C-97 was a derivative of the B-29

First flight   July 1947
EIS Pan Am April 1949

1947

<table>
<thead>
<tr>
<th>Specification</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Type:</td>
<td>long-range airliner</td>
</tr>
<tr>
<td>Dimensions:</td>
<td>wing span 43m (141ft 3in), length 33.65m (110ft 4in), height 11.66m (38ft 3in)</td>
</tr>
<tr>
<td>Normal</td>
<td></td>
</tr>
<tr>
<td>take-off weight:</td>
<td>76,185kg (145,800lb)</td>
</tr>
<tr>
<td>Powerplant:</td>
<td>four 3500hp Pratt &amp; Whitney R-4360 Wasp Major 28-cylinder, four-row turbo-supercharged radial piston engines</td>
</tr>
<tr>
<td>Maximum speed:</td>
<td>603km/h (375mph)</td>
</tr>
<tr>
<td>Range:</td>
<td>7360km (4600 miles)</td>
</tr>
<tr>
<td>Service ceiling:</td>
<td>more than 9760m (32,000ft)</td>
</tr>
<tr>
<td>Flight crew:</td>
<td>5</td>
</tr>
<tr>
<td>Passengers:</td>
<td>typically 67 passengers on the upper deck and 14 below</td>
</tr>
</tbody>
</table>

Number built   56
A Bit of History  Boeing 377 Stratocruiser
Jet Engines European Wartime Inventions

- 1937 **Captain Frank Whittle** of RAF tests first jet engine designed for aircraft bench test
Jet Engines  European Wartime Inventions

• 1937 Captain Frank Whittle of RAF tests first jet engine designed for aircraft bench test

• 1938 Hans von Ohain designed Heinkel HeS3B jet engine is test flown beneath an He118
  • First flying test bed for jet engine
Jet Engines  European Wartime Inventions

- 1939 Heinkel He 178
- World's first turbojet powered aircraft
- Powered by von Ohain’s HeS3b engine
- Thrust ~1100 lbf
- RPM ~12,000
• 1942 First jet flight of **Messerschmitt Me262**
  • Twin turbo jet fighter
• Two **Jumo 004** engines powered the **Me 262**
• The first jet fighter to fly in combat
• Engine life was very short
  • Germans had no source of chromium
Whittle Jet Engine

- Type: Turbojet
- Thrust: 1,240 lb at 17,750 rpm
- Compressor: Single-stage, double entry, centrifugal
- Combustor: 10 reverse flow chambers
- Turbine: Single-stage axial
- Weight: 560 lb
First U.S. Jet Aircraft

• 1942 First flight of Bell XP-59A prototype
  • First U.S turbo jet aircraft
  • Powered by GE built version of Whittle engine
  • Aircraft not much better than piston engine fighters
Gas Turbine Aircraft Engines

Turbojet

Turboprop
Gas Turbine Aircraft Engines

**Turbojet**

**Turboprop**

**Turbofan**
Gas Turbine Aircraft Engines

https://www.youtube.com/watch?v=sHUYU5GuNM
Jet Engine Thrust

Turbojet

![Diagram of a turbojet engine]

Thrust = $F = \dot{m}_e V_e - \dot{m}_0 V_0$
Jet Engine Thrust

Turbojet

\[ \text{Thrust} = F = \dot{m}_{e} V_{e} - \dot{m}_{0} V_{0} \]

High Bypass Fan Jet Engine

\[ \text{Thrust} = \text{Thrust of Fan} + \text{Thrust of Core} \]
\[ F = \dot{m}_{f} V_{f} - \dot{m}_{f} V_{0} + \dot{m}_{e} V_{e} - \dot{m}_{c} V_{0} \]
\[ F = \dot{m}_{e} V_{e} - \dot{m}_{0} V_{0} + \text{bpr} \dot{m}_{c} V_{f} \]

\[ \text{Mass flows} \]
\[ \dot{m}_{0} = \dot{m}_{f} + \dot{m}_{c} \]
\[ \text{Bypass ratio} = \text{bpr} \]
\[ \text{bpr} = \dot{m}_{f} / \dot{m}_{c} \]
Turboprop Engine Thrust

Turboprop

\[ F = m_e V_1 - m_c V_e + m_c V_o - m_e V_1 \]  
(Large)

\[ F = m_e (V_1 - V_o) + m_c (V_o - V_1) \]  
(Small)

Mass Flows

\[ m_e > m_c \]
\[ m_e - m_c \]
A Bit of History  Vickers Viscount

• The **Vickers Viscount** was the first *turboprop* airliner, and became extremely popular for its smooth, quiet ride

• It debuted in 1950 with a 50-passenger configuration

• A quarter of all European passenger flights in the 1950s were booked on the **Vickers Viscount**

• 440 **Viscounts** were produced from 1948 thru 1963

  • **Crew**: 2 pilots + cabin crew
  • **Capacity**: 75 passengers
  • **Max takeoff weight**: 67,500 lb
  • **Powerplant**: 4 × Rolls-Royce Dart Mk 525 *turboprop*, 1,990 hp
  • **Maximum speed**: 352 mph
  • **Range**: 1,380 mi
A Bit of History  Vickers Viscount  Rolls-Royce Dart Mk.525

1,990 HP
A Bit of History  Lockheed L-188 Electra Turboprop

• The **Lockheed L-188 Electra** was developed to meet a 1954 **American Airlines** requirement for a domestic short to medium range 75 to 100 seat airliner

• June 1955 **American** awarded **Lockheed** an order for 35 such aircraft

• The **L-188**, was a low wing, four turboprop powered aircraft

• Many other airlines shared **American**'s interest in the L-188, and by the time the first prototype flew in December 1957, the order book stood at 144

• EIS was with **Eastern Airlines** (due to a pilot's strike at American) on January 1959

• Total production 170 aircraft

• **Allison 501-D13** 3750 hp turboprops

• With its unique high power-to-weight ratio, huge propellers the airplane had airfield performance capabilities unmatched by many jet transport aircraft—particularly on short runways and high field elevations

98 Passengers
A Bit of History  
Lockheed L-188 Electra Turboprop

- **Crew:** Three
- **Capacity:** 98 passengers
- **Max takeoff weight:** 113,000 lb
- **Powerplant:** 4 × Allison 501-D13 turboprop engines, 3,750 shp each
- **Propellers:** 4-bladed 13 ft 6 in diameter
- **Maximum speed:** 448 mph
- **Cruise speed:** 373 mph
- **Range:** 2,200 mi with maximum payload
- **Service ceiling:** 28,400 ft
Lockheed L-188 Electra

• Three aircraft were lost in fatal accidents between February 1959 and March 1960

• After the third crash, the FAA limited the Electra's speed until the cause could be determined

• After an extensive investigation, two of the crashes (in September 1959 and March 1960) were found to be caused by an engine-mount problem

• The mounting of the gearbox cracked, the reduced rigidity enabled a phenomenon called "whirl mode flutter" (analogous to the precession of a child's top as it slows down, an interaction of propellers with airflow) that affected the outboard engine nacelles

• When the oscillation was transmitted to the wings and the flutter frequency decreased to a point where it was resonant with the outer wing panels, violent up-and-down oscillation increased until the wings would tear off
Lockheed L-188 Electra

- Three aircraft were lost in fatal accidents between February 1959 and March 1960
- After the third crash, the FAA limited the Electra's speed until the cause could be determined
- After an extensive investigation, two of the crashes (in September 1959 and March 1960) were found to be caused by an engine-mount problem
- The mounting of the gearbox cracked, the reduced rigidity enabled a phenomenon called "whirl mode flutter" (analogous to the precession of a child's top as it slows down, an interaction of propellers with airflow) that affected the outboard engine nacelles
- When the oscillation was transmitted to the wings and the flutter frequency decreased to a point where it was resonant with the outer wing panels, violent up-and-down oscillation increased until the wings would tear off

‘Whirl mode” flutter  (a new investigation at NASA Langley)

- Wind tunnel tests of an Electra 1/8-scale model showed:
  - Overly stiff wing
  - Outboard nacelles responding differently than intended
  - Flutter “passes on” from nacelle to (even a “flutter-free”) wing
    - Growing flutter magnitude decreased the oscillation frequency from 5 to 3 Hz
    - Wing frequency was also 3 Hz
      - Harmonic coupling
Lockheed L-188 Electra

• Three aircraft were lost in fatal accidents between February 1959 and March 1960
• After the third crash, the FAA limited the Electra's speed until the cause could be determined
• After an extensive investigation, two of the crashes (in September 1959 and March 1960) were found to be caused by an engine-mount problem
• The mounting of the gearbox cracked, the reduced rigidity enabled a phenomenon called "whirl mode flutter" (analogous to the precession of a child's top as it slows down, an interaction of propellers with airflow) that affected the outboard engine nacelles
• When the oscillation was transmitted to the wings and the flutter frequency decreased to a point where it was resonant with the outer wing panels, violent up-and-down oscillation increased until the wings would tear off
• The company implemented an expensive modification program (the Lockheed Electra Achievement Program, LEAP) in which the engine mounts and the wing structures supporting the mounts were strengthened, and some of the wing skins were replaced with thicker material
• All Electras were modified at Lockheed's expense at the factory, with the modifications taking 20 days for each aircraft
• The changes were incorporated in later aircraft as they were built
• The damage had been done, and the public lost confidence in the type
• This and the smaller jets that were being introduced eventually relegated Electras to the smallest airlines
• Production ended in 1961 after 170 had been built
• Losses to Lockheed have been estimated as high as $57 million, not counting an additional $55 million in lawsuits
Next The Commercial Jet Age

DeHavilland, Boeing, Douglas