The Incredible Complexity of Commercial Aviation

Suspect all of you have flown on commercial airliners, but, have you ever thought about how complex the modern commercial aviation industry really is?

In this course we will discuss how current commercial airplanes are designed, manufactured and sold to and operated by the Airlines worldwide and what role various US Government Agencies, the Federal Aviation (FAA), National Transportation Safety Board (NTSB), Transportation Security Association (TSA) & other agencies outside the USA who play a big part in maintaining aviation safety, worldwide.

We will also describe some of the advances in airliner technology over the years that have further contributed to the safety and effectiveness within today’s commercial aviation industry, plus a lot more.

We will also discuss a bit about the Boeing 737 MAX issues as well as the effects of COVID 19 on the airline industry
The Incredible Complexity of Commercial Aviation

1. All the amazing numbers and a bit of history

2. Regulations and Agencies
   FAA, CAB, NTSB, TSA, ATA, IATA, ICAO, EASA how they have advanced to keep us safe.
   ETOPS. – Extended Twin Engine Range

3. Aircraft design and certification
   Safety records, performance improvements, engines.
   Basics of aerodynamics of flight, typical commercial flight.
   Airliners near ready for Service.

4. Aircraft manufacturing
   Manufacturers, wood to composites, outsourcing, engines & introducing new airliners from Boeing, Airbus & the competition from China & Russia.

5. Airline operations
   History, scheduling, fees, labor, fuel, catering, sales, introducing new airplanes.

6. Aircraft maintenance and Airports
   FAA regulations, aircraft check levels, component repairs, problem feed back to FAA and manufacturers.
   Major airports’ traffic, ownership, fees, regulations, employment.

7. Air traffic control, 737 MAX issues and the effects of Covid19 on the commercial airline industry
   FAA operations, purpose, system description the Next Gen system.

8. Future of Commercial Aviation
   What is next in commercial aviation, UDF, new fuels, Supersonic Transport, more advanced materials, or?
Session 1

All the Amazing Numbers and a Bit of History
Commercial Aviation Numbers

2,789,971
Passengers fly every day in and out of U.S. airports.

1 Billion
U.S. passengers flown yearly.

44,300,000,000
Pounds of freight per year.

5.1%
Aviation contributed to the U.S. gross domestic product.

$446.8 Billion
Annual earnings from aviation-related jobs.

10,600,000
U.S. jobs generated from aviation.
Commercial Aviation Numbers
All the Amazing Numbers

• Over a recent 20 year period aviation fatalities has reduced by 94% in the United States.

• 2017 was the safest year in Commercial Aviation Worldwide according to the Bureau of Aircraft Accidents with no reported fatalities

• In 15 years there will be 44,000 Commercial Airplanes, active in the world
  • In 2017 number was 23,600

• Atlanta’s Airport is currently the busiest in the world
  • At peak time, (Thanksgiving) there are 9,000 airplanes active in one day

• Today’s typical commercial airliner has four million parts and will travel 100 times the distance to the moon and back before it exceeds its life limitation

• At a max overhaul there are generally 1,600 major components removed for inspection, accepted and or repaired or replaced
  • This will occur several times in the total life of a typical current airplane

• A Boeing 747 uses approximately 1 gallon of fuel every second(5 gallons of fuel per mile)
  • 36,000 gallons during a 10 hour flight

• In flight oxygen masks are designed to last ~ 15 minutes -enough time to reduce the aircraft’s altitude to a safe level of ~ 11,000 feet

• U.S. and foreign airlines serving the U.S. carried an all-time high of 1 billion system wide passengers in 2018
  • 4.8 percent more than the 965.4 million of 2017 the previous record
All the Amazing Numbers

• The chance of an accident is little more than one in a million
• Fatal accidents occurred once every 200,000 flights in the 50s and 60s
• **Now, fatal accidents only occur once every two million flights**
• It’s been more than a decade since fatalities topped 1,000 in a given year, something that would regularly happen from the 1960s until the turn of the century

Data from the United States Statistics Department:
• You are **80 times** more likely to die by choking on food
• And **95 times** more likely to be killed by gunfire in the USA than dying in an airplane crash.

• If your plane is involved in some type of accident, there is a 95% chance of survival based on studies of past commercial aircraft accidents
  • This information is from a report dated in 2001
• For all transportation fatalities from 2012 to 2018, a mere 1% were the result of air travel
• “Air travel is the safest mode of mass transportation
• Based on the accident rate over the last few years, you would have to fly on average **once a day every day for 22,000 years** before you would perish in a U.S. commercial aviation accident
• In 1998 there were more than 10 million departures and not one fatality aboard a commercial aircraft.”
  • Source FAA
All the Amazing Numbers

National Transportation Safety Board
US Transportation Fatals in 2018¹ – by Mode

Total: 38,515²

<table>
<thead>
<tr>
<th>Mode</th>
<th>Fatalities</th>
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<tr>
<td>Highway</td>
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<tr>
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<tr>
<td>Marine</td>
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<tr>
<td>Total</td>
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¹ Aviation data is sourced from the NTSB’s 1999–2018 Preliminary Aviation Statistics. For other transportation modes, the NTSB used data from the Bureau of Transportation Statistics, Transportation Fatalities by Mode.

² National Highway Traffic Safety Administration

Federal Railroad Administration and Federal Transit Administration

Department of Homeland Security/US Coast Guard

Footnotes
1. Numbers for 2018 are preliminary estimates. Aviation data are from the NTSB, marine data are reported by the US Department of Homeland Security, and other data is reported by the US Department of Transportation.
2. To reduce double counting, NTSB non-boating fatalities involving moving vehicles at public highway-rail grade crossings and transit-related fatalities are not included in the total fatalities.
3. Including unreported and other fatalities.
4. Other refers to occupants of other vehicle types, non-motorized, and unknown.
5. Grade crossing fatalities are reported as a separate category but should not be added to the total because they are included in the highway and rail fatalities as appropriate.
6. Freight, passengers, and general rail data are reported by the Federal Railroad Administration. The FAA does not include suicides.
7. Transportation fatalities are reported as a separate category but should not be added to the total because they are included in the freight, passengers, and general rail fatalities. Transportation fatalities are not included in rail transit.
8. Rail fatalities are reported by the Federal Railroad Administration and include fatalities (excluding passengers) involving human, light rail, cable car, monorail, automated guided vehicle, streetcar rail, and hybrid rail.
9. Total fatalities may not equal the sum of each category because accidents may involve multiple categories.
10. Foreign/unregistered includes non-US registered aircraft involved in crashes in the United States.
All the Amazing Numbers

• 2017 in China ~600 million people flew compared to 62 Million in 2000 ~ a 10x growth in 17 years

• In 2019 China’s Airline’s accounted for 22% of the purchase of commercial airliners from Boeing and Airbus

• The International Air Transport (IATA) recently predicted that the number of worldwide travelers will increase from the 2016’s 3.8 Billion number to 7.2 Billion in 15 years

• By 2024 China will overtake the US as the number 1 country in air travelers and India will overtake Britain in the third spot the following year

• Boeing is projecting the need for new airliners to reach 39,000 by 2040
  • 15,000 needed for Asian markets, alone

• The top 4 Airlines in terms of serving other countries are as noted below:
  • 1. Turkish Airlines – 120 different countries
  • 2. Air France - 93
  • 3. Qatar Airways - 86
  • 4. British Airways – 82

  • USA’s United is seventh on the current list
A Bit of Aviation History

**December 17, 1903** - Orville Wright makes the first heavier than air manned flight at Kitty Hawk, NC. The plane, made of wood, wire, and cloth, traveled 120 feet and flew for 12 seconds.

How it was designed and built 8:32 Minutes

https://www.youtube.com/watch?v=LigpsX1KoQE&t=201s

Wilbur and Orville Wright
A Bit of Aviation History

- In 1908, Wilbur Wright travelled to Europe, and gave a series of flight demonstrations at Le Mans in France.
- The major French aviation experimenters were astonished by the clear superiority of the Wright Brothers' aircraft, particularly its ability to make tight controlled turns.
- 1909 saw the widespread recognition of powered flight as something other than the preserve of dreamers and eccentrics.
- July 25, 1909 Louis Blériot won worldwide fame by winning a £1,000 prize offered by the British Daily Mail newspaper for a flight across the English Channel.
- August 1909 half a million people, attended one of the first aviation meetings, the Grande Semaine d'Aviation at Reims.
- The years between World War I and World War II saw great advancements in aircraft technology.
- Airplanes evolved from low-powered biplanes made from wood and fabric to sleek, high-powered monoplanes made of aluminum and now composites.
- After World War I, many American pilots became barnstormers, flying into small towns across the country and showing off their flying abilities, as well as taking paying passengers for rides.
- Air shows sprang up around the country, with air races, acrobatic stunts, and feats of air superiority.
- The air races drove engine and airframe development, the Schneider Trophy, for example, led to a series of ever faster and sleeker monoplane designs.

Curtiss JN-4

Airbus A320
A Bit of Aviation History

World’s first passenger airline

• November 16, 1909 DELAG (Deutsche Luftschiiffahrts-Aktiengesellschaft, or German Airship Transportation Corporation Ltd) was established, as an offshoot of the Zeppelin Company

• DELAG airship Bodensee began scheduled service between Berlin and southern Germany in 1919
  • The flight from Berlin to Friedrichshafen took 4-9 hours, compared to 18-24 hours by rail

• DELAG offered the world’s first transatlantic passenger service, using LZ-127 Graf Zeppelin to make scheduled flights between Germany and South America beginning in 1931

Graf Zeppelin crossed the South Atlantic 136 times before being retired after the Hindenburg disaster in 1937
A Bit of Aviation History

- **May 23, 1926, Western Air Express** inaugurated the “first scheduled airline passenger service” in the U.S., flying the nation’s first commercial airline passenger from Salt Lake City to Los Angeles

- **WAE** began flying on Apr 17 as the fourth carrier to begin operations under a new air mail contract system that became the major source of income for the era's small but growing airline industry

- **May 21-22, 1927 – Charles Lindbergh** makes the first non-stop solo transatlantic flight from NY to Paris
  - He covered, 3,600-statute-miles in the 33 ½-hours (107 mph) in a single-engine purpose-built Ryan monoplane, the *Spirit of St. Louis*
  - It was the first transatlantic flight between two major cities, and the longest transatlantic flight by almost 2,000 miles
    - John Alcock and Arthur Brown made the first nonstop flight across the Atlantic in 1919 landing in Ireland
  - The flight exited people about aviation and was a major turning point in the advancement of aviation

[https://www.youtube.com/watch?v=nypXkhomHqE](https://www.youtube.com/watch?v=nypXkhomHqE)

*Lindbergh historic flight 4.5 Minutes*
A Bit of Aviation History

**Boeing Model 80** America's first airliner designed specifically for passenger comfort and convenience (first flight July 27, 1928)

Its fuselage was made of welded-steel tubing covered with fabric.

The **Model 80** carried 12 passengers in a cabin appointed with leather upholstery, reading lamps, forced-air ventilation, and hot and cold running water.

**Model 80A** (first flight Sept. 12, 1929)

(10) flew for **Boeing Airlines**

Wing Span: 80 feet
Length: 56 feet 6 inches
Gross weight: 17,500 pounds
Cruising speed: 125 mph
Range: 460 miles
Ceiling: 14,000 feet
Power: Three 525-horsepower P&W Hornet engines
3 crew, 18 passengers, 898 pounds of cargo
A Bit of Aviation History

• In the US, Stout Airways was the first to employ stewards in 1926, working on Ford Trimotor planes between Detroit and Grand Rapids, Michigan

• Western Airlines (1928) and Pan American World Airways (Pan Am) (1929) were the first US carriers to employ stewards to serve food

• The first female flight attendant was a 25-year-old registered nurse named Ellen Church

• Hired by United Airlines in 1930, she also first envisioned nurses on aircraft

• Other airlines followed suit, hiring nurses to serve as flight attendants, then called "stewardesses" or "air hostesses", on most of their flights
A Bit of Aviation History

• **Amelia Earhart** (1897-1937) became the most famous female flyer in the world

• She set numerous aviation records:
  - 1922—Feminine altitude record of 14,000 feet
  - 1928—First woman to fly across the Atlantic as a passenger in the Fokker F.VII *Friendship*
  - 1929—Feminine speed record
  - 1930—Feminine speed record
  - 1931—First woman to fly an autogiro
  - 1931—Autogiro altitude record of 18,415 feet
  - 1932—First woman (and only the second person) to fly solo and nonstop across the Atlantic. Also first person to cross the Atlantic twice by air
  - 1932—First woman to fly solo and nonstop across the United States
  - 1933—Reset her transcontinental record
  - 1935—First person to fly solo from Honolulu, Hawaii, to the U.S. mainland (Oakland, California)
  - 1935—Speed record between Mexico City and Washington, D.C.
  - 1935—First person to fly solo from Mexico City to Newark, New Jersey

• May 21, 1937, **Amelia Earhart** and navigator **Fred Noonan** began a round-the-world flight, beginning in **Oakland, California**, and traveling east in a twin-engine Lockheed Electra

• July 2, 1937, they took off from Lae, New Guinea,

• Their next destination was Howland Island in the central Pacific Ocean, some 2,500 miles away

• But Earhart never arrived on Howland Island
A Bit of Aviation History

**Boeing 307 Stratoliner**

- In 1935, **Boeing** designed a four-engine airliner based on its **B-17** heavy bomber then in development.
- First land-based airliner to use flight engineer.
- It used the wings, tail, rudder, landing gear, and engines from their production B-17C with a new, circular cross-section fuselage of 138 in diameter designed to allow cabin pressurization:
  - Allowed flight at up to 20,000 ft with cabin pressure equivalent to ~8000 ft.
- It entered service with **Pan Am** in 1940.
- Also operated by **Transcontinental and Western Air**.
- Production halted by World War II after 10 aircraft were produced.

**Crew:** two pilots, flight engineer, two cabin crew

**Capacity:** 38 passengers in daytime, 25 by night

**Length:** 74 ft 4 in  **Wingspan:** 107 ft  **Height:** 20 ft 9.5 in  **Gross weight:** 45,000 lb

**Powerplant:** 4 × **Wright GR-1820-G102A** radial engines, 1100 hp

**Maximum speed:** 241 mph  **Cruise speed:** 215 mph

**Range:** 2,390 mi
A Bit of Aviation History

**Douglas DC-3**

- Design work began in 1934 at the insistence of C.R. Smith, president of American Airlines
- The first DC-3 built was the Douglas Sleeper Transport — also known as Skysleepers by airline customers — and it was the height of luxury
- Fourteen plush seats in four main compartments could be folded in pairs to form seven berths, while seven more folded down from the cabin ceiling
- The plane could accommodate 14 overnight passengers or 28 for shorter daytime flights
- The first was delivered to American Airlines in June 1936, followed two months later by the first standard 21-passenger DC-3
- November 1936, United Airlines, which had been a subsidiary of Boeing until 1934, became the second DC-3 customer

**Crew:** two  
**Capacity:** 21–32 passengers

**Length:** 64 ft 8 in  
**Wingspan:** 95 ft 2 in  
**Height:** 16 ft 11 in

**Gross weight:** 25,200 lb  
**Fuel capacity:** 822 gal

**Powerplant:** 2 × Pratt & Whitney R-1830-S1C3G Twin Wasp 14-cyl. air-cooled two row radial piston engine, 1,200 hp

**Maximum speed:** 230 mph, at 8,500 ft  
**Cruise speed:** 207 mph

**Service ceiling:** 23,200 ft  
**Range:** 2,125 mi

**Production:** 607 DC-3 and 10,048 C-47/C53
A Bit of Aviation History

Howard Hughes and TWA

- Howard Hughes (1905-1976) was a millionaire at 18 he inherited the family business, Hughes Tool which manufactured drill bits for the oil industry.
- Hughes went to Hollywood where he pursued movies and aviation.
- In 1933, he founded the Hughes Aircraft Company, and hired engineers to build fast planes for him to fly.
- In September of 1935, he flew the H-1 Racer plane 351 miles per hour, the fastest speed on record.
- Then he flew around the world in three days.
- Howard Hughes became a household name in aviation.

Howard Hughes and the H-1 Racer
A Bit of Aviation History

**Howard Hughes and TWA**

- In 1939, Jack Frye, the president of TWA urged Hughes to quietly buy up TWA stock—he took over the company.
- Hughes approached Lockheed to build a new plane that would outperform TWA’s Boeing Stratoliners.
- The result was the **Lockheed Constellation** (developed in absolute secrecy) – entered service 1945.
  - Total produced 856.
  - The pressurized cabin provided passengers with a more comfortable flying experience.
  - Lower drag at altitude enabled the plane to cruise faster than its competitors.
- Hughes made TWA into an international carrier competing with Pan Am.
- 1960 Hughes was forced out of TWA.
- He sold his shares in the airline for $547 million, making Hughes one of the richest men in the world.

**Lockheed Constellation**

- **Crew:** 5 flight crew, varying cabin crew
- **Capacity:** typically 62–95 passengers
- **Length:** 116 ft 2 in
- **Wingspan:** 126 ft 2 in
- **Height:** 24 ft 9 in
- **Max takeoff weight:** 137,500 lb
- **Powerplant:** 4 x Wright R-3350-DA3 Duplex-Cyclone 18 cylinder air-cooled radial piston engines, 3,250 hp
- **Maximum speed:** 377 mph
- **Cruise speed:** 340 mph at 22,600 ft
- **Range:** 2,300 to 6,100 mi
- **Service ceiling:** 24,000 ft
A Bit of Aviation History

- Perhaps more than any other individual, Juan Trippe is responsible for the development of the commercial airline industry in the 20th Century.
- He thought that flying should be affordable for everyone - not just the wealthy.
- Backed by rich friends, Trippe opened the offices of Pan American Airways in 1927.
- Taking advantage of his connections with the political elite, he got Pan Am the first U.S. government air mail routes to the Caribbean.
- Pan Am was guaranteed all of the airmail contracts to the Far East as Pan Am began service across the Pacific.
- Pan Am Clippers crossed the Pacific making stops at Wake Island (1939-1948).

Boeing 314 “Clipper” - ten aircraft produced
1952

- **DeHavilland DH.106 Comet I** awarded first certificate of airworthiness for jet airliner

- **The Comet** first flew in 1949
- Early Comet models suffered from catastrophic metal fatigue, causing a string of well-publicized accidents
- The Comet was withdrawn temporarily and redesigned
- The Comet 4 series subsequently enjoyed a long and productive career of over 30 years, but sales never fully recovered

  - **Crew:** 4
  - **Capacity:** 56-109 pax
  - **Length:** 112 ft
  - **Wingspan:** 115 ft
  - **Loaded weight:** 162,000 lb
  - **Powerplant:** 4× Rolls-Royce Avon Mk 524 turbojets, 10,500 lbf
  - **Maximum speed:** 500 mph
  - **Range:** 3,225 mi (2,800 nm)
  - **Service ceiling:** 40,000 ft
A Bit of Aviation History

• **Trippe** thought **Pan Am** could benefit from the development of large long-range commercial jetliners.

• Pitting one manufacturer against the other, **Trippe** lured both **Boeing (707)** and **Douglas (DC-8)** into the jet building business.

• Both companies benefited, but **Pan Am** was ultimately the big winner.

• **Trippe** got the large new jet he wanted, the Boeing **707** (EIS 1958).

• **Pan Am** soon had an unheard of 90% occupancy on its fleet of jets.

• **DC8** (EIS 1959) **United Airlines** and **Delta Airlines**.

• **Trippe** was a driving force for “the airline jet age”
A Bit of Aviation History

- **Trippe**'s goal since the end of World War II was to make air travel affordable for the masses
- He envisioned a jumbo jet, a true oceanliner of the air
- **Trippe** sold **Boeing** on his idea for a new “jumbo jet” the **747** (EIS 1970)
- The **747** was a huge gamble for Trippe, and Boeing, which was driven to the brink of bankruptcy developing it
- Competing airlines were forced to keep pace with **Pan Am** and orders for the **747** soon came pouring in
- The **747** was the last in a long line of airplanes that **Juan Trippe** insisted had to be built
A Bit of Aviation History

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• When **Trippe** retired in 1968, **Pan Am** was flying to 85 nations in 6 continents

• **Trippe** died in 1981, his vision of a world where more people flew for less money had become a reality

• **Pan Am** collapsed in 1991, the victim of management errors and increased competition
A Bit of Aviation History

October 16, 1958 - First Lady Mamie Eisenhower and Pan Am Chairman Juan Trippe christen the Boeing 707-121, the plane that inaugurated the Commercial Jet Age for the United States with its flight from New York to Paris.

September 8, 1959 - A Pan Am Boeing 707, the first American-built jet airliner to land in Britain, lands in London. 10 crew members and 23 passengers made the historic trip from New York.

October 30, 1983 Trans World Airlines last scheduled 707 flight by a US carrier. 707s remained in scheduled service by airlines from other nations for much longer.
A Bit of Aviation History- Boeing 787 “Dreamliner”

- **Boeing 787** was designed in 2000
- Delivered to All Nippon Airways (ANA) September 2011
- First Boeing “fly by wire” airplane
- First commercial composite structure airliner
- The fastest recorded commercial revenue flight Feb. 2019 when a Boeing 787 was aided by a jet stream of 231 miles per hour
  - Where ~ 525 miles per hour is normal the airliner recorded speeds of 800 mph ground speed
- Longest non stop flight- Tahiti International Airport to Paris-Charles de Gaulle- 9,765 miles in just under 16 hours

- After Boeing began the 787 design using composite structures Airbus followed suit with the A350
A bit of Aviation History-Airbus A380

• The Airbus A380 is the world's largest passenger airliner

• The original plan was for Airbus and Boeing to go into the full design and build of this amazing aircraft, but Boeing dropped out of the agreement as it planned to focus more on the 747, 737 and 787 markets

• Airbus studies started in 1988 and the project was announced in 1990 to challenge the dominance of the Boeing 747 in the long-haul market

• Airbus launched the €9.5 billion ($10.7 billion) A380 program on December 19, 2000

• The first flight was 27 April 27, 2005

• Difficulties in electrical wiring caused a two-year delay and the development cost ballooned to €18 billion

• It was first delivered to Singapore Airlines on 15 October 15, 2007 and entered service on October 25th

• Production peaked at 30 per year in 2012 and 2014

• Airbus concedes that its $25 billion investment for the aircraft cannot be recouped

• On 14 February 2019, after Emirates reduced its last orders in favor of the A350 and the A330neo

• Airbus announced that A380 production would end by 2021
Next Session

• **Regulations and Agencies**
  • FAA, CAB, NTSB, TSA, ATA, IATA, ICAO, EASA how they have advanced to keep us safe
  • ETOPS – Extended Twin Engine Range