

# 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

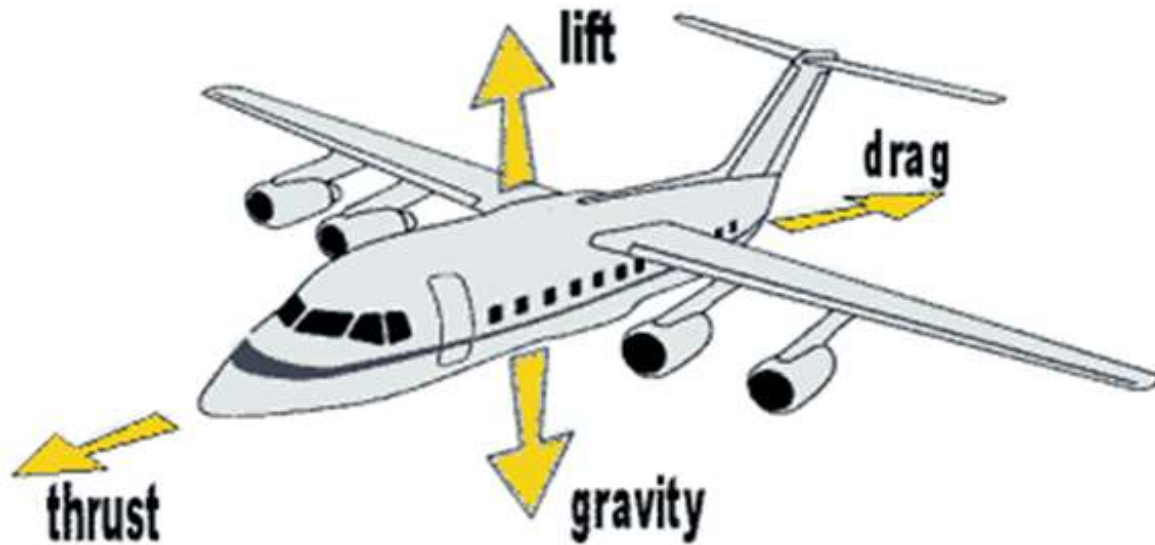
## **8. Future of Commercial Aviation**

What is next in commercial aviation, UDF, new fuels, Supersonic Transport, more advanced materials, or?

# Session 3

## Aircraft Design and Certification

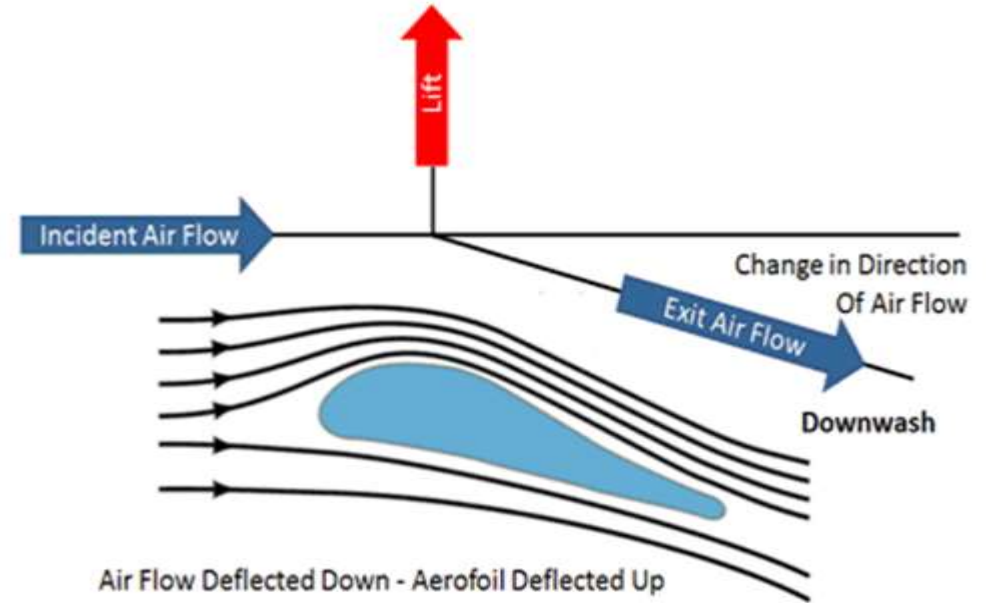
# Aircraft Design and Certification--How Airplanes Fly



<https://www.youtube.com/watch?v=F077WDnB8P8>

8 minutes

## Aerodynamic Lift – Explained by Newton’s Laws of Motion



Lift occurs when a moving flow of air is turned by a solid object. The flow is turned in one direction, and the lift is generated in the opposite direction, according to Newton’s Third Law of action and reaction. For an aircraft wing, both the upper and lower surfaces contribute to the flow turning or the downwash.

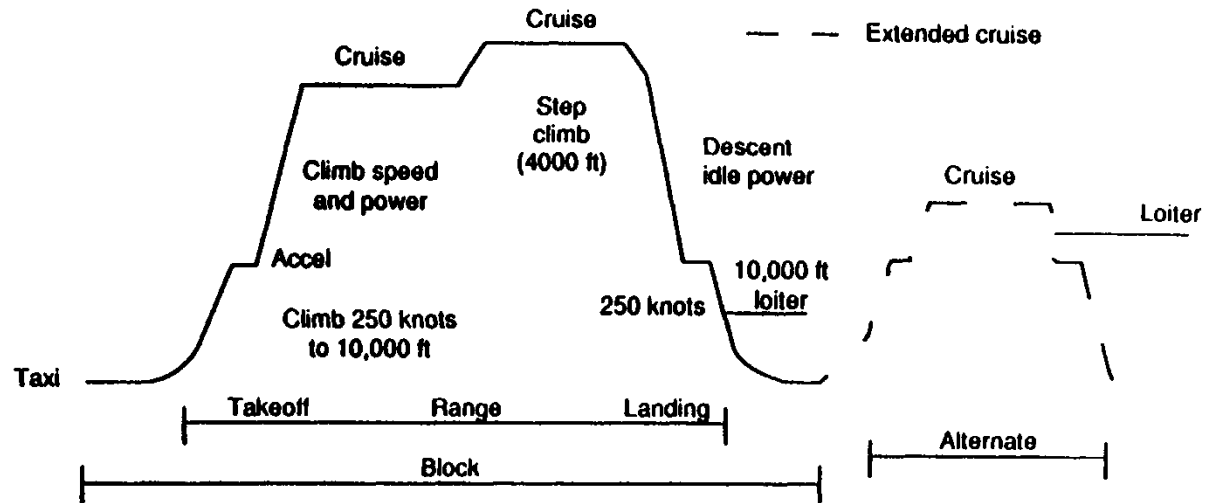
# Aircraft Design-- Overview

- **Need for aircraft**
- Based on aircraft market competition
  - Capacity
  - Range
  - Manufacturers current aircraft
  - Economic studies-national/international
  - Consultation with airlines
- **Decide configuration**
  - New aircraft--777X/A380
  - Derivative aircraft--737Max/A321
- **Conceptual Design**
  - A configuration that meets all requirements
    - Capacity/Range
    - Operating costs/Manufacturing costs
  - Factors include aerodynamics, propulsion, flight performance, structural and control systems, fuselage shape, wing configuration and location, engine size, and current FAA/EASA regulations
- **Preliminary design phase**
  - The design configuration is then tweaked and remodeled
  - Wind tunnel testing and computational fluid dynamics (CFD) calculations
  - Major structural and control analysis
  - The final design is drawn and finalized
- **Key decision**
  - Whether to go ahead with the production of the aircraft
    - Based on sales projections
    - Development and manufacturing costs estimates
- **Detail design phase**
  - Determines the number, design and location of ribs, spars, sections and other structural elements
  - Flight simulators for aircraft are developed

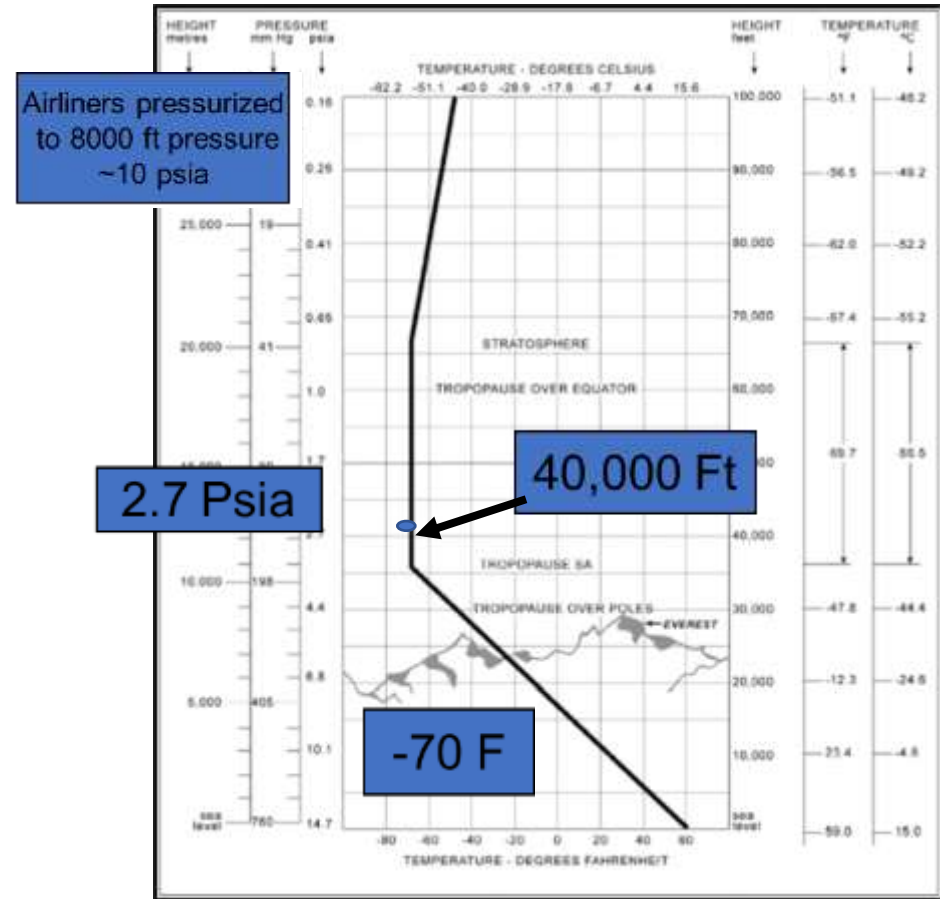
# Aircraft Design-- Overview

## Typical Commercial Transport Flight Mission

Typical cruise speed ~500-600 MPH  
 Typical takeoff speed ~160-200 MPH



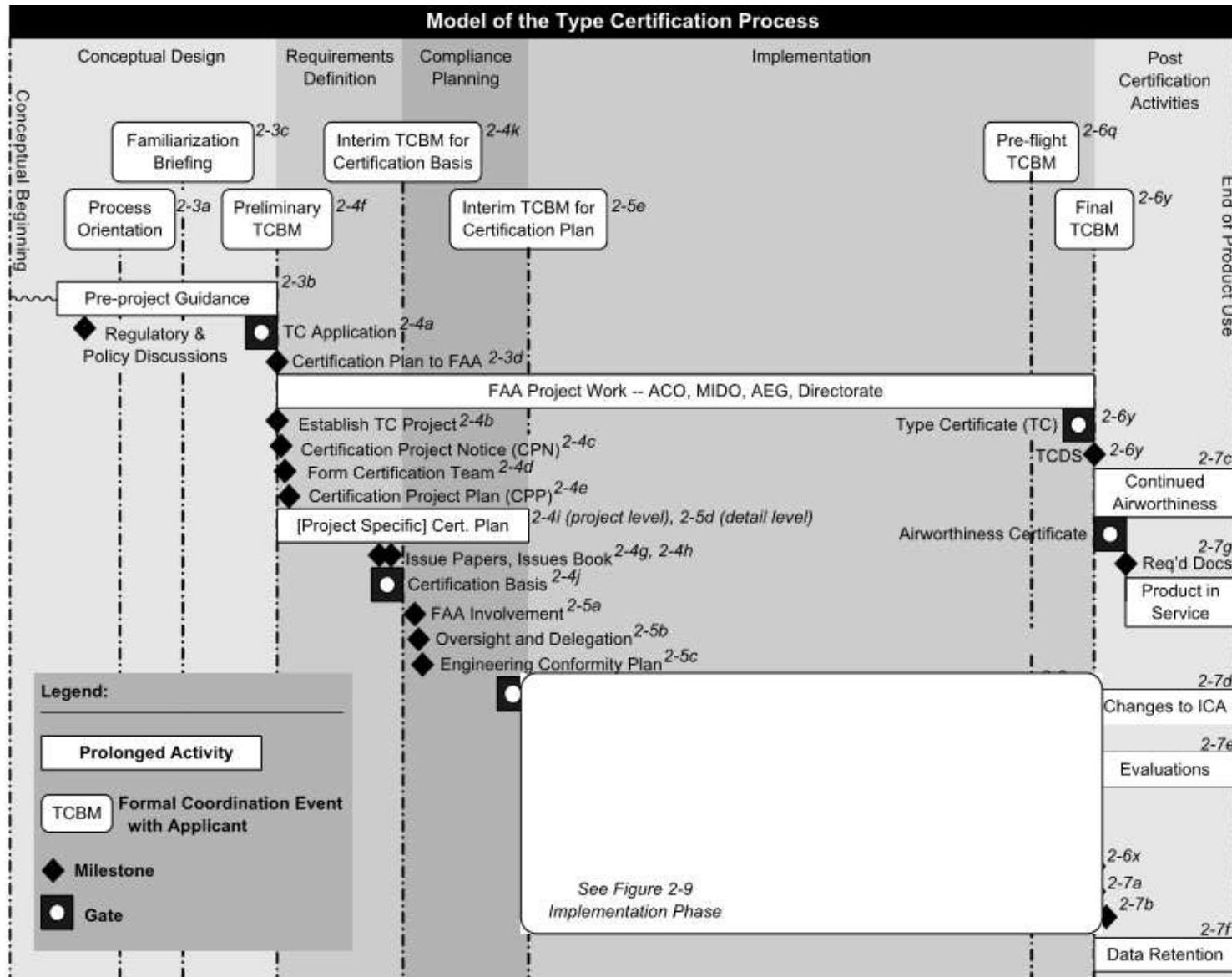
- City pair flight
- Represents reserve fuel allocations
  - Allocation depends on flight – Domestic/international
  - Fuel to alternate airport
  - Loiter/hold and extended cruise



# Aircraft Type Certification -Overview

- **Technical Overview and Certification Basis**
- Product designer presents the project to the primary certifying authority –the FAA /EASA
- The set of rules (**Certification Basis**) that will apply for the certification of this specific product type are established
  - Certification basis remains unchanged for a period of *five years* for an aircraft, *three years* for an engine
- **Certification Program**
- FAA/EASA and the designer define and agree on the means to demonstrate compliance of the product type with every requirement of the **Certification Basis**
- **Compliance demonstration**
- The designer must demonstrate compliance with regulatory requirements for all elements of the product e.g. the airframe, systems, engines, flying qualities and performance
  - Compliance demonstration is done by analysis combined with ground and flight testing
- FAA/EASA will perform a detailed examination of this compliance demonstration, by means of selected document reviews and test witnessing
- **Technical closure and Type Certificate** issue
- When technically satisfied with the compliance demonstration by the designer, the FAA/EASA issues a **Type Certificate (TC)**
- A **Type Certificate** applies to an aircraft (engine or propeller) of a particular Type Design
- Every individual aircraft of that type has to gain its own **Certificate of Airworthiness (C of A)** when it can be shown to conform to the certificated Type Design and is in a condition for safe operation
- Organization approvals, issued under Part 21, are based on regulatory assessment

# Aircraft Type Certification – Overview



# Aircraft Type Certification –Airframe Structure Testing

- **Airbus A380** and **A350 XWB** – undergo structural tests that include:
- Maximum wing bending at limit load, ailerons and spoilers functioning test during max wing bend
- Fuselage pressure test
- Fuselage fatigue tests and flight cycles simulation
- Fatigue testing examines how the aircraft structure responds to stress over a long period of time and during different stages of its operations, such as taxiing on the runway, take-off, cruising and landing
- To re-create these conditions, a combination of loads is placed on the airframe and activated by computer-operated hydraulic jacks
- The A380's fatigue testing lasted 26 months and was conducted to 2.5 times the design service goal
- ***Testing accumulated a total of 47,500 flight cycles: 2.5 times the number of flights that an A380 would make in 25 years of operations***
- A 16-hour flight was simulated in just 11 minutes. The tests pushed the aircraft structure to its limits to identify any necessary design improvement
- Final test and preparation for flight is a phase that includes calibration of the gauges, cabin pressurization testing and testing of navigation systems



# Aircraft Type Certification-- Structure Tests



<https://www.bing.com/videos/search?q=boeing+wing+tests&ru=%2fvideos%2fsearch%3fq%3dboeing%2bwing%2btests%26qpvt%3dboeing%2bwing%2btests%26FORM%3dVDRE&view=detail&mid=0A961E4F48DE45B395800A961E4F48DE45B39580&&FORM=VDRVRV>

787 fatigue test..... 3 minutes

## Aircraft Design and Certification – Current Boeing & Airbus Airliners

Founded - July 15, 1916

Boeing: In Production                      Delivered

787	Yes	789
777	Yes	1,584
767	Yes	1,135
757	No	1,049
747	Yes	1,548
737	Yes	10,463
727	No	1,831
720	No	154
717*	No	155
707	No	856

\* 717 is Boeing designation for McDonald Douglas MD80s

Founded – 1970

**AIRBUS**

Airbus: In Production

Delivered

A220	Yes	642
A320*	Yes	9,273
A330	Yes	1,819
A350	Yes	930
A380	No	251

\* Includes the A317, A318 & A319 models

*Designing an airplane is still a very complex engineering process. Today's airplanes designed after 2000, take advantage of quantum leaps in computer engineering and technology.*

*Equally important over the last several years are aircraft engine improvements in performance, and fuel efficiency.*

# Aircraft Design and Certification – Current Boeing Airliners

The Boeing Company Commercial Airliners Still In Production - 2020



From Left To Right  
Several 737 models, 747-8's, 767, 777, 787,  
747 Freighters, and Biz Jets.

Boeing is still hopeful that the new 777x and  
the 737MAX will be in service later this year.  
Or early in 2021.

Boeing's first "Market Forecast" was in 1961. Passenger traffic is now an  
increase of 70 times that report. Since 2000 the Global Network has expanded  
2.5 with 40% average lower fares in real terms.

The Boeing air travel market for airliners in this years update projects a  
doubling in size by 2038 with growth accounting for 56% while 44% will be to  
replace 75% of today's aging fleet.

# Aircraft Design and Certification

- The FAA certifies the design of aircraft and components that are used in civil aviation operations
- It is performance-based, proactive, centered on managing risk, and focused on continuous improvement
- Aircraft certification has relied on the exchange of information and technical data which has helped reduce risk of commercial aviation fatalities by 94 percent over the past 20 years
- The FAA's certification processes have produced safely designed airplanes for decades and continuously improve to maintain their position as the world's leader in aviation safety
- Since 1964, the regulations covering certification processes have been under constant review
- As a result, the regulations have been modified more than 90 times
- The rules applicable to large transport aircraft have been amended more than 130 times
- The FAA issues more than 300 safety-related Airworthiness Directives each year for operators to fix issues with aviation products
- Approximately 16,000 ADs issued to date

[https://www.youtube.com/watch?v=MyHUWG4\\_pXc](https://www.youtube.com/watch?v=MyHUWG4_pXc)

9 minutes – Lots of Why's

# Aircraft Design and Certification-FAA

- US Airline Regulation - **Federal Aviation Administration Aircraft Certification**
  - How Does the **FAA** Certify Aircraft? *Additional facts.*
  - The Federal Aviation Administration's (FAA) Aircraft Certification Service includes more than 1,300 engineers, scientists, inspectors, test pilots and other safety professionals
  - They are responsible for oversight of design, production, airworthiness certification, and continued airworthiness programs for nearly all U.S. civil aviation products:
    - Large and small airplanes
    - Rotorcraft
    - Engines and propellers
    - Foreign import products
  - The FAA collaborates with **the International Civil Aviation Organization (ICAO)** and other civil aviation authorities to maintain and advance the safety of international air transportation
- The FAA's aircraft certification processes are well established and have consistently assured safe aircraft designs
  - As part of any certification project, they conduct the following:
    1. A review of any proposed designs and the methods that will be used to show that these designs and the overall airplane complies with FAA regulations
    2. Ground tests and flight tests to demonstrate that the airplane operates safely
    3. An evaluation of the airplane's required maintenance and operational suitability for introduction of the airplane into service
    4. Collaboration with other civil aviation authorities on their approval of the aircraft for import

# Aircraft Design and Certification-FAA

- **The Boeing 737 MAX Certification**
- The Boeing **737 Max** design was noted as “minor changes” to the previous 737 Next Generation (NG) design?
- **However, the larger CFM LEAP engine diameter required for performance improvements, resulted in the different placement of the engines forward and up from the NG design**
- Do to the minor change notation, the **FAA** issued an **Amended Type Certificate** to the Max airplane, which was based on the Type Certificate of the previous **737NG**
- The **FAA** spent approximately *five* years certifying the **Boeing 737 MAX**
- If the change was not minor the introduction of this aircraft could have taken much longer, up to 9 years.
- Amended type certificates typically take 3-5 years to complete
- By comparison, the design, build, certification of a completely new aircraft type can take between 5 and 9 years, *i.e.* the **787 Dreamliner** and the **777X**
- During the certification process, FAA experts including chief scientists, engineers and flight test pilots, conducted in-flight testing of the flight control system, including the **MCAS**
- The **Maneuvering Characteristics Augmentation System (MCAS)** is a flight control system implemented on the **737 MAX** to improve aircraft handling characteristics and decrease pitch-up tendency at elevated angles of attack to abate any stall issues

<https://www.youtube.com/watch?v=GdkP9Y4QfRg>

Were they minor changes? 4 minutes

# Aircraft Design and Certification-FAA



Boeing 737 MAX

- Following two crashes FAA grounded the 737 Max aircraft
  - **Lion Air** on October 29, 2018 after taking off in Indonesia (189 died)
  - **Ethiopian Airlines** on March 10, 2019 after taking off in Ethiopia (157 died)
- FAA required changes to the aircraft's MCAS system
- FAA required pilot training using Flight Simulators programmed for the 737 Max MCAS system

## ***JUST THIS PAST WEEK***

- The Director of the FAA stated that when he is happy with and willing to approve the RTS of this airliner he would first fly in it with his entire family.
- He flew w/o his family and noted that all response systems are functioning extremely well, but, he is not quite ready yet to invite his family on-board.

The **Boeing 777X** is the latest series of the long-range, wide-body, twin-engine Boeing 777 family from Boeing. The 777X features new GE9X engines, new composite wings with folding wingtips, greater cabin width and seating capacity, and advanced technologies from the 787 Dreamliner.



*The 777X was launched in November 2013 with two variants: the 777-8 and the 777-9. The 777-8 provides seating for 384 passengers and has a range of 8,730 n-miles while the 777-9 has seating for 426 passengers and a range of over 7,285 n-miles. The 777-9 first flew on January 25, 2020, with deliveries expected to initiate in 2021.*

<https://www.youtube.com/watch?v=2CKET2tIN3s>

**5:21 Minutes and follow on 4:57 Minutes**



# Aircraft Design and Certification

- The **Boeing 777X** is the latest series of the long-range, wide-body, twin-engine **Boeing 777** family
- The **777X** features:
  - New **GE9X** engines-Certified September 28, 2020
  - New composite wings with folding wingtips
  - Greater cabin width and seating capacity
  - And advanced technologies from the **787 Dreamliner**
- The **777X** was launched in November 2013 with two variants: the 777-8 and the 777-9
- The 777-8 provides seating for 384 passengers and has a range of 8,730 n-miles
- The 777-9 has seating for 426 passengers and a range of over 7,285 n-miles
- The 777-9 first flew on January 25, 2020, with deliveries expected to initiate in 2021.



- 777X certification as derivative of 777 family
- Target 2021

# Aircraft Design and Certification



C919

<https://www.youtube.com/watch?v=YAXtYHiAqJ8>

2 minutes

- China's new **C919** – direct market competition with the Boeing 737 Max 8 & 9 models & the **Russian MC21**
- Planned for revenue service in 2021
- Use **CFMI Leap** engines
- There is evidence that this plane will be offered at a price that is 25% less than Boeing 737MAX?
- Will require FAA approval to land in the US
  - Certificate of Airworthiness

# Aircraft Design and Certification



MC-21

<https://www.youtube.com/watch?v=aWG-zYpTmXU>

- The new Russian **MC-21**
- 160 – 200 passenger aircraft
- First competitive Russian aircraft
- Planned for service entry in 2021
- Uses PW **PD-14 turbofan** engines
- Direct competition with the Boeing 737 MAX and the Chinese C919
- Will require FAA approval to land in the US
  - Certificate of Airworthiness

4 minutes

# Aircraft Design and Certification

- And of course the newer aircraft designs drive the way for better designed and more efficient “Gas Turbine Engines” like the **GE9X**
- **GE9X** Dimensions information:
  - - Diameter is ~ 13 feet – wider than the fuselage of a 737
  - - Length is ~ 18 feet
  - - Weight is ~ 18,300 #’s
  - - Thrust is capable up to ~ 130,000 lb’s
- Will only require 105,000 on its first **777X** application

777x – GE9X 3.5

<https://www.youtube.com/watch?v=fe8CV1yZQCc>



GE9X 2.5

[https://www.youtube.com/watch?v=XEiWwRyq\\_9E](https://www.youtube.com/watch?v=XEiWwRyq_9E)

## Next Session--Aircraft Manufacturing

- Manufacturers
- Wood to composites
- Outsourcing
- Engines
- Introducing new airliners from Boeing, Airbus & the competition from China & Russia

[https://www.bing.com/videos/search?q=MyHUWG4\\_pXc&&view=detail&mid=C87A6F168EC2A69FAA98C87A6F168EC2A69FAA98&&FORM=VRDGAR&ru=%2Fvideos%2Fsearch%3Fq%3DMyHUWG4\\_pXc%26go%3DSearch%26qs%3Dds%26form%3DQBVR](https://www.bing.com/videos/search?q=MyHUWG4_pXc&&view=detail&mid=C87A6F168EC2A69FAA98C87A6F168EC2A69FAA98&&FORM=VRDGAR&ru=%2Fvideos%2Fsearch%3Fq%3DMyHUWG4_pXc%26go%3DSearch%26qs%3Dds%26form%3DQBVR)

9 minutes – (could stop at 6 minutes) – Optional – only play if time permits