

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

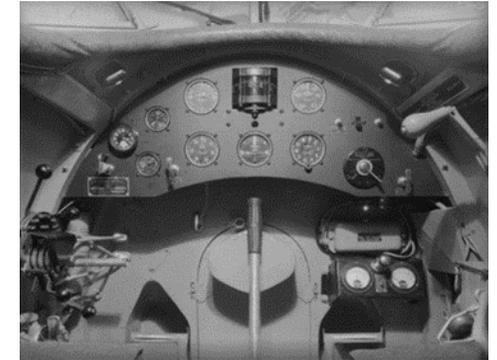
- **Allan Loughead** and his brother **Malcolm Loughead** had operated an earlier aircraft company, **Loughead Aircraft Manufacturing Company**, which was operational from 1912 to 1920
- The company built and operated aircraft for paying passengers on sightseeing tours in California and had developed 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**



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- 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

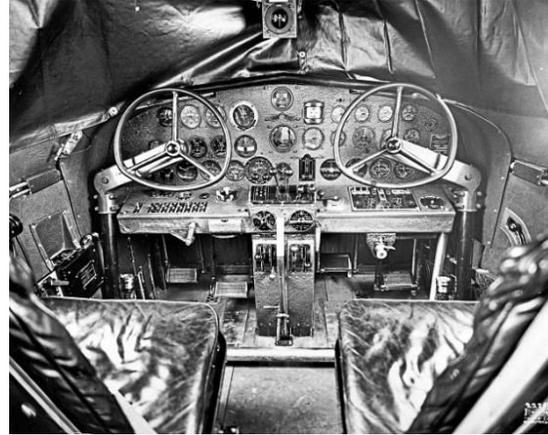
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- **Lockheed Model 10 Electra** was a twin-engine, all-metal monoplane airliner developed in the 1930s to compete with the **Boeing 247** and **Douglas DC-2**
- The type was flown by **Amelia Earhart** on her attempted around-the-world expedition in 1937
- 149 **Model 10 Electras** were built



A Bit of History Lockheed Aircraft Company Model 10 Electra

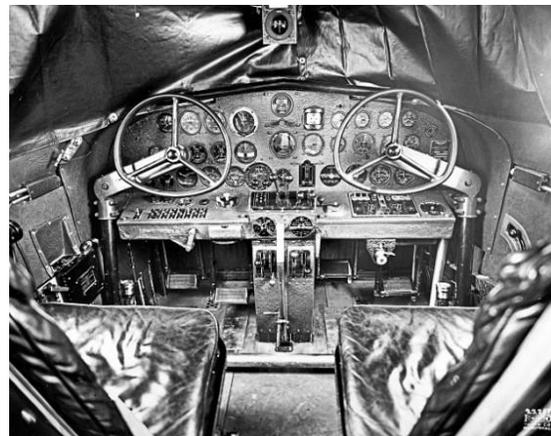


Model 10 Electra 10 passengers and 2 crew



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



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Lockheed Super Electra	1937	12-14 passengers	Cruise	215 mph	Range	850 mi	Production 354
Boeing 247	1933	10 passengers	Cruise	189 mph	Range	745 mi	Production 75
Douglas DC-2	1934	14 passengers	Cruise	190 mph	Range	1,000 mi	Production 156
Douglas DC-3	1936	21+passengers	Cruise	207 mph	Range	1,580 mi	Production 455 (10,174)

A Bit of History Lockheed Aircraft Company Military Aircraft

- 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

First flight	June 7, 1938 EIS 1939
Model number	314A
Classification	Commercial transport
Span	152 feet
Length	106 feet
Gross weight	84,000 pounds
Top speed	199 mph
Cruising speed	184 mph
Range	5,200 miles
Ceiling	19,600 feet
Power	Four 1,500-horsepower Wright GR-2600 Double Cyclone engines
Accommodation	10 crew, 74 passengers Number Built 12



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**

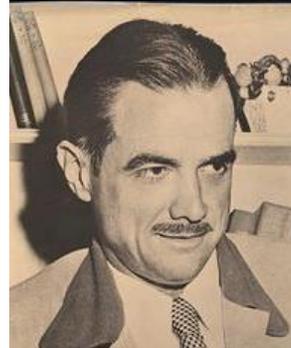
A Bit of History Boeing 307 Stratoliner

- 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

Specification (L-1049C)

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



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*

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	L-649	L-749	L-1049	L-1649
Crew	5	6 – 8	4	5
Capacity	60 – 81	60 – 81	47 – 106	99
Length	95'3"	97'4"	113'7"	116'2"
Wingspan	123'	123'	123'	150'
MTOW	94,000lb	107,000lb	120,000lb	156,104lb
Speed	327 mph	345 mph	304 mph	290 mph
Range	2,290 – 3,995 mi	2,600 – 4,995 mi	5,150 mi	4,940 – 6,180 mi

Boeing 707 4 engine jet

Crew 3

Capacity 189 max

Cruise speed ~600mph

Range ~5700 miles

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)

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



DC-6 (1946-1958) and DC-7 (1953-1958)
Both were pressurized

A Bit of History Boeing 377 Stratocruiser



First flight July 1947
EIS Pan Am April 1949



1947

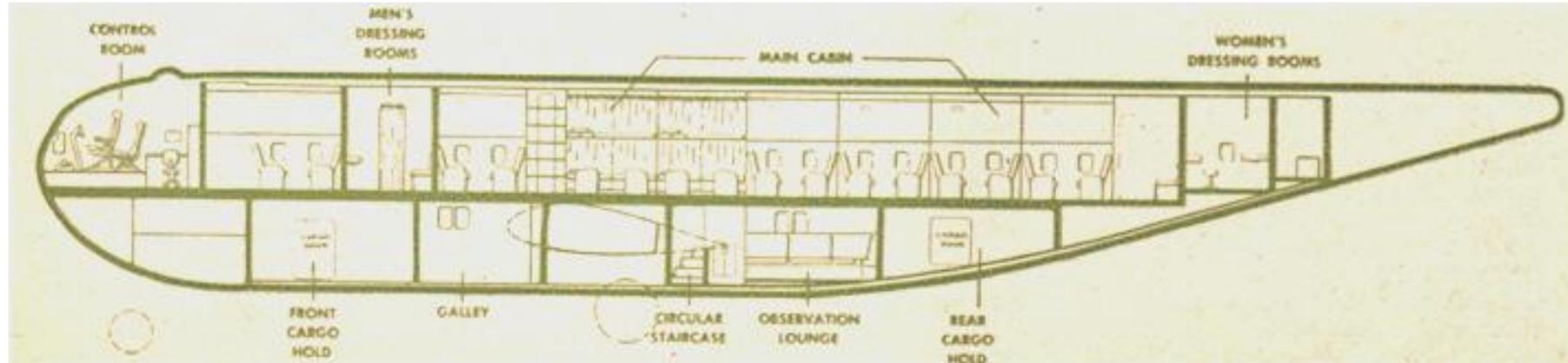
Specification

Type:	long-range airliner
Dimensions:	wing span 43m (141ft 3in), length 33.65m (110ft 4in), height 11.66m (38ft 3in)
Normal take-off weight:	76,195kg (145,800lb)
Powerplant:	four 3500hp Pratt & Whitney R-4360 Wasp Major 28-cylinder, four-row turbo-supercharged radial piston engines
Maximum speed:	603km/h (375mph)
Range:	7360km (4600 miles)
Service ceiling:	more than 9760m (32,000ft)
Flight crew:	5
Passengers:	typically 67 passengers on the upper deck and 14 below
	Number built 56

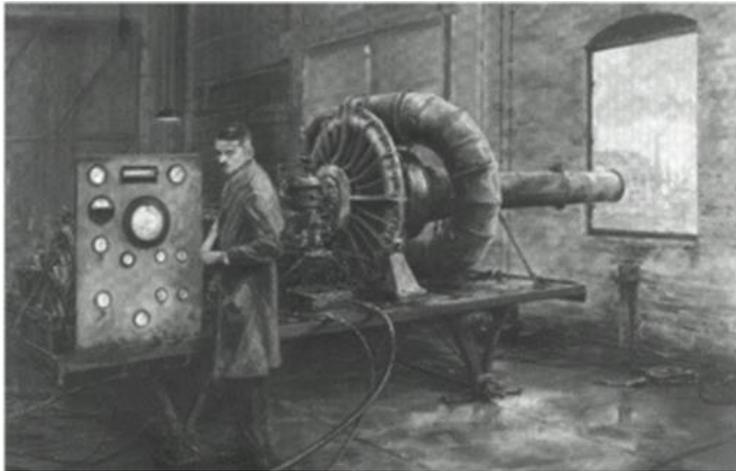
Boeing 377 Stratocruiser was developed from the **C-97** military transport

C-97 was a derivative of the **B-29**

A Bit of History Boeing 377 Stratocruiser

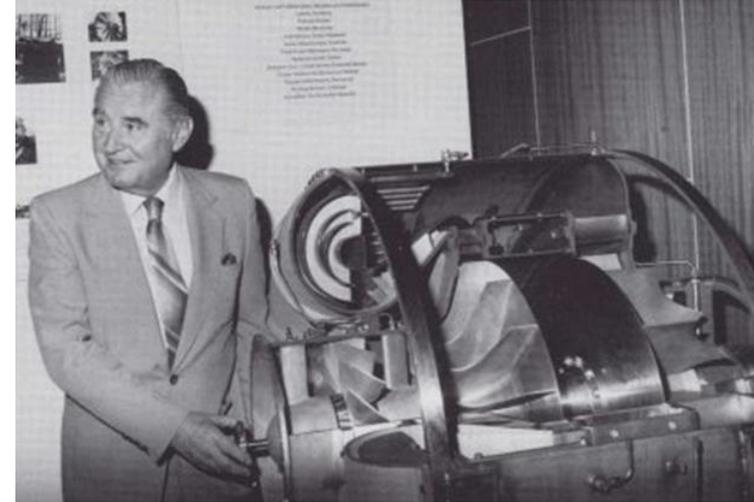
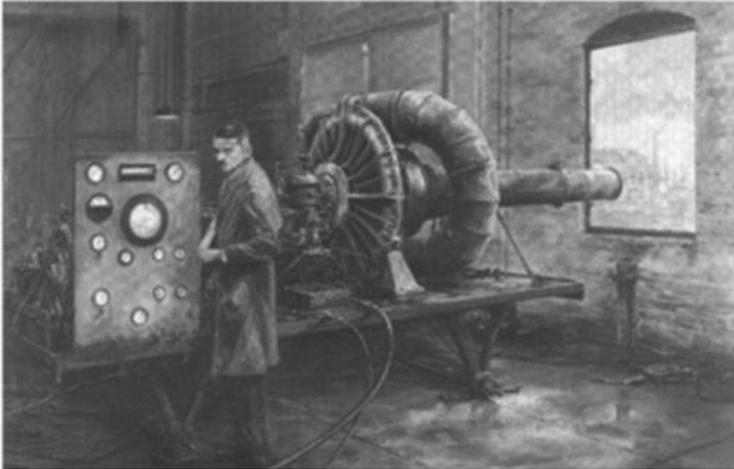


Jet Engines European Wartime Inventions



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

Jet Engines European Wartime Inventions



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- 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

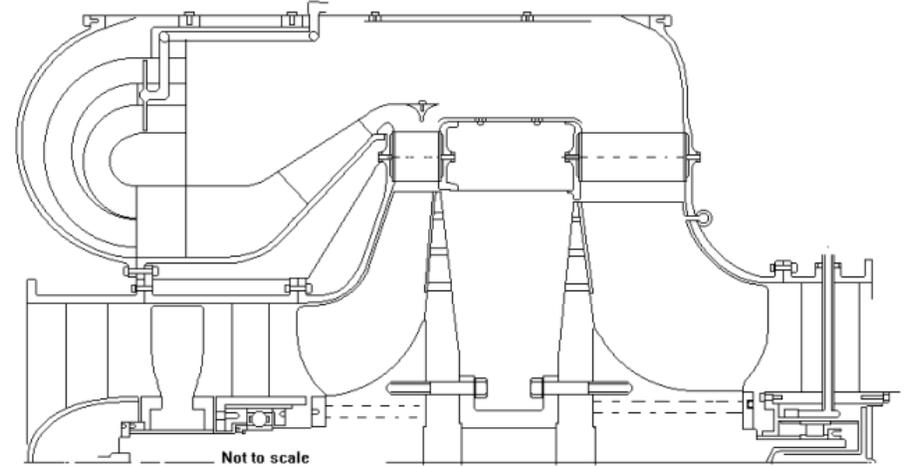
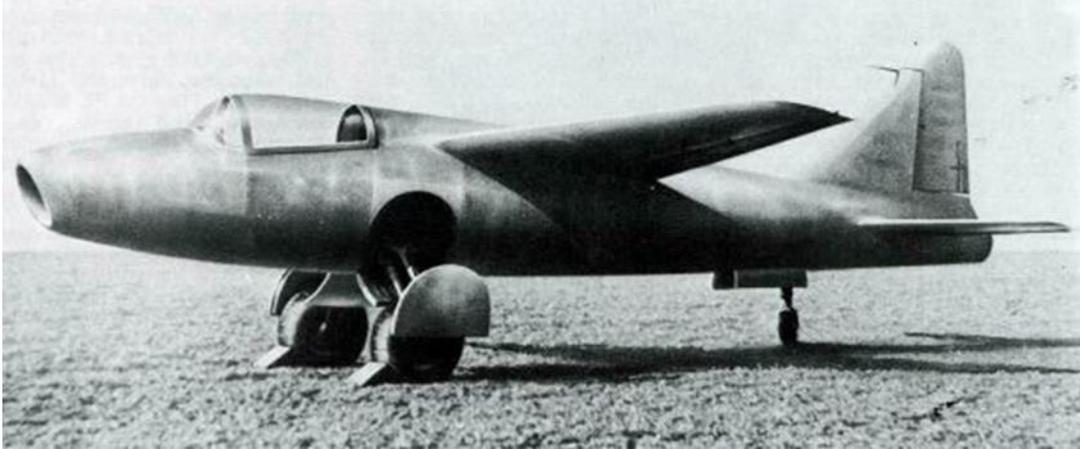
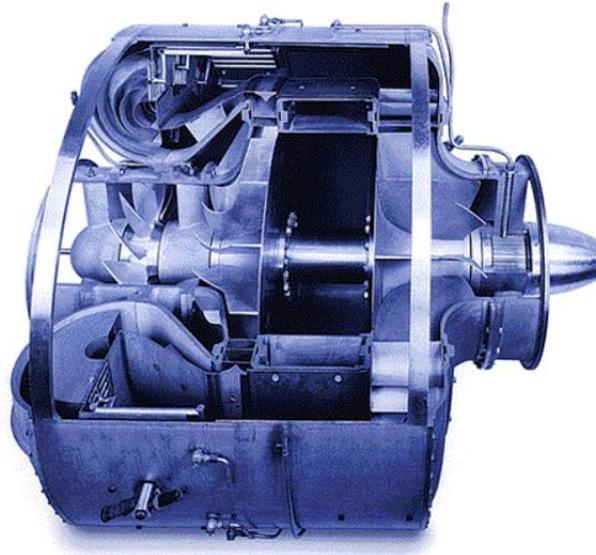


Fig 1 He S3B Turbojet Cross Section

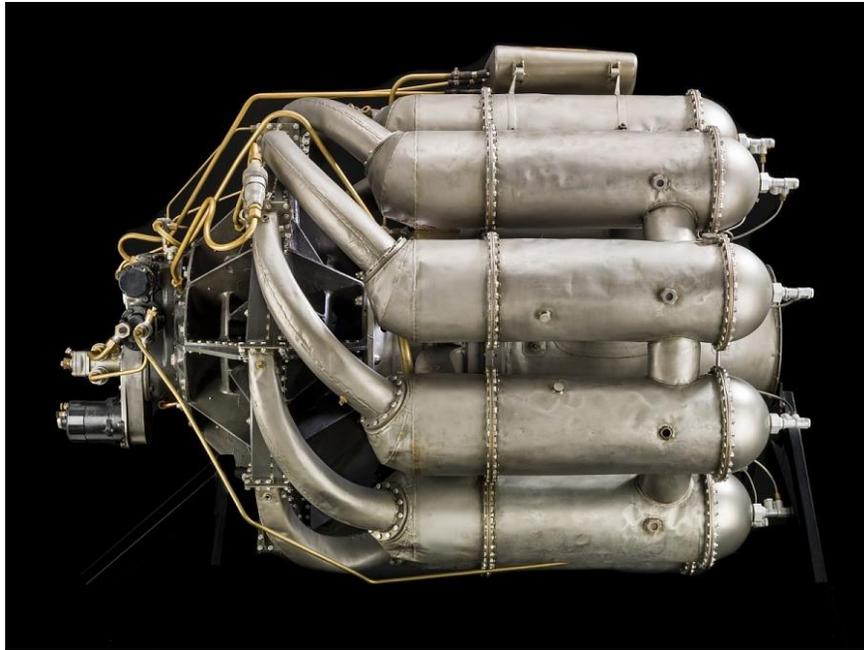
- 1939 **Heinkel He 178**
- World's first turbojet powered aircraft
- Powered by **von Ohain's HeS3b** engine
- Thrust ~1100 lbf
- RPM ~12,000



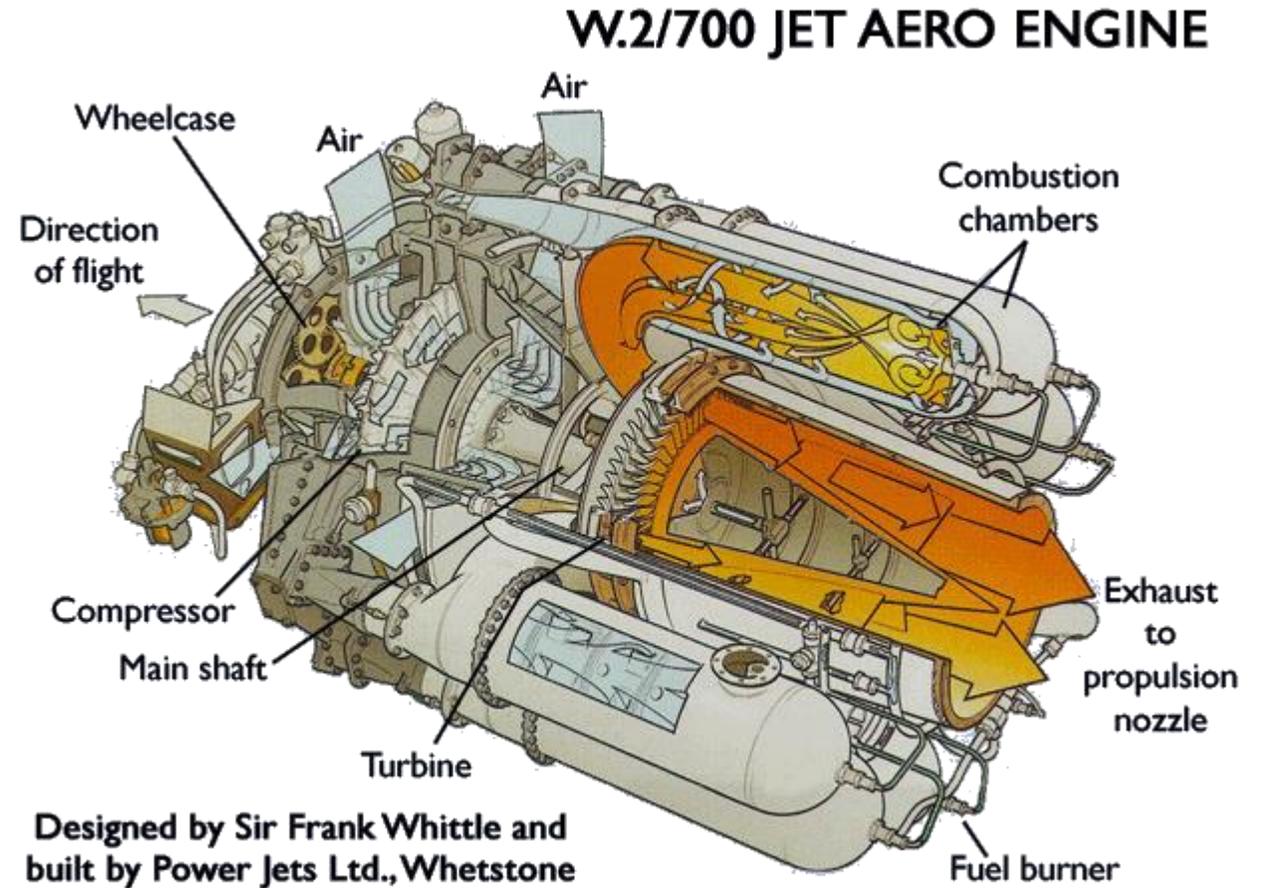
- 1942 First jet flight of **Messerschmitt Me262**
 - Twin turbo jet fighter
- Two **Jumo 004** engines powered the **Me 262**
- The first jet fighter to fly in combat
- Engine life was very short
 - Germans had no source of chromium



Whittle Jet Engine

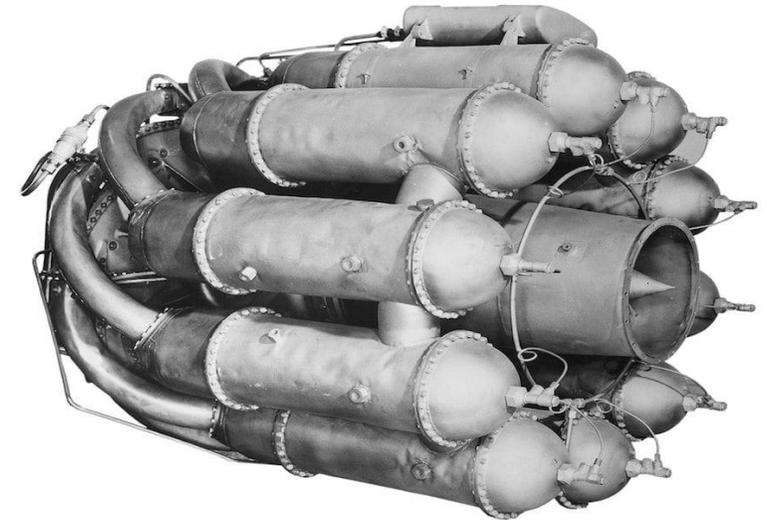


- Type: Turbojet
- Thrust: 1,240 lb at 17,750 rpm
- Compressor: Single-stage, double entry, centrifugal
- Combustor: 10 reverse flow chambers
- Turbine: Single- stage axial
- Weight: 560 lb

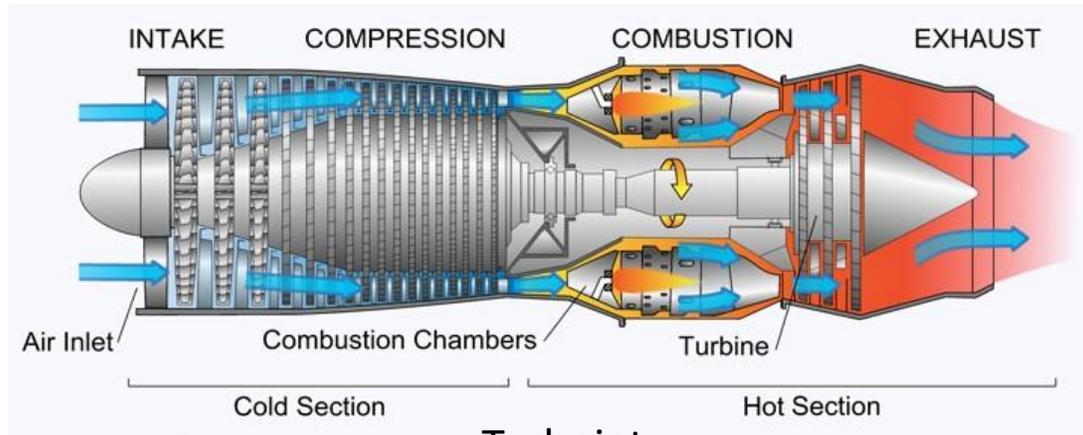


First U.S. Jet Aircraft

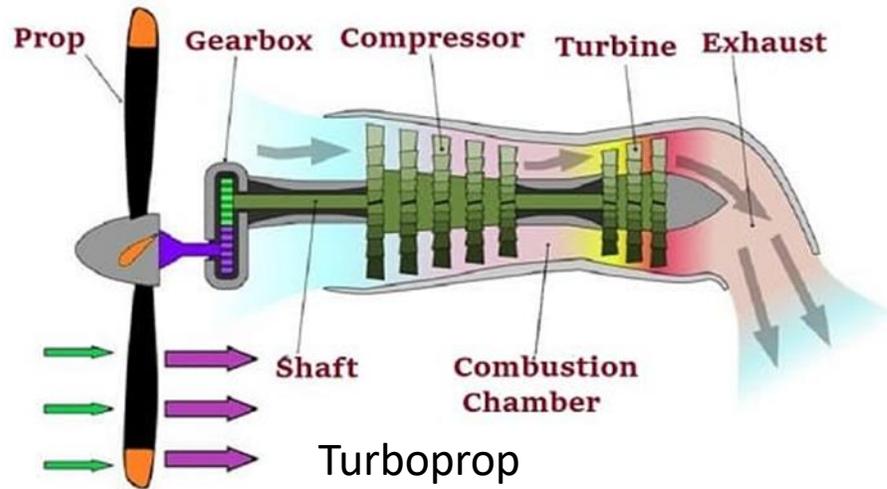
- 1942 First flight of **Bell XP-59A** prototype
 - First U.S turbo jet aircraft
 - Powered by **GE** built version of **Whittle** engine
 - Aircraft not much better than piston engine fighters



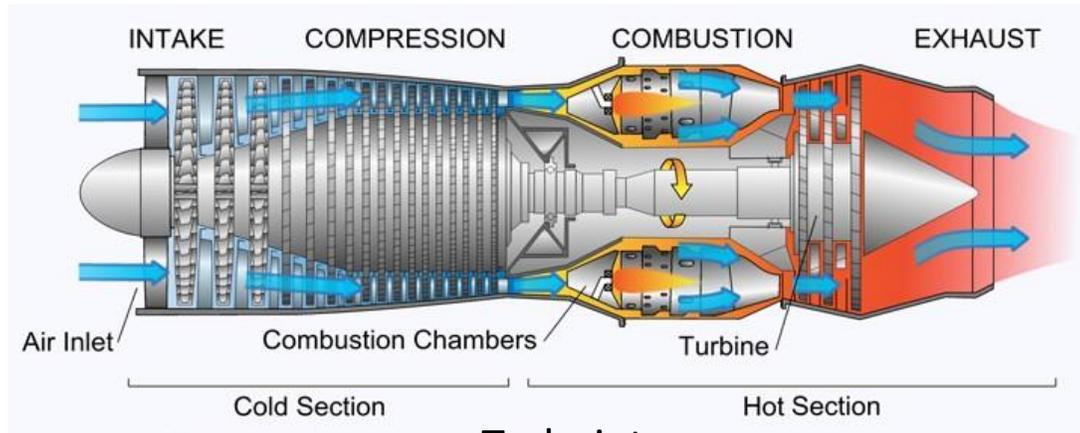
Gas Turbine Aircraft Engines



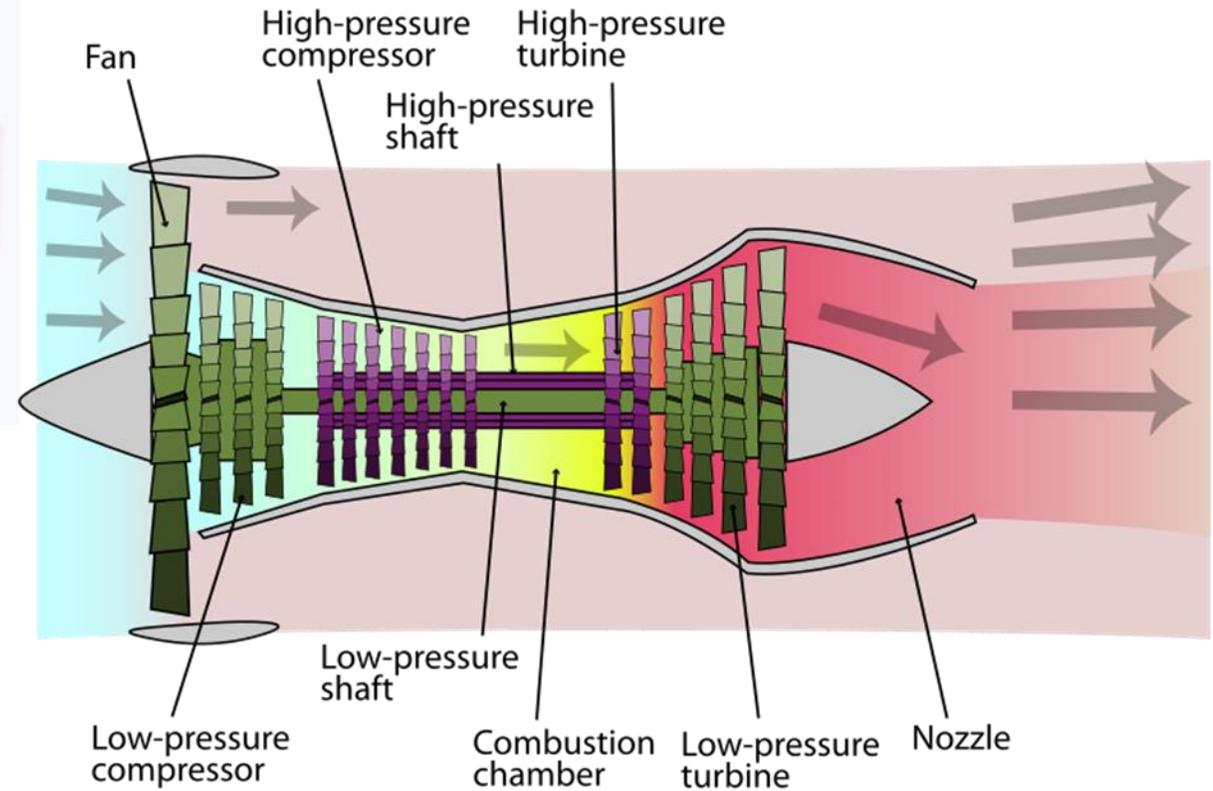
Turbojet



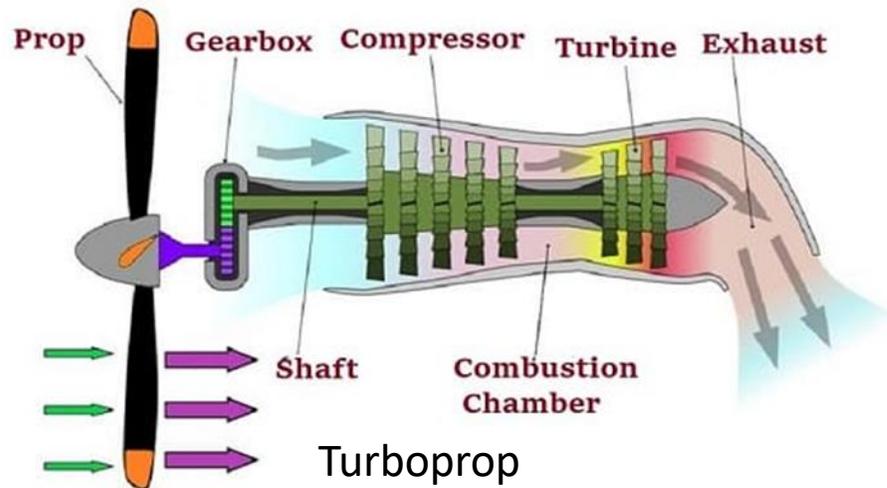
Gas Turbine Aircraft Engines



Turbojet



Turbofan



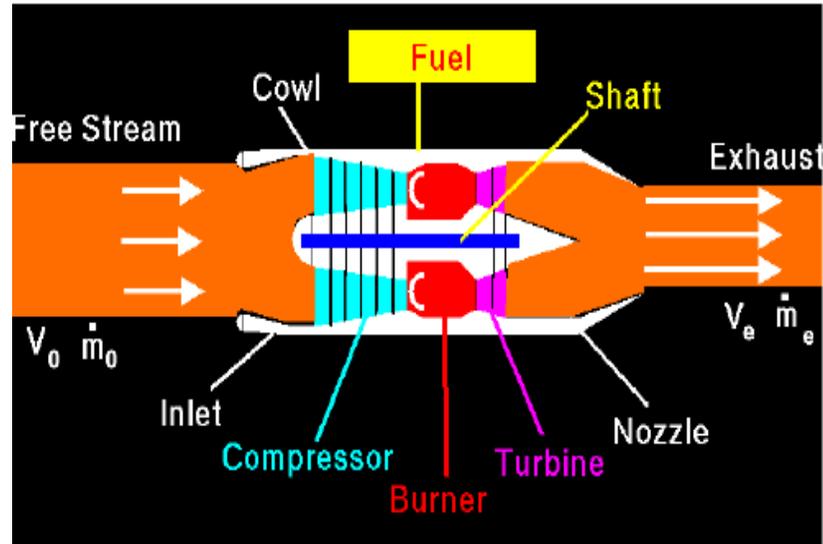
Turboprop

Gas Turbine Aircraft Engines

<https://www.youtube.com/watch?v=sHUUYU5GuNM>

Jet Engine Thrust

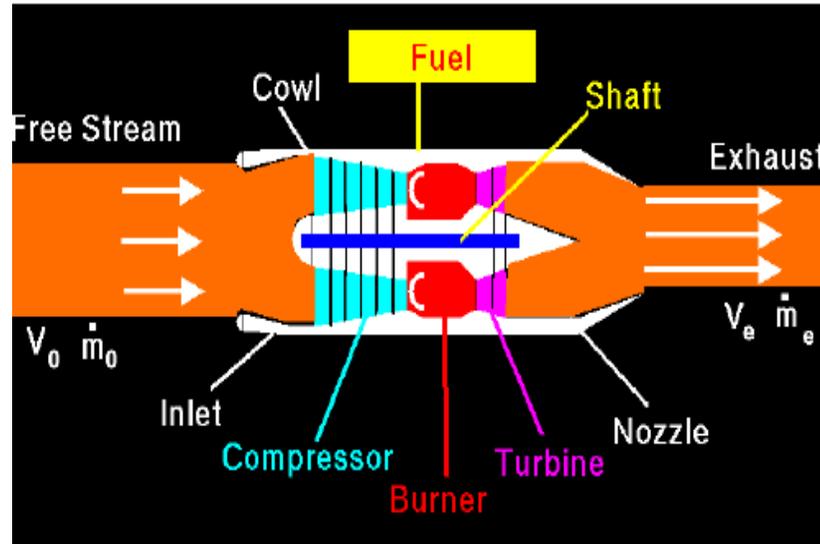
Turbojet



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

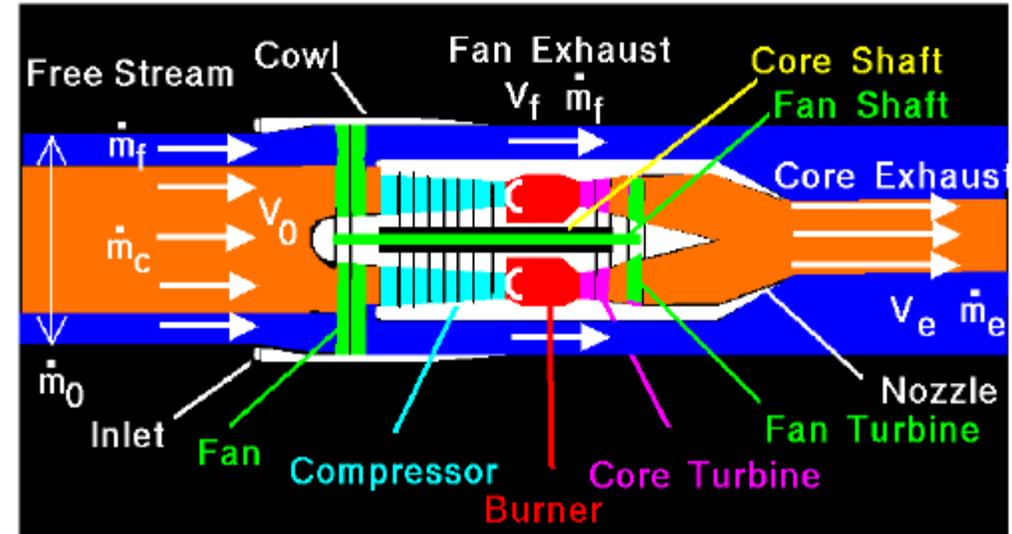
Jet Engine Thrust

Turbojet



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

High Bypass Fan Jet Engine



Thrust = Thrust of Fan + Thrust of Core

$$F = \dot{m}_f V_f - \dot{m}_f V_0 + \dot{m}_e V_e - \dot{m}_c V_0$$

$$F = \dot{m}_e V_e - \dot{m}_0 V_0 + \text{bpr} \dot{m}_c V_f$$

Mass flows

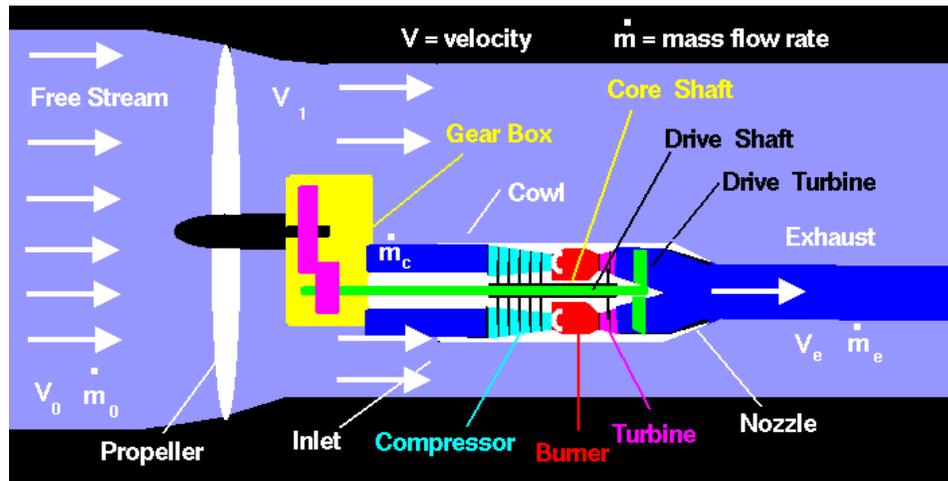
$$\dot{m}_0 = \dot{m}_f + \dot{m}_c$$

Bypass ratio = bpr

$$\text{bpr} = \dot{m}_f / \dot{m}_c$$

Turboprop Engine Thrust

Turboprop



Thrust = Thrust of Propeller + Thrust of Core

$$F = \dot{m}_o V_1 - \dot{m}_o V_0 + \dot{m}_e V_e - \dot{m}_c V_1$$

$$F = \dot{m}_o (V_1 - V_0) + \dot{m}_e (V_e - V_1)$$

(Large)

(Small)

Mass Flows

$$\dot{m}_o > \dot{m}_c$$

$$\dot{m}_e \sim \dot{m}_c$$



GE T64 turboprop

A Bit of History Vickers Viscount

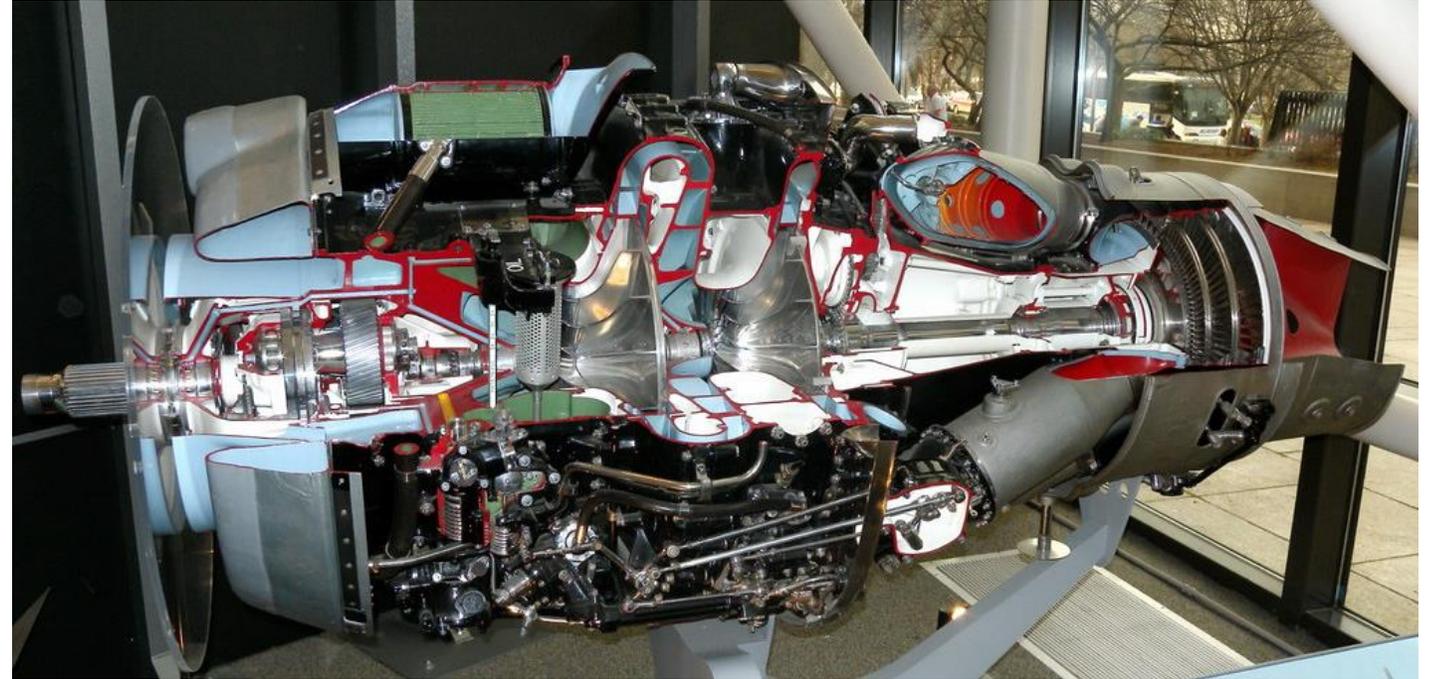
- The **Vickers Viscount** was the first *turboprop* airliner, and became extremely popular for its smooth, quiet ride
- It debuted in 1950 with a 50-passenger configuration
- A quarter of all European passenger flights in the 1950s were booked on the **Vickers Viscount**
- 440 **Viscounts** were produced from 1948 thru 1963
- **Crew:** 2 pilots + cabin crew
- **Capacity:** 75 passengers
- **Max takeoff weight:** 67,500 lb
- **Powerplant:** 4 x 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

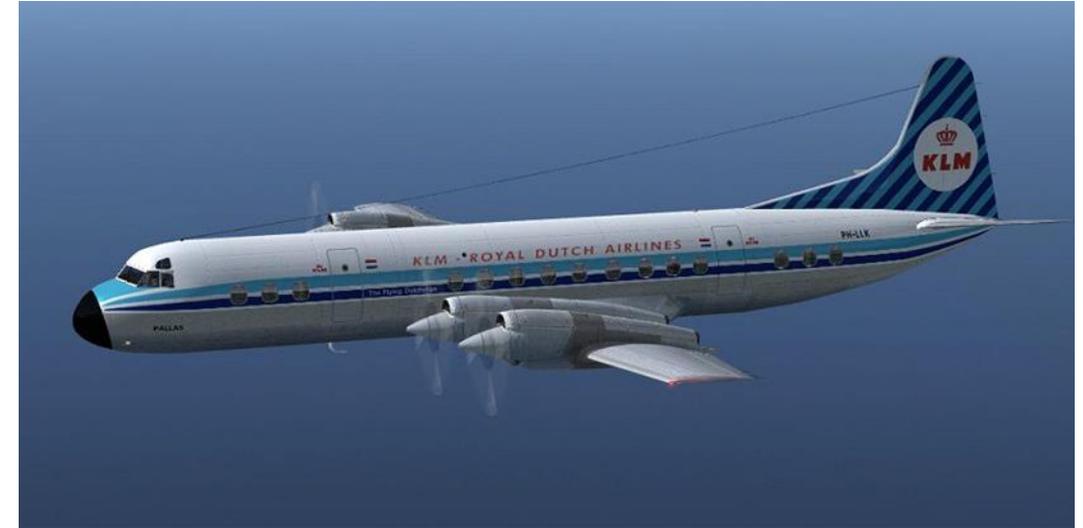


1,990 HP



A Bit of History Lockheed L-188 Electra Turboprop

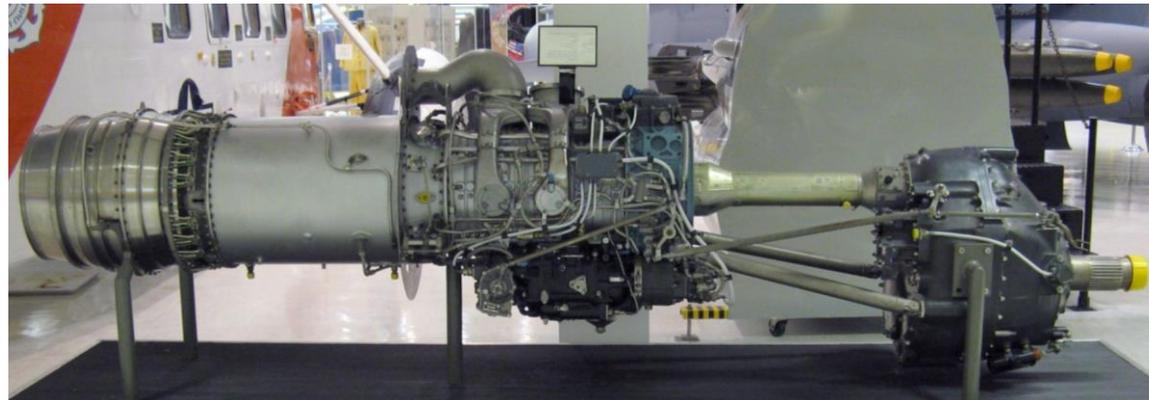
- The **Lockheed L-188 Electra** was developed to meet a 1954 **American Airlines** requirement for a domestic short to medium range 75 to 100 seat airliner
- June 1955 **American** awarded **Lockheed** an order for 35 such aircraft
- The **L-188**, was a low wing, four turboprop powered aircraft
- Many 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



Allison 501-D13 3,750 HP

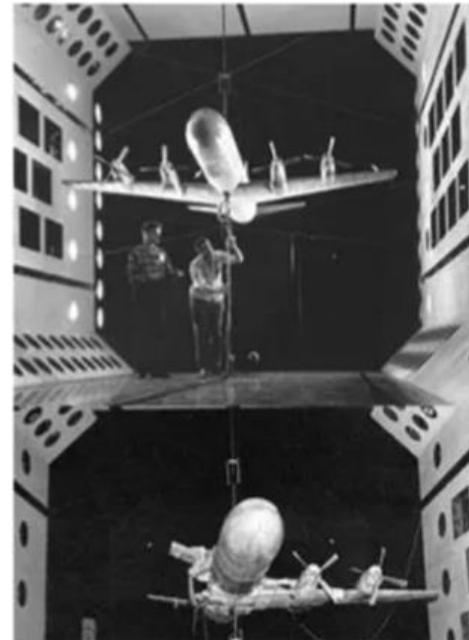
Lockheed L-188 Electra

- 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

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'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

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- 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