CEE 5614

Quick Overview of Aircraft Classifications

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Material Presented

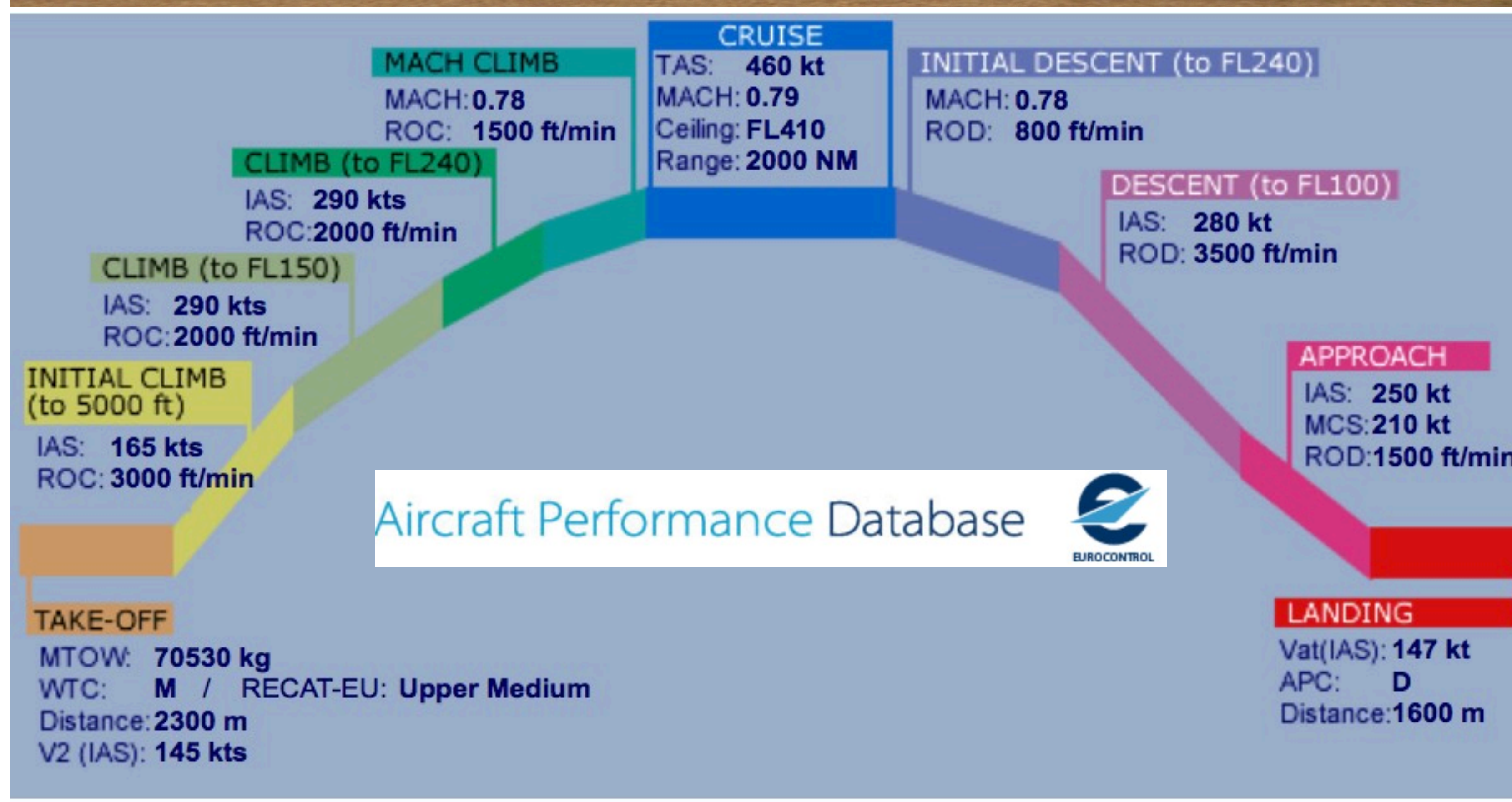
- Aircraft classifications
- Explain the impact of aircraft classifications and their effect in aviation operations

Relevance of Aircraft Characteristics

- Aircraft classifications are necessary in airport and airspace operations
- Most of the airport design standards are related to aircraft size (i.e., wingspan, aircraft length, aircraft wheelbase, aircraft seating capacity, etc.)
- Many of the same standards apply to the modeling and simulation of aviation operations
- The current air transportation system has a diverse pool of aircraft

Aircraft Performance in Aviation Operations

Important to know the performance aspects of the aircraft on the ground and in the air to model aviation operations

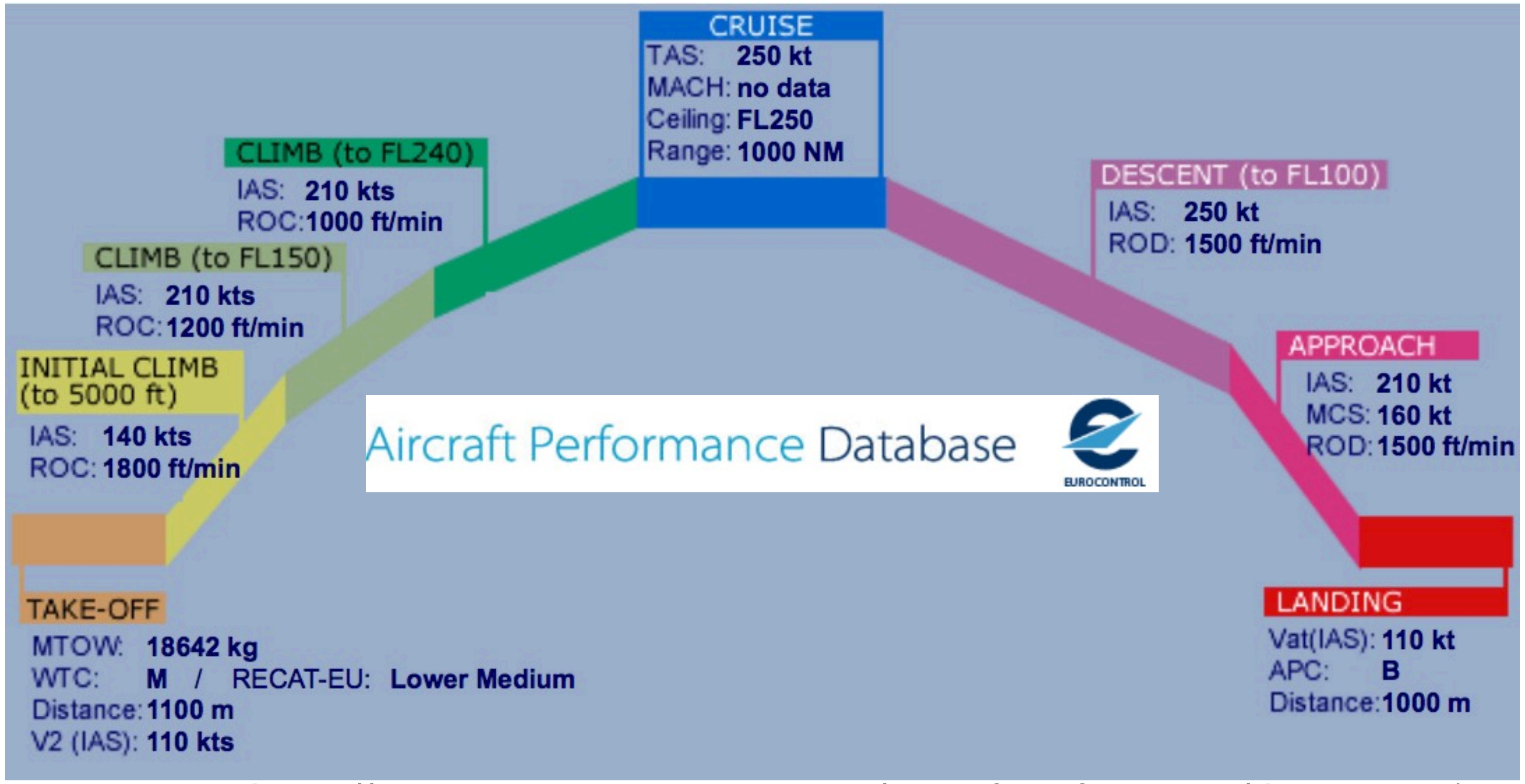


source: Eurocontrol Aircraft Performance database

source: https://contentzone.eurocontrol.int/aircraftperformance/details.aspx?ICAO=B738&NameFilter=737

Aircraft Performance in Aviation Operations

The turbo-prop aircraft shown to the right shows significant performance differences with the Boeing 737-800 presented in the previous slide



source: Eurocontrol Aircraft Performance database

source:https://contentzone.eurocontrol.int/aircraftperformance/details.aspx?ICAO=DH8C&GroupFilter=9

Important Nomenclature

- **Knot** = nautical mile per hour
  - The knot is the speed unit used in aviation
  - Knot = 1.15 miles per hour
  - Example: a Boeing 737-9Max typically cruises at 440 knots (506 mph)
- **Flight level = FL**
  - Height (in feet/100) above mean sea level conditions used by pilots and Air Traffic controllers
  - FL300 is equivalent to 30,000 feet

Federal Aviation Administration (FAA) Design Criteria

- Planning airport operations requires information of various aircraft features
- The FAA considers three important features of every aircraft:
  - Aircraft Approach Category (AAC)
  - Airplane Design Group (ADG)
  - Taxiway Design Group (TDG)
- The following slides provide some guidance in how to find these three attributes for each aircraft

Source to Find Aircraft Approach Speed and Aircraft Mass (weight) Data

- FAA Aircraft Characteristics Database (validated by Virginia Tech)

http://www.faa.gov/airports/engineering/aircraft_char_database/

	A	B	C	D	E
1	**ICAO_Code**	**FAA_Designator**	**Manufacturer**	**Model_FAA**	**Model_BADA**
2	A10	A10	FAIRCHILD	Fairchild A10	Fairchild A-10A
3	A124	A124	ANTONOV	Antonov AN-124 Ruslan	Antonov AN-124-100
4	A19N	A19N	AIRBUS	Airbus A319 Neo	Airbus A319 Neo
5	A20N	A20N	AIRBUS	Airbus A320 Neo	Airbus A320-271N
6	A21N	A21N	AIRBUS	Airbus A321 Neo	Airbus A321-251N
7	A306	A306	AIRBUS	Airbus A300 B4-600	Airbus A300B4-622
8	A30B	A30B	AIRBUS	Airbus A300-B2	Airbus A300B4-203
9	A310	A310	AIRBUS	Airbus A310	Airbus A310-204
10	A318	A318	AIRBUS	Airbus A318	Airbus A318-112
11	A319	A319	AIRBUS	Airbus A319	Airbus A319-131

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Federal Aviation Administration (FAA) Aircraft Design Group (ADG) Classification

Design Group	Tail Height (Feet)	Wingspan (feet)	Representative Aircraft Types
I	<20	<49	Cessna 172, Beech 36, Cessna 421, Learjet 35
II	20 to <30	49 to < 79	Beech B300, Cessna 550 Falcon 50, Challenger 605
III	30 to <45	79 to < 118	Boeing 737, Airbus A320 CRJ-900, EMB-190
IV	45 to < 60	118 to < 171	Boeing 767, Boeing 757, Airbus A300, Douglas DC-10
V	60 to < 66	171 to < 214	Boeing 747, Airbus A340, Boeing 777
VI	66 to <80	214 to < 262	Airbus A380, Antonov 124*

* The Antonov 225 has a wingspan of 290 feet (in a class by itself). Only one aircraft produced.

FAA Aircraft Approach Speed Classification (AAC)

Airport Terminal Area Procedures Aircraft Classification (FAA Scheme)

Group	Approach Speed (knots)[a]	Example Aircraft[b]
A	< 91	All single engine aircraft, Beechcraft Baron 58,
B	91-120	Business jets and commuter aircraft (Beech 1900, Saab 2000, Saab 340, Embraer 120, Canadair RJ, etc.)
C	121-140	Medium and Short Range Transports (Boeing 727, B737, MD-80, A320, F100, B757, etc.)
D	141-165	Heavy transports (Boeing 747, A340, B777, DC-10, A300)
E	> 166	BAC Concorde and military aircraft

a. At maximum landing mass.

b. See FAA Advisory Circular 150/5300-13 for a complete listing of aircraft TERP groups and speeds

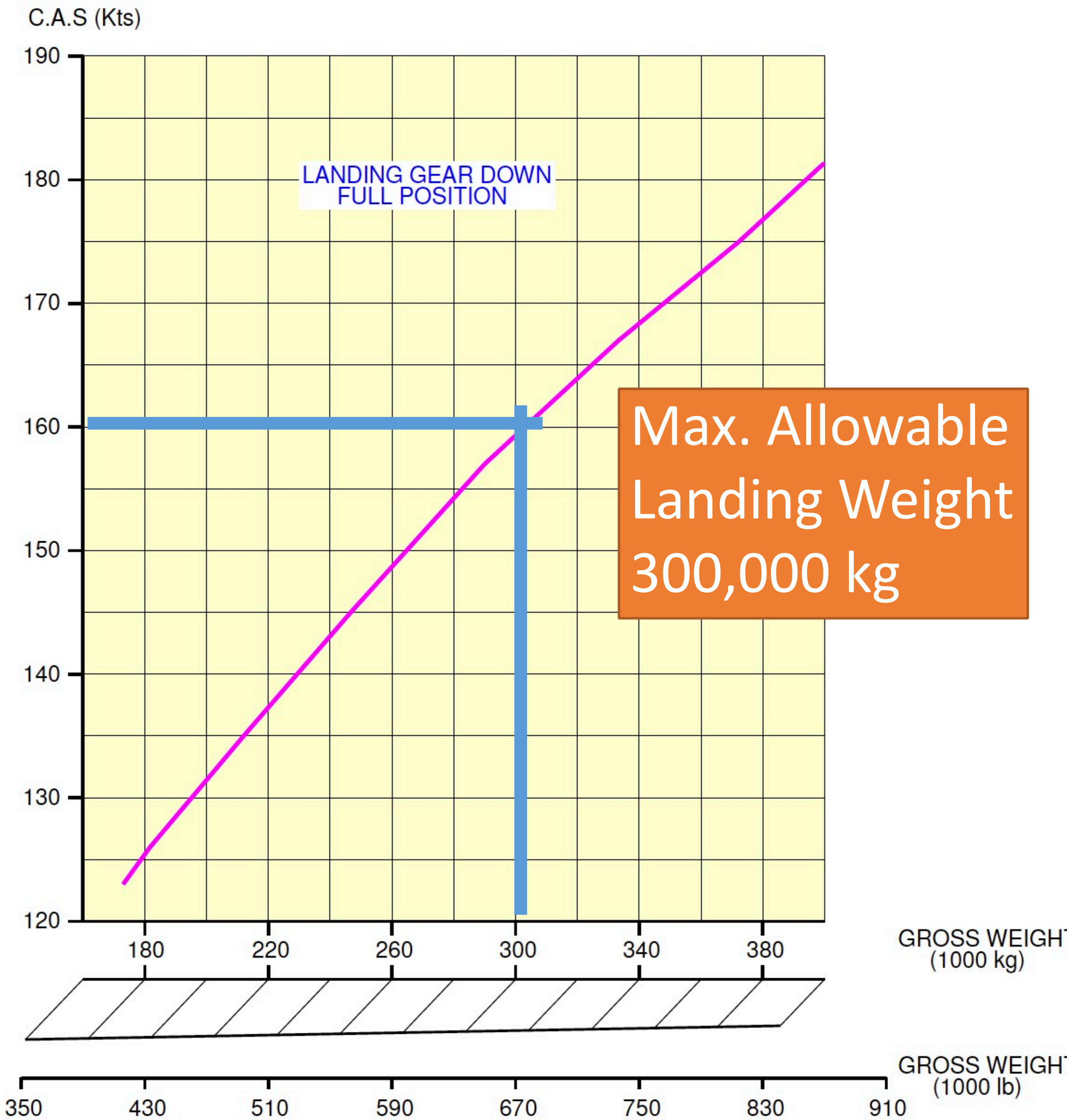
Note: Approach speed varies with aircraft mass

Example of Aircraft Approach Speed Variations

- Consider the Airbus A340-500 - a long-range aircraft
-

- Approach speed at 180,000 kg landing mass ~ 125 knots
- Approach speed at 300,000 kg landing mass (maximum allowable landing mass) ~ 160 knots

Approach Speed (knots)

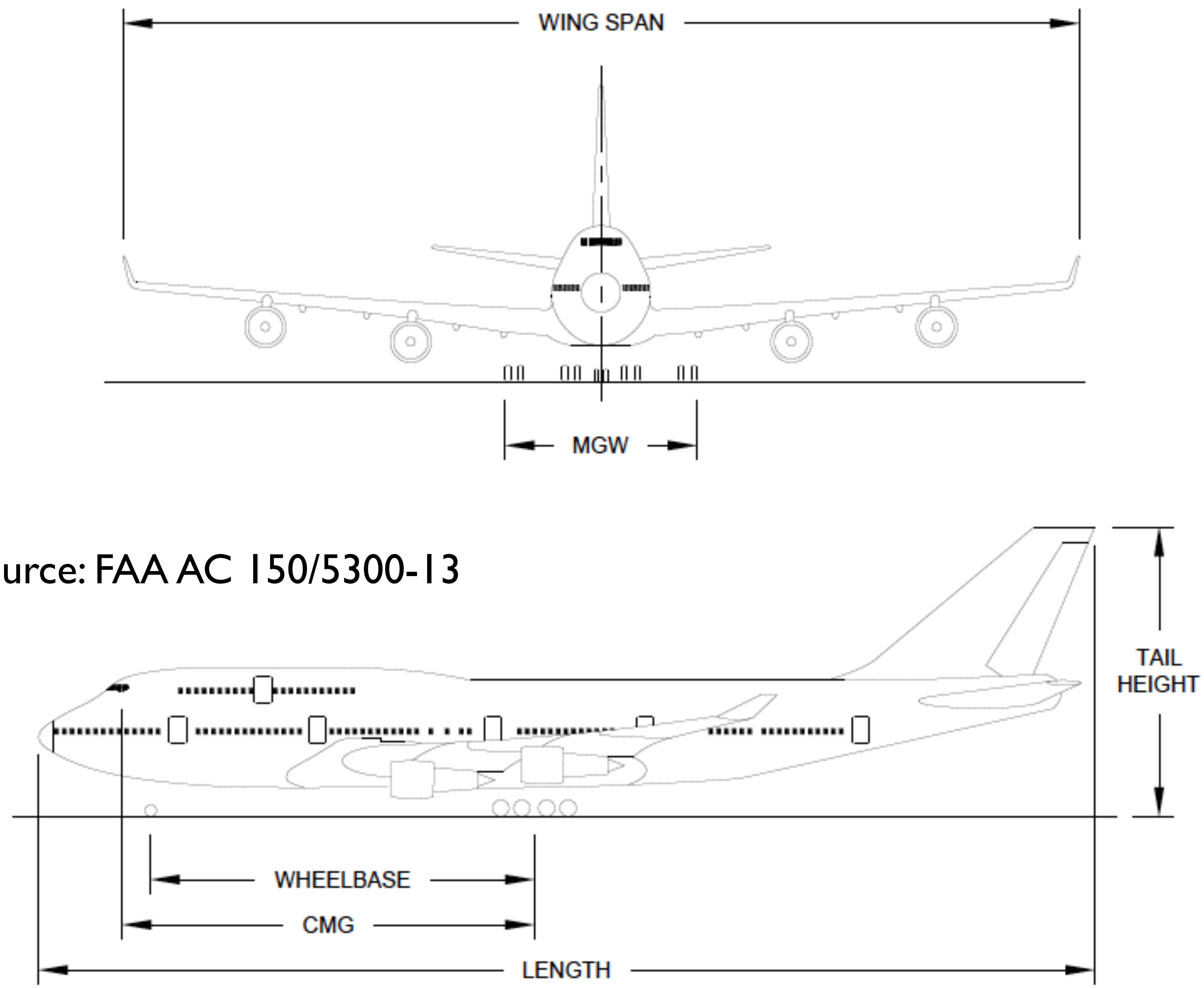


source: Airbus A340-500 Airplane Characteristics for Airport Planning

Taxiway Design Group (TDG)

- Previous FAA guidance considered tail height and wingspan as design factors for geometric design
- Dimensions of the aircraft undercarriage are also important in geometric design
- New guidance for taxiway design considers Main gear Width (MGW) and Cockpit to Main gear Dimensions (CMG)

FAA AC 150/5300-13B Appendix 1



source: FAA AC 150/5300-13

Figure A1-1. Typical dimensions of large aircraft

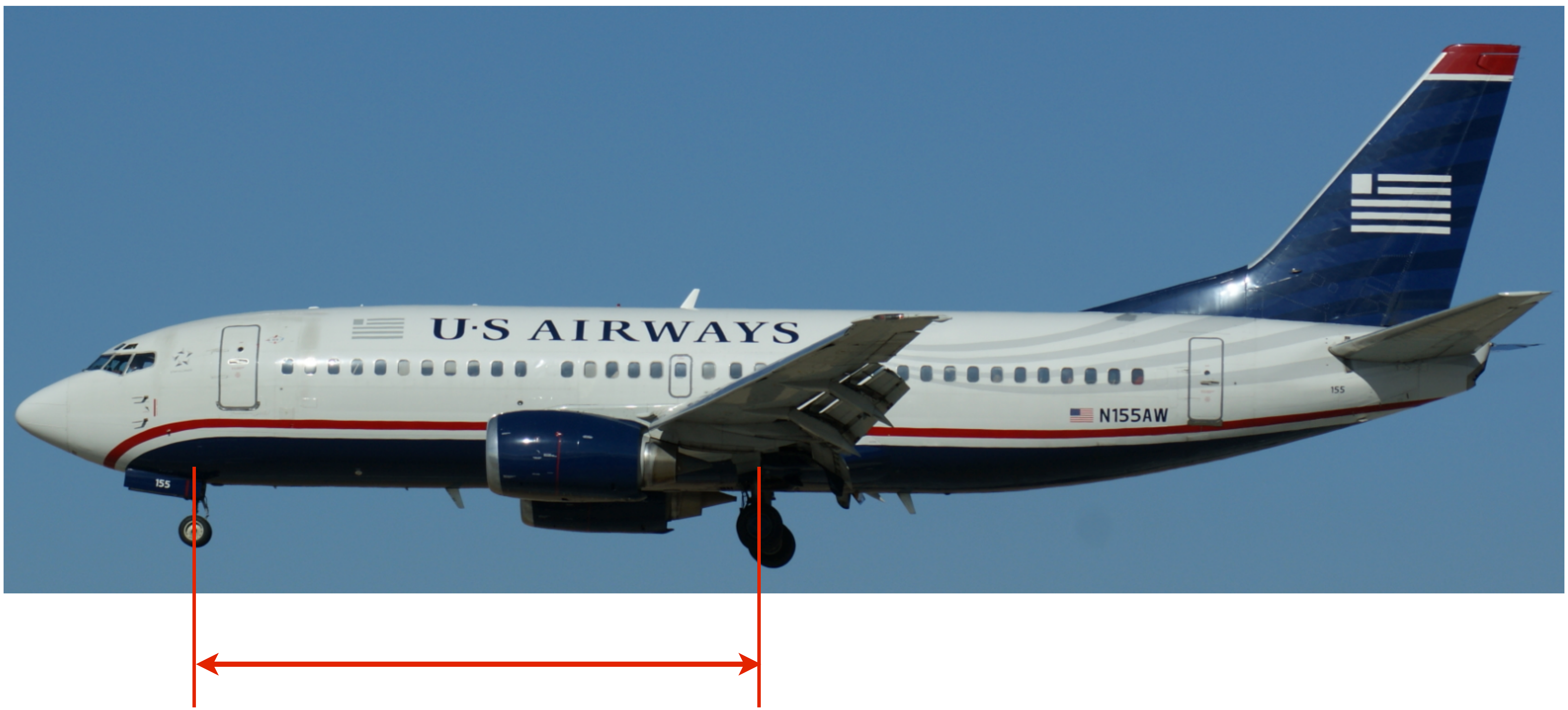
Consideration About CMG Distance vs Wheelbase Distance

- FAA specifies:
- Cockpit to Main Gear (CMG) dimension will be used instead of the aircraft wheelbase for aircraft where the cockpit is located forward of the nose gear (typically applies to commercial aircraft)
- For aircraft with the cockpit located aft of the nose gear, use the wheelbase instead of CMG to determine the Taxiway Design Group (TDG)
- See figures in previous slides

Example - Commercial Aircraft

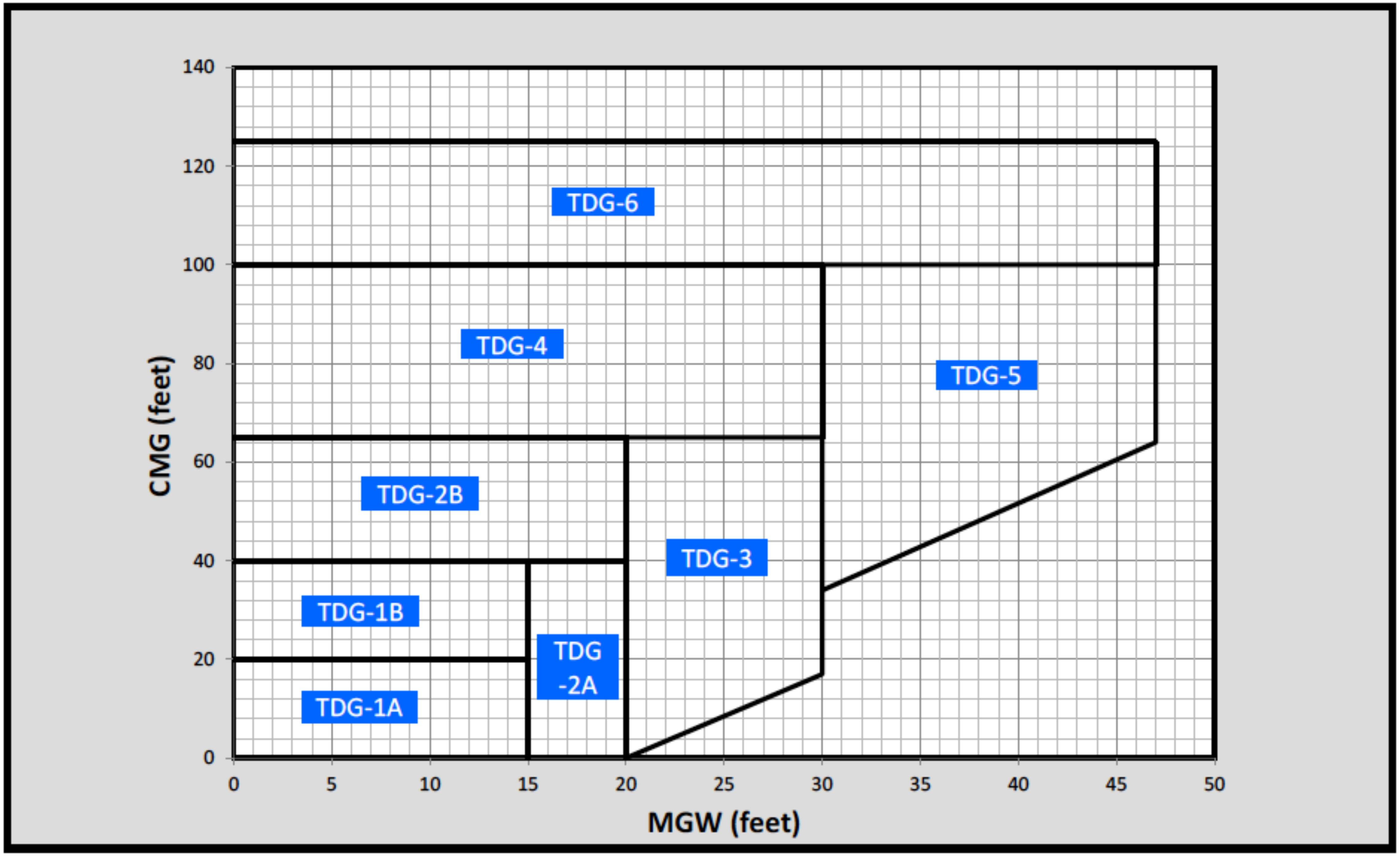
- Most commercial aircraft have the cockpit located ahead of the nose gear (use CMG distance)

Boeing 737-300. Twin-engine turbofan powered, commercial aircraft



Cockpit to Main Gear Distance (CMG)

Taxiway Design Group Chart



Note: Values in the graph are rounded to the nearest foot. 1 foot = 0.305 meters.

source: FAA AC 150/5300-13b

Approach Visibility Minimums

- Defined by a parameter called Runway Visual Range (RVR)
  - "*RVR is the range over which the Pilot of an aircraft on the centre line of a runway can see the runway surface markings or the lights delineating the runway or identifying its centre line.*" (ICAO)
  - RVR is normally expressed in feet or in meters

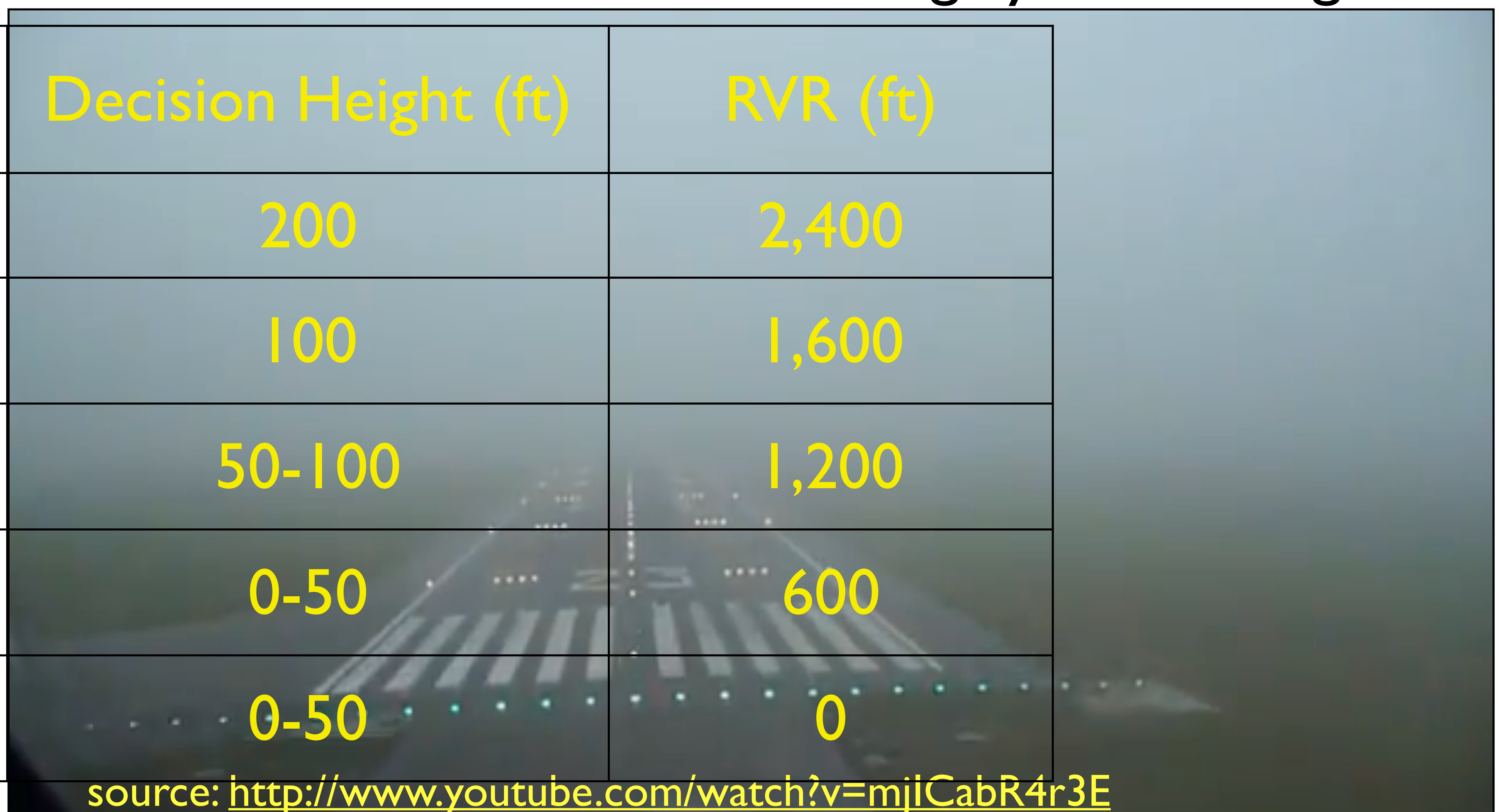
Approach Visibility Minimums

RVR (ft) *	Instrument Flight Visibility Category (statute mile)
5000	Not lower than 1 mile
4000	Lower than 1 mile but not lower than ¾ mile
2400	Lower than 3/4 mile but not lower than 1/2 mile
1600	Lower than 1/2 mile but not lower than 1/4 mile
1200	Lower than 1/4 mile

* RVR values are not exact equivalents.

Instrument Landing System Categories

Category	Decision Height (ft)	RVR (ft)
I	200	2,400
II	100	1,600
IIIa	50-100	1,200
IIIb	0-50	600
IIIc	0-50	0



source: http://www.youtube.com/watch?v=mjICabR4r3E

Example Problem # 1

- An airport is to be designed to accommodate the Boeing 757-300 aircraft. Determine the airport reference code and the taxiway design group to be used.

Solution:

- Use the FAA aircraft database: Approach speed is 142 knots (AAC = D) and Wingspan is 124.8 feet and tail height 44.5 feet (thus group IV)

Boeing 757-300 taking off at Punta Cana international Airport (A. Trani)

Example Problem # 1

- Boeing 757-300 : Approach speed is 142 knots (AAC = D) and Wingspan is 124.8 feet and tail height 44.5 feet (belongs to group IV)

Boeing 757-300 Belongs to Group IV

Reason: tail height falls into III group, wingspan belongs to group IV
Use the most critical

Design Group	Tail Height (Feet)	Wingspan (feet)	Representative Aircraft Types
I	<20	<49	Cessna 172, Beech 36, Cessna 421, Learjet 35
II	20 to <30	49 to < 79	Beech B300, Cessna 550 Falcon 50, Challenger 605
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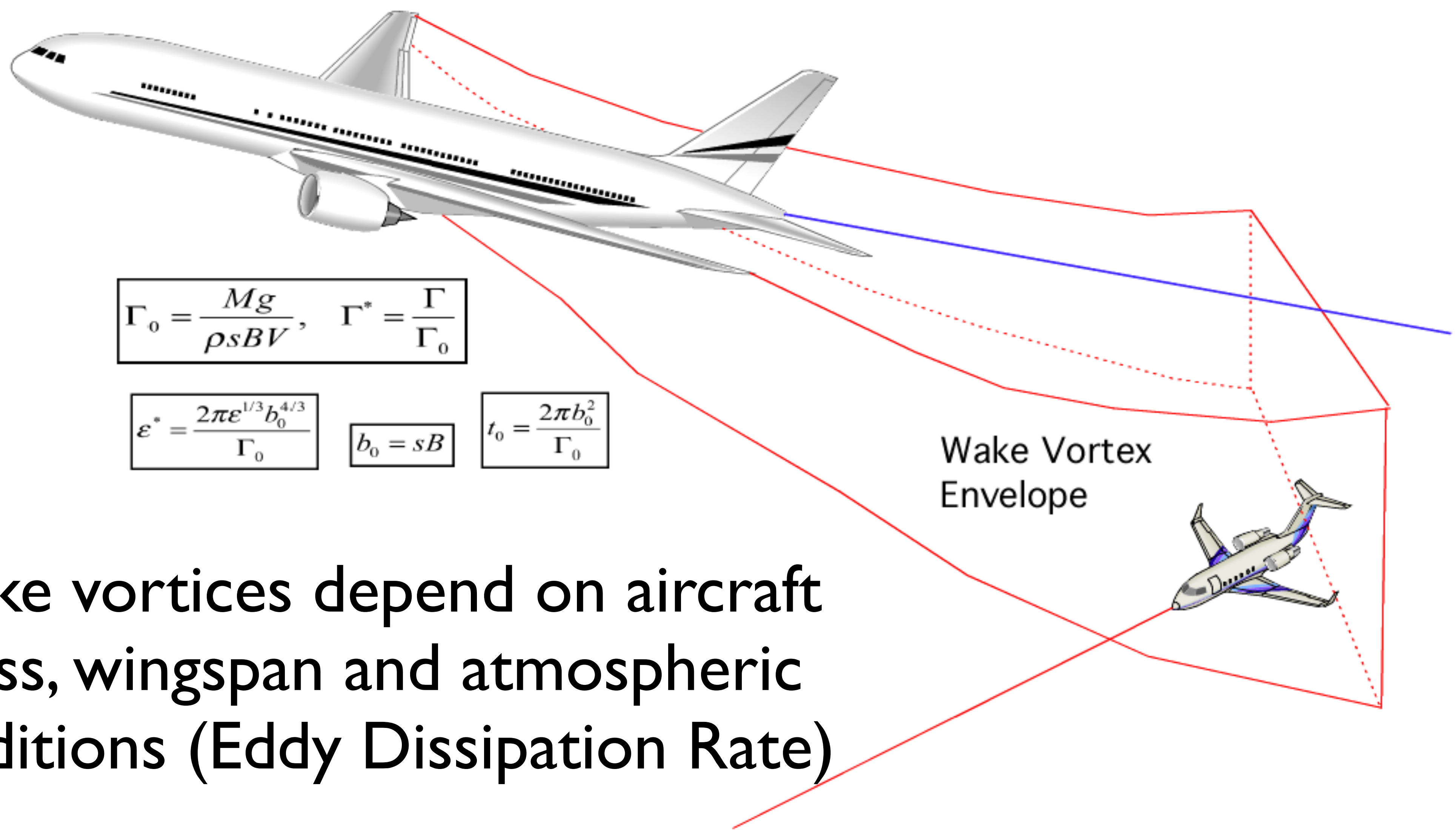
V	60 to < 66	171 to < 214	Boeing 747, Airbus A340, Boeing 777
VI	66 to <80	214 to < 262	Airbus A380, Antonov 124*

Wake Vortex Classes

- Every aircraft generates wakes behind the wing due to the strong circulation (Γ) required to generate lift

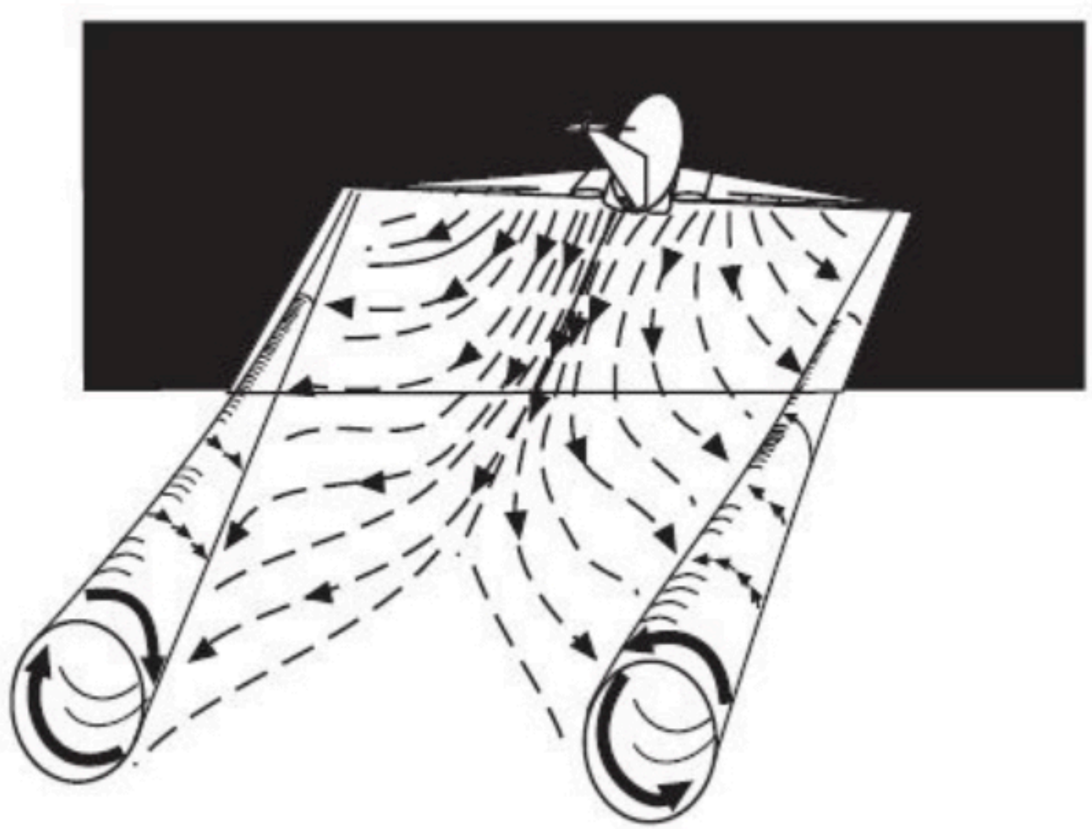


$$\Gamma_0 = \frac{Mg}{\rho s B V}, \quad \Gamma^* = \frac{\Gamma}{\Gamma_0}$$

$$\varepsilon^* = \frac{2\pi \varepsilon^{1/3} b_0^{4/3}}{\Gamma_0} \qquad b_0 = sB \qquad t_0 = \frac{2\pi b_0^2}{\Gamma_0}$$

Wake vortices depend on aircraft mass, wingspan and atmospheric conditions (Eddy Dissipation Rate)

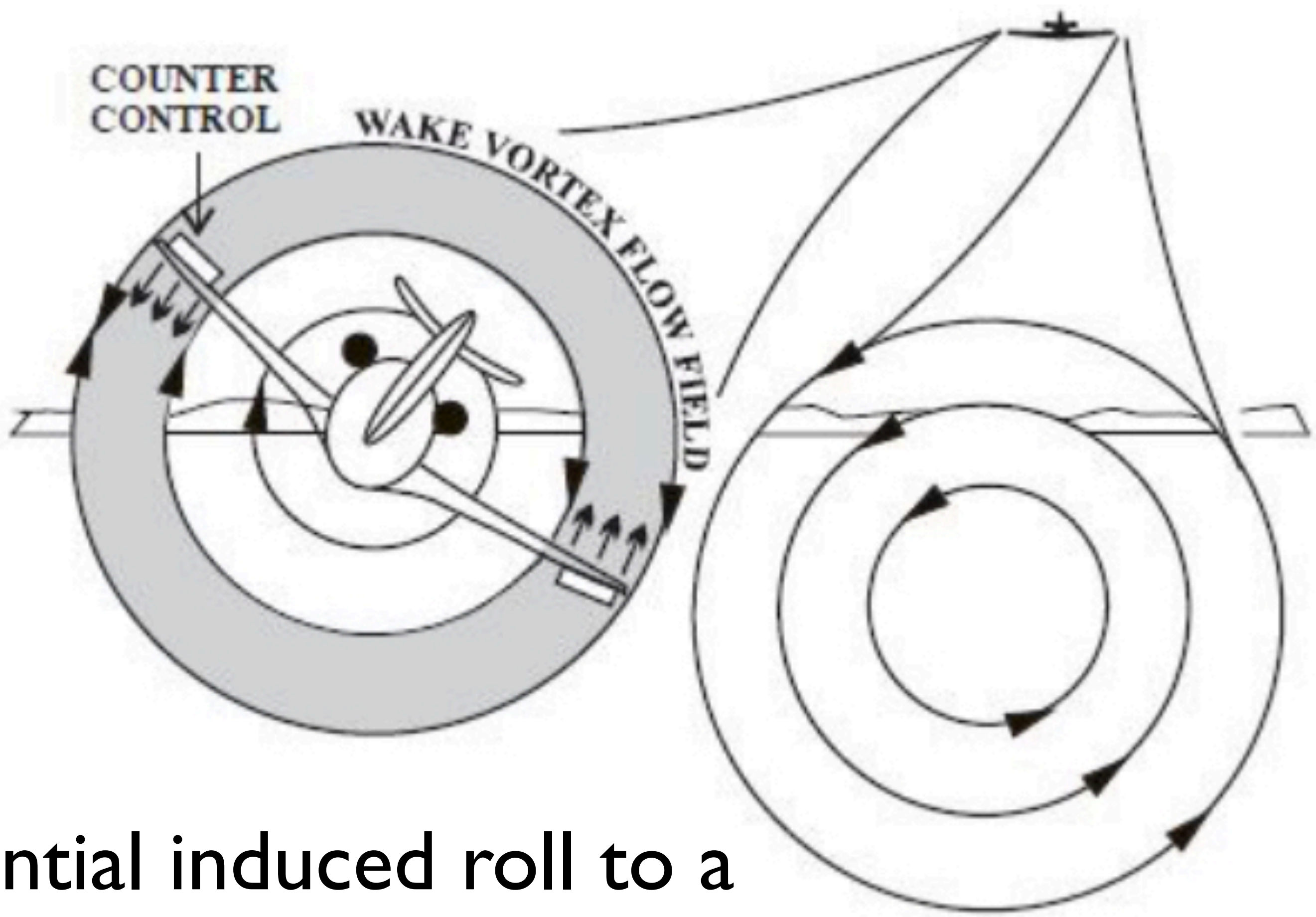
Wake Vortex Issues



Source: https://www.faa.gov/air_traffic/publications/atpubs/aim_html/chap7_section_4.html

Greatest danger is when aircraft are heavy, clean (no flap configuration and flying slow)

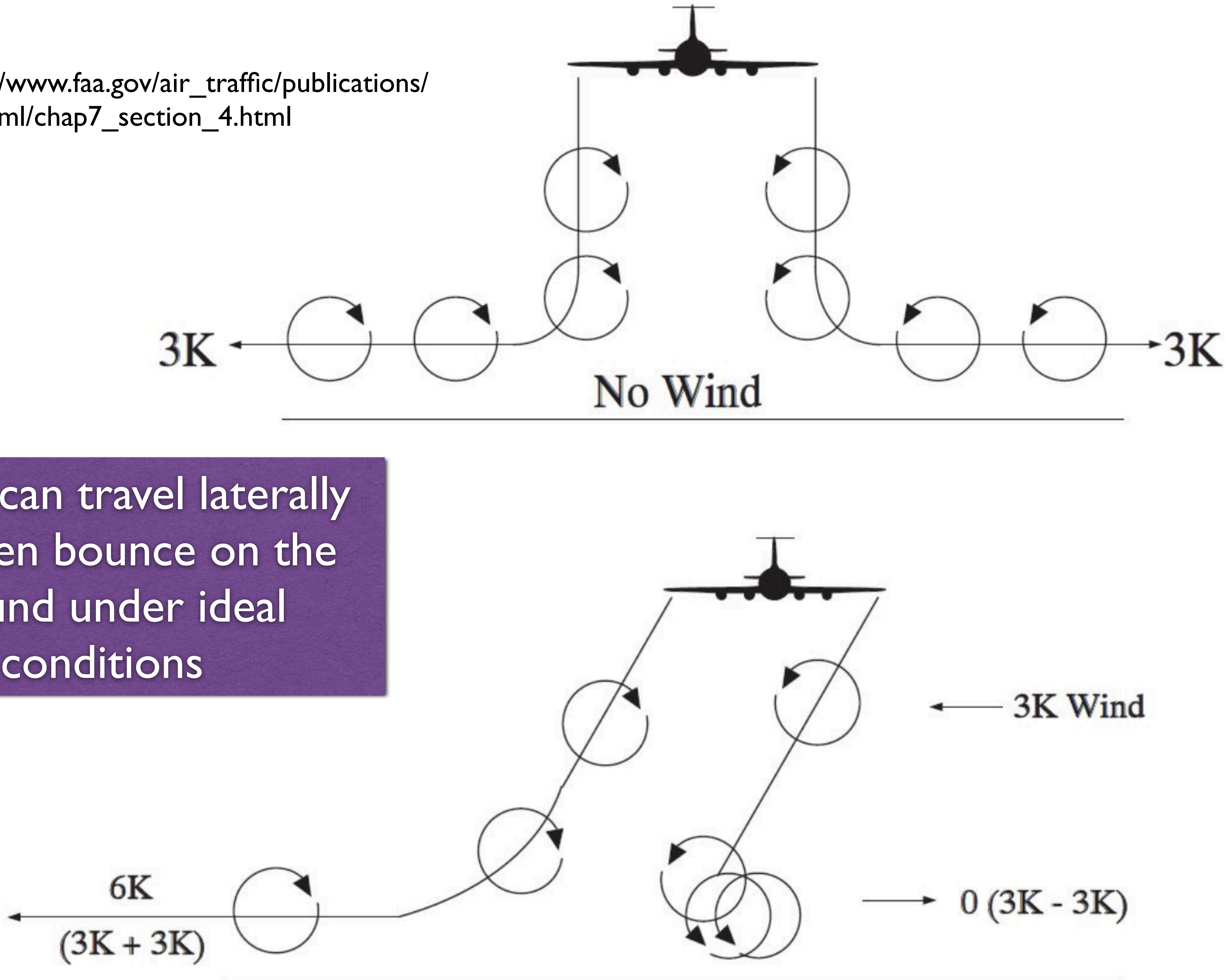
For heavy aircraft, wakes may last 60-100 seconds behind the generating aircraft



Potential induced roll to a following aircraft

Wake Vortex Issues (2)

Source: https://www.faa.gov/air_traffic/publications/atpubs/aim_html/chap7_section_4.html



Wakes can travel laterally and even bounce on the ground under ideal conditions

Wake Vortex Issues (3)

Wake vortex visualization behind a small regional jet (VFW 614)

https://commons.wikimedia.org/wiki/File:Visualisation_of_a_wake_vortex_ATTAS.jpg

Wake Vortex Classifications (History)

- 1970s - FAA develops a legacy wake vortex classification (small, large, heavy)
- 1993 - FAA adds Boeing 757-200 to the legacy classification as a group (at the time ATC handles the Boeing 757-200 like a heavy)

> FAA Orders 757 Turbulence Alert : Aviation: After crash of private jet in Santa Ana, air controllers are told to alert small planes to wake hazard posed by Boeing craft. Past incidents are cited.

Source: Los Angeles Times (December/23/1993)

- 2012 - FAA implements RECAT (re-categorization Phase 1) with 6 or 7 groups
- 2019 - FAA develops a Consolidated Wake Turbulence Classification (CWT) with 9 groups

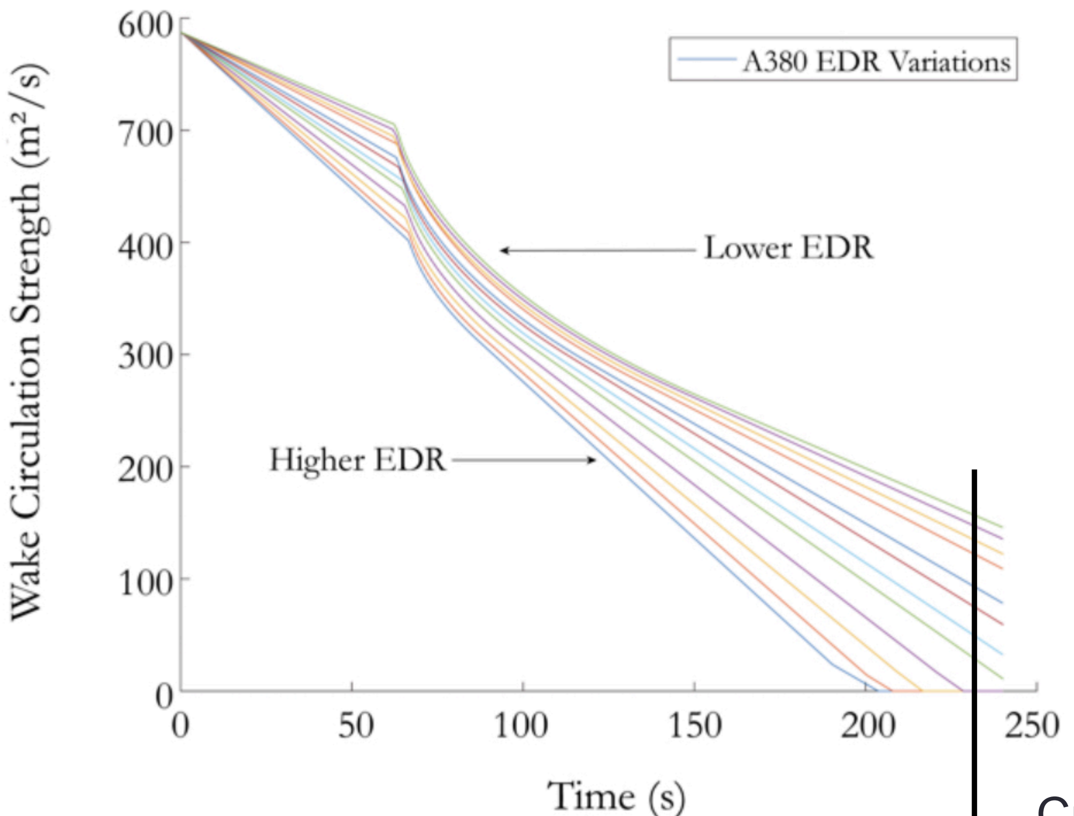
Legacy FAA Wake Vortex Classification

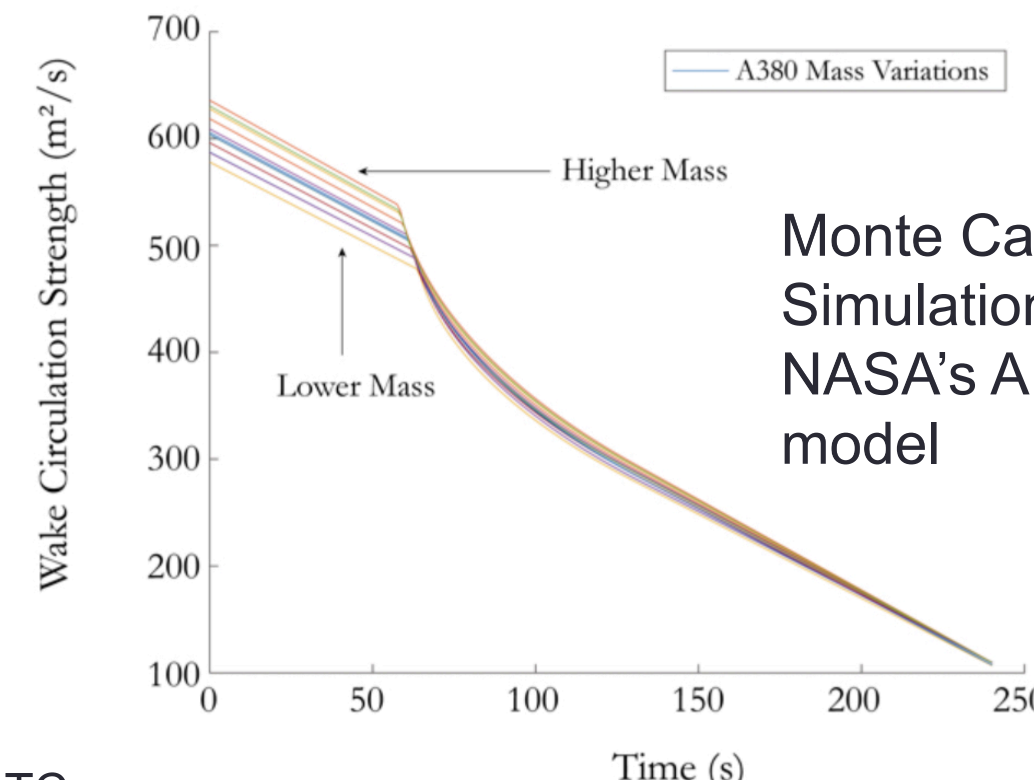
Final Approach Aircraft Wake Vortex Classification

Group	Takeoff Gross Weight (lb)	Example Aircraft
Small	< 41,000	All single engine aircraft, light twins, most business jets and commuter aircraft
Large	41,000-255,000	Large turboprop commuters, short and medium range transport aircraft (MD-80, B737, B727, A320, F100, etc.)
Heavy	> 255,000	Boeing 757[a], Boeing 747, Douglas DC-10, MD-11, Airbus A-300, A-340,
Superheavy	1,234,000	Airbus A380 (pending reductions)

a. For purposes of terminal airspace separation procedures, the Boeing 757 is classifed by FAA in a category by itself. However, when considering the Boeing 757 separation criteria (close to the Heavy category) and considering the percent of Boeing 757 in the U.S. feet, the four categories does provide very similar results for most airport capacity analyes.

Wake Modeling using NASA's APA Model : Arrival Configuration (Source: J. Roa, Virginia Tech, 2019)



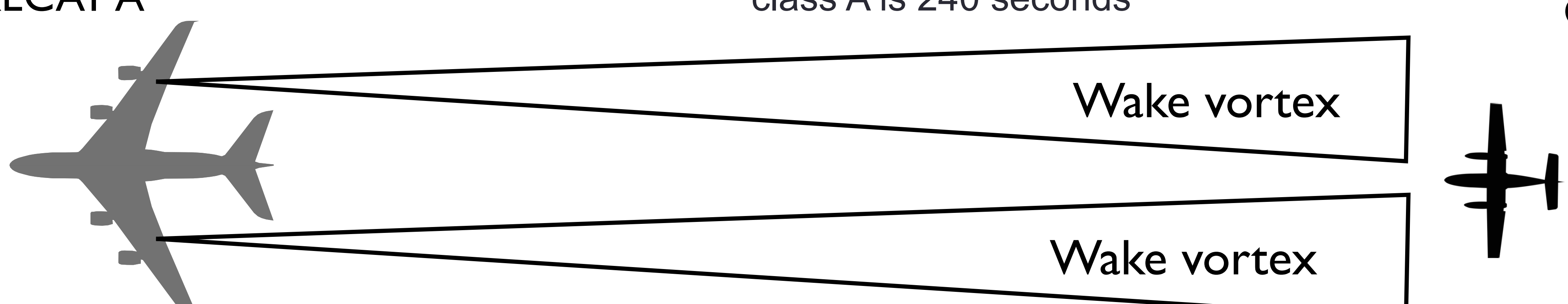


Monte Carlo Simulation using NASA's APA model

Current ATC separation behind class A is 240 seconds

Airbus A380 RECAT A

Cessna 441 RECAT F



Wake Vortex Behavior Implications for Small Aircraft

- Boeing 737-800 class (CWT F in new consolidated wake turbulence class)
  - Wake descends up to 500 feet in 60-90 seconds
  - **Minimum separation behind ~ 90 seconds**
- Boeing 777-300 class (CWT B)
  - Wake descends up to 800 feet in 100-150 seconds
  - **Minimum separation ~ 150 seconds**
- Airbus A380 class (CWT A)
  - Wake descends up to 1000 feet in 150-240 seconds
  - **Minimum separation behind ~ 240 seconds**

Learn More About Aircraft Wakes

NASA/TM–2016-219353

NASA AVOSS Fast-Time Models for Aircraft Wake Prediction: User's Guide (APA3.8 and TDP2.1)

Nash'at N. Ahmad and Randal L. VanValkenburg
Langley Research Center, Hampton, Virginia

Matthew J. Pruis
NorthWest Research Associates, Redmond, Washington

Fanny M. Limon Duparcmeur
Craig Technologies, Hampton, Virginia

Three-Phased Wake Vortex Decay

Fred H. Proctor[*] *and* Nash'at N. Ahmad[†]
NASA Langley Research Center, Hampton, Virginia 23681

George S. Switzer[‡]
AS&M, Inc., Hampton, Virginia 23666

Fanny M. Limon Duparcmeur[§]
Eagle Aeronautics, Inc., Hampton, Virginia 23666

A detailed parametric study is conducted that examines vortex decay within turbulent and stratified atmospheres. The study uses a large eddy simulation model to simulate the out-of-ground effect behavior of wake vortices due to their interaction with atmospheric turbulence and thermal stratification. This paper presents results from a parametric investigation and suggests improvements for existing fast-time wake prediction models. This paper also describes a three-phased decay for wake vortices. The third phase is characterized by a relatively slow rate of circulation decay, and is associated with the ring-vortex stage that occurs following vortex linking. The three-phased decay is most prevalent for wakes imbedded within environments having low-turbulence and near-neutral stratification.

Evaluation of Fast-Time Wake Vortex Prediction Models

Fred H. Proctor[*] *and* David W. Hamilton[†]
NASA Langley Research Center, Hampton, Virginia, 23681

Current fast-time wake models are reviewed and three basic types are defined. Predictions from several of the fast-time models are compared. Previous statistical evaluations of the APA-Sarpkaya and D2P fast-time models are discussed. Root Mean Square errors between fast-time model predictions and Lidar wake measurements are examined for a 24 hr period at Denver International Airport. Shortcomings in current methodology for evaluating wake errors are also discussed.

Consolidated Wake Turbulence Recategorization Classification (CWT)

- FAA Introduced a **consolidated wake re-categorization in 2019**
- Consult FAA Order JO 7110.126A

U.S. DEPARTMENT OF TRANSPORTATION
FEDERAL AVIATION ADMINISTRATION
Air Traffic Organization Policy

ORDER
JO 7110.126A

Effective Date:
September 28, 2019

SUBJ: Consolidated Wake Turbulence (CWT) Separation Standards

1. **Purpose of This Order**. This order provides procedural guidance to FAA Order JO 7110.65, Air Traffic Control, related to the use of Consolidated Wake Turbulence procedures and separation minima.

2. **Audience**. This order applies to all Air Traffic Organization (ATO) personnel authorized to use this order and anyone involved in the implementation and monitoring of Consolidated Wake Turbulence separation standards.

3. **Where Can I Find This Order?** This change is available on the FAA Website at http://faa.gov/air_traffic/publications and https://employees.faa.gov/tools_resources/orders_notices/.

4. **What This Order Cancels.** FAA Order JO 7110.126, Consolidated Wake Turbulence Radar

Consolidated Wake Vortex Recategorization Classification

- *"FAA Order JO 7110.659 (RECAT 1.5) classified aircraft according to certificated takeoff weight, landing speed, wingspan, and the aircraft's ability to withstand a wake encounter."*
- *"FAA Order JO 7110.123 (RECAT Phase II), Appendix A and Appendix B, described a pairwise separation matrix developed for the most common ICAO type identifier aircraft. Each aircraft was addressed as both a leader and a follower in each pair."*
- *"The development of a* ***pairwise separation matrix*** *relied on wake-based data, rather than weight-based data."*
- *"Separation reductions were achieved with a better understanding of wake behavior and with pairwise separation of aircraft."*
- *"CWT is based on a nine category system that further refines the grouping of aircraft, provides throughput gains at many of today's constrained airports, and is manageable for all airports throughout the NAS."*

Source: FAA Order JO 7110.126A

Consolidated Wake Turbulence (CWT) Re-categorization Classification

Category	Description
A	A388
B	Pairwise Upper Heavy aircraft
C	Pairwise Lower Heavy aircraft
D	Non-Pairwise Heavy aircraft
E	B757 aircraft
F	Upper Large aircraft excluding B757 aircraft
G	Lower Large aircraft
H	Upper Small aircraft with a maximum takeoff weight of more than 15,400 pounds up to 41,000 pounds
I	Lower Small aircraft with a maximum takeoff weight of 15,400 pounds or less

Source: FAA Order JO 7110.126B

Consolidated Wake Vortex Recategorization Classification

Aircraft Types Categorized

A	B	C	D		E	F		G		H	I
Super	Upper Heavy	Lower Heavy	Non-Pairwise Heavy		B757	Upper Large		Lower Large		Upper Small	Lower Small
A388	A332	A306	A124	DC85	B752	A318	C130	AT43	E170	ASTR	BE10
A225	A333	A30B	A339	DC86	B753	A319	C30J	AT72	E45X	B190	BE20
	A343	A310	A342	DC87		A320	CVLT	CL60	E75L	BE40	BE58
	A345	B762	A3ST	E3CF		A321	DC93	CRJ1	E75S	B350	BE99
	A346	B763	A400	E3TF		B712	DC95	CRJ2	F16	C560	C208
	A359	B764	A50	E6		B721	DH8D	CRJ7	F18H	C56X	C210
	B742	C17	AN22	E767		B722	E190	CRJ9	F18S	C680	C25A
	B744	DC10	B1	IL62		B732	GL5T	CRJX	F900	C750	C25B
	B748	K35R	B2	IL76		B733	GLEX	DC91	FA7X	CL30	C402
	B772	MD11	B52	IL86		B734	GLF5	DH8A	GLF2	E120	C441
	B773		B703	IL96		B735	GLF6	DH8B	GLF3	F2TH	C525
	B77L		B741	K35E		B736	MD82	DH8C	GLF4	FA50	C550
	B77W		B743	KE3		B737	MD83	E135	SB20	GALX	P180
	B788		B74D	L101		B738	MD87	E145	SF34	H25B	PAY2
	B789		B74R	MYA4		B739	MD88			LJ31	PA31
	C5		B74S	R135			MD90			LJ35	PC12
	C5M		B78X	T144						LJ45	SR22
			BLCF	T160						LJ55	SW3
			BSCA	TU95						LJ60	
			C135	VMT						SH36	
			C141							SW4	

Source: FAA Order JO 7110.126B

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Consolidated Wake Vortex Separations - **Directly Behind**

WAKE TURBULENCE APPLICATION

Source: FAA Order JO 7110.126B

g. Separate aircraft by the minima specified in TBL 5–5–1 in accordance with the following:

1. When operating within 2,500 feet and less than 1,000 feet below the flight path of the leading aircraft over the surface of the earth of a Category A, B, C, or D aircraft.

2. When operating within 2,500 feet and less than 500 feet below the flight path of the leading aircraft over the surface of the earth of a Category E aircraft.

3. When departing parallel runways separated by less than 2,500 feet, the 2,500 feet requirement in subparagraph 2 is not required when a Category I aircraft departs the parallel runway behind a Category E aircraft. Issue a wake turbulence cautionary advisory and instructions that will establish lateral separation in accordance with subparagraph 2. Do not issue instructions that will allow the Category I aircraft to pass behind the Category E aircraft.

		FOLLOWER								
		A	B	C	D	E	F	G	H	I
LEADER	A		5 NM	6 NM	6 NM	7 NM	7 NM	7 NM	8 NM	8 NM
	B		3 NM	4 NM	4 NM	5 NM	5 NM	5 NM	5 NM	5 NM
	C					3.5 NM	3.5 NM	3.5 NM	5 NM	5 NM
	D		3 NM	4 NM	4 NM	5 NM	5 NM	5 NM	5 NM	5 NM
	E									4 NM
	F									
	G									
	H									
	I									

Empty Cells: Apply Minimum Radar Separation
3 nm default
2.5 nm for runways that meet a 50 second Runway Occupancy Time criteria

Consolidated Wake Vortex Separations - **On Approach**

h. *ON APPROACH.* In addition to subparagraph g, separate an aircraft on approach behind another aircraft to the same runway by ensuring the separation minima in TBL 5–5–2 will exist at the time the preceding aircraft is over the landing threshold.

NOTE–
Consider parallel runways less than 2,500 feet apart as a single runway because of the possible effects of wake turbulence.

Wake Turbulence Separation for On Approach

		FOLLOWER								
		A	B	C	D	E	F	G	H	I
LEADER	A		5 NM	6 NM	6 NM	7 NM	7 NM	7 NM	8 NM	8 NM
	B		3 NM	4 NM	4 NM	5 NM	5 NM	5 NM	5 NM	6 NM
	C					3.5 NM	3.5 NM	3.5 NM	5 NM	6 NM
	D		3 NM	4 NM	4 NM	5 NM	5 NM	5 NM	6 NM	6 NM
	E									4 NM
	F									4 NM
	G									
	H									
	I									

Empty Cells: Apply Minimum Radar Separation
3 nm default
2.5 nm for runways that meet a 50 second Runway Occupancy Time criteria

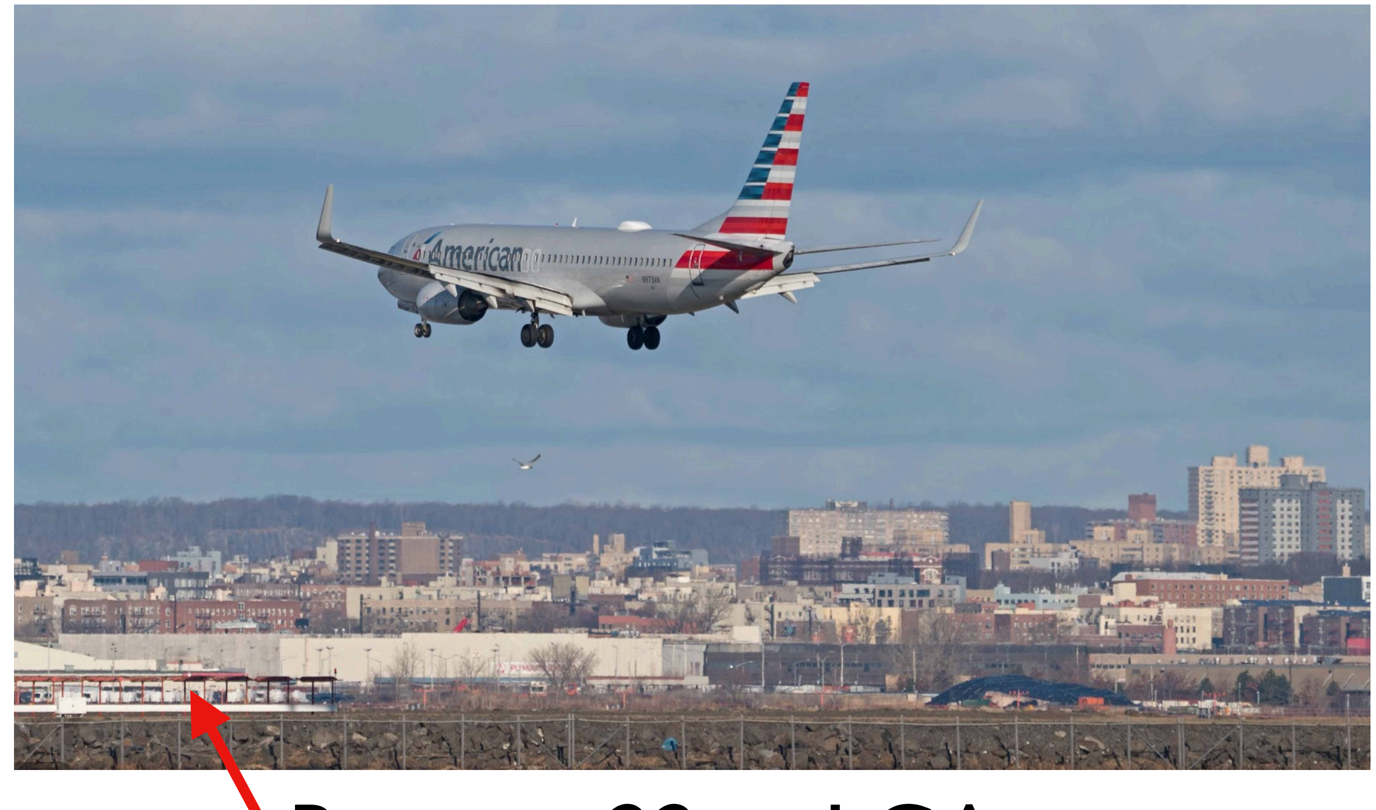
Source: FAA Order JO 7110.126B

Implications of Aircraft Wake Classes

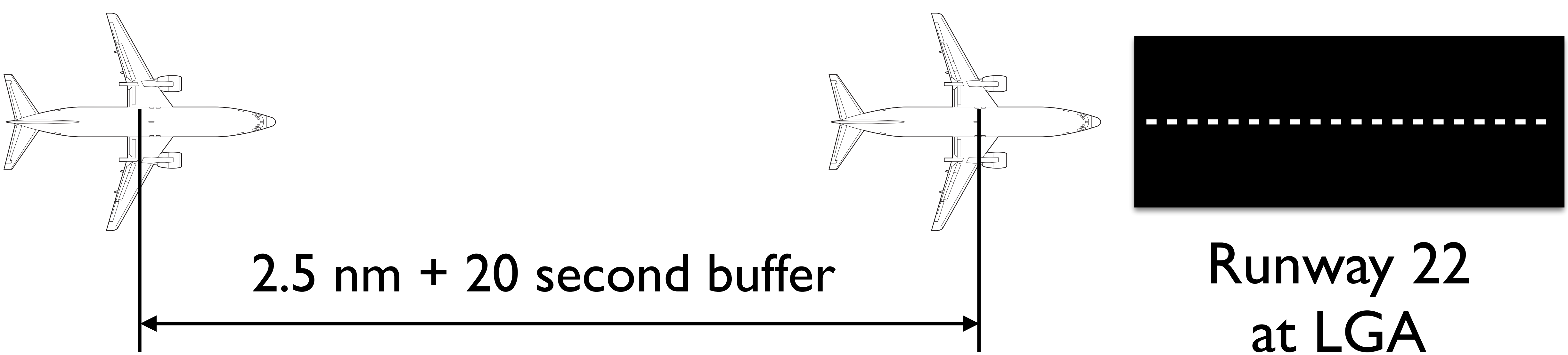
- In-trail separations are driven by wake class groups
- Runway capacity today is usually limited by in-trail separations
- In the future runway occupancy times will also be important

Example # 2

- Estimate the approximate arrival capacity to a single runway at La Guardia airport with 100% of the arrivals belong to the large wake class (Category F under CWT)
- Assume the typical approach speed of arrivals is 140 knots from the final approach fix to the runway



Runway 22 at LGA



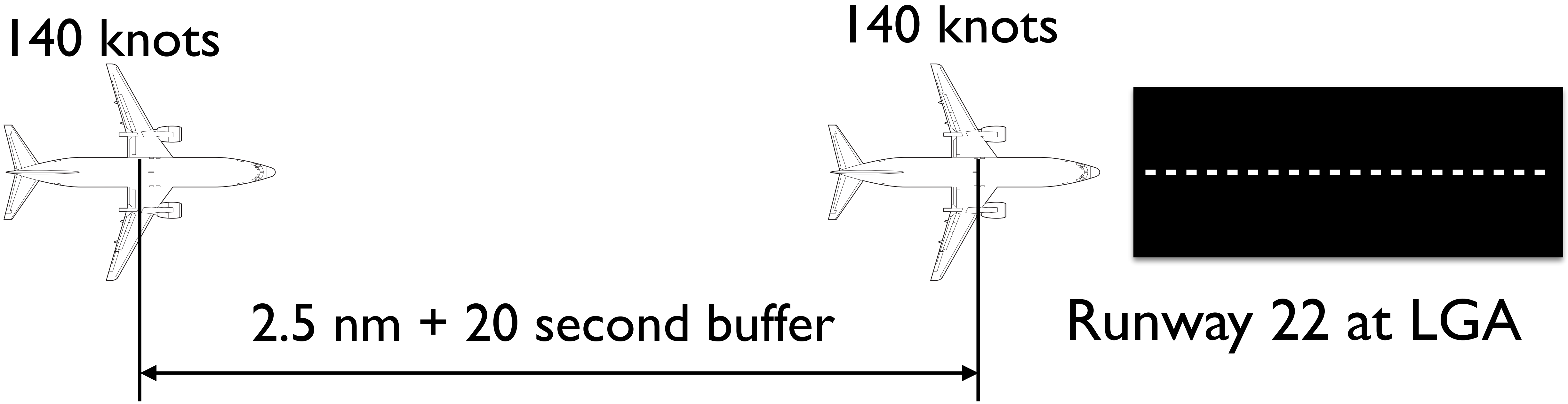
Example # 2 (cont.)

- A 2.5 nautical miles + 20 second buffer translates into a headway (i.e., time between successive arrivals) of :

$$headway = \left\{ \frac{2.5nm}{140nm/hr} \right\} 3600s/hr + 20s = 84.3s$$

- The arrival capacity is the inverse of headway

$$C_{arrivals} = \frac{3600s/hr}{84.3s} = 42 \text{ arrivals/hr}$$



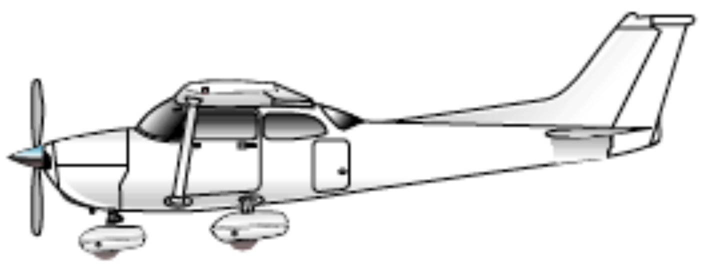
Other Classifications often mentioned in Aviation Magazines and

- Aircraft classification based on the aircraft use
- General aviation aircraft (GA)
- Corporate aircraft (CA)
- Commuter aircraft (COM)
- Transport aircraft (TA)
    - Short-range
    - Medium-range
    - Long-range

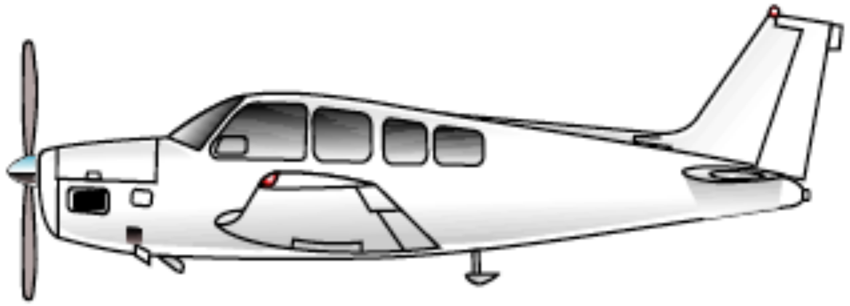
General Aviation Aircraft

Typically these aircraft can have one (single engine) or two engines (twin engine). Their maximum gross weight usually is always below 14,000 lb.

Single-Engine GA

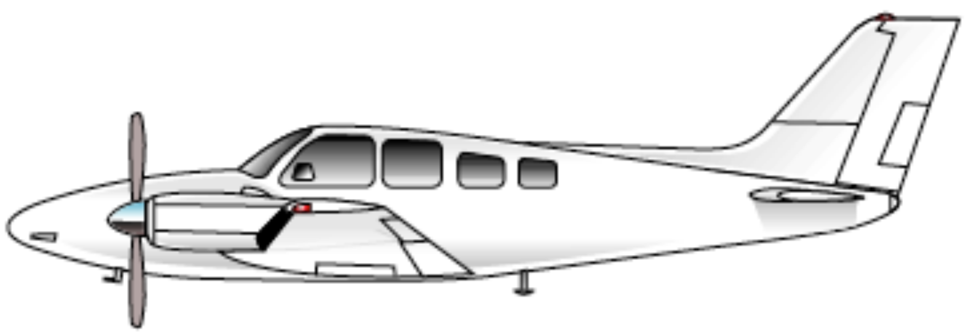


Cessna 172 (Skyhawk)

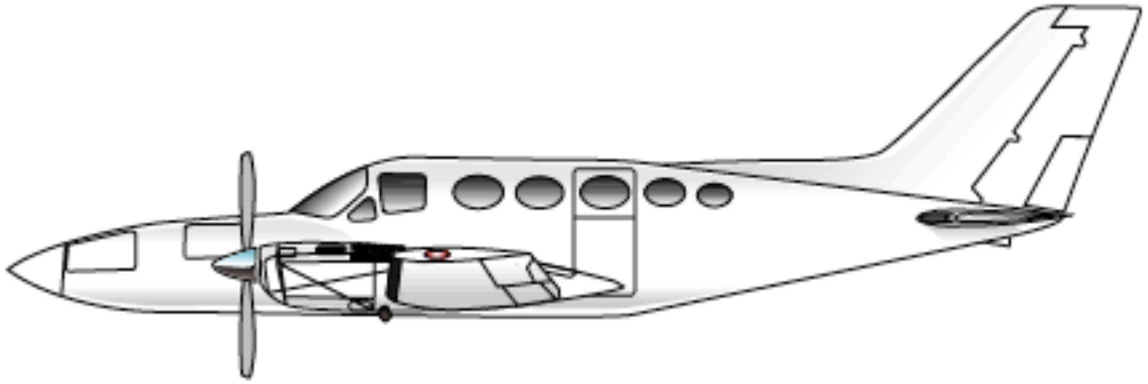


Beechcraft A36 (Bonanza)

Twin-Engine GA



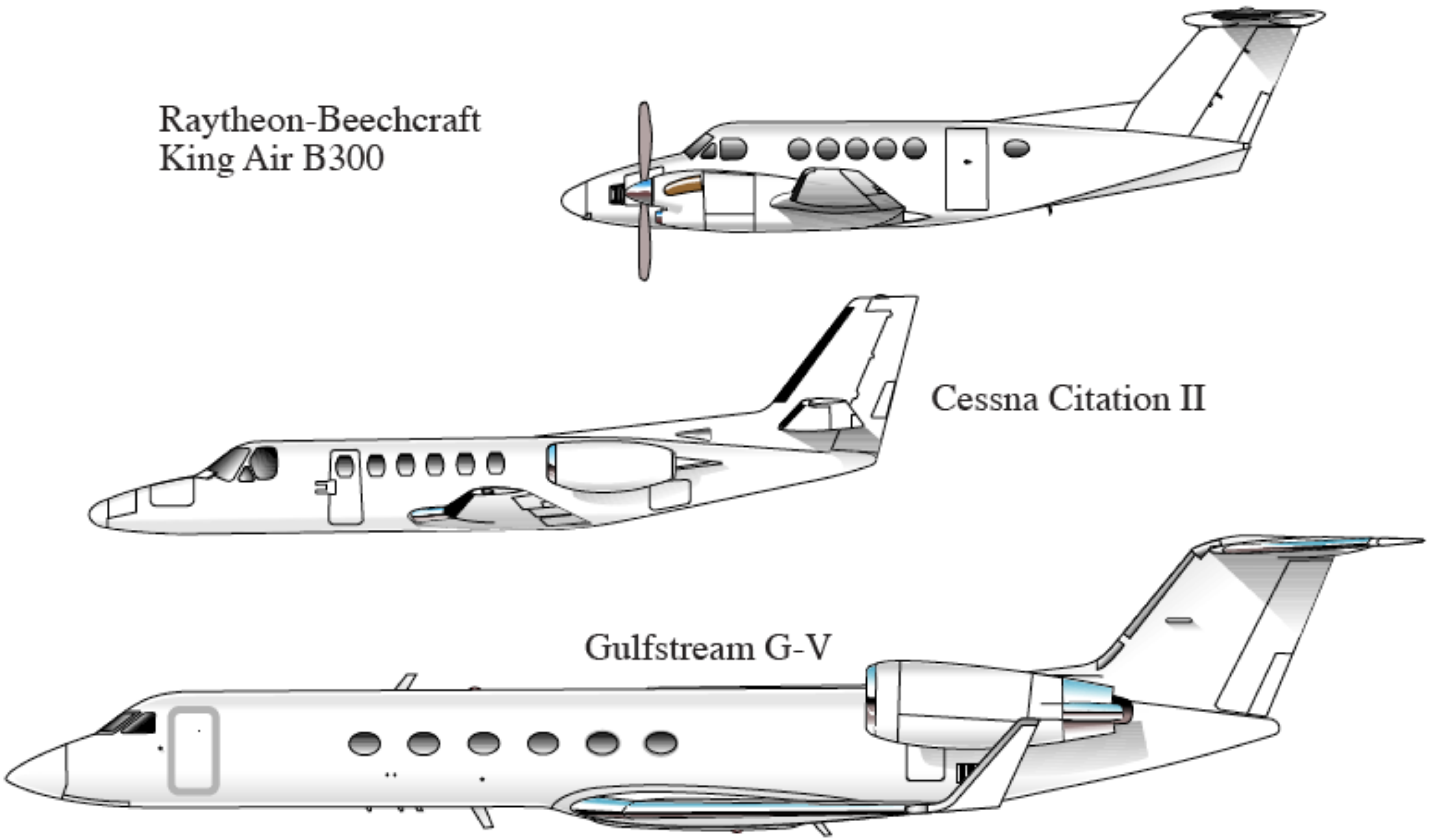
Beechcraft 58TC (Baron)



Cessna 421C (Golden Eagle)

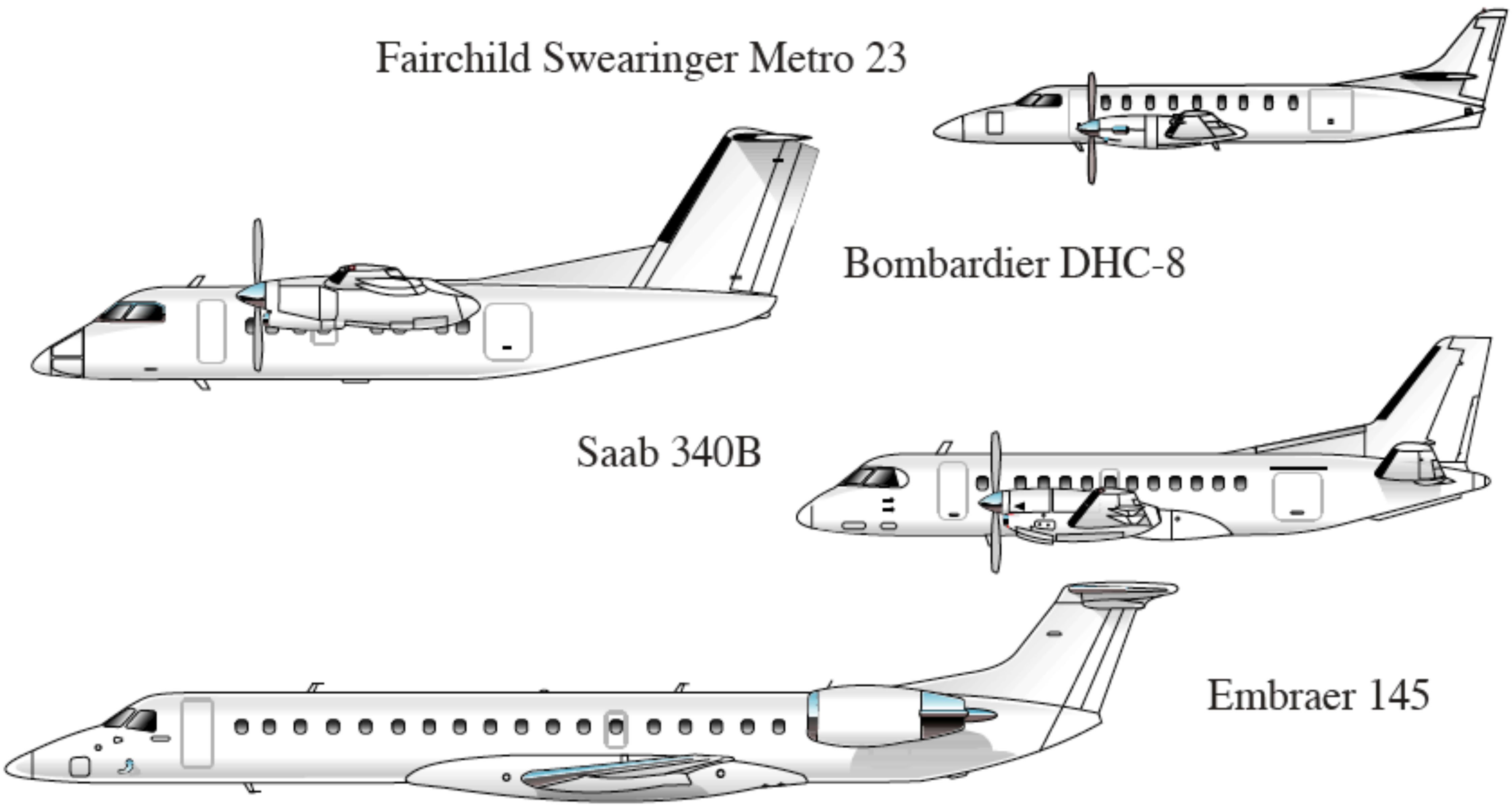
Corporate Aircraft

Typically these aircraft can have one or two turboprop driven or jet engines (sometimes three). Maximum gross mass is up to 40,910 kg (90,000 lb)



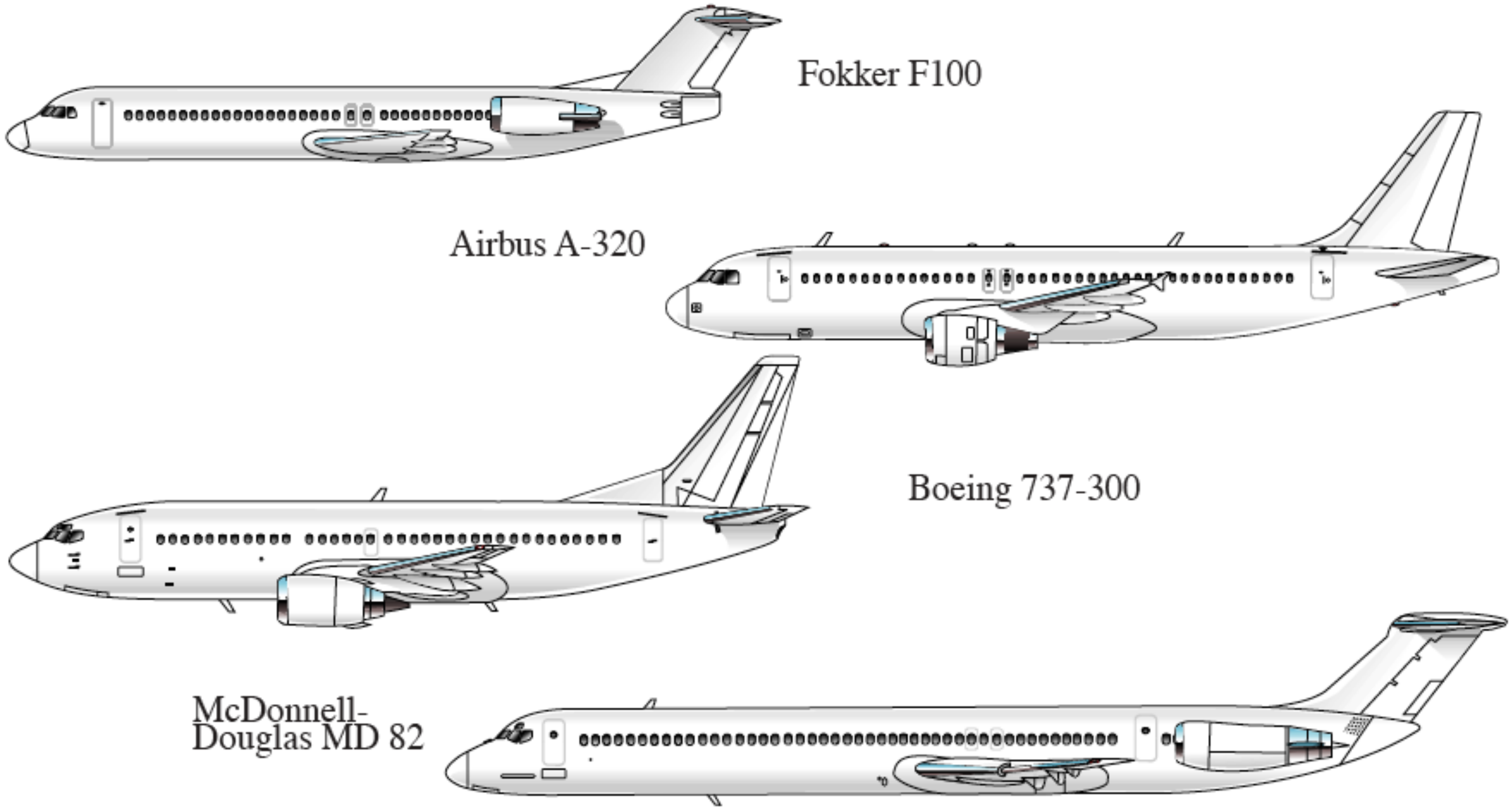
Commuter Aircraft

Usually twin engine aircraft with a few exceptions such as the DeHavilland DHC-7 which has four engines. Their maximum gross mass is below 31,818 kg (70,000 lb)



Short-Range Transport Aircraft

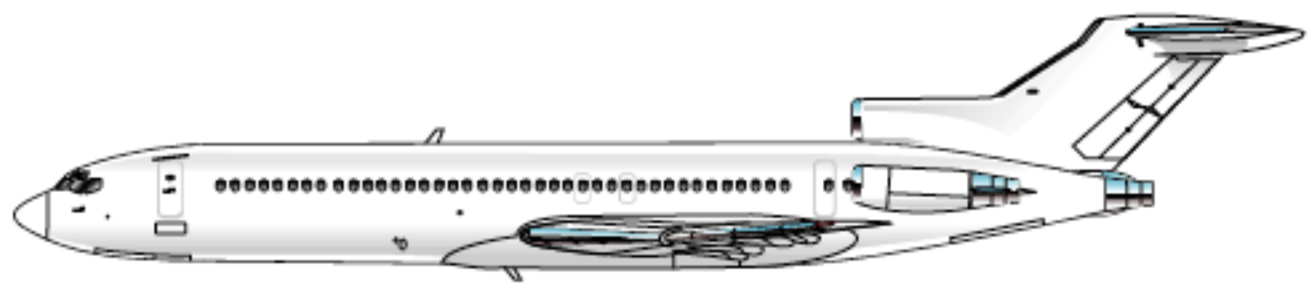
Certified under FAR/JAR 25. Their maximum gross mass usually is below 68,182 kg (150,000 lb).

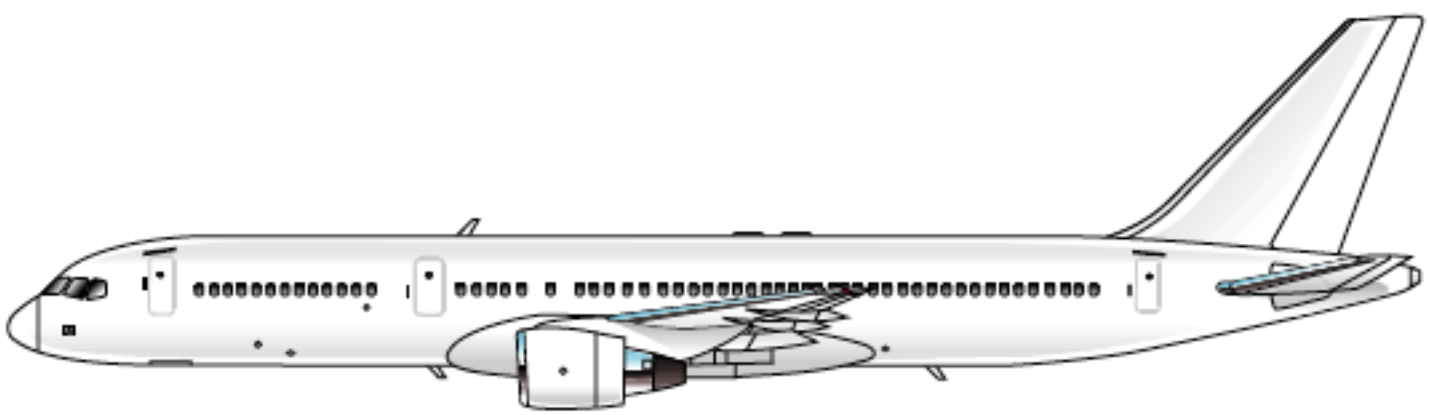


Medium-Range Transport Aircraft

These are transport aircraft employed to fly routes of less than 3,000 nm (typical).Their maximum gross mass usually is usually below 159,090 kg (350,000 lb)

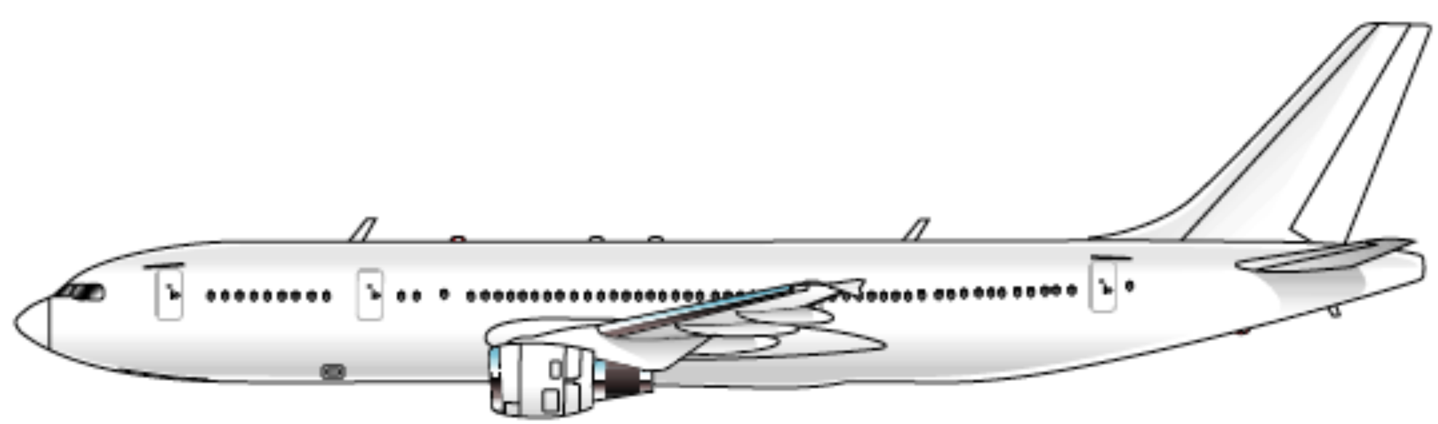
Boeing B727-200





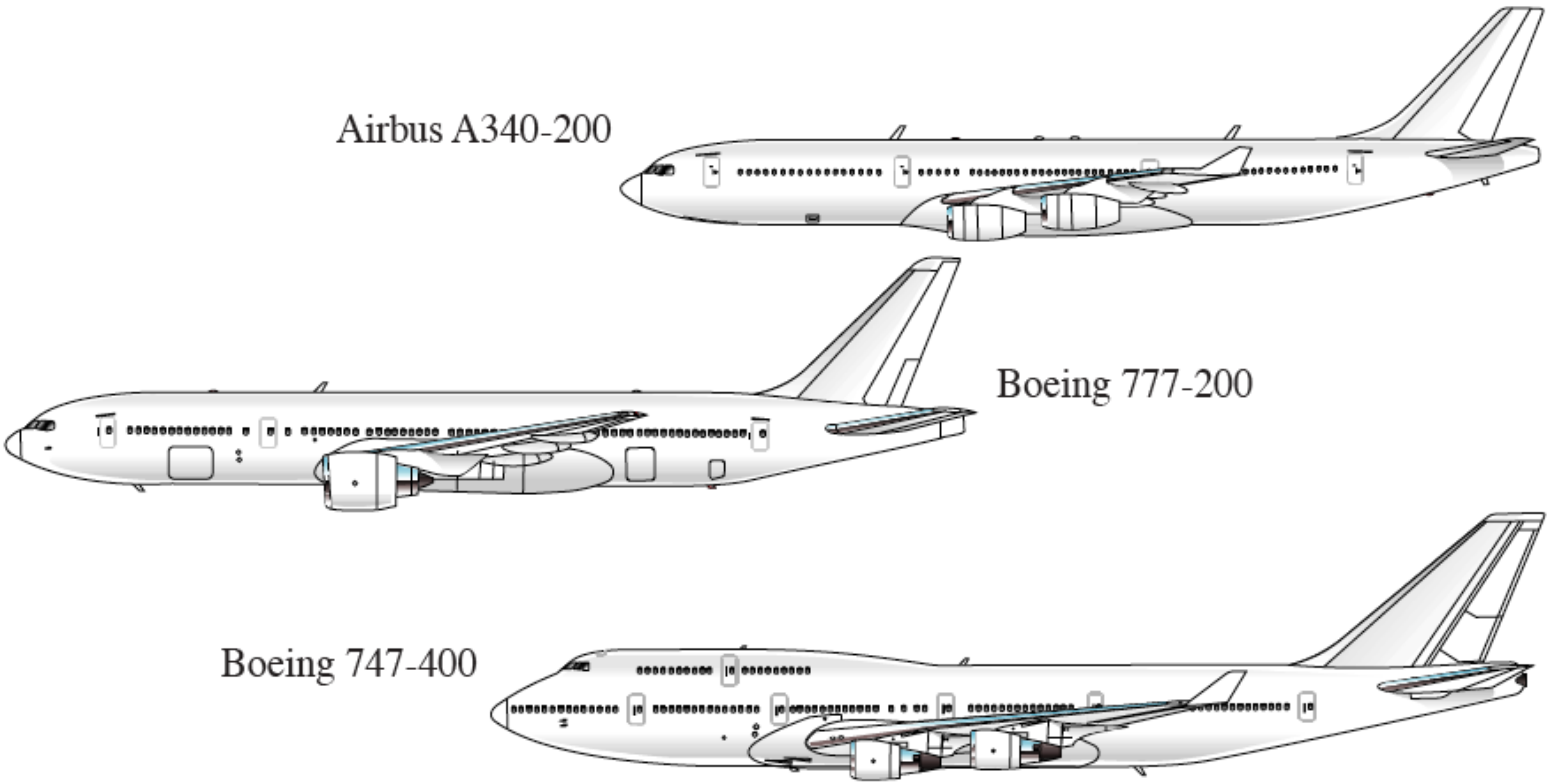
Boeing 757-200

Airbus A300-600R



Long-Range Transport Aircraft

These are transport aircraft employed to fly routes of less than 3,000 nm (typical).Their maximum gross mass usually is above 159,090 kg (350,000 lb)



Web Sites to Learn to Recognize Various Aircraft

- Pictures taken by the author at various airport (https://photos.app.goo.gl/8bdSvdwPQU7lHIDi2)
- Airliners site airliners.net
- Jetphotos (https://www.jetphotos.com)
- Eurontrol Aircraft Database (https://contentzone.eurocontrol.int/aircraftperformance/default.aspx?)

Aerospatiale ATR-42-500

Airbus A380-800

Aircraft Trends

- Very large capacity aircraft (introduced in the third quarter of 2007)
  - Airbus A380 and Boeing 747-8
- New generation ultra-efficient, long-range transport
  - Boeing 787 and Airbus A350
- New generation short range aircraft
  - Airbus A220, Comac 919 and Irkut MC-21

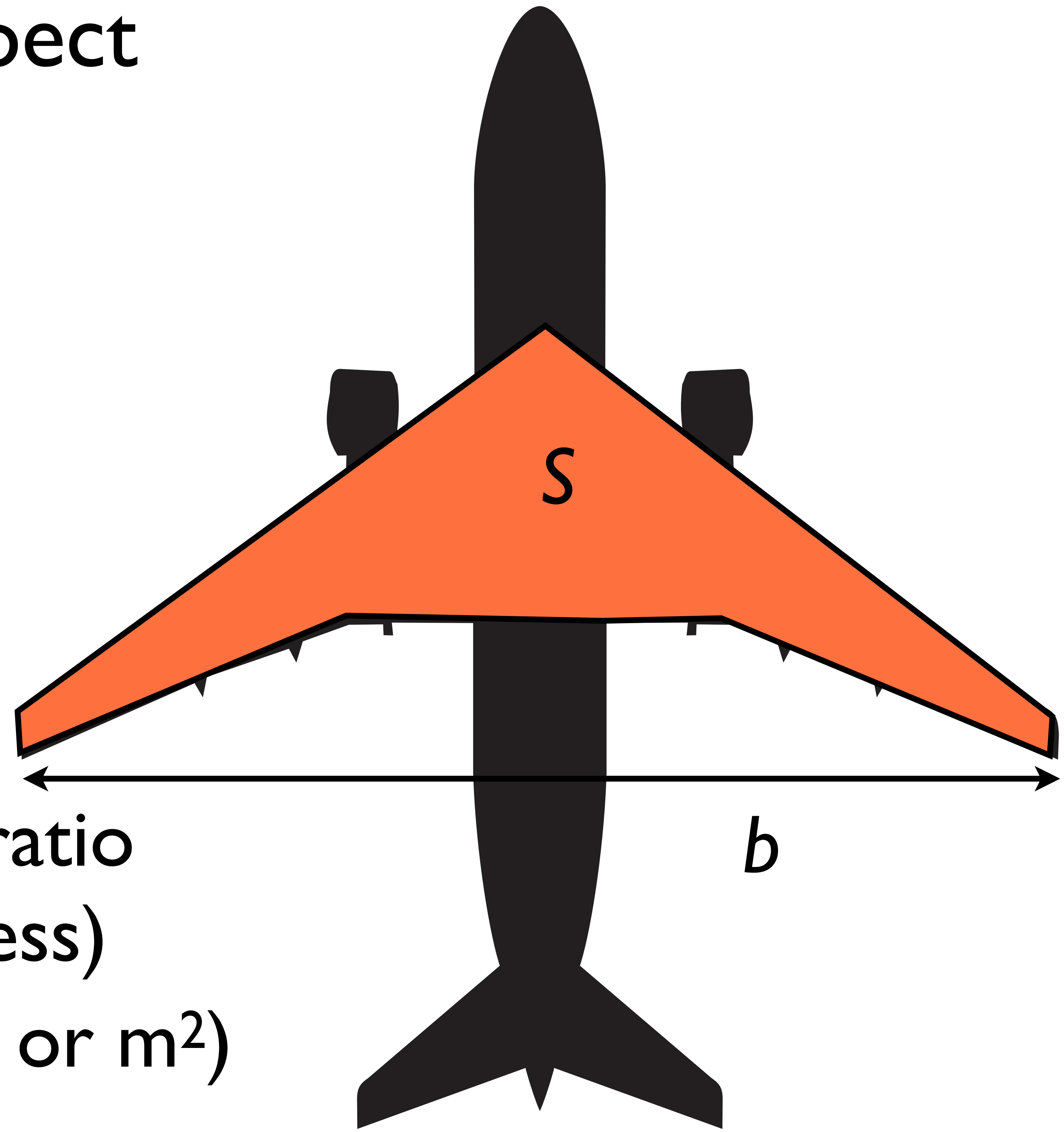
Aircraft Wing Aspect Ratio (AR)

$$AR = b^2 / S$$

AR wing aspect ratio (dimensionless)

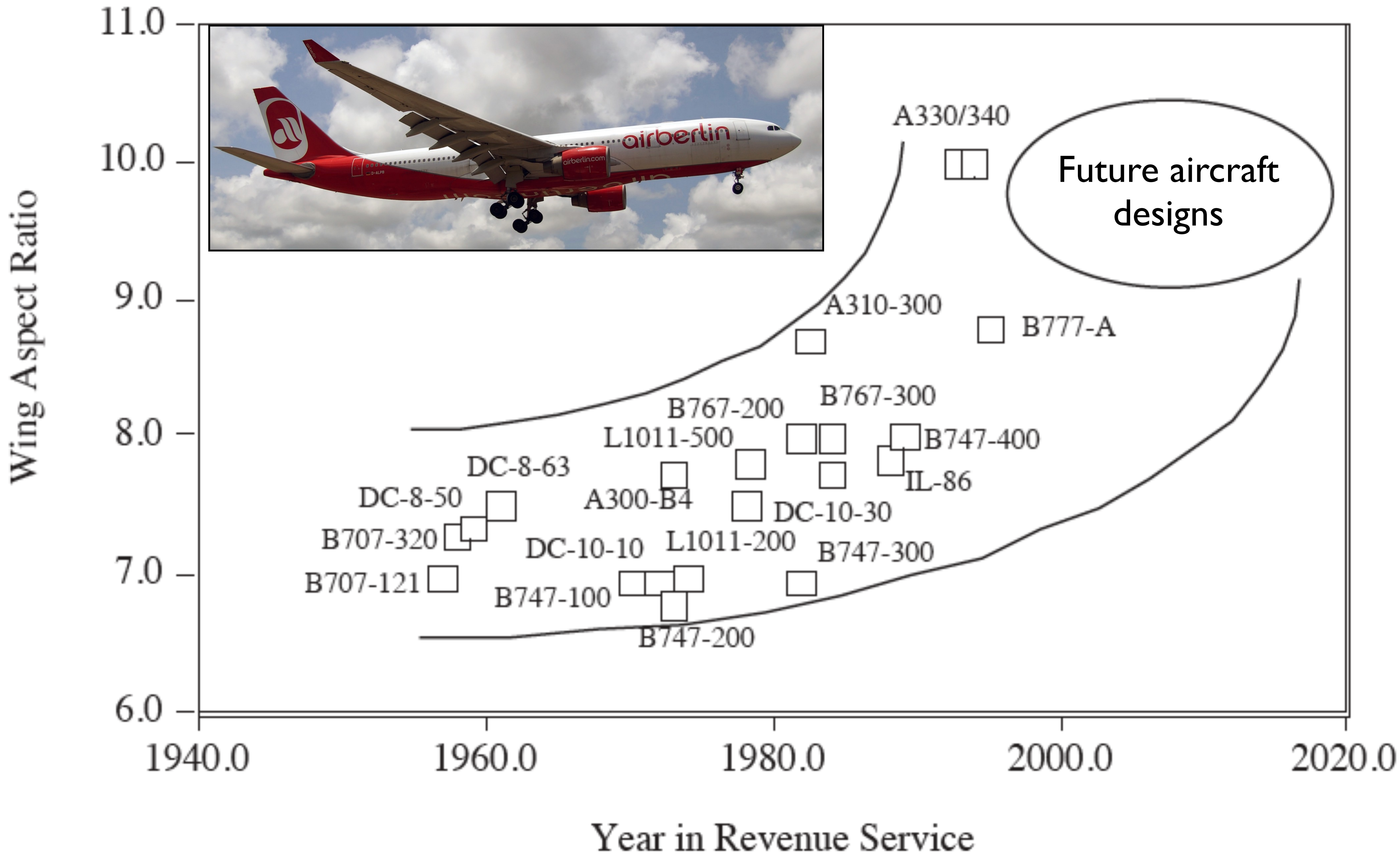
b^2 wingspan (ft² or m²)

S wing area (ft² or m²)



Evolution of Aircraft Wing Aspect Ratios

- Long range aircraft require very long and thin wings to be aerodynamically efficient



Evolution of Aircraft Mass and Wingspan