Aircraft Classifications

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Material Presented

- The aircraft and the airport
- Aircraft classifications
- Aircraft characteristics and their relation to airport planning
- Large capacity aircraft impacts

Relevance of Aircraft Characteristics

- Aircraft classifications are useful in airport engineering work (including terminal gate sizing, apron and taxiway planning, etc.) and in air traffic analyses
- Most of the airport design standards are related to aircraft size (i.e., wingspan, aircraft length, aircraft wheelbase, aircraft seating capacity, etc.)
- Airport fleet compositions vary over time and thus is imperative that we learn how to forecast expected vehicle sizes over long periods of time
- The Next Generation (NextGen) air transportation system will have to accommodate to a more diverse pool of aircraft

Airport Engineering and Aircraft Characteristics

Important to know the performance aspects of the aircraft on the ground (low taxiing speeds) as well as on takeoff and landing

Boeing 737-800 Landing at Runway 36L in Charlotte (A.A.Trani)

Web Sites to Learn to Recognize Various Aircraft

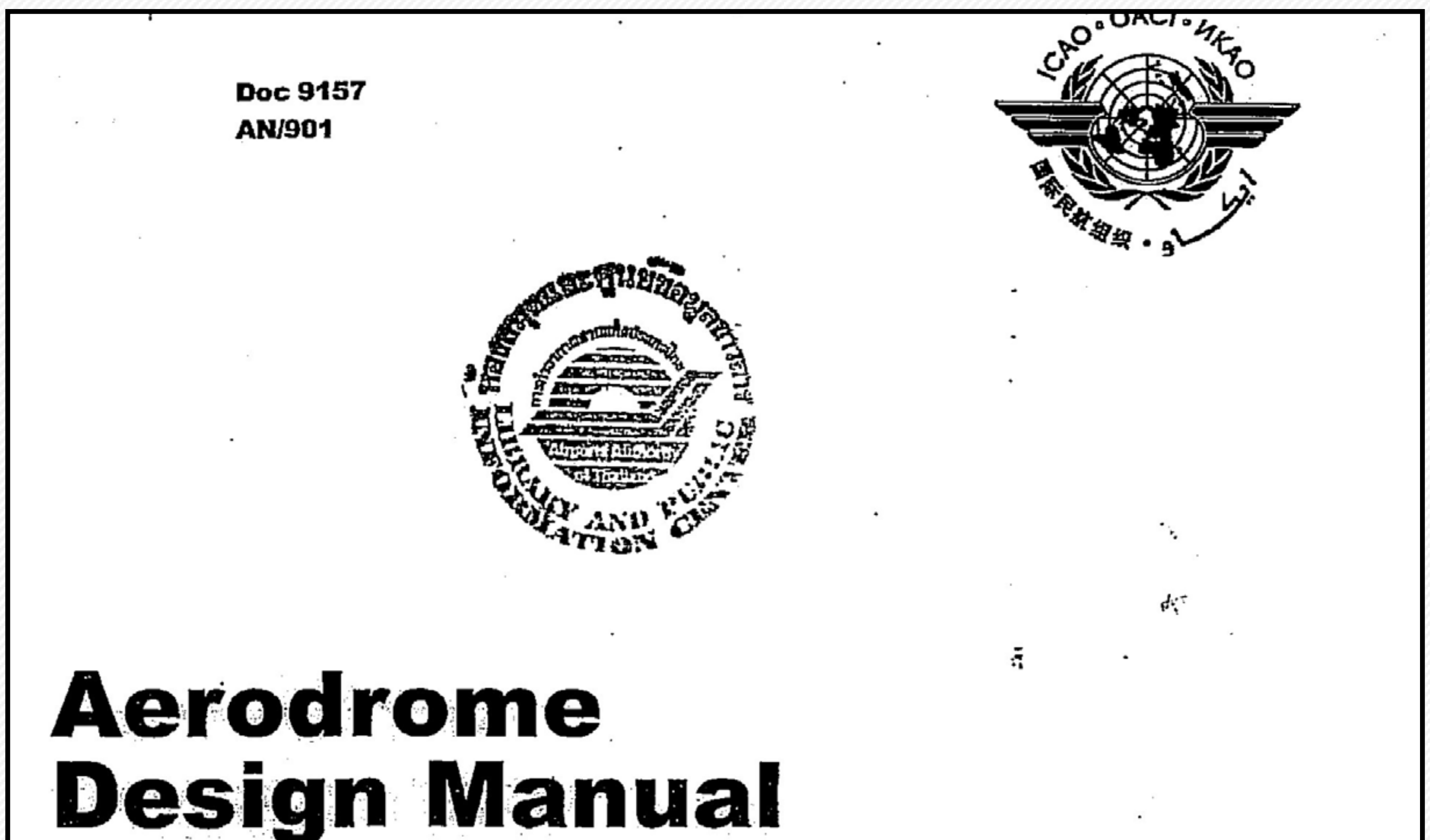
- Pictures taken by the author at various airport (https://photos.app.goo.gl/8bdSvdwPQU7IHIDi2)
- Airliners site airliners.net
- Jetphotos (https://www.jetphotos.com)

Aerospatiale ATR-42-500

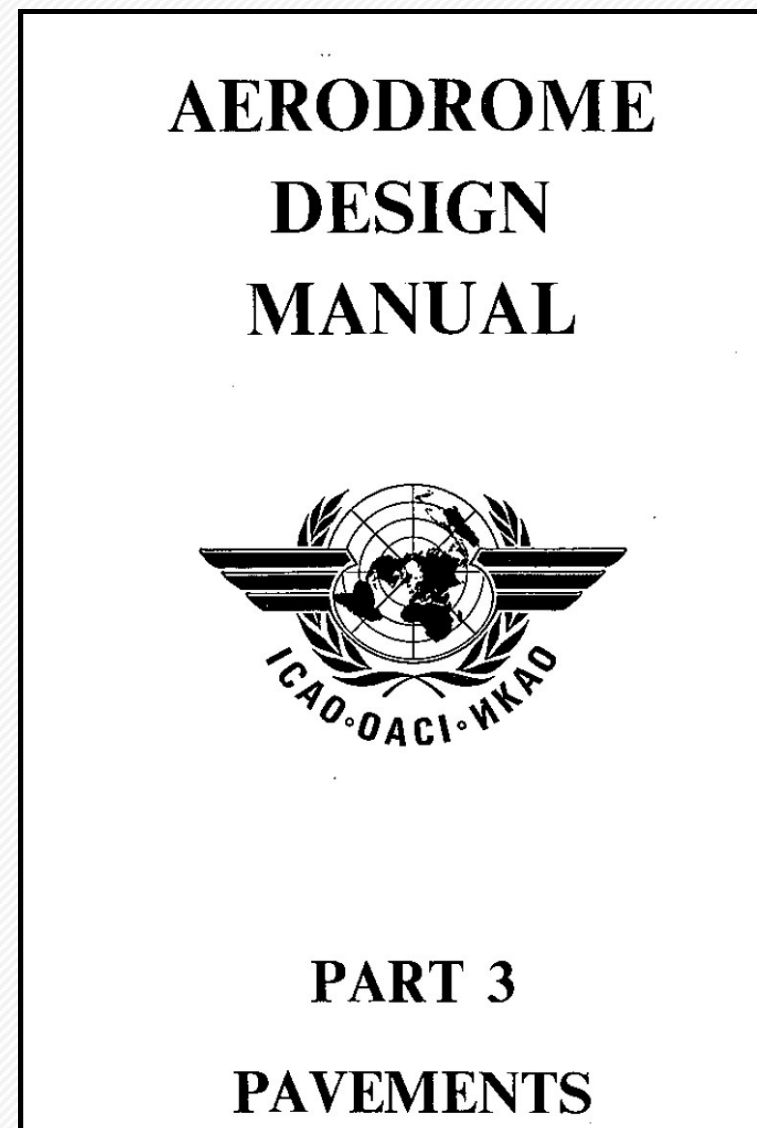
Airbus A380-800

ICAO - International Civil Aviation Organization

Provides guidance about airport design in all countries of the World
FAA design standards and ICAO standards are trending to the same values with time



ICAO Documents 9157 - Aerodrome Design Manual



ICAO Aerodrome Reference Code Code Element 1

ICAO Aerodrome Reference Code used in Airport Design

Code Number	Aeroplane Reference Field Length (meters)
1	Less than 800
2	800 but less than 1200
3	1200 but less than 1800
4	More than 1800

ICAO Aerodrome Reference Code Code Element 2

ICAO Aerodrome Reference Code used in Airport Geometric Design

Design Group	*Wingspan (m)*	*Outer Main Landing Gear Width (m)*	*Example Aircraft*
A	*< 15*	*< 4.5*	*Cessna 172, Cessna 421, Piper PA28, Cessna 510*
B	*15 to < 24*	*4.5 to < 6*	*Commuter aircraft, large business jets (EMB - 120, Saab 2000, Saab 340, etc.)*
C	*24 to < 36*	*6 to < 9*	Boeing 737-700, Boeing 737-800, Boeing 737-8Max, Airbus A320, Airbus A320neo
D	36 to < 52	9 to < 14	Boeing 757-200, Boeing 767-300, Airbus A300-600
E	52 to < 65	9 to < 14	*Boeing 787-8, Boeing 777-200, Airbus A330-300, Airbus A350-900*
F	65 to < 80	*> 14*	*Airbus A380, Boeing 747-8, Antonov 124, and Antonov 225**

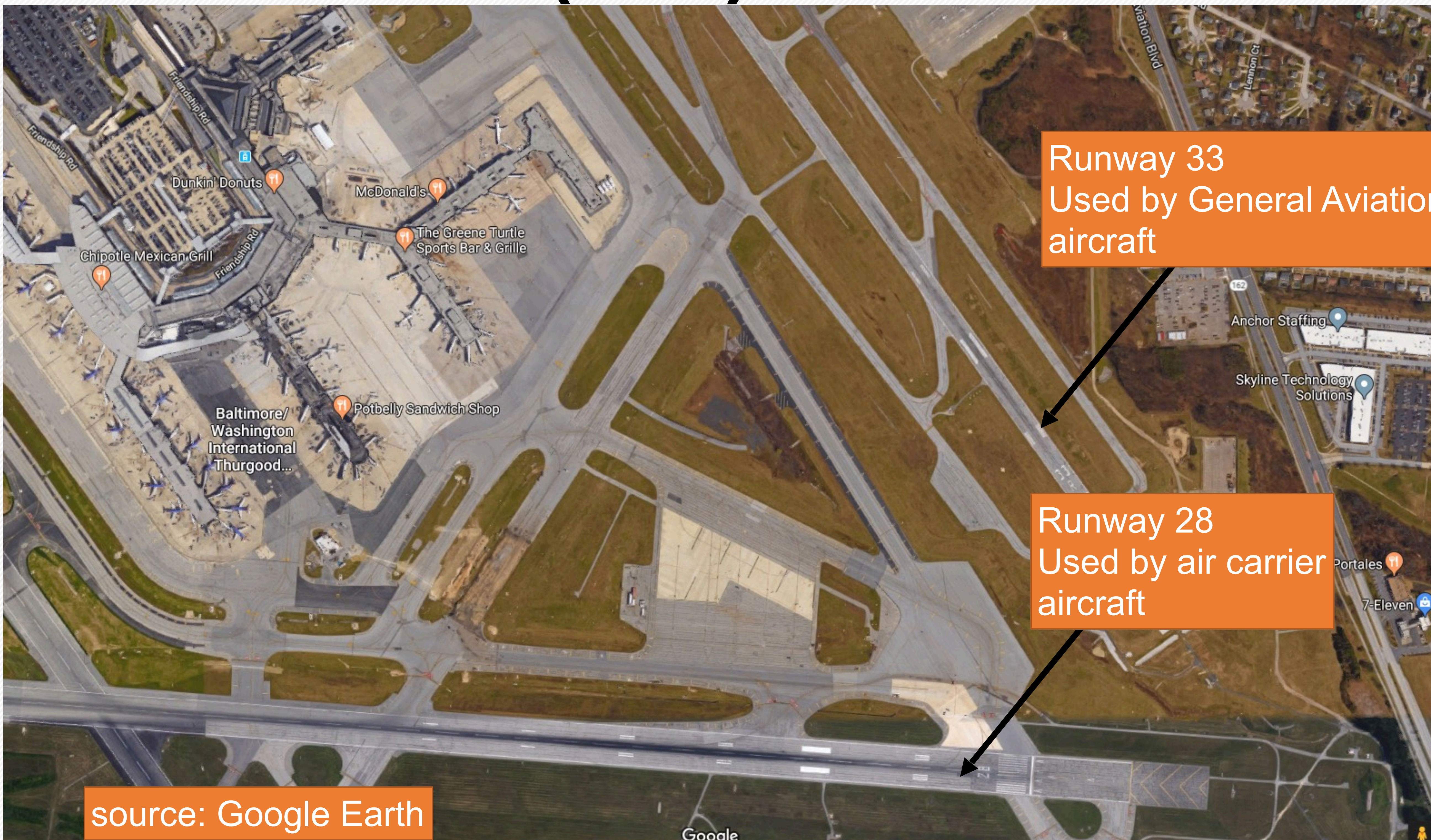
* The only Antonov 225 was destroyed in 2022

Federal Aviation Administration Runway Design Code (RDC)

- Combines **three classification criteria** to define the design specifications of each runway of the airport:
  - Aircraft Approach Code (AAC)
  - Aircraft Design Group (ADG)
  - Approach visibility minimums
- **A fourth classification** - called Taxiway Design Group (TDG) is also used in airport design
- The following slides provide some insight about each classification scheme

Note: An airport may have different RDC standards for different runways
For example, a runway used for air carrier operations may use a higher RDC standard
than a runway used for General Aviation Operations

Example: Baltimore-Washington International (BWI)



Federal Aviation Administration Aircraft Design Group (ADG)

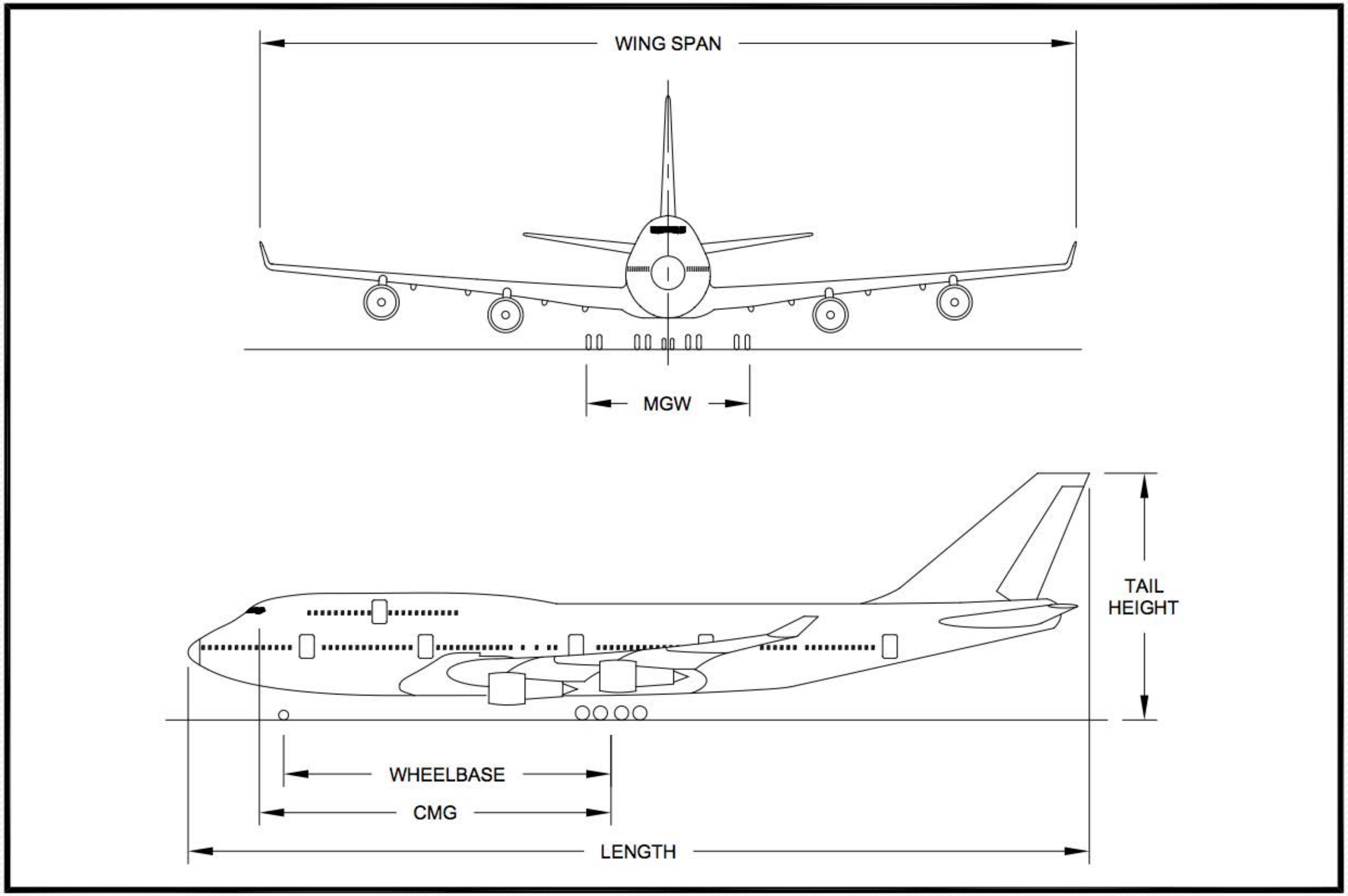
Design Group	Tail Height (feet)	Wingspan (feet)	Representative Aircraft Types
I	< 20	< 49	Cessna 172, Beech 36, Cessna 421, Learjet 35
II	20 to < 30	49 to < 79	Beech B300, Cessna 550, Falcon 50, Challenger 605
III	30 to < 45	79 to < 118	Boeing 737, Airbus A320, CRJ-900, EMB-190
IV	45 to < 60	118 to < 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, Boeing 747-8

Federal Aviation Administration Aircraft Design Group (ADG)

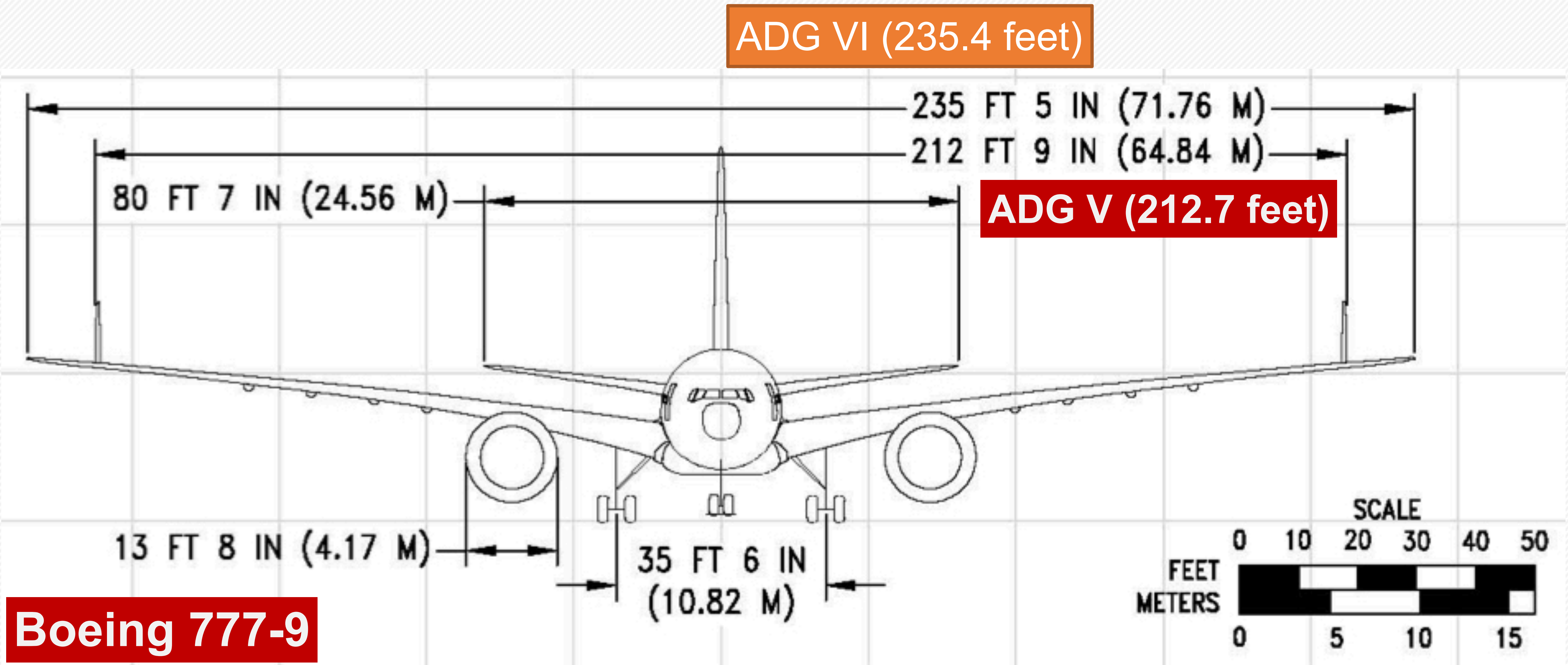
Group #	Tail Height	Wingspan
I	< 20 ft (< 6.1 m)	< 49 ft (< 14.9 m)
II	20 ft to < 30 ft (6.1 m to < 9.1 m)	49 ft to < 79 ft (14.9 m to < 24.1 m)
III	30 ft to < 45 ft (9.1 m to < 13.7 m)	79 ft to < 118 ft (24.1 m to < 36 m)
IV	45 ft to < 60 ft (13.7 m to < 18.3 m)	118 ft to < 171 ft (36 m to < 52 m)
V	60 ft to < 66 ft (18.3 m to < 20.1 m)	171 ft to < 214 ft (52 m to < 65 m)
VI	66 ft to < 80 ft (20.1 m to < 24.4 m)	214 ft to < 262 ft (65 m to < 80 m)

source: Table 1-2 of FAA AC 150/5300-13B

Federal Aviation Administration Aircraft Design Group (ADG)



Aircraft with Folding Wings Fit into two Aircraft Design Groups (ADG)

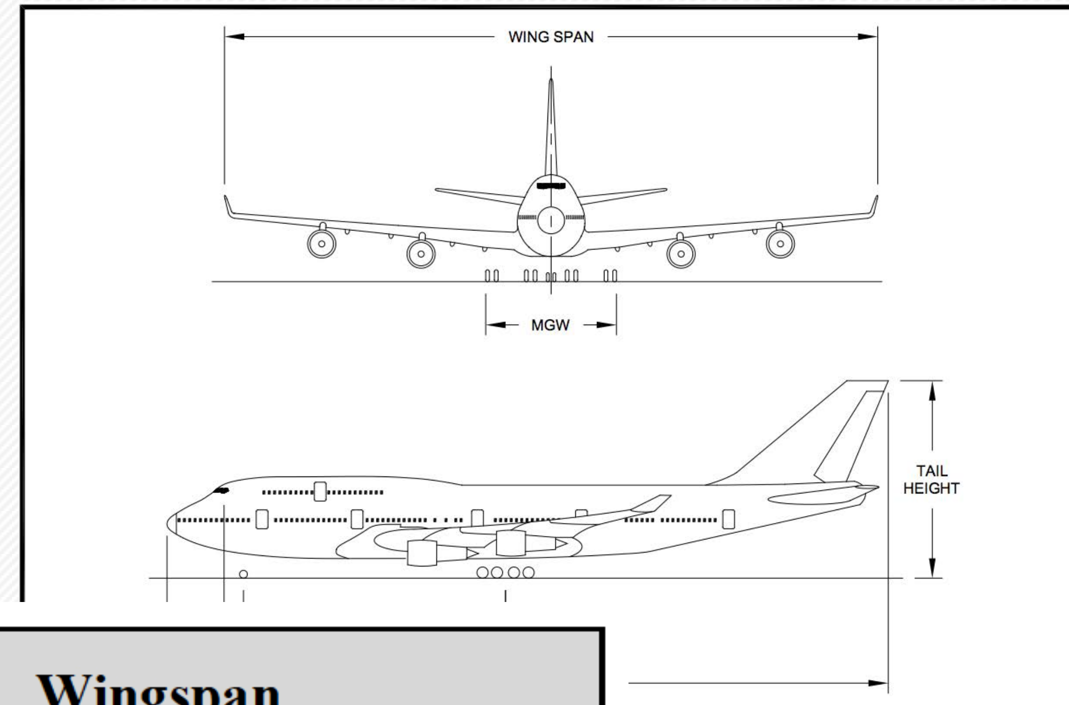


Aircraft can use existing ADG V gates (ICAO Design Group E)

Source: Boeing Airplane Characteristics for Airport Design (https://www.boeing.com/resources/boeingdotcom/commercial/airports/acaps/777X_RevD.pdf)

If an Aircraft Belongs to two ADG Groups, Select the Most Demanding for Design (Except for Aircraft with Folding Wings)

Note: Always use the most critical dimension of the two criteria shown in Table 1-1



Group #	Tail Height	Wingspan
I	< 20 ft (< 6.1 m)	< 49 ft (< 14.9 m)
II	20 ft to < 30 ft (6.1 m to < 9.1 m)	49 ft to < 79 ft (14.9 m to < 24.1 m)
III	30 ft to < 45 ft (9.1 m to < 13.7 m)	79 ft to < 118 ft (24.1 m to < 36 m)
IV	45 ft to < 60 ft (13.7 m to < 18.3 m)	118 ft to < 171 ft (36 m to < 52 m)
V	60 ft to < 66 ft (18.3 m to < 20.1 m)	171 ft to < 214 ft (52 m to < 65 m)
VI	66 ft to < 80 ft (20.1 m to < 24.4 m)	214 ft to < 262 ft (65 m to < 80 m)

source: Table 1-2 of FAA AC 150/5300-13B

FAA Aircraft Approach Speed Classification (AAC)

source: Table 1-1 of FAA AC 150/5300-13B

AAC	V_{REF}/Approach Speed
A	Approach speed less than 91 knots
B	Approach speed 91 knots or more but less than 121 knots
C	Approach speed 121 knots or more but less than 141 knots
D	Approach speed 141 knots or more but less than 166 knots
E	Approach speed 166 knots or more

a. At maximum landing weight

b. See the FAA Aircraft Characteristics Database for a complete listing of aircraft approach speeds

Knot is the unit of speed used in aviation
1 knot = 1.15 miles per hour (statute miles per hour)
Example: A Boeing 737-800 has an approach speed of 142 knots or equivalent to 163 miles per hour

FAA Aircraft Approach Speed Classification (AAC)

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C	Approach speed 121 knots or more but less than 141 knots
D	Approach speed 141 knots or more but less than 166 knots
E	Approach speed 166 knots or more

source: Table 1-1 of FAA AC 150/5300-13B

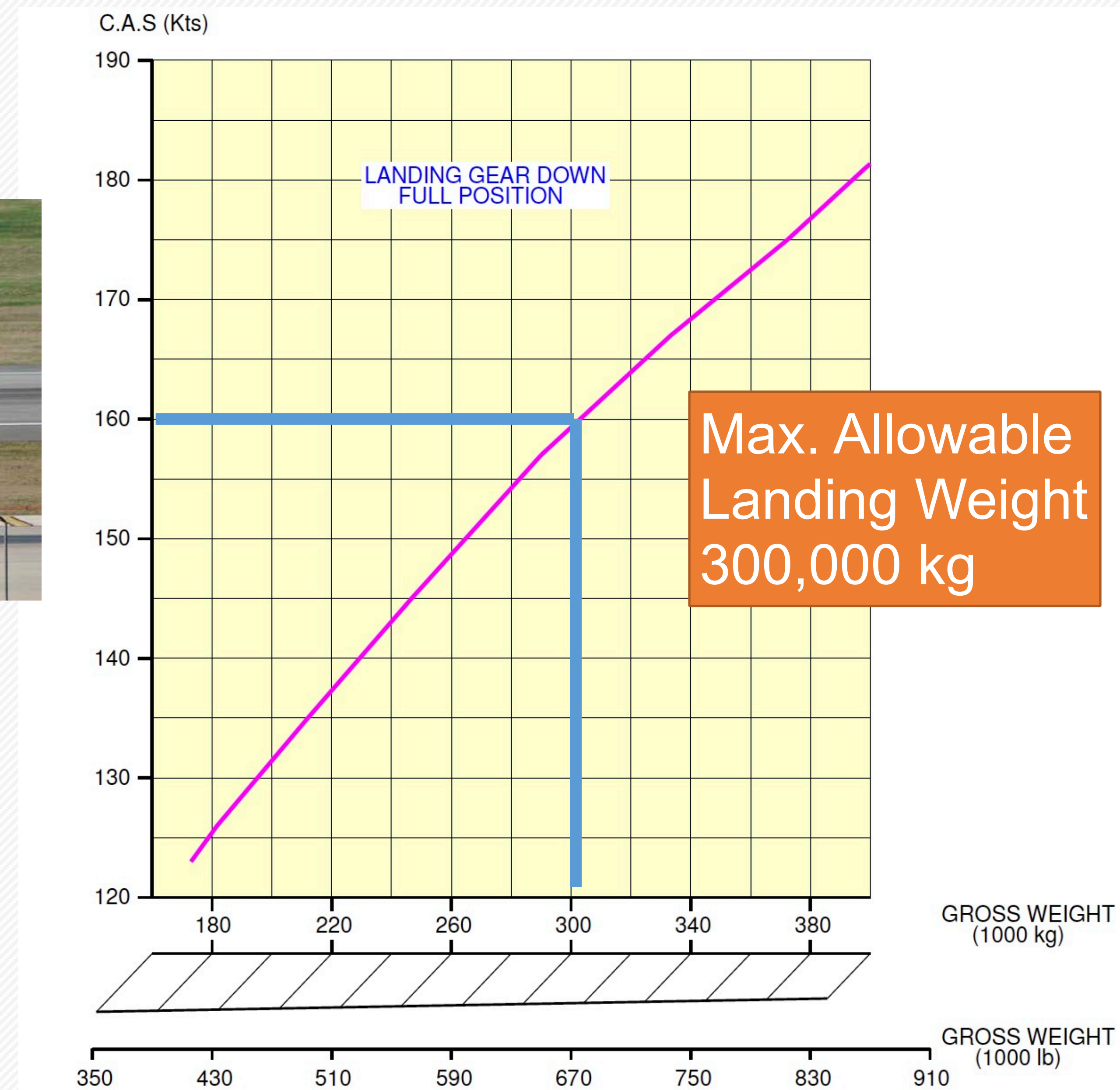
- Aircraft approach speeds are taken at **maximum allowable landing weight**
- For the same aircraft, **approach speeds vary with landing weight**
- For typical commercial aircraft, approach speeds can vary as much as 15-35 knots between maximum landing weight and operating empty weight

Example of Aircraft Approach Speed Variations

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

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

Approach Speed (knots)



source: Airbus A340-500 Airplane Characteristics for Airport Planning

Aircraft Characteristics Database

Aircraft characteristics database - sorted by aircraft manufacturer model

Manufacturer	Aircraft	AAC	ADG	TDG	Wing-span ft (m)	Tail Height ft (m)	Length ft (m)	CMG ft (m)	Wheel-base ft (m)	MGW Outer to Outer ft (m)	MTOW lbs (kg)	V_{REF}/ Approach Speed kts
Airbus	A-300	C	IV	5	147.1 (44.83)	55 (16.72)	175.9 (53.61)	75 (22.86)	61 (18.6)	36.1 (11)	363,763 (165000)	137
Airbus	A-300-600	C	IV	5	147.1 (44.84)	55 (16.7)	177 (54.1)	75 (22.87)	61 (18.6)	36 (10.96)	375,888 (170500)	137
Airbus	A-310	C	IV	5	144 (43.9)	52.1 (15.87)	153.1 (46.66)	63.9 (19.49)	49.9 (15.22)	36 (10.96)	361,558 (164000)	139
Airbus	A-318	C	III	3	111.9 (34.1)	42.3 (12.89)	103.2 (31.45)	42.4 (12.91)	33.6 (10.25)	29.4 (8.95)	149,914 (68000)	121
Airbus	A-318 Sharklet *	C	III	3	117.5 (35.8)	42.3 (12.89)	103.2 (31.45)	42.4 (12.91)	33.6 (10.25)	29.4 (8.95)	149,914 (68000)	121

Aircraft Approach Class

Aircraft Design Group

Taxiway Design Group

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 Equipment

Approach Visibility Minimums

VirginiaTech
Invent the Future

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.

source: Table 1-3 of FAA AC 150/5300-13A

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

Recap: Runway Design Code (RDC)

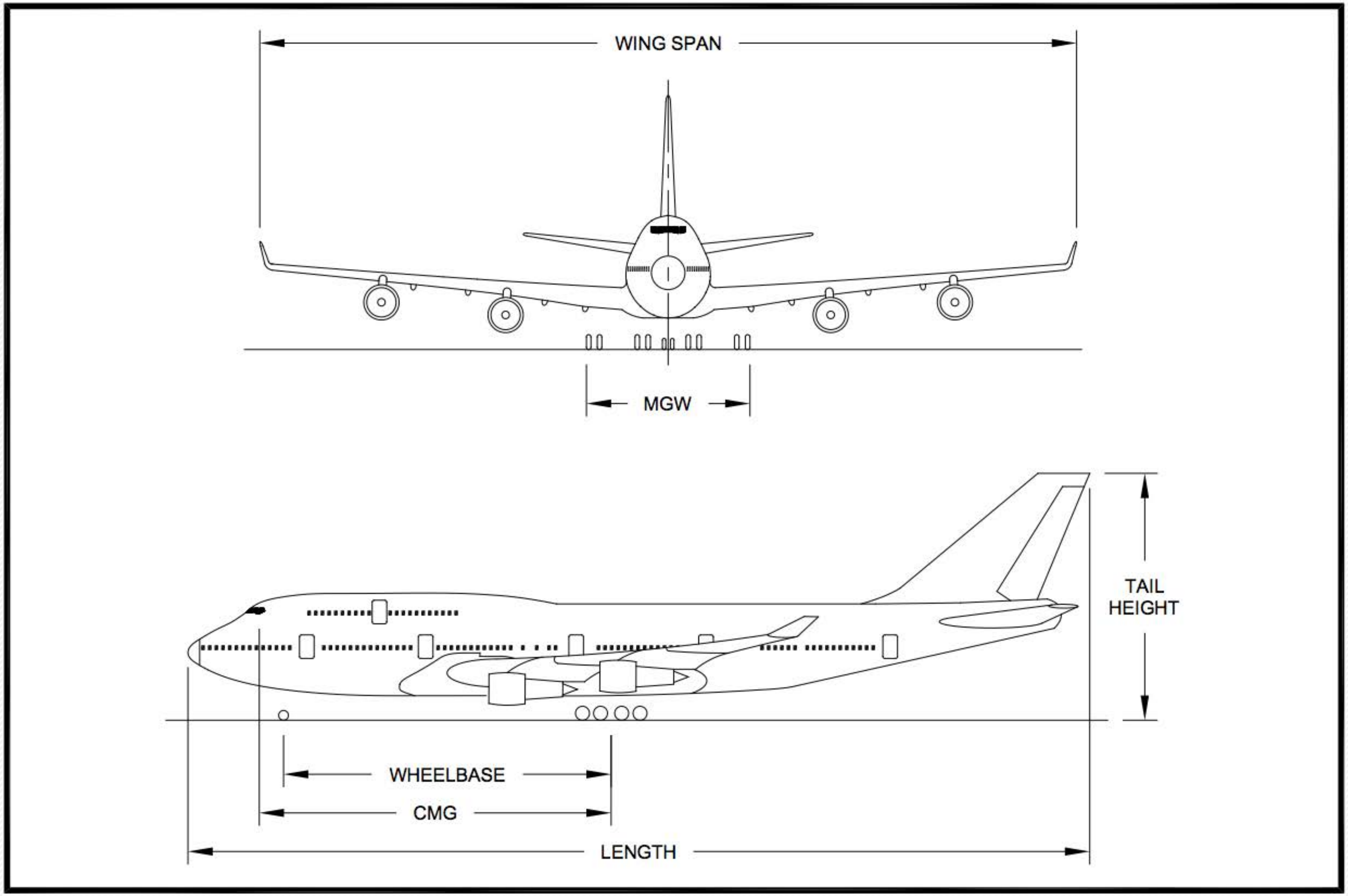
- Three parameters are combined to derive a so-called Runway Design Code (RDC)
  - AAC, ADG and Approach Visibility Minimums
- RDC provides three parameters needed to determine design standards for an airport
- Note: for most airport design projects the TDG parameter is also critical to determine taxiway-to-runway distances

Taxiway Design Group (TDG)

- Previous FAA guidance considered tail height and wingspan as design factors for geometric design

- New guidance implemented in September 2012 considers:
  - Dimensions of the aircraft undercarriage
  - Main gear width (MGW)
  - Cockpit to main gear dimensions (CMG)

FAA AC 150/5300-13B (Appendix A)



CMG is used because pilots normally try following a taxiway centerline

FAA AC 150/5300-13B Appendix I

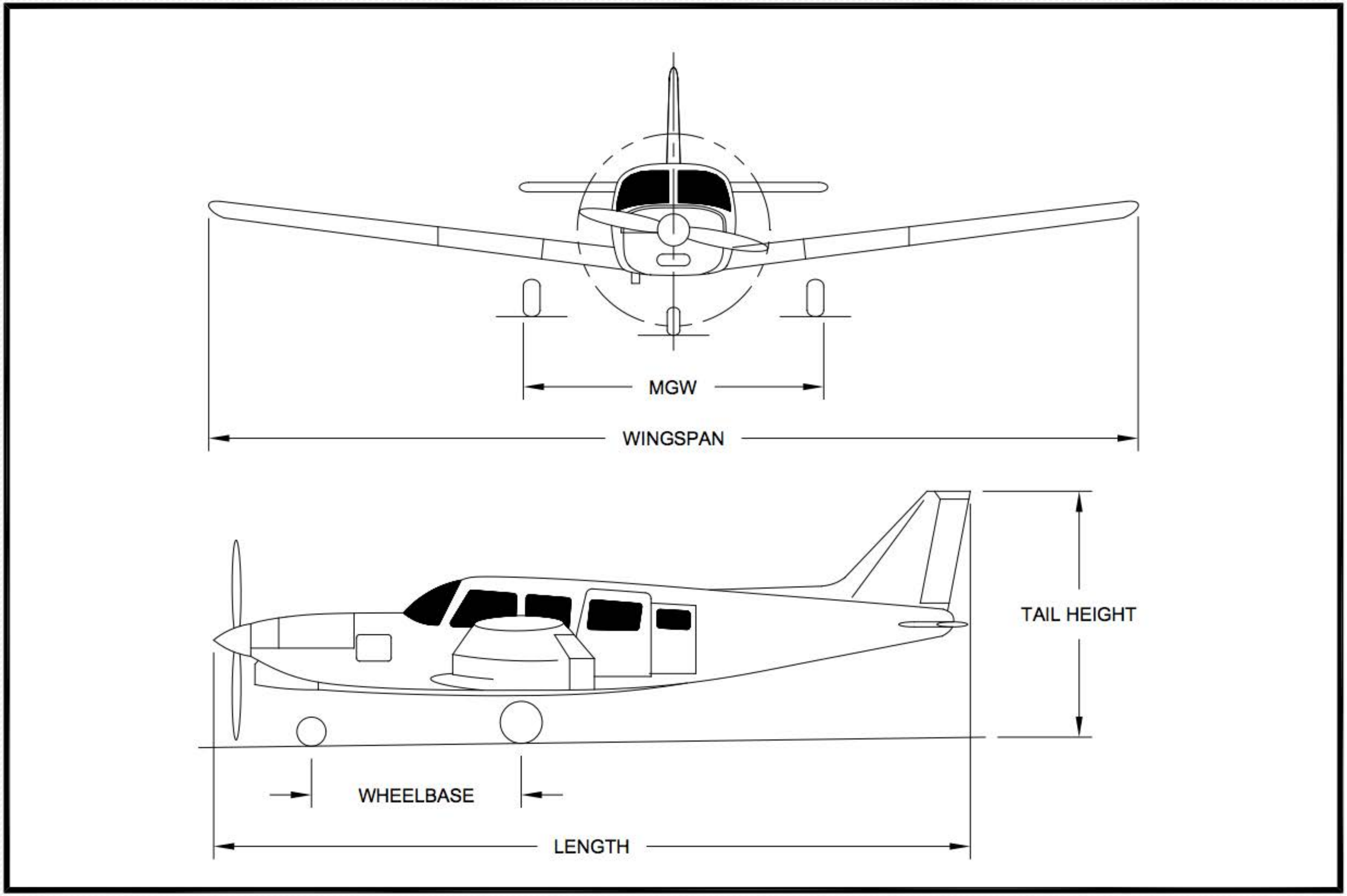


Figure A1-2. Typical dimensions of small aircraft

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 the previous slides

Examples : Small Aircraft

Many general aviation aircraft (called GA) typically have the nose gear located in front of the cockpit (use the wheelbase distance for design)

Cirrus SR-20
4-seat single
engine piston
power aircraft

Cessna Citation
Excel 560XL Twin
turbofan powered
aircraft

Examples - Commercial Aircraft

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

Airbus A320.Twin-engine turbofan powered, commercial aircraft

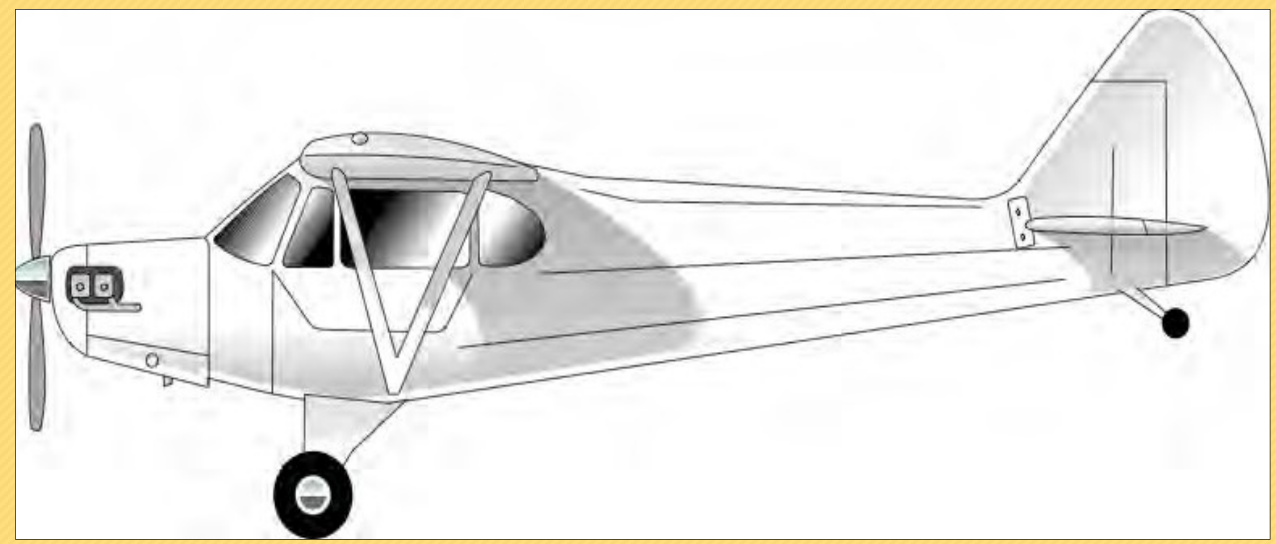
Cockpit to Main Gear Distance (CMG)

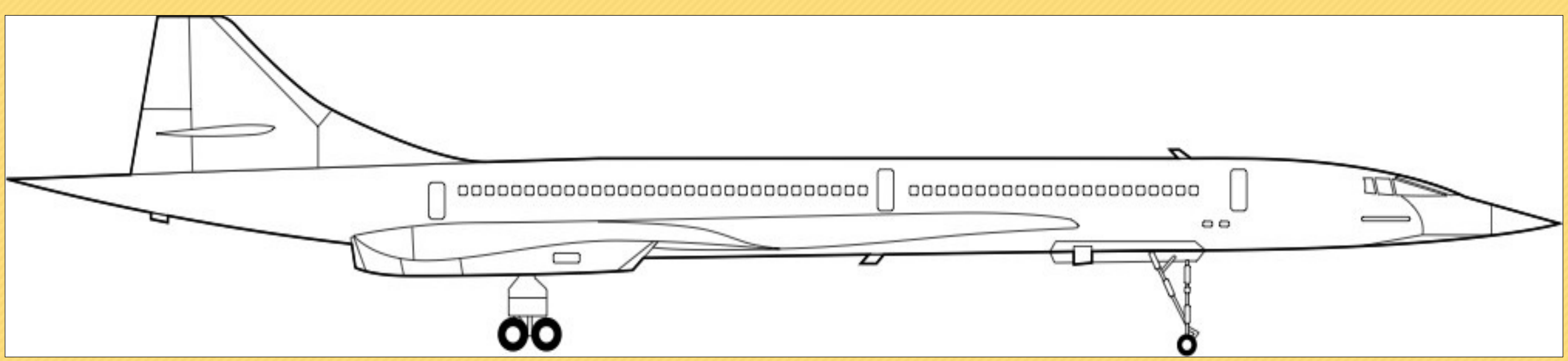
Special Landing Gear Configurations

Some aircraft have special landing gear configurations

Piper J-3 Cub
2-seat single engine
piston power aircraft

Tail Dragger
Configuration

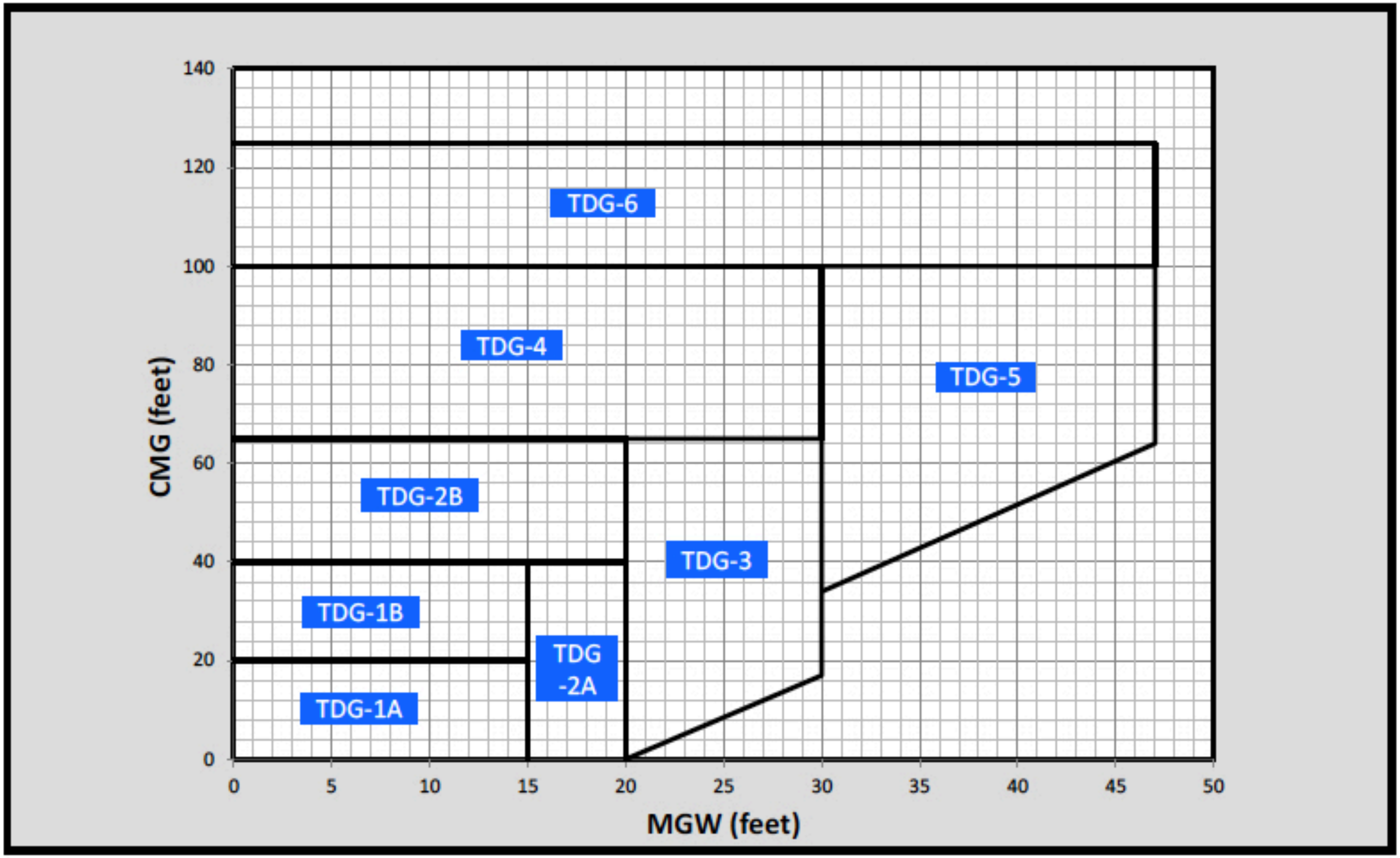




BAC Concorde - Supersonic Transport (very long CMG distance)

Taxiway Design Groups

Figure 1-1. Taxiway Design Groups (TDGs) source: FAA AC 150/5300-13B



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

Excel Database of Aircraft Characteristics

Provides information for thousands of aircraft

Database is not complete (Virginia Tech is helping FAA to complete the database)

- www.faa.gov/airports/engineering/aircraft_char_database

Manufacturer	Model	FAA Code	MTOW (lb)	Approach Speed (knots)	Wingspan (ft)	Tail Height (ft)	ARC
Adam Aircraft Industries	A500	A500	7,000	98	44.00	9.58	B-I
Aero Spacelines	B-377	SGUP	170,000	123	156.25	48.50	C-IV
Aeronca	11AC Chief	AR11	1,250	64	36.00	6.00	A-I
Aeronca	15AC Sedan	AR15	2,050	67	37.50	10.33	A-I
Aerospatiale	ATR-42-320	AT43	36,817	124	80.58	24.92	C-III
Aerospatiale	ATR-42-500	AT45	41,005	128	80.60	24.90	C-III
Aerospatiale	ATR-72	AT72	48,501	128	88.75	25.00	C-III
Aerospatiale	NORD-262	N262	23,810	96	74.17	20.40	B-II
Aerospatiale	SE 210	S210	110,200	127	112.50	28.58	C-III
Aerospatiale	SN 601 Corvette	S601	14,550	118	42.25	13.92	B-I
Aerostar Aircraft Corp	700	AEST	6,315	94	36.70	13.20	B-I
Aerostar Aircraft Corp	602P	AEST	6,000	94	36.71	12.13	B-I
Aerostar Aircraft Corp	601P	AEST	6,000	94	36.71	12.13	B-I
Air Tractor	AT-301	AT3P	3,492	76	45.15	8.50	A-I

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:

Look at the FAA aircraft database:Approach speed is 143 knots (AAC = D) and Wingspan is 124.8 feet and tail height 44.9 feet (thus group IV)

Manu-facturer	Aircraft	AAC	ADG	TDG	Wing-span	Tail Height	Length	CMG	Wheel-base	MGW Outer to Outer	MTOW	V_{REF}/ Approach Speed
					ft (m)	ft (m)	ft (m)	ft (m)	ft (m)	ft (m)	lbs (kg)	kts
Boeing	757-300	D	IV	5	125.0 (38.10)	44.9 (13.69)	178.5 (54.40)	85.3 (26.00)	73.3 (22.34)	28.2 (8.60)	270,000 (122470)	143
Boeing	757-300/W	D	IV	5	134.8 (41.10)	44.9 (13.69)	181.8 (55.40)	85.3 (26.00)	73.3 (22.34)	28.2 (8.60)	270,000 (122470)	143

Picture the Aircraft in Question (Sanity Check)

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

Aircraft pictures are available at: http://www.airliners.net

Example Problem #1

Boeing 757-300 :Approach speed is 143 knots (AAC = D) and Wingspan is 124.8 feet and tail height 44.5 feet. **Hence the aircraft belongs to ADG group IV.**

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 2124*

Boeing 757-300 Belongs to Group IV

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

Note: The most critical element for this aircraft is the wingspan ADG Group IV. The tail height belongs to ADG Group III.

Example Problem #1

Boeing 757-300 has a wheelbase of 73.3 feet, a Main Gear Width of 28.2 feet (8.6 meters) and a Cockpit to Main Gear distance of 85.3 feet (26 m)

Manufacturer	Aircraft	AAC	ADG	TDG	Wing-span ft (m)	Tail Height ft (m)	Length ft (m)	CMG ft (m)	Wheel-base ft (m)	MGW Outer to Outer ft (m)	MTOW lbs (kg)	V_{REF}/ Approach Speed kts
Boeing	757-300	D	IV	4	125.0 (38.10)	44.9 (13.69)	178.5 (54.40)	85.3 (26.00)	73.3 (22.34)	28.2 (8.60)	270,000 (122470)	143
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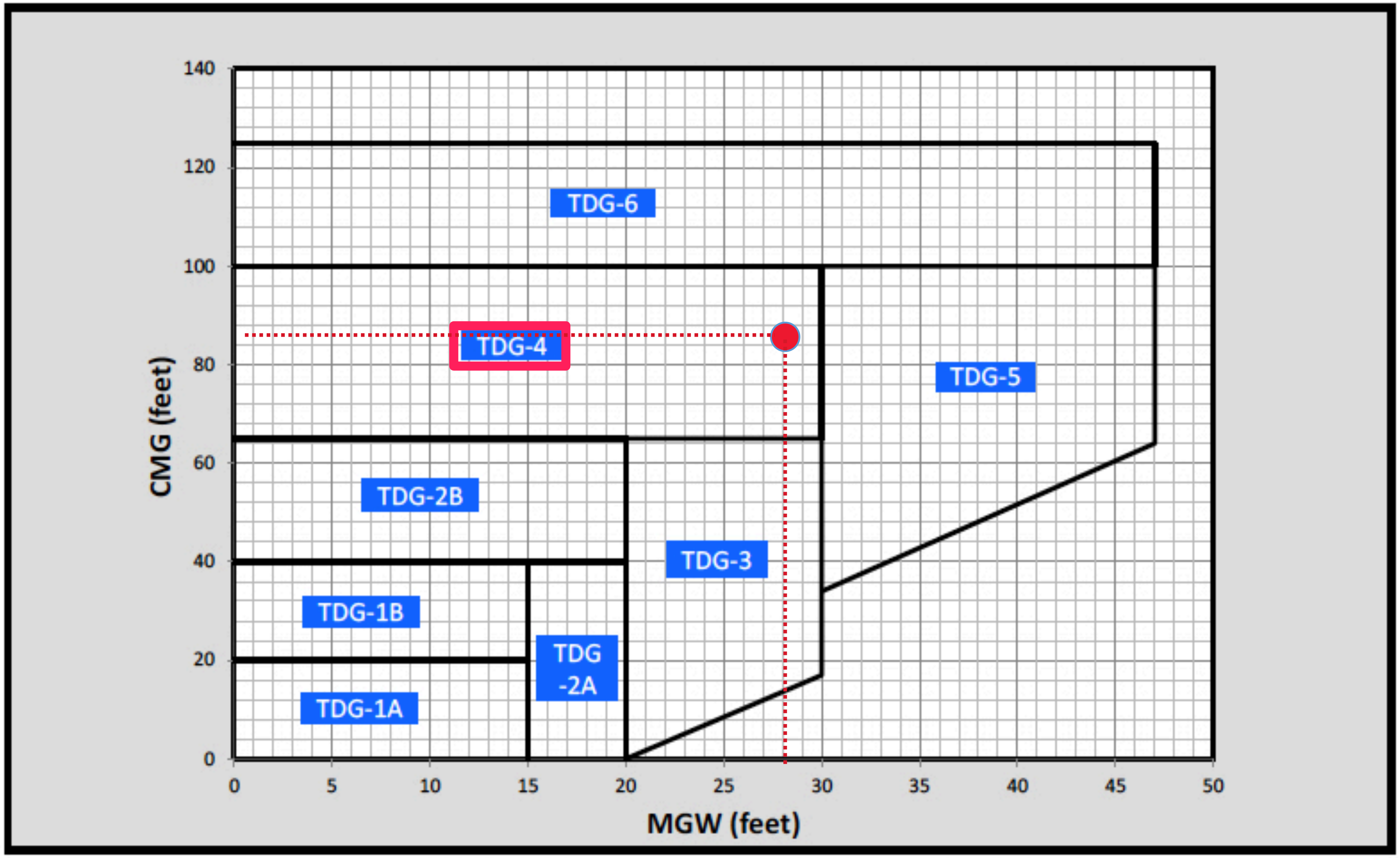
Boeing 757-300 Belongs to Taxiway Design Group (TDG) 4

Example Problem #1

Boeing 757-300 has a CMG distance of 85.3 feet, a Main Gear Width of 28.2 feet (8.6 meters)

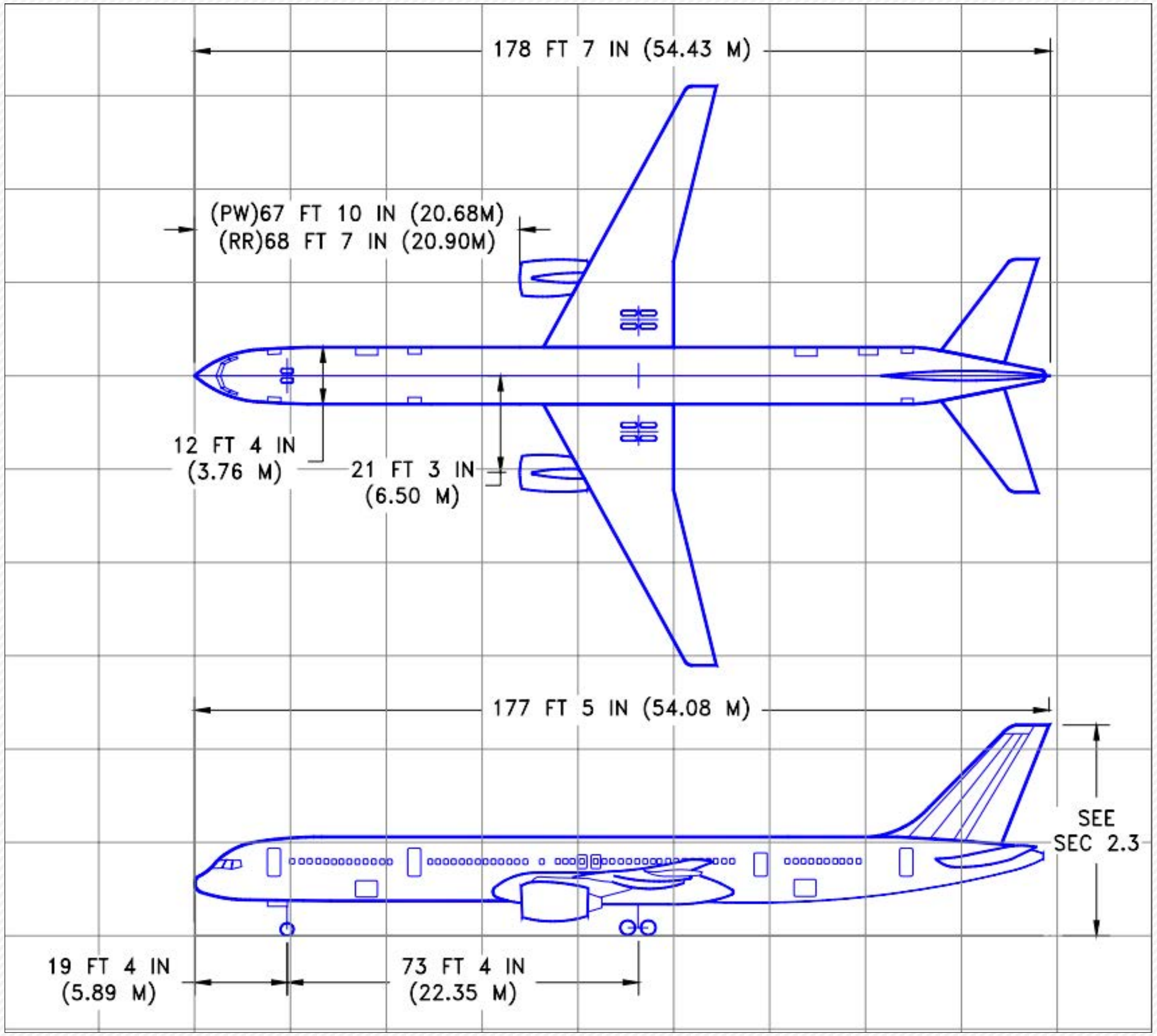
Boeing 757-300 Belongs to Taxiway Design Group (TDG) 4



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

Boeing 757-200/300 Document for Airport Design

Aircraft Manufacturer documents provide another source of aircraft data

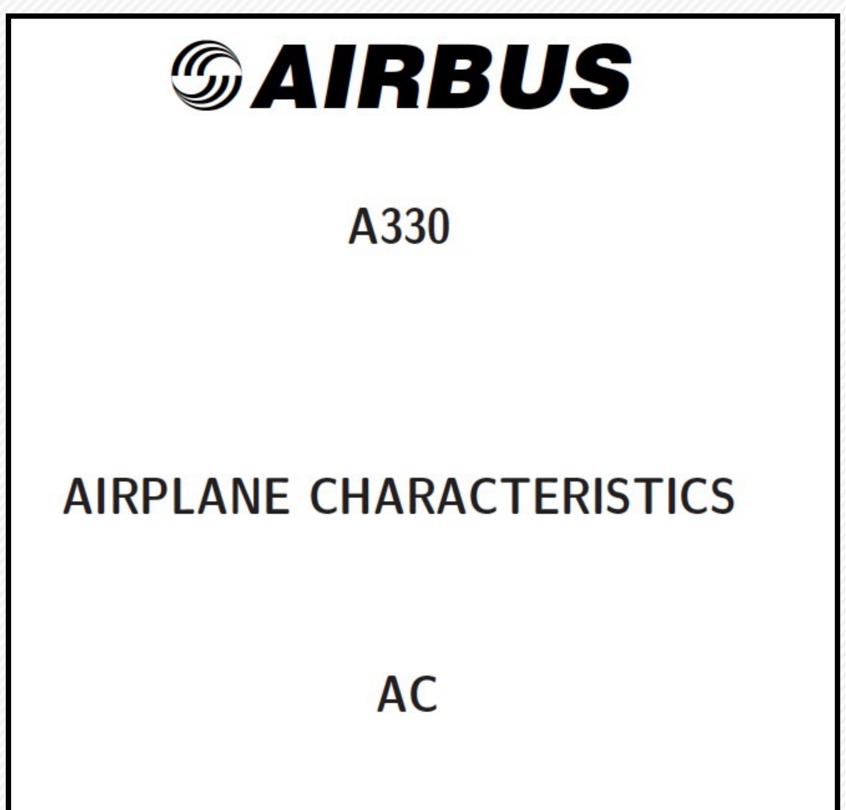


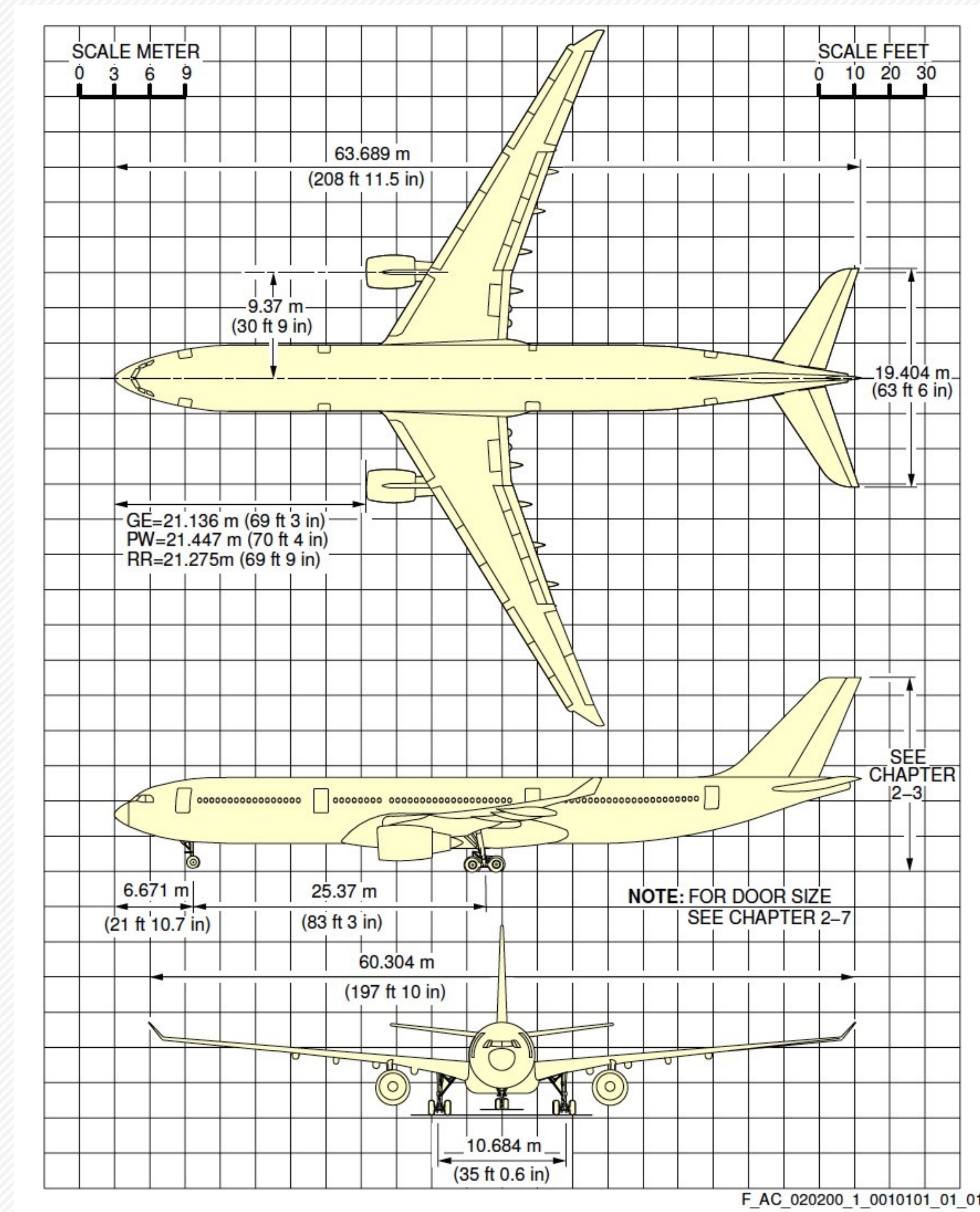
Example Problem #2

An airport is to be designed to accommodate the Airbus A330-300 aircraft. Determine the ICAO airport reference code element 2 to be used in design.

Solution:

Look at the aircraft characteristics provided by Airbus





Example Problem #2

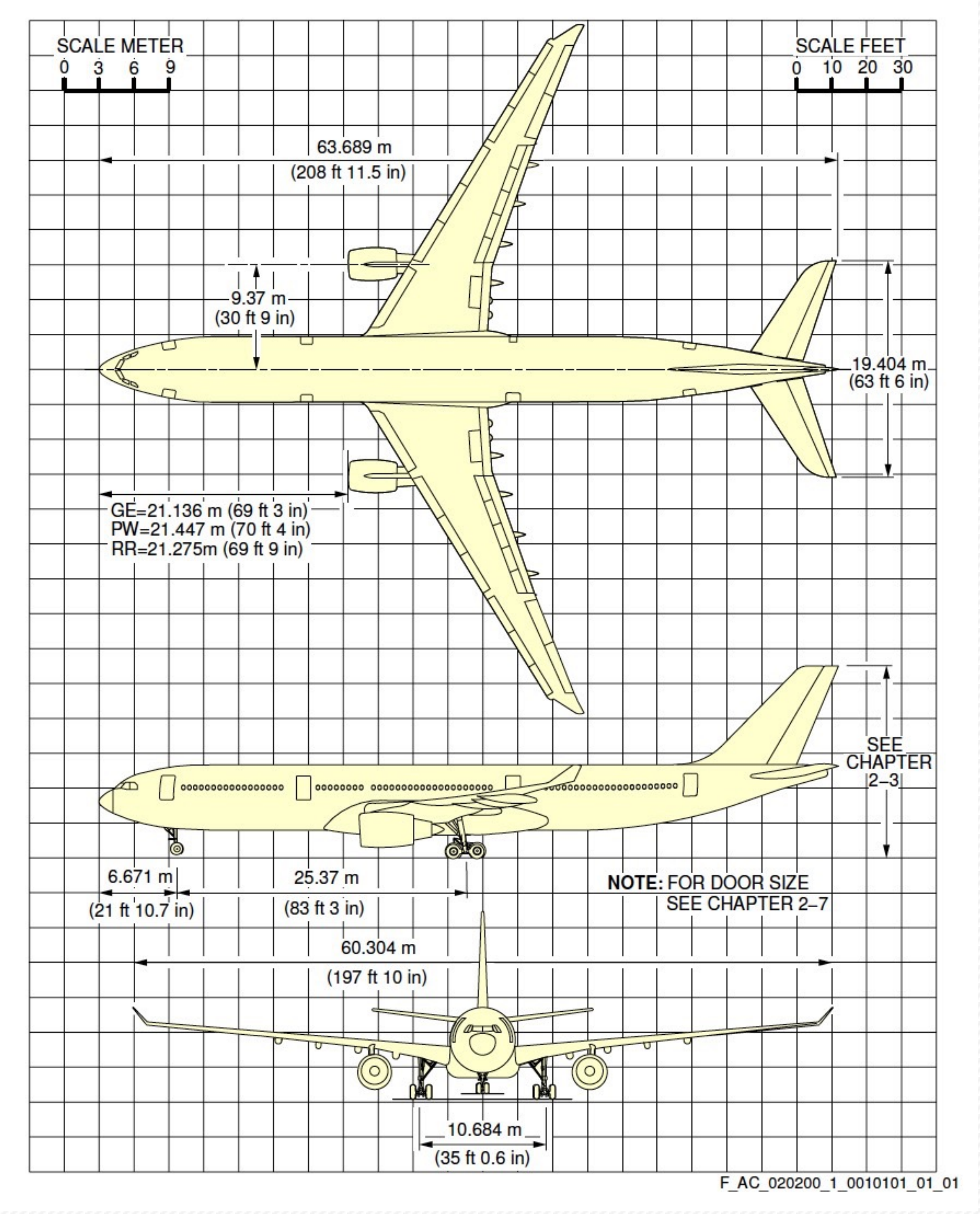
Solution:

The aircraft wingspan is listed

at 60.3 meters

Outer main gear width is 11.3 meters

Aircraft belongs to **ICAO Code E**



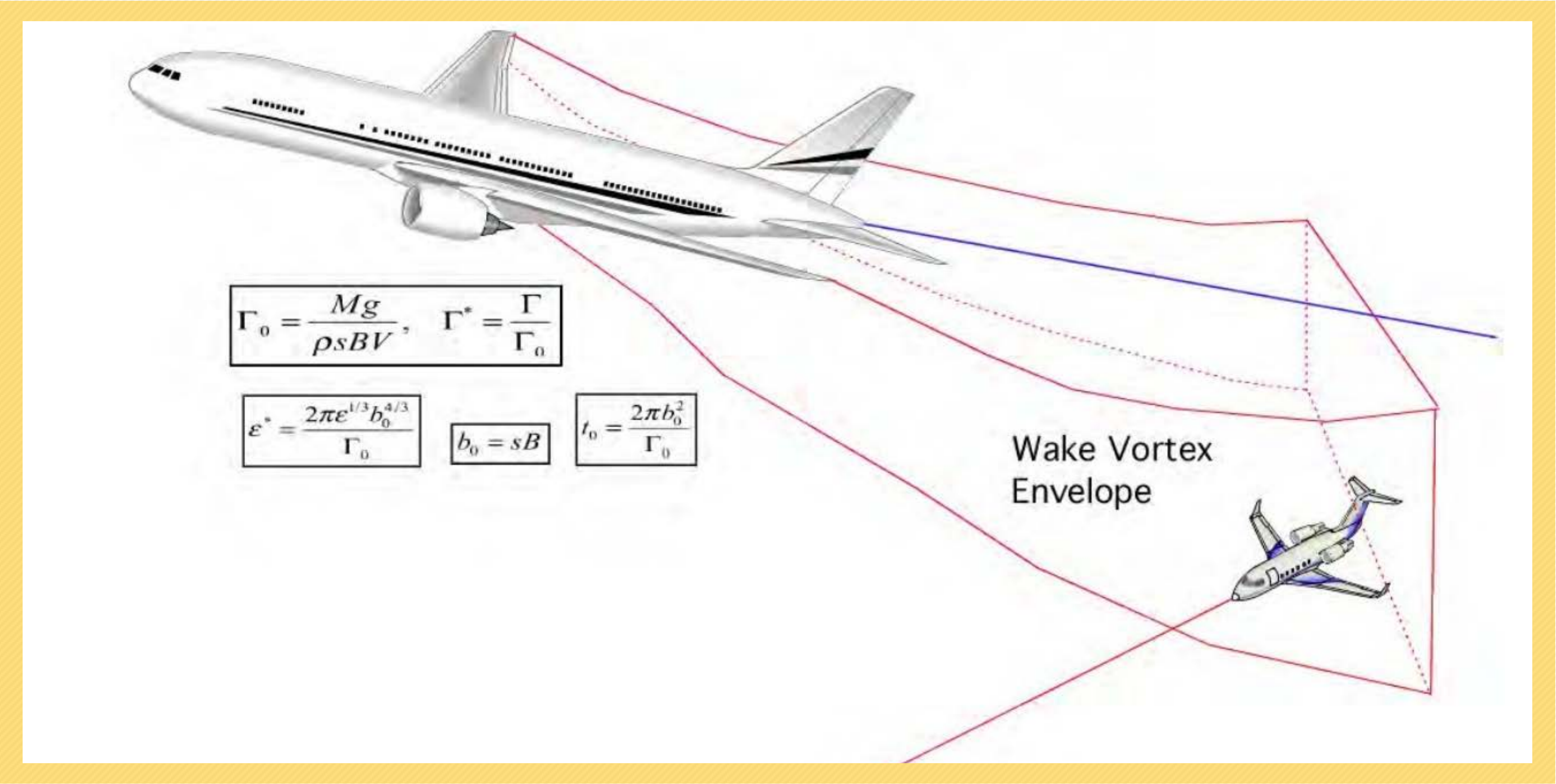
Picture the Aircraft in Question (Sanity Check)

Airbus A330-300 landing at Charlotte Douglas International Airport (A.Trani)

Aircraft pictures are available at: http://www.airliners.net

Wake Vortex

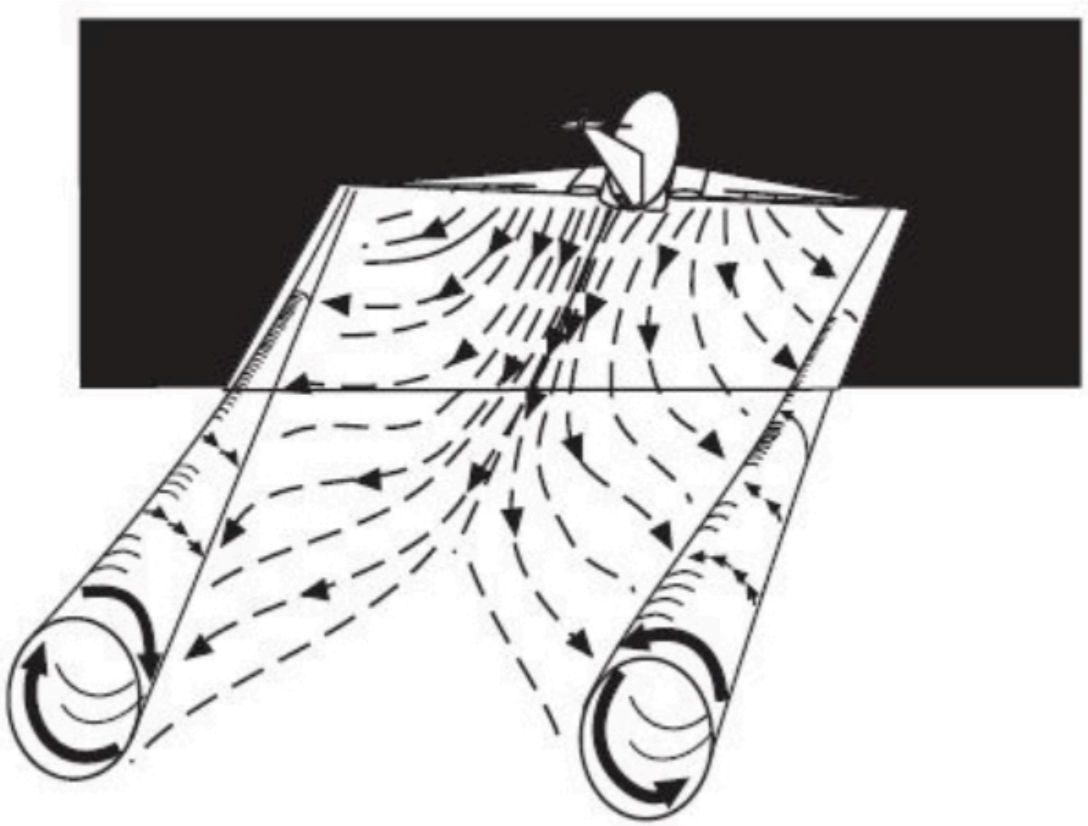
Every aircraft generates wakes behind the wing due to the strong circulation required to generate lift



Circular Strenght Boundary

Wake vortices depend on aircraft mass, wingspan and atmospheric conditions

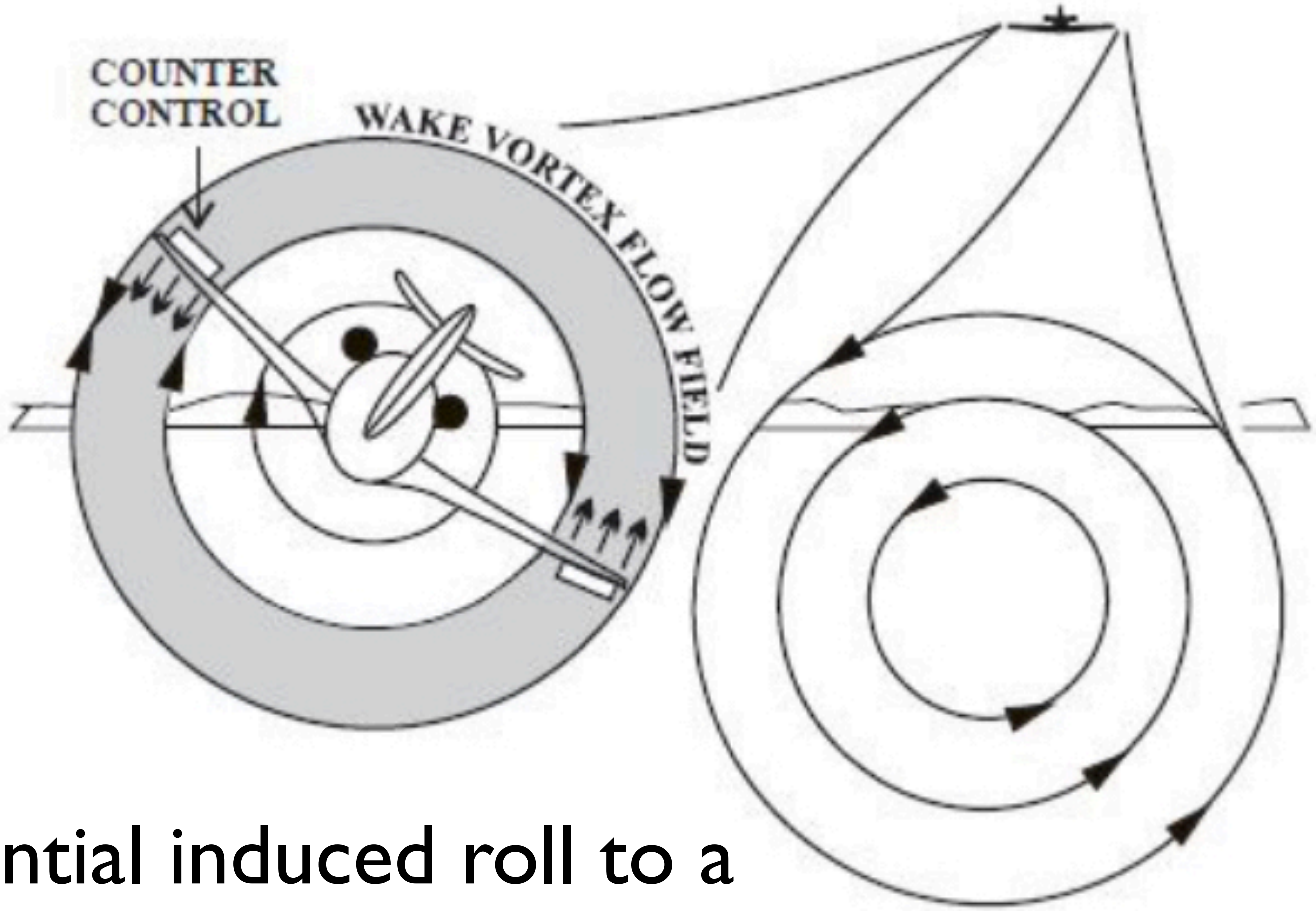
Wake Vortex Issues



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)

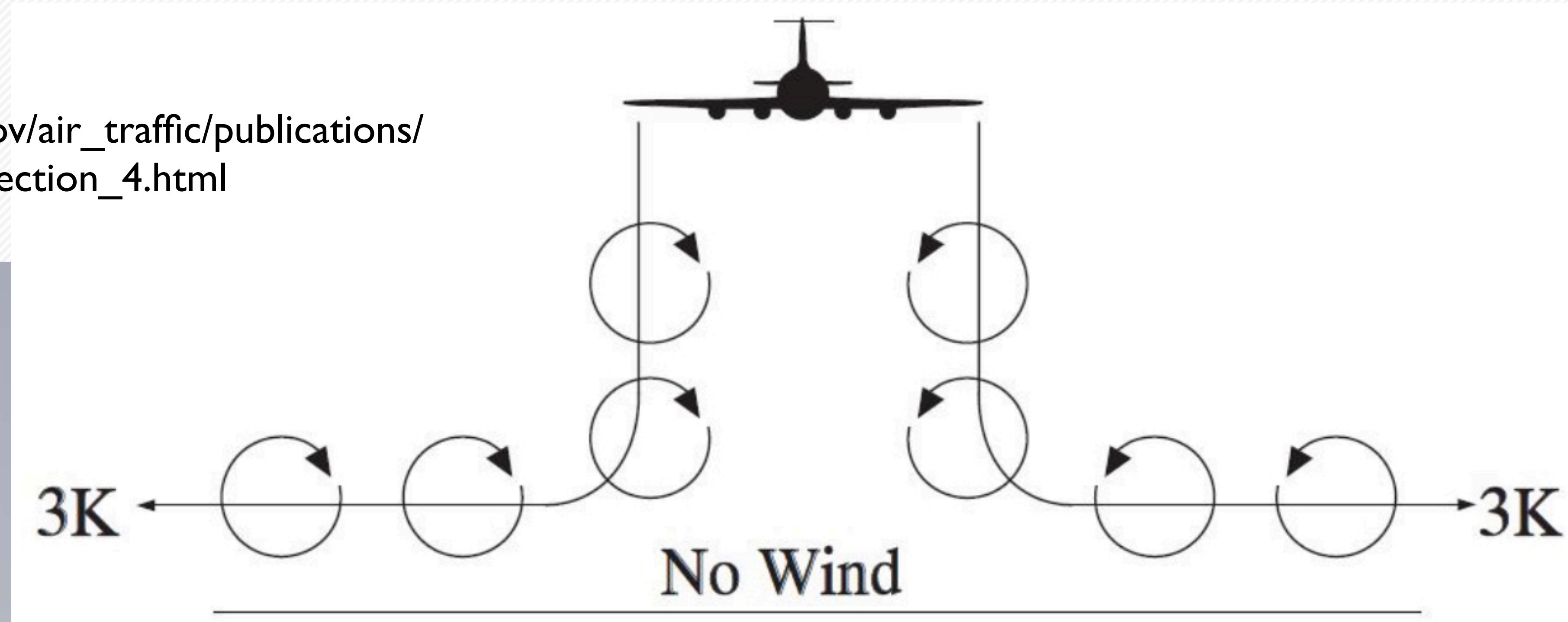
For heavy aircraft, wakes may last 60-90 seconds behind the generating aircraft



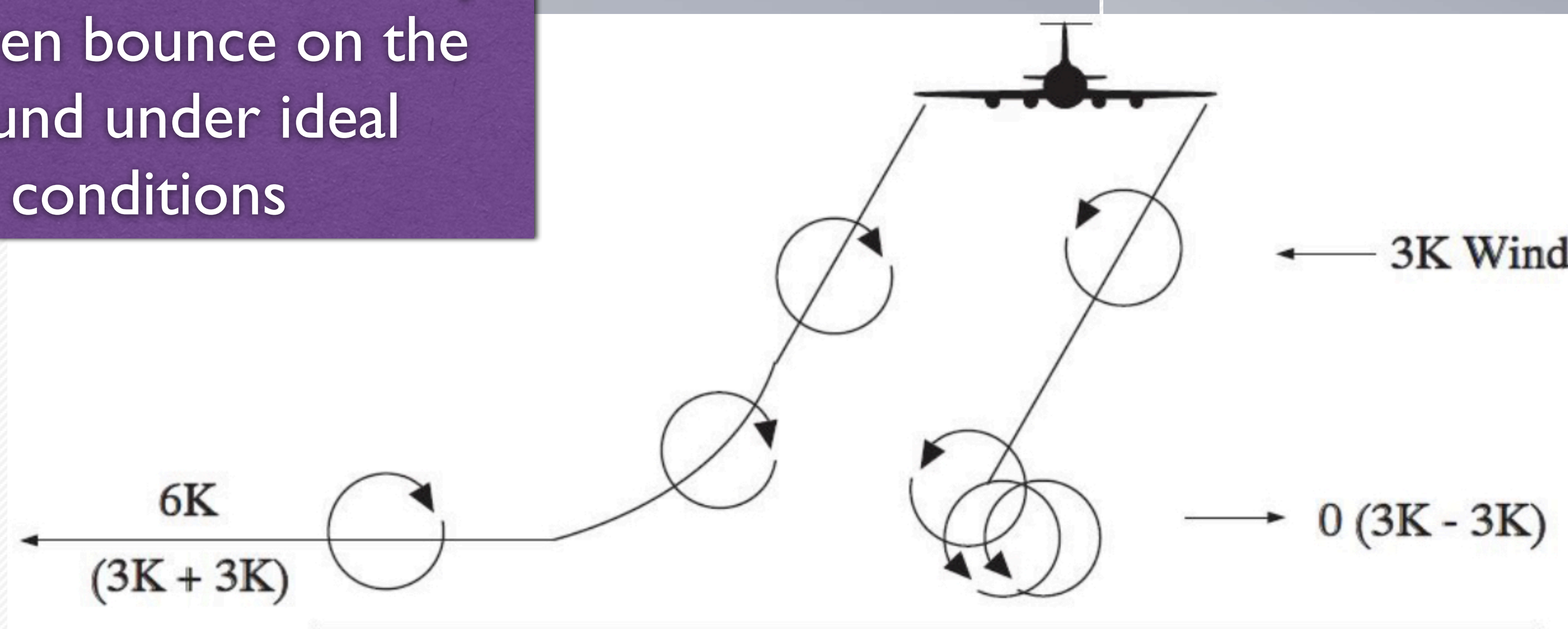
Potential induced roll to a following aircraft

Wake Vortex Issues

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

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 Separation Standards

- 1970s - FAA develops a legacy wake vortex classification (small, large, heavy - Superheavy added in 2007)
- 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 wake groups (A-F)**
- 2019 - FAA develops a Consolidated Wake Turbulence Classification (CWT) with **9 groups (A-I)**

Legacy 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

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.

RECAT Phase 1 Wake Vortex

- Re-Categorization (Phase 1) standards developed by FAA in coordination with ICAO
- **Wake Classification implemented in 2012**
- A = Superheavy aircraft, F = small aircraft

TBL 5-5-2

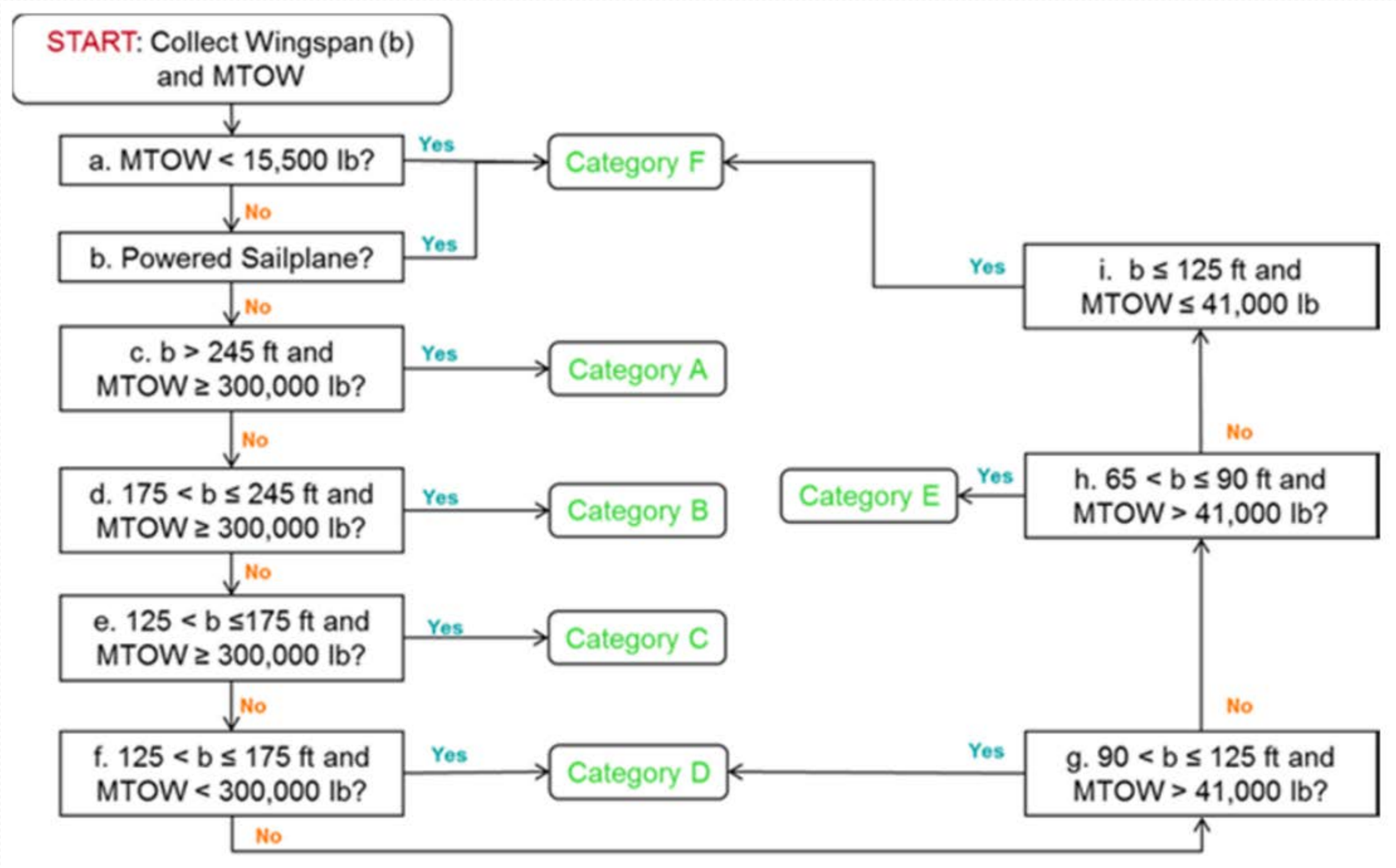
Wake Turbulence Separation for Approach

		Follower					
		A	**B**	**C**	**D**	**E**	**F**
Leader	**A**		5 NM	6 NM	7 NM	7 NM	8 NM
	B		3 NM	4 NM	5 NM	5 NM	7 NM
	C				3.5 NM	3.5 NM	6 NM
	D						5 NM
	E						4 NM
	F						

Blank cells are either 3 nm or 2.5 nm depending on the airport

Source: FAA Order 7110.65Y - Air Traffic Control

2012 Wake Vortex Classification (RECAT Phase 1)



Source: Tittsworth, et al., 2012. Wake Turbulence Program - Recent Highlights

Wake Vortex Classification (RECAT Phase 1)

RECAT Class	Representative Aircraft	Picture of Representative Aircraft
A	Airbus A380-800	
B	Boeing 747-400, Boeing 777-300ER, Airbus A330-300, Airbus A350-900, Airbus A300-600, Boeing 787-8/9	
C	McDonnell Douglas DC-10, Boeing MD-10, Boeing Douglas MD-11, Boeing 767-300	
D	Boeing 757-200 and -300, Boeing 737-800, Airbus A320, Airbus A321, McDonnell Douglas MD-80, Embraer 190, Bombardier CS-300, Gulfstream 550 and 650	
E	Bombardier CRJ-900, Embraer 170/175, Bombardier CRJ-700, Embraer 145, Bombardier CRJ-200, Dassault Falcon 7X	
F	Cessna CitationJet 4, Gulfstream G280, Bombardier Challenger 350, Cessna 182, Cessna 172	

Consolidated Wake Turbulence Recategorization Classification (CWT)

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

U.S. DEPARTMENT OF TRANSPORTATION
FEDERAL AVIATION ADMINISTRATION

Air Traffic Organization Policy

ORDER
JO 7110.126B

Effective Date:
November 9, 2021

SUBJ: Consolidated Wake Turbulence (CWT)

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.

Consolidated Wake Turbulence Recategorization Classification (CWT)

Defines nine wake classes including pairwise classes

Appendix A
Aircraft Wake Categories

Category A – A388 and A225.

Category B – Pairwise Upper Heavy aircraft.

Category C – Pairwise Lower Heavy aircraft

Category D – Non-Pairwise Heavy aircraft.

Category E – B757 aircraft.

Category F – Upper Large aircraft excluding B757 aircraft.

Category G – Lower Large aircraft.

Category H – Upper Small aircraft with a maximum takeoff weight of more than 15,400 pounds up to 41,000 pounds.

Category I – Lower Small aircraft with a maximum takeoff weight of 15,400 pounds or less.

Source: FAA Order JO 7110.126B

Consolidated Wake Turbulence Recategorization Classification (CWT)

Defines nine wake classes including pairwise classes

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 Turbulence Recategorization Classification (CWT)

Aircraft Types Categorized

A Super	B Upper Heavy	C Lower Heavy	D Non-Pairwise Heavy		E B757	F Upper Large		G Lower Large		H Upper Small	I 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

Source: FAA Order JO 7110.126B

In-Trail Separation Rules under CWT Standards

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Source: FAA Order JO 7110.126B

WAKE TURBULENCE APPLICATION

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									

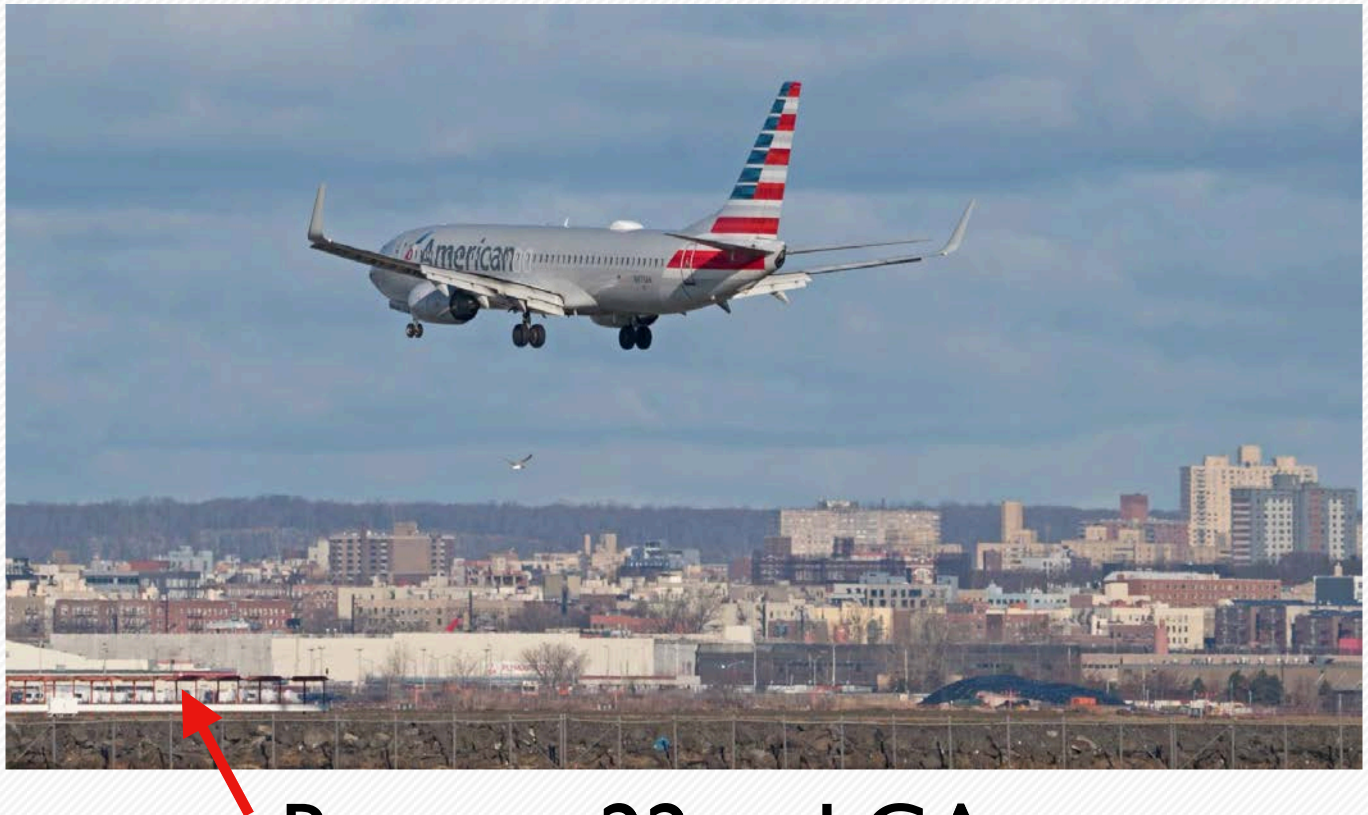
Empty Cells: Apply Minimum Radar Separation
3 nm default
2.5 nm for runways that meet a 50 second Runway Occupancy Time criteria

Implications of Aircraft Wake Classes

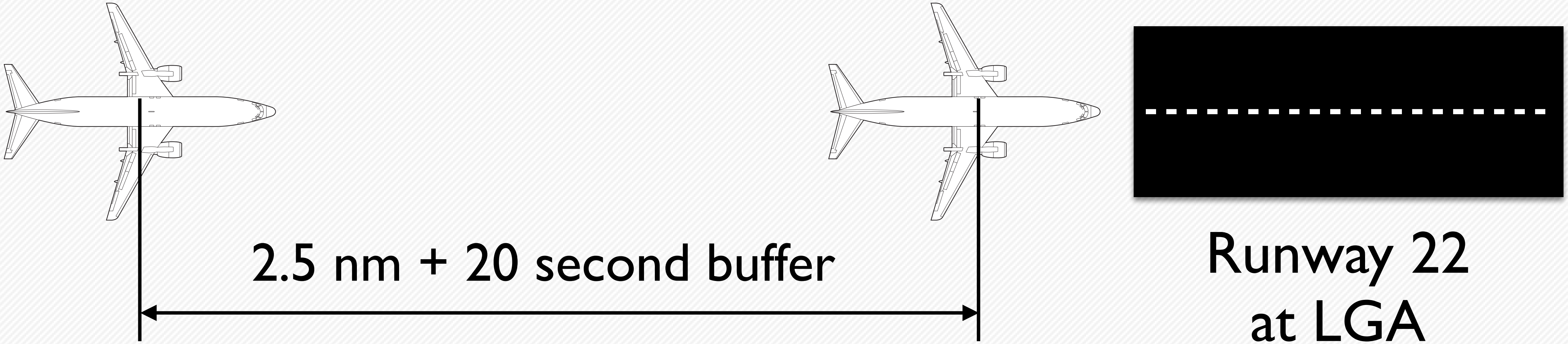
- In-trail separations are driven by wake class groups
- Runway capacity today is usually limited by in-trail separations
- In the future runway occupancy times will also be important

Example # 3

- 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



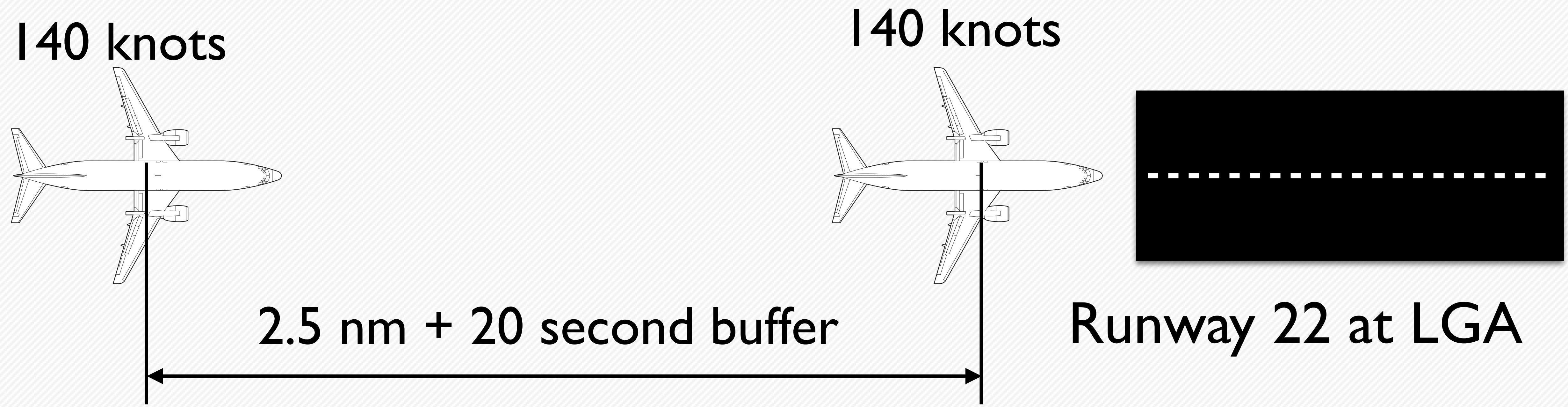
Example # 3 (cont.)

- 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

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



International Air Transport Association (IATA) Classification

Used in the forecast of aircraft movements at an airport based on the IATA forecast methodology.

IATA Aircraft Size Classification Scheme.

Category	Number of Seats	Example Aircraft
0	< 50	Embraer 120, Saab 340
1	50-124	Fokker 100, Boeing 717
2	125-179	Boeing B727-200, Airbus A321
3	180-249	Boeing 767-200, Airbus A300-600
4	250-349	Airbus A340-300, Boeing 777-200
5	350-499	Boeing 747-400
6	> 500	Boeing 747-400 high density seating

Other Classifications that You Will Read About in Trade Magazines

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

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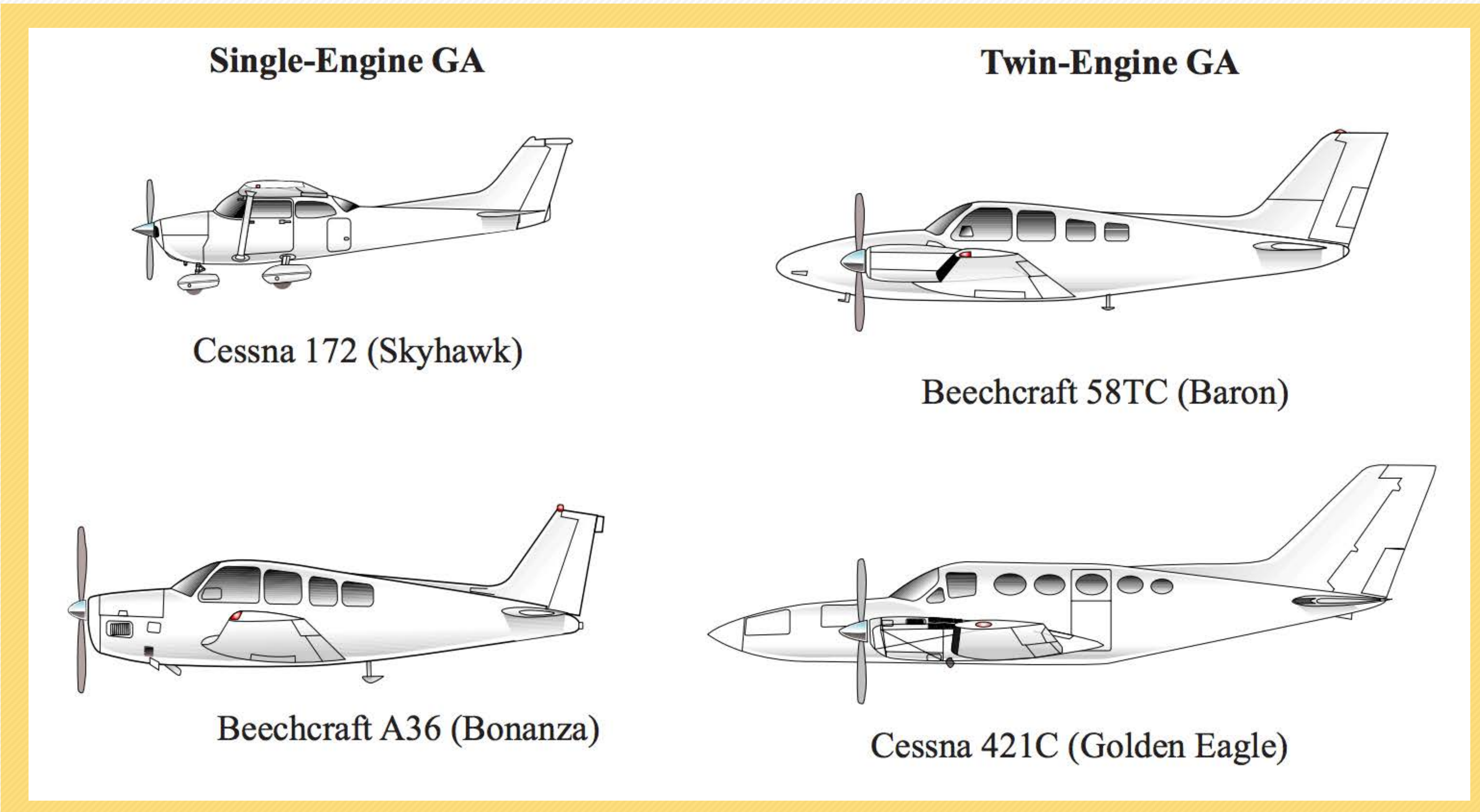
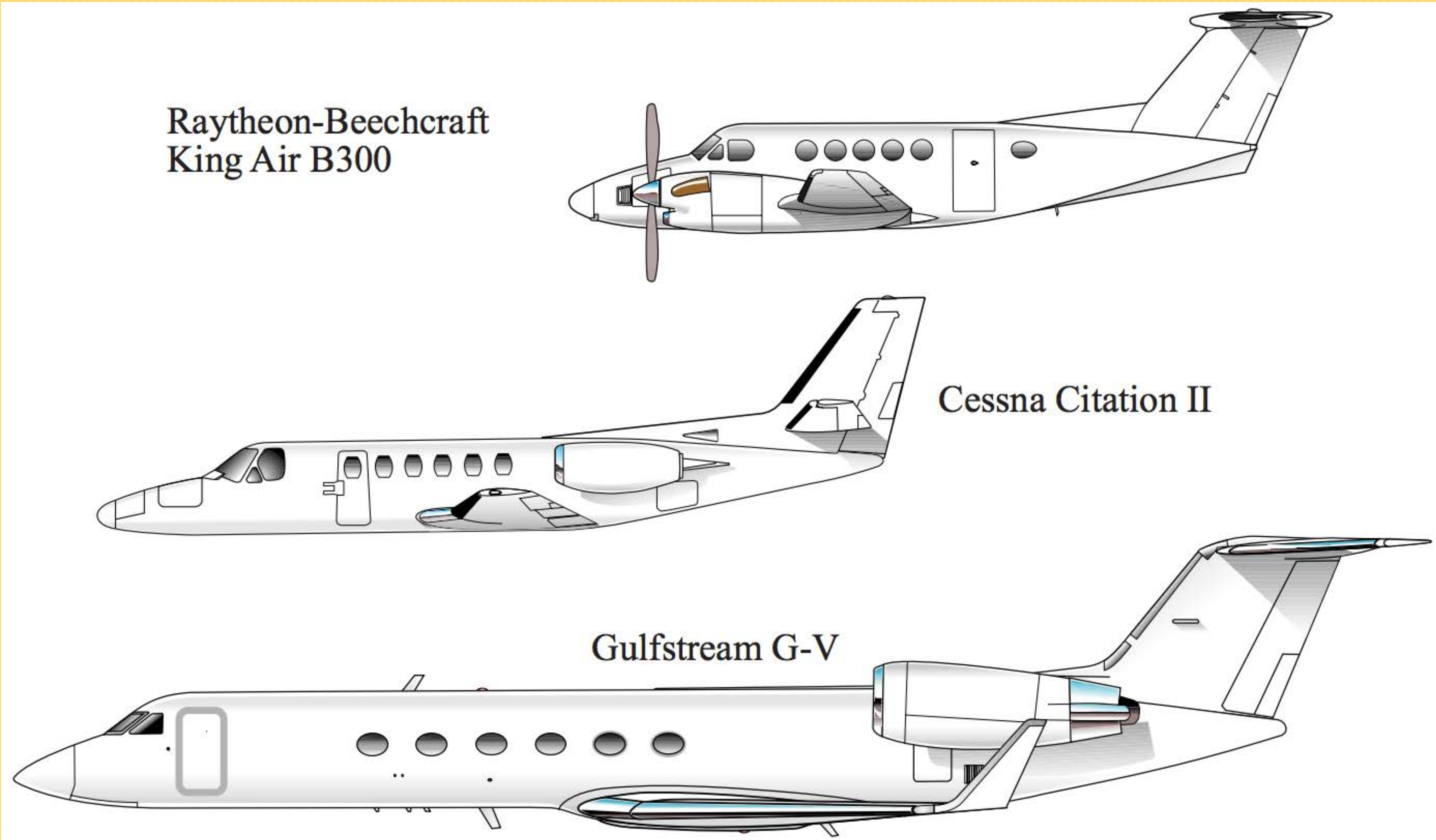
General Aviation Aircraft

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



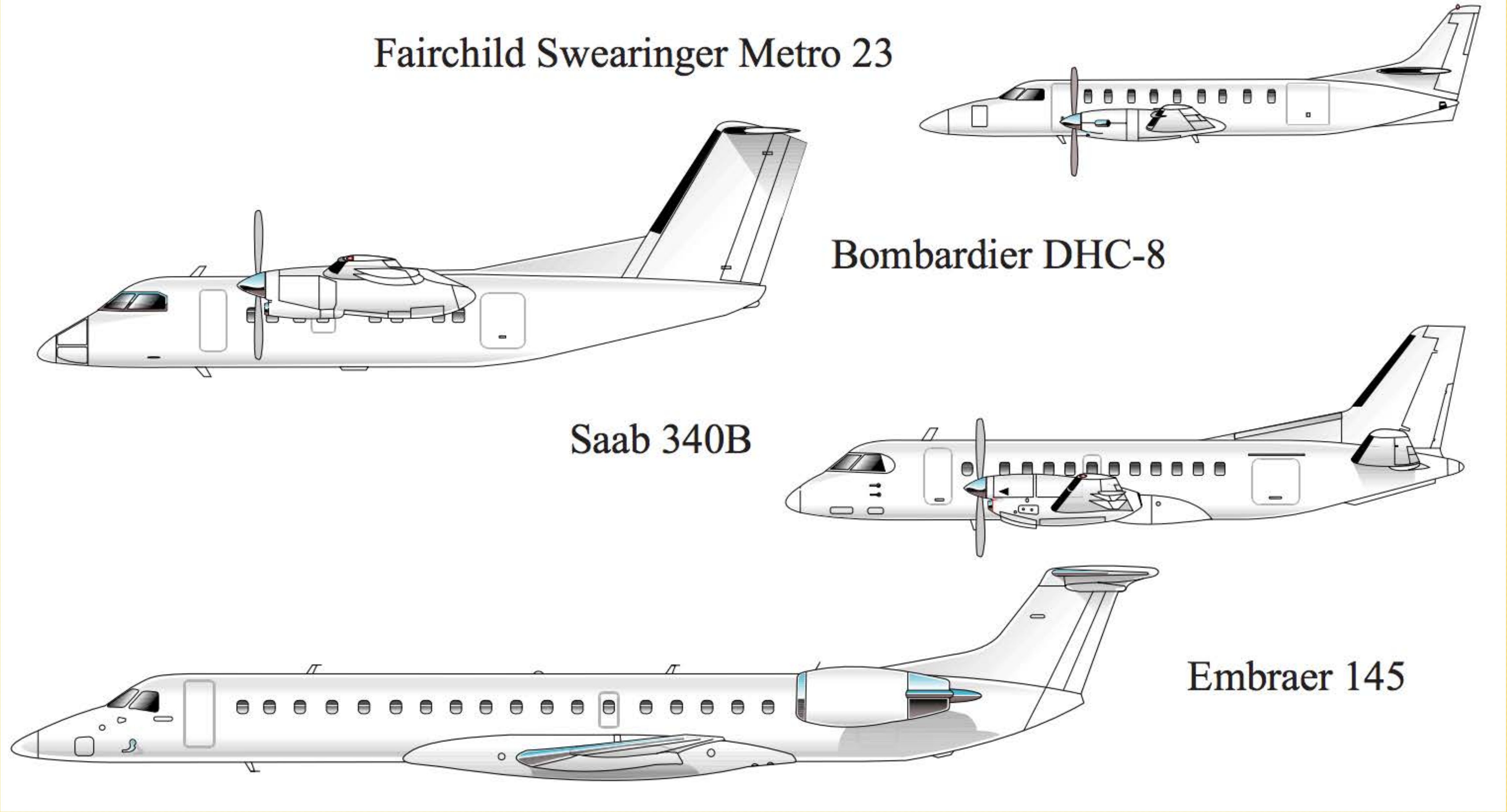
Corporate Aircraft

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



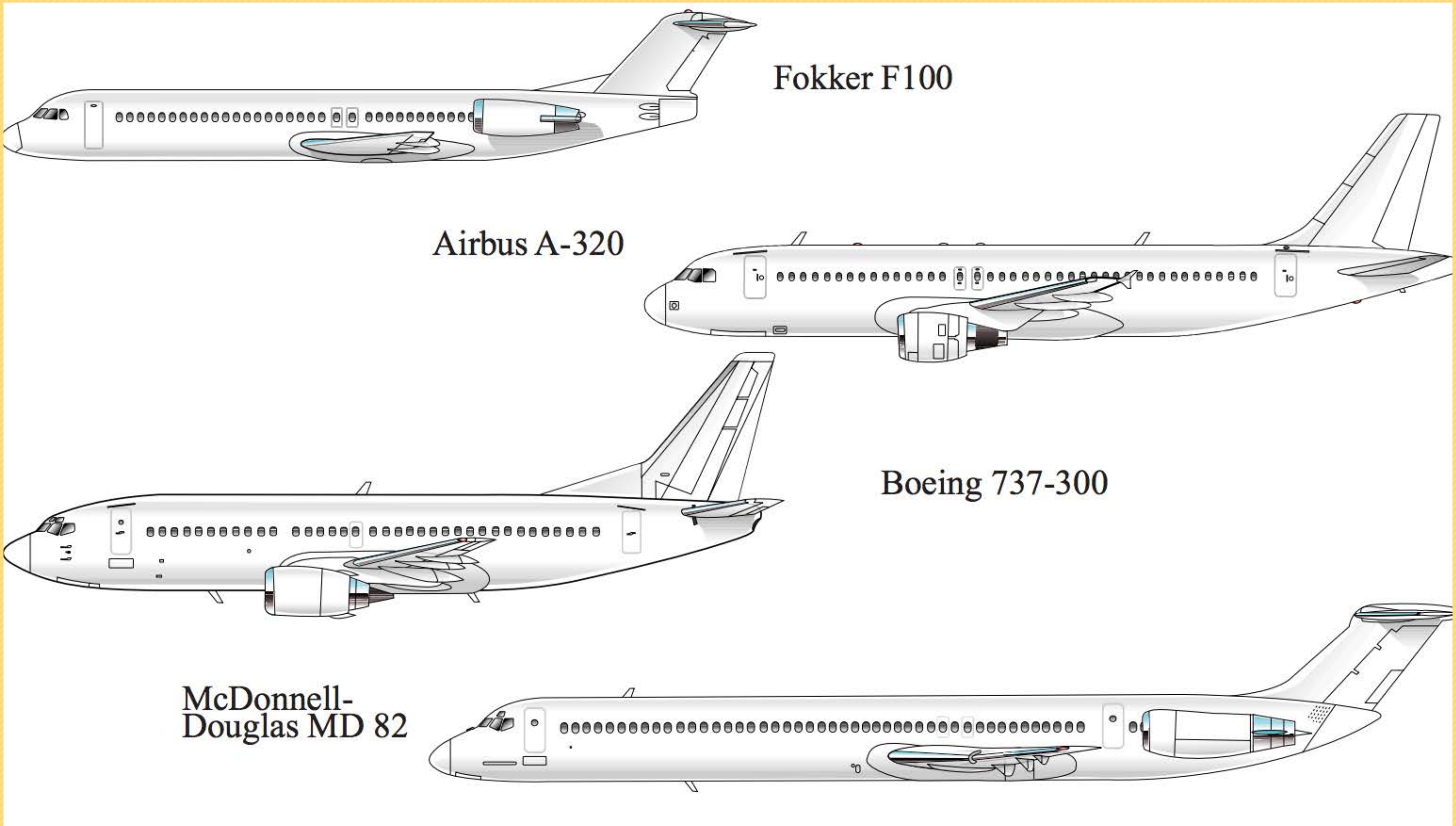
Commuter Aircraft

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



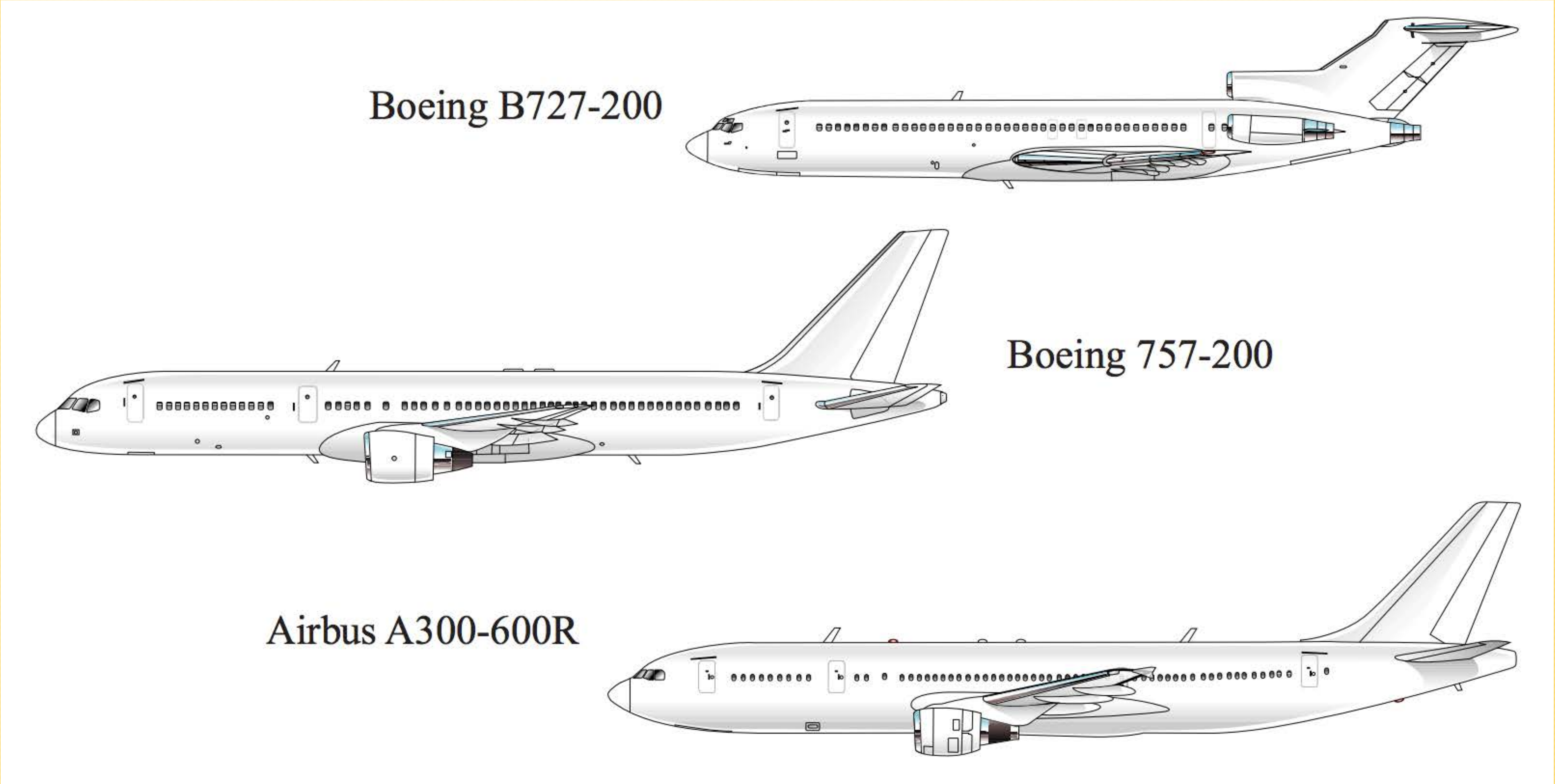
Short-Range Transport Aircraft

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



Medium-Range Transport Aircraft

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



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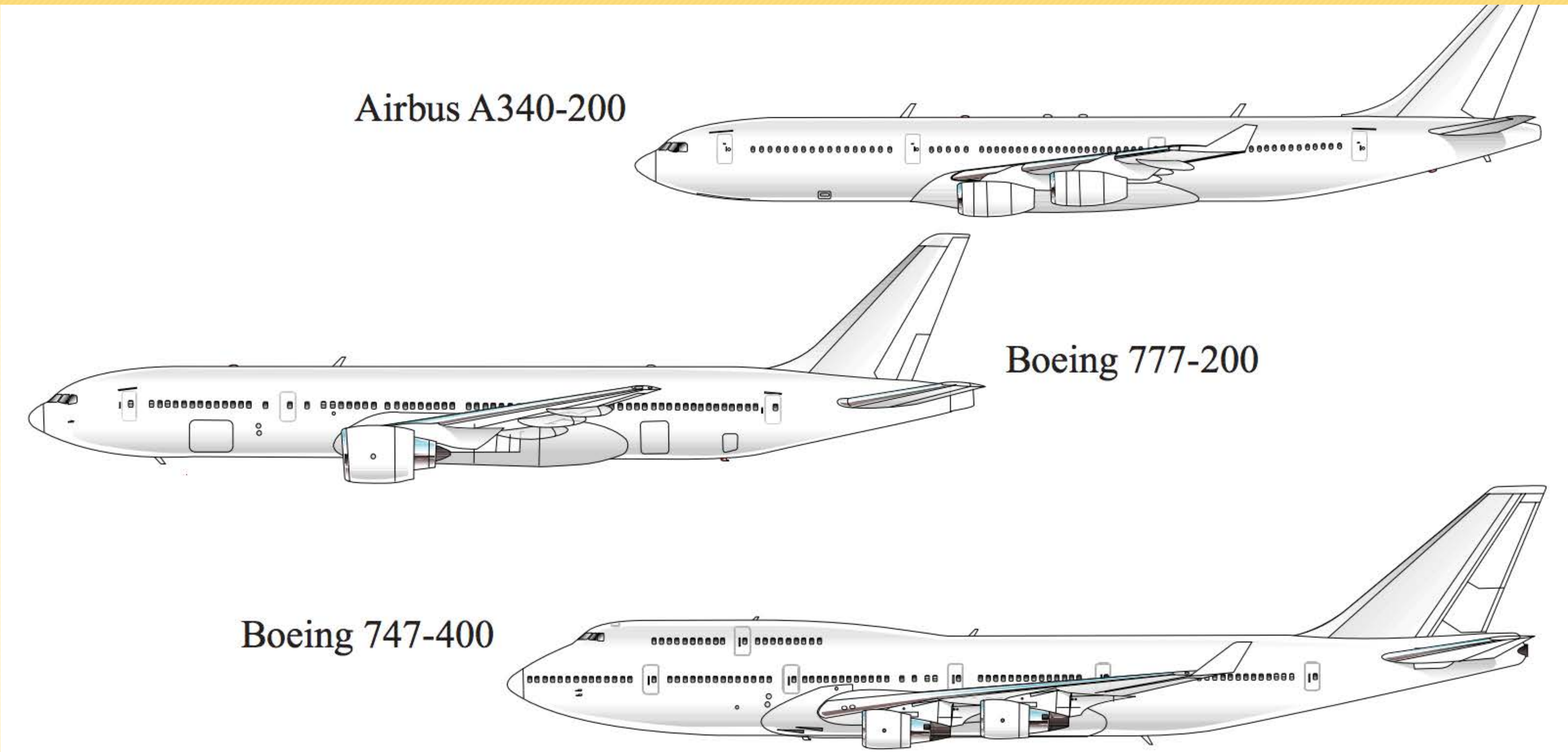
Long-Range Transport Aircraft

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



Aircraft Trends

Very large capacity aircraft (NLA or VLCA)

- Airbus A380 and Boeing 747-8

New generation long-range transport

- Boeing 787 and Airbus A350

New generation short range aircraft

- Bombardier C-Series, Mitsubishi Regional Jet (MRJ), Comac 919 and Irkut MC-21

Very Large Capacity Aircraft (NLA/VLCA)

- Airbus A380 was introduced into service in 2008
- Boeing 747-8 was introduced in 2012

A380-800 at LAX Airport (A.Trani)

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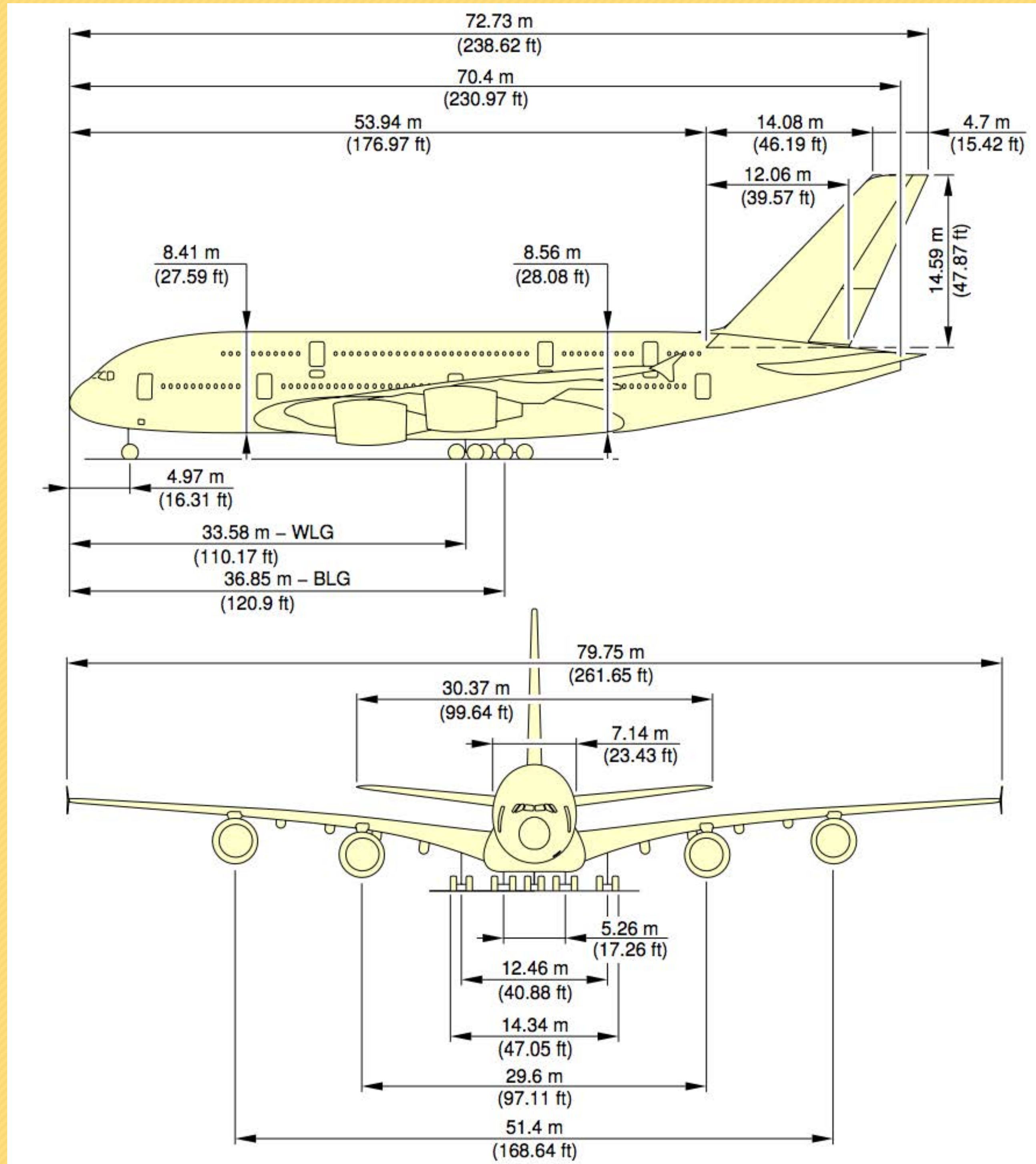
Tradeoffs in the Design of Aircraft

- Aircraft designed purely on aerodynamic principles would be costly to the airport operator yet have low Direct Operating Cost (DOC)
- Aircraft heavily constrained by current airport design standards might not be very efficient to operate
- Adaptations of aircraft to fit airports can be costly Some impact on aerodynamic performance
- Weight considerations (i.e., landing gear design)
- Tradeoffs are needed to address all these issues

Impacts of Very Large Capacity Aircraft

- Large capacity aircraft requirements
- Airside infrastructure impacts (taxiways and runways)
- Runway capacity impacts
- Airport terminal impacts (gates and aprons)
- Pavement design considerations
- Noise considerations

Very Large Capacity Aircraft: Airbus A380-800



Source: Airbus

Comparative Size of Airbus A380 and Other Heavy Aircraft

Source: Airbus and Boeing documents for airport planning.
*Estimated by author

Aircraft	Overall Length (ft)	Overall Height (ft)	Wheelbase (feet)	WheelTrack (feet)
A340-600	228.9	58.8	112.1	35.1
A380-800	238.1	80.1	104.6	40.9
B747-400	231.8	64.0	84.0	36.1
B777-300	239.8	61.5	102.0	36.0
B747-8	250.2	63.0*	97.4	36.1
A380-900*	258.0	80.1	112.0	40.9

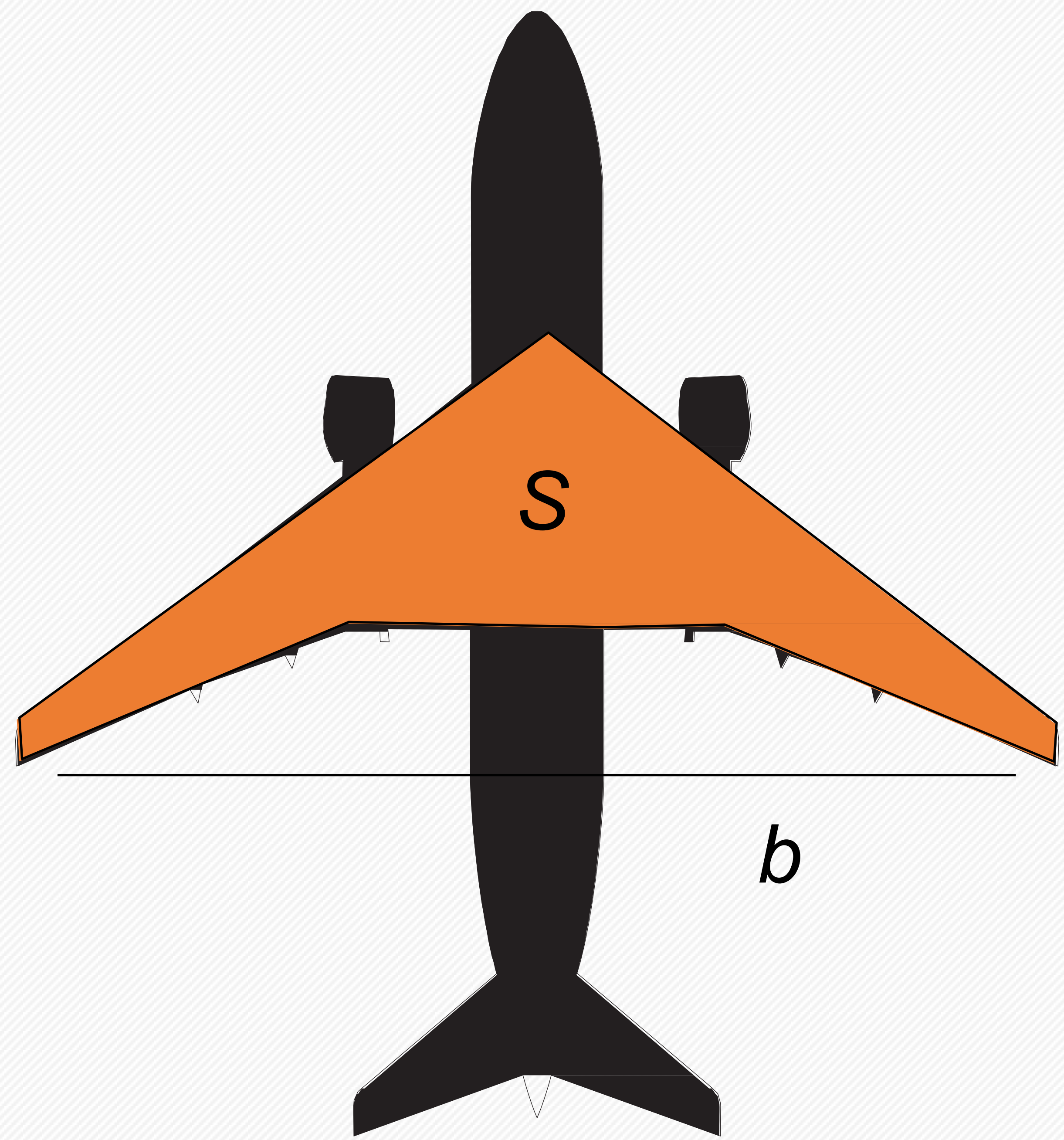
Aircraft Wing Aspect Ratio (AR)

$AR = b^2 / S$

AR wing aspect ratio (dimensionless)

b^2 wingspan (ft^2 or m^2)

S wing area (ft^2 or m^2)



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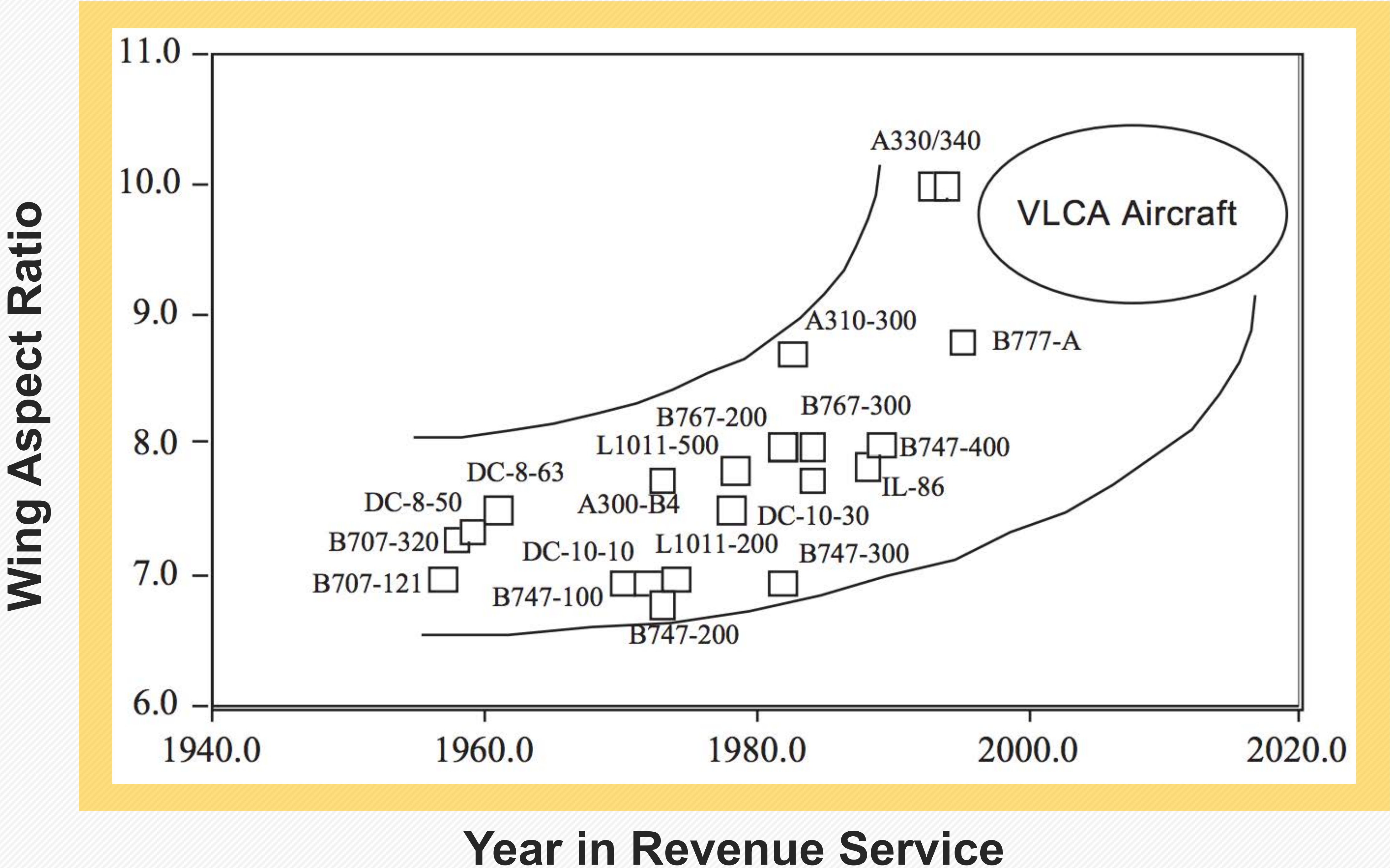
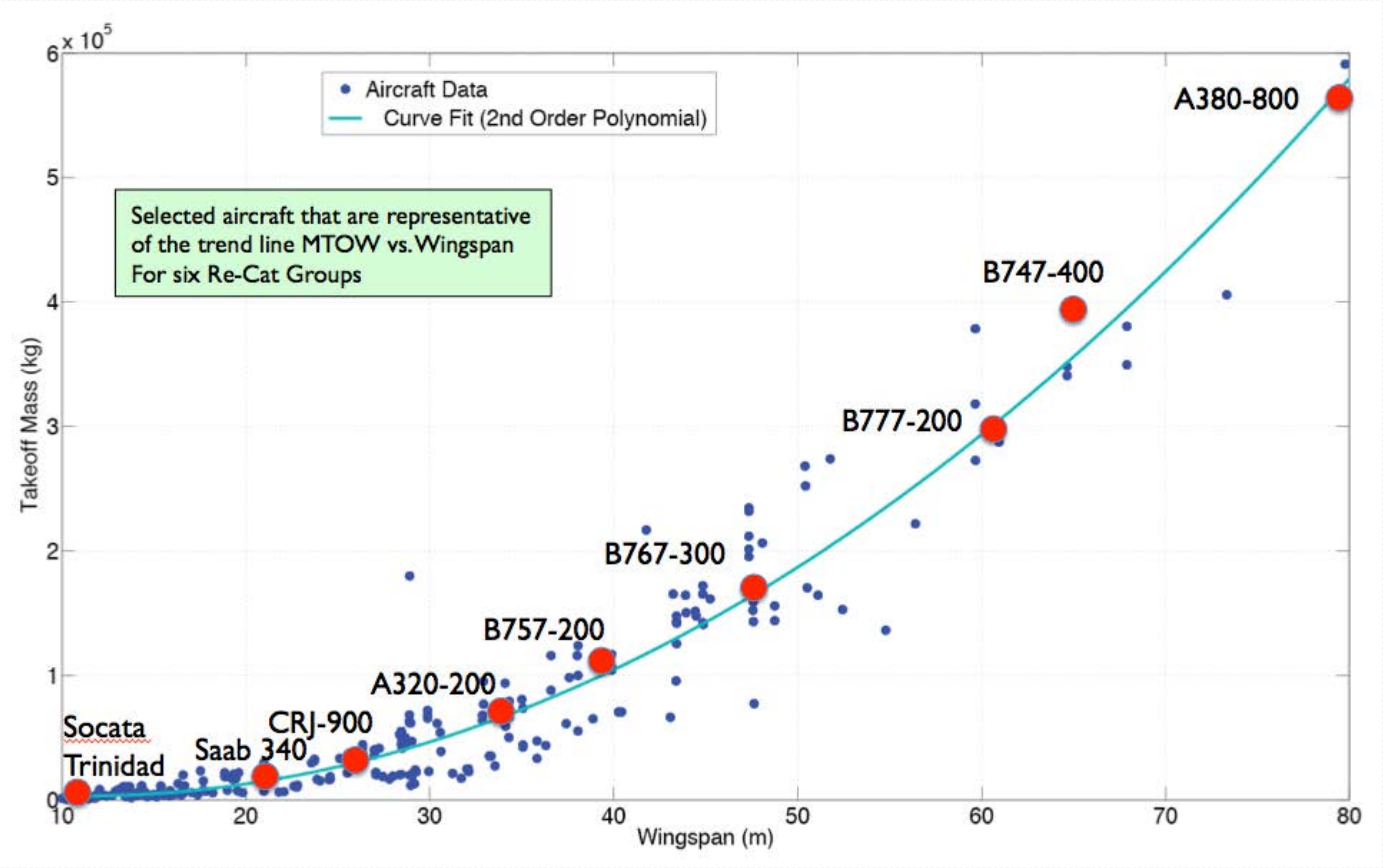
Evolution of Aircraft Wing Aspect Ratio

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

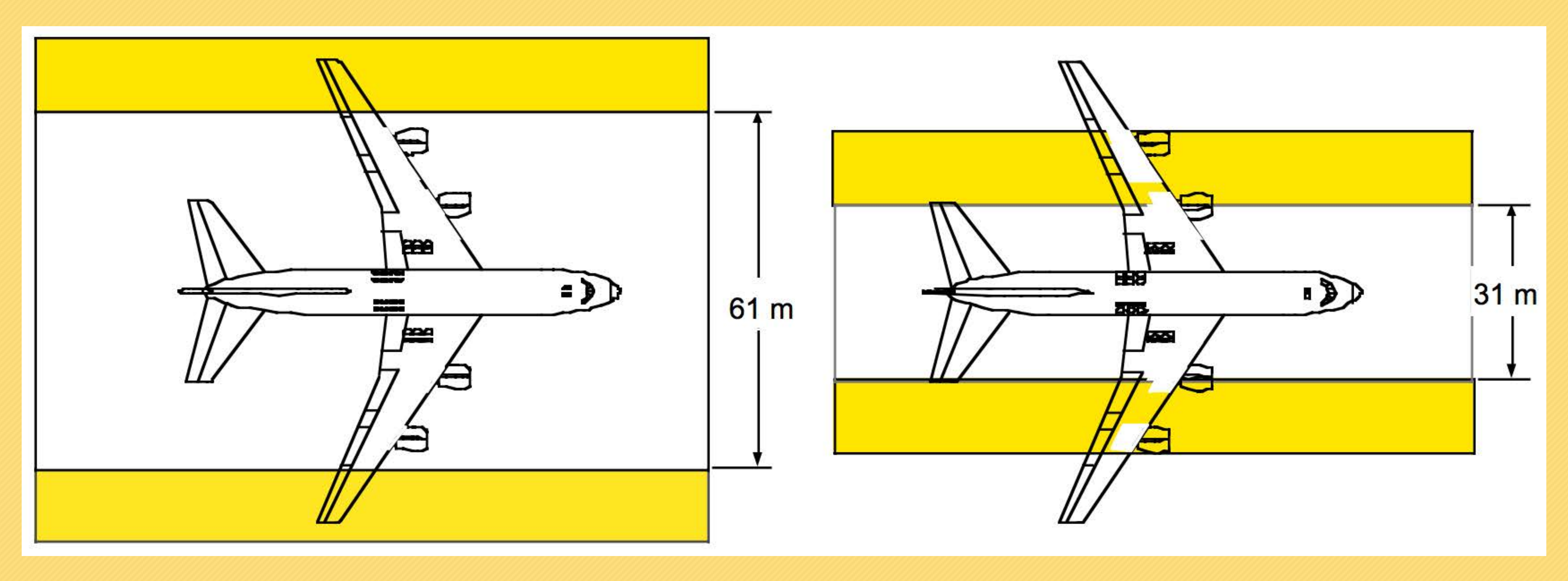


Evolution of Aircraft Mass and Wingspan



Very Large Capacity Aircraft Runway and Taxiway Requirements

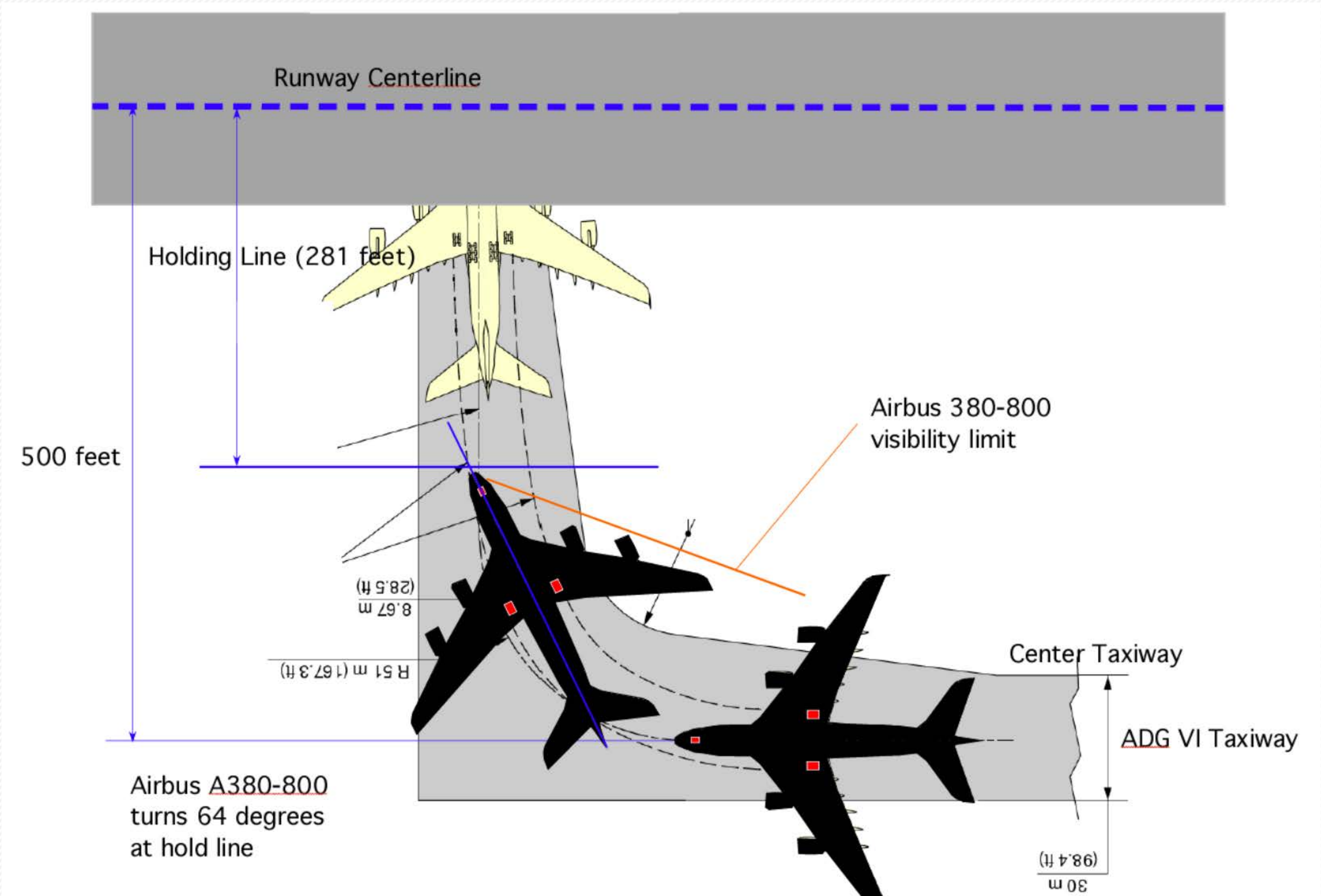
Very large capacity aircraft require wider runways and wider taxiways



A380 on ADG VI Runway

A380 on ADG VI Taxiway

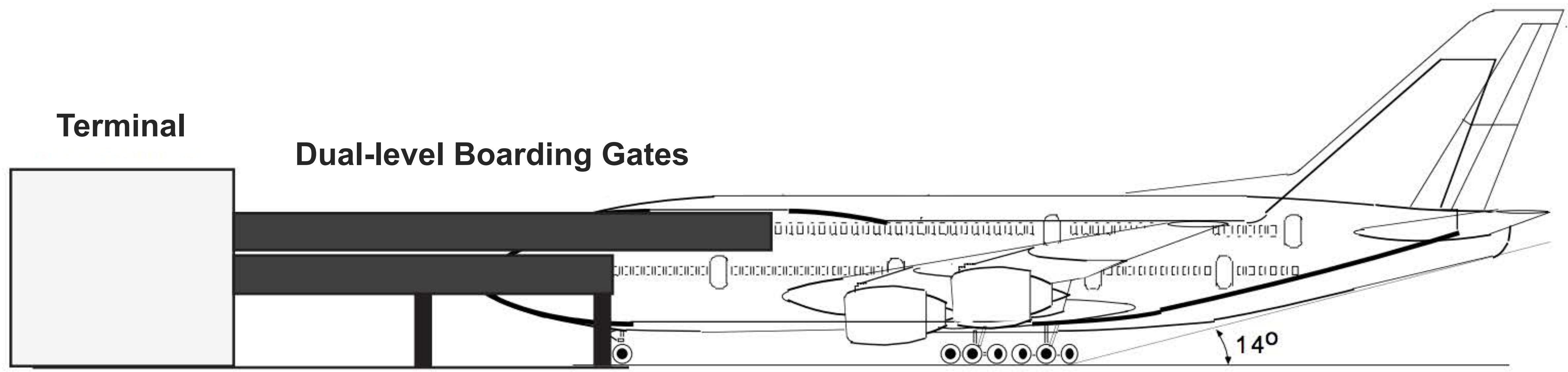
Large Capacity Aircraft Require Larger Maneuvering Envelopes



source: Airbus and the author

Airport Terminal Impacts

Large capacity aircraft require more complex gate interfaces to expedite the enplaning/ deplaning of passengers



Two-level configuration

Airbus A380 (A.A. Trani)

Upper and lower deck doors

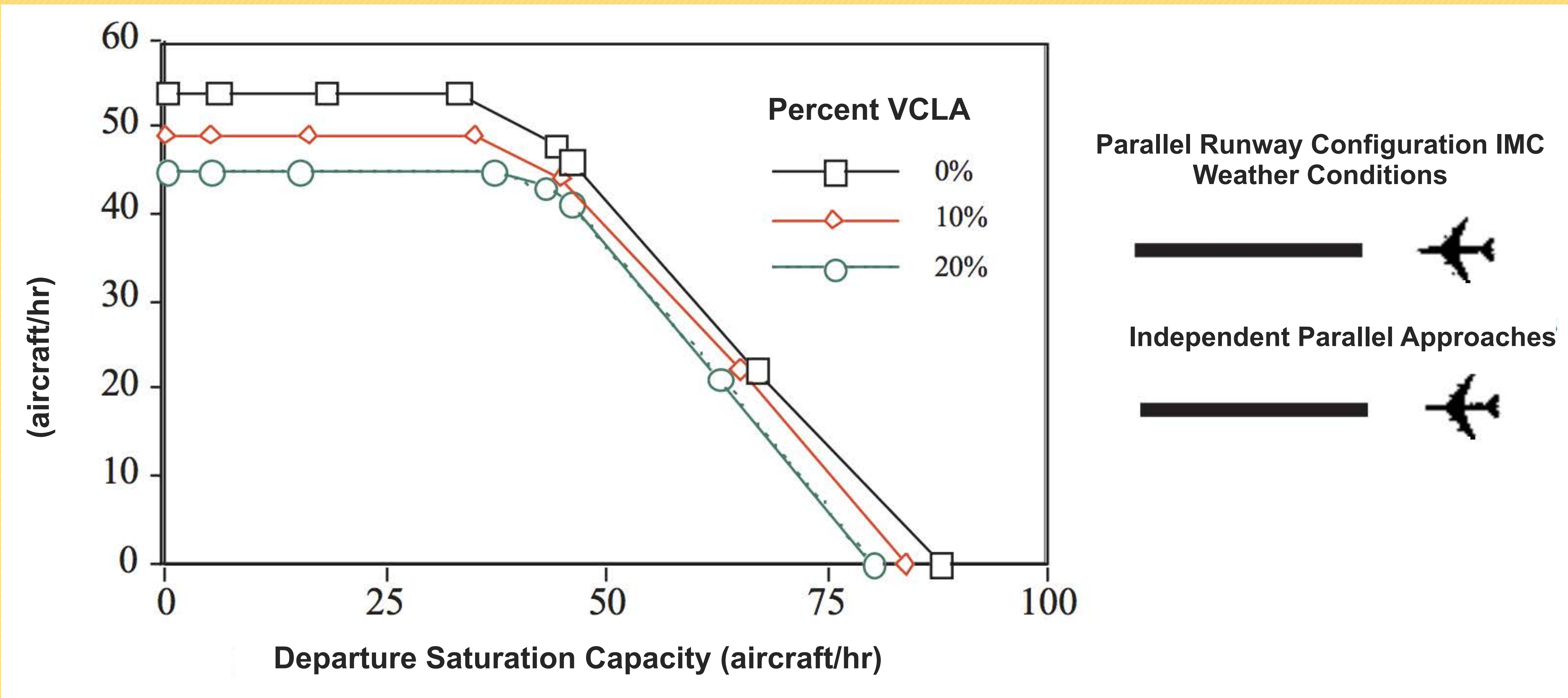
Capacity Impacts of Very Large Capacity Aircraft Operations

- Runway capacity is influenced by larger in-trail separations (i.e., reduction in runway capacity)

- Airport terminal volume requirements could increase due to the larger size of the aircraft (up to 850 passengers in a single class configuration)

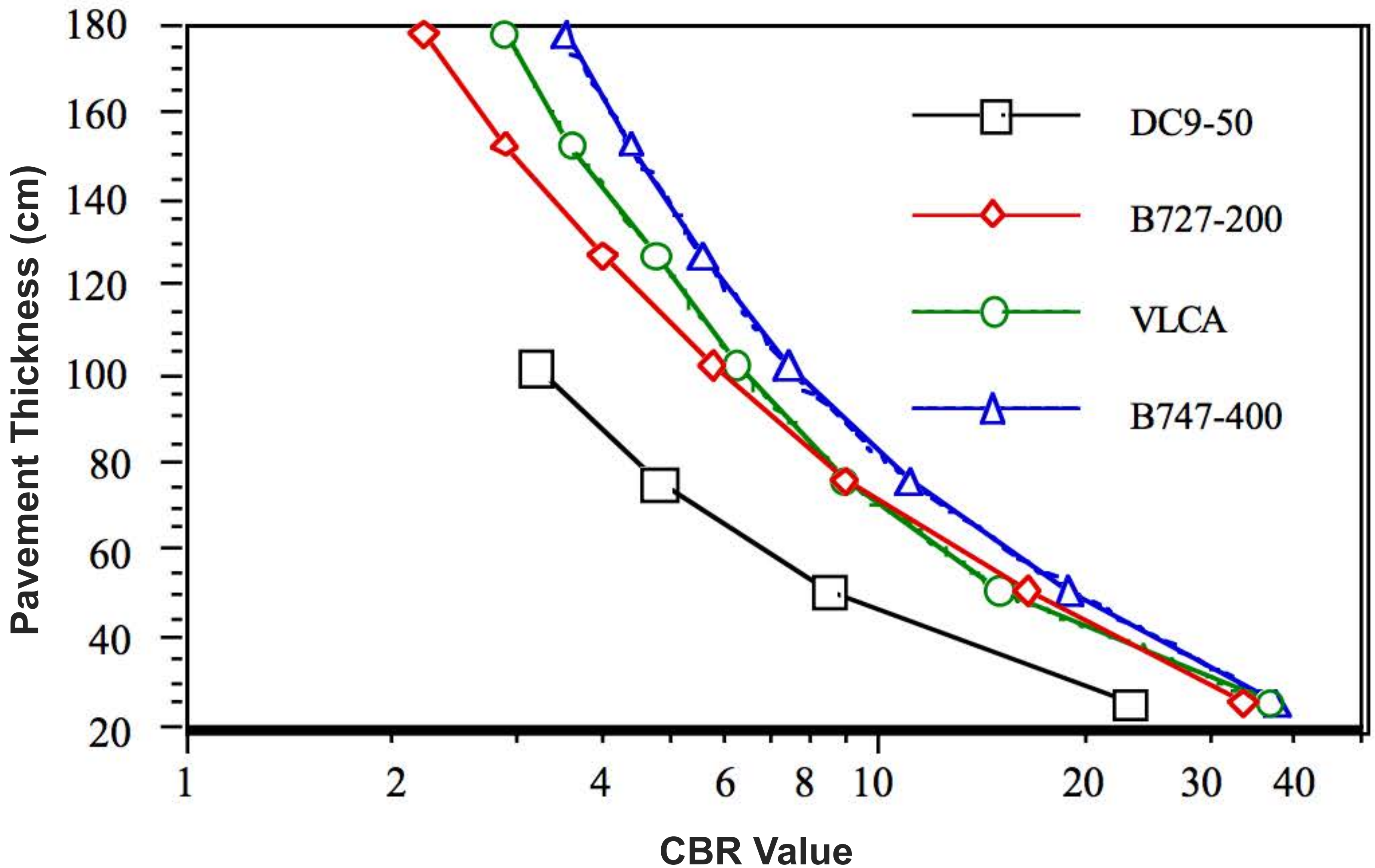
Runway Capacity Impact Analysis

The diagram shows that large capacity aircraft can reduce the runway hourly capacity of the airport

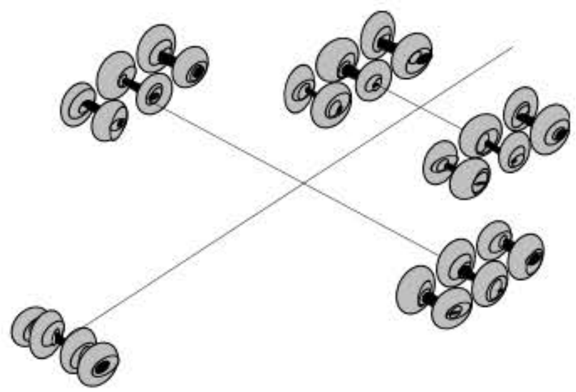


Airport Pavement Design Impacts

Very large capacity aircraft have complex landing gear configurations that require careful analysis to understand their impacts on airport pavements



Landing Gear Configuration



Quadruple + Triple-in-Tandem