DORNIER LUFTFAHRT
A Fairchild Aerospace Company

728 New Family of Regional Transport Aircraft

Market Situation

Demand in regional air transport is still growing fast. The hub and spoke system reaches ist limits in busy regions. More slots can not be made available at major hubs. Direct links to smaller communities/airfields could avoid congestion at hubs.
Propeller Aircraft are rated as less comfortable, noisy, unsafe and old fashioned. Some fatal accidents in flights under icing conditions are serious arguments. The public not fully understand the real causes:
- insufficient ice protection of critical leading edges in front of control surfaces,
- operational aspects when flying through frizzing drizzle or super cooled droplets at high liquid water content.

New regional transport aircraft must offer comfort and reliability like the modern large Airliners, but operate at lower cost.

In past 10 years period (1989-1998) 2336 aircraft in the capacity range of 40 to 110 seats (1005 turboprops and 1331 jets.) are delivered. Forecast for the next 10 years period is 3710 aircraft in that capacity range, in a split of 560 turboprops and 3150 jets.

Strong cost driven competition forced major airlines to form global alliances and get also control on regional Air transport. The big 4 group: Star Alliance, Wings; Qualiflyer and Oneworld are dominating today's air transport by serving more than 2800 international cities world-wide, flying more than 600 million passengers a year and a turnover of 110 billion US$ per year. They play an important role now in decision making process on regional aircraft. It is not the small airline any more we are selling to.

Number of OEM's are down to 3 in the regional jet market. Cost competition and risky investment in new programs limit survival chances to 2 or 3 OEM's at maximum.

Aircraft Layout

New aircraft have to be overall more attractive than competing one's already in service. Beside performance and cost, cabin layout has high impact on passenger appeal. Seat width, -pitch, head-, shoulder-, window seat foot clearance and isle width are rated comfort parameters. In 728 design a family of aircraft sizes (55, 70, 100 seats) is considered from the beginning. Trade-off studies advised optimum cabin width of 128 inch in a 5 abreast seat arrangement for tourist- and 4 abreast in first class. It offers more space than today's regional aircraft and is like A320 ore Boeing 717.
The required field-, climb- and cruise performance could best be met by a low wing, below wing mounted engines and low horizontal stabilizer configuration, at lower weight and less drag. With doors front and aft it allows an undisturbed cabin (no emergency exits in between), it provides flexibility for any cabin arrangement from 55 seater 528 to 105 seater 928.
A common wing of 75 sqm with slats, inboard Krüger flaps and single slotted flaps meets performance required for 728 and 528. For 928 wing size will increase to 84sqm by extended wing tips and redesigned inboard section. Fine tuning of wing design by reshaping of pylon leading edge and reduced gap between extended Krüger flap and pylon helped to increase max lift coefficient. Beside a drag cleanup, staggering of fin and tail with fin tuning of rear fuselage reduced drag by 6 %. Results are now confirmed by wind tunnel testing.
Power is provided by General Electric CF43-8D Engines with 46,2 inch fan for 728, derated for 528 and –10D derivative with 53 inch fan in a modified nacelle for 928.

Progress in Aircraft Systems

Aiming for reliable low cost operation with minimum time on ground at acceptable pilot work load are arguments for higher system integration and application of new technologies. Here only examples are given.

Avionics

Primus EPIC avionics system from Honeywell with it's bus systems links all other aircraft systems together, provides reliable data processing, indication, monitoring and control via 2 cursor. It provides additional capabilities for future communication and navigation systems. All systems status data are processed in smart centralized maintenance computer and necessary action after next landing are transmitted to the ground maintenance operation. All needed activities can be prepared before touch down and delays be minimized.

Flight controls

728 family will be equipped with all fly by wire flight controls with pilot fully in the loop. Mechanical inputs from the pilot be translated in electrical signals processed in duplex surface control modules, producing input signals to duplex actuator control units. Hydraulic actuator feed is by triplex power supply. Force feed back to pilot generates familiar handling qualities.

Electric Power Supply

Fly by wire flight controls require 4 independent electric power supply systems. 3 identical generators take power from each engine and APU, the forth generator is driven by ram air turbine in case of power loss in all 3 other supplies. Power is controlled by to 2 integrated primary -, 1 emergency- and 4 secondary control units; this avoids lots of fuses in the over head panel.

Operational Aspects

Technical efficiency can be measured in weight per passenger and block fuel burn per seat mile. Even with more comfortable fuselage diameter the 728 manufactures empty weight is below competitors aircraft and also is fuel burn. As final result the direct operating cost on example stage length of 500 NM 728 comes out 15 % better in seat mile cost and more or less equal in aircraft mile cost.
Cumulate noise level has margin of 15 EPNdB against ICAO Annex 16 requirements.
Emissions are fare below of ICAO Annex 16.

Impact of Commonality on Operation

In a mixed fleet of 42 aircraft with the capacity of 728 and 928 as common out of a family versus different models, investment saving can be 14 million US$ and an annual saving of 8,5 million US$.

Summary

Future traffic growth in regional transport can be served by bigger aircraft operated in the hub and spoke system and by more direct links. The 4 major alliances having more and more impact on regional air traffic now. The fierce competition is down to 3 OEM's. Regional aircraft have to offer comfort and operation like airliner but at lower cost. Higher aircraft system integration and fly by wire flight controls are good examples of technical improvements. Design for operational commonality can produce attractive cost savings in investment and operation of different capacity size family of aircraft.

- Is the Hub & Spoke System at its Growth Limits?
- Are More Direct Links Needed to Communities with Smaller Airfields?

- Propeller Aircraft are Out!
- Regional Aircraft must have Comfort and Reliability like Large Airliners
- \- But at Lower Operating Cost

Aircraft Deliveries, 1989 - 2008

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Aircraft Type (No. of Seats)	1989 - 1998	1999 - 2008
16 - 19 Turboprops	920	330
20 - 39 Turboprops	1.124	230
20 - 39 Jets	0	600
40 - 59 Turboprops	703	280
40 - 59 Jets	393	980
60 - 80 Turboprops	302	280
60 - 80 Jets	52	820
81 - 110 Jets	886	1,350
111 - 171 Jets	2,609	3,260
Single Aisle 171+ Jets	764	1,140
Medium Twin-Aisle Jets	1,501	1,820
Large Twin-Aisle Jets	479	420
Total (Aircraft)	9,733	11,510
Total (Seats)	1,406,845	1,839,626

Source: STG and AvSat (Commuter/Regional Airline News Sept. 6, 99

- **Less Comfortable than Jets**

  Narrower seats, smaller seat pitch, narrower aisle, no standing room in the aisle

  Too little space for hand luggage

  Noisier

  Vibration felt in the cabin

- **Unsafe (?)**

Turboprops are considered „old fashioned“ and outdated

Conclusions from accidents with turboprops

- **Run-back Ice on wing leading edge ahead of aileron**

  Insufficient chordwise ice protection coverage

  Lost control and crashed

- **Ice build-up resulted in higher stall speed**

  Aircraft flown too slow

  Lost control and crashed

- **Comfort equivalent to airline standard**
- **Same level of reliability**
- **All-weather capable (CAT IIIa)**
- **Turn-rounds in less than 20 minutes**
- **Airlines put more pressure on manufacturers**
- **Competition involves larger fleet deals**
- **Large airlines have more influence on selection & specification of regional a/c**

STAR

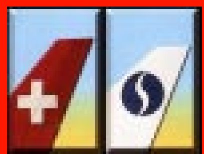
Lufthansa, United Airlines, SAS,
Air Canada, Thai, Varig, SIA,
Air New Zealand, Ansett, ANA,
(Austrian)

WINGS

Alitalia

KLM, Northwest, Aer Lingus, Martinair,
Transavia, JAS, Jet Airways, Garuda

Qualiflyer Group

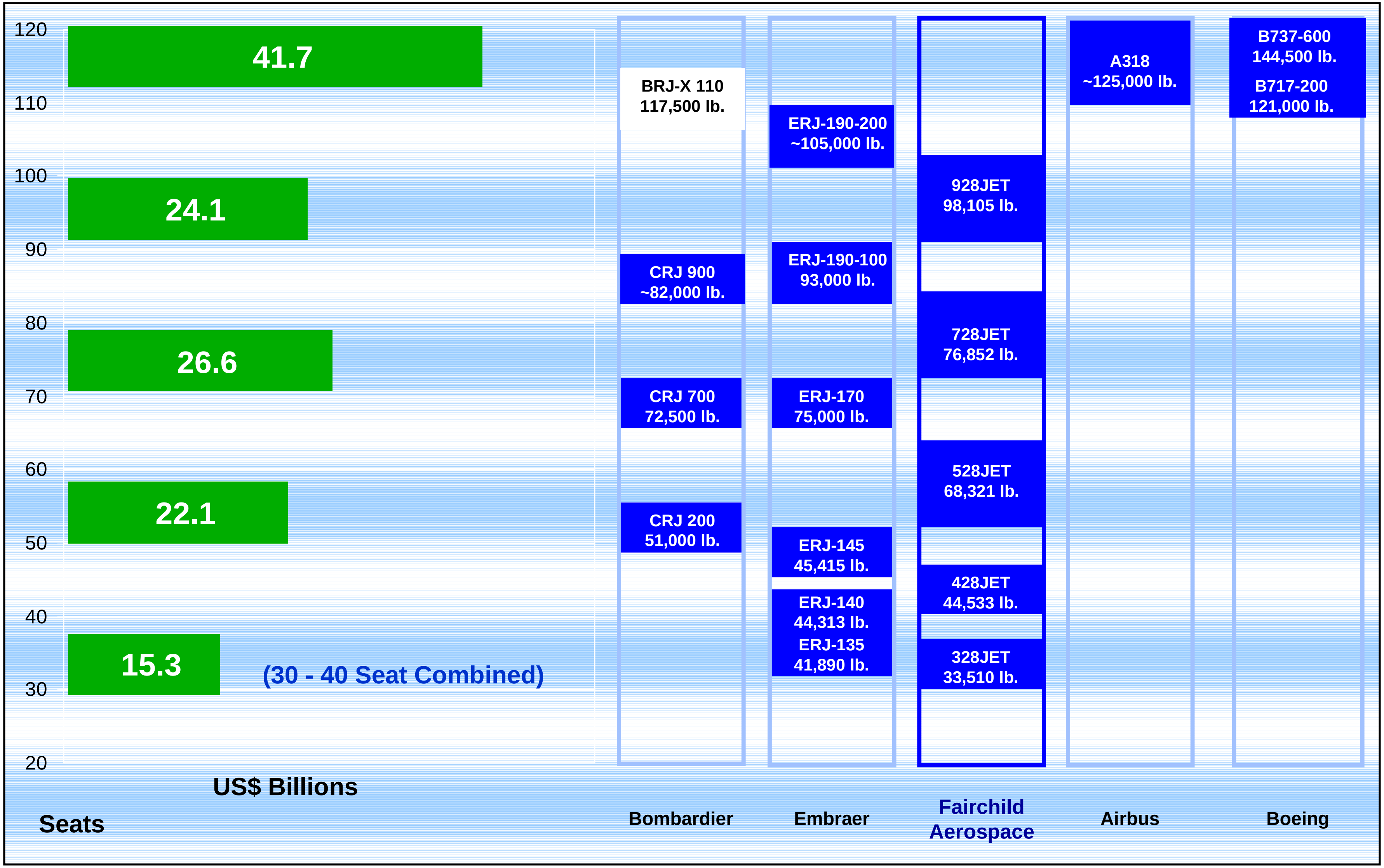


Swissair, Sabena, Turkish Airlines,
TAP Air Portugal, Crossair, Lauda Air,
Tyrolean Airways, Air Littoral, AOM,
Air Europe, (Austrian)

oneworld

British Airways, American Airlines,
Canadian Airlines, Cathay Pacific,
Qantas, Finnair, Iberia
(LanChile, Aer Lingus)

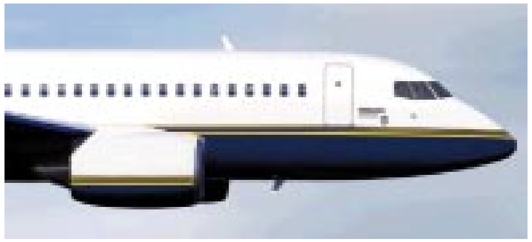
The 10 Year Market (Estimation: No. of Aircraft x list prices, in US $ Billions)



Bombardier

CRJ 200
CRJ 700

BRJ-X-90
BRJ-X-110



Embraer

EMB 145
EMB 135
EMB 140

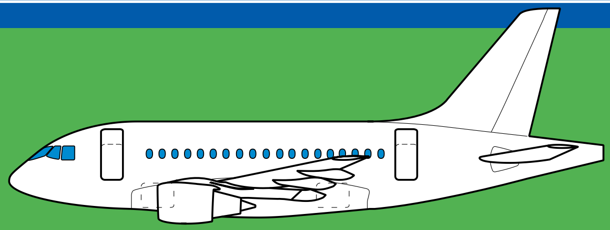
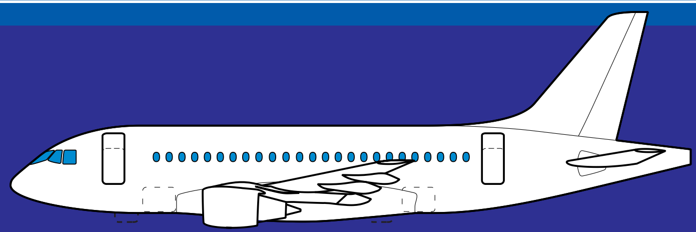
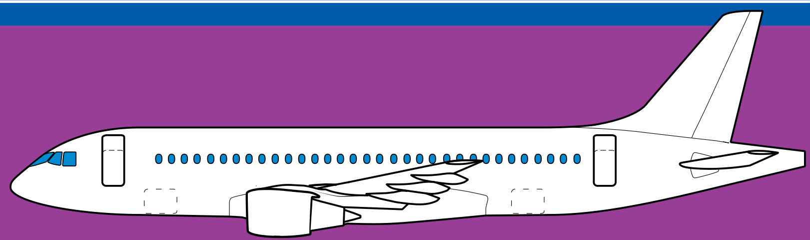
EMB170
EMB 190

Dornier Luftfahrt

328JET
428JET

728JET
928JET
528JET

728JET Family Members

	5-abreast	
	Seats	Designations
	55-65	528JET
	70-80	728JET (Ref. Design)
	95-110	928JET

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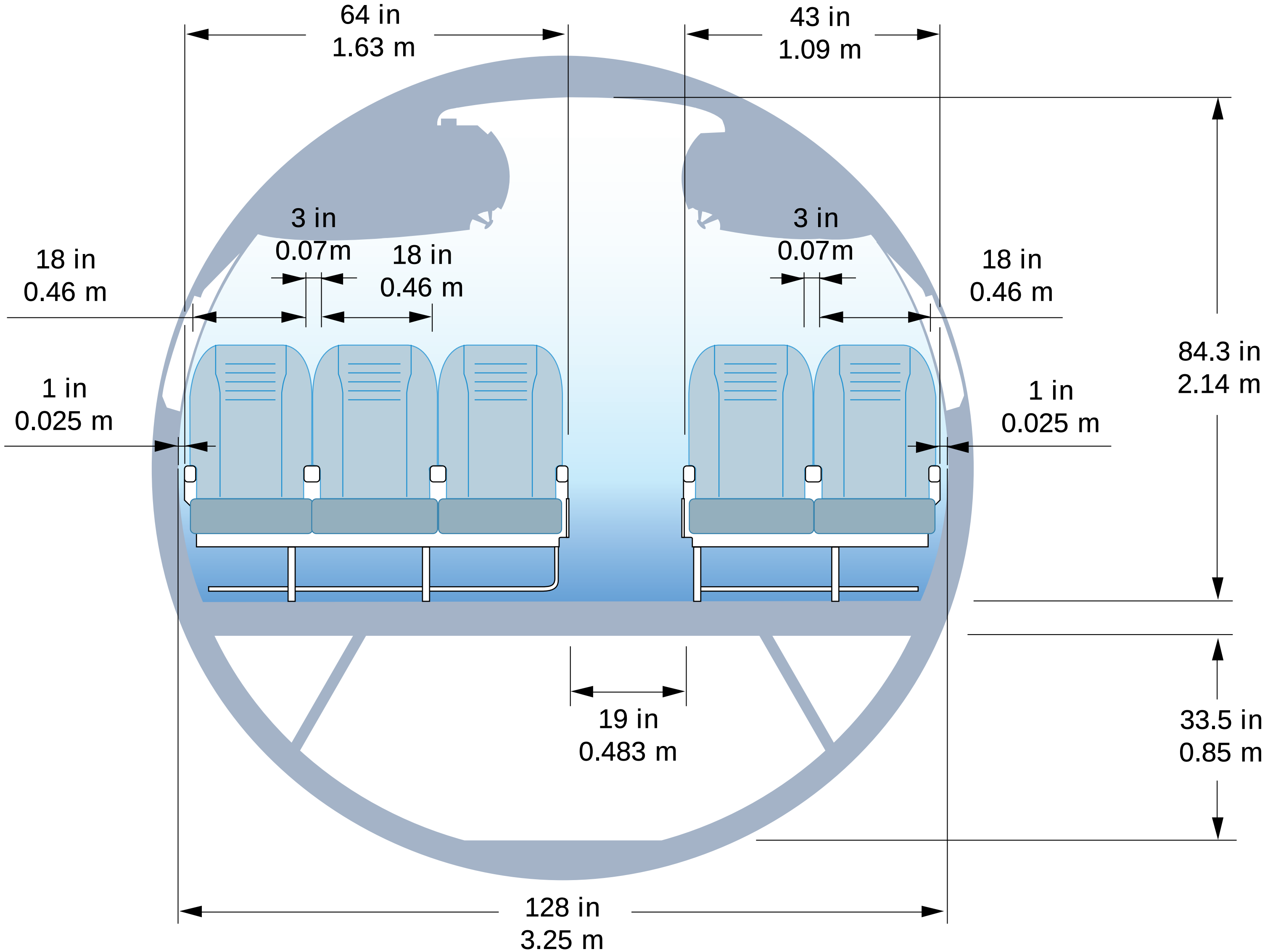
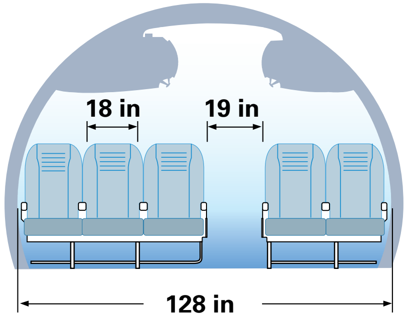
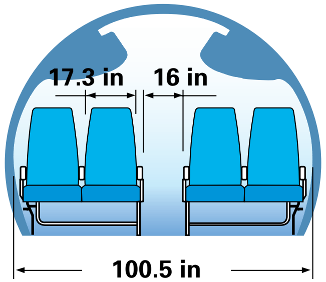
Cross-Section 5-Abreast – 128 in



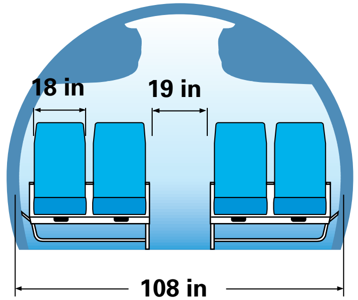
Cross section comparison



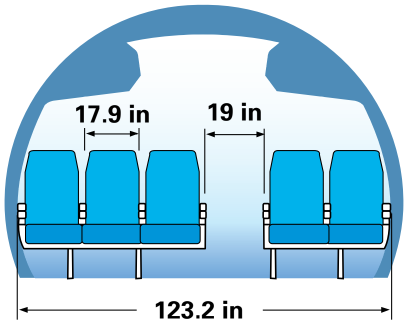
728JET



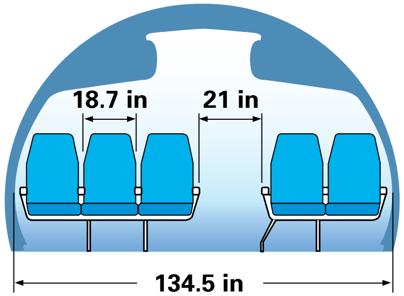
CRJ-700/900



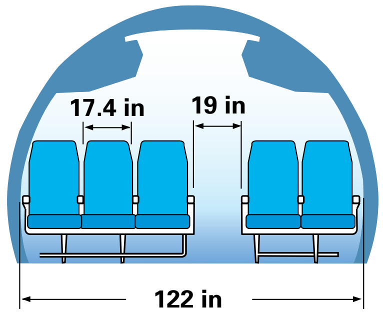
ERJ-170/190



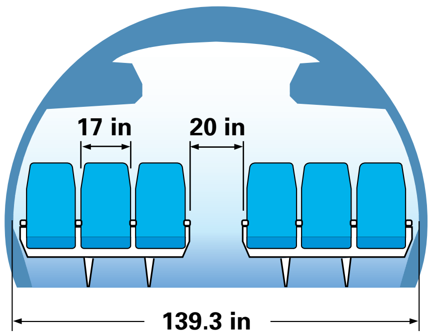
Boeing 717/DC9/MD80 series



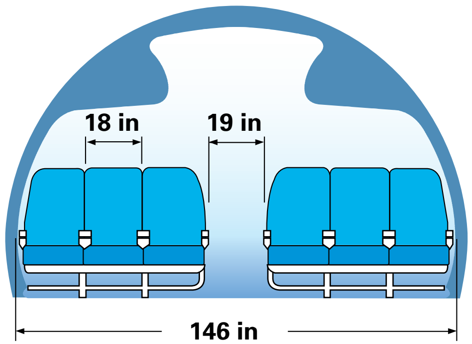
BAe146 (5 abreast)



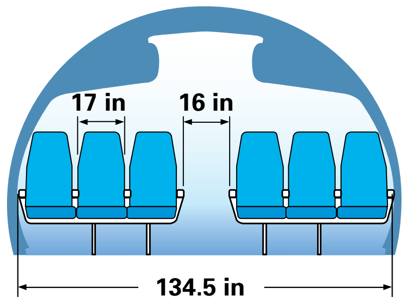
Fokker 70/100



Boeing 737



Airbus A320



BAe146 (6 abreast)

FC 99 FC 097 E – 2000-02-07-SvK

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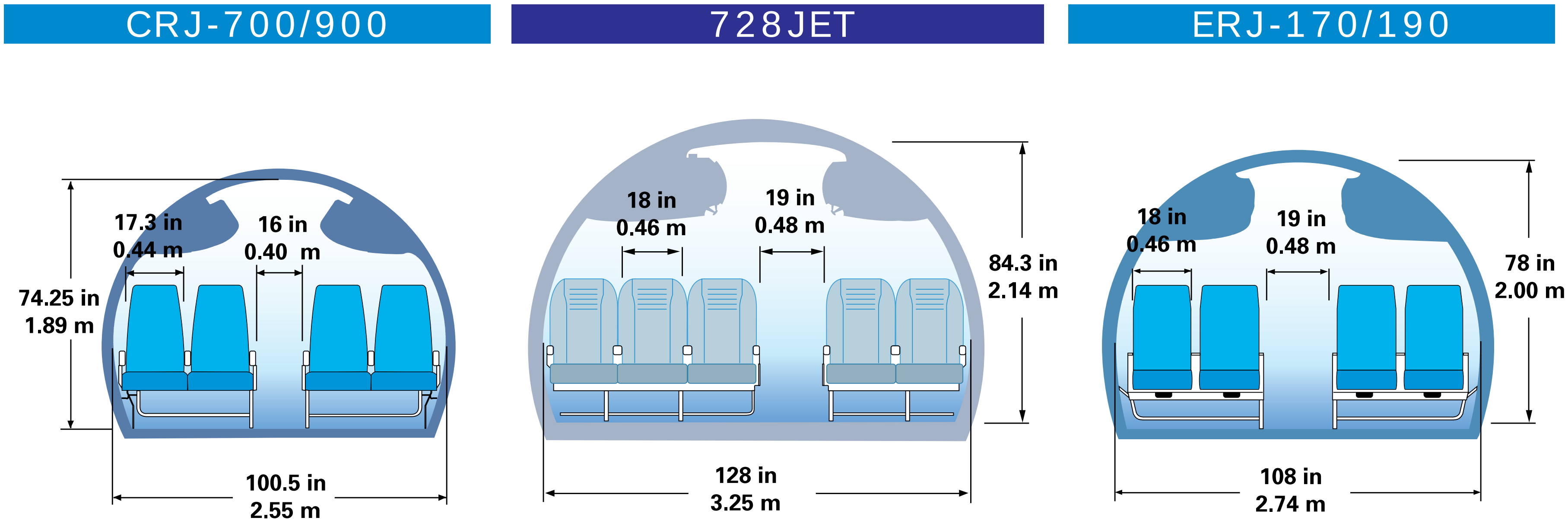
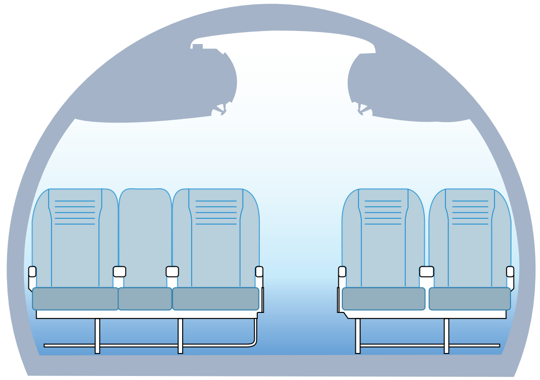
728JET vs CRJ/ERJ – Cabin Cross Section

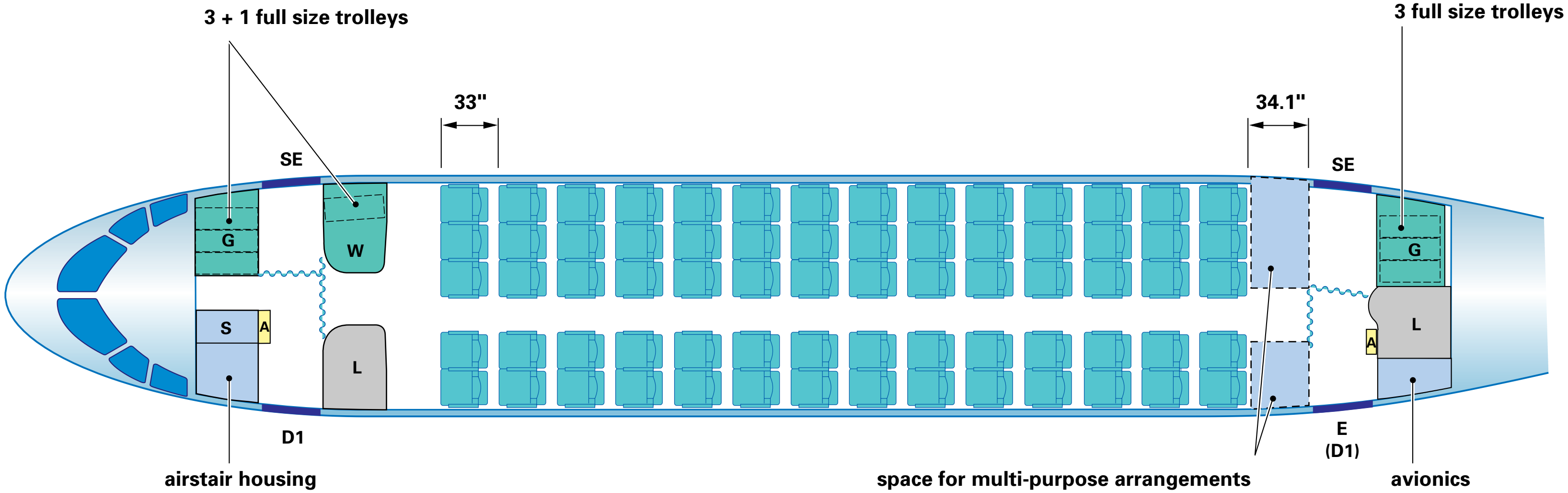




Business Class Arrangement
(with Convertible Seats)

728JET Cabin Layout for 70 Passengers

70 Seats at 33" Seat Pitch



D1 = Passenger Door (Typ C) A = Attendant Seat W = Wardrobe	SE = Service Door & Emerg. Exit (Typ C) E = Emergency Exit (Typ C)	L = Toilet & Lavatory G = Galley S = Storage

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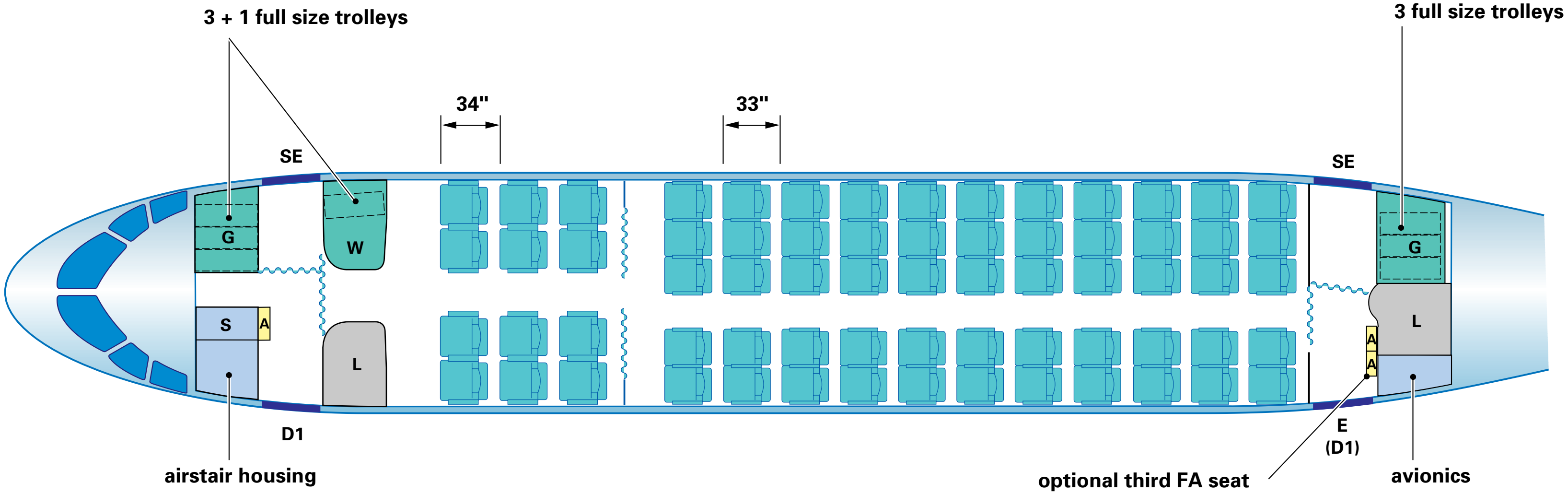
728JET Mixed Class Cabin Layout 12/55 Passengers

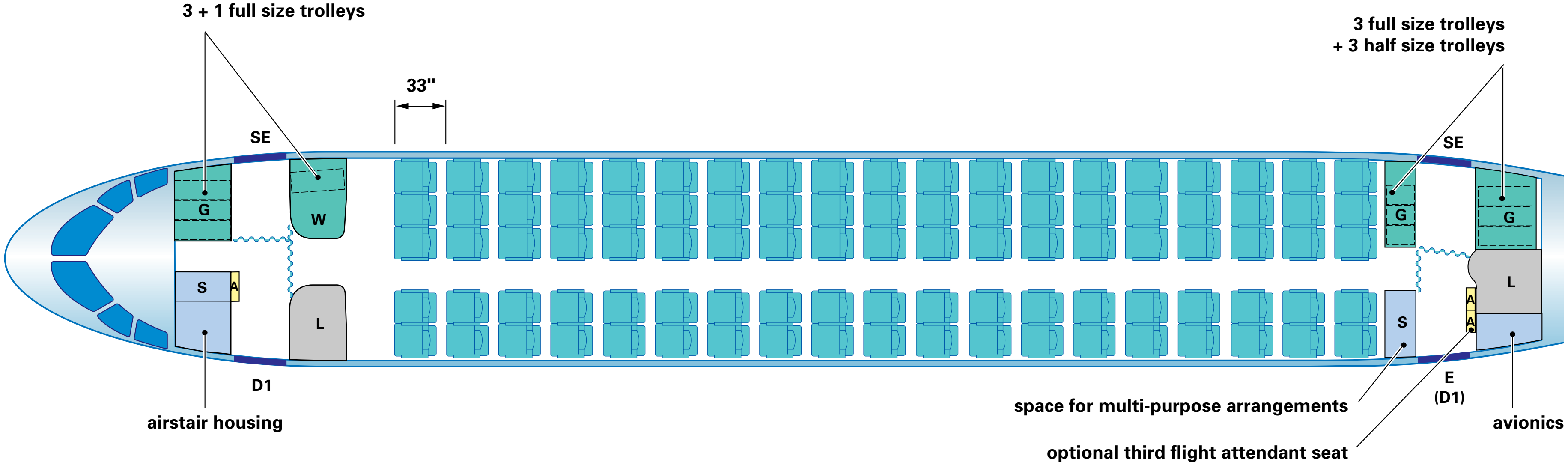
67 Seats – 12 Seats at 34" and 55 Seats at 33" Seat Pitch



D1 = Passenger Door (Typ C) A = Attendant Seat W = Wardrobe	SE = Service Door & Emerg. Exit (Typ C) E = Emergency Exit (Typ C)	L = Toilet & Lavatory G = Galley S = Stowage

928JET Cabin Layout for 95 Passengers

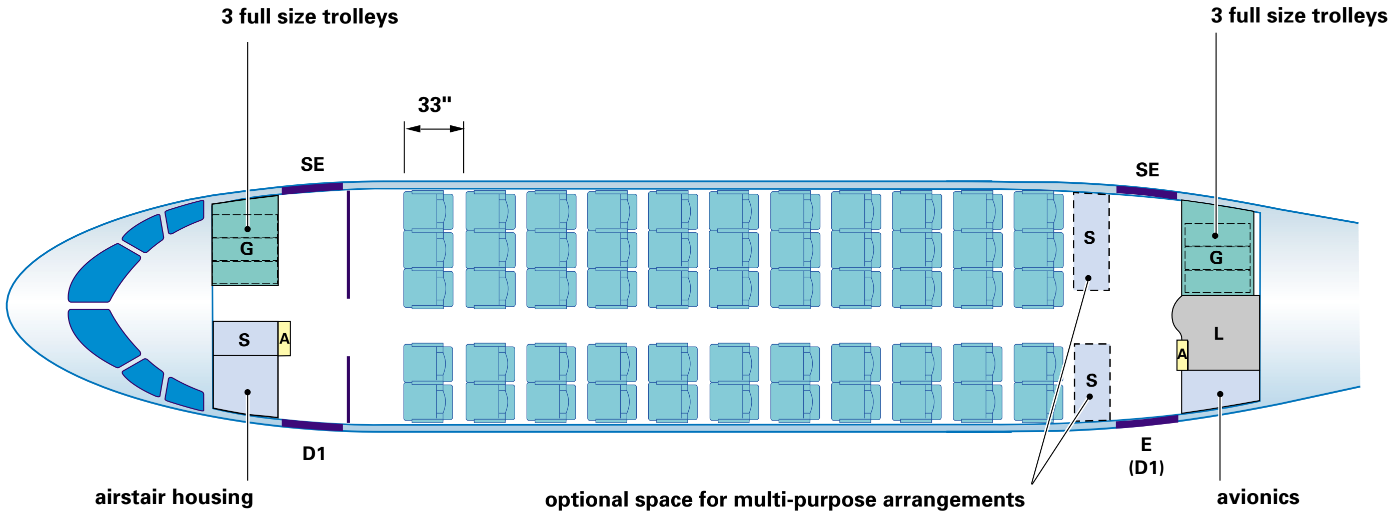
95 Seats at 33" Seat Pitch



D1 = Passenger Door (Typ C) A = Attendant Seat W = Wardrobe	SE = Service Door & Emerg. Exit (Typ C) E = Emergency Exit (Typ C)	L = Toilet & Lavatory G = Galley S = Storage

528JET Cabin Layout for 55 Passengers

55 Seats at 33" Seat Pitch



D1 = Passenger Door (Typ C) A = Attendant Seat W = Wardrobe	SE = Service Door & Emerg. Exit (Typ C) E = Emergency Exit (Typ C)	L = Toilet & Lavatory G = Galley S = Storage

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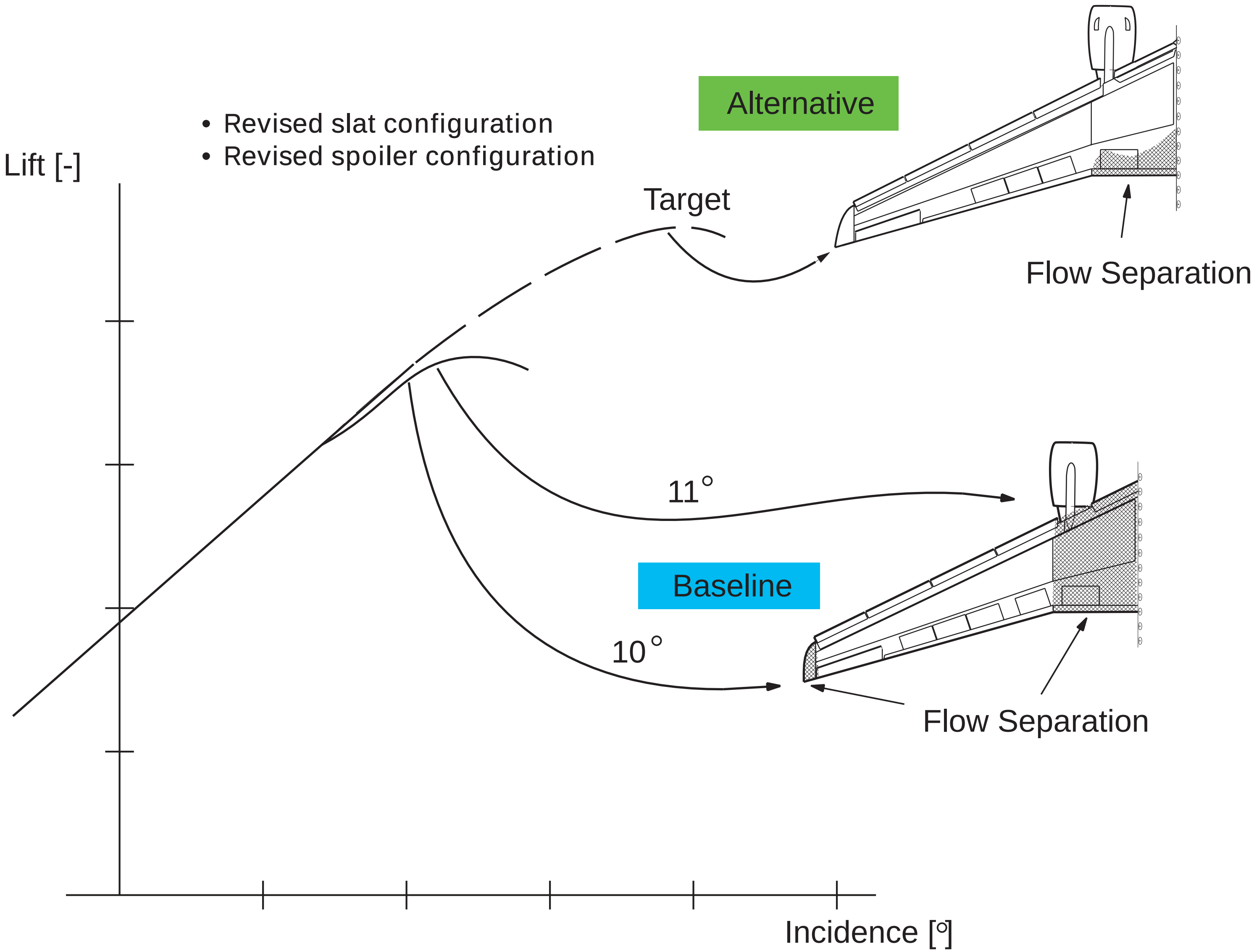
CF34-8D – Propulsion System Family

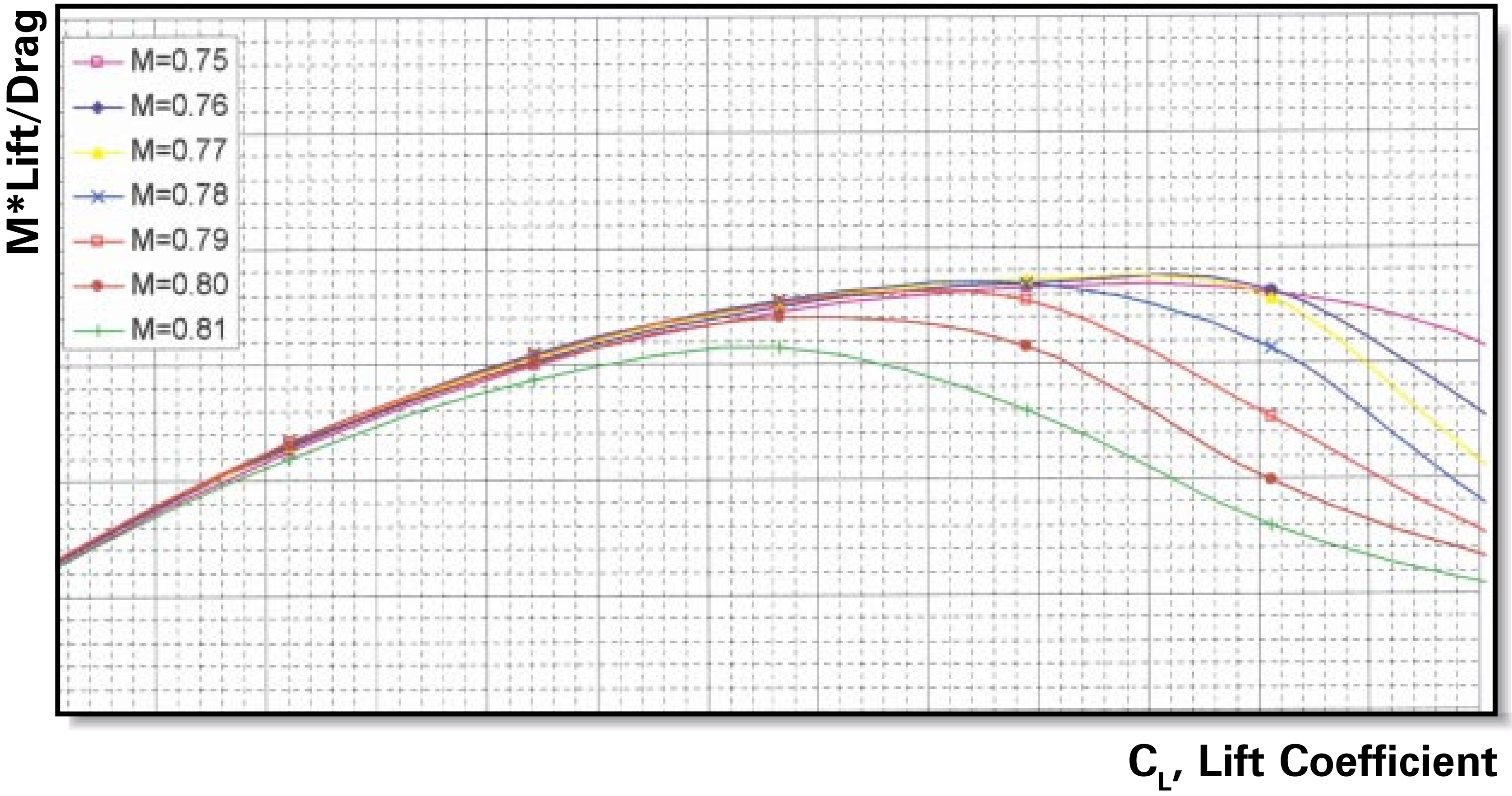
	728JET	528JET	928JET
Propulsion System Features	CF34-8D3	CF34-8D1	-10D
• Fan Diameter	46.2"	46.2"	53"
• Nacelle	Base	Base	Larger Nacelle with Common Features/Architecture
	← Common Nacelle →		
• Booster Stages	0	0	3
• HP Compressor	Base	Base	Derivative CFM-56
• Combustor	Base	Base	Derivative CFM-56
• HP Turbine	Base	Base	Derivative CFM-56
• LPT Turbine	Base	Base	New Design
• % Identical with CF34-8D3	Base	100%	Minor commonality only
Performance			
• Installed Thrust (lbf)*			
– APR Take-off	13,575*	Derate -8D3	18,000-20,000 exact requirments at a later date
– Normal T/O	12,500	Derate -8D3	

* Take-off ratings are installed SLS, flat rated to ISA+15°C except for the CF34-8D3 APR rating which is flat rated to ISA+9°C

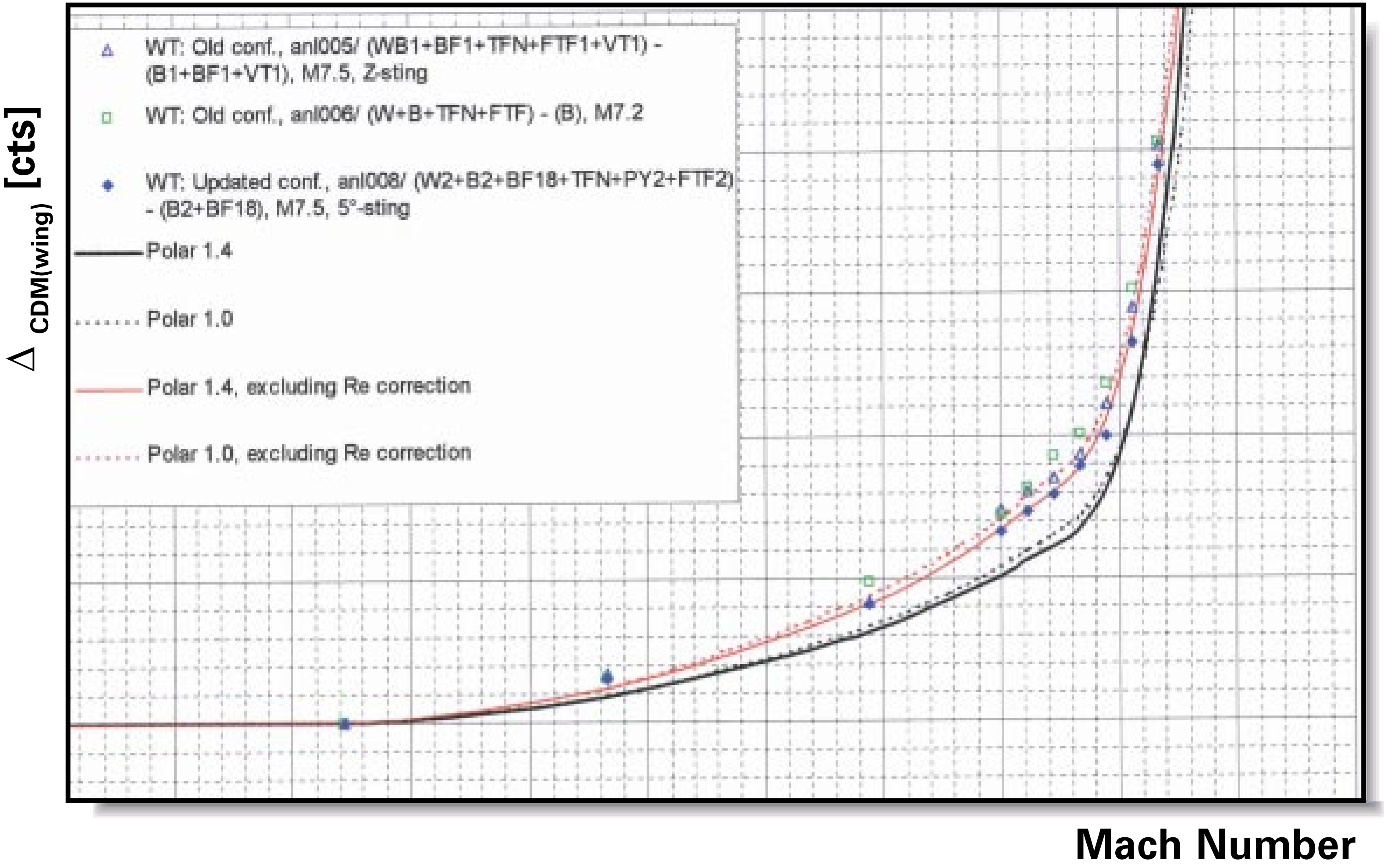
Wing Configuration Changes



Aerodynamic Efficiency, Polar 1.4



Mach Dependant Drag Due to the Wing



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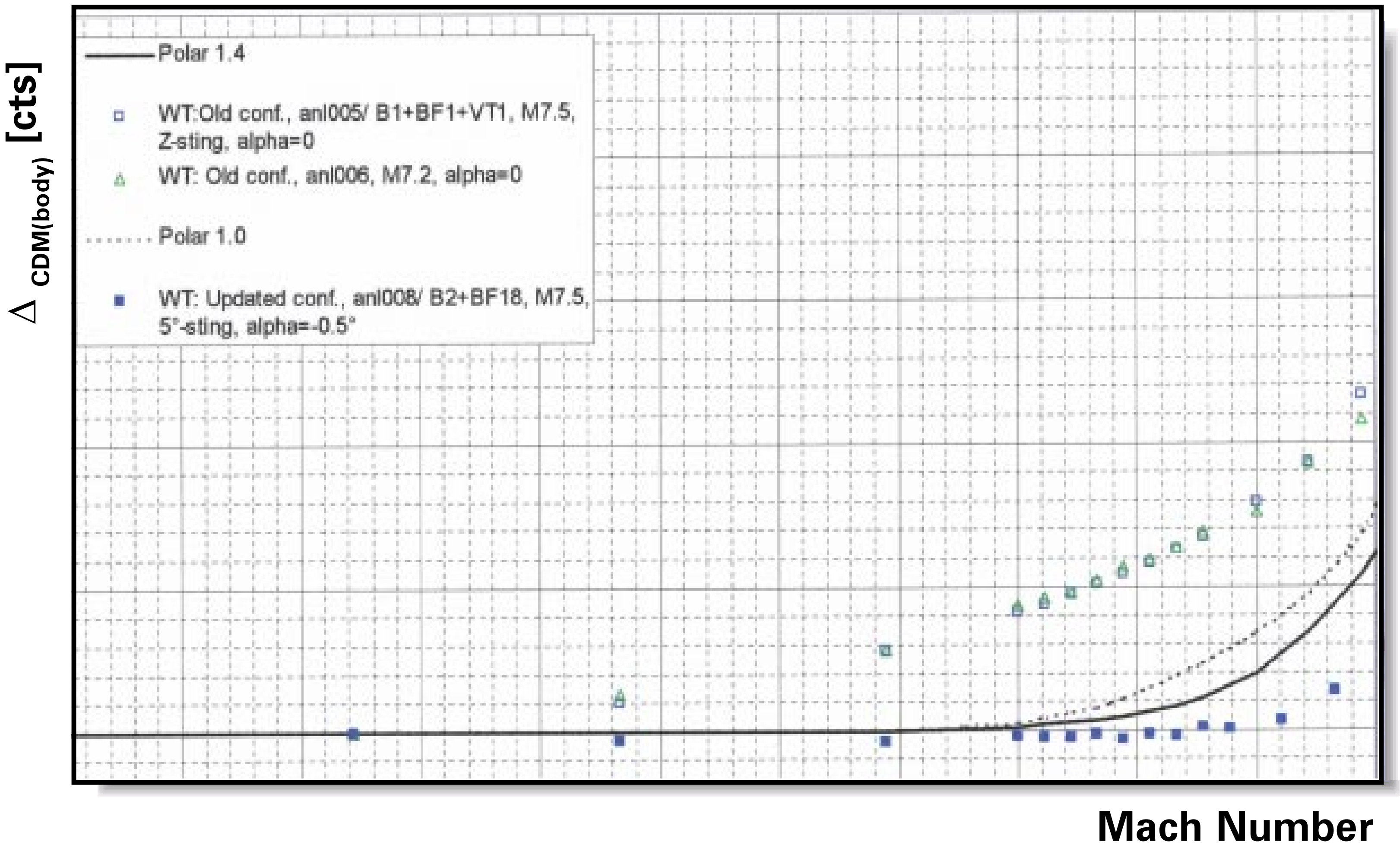
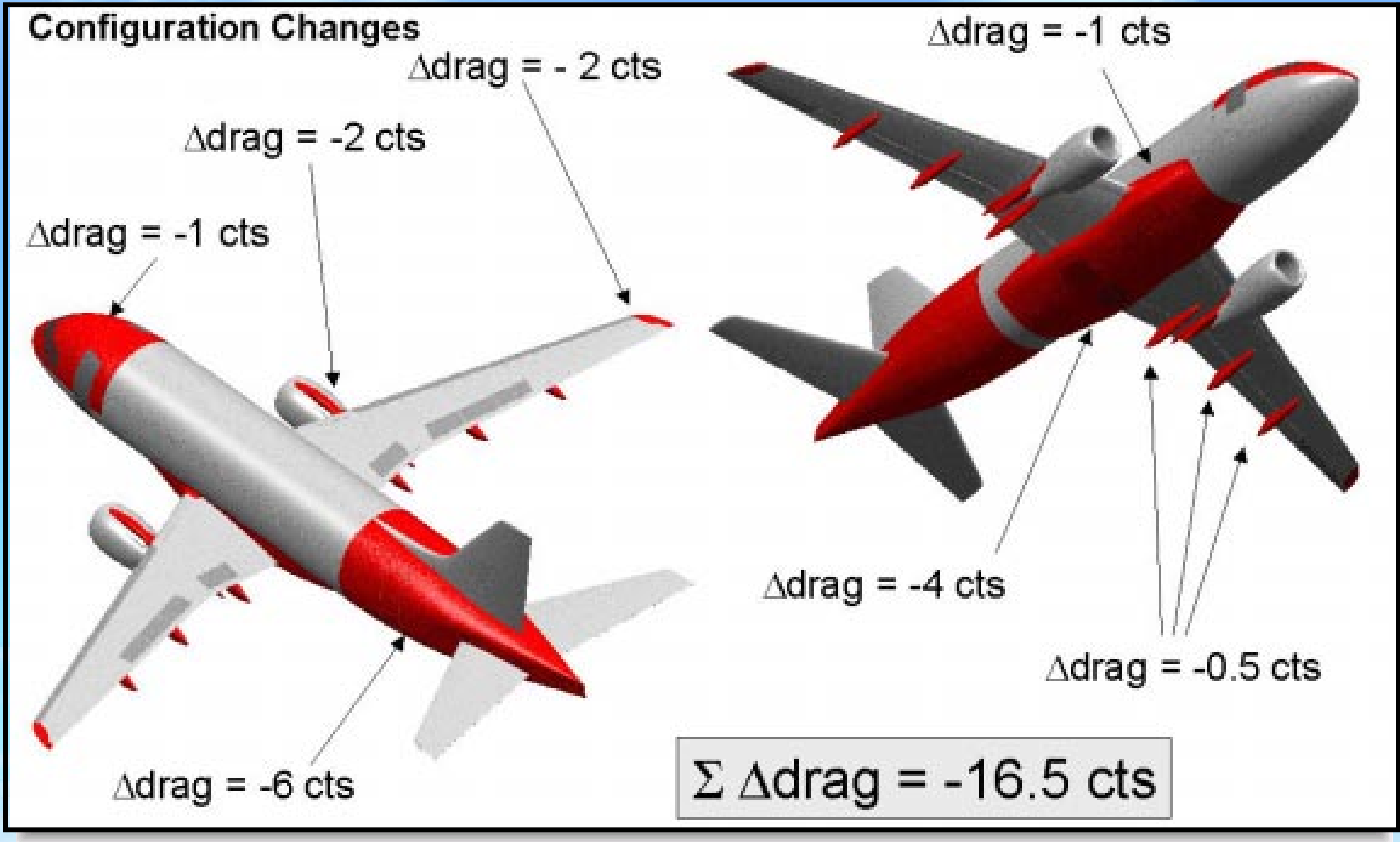
Mach Dependant Drag Due to the Fuselage Body



Drag Reduction Due to Configuration Changes



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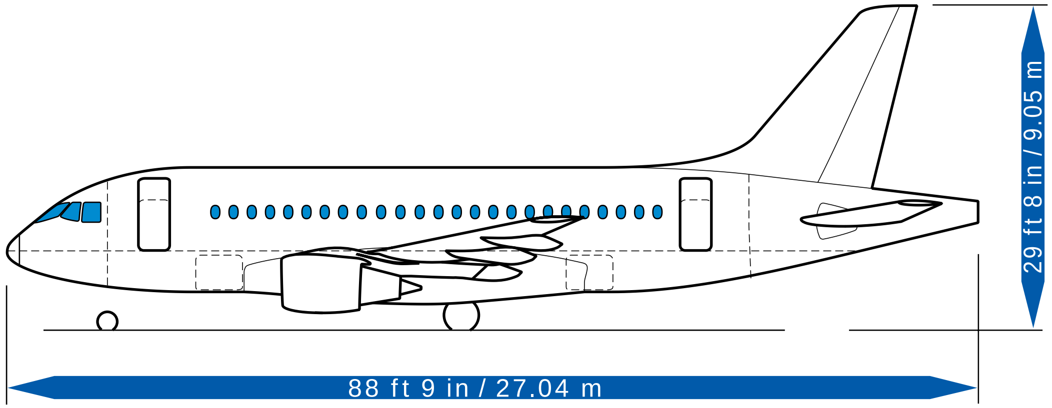
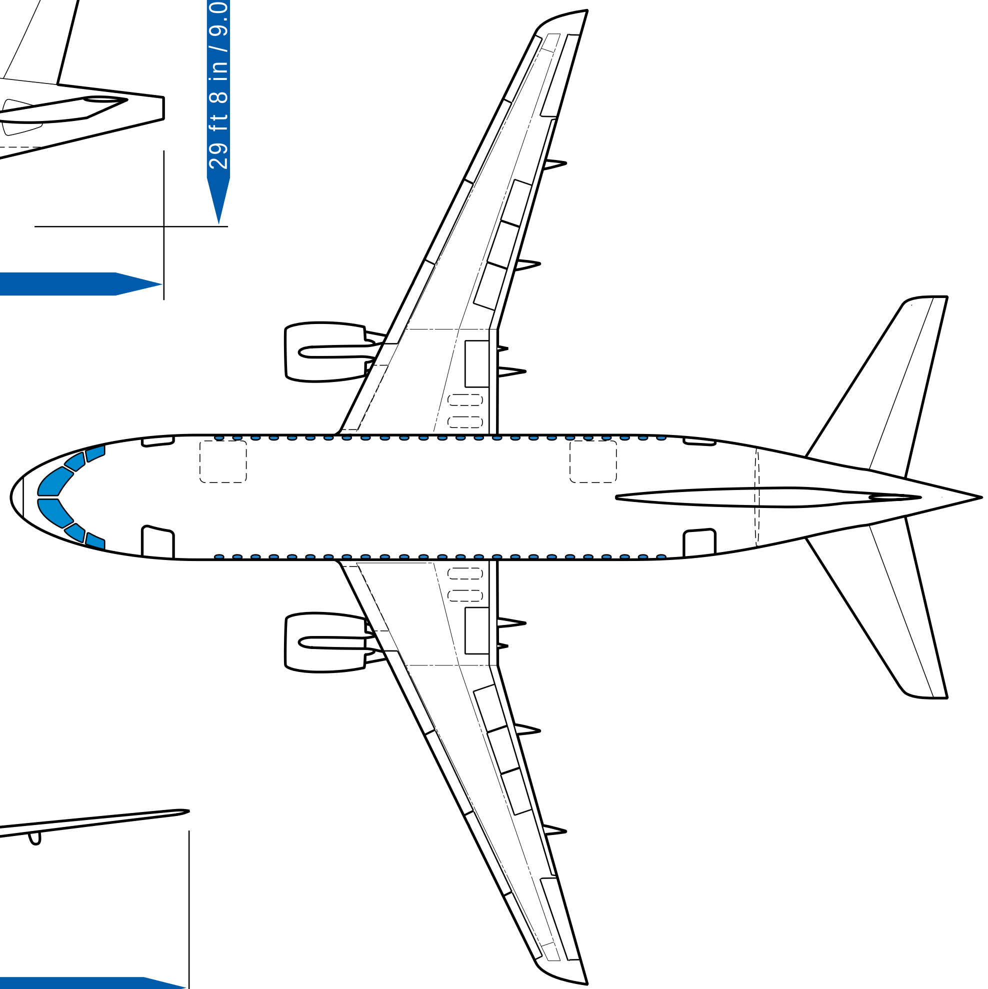
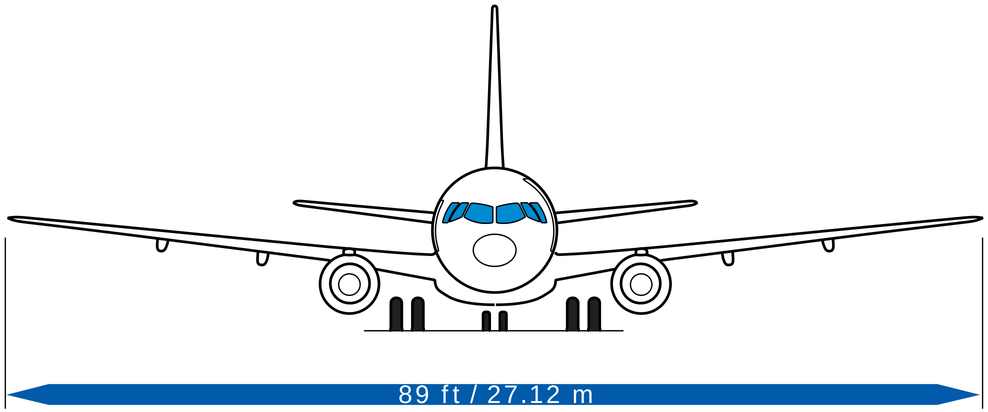
728JET – 3 View





Wing Area	807 ft²/75 m²
Aspect Ratio	9.81
Sweep	23.5°



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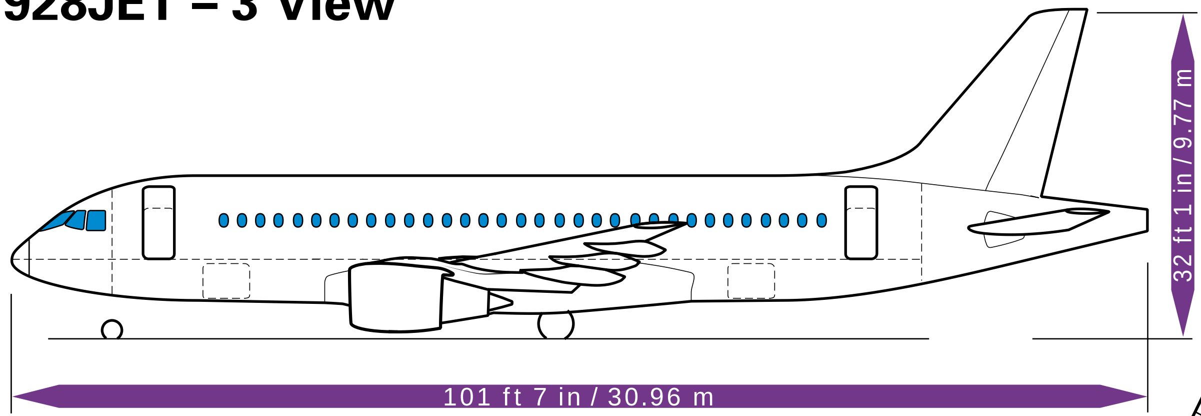
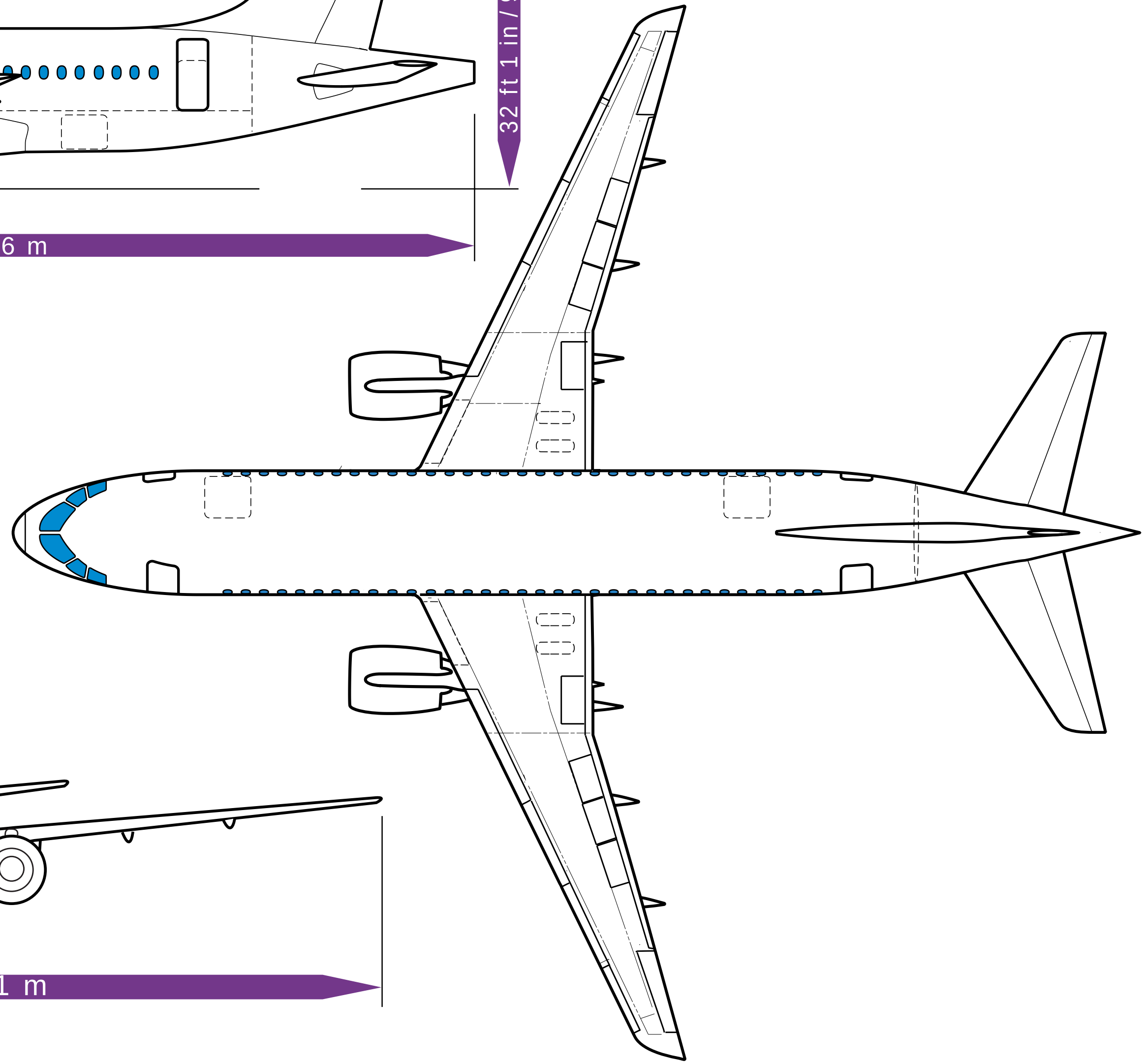
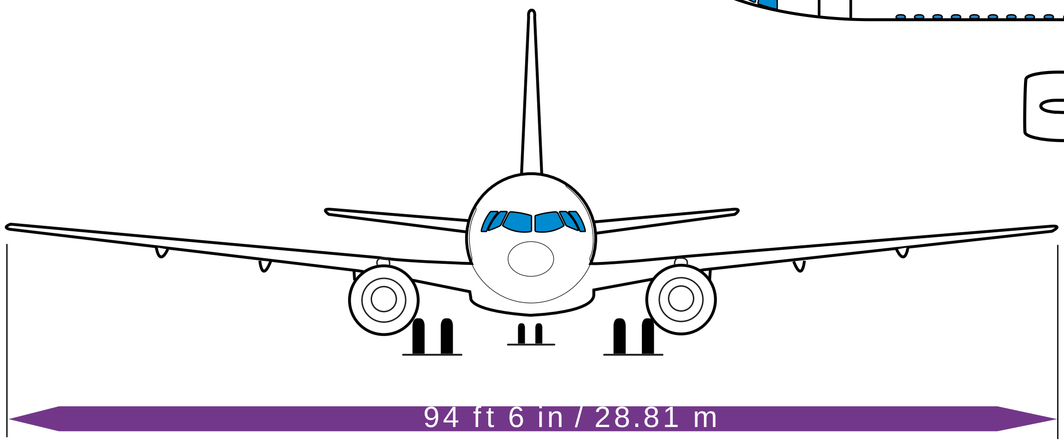
928JET – 3 View



Wing Area	**904 ft²/84 m²**
Aspect Ratio	**9.83**
Sweep	**23.5⁰**





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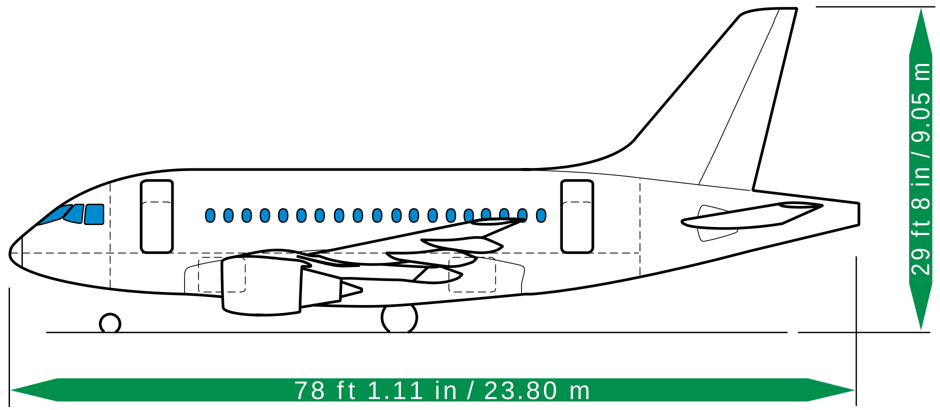
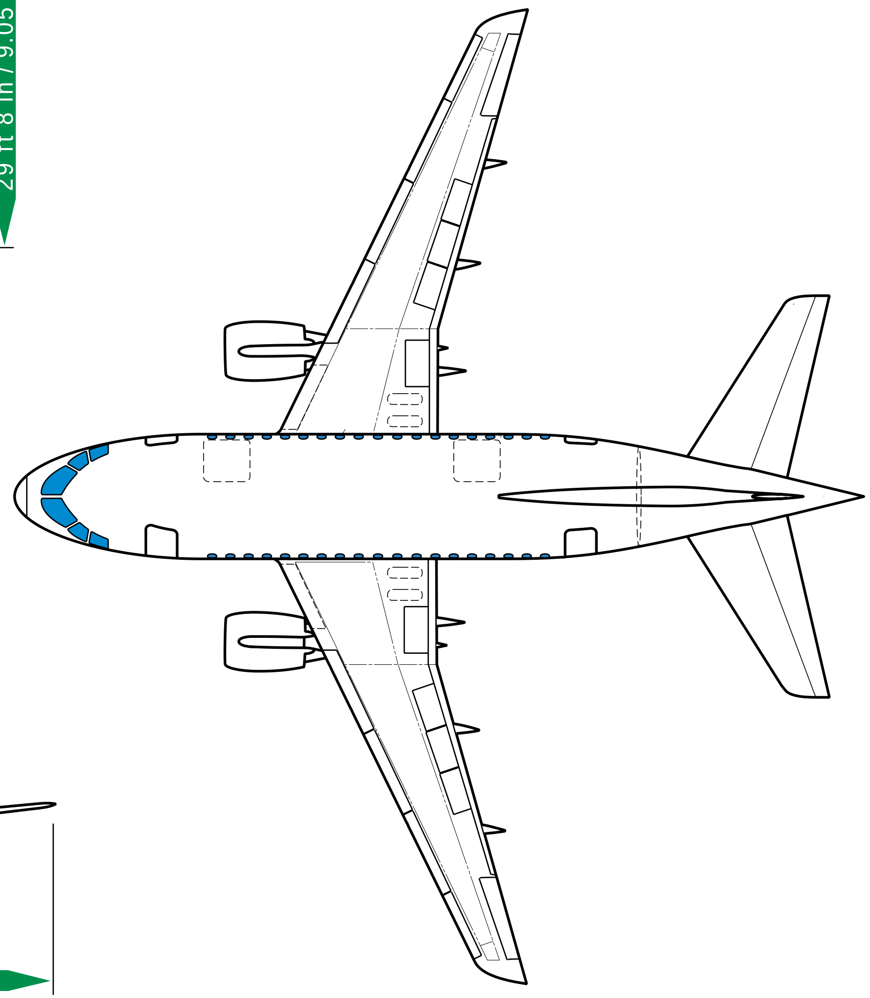
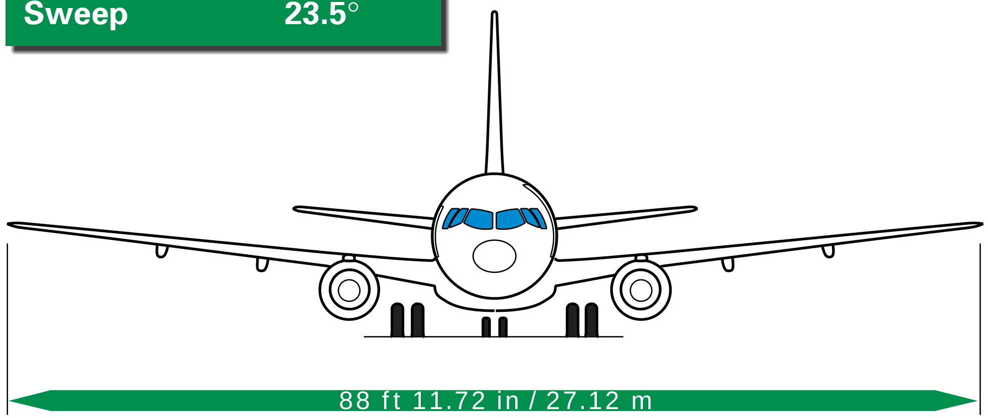
528JET – 3 View





Wing Area	**807 ft^2/75 m^2**
Aspect Ratio	**9.81**
Sweep	**23.5°**



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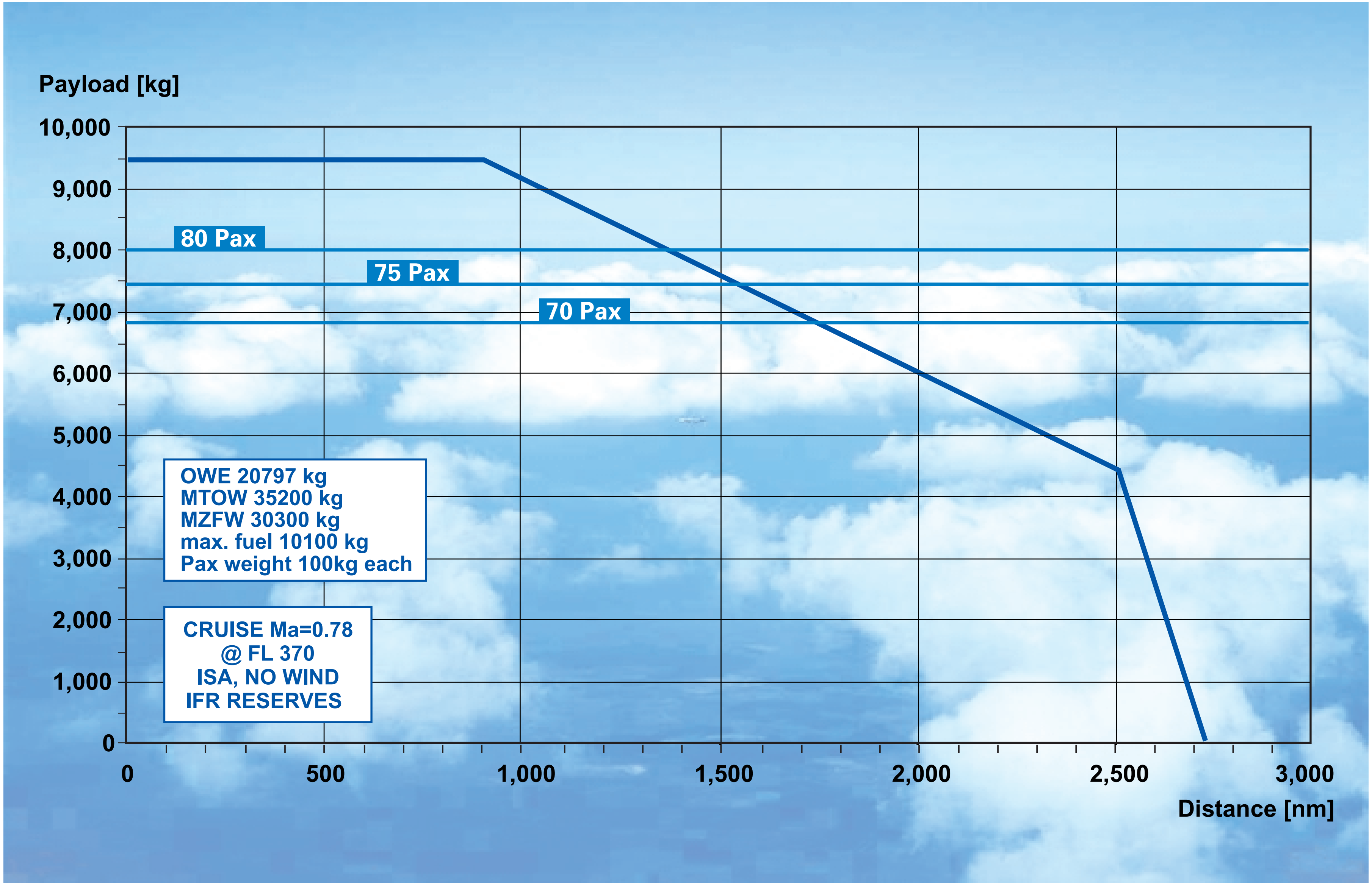
Leading Particulars, Weights & Performance Summary

Designation	528JET	728JET	928JET
Capacity (33"/31" pitch)	55-65	70-80	95-110
Cross Section	5-abreast	5-abreast	5-abreast
Powerplant	General Electric CF34-8D1	General Electric CF34-8D3	General Electric CF34-10D
T/O Power Rating (normal)	11,880 lb	12,500 lb (13,575 lb APR)	18,000- 20,000 lb**
Weights – Max. Take-off Weight – Max. Payload	30,990 kg/68,320 lb 7,308 kg/16,110 lb	35,200 kg/77,601 lb 36,990 kg/81,548 lb * 9,500 kg/20,944 lb	44,500 kg/98,106 lb ER to be issued later * 12,574 kg/27,720 lb
Range (with IFR reserves) 100kg/pax, FL370, M=0.78, ISA	55 Pax / 65 Pax 1,520 nm / 1,230 nm	70 Pax / 80 Pax 1,660 nm /1,340 nm (≈ 2,140 nm /1,820 nm)*	95 Pax /110 Pax 2,000 nm / 1,620 nm
Max. Cruise Speed ISA, 95% MTOW, FL350	467 KTAS (M≈0.81)	464 KTAS (M≈0.805)	462 KTAS (M≈0.8)
M_{MO} / V_{MO}	0.81/335 KCAS	0.81/335 KCAS	0.81/335 KCAS
Take-off Field Length (Std. version, ISA, SL MTOW)	4,200 ft	5,200 ft	5,530 ft
Single Engine Service Ceiling	21,000 ft	20,200 ft	to be issued later
Landing Field Length (Std. version, MLW)	4,200 ft	4,300 ft	4,630 ft
Hot&High Performance Climb-limited T/O Wt. (Std. version, ISA + 20°C, 5,000 ft)	MTOW	MTOW	MTOW

* ER version ** exact requirement will be issued at a later date

Payload/Range Diagram for 728JET



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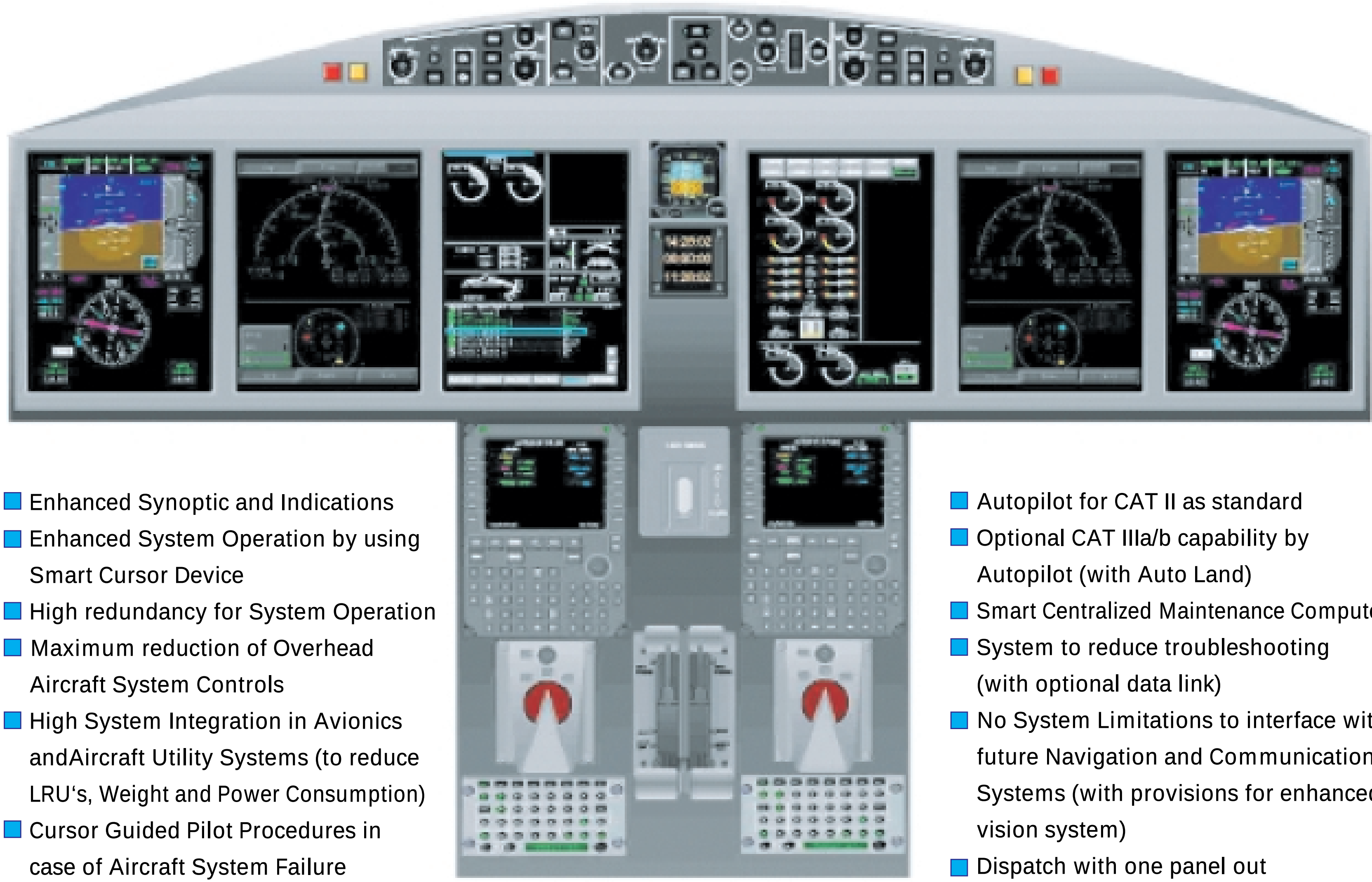
Primus *EPIC* Avionic System (Honeywell)



- Enhanced Synoptic and Indications
- Enhanced System Operation by using Smart Cursor Device
- High redundancy for System Operation
- Maximum reduction of Overhead Aircraft System Controls
- High System Integration in Avionics andAircraft Utility Systems (to reduce LRU's, Weight and Power Consumption)
- Cursor Guided Pilot Procedures in case of Aircraft System Failure

- Autopilot for CAT II as standard
- Optional CAT IIIa/b capability by Autopilot (with Auto Land)
- Smart Centralized Maintenance Computer
- System to reduce troubleshooting (with optional data link)
- No System Limitations to interface with future Navigation and Communication Systems (with provisions for enhanced vision system)
- Dispatch with one panel out

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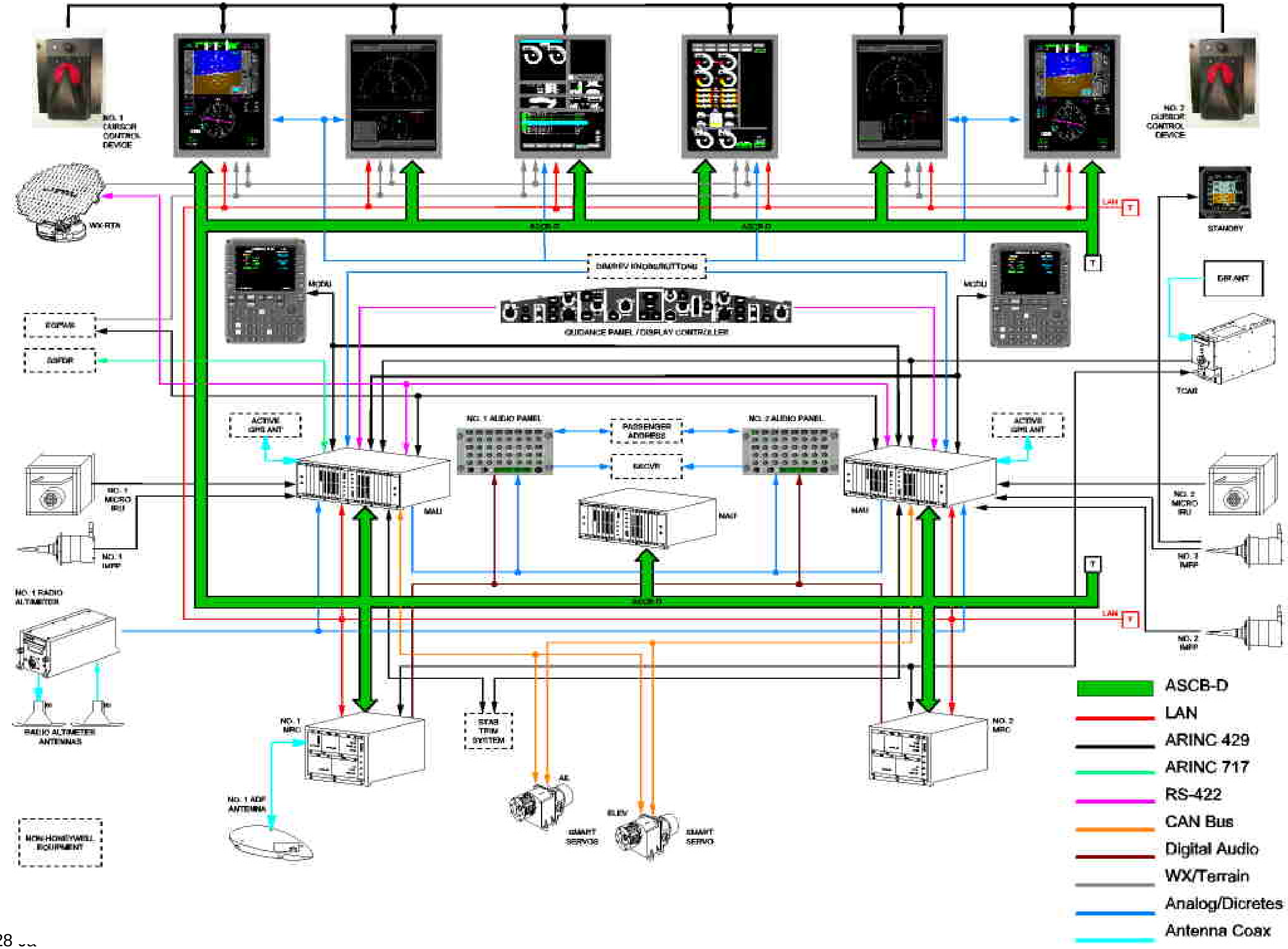
Baseline Avionics



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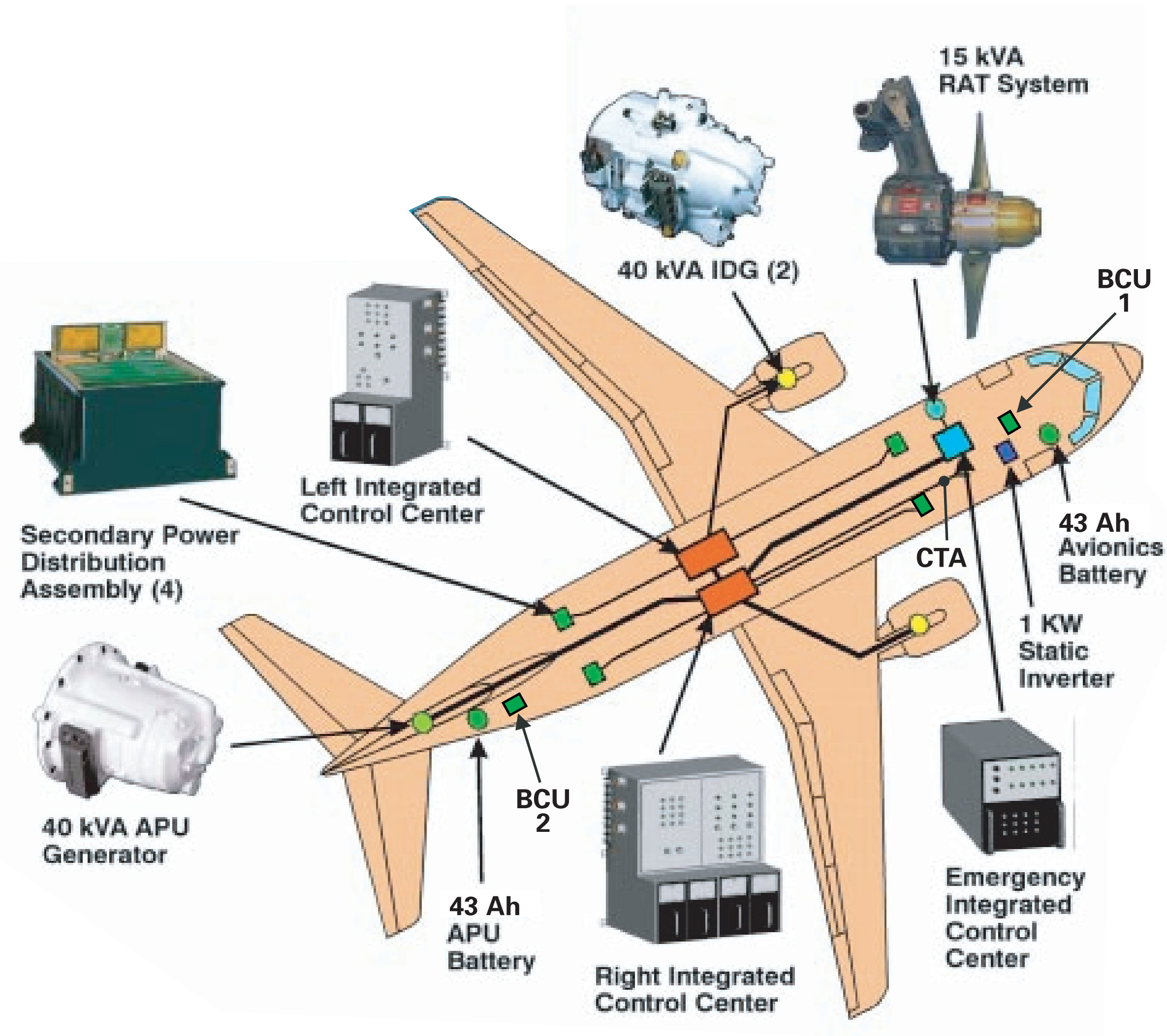
Beneficial Advancements of the Avionic System

- **Integrated Utilities**
  - Centralize systems and functions
- **Minimize Data-Source and - Processors**
  - Centralize important aircraft data
- **Minimize Paper in Cockpit**
  - Automate procedures and checklist for pilots and maintenance personel
- **Commanding of other A/C Systems via Cursor Control Device**
  - Reduce number of controllers in the panels

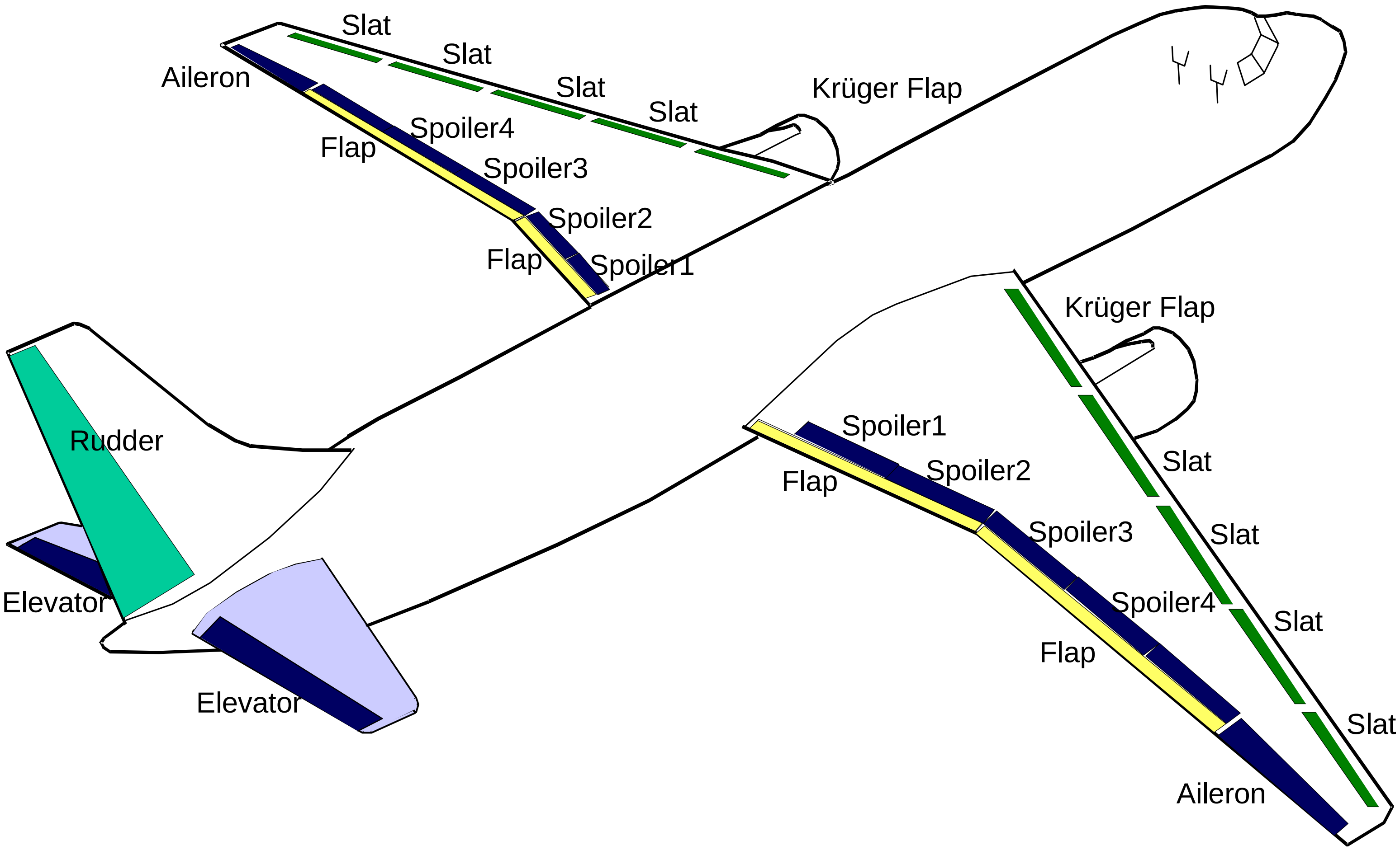
Electrical Power Generation and Distribution System



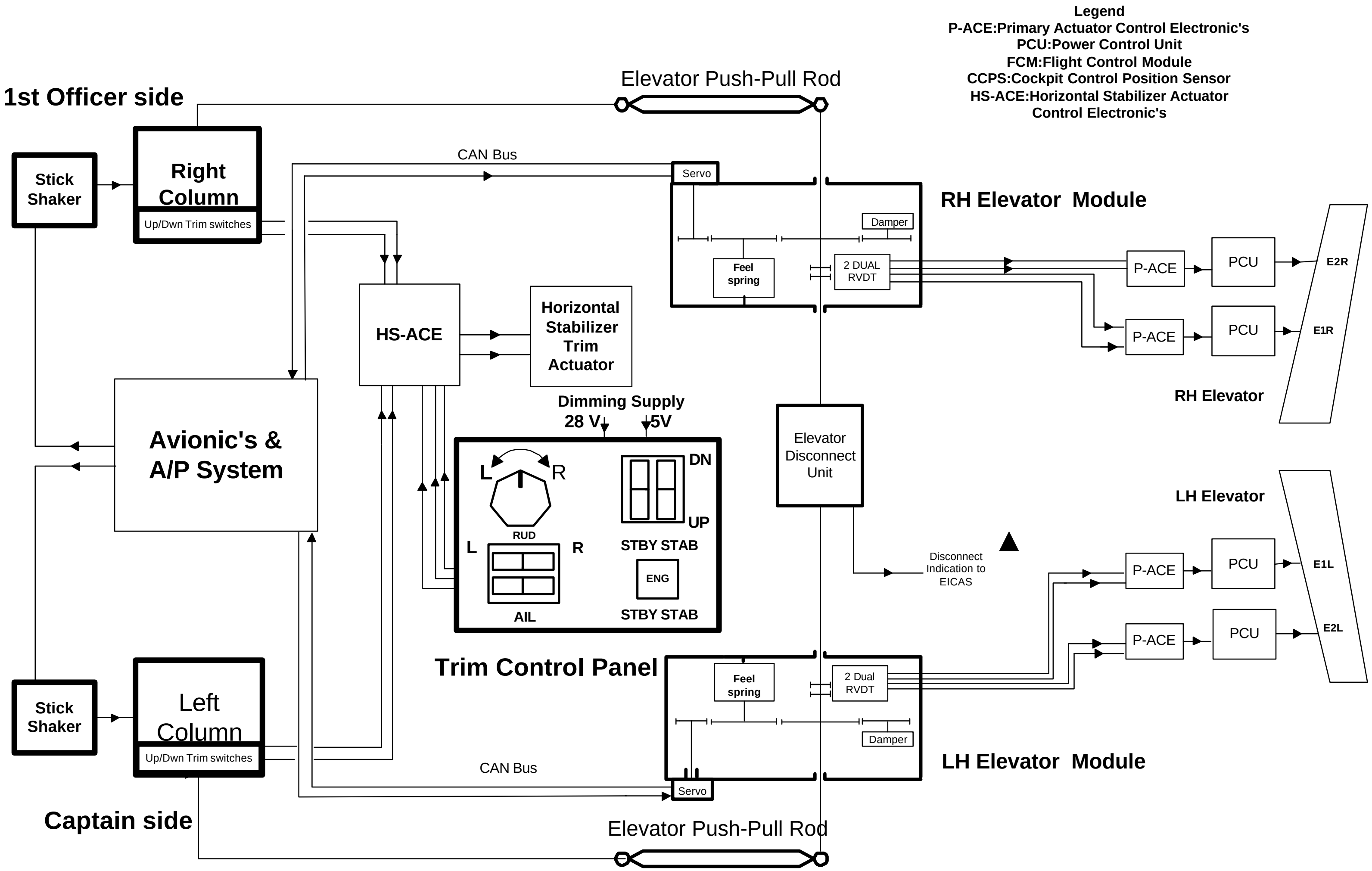
- System Configuration:
  - Generation:
    - (2) Main Engine (IDGs)
    - (1) APU (AUX GEN & Seal Plate)
  - Primary Distribution:
    - (1) Left Integrated Control Center
    - (1) Right Integrated Control Center
    - (1) Emergency Integrated Control Center
    - (1) EXT AC Current Transformer Assy
  - Secondary Distribution:
    - (4) Secondary Power Distribution Assy
  - Emergency Power:
    - (1 each) Ram Air Turbine, Generator Control Unit, Ejection Jack, Restow Pump, Uplock
    - (1) Static Inverter
    - (2) Batteries & Battery Contactor Units

General Overview

Aircraft Plan View



Pitch Cockpit Control Module



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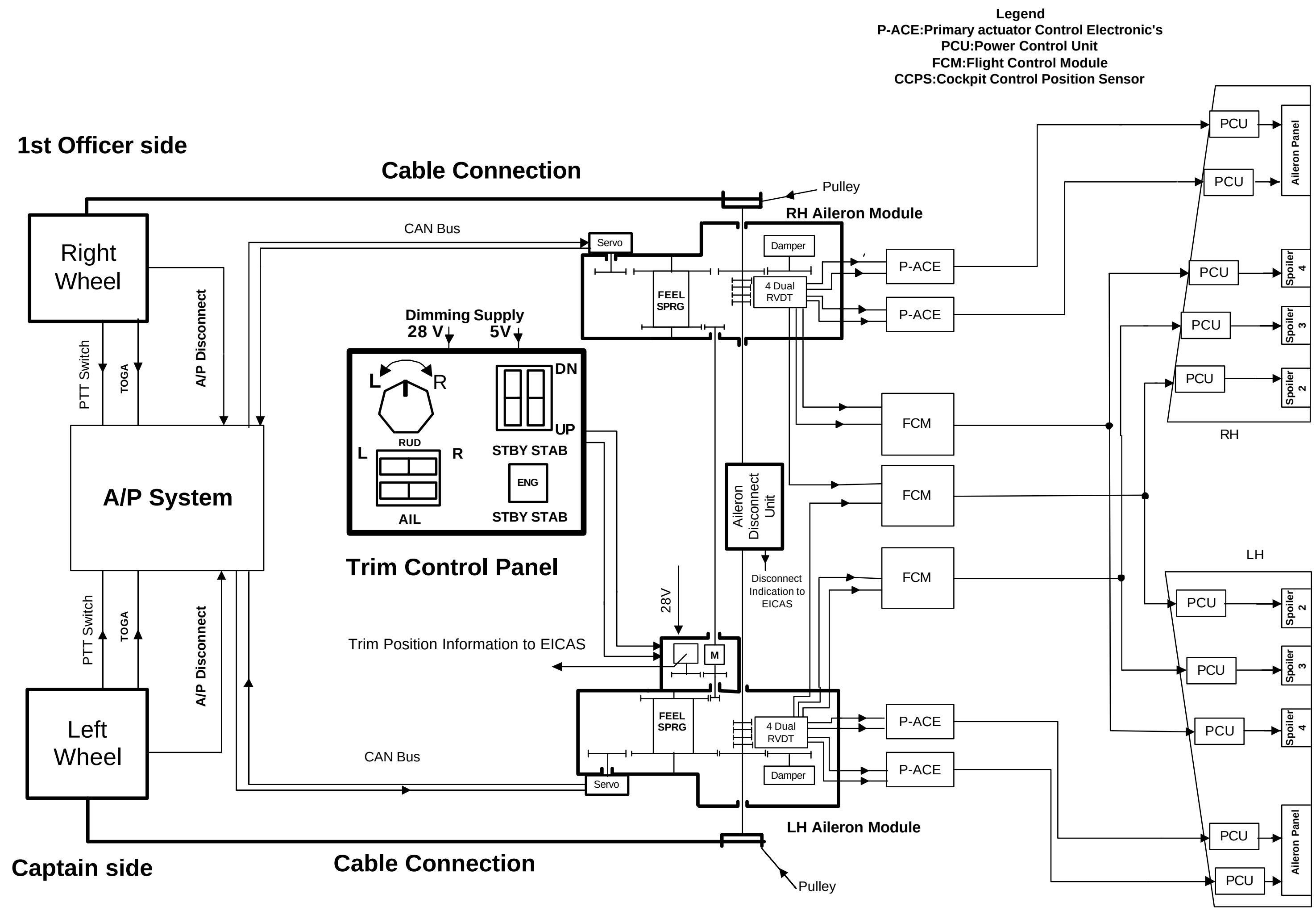
Roll Cockpit Control Module



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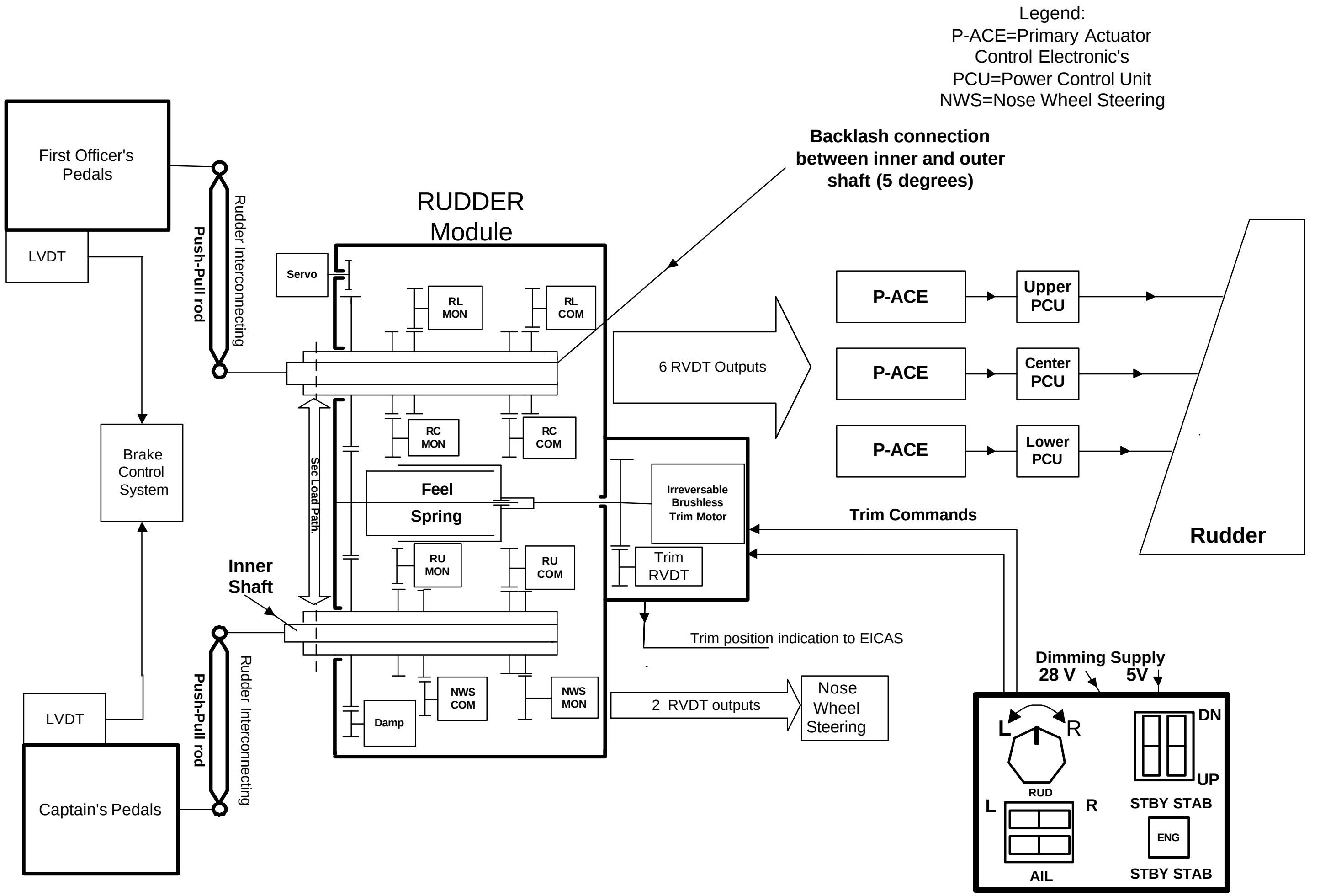
Yaw Cockpit Control Module



Trim Control Panel

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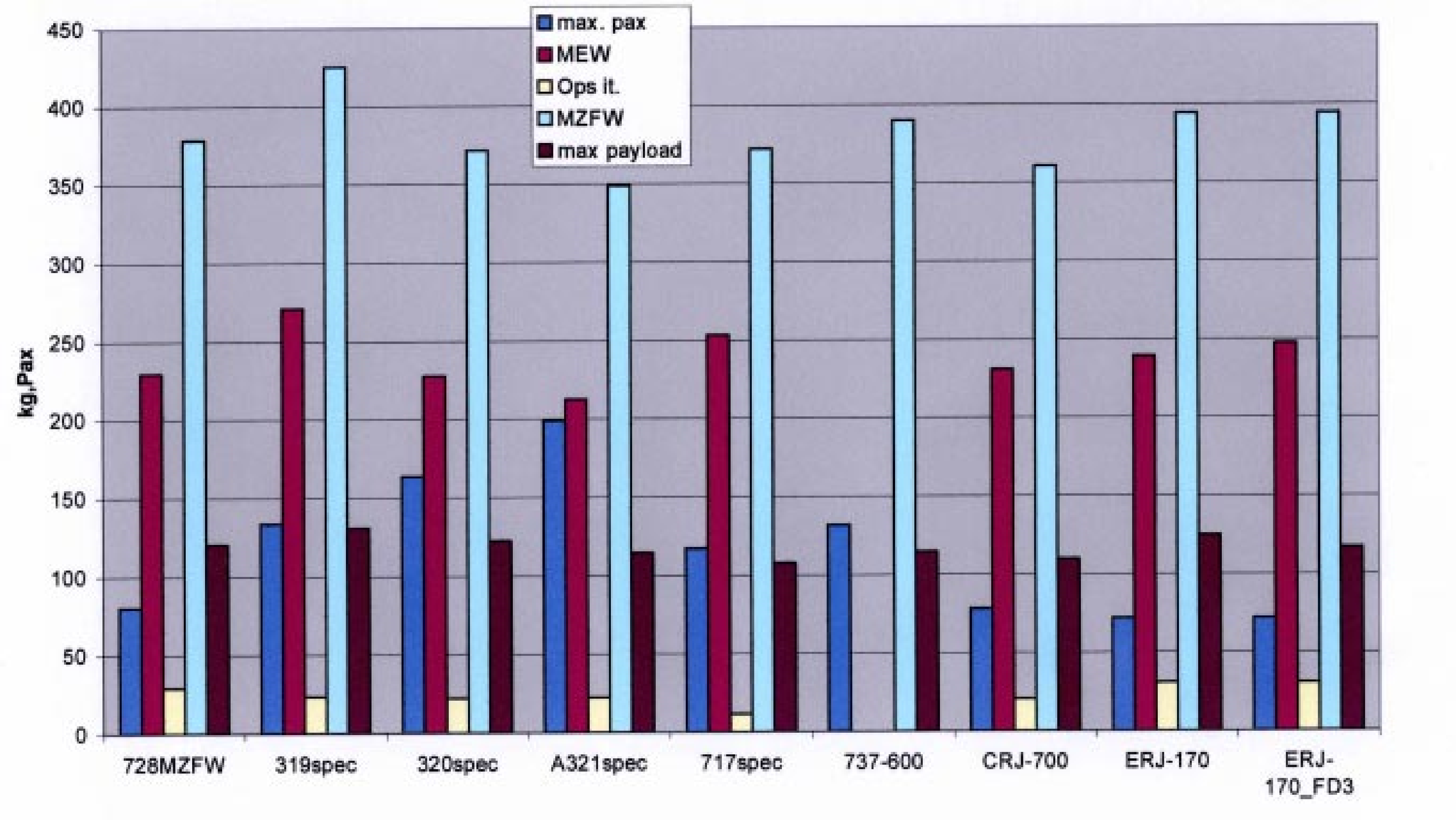
Weight/Max Pax (kg)



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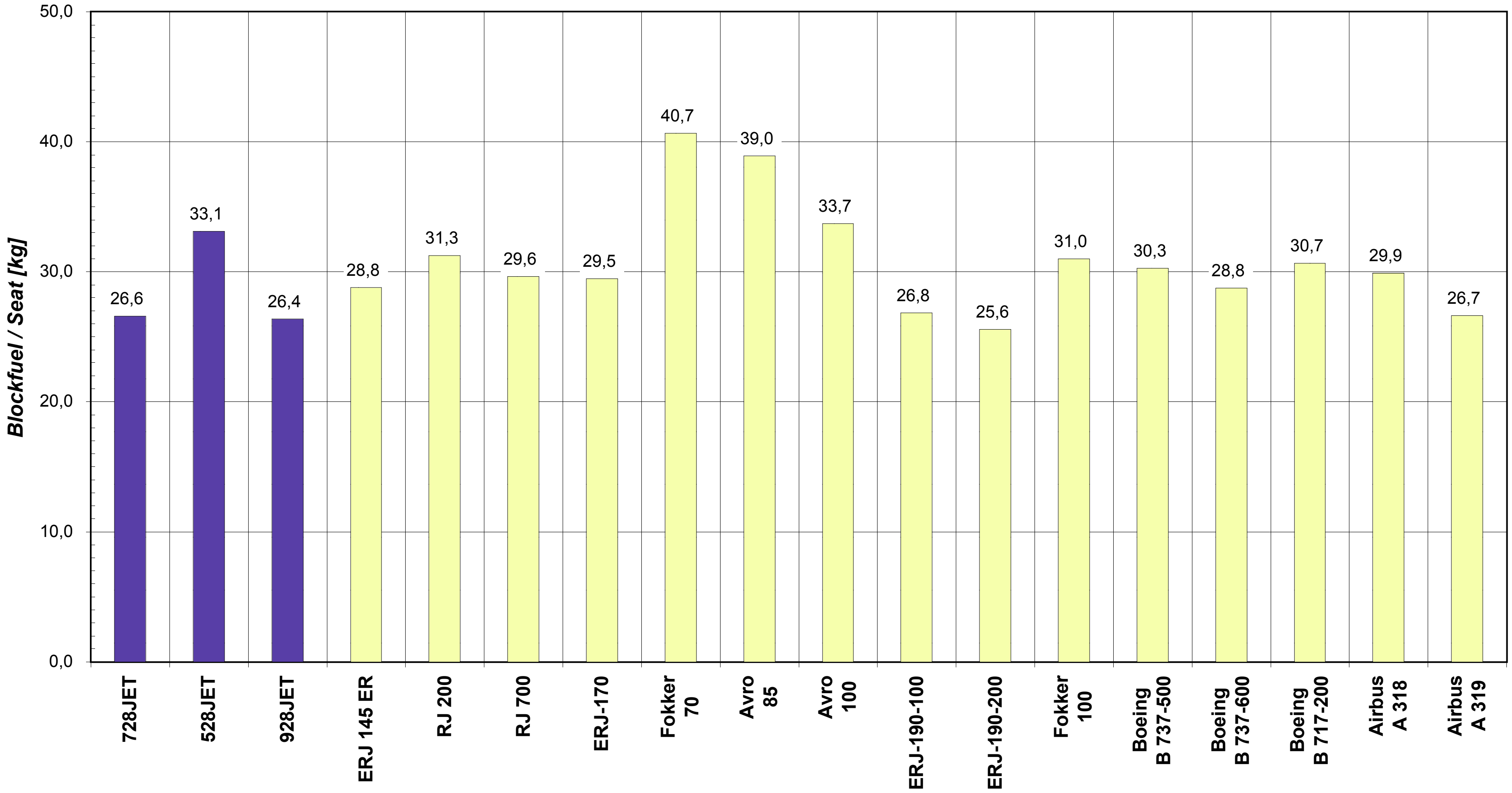
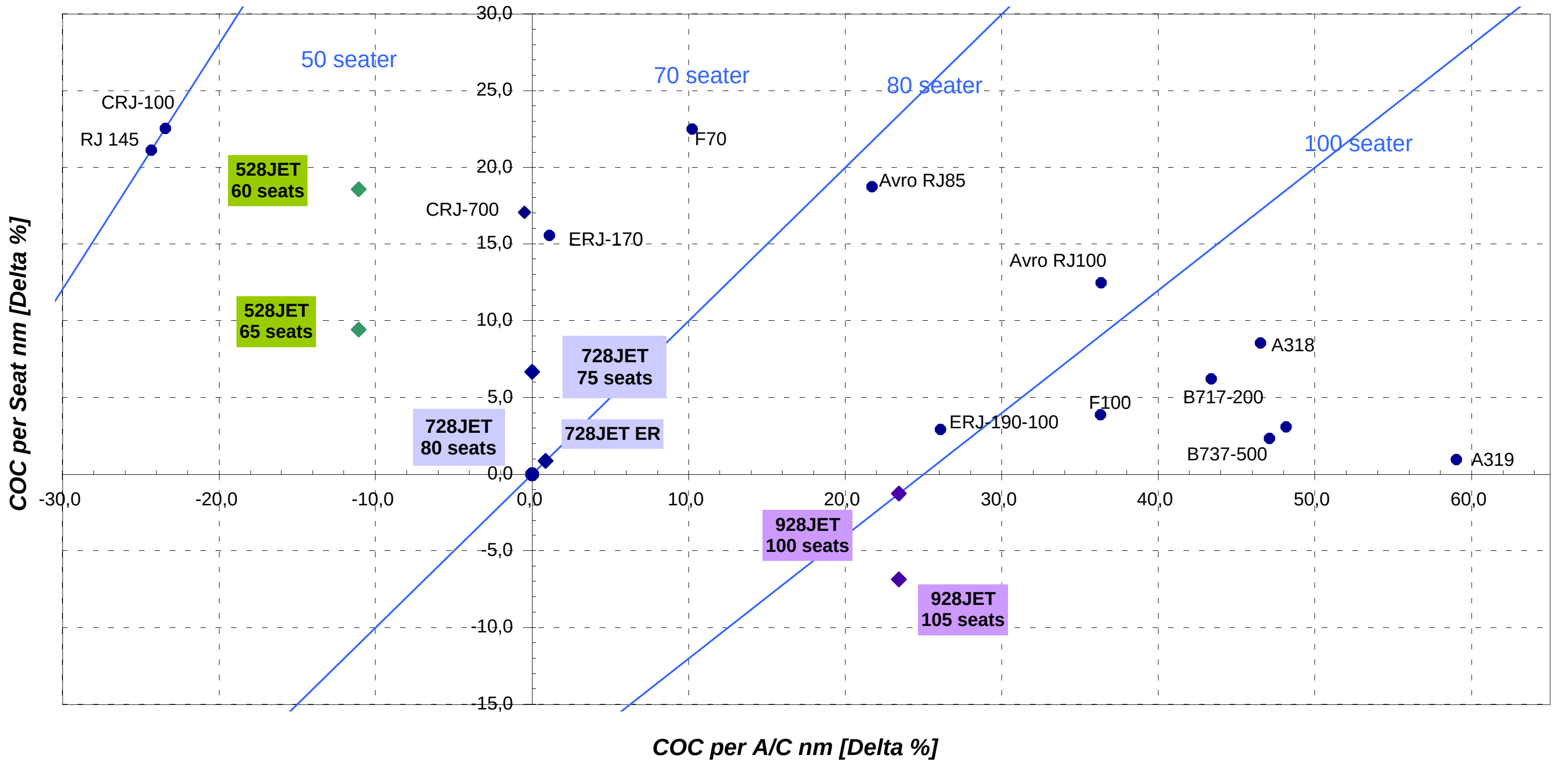
Index Blockfuel per Seat - Comparison   Stage Length 500 nm



seats	80	60	100	50	50	68	70	72	82	97	98	108	105	115	115	108	108	126

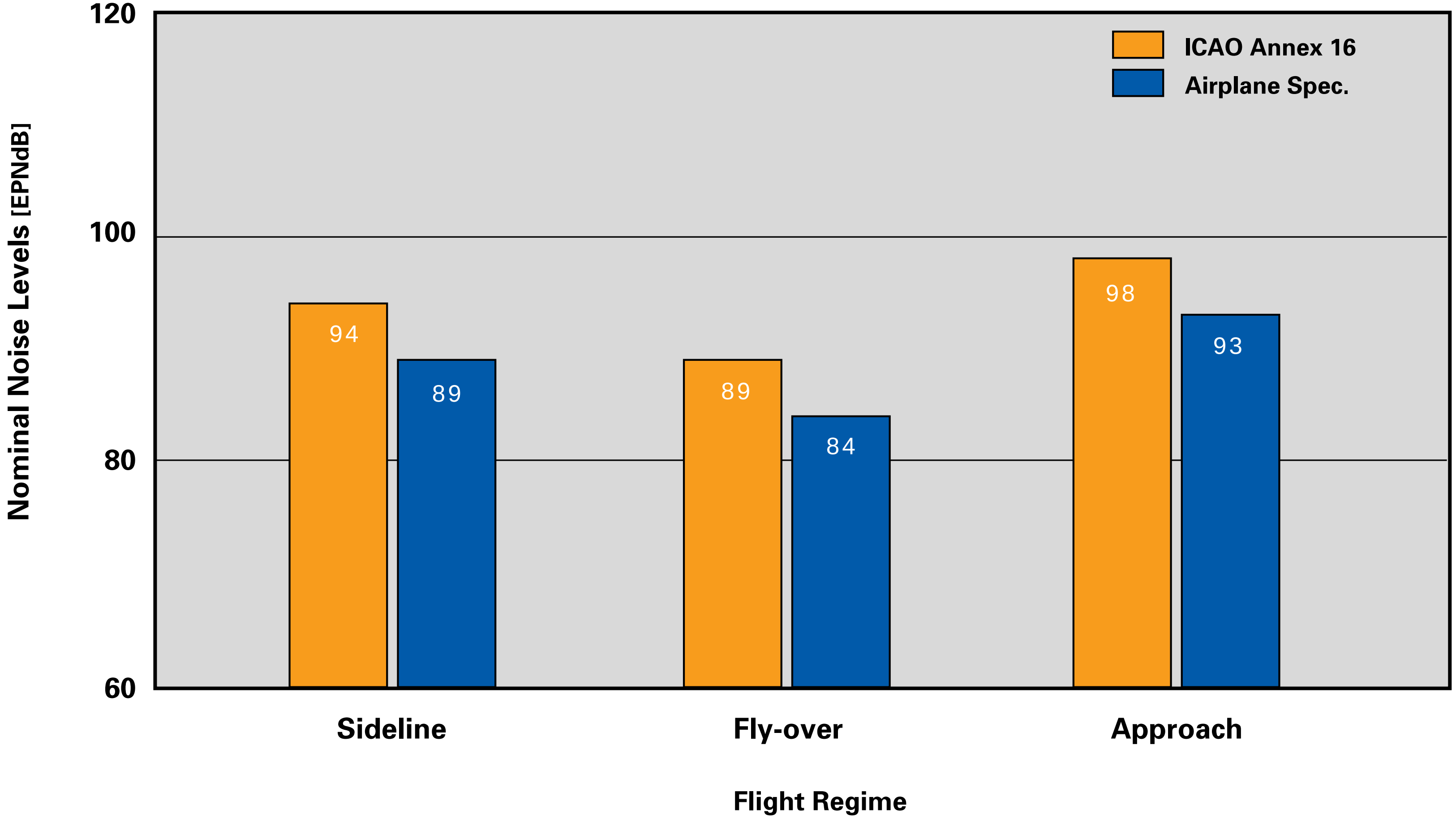
Delta COC per Seat / per A/C nm - Comparison — Stage Length 500 nm



728JET Family Seating Layouts

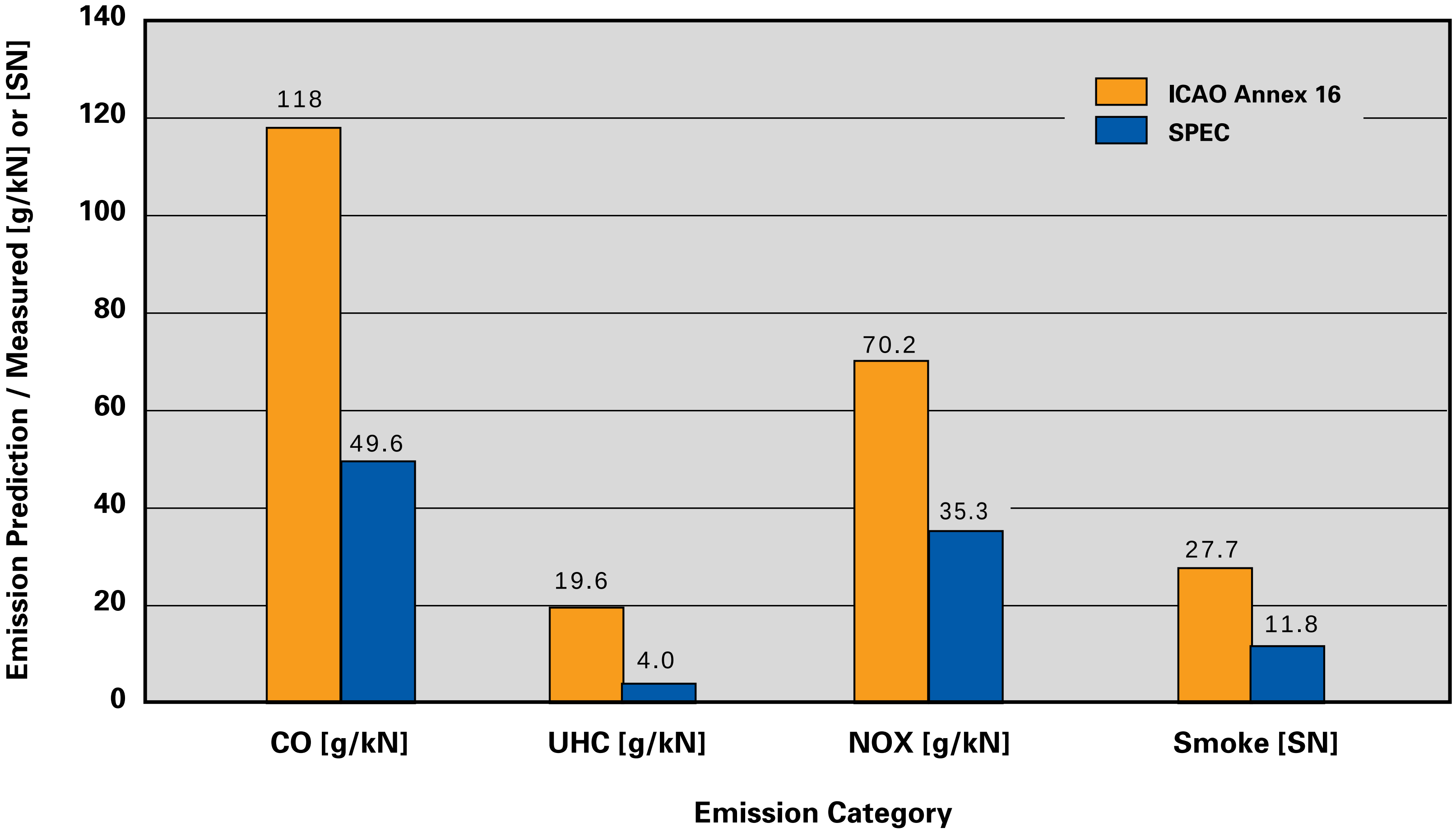
seat pitch	528JET	728JET	928JET	
31 inch	65		105	max. capacity
32 inch	60	80	100	standard comfort
33 inch		75		high comfort

Certification Flight Noise



GEAE assumed airframe noise of 86 dB for approach condition.

Emissions



140
120
100
80
60
40
20
0
Emission Prediction / Measured [g/kN] or [SN]
118
49.6
19.6
4.0
70.2
35.3
27.7
11.8
ICAO Annex 16
SPEC
CO [g/kN]
UHC [g/kN]
NOX [g/kN]
Smoke [SN]
Emission Category

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The Situation

Airlines must decide on the future fleet today. The decision for the right equipment must address the following requirements:

- **The market requires aircraft of different sizes for flexible scheduling and effective yield management.**
- **Marketing requires a common product identity.**
- **Operation requires small numbers of aircraft types and standardization to achieve low operating cost.**
- **Strategic planning requires aircraft capacity optimization in line with the future development of the business.**
- **Limited predictability of the future requires high adaptability of the aircraft fleet to changing market requirements, without increasing cost.**

Cost Saving Issues

Aircrew

The common type rating for the 728JET family aircraft enables pilots to operate each type within the fleet, simplifying crew scheduling. It also reduces the cost for type rating, training and salaries throughout the whole service life of the aircraft and reduces operational constraints, such as crew positioning, dead heading costs, etc. These savings will be even more substantial, should an air-line's route structure require more crews per aircraft.

Simulator

An airline operating its own simulators will necessarily have to have a simulator for each type of aircraft, representing additional high investment. This dis-advantage of a non-common fleet can, however, be avoided by out-sourcing simulator training to a specialized pilot training provider.

Cost Saving Issues

Maintenance

The required number of maintenance engineers is lower for a common fleet, due to common type ratings, resulting in reduced labor costs, coupled with higher efficiency and lower burden as a direct result of the learning curve effect.

Spares

The volume of spares holding can be decreased for a common fleet without sacrificing dispatch reliability. This means less money is tied up in spares stocks.

Operation & Administration

Many administration areas benefit from a common fleet. Purchasing, spares administration, crew training and planning, catering, ground handling and maintenance planning will be less labor intensive.

Purchasing Issues

A manufacturer can reduce costs by producing a high number of aircraft of the same type. This results in lower prices for the airlines.

There are more advantages in purchasing a common fleet:

- **Purchasing from vendors follows the known patterns**
- **The evaluation process will be simpler, due to the known profitability and costs of the aircraft and its systems.**
- **As a manufacturer of a family of aircraft, Dornier Luftfahrt can provide shorter lead-times for the customer and his decision what version (size) his airline should select when exercising options. This improves the reaction time to the challenges of a changing market.**

Product Identity

The 728JET family concept offers multiple advantages to an airline:

- **Across the fleet**
  - **Same cabin layout in all aircraft**
  - **Identical service items (galleys, lavatories, ...)**
  - **Common catering equipment**
  - **Easier seat assignments/reservations**

  - **The Commonality of the Cabin Standard in the aircraft family can be used by Marketing as a unique selling point for the airline.**

  - **A seamless standard of comfort with the mainline fleet (e.g. Airbus A320 series) is key to customer loyalty. The same standard, for example, can be kept in seat pitch (31 to 33 in) and seat width (18 in).**

Future Development of the Market

**Aircraft are sold in an ever-changing market place.
An airline, therefore, has to meet the following requirements,
which can be met by an aircraft family concept:**

- **The composition of the future fleet can be easily adopted to growth or shrinking of the market's demands.**
- **The planning risk is greatly reduced.**
- **Limited predictability of the future requires high adaptability of the aircraft fleet to changing market requirements, without increasing cost.**

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Cost Savings - Executive Summary

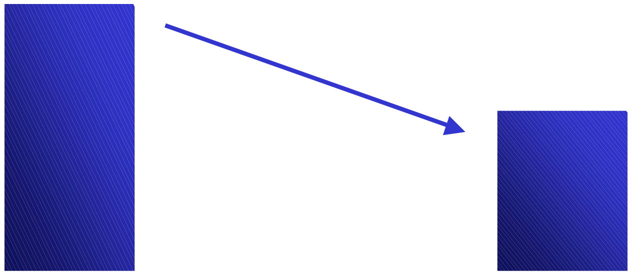
27 x A/C X + 15 x A/C Y versus 27 x 728+ 15 x 928	Savings	
	Less Investment Cost	Less Annual Cost
Simulator Economics (buy-in of training considered)	0 US$	⇐ no simulator required
Aircrew Training (Type Rating) in 2 years	961.000 US$	
Aircrew Attrition Training		1.056.100 US$/year
Aircrew Recurrent Training		259.000 US$/year
Aircrew Productivity (Crew Cost)		6.132.000 US$/year
Airframe Spares	11.305.000 US$	
Engine Spares	1.600.000 US$	
Maintenance Training (Type Rating) in 2 years	100.000 US$	
Maintenance Recurrent Training		0 US$/year
Maintenance Crew Productivity (Crew Cost)		1.059.300 US$/year
Total Fleet Add. Investment Savings:	**13.966.000 US$**	
Total Fleet Add. Annual Savings:		**8.506.400 US$/year**
Total Fleet Investment Savings	**71.966.000 US$**	

Public Acceptance

An airline depends on public acceptance. The family concept help to increase this, because
an optimized fleet size will result in:

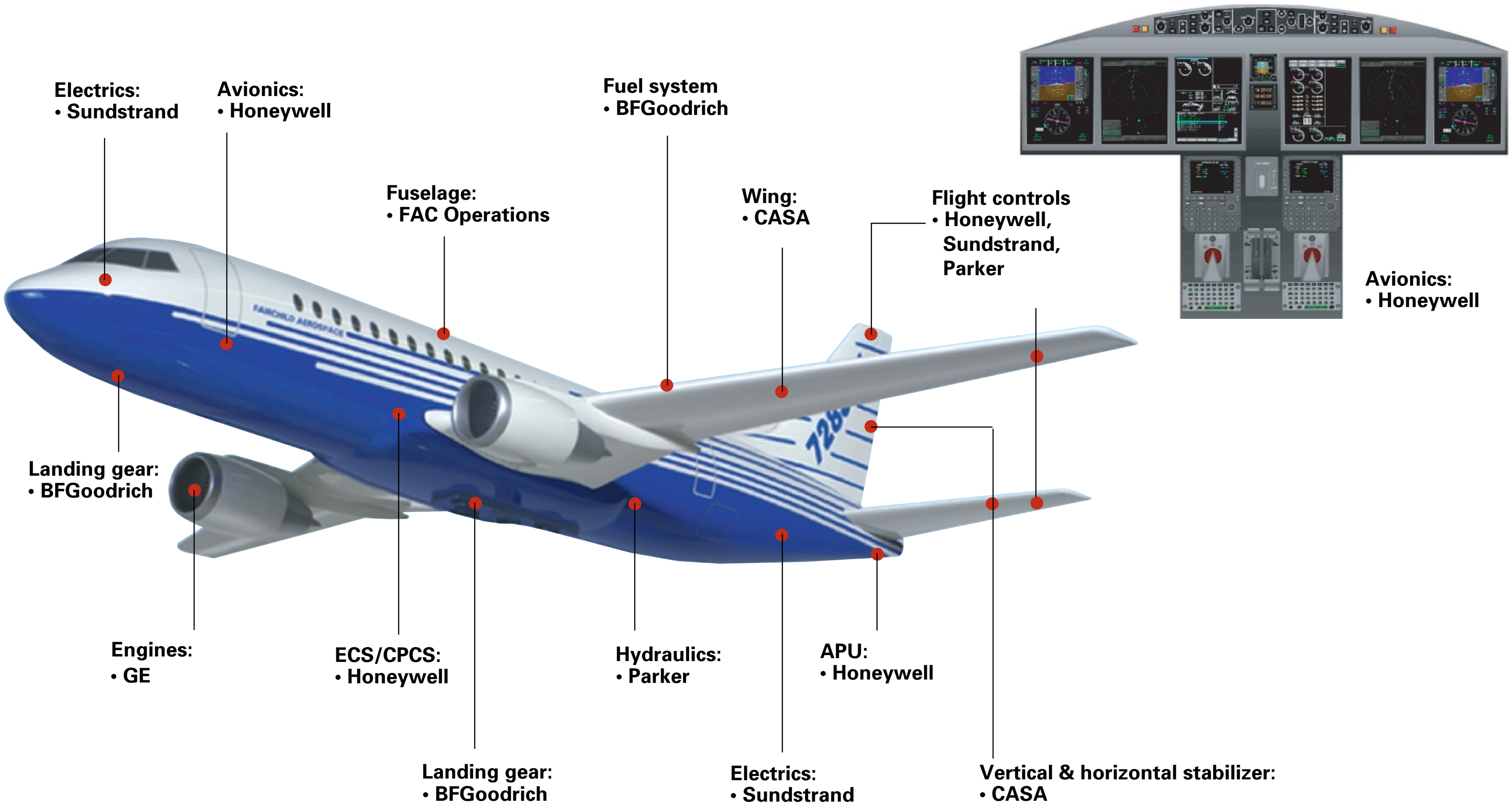
- **Lower noise**
- **Fewer emissions**
- **Less energy consumption**

by being able to use the right-sized aircraft depending on demand



Emissions per pax go down (higher loadfactors)

Selected suppliers for the 728JET components…



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Selected Partners for Systems and Built Units

System / Built Unit	Selected Partner
APU	Honeywell
Avionics	Honeywell
Cabin Mgmt. System	Diehl
Cockpit Controls	AVIAC
Crew Seats	Fischer+Entwicklung
Doors	Eurocopter
ECS	Honeywell
Electrics	Sundstrand
Horz. & Vert. Stabilizer	CASA
Empennage Fairings	Adprotec
Evacuation Slides	Aircruisers
EVM	Vibrometer
Flight Controls	Honeywell/Sundstrand/Parker
Flight Data Recorder	L3
Fire & Smoke	Kidde Deugra, AOA
Fuel	BFGoodrich
Fuel Tubing	Stanley

System / Built Unit	Selected Partner
Fuselage	FAC Operations
Hydraulics	Parker
Hydraulic Tubing	Aeroquip
Ice Warning	BFGoodrich
Insulation	Mexmil
Interior Integrator	Hexcel
Landing Gear/Braking System	BFGoodrich
Leading Edge Anti-Icing	CASA
Lights	Hella
Oxygen	B/E Aerospace
Powerplant	General Electric
Utilities Management	Honeywell
Stowage Area	Driessen
Water/Waste	AOA
Wing	CASA
Wire Harnesses	Sundstrand/Fokker

728JET - A New Family of Regional Aircraft

Future traffic growth in regional transport can be served by bigger aircraft operated in the hub-and-spoke system and by more direct links

The 4 major alliances are having more and more influence on the regional airlines

The fierce competition is down to 3 OEMs

Regional aircraft have to offer comfort and operation like airliners, but at lower cost

Higher aircraft system integration and fly-by-wire flight controls are good examples of technical improvements

Design of operation commonality can produce attractive cost savings in investment and operation of aircraft sized for different capacities