Seminari Interdisciplinari di Cultura Aeronautica

II Serie – I Ciclo – II incontro

9 giugno 2018

ATR. Gli elementi strategici del programma e le evoluzioni che ne hanno consolidato il successo

L' evoluzione nel tempo dei sistemi Propulsivi

SCUOLA POLITECNICA E DELLE SCIENZE DI BASE
DELL'UNIVERSITA' «FEDERICO II»

Mi Presento

Luigi Cascone – Socio Aeropolis

- Laurea in Ingegneria Aeronautica Politecnico di Napoli; in Leonardo dal giugno 1980 al novembre 2012.
- Topics di carriera: Responsabile Avamprogetto Velivoli da Trasporto Civili e Militari AleniaAermacchi Pomigliano D'Arco.
- Programmi: G222 Libia, A320, ATR42/72, R92/122, Anfibio, Supersonico, AirJet Family, C27J, AIA Family, A400M, SSJ100, NTP.
- Programmi di ricerca: VMA, VTA, Cryoplane, Awiator, Hisac, JTI

Introduzione

La filosofia di progetto di un nuovo velivolo ha subito negli anni una radicale trasformazione.

Il mercato richiede macchine sempre più efficienti:

- **Riduzione dei costi di esercizio**
  - Bassi consumi
  - Manutenzione facile ed economica
- **Migliore Impatto ambientale**
- **Maggiore confort per il passeggero**

La propulsione permette di ottener per nuovo prodotto i vantaggi più rilevanti in termini di consumo e impatto ambientale e quindi di costi operativi.

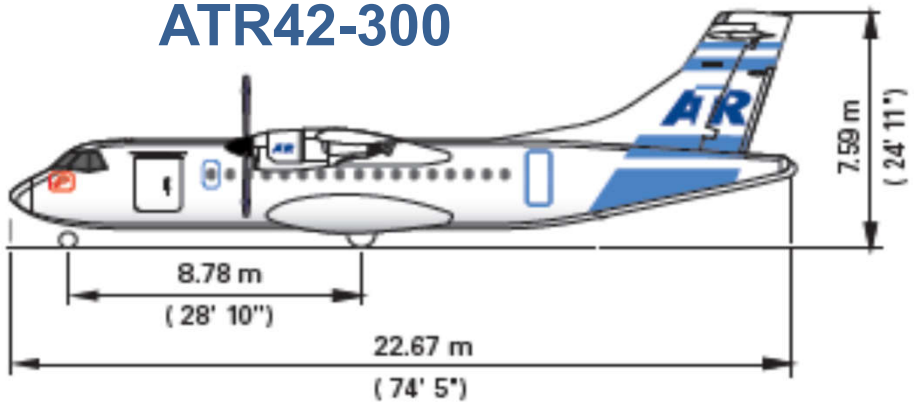
Lancio programma ATR

Aeritalia oggi Leonardo
AIT 230

1981

Aérospatiale oggi EADS
AS 35

ATR42-300



Prima consegna 3 dicembre 1985 ad Air Littoral

Continuous Product Development

1985
ATR 42-300
PW120
4 blades 14SF5

1987
ATR 42-320
PW121
4 blades 14SF5
« Hot & high »

1995
ATR 42-500
New engine – New 6 blades propeller – New interior
Enhanced comfort

1989
ATR 72-200
PW124B
4 blades 14SF11

1992
ATR 72-210
PW127
4 blades 247F - « Hot & high » - Short runway

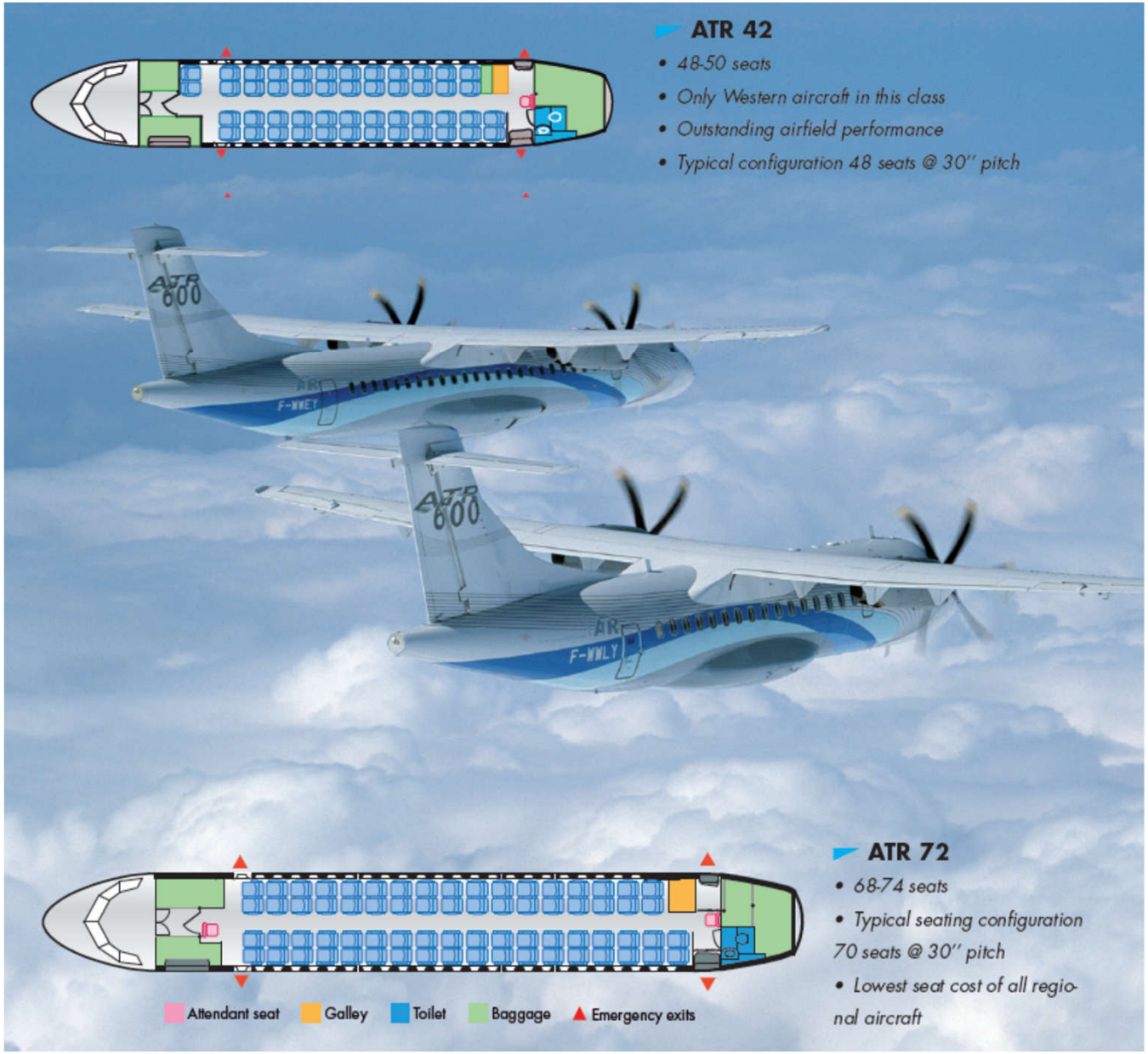
1997
ATR 42-500
New engine – New 6 blades propeller – New interior
Enhanced comfort

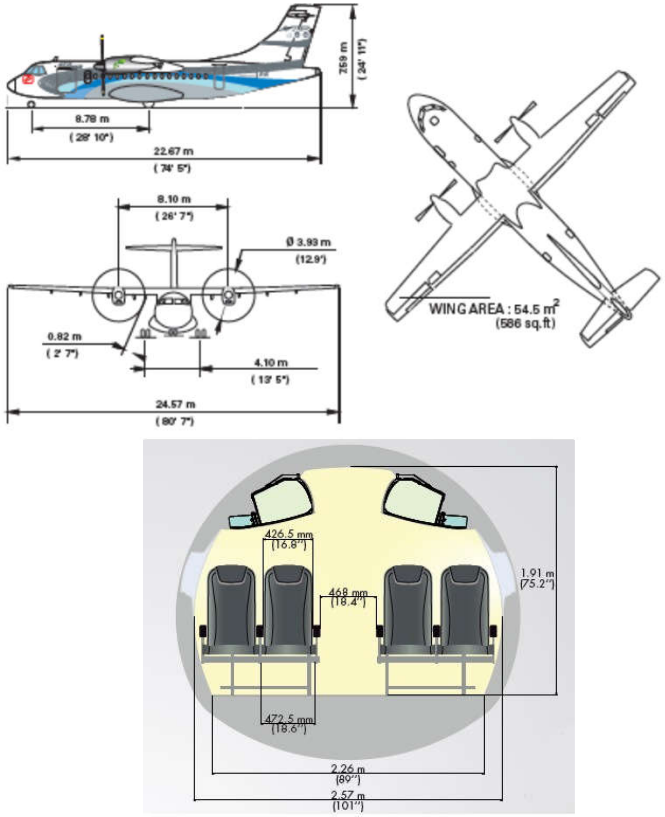
CONTINUOUS IMPROVEMENT

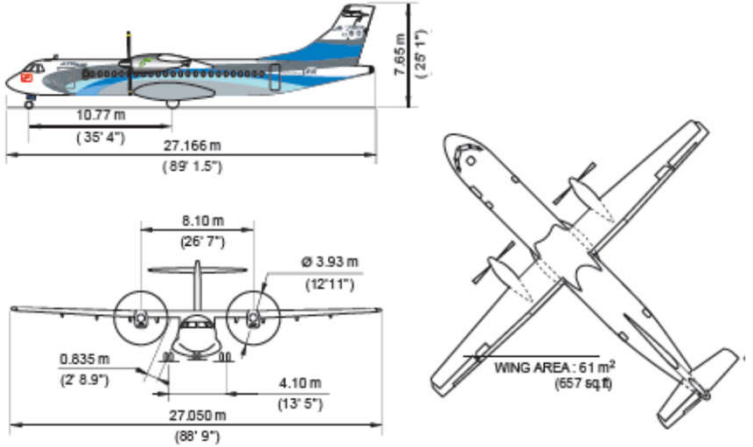
ATR -600 Series

Better Performance, Safety, Flexibility, Passenger Comfort, Commonality
at reduced Operating Costs

ATR600 The Unique Turboprop Family

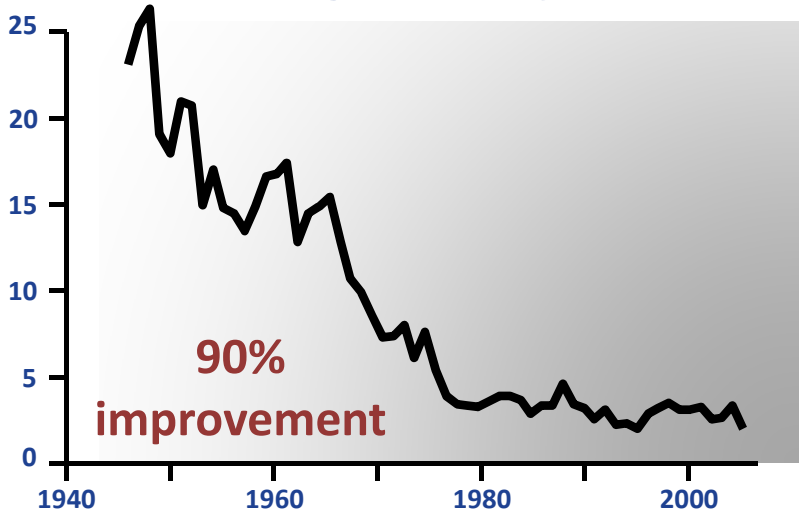




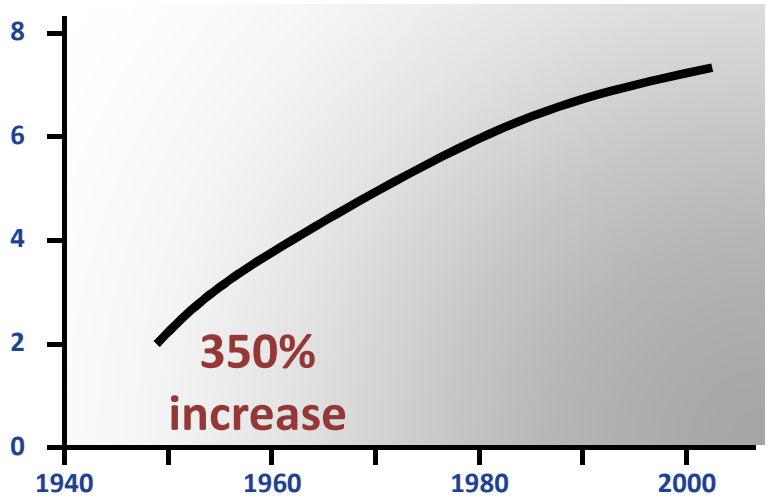


50 years of engine improvements

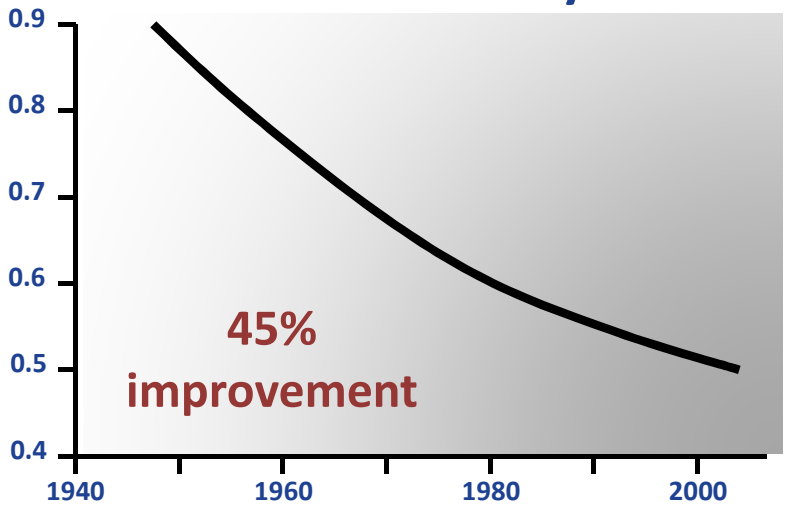
Flight Safety



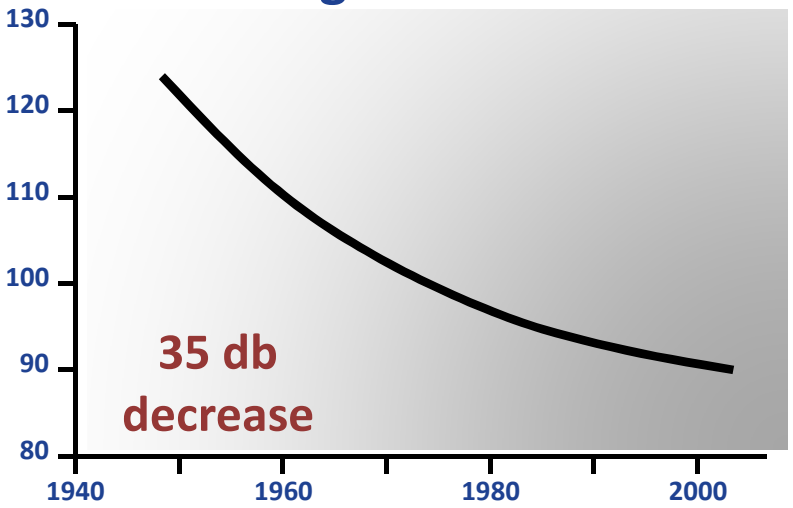
Thrust to Weight



Fuel Efficiency

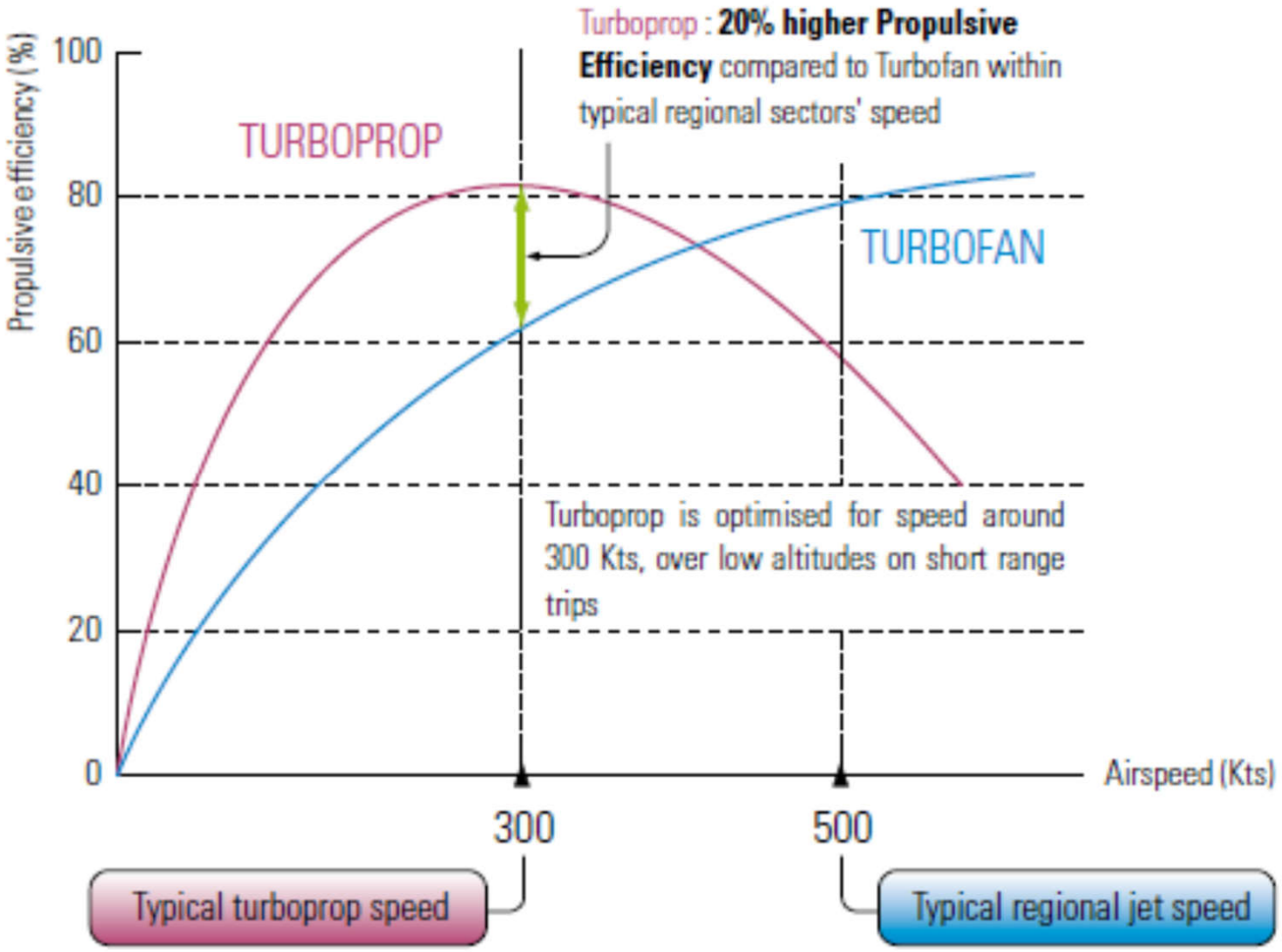


Engine Noise

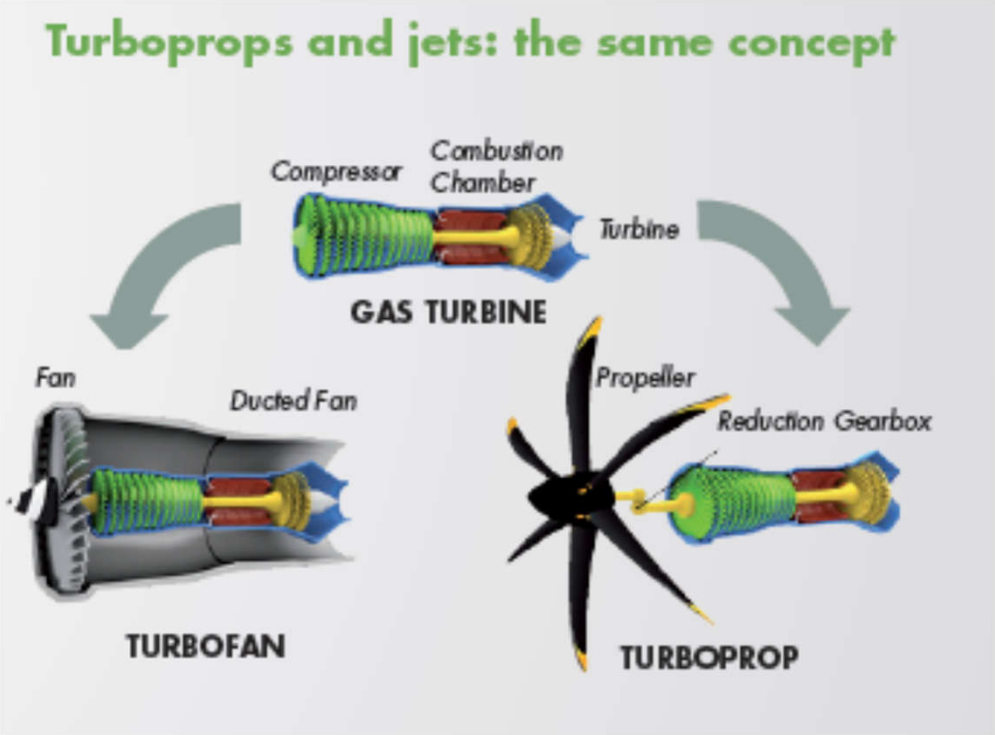


Turboprop Vs Turbofan

Un punto di forza del successo ATR è stata la scelta della motorizzazione.



Turboprop Vs Turbofan



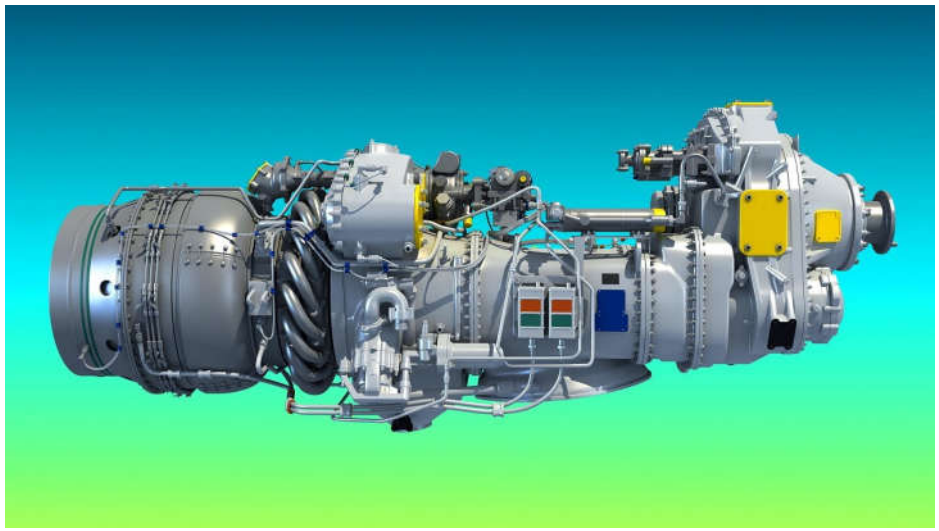
A turboprop is :

- A regular jet aircraft
- With a gas turbine
- And a very large fan (called propeller)
- It burns 40% less fuel than a turbofan
- And costs 1/3 less to operate an short-haul distances

The main lever to optimize fuel efficienty is the powerpalnt. Turboprops and jets use the same engine technonology but turboprops offer the best trade-off between fuel burn and speed

PW100 Series Vs GE CT7

PW100



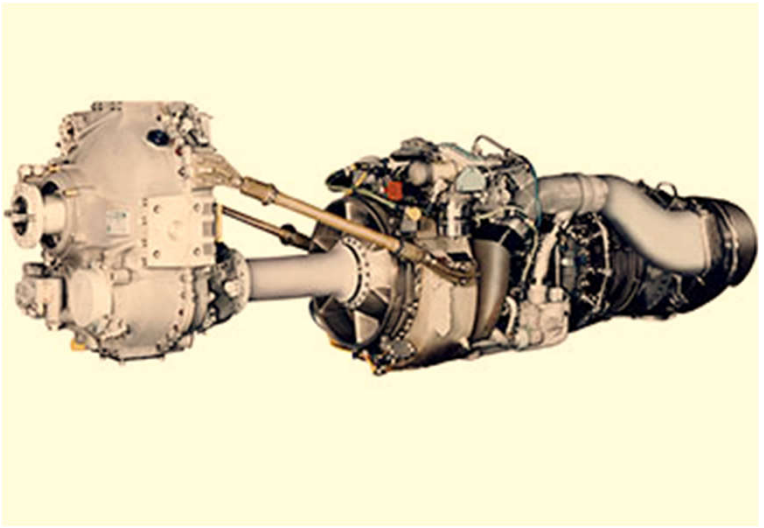
	Thermodynamic Power Class* (ESHP***)	Mechanical Power Class* (SHP)	Propeller Speed (Max. RPM)	Height** (Inches)	Width** (Inches)	Length** (Inches)
PW150 Series	6,200	5,000	1,020	44	30	95
PW127 Series	3,200	2,750	1,200	33	26	84
PW123/124 Series	3,000	2,400	1,200	33	26	84
PW120 Series	2,400	2,100	1,200	31	25	84
PW118 Series	2,180	1,800	1,300	31	25	81

*Powers are approximate values at take-off. Available at sea level, standard day, static conditions, uninstalled.

** Dimensions are approximate values.

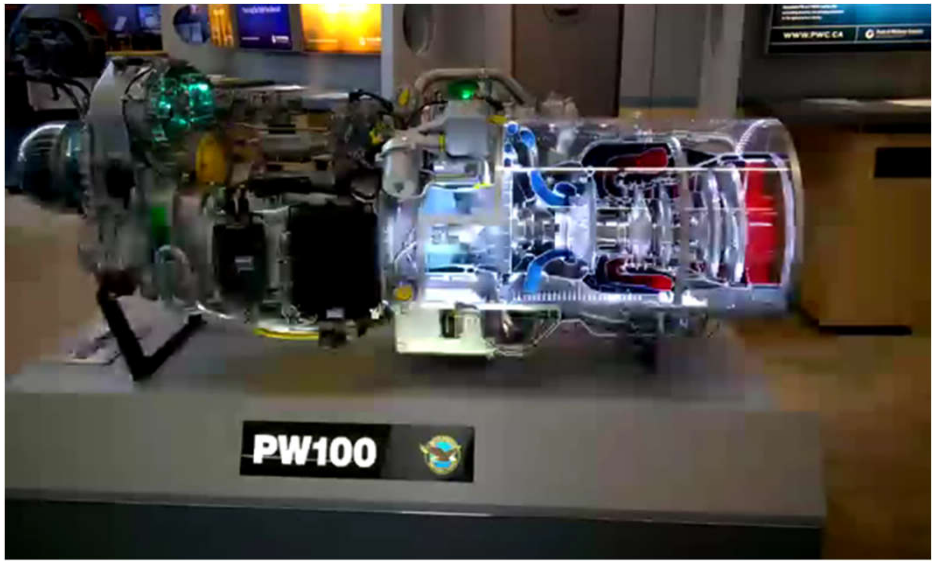
*** Equivalent Shaft Horsepower : includes estimated equivalent contribution of exhaust thrust.

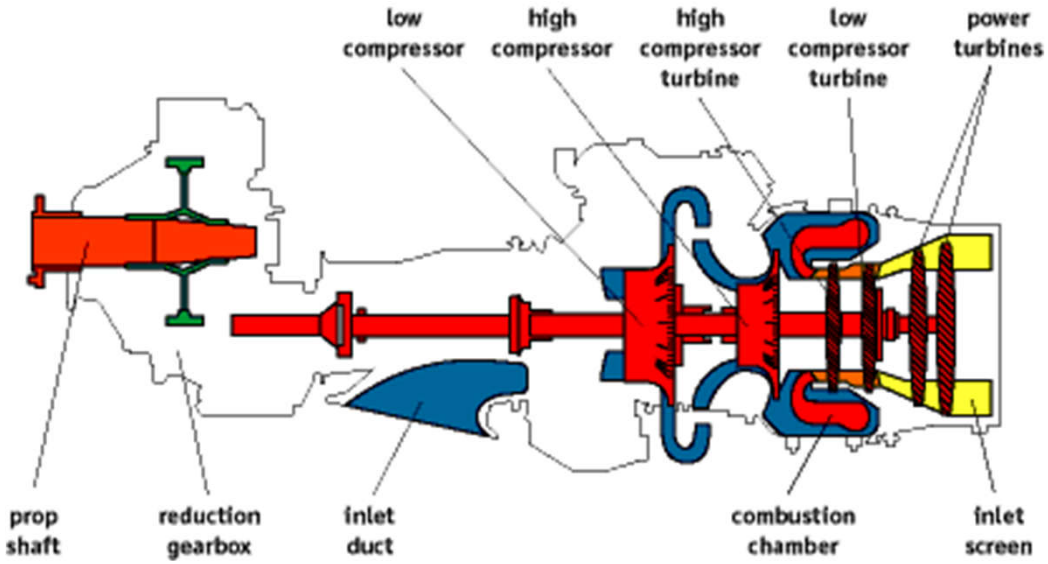
GE CT7



	CT7-2	CT7-6/6A	CT7-8	CT7-9
Physical Information				
Compressor Stages	6	6	6	6
Low Pressure Turbine	2	2	2	2
High Pressure Turbine	2	2	2	2
Nominal Diameter (inches)	15,6	15,6	26	29
Length (inches)	46	47	48,8	96
Power Specifications				
Take off Rating at Sea Level	1625	2000	2634	1870-1950
SFC at Take Off Rating	0,474	0,454	0,452	0,555

Motore scelto per ATR: PW100 Series





Two-spool, two-stage centrifugal compressors

- All rotors integrally bladed
- Each driven independently by low pressure and high pressure compressor turbines
- No variable geometry
- Easy electric start – no APU required

Single-stage low pressure and high pressure turbines

- Advanced materials and cooling technology for long life

Two-stage power turbine

- Free turbine, shrouded blades

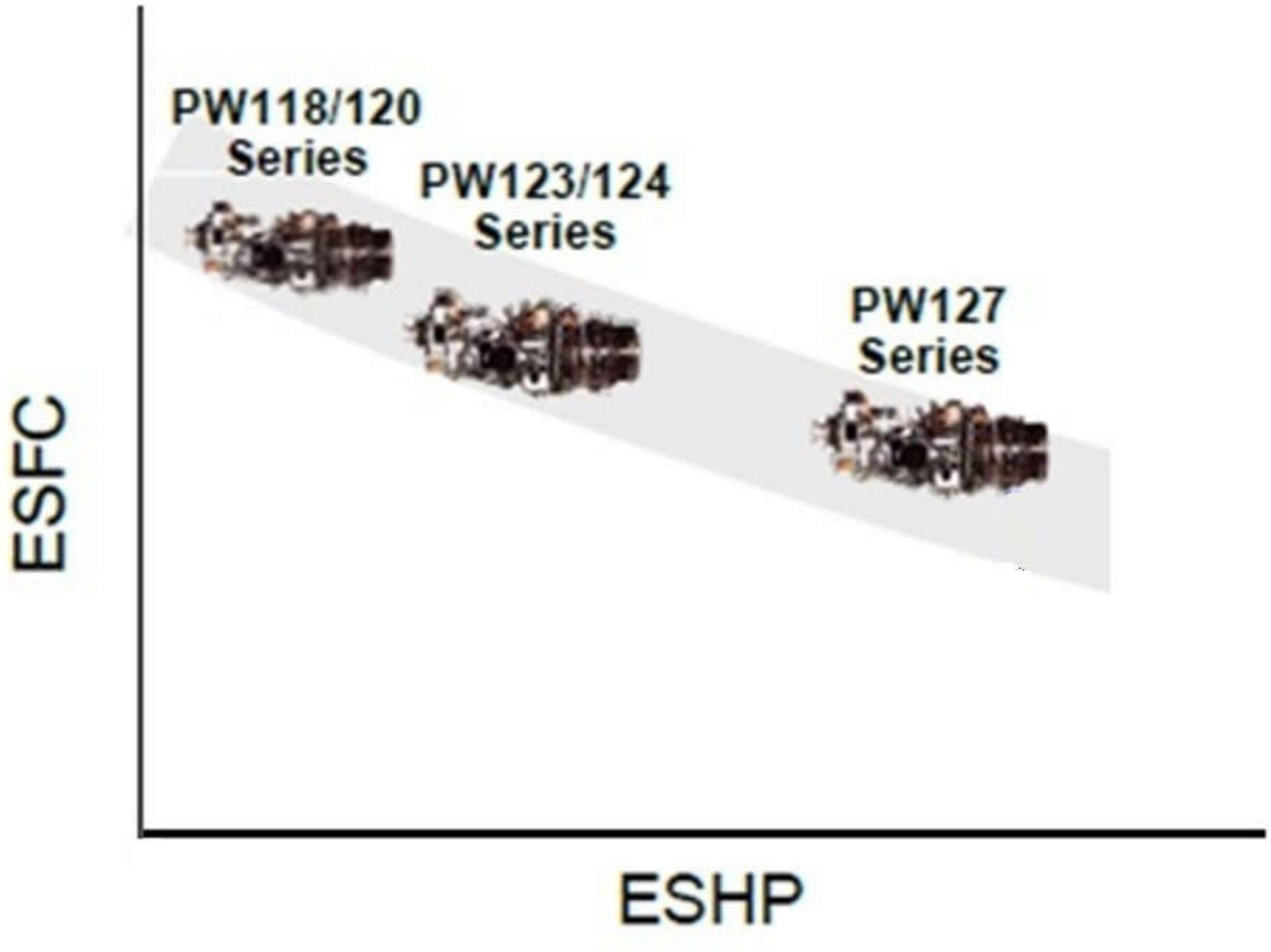
Off-set reduction gearbox

- Rugged design for high durability
- 1,200 to 1,300 rpm output speed for low propeller noise

Electronic engine control

- Ease of operation, reduced workload
- Security of mechanical back-up

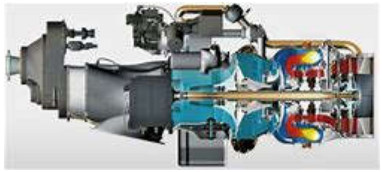
PW100 Series for ATR Family



ATR 42 Power setting

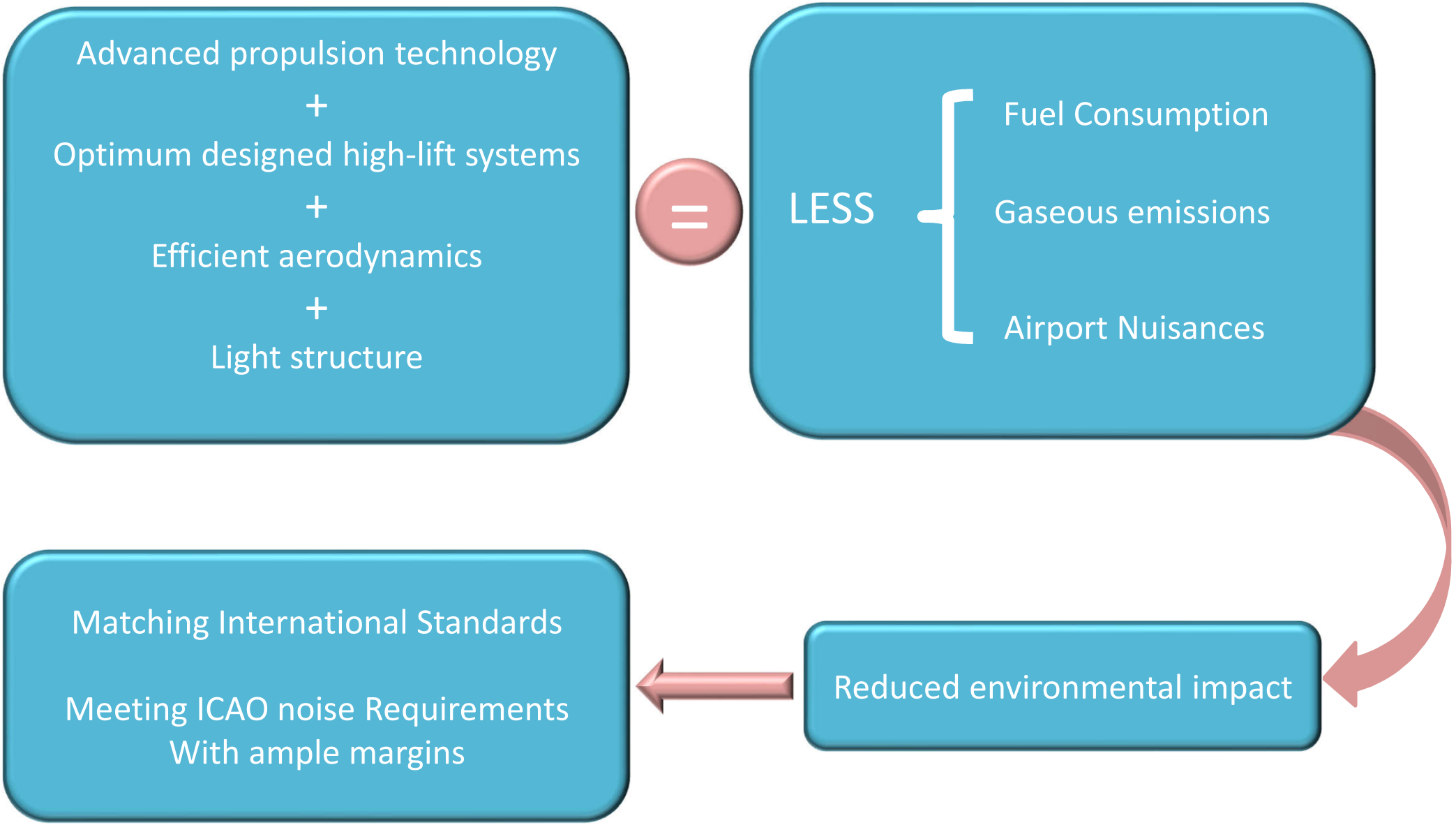
	ATR42-300	ATR42-320	ATR42-500	ATR42-600
Engines Pratt & Whitney Canada	PW120	PW121	PW127E/M	PW127M
Take-off power	1800 SHP	1900 SHP	2160 SHP	2160 SHP
Take-off power - One engine	2000 SHP	2100 SHP	2400 SHP	2400 SHP
Max continuous	1700 SHP	1900 SHP	2400 SHP	2400 SHP
Max climb	1700 SHP	1700 SHP	2160 SHP	2160 SHP
Max cruise	1619 SHP	1700 SHP	2132 SHP	2132 SHP
Propellers Hamilton Standard	14 SF-5	14 SF-5	568F	568F
Blades/Diameter	4/3.96 m - 13 ft	4/3.96 m - 13 ft	6/3,93m-12,9 ft	6/3,93m-12,9 ft
Weights				
Max take-off weight (basic)	16700 kg	16700 kg	18300 kg	18300 kg
Max take-off weight (option)	16900 kg	16900 kg	18600 kg	18600 kg
Max landing weight (basic)	16400 kg	16400 kg	16700 kg	16700 kg

ATR 72 Power setting



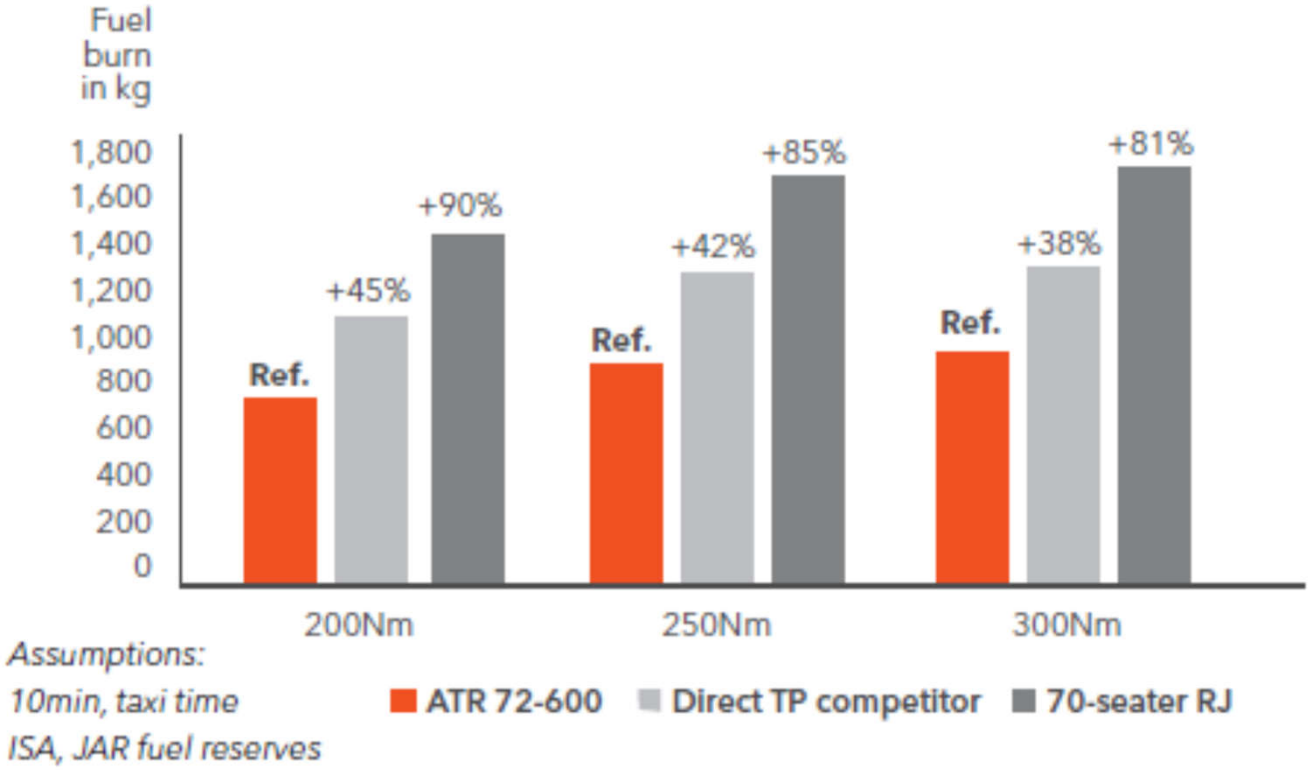
	ATR72-200	ATR72-210	ATR72-500	ATR72-600
Engines Pratt & Whitney Canada	PW124B	PW127	PW127F/M	PW127M
Take-off power	2160 SHP	2475 SHP	2475 SHP	2475 SHP
Take-off power - One engine	2400 SHP	2750 SHP	2750 SHP	2750 SHP
Max continuous	2400 SHP	2500 SHP	2500 SHP	2500 SHP
Max climb	2088 SHP	2192 SHP	2192 SHP	2192 SHP
Max cruise	2088 SHP	2132 SHP	2132 SHP	2132 SHP
Propellers Hamilton Standard	14 SF-11	247F-1	568F	568F
Blades/Diameter	4/3.96 m - 13 ft	4/3.96 m - 13 ft	6/3,93m-12,9 ft	6/3,93m-12,9 ft
Weights				
Max take-off weight (basic)	21500 kg	21500 kg	22000 kg	22800 kg
Max take-off weight (option)	22000 kg	22000 kg	22500 kg	23000 kg
Max landing weight (basic)	21350 kg	21350 kg	21350 kg	22350 kg

Continuous Product Development



Block Fuel Comparison

BEST IN CLASS FOR…. FUEL CONSUMPTION AND EFFICIENCY



Thanks to lighter structure, optimized speed and an engine designed for short sectors, the ATR72-600 is, by far, more fuel efficient than any other 70-seater aircraft.

In addition to the lower fuel bill, the fuel efficiency of ATR makes the aircraft the green turboprop of tomorrow and the most environment friendly aircraft of this category.

Fuel Economy

ATR IS THE NATURAL HEDGE AGAINST HIGH FUEL PRICES

250Nm stage length
10 min. taxi time

ATR 72-600

Direct TP Competitor

FUEL ECONOMY PER TRIP: 320 KG ➔ 42%

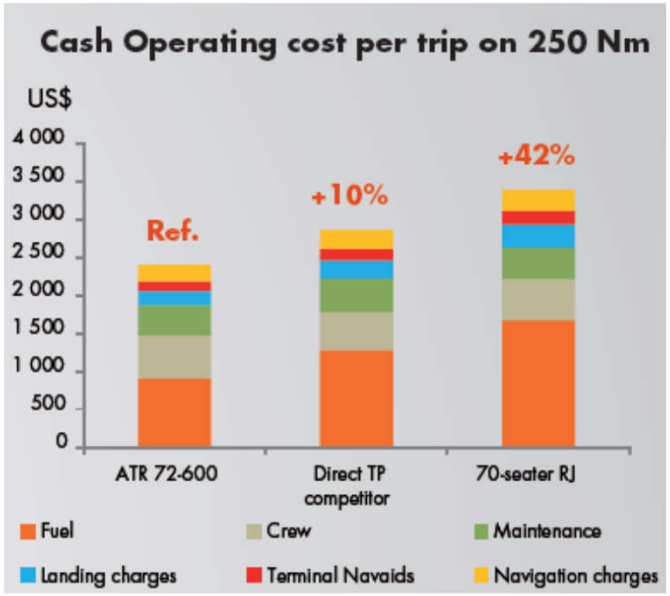
Competitor extra fuel bill per aircraft dramatically increases with fuel price.

Fuel Price	Direct TP competitor Extra US$/trip	Direct TP competitor Extra US$/year
3$/Gal	323	646,198
3,5$/Gal	**377**	**753,898**
4$/Gal	431	861,597

DIRECT TP COMPETITOR ANNUAL EXTRA FUEL COST > US$ 750,000 PER AIRCRAFT

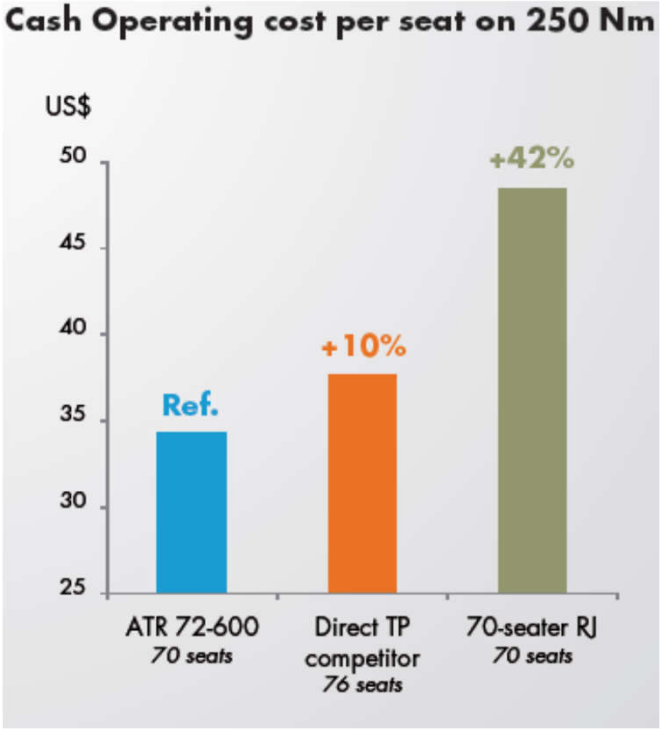
Based on a yearly utilisation of 2,000 flights per year

Operating cost Comparison



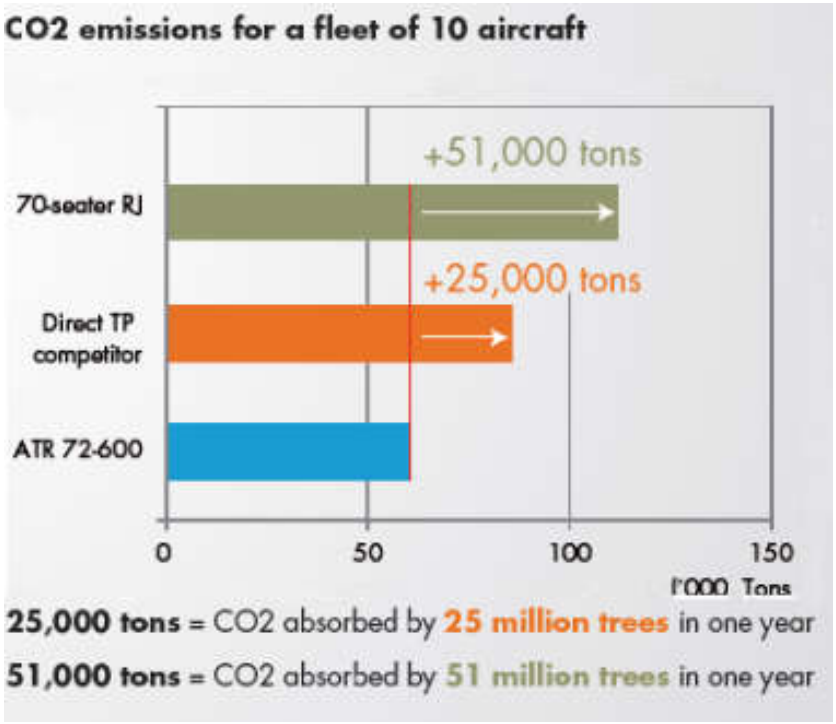
ATR aircraft, especially the ATR72-600, feature exceptionally low operating costs compared to competitors on typical regional sectors

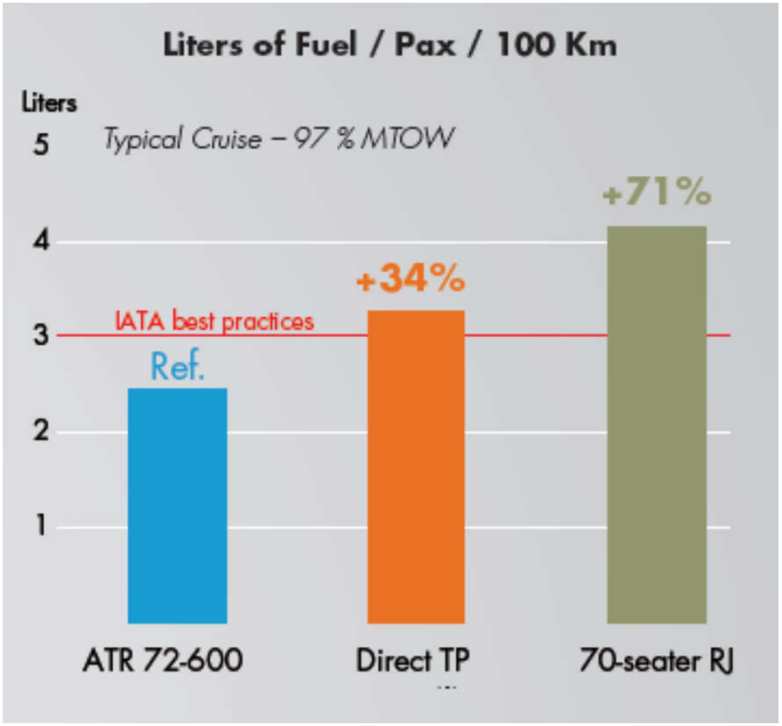
- Lower engine and airframe maintenance costs, simpler systems, better reliability, better accessibility, less expensive to maintain engine components.
- Significantly lower airport and en-route charges, linked to MTOW.
- Exceptionally lower fuel costs.
- Speed adapted to efficient, low cost regional operations.

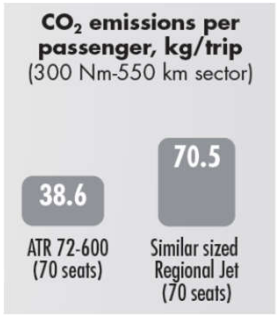


Emissions Comparison

ATR Yearly CO_2 Saving





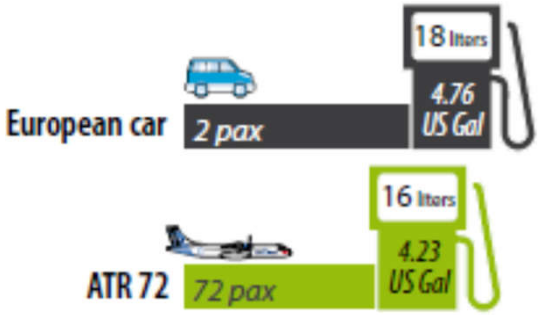


The ATR 72 is the only aircraft with a fuel consumption **lower than 3 liters per pax per 100 km** and already compliant con IATA best practices

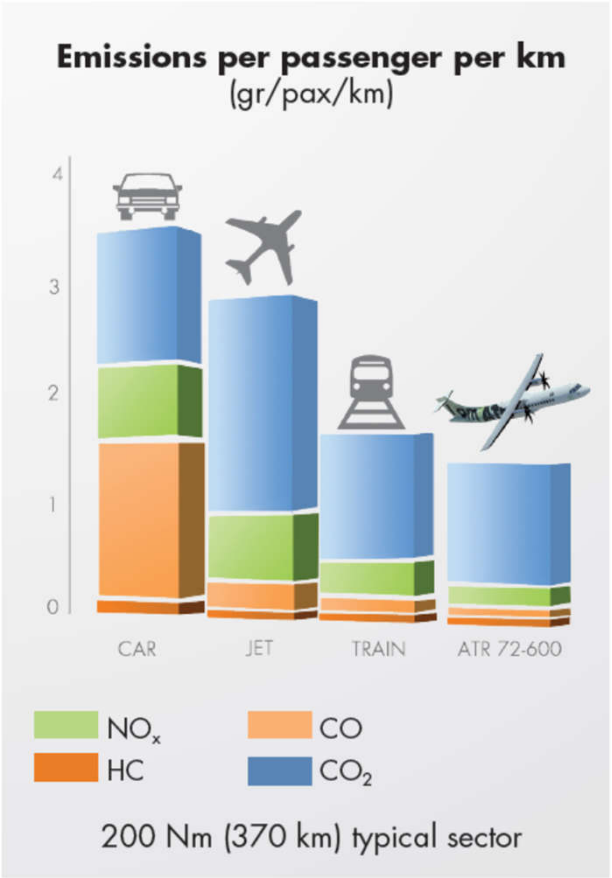
The ATR fuel consumption advantage directly implies lower cost, lower emissions and makes it the optimal aircraft to develop the regional market

Comparing with other transport modes

ATR is significantly cleaner and contributes to sustainable air transport development

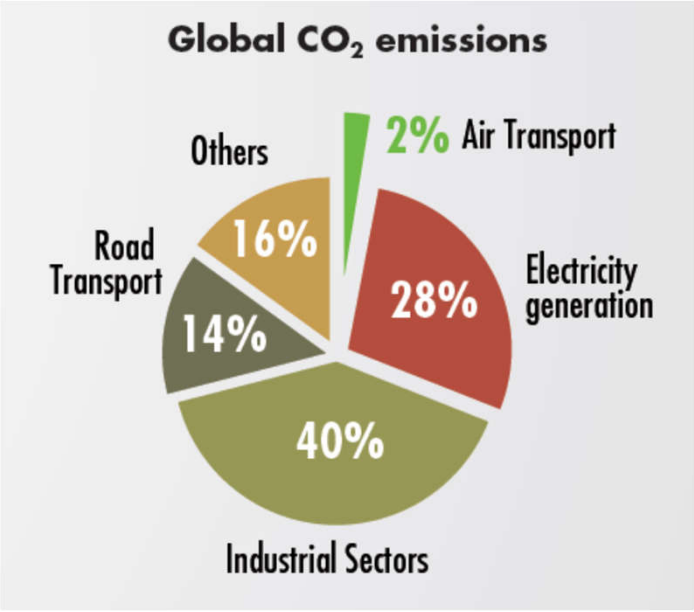


On a 200 Nm sector, the ATR 72-600 fuel consumption per passenger is up to 11% lower than a typical European car.



Gaseous Emission Spectrum

- ATR gaseous emissions per pax in terms of CO (Carbon monoxide) are 15 times less than car and comparable to the train.
- As far as the Nitrous Oxides are concerned, the ATR is 3 times less pollutant than a car and 40% less than train.



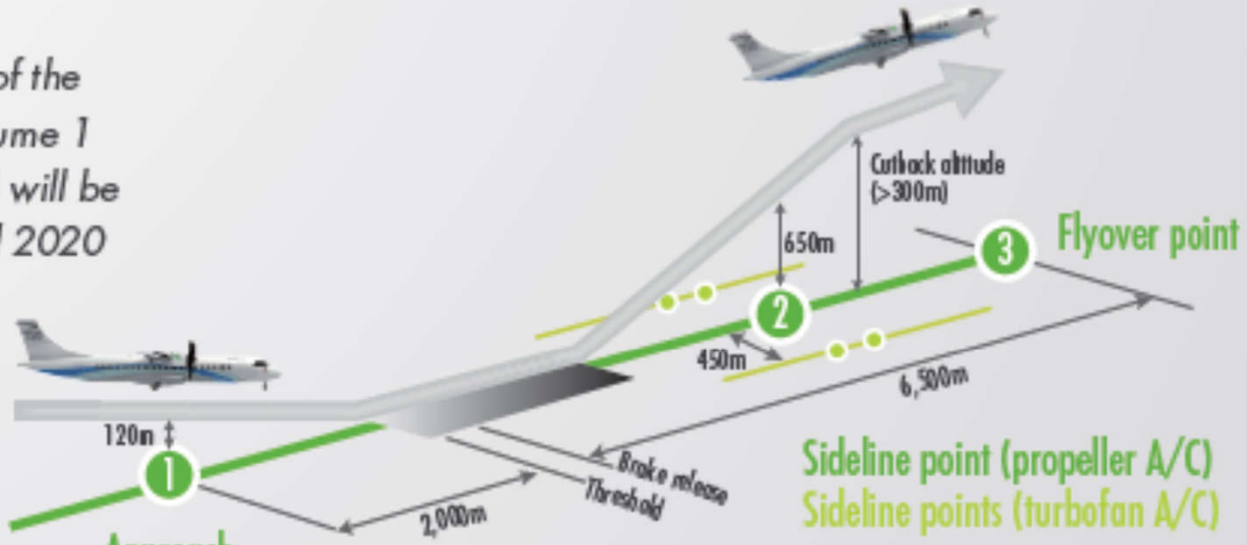
External Noise

- ATR aircraft have a very low noise level thanks to six-blades propeller design with a highly accurate electronic controller to synchronise the phasing between propellers.
- The ATR72-600's noise levels are significantly lower than the future regulatory requirements.

In 2013, a new actualization of the noise standards Annex 16 Volume 1 was adopted. This Chapter 14 will be applicable between 2018 and 2020 for new designed aircraft.

The Chapter 14 sets:

- *noise limits for each of the three reference point*
- *a limit on the sum of the 3 points levels, which shall not be less than 17 EPNdB.*



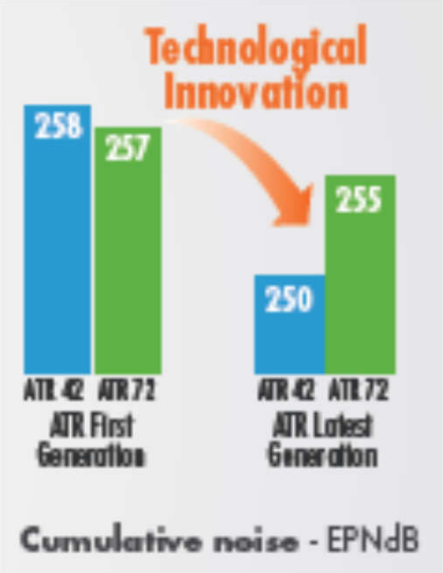
Noise Measurement

3 reference points: sideline (take-off), flyover and approach

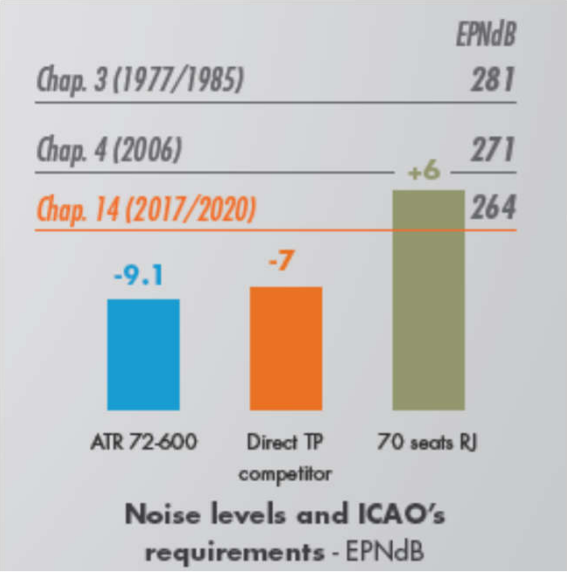
External Noise Comparison

Turboprops: good neighbours

In addition, ATR show a significantly reduced cumulative noise impact compared to regional competitors and benefit from highest margin, anticipating thus future stricter regulations.



As consequence, all ATR aircraft are welcome to operated all over the world even in countries where local regulations go beyond international legislation. All ATR aircraft comply the strict policy of the Bromma Stockholm Airport

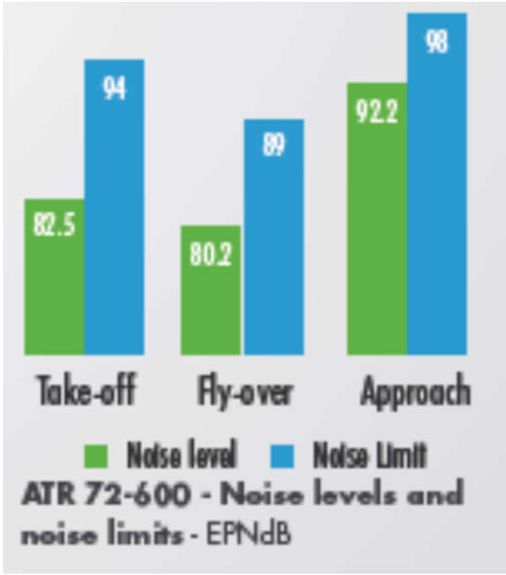


ATR 72-600

Chapter 3 Cumulative Margins: 26.1 EPNdB

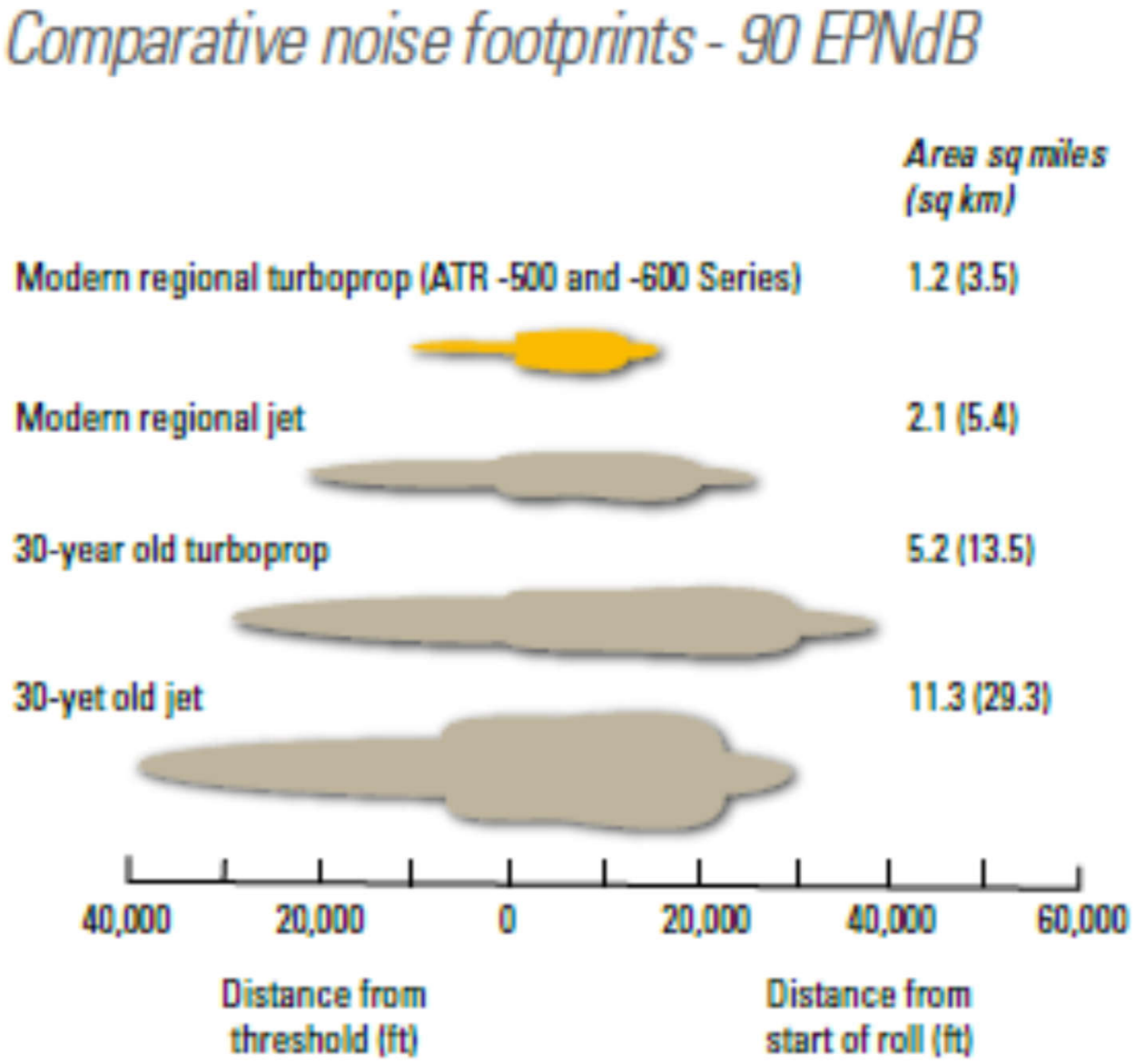
Chapter 4 Cumulative Margins: 16.1 EPNdB

Chapter 14 Cumulative Margins: 9 EPNdB



Noise Footprints Comparison

ATR-500/-600 Series is one of the quietest turboprop



ATR: Welcome visitors at the smaller city airports and regional hubs with minimum environmental impact

Internal Noise

ATR 600 offers comfort unmatched in its class and internal noise levels comparable to Regional Jets

ATR72 500 & 600 have incorporate many innovative interior noise control features in order to reduce the noise inside the aircraft and provide a very comfortable environment for the passengers. The following major noise treatments had applied :

- **A 6 blades propeller properly designed for low noise and having low RPM.**
- **A new blade sinchrophaser system assuring a very stable noise pattern in the cabin.**
- **Improved Tuned Dynamic Vibration Absorbers installed on frames and floor beams to damp the low frequency vibrations**
- **Damping treatments on the cabin skin to reduce noise coming from aerodynamic boundary layer excitation**
- **Mufflers installed on the ECS distribution to reduce noise transmitted in the cockpit and in the cabin mainly with high ECS performance conditions.**
- **Other local optimization were done to treat specific improvements**

Further Enhanced performance

BEST IN CLASS FOR…PERFORMANCE

UNRIVALLED VERSATILITY

By design, ATR aircraft has **excellent airfield capabilities**, allowing to operate at wide range of airports.

On The 600 Series, ATR has enhanced its family with powerful Pratt&Whitney 127M engines, which further improve the performance at challenging airfields in hot and high environments. Through two different options active by the pilot, the engine offers extra power on request.

From short runways, pilots can choose the reserve take-off torque (RTO) produce to increase the mechanical power in order to improve payload, reduce the take off distance and avoid close-in obstacles. Out of hot and high airports, such as Bogota airport in Colombia, pilots can choose to increase thermodynamic power of the engine and carryout more payload.

In addition to the airfield performance benefits, the Pratt&Whitney 127 engine has also improved net ceiling by up to 1000 ft on ATR 72-600 which further extends capability to fly in mountainous areas.

600 SERIES DISPATCH REALIABILITY: 99,7%

The ATR-600 Series aircraft feature an excellent dispatch reliability following a long in-service experience with 27 million flight track record

ATR Unrivalled performance & Versatility

- Temperature or altitude extremes from to Equator to the Artic Circle are part of routine flying environment for ATR aircraft.
- Operated today in all types of climate and conditions, ATR operational Flexibility and versatility are recognized worldwide by regional operators.

- Structural efficiency, together with an advanced aerodynamic design and state-of- the-art Pratt&Whitney Canada PW100 series engines, keep fuel burn to minimum.
- ATR's objective is to expand operational versatility even further by providing airlines with capability tailored suit regional operation and boost revenue.

Continuous Product Development

PROVIDING EXACTALY WHAT THE CUSTUMER NEEDS IN A FAST EVOLVING MARKET

Example of current Performance Characteristics:

- **Short runway** (less than 1000m)
- **6° steep slope** approach (ATR approved for operations in LCY)
- **Unpaved Runways** certification (laterite, soil, gravel, grass)
- **Narrow Runways** operations , down to 14 m width
- **4,5% runway max slope** allowed
- **120 min ETOPS**

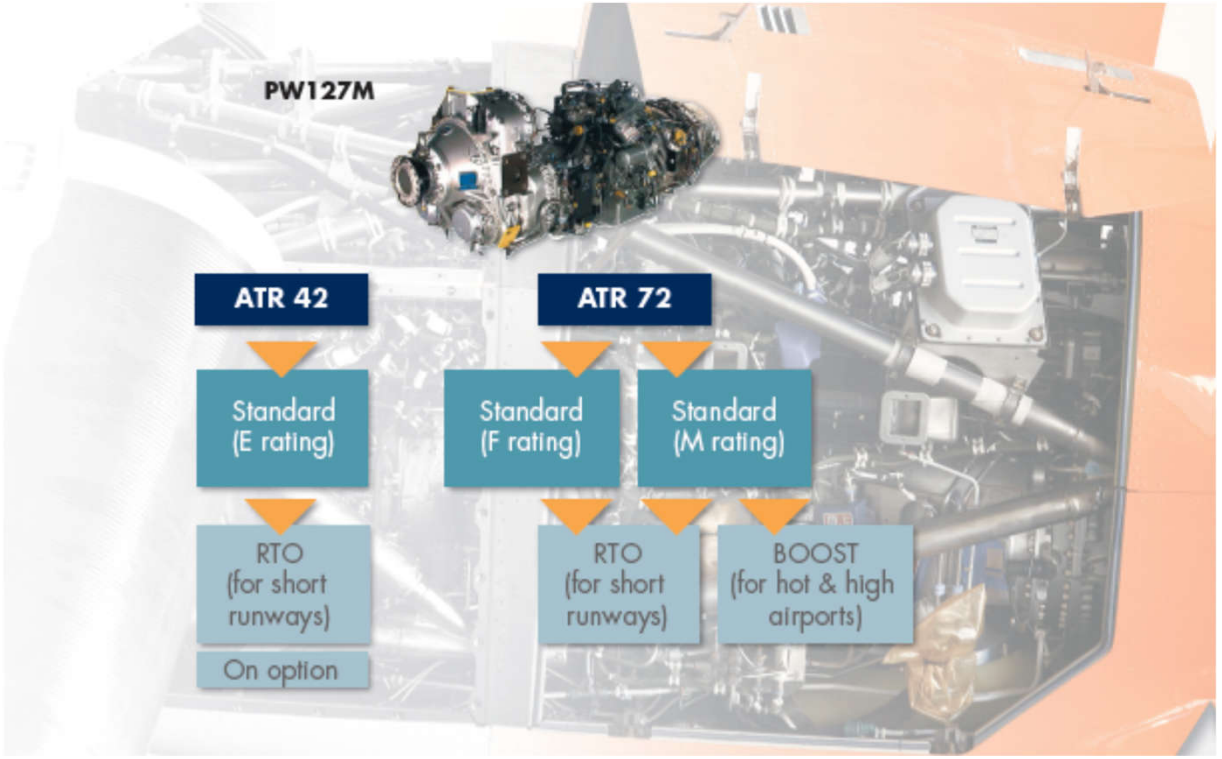
New Features

- New Design Weights
- Improved Short Runway Performance
- Performance Enhanced from 'hot &High' Airfields

A Single Multi-Rated Engine Power

A common engine for ATR42 & ATR72 leading to significant maintenance saving and operational flexibility

- A unique engine PW127 for 3 power settings: E, F and M
- Smart Card to account for cycles relevant to each model rating.
- Higher rating on request only for better control of maintenance cost



Engine rating selected through airframe identification system (EECR Electronic Engine Control Rating). Through the 'Flex Operation' concept, two levels of power are available for ATR72, allowing either PW127F ratings for standard operations or PW127M for 'Hot &High' operations

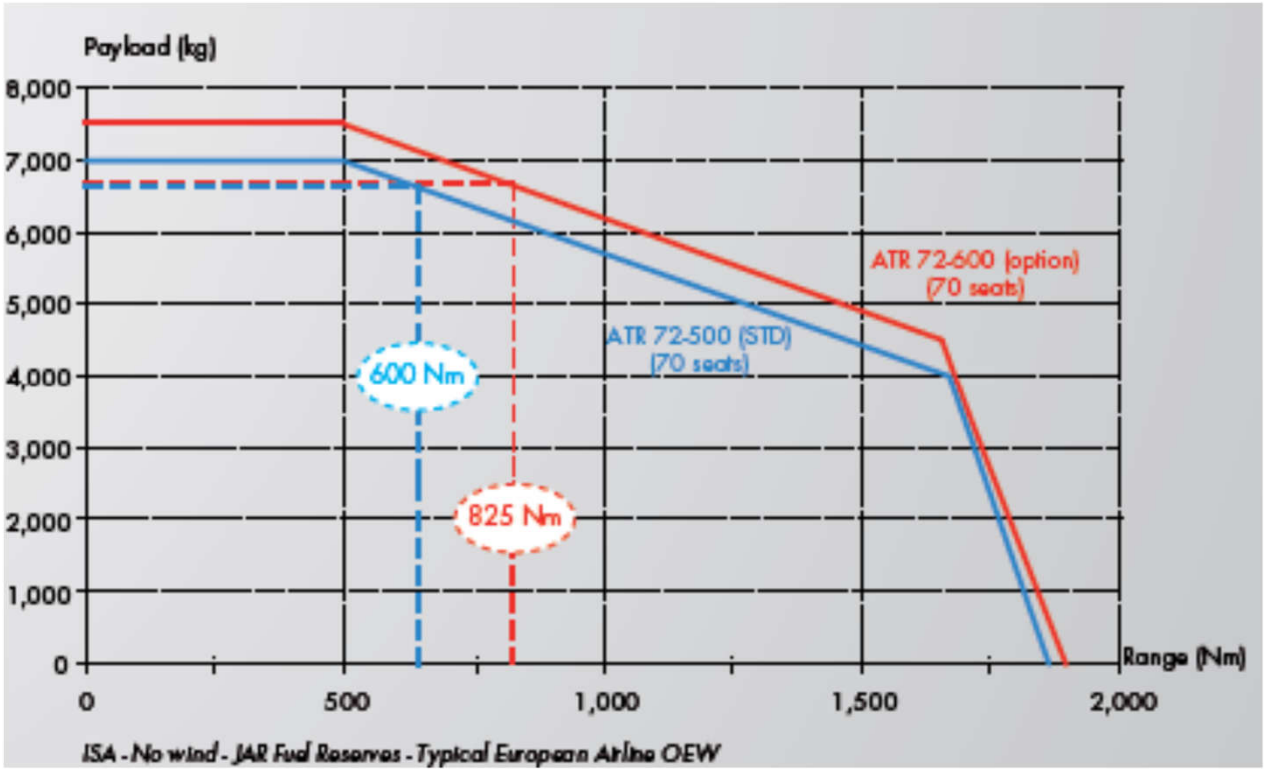
New Design Weights

	ATR 72-500	ATR 72-600	
	STANDARD	STANDARD	OPTIONAL
MTOW	22,500 kg 49,604 lb	22,800 kg 50,265 lb	23,000 kg 50,706 lb
MLW	22,350 kg 49,272 lb	22,350 kg 49,272 lb	22,350 kg 49,272 lb
MZFW	20,500 kg 45,195 lb	20,800 kg 45,855 lb	21,000 kg 46,296 lb
MAX PAYLOAD	7,000 kg 15,432 lb	7,300 kg 16,093 lb	7,500 kg 16,534 lb

INCREASED ATR 72-600 OPERATIONAL WEIHTS

Following a strong market demand, ATR2 72-600 offers increased payload, making the aircraft more attractive.
This results in:

- **Up to 500 kg** higher payload for the same range.
- **Up to 225 Nm** extended range at same payload.



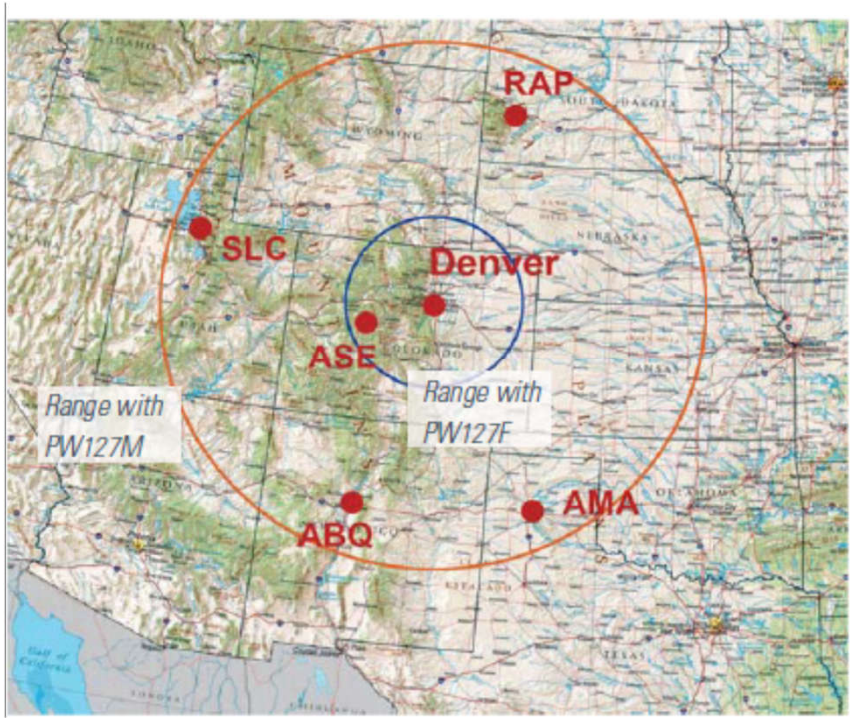
Performance Enhancement ‘Hot and High’ Conditions

Within the scope of providing even better performance and additional payload for the most demanding networks (hot & high airports, mountainous environment), ATR is offering a more powerful engine: the PW127M.

The PW127M delivers 5% higher thermodynamic power at Take Off and Max Continuous ratings.

Owing to new ratings, performance is improved in term of:

- **Take-off weight between 500 kg and 600 kg when limitation exist.**
- **Single-Engine Net ceiling increased about 1000 ft**.



TAKE-OFF FROM DENVER

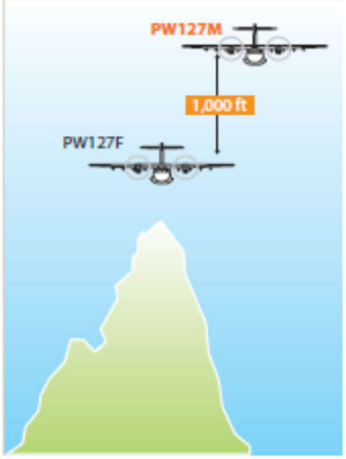
Altitude: 5,333 ft
OAT: 77°F (25°C)
64 pax @ 220 lb (100 kg)
OEW : 29,650 lb (13,450 kg)

130 Nm (240 km) range (PW127F)

355 Nm (658 km) range (PW 127M)

IMPROVED MAX CONTINUOUS RATING WITH PW127M

+ 1,000 ft Single-Engine Net Ceiling



Enhanced Performance on Short Runways

ATR has developed the take-off at 'Reserve Take-off Torque' option to improve take- off capabilities on very short runways or in case of near obstacles.

With this option, the ATR 72-600 can operate profitably from very short runways in different weather conditions, greatly improving TOW and payload.

	ATR 72-500 (standard)	ATR 72-600 with Reserve Take-off torque Option
950 m - dry runway, sea level - 30 °C conditions	Ref.	+640 kg - *1,415 lb*
1,000 m - wet runway - sea level - ISA conditions	Ref.	+480 kg - *1,065 lb*
1,200 m - 1,000 ft elevation - atmospheric icing conditions - 0 °C	Ref.	+600 kg - *1,320 lb*

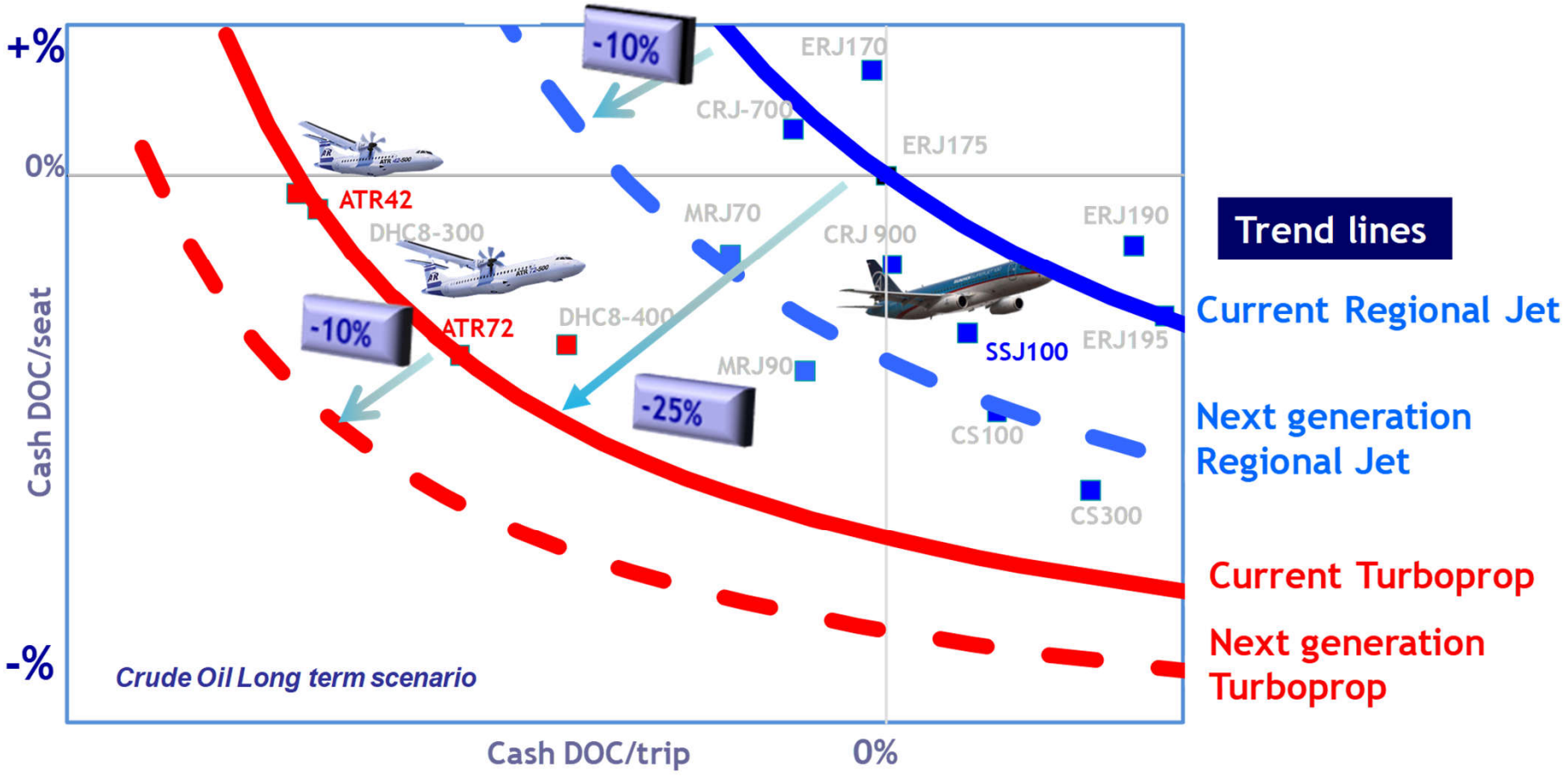
Profitable operation from London City Airport

With this procedure, the ATR 72-600 can carry up to 70 passengers on 300Nm sector.

ATR 72 aircraft have 6° steep slope approach capability, allowing operations at airports with difficult access

Next Generation Regional Turboprop

Casch DOC Comparison 300 NM Stage Length



Per mantenere la competitività attuale, i costi operativi dei futuri velivoli turboprop dovranno diminuire soprattutto attraverso l'introduzione di motori più efficienti a e minor peso per posto (OEW/seat), con maggiore velocità.

Next Generation Regional Turboprop

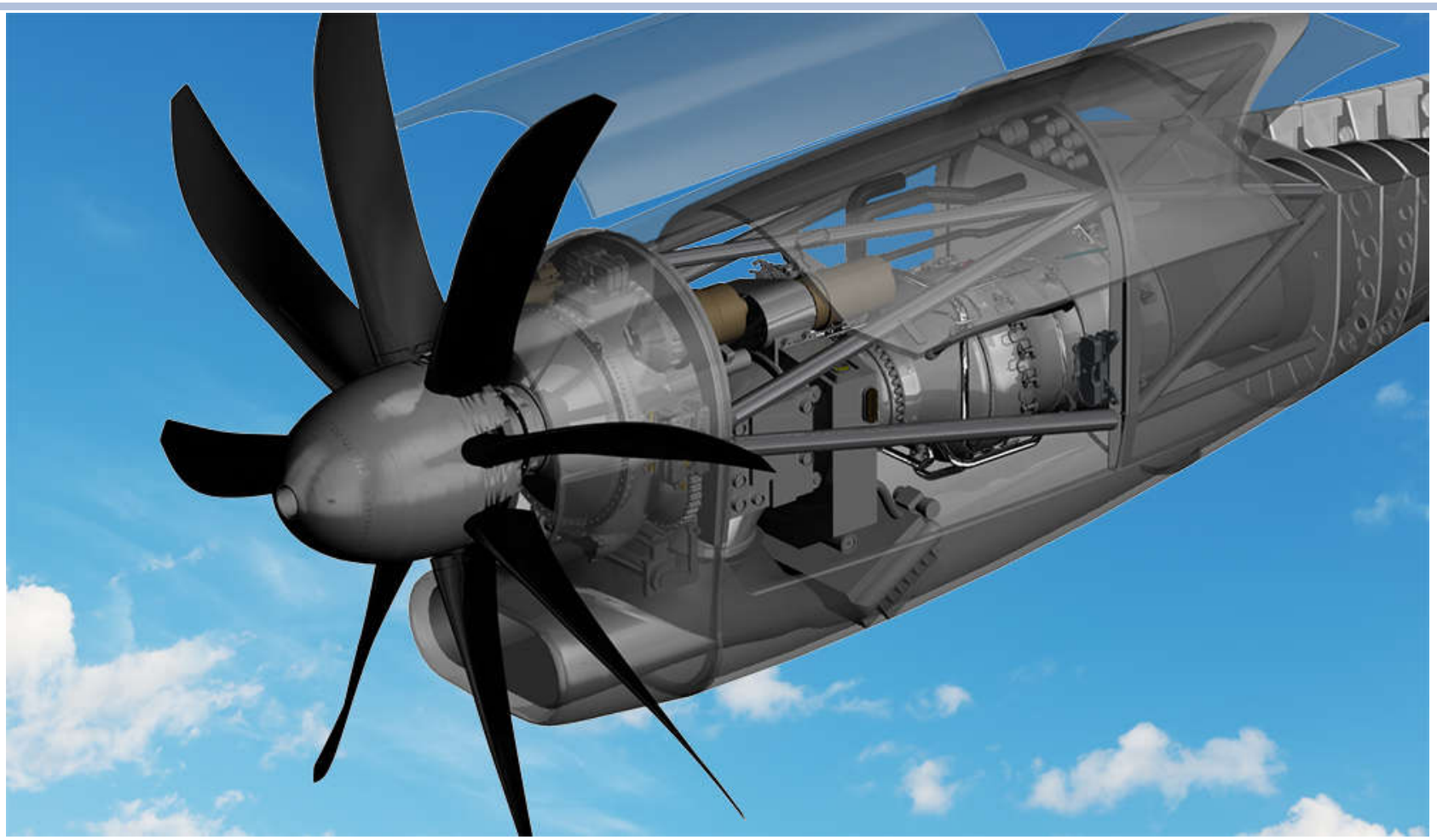
Ottenere un nuovo prodotto che soddisfi i requisiti, sempre più stringenti, del mercato e conseguire un successo come quello ottenuto dall'ATR è una sfida .

- **Motore: Next Generation Turboprop (-20%SFC;-30% Peso/Potenza rispetto all'attuale P&W 127) o Motore Ibrido**
- **Aerodinamica con alta efficienza e basso rumore**
- **Comfort in cabina, bassi rumore e vibrazioni, carrello e flap low noise, nuove tecnologie per interiors**
- **Ala ed impennaggi in carbon fiber di nuova generazione a basso costo di produzione**

Next Generation Regional Turboprop

- Avionica di nuova generazione : Navigazione satellitare per futuro ATM: FMS per 4D trajectories con riduzione dei consumi e del rumore
- Comandi FBW, leggi di controllo per load control
- Uso di equipaggiamenti more electric
- Health Management system

NGRT: Turboprop Engine



P&WC's NGRT is a totally new centerline engine that will deliver more than 20% improvement in fuel efficiency over today's fleet – and a double-digit reduction in maintenance costs. **The NGRT is highly scalable**, allowing P&WC to create a new family of engines to cover the 4,500 shp to 8,000 shp envelope, making it ideal for the 90-seat aircraft range – a segment poised for strong demand over the next decade and beyond.

NGRT: Turboprop Engine

June 5, 2018

AirInsight

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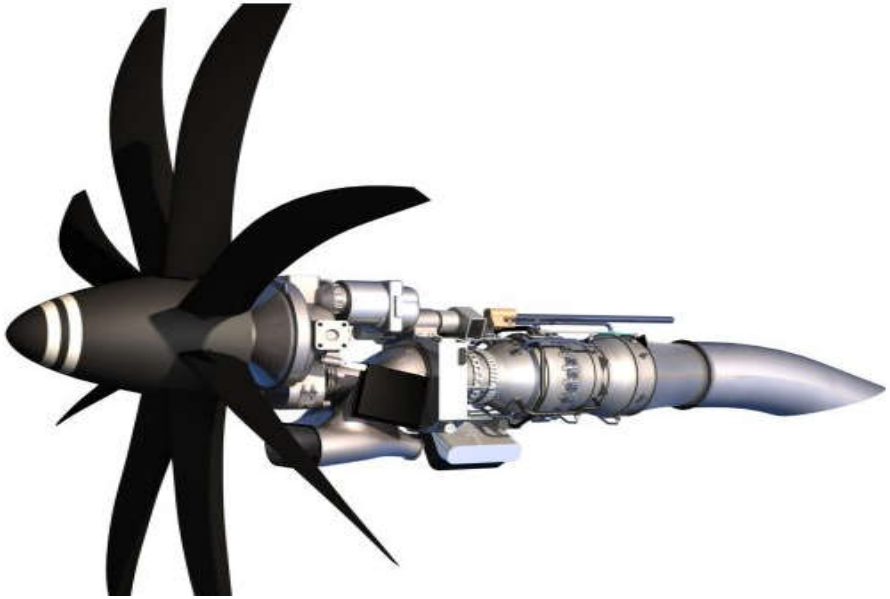
THE PRATT & WHITNEY CANADA NEXT GENERATION REGIONAL TURBOPROP ENGINE

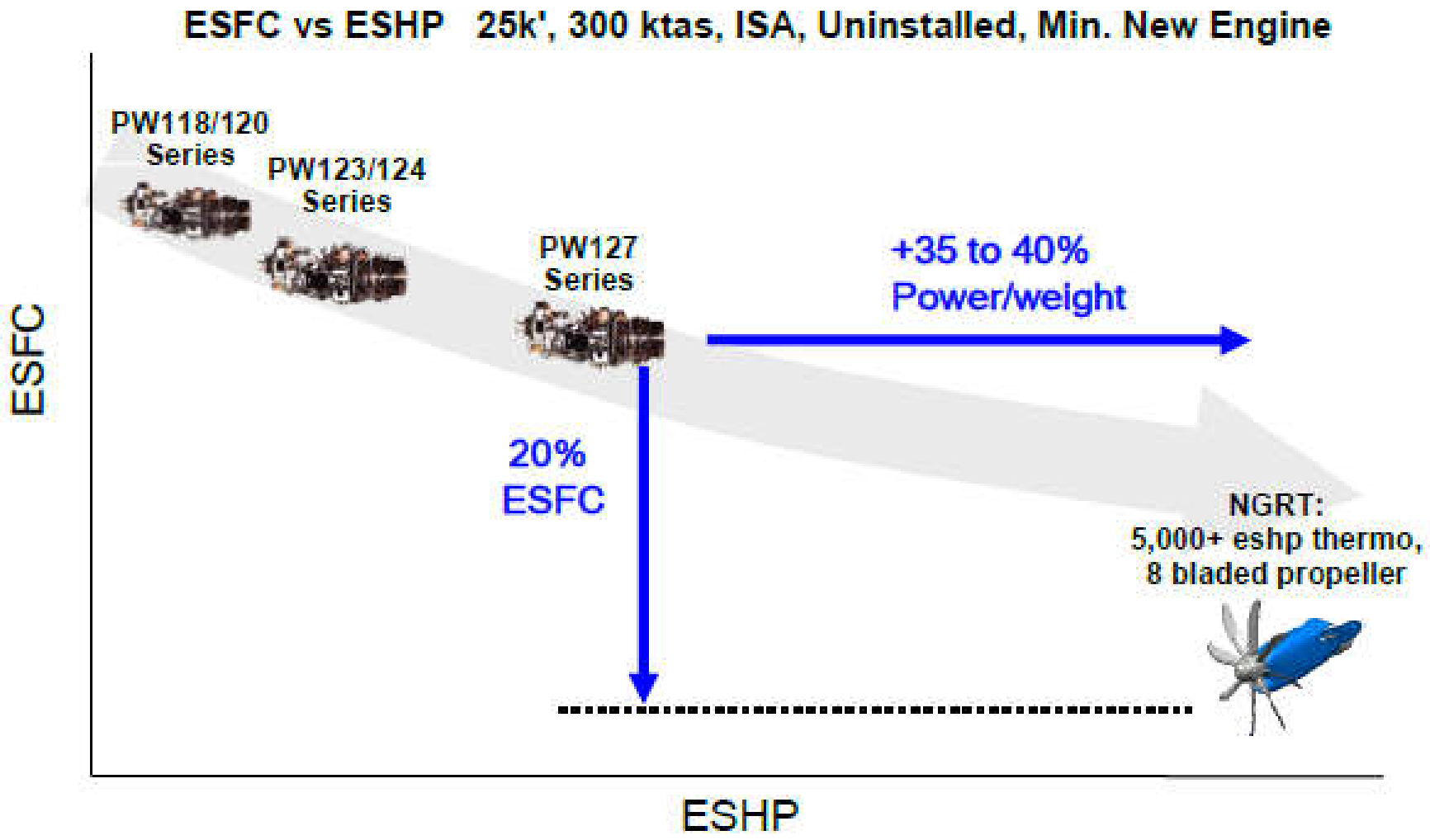
Yesterday at RAA, P&WC released information on their latest engine development. They have successfully completed Phase 2 testing of the Next Generation Regional Turboprop (NGRT) engine and are poised for rapid integration development. This phase has allowed P&WC to expand the design envelope ensuring the company has a fully optimized NGRT engine core.

P&WC's NGRT is a proactive response to airframe OEMs foreseeing a 90-seat turboprop within the next few years. P&WC developed a high pressure ratio compressor that contributes to the powerplant's ability to deliver 20% better specific fuel consumption and power from 4,500shp to 8,000shp. "Today, the vast majority of 30- to 70-passenger regional turboprop aircraft operating around the world are powered by the PW100 engine," Frederic Lefebvre, Vice-President, Marketing, P&WC, said. "It's a legacy of which we're obviously very proud, and one which has spurred us on to be ready when the larger 90-passenger turboprops enter the market. We not only remain committed to providing our customers with the latest enhancements and benefits on our PW100 and PW150 series of engines, we are also moving beyond that with the NGRT and will be first off the mark to fill that need with proven technologies."

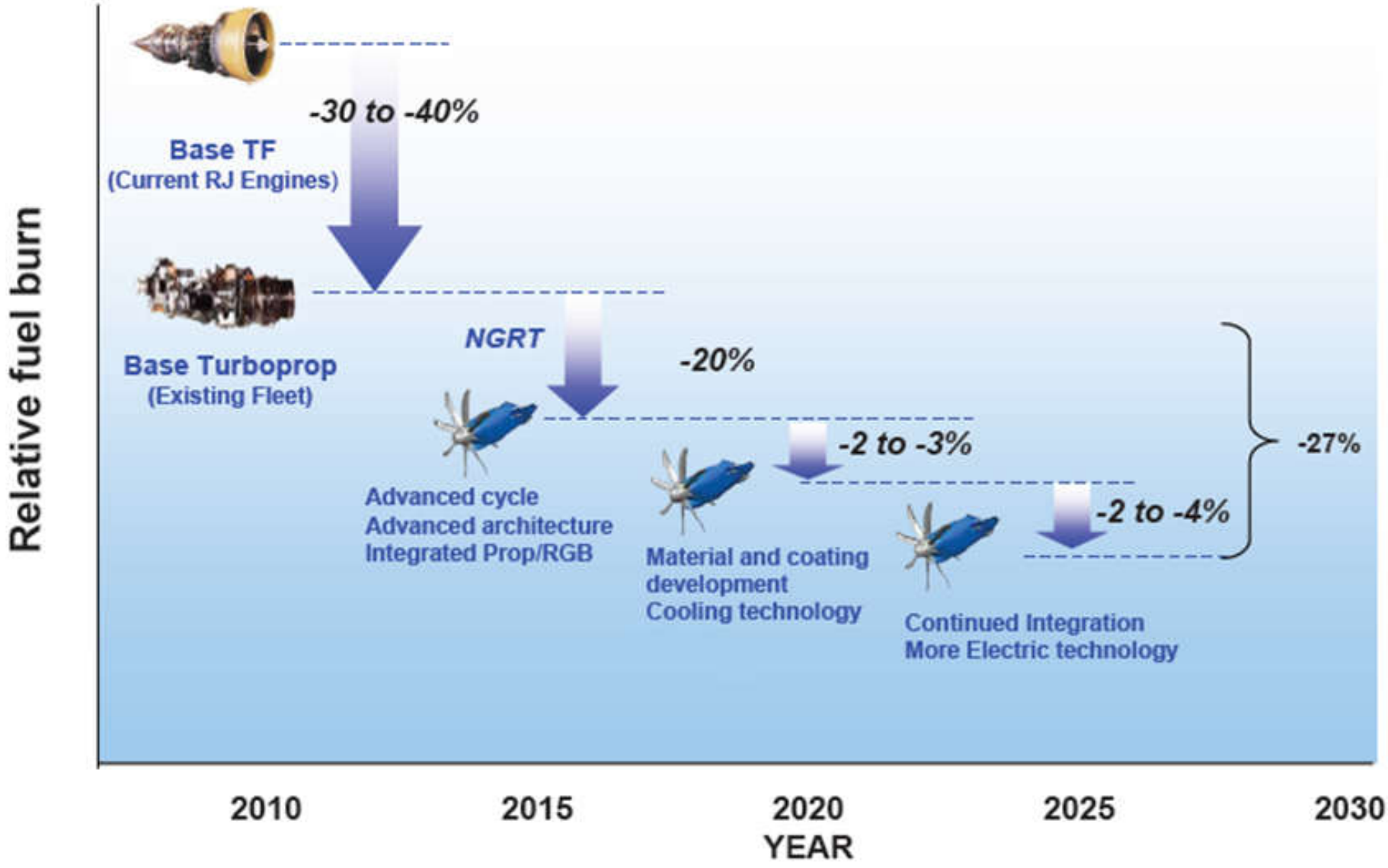


Next Generation Regional Turboprop Engine

New turboprop Engine



NGRT: Turboprop Engine Design Objectives



NGRT: Hybrid Engine

Seminari Interdisciplinari di Cultura Aeronautica

II Serie – I Ciclo – II incontro

9 giugno 2018

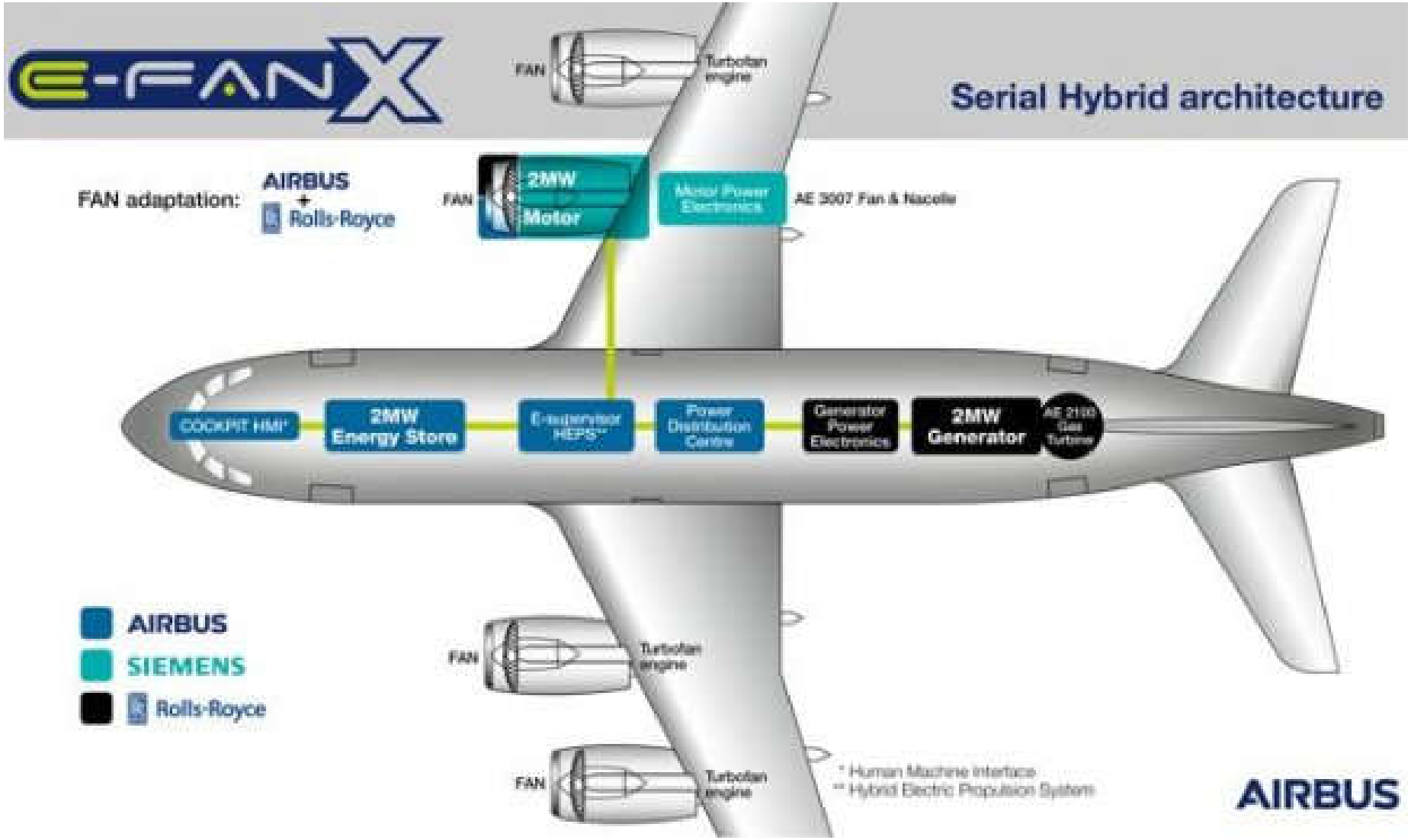
GRAZIE PER LA VOSTRA ATTENZIONE

L' evoluzione nel tempo dei sistemi Propulsivi

SCUOLA POLITECNICA E DELLE SCIENZE DI BASE
DELL'UNIVERSITA' «FEDERICO II»

BACK-UP

E- FAN X


E-FAN X
Serial Hybrid architecture
FAN adaptation:
AIRBUS
+
Rolls-Royce
FAN
2MW
Motor
Motor Power Electronics
AE 3007 Fan & Nacelle
COCKPIT HMI*
2MW Energy Store
E-supervisor HEPS**
Power Distribution Centre
Generator Power Electronics
2MW Generator
AE 2100 Gas Turbine
FAN
Turbofan engine
FAN
Turbofan engine
FAN
Turbofan engine
AIRBUS
SIEMENS
Rolls-Royce
* Human Machine Interface
** Hybrid Electric Propulsion System
AIRBUS

E- FAN X

Airbus, Rolls-Royce e Siemens hanno siglato una partneship per creare un aereo ibrido in grado di abbinare la spinta dei classici turbofan a potenti elettroventole alimentate da generatori costituiti da turbine a gas. Se un aereo totalmente elettrico è una chimera tecnologica per i noti limiti di densità delle batterie attuali, l'idea di ibridizzare un aereo di linea ha invece senso e in realtà riprende concetti già visti sulle navi dove, fin dagli anni Trenta, le eliche in molti casi sono attivate da motori elettrici alimentati da generatori diesel prima e nucleari dopo la seconda guerra mondiale o addirittura con turbo-alternatori di derivazione aeronautica.

Le tre multinazionali hanno messo insieme le forze per sviluppare un dimostratore, cioè un aereo di test che come dice il termine dimostra la fattibilità tecnica di un velivolo con quattro motori: due a reazione e due elettrici alimentati da una turbina a gas posta nella carlinga come se fosse una Apu Auxiliary Power Unit (Apu), cioè un generatore simile, ma ben più potente, di quelli che a bordo dei jet fornisco la corrente per i servizi di bordo.

L'obiettivo è ridurre pesi e consumi ed emissioni degli aerei di linea.