The Future of Propulsion

Highlights from ISABE 2017

ICAS

Belo Horizante, 9-14 September 2018

Professor Ric Parker — **with Ibrahim Eryilmaz**

President ISABE — **Cranfield University**

International Society for Air Breathing Engines

Agenda

- ISABE 2017, Manchester
- The Future of Propulsion
    - Commitments
    - Enabling Technologies
- ISABE 2017 Highlights
    - Words from Keynotes
    - Words from Presenters
- Electric propulsion (Rolls-Royce)
- Next Conference - ISABE 2019, Canberra

ISABE 2017, Manchester - Economy, Efficiency & Environment

Manchester Central Convention Complex

The city where The Honourable Charles Rolls met Sir Henry Royce

Hosted by Rolls-Royce and UK Organising Committee

Rolls-Royce

Co-hosted by Cranfield University

Cranfield University

Supported by

MANCHESTER CITY COUNCIL

Sponsored by

Rolls-Royce

Honeywell

MTU Aero Engines

MANCHESTER CITY COUNCIL

Canada CNRC-NRC

ITP the power of talent

UNSW

GKN AEROSPACE

Cranfield University

NASA

SAFRAN

ISABE 2017, Manchester - Economy, Efficiency & Environment

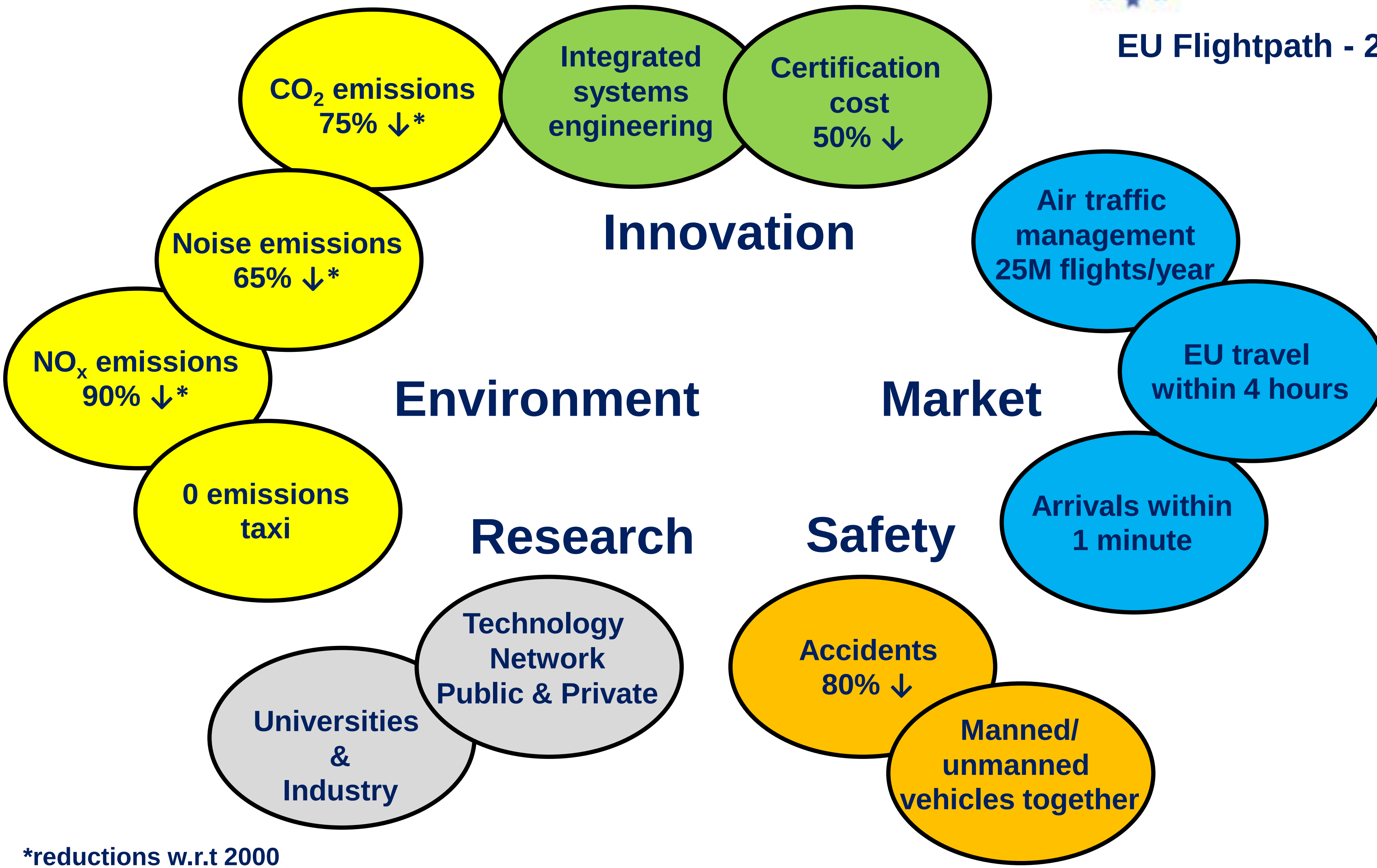
- **370 registered participants**
- **18 keynotes**

ISABE 2017, Manchester - Economy, Efficiency & Environment

- **Interactive parallel sessions**
  - **248 papers**
- **Panel discussions + Q&A**

The Future of Propulsion - Commitments

EU Flightpath - 2050



*reductions w.r.t 2000

The Future of Propulsion – Enabling Technologies

- **UHBR engine sizing - Integrity and installation challenges**
- **Cycle innovations – variable cycles**
- **Manufacturing - Additive manufacturing & fast prototyping**
- **Virtual engine design systems**
- **Integrated aircraft and propulsion system design**
    - **Boundary layer ingestion**
- **Electrification (Separate presentation)**
    - **More electric aircraft**
    - **Electric augmented**
    - **Hybrid electric**
    - **Electric propulsion**

From Keynotes – Safran Aircraft Engines

2018 LEAP-1C entering into service
- **Certified by EASA & FAA**

Powering COMAC 919
- **Narrow body, 2 engine aircraft**

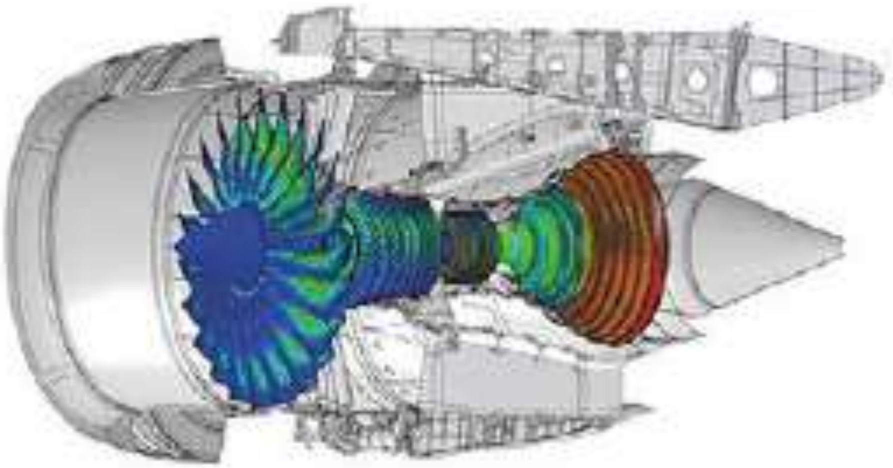
By additive manufacturing
- **20% reduction in engine parts by 2025**

Green taxiing®
- **2-4 % fuel burn reduction**

From Keynotes – Rolls-Royce

Global Partnership

- **31 University Technology Centres**
- **14 Research Centres and other Partnerships**



UltraFan® gearbox

- **The world's most powerful gearbox has run to max. power**

DaVinci

Design and Validate in the Computer Investment

- **Less testing, better quality, lower cost**

From Keynotes – Airbus

Existing product improvements – on track

- **Design for Additive Layer Manufacturing**
    - **5% waste material**
    - **up to 50% potential weight saving**

Better integration and architecture – BLADE: Breakthrough Laminar Aircraft Demonstrator in Europe

- **2017 – Flight tests on Airbus A340**

New configurations

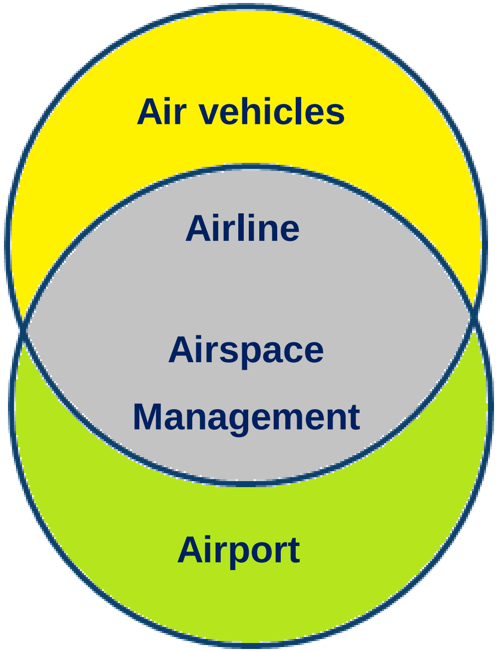
- **Hybrid electric propulsion**

Towards Urban Air Mobility

- **Pioneering role in opening the market**

From Keynotes – Cranfield AIRC & DARTeC

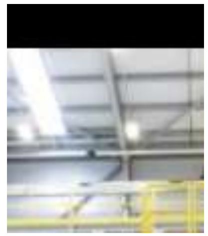
- **AIRC**
  - **A £35m investment by Cranfield, HEFCE, Rolls Royce and Airbus**
  - **Surrogate airframer for Rolls-Royce & surrogate component supplier for Airbus**
- **DARTeC**
  - **A £65m investment by Cranfield, HEFCE, Thales, SAAB, Boeing UK, Raytheon, Monarch Ltd**



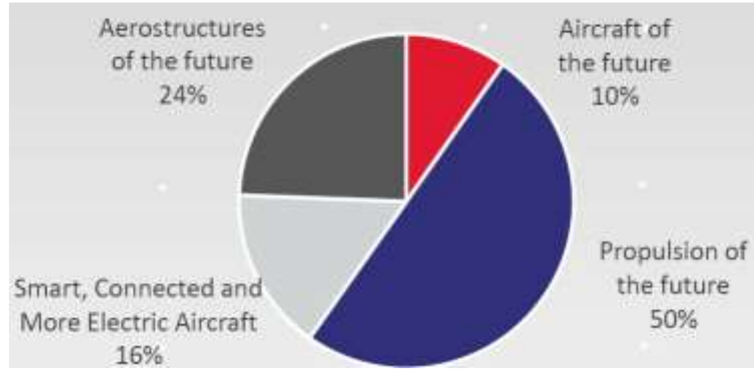
DARTeC - Digital Aviation Research and Technology **AIRC - Aerospace Integration Research Centre**

From Keynotes – Aerospace Technology Institute

UK Aerospace programme roles



ATI Portfolio by Value Stream



Impact of New Technologies – Case

Advanced Wing Assembly

- **Right first tie assembly**
- **Cost & lead time reduction**

Harsh Environment Electronics

- **250 ⁰C capable environment**

AMRC Titanium Casting

- **World's largest Ti casting facility**
- **£15M investment**

From Keynotes – Clean Sky Joint Undertaking

A public-private partnership- A focal point in European Aviation

- **14 Industrial leaders & EU Commission**
- **€1.8Bn EU funding, 4B € total cost, >800 participants**

Contra-Rotating Open Rotor, SAFRAN

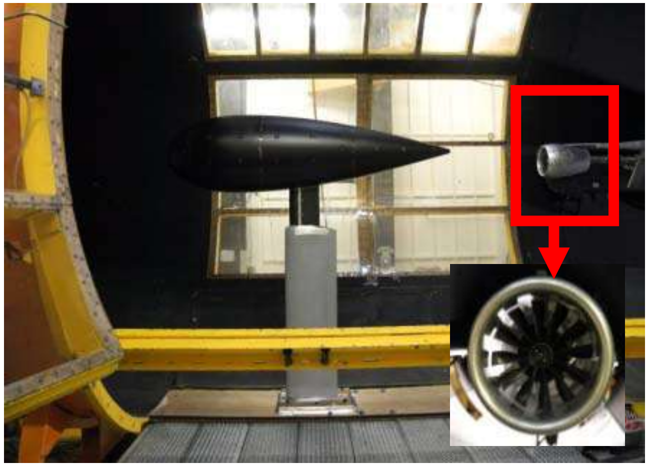
- **Ground test demonstrator**
- **Compliant with the new noise standards**
- **Offering 30% ↓ in fuel burn compared to 2000**

Geared turbofan demonstrator, MTU

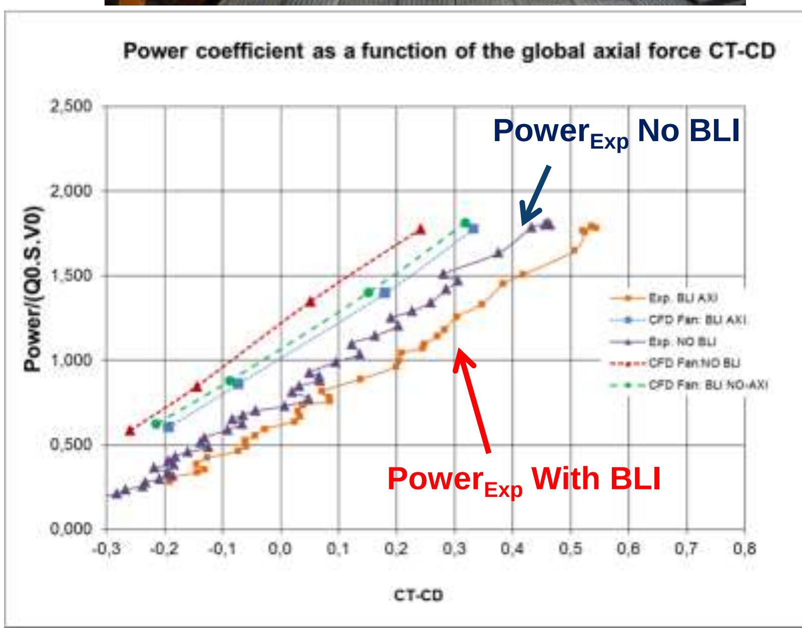
- **New systems for a more electric engine**
- **All electric VGV actuator**

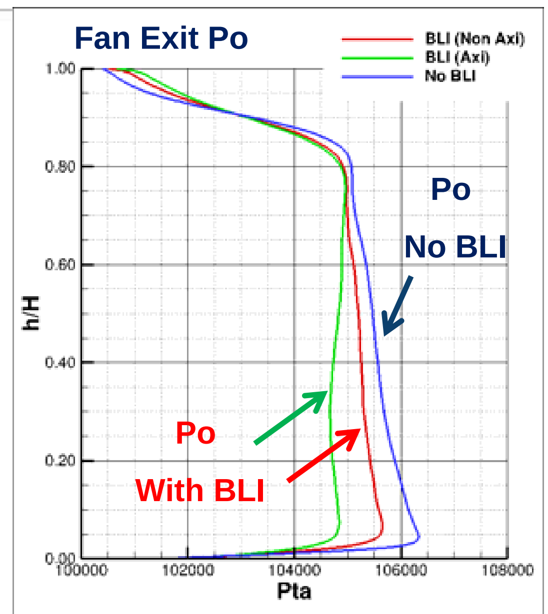
From Presenters – Boundary Layer Ingestion

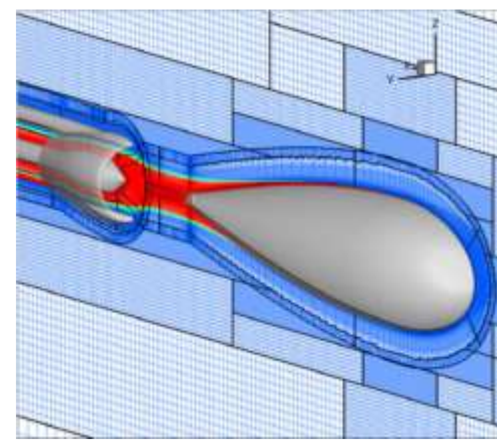
View of the RAPRO2 BLI experimental system in the L1 wind tunnel - ONERA



- Distorted fan flow
- Less drag on fuselage and nacelle
- BLI reduces global power needed
- Less fuel to drive the fan





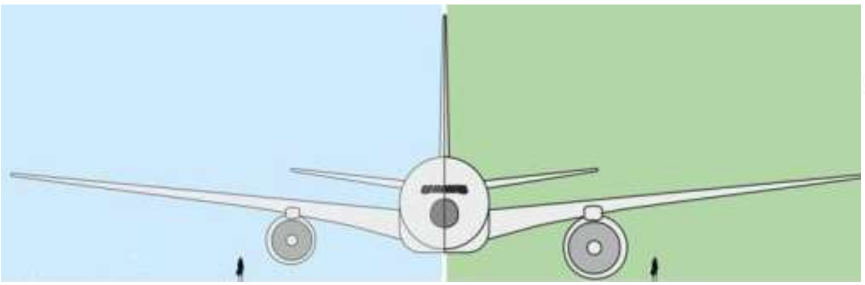


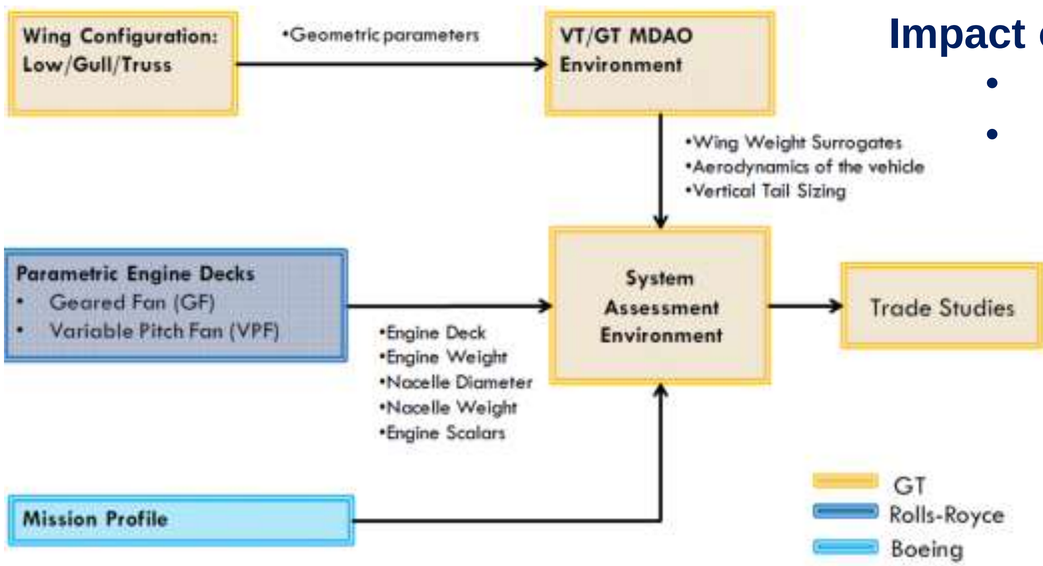
ISABE-2017-22536

From Presenters – UHBR Engine Sizing

Installation challenge, system sizing and synthesis

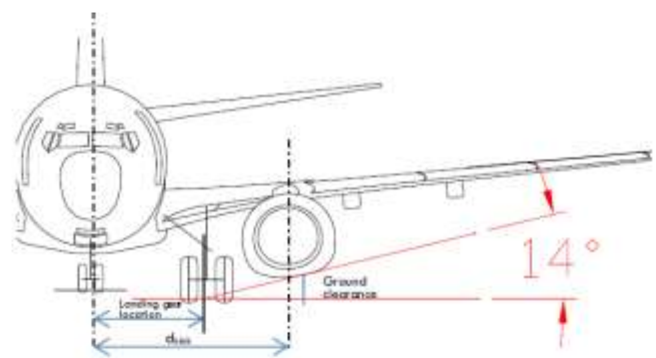
- **Optimized pylon & nacelle geometry and wing shape**
  - **Straight (low) wing, gull wing, truss braced wing**





Impact on landing systems length and weight

- **FAA minimum ground clearance ≥ 9in**
- **Minimum allowable roll angle ≥ 8 degrees**



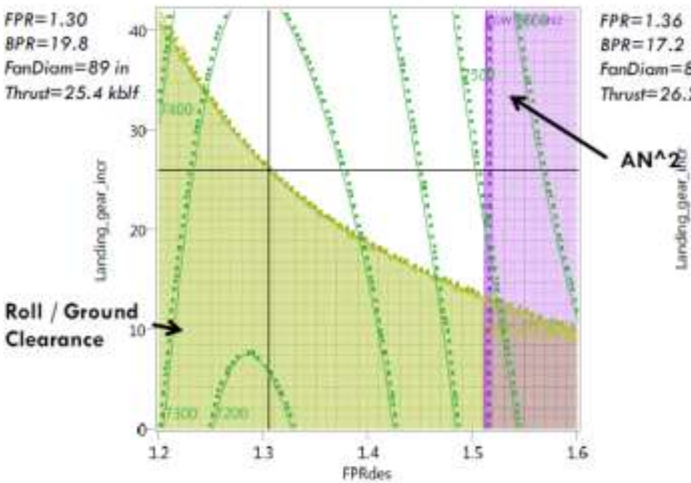
ISABE-2017-22605

ISABE-2017-22605 & J. Bonini SAFRAN keynote

From Presenters – UHBR Engine Sizing

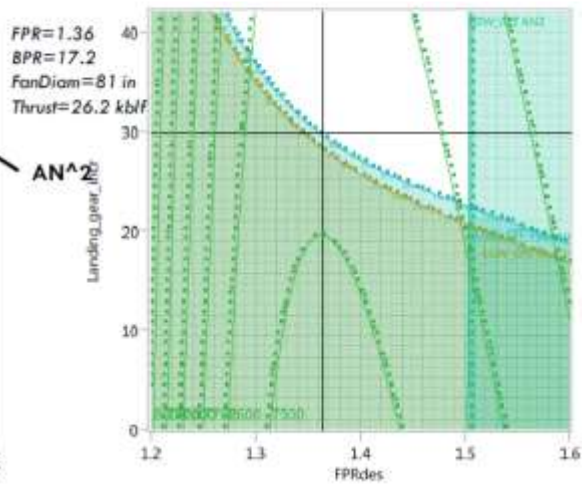
Low wing

Variable Pitch Geared Fan



Low wing

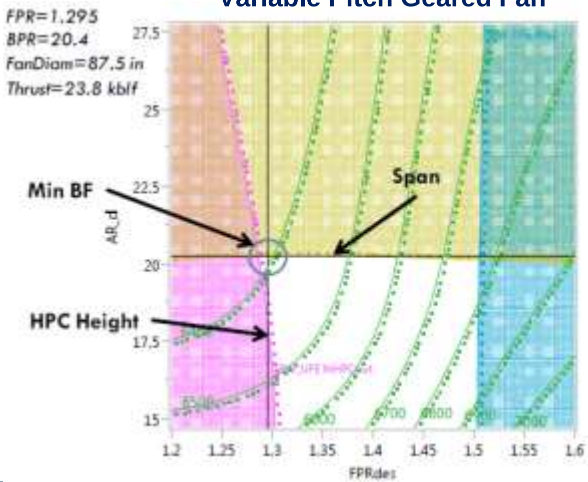
Fixed Pitch Geared Fan



- **VPF- No thrust reverser**
- **Less landing gear ↑ with a slimmer nacelle to accommodate UHBR**
- **opt. FPR ~1.3-1.35 - VPGF < FPGF**

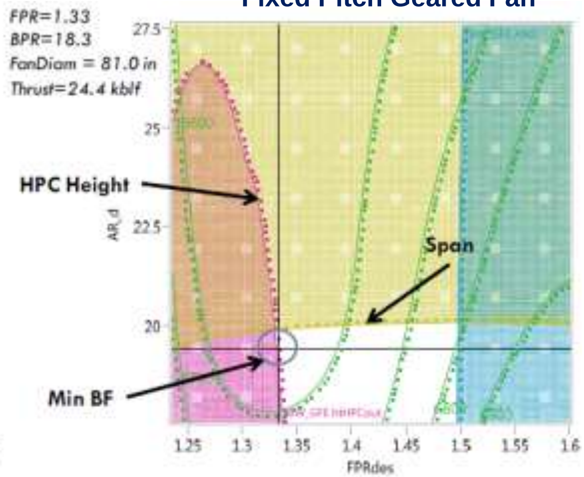
Truss braced wing

Variable Pitch Geared Fan



Truss braced wing

Fixed Pitch Geared Fan



- **High wing**
- **No ground clearance constraint**
- **High span - gate compatibility issues**
- **Further fuel burn↓ - opt. FPR<1.2**

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From Presenters – Manufacturing

EOS GmbH & Universität der Bundeswehr

- **Compressor vane with pressure probes - Additive Manufacturing, DMLS**

Rolls-Royce Advance3

- **Critical long lead time parts - Fast Make SCUs**
- **Intercase cast in sub-sections and bolted**
- **Blisk stages machined from solid and Electron Beam welded**

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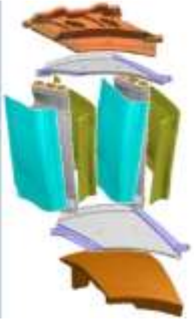
CastBond™ HP-NGVs

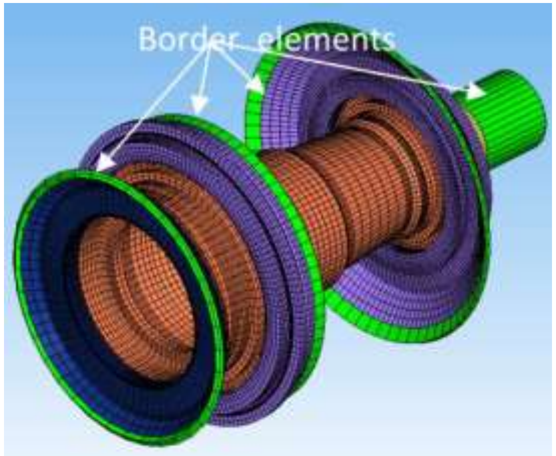
- **Cooling capability**

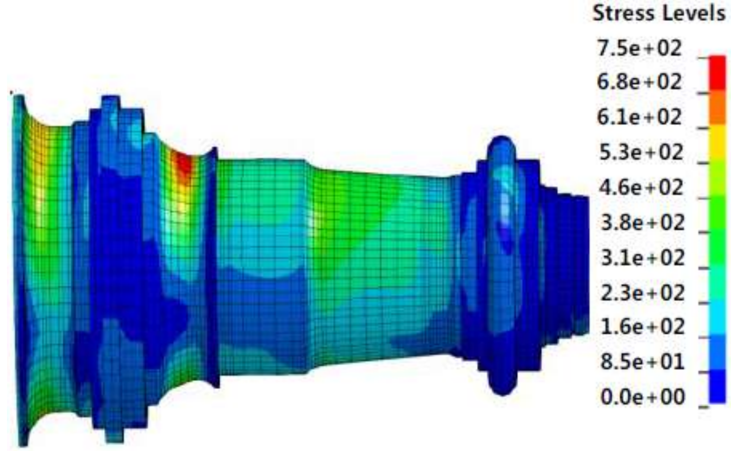


ISABE-2017-22705

From Presenters – Virtual Engine Design Systems

3-D transient dynamic sub-systems modelling, LS-DYNA

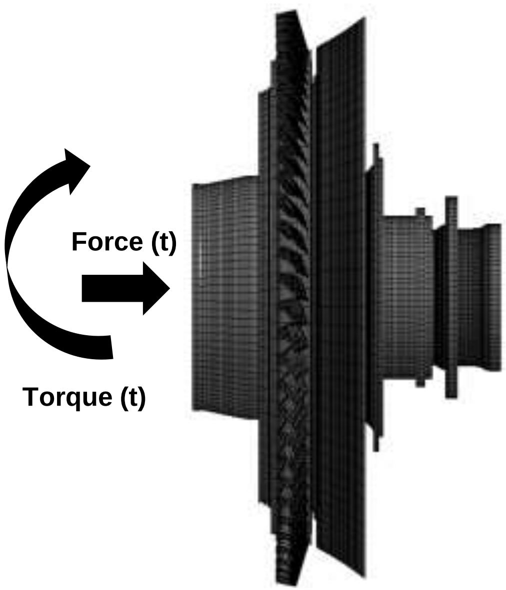


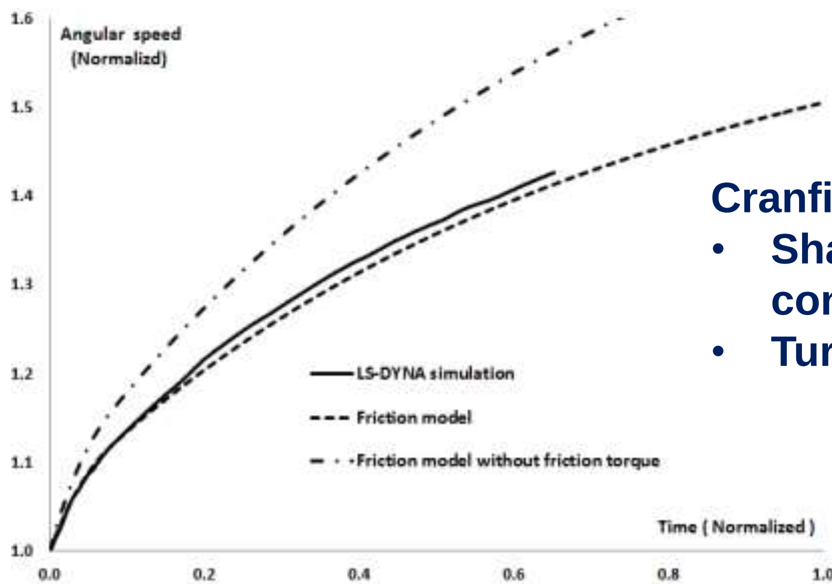


AECC Ltd.

- **Fan shaft is connected**
- **Stress under FBO loads**

ISABE-2017-22675





Cranfield Rolls-Royce UTC

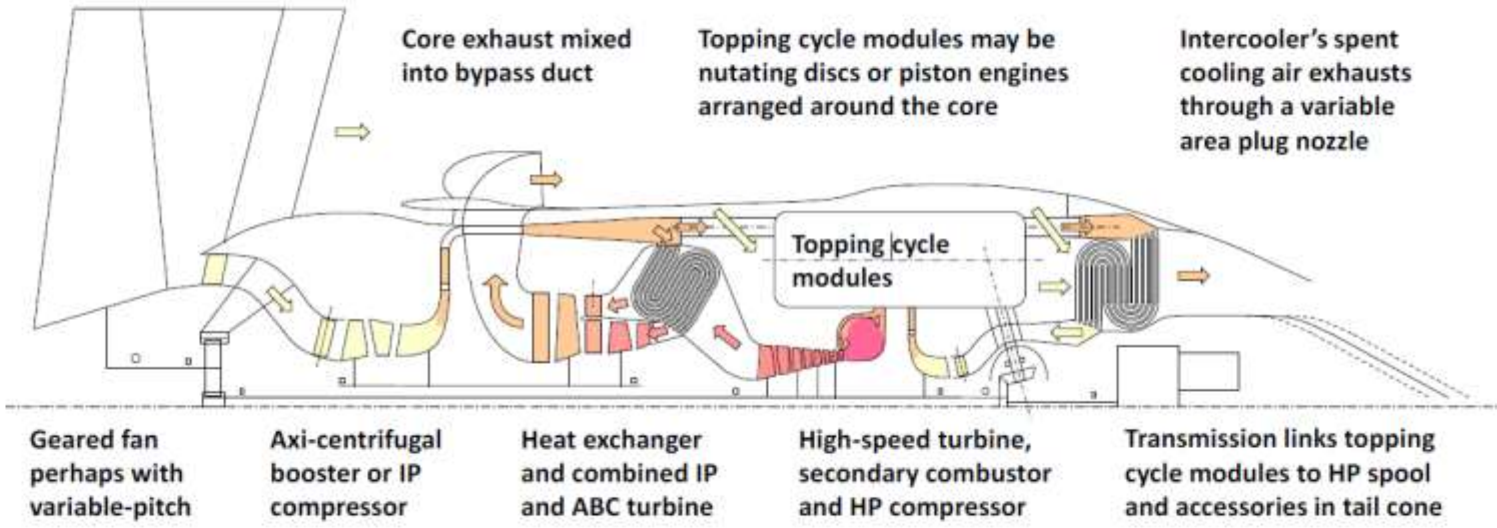
- **Shaft failure – no connection**
- **Turbine overspeed**

ISABE-2017-21440

From Presenters – Cycle Innovations

Candidate technologies for year 2050 engines – qualitative assessment

- Intercooling
- Recuperation
- Variable geometry
  - VIGVs for IP and HP compressors
  - Variable pitch fan
- Secondary combustion
- Topping cycles- pressure rise combustion
  - Pulse-detonation combustors
  - Piston engines
- Bottoming cycles
  - Use the core exhaust as heat input
  - S-CO_2



Reverse flow core turbofan engine architecture with several features

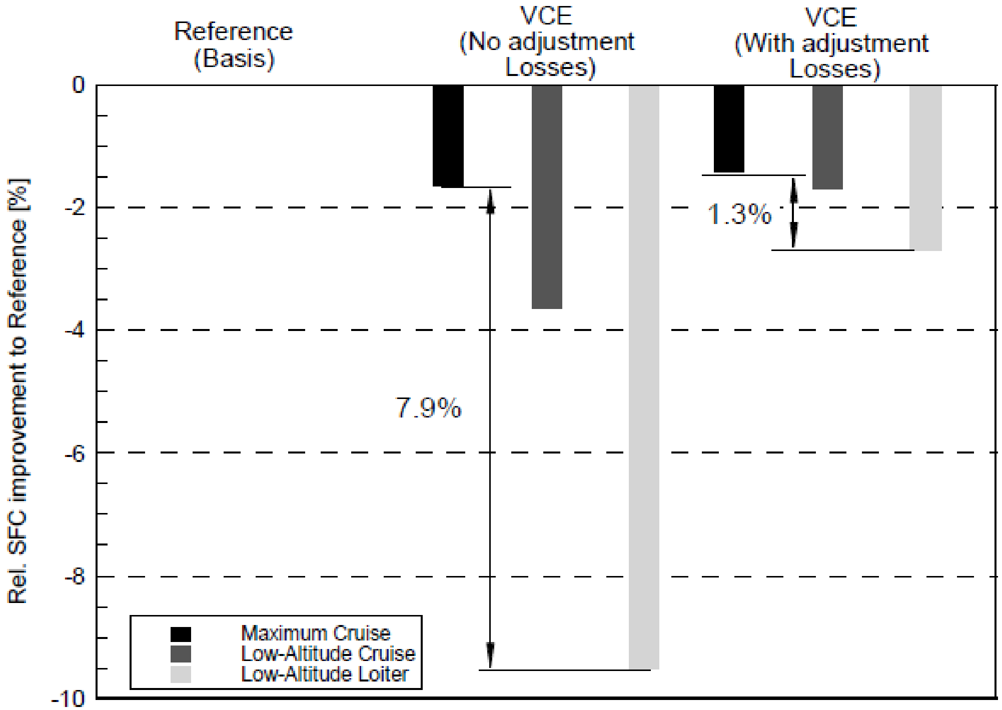
ISABE-2017-22660

From Presenters – Cycle Innovations

The variable cycle engine – quantitative assessment

- **3 spool mixed flow turbofan**
- **Variable fan IGV**
- **Variable compressors**
- **Variable turbines**
- **Variable mixer**
- **Variable nozzle**

- **MTU cycle code**
  - **Thermodynamics**
- **Meanline code**
  - **Flowpath design**
- **Preliminary mechanical design tool**
  - **Weight prediction**



SFC improvement

ISABE-2017-22704

From Presenters – Noise Reduction

The NASA Aircraft Noise Reduction Sub-project
- **Acoustic liner technology**
- **Propulsion airframe aeroacoustics**

Over-The-Rotor Liner (Acoustic Casing Treatment)
- **Casing grooves over the fan tip**
- **Groves have porosity to allow communication between unsteady flow and absorbers**

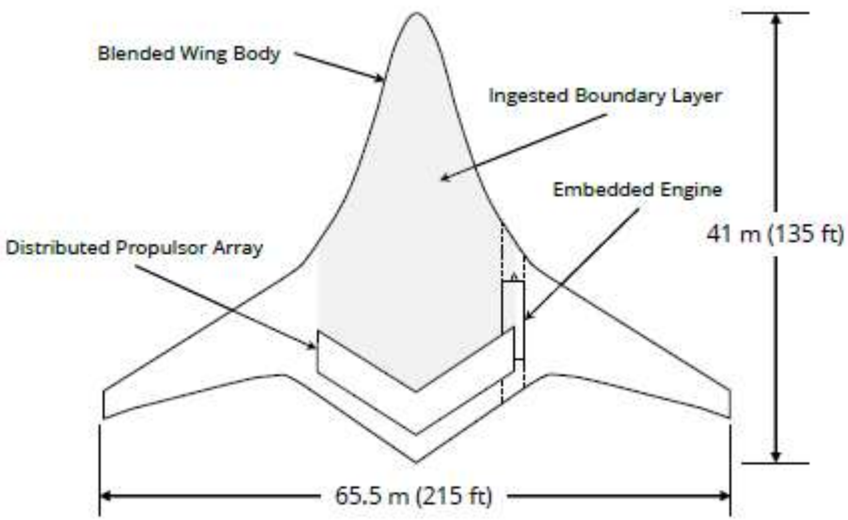
Challenges
- **Fan losses, already solved: to be published soon**
- **Fabrication**

ISABE-2017-22697

From Presenters – Turbo-Electric Propulsion

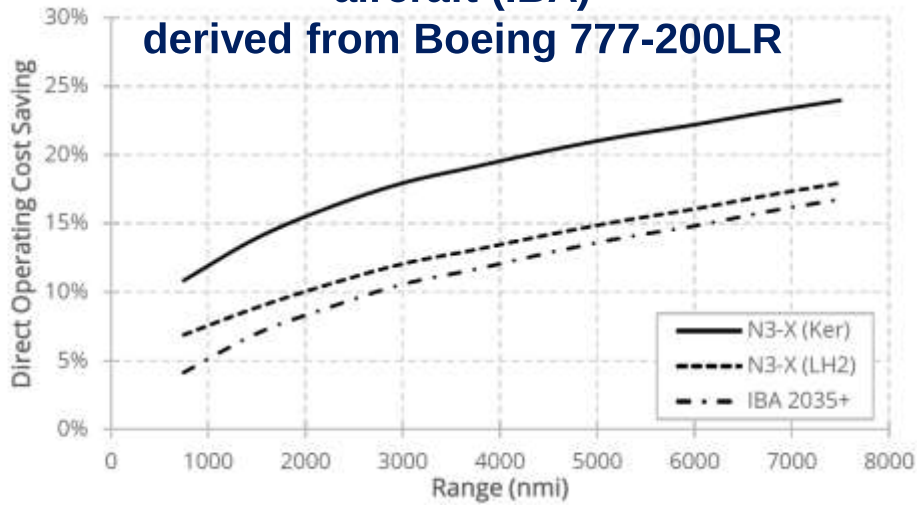
Techno-economic and environmental risk assessment (TERA) of NASA's N+3-X aircraft

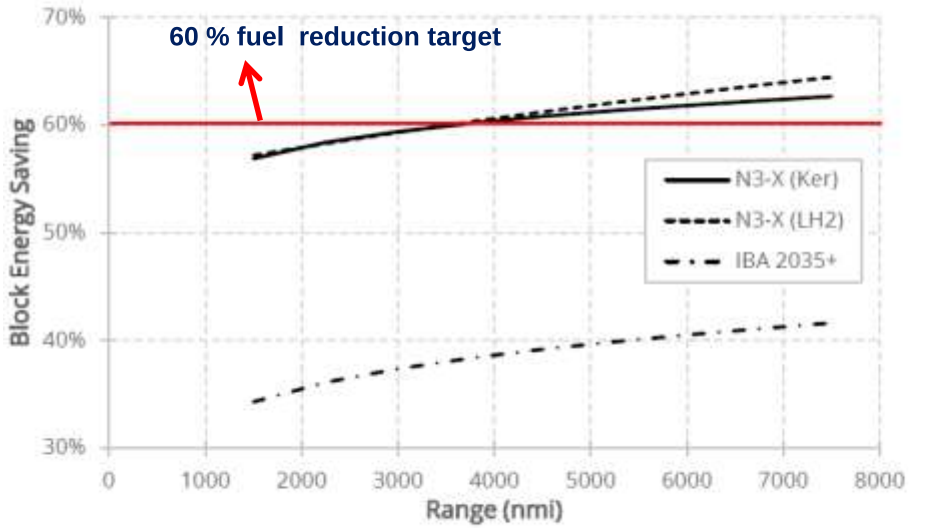
- **TERA methodology by Cranfield**
- **Boundary layer ingestion**
- **Turbomachinery**
- **Aircraft performance**
- **Economic modelling**



ISABE-2017-22535

Improvements w.r.t improved baseline aircraft (IBA) derived from Boeing 777-200LR





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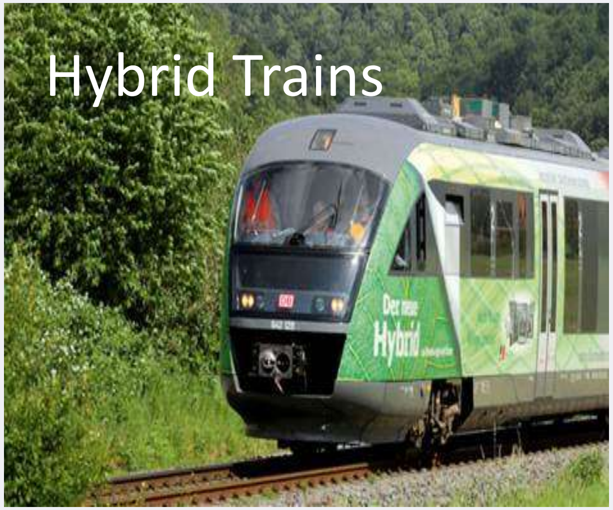
Electric propulsion

Professor Ric Parker – Special Advisor

ICAS 2018 – Belo Horizante

Electrification



Personal Air Taxi image © Airbus, Helicopter Replacement Image courtesy of Aurora Flight Sciences - a Boeing Company

Products	**Military**	**Personal Mobility**	**Hybrid Turboprop**	**Helicopter Replacement**	**Hybrid Turbofan**
					
Driver	Capability	Capability (time)	Local Environmental Impact	Capability & Safety	Efficiency
Timing	**Now**	**~2020s**	**>2025**	**>2025**	**>2030**

New directions for aviation through electrical power

Electric Propulsion Benefits

Hybrid Electric Propulsion Transforms Aircraft Design Space

Efficiency

High levels of efficiency
Allows energy-use optimisation

Capability

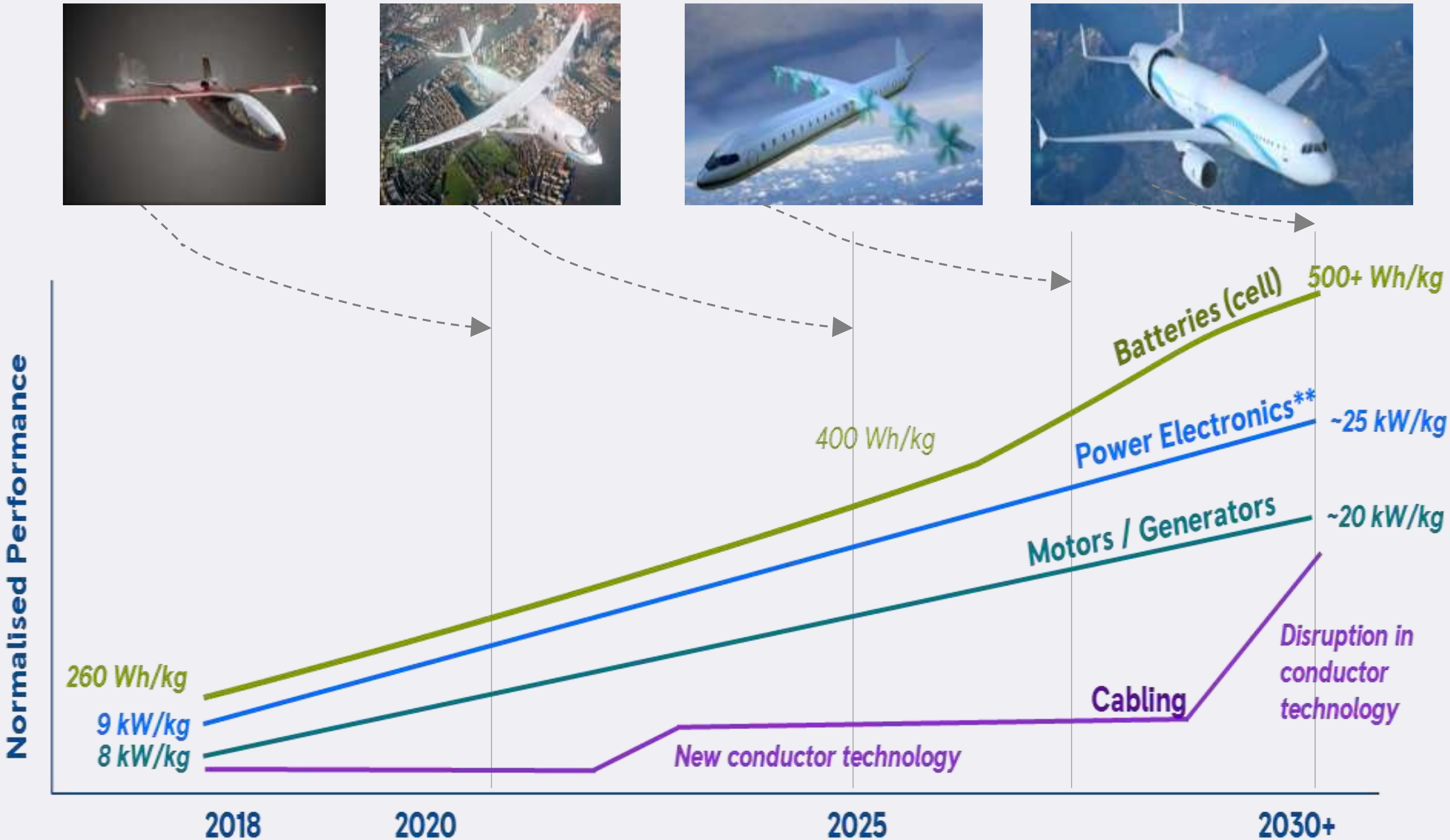
High level of control
Easily configurable
Propulsion airframe integration
Novel architectures

Emissions

Zero local emissions
Potentially lower levels of noise

Maintenance

Single engine, increased redundancy
Power Management control to reduce wear



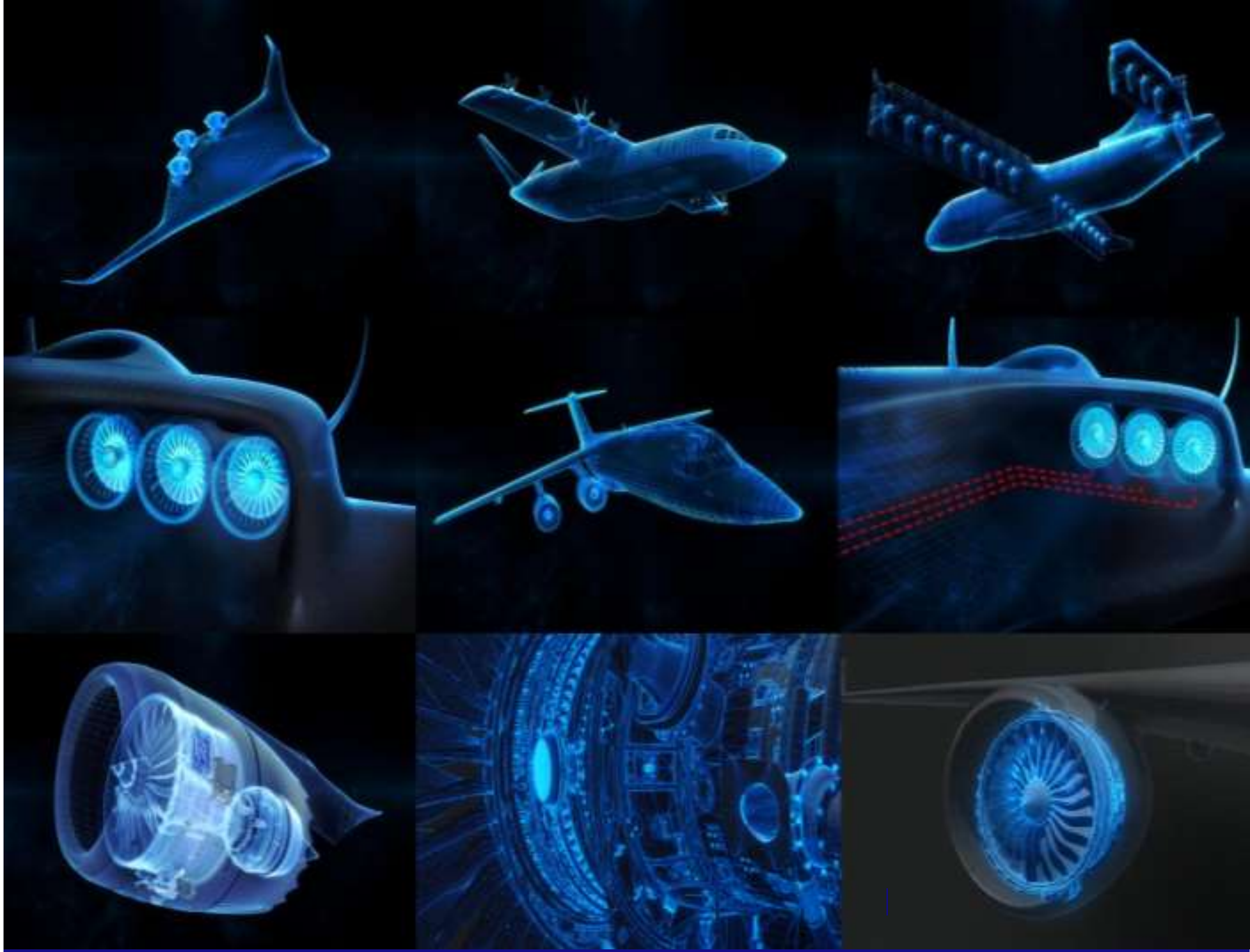
Data for "aerospace grade" technology

Growing electrical capability

How might it impact aviation?

Incremental
(Electrification)

Disruptive
(Electric propulsion)



Incremental
More electric Aircraft
Electrical content increasing
Electrical technology advancing
Electrical enhancement - BLI

Disruptive
New airframe and/or transport concepts could appear
Scope of supply may change
New entrants may appear in market

Disruption in short/medium travel.

		Short Range	Medium Range
1-4 pax	1 Personal Transport	Time Saver	
		Congestion Beater	Convenience Option
4-20 pax	2 Regional VTOL	VTOL unlocks new Markets	
		Local Commuter	Potential to take share of small business jet market
20-100 pax	3 Regional Hybrid	Alternative to rail and current aircraft	
		Economic advantage over new Rail Infrastructure Ability to operate closer to destination than conventional aircraft	

Disruption in short/medium travel.

A shift in transport mode

Enabling innovative civil aerospace and defence operations

- Reduced operating cost
- Reduced emissions
- Reduced aircraft noise

- Flexibility in vehicle propulsion integration
- Flexibility to energy source

It’s not just about the airplane…

New policies on transportation subsidies

Digital ticketing

New physical and cyber security systems

Minimalist city airport design

Security pre-clearance

Ground Infrastructure

Dynamic air traffic management

Single pilot operation

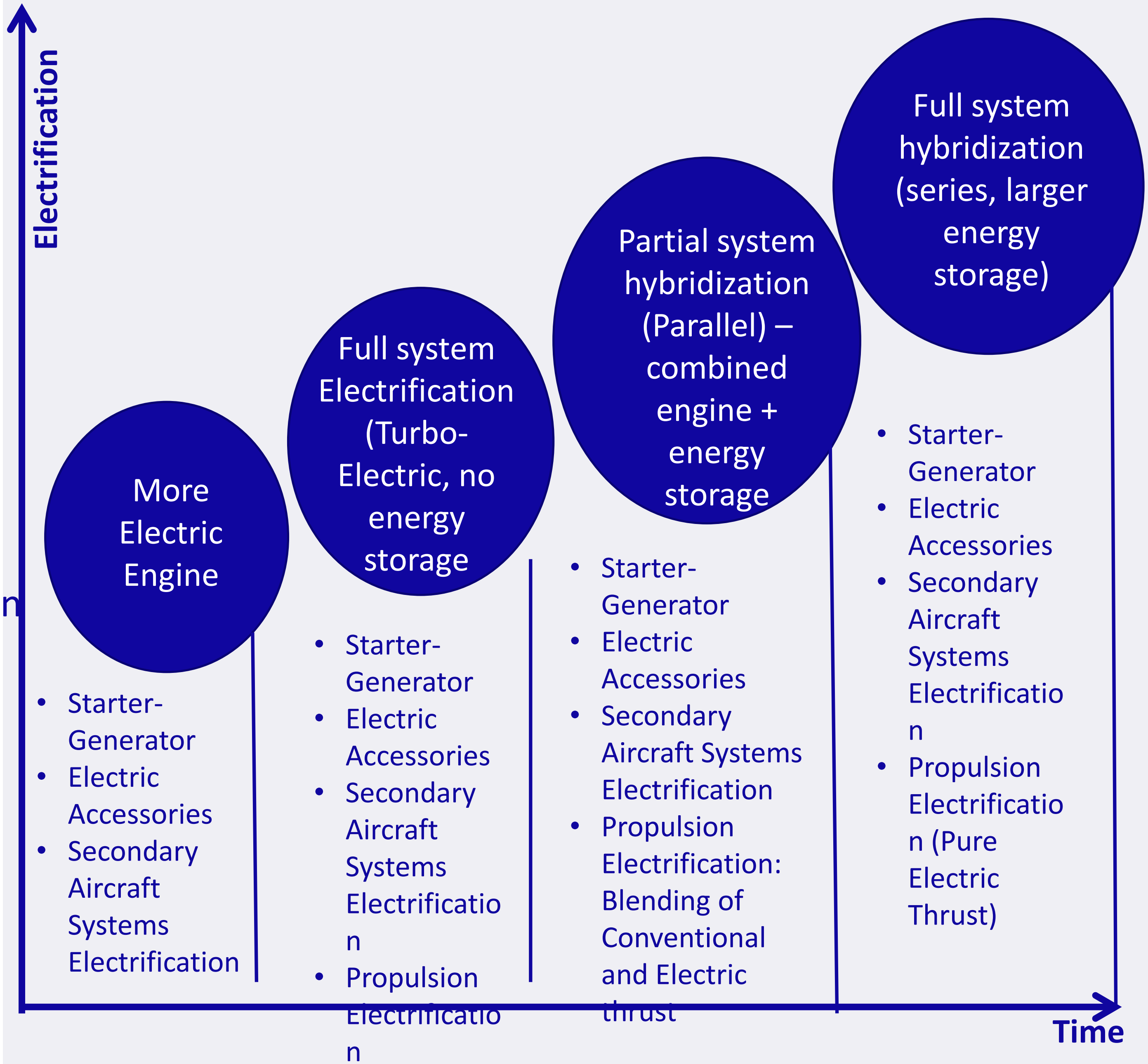
Mobility as a service

New aircraft types (STOL, low noise)

Technology Development

Rolls-Royce Electrical – Hybrid Technologies

- Parallel Hybrid
- Series Hybrid
- Turbo-electric distributed propulsion



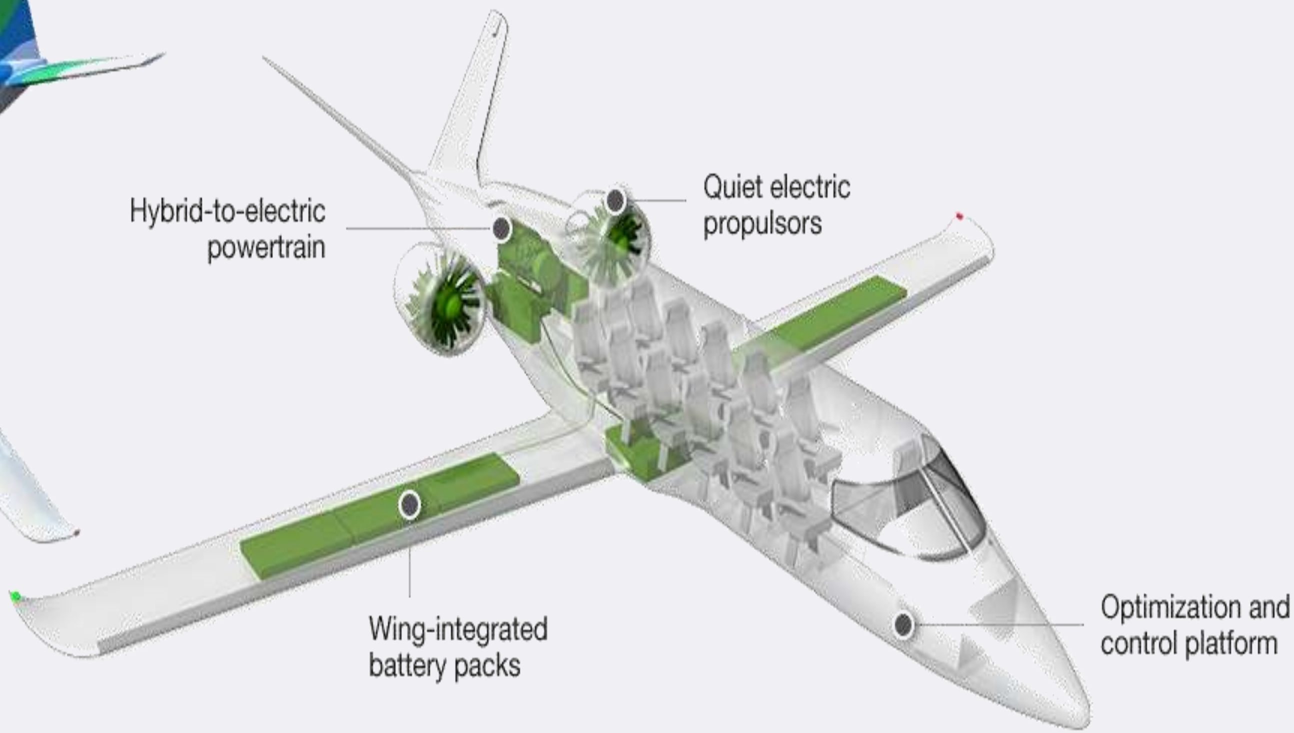
Focus on Technology Advancement and Demonstrators for Early Product Opportunities

Electrically enhanced larger aircraft – aft body BLI*

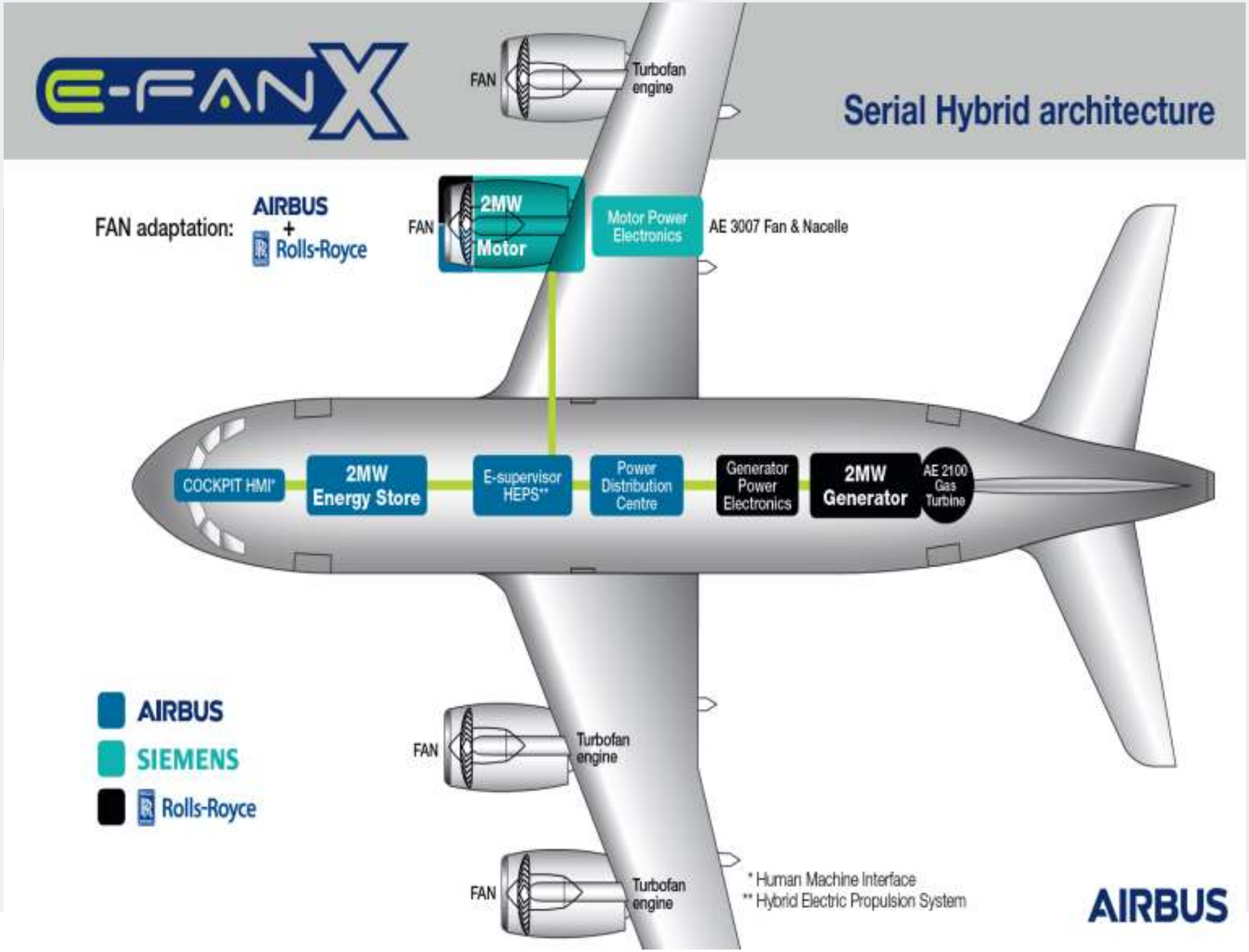
*Boundary Layer Ingestion

Zunum

ZUNUM Aero



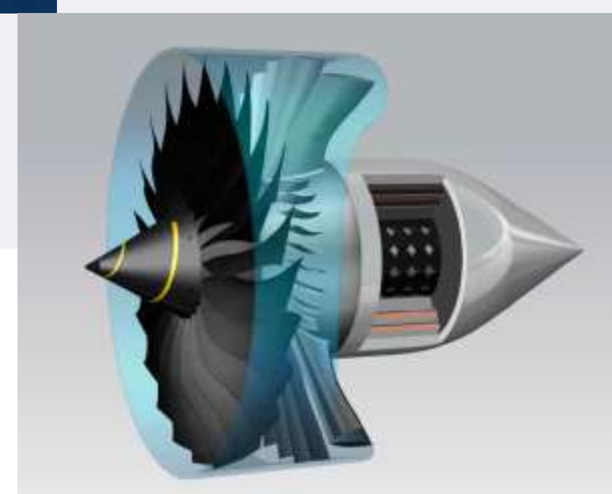
Hybrid short-range regional aircraft



Hybrid regional demonstrator

Airbus, Roll-Royce Siemens

E-Thrust



Hybrid MoM

Airbus, Rolls-Royce

Key challenges

Electric and Hybrid Electric propulsion are poised to reshape the aerospace industry

Systems Integration

The ability to integrate mechanical, electrical and thermal systems

- **Safety & certification**
- **Electro mechanical integration**
- **Cooling**
- **Control**
- **Corona discharge**

Component Technology

The ability to design high performance, high integrity components

- **Lightweight, high power density machines**
- **High temperature electrical materials**
- **Fault tolerant power electronics**

Next Conference – ISABE 2019, Canberra