UTC Aerospace Systems

Integrated Propulsion System (IPS)

THRUST REVERSER TECHNOLOGY DEMONSTRATOR

May 4, 2016

CONTINUOUS LOWER ENERGY, EMISSIONS AND NOISE (CLEEN II)

CLEEN II Consortium Public Session

ecoips™

OUTLINE

UTC/UTC Aerospace Systems company overview

Power plant system and historical trends

Next generation integrated propulsion system (IPS)

CLEEN II IPS thrust reverser demonstrator

Summary

United Technologies

United Technologies
Climate | Controls | Security

OTIS

PRATT & WHITNEY
DEPENDABLE ENGINES

UTC Aerospace Systems




Leading provider of high technology systems for the commercial building and aerospace industries

Employs approximately 220,000 people in more than 4,000 locations

Located in approximately 70 countries around the world

2015 net sales of $56B

UTC AEROSPACE SYSTEMS

8
Business Units

42,000
People

150
Locations

26
Countries

UTC AEROSPACE SYSTEMS

Business Units

Actuation & Propeller Systems

Aerostructures

Electric Systems

Engine & Environmental Control Systems

Interiors

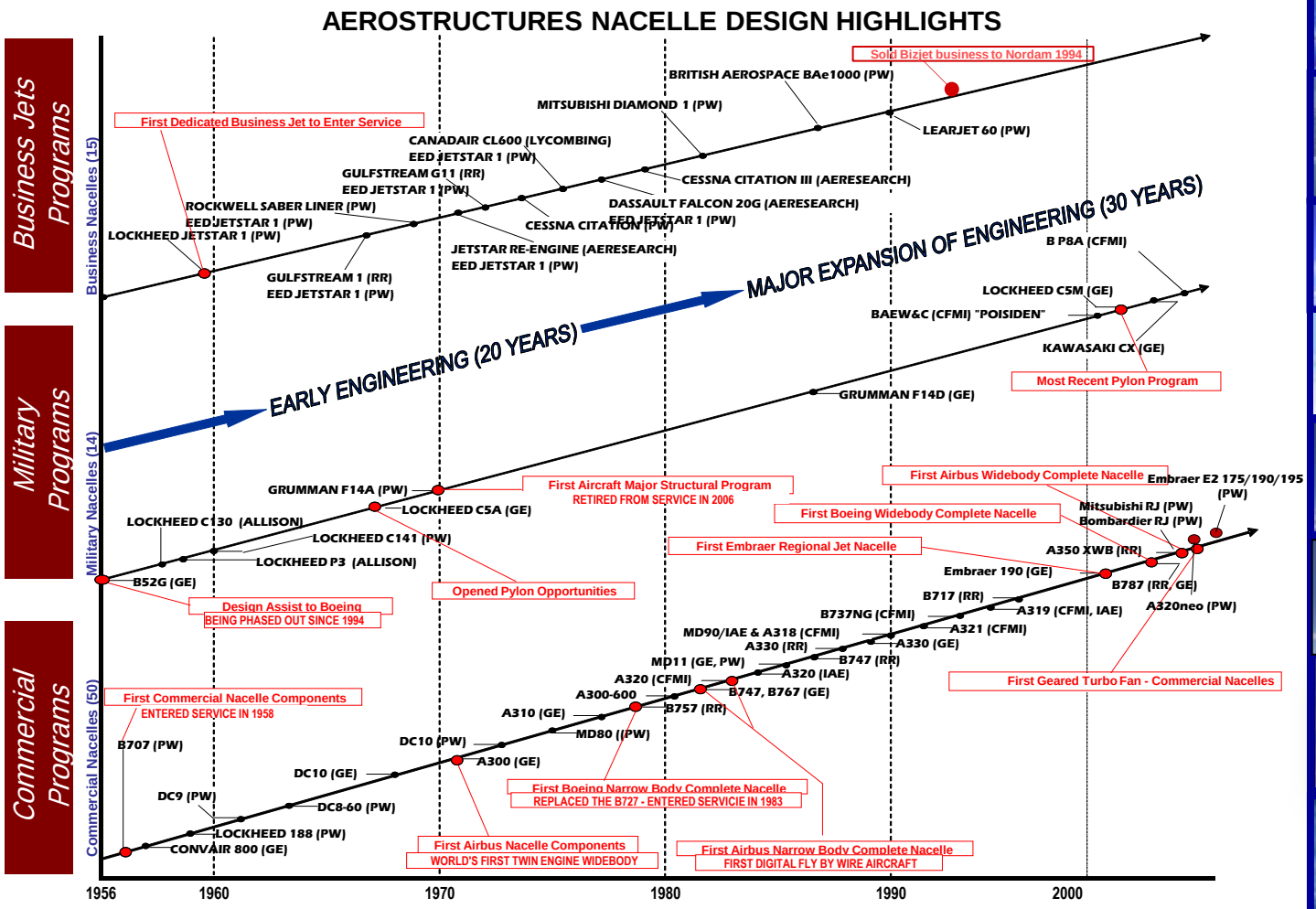
ISR & Space Systems

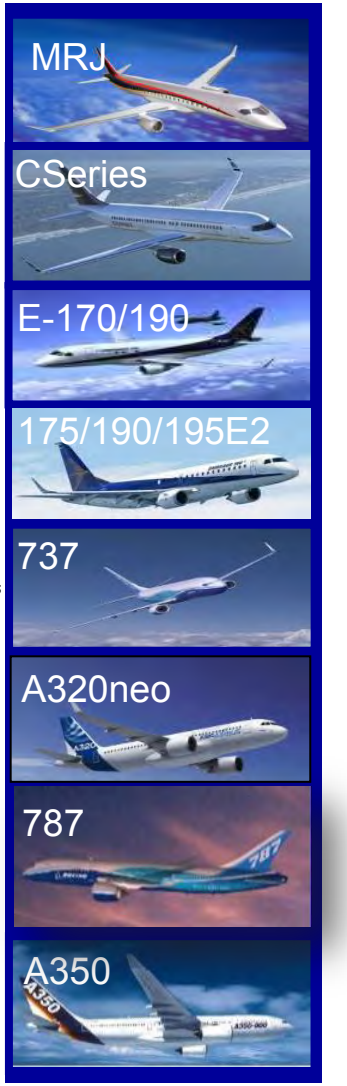
Landing Systems

Sensors & Integrated Systems

UTC AEROSPACE SYSTEMS

An Industry Leader: 50+ Years with 50+ Nacelle Programs





UTC AEROSPACE SYSTEMS

Aerostructures

Key Products and Systems

Nacelle systems

Pylons and fairings

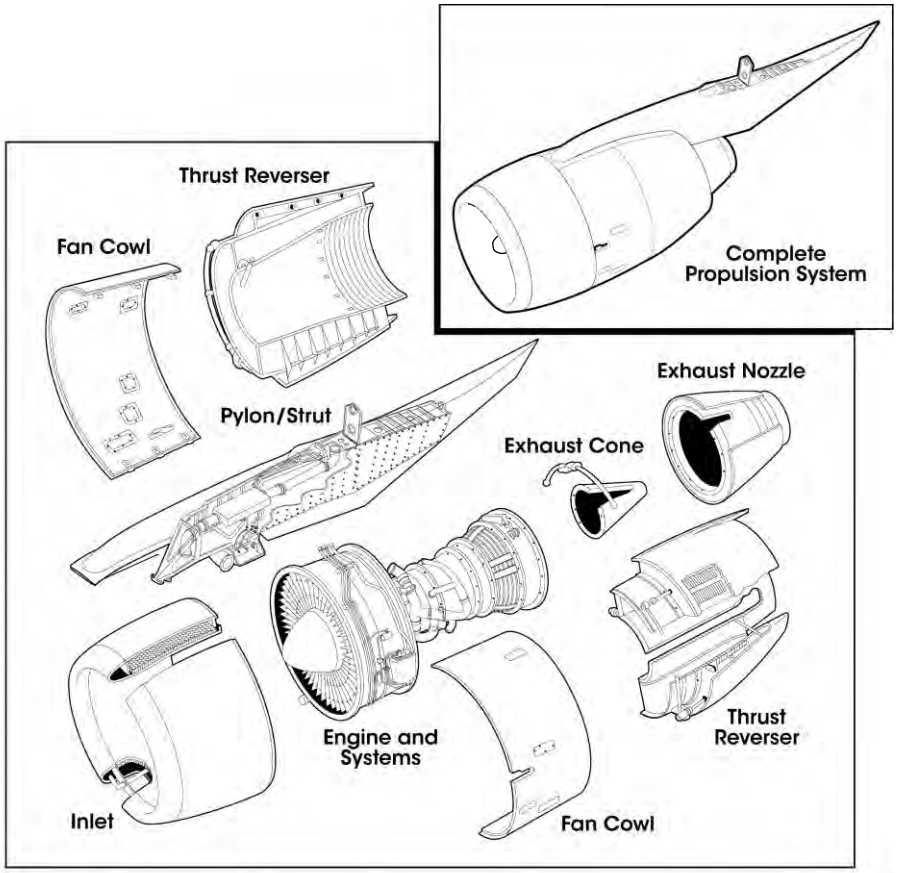
Tailcones

Key Platforms

UTC Aerospace Systems is a leading independent supplier and integrator of nacelles and pylons, offering complete life cycle design/build/support for large commercial and regional jet customers around the world

POWER PLANT SYSTEM (PPS) OVERVIEW

Elements of a legacy PPS



Nacelle provides:

Smooth aerodynamic airflow

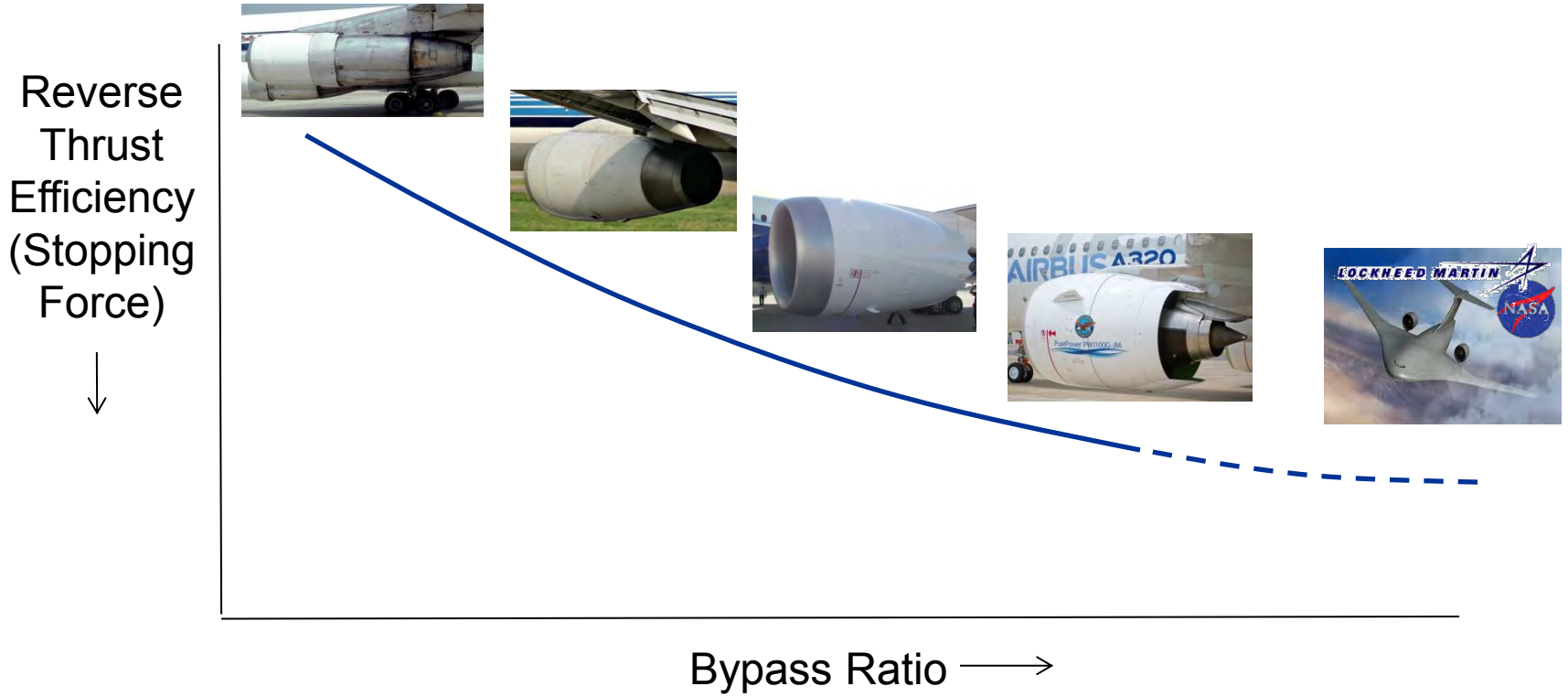
Reverse thrust stopping force

Acoustic systems to reduce engine noise

Protection of key engine and aircraft systems

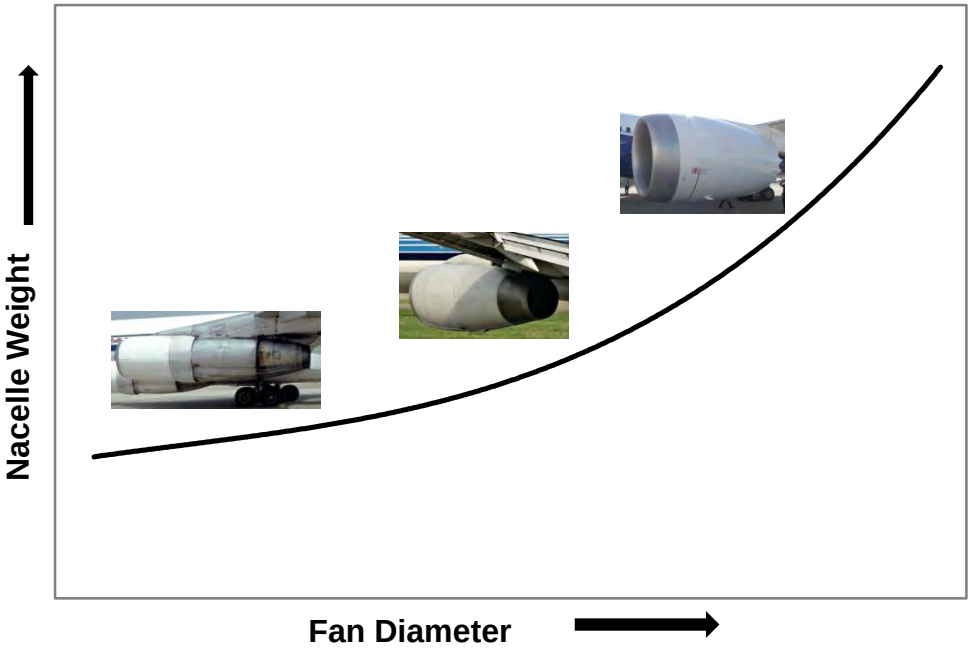
HISTORICAL TRENDS IN REVERSER THRUST

Reverse thrust efficiency trends



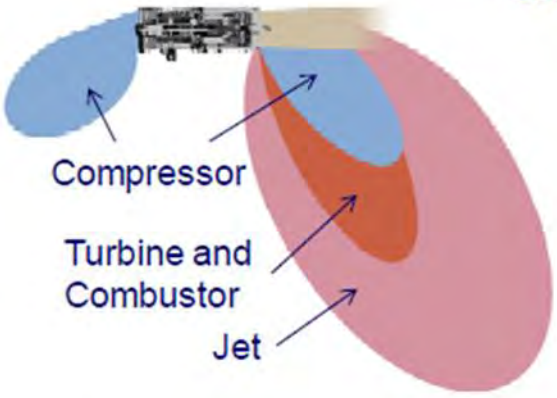
As bypass ratio, fan diameter and base drag increase for a given thrust, stopping force required from the thrust reverser can be reduced.

HISTORICAL TRENDS IN NACELLE WEIGHT

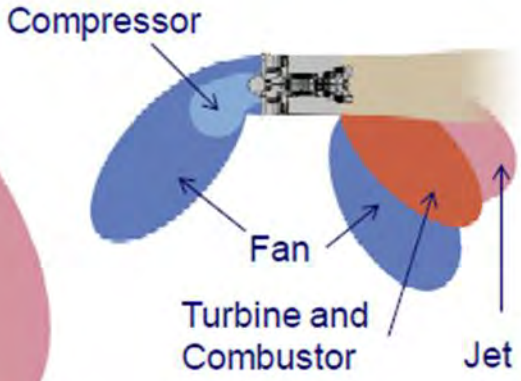


Nacelle weight increase with fan diameter, historical data from the 70s

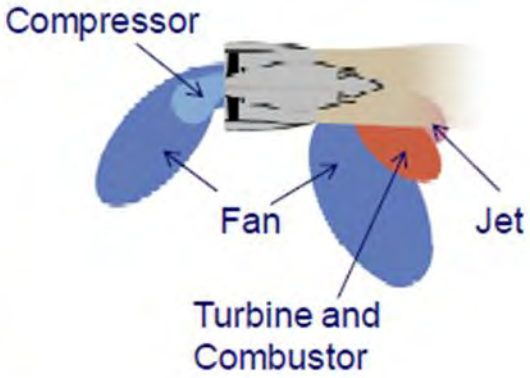
HISTORICAL TRENDS IN ENGINE NOISE SOURCE



Typical 1960s Engine
1:1 BPR



Typical 1990s Engine
6~8:1 BPR

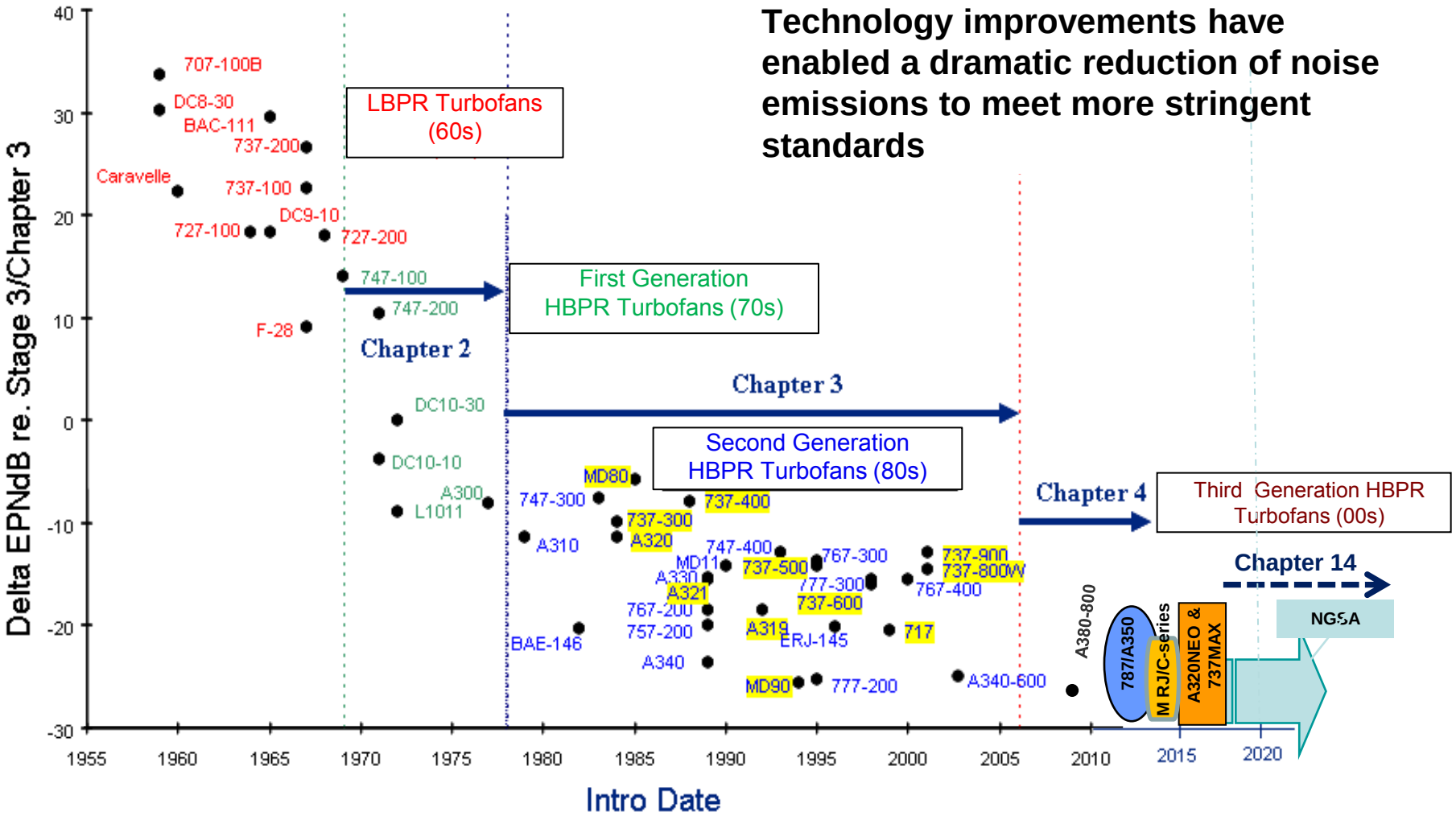


2015 Engine
12:1 BPR
Geared Turbofan

Aft fan noise becomes a dominant noise source for very high bypass ratio engine

* Source provided by Pratt & Whitney to NASA Acoustic Technical Working Group

HISTORICAL TRENDS IN COMMUNITY NOISE



GREEN INNOVATIONS

Increasing Bypass Ratio

Mitsubishi MRJ

Airbus A350 XWB

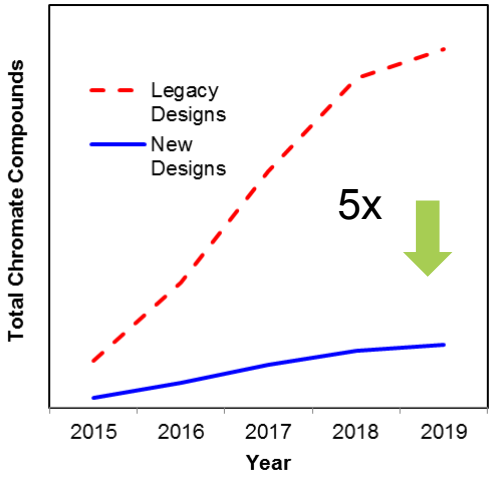
Bombardier CSeries

Embraer E2

Airbus A320neo

360º spliceless acoustic inlet liner

1-4 dB forward fan



Reduced materials of concern use compared to legacy designs

TECHNOLOGY DEMONSTRATORS

QTD2 inlet demonstrator

- ✓ 360º seamless acoustic inner barrel
- ✓ Main landing gear noise fairings
- ✓ Acoustic inlet lip
- ✓ Electric icing tunnel tests

GTF VAFN demonstrator

- ✓ Variable area fan nozzle
- ✓ Resin film infused fan cowl

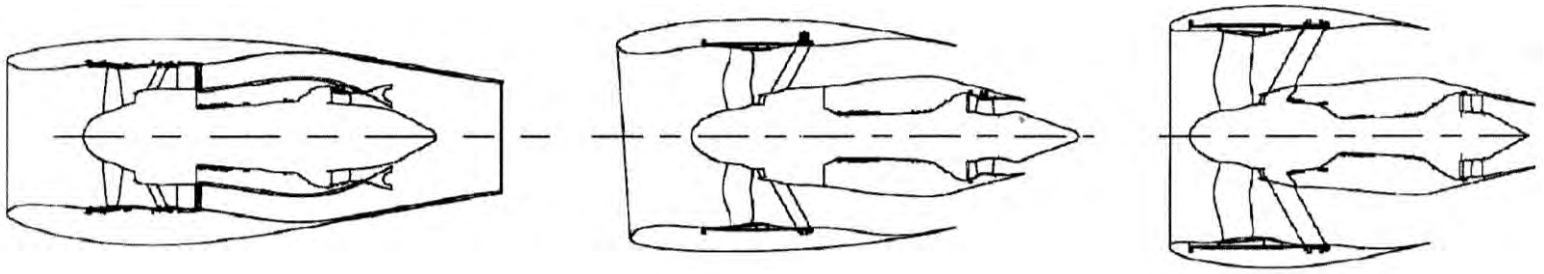
FAA CLEEN II T/R demonstrator

- ✓ Short, clean fan duct
- ✓ Tailored acoustics
- ✓ Advanced manufacturing
- ✓ Innovative materials

Technology demonstrators and collaboration key to maturing technologies

THE NEXT GENERATION

Ultra high bypass ratio (UHBR) engines



Legacy Current UHBR

It is more efficient to move a large amount of air slowly than it is to move a small amount of air quickly

Next generation engines achieve this by:

- Increasing fan diameters and bypass ratios (fan flow : core flow)
- Decreasing fan pressure ratios (out of fan : into fan)

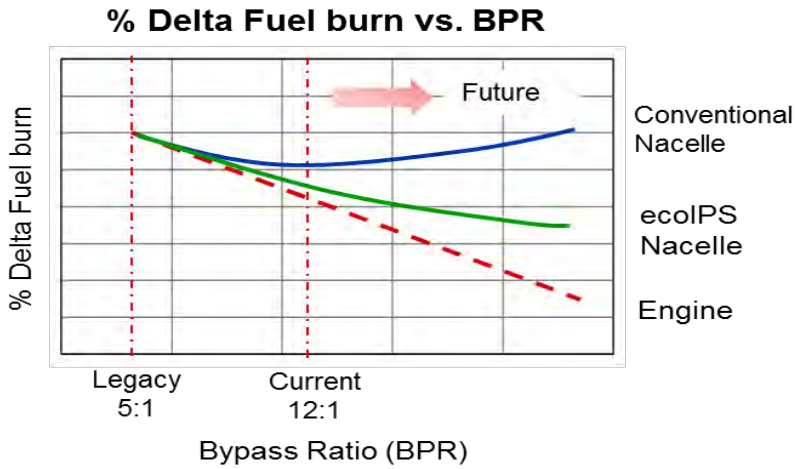
Low fan pressure ratio places a premium on nacelle drag

UHBR drives increased nacelle size, weight and drag

ULTRA HIGH BYPASS RATIO

Future technology solutions

UHBR: Fuel burn benefit



Weight and drag of increasingly larger conventional nacelle offsets performance benefit of lower fan pressure ratio

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Inlet/fan cowl (Fanlet)

Variable area fan nozzle

Novel thrust reverser architecture (FAA CLEEN II demonstrator)

- ✓ Hybrid laminar flow
- ✓ Tailored acoustics
- ✓ Advanced manufacturing
- ✓ Innovative materials




THRUST REVERSER TECHNOLOGIES

CLEEN II demonstrator – key to advance ecoips™

Technology	Benefit
Short, integrated fan duct thrust reverser	~1.0% fuel burn reduction
Advanced acoustics	~2.5 EPNdB noise reduction*

* to offset short fan duct

Legacy Thrust Reverser Fan Duct

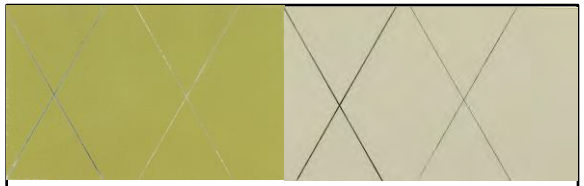
CLEEN II Thrust Reverser Fan Duct

GREEN INITIATIVES

Performance

Fuel burn reduction
Noise reduction

Materials of concern



Chromate replacement

Design for the environment
Alternate materials
Recyclability

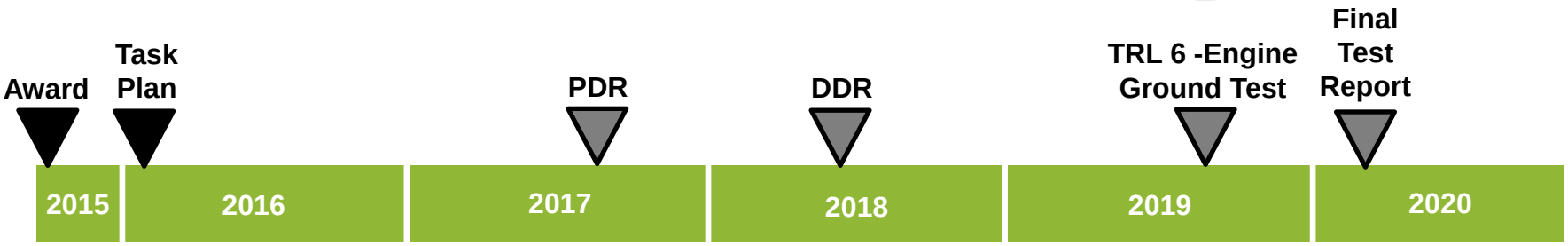
Industrialization

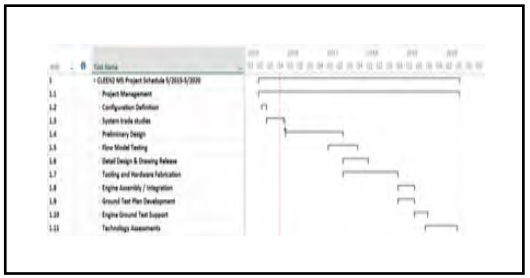
Reduced emissions
Reduced greenhouse gases
Reduced industrial process waste

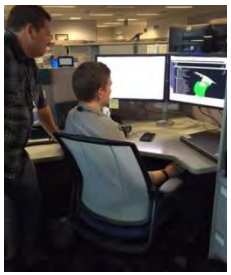
CLEEN II SCHEDULE

Thrust reverser demonstration on P&W GTF Engine

Major Program Milestones







THRUST REVERSER DEMO

Summary

Supports CLEEN II lower energy and noise initiatives

Maximizes efficiency of next generation PPS

Integrated thrust reverser to be matured to TRL6

Selected technologies applicable to the current fleet