COLLINS AEROSPACE

COMMERCIAL AIRCRAFT TECHNOLOGY DEMONSTRATOR

CLEEN II CONSORTIUM PUBLIC PLENARY SESSION

MAY 13, 2020

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ECCN: NSR, CLS12086964

Collins Aerospace

OUTLINE

- Company Overview
- Elevator Speech
- Case for Action
- Program Summary
- Nacelle Technologies
- Technology Risks
- Technology Risk Reduction
- Project Schedule
- Past Achievements
- Remaining Plans (2020)
- Future Plans (2021-2022)
- Summary

Collins Aerospace

COMPANY OVERVIEW

Collins Aerospace

United Technologies

Collins Aerospace
A United Technologies Company

Pratt & Whitney
A United Technologies Company

Carrier

Otis
A United Technologies Company

As of April 3, 2020, Carrier & Otis spun off from United Technologies Corporation (UTC) as UTC merged with Raytheon and became **Raytheon Technologies Corporation**

Collins Aerospace




Raytheon Technologies

The future of aerospace and defense

Raytheon Technologies is an aerospace and defense company that provides advanced systems and services for commercial, military and government customers worldwide.

Our key capabilities

Actuation, Propeller & Landing Systems

Aerostructures

Aircraft Engines & Auxiliary Power Systems

Avionics

Cybersecurity

Data Analytics

Interiors

Missile Defense

Precision Weapons

Systems Integration & Sensors

By the numbers

195,000

Employees

$74B

Pro forma combined annual sales
(2019)

~$8B

Annual company- and customer-funded research and development

60,000

Engineers

40,000

Patents

190+

Years of combined innovation and industry leadership

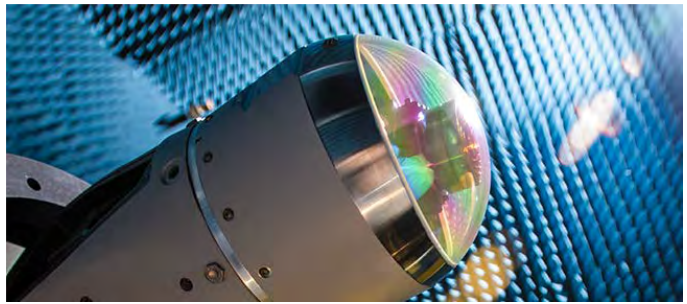
Raytheon Technologies

Collins Aerospace

Pratt & Whitney

Raytheon Intelligence & Space

Raytheon Missiles & Defense



Our businesses

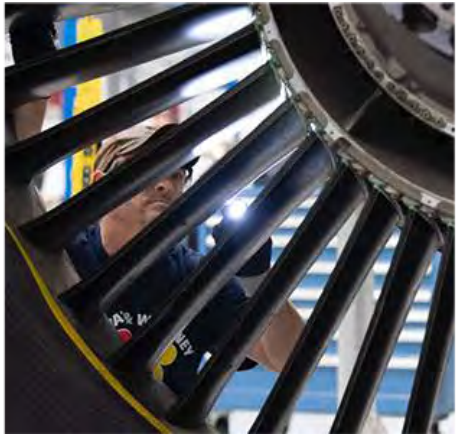
Raytheon Technologies

Collins Aerospace

Raytheon Intelligence & Space

Pratt & Whitney

Raytheon Missiles & Defense



Collins Aerospace

Specializes in aerostructures, avionics, interiors, mechanical systems, mission systems and power controls that serve customers across the commercial, regional, business aviation and military sectors.

$26 billion

2019 net sales

78,000

Employees

ABOUT COLLINS AEROSPACE

Collins Aerospace, a unit of Raytheon Technologies Corp. (NYSE: RTX), is a leader in technologically advanced and intelligent solutions for the global aerospace and defense industry.

Created in 2018 by bringing together UTC Aerospace Systems and Rockwell Collins, Collins Aerospace has the capabilities, comprehensive portfolio and expertise to solve customers' toughest challenges and to meet the demands of a rapidly evolving global market.

Collins Aerospace

OUR SYSTEMS MAKE MODERN FLIGHT POSSIBLE

WE **POWER** IT
WE **START** IT
WE **VENTILATE** IT
WE **CONTROL** IT
WE **MONITOR** IT
WE **PROTECT** IT
WE **LAND** IT
WE **STOP** IT

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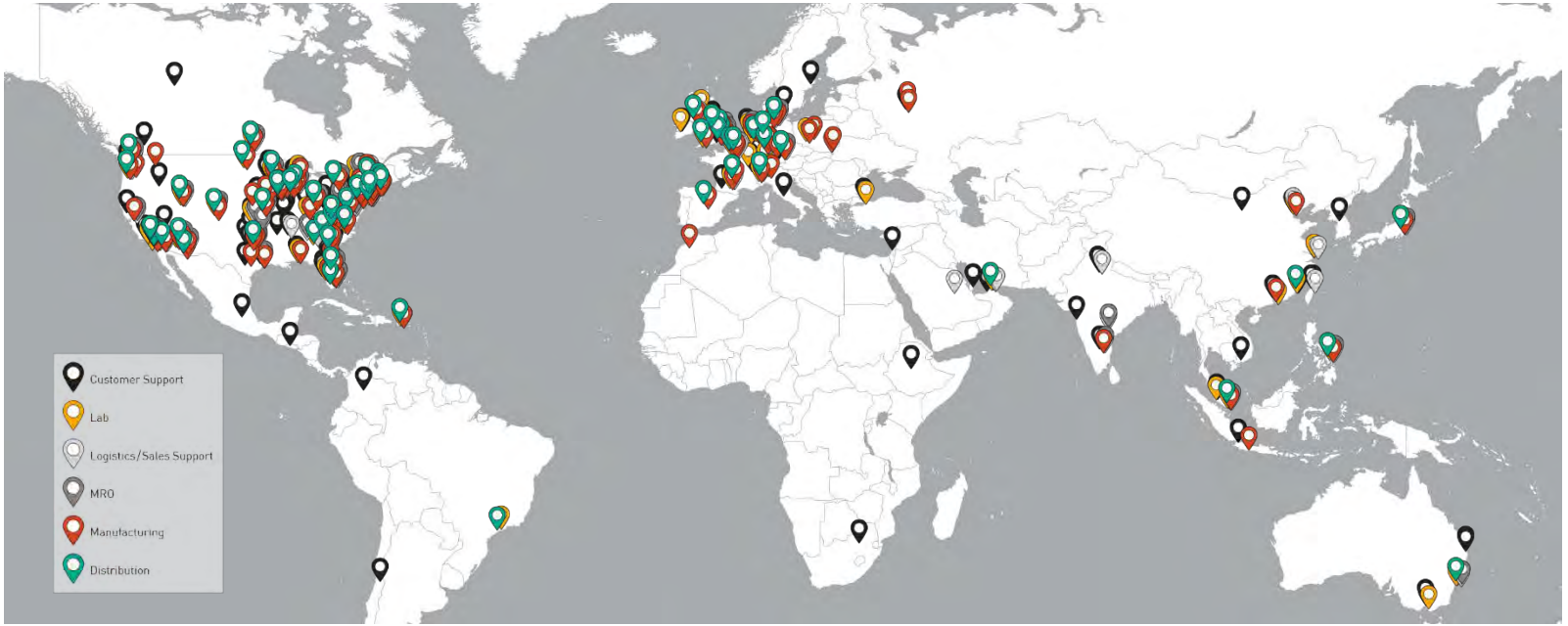
GLOBAL LOCATIONS, LOCAL SUPPORT



NEARLY 300 SITES WORLDWIDE

Where you need us, when you need us – everywhere, every day

Collins Aerospace

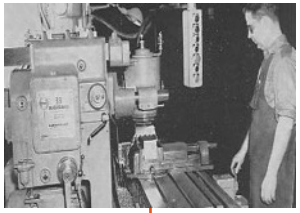
LEGACY OF INNOVATION

AVIONICS AND COMMUNICATIONS

Arthur Collins

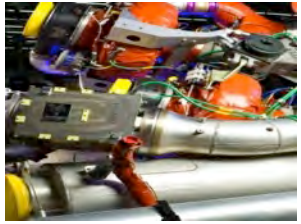
ELECTRIC SYSTEMS

David Sundstrand



ENVIRONMENTAL CONTROL SYSTEMS

Thomas Hamilton

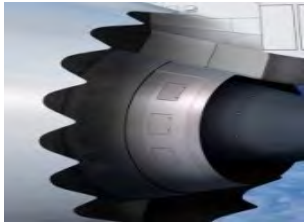


LANDING SYSTEMS

Benjamin Goodrich

NACELLES

Fred Rohr



PROPELLER SYSTEMS

Paulin Ratier

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STRATEGIC BUSINESS UNITS

Aerostructures

Avionics

Interiors

Mechanical Systems

Mission Systems

Power & Controls

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COLLINS AEROSPACE – AEROSTRUCTURES

Based in Chula Vista, California

We design, invent and deliver the
MOST ADVANCED AND DIVERSE
range of aerospace systems
- and solutions -
on the market

Propulsion

- Nacelle systems
- EBUs
- Engine mounts
- Pylons

Non-Propulsion

- Flight-control surfaces
- Tailcones
- Doors
- Radomes
- Naval composites

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COLLINS AEROSPACE – AEROSTRUCTURES

Key Products and Systems

Nacelle systems

Pylons and fairings

Tailcones

Key Platforms

Collins Aerospace – Aerostructures

Industry-leading independent supplier and integrator of nacelles and pylons, offering complete lifecycle design/build/support for large commercial, regional and business jet customers around the world

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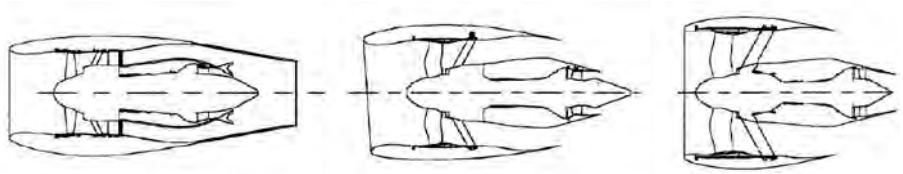
ELEVATOR SPEECH

Aerodynamically and acoustically optimized Inlet and Fan Duct architectures, enabling lower emissions, energy and noise initiatives, aimed at maximizing efficiency of the next-generation high bypass ratio propulsion systems for reducing climate impact from aviation.

CASE FOR ACTION



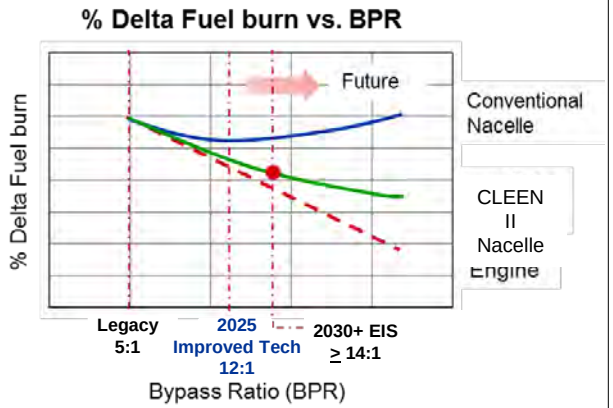
Legacy ~5:1 BPR or less

Improved technology ~12:1
Product Introduction 2025

Next Gen. technology ~15:1+
Entry into Service now 2030+

Collins Aerospace CLEEN II technology scope aligned with 2025 Middle of Market

UHBR: Fuel burn benefit



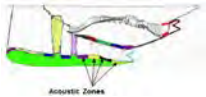
CLEEN II

Clean Fan Duct

Short Inlet

FAA CLEEN II acoustic demo

- ✓ Short Inlet & Clean Fan Duct
- ✓ Novel Acoustics
- ✓ Advanced Manufacturing
- ✓ Innovative Materials



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PROGRAM SUMMARY

BENEFITS

CLEEN II Short Inlet

No Increase

- 0.5%

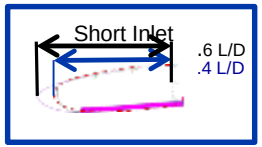
CLEEN II Clean Fan Duct

-2.0 EPNdB

- 0.55%

TECHNOLOGIES – SHORT INLET

Short Inlet



Anticipated Benefits:

- -0.5% fuel burn

Risks/Mitigations:

- Perforations requirements to produce attenuation may not be well understood.
  - Develop perforation model
- Scale up fabrication issues may not be well understood
  - Perform experimentation on large scale equipment

Objectives:

- Develop and demonstrate a low cost, structural, bond panel with DDOF acoustic performance

Work Statement:

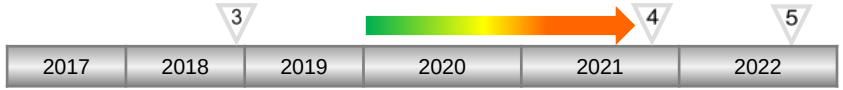
- Develop concepts & down select technologies
- Test prototypes to confirm attenuation
- Confirm producibility & cost
- Test fabricated panels in relevant environment

Accomplishments:

- Collaboration partner identified (Complete)
- Agreement in place (Complete)
- Design concepts developed (Complete)
- Initial prototypes fabricated (Complete)

Schedule:

- COVID-19 impact
- Proposed extension in work with the FAA



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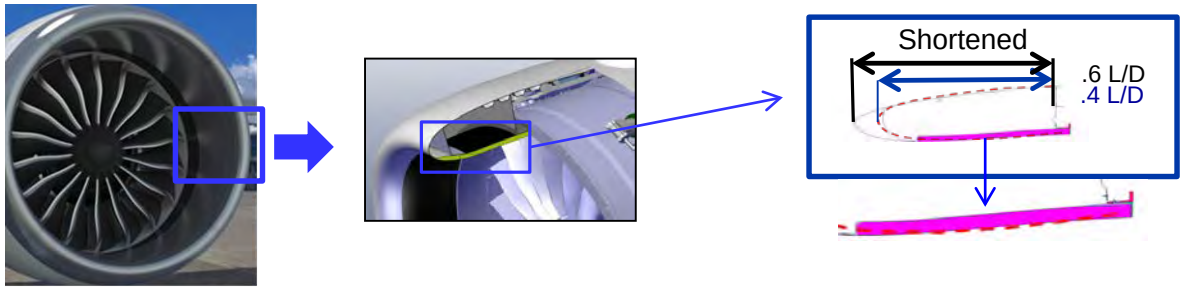
SHORT INLET TECHNOLOGIES

Technology	Goal Impact	Benefits and Application
Short Inlet	Fuel burn	~0.5% reduction.
Advanced acoustics	Noise reduction	~0.0 EPNdB reduction. (Maintain Acoustics with shorter inlet)

CLEEN II Short Inlet



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TECHNOLOGY RISKS OF SHORT INLET ARCHITECTURE

Challenge:
Inlet innovative core development for shorter nacelle aero lines

Risks:

- Acoustic area limitations due to shorter nacelle aero lines
- Manufacturing methods of new and more effective acoustic treatment
- Test limitations – validation of short inlet acoustics

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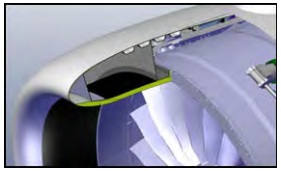
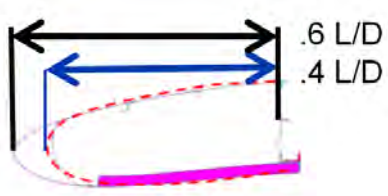
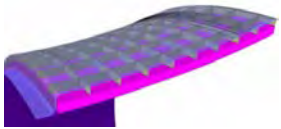
TECHNOLOGY RISK REDUCTION



- Developing **next-generation acoustic core**
  - **Improve acoustic** performance through unique **non-conventional geometries**
  - **Large acoustic cell** configuration **in development**
  - **Producible/Cost-effective** large acoustic cavity **configuration**





Large Acoustic Cell Concepts In Work
IP Sensitive

Producible design concepts in work for acoustic testing

TECHNOLOGY RISKS OF SHORT INLET ARCHITECTURE

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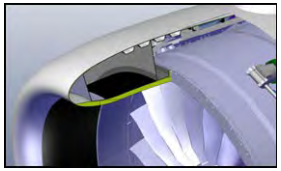
TECHNOLOGY RISK REDUCTION



- **Optimizing the acoustic** solution to **enable implementation**
  - I**nnovative industry source and Collins next-generation core** collaboration underway
  - **Cost-effective / producible solution** concepts identified
  - **Next-generation designs prototypes** in build for testing

Collins Aerospace Intellectual Property Sensitive

Collaboration initiated in 2020. Design concepts identified & initial prototypes created

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TECHNOLOGY RISKS OF SHORT INLET ARCHITECTURE

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- Manufacturing methods of new and more effective acoustic treatment
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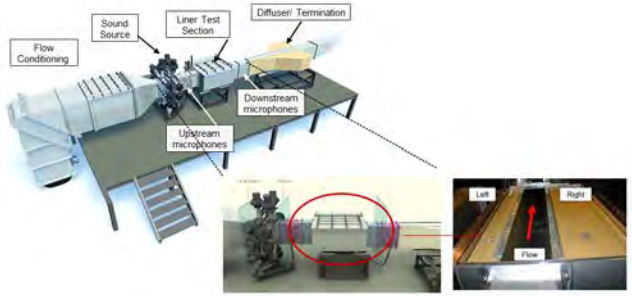
TECHNOLOGY RISK REDUCTION

- Utilize **NASA LaRC CDTR (Curved Duct Test Rig)** followed by **NASA ANCF (Advanced Noise Control Fan)**, operated by the University of Notre Dame Turbomachinery Lab, test facilities to validate acoustics
- CLEEN II **Acoustic prediction tools** will be **validated** based on CDTR test
- **CDTR core design optimization** initiated but now on hold
- **Short Inlet efforts** will resume in 2021

CDTR Test Facility



TRL 4

ANCF Test Facility

TRL 5

Advanced Tailored Acoustic design feasibility will be verified by test and analysis to resume in 2021

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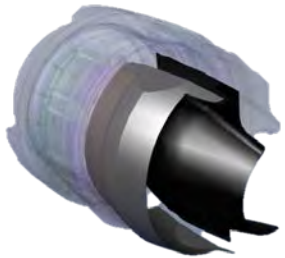
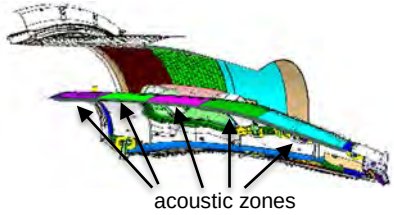
Acoustic Ground Test Clean Fan Duct for HBR Engines





Anticipated Benefits:

- -2.0 EPNdB noise

Risks/Mitigation Plans:

- Acoustic performance/subscale tests, acoustic optimization models
- Load levels & paths, subscale tests, stress model correlation
- Manufacturing tooling and assembly
- Test stand integration/work with P&W

Objectives:

- Achieve TRL6 for Clean Fan Duct acoustics
- Validate anticipated benefits

Work Statement:

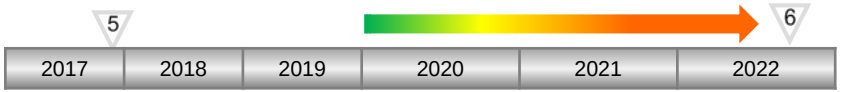
- Develop ground test demonstrator
- Do subscale acoustic tests to validate models
- Perform full-scale engine ground test
- Use test data & validated analyses to project aircraft-level benefits

Accomplishments:

- Engine platform & test facilities identified
- TRL5 achieved for three technologies
- Ground test TR passed DDR in Sep ’19
- IFS and XLS perforations complete; IFS bond panel assembly in progress as of May ’20

Schedule:

- COVID-19 impact
- Proposed extension in work with the FAA



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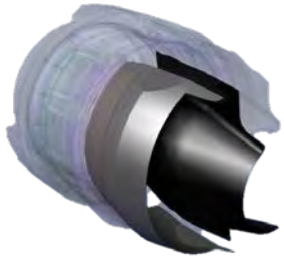
CLEAN FAN DUCT TECHNOLOGIES

Technology	Goal Impact	Benefits and Application
Clean fan duct Thrust Reverser	Fuel burn	~0.5% reduction Demo designed for 25,000-40,000 lb thrust-class engines with expected entry into service by 2025
Advanced tailored acoustics	Noise reduction	~2.0 EPNdB reduction. (Zoned Acoustics & Area Maximization)

Zoned/Thin Acoustics & Area Maximization



Low Drag Surface

Fewer Airflow Obstructions

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TECHNOLOGY RISKS OF CLEAN FAN DUCT T/R

Challenge:
Thrust Reverser design for a maximized acoustic clean fan duct

Risks:

- Acoustic maximization for clean duct aero lines
- Verification of structural capability and design
- Fabrication methods and locations for ground test TR

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TECHNOLOGY RISKS OF CLEAN FAN DUCT T/R

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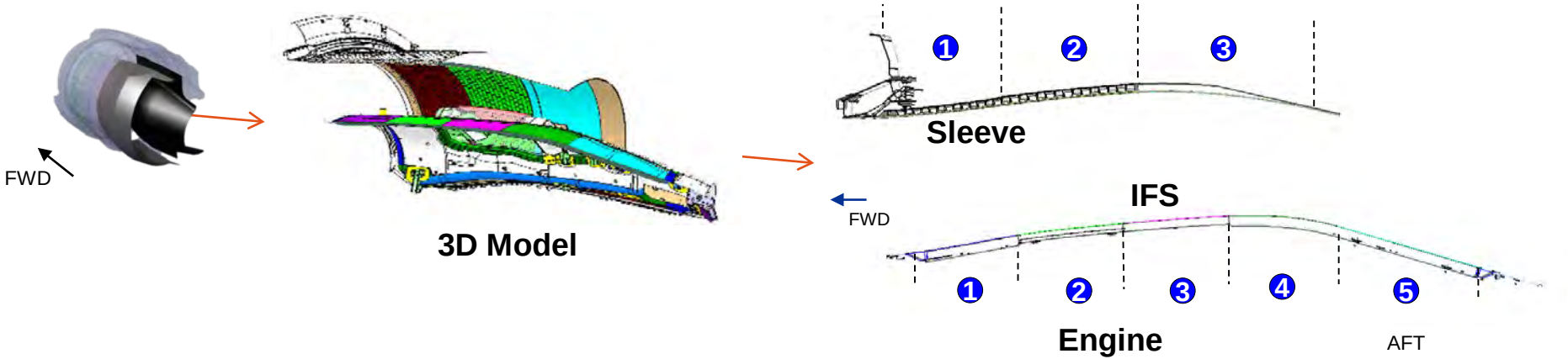
TECHNOLOGY RISK REDUCTION

- CLEEN II clean duct demonstrator design configuration finalized and all drawings released
  - Area maximized and zoned liner optimization complete: 3 zones in Sleeves & 4 acoustic zones + Aft in IFS
  - Low drag liner design integrated into zoned liner
  - Risk now in producing prototype configuration



Advanced tailored acoustic design fully released and in build

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TECHNOLOGY RISKS OF CLEAN FAN DUCT T/R

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- Verification of structural capability and design
- Fabrication methods and locations for ground test TR

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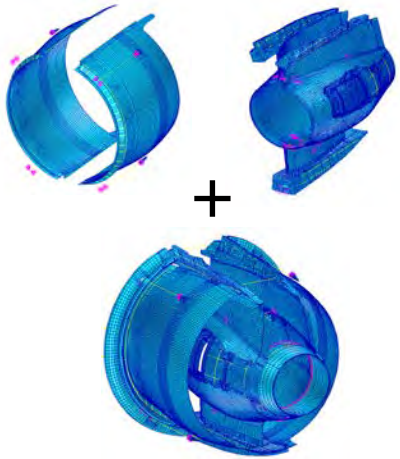
TECHNOLOGY RISK REDUCTION

Ground Test Structural Analysis Complete

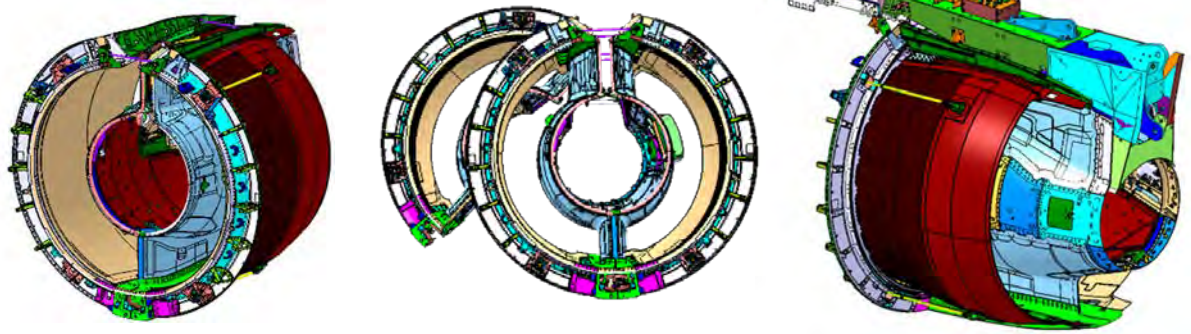
- All margins of safety positive
- Analysis records approved
- No detrimental impact on rotor dynamics

Bond Panel design complete

- 90 IFS and 159 XLS drawings released
- Test stand clash study complete
- Detail Design Review (DDR) successful
- IFS and XLS skin perforations complete



All Positive Margins



All Drawings Released

Structural analysis approved; Design 100% released; Acoustic & Low Drag objectives achieved.

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TECHNOLOGY RISKS OF CLEAN FAN DUCT T/R

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Risks:

- Acoustic maximization for clean duct aero lines
- Verification of structural capability and design
- Fabrication methods and locations for ground test TR

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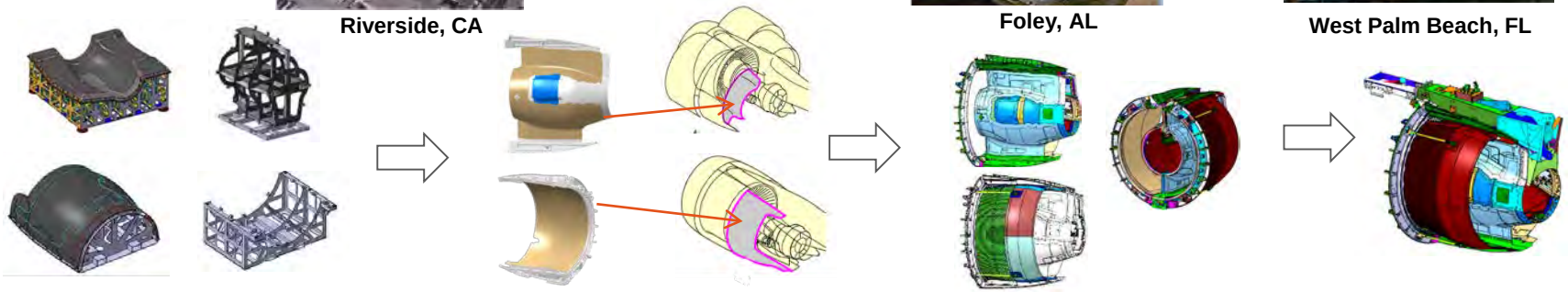
TECHNOLOGY RISK REDUCTION

- Tooling for bond panel fabrication on site in Riverside, CA facility
  - Supports 2020 build schedule
  - Core and flow skin fabrication complete as of January 2020 and skin perforation complete as of April 2020
- Bond panel and Thrust Reverser fabrication process finalized
  - XLS & IFS Bond panel fabrication in Riverside, California (2020)
  - Thrust Reverser assembly in Foley, Alabama (Q1/Q2 2021)

Riverside, CA

Foley, AL

West Palm Beach, FL



Bond panel fabrication in progress & TR hardware ordered

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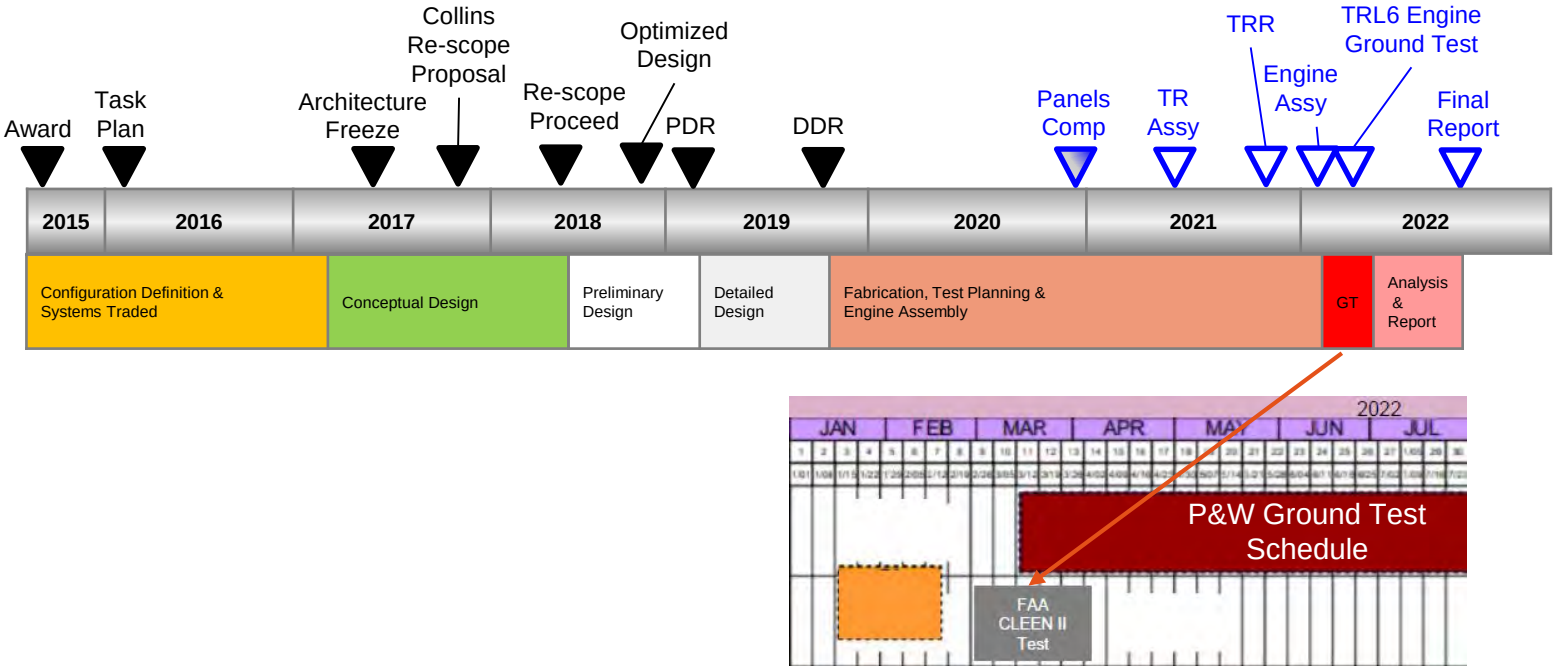
PROJECT SCHEDULE: POST-COVID19

(Proposed Extension to FAA)



Completed Milestone In Work Planned Milestone

PAST ACHIEVEMENTS

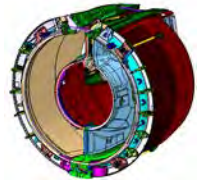
2012 – 2015 IRAD
30+ Short/Clean Duct Configs.

2 Short/Clean Duct Configs.

TR Actuation Integration Workshop

Test Engine/Pylon Integration Workshop

Preliminary Layout



Kick-Off Meeting w/PW and APS

Demo Config. Down Select

Demo Aerolines

Architecture Freeze

Scope Change Proposal

Engine Selected

Preliminary Design & Analysis

Release Initial Assembly Drawings

Hold PDR

Hold DDR

Complete Core & Flow Skin Fabrication

2016 | 2017 | 2018 | 2019

TRL4 Acoustics

TR Test Rig Design

TR Test Rig Fab

TRL5 Acoustics

Flow Model Design

Product Path Definition

TR Test Rig Kinematics / Vibration Testing

▲ Completed Milestone

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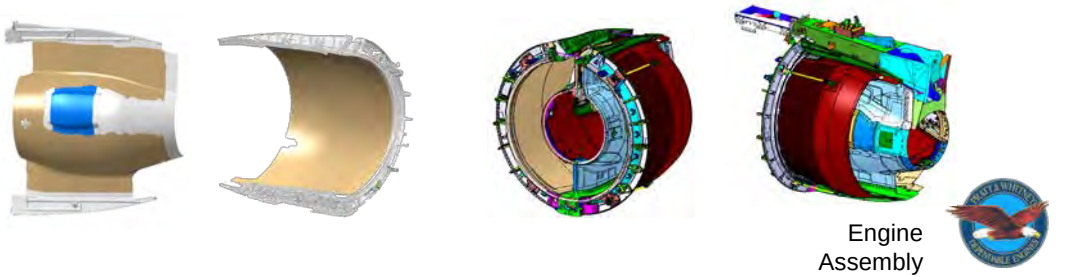
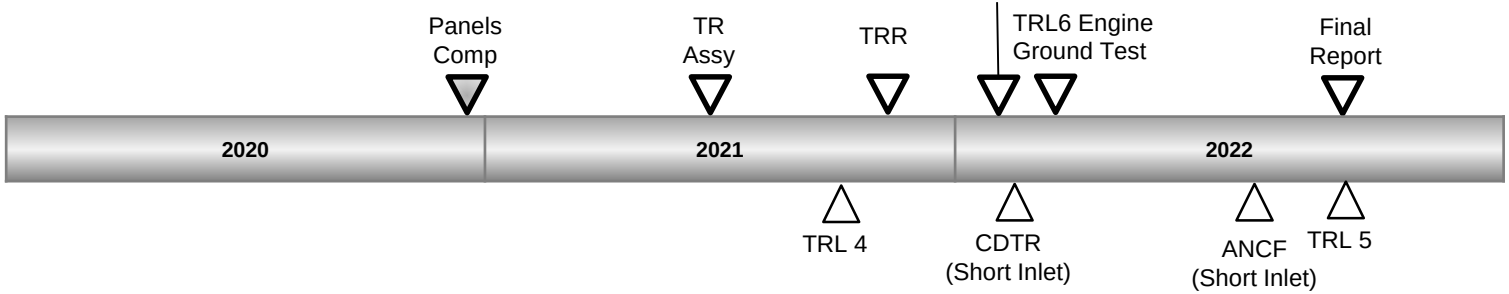
POST-COVID-19 PLAN (2020-2022)

(Proposed Extension to FAA)





▲ Completed Milestone △ Planned Milestone

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SUMMARY

- Efforts target maximizing efficiency of 2025 high bypass ratio propulsion systems
- Technologies align with next-generation single aisle, new midsize, and middle of the market aircraft
- Architectures support CLEEN II lower energy and noise initiatives
- Selected technologies applicable for performance insertion on current production programs
- Fabrication of flow skins and perforations have been completed and core details underway. Bond panel fabrication is to begin in May 2020.
- Due to COVID-19 impact, the proposed ground test has been moved to March 2022 per Collins fabrication schedule and P&W's ground test stand availability.

THANKS!

Any Questions?