UTC Aerospace Systems

INTEGRATED PROPULSION SYSTEM THRUST REVERSER TECHNOLOGY DEMONSTRATOR

CLEEN II Consortium Public Plenary Session

Presenter: Louis Jutras

May 3rd, 2017

Outline

- Company overview
- Case for Action
- Technologies
- Challenges / Solutions
- Program Organization
- Schedule
- Year 1 Achievements
- Year 2 Plans
- Spend Strategy
- 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

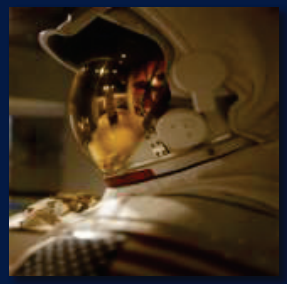
Located in approximately 70 countries around the world

2016 net sales of $58B

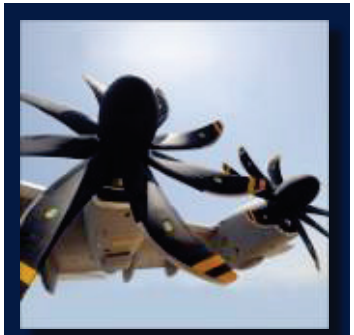
UTC Aerospace Systems (UTAS)

Business Units

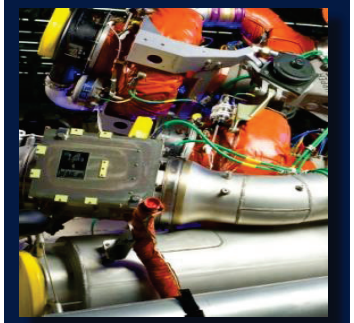
Aerostructures



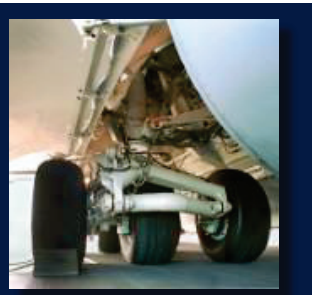
ISR & Space Systems



Interiors, Actuation & Propeller Systems



Electric, Environmental & Engine Systems



Landing Systems

Sensors & Integrated Systems

UTC Aerospace Systems

UTAS Aerostructures

Key Products and Systems

Nacelle systems

Pylons and fairings

Tailcones

Key Platforms

UTC Aerospace Systems – Aerostructures

Industry 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

UTAS Achieving a Low Carbon Footprint

Since 2006 we have …

Greenhouse Gas

20%

- Reduced the demand of natural resources by almost **148,000 metric tons** of GHGs.
- That's the equivalent of over 31,136 passenger cars taken off of the road!

CONSERVE

Solar Arrays
LEDs
Building automation
Equipment efficiency

… and will continue to conserve.

UTC Aerospace Systems

UTAS Achieving a Low Carbon Footprint

Since 2006 we have …

Water

16%

- Conserved nearly **131,000,000 gallons.**
- That amount could fill more than 198 Olympic sized swimming pools!

REUSE

Reclaimed industrial water
Rainwater harvesting
Wastewater treatment

… and will continue to conserve.

UTC Aerospace Systems

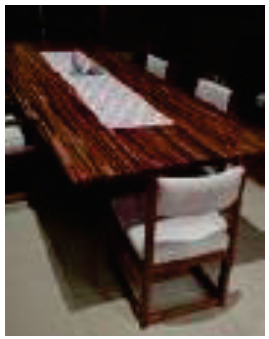
UTAS Achieving a Low Carbon Footprint

Since 2006 we have …

Waste

26%

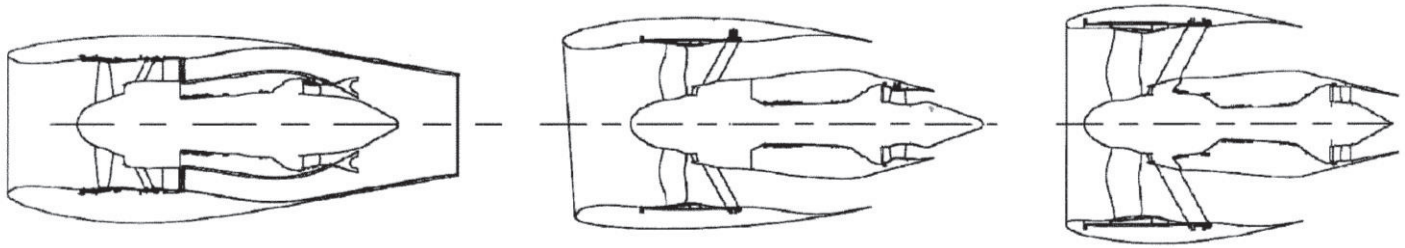
- Reduced waste produced by more than **30,000,000 pounds.**
- That amount of waste is estimated to be equal to 99 empty jetliners!!



INNOVATION
Reduce at supply
Appropriate use
Reuse

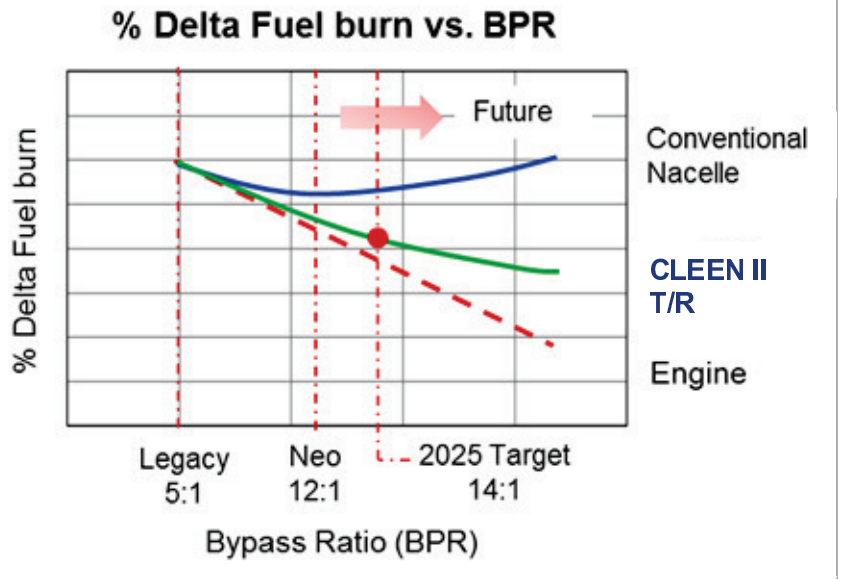
… and will continue to conserve.

Case For Action



Legacy- 6:1 BPR or less | Current technology- 12:1 | Next Gen. technology- 15:1+

UHBR: Fuel burn benefit



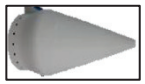
ecoIPS™

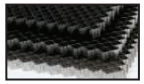
Inlet (NASA/PW FDC)

Variable area fan nozzle (option)

Novel thrust reverser architecture **(FAA CLEEN II demonstrator)**

- ✓ Short, clean fan duct
- ✓ Laminar flow
- ✓ Novel acoustics
- ✓ Advanced manufacturing
- ✓ Innovative materials

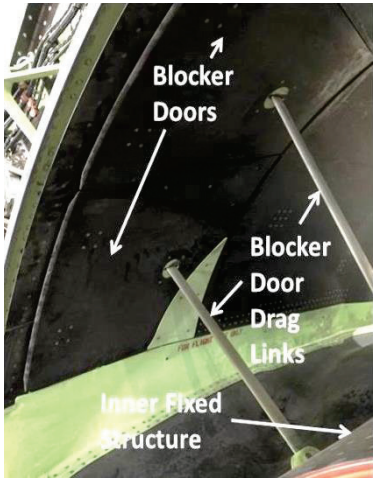


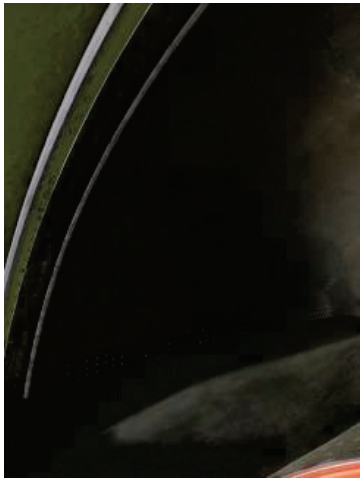



Thrust Reverser Technologies

Technology	Goal Impact	Benefits and Application
Short, clean fan duct Thrust Reverser	Fuel burn	~1.0% reduction. Demo designed for 25,000-40,000 lb thrust-class engines with expected entry into service by 2025.
Advanced tailored acoustics	Noise reduction	~2.5 EPNdB reduction. (to offset short fan duct)

Legacy Thrust Reverser Fan Duct

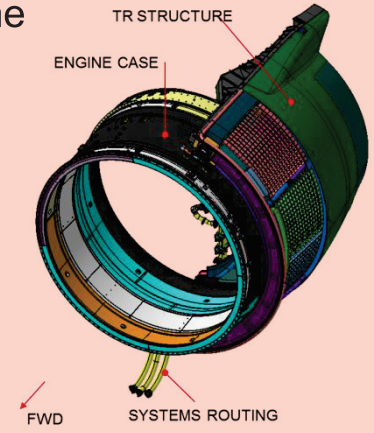


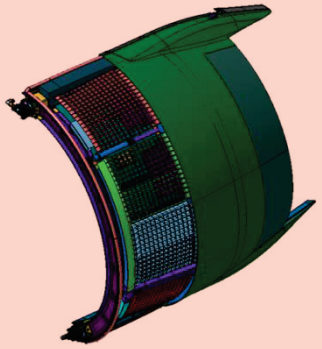


CLEEN II Thrust Reverser Fan Duct

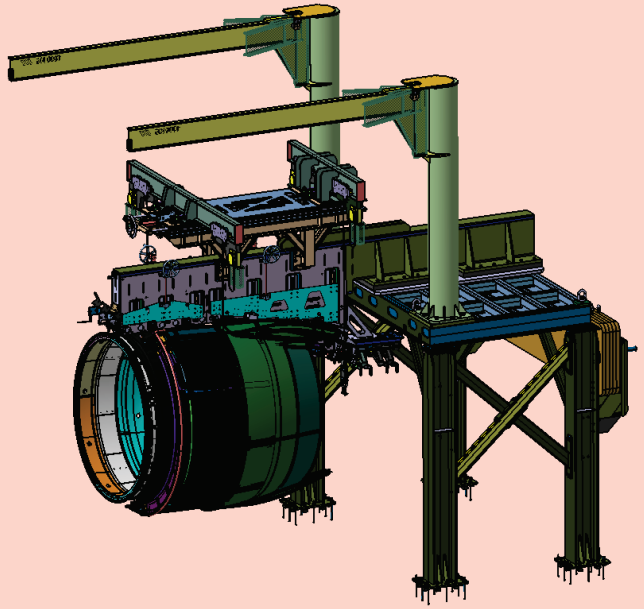
Challenges / Solutions of Novel T/R Architecture

Challenges	Solutions
Engine Packaging and Integration due to shorter nacelle aero lines but same A320neo engine case dimensions and pylon interfaces • T/R structure packaging on A320neo engine • Identifying idealized T/R interfaces • Maintaining reverser thrust performance with less nacelle volume	• Collaborating with UTRC aero and Pratt & Whitney test engineering • Novel T/R configuration and actuation mechanism • Integrated Technology Development Plan • UTAS Product Introduction Process • Conducting Failure Mode Effects and Analysis





Challenges / Solutions of Novel T/R Architecture

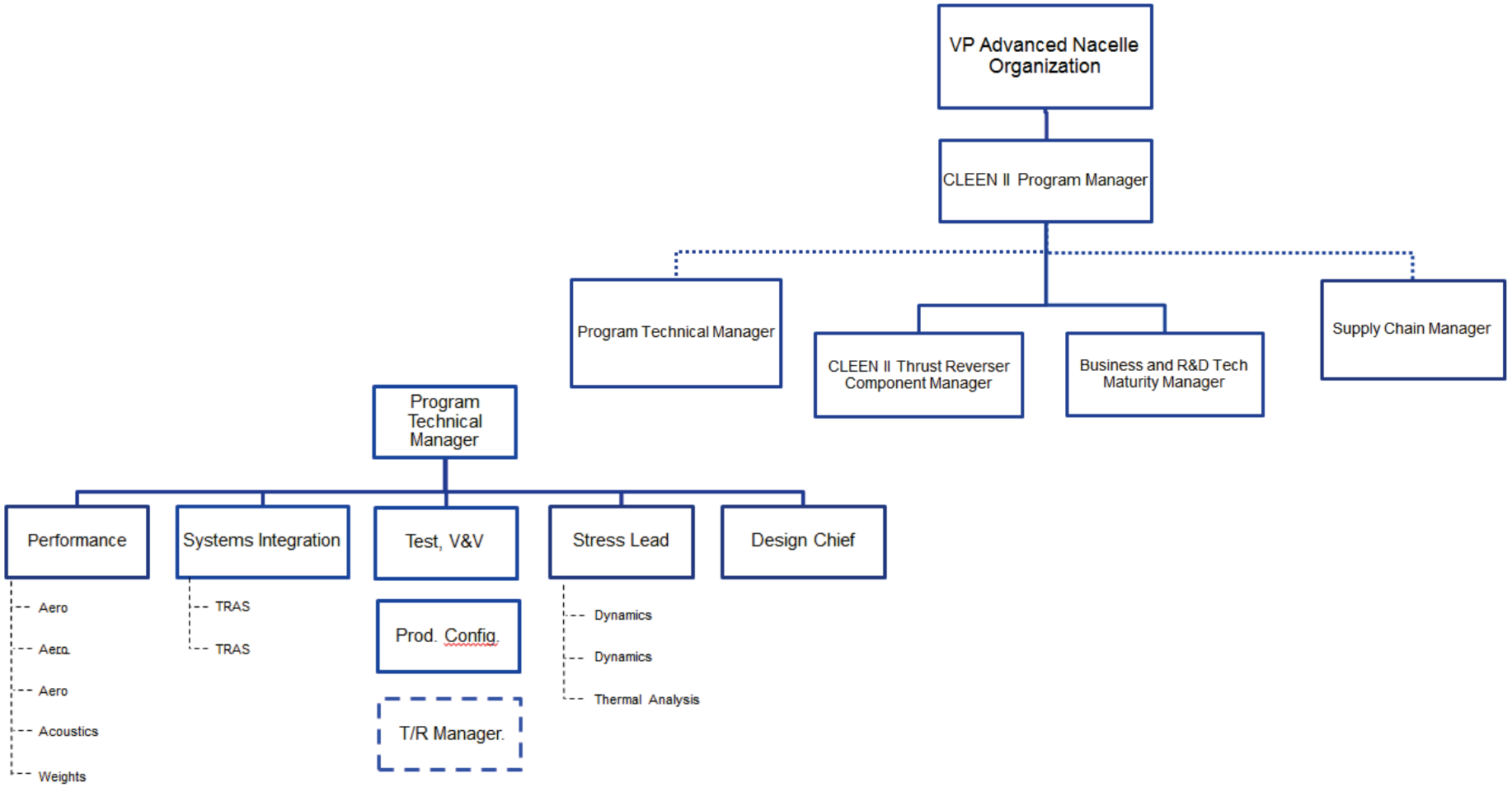
Challenges	Solutions
Changes in Vibration levels, Load Paths, Kinematics	Scaled validation test rigs for TRL-4, 5, 6 Utilizing A320neo C-Frame to evaluate all-up kinematics (TRL-5 rig)  Requesting out-of-balance engine to measure dynamic response

Challenges / Solutions of Novel T/R Architecture

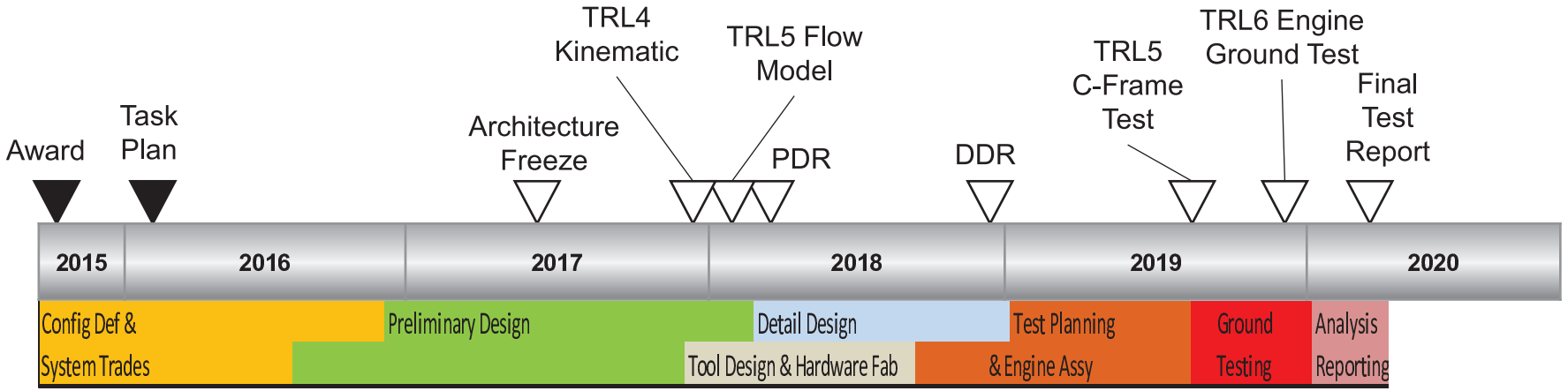
Challenges	Solutions
Acoustic limitations due to shorter nacelles aero lines  Shorter Thrust Reverser than Legacy designs	Novel acoustic treatments Noise testing 
Actuation system packaging, load paths and displacement.	Actively collaborating with industry leading suppliers
Test limitations – can't directly measure aircraft fuel burn and noise benefits on an engine ground test	Combining testing with validated performance models Sub-scale aerodynamic + acoustic testing to support model validations

Program Organization

Established a Program team structure:



Schedule



▲ Completed Milestone △ Planned Milestone

Year 1 achievements (2016)

Shorter Thrust Reverser than Legacy designs

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

Kick-Off Meeting w/PW and APS

2 Short/Clean Duct Configs.

TR Actuation Integration Workshop

Demo Config. Down Select

TRL3*

UPI Implementation / Deliverables Mapping

Q1 | Q2 | Q3 | Q4

TRL4 Acoustics

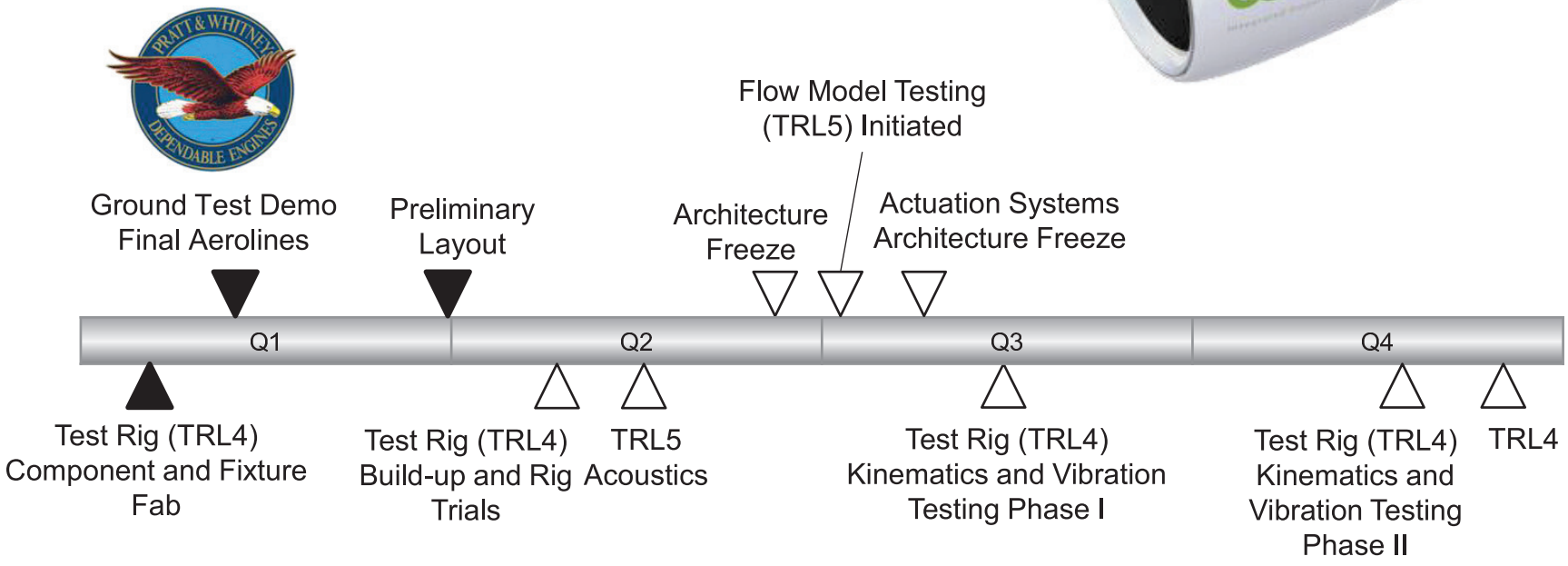
Test Engine/Pylon Integration Workshop

TR Test Rig Design TRL4

*TRL 3 attained 2015 for previous baseline short duct configuration

▲ Completed Milestone

Year 2 Plans (2017)



▲ Completed Milestone △ Planned Milestone

Summary

- Novel T/R architecture supports CLEEN II lower energy and noise initiatives
- Aimed at maximizing efficiency of next generation ultra-high bypass ratio propulsion systems
- Technologies applicable to next generation nacelles for Next Generation Single Aisle, New Midsize Airplane, Middle of the Market
- Novel T/R architecture to be matured to TRL6
- TRL4 Test rig detail parts on site in Chula Vista, CA
- Ground Test demonstrator configuration frozen
- Selected technologies applicable to performance insertion on current production programs