FAA Continuous Lower Energy, Emissions & Noise (CLEEN) Technologies

Rolls-Royce Program Overview

27 October 2010

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Rolls-Royce CLEEN Technologies Program

Fuel Burn Reduction

Dual-Wall Turbine Blades
Design, Fabricate, Engine Test

CMC Turbine Blade Tracks
Design, Fabricate, Engine Test

Alternative Fuels Feasibility

AE 3007 Demonstration
Lab & Rig Test; Engine & Flight Demo

RB211-524 Demonstration
Lab & Rig Test; Engine Demo

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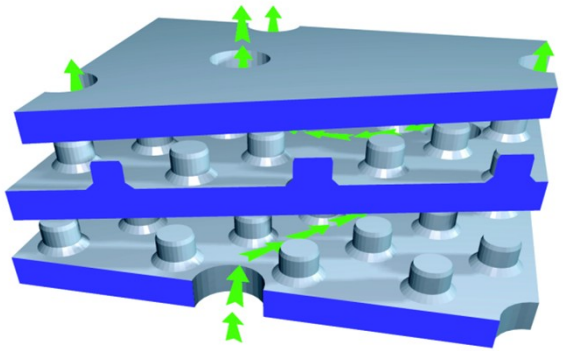
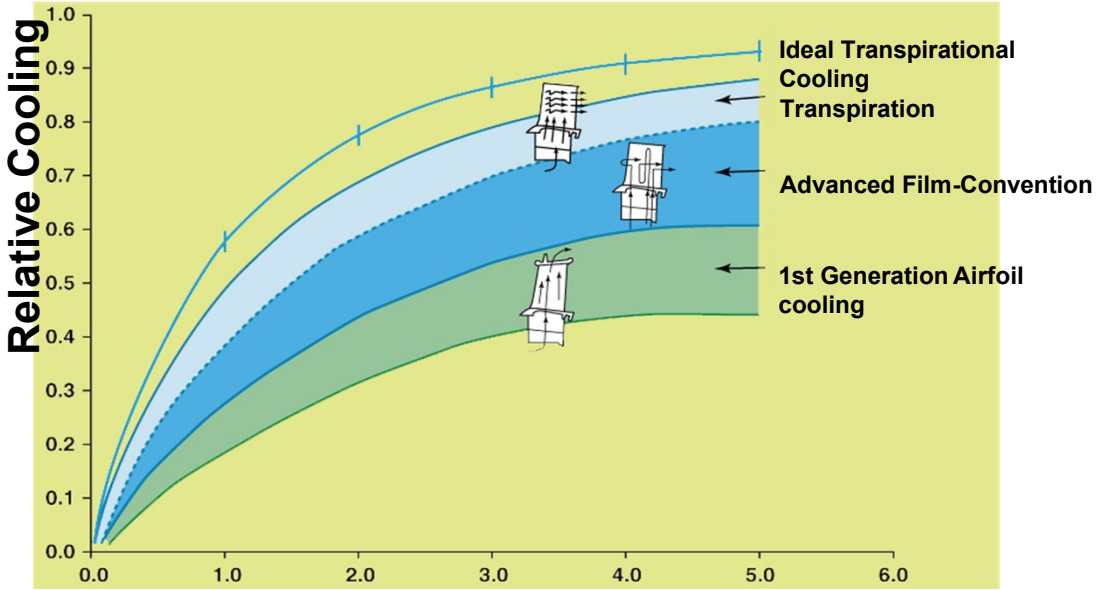
Dual-Wall Turbine Blades

- **Rolls-Royce has developed and patented high effectiveness, dual-wall turbine airfoil cooling systems for hot temperature applications**



Cooling Airflow



Cooling Airflow Parameter

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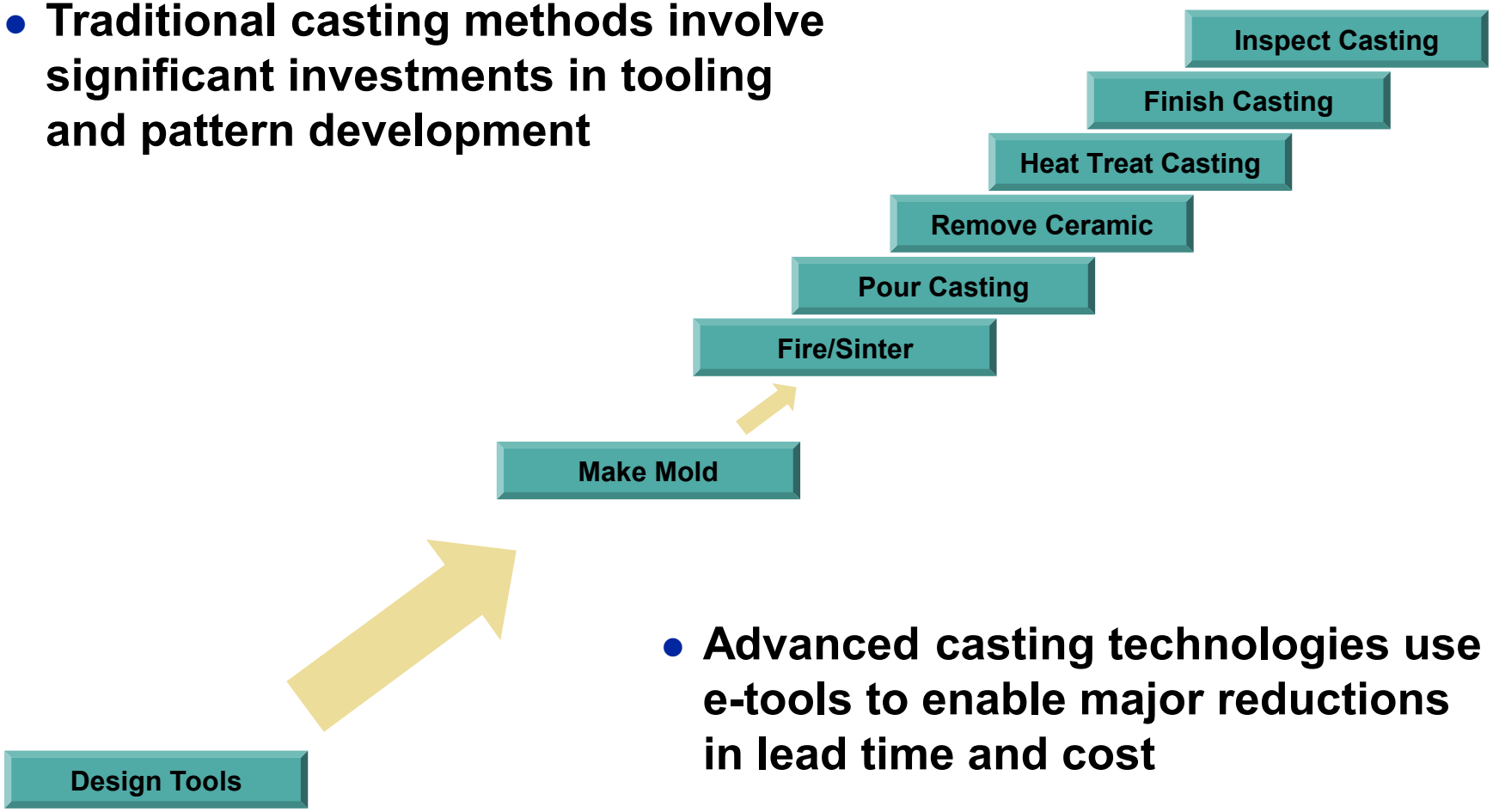
Dual-Wall Turbine Blades

- Traditional casting methods involve significant investments in tooling and pattern development



- Advanced casting technologies use e-tools to enable major reductions in lead time and cost

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Dual-Wall Turbine Blades

- **LeanCool™ technology combines these advanced cooling and casting technologies**
  - Achieves reduced fuel burn with low weight, long life, and affordability
- **Under FAA CLEEN, Rolls-Royce will design, manufacture, and test LeanCool blades**
  - Technology demonstration will be conducted as part of the UK Environmentally Friendly Engine (EFE) program
    - *Thermal Paint build will provide thermal effectiveness data*
    - *Cyclic Endurance build will demonstrate durability and useful life*
- **Key Challenges**
  - Casting yield due to the highly complex internal blade geometry
  - Cooling effectiveness due to capability/constraints of casting process

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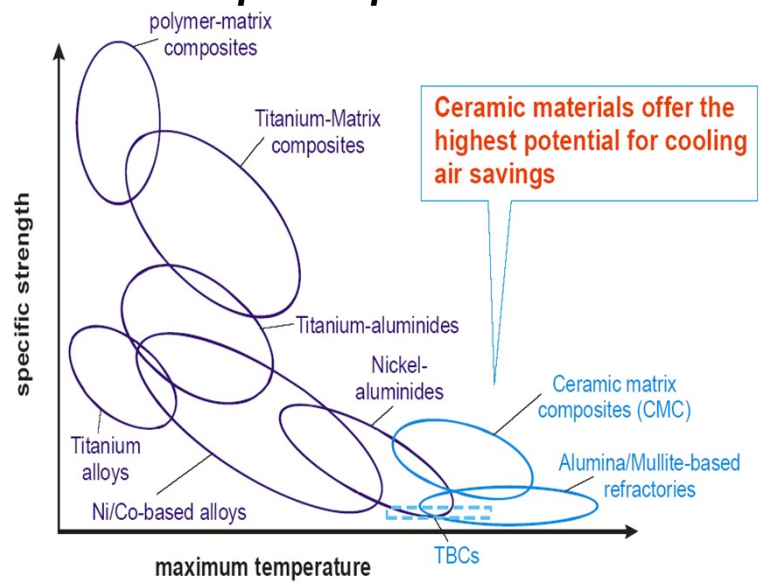
CMC Turbine Blade Tracks

- **Benefits of CMCs**
  - CMCs provide significant weight savings – 1/3 density of Ni-based superalloys
  - CMCs provide higher temperature capability
    - *Ox/Ox to ~2100-2200°F*
    - *SiC/SiC to ~2200-2450°F*
  - Hotter walls reduces cooling needs – reduced emissions
  - Low thermal expansion provides better match to functional coatings
  - Non-strategic materials

Unique Properties of CMCs



- **Issues for CMCs:**
  - Cost
  - Low Strength
  - Environmental resistance

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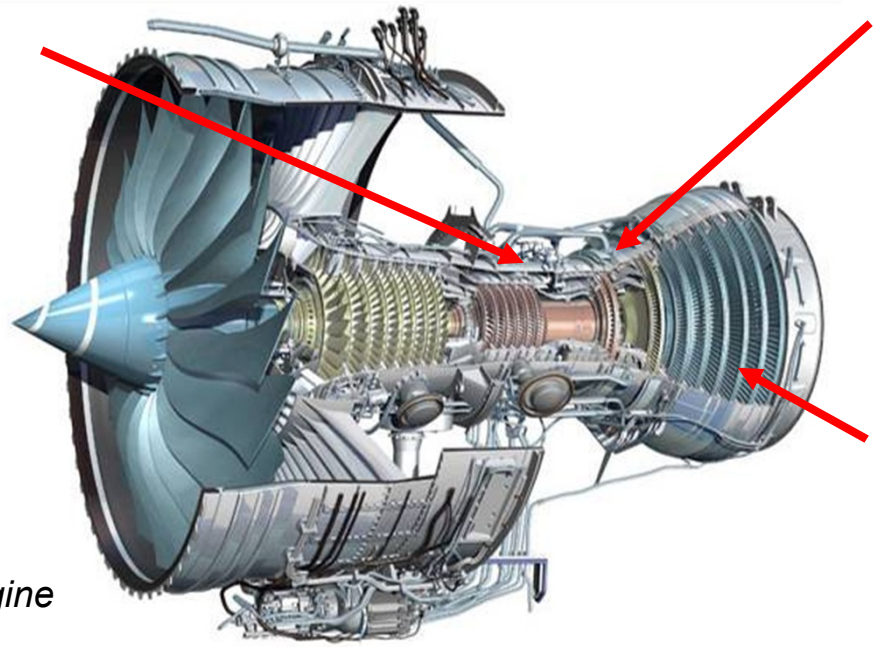
CMC Turbine Blade Tracks

- **CMC components offer significant advantages in capability, performance, and weight**

<u>Combustion liners</u>
Increased wall temperature
Reduced emissions



Large Civil
3-Shaft Engine

<u>Blade tracks/shrouds</u>
Increased temperature
Reduced weight
Improved SFC

<u>Airfoils (blades/vanes)</u>
Increased temperature
Reduced weight
Improved SFC

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CMC Turbine Blade Tracks

- **Application of advanced CMCs to turbine blade track permits significant reductions in cooling flow**
  - Achieves reduced fuel burn and enables weight savings compared to conventional metal technology
- **Under FAA CLEEN, Rolls-Royce will design, manufacture, and test CMC Turbine Blade Tracks for large civil engine**
  - Technology demonstration will be conducted as part of the UK Environmentally Friendly Engine (EFE) program
    - *Thermal Paint build will provide thermal effectiveness data*
    - *Endurance build will demonstrate durability and useful life*
- **Key technical challenges**
  - Design of the interface between CMC/Metal components
  - Development of effective environmental barrier and abradable coatings

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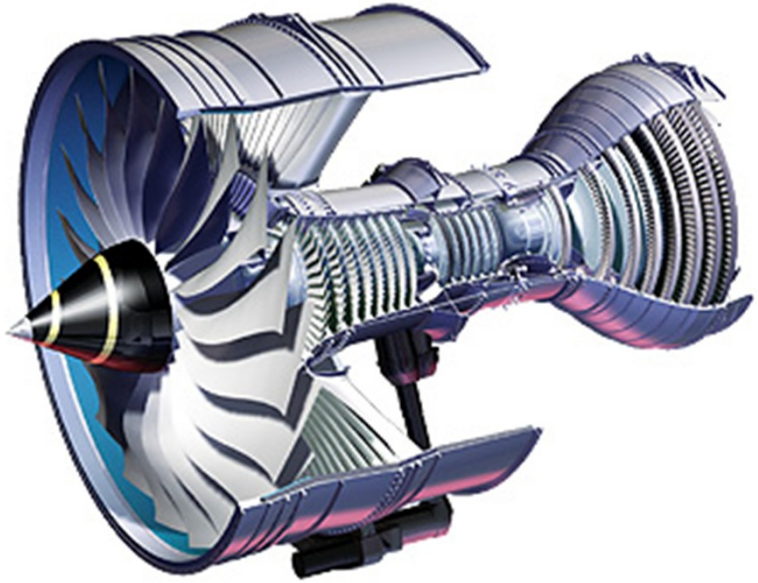
Environmentally Friendly Engine (EFE) Program

- **Demonstration program will validate new technologies aimed at reducing noise, fuel burn and emissions**
- **5 builds, first run start 2010**

- **Key Technology Areas**
  - High temperature materials
  - High efficiency turbines
  - Low emissions combustion
  - Advanced manufacturing
  - Engine control and actuation



- **Targets enabling technologies to deliver 2020 ACARE goals**

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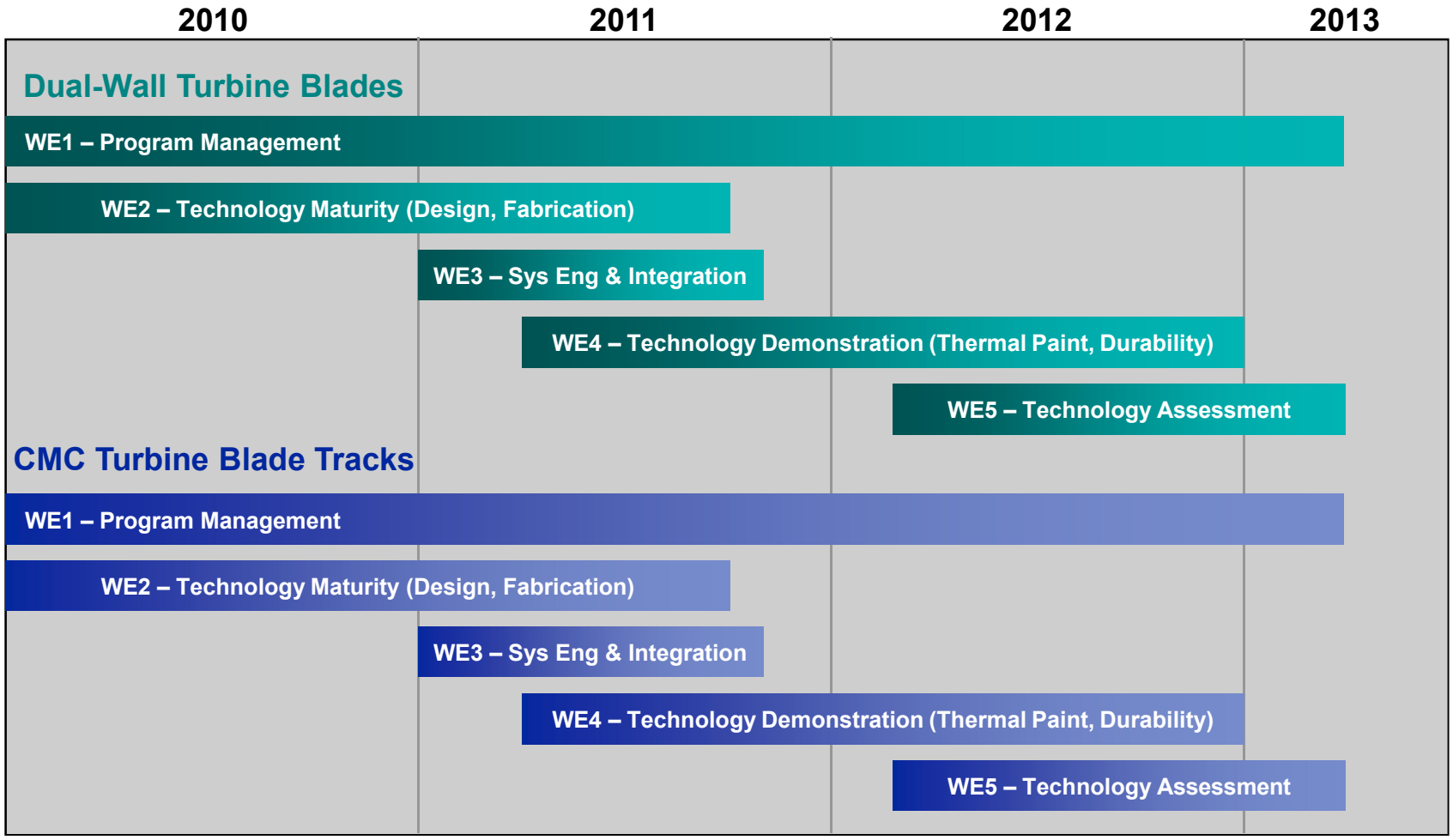
Fuel Burn Reduction Projects



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Alternative Fuels Objectives

Suitability

Energy density
Fuel specification
Operability
Aircraft compatibility

+

Sustainability

CO_2 benefit
Low agricultural impact
Renewable feedstocks

+

Industrialization

Mass production
Global distribution

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Alternative Fuels Projects

- **AE 3007 Demonstration**
  - Joint program with Syntroleum and Cessna Aircraft Company
  - Comprehensive evaluation of single fuel through sequential lab, rig, engine and flight testing
  - Syntroleum R-8 HRJ selected for AE 3007C engine ground test and Cessna Model 750 flight test

- **RB211-524 Demonstration**
  - Joint program with British Airways
  - Assessment of broad range of candidate fuels through lab testing, with down-selection prior to rig and engine testing
  - Engine ground test of selected fuel(s) to be conducted using RB211-524G/H provided by British Airways

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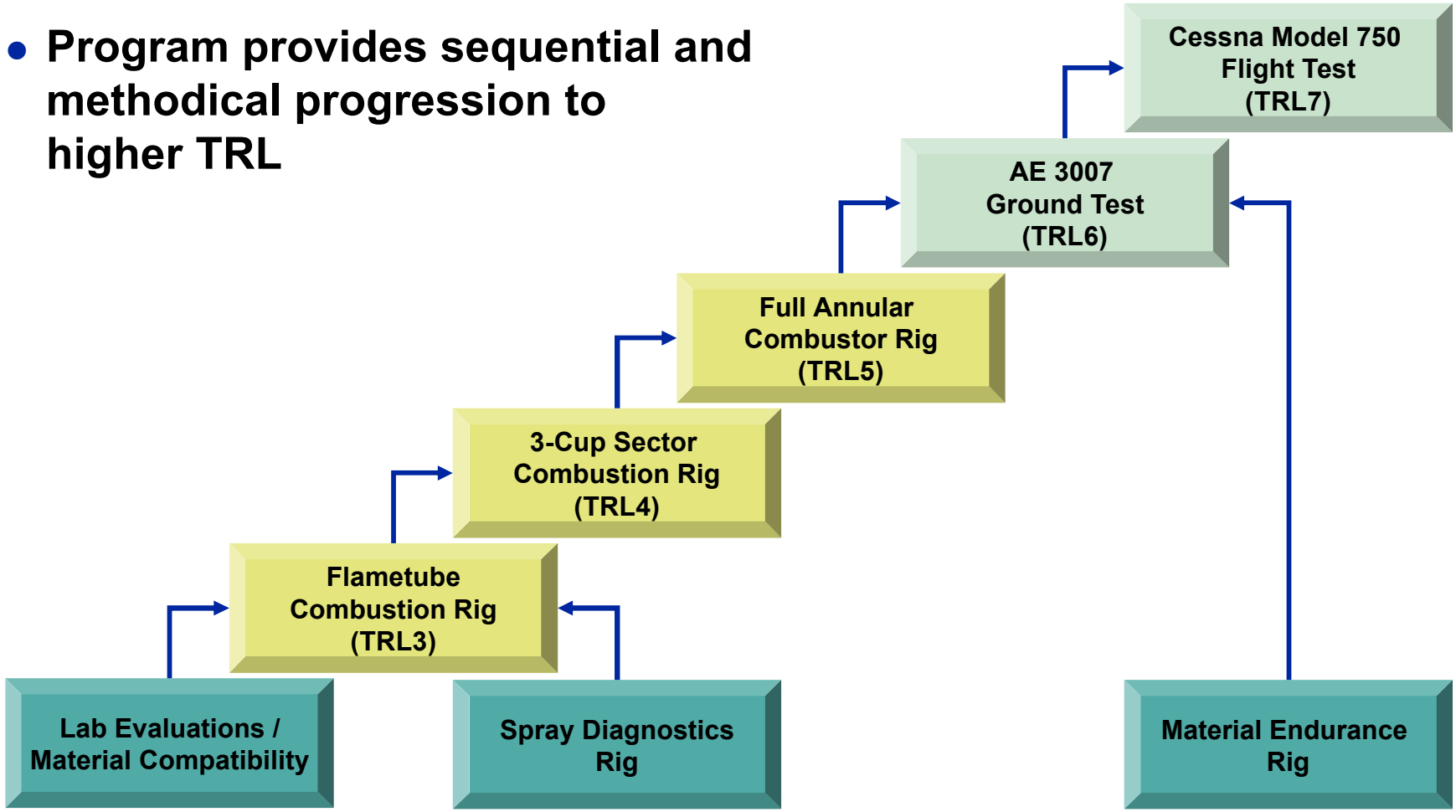
AE 3007 Alternative Fuels Demo

- **Program provides sequential and methodical progression to higher TRL**



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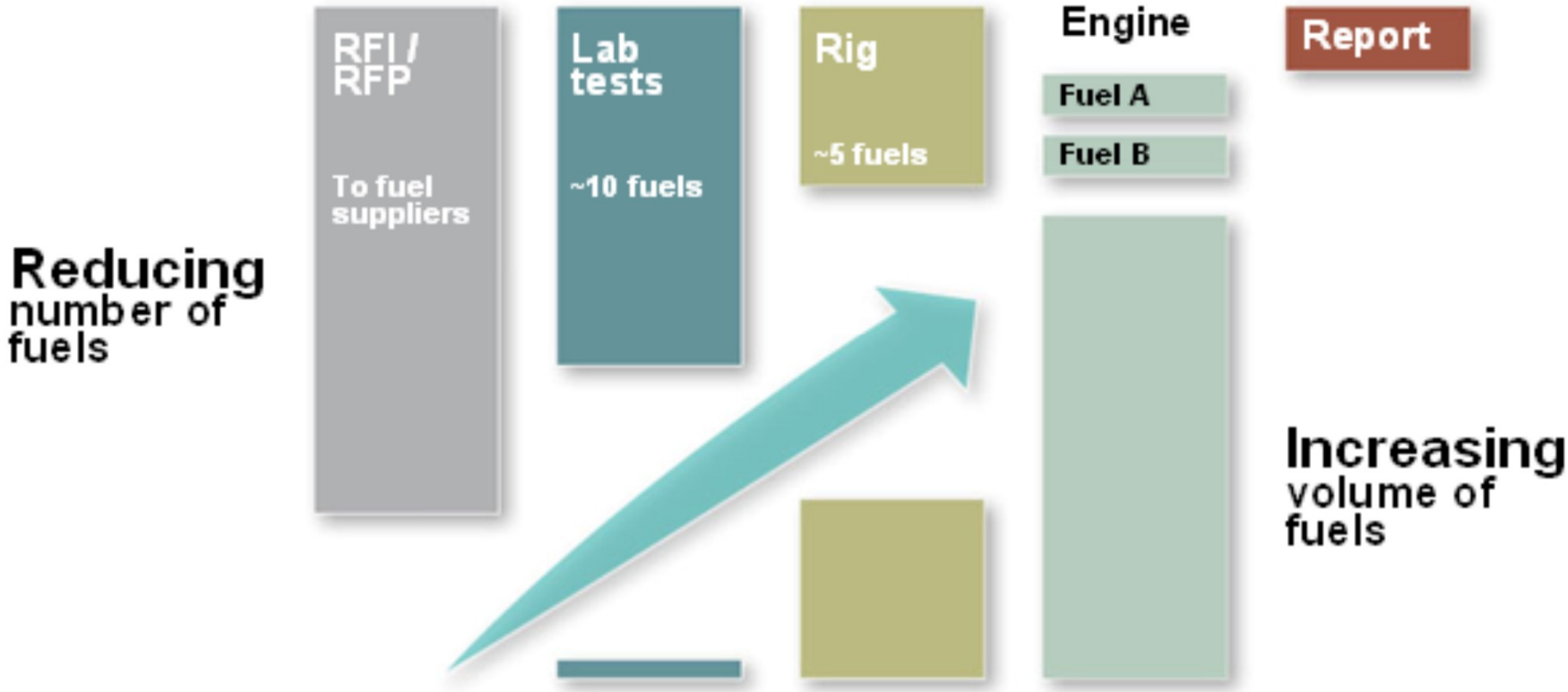
RB211-524 Alternative Fuels Demo



- **Program is focused on alternative fuels and/or fuel blend ratios not currently on ASTM roadmap for approval.**

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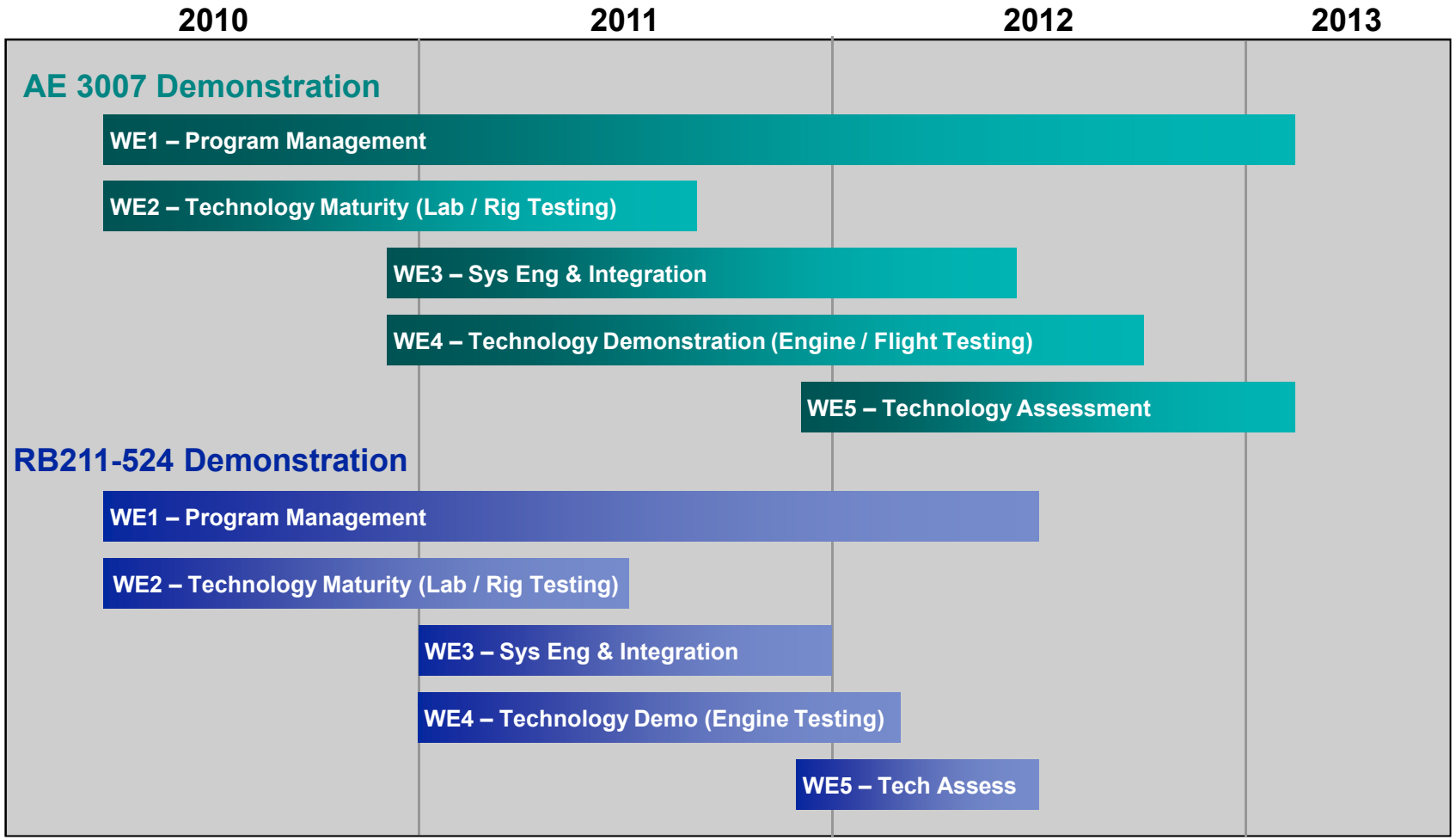
Alternative Fuels Projects



Rolls-Royce CLEEN Technologies Program
Summary

- **Rolls-Royce has assembled a diverse, experienced team to demonstrated leading technologies in reduced fuel burn and alternative fuels**
- **Projects leverage substantial technical advances and ongoing commitments by Rolls-Royce in the development of environmentally friendly technologies**
- **Technologies and approaches selected will provide a significant contribution to the FAA CLEEN program goals.**
- **Technologies will be advanced to TRL 6-7, positioning them for rapid implementation in certifiable engine products**