Rolls-Royce CLEEN Technologies Program

Dual-Wall Turbine Airfoils
Design, Fabrication, Engine Test

CMC Turbine Blade Tracks
Design, Fabrication, Engine Test

HEFA Fuel Blend Demonstration
Lab Analysis, Combustor Rig Tests, Materials Testing

Novel Fuels Demonstration
Lab Analysis, Combustor Rig Tests, Materials Testing

Fuel Burn Reduction
Alt Fuels Feasibility
Dual-Wall Turbine Airfoils

Highly-efficient turbine cooling is a key technology for Reduced Fuel Burn in NextGen product applications
- Provides significant reduction in cooling flow for today’s engines
- Enables progression toward tomorrow’s advanced engine cycles

Rolls-Royce has developed and patented high effectiveness, dual-wall turbine airfoil cooling systems
- To-date, manufacturing cost has limited this technology to advanced military applications
- We are focused on maturing these technologies for near-term civil engine applications
- Rolls-Royce turbine cooling technologies combine advanced cooling and manufacturing technologies

Goal: Demonstrate advanced dual-wall turbine airfoils for near-term civil engine applications
Dual-Wall Turbine Airfoils

In 2012, we completed blade design, manufacture, and bench testing of LeanCool™ turbine blades

- Casting process developed; frequency screening and HCF testing completed
- Final blades not cleared for engine testing due to casting quality issues

In 2013, we applied rapid prototyping lessons-learned to the design and fabrication of CastBond™ turbine vanes

- Successful casting trials using rapid prototyping approach
- Completed vane preliminary design and released castings for manufacture

In 2014, we have completed the vane detailed design, manufacturing trials, and received engine hardware castings

- Manufacture of engine hardware is underway for delivery / test in 2015
CMC Turbine Blade Tracks

Application of advanced CMC turbine materials enables Reduced Fuel Burn in NextGen product applications

- Provides significant reduction in cooling flow & weight for today’s engines
- Enables progression toward tomorrow’s advanced engine cycles

Goal: Demonstrate CMC turbine blade tracks for near-term civil engines
CMC Turbine Blade Tracks

In 2012, we completed design, manufacture, and rig testing
- All thermo-mechanical validation testing was conducted without issue
- Blade track hardware was instrumented and delivered for engine test

In 2013, CMC blade tracks were successfully tested as part of the UK Environmentally Friendly Engine (EFE) program
- Testing validated the performance of CMC components
- Some coating loss was observed; design and processing improvements identified
  - Subsequent improvements in coating system have been achieved in 2014

In 2014, blade tracks successfully completed their second test in the EFE demonstrator engine
- Full post-test inspection and analysis is underway
Fuel Burn Reduction – benefit assessment

Rolls-Royce turbine technologies significantly contribute to the CLEEN fuel burn reduction goals

- Ceramic Matrix Composite (CMC) blade tracks offer >50% reduction in cooling and component weight
- Dual-wall turbine airfoils provide >20% reduction in cooling and increased operating temperature capability

Our next-generation Civil products will realize up to 1% in fuel burn reduction by incorporating CLEEN technologies

- Further benefits are attainable through incorporation in advanced engine cycles
HEFA Fuel Blend Demonstration

Goal: Evaluate suitability of single HEFA fuel blend
- Dynamic Fuels R-8 HEFA – 50:50 blend with Jet A

Test plan successfully completed
- Full laboratory analysis
- Drop size measurements
- Ignition and LBO testing
- Emissions testing
- Hot section material endurance testing

Testing confirmed HEFA blend performed as drop-in fuel
- Final test report under review

Approved for Public Release
Novel Fuels Demonstration

Goal: Evaluate suitability of broad range of novel fuels
- 8 candidate fuels selected

Test plan successfully completed
- Full laboratory analysis
- Thermal stability testing
- Ignition and LBO testing
- Emissions testing
- Elastomer sealing force testing
  - Novel method of measuring seal performance developed

4 fuels identified as potential drop-in alternatives
- Significant improvement in smoke and particulate observed
- Final test reports under review

Approved for Public Release
Alternative Fuels – benefit assessment

CLEEN efforts have contributed to the development and deployment of sustainable alternative fuels

- Testing confirmed HEFA blend performed as drop-in
- 4 novel fuels showed potential as drop-in alternatives to Jet A

Novel method of measuring sealing performance under simulated engine conditions was developed

- Test method is available for future assessment efforts

Significant improvement in smoke and particulate emissions observed

- Emissions decrease with reduced aromatic content
Summary

Rolls-Royce continues to make significant progress

- Design of dual-wall HP turbine vane is complete
  - Manufacture of engine hardware is on track for 2015 delivery
- Engine testing of CMC blade track hardware is complete
  - Post-test inspection and analysis is underway
- Lab and rig testing of HEFA fuel blend is complete
  - Final report is in review
- Lab and rig testing of novel alternative fuels is complete
  - Final reports are in review

Technologies and alternative fuel data are providing significant contribution to FAA CLEEN program goals

- Significant fuel burn reduction in next-generation Civil products, and further benefits through incorporation in advanced engine cycles
- Potential drop-in alternatives to Jet A identified, and novel method of measuring sealing performance developed