DISRUPTIVE GREEN PROPULSION TECHNOLOGIES BEYOND THE COMPETITIVE HORIZON

Institution of
MECHANICAL
ENGINEERS

17-18 November 2014
One Birdcage Walk, London
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Aerospace Division
Conference

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Conceptual image of the NASA N3-X aircraft with Distributed Propulsion (Image courtesy of NASA)

DISRUPTIVE GREEN PROPULSION TECHNOLOGIES BEYOND THE COMPETITIVE HORIZON

17-18 November 2014, One Birdcage Walk, London

AS THE WORLD BECOMES INCREASINGLY CONCERNED WITH CLIMATE CHANGE, INTERNATIONAL CIVIL AVIATION'S CONTRIBUTION TOWARDS IT IS UNDER INCREASING SCRUTINY.

With the aim to ensure its environmental sustainability for the future, the aviation industry has set stringent and ambitious future environmental goals. This special two-day conference is aimed specifically at distributed propulsion and turbo-electric systems, presenting it as the next disruptive technology.

The search for future disruptive technologies in aviation requires cross-disciplinary effort. This effort will be focused on feasible airframes and propulsion systems, their optimal integration, application of alternative fuels, aviation safety and reliability, noise reduction and operating costs.

BENEFITS OF ATTENDANCE:

- **Understand** international civil aviation's environmental goals
- **Discover** the latest technology in green propulsion
- **Learn** from the experience of others in the industry
- **Discuss** the key issues affecting your organisation
- **Network** with peers and colleagues

SUPPORTING ORGANISATIONS:

AIAA American Institute of Aeronautics and Astronautics

Royal Aeronautical Society

KEY TOPICS:

- Propulsion technologies
- Electrical power engineering
- Airframe design and integration concepts
- Route-map to introduction to TeDP aircraft
- Economic and environmental benefits

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PROGRAMME

DAY 1	MONDAY 17 NOVEMBER 2014

09:00 **REGISTRATION AND REFRESHMENTS**

09:35 **OPENING ADDRESS**
Professor Emeritus Riti Singh, Cranfield University

09:50 **ADVANCED PROPULSION AND POWER SYSTEM INTEGRATION STRATEGIES FOR TRANSPORT AIRCRAFT**
Dr Askin Isikveren, Head of Visionary Aircraft Concepts, Bauhaus Luftfahrt e.V.
- Discuss the definition of the Propulsive Fuselage concept, piston-based "composite cycles," as well as serial and parallel hybrid-electric Propulsion and Power Systems (PPS) architectures, emphasising technology options covering years 2035-2050
- Implications to PPS design and integration
- The impact on aircraft sizing, optimisation and operations
- The level of potential to significantly reduce emissions and noise; in accordance with the European Commission Flight path 2050 goals and targets defined by ACARE's Strategic Research and Innovation Agenda

10:15 **INTEGRATION OF AN LH2 FUELLED DISTRIBUTED PROPULSION SYSTEM WITH A BLENDED WING BODY (BWB) AIRFRAME**
Professor Howard Smith, Centre for Aeronautics School of Aerospace, Transport & Manufacturing, Cranfield University
- Integration study of an advanced BWB configuration with an innovative distributed propulsion system
- Propulsion systems that utilise liquid hydrogen fuel
- High temperature superconducting technology utilised to improve efficiency of hybrid-electric systems
- Issues relating to the integration of larger fuel tanks

10:40 **A MODELLING AND SIMULATION FRAMEWORK FOR VEHICLE SIZING OF TEDP AND HYBRID-ELECTRIC ARCHITECTURES**
Professor Dimitri Marvis, Professor, Georgia Institute of Technology
- Additional degrees of freedom available to hybrid and turbo-electric systems create gaps in the traditional vehicle synthesis and sizing approach
- Recent developments and research at Georgia Tech towards the goal of a truly integrated modelling and simulation process for advanced configurations
- Plans for future development

11:05 **NETWORKING REFRESHMENT BREAK**

11:30 **CHALLENGES AND PROGRESS IN AERODYNAMIC DESIGN OF HYBRID WINGBODY AIRCRAFT WITH EMBEDDED PROPULSION SYSTEMS**
Dr Meng-Sing Liou, Senior Technologist, NASA Glenn Research Center
- Hybrid wingbody configuration
- Embedded turbofan and fan-propulsion systems
- High fidelity integrated propulsion airframe analysis and propulsion

11:55 **KEYNOTE ADDRESS - THE FUTURE OF LARGE CIVIL AIRCRAFT PROPULSION; EVOLUTION OR REVOLUTION?**
Professor Richard Parker, Director of Research and Technology, Rolls-Royce
- Tracing the natural evolution of today's engine technology through introduction of new technology
- More radical solutions for the future including open rotors, distributed propulsion and hybrid-electric propulsion

12:45 **NETWORKING LUNCH**

14:00 **KEYNOTE ADDRESS - WHICH QUADRANT FOR THE FUTURE OF AVIATION?**
Sebastian Remy, SVP Head of Airbus Group Innovations, Airbus Group
- Aviation and its stakeholders are faced with the exciting challenge of sustainable growth
- Researchers and engineers are both essential to pave the way to the future of aviation and unlock the technological barriers
- How can those achievements also be of service to the society? What are the trends?
- Achievements and perspectives will be discussed

14:50 **IMPROVING PROPULSIVE EFFICIENCY BY BOUNDARY LAYER INGESTION**
Andrew Rolt, Specialist Aerospace Strategic Research, Rolls-Royce
- Larger fans give better propulsive efficiency, but add weight and nacelle drag
- Increasing the number of engines can overcome constraints on fan diameter
- Driving multiple fans from just two core engines might be a better solution
- Fans that ingest airframe boundary layers offer higher propulsive efficiency

15:15 **CHALLENGES AND OPPORTUNITIES FOR ELECTRIC AIRCRAFT THERMAL MANAGEMENT**
Andrew Gibson, President & Aerospace Engineer, Empirical Systems Aerospace
- Challenges of thermal management for more electric, hybrid-electric, and all-electric aircraft with potential solutions
- A code algorithm was developed to facilitate architecture-level analysis of the coupled relationship between the propulsion system, the thermal management system, and the takeoff gross weight of aircraft with advanced propulsion systems
- A variety of coupled relationships between the propulsion and thermal management systems are identified, and their impact on the conceptual design choices for electric aircraft

15:40 **NETWORKING REFRESHMENT BREAK**

16:10 **A STUDY OF ENERGY MANAGEMENT THROUGHOUT THE FLIGHT CYCLE OF HYBRID-ELECTRIC AIRCRAFT**
Peter Malkin, Professor of Electrical Power Systems, Cranfield University
- Current aircraft have a highly "asymmetric" power requirement through the flight cycle
- Case study: a "multi-source Hybrid Electric Power System"
- This includes energy storage systems to help balance the various power demands using "peak-lopping" and other techniques
- By optimising the system against the full cycle we can show significant benefits in addition to any gains in propulsive efficiencies

16:35 **TOWARD MISSION ADAPTIVE AIRCRAFT: WING SHAPING CONCEPTS USING DISTRIBUTED PROPULSION**
Kevin Reynolds, Aerospace Engineer-Intelligent Systems Division, NASA Ames Research Center
- Hybrid-electric transport aircraft configurations with wing-mount distributed propulsion were modelled for a desired takeoff thrust
- A coupled non-linear aero-structural model was used for incorporating propulsive moments into rigid and flexible wing structures
- The span-wise lift and thrust distributions were tailored over a mission profile consisting of minimum fuel climb, minimum fuel cruise, and continuous descent
- A 4% reduction in fuel burn was achieved through trajectory optimisation of an unoptimised configuration by changing wing shape and twist to improve aerodynamic efficiency while maintaining aero-structural stability

17:00 **SIZING, PERFORMANCE AND FLIGHT TECHNIQUE OPTIMALITY OF HYBRID-ELECTRIC AIRCRAFT**
Clément Pornet, Aerospace Vehicle Architect, Visionary Aircraft Concepts Group
- Hybrid and universally-electric propulsion system architecture for transport aircraft
- Integrated prospects of fuel-battery hybrid for narrow-body transport aircraft
- Figure-of-merit for flight technique optimality of hybrid-energy aircraft

17:25 **CLOSE OF DAY ONE**

19:05 **DINNER**

DAY 2 — TUESDAY 18 NOVEMBER 2014

09:00 **OPENING ADDRESS**
Dr Ruben Del Rosario, Manager – Fixed Wing Project, Fundamental Aeronautics Program, NASA

09:15 **TURBO-ELECTRIC DISTRIBUTED PROPULSION BENEFITS ON THE N3-X VEHICLE**
James Felder, Aerospace Engineer, NASA Glenn Research Center
- A summary of recent study results on a turbo-electric distributed propulsion (TeDP) vehicle concept named N3-X
- The TeDP system used in N3-X employs multiple electric motor-driven propulsors that are distributed on an aircraft. The power to drive these electric propulsors is generated by wing-tip mounted gas-turbine-driven electric generators on the HWB airframe
- N3-X would be able to reduce energy consumption by 70–72% compared to a reference vehicle, a Boeing 777-200LR, flying the same mission. Predictions for landing and takeoff NOx are estimated to be 85% less than the Tier 6-CAEP/6 standard. Two variants of the N3-X vehicle were examined for certification noise and found to have ICAO Chapter 4 cumulative margins of 32EPNdB and 64EPNdB
- It is expected that the TeDP system may provide unprecedented reductions in fuel/energy consumption, community noise, and landing and takeoff NOx emissions required in future transport aircraft

09:40 **IMPACT OF DISTRIBUTED ELECTRIC PROPULSION (DEP) ON AIRCRAFT DESIGN**
William Fredericks, Aerospace Engineer, NASA Langley Research Center
- DEP enables a new paradigm for aircraft design
- DEP's benefits are found primarily at the aircraft system level
- DEP allows the designer to locate the thrust where drag is created
- DEP will provide benefits to all vehicle class, but start small and work up in scale

10:05 **FAN SYSTEMS FOR BOUNDARY LAYER INGESTION (BLI)**
Dr Cesare Hall, Senior Lecturer in Turbomachinery, University of Cambridge
- The overall performance of distributed fans with BLI
- Experimental and computational research into the aerodynamics of BLI fans
- Design implications of the research findings

10:30 **HYBRID ENGINE FOR MULTI-FUEL BLENDED WING BODY**
Dr Arvind Gangoli Rao, Associate Professor, Faculty of Aerospace Engineering, Delft University of Technology
- Low NOx multi-fuel propulsion system
- Propulsion system for multi-fuel Blended Wing Body

10:55 **NETWORKING REFRESHMENT BREAK**

11:20 **DISTRIBUTED PROPULSION - AN OVERVIEW OF OPPORTUNITIES AND CHALLENGES**
Dr Panos Laskaridis, Director of the Centre for Gas Turbine Diagnostics and Life Cycle Costs, Cranfield University
- Airframe configurations
- Effects of boundary layer ingestion
- Synergies including novel fuels and advanced thermodynamic cycles

11:45 **KEYNOTE SPEAKER**
James Free, Director, NASA Glenn Research Center
- The legacy of the National Advisory Committee for Aeronautics (NACA) lives on at NASA. Commemorating 100 years since the founding of the NACA, NASA is shaping the next 100 years of US aviation
- Air transportation is critical to US and global economic vitality. However, energy and climate issues challenge aviation's ability to be sustainable in the long term. Aviation must dramatically reduce fuel use and related emissions. Energy costs to US airlines nearly tripled between 1995 and 2011, and continue to be the highest percentage of operating costs
- NASA's aeronautics research strategic vision is driven by this challenge and significant global trends such as unprecedented economic growth of the Asia-Pacific region, rapid growth of urban areas, and revolutionary technology development
- NASA has identified environmental responsibility as one the "mega drivers" that will be changing the face of aviation over the next 20 to 40 years. NASA research centers and specifically NASA Glenn have efforts for advancing technologies for big leaps in efficiency, environmental performance and technologies for pioneering low-carbon propulsion

12:30 **NETWORKING LUNCH**

13:45 **PANEL SESSION:**
Dr Ruben Del Rosario, Manager – Fixed Wing Project, Fundamental Aeronautics Program, NASA
Professor Emeritus Riti Singh, Cranfield University
Dr Askin Isikveren, Head of Visionary Aircraft Concepts, Bauhaus Luftfahrt e.V.
Professor Dimitri Mavris, Professor, Georgia Institute of Technology
Georgio Abrate, Engineering General Manager, Avio Aero

14:30 **CHALLENGES OF DISTRIBUTIVE PROPULSION SYSTEMS FOR ADVANCED AEROPLANES**
Artur Mirzoyan, Central Institute of Aviation Motors (CIAM) Russian Federation, Moscow
- Consideration of the main challenges of development of advanced architectures of propulsion systems, i.e. Distributed Propulsion Systems (DPS)
- Mechanical driving DPS seems more feasible in near-term outlook, turbo-electric and full electric DPS are feasible in mid and far-term outlook
- Possible impacts of arrangement of DPS on aeroplane fuel efficiency
- Application of DPS on long range aeroplanes is a new engineering solution, which may allow us to meet future advanced efficiency goals

14:55 **ENABLING ELECTRIC PROPULSION FOR AIRCRAFT**
Starr Ginn, Chief Engineer for Aeronautic, NASA Armstrong Flight Research Center
- NASA ARMD Fixed Wing projects
  - Distributed Electric Propulsion Ironbird
  - Hybrid Electric Test Stand
- Small business initiatives
- NASA ARMD Convergent Aeronautics Solutions Project
  - Steps to building an electric aeroplane

15:20 **NETWORKING REFRESHMENT BREAK**

15:45 **SYSTEM LEVEL DESIGN CONSIDERATIONS OF A SUPERCONDUCTING TEDP MICROGRID**
Michael Armstrong, Aerospace Systems Engineering Specialist, Rolls-Royce North American Technologies
- Aircraft safety and reliability requirements govern the implementation of a superconducting turbo-electric distributed propulsion (TeDP) system's redundancy and protection strategies
- These requirements drive impact concept feasibility through the overall effect on system mass and efficiency
- Methods for determining optimal voltage, nominal operating voltage, power regulation, defining system protection, and recovery requirements were established considering NASA's N3-X aircraft concept
- Holistic electrical system parametric sizing and dynamics models were developed and exercised to determine the optimal nominal operating voltage and to perform isolation and protection trade studies

16:10 **POTENTIAL PROPULSION SOLUTIONS FOR HYBRID-ELECTRIC AIRCRAFT**
Paul Miller, Electrical Systems Specialist – Strategic Research, Rolls-Royce
- Hybrid propulsion has the potential to deliver reduced fuel burn through increased propulsive efficiency resulting from higher bypass ratios and lower drag aircraft designs
- To realise the benefits of hybrid propulsion, high efficiency energy transmission from the remote power generators to the propulsion fans is required. Superconducting electrical systems may have this potential
- High temperature superconducting conductors and control devices show the potential to greatly increase the transmission efficiency to the required levels when including the cryo-cooling sub-system
- Fully superconducting (both rotor and stator) electrical machines are being researched to maximise the mechanical/electrical/mechanical conversion efficiency

16:35 **ADVANCED TECHNOLOGY CONSIDERATIONS FOR FUTURE AVIATION**
Giorgio Abrate, Engineering General Manager, Avio Aero
- Aviation technology advancements in material technologies, cooling methods, aero-mechanical design capabilities, advanced manufacturing and more are enabling unprecedented performance
- However, continued pressure through higher fuel costs, increased energy demands, noise and emissions may drive a new approach
- Alternative and integrated architectures such as distributed propulsion, hybrid-electric and compound cycles may be among the many approaches needed to address the increasing demands on aviation
- GE Aviation is shaping the future of flight and taking on these challenges by driving today's gas turbines to new performance levels and by developing revolutionary propulsion and system architectures to meet the demands for the future of aviation

17:00 **CLOSING ADDRESS**
Professor Emeritus Riti Singh, Cranfield University

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- This programme is subject to change.
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Organising committee:

- Prof Emeritus Riti Singh, Cranfield University
- Dr Ruben Del Rosario, NASA
- Dr Askin Isikveren, Bauhaus Luftfahrt e.V.
- Dr Devaiah Nalianda, Cranfield University

SPEAKERS AND CONTRIBUTORS

RICHARD PARKER KEYNOTE
DIRECTOR OF RESEARCH & TECHNOLOGY, ROLLS-ROYCE

Richard Parker started working for Rolls-Royce in 1978, holding various posts including Chief of Composites and Ceramics and Chief of Compressor Engineering. In 2001, Richard was appointed Director of Research & Technology and is based in Derby, UK. He is responsible for the direction and co-ordination of research and technology programmes across all of the Rolls-Royce businesses worldwide. Richard was awarded a CBE in the 2013 New Year's Honours List for "Services to Engineering," and is a visiting Professor in Aviation Technology at Loughborough University as well as an Honorary Professor in Materials Engineering at Birmingham University.

SEBASTIEN REMY KEYNOTE
SVP HEAD OF AIRBUS GROUP INNOVATIONS, AIRBUS GROUP

Sebastien Remy started his career in 1984 at MBDA in Paris with flight tests of missiles, mostly AS15TT on EC Dolphin. He then moved to Airbus in Toulouse in 1986 to join the development of A320 in the propulsion community, taking care of the CFM engine performance. Over time, Sebastien moved several times within the Airbus propulsion community, participating on developments of all Airbus aircraft programmes. In 2013, Sebastien was nominated as Head of Airbus Group Innovations. The role involves leading the group's network of research centres with a highly skilled extended workforce of more than 800 people worldwide.

JAMES FREE KEYNOTE
DIRECTOR, NASA GLENN RESEARCH CENTER

James Free is Director of the National Aeronautics and Space Administration's Glenn Research Center in Cleveland, Ohio. He is responsible for planning, organising and directing the activities required in accomplishing the missions assigned to the center. The Glenn Research Center is engaged in research, technology and systems development programmes in space propulsion, space power, space communications, aeronautical propulsion, microgravity sciences and materials.

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GIORGIO ABRATE
ENGINEERING GENERAL MANAGER, AVIO AERO

To see the full speaker line-up and learn what they will be discussing, please visit **www.imeche.org/events/C1416**

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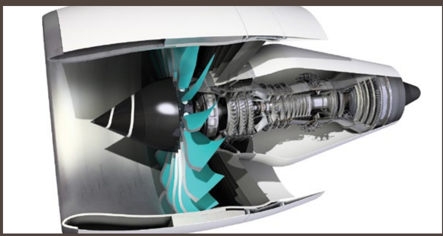

29 September 2014
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FUTURE CIVIL PROPULSION CONCEPTS AND TECHNOLOGIES

This lecture will discuss the opportunities and challenges that face the civil aviation industry into the next decade and beyond. Presented by John Whurr.

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