SCIENCE AND TECHNOLOGY ORGANIZATION

APPLIED VEHICLE TECHNOLOGY PANEL

Science & Technology Organization
Collaboration Support Office
Applied Vehicle Technology Panel

## AVT-393 Research Symposium on

# Environmental and Thermal Barrier Coatings for Military Aircraft Engines

## NRC Canada, Ottawa

## 15-17 May 2024

This Symposium is open to NATO Nations, Australia, Japan and Sweden

### Theme and Topics

The RWS is organized as a medium-sized event with around 30-50 participants that aims to bring together subject matter experts on Thermal Barrier Coatings (TBC)s and Environmental Barrier Coatings (EBC)s to identify military needs, limitations, data sources and relevant development efforts within thermal and environmental barrier coatings for military aircraft applications. This Research Workshop is classified as NATO Unclassified - Releasable to AUS, SWE and JPN.

Topics covered include:

- Evaluations of terms and definitions
- Existing state of the art on barrier coatings
- Technology investment and development efforts
- Emerging technologies which are applicable throughout the engineering lifecycle
- Understanding Fluid-Structure-Interaction modelling of particle and aerosol laden turbomachinery flow
- Existing test and acceptance criteria

This AVT activity will be an interactive event comprising of the following 3 distinct work streams:

- Work stream 1: Capability: Understanding capability requirements and operational context of TBCs and EBCs. Work stream will also identify national capabilities and S&T knowledge gaps.
- Work stream 2: Coating material characteristics and application methods: Identify and understand coating material composition + properties and manufacturing processes related to TBCs and EBCs.
- Work stream 3: Testing methods, modelling and cost benefit analysis: Understand coating durability, testing, modelling and cost benefit assessment methods.

The NATO AVT-393 programme committee have identified you as prominent member of the Thermal and Environmental Barrier Coatings research community and wish to extend an invitation to this participate in this workshop dedicated to TBCs and EBCs.

### Background

This proposed activity is the main output from ET-215 - Thermal and Environmental Barrier Coatings for Military Aircraft Engines which, evolved from findings and conclusions from Chapter 4 of AVT-250. AVT-250 concentrated on Environmental Particulate (EP) Foreign Object Damage (FOD) of aircraft gas turbine engines. The AVT-250 Technical Team's conclusions and recommendations have enabled enhanced engine design and test methodologies to mitigate the effects of EP-FOD, as well as more robust tools, models, and other products that establish best practices for flight in EP environments.

This proposal seeks to understand the problem space around the E/TBC materials and their damage and failures caused

by oxidation and hot corrosion. This two-year AVT activity culminates in a workshop to identify the current status of the research into E/TBCs and the current capability gaps. In addition, this activity will help establish NATO 'best practices' in E/TBCs processing, qualification and acceptance for combustor and turbine components in military aircraft engines. This proposal will be jointly administrated under the Applied Vehicles Technologies (AVT) Panel by the Power and Propulsion Systems (PPS) and Mechanical Systems, Structures and Materials (MSM) Technical Committees.

### Registration

This event is by invitation only. If you would like an invitation, please contact the Panel co-chairs and panel secretary.

### AVT Executive Office, Collaboration Support Office (CSO), Paris – Points of Contact:

Ms Erin BOLDI
AVT Executive Officer
Tel: +33 (0)1 55 61 22 93
Erin.Boldi@cso.nato.int

Mrs Isavela Kontolaimaki
AVT Panel Executive Assistant
Isavela.Kontolaimaki@cso.nato.int

Ms Edna Ferraz
AVT Panel Assistant
Edna.Ferraz@cso.nato.int

## Programme Committee

### CO-CHAIRS

**Anindya Ghoshal**
Army Research laboratory, USA
Email: anindya.ghoshal.civ@army.mil

**Dave Hallam**
Defence Science and Technology Laboratory, GBR
Email: dhallam@dstl.gov.uk

### PANEL MENTOR

**Prakash Patnaik**
National Research Council, CAN
Email: Prakash.Patnaik@nrc-cnrc.gc.ca

### PANEL SECRETERY

**Selvan Thamizhirai**
Defence Science and Technology Laboratory, GBR
Email: sthamizhirai1@dstl.gov.uk

### TECHNICAL EVALUATOR

**Jeff Bird**
Canada
Email: jeffbird@rogers.com

AVT-393 Research Symposium on Environmental and Thermal Barrier Coatings for Military Aircraft Engines

## Workstream 1 (Capability) Team


**United States**
Muthuvel Murugan
Army Research Laboratory
muthuvel.murugan.civ@army.mil

**United States**
Anindya Ghoshal
Army Research Laboratory
anindya.ghoshal.civ@army.mil

**France**
Jonathan Cormier
École Nationale Supérieure de Mécanique et d'Aérotechnique
jonathan.cormier@ensma.fr

**Italy**
Mario de Stefano Fumo
Centro Italiano Ricerche Aerospaziali
m.destefano@cira.it

**Poland**
Radosław Swadźba
Institute of Ferrous Metallurgy, Łukasiewicz
radoslaw.swadzba@git.lukasiewicz.gov.pl //
rswadzba@imz.pl


## Workstream 2 (Characterisation and application)


**Germany**
Uwe Schulz
Deutsches Zentrum für Luft- und Raumfahrt
Uwe.Schulz@dlr.de

**Poland**
Marek Goral
Politechnika Rzeszowska
mgoral@prz.edu.pl

**Spain**
Pauline Audigie
Instituto Nacional de Tecnica Aeroespacial
audigiep@inta.es

**United States**
Ryan McGowan
Army Research Laboratory
ryan.c.mcgowan3.civ@army.mil


## Workstream 3 (Modelling and costing)


**Canada**
Kuiying Chen
National Research Council
Kuiying.Chen@nrc-cnrc.gc.ca

**Canada**
Vladimir Pankov
National Research Council
Vladimir.Pankov@nrc-cnrc.gc.ca

**France**
Vincent Maurel
Mines Paris Tech
vincent.maurel@mines-paristech.fr

**Italy**
Mario de Stefano Fumo
Centro Italiano Ricerche Aerospaziali
m.destefano@cira.it

AVT-393 Research Symposium on Environmental and Thermal Barrier Coatings for Military Aircraft Engines

**United Kingdom**
Neil Martin
Defence Science and Technology Laboratory
npmartin@dstl.gov.uk

**United States**
David Shifler
Office of Naval Research, US Navy
david.a.shifler.civ@us.navy.mil

## Programme

### DAY 1

**Wednesday, 15 May 2024, 1000-1730**

| | | |
|---|---|---|
| 1000 | | NRC Aerospace Lab Tour |
| 1200 | | LUNCH |
| 1400 | | AVT-393 Opening Remarks<br>AVT-393 Co-chairs:<br>A Ghoshal, ARL, USA<br>D Hallam, Dstl, GBR |

**Session 1 Use of TBC / EBC in a military context**

| | | |
|---|---|---|
| 1410 | KN | KEYNOTE<br>Introduction to E/TBC, history and next steps/ challenges<br>TBD |
| 1440 | 0 | Opportunity for a show and tell session for those interested to present 1 slide to highlight recent research activity<br>All attendees |

**Session 2 Capability of E/TBC**

| | | |
|---|---|---|
| 1520 | 1 | Introduction and objective of WS1<br>M Murughan, ARL, USA |
| 1530 | 2 | Development of EBC in GE Aviation<br>J Wan, GE Aviation, USA |
| 1550 | | COFFEE BREAK |
| 1610 | 3 | Brief history of TBC from commissioning perceptive<br>D Shifler, ONR, USA |
| 1630 | 4 | EBC development in ORNL-USA<br>M Ridley, ORNL, USA |
| 1700 | | Open discussion |
| 1730 | | Adjourn for the day |

## DAY 2

**Thursday, 16 May 2024, 0900-1730**

### Session 3 Manufacture and characterization of E/TBCs

| | | |
|---|---|---|
| 0900 | 5 | Introduction and objective of WS2 – Manufacture of E/TBCs<br>U Schulz, DLR, DEU |
| 0910 | 6 | Thermal Spray<br>TBD |
| 0930 | 7 | Chemistries of E/TBCs and interaction between coating and deposits<br>TBD |
| 0950 | 8 | Thermal spray<br>R Vassen, Fz, Juelich, DEU |
| 1010 | 9 | Electron-beam physical vapor deposition (EP-PVD) Processing/testing<br>D Wolfe, Penn State, USA |
| 1030 | | Open Discussion |
| 1050 | | COFFEE BREAK |
| 1110 | 10 | Hot corrosion of TBC<br>TBD |
| 1130 | 11 | Fabrication of new EBCs<br>TBD |
| 1150 | | Open Discussion |
| 1230 | | LUNCH |

### Session 4 Durability, testing and modelling

| | | |
|---|---|---|
| 1330 | 12 | Intro and objective for WS3 – Durability, testing and modelling<br>K Chen, NRC, CAN |
| 1340 | 13 | History of modelling and simulation of E/TBC.<br>R Clarkson, RR, GBR |
| 1410 | 14 | High temperature coatings from Pratt and Whitney<br>D Litton, P&W, USA |
| 1430 | 15 | Modelling damage in TBCs<br>V Maurel, Mines Paris, FRA |

| | | |
|---|---|---|
| 1450 | 16 | Measurement and failure analysis of temporary TBCs / fast sintering of coatings<br>TBD |
| 1510 | | Open Discussion |
| 1530 | | COFFEE BREAK |

**Session 5 Lab tours of NRC Canada**

| | | |
|---|---|---|
| 1600 | | Interactive session<br>All |
| 1630 | | Lab Tours |
| 1730 | | Adjourn for the day |

**DAY 3**

**Friday, 17 May 2024, 0900-1400**

**Session 6 Costing of E/TBCs**

| | | |
|---|---|---|
| 0900 | 17 | Introduction and objective of Costing for E/TBCs<br>N Martin, Dstl, GBR |
| 0910 | 18 | Current (non-commercial) costing method and to give an indicative baseline costing of E/TBC<br>N Martin, Dstl, GBR |
| 1010 | 19 | Repair technologies utilized in RR – Defence Aerospace<br>A Richardson, RR, GBR |
| 1030 | | Interactive session |
| 1050 | | COFFEE BREAK |

**Session 7 Final**

| | | |
|---|---|---|
| 1120 | | Interactive session |
| 1200 | TE | Technical Evaluator Comments<br>J Bird, NRC, CAN |
| 1230 | | Research workshop adjourns |

## Science and Technology Organization in NATO

In NATO, Science & Technology (S&T) is defined as the selective and rigorous generation and application of state-of-the-art, validated knowledge for defence and security purposes. S&T activities embrace scientific research, technology development, transition, application and field-testing, experimentation and a range of related scientific activities that include systems engineering, operational research and analysis, synthesis, integration and validation of knowledge derived through the scientific method.

In NATO, S&T is addressed using different business models:

- The Collaborative business model where NATO provides a forum where NATO Nations and partner Nations elect to use their national resources to define, conduct and promote cooperative research and information exchange.
- The In-House delivery business model where S&T activities are conducted in a NATO dedicated executive body, having its own personnel, capabilities and infrastructure.

## The Science and Technology Organization - STO

The mission of the NATO STO is to help position the Nations' and NATO's S&T investments as a strategic enabler of the knowledge and technology advantage for the defence and security posture of NATO Nations and partner Nations, by:

- Conducting and promoting S&T activities that augment and leverage the capabilities and programmes of the Alliance, of the NATO Nations and the partner Nations, in support of NATO's objectives;
- Contributing to NATO's ability to enable and influence security - and defence-related capability development and threat mitigation in NATO Nations and partner Nations, in accordance with NATO policies;
- Supporting decision-making in the NATO Nations and NATO.




***Acknowledgement***

The Applied Vehicle Technology Panel expresses its thanks to Canada
for the invitation to hold this meeting in Ottawa and for the facilities and personnel,
which make this meeting possible.