# EPICEA Public Workshop in Canada – D6.2

**Date:** 17 April 2018  
**Venue:** Bombardier, Montreal - Canada

<table>
<thead>
<tr>
<th>Project Ref. N°</th>
<th>689007 - EPICEA</th>
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<tr>
<td>Start Date / Duration</td>
<td>01 February 2016 / 36 months</td>
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| Author / Organisation | Mohamed Elsharkawi and Fidele Moupfouma (Bombardier)  
                          Ke Wu (POLY)  
                          Jean-Philippe Parmantier (ONERA)  
                          Noémie Planchon (ARTTIC) |

<table>
<thead>
<tr>
<th>Date of the Meeting</th>
<th>17 April 2018</th>
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<tbody>
<tr>
<td>Host / Organisation</td>
<td>Mohamed Elsharkawi and Fidele Moupfouma / Bombardier</td>
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| Location             | Bombardier  
                          2351, Alfred Nobel Blvd  
                          Montreal, Quebec, H4S 2A9, CANADA |

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1 Agenda

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<th>Presenter</th>
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<tr>
<td>08:15 AM – 08:45 AM</td>
<td>Welcome and Coffee</td>
<td>-</td>
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<td>08:45 AM – 09:00 AM</td>
<td>Welcome Note</td>
<td>Dr. Dave Tidd</td>
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<td>09:00 AM – 09:15 AM</td>
<td>Welcome Note (Importance of Research Activity in Canada)</td>
<td>Dr. Ke Wu</td>
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<td>CARIC, NSERC, and European Commission Note</td>
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<td>09:30 AM – 09:50 AM</td>
<td>Project Objective</td>
<td>Dr. Fidele Moupfouma</td>
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<tr>
<td>09:50 AM – 10:15 AM</td>
<td>Project Organization</td>
<td>Dr. Jean-Philippe Parmantier</td>
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<tr>
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<td>Evolution of EM Modeling and E3 with Applications to Complex EM Environments</td>
<td>Dr. Amy Pinchuk</td>
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<td>11:15 AM – 12:00 PM</td>
<td>Antenna Activity</td>
<td>Dr. Jean-Jacques Laurin and Dr. André Barka</td>
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<td>12:00 PM – 01:00 PM</td>
<td>Lunch</td>
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<td>01:00 PM – 01:45 PM</td>
<td>EM Coupling on IS Activity</td>
<td>Dr. Isabelle Junqua</td>
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<td>Validation on Barrel Activity</td>
<td>Dr. Jean-Philippe Parmantier and Dr. Mohamed Elsharkawi</td>
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<td>Break</td>
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<td>Cosmic Radiation Activity</td>
<td>Dr. Claude Thibeault and Mr. Joel Chotte</td>
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<td>Platform Demonstration</td>
<td>Dr. Christophe Girard and Mr. Antonio Guidoni</td>
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<td>04:15 PM – 05:00 PM</td>
<td>Exploitation Plan</td>
<td>Mr. Kees Nuyten</td>
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<td>Closing Note</td>
<td>Dr. Fidele Moupfouma</td>
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### 2 Attendees

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<tr>
<td>CARIC</td>
<td>Canada</td>
<td>Clothilde Petitjean</td>
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<tr>
<td>NSERC</td>
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<td>Patrick Suter</td>
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<td>Adv. Board</td>
<td>Canada</td>
<td>Daniel Gratton</td>
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<td>ONERA</td>
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<td>AXESSIM</td>
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<td>Christophe Girard</td>
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<td>FOKKER E.</td>
<td>Netherlands</td>
<td>Kees Nuyten</td>
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<td>Netherlands</td>
<td>Arthur Blommers</td>
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<td>IDS</td>
<td>Italy</td>
<td>Antonio Guidoni</td>
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<td>POLY</td>
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<td>Kai Wang</td>
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<td>Fidèle Moupfouma</td>
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<td>Adam Skorek</td>
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<td>Claude Thibeault</td>
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<td>ISONEO</td>
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<td>Joel Chotte</td>
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<td>InFieldScientific</td>
<td>Canada</td>
<td>Amy Pinchuk</td>
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<tr>
<td>Bell Helicopter</td>
<td>Canada</td>
<td>Jon Williams</td>
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3 Objectives
The objective was to conduct a public workshop where the progress and achievements of the EPICEA project, with the disclosure of confidential materials, were shared with others.

4 Presentations

4.1 Welcome Note
Dr. David Tidd, Vice President of Core Engineering at Bombardier, welcomed to the meeting the Advisory Board, the Canadian funding authorities’ representative (CARIC being represented by Clothilde Petitjean and NSERC being represented by Patrick Suter), the Advisory Board represented by Daniel Gratton from Canada Space Agency, keynote speaker Amy Pinchuk from InFieldScientific and all other participants. The European Commission could not attend and was excused.

4.2 Importance of Research Activity in Canada
Dr. Ke Wu from Polytechnique, the Canadian Coordinator of the project, presented the project fact sheet with an overview of the project targets and its importance and benefits to both the industry and the academia.

4.3 CARIC, NSERC, and European Commission Note
Mme Clothilde Petitjean from CARIC presented the project progress report main points and highlighted the fact for future cooperation opportunities with a positive feedback on the project progress and achievements.

4.4 Project Objective
Fidele Moupfouma (BA) talked about the initiative of the EPICEA project and the expected final goals. He also talked about the industrial benefits that could be achieved using the EPICEA project, giving examples to the aviation industry.

4.5 Project Organization
Jean-Philippe Parmantier (ONERA), the European Coordinator of the project, gave a comprehensive overview presentation of the whole project. He presented two illustrative maps showing all the activities of the EPICEA project and how they are inter-related scientifically and practically. This map is not based on WP classification. This is to show the regions of overlap and inter-operability between WPs. The first map shows all electromagnetic activities and the second one is for activities on cosmic radiations. He also presented the Project Consortium European and Canadian partners and highlighted on the EPICEA’s scope and final reachable ambition. Jean-Philippe Parmantier also showed the current status at M27 with regard to WP deliverables and achieved results.

4.6 Keynote speaker; Evolution of EM Modeling and E3 with Applications to Complex EM Environments
Dr. Amy Pinchuk CEO of InFieldScientific gave a very interesting presentation related to a numerical simulation platform, which is aligned with the EPICEA project but on ship antenna mounting application.
4.7 Antenna Activity

Jean-Jacques Laurin (Polytechnique) and Andre Barka (ONERA) presented full wave antenna models for antenna simulation using equivalent models and domain decomposition. Jean-Jacques Laurin presented a GUI for the implementation of composite material definition in the simulation platform, by conversing data to surface impedances. Accordingly, the framework can accept the definition of anisotropic and asymmetric materials. Novel designed antennas for composite aircraft were presented: dual-band VHF-COM antenna, TCAS antenna and conformal mm-wave antenna. Discussion on a metallic wire mesh inspection probe developed by Polytechnique was presented.

4.8 EM Coupling on IS

Isabelle Junqua (ONERA) presented the EM modelling tool structuring scheme for the integrated systems (IS) within the EPICEA platform. She described the three levels of Numerical test Cases (NTCs) used to support the IS modelling; NTC1 Open air test case, NTC2 Cavity test case, and the Full scale barrel. She also presented EM numerical results for NTC1 and NTC2 using LIE and HIRF methods of excitations.

4.9 Validation on Barrel

Both, Mohamed Elsharkawi (BA) and Jean-Philippe Parmantier (ONERA) introduced the EPICEA full scale barrel requirements, limitations, and mitigations. A description of the EPICEA full scale barrel structure view was presented and explained. The difference between the current return network and the signal ground network was also presented. Pictures of the mounted LRUs in the barrel and the harness layout were presented. Preliminary results for the LIE test were discussed.

4.10 Cosmic Radiations

Claude Thibeault (Ecole de Technologie Supérieure) presented information related to cosmic radiation sensitivity estimation and modelling, while Joel Chotte (ISONEO) presented some inflight measurement and observations, taking in consideration data confidentiality.

4.11 Platform Demonstration by AXES and IDS

Christophe Girard (AxesSim) presented a demo of the EPICEA platform on a scenario including a 3D solver. He introduced the CuToo platform, the NASH software for the meshing definition, and the KAWA software for data representation. The presentation showed how to navigate through the EPICEA platform and how to define a 3D problem. A demonstration was presented for the NTC2 case.

4.12 Exploitation Plan

Kees Nuyten (Fokker ELMO) explored EPICEA’s ambition to provide an EMC simulation framework for composite electric aircraft to enable collaborative EMC design by Aircraft integrator and Electrical (Wiring) Systems suppliers. Through the exploitation plan, he talked about the business model of the project and the use case. He also talked about the success criteria, critical assumptions, and schedule.
5 Advisory Board Feedback

The overall feedback of the Advisory Board (AB) is positive. Daniel Gratton especially stressed the fact that the technical discussion of the 1st day was a demonstration for him of the consortium commitment and coherence of the actions planned in the project. He gave this statement comparing what he experienced with other projects. He also said that the presentations of the second day were very good even if he already knew the content since he had attended the rehearsal of the slides the morning of the day before.
6  Annexes: Slide Presentations

6.1  Importance of Research Activity in Canada

- Call: H2020 International cooperation in aeronautics with Canada.
- Start date: 01 February 2016.
- End date: 31 January 2019.
- Duration: 36 months.
- Collaborative Project.
- Consortium: 9 partners (industrials, academics, research centers, SMEs).
OVERVIEW OF TARGETS

More electrical systems → IS and EMC
Higher → Cosmic Radiations

Lighter → Composite structure
More connected → Antennas

CEA = Composite Electric Aircraft
EPICEA = Electromagnetic Platform for lightweight Integration/Installation of electrical systems in Composite Electrical Aircraft

Decision making on System Design
- Protection of equipment
- New antenna concepts
- Electrical System Installation
- Weight control

A computer modelling platform

IMPORTANCE OF EPICEA

Society

Industry

Academia
EXTENT OF EPICEA

EPICEA aims for the benefit of the Global society

Unique cooperative framework between Canada and Europe

PROJECT CONSORTIUM
CANADA / EUROPE PARTNERSHIP

Knowledge

Experiences
EXPECTED BENEFITS

- Academic side
  - Develop advanced solutions for EPICEA-related research questions based on strong academic foundation
  - Educate graduate students and HQP through projects supported by unique industry-university-government alliance

EXPECTED BENEFITS

- Industrial side
  - Expand R&D horizons through multi-dimensional exposures of industrial technical staff and research engineers
  - Support the avionics industry with practical and state-of-the-art solutions which help a rapid development of new and improved products to meet the requirements of the future
6.2 CARIC, NSERC, and European Commission Note

EPICEA AG-M24
17 APRIL 2018

WORD FROM THE CANADIAN FUNDING BODIES

EU-CANADA COORDINATED CALL FOR AEROSPACE RESEARCH PROJECTS 2015
COORDINATED CALL PREPARATION

- Coordinated call topics prepared through a Coordination and Support Action called CANNAPE – running between 2011 and 2013 (5th collaboration workshops organised)
- As a result a coordinated call between Europe & Canada under H2020 was launched in December 2014
- In Canada: CARIC lead, Projects Co-funded by NSERC and CARIC
- Projects launch in February 2016

KEY FIGURES COORDINATED CALL

- 6 proposals submitted
- 3 proposals approved
  - Project AMOS “Additive Manufacturing Optimization and Simulation Platform for repairing and re-manufacturing of aerospace components”
  - Project EPICEA “Electromagnetic Platform for lightweight Integration/Installation of electrical systems in Composite Electrical Aircraft”
  - Project PHOBIC2ICE “Super-IcePhobic Surfaces to Prevent Ice Formation on Aircraft”
KEY FIGURES EU-CA PROJECTS*

- 28 students are currently trained on the projects in Canada
- 22 publications (international) by the Projects
- 1 international Summer “camp” for the students
- 2 internships for Canadian students at international OEM

*Those figures are dated from last’s year progress reports for EPICEA, PHOBIC2ICE and AMOS projects
EPICEA PROJECT STATUS TODAY
NSERC & CARIC

Official Project extension request for 6 month received:
- Extension approval process in Canada pending to official extension approbation of EC

Request of NSERC-CARIC joint progress report sent to Canadian project coordinator on April 11th 2018:
- Deadline for reception on May 16th 2018

FUTURE COLLABORATIONS
FUTURE COOPERATION OPPORTUNITIES

- For H2020 Framework:
  Mobilise community on call H2020 LC-MG-1-7-2019: Future propulsion and integration: towards a hybrid/electric aircraft (identified in collaboration with Canada)

- For Future Framework Programme (FP9):
  ✓ Discuss alignment of EC and Government of Canada for the future research framework and funding
  ✓ Expression of interest to collaborate, goals and purpose of collaboration (Ex: environmental, competitiveness, infrastructure, Industry 4.0, regulatory, etc.)
  ✓ Key topics of interest

Invite community to follow-up in July at Farnborough (partnership building, topics, ideas, and funding support)

FACILITATING CONNECTIONS BETWEEN AEROSPACE ECOSYSTEMS

CANADA
- AIAC, AéroMontreal
- CARIC, CRIAQ
- GARDN
- NRC
- Industry
- Governments
- Agencies (NSERC)
- Universities
- Colleges
- Networks

EUROPE
- EACP and national cluster organisations
- Project ICARE
- National research centers
- Industry
- Governments (EC)
- Agencies
- Universities
- Colleges
- Networks

17/04/2018
KEY SUCCESS FACTORS

- Favorable conditions to be orchestrated
  - Dedicated funding envelopes: Europe, Canada (NRC, NSERC) and others
  - Intermediation is key (connections, assistance, clearinghouse)

- Engagement
  - Strong project leadership from industry partners
  - Alignment with companies’ strategic priorities must be validated early

- Differentiation and complementarity
  - Multi & interdisciplinarity, next value chain (data)
  - Select niche to excel, involve expert customers in development

- Intellectual Property Framework to be designed early in the process for multipartners’ projects

THANK YOU

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clothilde.petitjean@canc.aero
6.3 Project Objective

CONTENTS

- Rational and trend.
- Why EPICEA?
- Potential innovation.
- Tested effect of lightning on metallic and hybrid A/C.
- Induced lightning effect on cable shields.
- HIRF induced load current in H- and V-polarizations.
- Cables emissions on composite Vs. metallic A/C.
- Targeted results.
RATIONAL AND TREND

- Composite Electrical Aircraft (CEA) are future safe and energy efficient.

- Extra Electromagnetic (EM) protection is needed with increasing electrification of A/C due to the composite Fuselage.

- Low electrical conductivity of composite materials relative to metallic A/C leads to increased induced voltages on onboard systems.

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RATIONAL AND TREND

- Future operations at higher altitude/altitude for long times and cross polar routes are prone to Cosmic Radiations (CR).

- CR being part of the EM spectrum, they are then included in the definition of EM environmental hazards.

- Increasing the demand for navigation support and communication is leading to the proliferation of antennas on A/C.

Workshop  4
RATIONALE AND TREND

- Installation of antenna systems (antennas, RF equipment, interconnecting systems (IS), etc..) add weight.

- Antennas sticking out of the A/C increase A/C profile drag with negative impact on energy performance.

- Antennas are pointy and prone to static discharges or lightning strikes with critical impact on safety because of local direct effects on electrical systems.

WHY EPICEA?

- Consequently, to progress more rapidly towards safe and energy-efficient CEA it is necessary to anticipate integration constraints of electrical systems at early A/C design to relax weight and drag penalty for EM protection.

- Air-framers will need a unique computer environment to perform EM virtual prototyping to support decision making for EM protection while maintaining safety.

Electromagnetic Platform for lightning Integration/Installation of electrical systems in Composite Electrical Aircraft
POTENTIAL INNOVATION

- An innovative set of tools to do efficient and reliable electromagnetic modelling for the systems and cabling in composite aircraft

TESTED EFFECT OF LIGHTNING ON METALLIC AND HYBRID A/C

HYBRID AIRCRAFT  METALLIC AIRCRAFT
INDUCED LIGHTNING EFFECT ON CABLE SHIELDS

Coaxial cable current measured in composite barrel

Coaxial cable current measured in aluminum barrel

HIRF INDUCED LOAD CURRENT IN H- AND V-POLARIZATIONS

Composite Barrel
Metallic Barrel

E_z Uniform Field

E_x Uniform Field
CABLES EMISSIONS ON COMPOSITE VS. METALLIC A/C

Composite Aircraft

\[ \frac{I_{sh}}{I_C} = \frac{(L_{gn} - M_{2kgn} + M_{sh})}{(L_{sh} - M_{2kgn}) + (L_{gn} - M_{sh})} \left[ \frac{\frac{R_{gn}}{L_{gn} - M_{2kgn} + M_{sh}}}{\frac{R_{sh}}{L_{sh} - M_{2kgn} + (L_{gn} - M_{sh})} + \frac{j\omega}{L_{2kgn} + M_{sh}}} \right] \]

Metallic Aircraft

\[ \frac{I_{sh}}{I_C} = \frac{R_{sh} + j\omega M}{(R_{sh} + R_{2k}) + j\omega L_{2k}} \]

TARGETED RESULTS

- EPICEA simulation platform, offering a unique validated computer environment.
- EPICEA modelling methodology with best practice rules and guidelines.
- Novel concepts of antennas; multifunction and low profile.
- Full scale composite Fuselage test mock-up.
- Fundamental knowledge on conventional EM and CR on CEA.
- Roadmap to evolve towards higher Technology Readiness Levels.
QUESTIONS

THANK YOU

This project has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement No 689007. This publication reflects only the author’s view and the Agency is not responsible for any use that may be made of the information contained therein.

https://ec.europa.eu/programmes/horizon2020

http://www.nserc-ecrpe.gc.ca

http://caric.aero
6.4 Project Organization

CONTENTS AND OBJECTIVES

1. Scope of the project

2. Main achievements

3. Progress status at M27
OVERVIEW OF THE TARGETS

CEA = Composite Electric Aircraft

THE EPICEA CHALLENGE
The frequency spectrum split: EM + CR

Electromagnetic Platform for lightweight integration/installation of electrical systems in Composite Electric Aircraft

From: http://www.colourtherapyhealing.com/colour/electromagnetic_spectrum.php
PROJECT GENESIS

Coordinated call

Call reference H2020-MG1.9 – 2015 International cooperation in aeronautics with Canada

EU-Canada coordinated Call for Research Projects in Aeronautics 2015

EU Grant agreement No 689007

Innovation, Science and Economic Development Canada under CARIC Funding Agreement EPICEA & under NSERC CRDPJ 479636 – 15

EPICEA’s Coordination Agreement

PROJECT CONSORTIUM
EUROPE/CANADA PARTNERSHIP
WORK BREAKDOWN STRUCTURE

- **WP1**: Technology Maturity Assessment
- **WP2**: EM coupling on IS in CEA
- **WP3**: Antennas on CEA materials
- **WP4**: Cosmic radiation effects on CEA electrical systems
- **WP5**: EPICEA's methodology validation and demonstration
- **WP6**: Dissemination and Exploitation

EPICEA's SCOPE AND AMBITION

**Targets TRL4**

- *It is an applied research project*
- *Starts with current knowledge* (TRL3 minimum: proof of concept)
- *At the end of the project:*
  - TRL 4 (validation in laboratory environment)
  - Must be able to elaborate higher TRLs up to certification

**Does not develop**

- new computer tools from zero

**Focuses on**:

- Theory and principles
- Methodology development with existing knowledge

**Accounts for**:

- Real system installation
  - Complexity (3D geometry, materials, size, IS connectivity)
- TRL progress
  - Relevance of models and validations
  - Weight evaluation capabilities
MAIN ACHIEVEMENTS (1/7)

Reference objects

Prototype antennas

Numerical test-cases (NTCs)

EPICEA barrel

17 April 2018

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MAIN ACHIEVEMENTS (2/7)

EM modelling

Composite materials

Prototype antennas

Antenna NTC (Monopole on Fokker airplane)

EM coupling NTC1 and NTC2

EPICEA barrel

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MAIN ACHIEVEMENTS (3/7)
EM testing for model validation

Tests on prototype antennas

Tests on the barrel

MAIN ACHIEVEMENTS (4/7)
A cooperative and open EM modelling platform

PLATFORM COMPONENTS

1 - Pre-processing modules
   3D Pre-processing
   IS Pre-processing

2 - Conventional EM modules
   3D Calculation
   Full Wave and asymptotic
   Time and Frequency Domain
   IS
   Antennas
   Cable Networks
   Power Balance

3 - IS
   Material Tools
   Material
   Cables, connections, ...

4 - Material modules
   Environments
   Electromagnetic, ...

5 - Post-processing modules
   Weight budget processing
   EM Post-processing
   Antennas
   Antennas
   IS Band, ...

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MAIN ACHIEVEMENTS (5/7)
Modelling scenarios

MAIN ACHIEVEMENTS (6/7)
EM simulation
MAIN ACHIEVEMENTS (7/7)

Cosmic Radiations

Tests at TRIUMF lab

Flight tests (BA’s Global7000 flight vehicle)

FORESEEN PROJECT IMPACT

1. Global optimization of the protection and weight of the A/C electrical system to EM severe EM environment accounting for structure, IS (cables, antennas, sensors...) and current return networks

2. Standardization of data exchange between both A/C integrators and suppliers

3. New ways to think of EM numerical modelling in development and certification phases

4. Inclusion of CR mitigation at the same time as EM protection

5. Standardization of CR environment aboard aircraft
EXPECTED RESULTS

Status at M27

- The EPICEA cooperative simulation platform: 70%
- Models of composite materials for IS, antennas and CR: 100%
- CR effects on components and electronic systems: 50%
- The EPICEA modelling methodology: 100%
- The EPICEA database: 20%
- Novel concepts of antennas: 100%
- The EPICEA test mock-up: 100%

17 April 2018

QUESTIONS

17 April 2018
6.5 Antenna Activity

WP-3
APRIL 16-17-18 2018

DAY 2: 17 APRIL 2018
WP3: ANTENNAS ON COMPOSITE ELECTRICAL AIRCRAFT MATERIALS

April 17, 2018
PROBLEMATICAS OF ANTENNAS ON COMPOSITE AIRCRAFT

- Replacement of aluminum aircraft skin by composites motivated by environmental and operation cost issues: Lighter aircraft have a reduced fuel consumption
- Need for modelling antennas on aircraft:
  - Coverage prediction
  - Mutual coupling between antennas
  - Coupling of interference to systems inside aircraft
  - Interference could be: High Intensity Radio-Frequency (HIRF) from nearby sources (e.g. radars), Lightning, Other radio systems on aircraft, ...

PROBLEMATICAS OF ANTENNAS ON COMPOSITE AIRCRAFT

- Composites made of carbon fiber reinforced polymers (CFRP):
  - Conductivity about 1000 times less than aluminum
  - Shielding from external interference (e.g. HIRF, Indirect lightning) is reduced
  - Antenna properties (matching, gain, sidelobes, ...) can be affected
  - Aircraft is electrically large: modelling antenna on large aircraft, including complex wiring system not possible with existing simulation tools
  - Damage caused by lightning to aircraft skin needs to be detected
OUTLINE OF PRESENTATION

1. Objectives of the WP3
2. Methodology
   a. Composite Modelling
   b. Antenna on A/C Modelling Strategies
   c. Novel Antennas for Composite Aircraft
   d. Wire Mesh Diagnostic Method
3. Summary and Conclusions

1. OBJECTIVES OF WP3: ANTENNAS ON COMPOSITE ELECTRICAL AIRCRAFT MATERIALS

OBJECTIVES of WP3:
1. Study broadband CFRP models of A/C skin suitable for numerical simulation (T3.1), and implement them in proposed aircraft simulation platform (T3.4)
2. Explore methodologies and strategies to simulate antenna on complete wired A/C models and to assess potential EM coupling to antennas from external sources of interference (T3.2)
3. Proposed new antennas concepts with reduced drag (T3.3)
2A. METHODOLOGY: COMPOSITE MODELLING

- Multilayer anisotropic CFRP too complex to include details of geometry in computer model; a simplified model is needed.
- Goals: identify composite model simplifications for future implementation in the full-wave solvers of the EPICEA platform by providing answers to some key questions:
  1. CFRP made of non-homogeneous periodic fiber layers:
     a. When can we neglect higher-order modes?
     b. When can we use an homogenized layer?
     c. When should we consider anisotropy in the CFRP model?
  2. CFRP has a high index of refraction:
     a. Should we consider dependence of model on incidence angle?
  3. Considering shielding of A/C fuselage:
     a. SE loss dominated by material or leakage through apertures?
2A. METHODOLOGY: COMPOSITE MODELLING

1. Criterion for neglecting higher modes of periodic CFRP was derived using coupled wave analysis and was validated for cases of interest.

2. For the CFRPCFC conductivities and for the frequencies of interest, the dependence of shielding effectiveness of the Tensor Impedance Boundary Condition on incidence angle is negligible up to 80 degrees; TIBC for normal incidence can be used with only minor errors for all cases.

3. Effect of CFRP anisotropy decreases as soon as two orthogonal fiber layers are present, which is applicable to most practical cases.

Anisotropic 4-layer model, 0/45/-45/90, layer thickness 0.2 mm, conductivity 66000.
2A. METHODOLOGY: COMPOSITE MODELLING

- Electric Field Shielding
- Magnetic Field Shielding

- Infinite cylinder, TE case, isotropic material, 4 layers, layer thickness 0.127mm

WP3: Antennas on composite electrical aircraft materials

- H-field transfer function (1/shielding effectiveness) of a sphere
- Isotropic IBC implemented in 3D full-wave codes
2A. METHODOLOGY: COMPOSITE MODELLING

Slotted cylindrical structure
Effect of conductivity, small slot
CFRP: 4 layer, [0/45/90/-45];
r_a = 1 m

\[ \bar{\sigma} = \begin{bmatrix} \sigma & 0 & 0 \\ 0 & \sigma & 0 \\ 0 & 0 & 50 \end{bmatrix} \]

TM case

---

Slotted cylindrical structure
Effect of conductivity, large slot
CFRP: 4 layer, [0/45/90/-45];
r_a = 1 m

\[ \bar{\sigma} = \begin{bmatrix} \sigma & 0 & 0 \\ 0 & \sigma & 0 \\ 0 & 0 & 50 \end{bmatrix} \]

TM case
2A. METHODOLOGY: COMPOSITE MODELLING

Slotted cylindrical structure
Effect of slot size
CFRP: 4 layer, [0/45/90/-45];
\( r_a = 1 \) m

\[
\sigma = \begin{bmatrix}
\sigma & 0 & 0 \\
0 & \sigma & 0 \\
0 & 0 & 50
\end{bmatrix}
\]

TM case

---

**Implementation of material module in simulation platform:**
- Conversion data to Surface Impedance
- Modification of framework to accept the definition of an anisotropic and asymmetric material
- Output is an object Dielectric thin Plane defined as a surface impedance with a Multiport which contains the matrices which depend on the frequency
OUTLINE OF PRESENTATION

1. Objectives of the WP3
2. Methodology
   a. Composite Modelling
   b. Antenna on A/C Modelling Strategies
   c. Novel Antennas for Composite Aircraft
   d. Composite Wire Mesh Diagnostic Method
3. Summary and Conclusions

2B. ANTENNA ON A/C MODELLING METHODOLOGIES AND STRATEGIES

- Full-wave antenna models for antenna siting analysis are not always available: confidentiality reasons, information not available (materials), etc
- Goals: Development of EQuivalent Models (EQM) and Domain Decomposition Method (DDM) based on exact Full wave formulations:

1. ONERA: Domain Decomposition Scenarios for EPICEA modeling
2. IDS: Equivalent Models of antennas for EPICEA modeling
3. ONERA/IDS: Cross comparisons of DDM and EQM on NTC_FOKER
4. ONERA/IDS: Implementation of simulation tools in the EPICEA platform
2B. ANTENNA ON AIRCRAFT MODELLING METHODOLOGIES AND STRATEGIES

Computation of reduced operators on the interfaces (GSM)
- Inlets and Antennas are covered and masked by fictitious surfaces
- Global function expansion (GBF) or wave guide modes
- GSM for each sub-domain computed with BEM or FEM
- MLFMA products and Iterative solution for multiple right hand sides (MGCR)
- Efficiency for multiscale problems
- Resolution of a Graph Equation for connecting the subdomains

FACTOPO Domain Decomposition Method

L band antenna installed on PEC and COMPOSITE plate
- 40 SBF (20 TE, 20 TM) on the half sphere interface
- 1 TEM mode on the coaxial port

Coax port : 1 mode

Antenna : FEM module

Plate + BEM module

Plate GSM

Antenna GSM
2B. ANTENNA ON AIRCRAFT MODELLING METHODOLOGIES AND STRATEGIES

FACTOPO Domain Decomposition Method

- L band antenna installed on PEC and COMPOSITE plate

![Image of L Band antenna on PEC and COMPOSITE plate]

- Monopole antennas (1.326 GHz) installed on PEC and COMPOSITE barrel
  - Gain diagrams and VSWR

![Diagram of 0.3 m, 0.7 m, 0.5 m, 1.0 m dimensions with config #1 and 2]
2B. ANTENNA ON AIRCRAFT MODELLING METHODOLOGIES AND STRATEGIES

- Monopole antennas (1.326 GHz) installed on PEC and COMPOSITE barrel

---

2B. ANTENNA ON AIRCRAFT MODELLING METHODOLOGIES AND STRATEGIES

- Full-wave antenna models for antenna siting analysis are not always available: IPR reasons, information not available, etc.
- In these cases, the use of EQuivalent Models (EQM) is mandatory.
- EQMs can be generated starting from near-fields and far-fields. In general, these fields can be obtained from measurement data, datasheet, or simulations made with third-party tools.
2B. ANTENNA ON AIRCRAFT MODELLING METHODOLOGIES AND STRATEGIES

- Equivalent Models (EQM)

An antenna equivalent models (i.e. RWG currents) generator based on inverse source approach (field to currents) has been developed:

- Inputs:
  - meshed surface
  - antenna radiation pattern

- Output:
  - equivalent currents (i.e. RWG currents) on the mesh

---

S-band helix antenna LH pol.

Simulated (full-wave) pattern @ 2030MHz
2B. ANTENNA ON AIRCRAFT MODELLING METHODOLOGIES AND STRATEGIES

Equivalent Models (EQM)

IDS_FICU

Requirement vs. pattern radiated by equivalent model
2B. ANTENNA ON AIRCRAFT MODELLING METHODOLOGIES AND STRATEGIES

- **Equivalent Models (EQM)**
  - An antenna equivalent models (i.e. RWG currents) generator based on equivalence theorem in the Love form has been developed:
    - Inputs:
      - near field on meshed conformal surface surrounding the antenna (box, sphere, etc)
    - Output:
      - Equivalent currents (i.e. RWG currents) on the conformal (near field to equivalent currents)

- **Cross comparisons DDM / EQM on NTC_FOKER**
  - NTC_FOKER: cross comparisons DDM (FACTOPO) and EQM (IDS_MMMP)

**DDM (ONERA_FACTOPO)**

**EQM (IDS_MMMP)**
2B. ANTENNA ON AIRCRAFT MODELLING METHODOLOGIES AND STRATEGIES

Cross comparisons DDM / EQM on NTC_FOKER

- NTC_FOKER: cross comparisons DDM (FACTOPO) and EQM (IDS_MMMP)

Integration of module FACTOPO, ONERA:
- Started to work for integration converter
- Conversion of some end results produced by FACTOPO to floatingType in the Amelet-HDF format
- The integration continue, more end results are converted
2B. ANTENNA ON AIRCRAFT MODELLING METHODOLOGIES AND STRATEGIES

- Integration of module IDS_MMMP and IDS_FICU, IDS:
  - IDS_MMMP for antenna context and IDS_FICU are integrated inside the Galileo EMT
  - The simulation results will be contained inside the Galileo project

Conclusions and perspectives

- Tools for the computation of antenna equivalent models (EQM) starting from far field and near field have been developed

- EQM and DDM methodologies has been validated for antennas installed on a platform

- EQM and DDM are suitable to evaluate installed antenna performance when full-wave modelling is not possible due to the lack of detailed information about the antenna and/or when installing a full-wave model of the antenna on the platform is not strictly required or feasible

- Implementation of developed software tools in EPICEA platform is underway
OUTLINE OF PRESENTATION

1. Objectives of the WP3
2. Methodology
   a. Composite Modelling
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   d. Wire Mesh Diagnostic Method
3. Summary and Conclusions

2C. NOVEL ANTENNAS FOR COMPOSITE AIRCRAFT

- Dual-band VHF-COM and TCAS antenna (POLY)
- Low-profile GPS antenna (ONERA)
- Composite Rad-alt antenna (FE)
- Conformal mm-wave antenna (POLY)
- Metallic wire mesh inspection probe (POLY)
VHF-COM + TCAS (POLY)

2C. NOVEL ANTENNAS FOR COMPOSITE AIRCRAFT

<table>
<thead>
<tr>
<th></th>
<th>TCAS</th>
<th>VHF</th>
</tr>
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<tbody>
<tr>
<td>Frequency</td>
<td>1.03 – 1.09 GHz</td>
<td>117-137 MHz</td>
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<tr>
<td>Bandwidth</td>
<td>5.6 %</td>
<td>15.7 %</td>
</tr>
<tr>
<td>VSWR / S11</td>
<td>&lt;2 / -10dB</td>
<td>&lt;3 / -8dB</td>
</tr>
<tr>
<td>Radiation Pattern</td>
<td>Omni directional /Directional</td>
<td>Omni directional</td>
</tr>
<tr>
<td>Polarization</td>
<td>Vertical</td>
<td>Vertical</td>
</tr>
</tbody>
</table>

Fig. Simulated antenna model TCAs and VHF

Side view of simulated multiband antenna model

April 17, 2018

WP3: Antennas on composite electrical aircraft materials
2C. NOVEL ANTENNAS FOR COMPOSITE AIRCRAFT

Near Field line setup to get the strength of E-field at various points along the length

Antenna Under Test

h=1m to 4m

Infine Ground Plane

Antenna under test

GPS (ONERA)
2C. NOVEL ANTENNAS FOR COMPOSITE AIRCRAFT

- Single band (1.67 GHz)
- Bi band (1.35 GHz & 1.52 GHz)
- RHCP polarization
- Techno: cavity backed patch antenna
- Feed: 1 port SMA Radiall R125.414.001
- Size: D = 100 mm; H = 25 mm
- Materials: Rogers TMM13I (epsilon=12)

RAD-ALT (FE)
2C. NOVEL ANTENNAS FOR COMPOSITE AIRCRAFT

Model 1

Model 2: Cavity backed

Model 3: With foam

Model 4: With FR4 radome

WP3.3: NOVEL ANTENNA AND RADOME DESIGN

WP3. Antennas on composite electrical aircraft materials
CONFORMAL MM-WAVE FOR MOBILE SATELLITE SERVICES (POLY)

2C. NOVEL ANTENNAS FOR COMPOSITE AIRCRAFT

Single element

4 x 4 array
2C. NOVEL ANTENNAS FOR COMPOSITE AIRCRAFT

4 x 4 array performance

Radiation pattern at 29GHz

OUTLINE OF PRESENTATION

1. Objectives of the WP3
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   d. Wire Mesh Diagnostic Method
3. Summary and Conclusions
2D. WIRE MESH DIAGNOSTIC METHOD

- CFRP used for composite A/C is covered with thin metal wire mesh acting as Lightning protection
- Wire mesh could have defects at installation on A/C
- Wire mesh could be damaged by lightning
- Defects and damage under paint layer; could be invisible
- Paint layer thickness critical for mobility of lightning attachment point
- Non-Destructive Evaluation method is needed to:
  - Verify integrity of wire mesh
  - Assess thickness of paint layer

Area damaged by lightning

Optical image  X-ray

Mesh size: 3.1mm x 1.42 mm
2D. WIRE MESH DIAGNOSTIC METHOD

OUTLINE OF PRESENTATION

1. Objectives of the WP3
2. Methodology
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   b. Antenna on A/C Modelling Strategies
   c. Novel Antennas for Composite Aircraft
   d. Wire Mesh Diagnostic Method
3. Summary and Conclusions
3. SUMMARY AND CONCLUSIONS

- Model simplifications enabling inclusion of CFRP fuselage in EM simulations identified
- Domain decomposition method allowing importation of proprietary antenna models in complex simulations of electrically large A/C simulations validated
- Novel antenna concepts to reduce air drag have been proposed, and experimentally validated
- A new approach for non destructive evaluation of the lightning protection wire mesh based on EM near-field coupling was proposed and demonstrated
- Composite models and simulation tools are respectively completely and partially integrated in the EPICEA platform
6.6 EM Coupling on IS
EPICEA EM COUPLING ON IS
ORGANIZATION OF WORK

LFB (DC – 1 MHz)

Lightning

MFB (10 kHz – 3 GHz)

HFB (1 GHz – 18 GHz)

HIRF-LF (10 kHz – 400 MHz)

HIRF-HF (400 MHz – 3 GHz)

Global conduction on 3D structure

→ Common mode

Conduction on IS

Global conduction on 3D structure

+ EM scattering

Conduction on cables

Energy balance of EM scattering and

conduction effects on IS

Field-to-TL

Random-Field-to-TL

3D model of the structure

IS response

Distributed sources

Zone decomposition of the structure

Local response of IS

Localized source models

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EM MODELLING TOOLS FOR IS
IN THE EPICEA COOPERATIVE PLATFORM

1 - Pre-processing modules

IS Pre-processing

AXS-CABLES/M

3D Pre-processing

IDS-ARKE-MESHER

AXS-NASH

4 - Post-processing modules

EM Post-processing

AXS-KIWA

1 - Conventional EM modules

Interconnected Systems

3D Calculation

Full Wave Time Domain

Full Wave Frequency Domain

Asymptotic Frequency Domain

ONERA-ALICE

IDS-MRAM

IDS-THO

Power Balance Techniques

ONERA PWB

Material Tools

POLY-CODIA

POLY-EM

3 - Material modules

Material Properties

CRP, fiberglass, metal...

IS Cables, connectors...

4 - Conventional EM modules

CALCE-EM

CALCE-EM

EM Post-processing

AXS-KIWA

Data Bus

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PLAT FORM COMPONENTS

Processing Modules

Calculation module

Data base

Type of module

2 - Conventional EM modules

Cable Networks

AXS-MILO

ONERA-CRYPT

ONERA RANDOMAP

5 - Material modules

Material Properties

CRP, fiberglass, metal...

IS Cables, connectors...

Environments

Lightning, etc.

3D Calculation

Full Wave Time Domain

Full Wave Frequency Domain

Asymptotic Frequency Domain

ONERA-ALICE

IDS-MRAM

IDS-THO

Power Balance Techniques

ONERA PWB

Material Tools

POLY-CODIA

POLY-EM

3 - Material modules

Material Properties

CRP, fiberglass, metal...

IS Cables, connectors...

Environments

Lightning, etc.
APPROACH
3 LEVELS OF NTCS TO SUPPORT IS MODELLING

<table>
<thead>
<tr>
<th>Description</th>
<th>Challenges</th>
<th>Modelling Strategy</th>
</tr>
</thead>
<tbody>
<tr>
<td>NTC1 Open air test-case</td>
<td>Very low frequencies (Zmc)</td>
<td>Full Wave Method</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Time &amp; Frequency domain</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Field-to-TL</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Time domain</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Frequency domain</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Mixed domains</td>
</tr>
<tr>
<td>NTC2 Cavity test case</td>
<td>+ CRNs &amp; SGNs</td>
<td>+ 3D pre-processing</td>
</tr>
<tr>
<td></td>
<td>+ Multiconductor architecture capabilities</td>
<td>+ IS pre-processing</td>
</tr>
<tr>
<td></td>
<td></td>
<td>+ HFB Random-Field-to-TL</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Frequency domain</td>
</tr>
<tr>
<td>EPICEA barrel</td>
<td>+ Uncontrolled and complex inputs</td>
<td>+ Materials module</td>
</tr>
<tr>
<td></td>
<td>+ 3D pre-processing</td>
<td>+ Uncontrolled Complexity</td>
</tr>
<tr>
<td></td>
<td>+ Materials modeling capabilities</td>
<td></td>
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</tbody>
</table>

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LFB-MFB MODELING SCENARIO
FIELD-TO-TL METHODOLOGY

Preprocessing
3D Mesh-Tools
Cable Preprocessing
Equipment electrical model
MTLN solver Modules
MTLN calculation

3D calculation
Zmc calculation
3D solver Modules
Field-for-MTLN
3D solver Modules

Result Analysis tools
Postprocessing

Cable architecture
Sources
3D geometry
Materials

3D mesh, Mesh location of Zmc ground ports
Zmc matrix
Wire connections
EM fields, Currents,
EM fields, Currents,
EM fields, Currents,
EM fields, Currents,
EM fields, Currents,
EM fields, Currents,
EM fields, Currents,
EM fields, Currents,
EM fields, Currents,
EM fields, Currents,
LFB-MFB MODELING SCENARIO
APPLICATION TO NTC2

Preprocessing
3D Mesh-Tools
Cable Preprocessing

Field for MTLN
3D solver Modules

MTLN solver Modules
MTLN calculation

3D calculation
Zmc calculation
3D solver Modules

IDS-AEM.MESHER MoM/PEC
IDS-MMNDES.PEC

H-Lightning

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NTC1 – CURRENT INJECTION
COMPOSITE /PEC STRUCTURE
NTC2 – HIRF ANALYSIS
COMPOSITE /PEC STRUCTURE EFFECT

WUT1 short-circuited
Strong effect of composite up to 10MHz
Above 10MHz, No effect & coupling through apertures

WUT2 loaded on 50Ω
Effect of composite in VLF, below 100kHz
No effect above & coupling through apertures

WHICH 3D EM SOLVER FOR WHICH FREQUENCY RANGE?

Large fluctuations
Versus frequency

Smooth fluctuations
Versus frequency

For Low Frequency EM problems
(Lighting, HIRF-BF)
Use 3D Frequency domain codes

Large spectrum EM problems
(HIRF-MF)
Use 3D Time domain codes

55 frequencies (IDS) <-> 2000 frequencies (ONERA)
LFB-MFB MODELING SCENARIO CABLE HARNESS ARCHITECTURES

Overshielded & shielded cables

H-Lightning

HIRF

LFB-MFB MODELING SCENARIO CABLE HARNESS ARCHITECTURES

Overshielded & shielded cables

HIRF
EM COUPLING ON IS
CONCLUSIONS & PROSPECTS

- Development of Numerical Modeling Strategies to account for IS in CEA:
  - Field-to-TL for Lightning and HIRF-LFB-MFB
  - Random-Field-to-TL for HIRF-HFB
- Scientific validation of strategies (NTC1/NTC2)
- Application of strategies for test-case analysis and parameters sensitivity
- Implementation of strategies as scenarios in EPICEA in progress
  - See demo

Next steps:
- Validation on EPICEA BARREL with comparisons to experimental data
- Management of uncontrolled geometries, parameters and complexity

QUESTIONS

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EPICEA Public Workshop
6.7 Validation on Barrel

EPICEA PUBLIC WORKSHOP
EM VALIDATION ON BARREL ACTIVITY

Bombardier, Montreal (Canada)
17 April 2018
J-P. Parmantier
ONERA
F. Moupfouma
M. Elsharkawi
Bombardier

CONTENT

1. Introduction to the EPICEA barrel (ONERA)
2. Description of the EPICEA barrel (BA)
3. EM testing (BA)
4. EM modelling (ONERA)
5. Status and prospects (ONERA)
INTRODUCTION TO THE EPICEA BARREL

REQUIREMENTS

- A massively composite object for EM model validations
- Must be EM tested to:
  - Lightning indirect effects (LIE)
  - High Intensity Radiated Fields (HIRF)
- Must include:
  - Realistic wiring system in terms of topology, installation practices
  - Different current return structures for signals and lightning
  - Prototypes antennas connected to the wiring system
    → Implies a scale-one object
  - Measurement access points

The EPICEA barrel = BA’s scale-one business aircraft fuselage

INTRODUCTION TO THE EPICEA BARREL

LIMITATIONS AND MITIGATION

- No test-chamber large enough for measurements of antenna radiation patterns (far field measurement required)
  → Only reflection and coupling coefficients will be measured and simulated
- Passive equipment boxes (Only R, L, C loads)
  → Sufficient with respect to DO160 standards
- Heavy and large barrel structure which requires significant effort for:
  - Modifications and assembling
  - Transportations
  - EM Testing
    → ETC-MPB in Ottawa able to handle those issues
- Impossible to make CR accelerated tests
  → Simulation of CR effects by substituting some of the fake equipment passive loads by real electronic equipment
DESCRIPTION OF THE EPICEA BARREL STRUCTURE VIEWS

Current Return Network
- Two caps: RC and FC
- Two interior beams: HCR-R-Int and HCR-L-Int
- Four bulkheads: BR-Ext, BR-Int, BF-Int, and BF-Ext

Signal Ground Network
- Two exterior beams: HSG-R-Ext and HSG-L-Ext
- Two vertical signal ground frames: VSG-R and VSG-F
- Two side horizontal composite floor: SHCF-R and SHCF-L
DESCRIPTION OF THE EPICEA BARREL
INTERCONNECTED SYSTEM AND EQUIPMENT VIEWS

DESCRIPTION OF THE EPICEA BARREL
PROTOTYPE ANTENNA VIEWS
EM TESTING

**OBJECTIVES**

- **EM CHARACTERIZATION TESTS:**
  - Provide input data to the EM models (3D, IS and antenna)
  - Measurements performed directly on the barrel (ONERA)
    - Electrical continuity
    - Impedance of braids and contacts
    - Material EM characteristics
    - Transfer functions on IS (including receiving sources on antennas)

- **EM LIE/HIRF TESTS:**
  - Provide reference data
  - Demonstrate capability to simulate the whole frequency range of LIE and HIRF
  - Tests subcontracted to the ETC-MPB lab in Ottawa
    - Coaxial return,
    - Anechoic chamber,
    - MSRC
EM TESTING
TEST APPROACH

EMC standard requirements

LIE
LFB (DC – 1 MHz)
MFB (10 kHz – 3 GHz)
HIRF-LF (10 kHz – 400 MHz)
HIRF-HF (400 MHz – 18 GHz)
HFB (1 GHz – 18 GHz)

EPICEA test implementation

DC - 100 MHz
Coaxial return

50 MHz – 18 GHz
MSRC illumination tests

EM TESTING
EM EXCITATION SOURCES FOR LAB TESTS

- Lightning Indirect Effect (LIE)

- High Intensity Radiated Field (HIRF)
  - Standard HIRF – High Frequency Range (50 MHz – 18 GHz) – Mode Stirred Reverberation Chamber (MSRC)
EM TESTING
SOME PRELIMINARY RESULTS FOR LIE

Induced Voltage at Test Point TP-2

\[ V_{\text{max}} = 5.6 \text{ kV} \]
\[ V_{\text{min}} = 4.8 \text{ kV} \]

Induced Voltage at Test Point TP-2

\[ V_{\text{max}} = 5.4 \text{ kV} \]
\[ V_{\text{min}} = 2.6 \text{ kV} \]

Induced Current at Test Point LP-7

\[ I_{\text{max}} = 161.6 \text{ A} \]
\[ I_{\text{min}} = 332 \text{ A} \]

\[ I_{\text{max}} = 44.3 \text{ A} \]
\[ I_{\text{min}} = 332 \text{ A} \]
EM MODELLING
MODELING PLAN

- Two modelling steps:
  - **Validation** → modelling of the EPICEA LIE/HIRF test configurations
    - Models include test-set-up features
  - **Exploitation** (for end-user purposes) → modelling ideal LIE and HIRF configurations
    - Models are in « free space » (flight conditions)

- Challenges
  - Size of the models
  - Multiscale modelling
  - Management of uncontrolled input data (geometry, materials)
  - Calculation at very low and very high frequencies
  - Overall calculation time

EM MODELLING
MODEL GENERATION

17 April 2018
EM MODELLING

PRELIMINARY RESULTS: PW ILLUMINATION

Surface current distribution @ 40 MHz and 120 MHz

Internal current distribution @ DC, 100 kHz and 100 MHz

Surface current distribution @ 1GHz

STATUS AND NEXT BARREL STEPS

- Status:
  - Mock-up is available
  - LIE-HIRF Tests are currently being performed
    - Coaxial return
    - MSRC illumination to come
  - EM characterization tests to be done after this workshop
  - EM model to be finalized after the workshop
  - EM simulations to be continued after the workshop

- Next step: parameter analysis
  - Train partners
  - Hand over simulation tools to BA and FE
  - Define parameter analysis plan
  - Run EM simulations (EM coupling on IS and antennas)
  - Correlate EM response with weight and cost assessments
  - Define roadmap to upper TRLs
QUESTIONS

THANK YOU

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https://ec.europa.eu/programmes/horizon2020

http://www.nserc-crsng.ca

http://caric.aero
6.8 Cosmic Radiations

AGENDA

- Part 1: Cosmic radiation sensitivity estimation and modelling (C. Thibeault)
- Part 2: In-flight measurements (J. Chotte)
PART 1: COSMIC RADIATION SENSITIVITY ESTIMATION AND MODELLING

AGENDA (PART 1)

- Part 1: Cosmic radiation sensitivity estimation and modelling (C. Thibeault)
  - 1.0 Introduction
  - 1.1 Target integrated circuits
  - 1.2 Objectives
  - 1.3 Proposed approach
  - 1.4 Accelerated tests at TRIUMF
  - 1.5 Conclusions and future work
- Part 2: In-flight measurements (J. Chotte)
1.0 INTRODUCTION

- Cosmic radiation (CR): high energy particles (protons, heavy ions, etc.)
- Sources of CR [1]:
  - Galactic cosmic rays
  - Solar flares
- Good (but not perfect) protection from Earth magnetic field + atmosphere
- For avionics systems, primarily concern: neutrons [1]

Source: [2]

1.0 INTRODUCTION

- Impact of a high-energy neutron on silicon substrate [4]:
  - Charged particles created by collisions
  - If enough charge, state of a static memory element can be changed: (N)SEUs.
1.1 TARGET INTEGRATED CIRCUITS

- **SRAM-based FPGAs**
  - Increasingly popular for avionics and space applications
    - State-of-the-art technology
      - High density
      - High frequency
      - Reasonable power
    - Fast time to market
    - Easily (re)programmable

Zynq® UltraScale+™ MPSoCs [5]

---

1.1 TARGET INTEGRATED CIRCUITS

- **SRAM-based FPGAs**
  - Reprogrammability from SRAM configuration bits:
    - Define logic functions
    - Define routing to connect used resources
1.1 TARGET INTEGRATED CIRCUITS

- SRAM-based FPGAs
  - Reprogrammability from SRAM configuration bits:
    - Define logic functions
    - Define routing to connect used resources

1.1 TARGET INTEGRATED CIRCUITS

- SRAM-based FPGAs
  - Drawback:
    - Sensitive to CR
      - Configuration bit state modified
      - Corrupted logic functions or routing
1.1 TARGET INTEGRATED CIRCUITS

- SRAM-based FPGAs
  - Drawback:
    - Sensitive to CR
      - Configuration bit state modified
    - Corrupted logic functions or routing
  - N.B. BeeCube contains 4 Virtex6 FPGAs

- Metric:
  - Cross section (cm²) = Nb of errors/(Flux*time)
  - Flux = Particles/(sec * cm²)
1.2 OBJECTIVES

- Questions:
  - How sensitive to CR SRAM FPGA-based avionics systems really are?
  - How do SRAM FPGA-based avionics systems react to SEUs induced by CR?
  - How to model SEUs impact on SRAM FPGA-based avionics systems early in the design process?

1.3 PROPOSED APPROACH

- Questions:
  - How sensitive to CR SRAM FPGA-based avionics systems really are?
  - How do SRAM FPGA-based avionics systems react to SEUs induced by CR?
  - How to model SEUs impact on SRAM FPGA-based avionics systems early in the design process?
1.3 PROPOSED APPROACH

- 3 types of estimation:
  - Static:
    - Critical Cbits vs. nominal neutron flux
  - Semi-static:
    - Critical Cbits vs. changing neutron flux (e.g. in-flight route)
      - ISONEO simulator
  - Dynamic:
    - Matlab/Simulink simulation with SEU/fault injection

1.4 ACCELERATED TESTS AT TRIUMF

- Using neutron beam reproducing atmosphere spectrum
- Originally 4 days of experiment planned
- Lost the last day because of a power outage
- Experiments performed:
  - Impact of fuselage
  - Relative sensitivity of Xilinx Artix-7 and of Xilinx Virtex-5
  - Delay measurements
1.4 ACCELERATED TESTS AT TRIUMF

• Impact of fuselage
  • Without any
  • Metal fuselage
  • Composite fuselage
  • About 4% loss

95% Confidence Interval Cross-Sections; 1 = no cover, 3 = composite, 5 = metal; loss ≈ 4%

• Metric:
  • Cross section (cm²) = Nb of errors/Fluence
  • Fluence = Particles /cm² = Flux * time
  • Flux = Particles /((sec * cm²)

1.4 ACCELERATED TESTS AT TRIUMF

• Relative sensitivity of bits
  • CBits@1 more sensitive than CBits@0
  • Very important for realistic emulation

<table>
<thead>
<tr>
<th>FPGA</th>
<th>Protons</th>
<th>Neutrons</th>
</tr>
</thead>
<tbody>
<tr>
<td>Artix-7  (28nm)</td>
<td>2.8</td>
<td>1.7</td>
</tr>
<tr>
<td>Virtex-5 (65nm)</td>
<td>2.1</td>
<td>3.1</td>
</tr>
</tbody>
</table>
1.4 ACCELERATED TESTS AT TRIUMF

- Delay measurements
  - CR-induced SEUs can cause extra delay
  - Different routing resources characterized
  - Observed an increase in sensitivity with time

1.5 CONCLUSIONS AND FUTURE WORK

- So far:
  - Got important results from TRIUMF:
    - Negligible impact of fuselage
    - Relative sensitivity of Cbits
    - Increasing sensitivity wrt SEU-induced delays
  - Modelling:
    - Fault models for combinational circuits
    - Preliminary fault injection simulation with Matlab

- Next:
  - Go back to TRIUMF
    - Block sensitivity + fault models
    - ADCs
  - Develop more complex fault models for sequential circuits + fault injection in Matlab
  - Build a library of pre-characterized blocks

[2]
6.9 Exploitation Plan

EXPLOITATION PLAN
APPROACH TO PREPARE EXPLOITATION PLAN
GA – 2018

Kees Nuyten
Fokker Elmo

EXPLOITATION PLAN
OVERVIEW OF THE TOPICS

- Introduction
  - Definition Exploitation Plan

- Exploitation Plan
  - Structure
  - Activities

- Scope
  - EMC
  - CR maturity is too low to incorporate at this stage
  - The preparation of the exploitation plan

16 April 2018
EPICEA – GA – 2018
INTRODUCTION

EXPLOITATION PLAN - DEFINITION

- EPICEA's ambition is to provide an open EMC simulation framework for composite electric aircraft to enable collaborative EMC design by Aircraft Integrator and Electrical (Wiring) Systems suppliers.

- The exploitation plan will define all activities at the appropriate level of detail to achieve this ambition.

- Stakeholders
  - Solution providers (ONERA, AXE, IDS ...)
  - End users (BA, FE ...)
  - Certification authorities (...)

INTRODUCTION

PRESENTATION HAS END USER PERSPECTIVE

- EPICEA project proposal activities have a strong solution provider perspective.
  
  - p. 14: The exploitation plan will be developed and will organize all the necessary dissemination actions to:
    - Raise the awareness of the stakeholders to access and use the results (airlines, certification authorities, airlines, systems providers, equipment providers, academic research centres, etc.)
    - Widely inform the scientific and technical community on project achievements to access and use the knowledge gained (dissemination)
  
  - p. 24: The partners' exploitation plan includes the design of training courses based on the ongoing collect of knowledge generated by the project to be integrated in educational material.
  
  - p. 27: Table 5: Exploitation plan for education and training of all partners
  
  - p. 31: To support the exploitation plan and secure the strengthening of the industrials competitiveness and the reinforcement of Research and Education, IPR must be well managed since the beginning of the project.
  
  - p. 52: WP6 Exploitation plan written from solution provider point of view (AXED)

- And is complemented and completed with a end user perspective.
  
  - p. 53: D6.4: Business case with final exploitation plan. Decision document and plan for the future that projects the likely financial results and other business consequences of the project; AXES; CO; T6.1, M50
EXPLOITATION PLAN STRUCTURE

- Business Model
- Business Case
- Use Case
- Success Criteria
- Critical Assumptions
- Schedule

BUSINESS MODEL ACTUAL MODEL

- Aircraft manufacturer integrates systems and outsources part of the systems design and build (Bombardier)
- EWIS supplier designs and manufacturer EWIS for aircraft (Fokker Elmo)

- Solution providers supply licensed analysis tools to support the EMC design and specific computational power (ONERA, IDS, AxesSim)
BUSINESS CASE
EPICEA BENEFITS TO BE EVALUATED

- Quantitative approach of ROI
  - Returns with a fair risk should outweigh investments

- Strategic benefit
  - To end user benefit is also a qualifier (weight, volume)
  - Credibility gain for solution provider services and tools
  - Adjustment of platform to end user needs

- Qualitative arguments
  - Improved EMC design quality
  - Less EMC tests required
  - EMC risk areas better substantiated to direct tests

BUSINESS CASE
METHOD TO DETERMINE RETURNS FOR ROI

- Guidelines
  - Provide representative costs figures accurate enough to enable taking the right decisions
  - Inaccurate or generic enough to respect commercial interest of stakeholders

- Cost model setup
  - Cost Breakdown according Life Cycle Costs, including weight breakdown
  - Parametric model avoids high effort for detailed design
  - Complete for the job
    - Topics that EPICEA can manipulate
    - Topics that effect Return on Investment

- ROI Scope
  - Investment: everything up until TRL7
  - Returns: Product cost price – weight is feature
BUSINESS CASE
LCC CALCULATION – A COST SAVING EXAMPLE

- **Sales case**
  - Aircraft series 300 pcs
  - Aircraft cost price 80 M€

- In case you reduce 1% of cable shields
  - A shielded cable costs 50% of a shielded cable
  - 60% of the cables are shielded
  - 25% of the material costs are for cables
  - 70% of the EWiS recurring costs are material costs
  - 1% of the aircraft recurring costs are EWiS costs
  - 90% of the cost price are recurring costs

- The cost reduction achieved by material cost reduction is 50% of 60% of 25% of 70% of 1% of 90% of 300 aircrafts of 80 M€/piece

- **Material cost saving**
  - 227 k€/% cable shield reduction for the aircraft program
  - 756 €/% cable shield reduction per aircraft

- Manufacturing labor cost reduction, NPV and IRR not included, fidelity will be improved

---

BUSINESS CASE
LCC CALCULATION – PARAMETER SENSITIVITY

- All percentages multiplied by 0.9 for a conservative estimate and by 1.1 for an opportunistic estimate
  - A shielded cable costs 45% and 55% instead of 50% of a shielded cable
  - 54% and 66% instead of 60% of the cables are shielded
  - ...

- **Material cost saving estimate**
  - Baseline: 227 k€/% cable shield reduction for the aircraft program
  - Conservative: 128 €/% cable shield reduction per aircraft
  - Opportunistic: 402 €/% cable shield reduction per aircraft

- In case approach is objective, the risk of all estimates being conservative or all of them being opportunistic is small
**BUSINESS CASE**

**THE RISK OF OVERDESIGN**

Risk of Chain – Margins Stack to Over Design (example)

<table>
<thead>
<tr>
<th>Threat</th>
<th>Protection 1</th>
<th>Protection 2</th>
<th>Protection 3</th>
<th>Protection 4</th>
<th>&lt; System sensitivity</th>
</tr>
</thead>
<tbody>
<tr>
<td>HIRF coupling to signals</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>Signal disruption level</td>
</tr>
<tr>
<td>A/C structure shielding</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td></td>
</tr>
<tr>
<td>Ground Return Network</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td></td>
</tr>
<tr>
<td>Bundle shield</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td></td>
</tr>
<tr>
<td>Cable shield</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td></td>
</tr>
</tbody>
</table>

2 dB margin + 2 dB margin + 2 dB margin + 2 dB margin + 2 dB margin

Bottom line. Worst case approach with high accuracies in the chain has overall margin of 12 dB (factor 4)

---

**BUSINESS CASE**

**INVESTMENTS OVERVIEW FOR ROI**

- **Platform development**
  - Increase EMC model fidelity to TRL 7 level
  - Complete EPICEA platform functions
  - Fill parts and materials EMC performance library

- **Platform implementation**
  - Use case with an 3 layer architecture
USE CASE
ANTICIPATED DESIGN PROCESS WILL DRIVE ARCHITECTURE

IT Architecture
- Locations
- Servers
- Clients

Application Architecture
- CAD/CAE
- PDM
- EPICFA

Functional Architecture
- Aircraft shielding effectiveness
- Crosstalk

Engineering Design Process
- Concept Design
- Preliminary Design
- Detailed Design
- Design Iteration
- ...

DESIGN PROCESS – ACTUAL PRACTICE
EMC DESIGN IN CONCEPTUAL PHASE – WORST CASE APPROACH

Aircraft Design
- Concept Design
  - Aircraft shaping
  - Ground Return Network

EWIS Design
- Concept Design
  - Respiration / application
  - Bundle Sheath Selection
  - Cable Shield Selection
  - Materials / constructions

Electrical Systems Design
- Concept Design
- Preliminary Design
- Detailed Design
- Design Verification
  - EMC tests

Design Adjustment

EMC Qualification Tests
- Precertification
  - Initial certification
  - Design verification
- Certification
  - Component selection

Design Adjustment
DESIGN PROCESS – POTENTIAL PRACTICE
EMC IN DETAILED DESIGN PHASE – REDUCTION OVERDESIGN

Aircraft Design
- Concept Design
  - Aircraft shielding
- Preliminary Design
  - Ground Return Network
- Detailed Design
- Design Verification (EMC test)

EWIS Design
- Concept Design
  - Separation / appropriation
  - Methods / constructuaion
- Preliminary Design
  - EM Modeling / geometry
  - Space allocation
- Detailed Design
  - Signal Routing
  - Bundle Shield Selection
  - Cable Shield Selection
  - Component selection
- Design Adjustment

Electrical Systems Design
- Concept Design
- Preliminary Design
- Detailed Design
- Design Adjustment

EMC Qualification Tests

FUNCTIONAL ARCHITECTURE
SIMULATION / CALCULATION FUNCTIONS DURING THE DESIGN

Aircraft Design
- Aircraft Skin Impedance
- HIRF Induced EM Fields
- Ground Return Network Impedance
- ... Bundle Shield Transfer Impedance
- Cable Shield Transfer Impedance
- Cable HIRF Coupling
- ... Sensitivity to Noise (SNR)
- Filtering

EWIS Design

Electrical Systems Design

Functions can be part of different applications: EPICEA platform, external CAD/CAE tool, multiphysics simulation, company proprietary tool, spreadsheet ...

16 April 2018
EPICEA – QA – 2018
APPLICATION ARCHITECTURE
EPICEA GENERIC SOLUTION

Aircraft Design
- CAD/CAE
- PDM
- ERP

EWIS Design
- CAD/CAE
- PDM
- ERP

Electrical Systems Design
- CAD/CAE
- PDM
- ERP

APPLICATION ARCHITECTURE
WILL REQUIRE SEVERAL INTERFACES (AMELET HD)

EPICEA
- CRIPTE
- ALICE
- CuToo
- ...

EWIS Design
- PDM
- Geometry (CATIA)
- Multiphysics
- ERP
- ...

Aircraft Design
- PDM
- Geometry (CATIA)
- Multiphysics
- ERP
- ...

Electrical System Design
- PDM
- Electronic Network (SPICE)
- Geometry
- ...
- ...
IT ARCHITECTURE
SIMULATION / CALCULATION FUNCTIONS DURING THE DESIGN

EXPLOITATION PLAN
CRITICAL ASSUMPTIONS

- Benefit is substantial and sustainable and outweigh the effort to make
- An opportunity arises to raise funding via subsidy to build a consortium continuing on EPICEA
- Security (data) can be achieved
- Risk of rework after pilot application is acceptable to aircraft program and compensated by substantial benefits
EXPLOITATION PLAN
SUCCESS CONDITIONS

‘A strategy is a believe system’
(Vlerick Business school)

- Partners to share the same vision (believe)
- Objective collection and evaluation of facts and figures shall support the believe

Persistence, continuity and commitment

Willingness to invest and willingness to collaborate

PROPOSITION
ACTIVITIES ACCORDING MID TERM CONTRACT REVIEW

<table>
<thead>
<tr>
<th>№</th>
<th>Activity</th>
<th>Partners</th>
<th>Comment</th>
<th>Output</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Prepare exploitation use case for reference</td>
<td>FE + BA</td>
<td>Consider the design process and responsibilities at the aircraft manufacturer, the EWIS supplier and the suppliers of other electrical systems w.r.t. EMC. Determine scope of exploitation (conceptual trade off, conceptual design, detailed design)</td>
<td>High level definition of process, input and output</td>
</tr>
<tr>
<td>2</td>
<td>Define envisioned reference IT architecture</td>
<td>ONERA + FE + BA</td>
<td>ONERA will focus at EPICEA, FE and BA at PLM/PM, CAD and CAE tooling of the design environment for EWIS and the aircraft respectively.</td>
<td>Definition of application architecture, functional architecture and infrastructural architecture</td>
</tr>
<tr>
<td>3</td>
<td>Define interface point between EPICEA and environment</td>
<td>All</td>
<td>Determine where and how EPICEA simulation platform will interact with the reference architecture to identify gaps and activities to roadmap</td>
<td>Inventory activities to roadmap</td>
</tr>
<tr>
<td>4</td>
<td>Determine key exploitable results EPICEA + SWOT</td>
<td>All</td>
<td>To provide direction towards the roadmap</td>
<td>-</td>
</tr>
<tr>
<td>5</td>
<td>Prepare roadmap towards exploitation</td>
<td>All</td>
<td>Prepare roadmaps based upon a stage gated process with increased level of confidence of benefit (TRL assessment). Consider a publishable part, a consortium internal part and a partner part for commercial strategic content. Consider business and cost model (licences etc.)</td>
<td>Roadmap</td>
</tr>
</tbody>
</table>
EXPLOITATION PLAN

SCHEDULE

- Take care of progress
  - Finish date April 2019
  - Schedule margin of 6 months
  - 2 months of this margin dissipated

- Plan will be there before end of the project

- Need to collect contributions from partners (back up slkide)

EXPLOITATION PLAN

MISCELLANEOUS

- Get a per partner stakeholder involvement
- Chase tenders for funding – see where EPICEA adheres to their agenda
- Determine pilot application to be targeted (next generation TBD aircraft)