Methodology and Algorithms for High-level Modelling of Cosmic Radiation Impacts on Electrical Systems

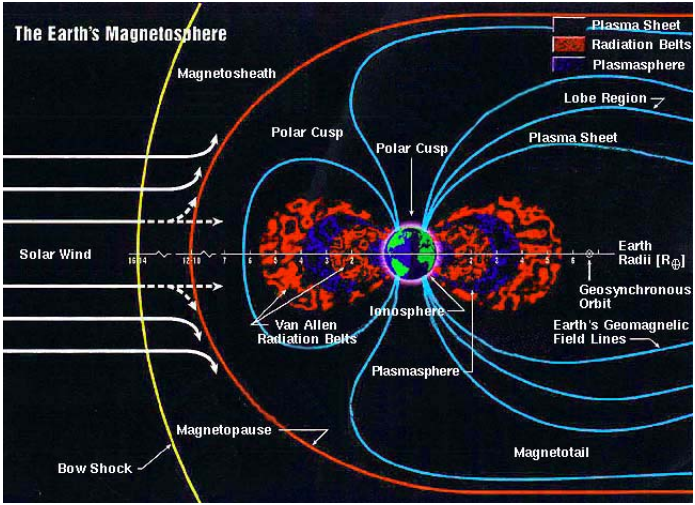
Hassan Anwar

Director : Claude Thibeault

École de Technologie Supérieure

Space Radiation

The Earth's Magnetosphere



Space Radiation

Cosmic Radiation on Aircraft:

- **Cosmic rays - high-energy particles that bombard the earth from outer space - are responsilble for the on-flight computer malfunction. "Something happened in that box that sent the wrong data at various times to the (main) flight computer," ATSB chief commissioner Martin Dolan said.**

'Cosmic rays' may have hit Qantas plane off Australia's northwest coast

By Ben Packham, HeraldSun
November 18, 2009 8:01am

'Cosmic rays' may have hit Qantas plane

COSMIC rays may have been responsible for a near disaster involving a Qantas jet off Australia's northwest coast.

Safety investigators have isolated the cause of two terrifying dives by the Airbus A330-303 to an onboard computer.

But the computer itself, fitted to about 900 aircraft worldwide, was found to be in perfect working order, the *Herald Sun* reports.

A flight attendant and 11 passengers were seriously injured and many others experienced minor injuries in a near-miss on October 8 last year.

Foreword

What we propose to research:

Algorithms and methodology for CR effects WHAT

high levels modeling of cosmic radiation, aircraft, altitude/latitude of 55,000 ft

Signature HOW

i.e. Fault emulation, radiation-based experiment TRIUMF, Flight Experiment

Radiation impacts on electrical systems WHY

i.e. a domain having particular **requirements**, and specific **constraints**

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Table of contents

Context & Motivation

Algorithms and methodology for cosmic radition effects study on aircraft's

- Dynamic highlevel fault simulator

Analyses of the result of the CR characteristics recorded and derive the effects on the electrical components

- Develop the computer model of the CR effects. Use the models to control the CR effects on electrical systems

Problem Statement

What we want to achieve:

(1) Characterize the CR enviornment

- Effects of the Embedded Systems

(2) Fault emulator, Radiation-based experiment

- Behaviour of the complex hardware, CR effects at component and system level

(3) Modelling

- Faulty behaviour at high-level modelling for analysis - Signature

Research Objectives

How to do it:

(1) Design and implementation of a target electrical system

- FPGA based emulation setup

(2) Design and implementation of an experimental setup for bombardment

- Radiation-based experimental setup at Triumf, flight experimental set-up

(3) Methodology and algorithms for high level modelling of CR impacts on electrical systems

- Simulate numerically the effect at component and electrical system level

Related Work: Fault Emulation and Radiation

Christelle *et al.* Radiation single event upset

- Single-event upsets
- Radiation effects on FPGA
- Fault Simulation

Anis *et al.* SEU Emulation on SRAM FPGAs Based on Sensitivenes Analysis

- Sensitivity of the hardware components

Quinn *et al.* Radiation Testing of Microprocessors and FPGAs

- Software & Hardware benchmark
- FPGA & microprocessors under radiation

Research Axes

(1) Fault Emulation

FPGA, Fault injection, and implementation, Signature generation

(2) Radiation-Experiment

Real-time data, Set-up, and Fault observation

(3) Modelling

Analysis, Monte Carlo, Markov Chain, and Symbolic Modelling

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Preliminary Results

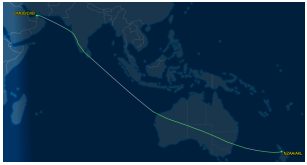
CIVIL AEROSPACE MEDICAL INSTITUTE (CARI)

- Calculates the cosmic radiation dose for flights
- Program takes into account changes in altitude and geographic location
- Appropriate databases are used to account for effects of changes in the earth's magnetic field and solar activity on galactic radiation levels in the atmosphere
- Altitudes up 60,000 feet
- `http://jag.cami.jccbi.gov/cariprofile.asp`

DXB-NZAA

DXB-NZAA

- Radiation Calculation



DXB-NZAA

Galactic Radiation Received In Flight

Enter Flight Data		
Date of Flight	07/2016	
Origin Code	OMDB	DUBAI, UNITED ARAB EMIRATES
Destination Code	NZAA	AUCKLAND, NEW ZEALAND
Number of en route altitudes	4	
Minutes to 1st en route altitude	35	

En route altitude(s) and time(s)	Altitude (in feet) 60000 maximum	Minutes at altitude*
	1) 29000	1) 292
	2) 31000	2) 94
	3) 35000	3) 60
	4) 36500	4) 222
	Whole numbers only, no commas	
Minutes descending to touchdown	67	Whole number only

Continue

Please Be Patient
Intensive processor calculations

Flight Data

Galactic Radiation Received In Flight

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Date of Flight	07/2016	
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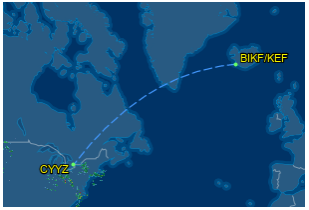
	29000	292
	31000	94
	35000	60
	36500	222
Minutes descending to touchdown	67	
Effective Dose	30.99 microsieverts (0.03099 millisieverts)	

Flight Radiation

REK-YYZ

REK-YYZ

- Radiation Calculation



REK-YYZ

Galactic Radiation Received In Flight

Enter Flight Data		
Date of Flight	08/2016	
Origin Code	BIRK	REYKJAVIK, ICELAND
Destination Code	CYYZ	TORONTO, ONT, CANADA
Number of en route altitudes	4	
Minutes to 1st en route altitude	29	

En route altitude(s) and time(s)	Altitude (in feet) 60000 maximum	Minutes at altitude*
	1) 37000	1) 88
	2) 35000	2) 25
	3) 38000	3) 144
	4) 36000	4) 16

Whole numbers only, no commas

Minutes descending to touchdown	27	Whole number only

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Minutes to 1st en route altitude	29	

En route altitude(s) and time(s)	Altitude (in feet)	Minutes at altitude
	37000	88
	35000	25
	38000	144
	36000	16

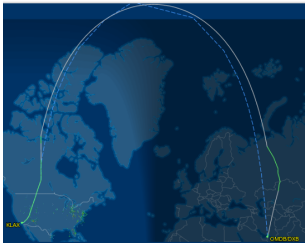
Minutes descending to touchdown	27	
Effective Dose	**38.72 microsieverts (0.03872 millisieverts)**	

Flight Radiation

DXB-KLAX

DXB-KLAX

- Radiation Calculation



DXB-KLAX

Galactic Radiation Received In Flight

Enter Flight Data		
Date of Flight	08/2016	
Origin Code	OMDB	DUBAI, UNITED ARAB EMIRATES
Destination Code	KLAX	LOS ANGELES, CA
Number of en route altitudes	5	
Minutes to 1st en route altitude	18	

En route altitude(s) and time(s)	Altitude (in feet) 60000 maximum	Minutes at altitude*
	1) 35000	1) 25
	2) 36000	2) 176
	3) 38000	3) 180
	4) 38500	4) 492
	5) 40000	5) 141

Whole numbers only, no commas

Minutes descending to touchdown	68	Whole number only

Continue

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Flight Summary		
Date of Flight	08/2016	
Origin Code	OMDB	DUBAI, UNITED ARAB EMIRATES
Destination Code	KLAX	LOS ANGELES, CA
Number of en route altitudes	5	
Minutes to 1st en route altitude	18	

En route altitude(s) and time(s)	Altitude (in feet)	Minutes at altitude
	35000	25
	36000	176
	38000	180
	38500	492
	40000	141

Minutes descending to touchdown	68	
Effective Dose	**127.87 microsieverts (0.12787 millisieverts)**	

Flight Radiation

PEK-KIAD

PEK-KIAD

- Radiation Calculation

PEK-KIAD

Galactic Radiation Received In Flight

Enter Flight Data		
Date of Flight	00/2016	
Origin Code	ZBAA	BEIJING, CHINA
Destination Code	KIAD	WASHINGTON, DC
Number of en route altitudes	4	
Minutes to 1st en route altitude	30	

En route altitude(s) and time(s)	Altitude (in feet) 60000 maximum	Minutes at altitude*
	1) 26000	1) 9
	2) 33000	2) 307
	3) 35000	3) 266
	4) 37000	4) 300

Whole numbers only, no commas

Minutes descending to touchdown	46	Whole number only

Continue

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Intensive processor calculations

Flight Data

Galactic Radiation Received In Flight

Flight Summary		
Date of Flight	00/2016	
Origin Code	ZBAA	BEIJING, CHINA
Destination Code	KIAD	WASHINGTON, DC
Number of en route altitudes	4	
Minutes to 1st en route altitude	18	

En route altitude(s) and time(s)	Altitude (in feet)	Minutes at altitude
	26000	9
	33000	307
	35000	266
	37000	300

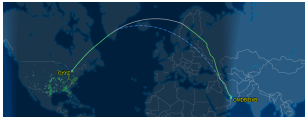
Minutes descending to touchdown	46	
Effective Dose	**94.45 microsieverts (0.09445 millisieverts)**	

Flight Radiation

DXB-YYZ

DXB-YYZ

- Radiation Calculation



DXB-YYZ

Galactic Radiation Received In Flight

Enter Flight Data		
Date of Flight	04/2016	
Origin Code	OMDB	DUBAI, UNITED ARAB EMIRATES
Destination Code	CYYZ	TORONTO, ONT, CANADA
Number of en route altitudes	5	
Minutes to 1st en route altitude	60	

En route altitude(s) and time(s)	Altitude (in feet) 60000 maximum	Minutes at altitude*
	1) 34000	1) 189
	2) 36000	2) 417
	3) 34000	3) 93
	4) 38000	4) 183
	5) 40000	5) 30

Whole numbers only, no commas

Minutes descending to touchdown	67	Whole number only

Continue

Please Be Patient
Intensive processor calculations

Flight Data

Galactic Radiation Received In Flight

Flight Summary		
Date of Flight	04/2016	
Origin Code	OMDB	DUBAI, UNITED ARAB EMIRATES
Destination Code	CYYZ	TORONTO, ONT, CANADA
Number of en route altitudes	5	
Minutes to 1st en route altitude	60	

En route altitude(s) and time(s)	Altitude (in feet)	Minutes at altitude
	34000	189
	36000	417
	34000	93
	38000	183
	40000	30

Minutes descending to touchdown	67
Effective Dose	**96.20 microsieverts (0.09620 millisieverts)**

Flight Radiation

Summary

Flight Radiation

Flight	Highest altitude (ft)	Minutes	Radiation (total-flight)
DXB-NZAA	36500	222	30.99μSv
REK-YYZ	38000	144	38.99μSv
DXB-KLAX	40000	141	127.87μSv
PEK-KIAD	37000	300	94.45μSv
DXB-YYZ	40000	30	96.20μSv

Technology Demonstration

- Integrate our prototype with Real flight

The *EPICEA* Project

Integration/Installation of electrical systems in Composite Electrical Aircraft), in collaboration with several companies and agencies (Bombardier, Isoneo, ARTTIC, ONERA, AXESSIM, FOKKER ELMO BV, IDS)

CMC BEE-4

Thank You!
Questions and Suggestions