ATMOSPHERIC IONIZING RADIATION (AIR) PROJECT REVIEW

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INTRODUCTION

The National Council on Radiation Protection and Measurement (NCRP) and the National Academy of Science (NAS) established that the uncertainty in the data and models associated with the high-altitude radiation environment could and should be reduced [1,2]. In response, the National Aeronautics and Space Administration (NASA) and the U.S. Department of Energy Environmental Measurements Laboratory (EML) created the Atmospheric Ionizing Radiation (AIR) Project under the auspices of the High Speed Research (HSR) Program Office at the Langley Research Center. NASA's HSR Program was developed to address the potential of a second-generation supersonic transport. A critical element focussed on the environmental issues, including the threat to crew and passengers posed by atmospheric radiation. Various international investigators were solicited to contribute instruments to fly on an ER-2 aircraft at altitudes similar to those proposed for the High Speed Civil Transport (HSCT). Table 1 contains a list of participating investigators, their institutions, and instruments with quantities measured. The flight series took place at solar minimum (radiation maximum) with northern, southern, and east/west flights. The investigators analyzed their data and presented preliminary results at the AIR Workshop in March, 1998. A review of these results follows.

REVIEW OF AIR WORKSHOP PAPERS

Approximately half of the preliminary workshop papers from the investigators have been completed and submitted for publication (references [3-7]). Tables 2 through 6 show results from the various detector systems (EML's preliminary neutron spectra and ionization chamber results [8] will be presented separately at this workshop by Paul Goldhagen). As shown in these data, all the reported instruments show approximately the same dose equivalents or dose equivalent rates for the same flight paths, within a factor of three. Some problems of intercomparablity of data do exist because different analysis and reporting techniques were used. In this report, an effort was made to make the units as similar as possible; however, some problems like the choice of conversion factors from particle fluences to dose equivalent still exist. As the final reports, which will standardize their results, are gathered and published, these results should converge. Therefore, a comprehensive atmospheric computer model for the AIR Project, called the AIR Code, can be developed with some limitation according to the recommendations set forth by the NCRP and NAS.

STATUS OF HSR PROGRAM OFFICE AND THE AIR PROJECT

A number of factors contributed to the demise of the HSR Program and the associated industry support for the High-Speed Civil Transport development. While the program met all of its technical goals, the environmental barriers became more severe. At the same time the major industry partner, Boeing, could not continue to advocate and support a year 2006 HSCT in light of challenging production problems associated with their current line of subsonic transport. The program was scheduled for completion in 2001 with a possible extension, but will now be terminated at the end of Fiscal 1999. This premature closure directly impacts the AIR Project because the neutron analysis and incorporation of all the data into the AIR Code will take until the end of the next fiscal year (FY00). Therefore, negotiations are in progress to fund the AIR project to completion. Resolution is not at hand at this time and completion of the AIR Project is in jeopardy.

PROJECT CONTINUATION

Assuming the AIR Project is funded to completion, the neutron data analysis, incorporation of the AIR data into the AIR Code, incorporation of the Japanese collaboration [9] model results into the AIR Code, and the final investigator's workshop are the primary tasks that need to be completed. This will take the Project to the end of FY00. The final product will be a code that will predict aircrew and passenger maximum exposure to normal flight with about a 20% uncertainty in the effective dose (the exact uncertainty will need to await the final analysis). This will allow regulatory bodies and the airline industry to establish radiation limits and economic analyses for vehicles of similar type to the HSCT. It will also result in an atmospheric environmental model for use in subsonic operations for which broad input has been derived from an international community.

REFERENCES

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[3] D.T. Barlett, L.G. Hager, R.J. Tanner; *The Determination Using Passive Dosimeters of Aircraft Crew Dose: Results for 1997 NASA ER-2 Flights*.

[4] P.A. Chee; *TEPC Measurements of High Altitude Radiation*.

[5] P. Tume, B.J. Lewis, L.G.I. Bennett, M.Pierre, T. Cousins, B.E. Hoffarth, T.A. Jones, and J.R. Brisson; *Assessment of High-Altitude Cosmic Radiation Exposure Using Tissue Equivalent Proposal Counters and Bubble Detectors*.

[6] E. Normand; *Assessment of High Altitude Cosmic Radiation Exposure using a Simple Electronic Neutron Dosimeter, the PDM-303*.

[7] H. Tai, P. Goldhagen, J. L. Shinn, J. W. Wilson, D. L. Maiden: *Atmospheric Ionizing Radiation (AIR) ER-2 Stratospheric Measurements Post-flight Analysis: The Argon Filled Ion Chamber*.

[8] P.E. Goldhagen; *Overview of Aircraft Radiation Exposure and Recent ER-2 Measurements*, NCRP Proceedings No. 20, in press.

[9] R.C Singleterry Jr., J.W. Wilson, H. Tai, I.W. Jones; *Overview of the Atmospheric Ionizing Radiation Model and Validation Measurements*, 9^{th} Annual Space Radiation Health Investigator's Workshop, Loma Linda, CA, June, 1998.

Table 1: Principal Investigators of Instruments on the ER-2 AIR Flights

Paul Goldhagen, U. S. Department of Energy Environmental Measurements Laboratory (EML) • Multisphere (Bonner Sphere) Neutron Spectrometer – *full range neutron spectrum* • Pressurized Argon Ionization Chamber – *total ionization, exposure rate, dose rate* • Scintillation Counters – *charged and neutral particle fluence rates and partial spectra*
Gautam Badhwar, NASA Johnson Space Center (JSC) • Particle Telescope – *charged particle fluences and spectra with species identification*
David Bartlett, National Radiation Protection Board (NRPB), United Kingdom • Track Etch Dosimeters – *dose equivalent*
Leslie G. I. Bennett, Royal Military College of Canada (RMC) • Superheated Drop/Bubble Detectors – *neutron dose equivalent*
Eugene Benton, University of San Francisco • Plastic Nuclear Track Detectors (PNTDs) – *fluence of target fragments*
Alexander Chee, The Boeing Company • Tissue-Equivalent Proportional Counter (TEPC) – *microdosimetric spectra, dose & dose-equivalent rates*
Thomas Cousins, Defence Research Establishment Ottawa (DREO), Canada • TEPC – *microdosimetric spectra, dose & dose equivalent rates* • Al_2O_3 Thermoluminescent Dosimeters (TLDs) – *non-neutron dose*
Francesco d'Errico, University of Pisa, Italy, and Yale University • Active Superheated Drop/Bubble Detector – *neutron dose equivalent*
Thomas Fogarty, Prairie View A&M University • Single-Event Upset Experiment – *single-event upsets in computer memories (not flown)*
Eugene Normand, The Boeing Company • PDM-303 Dosimeter – *high-LET dose equivalent*
Guenther Reitz, German Aerospace Research Establishment (DLR), Germany **Rudolf Beaujean**, University of Kiel, Germany • DOSTEL Particle Telescope – *HZE ion fluences and spectra* • PNTDs - *HZE ion fluences*

Table 2: NRPB's Track Etch Dosimeter Results

Flight Path	Neutron Dose Equivalent (μSv)	Non-neutron Dose Equivalent (μSv)	Total Dose Equivalent (μSv)
Northern Flight	104 ± 19	57 ± 2.3	161 ± 19
Southern Flight	19 ± 15	23 ± 1.7	42 ± 15
Easterly Flight	25 ± 10	15 ± 1.8	40 ± 10

Table 3: Boeing's (Dr. Chee) TEPC Results

Flight Path	Dose Equivalent Rate (μSv/h)	Quality Factor
Ames (east/west)	12	2.2
Northern Flight (max)	30	2.5
Southern Flight (min)	4.8	1.75

Table 4: DREO's TEPC Results

Flight Path	Total Dose Equivalent (ICRP-60) for Neutrons (μSv)
Northern Flight	200
Southern Flight	75
Easterly Flight	115

Table 5: RMC's Bubble Detector Results

Flight Path	Total Dose Equivalent (ICRP-60) for Neutrons (μSv)	Dose Equivalent Rate for Neutrons (μSv/h)
Northern Flight	59	7.4
Southern Flight	14	2.2
Easterly Flight	39	6.5

Table 6: Boeing's (Dr. Normand) PDM-303 Dosimeter Results

Flight Path	Raw PDM Reading (μSv)	Corrected PDM Dose Equivalent (μSv)
Northern Flight	570	114
Southern Flight	140	28
Easterly Flight	260	52