

## High Altitude Radiations Relevant to the High Speed Civil Transport (HSCT)

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The Langley Research Center (LaRC) performed atmospheric radiation studies under the SST development program in which important ionizing radiation components were measured and extended by calculations to develop the existing atmospheric ionizing radiation (AIR) model. In that program the measured neutron spectrum was limited to less than 10 MeV by the available 1960-1970 instrumentation. Extension of the neutron spectrum to high energies was made using the LaRC PROPER-3C monte carlo code. It was found that the atmospheric neutrons contributed about half of the dose equivalent and approximately half of the neutron contribution was from high energy neutrons above 10 MeV. Furthermore, monte carlo calculations of solar particle events showed that potential exposures as large as 10-100 mSv/hr may occur on important high latitude routes but acceptable levels of exposure could be obtained if timely descent to subsonic altitudes could be made. The principal concern was for pregnant occupants onboard the aircraft [1]. As a result of these studies the FAA Advisory Committee on the Radiobiological Aspects of the SST recommended [2]:

1. Crew members will have to be informed of their exposure levels
2. Maximum exposures on any flight to be limited to 5 mSv
3. Airborne radiation detection devices for total exposure and exposure rates
4. Satellite monitoring system to provide SST aircraft real-time information on atmospheric radiation levels for exposure mitigation
5. A solar forecasting system to warn flight operations of an impending solar event for flight scheduling and alert status

These recommendations are a reasonable starting point to requirements for the HSCT with some modification reflecting new standards of protection as a result of changing risk coefficients.

One result of the SST studies was the realization that subsonic aircrew members are among the most high occupationally exposed groups [1,3] which prompted the FAA to develop methods to further study exposures resulting in the CARI exposure estimation code (named after the Civil Aeronautical Research Institute) based on the LUN transport model (developed by the DOE Environmental Measurements Laboratory) to generate the database [4]. The estimated risk of serious illness to the child of a subsonic aircrew member during pregnancy is on the order of 1.3 per thousand [5] and the FAA recommended that air carriers begin a program of training of their employees on the risks of inflight subsonic exposures [6]. The dose rates at the HSCT altitudes are a factor of 2-3 higher than for subsonic operations and the HSCT crew annual flight hours will have to be reduced by this same factor to maintain exposure levels comparable to the subsonic crews.

Regulations on exposure limitation are based mainly on the estimated cancer risk coefficients. These coefficients have increased significantly over the last decade as solid tumor appearance is higher among the WW2 nuclear weapons survivors than initially anticipated [7-10]. As a result, new recommendations for reducing regulatory limits have been made by national and international advisory bodies [10,11]. Whereas subsonic crew exposures were well under the older regulatory limits, the substantial reductions (by factors of 2.5 to 5) in exposure limitations recommended by these advisory bodies resulted in the need to improve aircrew exposure estimates [12]. Hence, a workshop on Radiation Exposure of Civil Aircrew held in Luxembourg on June 25-27, 1991 was sponsored by the Commission of the European Communities Directorate General XI for Environmental Nuclear Safety and Civil Protection [12]. To be noted in the workshop is the closure of the gap between subsonic aircrew exposures and the newly recommended regulatory limits and in fact some concern that limits may be exceeded in some cases. Thus uncertainty in exposure estimates becomes a critical issue and emphasis on the numbers of and spectral content of high energy neutrons as well as the penetrating multiple charged ions were identified as a critical issue for subsonic flight crews. More recently Japanese flight crews have requested from their government, health benefits on the basis that their exposures are "far greater than the exposure of the average nuclear power plant worker" [13]. The issues for HSCT commercial air travel are compounded by the higher operating altitudes (higher exposure levels) and the possibility of exposures to

a large solar particle event wherein annual exposure limits could be greatly exceeded on a single flight [1,14].

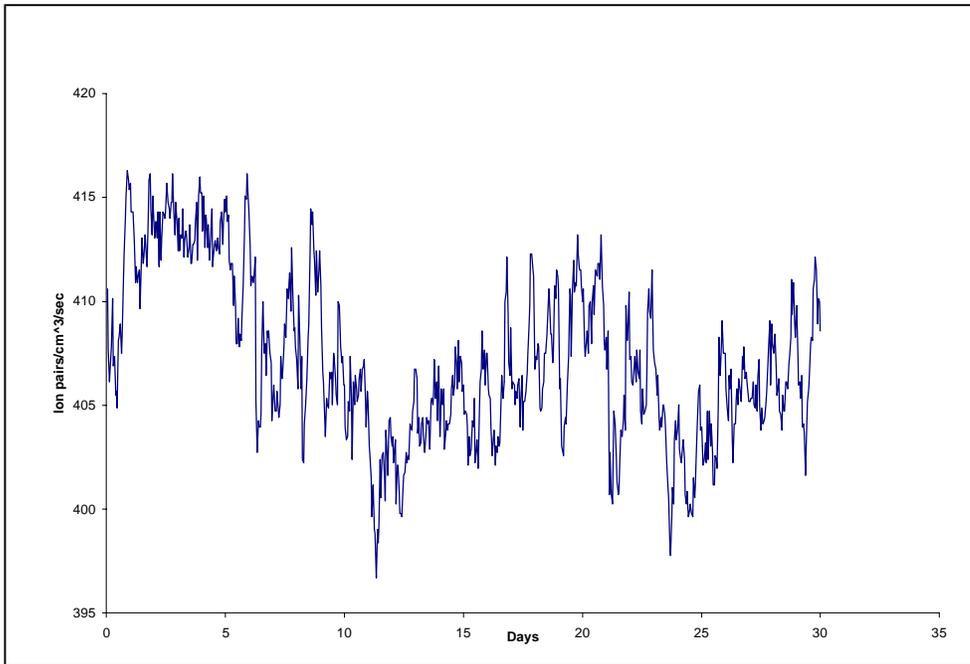
As a result of the higher expected exposures in high altitude flight, the US congressionally chartered federal advisory agency on radiation protection, NCRP, examined the data on atmospheric radiation and made recommendations [15] on the need for future studies as follows:

1. Additional measurements of atmospheric ionizing radiation components with special emphasis on high energy neutrons
2. A survey of proton and neutron biological data on stochastic effects and developmental injury for evaluation of appropriate risk factors
3. Develop methods of avoidance of solar energetic particles, especially for flight above 60,000 ft
4. Develop an appropriate radiation protection philosophy and radiation protection guidelines for commercial flight transportation, especially at high altitudes of 50,000 to 80,000 ft

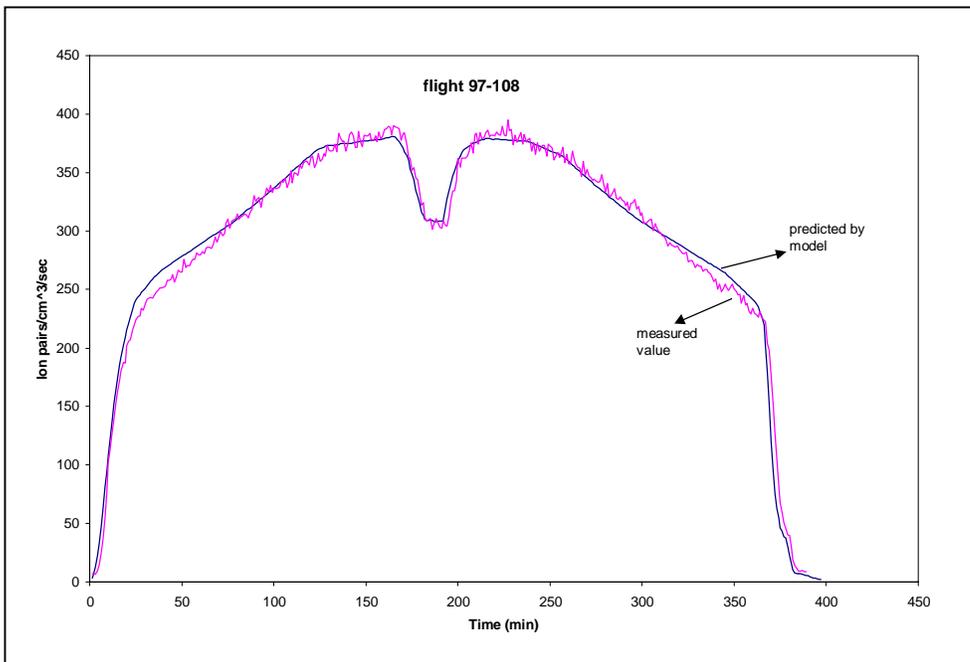
Clearly, these recommendations must be addressed before the HSCT goes into commercial service to ensure the safety of the crew and passengers. The current effort in this assessment is the use of an experimental flight package to reduce the uncertainty in AIR models in direct response to the NCRP recommendations.

An instrument package was developed in accordance with the NCRP recommendations through an international guest investigator collaborative project to acquire the use of existing instruments to measure the many components of the radiation spectra. Selection criteria was established which included: (a) the instruments had to fit into the cargo bay areas of the ER-2 airplane and able to function in that environment (Some high quality laboratory instruments were rejected because of their large size or inability to operate in the ER-2 environment.), (b) the instrument had to come at no-cost for use by the project to meet budget constraints, (c) the instrument must have a principal investigator with their own resources to conduct data analysis, and (d) the array must include all significant radiation components for which the NCRP had made minimal requirements. The flight package must be operational and the first flight occur before or near the maximum in the galactic cosmic ray intensity (ca. spring/summer 1997) and extend through the next cosmic ray minimum.

The flight package developed uses all of the available space in the ER-2 cargo areas. The primary instruments in the package consist of neutron detectors, scintillation counters, and an ion chamber from the DOE Environmental Measurements Laboratory and charged particle telescopes from Institute of Aerospace Medicine of Deutsche Forschungsanstalt für Luft- und Raumfahrt (DLR), and Johnson Space Center. Ten other instruments from Germany, Italy, the United Kingdom, and Canada make up most of the remainder of the flight package. These include passive track detectors from Institute of Aerospace Medicine, DLR, and University of San Francisco; TEPCs from Boeing and Defence Research Establishment Ontario; and dosimeters from Boeing, Royal Military Academy in Ontario and National Radiological Protection Board (NRPB) in the UK. The existing primary instruments and data system were modified for operation on the ER-2. A data acquisition system was incorporated to control operation of the entire instrument package, and to record data from the primary instruments during flight. Data from the other instruments are recorded separately by each instrument and recovered after a flight. The AIR model was modified for diurnal and solar rotational corrections as shown in figure 1a with the results for the ion chamber in a northern flight into Canada shown figure 1b. The dosimetry of the neutron component is being updated with ambient dose and dose equivalent for comparison with the TEPC data. Preliminary bonner sphere functions are likewise being used for preliminary flight comparisons.



**Figure 1a.** Ionization rate in the month of June, 1997, at 19.8 KM near polar region. Atmospheric pressure = 55.2 mb.



**Figure 1b.** Predicted and measured values of Air Ionization Rate as function of time for Flight 108.

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