Radiation Dosimetry Experiment (RaD-X): High-Altitude Balloon Flight Mission for Improving the NAIRAS Model

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NAIRAS Model

- NASA Nowcast of Atmospheric Ionizing Radiation for Aviation Safety (NAIRAS) Model
  - Prototype operational model
  - Running in real-time at the NASA Langley Research Center since April 2011
- Distinguishing Features
  - Real-time physics-based, deterministic, global model
  - Real-time inclusion of both galactic cosmic radiation (GCR) and solar energetic particle (SEP) radiation
  - Real-time solar-magnetospheric effects on geospace radiation environment
  - Real-time meteorological data (NCEP/GFS)

Public Web site: http://nspaceenvironment.net/nairas (or google NAI RoS)

Upper/Left: Climatology of zonal-average GCR effective (full-body average) dose rates at various altitudes and flight levels (FL)
- Solar Minimum (solid green line); Solar Maximum (solid blue line)
- The dashed lines: +/- 1-standard deviation

Upper/Right: Climatology of GCR effective dose rates as a function of vertical geomagnetic cutoff rigidity at various altitudes and flight levels (FL). Line style/color same as upper/left figure

Adjacent Figure: Dosimetric flight measurements from Dusseldorf, Germany (DUS) to Maui University (MRU) on 13-14 February 2008 (courtesy of Matthias Meier, DLR)
- 1 min TEPC ambient dose equivalent rate (uSv/hr, red line)
- Ambient dose equivalent operational surrogate for effective dose
- 1 min TEPC tissue absorbed dose rate (uSv/hr, blue line)
- 1 min Liulin silicon absorbed dose rate (uSv/hr, green line)

Upper/Left: TEPC/NAIRAS comparisons of 1-hour averaged ambient dose equivalent rates for DUS-MRU 13-14 February 2008 flight
- NAIRAS underestimates TEPC by about 50%
- These results consistent with comparisons with ICRU Report 84 reference aircraft measurements (Mertens et al., 2013)

Upper/Right: Liulin/NAIRAS comparisons of 1-hour averaged silicon absorbed dose rates for DUS-MRU 13-14 February 2008 flight
- NAIRAS underestimates Liulin by about 70%

Conclusions
- Suggest largest NAIRAS uncertainty in charged particle source/transport/interactions
- Measurements at flight altitudes alone cannot unambiguously identify source of NAIRAS model uncertainty

RaD-X Science

Goals and Objectives

- Goal 1: Improve NAIRAS model by characterizing energy deposition of cosmic ray primary (CR) particles
  - Objective 1: Measure dosimetric quantities in the upper atmosphere above the Pfotzer maximum to isolate CR primaries
  - Objective 2: Utilize dosimeters that can isolate proton and heavy-ion CR primaries and atmospheric neutrons
  - Goal 2: Identify low-cost atmospheric radiation dose measurement solutions for global, continuous monitoring
  - Objective 3: Characterize the relationship between silicon-based dosimetric measurements and radiobiological response

High-Altitude Measurements

Taking data at high altitude above the Pfotzer maximum provides a direct measurement of CR primaries, permitting the separation of discrepancies due to source uncertainties from discrepancies caused by the ensemble of complex physical processes at aircraft flight altitudes

- The radiation environment in the upper atmosphere above the Pfotzer maximum is a large source of uncertainty for radiation exposure at aircraft flight altitudes (Lindborg et al., 2004)
- Model/measurement comparisons at aircraft altitudes point out discrepancies, but do little to reveal a causal source of discrepancy due to variation in composition and energy of the radiation environment with atmospheric depth

Instrument Selection

The choice of dosimeters was motivated by:
- Ability to separate CR primary protons and heavy-ions and atmospheric ions by combining measurements at two flight altitude regions (Region-A and Region-B shown below)
- Viable low-cost dosimeters for continuous, global monitoring of radiobiological response (direct measurement or empirical fit)

- TEPC: Industry standard microdosimeter provides radiation protection (operational) dose measurement, which is defined as ambient dose equivalent [ICRU, 2010; ISO, 2012].
- Liulin: Silicon-based LET spectrometer that permits identification of protons at Region-A and separation of heavy-ion contributions at Region-B.
- TID: Teledyne total ionizing dose detector that is mostly sensitive to charged particles at RaD-X altitudes. Viable silicon-based dosimeter for continuous, global radiation monitoring. Requires empirical fit to TEPC ambient dose equivalent to characterize radiobiological response.
- RaySure: Viable silicon-based microdosimeter “emulator” which is easy to manufacture, internal calibration directly computes ambient dose equivalent.

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RaD-X Mission

Mission and Instrument Parameters

- Platform: High-Altitude Balloon
- Launch Site: Fort Sumner, NM
- Mission Duration: 24-hours
- Temporal Sampling: 1-5 minutes
- Launch Readiness Date: September 2015
- Instruments: (1) TEPC, (2) Teledyne TID dosimeter, (3) Liulin LET Spectrometer, and (4) RaySure microdosimeter emulator
- Measurement Uncertainty: < 30%
- Instrument TRL: All components TRL 6 or higher

Concept of Operation

Science Payload and Gondola

Milestones and Science Activities

- Project Milestones
  - Selection Conference (08/20/2013)
  - Kickoff (10/31/2013)
  - SRR: Systems Requirements Review (02/19/2014)
- Near-Term Science Activities
  - Modeling instrument and radiation shielding environment (05/2014)
  - PDR: Preliminary Design Review (05/2014)
  - Dosimeter Beam Test and Calibration (08/2014)